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Franz-Josef Behr, Moses Ngigi, Anakkathil Purushothaman Pradeepkumar, Mirka Zimmermann (Editors)

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Preface

The field of geoinformatics has shown tremendous growth not only in its technological advancement, but also in its applications arena in the realms of society and environment. The use of technology in day-to-day life has become ubiquitous. The growth of the application areas of geographical information systems, remote sensing, photogrammetry, and related technologies has also kept pace. The advances of the geoinformatics technologies as well as their applications have not only been felt in the developed countries, but also in the developing countries too, especially in addressing environmental issues and the millennium development goals. The papers presented in the Fourth Applied Geoinformatics for Society and Environment (AGSE) international conference-cum-summer school elucidate this in the collection of research papers and workshops that span a wide range of specialised areas under the umbrella of the year's theme '*Geoinformation for a better world*'.

This year's motto resonates around the motto of the AGSE series of conferences: 'an interdisciplinary, international forum for sharing knowledge about the application of geoinformatics with focus on application and on developing countries'. AGSE has been doing this with yeoman spirit ever since its inception in 2008 through the vision of Prof Franz-Josef Behr of the Stuttgart University of Applied Sciences, Germany. The first AGSE at Trivandrum, in Kerala, India (AGSE 2008) signalled the tremendous enthusiasm the developed world holds for geoinformatics, especially in the use of the Free and Open Source Software (FOSS) variety. Subsequent forums have travelled to Stuttgart, Germany (AGSE 2009), Arequipa, Peru (AGSE2010) and now Nairobi, Kenya (AGSE 2011), which shows the tremendous potential that geoinformatics has.

AGSE 2011 conference is special; it is being held for the first time in Africa, and particularly so in Nairobi, Kenya, the city that hosts the headquarters of the United Nations Environmental Programme (UNEP). Besides drawing a variety of papers from the international forum of the alumni of Stuttgart University of Applied Sciences, a considerable contribution from other researchers has addressed the use geoinformatics in Africa, and more so from the host country. The conference has attracted papers from more than 10 countries, spanning from Malaysia to Chile, and from Germany all the way to Zambia. The scientific and application areas presented in the papers are classed into eleven broad tracks or sub-themes namely: (1) General application papers, (2) Internet-based and open source solutions, (3) Advances in GIScience and current developments, (4) Spatial data infrastructures, (5) Environmental issues and sustainable development, (6) Natural resource management, and monitoring (7) Disaster and risk management, (8) Geoinformatics in health, (9)Urban and regional planning, (10) GIS in Education, and (11) Alumni experiences and business development. The importance of geoinformatics in the environment cannot go unnoticed, as the applications of the technology and science continue to draw a lot of interest. Examples of the application areas range from land use/land cover analysis for sustainable tourism, land use dynamics in forest management systems, to pollution, among other environmental oriented applications.

The conference would not have been successful without the support of different people and organisations. The editors are particularly grateful to the Jomo Kenyatta University of Agriculture and Technology (JKUAT) Division of Research Production and Extension, the Department of Geomatic Engineering and Geospatial Information Systems of JKUAT for hosting and facilitating the conference, the Faculty of Geomatics, Computer Science, and Mathematics, Stuttgart University of Applied Sciences, and especially Ms Mirka Zimmerman and Ms Beate Bauer. The support of all generous sponsors, especially ESRI Eastern Africa Ltd and the German Academic Exchange Service (DAAD) for their generosity, and Oakar Services Ltd, ESRI Rwanda, and other organisations who through exhibiting advances in geoinformation technologies and related products contributed greatly towards the success of the conference.

The conference organisers acknowledge the alumni of the Stuttgart University of Applied Sciences based in Kenya, and especially so in the Jomo Kenyatta University of Agriculture and Technology who have taken the initiative in bringing this conference to Kenya. The AGSE will strive to carry on its mission in the years to come, moving from continent to continent, carrying the message of knowledge and technology sharing in the fields of environment and society for the betterment of the world.

Dr. Moses M. Ngigi, Representative, Stuttgart Active Alumni Group, Jomo Kenyatta University of Agriculture and Technology, Kenya

Keynotes

We resolve … to develop and implement strategies
that give young people everywhere a real
chance to find decent and productive work

United Nations Millennium Declaration, 2000

Combining Advanced GPS Technology & Smart Satellite Imagery for the Mapping of Informal Settlements

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KEYWORDS:
GPS, Satellite Imagery

ABSTRACT

During the past decade digital collection of geodata has become a common subject for the public. Due to the free availability of the GPS signal with selected availability off since May 2000, everybody on Earth is able to determine the actual geo-position within an accuracy radius of about ten meters. GPS is under revision and the new generation of satellites is currently installed in the orbit. This will provide a higher reliability and more precise position accuracy. In addition new and competitive global positioning systems have and will become available, e.g. the Chinese COMPASS, Russian GLONASS and finally the European GALILEO. The next decade will bring a series of new receivers and those will make advantage of all available GPS signal in combination. The public, professional geodetic services and especially the mapping community will truly benefit from these developments and open map services like Open Street Map (OSM) will provide increased geo-precision.

Optical satellite remote sensing images are another important source for the acquisition of geoinformation. For the mapping of urban objects, a fine spatial resolution is necessary providing enough detail for reliable object recognition. A series of new spaceborne sensors have been launched recently, those collect image data with a spatial resolution up to 0.41 m in the panchromatic (pan) band. This spatial resolution can be compared with the detail-accuracy offered by classical aerial photos. However, some more advanced features are pushing the satellite images in the first position compared to aerials: spectral bands are not limited to three colors only, the radiometric capabilities exceed the image quality of aerial by far and finally the revisit period of these satellite sensors is in the range of about three days. [The price of the satellite images (per area unit) might be reduced compared to aerials but it will not be considered here.] Having all these criteria in mind we can state that a new generation of remote sensing information source has become available, a true substitute for the classical aerial photos.

These two substantial new developments, combined GPS signals, 2nd generation, and super high resolution satellite remote sensing, will facilitate the precise mapping of urban areas substantially. On the one hand unplanned urban settlement regions with a highly diverse, inhomogeneous structure are difficult to survey, on the other hand especially these region need to be mapped first, because an infrastructure network has to be established. Infrastructure in these cases means: freshwater supply and wastewater drainage, electricity grid and a telecommunication network. The Kibera informal settlement in Nairobi, Kenia, is one of the rapidly changing suburban regions with a highly diverse, unmanaged -and in some areas unknown- structure. "Map Kibera" is the name of a mapping project especially for this slum, and Map Kibera may definitely benefit from the new developments of geodata acquisition..

Rainforest Change over Time

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KEYWORDS:
Deforestation, rain forest, BIOTA project

ABSTRACT

There is much concern and debate about the continuing deforestation in the tropics. Rainforests are not only sheltering a vast biodiversity, but they play a significant role in sequestration and storage of carbon. Therefore, science has and is contributing to the monitoring of forest loss and states by making in particular use of satellite imagery timeseries.

Within the BIOTA East Africa project three truly comparable timeseries have been derived for the Kakamgea-Nandi forests area in western Kenya and Mabira and Budongo Forest areas in Uganda. Here besides Landsat data also historical aerial photography and old topographic maps were used to distinguish between various forest formations and to cover via 12/13 time steps a time span of almost 100 years. The additional use of archive material (old maps, oral histories of early travellers), forestry records, thematic maps, interviews with the oldest people living in the areas, place names, and pollen analysis of soil cores allowed for an even more detailed and time-wise extended view revealing also the causes of forest change. The analysis of the manifold data in a geographic information system (GIS) thus has contributed to detailed information on the forests' states and disturbance levels today which are needed for a sustainable forest management.

From the research it can be concluded that generalisations on forest change for the forest remnants in Eastern Africa would not reflect reality. It seems that every forest has its own unique forest use history.

Participatory Digital Mapping in slum communities: Map Kibera and Map Mathare

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KEYWORDS:
Participatory GIS, Slum Mapping, Kibera, Mathare

ABSTRACT

Practitioners of participatory mapping recognize that local communities are experts in their own geographies. This presentation examines two case studies of participatory digital mapping in slum communities, including tools and techniques that encourage community ownership over the process of identifying local resources.

The case studies, Map Kibera and Map Mathare, demonstrate how mapping and digital tools can contribute to increased influence and representation of marginalized communities. Map Kibera works with a team of local youth in their communities to create information and tell stories through mapping, new media and video. With skills and experience in using handheld GPS devices and GIS techniques, the youth and communities can map slums, and other areas for which there is little publicly available geographic information. This allows them to tell their own stories and highlight issues facing residents, with an explicit focus on participatory techniques for community engagement. Open source tools and open data provide an opportunity for sustainable solutions to managing community information and increasing influence and representation.

Situs Addressing in Rapidly growing African Cities: Benefits, Prospects and Challenges

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KEYWORDS:
Situs addressing, Land management, Mobile phones, Urban management, Africa, Cameroon, Douala, Yaoundé

ABSTRACT

This paper highlights the benefits and untapped potentialities of situs addressing. One of the most ambitious street addressing projects implemented in Africa was implemented in about 50 African cities under the auspices of the World Bank and French Cooperation. Examples are drawn from two Cameroonian cities to assess how addressing project has performed. A decade after the handover of the project to the local authorities, we review the lessons to be learnt from the project through a combination of field observations, literature reviews and interviews of both users and authorities. Our investigation suggests that the project has achieved important milestones such as raising awareness on street addressing.

However, we find that the Project has some shortcomings, especially with regards to public uptake and usage, sustainability and maintenance, resources and management. Recommendations are made to improve addressing initiatives in African cities particularly in the context of the explosion and rapid penetration of Information and Communication Technology (especiallymobile phones and internet) applications. Key recommendationsdraw particular attention on standard and ways in which situs addressing can effectively work in rapidly growing African cities.

Earth Observation Systems, Information Extraction, and Photogrammetry

We resolve … to intensify our collective efforts
for the management, conservation and
sustainable development of all types of forests

United Nations Millennium Declaration, 2000

Road Classification and Condition Investigation Using Hyperspectral Imagery

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KEYWORDS:
Hyperspectral, urban, ALK vector data, classification, condition, HyMap

ABSTRACT

Hyperspectral data has significant capabilities for automatic identification and mapping of urban surface materials (e.g. road materials) because of its high spectral resolution. It includes a wealth of information which facilitates an understanding of the ground material properties. In this study an automatic approach for classification of road surface materials using hyperspectral data is developed. In addition, the condition of the surface materials of roads, in particular asphalt, is investigated. Different supervised classification methods such as spectral angle mapper are applied based on a spectral library which was established from field measurements and in-situ inspection. In addition, the role of spectral features and spectral functions for classification is investigated. Experiments have shown that simple spectral functions such as mean and standard deviation of image spectra are suitable for discriminating asphalt, concrete and gravel. In terms of distinguishing different asphalt conditions into good, intermediate and bad ones, the best results have been achieved using the spectral features brightness and increase or decrease in reflectance together with the spectral functions mean and image ratio. Vector data is integrated in order to confine the analysis to roads. The vector data helps to improve the accuracy of the classification as it reduces confusion between roads and surrounding objects such as building roofs. The assessment of the results is based on a comparison with orthophotos and field information of selected roads.

1 Introduction

Retrieval of road information such as road surface material and pavement type condition is one of the essential issues in urban areas. This is done with either traditional surveying or remote sensing (Zhang and Couloigner, 2004). Hyperspectral imaging, also known as imaging spectrometry, is the acquisition of data in many narrow, contiguous spectral bands (Goetz et al., 1985). It provides more detailed information than other remote sensing techniques. Chemically different materials such as asphalt and gravel can be detected in hyperspectral images by their corresponding physical properties (absorption, albedo etc). Road surface materials can be identified from hyperspectral imagery more efficiently than by field surveying. However, most of the available methods for mapping of roads are manual or semi-automatic, therefore time-consuming and expensive. Up to date no standard approach exists for automatic mapping of road surfaces and identifying the condition of road surface materials. Most of the methods for hyperspectral image processing were originally developed for mineral detection. Thus it is a challenge to adapt these methods for identifying road surface materials, particularly in view of the high spatial variation of these materials.

Due to the fast developments in urban areas the demand increases to find suitable methods for extracting information from hyperspectral data. (Noronha et al., 2002) focus on extracting road centerlines, detecting pavement conditions and developing a spectral library. Maximum likelihood classification is applied and the Bhattacharyya distance is used for a separability analysis between road materials and roof types. For better discrimination of roofs and roads, object-oriented image classification is used. This technique tries to analyse homogeneous image objects rather than independent pixels. Separability analysis has indicated that concrete and gravel roads are easily distinguishable from asphalt roads. On the other hand, it is not easy to differentiate between some roads and roof types such as dark new roads and dark tile roofs. (Segl et al., 2003) confirm that it is a challenge to identify urban surface materials due to the variation of these materials in relatively small regions. A hyperspectral pixel in an urban scene generally contains a mixture of different material components, which makes it difficult to identify the constituents (Bhaskaran & Datt, 2000).

Many methods for the analysis of hyperspectral data determine materials by measuring the similarity between image spectra and reference signatures. Other techniques are able to identify the materials using spectral features. A lot of research has been done for applying these techniques to image spectrometry. (Van der Meer, 2004) developed a method for the analysis of hyperspectral images using absorption band depth and position, mainly for the application on mineral materials. This method applies linear regression in order to estimate absorption-band parameters. The sensitivity analysis shows that more reliable results are achieved by a more accurate determination of the absorption band parameters (shoulders, absorption points). (Heiden et al., 2007) develop an approach for urban feature identification using specific robust characteristics. These spectral characteristics include absorption bands (depth and position) or sharp increase and decrease of reflectance. Separability analysis is used to evaluate the robustness of spectral features. It is concluded that urban materials need to be described by more than one type of feature. A similar approach is followed in this research.

In this research various methods have been investigated for the classification of roads using hyperspectral data (Mohammadi, 2011) but only those which led to most successful experimental results are discussed in the following. The analysis of the road surface conditions is focused on asphalt roads with good success in identifying roads with good, intermediate and bad surface condition.

2 Study area, hyperspectral image data and preprocessing

The classification of road surface material is performed with data from the city of Ludwigsburg, Germany. Apart from the city of Ludwigsburg, the image data covers a wider area of approximately 11 km x 16 km extension. The hyperspectral data was acquired during a HyMap campaign on 20th August, 2010 by the German Aerospace Center (DLR) and consists of six strips. The data comprises 125 bands (ranging from 0.4 µm to 2.5 µm) and has a ground sample distance of 4 m. ALK vector data for roads is provided by Fachbereich Stadtplanung und Vermessung der Stadt Ludwigsburg. The vector data is used for limiting the analysis to roads. Information on road conditions based on field visits is available from the municipality of Ludwigsburg and the surveying company Praxl und Partner GmbH. The preprocessing of the hyperspectral data has been done by DLR. The data is corrected for radiometric, geometric and atmospheric effects. A high resolution LiDAR surface model of Ludwigsburg with 2 m raster size was made available for this purpose.

The HyMap and the ALK vector data are overlaid by precisely georeferencing the HyMap data for which the vector layer for roads is selected as a source of ground control points. By georeferencing with an affine transformation an overall RMS error of about 0.7 pixels is obtained. A road mask is created from the road vector data. However, it is observed that the road mask also covers some areas with vegetation and thus these areas have to be eliminated. Vegetation spectra for different areas in the HyMap data are collected and used to create a spectral library. The HyMap data is classified using this spectral library in order to identify the vegetation areas. A mask is created from the output classification map. This mask is subtracted from the road mask in order to obtain a mask limiting subsequent analyses to road surfaces only.

3 Methods and results

In order to identify road material types and conditions, different supervised classification approaches are tested. The experimental investigation is carried out in two parts. The first part discusses the methods and results obtained for roads surface material identification while the second part focuses on the determination of surface conditions.

3.1 Road surface material identification

Asphalt or more specifically bituminous asphalt is the mostly used material of road surfaces (pavements) in Ludwigsburg. It is a composite material of construction aggregates (e.g. gravel, crushed stone etc.) and bitumen which serves as a binder. The mixing is formed in various ways which leads to a certain “asphalt variety” within classification. Also concrete road surfaces are encountered in Ludwigsburg, however to a much lesser extent. Concrete contains cement as a binding agent, which is an inorganic material. Very few roads or public places are unpaved or just covered by gravel. These three main classes, simply called ‘asphalt’, ‘concrete’ and ‘gravel’ are taken into account for road material identification. In order to map these materials, the spectral angle mapper (SAM) criterion and the brightness spectral feature are used. Training regions are selected over the calibration sites for the three materials. Each training region defines a spectrum as an average of the region of interest (ROI). Using the ROI spectra, the roads within the investigation area are classified based on SAM with the default threshold setting (ENVI) of 0.1 radian. If the angles between an observed spectrum and all reference spectra are larger than this threshold, the corresponding pixel remains unclassified. In addition to 0.1 two more spectral angle thresholds are tested: 0.08 and 0.15 (radians). Best classification results have been achieved with the lowest threshold of 0.08 but at the cost of a high percentage of unclassified pixels (see below). The output classification map based on the threshold of 0.08 is shown in figure 1. A color orthophoto is used as background image for this visualization. Four different subclasses, or reference spectra, respectively, are defined for asphalt. Hereby the considerable variability of the asphalt spectra is taken into account, which exceeds the threshold angle of 0.08 by far. After classification these subclasses are recombined to the superclass "asphalt".

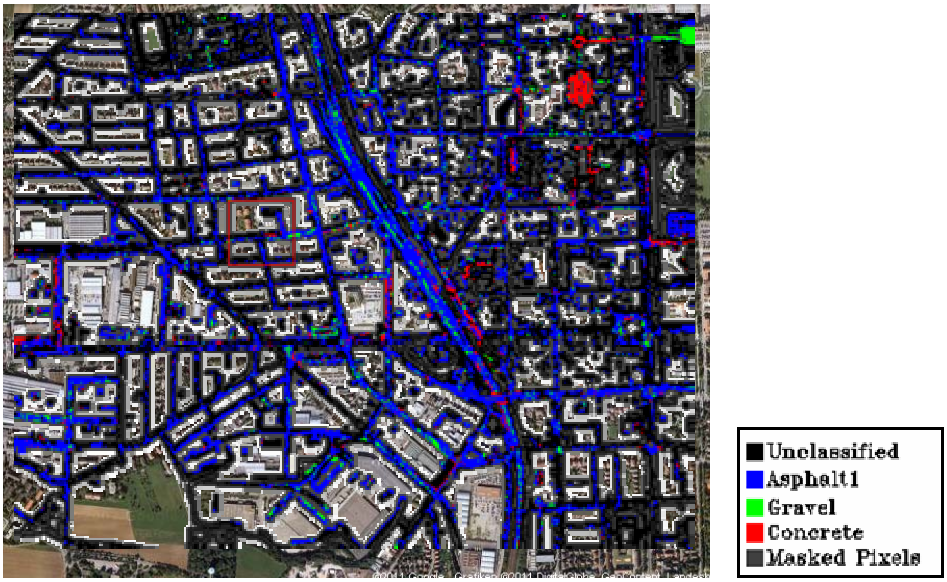

Figure 1: SAM classification using threshold of 0.08 (radians)

In the classification results (excluding non-road pixels), about 29% of the pixels are identified as asphalt, 2% as concrete, 3% as gravel and a high percentage of 66% of the pixels remains unclassified. Figure 2 is an example of an area that shows a road segment of concrete pavers which is correctly classified (verified by field visits). The corresponding spectra (Figure 2) indicate that the SAM similarity measure is relatively insensitive to illumination and albedo effects.

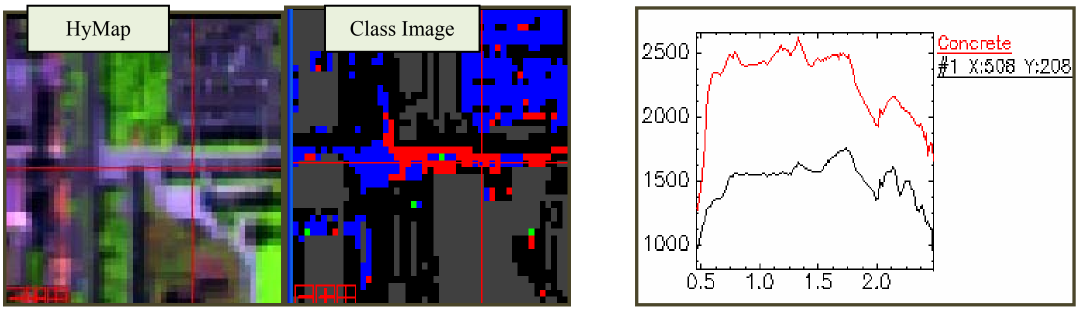

Figure 2: An example of a correctly classified area of concrete pavers

Another approach used in the identification of road surface materials involves the use of the brightness spectral feature. Brightness is one of the spectral features which is more distinct for materials with relatively flat low reflectance curves (see figure 3) such as asphalt (Heiden et al., 2005).

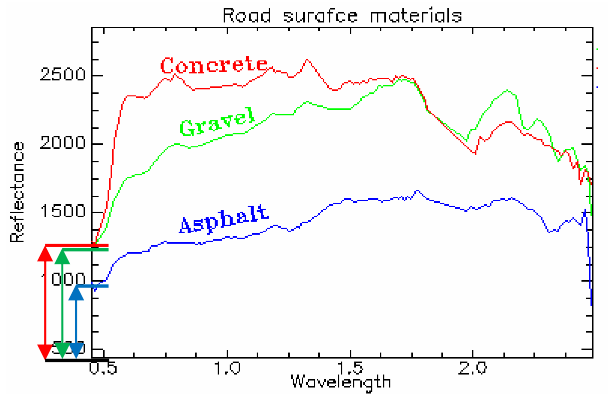

Figure 3: Asphalt, concrete and gravel spectra

For evaluating the brightness of surface materials, the mean and standard deviation functions are used. In order to distinguish asphalt, concrete and gravel, the mean of the reflectance values is determined over the complete wavelength range of the HyMap sensor (445 nm-2448 nm). Asphalt has the lowest mean (as can be already seen in figure 3) and can be easily distinguished from the other two materials. Concrete and gravel have similar mean values over the specified wavelength range which makes it more difficult to differentiate between these two materials. By inspecting the signatures of concrete and gravel it can be expected that the standard deviations differ significantly if applied over the wavelength range of around 620 nm-1320 nm (see also figure 3; more precisely the included range was 619.9 nm-1323.7 nm). This is experimentally confirmed; in particular, concrete has a low standard deviation in this wavelength range. Based on these findings a simple procedure for the identification of asphalt, concrete and gravel is proposed (figure 4).

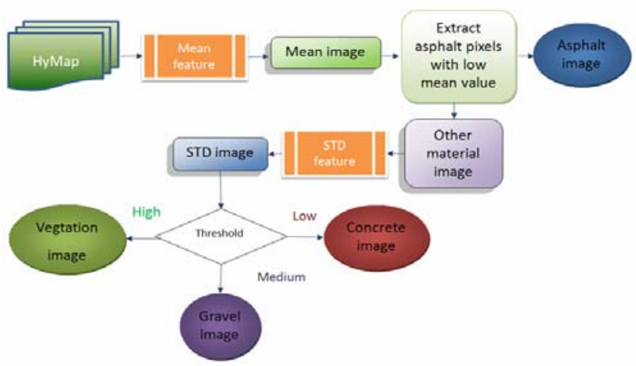

Figure 4: Classification of asphalt, concrete and gravel using the brightness feature with mean and standard deviation

The sequential process of applying mean and standard deviation features has a desired side effect which is the detection of vegetation pixels (high standard deviation) which might have remained after the first attempt of vegetation removal.

The classification result based on this procedure is shown in figure 5 for the central part of the project area. 42.0% of the pixels (excluding non-road pixels) are identified as asphalt, 2.3% as concrete, 3.2% as gravel and 52.5% of the pixels are unclassified. The number of unclassified pixels in the a priori given road layer is still high. Compared to the SAM result the reduction of unclassified pixels is obvious.

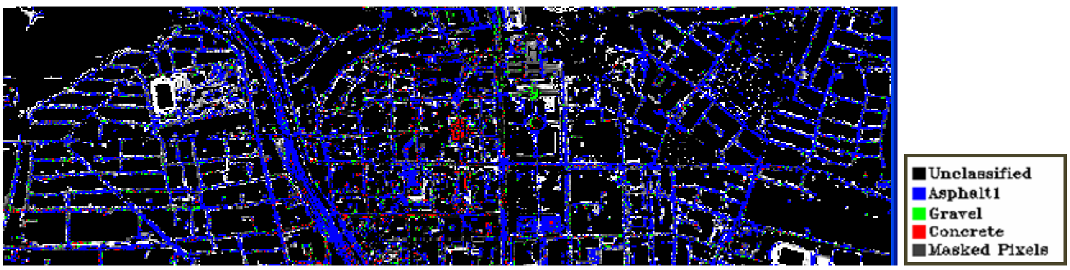

Figure 5: Classification map based on mean and standard deviation functions

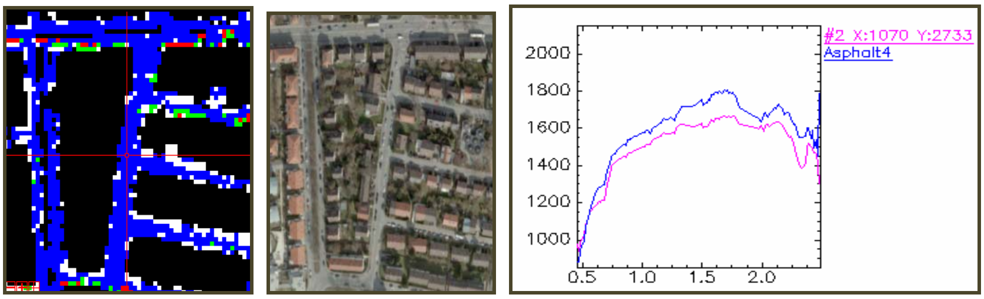

Figure 6: An example of a well classified area

A closer look to a detail (figure 6) reveals the high quality of the classification. It should be noted that no post-processing was applied to reduce the number of unclassified pixels.

3.2 Road surface condition determination

The condition of the road surfaces is another critical issue in road inventory. Recent studies (Gomez, 2002, Herold et al., 2005, Noronha et al., 2002) in hyperspectral remote sensing and spectrometry have shown that it is possible to map road surface condition using hyperspectral data. In terms of condition determination, the investigation is focused on asphalt. Three categories are defined, namely "good", "intermediate" and "bad". Again, spectral features are used in order to determine the different surface conditions. Among the tested spectral features the brightness using the mean function, the decrease or increase in reflectance using the ratio function and the hydrocarbon absorption bands have been most promising.

The mean is helpful for asphalt condition identification, because new asphalts have lower means and as the condition gets worse the mean gets higher. In addition there are two image ratios which are significant in revealing asphalt condition differences (Herold et al., 2005). These are situated in the visible and short wavelength infrared bands.

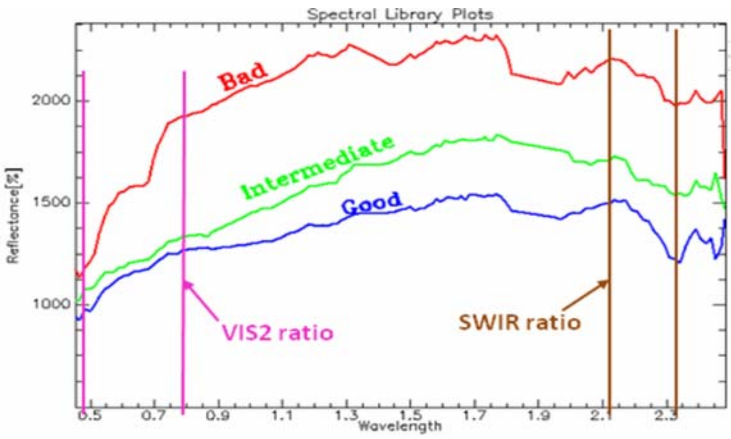

Figure 7: VIS2 and SWIR ratio ranges

These ranges (see figure 7) are 490 nm – 830 nm for visible (VIS2) and 2120 nm - 2340 nm for short wavelength infrared (SWIR). Good asphalt has the lowest value in the VIS2 ratio and the highest value in the SWIR ratio. The converse is true for bad asphalt. Another approach for identifying different asphalt states is to use hydrocarbon seeps. These features are typically the maximum absorption bands situated around the wavelengths of 1730 nm and 2300 nm (Clutis, 1989). The amount of oily components existing in asphalt is one of the factors creating different conditions since this characteristic influences the molecular structure and consequently the degree of viscosity of the asphalt surface. The higher the oily components, the more viscous the road surface and in turn the stronger the hydrocarbon absorption bands. Deeper absorption bands indicate better condition of the asphalt surface material. As the asphalt gets older (condition of the asphalt gets worse), the degree of viscosity reduces and it becomes prone to cracks (Weng Q., 2008). As a result, the reflectance of the surface increases and eventually the hydrocarbon bands become weak and approximate a straight line. This means that the condition of asphalt is bad. The results of the investigation indicate, however, that the mean function is more reliable for identifying different conditions of asphalt.

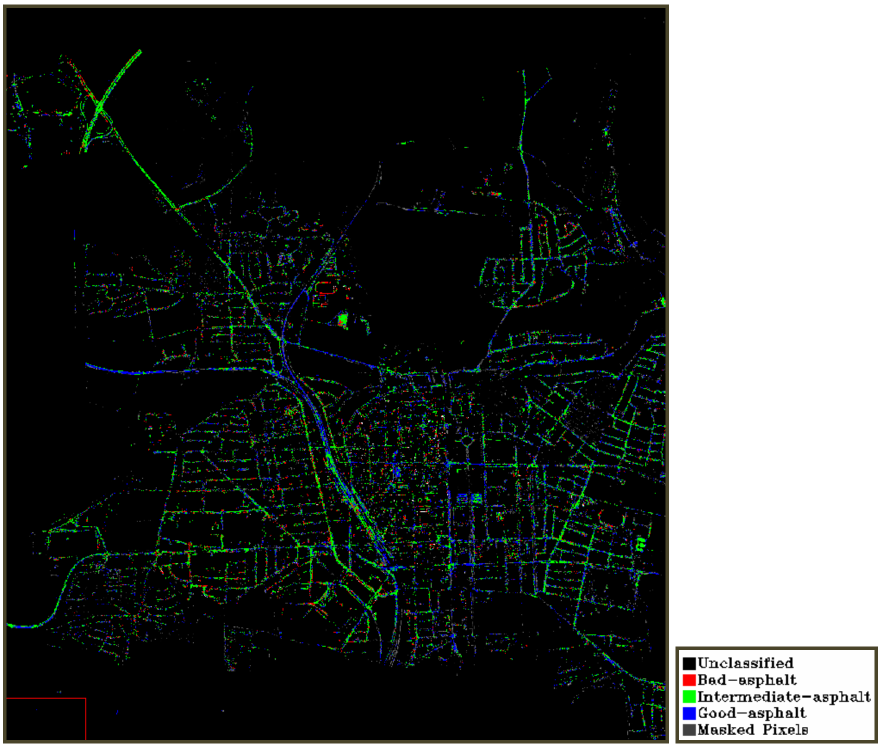

Figure 8: Classification result for the whole study area

The classification result for the whole study area based on the mean function is shown in figure 8. The classification statistics indicate that 23% of the pixels are identified as good asphalt, 23% as intermediate and 14% as bad asphalt. The remaining pixels are unclassified. The statistics hold with respect to the area covered by roads only. Figure 9 shows an example road (Steinbeisstraße) which is classified as bad. Field investigations support this result.

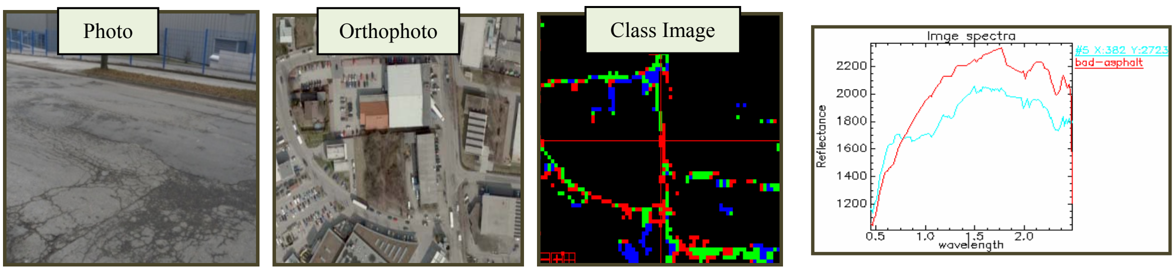

Figure 9: Assessment of classification results on Steinbeisstraße

Even though the comprehensive ground truth evaluation is not yet finished, the spot checks supported by field visits indicate a high potential of the approach for identifying roads with good, intermediate and bad surface conditions.

4 Conclusion

This study focuses on two main purposes, namely the identification of road surface materials and the investigation of different road conditions focused on asphalt. The classification results show that the SAM classification based on regions of interest is helpful for discriminating road surface materials. The mean spectrum collected in a sufficiently large number of training regions must take into account variations in the spectra of materials due to age or usage. Combining mean and standard deviation of a proper spectral range is helpful for distinguishing asphalt, concrete and gravel. This is possible since asphalt has a lower mean value compared to the other two materials and concrete has a lower standard deviation than gravel over the wavelength range of 619.9 nm-1323.7 nm. In terms of condition determination for asphalt roads, it is observed that the mean function gives reliable results with good success in identifying roads with good, intermediate and bad surface condition. This is because the spectra of different surface conditions differ significantly in albedo. Image ratios in the visible and in the short wave infrared help to distinguish between different surface material conditions. Experimentally, however, no significant improvement of the classification result has been observed. In particular the postulated suitability of the wavelength range 1.7082 µm to 1.7323 µm for identifying different states of asphalt requires further research.

It is observed that the number of unclassified pixels in the results presented in this paper is quite high. Further investigations are required to reduce the number of unclassified pixels. Additionally, image fusion may take advantage of the available high resolution aerial color images to overcome limits of the 4 m spatial resolution of the hyperspectral data.

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Remote Sensing and GIS in Hydrogeomorphological Studies of the Humid Tropical Meenachil River Basin, India

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Groundwater assessment, Remote Sensing, GIS, Meenachil River Basin, Kattachira subwatershed, Hydrogeomorphology, Landuse/Land Cover, Kerala, India

ABSTRACT:

Water is the most important natural resource which is at the core of the ecological system. Remote sensing and GIS provide several vistas in groundwater prospect evaluation, exploration and management. This study is aimed at identifying and delineating the groundwater potential areas in the lower catchment of Meenachil river, within the humid tropical environment of Kerala in southern India. The groundwater resources of the Meenachil river basin are under threat due to sand and clay mining and land use changes, mostly involving land reclamation through soil filling of low-elevation areas. This results in the pressing need for sustainable use of water resources, despite the area getting copious rainfall. The role of drainage, slope, lithology and landuse, besides other parameters have been emphasised for delineating groundwater potential zones. The Resourcesat (IRS P6 LISS III) data and Survey of India (SoI) toposheets of scale 1:50,000 (surveyed in 1969) together with field checks and traverses have been used as the data source. The manifestation of groundwater may thus be indirectly deduced through an analysis of remotely sensed data aided by field checks and integrated with GIS. This technique saves on time and money, which is the drawback of geophysical techniques. The subwatershed that was studied exhibits diverse hydrogeomorphological conditions where the groundwater regime is controlled mainly by topography, landuse and geology. On the basis of hydrogeomorphology, four categories of groundwater potential zones were identified and delineated. The study shows that remote sensing and geoinformatics techniques can be applied effectively for groundwater prospect evaluation, especially in the tropical south Asian nations. Such evaluations are in tune with the MDG's stated purposes of satisfying sustainably the needs of the poor and less privileged in society.

1 Introduction

The Meenachil river basin occupying three-fourths the area of Kottaym district of Kerala, India though located in an area of copious rainfalls, seasonally experiences drought and faces shortage of water for drinking and agricultural needs. Indiscriminate sand mining on the land and from the base of the river has led to the lowering of the water table. Also the surface water resources are inadequate to meet domestic as well as agricultural needs during the summer months. Thus the need to delineate groundwater potential zones in this area.is acutely felt and newer locations and potential zones of groundwater need to be identified. Remote Sensing and the Geographical Information System (GIS) with their advantages of spatial, spectral and temporal spread and availability and ease of data manipulation have become very handy tools in accessing, monitoring and conserving groundwater resources. It also has been found that remote sensing, besides helping in targeting potential zones for groundwater exploration, provides input towards estimation of the total groundwater resources in an area. Analysis of remote sensed data along with Survey of India topographical sheets and collateral information with necessary field checks help in generating the base line information for groundwater targeting. Remote sensing data has made it easier to define the spatial distribution of different groundwater prospect classes on the basis of geomorphology and other associated parameters (Sinha *et al.,* 1990; Prakash and Mishra, 1991; Tiwari and Rai, 1996; Ravindran and Jeyaram, 1997; Pradeep, 1998; Kumar *et al.,* 1999, Bhattacharrya and Reddy, 1991). Study area

Kattachira subwatershed, containing one of the major tributaries of Meeenachil river, covers an area of 71.28 km^2. The geographical location of the subwatershed extends from 9^0 40' to 9^0 46' 54" N latitudes and 76^0 31'

54” to 76^0 36’ 54” E longitudes (SOI, 1969). The climate of the region is humid tropical. The watershed comprises midlands (300-600 m elevation), lowlands (10-300 m elevation) and parts of the wetland ecosystem of Kerala. Geologically, the area has Quaternary sedimentary formations underlain by Precambrian metamorphic rocks. The area experiences high rainfall during the southwest monsoon (July-August) and northeast monsoon (October-December) seasons (avg. 2000 mm per year). Temperature ranges from 22^{0}C – 34^{0}C.

2 Materials and Methods

Resourcesat (IRS P6 LISS III) data acquired on 19th February 2004 (P100/R67) and Survey of India (SOI) toposheets 58C/10 and 58C/9 of scale 1:50,000 (1969) and geological map published by Geological Survey of India (scale 1:250000 of the year 1987) were used. The technical guidelines prepared by National Remote Sensing Agency (NRSA, 1995 & 2000) formed the basis of the methodology for the preparation of various thematic maps and final groundwater potential map. Weighted overlay analyses of drainage, lithology , landuse/landcover , geology and geomorphology is used to assess the groundwater potential of the study area.

3 Results and Discussion

3.1 Geomorphological studies

Five geomorphologic features viz., denudational hill, denudational slope, floodplain, valley fills and residual mount have been identified and delineated from the study area (Fig 1). Denudational hills are spread over the northeast of the study area. These uplifted areas, underlain by hard crystalline rock might have resisted the weathering process and is still undergoing evolution. Denudational slopes are sloping areas with rugged topography, composed of rock fragments and unconsolidated weathered materials of varying lithology which mainly act as run-off zone. Residual mounds are isolated relief projections formed due to differential erosion and resistance to erosion. Residual mounds are formed in small patches in the northwest and southeast part of the study area. Valley fills are the accumulation of unconsolidated colluvium by streams. Floodplains are flat surfaces adjacent to a river composed of unconsolidated fluvial sediments. These areas are frequently inundated during monsoon. They are primarily composed of unconsolidated materials like gravel, silt, sand and clay.

3.2 Geological setup

The major rock types are Quartzite, Charnockite, Dolerite, Pyroxenite and Magnitite-quartzite. The predominant rock types are Charnockite (66.23 km^2) and Dolerite (4.28km^2). Quartzite (0.38 km^2) is found in the northern part of the study area. Pyroxenite (0.33km^2) and Magnitite-quartzite (0.06km^2) occupy the southern region (Fig.2).

3.3 Landuse/Land cover change

Various landuse/land cover classes were identified and demarcated based on visual interpretation using Geocoded IRS IB LISS and IRS P6 LISS III satellite data (Table 1). This data was used to identify the changes that have occurred during the past 40 years. Two Level-I landuse/land cover classes were obtained from the Survey of India topographical maps (Fig 1) namely agricultural land and built up land as per modified classification system of NRSA. These two classes, with varying extents, were obtained from the 1996 and 2004 imageries. Overlay analysis was performed in order to identify the changes during the past 40 years (Fig 3, 4, 5, 7, 8). Among the agricultural land system five classes were obtained at Level–II, i.e., paddy fields, palm, rubber plantation, mixed cultivation and cleared area.

3.4 Groundwater potential zones

The thematic maps derived through the interpretation of satellite data i.e., hydrogeomorphology, drainage and geology, were digitized, edited and saved as shape files in Arcview GIS. The drainage map was digitized as line coverage whereas hydrogeomorphological and geological maps were digitized and saved as polygon coverage, assigning unique polygon IDs to each hydrogeomorphological/geological units. The maps were then projected to a common UTM projection system so as to subsequently superimpose in Arcview GIS using its overlay sub-module to demarcate groundwater prospect zones based on the above themes. Multicriteria evaluation techniques whereby each feature was given weightage according to its moisture retaining capabilities helped in narrowing down the potential groundwater rich zones. The themes outlined above were rasterised , and normalized with Spatial Analyst. It is found that floodplains with alluvium are good for groundwater development. Valley fills come under the moderate to good category, whereas residual mounds and denudational hills are categorized as having nil to poor groundwater prospects. Integration of thematic maps led to the demarcation of ground prospect map (Fig 6) which qualitatively defines the prospect zones for future ground water development in the Kattachira watershed (Table 1)

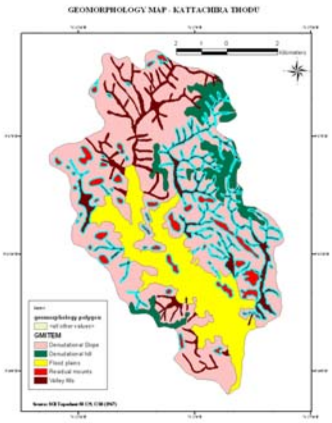


Figure 1 Geomorphology of the area

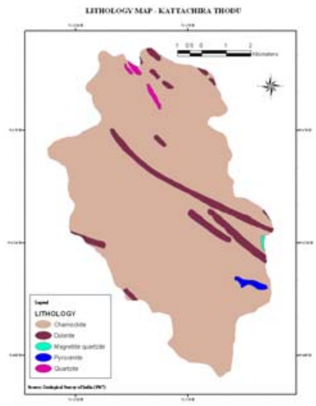


Figure 2 Rock types

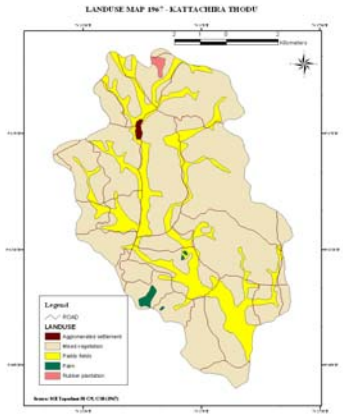


Figure 3 Landuse in 1967

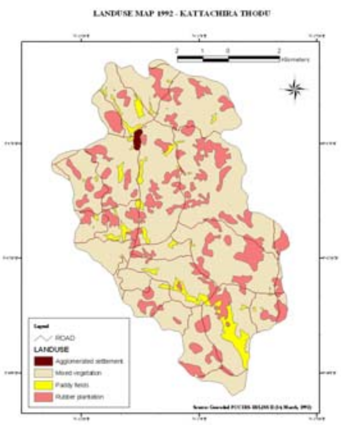


Figure4 Landuse in 1992

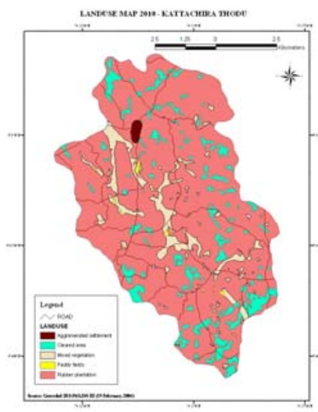


Figure 5 Landuse in 2010

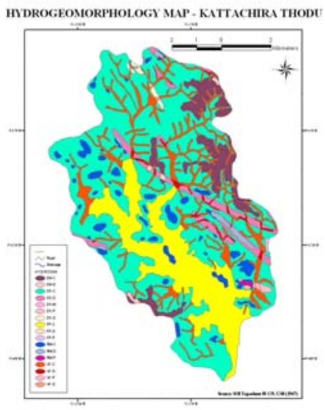
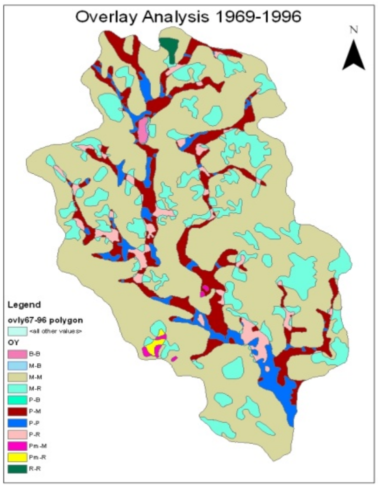


Figure6 Hydrogeomorphology



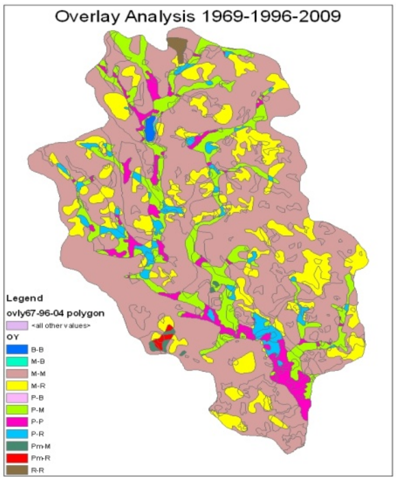


Figure.7 Overlay analysis 1969-1996

Figure8 Overlay analysis 1969-1996-2009

Table 1: Results of the GIS analysis showing groundwater prospects

Rospect Units	Rock type	Geomorphic Unit	Groundwater Prospects	Remarks
DH-C	Charnockite	Denudational hill	Nil to Poor	Runoff zone
DH-D	Dolerite	Denudational hill	Nil to Poor	-----
DS-C	Charnockite	Denudational slope	Moderate	Runoff zone
DS-D	Dolerite	Denudational slope	Poor to Moderate	Dyke acts as a barrier for groundwater flow. Upstream end of dyke is favourable zone.
DS-M	Magnetite-quartzite	Denudational slope	Poor to Moderate	Runoff zone
DS-Q	Quartzite	Denudational slope	Poor to Moderate	Runoff zone
DS-P	Pyroxenite	Denudational slope	Poor to Moderate	Runoff zone
RM-C	Charnockite	Residual mound	Nil to Poor	Prospect depends on the residual material. Generally laterites are good aquifers.
RM-D	Dolerite	Residual mound	Nil to Poor	Prospect depends on the residual material. Generally laterites are good aquifers.
RM-P	Pyroxenite	Residual mound	Nil to Poor	Prospect depends on the residual material. Generally laterites carry water.
FP-C	Charnockite	Floodplain	Good	Thick deposits of fine alluvium. High water holding capacity. Good groundwater potential zone.
FP-D	Dolerite	Floodplain	Good	Thick deposits of fine alluvium. High water holding capacity. Good groundwater potential zone.
FP-P	Pyroxenite	Floodplain	Good	Thick deposits of fine alluvium. High water holding capacity. Good groundwater potential zone.
VF-C	Charnockite	Valley fill	Moderate to Good	Loose unconsolidated fill materials add more water. Casings are required in the case of dugwells.
VF-D	Dolerite	Valley fill	Poor to Moderate	Loose & unconsolidated materials in the valley fill. Recharge zone.
VF-P	Pyroxenite	Valley fill	Moderate to Good	Loose & unconsolidated materials only hold water. Vary according to the nature and thickness of deposits Recharge zone.
VF-Q	Quartzite	Valley fill	Poor to Moderate	------------------------

4 Conclusions

GIS has been used to integrate various geoinformatics thematic maps. The integrated map thus deciphered could be useful for various purposes such as development of sustainable schemes for groundwater development in this area. The hydrogeomorphic units of the study area are mapped. From the study, floodplains underlain by charnockite, pyroxenite and dolerite are good zones for groundwater exploration and development. These zones should receive attention in future watershed development activities.

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Remote Sensing and GIS based Water Information System for the Mekong Delta / Vietnam

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KEYWORDS:
IWRM, Mekong Delta, Vietnam, Web GIS, Climate Change

ABSTRACT

The Mekong Delta in Vietnam, which covers an area of about 70,000 km², offers natural resources for several million inhabitants. However, a strong population increase, regulatory measures at the upper reaches of the Mekong, coastal erosion and changing climatic conditions lead to severe changes in the Delta. Extreme flood events occur more frequently, drinking water availability is increasingly limited, soils show signs of salinization or acidification, species and complete habitats diminish. Integrated natural resource management is required to face these problems. With that, detailed knowledge and hydrologic-, hydraulic-, ecologic-, and sociologic factors must be available. This is the subject of the WISDOM Project (Water Related Information System for the Sustainable Development of the Mekong Delta in Vietnam). It is a bilateral project between the Federal Republic of Germany and the Socialist Republic of Viet Nam. About 60 scientists from Germany and Vietnam of nine Vietnamese and ten German Institutions are involved in the project. The WISDOM project itself consists of two core components. On the one side there is a scientific component focusing on multidisciplinary issues of an integrated water management in the Mekong Delta, located in Vietnam. This scientific oriented component looks on developing methods and providing solutions for water quantity and hydrologic modelling, water quality, land use change, vulnerability, climate change related topics, socio-economic variables as well as knowledge management in pilot areas in the Mekong Delta. The second component focuses on knowledge and data dissemination issues. For this purpose a borderless customised web based Information System was developed by the project. All relevant results of the interdisciplinary project are centralized stored on a server and can be accessed through the internet. Based on the user requirement analysis a multilingual graphical user interface was developed. Customizable maps for decision support and monitoring tasks can be generated easily by the end user. Further it is possible to retrieve statistical data on geo chemistry, sociology, legal documents from the water sector, as well as literature and publications; all linked to the corresponding geo location within the Mekong Delta.

1 Introduction

The Mekong Delta as a part of the lower reaches of the Mekong River Basin covers an area of 70,000 km² and is located in South Vietnam. It marks the end of the 4,800 km long travel of the Mekong from the river head in the Tibetan plateau irrigating six countries. The Mekong plays a vital role in the Delta for the livelihood of the local population, transportation, aqua- and agriculture. The Mekong Delta is home to 22% of Vietnam's population, produces half the nation's rice output of 49 million tons a year, 60% of seafood, and 80% of fruit crops in Vietnam (Brown 2009). Seasonal floods during the wet season bring fertile sediments, necessary for agriculture. However, the probability of extreme flood and drought has increased in recent years (Delgado 2009). Damage caused by high level floods is aggravated due to increasing population density, intensified farming/aquaculture practices as well emerging industrial sites along the river and its branches. The Mekong Delta encounters further challenges and problems, such as deteriorating water quality due to strong pesticide use in rice farming areas (Huan et al. 1999), increased hormone and antibiotics concentration due to unfiltered discharge of rural and industrial wastewater as well as intensification of aquaculture practices. Changing climatic conditions and on-going rises in sea level result in salinization and acidification of soils (Husson et al. 2000), aquifers and surface water, and species/habitats de-crease. These changes are framed by regulatory measures (hydropower) happening at the upper reaches of the Mekong.

2 Project Background Information

The national Government of Vietnam formulated a policy to improve cross-functional cooperation between local authorities and citizens by knowledge transfer, strengthening local capacities, and providing downstream services for decision taking processes for water- and land resources management. This requires an interdisciplinary linkage of natural science information, socio economic information and legal information, which originates from different institutions and agencies, distributed via a virtual Information System network. It should provide decision making institutions at all levels a simple to use, borderless and up to date access to graphical enriched user interface, through which information originating from all involved interdisciplinary institutions and scientific domains can be accessed. In this way an improved regional cooperation in terms of information-, data- and knowledge exchange for a sustainable development of water- and land resources between different institutions in Vietnam should be achieved. The WISDOM Project, which acronym stands for "Water Information System for the Sustainable Development of the Mekong Delta" takes up the intention of the Vietnamese Government and tries to provide an exemplary approach which matches predefined criteria in a bilateral scientific approach. The WISDOM Project is jointly funded by the German Federal Ministry of Education and Research (BMBF) and the Vietnamese Ministry of Science and Technology (MOST). It focuses on monitoring environmental effects of Climate Change and developing adaptation strategies in the Mekong Delta, by combining socio economic with biophysical components, which results are provided through a borderless web based information system. About 60 German and Vietnamese scientists are working jointly together on several Integrated Water Resources Management (IWRM) related topics, such as "Knowledge Management", "Water Resources, River System and Water Related Hazards", "Water Knowledge and Livelihoods" accompanied by intensive capacity building measures. The project is currently in its second phase, which will last until 2013 and has seven work packages (WP): WP 1000 is the project management package, in which most of the organisational matters, such as coordinating the German partners, or the liaison to the Vietnamese partners, contacts to ministries, regional organisations and funding organisation for long term project sustainability, as well as the general administration of the project is conducted. The overall objective of WP 2000 is to implement the WISDOM Information System in Vietnam. Therefore it is necessary to understand the needs of potential end-users of the information system, which should be achieved by analysing requirements of potential end-users of the information system, Institutional Mapping of the Water Sector and capacity building measures. WP 3000 covers the design of the information system, which is the central component of the WISDOM project. All other WP from different disciplines feed their results into this system. Quantification of water resources and water quality and the relevant processes is the overall topic of WP 4000. In terms of water quantity WP 4000 analysis the impacts of climate change in the Mekong Basin, flood hydraulics and sediment dynamics, specific sediment dynamics studies like river bed sedimentation. In terms of water quality issues in the delta, WP4000 monitors the current state of water quality by on site observations and remote sensing technologies. WP 5000 addresses social issues, such as social conditions, social implications of floods, vulnerability characteristics, and impact of social parameters on water management. WP 6000 addresses the issue on developing and sustainable implement the information system for IWRM. Therefore it is necessary to find incentives for data sharing amongst the different institutions, analyse the need in terms of remote sensing data products in terms of different thematic, temporal and spatial scales. Besides, WISDOM funds 15 PhD students, who are working jointly on different IWRM related topics in the Mekong Delta. The PhD program is implemented in WP7000.

The WISDOM Project focuses its work on three case study sites, representing the main distinctive characteristics of the Mekong Delta (Figure 1). These areas are located in the Can Tho Province, the District of Tam Nong and the District of Tra Cu. Can Tho City with an estimated population of 1.2 Mio., is the biggest city in the Mekong Delta and located on the south bank of the Hau River, the bigger branch of the Mekong River. Cities and its vicinities characteristics are relevant for the WISDOM research topics in terms increasing urbanisation, immigration, average inundated area, rice production, aquaculture, poultry production, and pesticide usage for rice production. The Tam Nong district in the Dong Thap province is situated in the north-western part of the Mekong Delta also referred to as "Plain of Reeds". It is characterized by regularly deep inundated areas in the rainy season, major rice production, presence of social minorities and poverty, plans for immigration settlements. Tra Cu district in the Tra Vinh province is situated in the eastern part of the Mekong Delta and is heavily influenced by the effects of rainy and dry season and the potential impacts of Sea Level Rise such as permanent inundation and salt water intrusion into the surface and ground water.

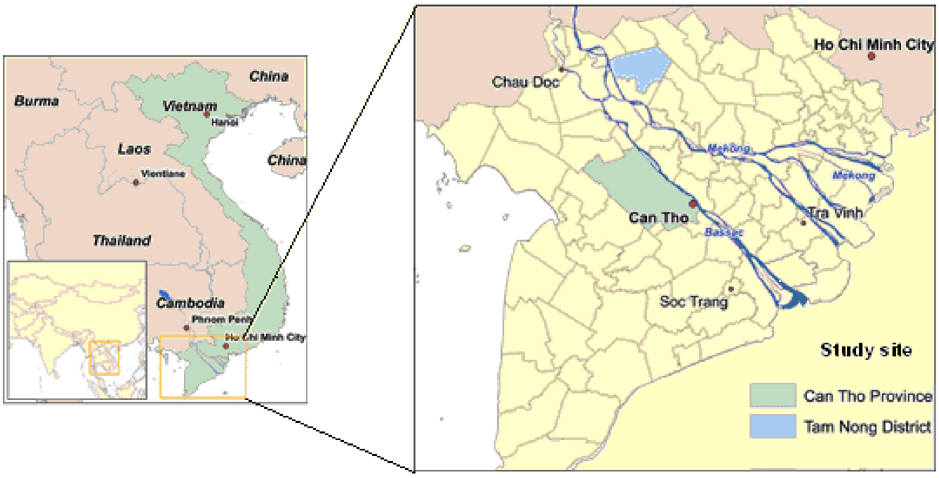

Figure 10: Field work and ground truth areas of the WISDOM project in the Mekong Delta, Vietnam

3 Methods

Prior to the technical development of the WISDOM Information system, a detailed user requirement analyses was carried out in 2008 prior to the technical development of the WISDOM Information System Prototype. The user requirement analysis evaluated what kind of data should be hosted, processed and distributed by the system. This was necessary to define and to develop the underlying data standard and was discussed and finally developed with all involved data providers of the WISDOM project. Requirements on technical aspects and the content of the WISDOM Information System were evaluated by questioning end users. Different interests and requirements resulting from different institutional as well different disciplinary background were compiled and finally poured in an overall technical system definition for the WISDOM Information System Prototype. The methodological software development approach was adjusted toward predictive software engineering models. The strength of this method is that there is no need to plan the project in detail from the tips to toes, rather than underlying evolutionary process. Therefore, feedback from the potential users is necessary, to follow this approach of vertical prototyping. A prototype comes with reduced functionality the users can test and give feedback on. By this way the user can get a feeling of the potentials the system has and how it might look like, and also identify drawbacks and missing functionalities. Furthermore, it makes it easier to adapt the whole system on changing circumstances. Key components were designed and implemented already in an early stage of the WISDOM Project to provide major functionalities to the users. Additional components were added successively, which was possible due to the modular design. This design also ensures that future adaptations of certain components and extensions can be easily implemented. The first prototype was implemented in the year 2008 and followed by a second improved one in 2010. The whole development process is accompanied by capacity building measures to support the idea of ownership und sustainability. For implementation purposes on local level in the Mekong Delta a trainer of trainer (ToT) group has been recently established which will train governmental institutions in the Mekong Delta.

The thematic specification itself has been proved to be challenging, since different end users had their focus interest on different components of the system. While e.g. the Ministry of Natural Resources and Environment, MONRE, in Hanoi is especially interested in a wide range of national data to be fed into the system, so that it can also serve further catchments in the future, some players like the DONRES (District branches of the MONRE) in the Mekong Delta are interested in as precise as possible up to data for their specific province. While socio-economic institutions in the Delta might be especially interested in the legal document database or vector data on demographic parameters, natural science institutions might especially be interested on water level data or forecasting models on sea level rise impact. Furthermore, some customers and users are extremely computer literate, while other might need more training to use the data. Some users have well established fast linked internet access, while for others the transfer speeds are too low to use the System in an efficient manner. Finally the thematic specifications had to compromise the multidisciplinary approach limited by technical, financial and time constrains.

4 Results

As already indicated, the Government of Vietnam identified the need to improve cross-functional cooperation among local authorities and citizens by an interdisciplinary linkage of natural science information, socio economic information and legal information. Information, data and knowledge are dispersed on different provincial and district level at different institutions available; however a standardized approach in sharing those is hardly in place. Information systems as they were for example designed by the WISDOM Project should provide decision making institutions at all levels a simple to use, borderless and up to date access to graphical enriched information containing information from all involved interdisciplinary institutions and scientific domains. In this way an improved regional cooperation in terms of information-, data- and knowledge exchange for a sustainable development of water- and land resources between different institutions in the Mekong Delta could be improved. The WISDOM Information System consists of five different thematic components realised through three mode client/server architecture. The three components are the data layer in the back end of the system, the business logic tier or application layer and the client layer as front end, using Java Web applications. The business logic tier is separated from the presentation tier and relates data by applying Model-View-Controller architecture patterns. Database access itself uses Data Access Object pattern (DAO) for the encapsulation of data access and its necessary data base system dependent libraries. An object relational mapping was implemented at Java side to connect data with the business logic components. An object oriented design was fully applied to ensure later extensions and adaptations to new data and additional functions. The web application itself is based on JavaScript GUI framework and communicates with the Java web applications asynchronously (AJAX technology). All necessary functions are mapped directly to server-side web actions or web services. This resource mapping to web resources guarantees an easy integration of all developed components (data query and access, processing, visualisation and so on) into other applications using simple web requests. No additional software installations are necessary to integrate WISDOM Information System into existing software infrastructures. In using web services all existing internet technologies (security, caching or distribution) can be integrated into WISDOM architecture.

The data layer consists of several relational and XML database management systems and holds all spatial and non-spatial project data. The novel aspect of this model is a semantic enabled referencing. The data layer also includes the unique feature of data processors for data value adding, developed for the specific needs of the users. This enables the system to derive information fully automated out of raw data such as satellite images. The following water management related processors are already integrated.

- Inundation monitoring: The processor allows automatic processing of radar imagery and generates inundation maps for the Mekong Delta Catchment. For this processor data from a German satellite named TerraSAR-X and a European sensor called ASAR (on board the ENVISAT satellite from European Space Agency) are applied. Radar sensors have the unique characteristic, that they can operate weather independent. Hence, this is especially in the tropics advantageous, since the moist content in the atmosphere is very high and limits the use of optical sensors. To understand the seasonal regional flood patterns in the Mekong Delta inundation time series are also generated. The inundation monitoring processor has been developed by the German Aerospace Center (DLR).
- Precipitation monitoring: The Southern Asia Daily Rainfall Estimate (RFE) of the Asian Flood Network (AFN) of the National Oceanographic and Atmospheric Administration Climate Prediction Center (NOAA-CPC) and the Tropical Rainfall Measuring Mission (TRMM-3B43) are continuously acquired and integrated into the system. This includes historic RFE data starting from the year 2003. Historic as well up to data RFE data are then enhanced by the processor to generate monthly and yearly image accumulations as an input for runoff models.
- Water quality monitoring processor: The water quality monitoring processor is not yet incorporated into the information system; however the algorithms exist and proofed to work. Applying optical remote sensing sensors natural and anthropogenic impacts on aquatic ecosystems can be observed through multi temporal monitoring of flood sediment transport, river bank erosion, diffusion of water quality parameters in the river mouth and interactions with aquaculture and industrial impacts. The turbidity products, generated by this processor utilize optical sensors such as MODIS 500m, 250m, SPOT 10m, Quick Bird 4m, ASTER 20m and IKONOS. The water quality monitoring processor was developed by company EOMAP and will be implemented by 2011.
- Soil moisture: This processor provides products on soil moisture on the Lower Mekong Basin based on ENVISAT ASAR sensor. Soil moisture is a crucial component of the hydrologic cycle, having a strong influence on runoff, sedimentation and erosion processes in river catchments. As a temporal and spatial highly variable parameter, soil moisture can hardly be monitored over larger areas by solely building on in-

situ measurement techniques, hence remote sensing techniques offer a suitable solution (see Figure 2). This processor was developed by the TU Wien in Austria.

- Detection and monitoring of changes at the earth surface: This processor, which is not yet in place, intends to implement target-actual comparisons conducted on MODIS satellite imagery time-series for the whole Mekong Delta. The challenge lies in detecting automatically significant changes in pixel or object properties, independent of periodic changes like natural phenology. Hence, indicators which are based on remote sensing time-series allow the detection of unnatural changes in the environment. The processor, which is developed by the DLR, targets on providing an environmental monitoring and alarming tool.
- Data access: Data access is granted by several web services. These services are controlled vie Open Geospatial Consortium (OGC) compliant Web Processing Services (WPS), which allows an easy borderless data exchange. Data access is managed by Web Coverage Service (WCS) for raster data and Web Feature Service (WFS) for vector data. With this encapsulation every process can be controlled by the middleware for data processing. Thereby a process can be designed simple (data re-projection) or more complex (ready compiled PDF report) and offers to process resource intensive data on the server side. Results can be visualised on the client side with very little effort. Beside WISDOM client, other OGC compliant software is able to connect to our data and processes. The main advantage is a possible integration into other software environments using these services.

The business logic is implemented in the application layer as middleware. Necessary libraries and functionalities for direct user interactions is organised through a web layer. All applied libraries and applications are open source licensing models (OGC).

The client layer provides the graphical user interface (GUI). It allows the system user to perform different queries in different tool boxes; to visualize maps, to search for legal documents, to download data and so on. The database of the System has been structured based on spatial, thematic and temporal aspects of the data. Data with different geographic extend and from different locations on socio economy, agriculture and forest land use, water quality, infrastructure and water levels have been integrated. Those data have been generated, collected and compiled during the last three years by Vietnamese and German partners of the WISDOM project. Together, all these data sets form the data basis on which the information system builds upon.

From the user's perspective, six thematic interfaces are provided:

- Overview portal: Users get an overview of new imported datasets and can access import documentation
- Data Explorer: Data can be queried using thematic, temporal and spatial arguments due to internal organization in a semantic way
- Map Explorer: Every dataset can be viewed in a map application. Datasets can be rearranged and combined to different purposes (Figure 2)
- Yellow Pages: Organizational data and points of contact can be searched and accessed via our yellow page application. Administrative and legal documents are connected to the publishing organizations
- Campaign Explorer: In situ data is one key element for data understanding, evaluation and validation. User can access published data derived from field and measurement campaigns
- Upload Module: Authorized users can upload their OGC compatible data to the Information System through an interactive graphical user interface.

4 Outlook and Discussion

The second phase of the project was approved in August 2010, which enabled the project to continue its scientific work seamless for further three years. The focus in Phase II of the WISDOM Project is set on climate change and adaptation strategies, by combining the socio economic with the biophysical components of the project. This comes along with the formulation of the 'National Water Resources Strategy until 2020', the 'National Target Plans for Water Resources Management' and 'Climate Adaptation' released by the Ministry of Natural Resources and Environment. Since the effects in the Mekong Delta such as floods depend strongly on the run off scheme up streams, the project area itself was extended, covering almost all 13 Provinces of the Mekong Delta and parts of the Mekong Basin. WISDOM will develop the information system further towards a highly automated open source based information system, requiring minimal human interaction for acquiring and analysing data and generating maps, which can be easily interpreted. The expected project outcome will be the operationalization and implementation of the WISDOM Information System, providing local authorities and other IWRM related intuitions a valuable tool for the management of the Mekong Delta Catchment, which should be ensured by appropriate capacity building measures in the Mekong Delta on local level.

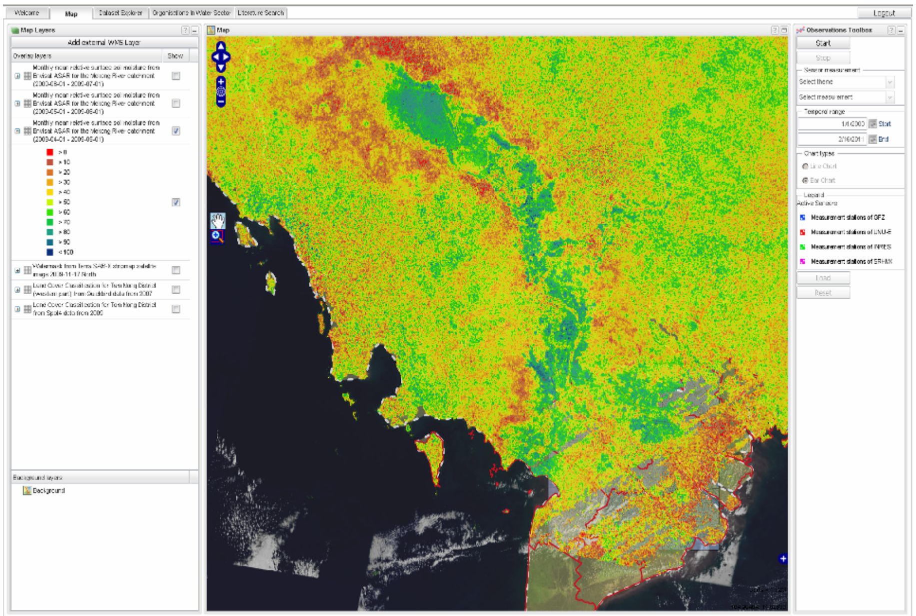

Figure 2: The Map Explorer of the WISDOM Information System shows soil moisture data derived from ASAR, which are updated weekly

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Integration of Area Frame Sampling Technique and Classification of Satellite Images for Crop Area Estimation

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KEY WORDS:
Area Frame Sampling (AFS), remote sensing, supervised classification, unsupervised classification, LANDSAT, stratification

ABSTRACT

FATA (Federally Administered Tribal Areas) is Pakistan's poorest tribal mountainous region bordering Afghanistan. Agriculture is the largest economic activity but the availability and estimation of cultivated and non-cultivated agricultural land is one of the major issues for agriculturists and planners. The aim of the study was to estimate crop area to be used for land reclamation intervention by the Livelihood Development Programme (LDP). Three independent processes were conducted and integrated to estimate crop area like a ground survey of randomly sampled areas based on Area Frame Sampling (AFS); satellite image classification of target area (FATA); integration of classification and AFS. The Material of Interest (MOIs) or samples for this study were sets of crops like wheat, vegetables, tobacco, sugar cane, maize etc. The AFS tools were utilized to provide a statistical procedure to estimate MOI using a single sampling strategy. The LANDSAT 5 satellite images from U.S Geological Survey were used for supervised and unsupervised classification. Our study outcome shows that out of the total land area, about 89.54% (including barren, mountain and unclassified land) is non-cultivated land while only 6.69% is cultivated land and forest (3.42%). The reason for non-cultivation of land is insufficient rainfall, and also militancy and recent military operations. Out of the total cultivated land, wheat crop (3.91%) is the major cultivated crop followed by maize (1.55%), vegetables (0.96%) and tobacco (0.26%). No sugar cane crop is reported as part of this study.

5 Introduction

Agriculture is FATA's largest economic activity but people face many input and resource problems. The availability of agricultural land is one of the major issues that constrain food security and commercialized farming. LDPs' Land Reclamation intervention program was initiated to transform non-cultivated land into cultivated land. Derivation of land use/cover and estimation of agricultural production through classical methods are costly, time consuming, and subject to a variety of errors in terms of types and sources. Recent developments in GIS and remote sensing technologies and crop modeling have created promising opportunities for improving agricultural statistics systems (Aronoff, 1989; Burrough, 1986; Laurini & Thompson, 1992; Molenaar 1998; Buiten & Clevers, 1990; MacLean, 1995; Sharifi, 19921).

AFS for estimation of cultivated crops is a statistical method to measure the area of land cultivated to a specific set of crops to Agriculturists (Surveyors) over a geographic study area of interest. The 'area frame' limits the area of interest, or study area. It may be covered by a natural boundary or an administrative unit like district. The area frame can be constructed using a combination of both natural and administrative boundaries (Pradhan, 2001). In this study, district 'Charsadda' was proposed as area frame, which lies between settled area of Khyber-Pukhtunkhwa Province and mountainous area of FATA of Pakistan. Remote sensing (LANDSAT 5) images were used for land use classification to assist the agriculturalists in producing the most accurate estimates for the

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[a] UPPER FATA Livelihood Development Programme (LDP) is a USAID (United States, Academy for International Development) assisted Government of Pakistan initiative for Federally Administered Tribal Areas (FATA) of Pakistan.

least possible cost. The Material of Interest (MOIs) identified in this area frame are set of crops (wheat, sugar cane, tobacco etc).

The AFS tools were used to provide a statistical procedure to estimate MOI using a single sampling strategy. Allocation, collection and identification of samples from the area frame are required for AFS. (Turner, 2003). Allocation and analysis of samples within FA was carried out as part of stratification process. For this purpose, fewer samples (crops) were allocated for potential equivalent result. The AFS processes performed as part of this paper include: preparation for AFS; defining area frame and MOI and allocation of samples; defining Principle Sampling Unit (PSU), allocation and analysis of samples and land use classification. The findings of this study were compared with outcomes of FATA secretariat.

6 Methology for Frame Sampling

Set of source materials from which the sample is selected is simple definition of a sampling frame or frame sampling. The purpose of sampling frames is to provide a way for choosing the particular crop of the target cultivated area. Generally, more than one set of materials may be necessary but in our case only a one set of crops are required.

6.1 Data and Tools

The available functions of Frame Sampling Tools within the framework of ERDAS IMAGINE were used to conduct the Frame Sampling. The Frame Sampling Tools program keeps track of required files and results, as well as the project history during processing of operations in the statistical procedure. An existing land-use map of study area was helpful for stratification of area against other areas. Project base data such as boundaries, area visited for samples etc was retrieved from LDP databases. LANDSAT 5 imagery was used to stratify study area into 9 “classes.” selected for cultivated cover content analysis.

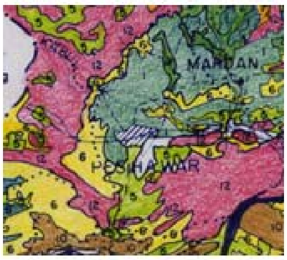

Figure 1 Land use map of study area

6.2 Defining Area Frame

In this study, Area Frame (AF) is a geographical designation that includes a group of villages with farmers growing and having potential for a specific crop. The area visited and collected samples for this study covers a small portion of settled and mountainous area (district Charsadda) adjacent to FATA. Figure 2 shows the AF which covers an area of about 3900 km^2. The frame area lies at 34°11'54.60'N, 71°42'33.24'E and 34° 17' 04.6'N, 71°47'44'E. Charsadda district shown in Figure 2 is 17 miles away from Peshawar city located in the west of the Khyber Pukhtunkhwa province of Pakistan. The area is surrounded by Malakand District on the north, Mardan district on the east, Nowshera and Peshawar districts on the south. Mohmand Agency of the FATA lies on the west of our AF. Vegetables include Potato, Tomato, Cabbage, Brinjals, Okra and Spinach.

6.3 Material of Interest (MOI)

Amount of land cultivated to a specific crop, or set of crops in study area as MOI is required for AFS. Sample labels assigned to each parcel such as “Wheat”, “Vegetables”, “Tobacco”, “Sugar Cane”, “Maize Crop”, “Fruit Orchards” and “Forest and Trees”. Estimates for more than one MOI by iterating analysis were derived. Material of every parcel of land shown in Table 1 in the area frame (Charsadda) was correctly identified to guarantee accurate result. The Frame Sampling Tools software assumes one MOI during the implementation of statistical procedure ERDAS (2003).

6.4 Defining Principal Sampling Grid

The first step for defining sampling frame is to choose the option for Principal Sample Unit (PSU). Sample selection requires sampling grid. This grid contains vector polygons. Although, two options for sample frame definition are available: definitions PSU as "Vector" and "Grid Generation" of Frame Sampling Tools (FST). We choose the later one to define a uniform grid over the area frame as FST supports only single sampling technique. The other reason was the smaller and manageable size of the frame area. So, it was easy for us to identify all parcels in the sample as accurately as possible.

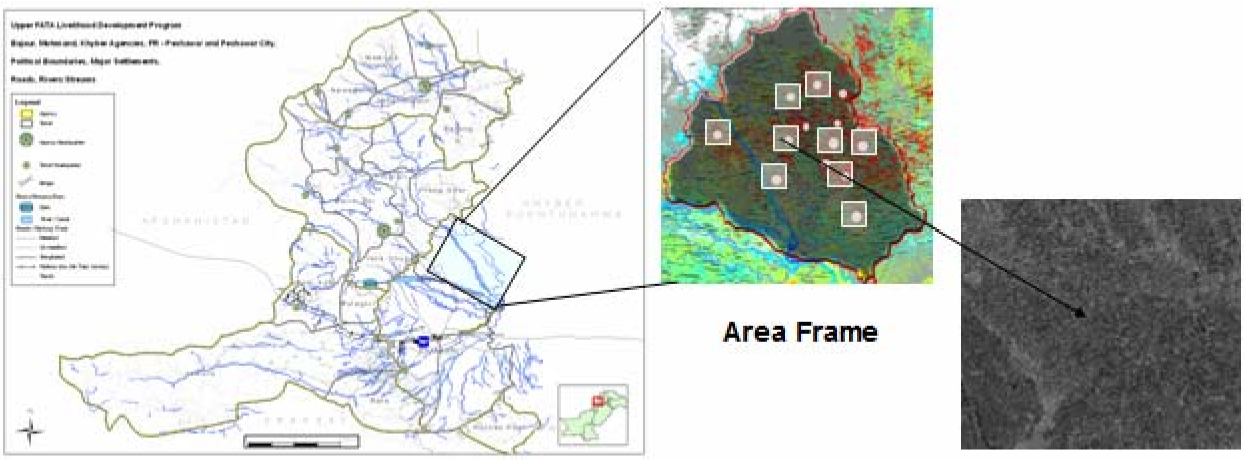

Figure 2: Area Frame (district Charsadda) with geographical boundary of FATA

6.5 Allocation and Analysis of Crop Samples for Stratification

The next step for defining the sampling frame is stratification which involves a process of grouping homogeneous areas relative to the MOI described above. Desired accuracy can be achieved by defining fewer samples to make each stratum more homogeneous. It is not necessary to stratify, if we can allocate and analyze a sufficient number of samples to achieve the statistical performance desired. We have tried to correctly allocate and analyze seven samples as part of stratification process. The steps involved in stratification process were: sampling project is created; project files are assigned; grouped files are recorded; sampling grid is created; samples were selected for interpretation; Dot Grid Tool is used to label the samples; and final analysis is carried out using fraction files.

Table 1: Location and covered area of clusters surveyed for random sampling (crops samples collected from shaded area)

Ground survey of randomly sampled areas based on AFS				Samples (Crops) Collected						
Clusters surveyed for Sampling	Latitude	Longitude	Cluster Area [ha]	Wheat	Vegetables	Tobacco	Sugar Cane	Maize Crop	Fruit Orchard	Forest and Trees
Chine	34° 13' 43.6182"N	71° 41' 20.6982"E								
	34°14'10.01"N	71°41'58.54"E	144,000.0							
Kot	34° 11' 54.6"N	71° 42' 33.2382"E								
	34°11'3.37"N	71°44'41.23"E	56,250.0							
Nimare Baba Ziarat	34° 12' 13.68"N	71° 43' 5.2212"E								
	34° 12' 19.7388"N	71° 43' 7.86"E	2,560.0							
Momuri baba	34° 12' 20.52"N	71° 43' 23.4588"E								
	34°12'12.97"N	71°43'19.86"E	3,240.0							
Nimoday Base	34° 12' 19.08"N	71° 43' 35.5188"E								
	34° 13' 1.4412"N	71° 43' 38.3406"E	90,250.0							
Turangza	34° 12' 38.4588"N	71° 44' 39.5406"E								
	34° 13' 08.321"N	71° 44' 44.56"E	56,250.0							
Shanpyac	34° 16' 57.7806"N	71° 43' 37.5594"E								
	34° 16' 57.7194"N	71° 43' 34.4994"E	360.0							
Abdulabad	34° 12' 23.3382"N	71° 46' 27.2994"E								
	34° 12' 41.7594"N	71° 46' 37.74"E	29,160.0							
Ajara	34° 13' 10.0812"N	71° 46' 55.3182"E								
	34° 13' 14.8182"N	71° 46' 50.6994"E	1,440.0							

6.6 Land Use Classification Using "Class Grouping Tool"

The use of Frame Sampling and remote sensing (LANDSAT 5) assisted in achieving the most accurate estimate for the least cost. Satellite imagery provides the analyst with a synoptic view of the entire Frame. The classification methods "Unsupervised Classification" within "Class Grouping Tool" provide two methods of "stratification", or creating smaller homogenous units that represent the entire Frame. This stratification reduces the number of samples that are allocated to provide an accurate result. Table 1 shows the total area covered in each cluster and presence of cultivated crops in these clusters as part of this Frame Sampling study. LANDSAT 5 imagery was used to stratify study area into 9 "classes." selected for cultivated cover content analysis. Dot Grid approach was utilized to delineate each sample's crop cover area.

The accuracy of the final result, for example, the area cultivated to crops depend on the number of samples identified, and the accuracy of the labels assigned to each sample. Amount of material of every parcel of land shown in Table 1 within the area frame was correctly identified to guarantee accurate result. LANDSAT 5 satellite imagery taken in June 2009 was used for unsupervised and supervised classification for cultivated land cover content analysis shown in figure 3 and figure 4 respectively.

7 Errors – Commission and Omission

Random error was a source of variance in this research. The FS tools were used to approximate the variance in the estimate deterministically for three sources: sample size, stratum stationarity coupled with cluster sample size, and labeling errors. Significant variance was experienced due to strata in which the MOI was under-sampled. Such areas were omitted from the area frame.

7.1 Unsupervised Classification

Unsupervised classification is simpler than a supervised classification, because the signatures are automatically generated by the ISODATA algorithm. ISODATA algorithm of ERDAS IMAGINE was used to perform an unsupervised classification. Minimum Spectral Distance (MSD) formula of ISODATA clustering method was used to form clusters. It begins with either means of arbitrary cluster or an existing signature set. Each time the clustering repeats, the means of these clusters are shifted. The new produced means of cluster are used for the next iteration. Clustering of the image is repeated until either a maximum number of iterations are performed, or a maximum percentage of unchanged pixel assignments are reached between two iterations.

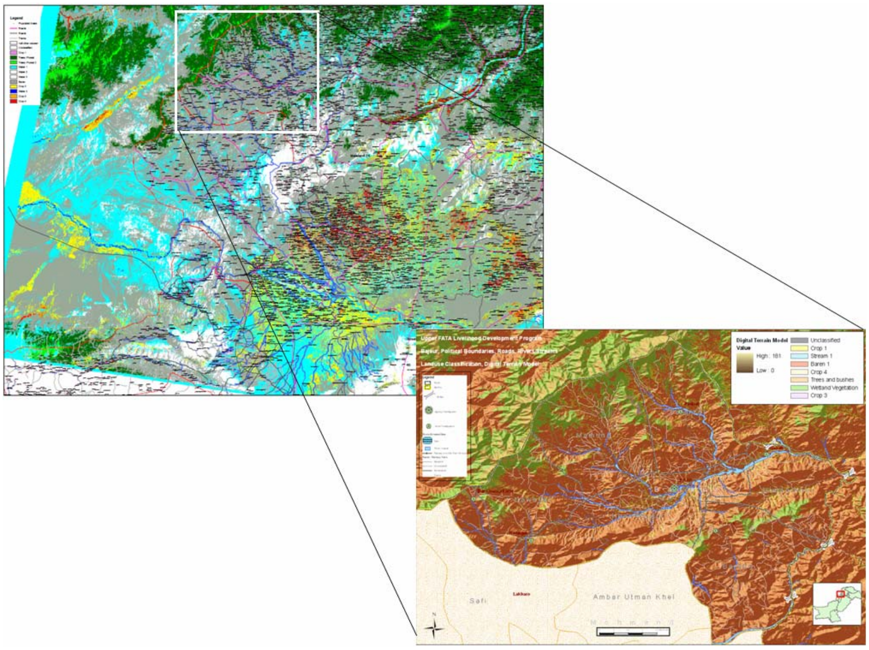

Figure 3: Result of unsupervised classification (top) and with hill shade (DTM) in Bajaur Agency of FATA (bottom)

7.2 Supervised Classification

In this process, we need to select pixels that represent patterns we recognize or that we can identify with help from other sources. Knowledge of the data, the classes desired, and the algorithm to be used is required before we begin selecting training samples. By identifying patterns in the imagery, we can train the computer system to identify pixels with similar characteristics. By setting priorities to these classes, we supervise the classification of pixels as they are assigned to a class value. If the classification is accurate, then each resulting class corresponds to a pattern that you originally identified. We kept separate signatures for each variation within a single land cover type. Three or more signatures were collected for every land cover type to be classified. Signatures contained 28.5 as pixel size. Table 2 shows the distribution of pixel count number obtained for each class.

Table 2: Distribution of pixel count number obtained for each class

Results Based on AFS (2010)								
Crop	Wheat	Tobacco	Maize	Vegetables	Forest	Water	Unclassified	Barren / Mountain
Pixel (Count)	2,227,023	148,089	882,835	546,788	1,947,934	216,437	11,567,991	39,431,415
Percentage	3.91%	0.26%	1.55%	0.96%	3.42%	0.38%	20.31%	69.23%

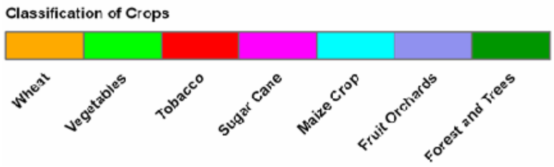

Figure 4: Result of supervised classification based on AFS

8 Findings

Crop production in FATA is mainly subsistence. There are few livelihood opportunities available to the people. The local economy is mainly pastoral, with agriculture practiced in a few fertile valleys. Most households are engaged in primary-level activities such as subsistence agriculture and livestock rearing, or small-scale business conducted locally. Others are involved in trade within the tribal belt or with down-country markets FATA Secretariat (2003-04).

Update-to-date estimates from FATA Secretariat were not available as survey is conducted in after each ten years by FATA Secretariat. The outcome resulted from this AFS study is compared with outcome of land use data processed by FATA Secretariat of 2003–04. FATA Secretariat (2003) shows that 73 % of the total geographic area of FATA is cultivated compared to 6.69% of cultivated land result obtained from this study. The table 3 below shows that about 90.87% of the land is not available for cultivation as compared to our study result of 89.54% (included barren, mountain and unclassified land) as non-cultivated land. This study result shows that wheat crop (3.91%) is the major cultivated crop followed by maize (1.55%) and vegetables (0.96%) and tobacco (0.26%). No Sugar cane crop is reported as part of this study in FATA. The estimated average production of wheat under rain fed condition is 600 kg grain and 1,000 kg straw per acre while 1,000 kg grain and 1,500 kg straw under irrigated conditions with total income per acre US$ 145.2 in former case while US$ 232.2 in later case LDP (2010).

There are farm households that are engaged in commercial level production of specific vegetables, such as autumn vegetables in Arang Bajaur Agency, off-season tomato in Prang Ghar, and Chilies in Pandiali, Mohmand Agency. Similarly, Jana kor in FR Peshawar and Miri Khel, Khyber Agency were potential areas for growing off-season vegetable production under plastic tunnels LDP (2010).

Table 3: A comparison of land use assessment between the FATA Secretariat and outcome of this study

Outcome of this study (2010)			Results Based on (FATA Secretariat) Estimates	
Crop	Percentage	Estimated Area (ha)		Estimated Area (ha) – 2004
Wheat	3.91%	106,432	Cultivated area	7.33%
Tobacco	0.26%	7,077		
Maize	1.55%	42,192		
Vegetables	0.96%	26,132		
Sugar Cane	0.00%	0	Current fallow	1.12%
Forest	3.42%	93,094	Forest area	1.70%
Water	0.38%	10,344		
Unclassified	20.31%	552,847	Uncultivated area	90.70%
Baren or Mountain	69.23%	1,884,470		
Total Area (FATA)		2,722,042		

9 Conclusion

The reasons for non cultivation of the vast land are insufficient rainfall, and also militancy and recent military operations. However, different initiatives for soil conservation and irrigation schemes can be initiated to maximize the land productivity and protect it from floods. Advanced agricultural techniques can be initiated for this purpose. The results were compared with results derived by the FATA secretariat and Federal Bureau of Statistics, Ministry of Economic Affairs, Govt. of Pakistan to assess the accuracy and reliability of the system. The overall accuracy was 91.82% (1.77% difference in cultivated area, 1.72% in forest, and 1.16% in non-cultivated area), which was satisfactory; it can be concluded that the reliability and the accuracy of the system is acceptable.

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Classification of Roof Materials Using Hyperspectral Data

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KEYWORDS:
Hyperspectral, Urban, ALK Vector data, Classification, Feature extraction, Roof

ABSTRACT:

Mapping of surface materials in urban areas using aerial imagery is a challenging task. This is because there are numerous materials present in relatively small regions, which contribute to the reflected radiance. Hyperspectral data features a fine spectral resolution and thus has a significant capability for automatic identification and mapping of urban surface materials. In this study an approach for identification of roof surface materials using hyperspectral data is presented. The study is based on an urban area in Ludwigsburg, Germany, using a HyMap data set recorded during the HyMap campaign in August, 2010. Automatisierte Liegenschaftskarte (ALK) vector data with a building layer is combined with the HyMap data in order to confine the analysis to roofs and thus avoid confusion between roofs and other objects such as roads with similar spectral properties. A spectral library for roofs is compiled based on field and image measurements. In the roof material identification process, supervised classification methods, viz. the pixel-based Spectral Angle Mapper (SAM), Spectral Information Divergence (SID) and the object-oriented Extraction and Classification of Homogeneous Objects (ECHO) approach are compared using the established spectral library. In addition to the overall shape of spectral curves, the position and strength of absorptions features are used to enhance material identification. Feature extraction methods such as the Discriminant Analysis and Decision Boundary Feature Extraction (DAFE, DBFE) are also applied to the data in order to identify features or band combinations suitable for discrimination between the target classes. The identified optimal features from the feature extraction are used to create a new data set which is later classified using the ECHO classifier. The classification results with respect to material types of roofs are presented in this study. The most important results are evaluated using orthophotos, probability maps and field visits.

1 Introduction and related research

Urban environments are characterised by many different artificial and natural surface materials which reflect and influence ecological, climatic and energetic conditions of cities. They include mixtures of materials ranging from concrete, wood, tiles, bitumen, metal, sand and stone. Complete inventories based on analog mapping are very expensive and time consuming. Additionally, the information that can be extracted by the interpretation of aerial RGB images is limited.

Hyperspectral data has a high spectral resolution and thus a high potential for the recognition of urban surface materials on a very detailed level and in an automated way. However, the development of optimal methods for analysing hyperspectral data is still a challenge. So far there is no standard approach to material classification. Problems are the high within-class variability of the most common materials and the presence of numerous materials in relatively small regions. A hyperspectral pixel in an urban scene features most frequently a mixture of different material components; the classification therefore requires a decomposition of the corresponding spectral signature into its pure constituents (Bhaskaran & Datt, 2000).

Most of the research done on hyperspectral data in the past focused on mineral detection rather than urban surface materials such as roofs. This has changed recently due to the high pace of city development and the increase in the need to find efficient methods for mapping urban surface cover types. (Roessner et al., 2001) develop an automated method for hyperspectral image analysis exploiting the spectral and spatial information content of data in order to differentiate urban surface cover types. To achieve this, a hierarchical structure of categories is developed. The main categories are defined as sealed (buildings, roads etc.) and non-sealed surfaces (vegetation, bare soil). Similar research is carried out by (Segl et al., 2003). They analyse urban surfaces taking into account their spectral and shape characteristics in the reflective and thermal wavelength. A new algorithm for an improved detection of pure pixels is incorporated in an approach developed for automated identification of urban surface cover types, which combines spectral classification and unmixing techniques to facilitate sensible endmember detection. (Dell'Acqua et al., 2004) investigate spatial reclassification and mathematical morphology approaches. Spectral and spatial classifiers are combined in a multiclassification framework. The use of morphological approaches yields high overall accuracies.

The approach taken by (Powell et al., 2007) is similar to that adopted in the present study. They build a regionally specific (Manaus, Brazil) spectral library of urban materials based on generalized categories of urban landcover components such as vegetation and impervious surfaces. Almost 97% of the image pixels are modeled within a 2.5% RMS error constraint. The RMS error indicates the overall fit of the linear unmixing process. (Heiden et al., 2007) propose a new approach for the determination and evaluation of spectral features that are robust against spectral overlap between material classes and within-class variability. The approach is divided into two parts. In the first part, spectral features for each material of interest are defined that allow an optimal identification and separation based on the reference spectra contained in the spectral library. For the second part, the robustness of these features is evaluated by a separability analysis. The results show that urban materials need to be described by more than one type of feature. Materials characterized by distinct absorption bands and/or reflectance peaks can be well detected using functions such as ratio, area, absorption depth and position. Additionally, the idea of integrating ancillary data in HyMap analysis used by (Heldens et al., 2008) is also adopted in this research. The goal of the research by (Heldens et al., 2008) is to identify urban surface materials in Munich from HyMap data. They use an unmixing approach to identify surface materials. The unmixing approach is performed with and without a building mask. The quality of the co-registration of the hyperspectral data and the building mask has a large impact on the results. Applying the approach with the building mask gives the following results: 26.6% of the pixels are identified as spectrally pure, 70% of the pixels are mixed and the amount of unclassified pixels is about 3.6%. The results obtained without the building mask are: 19% of the pixels are spectrally pure, 78% are mixed and 2.6% are unclassified. For a more comprehensive review of related work please refer to (Chisense, 2011).

In the present study, a material classification is performed for roofs only. The corresponding areas are identified by means of ALK vector data; hereby the confusion between roofs and roads with similar spectral properties is avoided. Information is extracted from the hyperspectral data using the Discriminant Analysis Feature Extraction (DAFE) method. This method is used to determine an optimal set of features for further analysis, where in this particular case the term “feature” means “spectral band”. Those linear combinations of bands are considered as optimal, for which the ratio of between-class variability and within-class variability is a maximum, see e.g. (Kuo & Landgrebe, 2004). The corresponding variational problem leads to a generalized eigenvalue problem. A subset of the transformed bands is selected depending on their respective eigenvalues. The new data set is classified using a spatial-spectral (object-based) classifier known as Extraction and Classification of Homogeneous Objects (ECHO). This method provides for a good discrimination of spectrally similar materials belonging to spatially distinguishable objects. Orthophotos, classification probability maps and field visits are used in order to evaluate the quality of the classification results. For the classification of roofs using hyperspectral data various methods have been investigated, but only those which led to the most successful experimental results are discussed in the following.

2 Study area, hyperspectral image data and preprocessing

The hyperspectral data used in this study was acquired by German Aerospace Center (DLR) on 20th August, 2010 in the course of its annual HyMap campaign. The data covers the city of Ludwigsburg, Germany, which is located close to Stuttgart in the Neckar basin. The scene comprises six strips and extends also over adjacent rural areas apart from Ludwigsburg city itself. The total area amounts to 11 km x 16 km. The data includes a variety of typical urban structures such as residential and industrial zones, railway stations and different roads. We restricted our tests to a small urban area of approximately 2.0 km x 1.1 km. The data consists of 125 bands (ranging from 0.4 µm to 2.5 µm) and has a ground sample distance of 4 m. ALK vector data with a building layer is provided by Fachbereich Stadtplanung und Vermessung der Stadt Ludwigsburg. The vector data is used for limiting the analysis to roofs. The preprocessing of the hyperspectral data was done by DLR; in particular the data was corrected for radiometric, geometric and atmospheric effects. A high resolution LiDAR surface model of Ludwigsburg with 2 m raster size was made available for this purpose.

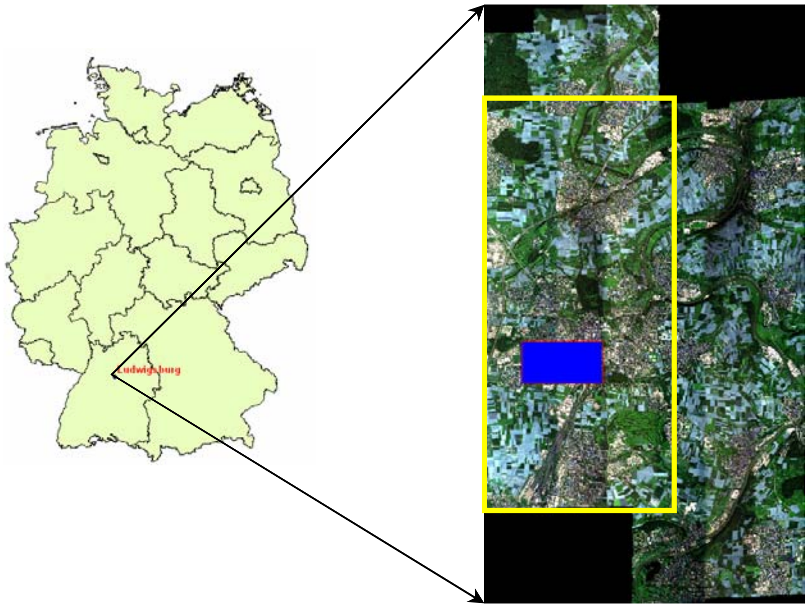

Figure 1: Location of test (blue) and research area (yellow) in Ludwigsburg city

An overlay of the HyMap data and the vector data reveals an offset between the two datasets in the order of 10m. The vector layers for roofs are selected as sources of ground control points. The GCPs are used to georeference the HyMap data. It is observed that an overall RMS error of about 0.7 pixels is obtained after carrying out an affine transformation.

3 Methods and results

The investigation is divided in two parts. The first part discusses the roof material identification in the test area while the second part focuses on the whole research area.

3.1 Roof surface material identification

A first look in a shop of roofing materials already reveals that a great variety of materials has to be expected in roof surface material identification. Roof tiles made of materials like clay and slate are on the market as well as those made of concrete and plastic. The widely used clay tiles are manufactured again in different ways; for instance some clay tiles have waterproof glaze.

In the initial stage of the research work, 10 materials are selected for roof material identification. Three materials, viz. bitumen, red roof chipping and zinc plated sheet are identified by name from previous field visits. The remaining seven are assigned arbitrary names for identification purposes and include roof material from the Kaufland shopping centre (Ludwigsburg), roof material 1, 2, 3, 4, 5 and 6. In order to map the distribution of the ten roof materials in the scene, the Discriminant Analysis Feature Extraction (DAFE) available in MultiSpec is applied. This is followed by a classification of the data set consisting of the optimal features (band combinations) resulting from the feature extraction. MultiSpec is a data analysis software intended for analysis of multispectral image data or hyperspectral data. The following steps are used in order to accomplish the analysis tasks:

3.2 Selection of classes and their training sets

In order to identify and define suitable training regions, the HyMap data is classified using an unsupervised classification algorithm. The ISODATA algorithm is used for this purpose. With the aid of the output map, training regions for the 10 material classes are defined. A class for vegetation (eleventh class) is added as certain building parts include vegetation. Additionally, a class for the masked out area (background) is defined.

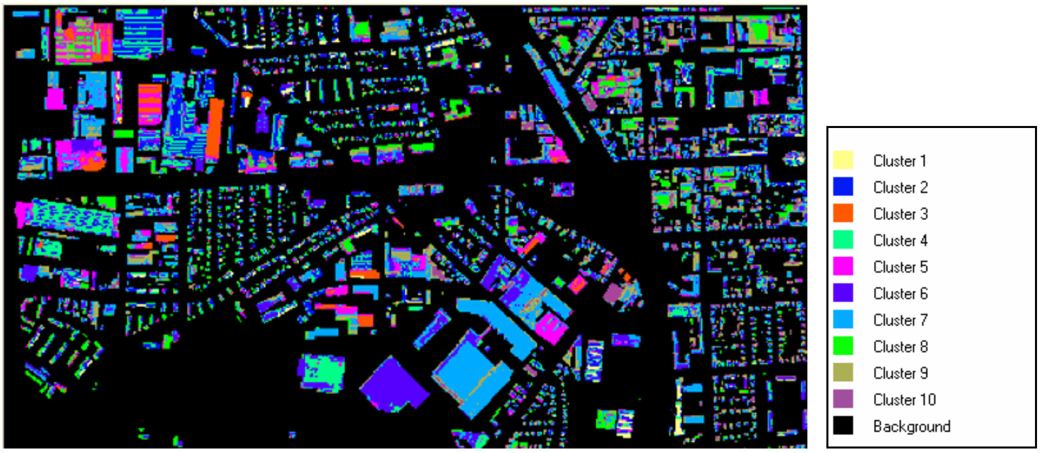

Figure 2: Output map of the unsupervised classification process (ISODATA).

3.2.1 Feature extraction and classification

After designating a set of training regions, a class conditional preprocessing algorithm based on a method known as Projection Pursuit is performed. This algorithm does the necessary calculations in projected space rather than the original, high dimensional space thus reducing the dimensionality of the data. This is followed by DAFE (determines a feature subspace that is optimal for discrimination between defined classes). The output of the extraction consists in linear combinations of the 125 original bands that automatically occur in descending order of their generalized eigenvalue for producing an effective discrimination. Twenty-two (22) features are obtained from the feature extraction process. However, only the 11 features obtained in the final feature extraction transformation matrix (DAFE) are used to form a new data set since these provide most of the available separability; this is confirmed by the magnitude of the corresponding eigenvalues. The new data is classified using the ECHO classifier. The output classification map is overlaid with an orthophoto covering the area as shown in figure 3.

Figure 3: Overlay of classification map and orthoimage

The classification map fits well with the orthophoto and this gives an indication of the accuracy of the classification in terms of geometry. In order to identify areas in the classification map which require improvement, the corresponding classification probability map is inspected (see figure 4). The pixels represented by yellow to red colours in the probability map indicate a high probability of being correctly classified. The transformed spectral signatures of these pixels are very close to the signatures of the corresponding training pixels. Dark blue colours represent a low probability of correctness. The pixels represented by these colours are very far from the training pixels for all the classes and are candidates for the definition of additional training regions.

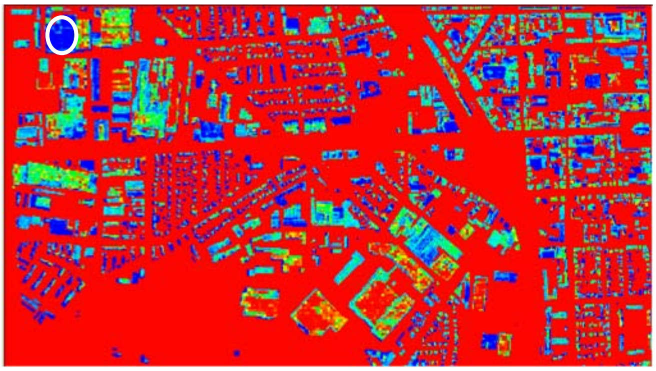

Figure 4: Classification probability map.

Defining additional training regions for areas with a low probability helps to improve the result. Most of the roofs in the probability map with a low likelihood of being correct consist of heterogeneous surface materials. For instance, the material of the roof in a white circle is not homogeneous. Defining training regions for areas requiring improvement is sufficient for achieving a classification result that represents ground features accurately. However, the required number of additional training regions depends on the scene, the material classes of interest and the accuracy requirements.

The Discriminant Analysis Feature Extraction and the ECHO classifier are applied to the whole research area. The processing and analysis is done for each strip. The result obtained for three individual strips is shown in figure 5.

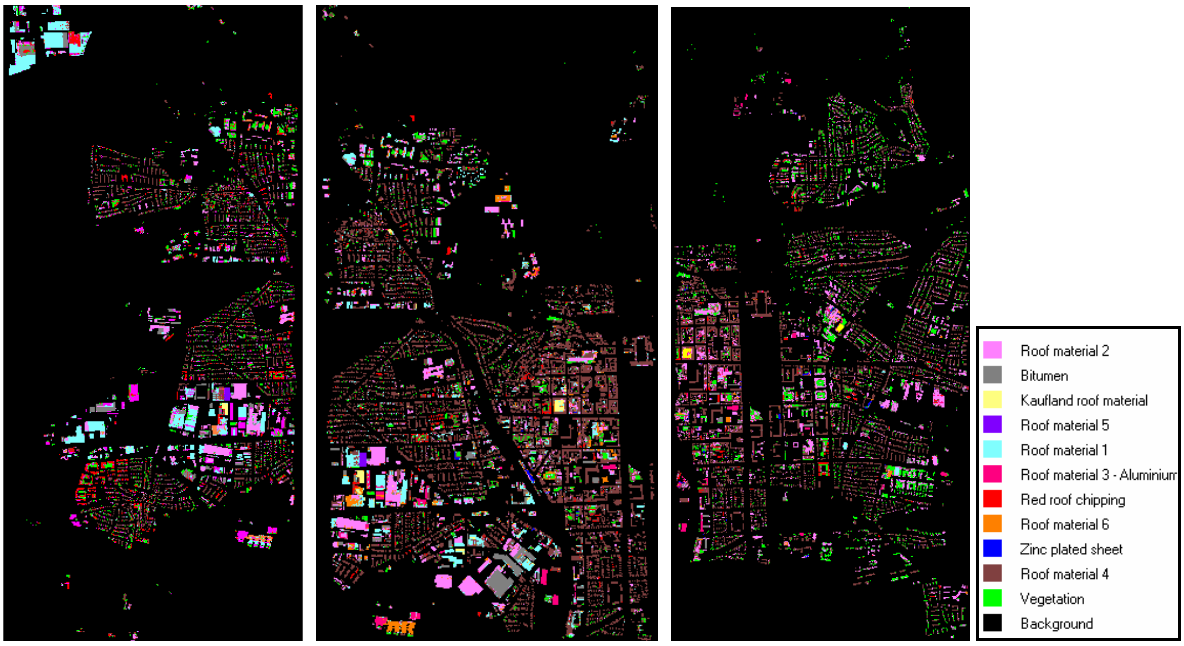

Figure 5: Classification results of three strips covering the research area.

The output classification maps (figure 5) fit well with orthophotos covering the research area in terms of geometry. Inspection of the corresponding classification probability maps shown in figure 6 indicates that most of the classified building roofs especially in strip 1 and 2 have a high probability of being correct (red and yellow colours by default). Some of the classified building roofs especially in strip 3 have a low probability of being correct (dark blue colour by default). These building roofs mostly consist of heterogeneous surface materials. Therefore, depending on the scene, accuracy requirements and material classes of interest, more training regions should be defined for these areas and the classification process should be performed again to achieve results that represent ground features more accurately.

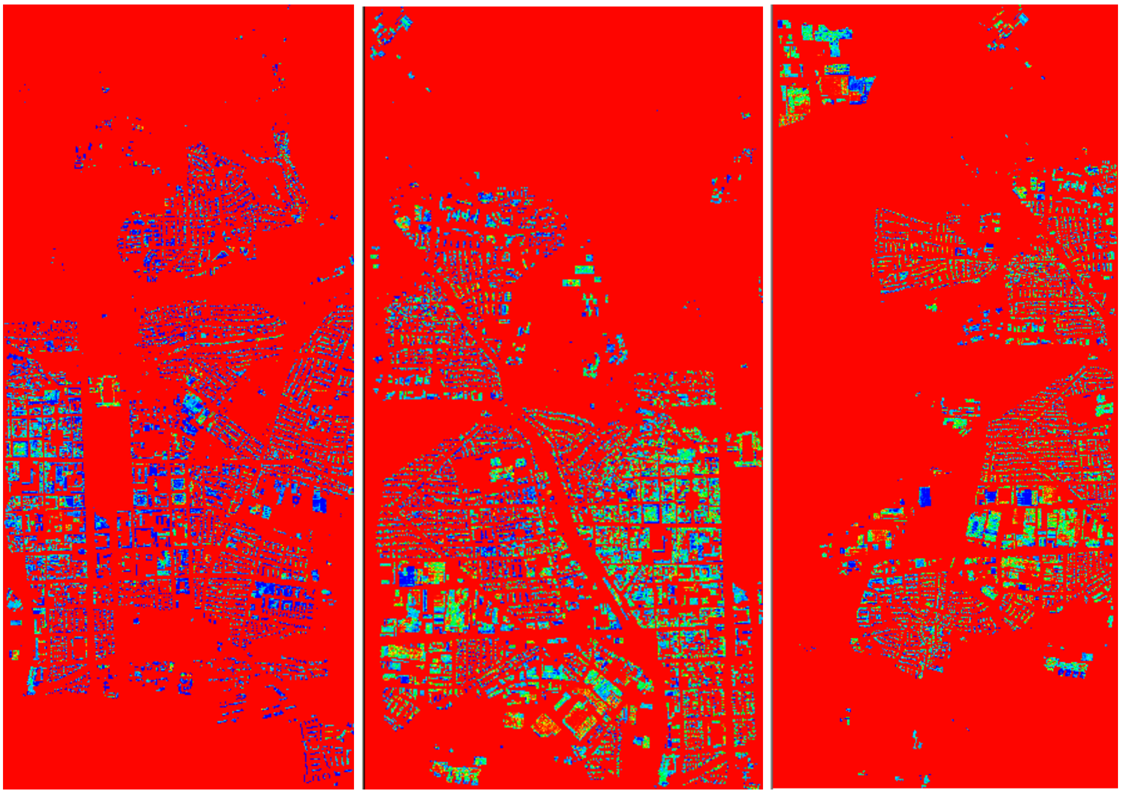

Figure 6: Classification probability maps for strips 1, 2 and 3.

4 Conclusion

This paper focuses on the development of an approach for classification of roofs using hyperspectral data. The application of feature extraction methods such as the Discriminant Analysis in the identification of roofs using hyperspectral data shows good potential. In the investigation, the DAFE is combined with a spatial-spectral classifier (ECHO) to classify 10 roof materials. The ECHO classifier segments the scene into statistically homogeneous regions and then classifies the data based upon the maximum likelihood object classification scheme. The probability maps of the classification results for the test and research area indicate that the output classification maps have very few errors and thus confirm the success of the approach. In addition, the integration of ALK vector data for roofs in the classification process results in better discrimination of spectrally similar materials belonging to spatially distinguishable objects. This work will be continued by involving a specialist on roof surfaces for a future ground truthing.

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Application of the Terrestrial Laser Scanning System for Mining in East Africa

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KEY WORDS:
Global Positioning System (GPS), Global Navigation Satellite System (GNSS), Multi Station Adjustments (MSA), Root Mean Square Error (RME).

ABSTRACT

The advent of precise measuring systems in surveying and mapping is immensely working towards saving time and money. Technology is advancing in the products that are used to capture data very fast and accurately giving almost real time information. With the incorporation of a GPS (Global Positioning System), terrestrial metric camera system attached to a laser scanning system, it is possible to have a terrestrial laser scanning system in place. This system captures millions of points and imagery is acquired of the same scene in a short period of time. RIEGL terrestrial laser scanners provide detailed and highly accurate 3 Dimensional data rapidly and efficiently. Applications are wide ranging, including topographic mapping, mining, as-built surveying, architecture, archaeology, monitoring, civil engineering and city modeling.

This paper shows the techniques that are used in mining industry. Specifically deals with the techniques used to compute the volumes and surface-comparisons for earthworks of the mine pits. It features on the gold mining in East Africa – Tanzania. The positioning of the scans, filtering and analysis is outlined. Area, volume computations and analysis of the results for duration of six months is shown. Multicriteria Surface Analysis (MSA) for assessing the accuracy of the scans is also discussed. The use of terrestrial camera attached onto the scanner is also of importance in recognizing the surfaces scanned. The use and importance of the equipment is analyzed considering its cost-benefits and other information regarding the application of the equipment in other areas such as topographic mapping and road construction.

1 Introduction

1.1 Laser Scanning

Laser scanning is one of the efficient methods of data capture. The rate at which data is captured has improved due to the introduction of these very sophisticated equipments. A 3 dimensional scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. color) through the integration of a digital camera which incorporates the color component onto the point cloud of that scene.

1.2 Riegl Terrestrial Laser Scanners

With these 3 dimensional data collecting equipment, the rate is so fast and economical, "*32 scans in just two hours, collecting an estimated 16 million data points, for 230m of tunnels*".(3D mining survey). Riegl terrestrial laser scanners provide detailed and highly accurate 3D data rapidly and efficiently. Point cloud of the area of interest is well captured with high accuracies (10mm). Riegl terrestrial laser scanners are rugged and fully portable instruments, tested under strict conditions for a reliable performance even under highly demanding environmental conditions. This suits their application in remote areas and challenging environments such as mining areas, forested areas and many others.

The terrestrial laser scanner system *RIEGL* LMS-Z420i consists of a high performance long-range 3D scanner, the accompanying operating and processing software RiSCAN PRO, and a calibrated and accurately orientated and mounted high-resolution digital camera. The system provides data which lends itself to automatic or semi-automatic processing of scans and image data to generate products such as textured triangulated surfaces or orthophotos with depth information. It provides a wide field-of-view, high maximum range, and fast data acquisition. A standard Windows notebook and the bundled software package RiSCAN PRO enable the user to instantly acquire high-quality 3D data in the field and provide a variety of registration, post processing and export functions.

Features

- Measurement Range 2 - 1000 m
- Accuracy 10 mm
- Laser class 1
- Minimum angle step width 0.004°
- Target detection mode: first target, last target or alternating

Application areas

- Topography & Mining
- Monitoring
- Archaeology & Cultural Heritage
- City Modelling
- Civil Engineering

Figure 1: Riegl LMS-Z420i Features and its applications

2 Application in Mining Industry

2.1 Gold Mining in East Africa

Tanzania has become one of the fastest-emerging gold producers in Africa, and is now the continent's third-largest gold-producing country after South Africa and Ghana. Geita mine is one among the open-pit mines producing lots of gold in Tanzania.

Figure 2: Geita Gold Mine in Tanzania

Figure 3: Geita Mine Pit being excavated

2.2 Scanning in the Mine Pits

Scanning will require one to set up the equipment over control points. The control points having been pre-marked on the ground and their positions determined accurately. For the mine pits, the challenge is always the choice of the best points to set the controls. The best choices were chosen to be those that were accessible and with low risks to the operator. These controls were established and about 10 were surveyed and their coordinates determined using a precise GPS measuring system. For this operation, only 8 controls were used to capture data and it gave a good coverage of the mine pit. Accuracy of less than 10 mm was achieved.

The process of data capture takes a very short time once the equipment is set up over the control. Data is then picked. Using the Riscan Pro software which is directly connected to the scanner, the data can be viewed on the screen as the process of data collection progresses. This takes a about 10 minutes to scan at a station 360 degrees. Depending on the choice of the operator, the capturing of imagery can happen after the point cloud has been selected or can be synchronized to be simultaneous with point data capture.

2.3 Pre-Processing the Scans

After scanning, data is processed using the same software. First is checking all the parameters of the scans, then checking if the data were well captured to the required parameter choices. This enables the positioning of the scans to their accurate coordinates. It entails integration of the GPS coordinates to the positions of each scans respectively. A good fit is estimated. The scans are then rotated to fit each other as they were captured with the help of photographs taken at each station. A Multicriteria Surface Analysis (MSA) is used to position the scans to the best fitting position and a surface is generated. The surface is meant to help in the checking for “holes” in the data indicating that less data was captured or wrong positioning. A root mean square (RMS) error is always generated during MSA process which helps the operator to know if the positioning was good. When the result is not good, a re-run of the result is done till a good fit achieved. This is indicated by the expected value that should be achieved under these conditions.

2.4 Post-Processing the Scans

After pre-processing, then follows the post- processing stage in which data quality is checked. Outliers are removed from the already positioned data (georeferenced). This provides a pictorial view of the project area. Coloured scans can be made from the photos such that each point takes a gray value relating to the incident object. Any other discrepancy is corrected for and the data is ready for analysis.

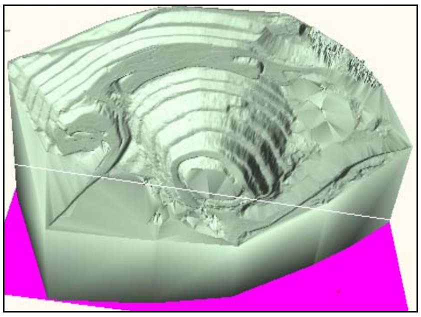
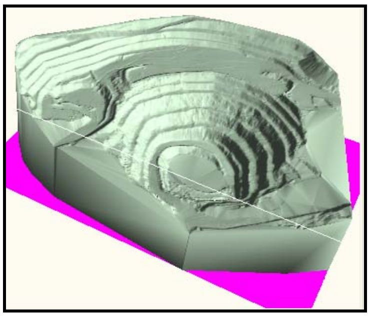
Figure 4: Scanned data positioned

3 Data Analysis

3.1 Surface Generation

After post-processing, surface generation takes place. For data analysis, the most important aspect in mining is to determine changes in volume and generate a surface comparison analysis. These two types of analysis help to determine the amount of volumes that have been excavated over time. In this study, two data sets were collected for the same area having a period of six months difference. The September 2010 and the April 2011 for the same area were used. Surfaces were generated using Riscan Pro software to view the difference even before analysis. The same parameters were used for both data sets in generating the surfaces so as to have a good comparison.

Table 1: Surfaces for the two datasets

	
September 2010 Data	Aril 2011 Data

1.1 Volume Computations

Volume computation is essential for comparing two surfaces. The Riscan Pro software comes with application (Plug-in) that enable volumes to be determined for various surfaces. To generate volume, a base from the surface needs to be determined. This base is the horizontal surface in which the surface model sits on and it is then from this base that volumes can be generated. The two volumes are output in values and can be exported to any spreadsheet as may be determined by the operator.

1.2 Surface Comparisons

Surface comparisons are essential in analysing various changes that have occurred in the mine pit over time. The most crucial issue is to know what has happened over a certain period of time with regard to the mine pit. For sure, there is always change in terms of the surfaces. Other things to look for include soil erosion and surface siltation. These enable the management to consider the operation techniques to be applied in everyday mining. It also helps for safety precaution whereby a prior knowledge of some areas is known for example where there is frequent erosion may not be a good area to carry on with excavation activities.

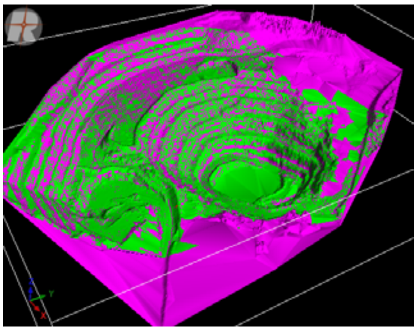
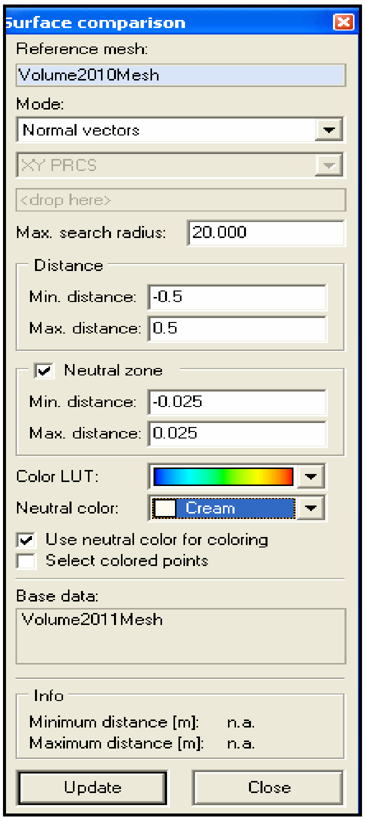


Figure 5: Surfaces Combination (2011 (green) and 2010 (Magenta)

Table 2: Parameters for surfaces comparison



Selection of Parameters for Comparison:

Data

Basedata: = 2011 this is the one to be checked or to be compared.

Reference data = 2010, this is the data that is to be used in the comparison work.

Parameters

Maximum search radius being 20 meters. The maximum radius that is within the search space for any changes occurring.

Distance: These are the vectors that move inside the search radius to find any place where the changes are occuring. The vector distances are about 50cm above or below threshold of zero.

Neutral zones: where there is minimal change in the separation between the two surfaces. This is kept at +2.5 cm to -2.5cm.

Results and Interpretation

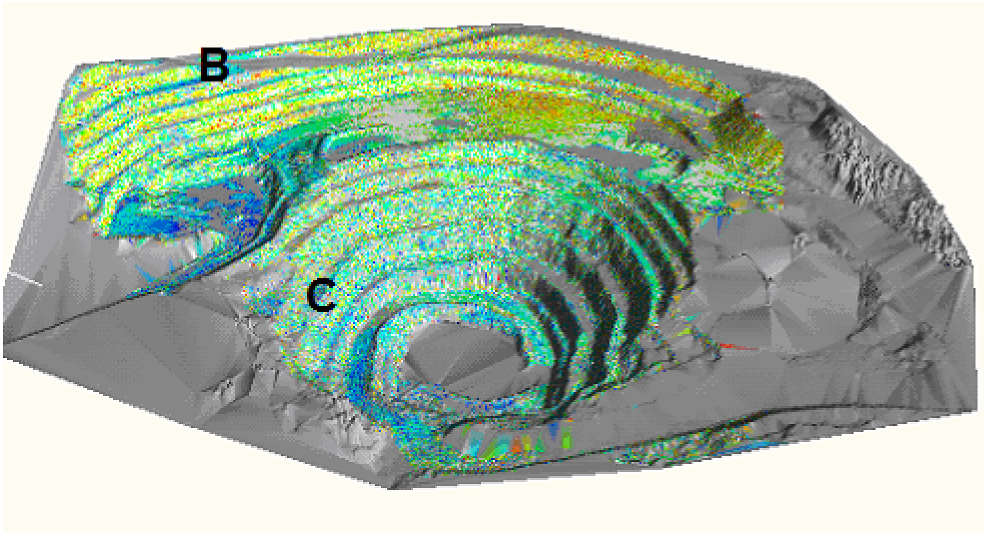


Figure 6: View of surfaces compared

From Figure 6, it is clearly visible that the changed areas are coloured. Looking at the best parameters used i.e the maximum search distance of 50 cm and the vector distance of (- /+) 10 cm; the changes are quite minimal in that they are within 20 cm (0.2 meters) which are so minimal. Clearly, at the watermark (labeled C), see figure 6. It means that there was a rise between surfaces. The whitish part being the neutral zone of (-/+) 2 cm are quite scattered on the surfaces. One part that had almost complete white colour is labeled B as in figure 6 above. This can be concluded that these areas never changed at all. Probably these areas could be consisting of strong rocks or strong surfaces that do not show any surface changes. Siltation and erosion were not evident in this case.

Conclusion

Generally, terrestrial laser scanning systems are good for applications in mining industry. Results emerging from such equipments are accurate and reliable. Further combinations of results such as volumes, surface areas and surface comparison of the analyzed data provides more information that could be used in decision making for such industries. The cost-cutting mechanisms of mining such as adding of staff due to workload, machinery and any other method could be drawn from the results of this research. In determining the eroded and silted areas, one can tell what can be done to avoid them happening in the future. With the help of GPS gadgets, the mining engineers could carry out surveys on the site by finding the areas where the erosion and siltation could have occurred. These systems could also be used in other fields such as archaeology, civil engineering among many others.

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Texturing Sophisticated Geometries in Putrajaya

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ABSTRACT:

In this research we investigate whether CityGML is a suitable information exchange format for Malaysian geo-special data infrastructure (SDI). 2D existing highly detailed CAD data with lots of layers and rectified vertical symmetric photos of intricate constructions are used to generate the 3D models of Putrajaya in CityGML and CityServer3D. Our 3D models are in LOD2.5 along with higher Level of Realism (LoR). Texture enhancement methods such as texture left-right or up-down symmetrical transformation and higher radiometric adjustment for raised surfaces and Dynamic Pulse Function are used in this research based on facet situation and observation on the tessellating of the textures. The problem of missing faces of polyhedrons and missing objects have been solved and described in this paper in CityGML and some Code-Lists defined for complex and intricate structures such as domes of the Putra Mosque, Iron Mosque, Prime Minister Department and Court of Justice buildings.

1 Introduction

In the last decade, developing different methods for 3D city modeling became one of the most exciting topics in the field of computer graphics and GIS. The concept is to address 3D modeling of any objects within the city such as terrain, road network, building wireframes and street furniture. For instance procedural method along with L-system used for 3D virtual city model of Manhattan with nearly 26000 buildings(Parish and Müller, 2001). (Müller et al., 2006) Introduced procedural modeling of buildings for well-defined constructions. Rule-driven procedure approach for large scale virtual 3D city models were employed by (Wang and Hua, 2006). 3D navigation system for virtual reality based on 3D game engine is introduced by (Sharkawi et al., 2008). Synthetic texturing for the façade based on pulse function is addressed by (Coors, 2008). Mobile navigation system using 3D city model based on synthetic texturing and pulse function with unlimited number of layers is completed by (Alizadehashrafi et al., 2009) and (Bogdahn and Coors, 2010b) and (Bogdahn and Coors, 2011). Mobile location aware messaging application for 3D navigation system that runs VRML file on mobile along with GPS and LBS developed by (Nurminen, 2006b, Nurminen, 2006a). Conventional photogrammetric method using terrestrial laser scanning and geo-referenced images for 3D modeling is surveyed by (Schulze-Horsel, 2007). Pictometry is a new highly automated 3D modeling technique (Wang et al., 2008) and can be used for lots of different applications (Nyaruhuma et al., 2010). In this system five cameras take five geo-referenced photos in north, east, south, west at a 40 degree oblique and vertical angle simultaneously from a low-flying airplane. Lots of measurement and overlaying with the shape files can be done based on multiple perspectives that are overlapping in as many as 12-20 photos of each control point on the ground. Majority of the 3D modeling techniques are very costly, time consuming, lacking database, suffering from heavy data size of 3D models and low quality because of leaning and disturbing objects. Mostly they are employing very expensive tools, affecting total cost and targeting more visualization than semantic modeling and databases.

In this paper, setting up the test infrastructure is explained in sections 2 to 5 .In section 2 CAD-based 2D to 3D conversion and modeling is addressed. In section 3 and 4 inventions of the Dynamic Pulse Function by our group and the concept of tessellating are explained respectively. Different methods that are applied for texturing and generating intricate elliptical and dome form geometries along with street furniture are covered in section 5.

Advantages and disadvantages of CityGML and CityServer3D and some solutions to the problems are presented in section 6.

2 CAD-based 3D modeling and floor plan extrusion

(Lewis and Séquin, 1998) Created a semiautomatic system to convert 2D floor plan to 3D models. A similar system developed by (Yin et al., 2009) for more complex buildings. Mostly these algorithms are based on pattern recognition and image processing techniques. The input is CAD file or scanned plan. Only a few researches address the problem of 3D generation process from 2D CAD files, even though they are not fully automated. The standard representation of objects in CAD, is the key for this issue. Pattern recognition is used to recognize the objects and create closed polygon on the basement for excluding. Google SketchUp is a simple, efficient 3D modeling software including enhanced and beneficial tools. Users can draw footprint in a form of closed polygon and then use a push/pull tool to extrude 3D volumes and geometries. SketchUp can also export KML (Keyhole Markup Language) files of 3D building for Google Earth. In this research due to very complex geometries of plans in Putrajaya with lots of layers, SketchUp was employed to convert 2D floor plan to textured 3D models. CAD files were imported to SketchUp and unnecessary layers omitted and finally grouped. Generalized floor plan for each building was sketched in a very high accuracy as a closed polygon. Closed polygons were extruded based on the information from section view from CAD files. Generalization and simplification of the floor plan must be done for having very light-weighted geometry in LOD2.5 with limited number of textures for web-based applications and navigators. In Fig: 1(a), 1(b) are some detailed CAD files of MaCGDI building including furniture's with lots of unnecessary layers. 1(c) is our generated model in LOD4 including furniture and real textures. Fig 2: illustrates the modeling process of Putrajaya Corporation building. 2(a) is a refined and simplified DWG file including landscapes and trees along with closed polygons. Alpha channel used for texturing transparent parts of columns and fences in order to have a very light-weighted geometry (See Fig 2 (b)). The comparison between real world and virtual 3D model represented in Fig 2(c) and 2(d).

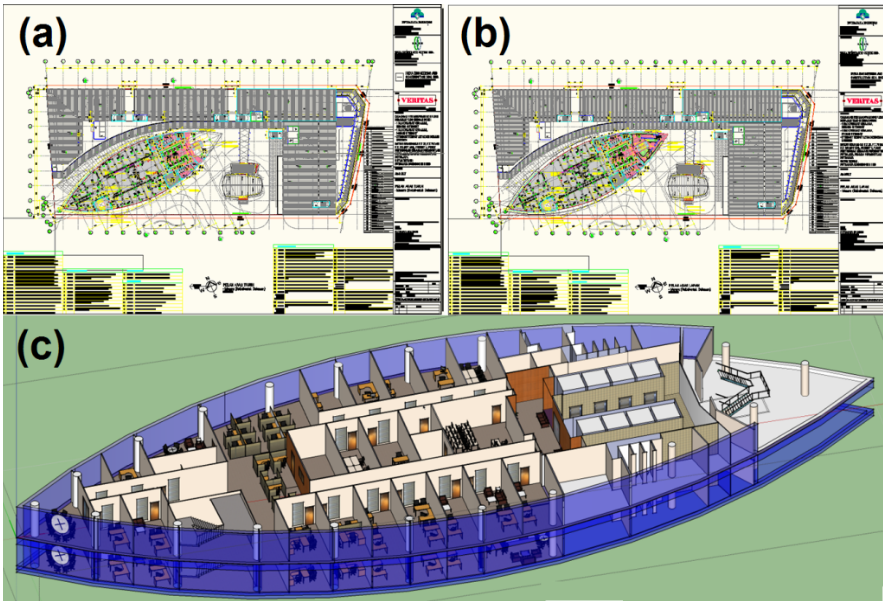

Fig 1: (c) Level 10 and 11 of MaCGDI including furniture's in LOD4 designed based on detailed DWG files (a and b).

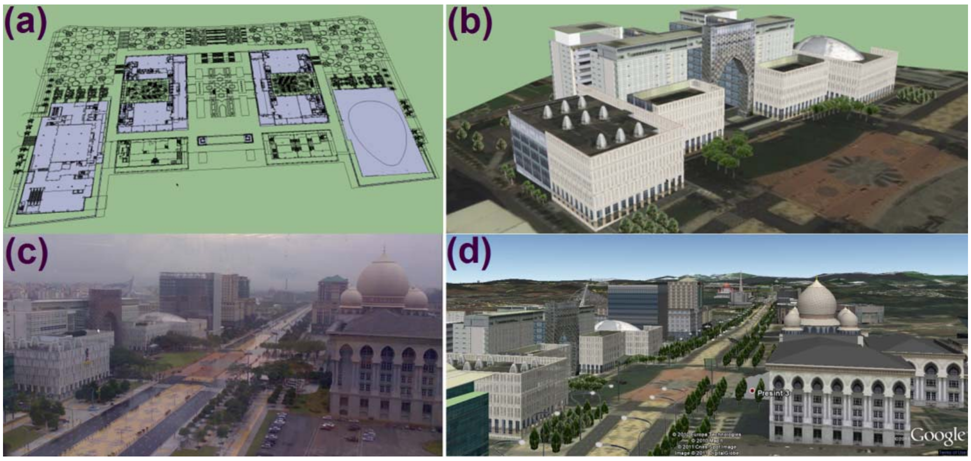

Fig 2: (a) is a generalized and simplified DWG file of Putrajaya Corporation building including landscapes. Closed polygons created the foundation and (b) extruded based on section view from DWG file. Comparison between real world and virtual 3D models is illustrated in (c) and (d).

3 Rectification and Dynamic Pulse Function

(Coors and Zipf, 2007) Defined an algorithm for creating the texture for the façade on the mobile devices based on limited number of layers using J2ME. The priority of the door layer is higher than window layer and it can be placed on left, middle or right side of the façade and the window cannot be placed on the door. (Alizadehashrafi et al., 2009) Enhanced aforementioned pulse function method to simulate the 3D model in VRML environment based on unlimited number of layers using Java graphics and JavaScript programming languages. The system can create the output image file in a very high quality and small data size. Mostly the output image file is even smaller than the textures which are used to create the façade. Texture deformation while mapping the square output image on rectangle geometry, is the main problem of this method which leads to lack of quality in the 3D model. To deal with this problem Dynamic Pulse Function comes in handy which is developed by our group (Musliman et al., 2009) & (Rahman et al., 2010). Semantic modeling along with synthetic texturing has been done in this method and the database can be queried from XML schema. In this technique the perpendicular terrestrial photo from the façade was rectified by employing projective transformation functions and parameters from the camera after calibration. The rectified photo is down-sampled or resized based on constrain proportion. The result is not suitable for texturing the 3D model due to problems such as leaning geometries, shadow, disturbing objects and reflection but can be used for measuring parameters. For instance height and width of the resized and rectified photo can be employed for compiling the java program and generating the output frame. The height and width of windows, doors, horizontal and vertical distance between windows from upper left corner of this photo can be measured. The system can use these parameters and texture file names and file paths to create the façade semi-automatically. The final image file resolution is proportional to the real geometry of the façade which can prevent the image from distortion and deformation while mapping. To avoid leaning geometry the textures which are going to be used in this process must be created from perpendicular photos from the window, door and etc. Texture enhancement should be done in advance such as removing disturbing objects, exposure setting, left-right up-down transformation, and so on. Fig 3: illustrates the process of texture generation based on dynamic pulse function and Fig 4(d) shows the output of the aforementioned method nearly 17KB in a very high quality including semantic database on XML schema. It is possible to use random textures for each window layer to increase LoR. For instance Upper left, upper right and downer right window layers are using three random textures (See Fig 4(d)).

The database for the layers is in XML schema format which is a part of semantic modeling. In fact the quality, small data size and scale along with semantic database for each façade are the advantage of this method. The system is not fully automatic and needs some data entry but still fast enough to create the textures for a 3D model within less than one hour excluding data collection.

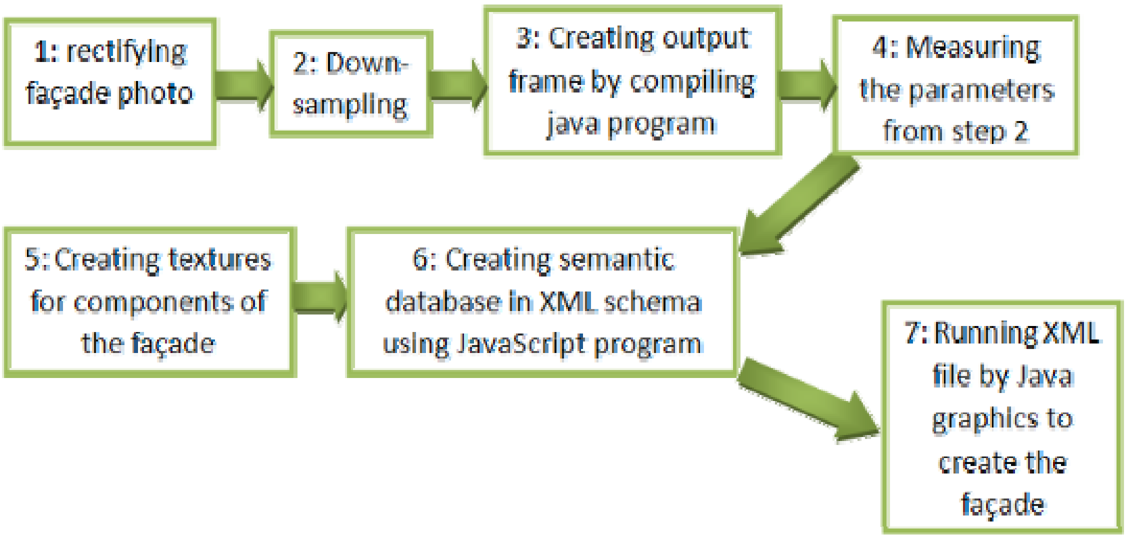

Fig 3: The pipeline for Dynamic Pulse Function.

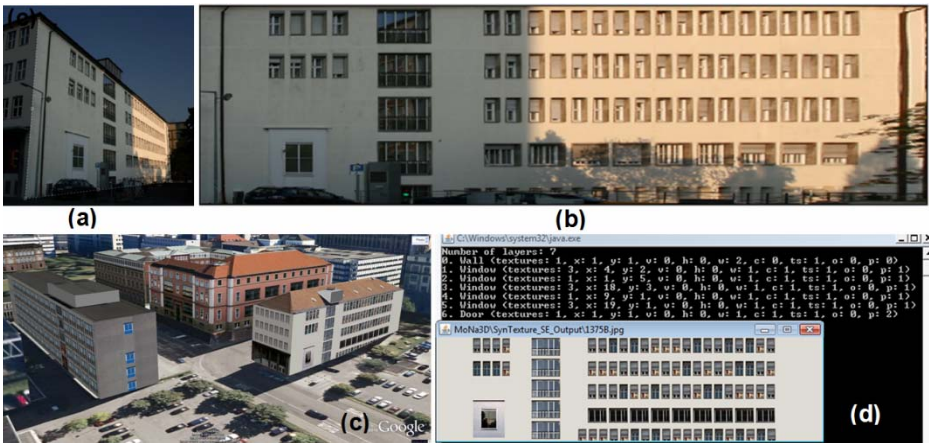

Fig 4: Original photo is 4MB (a) and the rectified photo is 7MB before down sampling (b). Our created façade image is just 25KB in a very high quality (d). One pixel is used for the wall texture and three random textures are used for some window layers to increase LoR.

4 Tiling and tessellating

Pictures are taken by 10.2 mega pixel Nikon D60 camera (AF-S NikKKOR 18-55mm). The image files are prohibitively large. Although we can overcome this problem by reducing the resolution of the image, such down-sampling can cause lack of quality and information loss. The textures which are tessellating vertically should be up-down transformed symmetrically and those which are tessellating horizontally should be transformed in left-right direction symmetrically. This can create a horizontal or vertical symmetric texture. In case of tiling the texture both vertically and horizontally, the combination of aforementioned methods can be used. A code in Matlab can produce such a nice texture. This technique applied to the floor of Puta Mosque (See Fig 4). Normally while tiling texture, the overlapping parts should match, this is the main reason that we should apply this technique for better visualization and higher LoR. Fig 6: illustrates textures which are created based on symmetrical left-right transformation to increase LoR.

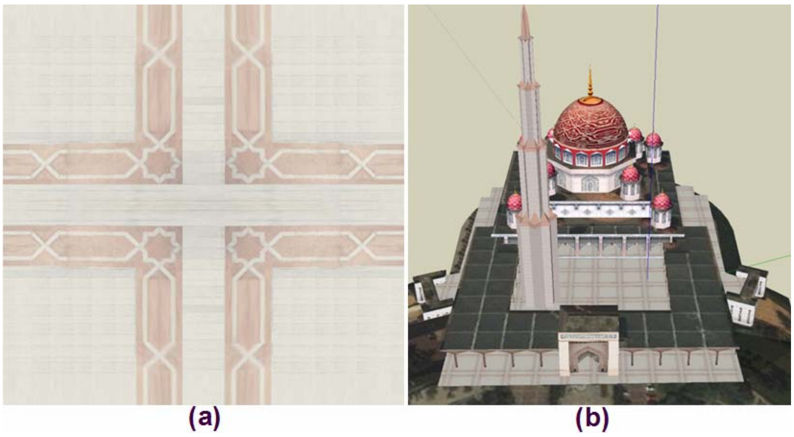

Fig 5: (a) is the created texture for the floor based on rectification and symmetric transformation. Better visualization and higher LoR can be seen in the model after tessellating (b).

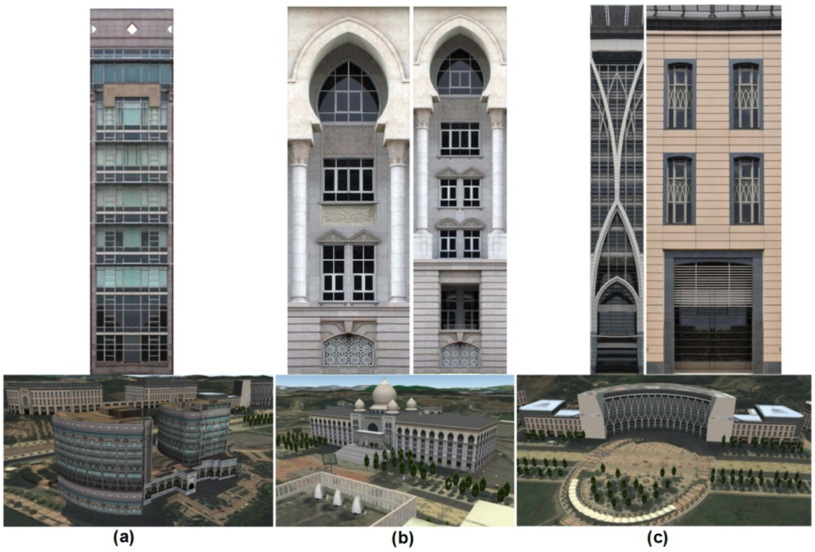

Fig 6: Illustration of the textures which are created based on symmetrical left-right transformation to increase LoR. (a) is the building of Putrajaya holdings, (b) is the Court of Justice and (c) is the Ministry Of Finance building with their related textures in LOD2.5.

5 Texturing sophisticated geometries

5.1 Texturing based on symmetric rectified pictures

In some of the complex geometries such as the dome of the Putra Mosque, Iron Mosque and Palace of Justice, perpendicular photos were taken from the dome and after rectifying symmetrically; the image is imported to the SketchUp as a standalone object. Half of the dome geometry is sketched in a planer surface of the image. A void or hollow circle is sketched as a footprint of the dome based on its diameter. Available tools are used to generate the geometry of the dome. Finally the texture projected from the image on the dome geometry (See Fig 7 and 8).

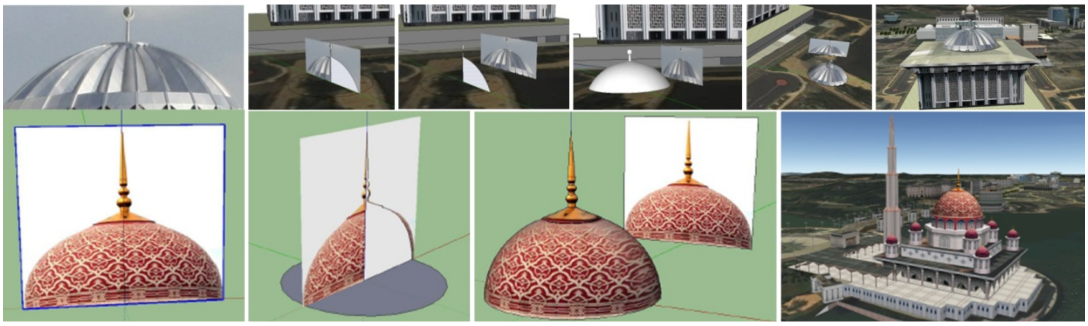

Fig 7: Modeling dome of the Putra and Iron mosque based on rectified and symmetric photo form perpendicular pictures in Putrajaya.

5.2 Texturing based on different exposure setting

From the architectural point of view, the geometries which are closer to the camera should be brighter and those which are farther should be darker. It is possible to create a very light-weighted geometry in LOD 2.5 for web-based applications such as Google Earth, Microsoft Virtual Earth and mobile navigators based on this concept to reduce the geometries and textures accordingly. To increase LoR, the geometry with lots of raised columns represented as flat rectangle geometry and the brightness of the columns are increased or for the deeper parts the brightness decreased. This is a trick which can be used for reducing the geometry and number of texture files and increase LoR as well. Fig 8: shows the concept. In the texture of the façade, the pixel values are increased for the column in left side of the texture to represent raised geometry and then the texture left-right transformed symmetrically.

Fig 8: The texture created based on Left-Right symmetrical transformation and the brightness of raised column geometries (a) and tessellated on the 3D model of the Putrajaya Prime Minister Department (b).

5.3 Texturing based on Alpha Channel

Portable Networks Graphics (PNG) introduced in 1994-1998 by (Boutell et al., 1999). PNG is a suitable image format for transmitting via network and uses lossless data compression algorithm. This format supports RGBA (Red, Green, Blue, Alpha). Alpha channel varies from 0% up to 100% which is completely transparent. This concept was employed to create lamp posts, trees, fences in front of Putrajaya corporation building, traffic lights and other street furniture. In order to reduce the heavy geometries of these objects, just cubic geometry is defined and the texture file in PNG format with transparent parts mapped on the geometry. The textures rectified and left-right transformed symmetrically and unneeded parts deleted before mapping on the geometry before converting to CityGML (See Fig 9).

Fig 9: Statues, annexes between the departments and fence textures were created based on Alpha Chanel and mapped on the rectangle light-weighted geometry. Some of lamp posts and trees were created on tow perpendicular rectangle geometries with transparent parts intersecting each other from the middle at 90 degree angle or three rectangles at 60 degree angle.

5.4 Texturing based on polygonal concept

(Tsai and Lin, 2006) introduced a polygon based texturing method for non-planer and irregular geometries such as semi-cylindrical and semi-elliptical shapes. Geometric distortion of this kind of façade tremendously depends on the exposure angle. It is really challenging to map such a texture either on a rectangle image frame or on the generated virtual 3D geometry. In polygonal based texture mapping a two-step adjustment were processed before registration. The approximation of top and bottom lines of the façade, processed in the first step by employing polynomial functions in order to make the curved top and bottom lines horizontal. In the second step the image stretched horizontally until the vertical lines in left and right side of the image were aligned correctly.

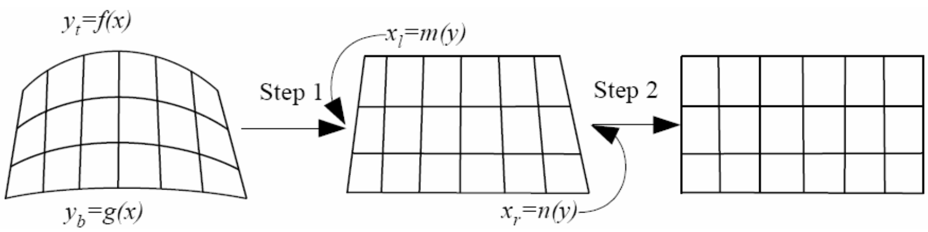

Fig 10:(Tsai and Lin, 2006) Two step adjustment of irregular-shaped façade image.

$$y_j = y_t + \frac{y_t - y_b}{MAX(y_t - y_b)} j \qquad (1)$$

$$x_i = x_l + \frac{x_r - x_l}{MAX(x_r - x_l)} i \qquad (2)$$

Where y_t, y_b, x_r, x_l are polynomial functions, representing bottom, top, left and right sides of the frame and i, j are horizontal and vertical pixel indices respectively. MAX in equations (1) and (2) measure the maximum distance of top-bottom and right-left polynomials respectively. It is also possible to use some photo editing commercial software such as Photoshop with user-friendly toolboxes for free transformation which could be time consuming. Finally the generated texture should be mapped on the rectangle geometry which is created temporarily parallel to the curved geometry. The texture must be projected on the curved geometry from the rectangle flat geometry. The rectangle geometry which is created temporarily can be omitted after projecting the texture.

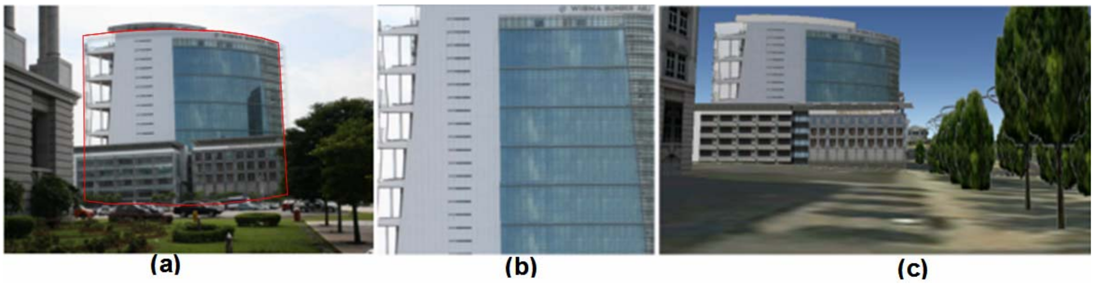

Fig 11: Texturing semi-elliptical building of MacGDI.

CityGML and CityServer3D

CityGML is a profile of GML3, which implements an interoperable, multifunctional, multi-scale and semantic 3D city model (Kolbe et al., 2006). Cityserver3D is a client-server DBMS (Data Base Management System), developed by Fraunhofer IGD (Germany). It can support any kind of sophisticated geometry in varying LODs based on polygons within CityGML format via MySQL (My Structure Query Language) and JVM (Java Virtual Machine). Polyhedron geometry which is supported by CityGML is sufficient to model every object such as street furniture and building in Putrajaya. CityGML format is beneficial for managing 3D city model as a multipurpose data source. External code list is a value defined by OGC for semantic modelling of objects by their type of class, function, usage, roof type, installation, material, and so on. It is a sort of indexing database and can be used for querying and analyzing for multipurpose issues. The end users may not need to know these codes but they can recognize the semantic definition of the external code list by query in the interface of CityServer3D. The operator can define different attribute for the different part of a building based on layers or components. Billboards, movies, animation and image as a standalone object are supported neither in CityGML nor in CityServer3D. There must be geometry based on polygon or polyhedron and the texture can be mapped on the geometry. Majority of the 3D virtual environments support image files as a standalone objects in any format (See Table 1) except CityGML and CityServer3D. To solve this problem the polyhedron geometry should be created and the texture must be mapped on the geometry before converting to CityGML via CityGML Plugin or FME and then can be imported to CityServer3D. Polygon and polyhedron can be converted from any 3D format to any other 3D file format without many changes in the content and the size of the file. For instance the result of converting cylinder form 3DMAX to VRML creates smaller file size than converting the same cylinder from SKP to VRML. Cylinder is defined both in VRML and 3DMAX but not in SKP so that it must be represented by lots of polygons which make a huge VRML file size. The same problem may happen while converting SKP to CityGML where polygon is the only thing that already defined. This is the main reason that CityGML files are of a huge size of text file especially for complex and sophisticated geometries. The list of nodes for each polygon in CityGML must be counter clockwise facing to the camera position so that it can be visible in CityServer3D. The solution for this problem is by making all the faces counter clockwise before converting to CityGML. Checking the 3D model in monochrome mode, can help to find those faces which are in gray colour or clockwise. These faces must be reversed or oriented before texturing and converting to CityGML (See Figure 15). An automated 3D healing model has been started (Bogdahn and Coors, 2010a) in Stuttgart University of Applied Science. The system receives original model and based on a validation and healing plan it will generate correct model automatically or create correction recommendation for the operator to heal the 3D model. Finally the system creates the quality and healing report.

SketchUp supports moving objects using Sketch Physics Plugins which is not in the field of GIS. VRML also supports moving objects like the sign of Mercedes on the top of the tower of main Station in Stuttgart which is rotating in the 3D model the same as reality (See Fig 12). In addition some of the shapes are not defined in sketchUp such as circle or sphere but they are defined in VRML. Physics engine, billboards, shapes such as arc, circle, sphere, moving objects, animations and movies are out of the scope of CityGML and CityServer3D.

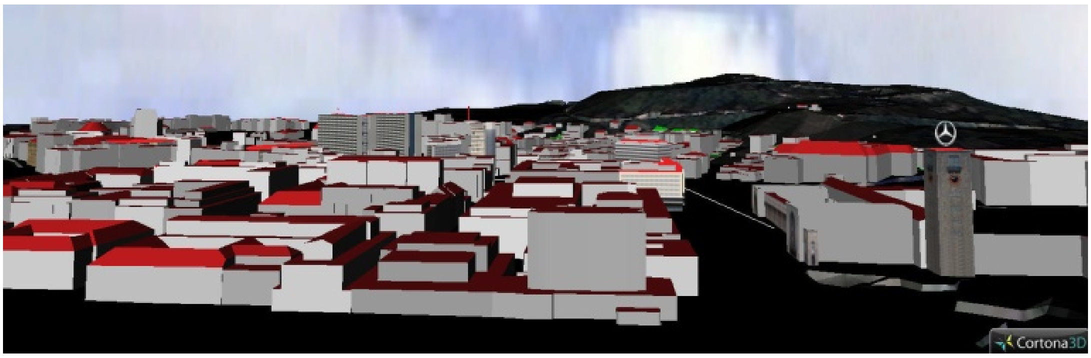

Fig 12: The sign of the Mercedes Benz is rotating the same as reality on the top of the tower in main station in our 3D model of Stuttgart in VRML.

In VRML we can use ***TimeSensor*** and ***OrientationInterpolator*** keywords in order to animate and rotate an object in BitManagement (VRML/X3D viewer) or VRML cortona environment. These keywords are used to rotate textured circle geometry on the top of the tower of main station in Stuttgart virtual 3D model.

The most important part of CityGML is semantic modelling within the CityServer3D and querying database on demand. Direct access to the MySQL database behind the scene of CityServer3D is possible using DDL (Data Definition Language) and DML (Data Manipulation Language) to define and manipulate the data directly, but it is not recommended. Access to the database should always be done via CityServer3D along with Java Framework. A Web3D-Service interface can be used to access the database which is rather difficult and challenging. However, this will be the best interface to access the CityServer3D database from other programs. Fraunhofer is currently preparing an OGC (Open Geospatial Consortium) experimental interoperability to test the Web3DS specification (see OGC website http://www.opengeospatial.org/standards/gml). To change or add external code-lists for some religious landmarks such as the dome of the mosque, or the tower of the mosque for mounting the speakers on that, we need some knowledge on the implementation which could be done only in a joint project with Fraunhofer IGD. There is an error in the specification of external code-lists in CityGML 1.0; must be fixed in CityGML version 1.1. So far, the only solution is to extend existing code-lists to define semantic database for geometries such as dome of the mosque. We proposed to add the code lists developed in the Putrajaya3D project to the CityGML standard working group as an example of the recommended use of external code lists in CityGML 1.1. However, some formal issues are required. An official organization such as MaCGDI together with our 3D GIS RESEARCH LAB members in UTM should be in charge of supporting and maintaining these code lists and make them public available. The data management component in Google Earth is file based such as KML files that are not feasible for large models and done by Google with their own 3D geo-special database. With CityServer3D, data management is in control of MaCGDI and UTM. The size of the 3D models in Google Earth is restricted and normally is in LOD2.5 along with textures for each object but in CityServer3D buildings in LOD4 such as MaCGDI can be imported along with semantic data.

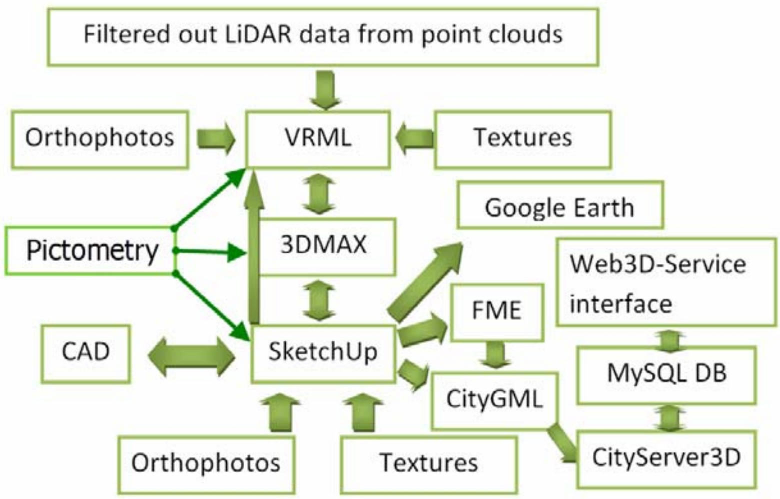

Fig 13: 3D model production pipeline for visualization, analysis and semantic modeling.

Table 1: Represents the defined shapes in different 3D environments

Shapes\3D environment	VRML97	SketchUP	3DMAX	CityGML
Circle	√		√	
Sphere	√		√	
Cone and Cylinder	√		√	
Arc	√		√	
Polygon	√	√	√	√
Animation	√	√ using Sketch Physics Plugins	√	
Billboard	√	√	√	
Image as a standalone object	√	√	√	

Converting models which include shapes such as circle, or moving and dynamic geometries from VRML to 3DS, using 3DMAX, encounters errors (See Fig 13). The only way to solve this problem is to delete that part of the VRML code before converting to CityGML (See Fig 12 and related code which should be omitted before converting). These shapes are represented as a smooth polygon in other 3D formats such as SKP (See Table 1). X3D and M3G support movies within the virtual 3D environment on the virtual display which is not supported by CityServer3D. Fig 14 shows some of the problems of converting billboard and images as a standalone object to CityGML.

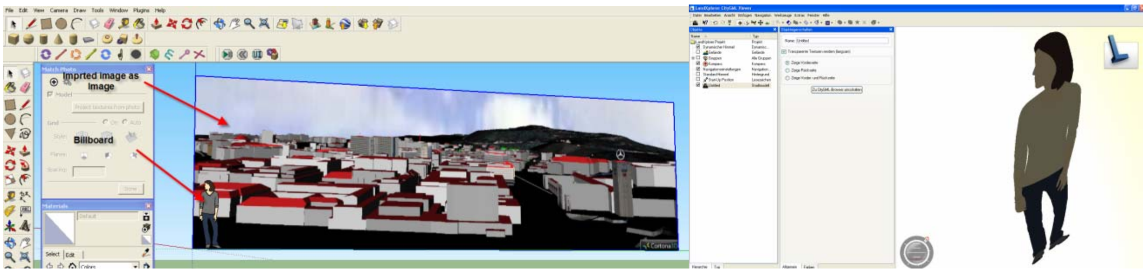

Fig 14: A billboard and a standalone image were converted to CityGML. The image was lost and the billboard became a fixed object which is not facing to the camera.

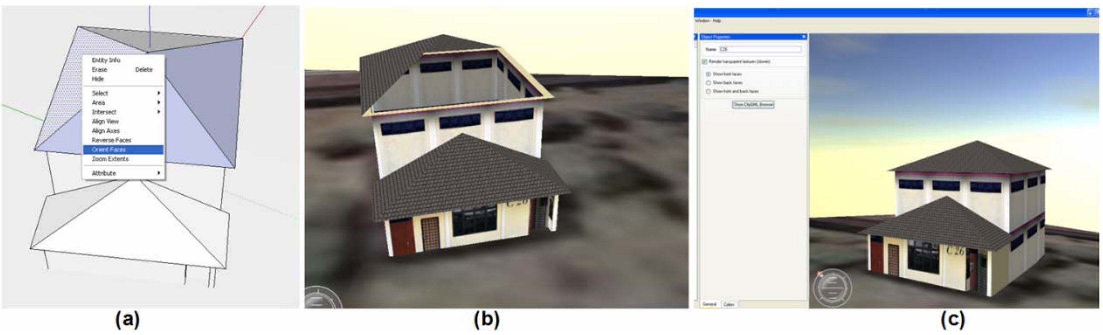

Fig 15: Two faces of C26 in UTM are in grey color in monochrome mode (a). After converting to CityGML these faces are invisible from outside as they are not oriented (b). This problem was solved in (c) after reversing and retexturing.

Visualization of the name or label of the building while hovering the mouse on the 3D model or navigating within the cityServer3D is not supported as well.

SketchUp is using WGS84 coordinate system. After converting the model to CityGML using CityGML-Plugin in Google SketchUp the model was not geo-referenced in previous version. This problem was fixed in the newer version of the CityGML-Plugin which can be downloaded from CityGML webpage.

The terrain and Ortho-photo from Putrajaya Prime Minister Department to Putrajaya International Conventional Centre about 5 kilometres by one kilometre created using Google terrain with the grid size of 76 meter. 25 buildings, 4 bridges and all the street furniture such as spot lights, lamp posts, trees, and traffic lights were modelled and textured by aforementioned methods in this area along with semantic data in CityServer3D(See Fig: 16, 17).

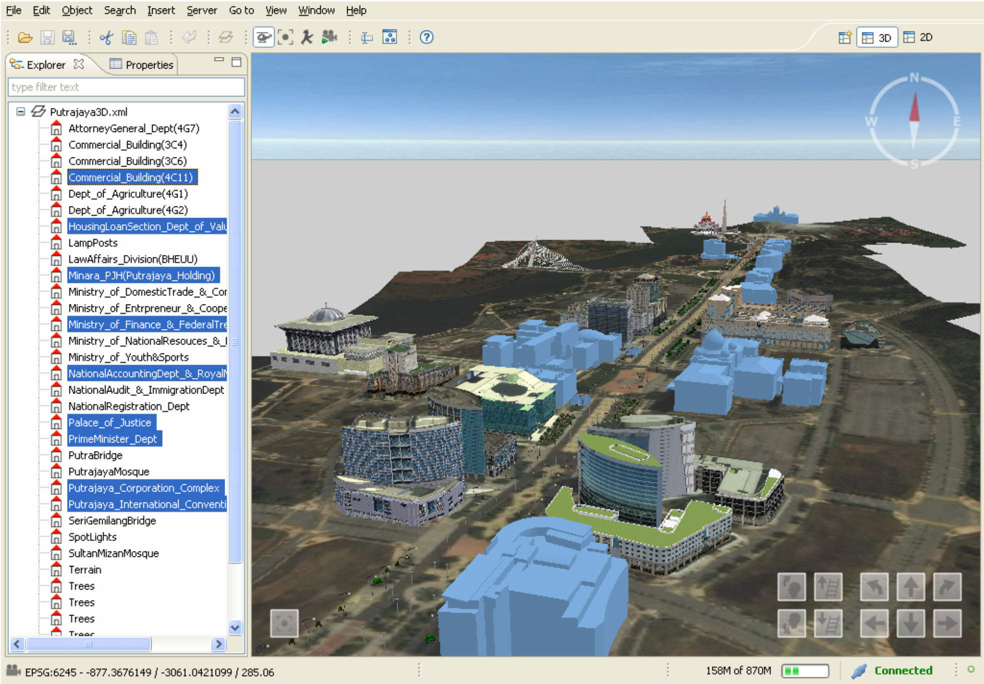

Fig 16: 3D model of Putrajaya from PICC to PPMD along with semantic data in CityServer 3D.

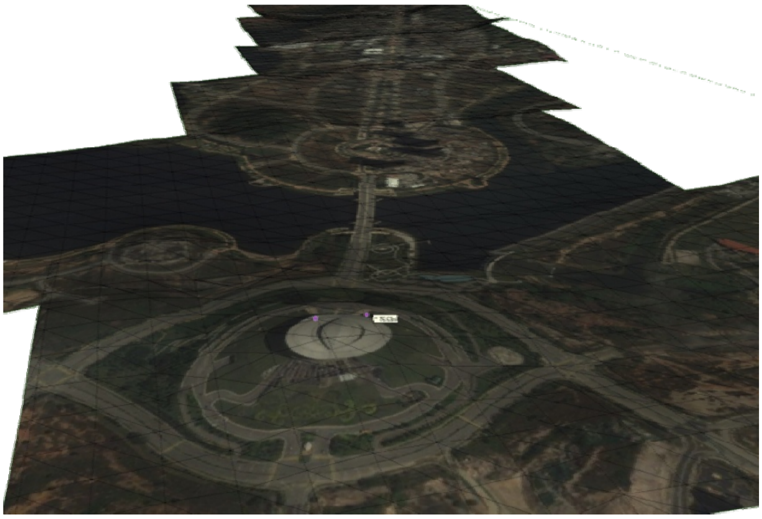

Figure 17: DTM produced using Google Earth terrain.

6 Conclusion and future work

In this research we tested CityGML for Putrajaya SDI based on CityServer3D. Solutions for generating high quality textures based on symmetrical transformation and symmetrical rectified photos are introduced. Some techniques are employed for modelling and texturing sophisticated geometries. We addressed some of the visualization and semantic problems in CityGML and CityServer3D along with their solutions. Developing a nice GUI (Graphic User Interface) for Dynamic Pulse Function can be done in future. Creating semi-automatic generalization method for 3D modelling in LOD2.5 for web-based applications from 2D detailed CAD data might be the next research. Definition of our national external code list should be done in the future.

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A Conceptual Approach to Estimate Biomass using Airborne and Terrestrial LiDAR Data

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KEY WORDS:
Biomass, LiDAR, ALS, TLS, diameter at breast height (dbh)

ABSTRACT:

Accurate estimation of biomass is indispensible especially in urban environment. Remotely sensed LiDAR data provide the opportunity to measure key plant parameters such as tree height, crown diameter, and diameter at breast height (dbh). These parameters are further used to estimate the biomass. The main objective of the present study is to develop a procedure for estimating aboveground biomass of trees in urban environment using LiDAR data. More specific objectives included: measuring the tree parameters such as tree height, crown width or diameter, and diameter at breast height. In this study we like the ability of LP 360 software to extract the single trees from rest of the LiDAR point cloud and effortlesslymeasure the tree parameters, whichis a tedious task in field surveys.

1 Introduction

World's population is increasing rapidly in urban areas. This increase exhibits pressure on land use. Biomass plays a great role to determine global carbon cycle (Lefsky, 2001). Therefore accurate estimation of biomass is indispensible for urban environment. Remotely sensed LiDAR data provide the opportunity to measure key plant parameters such as tree height, crown diameter, and diameter at breast hight (dbh). These parameters are further used to estimate the biomass (Persson et al., 2002; Sah et al., 2004).

LiDAR systems are widely used in the present day remote sensing industry. LiDAR data has proven pretty effective in mapping objects for numerous applications. Primarily, there are three types of laser scanners; airborne laser scanners, terrestrial laser scanners and mobile laser scanners. For vegetation measurements and analysis, airborne and terrestrial LiDAR are mostly used. Airborne laser scanner (ALS) can record in several returns. But first, reflected from surfaces, and last returns, reflected from the terrain are customarily used. ALS is used for mapping at large areas. Terrestrial laser scanner (TLS) is used to carry out precise mapping for considerably small areas.

This present study is based on airborne LiDAR and terrestrial LiDAR data.

1.1 Objectives

The primary objective of the study is to development of a procedure for the estimation of biomass with focus on trees in urban environment. More specific objectives included are measuring the tree parameters such as

- Tree height
- Crown width or diameter
- Diameter at breast height (dbh)

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2 Data and Software

2.1 Study area

Stadtgarten (city garden) is selected as the study area, which is the neighborhood ofUniversity of Applied Sciences Stuttgart, Germany.

2.2 Data

First return and last return airborne LiDAR data is availablewith point cloud density of about 1 meter. Terrestrial LiDAR is captured with point cloud density of 0.03m. The terrestrial laser scanning is done with Leica ScanStation2. The data is captured twice (spring and summer) to assess whether seasonal variation has any effect on the measurement of tree parameters. Terrestrial LiDAR is captured for ground truthing purpose. During the scanning exercise, three strategic scan stations are chosen to give a complete overview of the three identified trees. The recorded 3D point cloud is in local coordinate system and to enable georeferencing of the said data to a common world coordinate system as the Airborne LiDAR (ALS) data, four targets were distributed in the scanned area at predefined locations of known GPS coordinates.

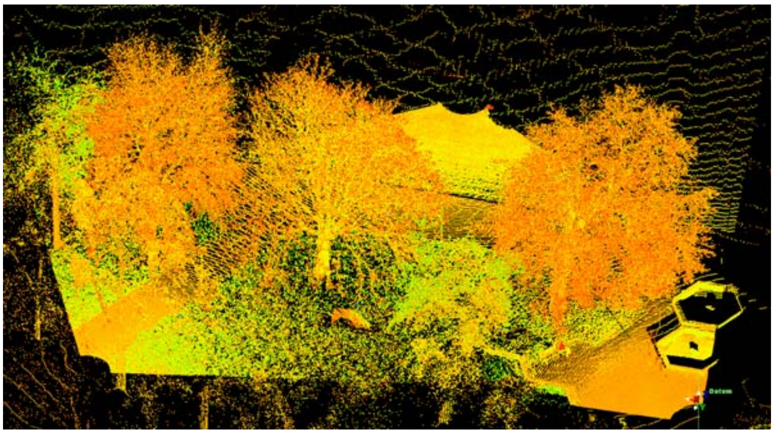

Figure 1: TLS data captured from three well distributed stand points

2.3 Software:

Leica Cyclone 7.0.2, LP 360(LP Viewer) and MATLABsoftware are used in the study.

3 Methodology

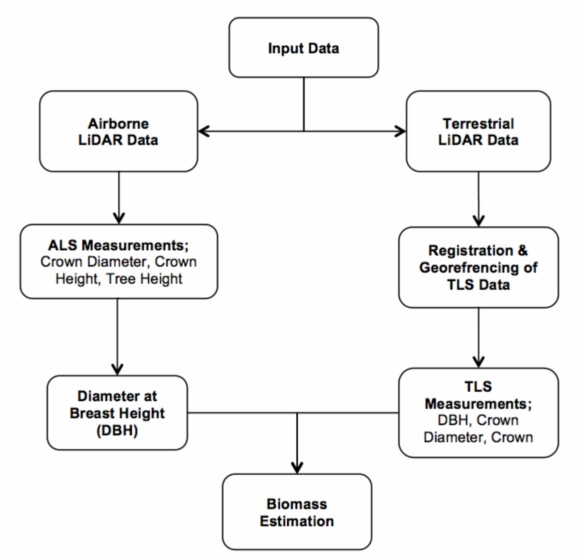

Figure 2demonstrates the overall workflow of the study.

3.1 Preprocessing of TLS data

Airborne LiDAR is already set up for measurement and analysis. However recorded terrestrial LiDAR data has to be first registered and georeferenced before doing any analysis. Registration of points from the three scan locations is then performed in Leica Cyclone 7.0.2 using algorithm called the ICP (iterative closest point) that matched the point clouds with an accuracy of 2mm (which is within the expected accuracy level of 5mm).Georeferencing of the distributed targets is done based on their GPS coordinates thus bringing the TLS data to the same coordinate reference system as the ALS data i.e. UTM zone 32N, WGS 84. Once the TLS data is now in the same coordinate system as the TLS, the two data were then merged together if desired.

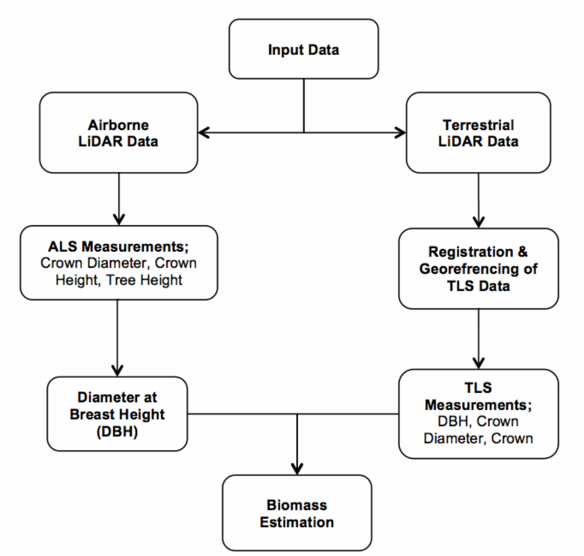

Figure 2: Workflow of the study

3.2 Measurement of Tree Parameters:

Height and crown diameter of the trees can be measured directly from airborne LiDAR. Diameter at breast height (dbh) cannot be measured directly because there are no points on the trunk of the tree in ALS. Dbh is the most significant parameter in estimation of above ground biomass. Crown width and height of the tree are precisely measured from ALS particularly. The cross section of the crown is not uniform. To reduce errors in measurement, crown diameter is measured in two transverse directions and the average value isused in each case.

In very large forest covers, it is necessary to develop a canopy height model (CHM) and a digital terrain model (DTM) for automatic derivation of tree parameters. For typical urban areas where there exist only pockets of tree stands, individual trees can precisely be extracted without much labor. In this study all the measurements are carried out in LP360 software. In terrestrial LiDAR, dbhcan be directly measured. The terrain of the study area is almost flat, at approximately 301.4m above mean sea level. In Europe dbh is measured at 1.3m above ground. Hence, a filter is run to get rid of points below 301.4m and those above 302.7m. The bare tree stems were thus precisely measured (see Figure 3).

The measured dbh can thus be used as input parameter for for the biomass estimation.

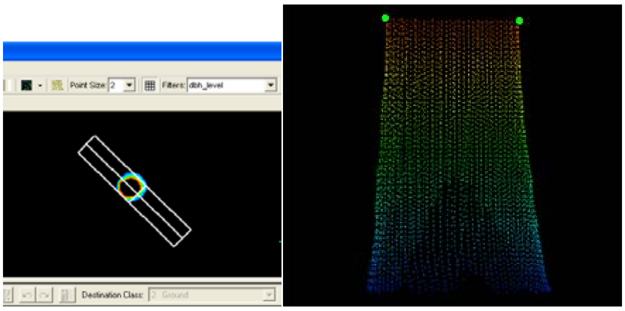

Figure 3: Measurement of dbhbased on TLSpoint clouds (left) Selection Window (right) Extracted Tree (Visualized in LP 360*)*

3.3 Comparison of ALS and TLS measurements

It is observed that ALS data measurements are lower than the TLS data measurements. It is because the ALS point cloud density is much lower than the TLS data. Suárez (2004) also observed that tree heights determined from ALS data were 7% to 8% less as compared to reference data.It is found that seasonal change does have effect of the measurable parameters i.e., tree height and tree crown diameter. Nevertheless dbh remains the same. An increase in the height and crown diameter is observed in TLS data measurements. This increase is due the fact that in spring there were few leaves on the tree branches as compared to summer. Therefore for determining the biomass of deciduous trees, one has to take care of the seasonal variations.

Table 1: ALS data measurements

Tree No.	Average of Measurement (m)		
	CD	H	DBH
Tree No. 1	12.05	17.58	N/A
Tree No. 2	11.91	13.58	N/A
Tree No. 3	11.26	15.43	N/A

Table 2: Spring TLS data measurements

Tree No.	Average of Measurement (m)		
	CD	H	DBH
Tree No. 1	14.98	17.89	0.90

Tree No. 2	15.24	15.05	0.81
Tree No. 3	13.18	17.05	0.65

Table 3: Summer TLS data measurements

Tree No.	**Average of Measurement (m)**		
	CD	**H**	**DBH**
Tree No. 1	15.98	18.01	0.90
Tree No. 2	15.32	15.22	0.81
Tree No. 3	14.54	17.30	0.65

4 Regression Analyses and Biomass Estimation

Different types of equations have been used in past to calculate the above ground biomass. According to Zianis et al., (2005) majority of the biomass equations in Europe are the modified form of following equation simple linear equation

$$\log (M) = A + B \times \log (Dbh)$$

Where log (M) is logarithmic transformation of the biomass, log (Dbh) is the logarithmic transformation of diameter at breast height while A, and B are the estimated parameters (ibid).

The parameters, A and B, differ from tree species.

Biomass estimation equation used in Germany for tree specie *Fagus sylvatica* (Beech, Rotbuche, Beuk) is as follows (ibid);

$$\text{Biomass} = a + b \cdot Dbh \cdot H^2 + c \cdot Dbh^3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where;

$a = 15.589 \cdot 10^{-3}$, $b = 0.01696 \cdot 10^{-3}$, $c = 0.01883 \cdot 10^{-3}$

Dbh is diameter at breast height

In our study area, two out of three trees (Tree 1 and Tree 2) scanned with TLS belong to the specie Rotbuche. Using above equation biomass of only two trees of these species (i.e. Rotebuche) can be determined in stadtgarten. That is because dbh for other trees of said specie is not available in ALS.

Though dbh is a tree dimension that cannot be measured directly from ALS data but it can be measured indirectly as it is strongly correlated to Crown Diameter (CD) and Height (H) of the trees. Regression models can be used to develop equations for determining dbh. Sorin (2007) used the following equation to calculate the dbh of pine trees from lidar data.

$$dbh = a_0 + a_1 CD + a_2 H \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where;

CD is crown diameter

H is tree height

a_0, a_1 and a_2 are estimated parameters whose values vary from tree to tree specie

After inserting the values of dbh measured from TLS data, crown diameter and height of the tree, values of unknown parameters (i.e., a_0, a_1 and a_2) is determined by using least square estimation.

$$\underbrace{\begin{pmatrix} dbh_1 \\ dbh_2 \\ dbh_3 \\ \cdot \\ \cdot \\ \cdot \end{pmatrix}}_{B} = \underbrace{\begin{pmatrix} 1 & CD_1 & H_1 \\ 1 & CD_2 & H_2 \\ 1 & CD_3 & H_3 \\ & \cdot & \\ & \cdot & \\ & \cdot & \end{pmatrix}}_{A} * \underbrace{\begin{pmatrix} a_0 \\ a_1 \\ a_2 \end{pmatrix}}_{X}$$

$$X = (A^T A)^{-1} A^T * B$$

For regression model, more than five trees measurements have to be used; otherwise there could be errors because of variation in tree parameters at different growth stage. The resulted values of parameters a_0, a_1 and a_2 were found out to be -164.47, 11.90 and 4.26 respectively. Now biomassfor Rotbuchecan be determined by inserting LiDAR estimated dbhalong with height, a, b, and c valuesin equation 1. But for the other species, one has to first find the appropriate equation used to determine the biomass of that particular specie. Secondly, if the values of unknownparameters are not available then a similar regressionmodel has to be developed for estimating those unknown parameters. Nonetheless the method of estimating above ground biomass is very much clear.

5 Conclusions

LiDAR data is very useful to determine key parameters such astree height, crown height, crown diameter and dbh that are used to estimate above ground biomass of trees. With higher point cloud density of airborne data, measurement of parameters will be more accurate and hence will improve the overall accuracy of estimated biomass.

Cyclone is promising software in automated registering and georeferencing of TLS point clouds. However manual georeferencingin Cyclone is a tedious task. Cyclone does not have the ability to extract single trees from rest of the point cloud therefore it is very challenging to measure the correct distance between point clouds. On the other hand LP 360 is excellent software for extracting individual trees and parameter measurements.

In our study area different tree species exist. Thus there is a need of identifying all the tree species. Thereafterregression analysis has to be done for all the tree species separately to determine first dbh and finally biomass. To calculate the unknown parameters, tree specie must be known. If the field inventory data is not available, then multispectral images can be integratedwith LiDAR to identify tree species remotely over large area.

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Object Based Image Analysis (OBIA) for Decadal Landscape Change in the Kisumu, Kenya Region

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KEYWORDS:
Remote Sensing, Object-based Image Analysis, OBIA, Landsat, Land-use land-cover Change

ABSTRACT

Multi-temporal remote sensing is a tool that can aid in observing and monitoring increased pressure on land, such as land clearing, deforestation, agricultural stress, crop loss and water resource degradation, such as wetland loss. All of these can be related to socioeconomic patterns at intra- and inter- annual temporal scales through further geospatial analysis. Remote sensing image analysis was founded on manual image interpretation skills of the image analyst, however, with coarse resolution imagery such as Landsat, computer algorithm driven per-pixel based classifications were developed to automate and accelerate processing. Although per-pixel methods are efficient, these methods do not appreciate the local and contextual knowledge that an image analysis is able to supplement to the analysis. Object-Based Image Analysis (OBIA) is devoted to partitioning imagery into meaningful image-objects, and assessing their characteristics through spatial, spectral and temporal scale. At its most fundamental level, OBIA requires image segmentation, attribution, classification and the ability to query and link individual objects or segments in space and time. In order to achieve this, OBIA incorporates knowledge from the image analyst. We demonstrate a repeatable OBIA approach for landuse/landcover (LULC) decadal change analysis which utilizes Landsat imagery in the Kisumu region of Kenya. We compare our results to the most recent Africover classification for the region. Our results show a good agreement with the Africover data, moreover we are able to refine detail in some of the classes, such as the 'Aquatic Or Regularly Flooded Graminoid Crops', due to the ability to segment individual field or field complexes under the same management regime with the OBIA approach.

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Two stage sampling procedure to estimate forest biomass using airborne LiDAR

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KEYWORDS:
LiDAR, remote sensing, statistical modeling, REDD+, carbon monitoring

ABSTRACT

Accurate estimation of forest biomass using remotely sensed data is a key for high-resolution Reducing Emissions from Deforestation and Forest Degradation (REDD+) monitoring and performance based carbon payments. In two-stage sampling procedure the biomass values are first computed for field reference units in theforest. These values are then used to calibrate LiDAR data covering a certain per cent of the study area. LiDAR derived forest variables are subsequently used to calibrate satellite images to get a complete coverage over a greater area. The study aim was to test biomass estimation accuracy obtained with airborne LiDAR and multispectral Landsat ETM+ data in two-stage sampling procedure. The test area was located in Eastern Finland (62°04' North, 28°0' East) in mixed evergreen forests consisting of spruce (Piceaabies), pine (Pinussylvestris) and birch species (Betula ssp.). The area covers approximately 2,000 hectares of forest land. Plot-specific above ground biomass was calculated and scaled as tons per hectare. A network of polygon grids was established as estimation units. Linear regression was applied to relate datasets. A number of features were extracted from LiDAR and multispectral data to estimation grids, and linear regression model was fitted in R software. The models were cross-validated. The accuracy was tested as root mean square error (RMSE) and goodness of fit of the model by coefficient of determination (R2). The estimations resulted an RMSE value of 20.9 tons/ha between field measured and LiDAR predicted biomass, and 37.5 tons/ha between field measured and LiDARLandsat ETM+ predicted biomass. The regression model between field data and Landsat 7 ETM+ gave an R2 value of 0.55; the model between field data and LiDAR prediction gave an R^2 value of 0.85 and the model between LiDAR and Landsat 7 ETM+ predicted biomass a R^2 value of 0.47. According to resultsLiDAR outperformed Landsat 7 ETM+ based estimation. However, for large area inventory the two-stage sampling procedure or Landsat 7 ETM+ based inventory give satisfactory results.

The Capabilities of SPOT4 and Landsat SLC-off Data to Extend Existing Landsat-Derived Land Cover Time Series Data for East African Rain Forest Areas

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KEYWORDS:
High resolution satellite imagery, Landsat SLC-off, SPOT, supervised classification, artificial bands, accuracy assessment

ABSTRACT:

The BIOTA East Africa sub-project E02 used remote sensing time series data for investigating the influence of fragmentation and human use on the biodiversity of three East Africa rain forest areas: Kakamega-Nandi forests area in Kenya, Mabira and Budongo Forest areas in Uganda. Analyses of the land cover changes since the early 1970s until 2003 for these three rain forests were done by processing Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and ETM+ imagery for eight or seven time steps at regular intervals. This has resulted in 12 land cover classes for Kakamega-Nandi and Budongo forests areas and 10 classes for Mabira Forest area out of a consistent set of 15 land cover classes. For continuous forest change analysis, the three existing time series data had to be extended by another two time steps from more recent years (2005/2006 and 2007/2008).

Since, on 31 May 2003 Landsat ETM+ suffered the loss of its scan line corrector (SLC) with a data loss of about 22% per scene, this paper explains the alternative solutions that have worked out for extending the Landsat-based time series. One alternative approach is the continuous use of Landsat imagery while handling the SLC-off data gap issue. The second approach involves the use of SPOT imagery with all its differences mainly regarding spatial and spectral resolutions and the difficulties in providing similar land use / cover classes for time series extension. Here, for Mabira Forest artificial SPOT bands were tested to enhance forest class separability which resulted in only very minimal improvement on the overall classification. SPOT imagery was also used for the Kakamega-Nandi forest area handling the challenge of splitting across two scenes with unsolvable problems of distortions along the edges and differences arising for the farmland. For Budongo Forest area, SLC-off imagery was the choice as one scene had been available from the vendor with already filled gaps while in the other gaps were not stretching across forest areas.

It can be concluded that even though a fully working Landsat would be preferred, both SPOT and Landsat SLC-off data offered the chance of extending the existing times series with truly comparable classification results. The same land cover classes have been distinguished as in the previous time steps using supervised multispectral classification. The applied methodology resulted in high classification accuracies.

Advances in GIScience and current developments

Improving Existing Spatial Reference Systems - Comparing and Evaluating Transformation Modells Based on German Examples

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KEYWORDS:
Geodetic datum, transformation, grid based transformation, NTv2, BeTA 2007, ETRF, WGS 84

ABSTRACT:

Coordinate reference systems (CRS) are essential for combining spatial data in maps and in GIS. So it is an important task of survey administrations to provide users with easy to use reference systems for their daily work. CRS usually are theoretically defined as reference systems and realized physically by monuments. This realization are called reference frames. Examples are the International Terrestrial Reference System (ITRS) and the International Terrestrial Reference Frame (ITRF).

All the classic reference systems have been realized by using the latest technology for measurements, which has been triangulation until approx. 1970 and then trilateration until GPS comes up for long distance measurements in the late 1980th. All the classical measurements (angles and distances) are very precise in a close neighbourhood, but not absolutely. With global navigation satellite systems (GNSS) we now have the possibility for precise positions independent from distances and it is easy for everyone to determine precise positions everywhere. Now the task is to adjust absolutely accurate data to reference systems that are precise only locally. Therefore mostly 7 parameter transformations (7PT) are in use. The result of each 7PT is depending on the control points used and not suited to adjust large areas precisely.

For users who have to combine own data with administrative data or for users that have to combine data based on a given reference system, it is essential to have a common transformation which is unique for big areas, e.g. for a country. Such transformations can be applied by using a grid based approach. An example therefore is the NTv2 transformation developed for Canada which can be applied for any area. It is able to model and adjust local distortions in CRS in a unique way.

In Germany the NTv2 approach is used for transforming topographic data based on the current geodetic datum Deutsches Hauptdreiecksnetz (DHDN) into the new European Terrestrial Reference Frame (ETRF 89).

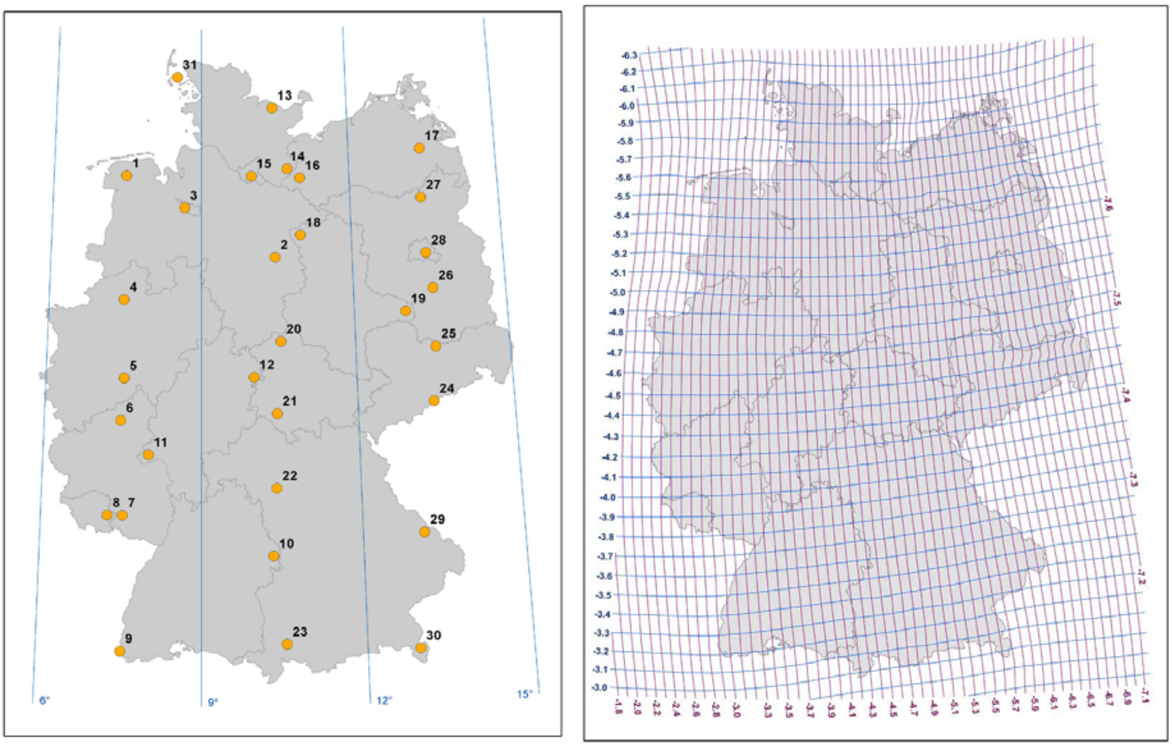

Figure 1: Control popints (left) and shift values (right) of the German transformation BeTA2007 for topographic data. Accuracy is on decimeter level.

Within the next years all locally precise cadastral data has to be transformed and improved from DHDN to absolutly precise ETRF 89. In the authors opinion NTv2 will be the best solution for this task. Therefore the German states have to publish local NTv2 grid files which are harmonized at the states boudaries.

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Precise Point Positioning: A GNSS Method for Georeferencing Isolated Regions

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KEYWORDS:
GNSS, GPS, precise point positioning, geodetic reference system, post processing

ABSTRACT:

The use of GNSS, especially GPS, is a standard technique for georeferencing spatial data. Its precision is depends on receiver types and on the methods to eliminate systematic errors.

Precise Point Positioning is an upcoming technique for precise GNSS positioning which is based on observations of a single rover and information about satellites from monitor stations around the world.

This solution is explained and compared with existing GNSS techniques. Free service providers are introduced and some results from research at HFT Stuttgart are given together with ideas for using it in areas with no geodetic infrastructure.

1 Standard GNSS methods overview

Single Point Positioning is the stand alone solution in all consumer devices. It works autonomously based on pseudo ranges (run time observations). Its accuracy is about 10 meter everywhere.

Differential solutions based on pseudo ranges (DGNSS) are integrated in all GNSS rovers. They need corrections for all pseudo ranges which can be broadcasted by local or satellite based services, e.g. Beacon, OmniStar or the free European service EGNOS. Position quality under good conditions is 3 to .3 meter depending on the equipment.

Differential solutions based on carrier phase measurements derive baselines from observations of neighouring GNSS units with centimeter accuracy. If the baselines are calculated in Real Time, the technique is called Real Time Kinematic (RTK) GNSS. If a GNSS reference network exists, like SAPOS in Germany, the base station can be calculated as a virtual station.

Both differential techniques are based on nearly parallel satellite signals at the base stations and the rover. Differences in broadcasted satellite ephemerides, satellite clock offsets and the influence of ionosphere and troposphere on speed of light are eliminated in the differential solution. The distances between base station and rovers are limited. They depend on broadcasting techniques and required precision. Differential solutions only determine coordinate differences (baselines) between receivers. So connection to control points is necessary to get positions related to a geodetic datum.

2 Precise Point Positioning

The Precise Point Positioning (PPP) brings centimeter accuracy in a well defined global reference system (absolute positions). This is possible with precisely known orbits of all satellites and exact offsets of the satellite clocks. In addition the effects of ionosphere and troposphere must be eliminated by models and observations based on two carrier phase frequencies. The information about satellite orbits, clocks, ionosphere and troposphere are collected and published from monitor stations around world by several organizations. One is IGS the International GNSS service. Figure 1 shows a cutout from the IGS product table on the Internet. We can see that broadcasted satellite information can be improved very much for post processing purposes.

IGS Product Table [GPS Broadcast values included for comparison] -- updated for 2009!						
		Accuracy	**Latency**	**Updates**	**Sample Interval**	**Archive locations**
GPS Satellite Ephemerides/ Satellite & Station Clocks						
Broadcast	orbits	~100 cm	real time	--	daily	CDDIS(US-MD) SOPAC(US-CA) IGN(FR)
	Sat. clocks	~5 ns RMS ~2.5 ns SDev				
Ultra-Rapid (predicted half)	orbits	~5 cm	real time	at 03, 09, 15, 21 UTC	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. clocks	~3 ns RMS ~1.5 ns SDev				
Final	orbits	~2.5 cm	12 - 18 days	every Thursday	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. & Stn. clocks	~75 ps RMS ~20 ps SDev			Sat.: 30s Stn.: 5 min	

Figure 1: Cut out of IGS product table. The better accuracy of post processed satellite information can be seen clearly. The influence of satellite clocks decreases from 1.5m (5ns) to 2.2 cm (75ps).

With the precise information about satellites it is possible to calculate GNSS positions from only one dual frequency receiver with centimeter accuracy in post processing if satellite signals are observed for a long time (> 10 h).

There are several organizations offering free post processing services on the internet, e.g. Natural Resources Canada and the NASA Jet Propulsion Laboratory. Loading up an observation file will bring back positions related to ITRF within some minutes.

The method has some advantages:

1. A single GNSS receiver can be used to get centimeter accuracy.
2. All positions are related to a well defined geodetic datum which is valid globally.
3. Observations can be done during nights, when the equipment is not in use for other measurements.
4. The services are free (at the moment).

Disadvantages are long observation times, the restriction to post processing if precise results are required, and costs for dual frequency receivers.

3 Recommendation for the use of Precise Point Positioning

The possibility to get precise coordinates related to a well defined global coordinate reference system (CRS) everywhere makes it a good tool in regions with no geodetic infrastructure like fields of monuments or GNSS reference networks. It enables users to fit their collected data into a global CRS. Therefore the GNSS receivers can run during nights on control points which are used during days for data collection with DGNSS equipments or tacheometer.

Using PPP for georeferencing some control points, data can be collected in isolated regions in a way that fits it precisely to all other data collected on earth. Local measurements between the PPP control points will check and improve PPP results.

4 Results from HFT Stuttgart

HFT Stuttgart performed some first tests on Precise Point Positioning. Therefore pillars on the roof of our building 2 have been equipped with dual frequency receivers TOPCON Hiper Pro to observe GPS and GLONASS satellites continuously for 12 hours at May 15th and July 4th.

Figure 2: Pillars on the roof of HFT Stuttgart building 2 equipped with dual frequency GNSS receivers TOPCON Hiper Pro.

The PPP equation was done using the service of Natural Resources Canada, which delivers the results immediately after the upload of a RINEX file in geographic coordinates and in UTM projection related to ETRF 08. We used projected coordinates to compare the results of the two sessions directly and with baselines between the pillars calculated from the long term observations using Leica LGO software.

PPP-Calculation (ITRF08-UTM) **Nat. Res. Canada solution**

Punktnr	duration [min]	Easting	ITRF 05 Nothing	Ell.Height	Estimated Qualities East [m]	North [m]	Height [m]	Differences East [mm]	North [mm]	Height [mm]
Observation 17.05.2011										
PFEILER5	675	512731,028	5402984,782	323,937	0,002	0,004	0,007			
PFEILER4	765	512728,812	5402989,267	323,948	0,002	0,004	0,006			
PFEILER3	765	512726,592	5402993,742	323,945	0,002	0,004	0,007			
PFEILER1	690	512722,147	5403002,696	323,938	0,003	0,006	0,008			
Observation 04.07.2011										
PFEILER5	660	512731,038	5402984,785	323,927	0,006	0,013	0,024	10	3	-10
PFEILER4	765	512728,816	5402989,261	323,930	0,006	0,011	0,023	4	-6	-18
PFEILER3	735	512726,598	5402993,739	323,928	0,006	0,011	0,022	6	-3	-17
PFEILER1	690	512722,159	5403002,693	323,911	0,009	0,017	0,028	12	-3	-27
							Mean	8	-2	-18
Standard [mm] deviation from direct comparison								4,4	2,0	9,5

Figure 3: Comparison of two 12 hour sessions solved by the free service of Natural Resources Canada. The results of the two independent sessions are fitting perfectly

The comparison of the two independent sessions shows perfect results. Differences in easting and northing are less than 10 millimeters and in height less than 3 centimeters. The Standard deviations calculated from the independent results are all better than 1 centimeter. Height is a bit worse than easting and northing, which is usual for GNSS.

A second comparison (Fig. 4) was made between directly calculated baselines using differential carrier phase technique in Leica LGO software and differences calculated from the PPP solutions. Hereby it could be assumed that there are no rotations between the solutions and the scale factor is the same. Thus it is possible to compare the solutions by introducing 3 shift values in easting, northing and in height.

Baselines			solved with Leica LGO ETRS89			calculated from PPP ITRF 2008			Mean Offset between results ased on ETRS89 and ITRF08		
From	To	Obs. Time [min]	dEast [m]	dNorth [m]	dHeight [m]	dEast [m]	dNorth [m]	dHeight [m]	[mm]	[mm]	[mm]
Observation 17.05.2011											
P 3	P 1	690	4,435	-8,952	-0,012	4,436	-8,960	-0,008	2	-8	3
P3	P3		0,000	0,000	0,000	0,000	0,000	0,000	0	0	0
P 3	P 4	765	2,219	-4,476	0,001	2,220	-4,475	0,003	2	1	2
P 3	P 5	675	-4,438	8,957	-0,001	-4,445	8,954	-0,007	-7	-3	-6
Observation 04.07.2011											
P 3	P 1	690	4,435	-8,952	-0,007	4,441	-8,954	-0,001	5	-2	6
P3			0,000	0,000	0,000	0,000	0,000	0,000	0	0	0
P 3	P 4	765	2,219	-4,478	0,001	2,218	-4,478	0,002	-1	0	1
P 3	P 5	675	-4,439	8,957	-0,002	-4,438	8,954	-0,017	0	-3	-15
								Mean	0	-2	-1
								St.Dev.	3,1	2,7	6,2

Figure 4: Comparison of independent baselines calculated in standard GNSS software Leica LGO with PPP results from Natural Resources Canada. The differences in the baselines from LGO can be neglected.

For this comparison it can be assumed that the short baselines calculated from long term observations are more precise than the coordinate differences from the PPP solutions. Figure 4 shows that this assumption is true. Differences between independent baselines can be neglected. The standard deviations along the PPP axes confirm the results from the direct comparison of PPP sessions. They attest, that PPP brings very good results in post processing when the observation time is long enough (here 12h).

5 Conclusion

Precise Point Positioning is a perfect and cheap method for geroreferencing control points directly to a global reference system. It can be used everywhere if there are no obstacles between a GNSS receiver and satellites. It enhances the relative methods for data capturing with the possibility to get absolute coordinates easily.

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Implementation of Full Text Search for Opengeocoding.org

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Full Text Search, phonetics matching, intelligent data retrieval, PostgreSQL

ABSTRACT

This paper describes the stepwise procedure for integration of full text search functionality in Opengeocoding.org which is a free and participatory community oriented project for assembling geocoded address. The full text search functionality provides an intelligent retrieval and suggestion of the addresses already stored in the database as a user types in a field to find a specific address. For the development of such tool, PostgreSQL has been used as Database Management System (DBMS), PHP has been used for server side scripting, and JavaScript and jQuery libraries have been used for client side scripting

1 Introduction

1.1 Background

The addition of a spatial component to other types of information exponentially increases ability of decision makers in diverse fields to take well informed decisions. Therefore, people always have been interested to know ‘where is something’ and wanted to have an ability to visualize it in an interactive map. This has been greatly simplified with the emergence of freely available web mapping applications like Google Maps, Yahoo Maps or Virtual Earth. However these commercial online mapping tools have great detail coverage of street data and address data in most of the developed countries but address information is limited in ‘information poor’ developing countries which cover most of the part of southern part of the Earth. Therefore to build the gap between ‘information rich’ North and ‘information poor’ South, a free and participatory community oriented geocoding service project named "Opengeocoding.org" was initiated in 2007. The project aims to collect geocoded address data, e. g. postal addresses and coordinates, in order to make them available and usable by web based services on a worldwide level with a focus on developing countries (Behr, Rimayanti and Li, 2008; Behr, 2010). The project was founded with the belief that a person living in a particular area best knows local surrounding and many more locations around the vicinity. The idea was to attract people to voluntarily contribute and assemble geographic data and store the information in a database which could be later provided as a service to geocode a place in different format such as XML, KML or JSON. Thus the project aims to be one of the major hubs of freely available data collected based on principle of Volunteered Geographic Information (VGI, Goodchild 2008).

Since its inception, only about 700 users have come together to collect geographic data from different parts of the globe. The database has been continuously growing but not in a pace that was expected before. Therefore, the database as well as the web interfaces of the project is in the process of major overhaul to attract many more users providing with many additional features which enhance the functionality aspect as well as performance. The database has been moved from MySQL to the more robust open source database management system (DBMS) PostgreSQL.

This paper describes the integration of PostgreSQL’s full text search (FTS) functionality to provide an intelligent retrieval and suggestion of the addresses already stored in the database as a user types in a field to find a specific address.

2 Overview of FTS in Opengeocoding.org

The database of opengeocoding.org contains vast source of address information, either collected from its users or acquired from publicly available datasets on the internet. Therefore, it is felt that there is an immediate necessity to develop a tool by which a user can filter and find desired address information from a gigantic source of information pool. The tool should execute the search in a quick time and should provide an intelligent mechanism that automatically searches for matching entries and displays a list of results to choose from. The suggested results should be narrowed to find better matches as user types more characters of an address he/she is interested in. The tool should also accommodate room for mistyped words to provide more flexibility to the users.

For the development of such a tool, PostgreSQL was used as Database Management System (DBMS), PHP for server side scripting, and JavaScript and jQuery libraries were used for client side scripting. jQuery is a fast and concise JavaScript library that simplifies many task on client-side, i. e. document traversing, event handling, animating, and AJAX interactions for rapid web development (The jQuery Project, 2010). In addition, the autocomplete plugin found in the official website of jQuery is used.

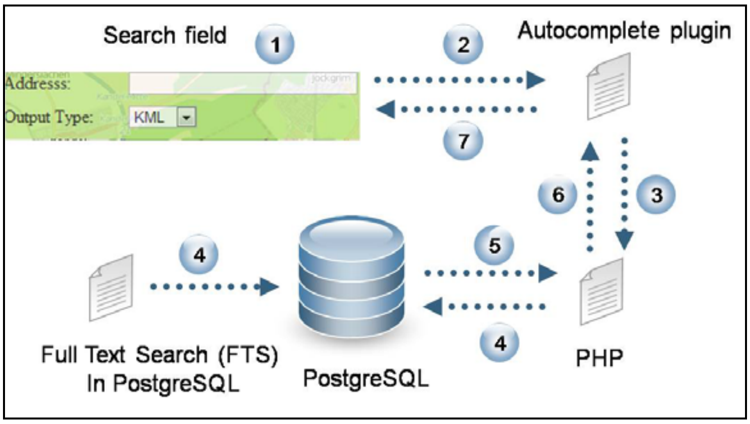

Figure 1: Executing steps in implementation of FTS with PostgreSQL backend

2.1 Autocomplete plugin jQuery

The autocomplete plugin is one of the most popular plugins in jQuery. When linked with an input field, it enables users to quickly find and select values from the matching list as they type, leveraging searching and filtering. Autocomplete can be customized to work with various data sources such as array with local data, a string specifying a URL or a Callback (The jQuery Project, 2010). For database driven application, a callback is most appropriate where a PHP file can be attached to select data from a database. Integration of autocomplete in a web page can be achieved in a very simplistic and convenient way without much hassle and time requirement. To get started, one needs a copy of jQuery as well autocomplete plugin which can be easily downloaded from the official jQuery website. Else, one can also link to the resources where files are stored saving bandwidth, if bandwidth is an issue, preventing the multiple loading of the files if a user's website cache has already stored ht jQuery library. Once the required jQuery files are properly linked, attaching autocomplete feature to any input field is a piece of cake as shown in Table 1.

Table 1: Using an autocomplete feature with a particular div in a html

```
$("#input_field").autocomplete("XYZ.php",{options})
```

Once a user starts typing in a test input field identified as ‘input_field’, typed words are sent to a ‘XYZ.php’ as a HTTP GET request with a parameter ‘q’. Now, ‘XYZ.php’ communicates with the database and uses the FTS feature of PostgreSQL to retrieve the most appropriate results and to send them back to the client. The data fed into the autocomplete feature can be customized for display as required. In our case, the address data extracted from the database using FTS also have ‘row id’ and ‘tablename’ which are necessary for displaying the extracted data on the map are hidden when displaying results by the autocomplete. Also, many other customizations were done such as to control numbers of character needed to type before the autocomplete request is to invoke and the time frame between each request.

2.2 Full Text Search in PostgreSQL

The full text search (FTS) feature in PostgreSQL was developed by Oleg Bartunov and Teodor Siegev (2007) from University of Moscow who are actively engaged in the development of PostgreSQL. According to the developers, FTS is a search for documents which satisfy a query string 'query' and returns documents in some order according to their 'similarity' to the 'query'. In earlier versions of PostgreSQL, FTS was available as a contribution module, first as 'tsearch' and then as 'tsearch2' which has to be downloaded and installed afterwards but since PostgreSQL 8.3 version, it is installed by default.

FTS mainly involves three major steps (Bartunov and Sigaev, 2007).

- Parsing documents to lexemes: The initial step is to parse the documents into so called 'lexems' or 'tokens'. There are various classes of lexemes in PostgreSQL for example E-mail addresses, numbers, words and many more.
- The next step is to normalize the 'lexems' into so called *stem* or *infinite* from using a linguistic rule. This means all the similar words such as giving, given, gave or gives are reduced to the common stem word give. PostgreSQL provides linguistic support for all the major languages such as English, French, German, Spanish etc. Altogether 15 major linguistic configurations are available in PostgreSQL.
- The last step is to store the normalized stem words in an optimized way to allow faster searching operation. Therefore, it is always necessary to perform indexing in a stem words. PostgreSQL provides four different types of indexing namely B-tree, Hash, GIST and GIN indexing (The PostgreSQL Global Development Group, 2010).

2.3 Functional aspects of opengeocoding.org

Before describing the implementation of the FTS for the opengeocoding.org, it is worthwhile to have a short description about the functional aspects of the site. As mentioned previously, the site is voluntary driven by many users who have a common motto to assemble geographic data throughout the world with high emphasis on developing countries. The site provides a geocoding service for postal address on that data free of charge through a REST based web service (Behr, Rimayanti and Li, 2008). The application does not rely only on its internal database filled by the community but also on comprehensive lists of POI (Point of Interest) from other publicly available data services which are integrated in its database. If no relevant results are found from its database, the request will be forwarded to Google's geocoding service (http://code.google.com/apis/maps/-documentation/geocoding/), forwarding the results to the client. The address database is stored across two database table, one for the address data submitted by the community and one for the POI data.

The structure of the table storing address data collected by various users is shown below. It mainly has columns storing address information and columns storing its geographical coordinates. 'the_geom' storer the geometry information populated using 'Longitude' and 'Latitude' fields required for a Web Map Service (WMS) service using Geoserver.

Table 2: Data structure of a table storing address information collected from users

Column name	Data type
country	character varying(60)
province	character varying(30)
city	character varying(60)
name	character varying(160)
district	character varying(60)
street	character varying(60)
housenumber	character varying(60)
postcode	character varying(60)
latitude	numeric
longitude	numeric
username	character varying(60)
source	character varying(20)
addressaccuracy	integer
geometricalaccuracy	integer
version	integer
modtime	timestamp
comment	text
the_geom	geometry

3 Integration of FTS

The main purpose of integrating FTS is the provision of intelligent suggestions for the user to find a closely matched address as he/she types in a field to find a specific address. Providing such a mechanism has the advantage that the user does not have to type whole address information which sometimes is pretty long. Consider an address *'United States California San Diego Meadowrun Wy 9157'* which is a 53 character long address. A user will obviously not want to type such long address every time. In addition a user can search the above address in number of different ways such as *'Meadowrun Wy 9157'*, *'9157 Meadowrun Wy 9157 San Diego'*, '*United States Meadowrun Wy 9157*' or '*Meadowrun Wy 9157 United States*'. The conventional pattern matching operator 'LIKE' which is very commonly used in both MySQL and PostgreSQL will fail miserably in above mentioned circumstance because 'LIKE' operator is highly dependent on positioning of string to be searched. The FTS eliminates such shortcomings and provides an efficient way for a search where a user can look for an address in different word form and in different word order.

3.1 Parsing address to lexemes

The address information in the database is structured as shown in Table 2. The individual columns have to be concatenated to form a complete address in the sense of a 'full text' address. In many instances certain columns are either empty or NULL. Therefore use of string concatenation operator ('||') is not suitable in this case as it would yield NULL if any of the column used in concatenation operation is empty. Therefore, string concatenation is done in conjunction with PostgreSQL's *coalesce* function so that if any of the columns is NULL, then it will not be used in concatenation procedure. In addition, POSIX regular expression which provides more powerful means for pattern matching was used to remove space among the concatenated string.

Depending upon the dictionary used, the result of parsing a string yields different results (cf.Table 3). When parsing, each dictionary excludes certain sets of common words (such as a, the, and) known as STOP words in PostgreSQL. It is up to the specific dictionary how it treats stop words.

Table 3: Influence of language configuration in ts_vector

SELECT to_tsvector('english', 'Flughafen stuttgart of germany'); >>>'germani':4 'flughafen':1 'stuttgart':2	SELECT to_tsvector('german', 'Flughafen stuttgart of germany'); >>>'of':3 'flughaf':1 'germany':4 'stuttgart':2

Since, the address information stored in the database is collected from all over the world, it is apparent that addresses stored have many language specific words which would incorrectly parsed if an incorrect language dictionary is used. For example, in the above table, string *'Flughafen'* was parsed in stem word *'flughaf'* correctly when used *'German'* dictionary but *'English'* dictionary could not recognize the word and hence returned whole word 'flughafen'. Therefore, it is necessary to use correct dictionary when parsing an address. But then again, it is very difficult to predict in which language a user is entering an address to search. Therefore, it was decided to use a 'simple' dictionary configuration which is a language independent dictionary which just converts the input string into lower case and returns it as stem words.

3.2 Storing of stem vectors as separate columns

As shown in Table 3, the addresses are converted to stems by using *to_tsvector* function in the PostgreSQL. There are two possible ways in which *to_tsvector* function can be used. In the first method, the results of the *to_tsvector* are stored in an another column and stem matching is done on that new column. This has the advantage that a person can see an address string and its stem variation side by side which is very helpful to understand and debug FTS. Alternatively, *to_tsvector* can be directly used in the query without storing the stem words. This would save some space in the database but needs more computation time afterwards. For our case, we have chosen the first method of storing stem vector in a separate column in a table, as suggested by Scherbaum (2009). Besides stem words can be seen and also, it is faster compare to latter method because once the stem vectors are stored, only matching has to be done where as in second method parsing of address in lexeme stems occurs in every query (see Table 4).

Table 4 also shows the difference between the ways *to_tsvector* can be used. In query 1, *address_vector* is a column populated with stem vectors resulted from *to_tsvector* and *search_string* is the string to be matched. For matching stem vectors, PostgreSQL provides the function *to_tsquery* and *plainto_tsquery* for converting a query *to_tsvector* type. In our case, *plainto_tsquery* is more appropriated as it transforms search string into normalized stems and inserts "&" operator within the resulted string.

Table 4: Storing ts_vector vs. without storing ts_vector

Select * from TABLE where address_vector @@ plainto_tsquery('simple', 'search_string') >> Query 1	Select *from TABLE where to_tsvector('simple', 'address') @@ plainto_tsquery('simple', 'search_string'); >>Query 2

3.3 Creating indexes for faster search

Once the column address_vector is populated with stem vectors resulted from to_tsvector using 'simple' language configuration, it is necessary to use indexing in that column which would greatly enhance speed of execution of a query. PostgreSQL provides two types of indexes which can be used for FTS: Generalize Inverted Index (GIN) and Generalized Search Tree Index (GiST)[1]. In The PostgreSQL Global Development

[1] For detailed description, please refer The PostgreSQL Global Development Group (2010)

Group (2010) as well as in a Watermann (2010), it is stated that following performance differences exist between GiST and GIN.

- GIN index lookups are about three times faster than GiST
- GIN indexes take about three times longer to build than GiST
- GIN indexes are about ten times slower to update than GiST
- GIN indexes are two-to-three times larger than GiST

Since speed of query execution is of utmost importance for implementing FTS with autocomplete and longer build time for the GIN index is not a constrain for our application, GIN index appear to be ideal for us. The updating of indexes will be performed every day or week during night time with low user interaction. Nevertheless, time required to build both GIN and GiST indexes were compared. For a table in a database with about 600 thousands records, time required for building GIN and GiST was ~36 s and ~72 s respectively whereas for another table populated with data from Geonames.org with much higher numbers of records (~ 7 Millions), time required for building GIN and GiST was ~13 min and ~30 min. In both of the cases, the time required for building the GIN index was twice as much as for the GiST index. However, owing its superior execution speed, GIN index was selected as most appropriate and hence implemented for the FTS.

3.4 Ranking search results

With above described step wise procedure, the FTS is a fully functional search feature providing near instant results as a user looks for a particular address. However, it is not yet fully optimal because it still lacks an ability of measuring relevancy of found results with a particular query when many matches are found. For example, if a user looks for *'Dee'*, the FTS implemented in the database would find '*United States California San Diego Deer Lake'*, *'Red Deer'* or *'Deer Park, Maryland'* out of many others. Since, the results of a query could be many, a common practice is to limit the results that are displayed. In such case, query results are displayed in the order it is found in the database, hence in such case only 'United States California San Diego Deer Lake' might be presented to users in spite of the fact that other results are more relevant to the query when we consider the length of the results. Such limitation can be alleviated in the FTS when some ranking for search results are integrated so that the results are displayed according to relevancy which takes into account proximity information or how often the query terms appear in the results. PostgreSQL provides functions *ts_rank* and *ts_rank_cd* for ranking search results. The latter function is used because it is considered more superior than the previous function as it computes cover density ranking for given vector and query utilizing positional information in input vectors (Bartunov and Sigaev, 2007). When ranking search results, size of the results is also taken into account as a two words result with one instance is probably more relevant than a six words result.

Table 5: Query to account for ranking search results

```
Select REQcolumns,ts_rank_cd(index, query, 32 ) AS rank from TABLE, plainto_tsquery
('simple', 'search_string') query where query @@ index
```

3.5 Incorporating provision for alternatives names

It is obvious that a same place can have different names within the same language as well as based on different language (aliases and vernacular names, see Behr 2010). For example, 'Germany' has other names such as Deutschland (common, German), Bundesrepublik Deutschland (official,German), Duitsland (common,Dutch) or Alemania (common, Spanish) among many others. It is important that FTS implementation should also incorporate provision for alternative names so that when a user residing in Spain or Portugal searches "Almania" using native regional language Spanish, the search string should be considered as " Germany ". For the same purpose, PostgreSQL provides provision of extending FTS configuration with user defined synonym dictionary and thesaurus dictionary configuration. Synonym dictionary is used to replace a word with a synonym whereas thesaurus dictionary is used to replace a collection of words with other words. These dictionaries are list of '*FROM* ' to '*TO'* words which have to be created in a Notepad or similar text applications for each language configuration that will be used in FTS and placed in a certain PostgreSQL installation. In addition, FTS configuration has to be altered before these dictionaries can be used[2]. Since *simple* configuration for FTS was used, which is a language independent configuration, synonyms and thesaurus words in different languages can easily be placed in a single text file. Table 6 shows the structure of the thesaurus dictionary and the output when the dictionary is incorporated in FTS. For example, if a user queries 'UAE' which is a short form of the country ' United Arab Emirates ', the FTS with user defined synonym and thesaurus configurations results 'arab':2'united':1 'emirates':3. The numbers in the results indicates position of strings in the parent string 'United Arab Emirates'.

Table 6: Using custom thesaurus dictionary and its results

File	Query	Result

University of Applied Sciences : HFT
 	
UAE : United Arab Emirates
	to_tsvector('simple','UAE');
	
	to_tsvector('simple','University of Applied Sciences');
		'arab':2'united':1 'emirates':3
		'hft':1

The speed of execution of a query with FTS configuration with integrated custom made dictionary configuration seems to be relatively fast up to a certain numbers of lines or records. For thesaurus configuration with about 60000 records, execution speed was in the order of less than a second. Since, the thesaurus list, that we have, contains lines in the orders of millions (alternatives names collected mainly form geonames.org), the speed of query execution was considerably slow (~40 to 50 s).This was not acceptable for the FTS with autocomplete where results should be ideally displayed with less than a second. Hence, the idea of using custom dictionary configuration was totally abandoned but an alternative way was implemented. In this alternative approach, all the alternative names were also stored in the table, which was later concatenated with the main name and *tsvector* of the new column. But one difficulty was that the alternative names had many duplicate values which have to be removed before it is converted into *tsvector* otherwise, it would negatively affect the ranking of search results. Since, PostgreSQL does not have a built in function to remove duplicate values from a list, a custom functions was implemented (Table 7**)**. For example if string 'name a, name b, name c, name a' is provided to that function, it would yield 'name a, name b, name c'. Since we are using PostgreSQL 8.3 which does not have *unnest* function which is available in higher versions, the *unnest* function is added as custom function as well. After removing duplicates words from concatenated strings, the *tsvector* is stored and FTS is implemented as described above.

Table 7: Custom function written for replacing duplicate words from a list of strings

```
CREATE OR REPLACE FUNCTION uniq_words(text)
RETURNS text AS $$
SELECT array_to_string(ARRAY(SELECT DISTINCT trim(x) FROM
unnest(string_to_array($1,',')) x),', ')
$$ LANGUAGE sql;
```

3.6 Incorporating provision of mistyped words

When a user types an address, there might be some spelling mistakes, most probably there would be only few letters difference in what he/she intended to type and what he/she has typed. FTS is pretty unforgiving in the case of misspelled words which means if an user types *'Uneted States'* instead of *'United States'*, the FTS would not yield any results. This is less than ideal because it is a natural tendency that most of the users tend to type fast, and spelling mistakes are likely to occur when typing in a fast speed. Therefore, to cater room for spelling mistakes, PostgreSQL's *fuzzystringstrmatch* module which provides several functions to determine similarities and distances between strings is examined for its suitability. Basically there are two main categories of matching of string similarity: the first class comprises equivalence methods which return true or false and the second similarity ranking methods which returns some sort of similarity measures (Behr, 2010). The fuzzystringstrmatch module provides functions such as *Soundex*, *Metaphone* and *Double Metaphone* which are based on methods of matching similar sounding names and falls in the second category mentioned before. The PostgreSQL Global Development Group (2010) states that these functions are not very useful for non-English

[2] For more detailed explanation about the how configuration of the FTS can be changed, please refer to The PostgreSQL Global Development Group (2010).

names. But our database contains addresses coming from different languages with different phonology and etymology. This already makes *Soundex*, *Metaphone* and *Double Metaphone* functions less ideal. In addition, these functions are greatly dependent on ordering of words within the string. Since a user can type a particular address in a numbers of different ways, these functions are not very appropriate. For example the difference function which is based on the Soundex system gives difference of 4 (0 means different and 4 means similar) when comparing *'stutgart'* with *'stuttgart Germany'* but results 0 when comparing *'stuttgart'* with *'Germany stuttgart'*. A user could type address in the order of house number, street, city, province and country, or in the order of country, city, house number and street. Hence, these functions do not fulfill the requirements. The *fuzzystringstrmatch* module also provides another function named as *Levenshtein distance* which works differently than the phonetics matching functions like *Soundex* and *Metaphone*. *Levenshtein distance* compares strings in terms of alphabetical positions in source and target string. But it also encompasses same drawback associated with *Soundex* and *Metaphone*, i.e. it is also affected by the ordering of words within a string.

Hence, it turns out that *fuzzystringstrmatch* module functions contain drawbacks and therefore could not be used for incorporating provision for mistyped words. PostgreSQL provides another module named *pg_trgm,* which provides functions and operators for determining similarity of string based on trigram matching. Trigram matching is a technique where trigrams (groups of three consecutive characters taken from a string) from source and target are matched against each other and similarity is measured by counting the number of trigrams source and target share. Afterwards the similarity measure is calculated which is a ratio of intersection size of trigrams divided by union size of trigrams. When comparing, trigram first converts strings to lower case. It also supports indexes such as GiST and GIN for very fast similarity searches. Therefore, trigram matching function *similarity* was used to make room for mistyped words because of the advantage that it is not affected by word ordering within the string as shown in .

Table 8: Similarity score does not affected by ordering of words in a string

select similarity ('Germany Munich', 'Munich')	0.466667
select similarity ('munich germany ', 'Munich')	0.466667

However, it was discovered that it has a slight disadvantage that it cannot identify non-English characters while forming trigram and instead considers them as a space. This has been illustrated in Table 9. Notice that when forming trigram of a string 'Germany Münich' with non-English letter 'ü', the letter is replaced as space and hence is present in the trigram. This drawback does however not affect the similarity score if the non-English letter is present in source *and* target string because it is considered as space. But it affects the similarity score for place names like Münich (in English it is known as Munich). If a source string is stored as *'Germany Münich'* and target string is *'Germany Munich'* then the similarity score is quite different than what it would have been if the source string was stored as *'Germany Munich'*(c.f. Table 9). This is not an ideal solution for the database with many non-English characters; nevertheless there is no other alternative available in PostgreSQL than to accept trigram with its shortcoming and to use it.

Table 9: Similarity function takes non-English characters as space

select show_trgm('Germany Munich')	{" g"," m"," ge"," mu",any,"ch ",erm,ger,ich,man,mun,nic,"ny ",rma,uni}
select show_trgm('Germany Münich')	{" g"," m"," n"," ge"," m "," ni",any,"ch ",erm,ger,ich,man,nic,"ny ",rma}
select similarity (lower('Germany Münich'), 'münich')	0.466667
select similarity (lower('Germany Münich'), 'munich')	0.466667

4 Conclusions

The paper describes a stepwise procedure to implement full text search (FTS) using the open-source database management system PostgreSQL and the jQuery autocomplete plugin which is a great way to provide an intelligent suggestion of the address already stored in the database as a user type in a field to find a specific address. With this features, address retrieval from the database is performed in a more intuitive manner providing intelligent suggestion for users as they type, in nearly real time. Alternative names were also incorporated in FTS when such information is available for places. But the drawback of FTS is that it is pretty unforgiving in the case of mistyped words. If there is even a single mistyped letter in a word, FTS would not result in any suggestion list. It was attempted to provide room of mistyped with *fuzzy string matching* and *trigram* module. It can be said that the function provided in *fuzzy string matching* was not appropriate for the purpose, but trigram module was found to be suitable to a certain extent. But due to its slow speed and the huge database, it could not be coupled with autocomplete feature of FTS.

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Application of Mobile Telecommunication Technology in Kenya: Trends and Challenges

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KEYWORDS:
Telecommunication, Mobile phones, Kenya, LBS

ABSTRACT

In the last two decades communication has been revolutionized, moving from the fixed land line and computer systems to the sophisticated mobile devices and the internet. This has greatly affected the lifestyle and indeed the human habits and behavior, with a tendency of over dependence on these gadgets for most of communication services and information delivery. This generation of technologies proves to be the future pillar for information and thereby vessel to globalization. The question is what next in the technological world for these devices? The paper analyses trends and challenges in mobile technology.

Internet-based Applications and Open Source Solutions

OpenStreetMap: Data Model, licensing, and Technology

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KEYWORDS:
OpenStreetMap, CrowdSourcing, Mashups, Google Maps, Open Source, OpenLayers, Creative-Commons-Attribution-ShareAlike-License, Open Database License

EXTENTED ABSTRACT

Volunteered Geographic Information (VGI), is one of the characteristics of the Web 2.0. Every person having local spatial expertise can act as a "living sensor". If this local knowledge is collected on a regional or global level in a structured way a valuable and comprehensive information repository is established for a multitude of use cases.

The OpenStreetMap (OSM) project currently is one of the most successful VGI projects. Up to now approximately 1.8 billion GPS points have been uploaded by more than 250.000 registered users, converted to 700 Million nodes (points) and 56 Million ways (linear features) .

In contrary to the approach used in Geographic Information Systems (GIS) where geo-objects (features) are categorized into feature classes or layers, OSM is based on a surprisingly simple data model consisting of just four data types: Nodes, representing points of interest (POIs) and acting as vertices, ways, and relations which aggregate nodes, ways and other relations to larger units. Relations are used for geo-features comprising several sub-features, similar to a feature collection in the Geographic Markup Language (GML), and are among others used to model turn restrictions for further routing. These structural elements are used to build polygons as well as topological relationships.

In order to create map features users can tag nodes, ways, and relations in a very flexible way by key value pairs, e.g. key=amenity, value=Parking or key=Highway, Value=Residentia. In addition they are uniquely identified by an identification number.

The tags are based on a consensus principle, i. e. there is no fixed catalogue of features classes which is defined by a custodian instance. In contrary, it is based on user agreement and is subject to some userdebates, modifications, and developments encompassing the evolvement of the whole project. For orientation a list of commonly used features is listed in the wiki (http://wiki.openstreetmap.org/wiki/Tag). This flexibility of course has some disadvantages but enables easily to capture new kind of features.

Typically data collection is based on using GPS devices. In addition it is possible to use licence free maps or records for data collections. In addition Yahoo!'s geo-imagery or freely available web map services can be used for digitization. According to different level of user experience and requirements different editors for data capture and update are available. For many purposes, the Flash-enabled browser-based editor Potlach can be used. The Merkaartor editor offers some more functionality which is still exceeded by the Potlach editor, at the expense of complexity.

All data are stored in a common geo-database. Through an application program interface it is possible to obtain the whole dataset (the so-called planet file), incremental updates, features for certain regions on the earth, and features with specific tags or other characteristics. Also a web-based graphical user interface is available for data export in different formats.

OpenStreetMap has its own data format, mirroring the structure of nodes, ways, relations, and tags in its own XML based markup language. Conversion programs support the transformation in other formats and the bulk loading into geo-databases. Some Geographical Information Systems already support import of OSM data.

Closely related to OpenStreetMap are some software packages like Mapnik and Osmarender supporting the rendering of the geodata.The visualization is based on style rules which can be adapted for many cases of cartographic needs. The generation and provision of tiles allows the integration in mapping application, e. g.

the browser based OpenLayers mapping solution.

Its data usage is principally not dominated by a restrictive licence. This flexibility and freedom (see Creative-Commons-Attribution-ShareAlike-Licence encourage the usage of OpenStreetMap data and tools in many fields of application. The upcoming license change to the Open Database License however might impose some new aspects.

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Hosting and Sharing Your GIS Data – To Pay or Not To Pay

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KEYWORDS:

Enterprise GIS, FOSS, OGC Services

ABSTRACT

The significance of GIS in managing both spatial and non-spatial information cannot be overstated. Moreover, its integration with the Internet has now made it even worthier than ever before. However, gathering all the information needed for one's business solution into a central storage system where it can be effectively managed and shared with others within and outside an organization often has its own challenges – primarily cost!

The cost of investment in software for warehousing and sharing GIS data might have either discouraged your institution from maintaining a manageable system or left you wandering whether you'll cope with the growing cost in subsequent years. Whichever the case, there is a great opportunity waiting to be explored – Open Source. This presentation will therefore focus on Free and Open Source Software (FOSS) for Enterprise GIS solutions. FOSS integration offers a lot of gain without any pain – great savings without compromising the quality of service to clients. The presentation will last for 30 minutes.

Since understanding comes by doing, the presentation will be followed by a workshop. The workshop will work attendees through 45 painless minutes of implementing a complete Enterprise GIS solution using mainly FOSS. It will begin with developing a spatial database with PostgreSQL/PostGIS, through configuring GeoServer for OGC Services (like WMS and WFS) to authoring interactive client maps using OpenLayers+GeoExt.

At the end of the presentation and workshop, it is hoped that attendees will decide 'not to pay' those huge sums anymore for software applications that make little or no difference.

An Open Source GIS Solution for Managing Water Supply, Distribution and Billing

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Keywords:

Open source GIS, Water supply, billing, distribution

ABSTRACT

In this work a comprehensive geocomputing solution for the Gatanga Water Trust (GWT) has been developed to assist it in managing its water supply and distribution. The solution comprises two subcomponents: a mapping component and a billing component which are tightly coupled together. The proposed system uses stable open source products for the mapping component and the database. At present the GWT uses outdated maps and sketches for design and installation of a new water supply infrastructure. A billing system is in place which is used to manage client accounts, record meter readings, prepare bills and record payments made. This presents a somewhat disjointed approach to management of the water supply and its attendant infrastructure. The database that stores the account information is very different (softcopy) from that storing the spatial information (hardcopy/paper based).

In the proposed solution, a single database is used, centralized or distributed. The mapping component provides an interface through which preliminary design of new and planned infrastructure can be done. After installation of such infrastructure and their subsequent mapping, these are reflected in the database and the information becomes available as soon as it is stored. The billing component uses the same database to manage account information. Since the information is managed in one system, there is a streamlined and orderly flow from data collection to the final products from the system.

The proposed solution leverages advancement in technology by providing two approaches A desktop application for users within the Trust's intranet and a web mapping application for users utilizing the wider internet.

1 Introduction

Improvements in information technology have provided unimaginable opportunities to support data analyses and communications in the last two decades. Geographic Information Systems (GIS) have provided new and exciting ways of acquiring natural resource data and are also providing efficient means of processing, managing and integrating this data, such as in watershed management (Opadeyi, 2007). While varying definitions exist for what a GIS, (see Aronoff (1989) and Tomlinson, (2003) for some of the definitions), there is a general consensus that a GIS is an organized collection of computer hardware, software, geographic data, procedures and rules and personnel, designed to efficiently capture, store, update, manipulate, analyze and display all forms of geographically referenced information.

A Geographic Information System allows one to create and manage spatially referenced data which is useful for any field or situation that utilizes spatial information. In the recent past GIS has been mainstreamed, since every conceivable field can potentially be enriched by using GIS technology to manage the location based information. On this front, there are a number of GIS products that can be used – proprietary (closed source) and open source. Commercial products while possessing powerful analysis features are expensive and for most clients, such solutions may not be fully utilized when procured. On the other hand, while open source products may not have the same level of complexity, they have features that can be used to answer some simple analyses. In some cases though, they are excellent alternatives since some have advanced analysis features (Sherman, 2004).

[*] corresponding author

For planning and design, the Gatanga Water Trust (GWT) uses outdated topographical maps and sketches drawn when the pipes were laid out. At present it does not have any softcopy spatial management system in place. This approach implies that it is very difficult to visualize this information in real-time incorporating proposed designs and new infrastructure installations. There is an electronic billing system in place which the management says is fraught with inconsistencies. Since this system is not connected with the spatial management system, it is not easy for employees to visually connect between client accounts and their locations in space. This current approach is thus very limited and the Trust is not able to leverage technological advances to improve the management of the water trust.

This work sought to develop an open source geocomputing solution to assist GWT manage its water supply infrastructure and distribution network. This solution comprises a desktop mapping and billing solution targeted for the intranet user and a web mapping and billing solution for both internet and intranet users. To realize this, the following specific objectives were formulated: (i) determine current and future system needs for the Trust, (ii) formulate a desktop GIS strategy to solve the needs, (iii) formulate a web based GIS strategy for internet users, (iv) combine the two solutions (strategies) into one overall solution for the Trust.

2 The study area

The study area (Figure 1) was the region covered by the GWT which covers the whole of the Gatanga District as an administrative region which incidentally has the same boundaries as the Gatanga Constituency as a political region. It comprises of 4 main sublocations namely Gatanga, Kariara, Kigoro and Kihumbuini. It has several shopping centers (settlements) distributed throughout the district. Figure 1 shows the spatial extent of the district.

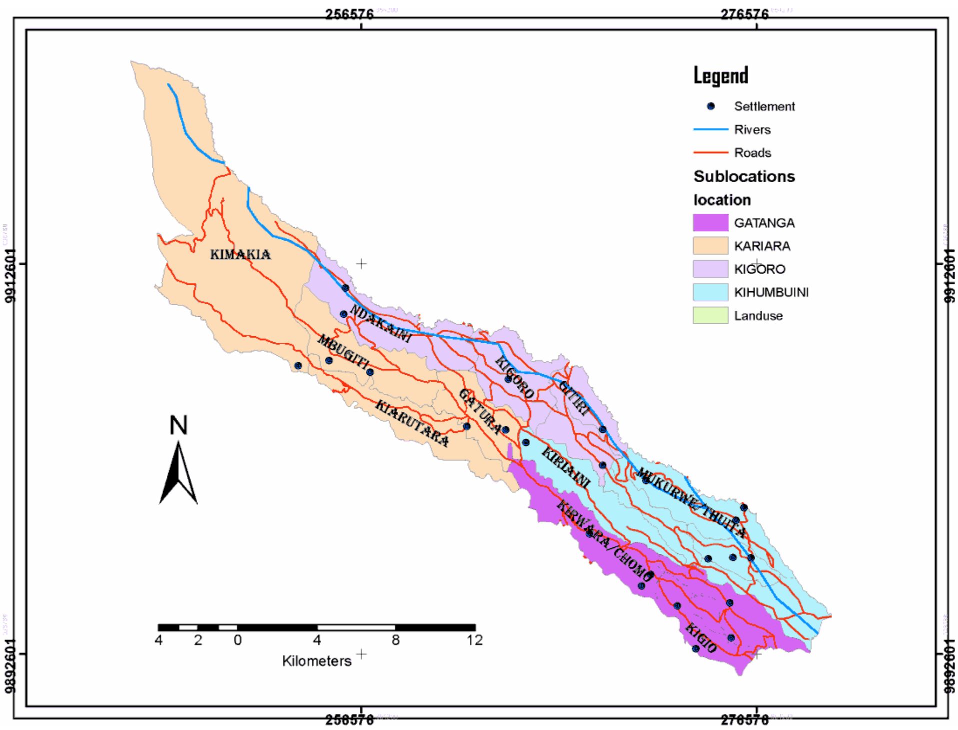


Fig. 1: The study area

The main economic activities of this region are agriculture and forestry with much of Kimakia forest being part of the Aberdare forest system. Kimakia sublocation is mainly covered by the forest with the rest of the sublocations under small-holder coffee and tea plantations.

GWT was formed as a result of the water sector reforms initiated in 2002. It is run by a board of trustees drawn from Gatanga District representing individual locations. The distribution system in the scheme is wholly gravity-induced and is served by two water intakes constructed inside the Kimakia forest. The intakes draw water from the Kimakia and Thika rivers. Initially the GWT had 2000 active connections but since the injection of funds the number rose to 4000. The current water production stands at 7000 m3 per day. It serves approximately 9000 active consumers of which 4000 have been metered. The core functions of the GWT are sourcing of water, treatment and conservation of water, distribution of water, billing and revenue collection (Gatanga, 2010)

The scheme has two subsystems which are independent of each other. They are referred to as North and South of Kiama. The North of Kiama River system gets its water from the old intake constructed on the Thika River. It serves Kigoro, Mukarara, Kiriaini and Kihumbuini locations. The South of Kiama River system gets water from the newly constructed intake on the Kimakia River. It serves Kariara, Gatanga and Mugumoni locations. The pipe network stretches from Kinguri – Gatura – Chomo – Kirwara – Kigio and Gatunyu (Gatanga, 2010).

3 Methodology and Activities

The composite system uses two design approaches geared at coming up with (i) an internet application and (ii) a desktop application.

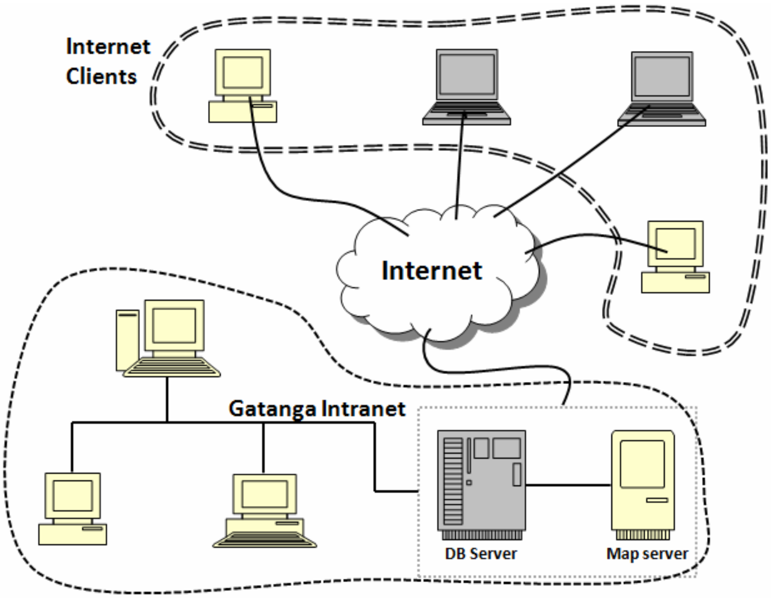


Fig. 2: The envisaged system infrastructure

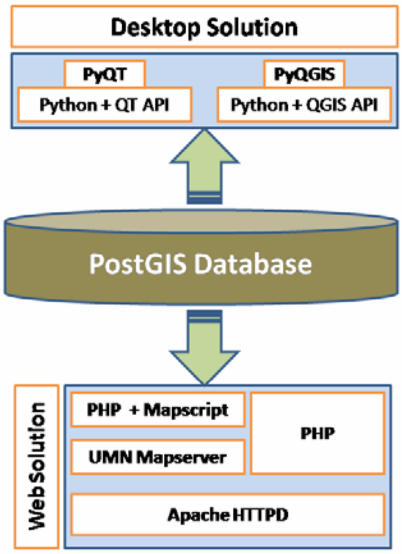


Fig. 3: Open source tools used

Figure 2 captures this design viewpoint where two types of users are anticipated: the intranet user and the internet user. The intranet user is a staff member of the Trust while the internet user is thought of as (i) an account holder or (ii) a general internet visitor or (iii) a staff member working from home or remotely. For this purpose two application approaches have been adopted, with the desktop solution addressing the needs of the intranet user, while the web mapping application addresses the needs of the internet users. The composite system uses the same underlying database server to manage the information. The desktop application connects and communicates with the database server but does not make use of the map server. On the other hand, the internet application connects to the database via the map server. In this case the map server serves as a proxy and as a rendering engine to prepare the maps for onward transmission to the internet client.

Figure 3 shows how the various open source tools were used in the solution development. Figure 4 shows the associated logos which belong to the respective developers and the Open Geospatial Community (OSGeo). For the desktop solution, a standalone application was developed using Python and the Python bindings for QT (PyQT version 4) and QGIS (PyQGIS) allowing access to the respective Application Programming Interfaces (APIs) (Dobias, 2011). The web solution uses P.Mapper framework, which is a custom PHP Mapscript application that utilizes PHP Mapscript and University of Minesota Mapserver as the map rendering interface, with billing implemented using PHP and extending the P.Mapper based application. Both systems utilize a PostGIS database which is a spatially aware PostgreSQL database.

Figure 5 captures the flow of activities that were undertaken to realize this research. It comprises four phases (i) a preliminary (conceptualization) phase, (ii) a development phase, (iii) an evaluation and assessment phase and, (iv) an implementation phase.

UMN Mapserver
PostGIS
Quantum GIS
PostgreSQL Server
QT Framework

Figure 4: The GIS Stack

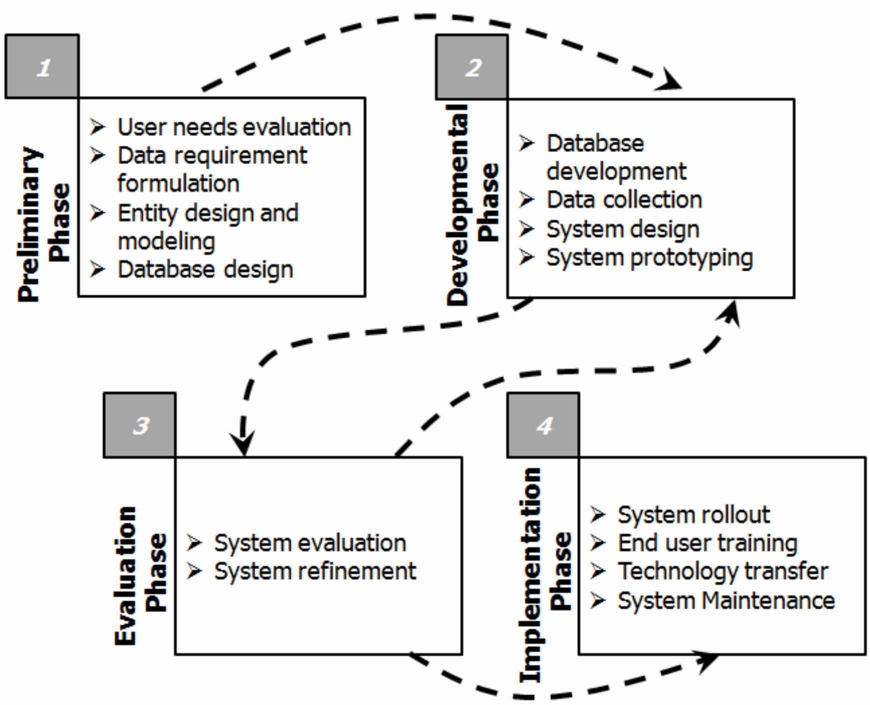


Figure 5: Project Workflow

During conceptualization phase, a detailed inventory of the current and anticipated future needs was carried out based on interviews. This yielded information on the data required to address those needs. In this phase all entities that needed to be stored in the database and their relationships were identified. The entities that were identified in this step were: water meters, customers, pipes, pipe nodes, valves, break pressure tanks, normal tanks, intakes, meter readings, bills, payments and parcels. For the general basemap, other entities identified include: sublocations, roads, rivers, settlements and landuse. There were attributes that were identified and connected to each of the entities identified.

During the developmental phase, the necessary database schema for the entities identified was implemented. In parallel, all necessary data was collected and aggregated into this database. Data collection was done using hand held Global Positioning System (GPS) receivers. The entire system was designed identifying the various features and functionalities that needed to be implemented to answer all (or most) of the user needs. In this phase a prototype of the whole system was made available incorporating as many of the features as possible.

The evaluation phase was used for rigorously testing all the implemented features of the prototype, carefully assessing how well the proposed system was able to address all the needs of the end users. In this phase any refinements required were be undertaken. In case of major refinements, these were developed and incorporated in the prototype and reevaluated. Hence the development and evaluation phases fed back and forward until a stable prototype was achieved. It is during this phase that user manual manuals and system documentation were written.

At the implementation phase, the prototype was migrated to the Trust's network, installed and configured for daily usage. To ensure proper use of the solution, end user training was conducted. This training served as a means to transfer knowledge about the underlying technologies to the Trust. All these phases have already been completed for the desktop solution. Portions of the web solution are still being developed and it is yet to be deployed to GWT. For the desktop solution, a maintenance schedule is currently being discussed with a view of keeping the system up-to-date and incorporating new ideas and needs. This will also help refine the web mapping solution as a consequence.

4 Results

The following mapping features were included in the solution: (i) interface with a map window with tools that allow users to zoom in/out, pan, zoom to full extent or zoom to a window of interest, (ii) tools to allow turning on/off of data layers in the window, (iii) tools to allow users to interrogate the map displayed to retrieve non spatial attribute information for the point under a cursor, (iv) tools that allow the users to display a layer using default symbolization (using symbols from the Gatanga) or allow the user to use other symbolization, display a thematic display of the layer using any of the available attributes, (v) allow the users to perform attribute querying using available attributes, (vi) tools to allow entering of GPS coordinates for new features and their attributes, (vii) tools for deleting data that may need to be removed. Figure 6 show the main desktop interface to the system.

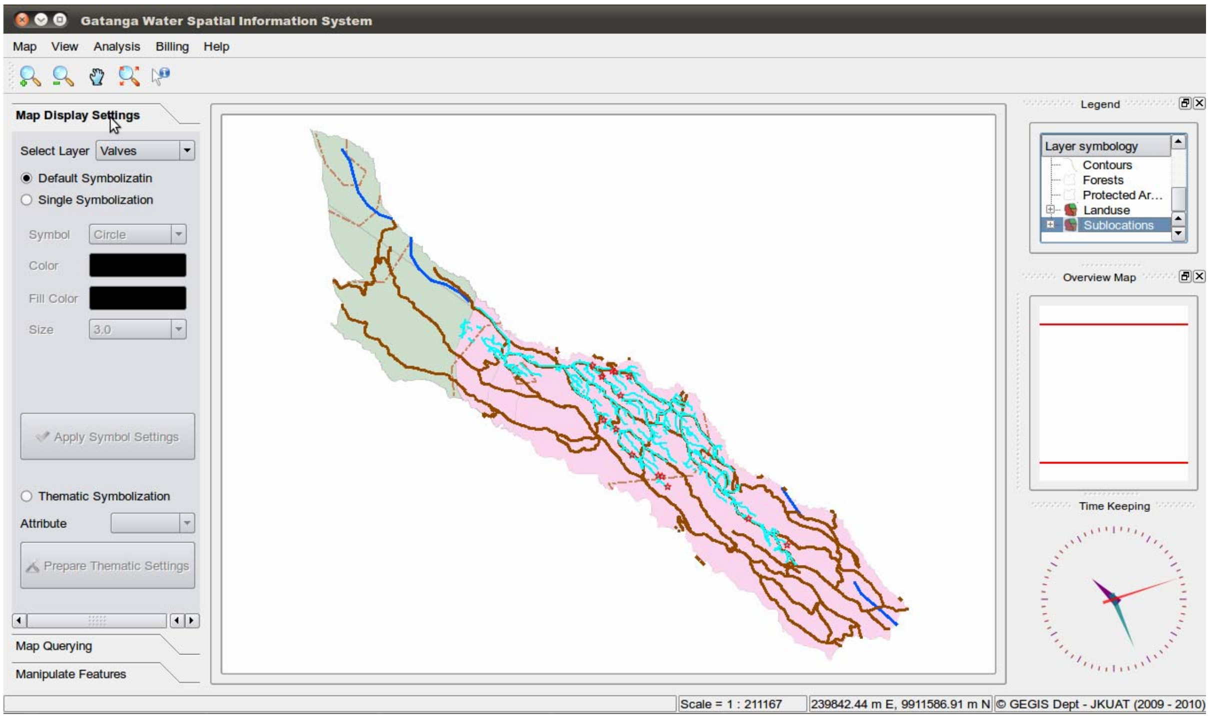
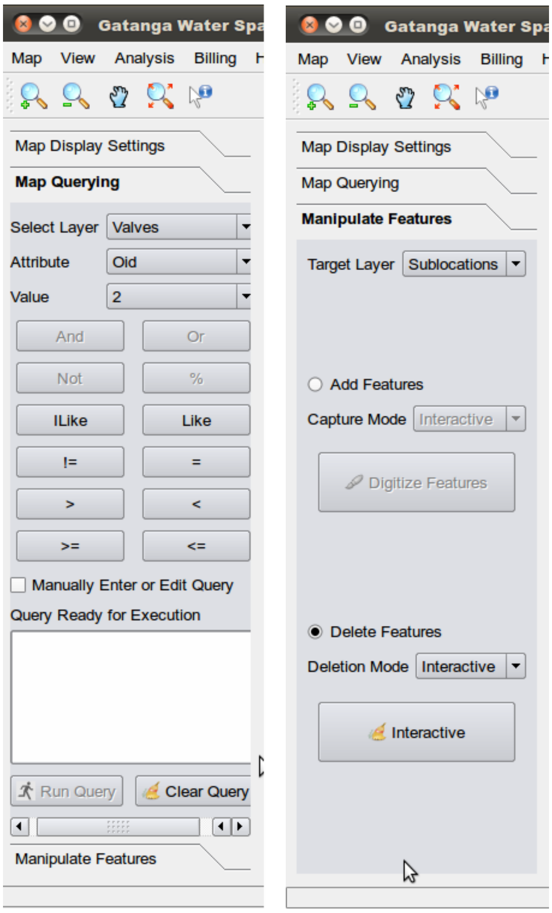
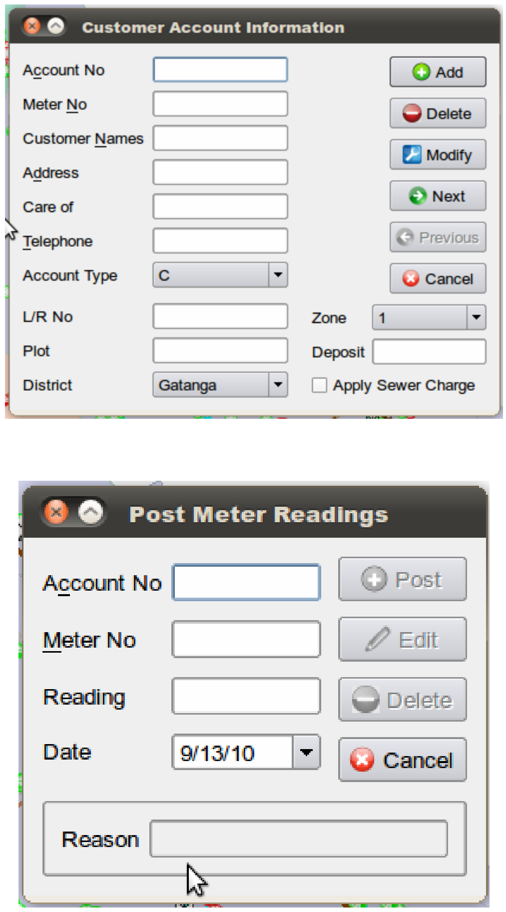


Fig. 4: The main interface of the desktop solution.

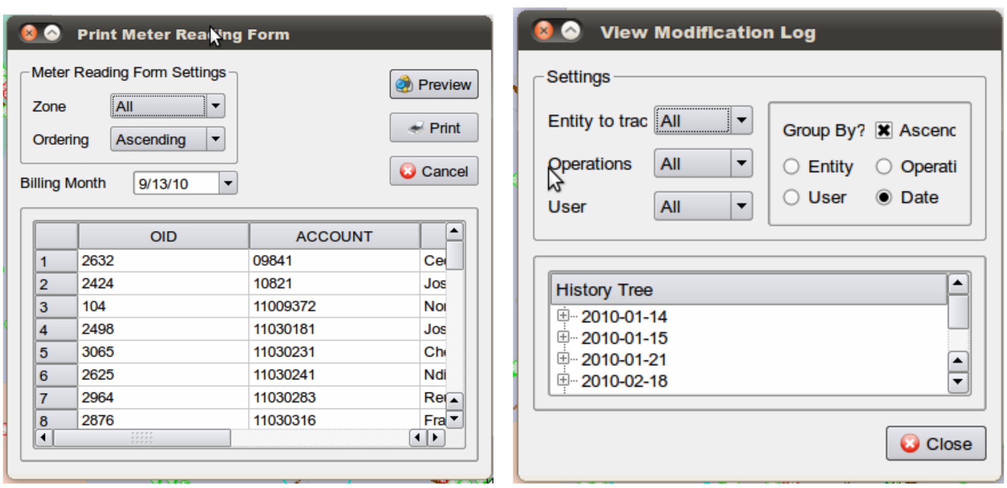
To access this interface the user has to log into the system using credentials that allow tracking in case there are changes made and therefore can assign responsibility for any actions made. On the billing front, the following features were implemented: (i) tools to allow addition of new clients, edit client details, delete former clients, (ii) tools to record meter readings, edit or delete erroneous meter readings and printing out of meter reading forms, (iii) tools to process account billing, allowing printing of receipts. These tools are a sampling of the collection of tools that were developed in this project venture.



a. Map querying functionalities (part of main map interface)



b. Some data entry functionalities



c. Printing functionalities

Figure 2 Some of the implemented functionalities in the desktop application

Figure 7 show some of the interfaces exposing these functionalities, with figure 7(a) showing some of the mapping and spatial analyses capabilities, figure 7(b) showing some of the data entry (insertions) capabilities and 7 (c) showing some of the dialogs for generating reports from the system. The web mapping solution has some of these capabilities (login support, map display and querying, data entry) but report generation was not implemented since it was not anticipated that internet users would require such capabilities.

While no statistics on usage have been obtained so far, the system has been demonstrated as being able to significantly reduce time taken between a new customer (meter) installation and the recording of this in the billing database.

While no statistics on usage have been obtained so far, the system has been demonstrated as being able to significantly reduce time taken between a new customer (meter) installation and the recording of this in the billing database.

5 Conclusion

The proposed system has been demonstrated as meeting the objectives set out. The following products have been developed: (i) an open source desktop geocomputing application featuring GIS tools and a billing system, (ii) an open source web mapping solution featuring scaled down GIS tools and billing capabilities (not demonstrated in the paper). To support this system, (iii) a spatially aware database system of the Gatanga water infrastructure was developed and deployed.

This solution can be further customized and extended, with these extensions and customizations being offered to other utility management enterprises. This solution demonstrates that with open source solutions, it possible to come with fairly high quality, production grade products leveraging the strengths of the open source community and geocomputing capabilities, and hence the utility of open source GIS software and the coupling of systems to enhance infrastructure and asset management.

This system has already been deployed on the Gatanga Water Trust's offices and is currently being evaluated and used before it can be fully rolled out. It is therefore recommended that the system, once found to be satisfactory be cascaded to other water service providers.

Acknowledgement

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Building spatial information system for natural resource management by using UMN Mapserver

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KEY WORDS:
Natural Resource Management, Web GIS, Open Source, Land Cover, UMN Map Server

ABSTRACT

Geographic Information System (GIS) applications are trickling down to grassroot levels. While conventional cartography includes only the use of static maps, the advent of geo-information science has brought in new vigour to this field. The spatial information system (www.dss-foreverindus.org) launched at the Indus Ecoregion level for Natural Resource Management is in line with this trend. The significance of this application is its provision of a virtual journey to Indus Ecoregion through interactive atlas with basic mapping operations.

The application is being hosted by Apache webserver 2.2.4 with embedded modules of UMN MapServer 5.0.0. The whole structure of this Geographic Information Technology and System (GIT&S) application is based upon PHP, HTML, JavaScripts, MapScript, PostgreSQL (as database). The combination of all above enhanced the user interface and functionality. A detailed GIT&S database was established by using PostgreSQL as a powerful, open source relational database system.

The system architecture is a result of the cumulative contributions of major stakeholders in three planning workshops. Extensive surveys were conducted to collect the GPS data for the land cover mapping and accuracy assessment of the topographic sheets. District profiles of the mammals, birds and fishes were generated using data collected by wildlife scientists. In addition, District Census Reports have been used to upload the socioeconomic data. This application allows the user to search data at meso and micro levels. The first ever provincial level WebGIS application developed in Pakistan is expected to help researchers and decision makers.

1 Background

Human beings have been developing/using maps for more than 5,000 years. Early maps, carved on stones or painted on walls, were mainly used for strategic planning during war. Over the past few centuries, advancements in engineering and computer technology have brought a bloom in the mapping technologies. Today not only government agencies but also private organizations and even individuals are using Geographic Information Technology and System (GIT&S), Global Positioning System (GPS) and WebGIS for planning and monitoring of social, commercial and environmental processes.

World Wide Fund for Nature – Pakistan (WWF – P) is currently implementing the five-year “Indus for All Programme” which is the first phase of a 50-year Indus Ecoregion Conservation Programme, developed in collaboration with the Government of Sindh and other stakeholders for long-term biodiversity conservation and poverty alleviation in the Indus Ecoregion. Considering the need of a GIT&S based inventory at Ecoregion level, an online interactive social and environmental GIS atlas was designed and launched on the web portal www.dss-foreverindus.org (Figure 1). It includes micro level data for the four selected sites i.e. Keti Bunder, Keenjhar Lake, Chotiari Reservoir and Pai Forest and meso and macro level details at districts and at Ecoregion level.

A significant feature the GIS atlas is its provision of a virtual journey to the Indus Ecoregion through interactive atlas with basic mapping operations. Persons who ordinarily would never have access to traditional desktop GIS tools can access the Indus Ecoregion even in the comfort of their room at no extra cost [1]. WebGIS has the capability to distribute GIS data to a wide audience without purchasing specific GIS software and extensive GIS training. [2]. Over the past few years, such interactive map applications have widely been adopted by the GIS community due to its highly communicative forms of spatial representation [3].

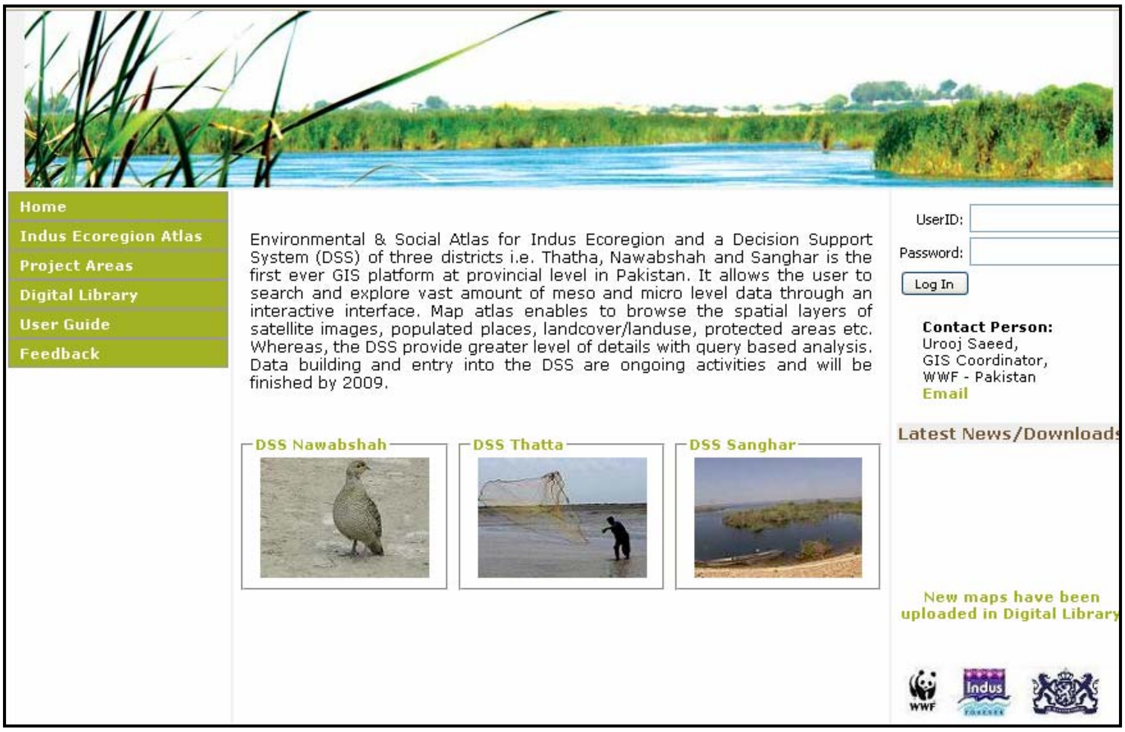

Figure 1: Application Main Page

2 Objectives

The idea of designing the application was to fill the information gaps that were long felt at Ecoregion level in Pakistan. The main objective was to develop an atlas that addresses three primary areas;

- Provide GIS based data for navigation and management of natural resources
- Provide information to policy planners and decision makers
- Develop patterns of temporal variance

3 Why Open Source Software (OSS)

To develop a spatially endowed OSS, extensive programming skills and hard work are required. As we look into the WebGIS history, GRASS is the oldest of the open source GIS software products developed by US army in 1982 [4]. In 1995, Argus Technologies developed an online spatial data platform under the name as Argus MapGuide [5]. With the passage of time, OSS started to drag attention with an objective to educate people and build the bridges between the GIS communities. OSS is also used for the development of spatial data infrastructure (SDI) [6].

In this study, the open source MapServer was preferred due to its map rendering web based customization and handling of large range data formats [7]. Since the primary purpose of this application was to create an interactive application for GIS data handling and visualisation, MapSever was the best available option that was cost effective too. The MapServer application is based on C language and is a combination of server-side and client-side applications. It was developed at the University of Minnesota with the collaboration of NASA and the Minnesota Department of Natural Resources [8]. MapServer works in a web environment as a Common Gateway Interface (CGI) script or as a stand-alone application via an API accessible from several programming languages.

4 Technology and Software Used

Apache Webserver 2.2.4 hosts the application with embedded modules of MapServer 5.0.0, CGI and MapScript. MapServer uses OGR and GDAL libraries to translate GIS data from one file format to another [9]. The interface to the application is provided by HTML and Javascript whereas PHP, mapscript and PostgreSQL are controlling the whole functionality of the application [10]. The combination of all components enhanced the user interface and functionality. Prompt internet connection and specific hardware configuration are required for the efficient enterprise GIS application. For the GIS data processing, ArcGIS 9.0®, ERDAS IMAGINE 8.7®, Definien Developer 7.0®, Garmin 76 CSX, Canon camera and MapSource were used to collect and process the vector and raster data. A powerful relational database system was established to publish the data by using PostgreSQL [11].

5 System Architecture

The application is hosted by the web mapping server that is based on open specifications of W3C and OGC having web mapping service (WMS) and web feature service (WFS). CGI MapServer has four components; Mapfiles, HTML initialization form, HTML template file(s), and a spatial database [12]. The spatially enabled GIS database was established by using PostgreSQL. PostGIS is open source relational database system. Server side programming PHP is used for predefined functions at server side and JavaScript for client side application deployment.

The hierarchy of the Mapfile is shown in Fig.2.

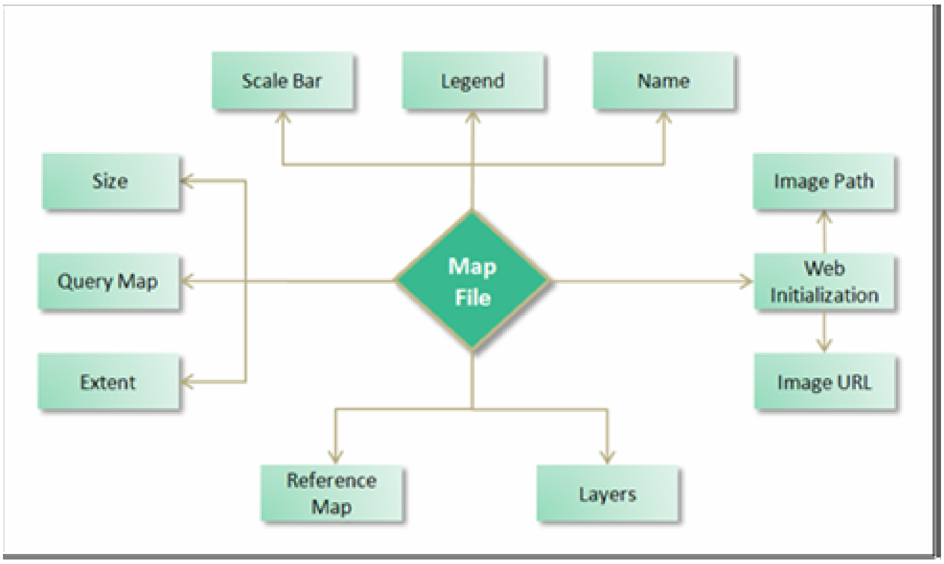

Figure 2: Structure and hierarchy of a Map file.

As Figure 2 indicates, a Map file contains geometry, annotation and symbology of the GIS data layers. It gives cartographic layout to the map window by providing various options for symbols, legend, scale bar and reference map. Four Mapfiles were used to develop the application i.e. one 'main' for the Ecoregion and three for Nawabshah, Sanghar and Thatta Districts.

When the user performs any action at client-side, the MapServer gets invoked by Apache from the HTML initialization form that is a variable being used to specify the targeted mapfile. This Mapfile was customized to allocate the name of the CGI program, spatial extent of the map and the layers to be displayed at first invocation [13]. Biodiversity, socioeconomic and landcover/landuse profiles and query operations are being managed by the template file. Template files consist of conventional HTML markup tags and special MapServer substitution strings.

6 Datasets

Effectiveness of Geographic Information Technology and Science (GIT&S) data applications depends upon the quality and accuracy of the data. A dedicated team was involved at the data development side. Three categories of the data were developed i.e. core GIS layers, socioeconomic profiles and natural resources. Survey of Pakistan's topographic sheets of 1:250,000 and 1:50,000 were digitized for Indus Ecoregion and three selected districts respectively. Extensive field surveys were conducted to collect the GPS data for the land cover mapping and accuracy assessment of the topographic sheets. The accuracy of the data was checked to ensure the integrity and completeness.

7 Application

The spatial and thematic aspects of the application enable the users to overlay raster and vector datasets. This online Atlas allows browsing the generalized spatial layers of the administrative boundaries, rivers, roads, cities, satellite images etc (Figure 4). Spatial visualization of the data has been customized with the data layers at different zoom levels i.e. the smaller the scale, more is the information displayed and vice versa. This application allows the user to search and explore huge amount of data of different resolution and scale. It provides search utility, displaying and viewing multiple data layers, landcover/landuse change graphs etc.

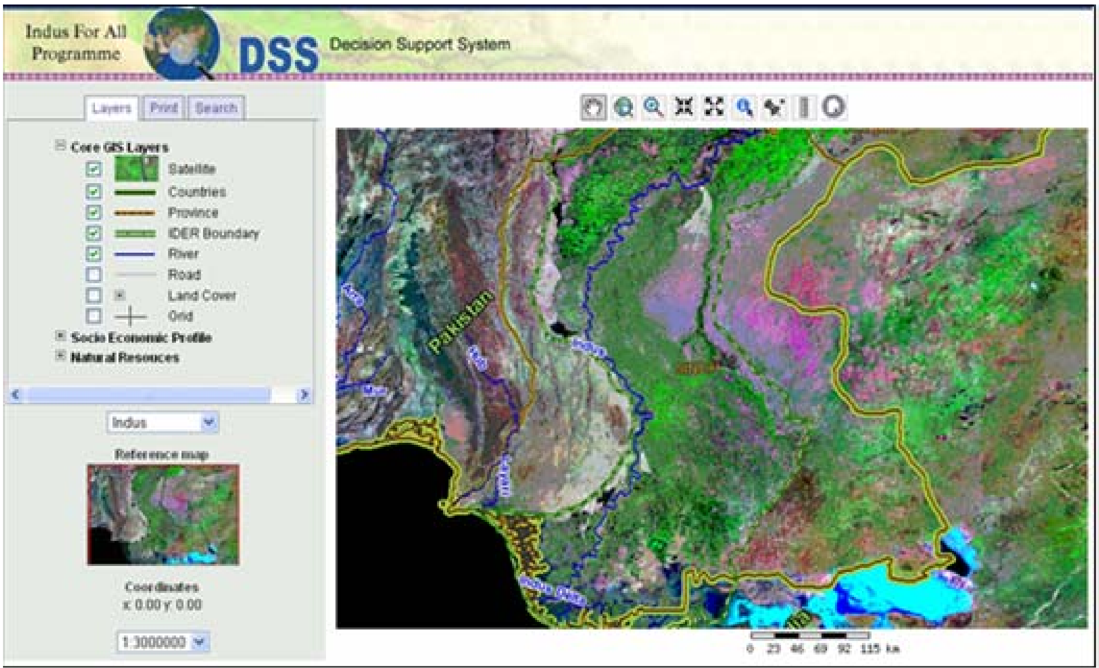

Figure 3: Map window interface

Another interesting utility of the application is accessibility of temporal variation at the Programme Sites level. For this purpose, temporal land cover maps at 1:10,000 scales have been implanted in the application.

With a single click users can access the district profiles of population, land use, health, education and agriculture. To provide a glimpse of the natural resources; profiles of birds, fish and mammals have also been uploaded. Birds and mammals detail have been compiled from TJ Robert's books. Dr Thomas Jones Roberts is the famous ornithologist and writer of Birds of Pakistan and Mammals of Pakistan. The information of fish has been taken from the data collected under Conservation Assessment and Management Plan (CAMP) workshop. The socioeconomic data of Sindh districts were extracted from the 1998 District Census Reports. The map page and the district profiles can be printed by exporting the data at different available formats and resolutions.

To improve the overall performance and to maximize the usage by the major stakeholders, series of orientation and training workshops were organized. The participants appreciated the launch of first ever WebGIS application at Ecoregion level. The comments and suggestions of the participants were significantly helpful in modifying the system.

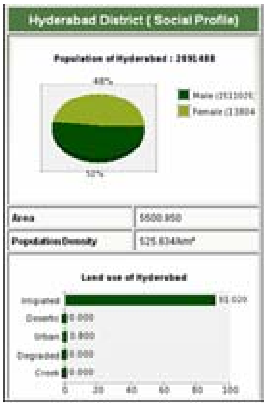

Figure 4: Socioeconomic Profile

8 Conclusion

In this paper we have examined the use of Web-based GIS application for natural resource management. This is the first ever provincial level WebGIS application in Pakistan and is expected to help researchers and planners. This specific application developed by Indus for All Programme of WWF – Pakistan, provides a user friendly interface for accessing geospatial data of the Indus Ecoregion. It serves as an easily accessible platform for the research, monitoring and environmental management activities in the Ecoregion.

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Activating OpenStreetMap Data for GIS: Transforming OpenStreetMap XML Data to ESRI's Shape Format

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KEYWORDS:

Open Street Map, converting OSM data, OSM data structure, ESRI Shape format, osm2shape format conversion

ABSTRACT:

Prerequisite for any GIS application is reliable geodata. Unfortunately, official data are in many countries either not available or not easily affordable. Fortunately, nowadays free alternatives exist to fill the gap. OpenStreetMap (OSM) is such an alternative; the difference between OSM and commercial map providers is that the OSM data is free of charge for everyone. Although the primary goal of OSM is map generation, OSM data is interesting and useful in a GIS environment as well as the data are for many regions of the world very rich of information.

One of the hindrances of direct use of the data is the difference in data structures. OSM data is XML-based, thus an OSM-file contains self-describing semi-structured data, where as GIS formats, like the simple feature approach in ESRI's shape format, uses a flat structure, where hierarchies of features are unknown. The existing conversion programs allow mainly converting only simple type of data, i.e. points (nodes) and lines (ways) which have their direct correspondence in the simple feature structure, though not considering the "richer" OSM information, like the data type "relation".

To extract all the information from an OSM file a user-friendly desktop application has been developed, based on VB.NET and the integrated developing environment Visual Studio 2008. The developed program, called OSM2Shape converter, takes all three OSM types node, way and relation into account. The major issues addressed in the program were the handling of the semi-structured data, references to elements not included in the OSM file and the modeling of polygon geometries, as OSM do not have an explicit structure for areas.

The solution first extracts the key-value-pairs of the elements allowing the user to select the features to be converted. The keys of the elements are defined in a configuration file and therefore can be edited according to the user's need. All elements containing the same key defined in the configuration file will be placed in the same shape file respectively. The generated files can be used in any GI-Systems supporting ESRI's shape format for spatial analysis or creating maps. The program has been tested using different OSM files as input, giving some insight into performance issues as well.

1 Introduction

OpenStreetMap (OSM) is currently one of the most popular open map providers on the internet. It is so popular for several reasons:

1. It can be embedded in any website, printed, used in publications and many more under the terms of the actual license, see [1].
2. It can be extended or manipulated/corrected by each and every registered mapper, see e.g. beginner's guide. [9]
3. When adding data to the OSM database, the mapper will not lose his or her rights over the data [10]

OSM has a very active and worldwide distributed community, thus fast reaction, e.g. for crisis mapping is possible. [1]

Up to now it was no problem to use OSM data in many ways – in particular to combine it with other data. This may become different due to a change in license (from CC-BY-SA to ODbL) which came into force in April 2011 [2]. Due to this new license, as soon as OSM data gets in touch with other data, these additional data must be freely provided under the same terms as well. Without combination of data the OSM data can be used freely, according to the current license [3].

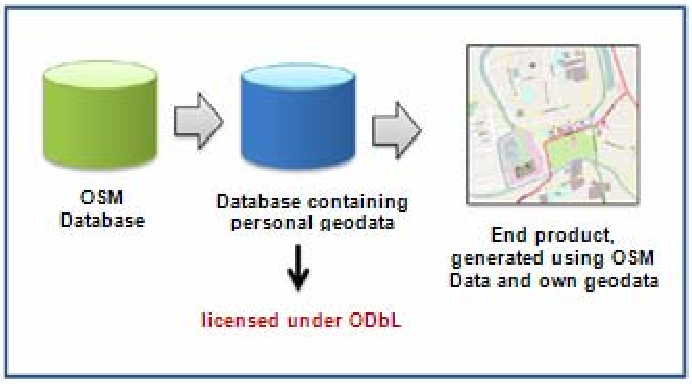

FIG 1: about the new OSM license

OSM map data usually is up to date and – at least in many regions of Europe and North-America – more detailed then data of commercial competitors like GoogleMaps or Microsoft Bing. Moreover it has a global cover - which makes OSM more and more interesting in many areas. Having these much spatial data, it would be a huge advantage if it could be used in GI-Systems as well. Hence, tools are required to transform all OSM data types (*node, way, relation*) into GIS data formats like the quasi-standard format ESRI Shape. The following pages will give a short introduction to such a program which is currently under development. In addition, a short review of the data structures involved is given as well as a discussion of alternative programs.

2 OSM data structure and its mapping

OSM provides free cartographic map data in semi-structure, i.e. in a parent-child-node structure, following the XML conventions. Below, the three data types are discussed shortly.

1. *Node*: Minimum requirements for defining a point are latitude and longitude as attributes of the node-tag. If the point is supposed to be a point of interest (POI), not just a vertex of a way element, it needs to be marked with additional tags which are defined as key-value pairs; e.g. k="amenity" v="hospital".
2. *Ways*: Line elements are defined by a list of nodes. The node-elements are only referenced by nd-tags. The semantic meaning of the way elements are again defined by key-value-tags, e.g. k="highway" v="residential". As the OSM model does not know an explicit element for polygons, simple polygons, i.e. polygons with only one single borderline, are defined as closed polylines. The interpretation as polyline or polygon follows the map features catalogue defined by the OSM community. Exceptions, i.e. map features defined as polylines but to be interpreted as polygons, can be defined with the additional tag k="area" v="yes".
3. *Relation*: relations are meta-objects, i.e. "reasonable" groupings of other elements. A relation consists of references to other elements, i.e. to nodes, ways, and relations and key-value-tags, defining the meaning of the relation. Relations are used to model complex structures like networks or routes. A relation may contain mixed geometries, e.g. the boundaries of a province as way elements and its capital as a node element. Further on, it may define a recursive structure. This may be used for instance for grouping the streams of a sub-basin, which are part of a watershed, which are part of a larger watershed, etc. In addition, relations are use to define complex polygons, e.g. polygons with holes. Here the additional tag k="multipolygon" v="yes" in conjunction with the attribute role="inner" respectively "outer" are used to define inner and outer boundaries.
4. Downloading OSM data using the normal or extended API, a problem may appear regarding the completeness of spatial reference points. As ways and relation hold no geometry information but only

references to other elements, it may happen that these references are not included in the downloaded file.

5. The OSM model and its mapping to the shape file structure with the geometries point, polyline and polygon implemented in the tool is shown in fig 2. The information contained in the meta-structure relation is mapped into additional dbf-tables not containing any geometry.

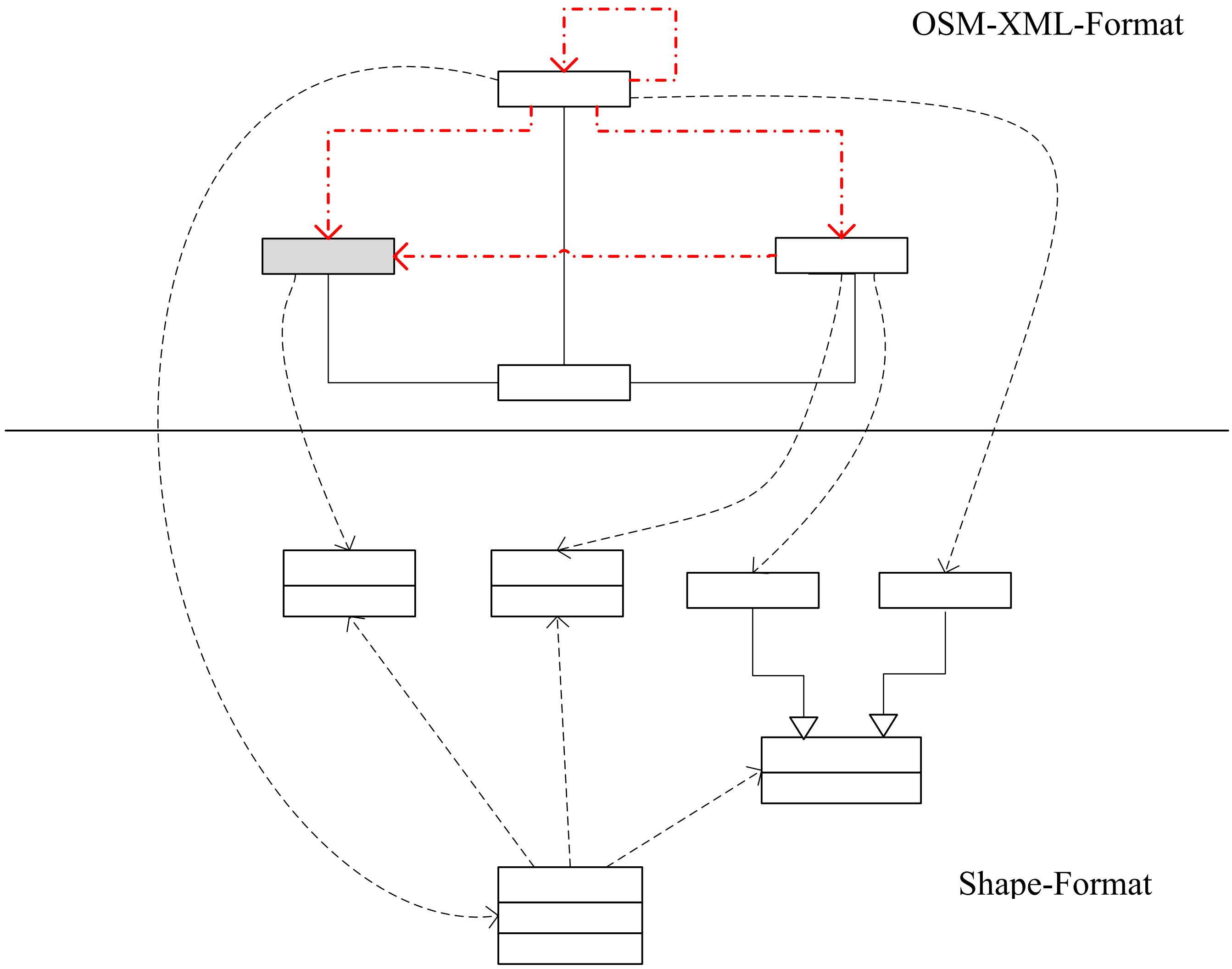

Fig 2: The OSM data model and its mapping

3 State-of-the-Art

Currently, there are several software tools available to convert OSM to shape format, e.g. OSM2SHP, a desktop application, and OSMLib, a command line based program, just to mention two open source tools.

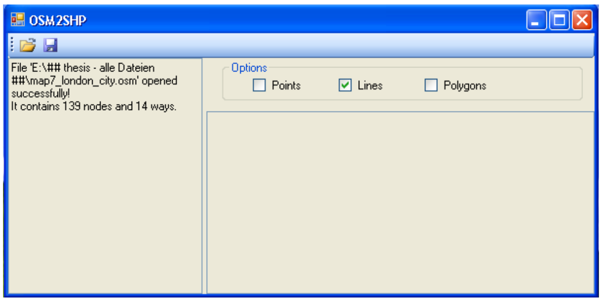

Fig 3: OSM2SHP application GUI

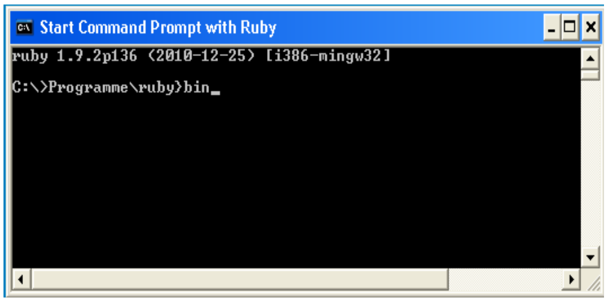

Fig 4: OSMlib - shell environment, running ruby

OSM2SHP allows the user to convert all point and/or line and/or polygon elements to an ESRI Shape file – transforming relations is not possible; also there is no way to select single elements like just hospitals. Converting the data, the dbf file contains almost no information, which means the richness in detail is getting lost on the way. [4]

OSMLib – a ruby library/shell environment allows extracting information in a very sophisticated way: very detailed information can be extracted, like all parking spaces that charge fees. However, this requires quite some shell programming and therefore is not that handy for most of the users. [5]

Converting into other GIS formats using tools like OSM2KML or OSM2GML is possible as well, but not as "popular" as those mentioned above.

4 Developed application

The tool OSM2Shape was developed using a higher object-oriented programming language, not a scripting language. The platform chosen was Visual Studio 2008 provided by Microsoft, using VB.NET for programming. The chosen environment has the advantages of an easy design of a GUI, having access to all features of a modern programming language like complex data structure and support of XML, and having a good performance, which is needed, as the OSM file may contain a large amount of data

For writing the shape format, the Shapefile C Library from MapTools [6] with the .NET wrapper has been used. It creates and writes records into the shape format, which is based on the "simple features" vector data structure, standardized by the OGC. The standard defines how geographic information, such as points, lines or polygons, should be stored along with their spatial attributes in a normalized form. Used shape geometry types are points, polylines and polygons. Though the shape format is a sophisticated data structure, which is easy to update and does not need a lot of storage capacity, it does not include anything like a relationship between single elements. Therefore it cannot be solely used for OSM data; as it is XML compliant and uses a rich data typing system, allowing more complex and detailed constraints on the logical structure of an element. For holding the additional information, additional dbf-tables have to be created. [7]

To control the application, different configuration files have been defined. They are used to restrict the map features and tags to be converted, thus improving the run-time of the tool dramatically. The configuration files can be easily edited by the user.

For developing a desktop application that reads data from OSM files, few points have to be taken into consideration:

- A lot of data comes along with most of the points/ways/relations. However, there is no rule which information must be covered as attributes. It is up to the single mapper to decide which information to add in additional tags. So not to lose any information, it is necessary to collect first all information and select secondly those which are important to the user.

- Nodes are the only elements holding geometry information; hence, there is no node without spatial information. However, that is not the case with ways or relations. Therefore, a solution has to be found, to deal with missing geometry information in the later.

5 Case Study

Comparing achieved results of osm2Shape converter and osm2shp, it can be said that the recently developed application is able to extract more useable points. Fig 3 shows converted points over the study area Stuttgart - yellow points indicate that they are created using OSM2SHP; all other colors were chosen for the files created with the OSM2Shape converter.

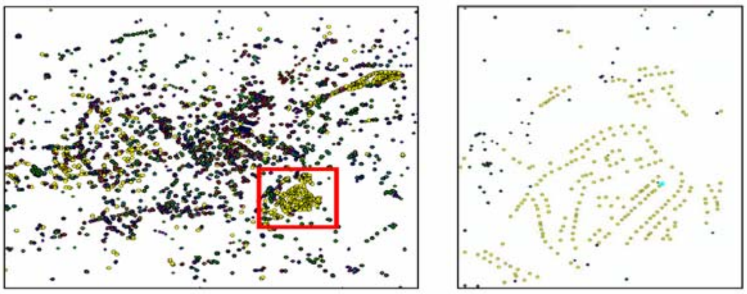

Fig 3: Showing converted points out of a test region in Stuttgart - left using OSM Converter and Osm2Shp, right enlarging the marked area

The enlarged image in Fig 3 shows one of the problems occurring when using OSM2SHP – if a node is described by one or more tags (e.g. "created_by"), then the algorithm of OSM2SHP assumes that it is a point feature, though it might be just a vertex of a line.

Having a look at streets covering the same area, the results (Fig 6) appear to be much better for OSM2SHP. Due to that it can be said that OSM2SHP is of more use if the user is not interested in detailed information about the single streets, but just wants to have a look at the area. Same behavior can be observed for polygon elements (Fig 7), as certain map features, like waterways, may not be listed in the configuration file.

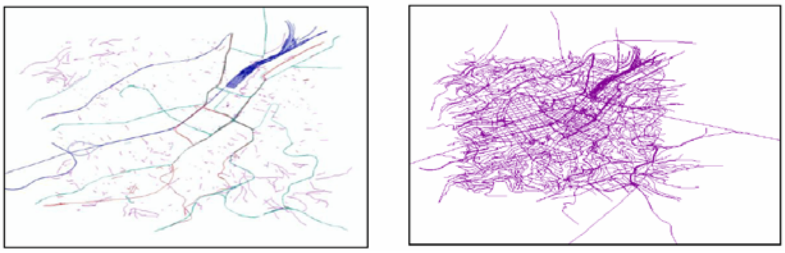

Fig 4: Converted line elements - left hand side using the developed converter, right hand side using OSM2SHP

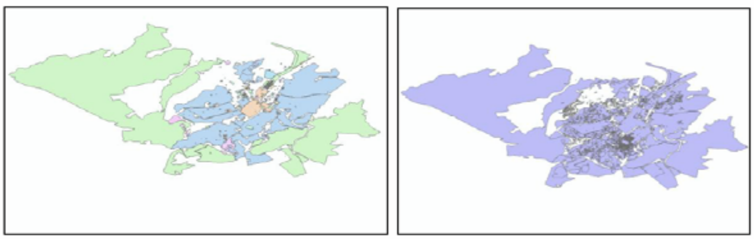

Fig 5: Converted polygon elements - left hand side using the developed converter, right hand side using OSM2SHP

Converting relations still is a challenge that needs to be improved; there still are two main problems– first there can be relations inside relations, so the process of reading the data must be recursive. The second reason for having strange result like in Fig 8 is more a problem than a challenge: nodes, ways, or relations referenced by other elements might be missing – and due to that, those parts cannot be drawn.

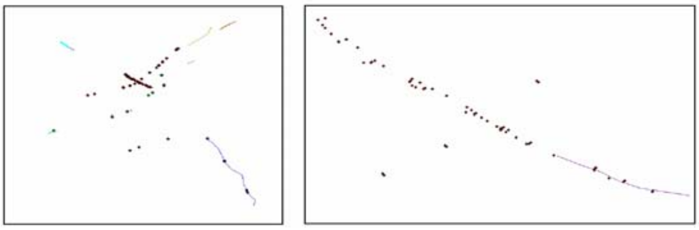

Fig 6: Converted relation using the developed converter - problems of missing data can be seen in the occurring gaps in between lines

6 Discussion and Conclusion

Converting nodes and simple ways to shape format, using the tool developed, returns a much more satisfying result than transforming relations. However, it is a huge advantage that the elements are separated in different files giving much more flexibility to the user – by assigning other names or turning off feature classes in the GI-System.

Concerning ways, OSM2SHP converts more elements. However, this can be changed by simply adding additional map features to the configuration files. Converting relations is not possible with OSM2SHP and does still need some improvement in OSM2Shape.

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Tiling Concepts and Tile Indexing in Internet Mapping APIs

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KEYWORDS:
Tiles, online Map Viewer, OpenStreetMap, Bing Maps, Google Maps, tiling, asynchronous web map, online map services

ABSTRACT

Online Map Services use a technology called „tiling“, for generating flexible, dynamic and asynchronous slippy map interfaces. A rasterized map of a fixed size is recursively cut into a quadratic structure. These tiles are requested partially on client side, when zooming into the map, instead of loading the full picture. This way the image resources, requested through the http browser, were just a fraction of the whole map material and allow the user to manipulate it without much idle time.

For being able to generate tiles, there are few things that must be taken into consideration. First the shape of the picture used, must be quadratic and of a fixed size (the standardized size is 256x256 pixels); a conformal map projection must be used over the whole map. In addition, the ground resolution and the map scale at each point of the map must be known. Next, the pixel coordinates must be converted to geographic coordinates for all tile boundaries, following a tile indexing scheme, so that they can be indexed and stored in a fixed folder structure.

However, there still is a difference between the different online map providers – this difference concerns the indexing of tiles, not their way of generation. Indexing allows the server to provide tiles even faster and to store them more economically. The most important indexing schemes are Tiles Overlays (Google Maps), QuadKey (Microsoft Bing Maps) and TileMapService (OpenStreetMap). Whereas Tile Overlays and Tile Map Service (TMS) follow the same basic principle, which is indexing tiles by row and column – just starting in other locations – the QuadKey is totally different. Here, each tile has some kind of "master tile" and always refers to this one in the first place. Though this structure is a bit unusual, referencing tiles this way appears to be simpler, as one automatically knows the zoom level the tile is in and its approximate location.

Web Map Tile Service – an OGC standard for indexing tiles – is available as well, but not really taken into account, as it does not correspond to the methods being used by the main providers; due to that, interoperability becomes a problem.

On the following pages, the principle of tiling, the indexing scheme of Google Maps, Microsoft Bing Maps and OpenStreetMap (OSM) are explained, as well as the currently available standards WMTS and TMS.

1 Tiling principles

Tiling is not a standard, but a standardized process; due to compatibility reasons, tiles for online map applications are mostly generated with a size of 256x256 pixels, for mobile applications they vary between 64x64 pixels for OSM and 128x128 pixels for Google Maps (OpenStreetMap Wiki, 2010). Each zoom level increases the overall size of the imagery by factor 2. "The number of tiles in a map view varies depending on the zoom level of the map. If the zoom level is high, fewer tiles make up the map view. If the zoom level is low, more tiles are required to make up a map view (Microsoft , 2011)"

Not all tiles are requested at once; just those needed to cover the area visible in the map viewer plus the surrounding ones are being transferred from server to client and cached there. This method is used, because the map application becomes faster and the server is not busy because of sending bulk data to few users (Mapfish, 2009). "The general idea is to prepare, on server side, tiles which contain the data and, on client side, to load asynchronously the tiles in order to provide a better user experience" (ibid).

1.1 Map projection

To avoid overlaps or gaps between the single tiles, a uniform map projection is needed; therefore a conformal and cylindrical projection has been chosen: the *Spherical Mercator projection.* It preserves the shapes of relatively small objects, and goes to infinity at the poles, so they are cut off. Therefore, the coordinate extent is -180° to +180° latitude and approximately -85.05° to +85.05° longitude.

1.2 Ground resolution and map scale

Zooming into the map material decreases the area which is represented by a single pixel in each tile by the factor of 2; hence, visual details increase at higher zoom levels (MicroImages Inc, 2009). Specifying the ground resolution is necessary in order to render the map, as it indicates the distance on the ground that is represented by a single pixel in the map, depending on zoom level and latitude at which it is measured. Map scale must be defined, as it indicates the ratio between the map distance and the ground distance, when measured in the same unit.

TABLE 1: RESOLUTION WITH RESPECT TO THE ZOOM LEVEL

Zoom Level	Pixel Size at Equator
0	157km
10	153 m
20	15 cm
24	9.3 mm

1.3 Converting geographic coordinates to pixel coordinates

Once, scale and projection are defined, pixel coordinates can be derived from the geographic coordinates; this is done for each zoom level, as the number of pixel does vary. Each pixel depends on its location – latitude and longitude – and the zoom level; using pre-defined formulas (Microsoft , 2011) . All geographic coordinates must have the same datum, as converting will not work otherwise. Latitude and Longitude are therefore assumed to be WGS84 datum, even though a spherical projection is used.

5 Indexing

For each zoom level the tiles must be indexed according to a fixed structure, so that clients can send HTTP requests accordingly. Indexing systems used by Google Maps, Microsoft Bing Maps and OpenStreetMap will be explained in the following section

1.4 Google Maps: Tile Overlays

Google Maps uses a structure, called *Tiles Overlays* - "each of these tilesets consists of a single hierarchical directory structure containing uniformly-sized tile files" (MicroImages Inc, 2009). Each tile is indexed according to the row and the column it is placed in (FIG 1), like it is the case in a chessboard. Google Maps' lowest zoom level is represented by a single tile, showing the whole globe (according to the spherical map Mercator projection).

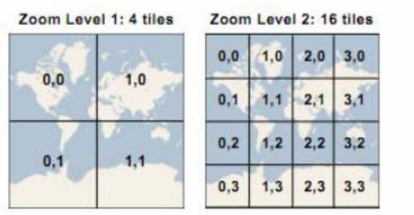

FIG 1: TILE OVERLAYS STRUCTURE (SOURCE: (MICROIMAGES INC, 2009), MODIFIED)

1.5 Microsoft Bing Maps: QuadTreeKey

Working with *QuadKeys* requires that the first zoom level consists out of four tiles; due to that, there is no zoom level 0 in Bing Maps. Each tile is assigned a number between zero and three, starting with the upper left corner – every number describes a region. On the next zoom level, each tile – for each "region" – the tile is assigned the number of the tile it origins from plus a number between zero and three. E.g. zoom level 2 splits the first tile (tile 0) into four new tiles – each tile is assigned the number zero in the beginning, then the new value is added. Fig 2 shows this indexing scheme.

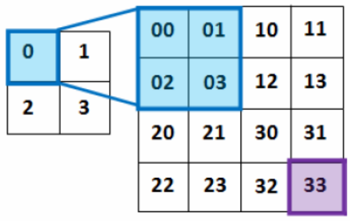

FIG 2: QUADKEY STRUCTURE (SOURCE: (MICROIMAGES INC, 2009), MODIFIED)

1.6 OpenStreetMap: Tile Map Service

For indexing and storing tiles, OSM uses a *Tile Map Service* structure, which is similar to the one, used by Google Maps; only difference is that it is vice versa. Therefore, the (0,0) tile is not located close to Alaska, but close to Chile. TMS mostly is used by Open Source projects like OpenLayers or TileCache.

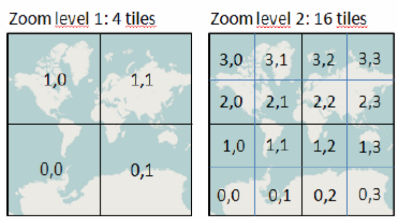

FIG 3: TILE MAP SERVICE STRUCTURE

Calculations to be included in your code for generating tiles

Designing an own program for generating tiles, there are certain formulas needed. Of course there are many different approaches, but the formulas most probably needed are provided as an example by Microsoft[3]. The most important ones are as follows:

Define the following values:

> Earth Radius (6378137 double), Min Lat (-85.05112878), MinLon (-180), MaxLat (85.05112878), MaxLon(180)

As you can see, those values for minimum and maximum of latitude appear to be strange,

[3] http://msdn.microsoft.com/en-us/library/bb259689.aspx

Determine the map width and height for each level of detail – which is for BingMaps from LOD1 to LOD23, for GoogleMaps or OSM from LOD0 to LOD20. Therefore:

Calculate the ground resolution, using latitude and zoom level:

Cos(latitude * PI /180)*2 *PI * Earth Radius / Mapsize(for according zoom level)

Determine the map scale, considering latitude, LOD and screen resolution

Ground resolution * screenDpi/0.0254 (inch)

Convert point from WGS84 coordinates to pixel coordinates

x = (longitude+180) / 360

y = log (1+ sin (latitude * PI /180))/(1- sin (latitude * PI /180)))/(4*PI)

pixelX = x*mapsize + 0.5

pixelY = y*mapsize + 0.5

To convert a pixel from pixel coordinates to WGS84 coordinates, we use the formula:

latitude = 90-360 * atan(exp(-y*2*PI))/PI

longitude = 360 * x

To calculate tile coordinates (pixels in the image on the containing tile)

tileX = pixelX / 256

tileY = pixelY/256

To calculate pixel coordinates out of the tile coordinates, we just use the opposite:

pixelX = tileX * 256

pixelY = tileY * 256

Next step is to transfer the created tiles by assigning the index wished, which might be either a QuadKey structure like the one Microsoft Bing Maps uses, or a normal indexing like GoogleMaps, or even the TMS structure.

6 Standards

Currently, there are two main standards on how to access tile sets, defined by non-profit organizations, the Web Map Tile Service and the Tile Map Service.

6.1 Web Map Tile Service

Web Map Tile Service (WMTS) is an OGC implementation standard, published in 2010. „A WMTS enabled server application can serve map tiles of spatially referenced data using tile images with predefined content, extent, and resolution.“ (OpenGIS Web Map Tile Service Implementation Standard, 2010). In short, WMTS does not focus on rendering custom maps (as WMS does), but on scalability of static data such as base maps, where BBox and sale have been constrained to discrete tiles (ibid); it returns single tiles out of single layers and therefore can be used for tile caching (Keller, 2009). Performance orientation and scalability as a goal, the server must support asynchronous access for tiles of a single view. The mandatory operations of WMS, which are also possible WMTS requests, are listed in TABLE 1.

TABLE 2: OPERATIONS ALLOWED FOR WMTS, SIMILAR TO OGC WEB SERVICES:

Request	Response	Explanation
GetCapabilities	ServiceMetadata	abilities and information holdings of specific server implementation
GetTile	tile	shows fragment of map representation of a layer
GetFeatureInfo	FeatureInfo	information about features located in particular pixel of tile map

6.2 Tile Map Service

TMS shall maximize the interoperability of tiles from different map providers like Google and OSM. (OSGeo, 2011)

Open Source Geospatial Foundation's (OSGeo) Tile Map Service (TMS) standardizes the way in which map tiles are requested on client side and how servers describe their holdings; access to cartographic maps of geo-referenced data is provided – available resources, just as rendered tiles at a fixed scale, can be accessed via REST interface (OSGeo, 2011). TMS shall maximize the interoperability of tiles from different map providers like Google and OSM. To ensure this interoperability, each TileMap (complete map representation at a specific zoom level) supports exactly one spatial reference system and one image format, and requires a defined BoundingBox (extent of data of interest) plus an origin.

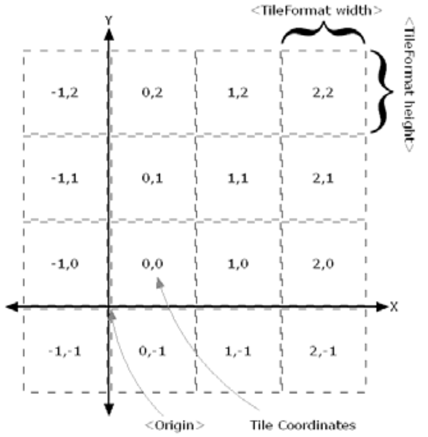

FIG 5: TileMap Diagram [8]

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Open Source GIS and GIS Cloud Computing – A Chance for Nations in Transition

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ABSTRACT

An open source approach for developing, deploying and managing a nation-wide GIS customized for tight budget economies is discussed based on a critical analyses of the impact of the so-called next generation GIS a.k.a cloud GIS, on national spatial data infrastructure for young economies. Although the ability to harness resources online via the World Wide Web on pay per use basis provides a window of opportunity for nations in transition, the technology is dependent to stable power supply and available internet connections. Failing the reliable availability of these two utilities, the author proposes a technique christened "cold GIS" which employs Open Street Map as an open source data source and takes advantages of Client-Side technologies and offline editing tools, for instance the JOSM (Java Open Street Map) editor, to author and publish data offline and upload the edits online when the resources are available. Additionally, the research contributes to how data sharing over the web could be augmented by using GeoPDF maps that could enable offline GIS planning and discussions within limited supporting resources. As opposed to the ultimate functionality of Cloud GIS, namely "warm GIS" a cold GIS approach may work better for developing nations with unstable power and internet services.

1 Introduction

Cloud Computing refer to consuming multiple computer resources (including software, data and processing capabilities), hosted by a server. It allows the client to view and sometimes test these resources without having to download or install them on their local computing devise as all data storage and computing is hosted on the server side. There are however some requirement on the client-side is to have an internet connection and an approved web access route (e.g. a web browser) to run the resources on the client's device through the World Wide Web. Although few free cloud services exist, sometimes with limited resources, good cloud services are available for computation on pay per use basis. That is, the client only pay for the Time x Cost of resources used for a particular task. While big companies including Microsoft and ESRI see Cloud computing as a technological revolution (or rather a new business opportunity window), open source activists see it as a trap [12] to force users to use only commercial cloud technologies. However, a new interesting group of developments are arising in support for free cloud technologies. The trend stems from other open source initiatives. Open Source Geographic Information Systems (OSGIS) refer to the availability of GIS resources and source code for free use, distribution and re-distribution. In simpler terms, open source GIS provides GIS resources or tools for the development of GIS but in addition, also provides the source code of the resources, allowing users to customize the tools as deemed fit. In his paper in AGSE 2010 in Peru [11] outlined several resources and opportunities for GIS development using free and open source tools. The interest of this paper is to appraise both free and enterprise GIS Cloud resources for development and environmental applications. A typically free cloud GIS as of the time of publishing this paper is www.GISCLOUD.com. Although a much customable version exist for commercial purchase, GISCLOUD's free Cloud GIS can host and support desktop GIS resources behind the users firewall. In the following discussions, this paper explores GIS Cloud's documentation and its suitability for nations in transition. However, a starting point will be to explore the technology behind the Cloud. This will enable readers to decipher what it is and what it is not.

2 What is GIS Cloud?

GIS Cloud employs web based geographic information system (GIS) to publish, edit and visualize data as maps [14]. The benefits are to help organizations and businesses improve decision making and optimize operations to save money by offering tools for the manipulation and analysis of spatial data, as well as enabling easy data sharing and collaboration within organizations. Running in the cloud, it can be integrated with other data formats and various external web applications. It provides significantly lower IT costs, and eliminates time maintaining, scaling and updating software and servers.

3 Traditional GIS software web technologies vs. GIS Cloud

GIS as an application of Cloud Computing service has three distinct characteristics that differentiate it from traditional web GIS hosting [4]:

1. GIS Cloud is sold on demand. To explain this is algebraic terms:

Cost of GIS Cloud = Unit Cost per user(s) x Time Used + Cost Subscription Renewal – Cost of Software – Hardware–IT Human Resources–Web Hosting Services Cost(if applicable) – IT Departmental Cost

The total cost for traditional GIS and web GIS will be:

Cost of GIS = Cost of Software + Licensing Cost per user(s) + Maintenance Cost + Hardware +IT Departmental Cost+ IT Human Resources+ Web Hosting Services Cost(if applicable)+ Licensing Renewal

2. It is elastic – a user can have as much or as little of a service as they want at any given time; and
3. The service is fully managed by the provider (the consumer needs nothing but a personal computer and Internet access). To use GIS Cloud there is no need to worry about hardware support. Everything is provided within the service

Cloud technology is applied in familiar application including Gmail, Facebook, Twitter, Flicker, Skype, Hi5 and LinkedIn [1]. As web platform, it has ability to supplement and perhaps one day completely replace expensive desktop software solutions. GIS cloud can be used in any aspect of public or private sector. It reduces software fragmentation, offers an affordable on-demand Web based GIS solution and simplifies exchange of geographically referenced information between users while enabling an easy way to analyze information independent of a user's location. GIS Cloud platform can be based on open source technologies including C/C++, PHP, PostgreSQL Linux, Apache, JavaScript, Adobe Flash and XML. Web services are used as interface to access these resources / information through the web. In terms of programming Cloud can be thought of as the API's which support large-scale parallel computing and expansion of users without loss to service quality. It uses the Software as a Service or SaaS (pay per use software system running on a remote computer, i.e. not the local computer) provided through a web service such as a SOAP/WSDL system. In traditional web hosting, there is a need for the Client to monitor, install, upgrade and configure programs, add sites deal with potential hacks, and troubleshoot systems. This need is not required in Cloud GIS. For instance, the availability of Internet connection enables giscloud.com users to create projects, analyze data, develop own mapping applications or collect data off-site with smartphones. Some advantages and disadvantages include the following:

3.1 Advantages:

3.1.1 Saving Money and Resources

Since the client does no need to buy the software or host the service, using GIS Cloud reduces cost of software, tools and training. It is on pay per use basis – users can consume services and pay as they would do for utility bills.

3.1.2 Enabling data sharing and collaboration

Access to information online as a single user or be shared among a group of users. The web maps generated can also be embedded in websites and online reports. To further promote data interoperability, several data formats are supported which include ESRI Shapefile (.shp), Mapinfo File (.mif, .tab), JPEG, JFIF (.jpg), TIFF / BigTIFF / GeoTIFF (.tif), Multi-resolution Seamless Image Database (.sid), and KML

3.1.3 Availability

GIS Cloud computing companies including the open source ones boast of "excellent" Service Level Agreements (SLAs). This promises high performance and availability of software and network resources at an annual uptime (measured as a percentage of uptime availability per annum). A hundred percent annual uptime will represent an all year availability of agreed services at 100 performances. For instance, our study website, giscloud.com advertises 99.95% annual Uptime performance during a service year. In the event GIS Cloud does not meet the annual uptime percentage commitment, a client may be eligible to receive a refund (following some conditions in the Service Level Agreement). Cloud resources are distributed efficiently over the internet to allow for high demand and processing power. Its continual elasticity discards the possibility of a user using more than their budgeted data traffic/space.

3.1.4 Data Security and Backups

Most clouds are built on Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL). These are cryptographic protocols for ensuring security and privacy when a user is online [1]. TLS and SSL work by encrypting network connection ahead of the transportation of information. However, 100% security cannot be guaranteed. User to may want to frequently vary login credentials to ensure privacy. In terms of data backups, public Cloud data centers backed-up data in multiple servers. Therefore, if a server fails, the user's data and applications are served from another server without the user realizing that their initial server has failed [Primault, 2010].

3.1.5 Service Scalability

APIs and support for increase in number of users and request is important for Cloud GIS. Applied technologies including Data Pyramiding and Tiling allow large datasets to be broken-up into manageable segments that can be handled quickly (for requests and responses) by the server.

3.2 Disadvantages

3.2.1 Security risks

Limited functionality is available for free on Open Source and Free platforms. Alternatively, the Client might purchase enterprise editions of free Cloud GIS which may perform better, be more customized and provide better security. However, Cloud hosting has security risks and loss of control once applications and data are no longer within the control of clients. Clients may want consider a private Cloud where achieving compliance for data confidentiality and integrity is required [1].

3.2.2 Interoperability

The integration of public and private Clouds may result in some issues of pertaining to system interoperability and portability. Data perceived to be available for all clients may be available only to a few private users.

3.2.3 Customer service

Perhaps the most pressing issue, especially, when nonphysical contact is possible at all times (outside office hours, considering difference in time zones). It is important to prospect for providers who can provide 24 hour assistance when required. Also, such understanding must be stated in the Service Level Agreement (SLA).

3.2.4 Customized use and openness

Most applications are "generic" and allow for some API and customizations. However commercial applications are closed and may not allow specific customization to a GIS application.

3.2.5 Cost

The best GIS Cloud Technologies do not come free (see table below). However it is important to state that the cost of GIS Cloud Technologies is reducing as more companies compete for new clients.

3.2.6 Customer Satisfaction and Changing providers

Depending on the agreement reached, if a provider does not meet demand, it may be difficult to change to a new provider. Users should be able to manage their Cloud servers through a web-based interface that includes a full

API access to guarantee a smooth transition. This enables transition between suppliers when clients are not satisfied with a service [1].^

Table 1: Catalogue of available GIS Cloud computing resources

NAME / Website	SaaS Price	Security	Performance1	Availability2	REMARKS
GISCLOUD www.giscloud.com	Free / Commercial	100%	80%	99,95%	new release more stable
eSpatial	US$ 55 / per user / per month	100%	80%	99,95%	99,95%
CartoView-Cloud www.cartologic.com/-cartoview/cloud.aspx	Open source	70%	75%	75%	Support a number of data formats
ESRI Business Analyst Online	$2,495 / year	unknown	Unknown	Unknown	no license for author
ArcGIS Server Geoportal Extension	Unpublished	Unknown	Unknown	unknown	no license for author

1, 2 deduced by a randomly accessing the software and its resources online from April to July, 2011

3.3 Power and Internet in Developing economies – performance, scalability, availability and security

The performance of internet technology to support Cloud resources is generally satisfactory considering the popularity of 3G and 4G networks around the globe.

However the real measure of suitability of deploying GIS using internet resources in developing countries is investigating the number of users in these parts of the world with stable internet (and power) resources per annum. Table 2 below from an online survey [16] estimates the following for developing countries:

1. Africa, with an estimated population of about one billion in 2011, only about one hundred and twenty million people use the internet [16]. This represents 11% percent of the population;
2. Asia has better internet availability. For a population of four billion, 24% have access the internet;
3. The middle east has a usage percentage of 32%; while
4. Latin America and the Caribbean have 36% of its population using the internet.

Currently only 30% of the world's population have access to the internet. Internet use around the world is however on the increase [17]. This situation calls for further utility analysis before hosting internet based solutions online. It is deductable from the statistics above that reaching the audience with information through the internet have limitations in developing countries (Asia, Africa, Latin America and the Caribbean). In Kenya, for example, only 3.4% of the country's population has access to internet access [16].

In terms of power availability, Kenya for instance provides 22.69% of its population with electrical power [18]. Nairobi, which hosts this year's AGSE conference, has quite stable power availability at 72.37%. However, if a Cloud Technology were to be consumed, twelve out of the forty-seven Counties (including Bomet, Bungoma, Homa Bay, Mandera, Siya, Tana River, Tharaka Nithi, Turkana and West Pokot) will face challenges to support the power requirements for utilizing this technology. These twelve Counties have less than 5% of their population with power supply. County offices in these catchment areas will not benefit from the full capacity of the Cloud under these poor power conditions unless alternative (additional cost) power support is provided in County offices. These limitations are not limited to Kenya alone. The trend is quite familiar in most developing economies. While main cities may have over fifty percent power availability, towns and many villages may lack power supply. The tendency usually required to support such additional power demands is to provide alternative sources (Solar or Generators). This additional cost usually is not sustainable. And with time the implementation of the technology terminates.

WORLD INTERNET USAGE AND POPULATION STATISTICS (2011)			
World Regions	Population (P)	Internet Users (I)	(I/P)%
Africa	1,037,524,058.00	118,609,620.00	11%
Asia	3,879,740,877.00	922,329,554.00	24%
Europe	816,426,346.00	476,213,935.00	58%
Middle East	216,258,843.00	68,553,666.00	32%
North America	347,394,870.00	272,066,000.00	78%
Latin America and the Caribbean	597,283,165.00	215,939,400.00	36%
Oceania / Australia	35,426,995.00	21,293,830.00	60%
WORLD TOTAL	6,930,055,154.00	2,095,006,005.00	30%

Table 2: World population versus Internet Usage [16]

Marrying internet and power availability against the four important requirements to consider for a successful GIS implementation and sustenance, namely [10]; Performance – How fast (time) system responds to user request; Scalability – Able to support growing number of users; Availability – How often can a user access service (0%-100%) and Security – Authentication/confidentiality of requests, the structures supporting Cloud GIS (chiefly, power and internet availability) tend to fail for developing countries with unstable power and internet resources.

4 Dealing with data security

Using resources online come with its security issues. For instance, inputting national natural resources data and sensitive community assets in a kind of cloud computing raises the questions as to "who else will leak this information" after the client have leaked it on the cloud. Although complete security is impossible to guarantee, it is possible to provide first to third level security of open GIS projects. In line with this, this paper proposes a new term for a sub-group of OSGIS, namely, Citizens Open Source Geographic Information System (COSGIS). This concept involves sharing the GIS online with levels of administrative rights that can be accessed and administered by specific communities only via a user name and password. Currently Google API provides this functionality. The same customization is application in Open Street Map community program. However, large corporations are wary of cloud computing. There is a lack of trust between these corporations and storage providers. Even if some companies do trust their storage provider, they still have security concerns. Most big corporations are hesitant or unwilling to allow any of their sensitive data to be put in "the cloud." There is always the possibility of hackers getting their hands on the data. In addition to that, users are not able to access the servers that have their stored data. Lastly, if the storage providers close up shop, it will be very hard to retrieve a company's data.

5 Some alternative resources available to developing countries

Power and internet availability support for the four important factors, namely, Performance, Scalability, Availability and Security for GIS implementation have been discussed above. The following discussion analyses available technology, software and tools that support Cloud GIS. Considering the four requirements and the need for power and internet availability, alternative resources and tools are suggested. Cost and sustainability concerns are discussed in the spirit of provided a holistic approach at helping stakeholders make decision on the implementation of cloud GIS for development and environmental management.

5.1 Cold and Warm GIS editors

To discuss the proposed alternative concept on how to deal with GIS availability online and offline during internet connections, a discussion of two concepts is introduced. "Warm GIS" is used to describe the availability of Cloud GIS services at runtime while "Cold GIS" is used to describe the availability of GIS resources offline".

Cold GIS could be warmed into a Warm GIS. Opposed to Cold GIS, Warm GIS refers to the ability to stay online and download, edit, commit, upload and publish maps without a break in the web or cloud service. In order to continue to make a case on the direction of choice for Cold or Warm GIS for developing countries, it will be interesting to survey the some available resources supporting Cold or Warm GIS technologies. An example is the OSM (Open Street Map) Cold and Warm editors. This paper will only discuss one Cold and one Warm GIS editor in OSM. (Readers are encouraged to do a further reading on the OSM wiki page in the reference below).

5.2 OSM Editors

There are several cold GIS editing tools available for Cloud-like technologies in OSM [2]. For instance one example employing Warm GIS in OSM is Potlatch2 for OSM. Potlatch 2 is an OSM editor that for making edits directly to the OSM database. All edits are done online and uploaded at runtime. The data served and service interaction is therefore “warm” in this case.

On the other hand, editing tools in OSM like the java plug-in JOSM (Java Open Street Map) is cross-platform offline editor for OSM. JOSM performs comparably to regular commercial GIS Software and Application with additional support to edit maps offline, update, upload and share mapping information when web resources are restored [4]. While internet connection is available, a user may download an area of the map (can be one or several bounding boxes) and save the data as an “.osm” file on a local disk. When there is power outage and or loss of internet connection, a user may still open the saved “.osm” files offline - without an internet connection. Users can open GPS traces and overlay them on the data offline and add local information captured during a related field surveying exercise and save the changes back to the file. The saved file will include information about all changes including moving and deleting data. If another user has changed exactly the same element in the mapping area, JOSM reports a "conflict" when the same area is about to be updated. It is mandatory to resolve the conflicts before upload. The latest user will have to analyze the previous entry and decide their entry should be discarded or should replace the previous edits. Available OSM editors exist for virtually any platform, including Android, Windows, Linux, iPhone, iTouch, Mac and JME. The interoperability prowess of the package is possible with major commercial software. For instance ArcGIS now has the ability to edit OSM data using a suite of desktop tools / add-ons within ArcGIS desktop software [15]. Adopting this approach may be a more practical solution to GIS sharing needs in nations in transition.

5.3 GEO PDFs

A GeoPDF is a geo-referenced, compressed PDF file for sharing GIS information using free an Adobe Reader and TerraGo’s free toolbar provide. About 90% of the world’s personal computers are able to view PDF files. This makes GeoPDF able to facilitate “access to geospatial information by everyone from mapping technicians to company executives to the average citizen” [13]. The free viewer for GeoPDF and its extra tools for common analysis tasks including measurement of coordinates, distances, lengths and areas make it quite intuitive to use. GeoPDF support multiple datum and projections and has markup capabilities that allow users to edit and send edits on the same map to each other by email. This is particularly useful in collaboration between institutions. Furthermore the mark-ups can be exported from a GeoPDF to a KML, GPX, TWZ, or Shapefile. Geospatial markups serve as an innovative way to QA/QC projects in a cost effective, less time consuming manner with data that can be hosted over the internet [13]. Furthermore, users are able to view 3D data, including LiDAR. 3D data can be rotated, zoomed, and panned and viewed in Adobe Reader [14]. As a cold GIS, GeoPDFs provide another opportunity for developing countries to share geospatial data within limited power and internet availability.

6 Conclusion

In this paper, the possible influence of Cloud GIS technologies on spatial infromation development and support for environmental and development information sharing in developing economies has been discussed. An unbiased reflection of both the merits and demerits involved in adopting the technology has been presented. The paper dealt with issues pertaining to data security, availability and customer privacy and service issues when consuming GIS resources in the Cloud. Also, while this new trend of GIS technology provides a window of opportunity for reducing cost in purchase of GIS software and web map hosting resources, a cautionary approach should be followed in migrating completely to this technology. This caution stems from the fact that the backbone for this technology is electrical power and internet availability - requirements not always available in most parts of developing countries. Alternatives have been suggested using Cold GIS approach which utilizes offline GIS editing tools like JOSM and GeoPDF to manipulate geographic information offline and upload data online when service is available. Employing GeoPDFs will allow online maps to be viewed, edited and printed using free adobe products. Having said all these, the choice to use part, or a whole or to wait or to ignore the use of cloud technologies is in the hands of mandated organizations. Ultimately, every applicable technology to development and environmental mandates should be sustainable, useable, stable, integrateable and economical. In terms of performance, it can be seen that alternatives to Cloud GIS technologies discussed provide a stronger case when considering issues pertaining to Performance, Scalability, Availability and Security. Do Open Source and Cloud GIS satisfy all these qualities? There may not be a clear yes or no answer to this question. It all depends on supporting resources like power and internet, user requirements and the user dynamics of the target consumers of the developed web application.

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Environment Incident Reporting System

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KEY WORDS:
Environment awareness, incident reporting, incident management, free and open-source software

ABSTRACT:

Environmental challenges in Kenya are vast and diverse from one region to the other. The National Environment Management Authority is mandated under Environmental Management and Coordination Act (EMCA), 1999 to supervise and coordinate all environmental related issues within the country.

As a result of NEMA's concerted efforts environmental awareness has increased immensely leading to an increase in number of reports on environment disasters and hazards affecting humanity. The media has been on the fore front of this but it limitations can be supplemented by other technological tools like geoinformation.

The challenge lies with retrofitting in respect to availability of such avenues for reporting these incidences, management of spatial information, awareness creation, monitoring, responding to issues raised and the use of the available information to give a clear indication on environmental challenges and how to mitigate them. However, With the advent of Web 2.0 (facilitates interactive information sharing, interoperability, user-centered design, and group effort on the World Wide Web) and availability of Free and open-source software (FOSS), a platform exists where all the concerned parties can report environment incidences to the concerned authority and follow up on the progress as actions as are being addressed. This paper therefore, highlights development of a web interface that has been developed by national Environment Management Authority (NEMA) Kenya, to report environment incidents. The system is envisaged to contribute greatly towards involving the public and the relevant institution to manage the environment in a more sustainable manner.

The system will therefore improve the efficiency of reporting and responding to environmental issues and also offer an avenue for citing changes in the environment, pinpoint hotspot issues. Geoinformation technology with its geodata infrastructure therefore offers opportunities for integrated informed planning and will greatly contribute towards evaluation of policies before and after implementation of various environmental policies and regulations.

Spatial Data Infrastructures and Land Management

A spatial data infrastructure provides for a basis for
spatial data discovery, evaluation, download and application for users and providers within
all levels of government, the commercial sector, the non-profit sector,
academia and the general public.

Hartmut Müller, Promoting Land Administration and Good Governance,
5th FIG Regional Conference
Accra, Ghana, March 8-11, 2006

Geospatial and e-Governance Readiness Assessment: A Case Study from India and South Africa

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KEYWORDS:
Geospatial Readiness, e-Governance, Geospatial Services, Web GIS, Metropolitan Municipalities, Municipal GIS

ABSTRACT

E-governance and Geospatial technology adoption in the context of service delivery of municipalities is meant to have transparent, efficient and responsive government. In this globalised world, the technology adoption and its application is emerging at a very rapid pace. However, world over municipalities are facing enormous challenges to have effective municipal service delivery with changing scale of cities and changing socio economic background state of its citizens. The prime objective to implement E-governance and Geospatial Technology is usually cost cutting and also minimizing the complexities of procedure by possible business process reengineering. Municipalities are entrusted to provide efficient service delivery to its citizens and subsequent technology adoption however they still have issues like digital divide, affordability etc. The municipalities are keeping abreast of latest technologies and implementing them to enable greater facilitation of its services and at the same time increasing the accessibility of its services to the citizens. The concomitant advantage could be empowering people through so called "disintermediation" or eliminating middleman between government and its citizen. Just to mention a small example, implementing online property tax assessment and collection system could eliminate element of corruption in form of "middleman" and also improve on service delivery or consumer convenience especially in developing countries. The paper discusses and evaluates the dimensions of e-Governance and Geospatial adoption at select municipalities in India and South Africa and their readiness level for further change. The scope of this Geospatial and e-Governance Adoption is kept within the context of GIS and web enabled services, which further leverage transparency, responsiveness and accountability. Based on this overview of Geospatial and e-Governance Adoption level study, the paper identifies the lessons learned from the qualitative analysis of the Geospatial and e-Governance adoption levels for strengthening the areas of planning, governance and service delivery services to the citizens.

1 Introduction

The Local government or municipalities world over are responsible to provide basic services to its citizen to satisfy their basic needs. However, The municipalities are often trapped in a vicious cycle of under resources and are economically stressed to facilitate the desired levels of services and infrastructure (Nel and Rogerson 2007). Often this system results in poor delivery of services, thus lowering of service level benchmarks. Depending on the municipal organizational structure, the municipalities have degrees of differences in terms of fiscal, spatial, functional, governance and technological capacities. Under the complex circumstances, measures like E-governance or application of Information and Communication Technology (ICT) and adoption of Geospatial technologies have given a ray of hope to enhance the service delivery to the citizens. "e-Government development very often aims to improve public service delivery capability, as well as public administration governance, transparency, and accountability through the development of e-government service delivery capability" (Chatfield and Alhujran 2009).

Integration of ICT with spatial interface for services delivery, planning and development brings in the concept of 'Geospatial' aspects of e-Governance. In order to manage complex governance challenges, the combination of Geospatial and e-Governance forms one of the widely accepted solutions / interventions.

2 Need for E-Governance and Geospatial Governance

The need for e-Governance or Geospatial governance can be traced to the fact that municipalities world over adopted various approaches to achieve good urban governance. Most of the good urban governance at the municipal level is associated primarily with the adoption of ICT in the form of e-Governance initiatives. The technology adoption programs in municipalities have traditionally evolved from an urge to make municipalities perform better for delivery of services to citizens and achieving overall performance in its functions. Some key areas of implementation of technology based solutions can be property enhancement applications, complaint redressal system, registration and issue of trade licenses, birth and death registrations, provision of information to citizens through kiosks, websites, etc. These approaches are not always integrated with other modules within the system resulting in approaches being adopted at the municipal level being isolated from one another.

3 Geospatial and e-Governance Adoption levels

Geospatial technologies have matured in the last two decades, and City Planners have continued to adopt and adapt these technologies through higher education, increased access to datasets, and wider use of related technologies in agencies. However, mostly in developing countries, Geospatial technology is seldom utilized for advanced applications like modeling or spatial analysis, but rather is most often used to create inventories, access information, and perform simple mapping for reports and public meetings. The use of GIS in municipalities has not reached the level envisioned by scholars and proponents of GIS (Venture and Gocmen 2010). E-Governance functions at local level include multitude of services but not limited to planning, preparation and approval of mega-plans, management of existing infrastructure and restructuring of facilities. Around 80% - 90% of municipal / government data is geographic in nature - containing location information, area / extents, pin code, or latitude and longitude co-ordinates. The availability of spatial data using Geographic Information technology (GIT) has opened planners / decision makers to think beyond 'conventional' Decision Support System (DSS) / e-Governance System to the 'Geo-Spatial' System. As per e-Governance web measurement assessment in 2008, South Africa ranked 39 with an index of 0.55 and India ranked 54 with an index of 0.47, among the 192 member states of United Nations (United Nations 2008). However, these rankings are based at country level and do not reflect the clear picture at municipal level within the dimensions of planning, governance and service delivery. Not much research has been done on geospatial readiness in terms of various parameters linked to municipal governance, planning and service delivery at local level.

4 Municipal Case Studies: South Africa and India

The present paper discussed two case studies in form of comparative analysis on select parameters for Geospatial and E-governance Readiness. The case study is focused on two metropolitan municipalities namely Johannesburg in South Africa and Surat in India, which assesses local government web enabled GIS service delivery and its access to citizens. A qualitative approach of assessment was adopted by reviewing the extent of services provided through web enabled mode in areas of planning, governance and service delivery with focus on citizen centric interface. A comparative assessment of case municipalities provides an overview of level of Geospatial readiness in service delivery and access to citizens.

South Africa has 283 municipalities, categorized into three constitutional categories which include: Metropolitan municipalities -Category A; Local municipalities -Category B; and District municipalities - Category C (LGMS 1998) based on the Municipal Structures Act (LGMS), No.117, 1998. There are 6 metropolitan municipalities, 231 local municipalities and 46 district municipalities as categorized in three constitutional categories (COGTA 2009). The six metropolitan municipalities namely: City of Johannesburg, City of Cape Town, eThekwini (Durban) Metropolitan Municipality, City of Tshwane (Pretoria), Ekurhuleni Metropolitan Municipality, and Port Elizabeth represent the 32% of the population with rapid urbanization exceeding 4% per annum (Naude et al 2006). For the present paper, we have selected City of Johannesburg.

In India, as of 2001, there were 1363 Census Towns in the country and 3798 Statutory Towns making a total of 5161 urban centers which constituted 27.8% of the total population. As per 2001 census there were 35 metro cities in India which accounts for 38% of the total urban population (Census 2001). The metro-cities are those cities having population more than one million & above. "Metropolitan area means an area having a population of 1 million or more, comprised in one or more districts and consisting of two or more municipalities or Panchayats or other contiguous area, specified by the Governor by public notification to be Metropolitan area for the purposes of this Part" (Sivaramakrishnan and Maiti 2009). From India, Surat Municipal Corporation has been studied and compared with city of Johannesburg.

4.1 Case Study 1: Surat Municipal Corporation (SMC)

Gujarat is one of the 28 states of India, which makes four of its major cities as part of 35 metro cities of India, namely : Ahmedabad, Surat, Vadodara and Rajkot. As per 2001 census, the population of Surat was 2876374. Surat Municipal Corporation (SMC) carries out all the obligatory & discretionary functions prescribed as per the municipal act and bye laws. Some of the services include: education, basic civic facilities like water supply, drainage, solid waste management, town development, tax collection, amusement, etc. SMC has received many awards in various categories and e-Governance, is one of the category where the corporation has set examples of best practices in various categories of services which have both citizen as well as business interface (Surat Municipal Corporation 2011).

4.2 Case Study 2: City of Johannesburg (COJ)

City of Johannesburg Metropolitan Municipality in South Africa offers a multitude of services to its citizens. Some of these services are offered through its established entities/ fully owned companies. The services offered through the independent companies include: water supply, solid waste management, electricity, public transportation, etc. Besides these services, the municipality provides various services through its civic centers and customer care centers which include: accounts and payments, building plans, licenses, traffic fines, valuations, building plans etc. The Johannesburg Metropolitan area is divided into seven regions which comprises of dedicated civic centers, customer care centers and pay centers for providing services to the citizens (City of Johannesburg Metropolitan Municipality 2011).

5 Analysis of Geospatial and e-Governance Readiness

Over the years, there have been various models presented by United Nations(UN), Gartner Group, World Bank(WB) etc having varied stages and functionality levels of E-governance and Geospatial adoptions. These models have been used to analyze the Business to Business (B2B), Business to Government (B2G), Government to Government (G2G), Government to Business (G2B) or Government to Citizens (G2C) interface. In this context, a well organized and efficient model similar to United Nations five stage web-based public service delivery models is relevant to analyze service delivery stages. The following are the key stages of the model:

- Elementary (L1) – Web presence: no or only static web presence
- Medium (L2) – Enhanced web presence : detailed information with basic functionality
- Good (L3) – Interactive web presence: interactivity connecting users and service providers.
- Advanced (L4) – Transactional web presence: Secure transactions and communications between the citizens and government.
- Futuristic (L5) – Seamless networked web presence: one-stop portal for citizens, the services and functions at any given time.

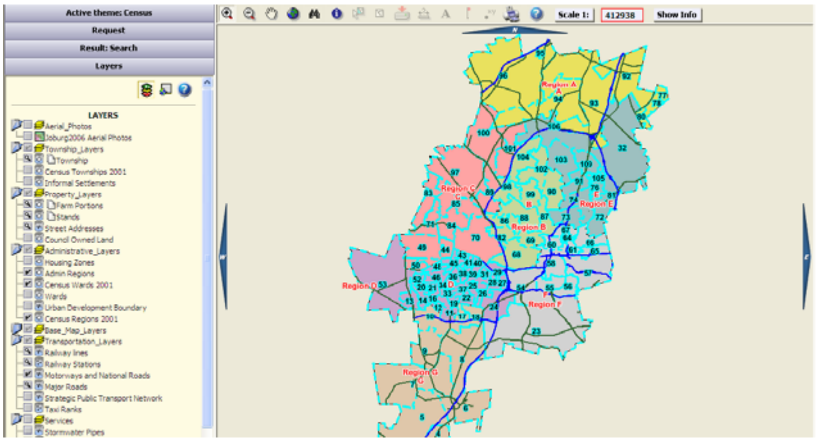

Figure 1: Web GIS layout / application from City of Johannesburg Metropolitan Municipality.

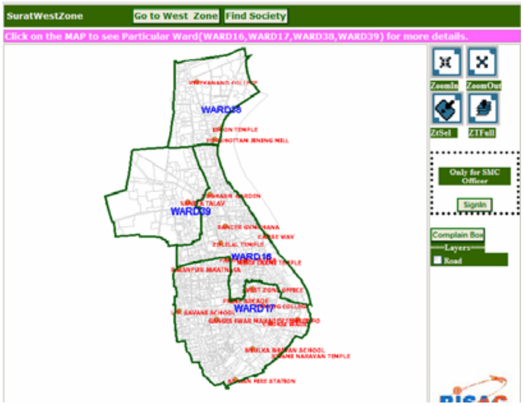

Figure 2: Web GIS layout from Surat Municipal Corporation.

The select municipalities in India and South Africa have been broadly studied on preparedness of e-Service delivery and GIS functionality /WebGIS services and also on efficiency of delivery of these services. Table. 1 outlines some of the key areas of E-governance and Geospatial implementation in both the municipalities.

Web Presence	**Elementary (L1)**		**Medium (L2)**		**Good (L3)**		**Advanced (L4)**		**Futuristic (L5)**	
Web based GIS Services and functionalities	**Not Available**		**Informational**		**One Way Interaction**		**Two Way Interaction**		**Transaction**	
	COJ	**SMC**	**COJ**	**SMC**	**COJ**	**SMC**	**COJ**	**SMC**	**COJ**	**SMC**
Water Supply										
Tariffs			x	x	x					
Payments		x	x							
New Connection			x	x						
Meter Readings		x	x				x			
GIS functionality	X	X								
Waste Management										
Tariffs		x	x		x					
Payments		x	x							
Bins		x	x		x					
GIS functionality	X	X								
Electricity										

Tariffs		x	x		x					
Payments		x	x							
New Connection		x	x							
Meter Readings		x	x		x		x			
Complaints		x	x				x			
GIS functionality	**X**	**X**								
Driving License		x	x		x					
GIS functionality	**X**	**X**								
Bus Services			x	x						
GIS functionality	**X**	**X**								
Building Plans			x		x	x	x			
GIS functionality				**X**			**X**			
Fines		x	x							
GIS functionality	**X**	**X**								
Street Lights	x					x				
GIS functionality	**X**	**X**								
Customer Care			x							x
GIS functionality	**X**	**X**								

Table 1. The symbol (x) inside the table represents the web based e-Services, and symbol (**X**) represents the Geospatial functionality.

In spite of various efforts and initiatives, many of the e-Governance programs/ projects do not realize its full potential due to the missing links. These missing links are none other but the missing links of spatial aspects of E-governance. The geospatial dimensions / Geographic dimensions of data are core to various spatial activities at local level. Traditionally GIS was used as a department specific function where mapping needs were forwarded to, in order to have an image created for publication or use in policy discussions. GIS has evolved from a function to a necessary component of policy creation (Morgan and LaFary 2009). It provides unparalleled power to examine social, economic and political circumstances. With the evolving of this technology, its usefulness / application becomes more prominent in the public sector, and thus to decision making (Haque 2001). The utilization of GIS technologies has been demonstrated for many applications in local government. Initial uses are typically limited to query and display applications. The application of more sophisticated analysis, modeling and prediction is limited primarily by organizational and institutional challenges (Venture 1995).

The key components of success at local government can be classified in form of three constituents (Lewis and Ogra 2010).

- Planning and Development: includes Building Approval, Land Parcel Management, Zoning & Development, Town Planning Schemes, Urban Renewal, Master Plan, Integrated Development Plans, City Development Plans, Spatial Plans, Structure Plans, Project Development and Management, Slum Development, Community Planning etc.
- Governance: include resource mobilization like property Tax System, Advertisement Management, Asset Management, employee management system, Complaint Management System, Traffic & Transportation/ fines, Park Management etc.
- Service delivery: includes Water Supply, Sewerage, Drainage, Solid Waste Management, Street Lighting, Streets & Roads etc. Keeping aligned with the concepts of Good Urban Governance, the dimensions of e-Governance at municipal level should primarily account / take into consideration such key areas with integration of GIS.

Table 2 provides the comparative analysis of e-Governance and Geospatial adoption levels reached in select two municipalities. The analysis is based on the structured qualitative analysis on select dimensions within the planning, governance and service delivery aspects based on WebGIS / e-Governance online access to citizens.

Sr. No.	Select Metropolitan Cities	Dimension	Key Aspects	Type of Dimension	Geospatial and e-Governance Readiness Levels				
1	**South Africa**				L1	L2	L3	L4	L5
	Johannesburg	Planning	Building Plan Approval	e-Governance				x	
	Population			Geospatial				X	
	3479723	Governance	Customer Care	e-Governance		x			
				Geospatial	X				
		Service Delivery	Water Supply (W/s)	e-Governance			x		
				Geospatial	X				
2	**India**				L1	L2	L3	L4	L5
	Surat	Planning	Building Plan Approval	e-Governance			x		
	Population			Geospatial		X			
	2876374	Governance	Customer Care	e-Governance					x
				Geospatial	X				
		Service Delivery	W/s - Tariffs	e-Governance		x			
				Geospatial	X				

Table 2. Comparative analysis of extent of Geospatial and e-Governance readiness assessment on dimensions of planning, governance and service delivery.

6 General Observations

The analysis of the select metropolitan municipalities from South Africa and India clearly shows the varied E-governance and Geospatial adoption levels while considering different dimensions of planning, governance and service delivery areas. The benefits of e-Governance and Geospatial adoption are yet to be seen as fully percolated down to citizen level. It is evident that municipalities from the same region from both the countries are at various maturity levels. In case of Johannesburg, the adoption stage for building plan approval is reached as Level 4 and it is observed moderate in case of SMC. In case of cities like Johannesburg the model is based on Interactive Voice System (IVS) managed through customer care centres or dedicated call centres, where as in case of Surat the information provided the system matches all the stages of maturity level with an exception feature where citizens can track the status of complaints registered within the municipality.

The service delivery dimension of urban infrastructure services like water supply etc has been analyzed on various parameters. In case of South Africa, Johannesburg metropolitan municipality has reached the level 2 with dynamic interactivity in all the parameters like tariffs, payments, new connection, and meter readings. In case of India, the situation in the select case municipalities is different.

7 Lessons Learned

It is clearly evident from the case municipalities that level of E-governance services initiated across various citizen centric services are at various levels of maturity depending upon the type of service. The common E-governance service like water supply, electricity, building plans is largely seen at advanced stage across the case municipalities. However, the integration of geospatial services is still at nascent stage across all the major basic services to the citizens. In terms of geospatial related services, only building plan related services are seen largely at advanced level with City of Johannesburg. The case analysis of web based geospatial services clearly provides a further scope of integrating citizen centric services through Web-GIS with access to common services like solid waste management, location based services, emergency services, social and other community asset information services. Besides access to citizen centric services, the municipalities can strengthen their decision making process by geospatial analysis across various services for better planning, governance and management.

The municipal context varies across regions and hence informs the adoption of integration of Geospatial and E-governance measures by the municipalities. The level difference of Geospatial and E-governance readiness level depicts the gaps of inter-operability within the dimensions of planning, governance and service delivery at municipal level. The maturity level gap also shows the future areas of improvements within the context of citizen centric, business and government interface. The gaps across the dimensions of planning, governance and service delivery across the municipalities can be bridged by integration of uniform E-governance measures and Geospatial adoption. The municipalities can replicate some of the measures depending on the E-governance maturity level reached, with an objective to enhance the multifunctional interface like: citizen centric, business and government interface.

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A geospatial Solution to the Land Registration Process in the Survey of Kenya

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KEYWORDS:
Land registration, SDI

ABSTRACT

The Survey of Kenya (SoK) is the national mapping agency for Kenya. It has eight divisions comprising the technical, cadastral, adjudication, geodetic, mapping, ydrographic, NSDI research and policy development and province divisions. The cadastral division is responsible for all transactions relating to survey records including land registration and quality control.

Cadastral survey has been practiced for over 100 years with data volumes growing daily driven by demand for land by the growing population. All cadastral survey work should be carried out by the government or by licensed private surveyors in accordance with the Survey Act (Cap 299). The SoK handles over 1,500 survey jobs per year from all over the country.

The current land registration process is very manual and complex, making it cumbersome to track job processing stages, which is further compounded by irregularities occurring during the process (e.g. loss of records). The current filing system is manual making it difficult to retrieve record and amend plans.

The proposed system combines all job processing stages and implements a feedback mechanism, thereby supporting tracking of survey jobs. Since it is computer-based, retrieval of information is very fast, and all information relating a particular job submission can be viewed. This solution streamlines the entire process from job submission to job approval and amendment of the Index map. In case of rejection, the surveyor is notified in time.

National Geographic Information Infrastructure (NGII) Initiatives in Nepal

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KEYWORDS:
Geo-information, Clearinghouse, stakeholder, Metadata, Standards, NGII, Partnerships

ABSTRACT

The use of Geographical Information Systems (GIS) has a short history in Nepal. GIS began as a simple map production tool at the beginning of the last decade. However, within the last few years its application has expanded to encompass a wide range of activities. Today many professionals are already speculating its impact on our society.

The NGII program was initiated since 2002, with an objective of developing a national GII in Nepal to strengthen the planning and resource management. The program was aimed to develop a platform to facilitate data sharing among all stakeholders. In addition it was also utilized to disseminate census results. It is conceptualized that in course of time this will accommodate entire data production and user communities in Nepal.

This paper examines the current status of NGII development in Nepal and discuss about its core components. The expected results from the implementations of NGII are identified as: its rationale for development towards the prosperous Nepal and create an environment for sustainable development. Similar to other kinds of digital efforts like building information modeling, digital cities approaches, the result can be vibrant, dynamic, inter-operative, interactive and serve as valuable platforms to support decision making from community to national levels. Furthermore, it would provide a list of action plans to address key issues of the initiatives taken to realize a full functional NGII in Nepal.

Developing a Spatial Data Infrastructure for the International water management Institute – strategies and tools

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KEYWORDS:
SDI, OGC, IWMI, Spatial data

ABSTRACT

The International water management Institute (IWMI) is one of the 15 international research institutes coming under the Consultative Group on International Agricultural Institute (CGIAR) and is focused on improving the land and water resources for food, livelihoods and the environment. IWMI works under four priority themes: Water availability and access, productive water use, water quality, health and environment, and water and society.

Being celebrating the 25th year of existence, IWMI has enormous experience in carrying out projects all over the world focusing on the third world countries. GIS and Remote sensing methods are used extensively to support IWMI's research. Over the last two decades IWMI has generated a vast amount of spatial data related to their projects and have an open data sharing policy once the respective project is over. IWMI uses web technologies to share their data and information. In the past, numerous websites were developed to share spatial data, though a centralized spatial data infrastructure was never materialized. The Water Data Portal is the latest initiative by IWMI, one stop access to all the spatial, non-spatial data, project information, reports, publications etc. The spatial data infrastructure (SDI) is a key block of this portal and will be serving geo spatial data to the public from a centralized, distributed data archive deployed over regional offices in Asia and Africa as well. THe IWMI-SDI is going to be an open geospatial consortium (OGC) compliant, service oriented architecture (SOA) where IWMI staff and public (based on the data policies) will have access to edit, download and update data using internet protocols.

This presentation will focus on the developments of water data portal like complexity of the data, spatial database preparation, SDI architecture, tools – open source vs. proprietary etc. It is also expected to gather feedbacks from the experts attending AGSE 2011 regarding the distributed architecture over regional offices, the selection of tools, OGC compliance, cascading issues with other servers, etc.

Remote Sensing

Automated Extraction of Morphologic and Hydrologic properties for River Njoro Catchment in Eastern Mau, Kenya

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KEYWORDS:
Digital Terrain Modeling, Catchment, Interpolation, Geormorphologic, Hydrologic

ABSTRACT

Automated extraction of geormorphologic and hydrologic properties from Digital Terrain Models (DTMs) was undertaken for River Njoro catchment, as a viable alternative to conventional engineering land surveying and manual evaluation of topographic maps. DTMs were used as an advanced method of availing information about terrain relief and once landscape models were generated, features were draped and information extrapolated for larger areas to be mapped. Automated catchment delineation was achieved using the Arc Hydro extension in ArcGIS. The outcome showed sub-catchments, flow accumulation, flow direction and drainage lines. The results closely matched the true ground features such as river valleys, drainage lines, slopes and hills hence the automated technique could be used for hydrological analysis of similar catchments and open the planning process of catchments to the full advantages of automated technology. This would make it possible for more responsive water resources management programs to be undertaken in the country.

1 Introduction

River Njoro catchment is undergoing rapid environmental degradation resulting from the effects of haphazard human settlements. To address the problem, automated extraction of geormorphologic and hydrologic properties from DTMs was undertaken as a viable alternative to conventional engineering land surveying using levelling equipment and manual evaluation of topographic maps. Hydrologic processes and water resource issues can be investigated by use of distributed watershed models (Olang et al, 2010). These models require physiographic information such as configuration of the channel network, location of drainage divides, channel length and slope, and sub-catchment geometric properties. The methods used in this study were based on integration of Remote Sensing, GIS and ancillary data. Hydrometeorological data was analyzed and integrated with land use within GIS to determine the impact of change on stream flows in the catchment. A mosaic of three sheets including Njoro (Sheet 118/4), Nakuru (Sheet 119/3) and Mau Narok (Sheet 132/2) was made. The catchment was traced on a clear acetate sheet, then digitized as a layer in GIS using ArcGIS software. DTMs were generated from contours which were digitized as polylines from topographic maps in one layer and tagged. Drainage was digitized, followed by morphologic facets of the landscape as polygons. With contours forming the source data for modeling, the TOPOGRID algorithm was selected to create DTMs upon which surface features were draped.

1.1 The Study Area

River Njoro catchment shown in Figure 1 lies between the Rongai-Njoro plains and the upper slopes of the Mau escarpment, at elevations ranging from 1759 m to 3420 m, mostly above 2000 m. It is located between Latitudes 0° 15’ S and 0° 25’ S and Longitudes 35° 50’ E and 36° 05’ E and measures 282 km2 in area. The average annual rainfall ranges from 840 mm to over 1200 mm. The topography is predominantly rolling land with slopes ranging from 2% in the plains to 54% in the hills. It is mainly covered by the Quaternary and the Tertiary volcanic deposits (Kinyanjui, 1979)

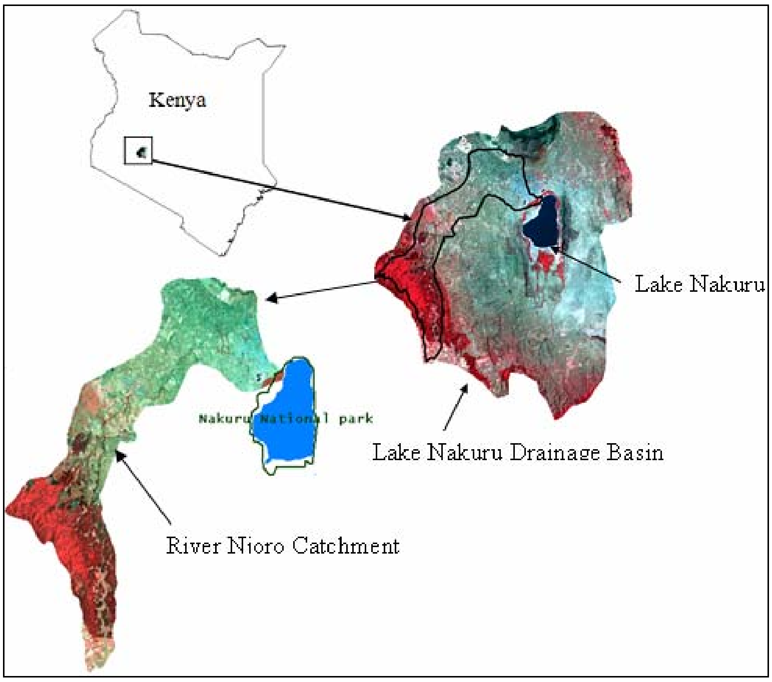

Figure 1: Study area.

2 Methods and Materials

2.1 Surface modeling

Surface modeling can be undertaken to translate discrete points into continuous surface that represent the geographic distribution of topographic data ( ). The study area was delineated from topographic maps of Njoro (sheet 118/4), Nakuru (sheet 119/3) and Mau Narok (sheet 132/2). Contours were digitized as polylines in one layer then assigned true elevation values. Drainage lines were digitized followed by the morphologic facets of the landscape which were digitized as polygons. The Fast Fourier Transform (FFT) that was used to create DTMs was of the form presented in equations (1) to (4).

$$\sigma_s{}^2 = 2\sum_{k=1}^{N/2}\{1 - H(v_k)\}^2 |F(v_k)|^2 \quad (1)$$

where, $|F(v_k|^2 = |F(k)|^2 = RF(k)^2 + LF(k)^2, v_k = kv_1 = \frac{k}{L}$ (2)

and $H(v_k) = 0$ for $v_k > \frac{1}{2\Delta x}$

was generalized as: $e(x,y) = f(x,y) - (f^{'}x, y)$ (3)

where,

$$f(x,y)=\sum_{k1=0}^{k1}\sum_{k2=0}^{k2}a_{k1k2}\sin(2\pi v_{k1}x+2\pi u_{k2}y+\varphi_{k1k2}) \tag{4}$$

with several intervals $\Delta x_1 = \Delta y_1$ by using bilinear interpolation.

Raster analysis using Arc-hydro extension in ArcGIS was performed to generate data on flow direction, flow accumulation, stream definition, stream segmentation, and catchment delineation. Areas with a value greater than one standard deviation from the mean value were included and were given a value of one, while those with a limited flow accumulation were given a value of zero.

2.2 Gauging stations

There were four gauging stations along river Njoro including 2FC11-Nessueit, 2FC05-Egerton, 2FC09-Ba ruti and 2FC10-Ronda. Their spatial locations and elevation were entered within GIS as layers. Each station was assigned a drainage area of influence after which ArcHydro tools were used for automated catchment delineation.

3 Results and discussion

The FFT generated the AgreeDEM showing the physical regions in River Njoro catchment as shown in Figure 2. Figure 3a shows the location of the gauging stations while Figure 3b shows the model sub-catchments or regions of hydrologic influence with the associated drainage lines. The results obtained were consistent with those reported by Donker, (1992) and Zhongbo, (1996) on automatic extraction of catchment hydrologic properties from DEM data. Based on this, the technique could be used for hydrological analysis of similar catchments and thereby open the planning process to the full advantages of GIS technology in Kenya.

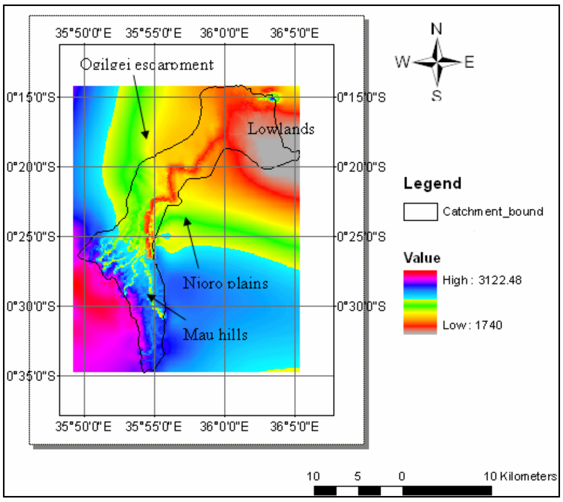

Figure 2: AgreeDEM showing the Physical Regions in River Njoro catchment

The sub-catchments would make it possible for more responsive water resources management programs encompassing assessment, planning, development, allocation, conservation, protection and monitoring to be taken at local scales.

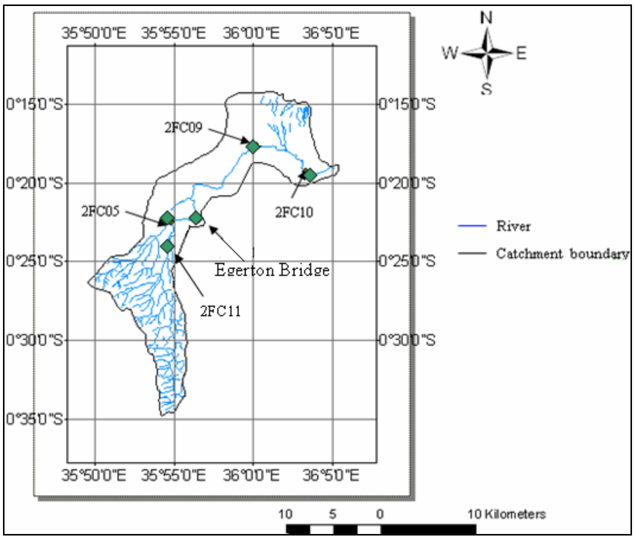

Figure 3a: River Njoro and the location of the Gauging Stations

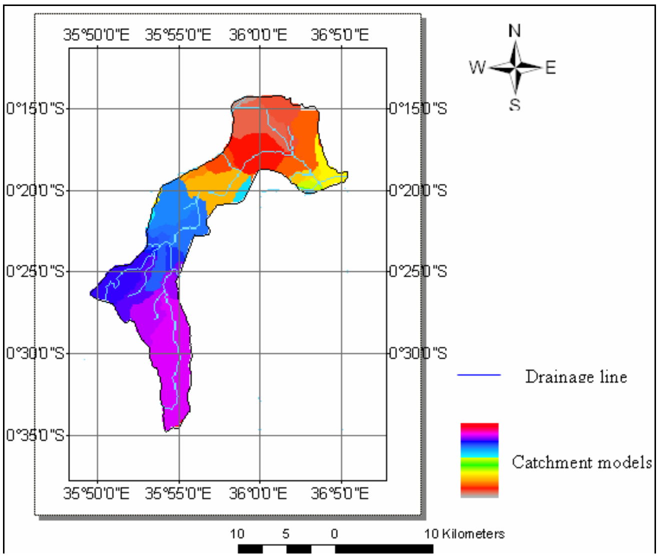

Figure 3b: The Sub-catchment and drainage line models

The Flow direction shown in Figure 4 was similar to the slope direction. This was in conformity with the fact that water takes the shortest path to find its own level. The map represented the direction that water would follow out of each cell towards drainage lines. The cell encoding showed Northward flow into the river valley in correspondence to the orientation of the valley gradient.

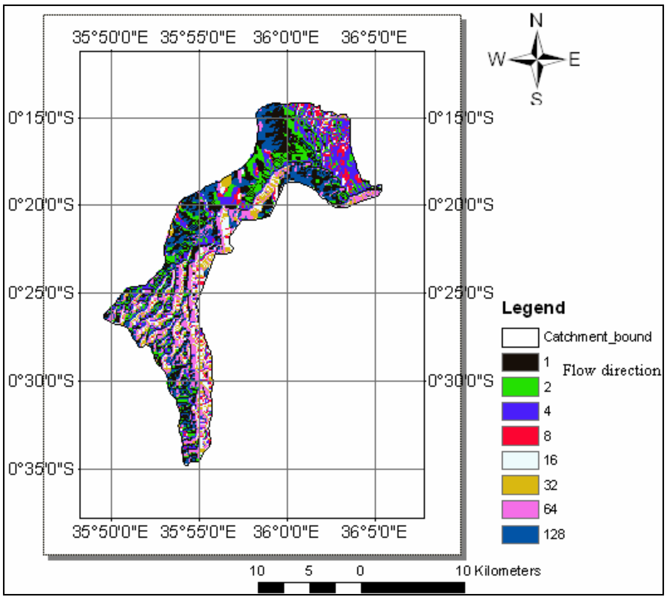

Figure 4: Flow direction

The drainage lines and model pour points in the catchment were shown in Figure 5. The pour points represented the locations where water would most likely be found throughout the year even during droughts. Such points would be the best sites for developing community water supply projects. They would serve as reliable sources of water to ensure availability throughout the year.

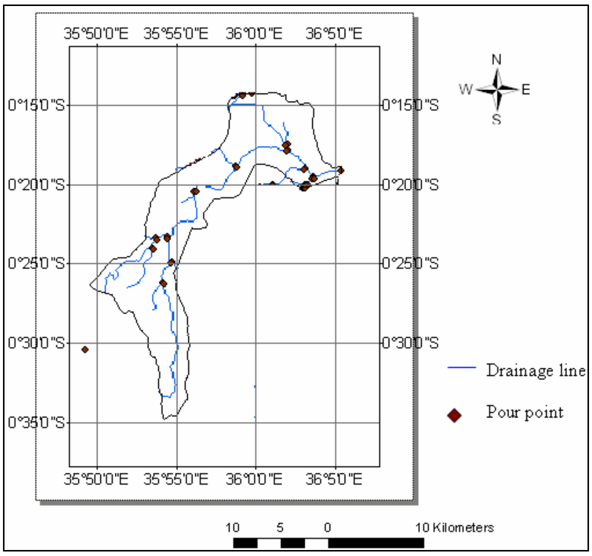

Figure 5: Drainage line and pour point models

4 Conclusions

The automated extraction of morphologic properties provided landform information showing hills, slopes and valleys, all of which are important components in development planning for catchments. It was deduced from the AgreeDEM that the catchment was characterized by the river valley and three distinct physical regions; the low lands, the uplands and the hills. The low lands covered Lake Nakuru and the surrounding area between the Ogilgei escarpment and the Menengai hills. Uplands covered the Njoro plains between the escarpment and Mau hills. The modeled drainage lines and the digitized lines for River Njoro fused well when overlain together. The highest altitude in the catchment was 3122.48 a.m.s.l while the lowest was 1740 a.m.s.l. It was concluded that the results closely matched the true ground features as outlined. This technique could therefore be adopted to improve land use planning, water management, communication and telecommunication and all projects which take slopes and elevations in consideration for their functional, structural and aesthetic requirements.

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Assessment and Mapping of Soil Degradation using Remote Sensing and GIS Techniques: Case Study Elthamid Group, Gezira and Managil Scheme, Sudan

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KEYWORDS:
Soil degradation, Spatial variability, Salinity, Sodicity, GIS, Gezira Scheme, Sudan

ABSTRACT

This study focused on the assessment of soil degradation in El Tahameid Sector, Gezira State, Sudan. This goal was achieved by assessing and mapping spatial variability of some soil properties. due to drought and mismanagement. The study covered the area about 706.8 km². The research was based on the data and information deduced and extracted from soil survey data, soil analysis, and remote sensed data. The soil analysis indicated that soil degradation had have taken place in the study area specially at top northern and southern parts of the area which were affected by salinity; while north-eastern and south- western parts were affected by sodicity. This finding was supported by digital soil maps of chemical soil properties which can be considered as database for the study area. The study proved that soil analysis, remote sensing technique, Geographic Information System (GIS), Global Poisoning System (GPS) and field work represent cost and time-effective techniques for assessment and mapping of soil degradation.

1 Introduction

Degree and extent of soil degradation is necessary for the decision maker so that to figure out their proper and necessary soil conservation programmes. According to Eswaran and Kapur (1998) type of degradation affect time interval for monitoring; they also stated that salinization monitoring, should be probably, done every year. Little is known about the land degradation in the Gezira scheme although some scattered studies mainly on White Ninle and Khartoum states were carried out on the fertility status of the soil to the west and north of the scheme respectively (Kapur, 1998).

Land degradation can be defined in many ways. In brief, it is any change in the land that reduces its condition or quality and hence its productivity potentials. It occurs whenever the natural balances in the landscape are changed by climate and human activity, through misuse or overuse (Williams, 1991). Land degradation reduces resources' potential by one or a combination of processes that acting on the land. These processes include salt-accumulation, water erosion, wind erosion and sedimentation (UNEP, 1992). Land degradation is considered to be a major global environmental problem during the 20th century and will remain high in the international agenda in the 21st century. The importance of land degradation is enhanced because of its impact on world food security and quality of the environment. Reich et. al. (1999) stated that desertification is a form of land degradation occurring particularly, but not exclusively, in semi-arid areas. He indicated that semi-arid to dry sub humid areas of Africa are particularly vulnerable, as they have fragile soils, localized high population densities, and generally low-input agriculture.

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2 Study area

The study area is located in central Sudan within Managil Agricultural Scheme which was established in 1966. Immediately after Sudan independence and annexed to Gezira Scheme which was established in 1911. El-Thamied Group is the largest section in Managil scheme at the far boundary of the scheme (Fig 1). This Section is situated between longitudes 32º28″ and 32º48″ East and latitudes 14º24″ and 14º35″ North and covers an area of about 706.8 km² (Fig. 2).

Population are mainly farmers. The soil of the study area is dark clay soil (Vertisols), and some parts are saline while others are alkaline. Salinity had led to the abandoning of many western blocks of the Managil scheme since 1962 (Al-amin1999).

In El-Thamied group, the land degradation and encroaching sand is whipping out a life that is centuries old. "Sand movement has exhausted us″. Like this farmer, thousands of villagers along the Gezira and Managil scheme have narrow strips of arable land that borders the scheme watch the sand moving closer every day. They are watching the land that degraded or eroded, so most of farmers are leaving their homeland searching for new opportunities. There are two major production systems namely: irrigated agriculture (Governmental sector, and traditional rainfed agriculture). The principal crops grown in the irrigated areas are cotton, wheat, sorghum, groundnuts and Sunflowers.

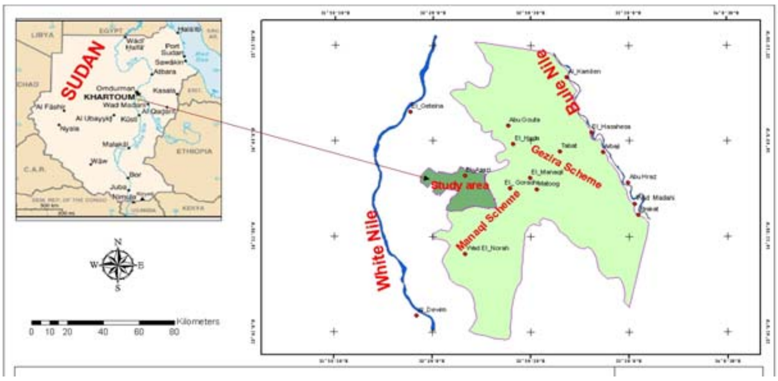


Figure 1. Location of the study area

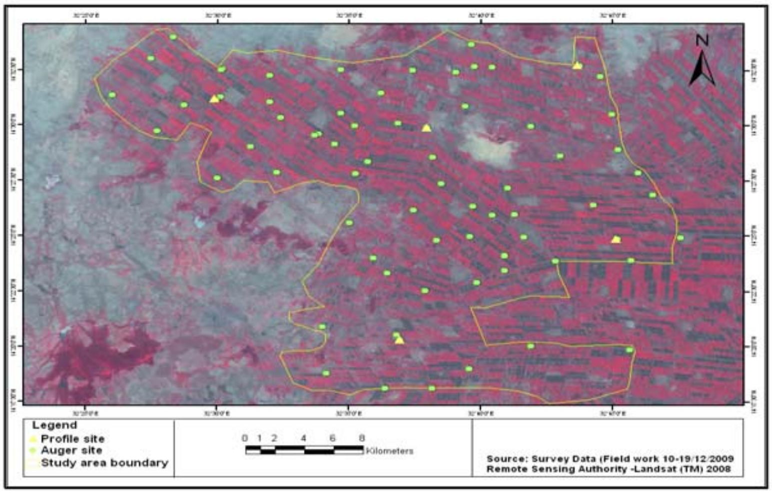


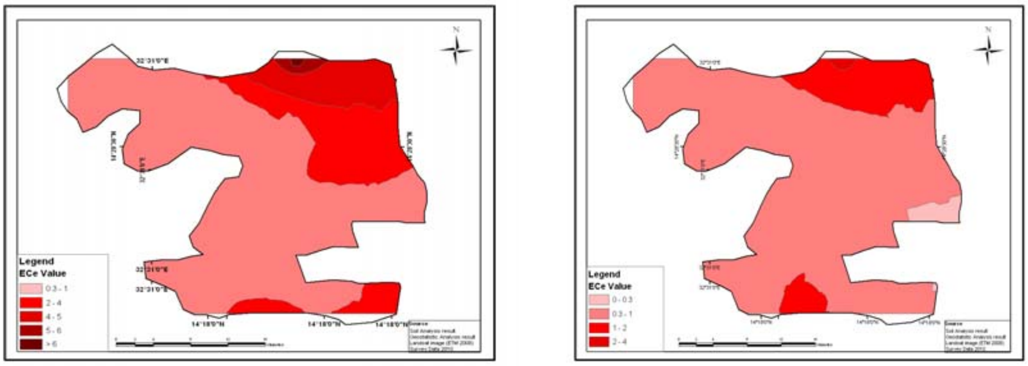
Figure 2. Study area: Location of check sites in the field

3 Methodology

False colour composite (FCC) subset from Landsat ETM covered the study area (706.8 km²) was used. The field work was conducted during the period 10-25th December 2009 aided by GPS receivers Garmin 60C. Radiometric and geometric correction corrections were conducted. Soil samples were collected from different locations selected to cover the variability that observed from satellite image analysis. Global Positioning System (GPS) was used to locate the position of the check sites. Different soil samples strategies were applied depending on satellite image interpretation, and morphological and physical properties differences (colour, texture, structure…etc). Soil samples were collected from two different depths (0-30 and 30-60cm) with a total number of 132, the distance between adjacent soil samples (in all directions) is 3 km (Fig 2). The soil samples were analyzed according to standard soil methods adopted by U.S. Salinity Laboratory (1954). The flowing properties were determined in soil samples: Soil Reaction in soil paste (pH), The Electrical Conductivity (ECe) of the extract; soluble calcium (Ca^{++}) and magnesium cation (Mg^{++}) cations; sodium cation (Na^{+}); Sodium Absorption Ratio (SAR); calcium carbonate and percent of organic matter.

4 Results and discussion

Spatial variability of ECe at top-surface indicated that higher values were found at the top north and south of the study area, while most of the area was non-saline (0.3 to 1.0) (Figure 3a). Figure (3b) showed the spatial variability of ECe at sub-suface which follow similar pattern to ECe at top-surface one. Weighted ECe spatial variation as expected follows the same pattern as that of surface and subsurface ones (Figure 4). These findings agreed with UNDP (1970).



(a) (b)

Figure 3. ECe Values for the Surface (a) and Sub Surface Layer (b)

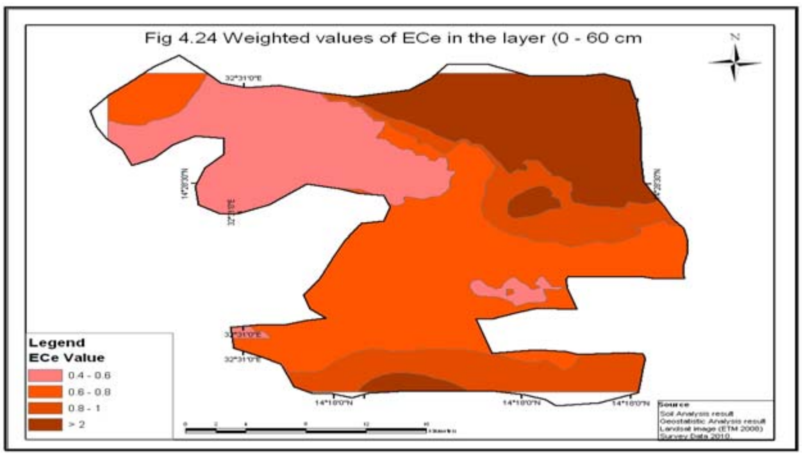
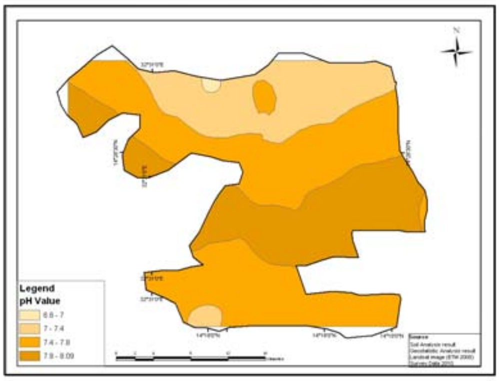
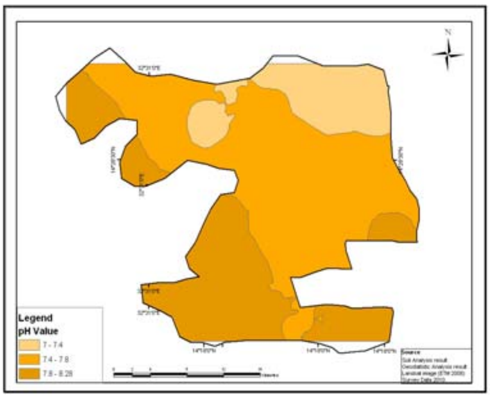


Figure 4. Weighted Values of ECe in the Layer (0-60 cm)

The analysis of the soil samples revealed that the soil reaction is moderate to slightly alkaline, which is not unexpected for soils of arid and semiarid region. Spatial pH variability for the top and sub surface is shown in figure (5a&b). Figure 5a reflects that high pH values at surface layer were found at the central and south west of the study area, while most of the area was ranged within the 7.4 to 7.8 pH values. Figure (5b) showed that the high pH values are concentrated at the south and south west of the study area.

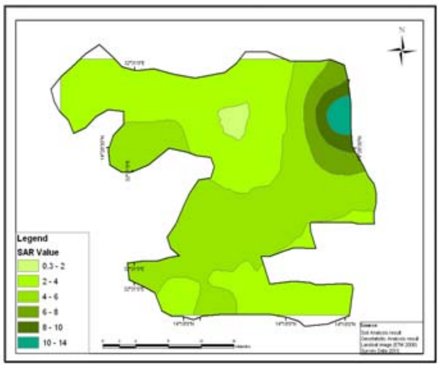


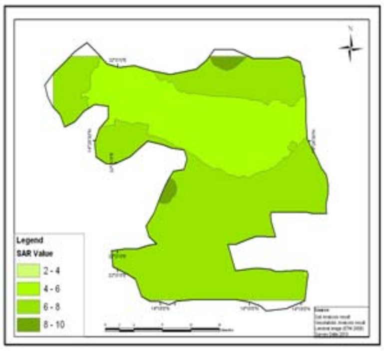


(a) (b)

Figure 5. pH Values for the Surface (a) and Sub Surface Layer (b)

The spatial variability of SAR for the top, sub surface and for the weighted values is shown in figures (6a&b) and (7) respectively. Figure 6a showed that high SAR value (10 to 14) were concentrated in the top north east of the study area, while SAR values in most of the area were within the normal non-sodic range (less than 10). Figure 6a showed that most of the area is non-sodic (less than 8). In addition weighted SAR values confirm the above mentioned and most of the SAR values fell within the normal range.





(a) (b)

Figure 6. SAR values for the Surface (a) and Sub Surface layer (b)

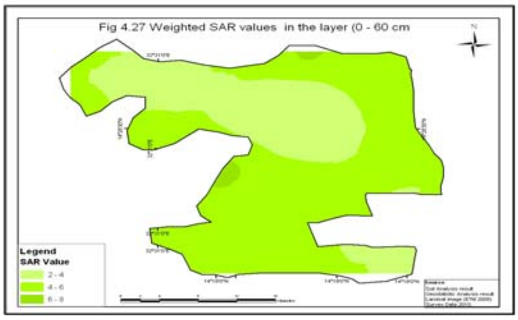


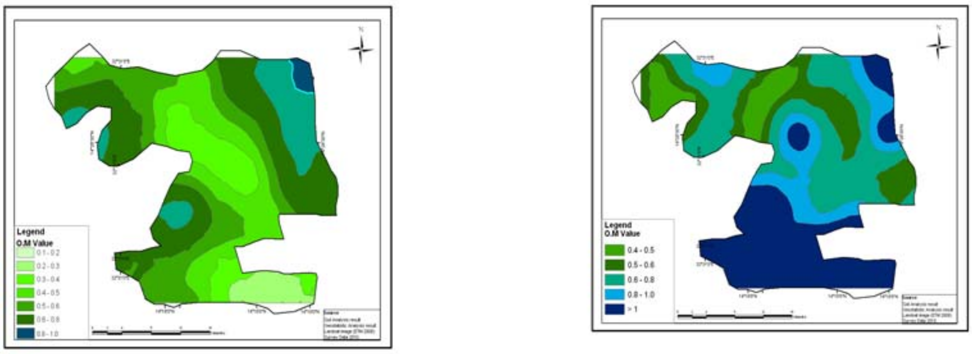
Figure 7. Weighted SAR Values in the Layer (0-60 cm)

The spatial variability of CaCO3 for the top and sub surface were shown in figures 8a and 8b; respectively. Figure (8a) showed that high CaCO3 values (7 to 10%) were found at the top northern part of the study area, while most of the study area was less than 7%. Figure (8b) showed that the CaCO3 at sub-surface followed the above mentioned pattern. Most of the study area was non-calcareous soil except small parts in the top medial and south west which were under arid climate according to UNDP (1970).

(a) (b)

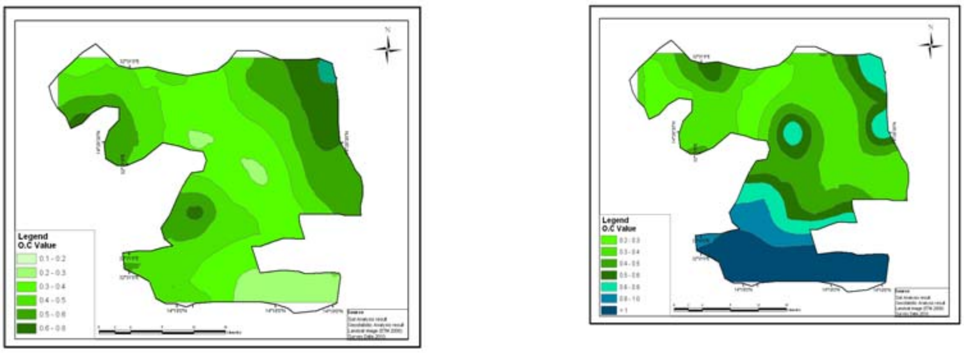
Figure 8. Percentage of $CaCO_3$ for the Surface (a) and Sub Surface layer (b)

Soil organic matter and organic carbon spatial maps for the top and sub surface are shown in Figures (9a&b) and (10a&b) respectively. Both Figures showed that the study area fell within the low O.C and O.M. At Figure 9a and 10a, higher O.M and O.C values (0.8 to 1.0) in the top northern east of the study area, while in most of the area O.C was less than 0.6%. Figure 9b and 10b showed that high concentration of O.M and O.C values (> 1) in the northern east, middle and southern part of the study area, while in most of the area O.M content was less than 1%. Organic carbon and organic mater were low in the study area; this could be due to low addition of O.M in the soil in arid climate and fast oxidation of O.M.



(a) (b)

Figure 9. Percentage of O.M for the surface (a) and sub surface layer (b)



(a) (b)

Figure 10. Percentage of O.C for the Surface (a) and Sub Surface layer (b)

5 Conclusion and recommendation

The study revealed that scatter pockets of salinity and sodicity were present in the study area. This had negative impact on the soil productivity. Based on these finding the following recommendation can be stated:

1. New polices and practices of agricultural extension should be adapted to alert farmers to the threat posted by land degradation.

2. Periodic monitoring of severity and extent of soil degradation is needed.

3. Soil analysis, geostatistics technique and field work are effective method to assess soil degradation.

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Environmental Issues and Sustainable Development

We resolve … to stop the unsustainable exploitation of water resources
by developing water management strategies
at the regional, national and local levels,
which promote both equitable access and adequate supplies.

United Nations Millennium Declaration, 2000

Land-Use Dynamics as Drivers of Degenerating Community-Based Forest Management Systems in the Kenyan Coast

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KEYWORDS:
Agricultural expansion; forest management systems; Landsat; ASTER; image classification; settlement areas; population expansion

ABSTRACT

An intense human population growth coupled with agricultural expansion is causing serious concerns to forest conservation globally. Kenya's human population has been growing at an alarming rate causing severe forest encroachment and fragmentation. Different forest management systems respond differently to human-induced pressures. Kenya's coastal forests are managed under either a traditional community-based or Kaya (religious shrines) systems, or; under statutory or government based system. Until the 1990s, the Kaya system was an effective management system that allowed communities to extract forest products and services in non-consumptive ways. We used Landsat and ASTER satellite imagery (1986, 2003 and 2008) to assess the effectiveness of government-managed against community managed systems in maintaining forest cover along the coast of Kwale District in Kenya; and assess the implications of land-use dynamics to forest conservation in the surrounding matrix. Six community-managed and 6 government-managed forests were assessed between 1986 and 2008. Land-use and land-cover dynamics in the surrounding areas were also analysed using supervised classification. We found that while government-managed forests retained or increased forest cover, community-managed forests lost cover during the study period; with one community forest losing over 50% of its original cover. In the surrounding matrix, farmlands were rapidly replaced by settlement areas and expanding towns especially in community forest areas; further exacerbating forest cover loss as people clear forests to create more area for farming. Therefore, the drivers of loss of community-managed forests are identified as agricultural expansion and urbanization. We propose the entrenchment of community forest management systems into legal systems in Kenya to ensure stricter measures that will better protect community forests.

1 Background

Conversion of natural habitats to meet demands of a growing human population has had massive effects on terrestrial and aquatic ecosystems. In particular, agricultural expansion and intensification has been one of the most significant forms of land-cover modifications, resulting in dramatic increases in yields during the previous 30 years (Tilman, 1999; Socolow, 1999). If current trends continue major and detrimental impacts on non-agricultural terrestrial and aquatic ecosystems can be expected. Agricultural intensification levels can also be an indicator of the ability of land-use systems to adapt to changing circumstances, such as increasing human population and policy changes. Global concerns over land-use and land-cover changes are based on the impacts these changes have on landscape attributes such as water quality, land and air resources, ecosystem processes and function, and the climate system (Lambin *et al*, 2000). Land-use change research would benefit from a better understanding of the complex relationships between people and how they manage land (Lambin, 1997 in Lambin, *et al*., 2000). Land-cover and land-use affect the environment in a variety of ways, including effects to local and regional climate conditions and degradation of urban environment (Arnfield, 2003). With increased availability of quality multi-resolution and multi-temporal remote sensing data and new analytical techniques it is possible to monitor change in ecosystems in a timely and cost-effective manner (Sohl, 1999). The most commonly used methods are spectrally-based (image-to-image) and classification-based (map-to-map) change detection (Johnston and Watters, 1996). Accurate and current information on the status and trends of ecosystems is needed to develop strategies for sustainable development and to improve the people's livelihoods.

Indigenous and Community Conserved Areas (ICCAs) have emerged as a major new phenomenon in formal conservation circles, though their existence is as old as human civilization itself (Borrini-Feyerabend and Kothari, 2008). International policies and programmes, notably those under the Convention on Biological Diversity, seek great recognition and support for ICCAs. Kaya forests owe their existence to the beliefs and culture of the nine coastal Mijikenda ethnic groups namely the Giriama, Digo, Duruma, Rabai, Kauma, Ribe, Jibana, Kambe and Chonyi. Historically, the forests sheltered small fortified villages of the Mijikenda groups when they first appeared in the region (Kibet and Nyamweru, 2008). The Mijikenda community use Kaya forests as sacred sites of worship and sacrificial offerings and such sacred groves are common in African societies (Ramakrishnan, *et al*. 1998). 5 The Mijikenda people are Bantu speakers who occupy the Kenya coast and its hinterland in the four administrative districts of Malindi, Kilifi, Mombasa and Kwale (Kibet and Nyamweru, 2008). The strength of spiritual beliefs and social rules and norms of the Mijikenda have over the years helped protect the coastal forests and taboos applied to regulate access and conduct at the Kaya sites. Over generations, the effectiveness of this system to proctect the kayas has eroded leading to general degradation of the Kaya forests along the coast.

Along the Kenyan coast, commercial agriculture is blamed for the increasing clearance and fragmentation of forests. Other lesser but key threats include: over-exploitation of forest for timber and poles; hunting; mining; charcoal burning; development of settlements; and urbanization e.g. in the Madunguni and Kaya Kinondo forests (CEPF, 2003).

2 Study area and methods

2.1 Study area

Kwale District (3˚30´-4˚45´S and 38˚31´-39˚31´E) lies in the south-eastern corner of Kenya (Figure 1). Topographically, the District is characterized by its coastal plain (a 3-20km wide belt below 30ma.s.l), the foot plateaus between 60-135masl, the coastal uplands including Shimba Hills, Tsimba and Dzombo that rise steeply from the foot plateau to 150-462 ma.s.l and the Nyika Plateau or the hinterland that rises gradually from about 180m to 300ma.s.l on the western boundary of the district.

Kwale's coastal strip forms part of Northern Zanzibar-Inhambane Coastal Forest Mosaic which in Kenya is mostly confined to a narrow coastal strip except along the Tana River where it extends inland to include the forests of the lower Tana River (the northern-most of which occur within the Tana Primate National Reserve) (Burgess and Clarke, 2000). The coastal strip consists of post-Jurrassic rocks, which are predominantly marine/estuarine sedimentary rocks (sandstone, limestone, marls, shales and mudstones). The area has a medium to high agricultural potential.

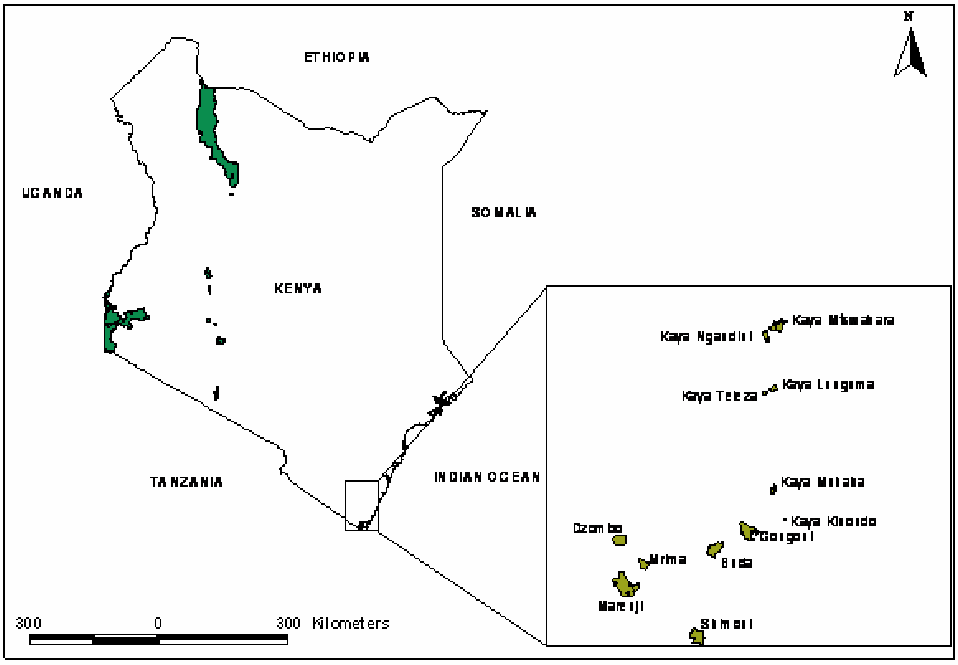

Figure 1: Map of the study area showing forests used in the analysis

2.2 Methods

We acquired Landsat images (1986 and 2003) from the University of Maryland's Global landcover facility (www.landcover.org); and Aster Imagery (2008) from African Regional Centre for Mapping for Development. Landsat bands 3, 4 and 5 (corresponding to blue, red and green respectively) were composited for each of the image sets to enhance forests, urban areas/ settlement and bare soil/ farmland. The Aster bands used were 1-1, 1-2 and 1-3 corresponding to blue, red and green. Supervised classification was used to isolate all major land use categories in all the image sets by developing signatures for each and using the maximum likelihood criteria to isolate them. Prior to image classification, visual interpretation was done, which revealed at least 7 major land use categories along the coastal strip of Kwale, namely forests, farmlands, urban areas/settlement, shallow water, ocean, beaches/reef and mangroves. The area of each of the land-use classes in the AOI was calculated in hactares. A combination of topographical maps, ground verification and high resolution imagery available at Google Earth (www.google.com) revealed that the most important land use types were farmlands, forests, mangroves, settlement and built-up areas, beach, shallow water and the ocean.

To facilitate accurate measurements of forest area, vector layers were created and polygons drawn around pre-selected forests sites, 6 community-managed and 6 government-managed (Table 1). Three of these vector layers were created over the 1986, 2003 and 2008 image sets, resulting in 3 layers (one for each of the time periods). The layers were then converted to raster format with the same projection as that of the original image. Idrisi's 'area' tool was then used to determine the area of each polygon in hectares. One way analysis of variance (ANOVA) and t test were used to analyse forest area measurements across image sets and management systems.

Table 1: the 12 forests used in the analysis

Government forests *(Custodian: Government Agenceis)*	**Community forests** *(Custodian: community leaders)*
Shimoni	Kaya Kinondo*
Marenji	Kaya Mtsakwara
Mrima Hill	Kaya Ngandini
Dzombo Hill	Kaya Teleza
Buda	Kaya Lunguma
Gongoni	Kaya Muhaka

3 Results and discussion

3.1 Landuse interactions

Seven main land use categories were separated using supervised classification. Settlement and urban areas increased five-fold between 2003 and 2008 while all other land use type either increased or reduced marginally or remained the same (Figure 2 and 3). There was an increase in farmlands between 1986 and 2003 coupled with a slight decrease in both forest cover and urban areas and settlements. Farmlands increased between 1986 and 2003, but reduced between 2003 and 2008.

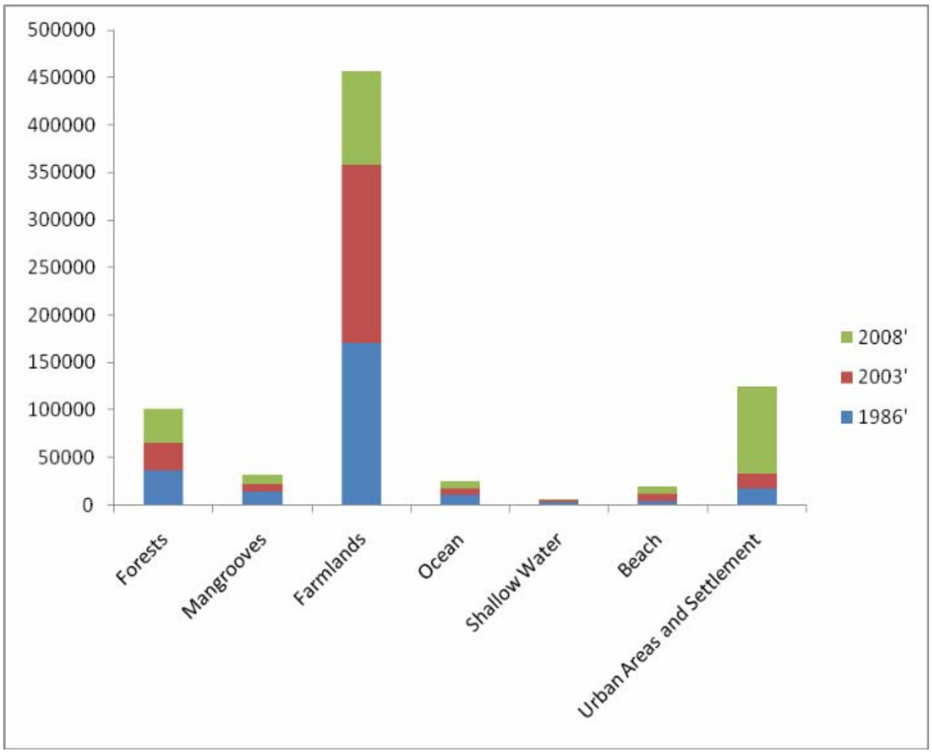

Figure 2: Major land use types in the coast of Kwale District between 1986 and 2008

The rapid replacement of farmland by urban areas and settlement has been attributed to an increasing human population. For example, in the Kwale County, the human population increased from 496,133 in 1999 to 607,752 in 2010 (KNBS, 2011). As human population increases, more areas are developed, gradually replacing farmlands. This is because farm areas are available to be converted to settlement and urban areas compared to other forms of land use, such as protected forests, mangroove areas and beach. As more areas are converted to settlements, fewer areas are available for cultivation, which will compromise the area's food security. Previous attempts to rank forest pressures in East Africa's coastal forests (e.g. WWF-EARPO 2002; GEF, 2002) identified the main forest pressures as agriculture, settlement and urbanization, lack of legal protection and human-wildlife conflicts as the most serious threats to East Africa's coastal forests. The root causes of these threats were identified as population growth, poverty, inefficient land use practices, limited effectiveness of forest management regimes among others.

Farmlands become increasingly unavailable due to settlements development, leading to channeling of human population pressure to the next available option (forests and mangrove areas). Tourism development can improve the socioeconomic situation of the area, especially ecotourism, since image analysis reveals an overall increase of forest areas between 1986 and 2003. Forested areas can be developed to encourage the use of non consumptive forest products, such as ecotourism. This will encourage the sustainable use of forest resources.

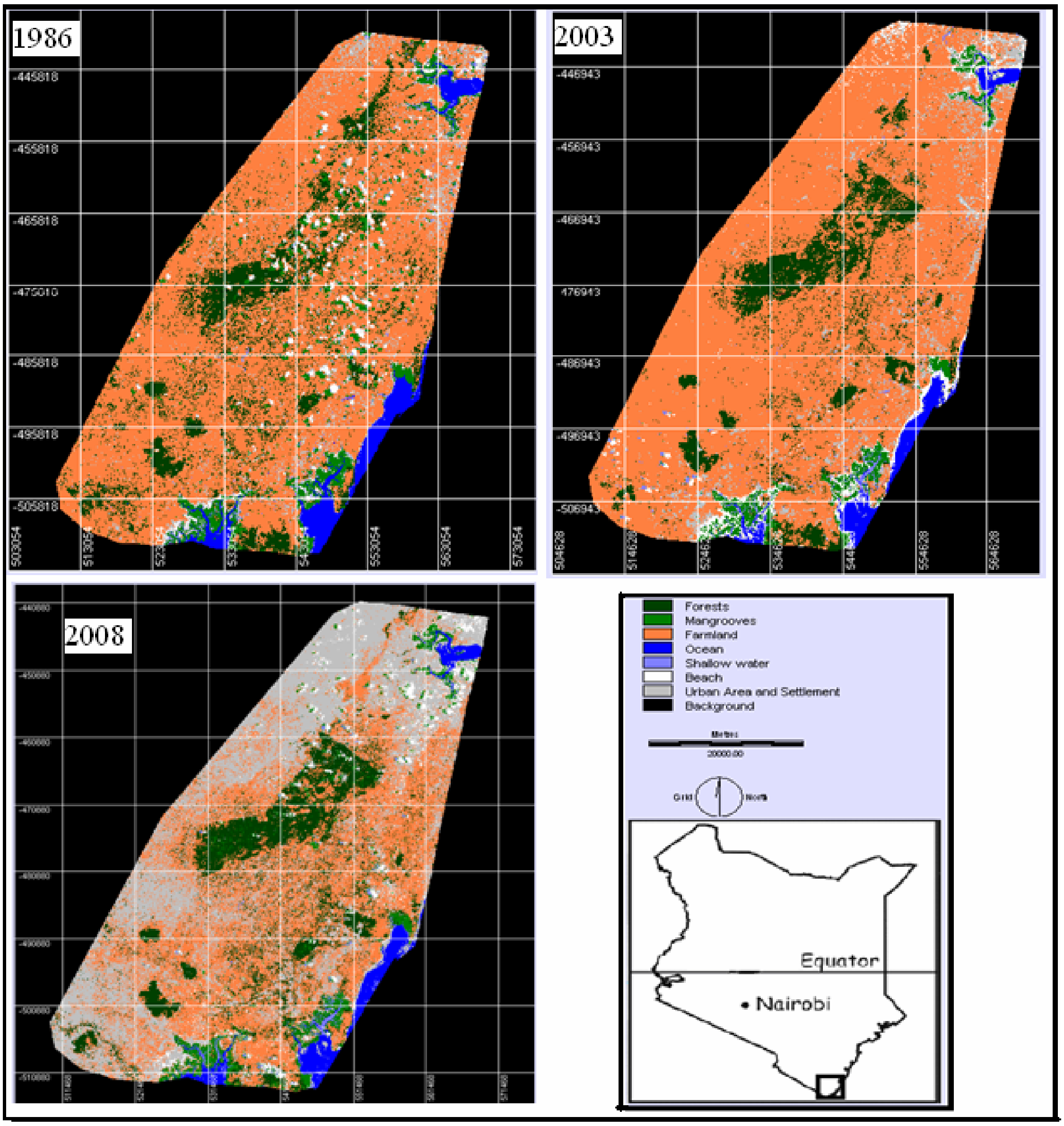

Figure 3: Land-use classification composites from Idrisi showing changing land-uses in three time period (1986, 2003 and 2008). Note the rapid replacement of farmlands (orange) into settlement areas (grey) between 1986 and 2008).

3.2 Effectiveness of Forest Management Systems

Government managed forests recorded overall gains in forest cover of 135.2ha between 1986 and 2003 and by 622.9ha between 2003 and 2008. In contrast, forest cover in community-managed forests declined 142.9ha and 9.6ha for the same periods, respectively.

These losses and gains were significant across the temporal periods ($F_{2, 33}$ =0.45; p= 0.05).

Table 2: Forest area gains and losses (in hectares) amongst the 12 forests used in the analysis

Forests	1986-2003	2003-2008
Shimoni	75.62047	-127.117
Marenji	-20.225	43.5366
Mrima Hill	50.0346	3.41145
Dzombo Hill	-11.4527	49.22235
Buda	-12.6711	294.0345
Gongoni	53.9334	359.8268
Kaya Kinondo	-6.1731	0.081225
Kaya Mtswakara	-96.1704	64.6551
Kaya Ngandini	-22.9055	-12.4274
Kaya Teleza	-4.38615	1.6245
Kaya Lunguma	-28.1039	-56.2077
Kaya Muhaka	15.5952	-7.31025

Between 1986 and 2003, three of the six government managed forests sampled increased or retained forest cover; Shimoni 75.6ha, Mrima Hill 50.0ha, and Gongoni 53.9ha (Figure 4, Table 2). The rest lost cover between the same period (Marenji 20.2ha, Dzombo Hill 11.4ha and Buda Forest 12.6ha). However, between 2003 and 2008, only one of the forests in the government category lost cover (Shimoni forest; 127.1ha).

The differences between gains and losses in forest cover were used to compare mean forest losses (and gains) across management regimes and temporal periods. Forest gains and losses were significant between temporal periods (1986-2003; 2003-2008); as well as between management regimes (government vs. community), where community forests (t_{22} =-1.22, p=0.05; t_{22} =1.87, p=0.05).

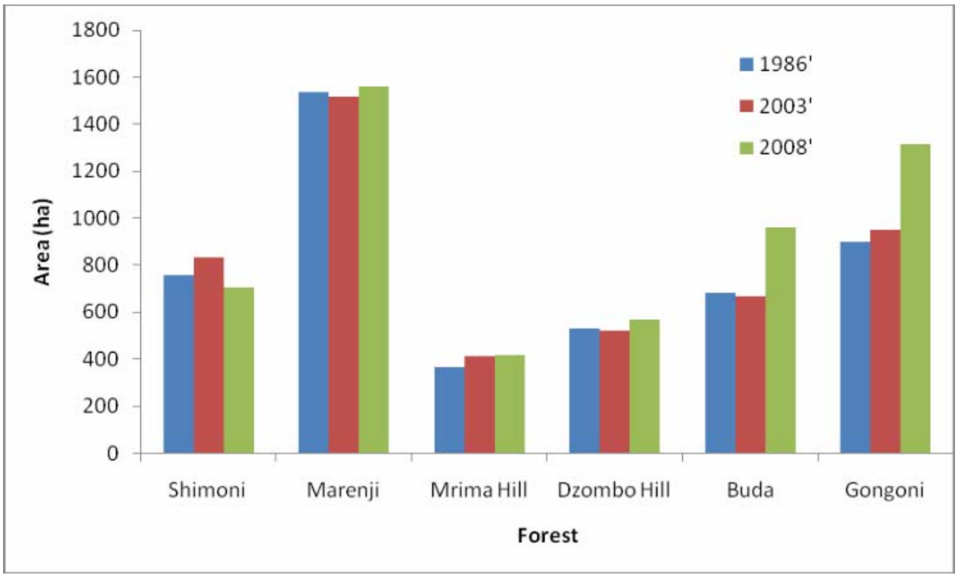

Figure 4: Forest areas in government category in three temporal periods showing an overall increase in forest cover between 1986 and 2008

Community managed forests lost between 4.3ha (Kaya Teleza) and 96.2ha (Kaya Mtswakara) between 1986 and 2003 (Figure 5, Table 2). Gains were recorded at Kaya Muhaka only (15.6ha). Between 2003 and 2008, half of the community managed forests lost cover while the rest gained or retained cover (Figure 5).

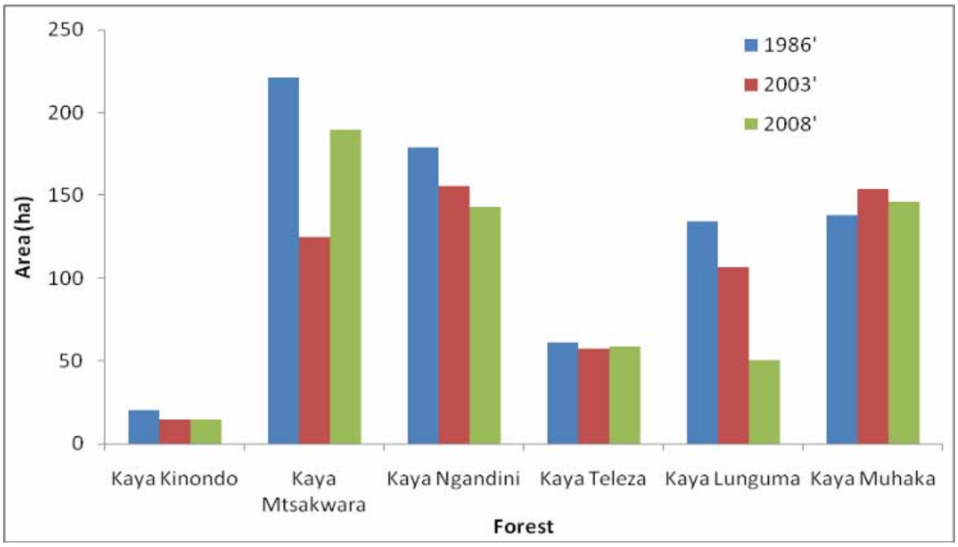

Figure 5: Forest areas in community category in three temporal periods showing a general loss in forest cover between 1986 and 2008

Our results show that government-managed forests are more effective in maintaining forest cover. Similar results were shown by Ngari (2007), who used Management Effectiveness Scores to assess the effectiveness of management options in eastern Arc and coastal forests of Kenya. The study revealed that state owned forests had higher Management effectiveness scores (48%) compared to community-managed forests (27%). Community-based forest management strategies should be entrenched into the law so that they are recognized as a legal entity. The inscription of Kaya forests into the list of Natural World Heritage Sites (UNESCO, 2008) is a major step towards recognition of traditional forest management strategies as valid forest management systems.

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Mapping Distribution and Habitat Suitability –An Example of the European Tree Frog (Hyla arborea L.) in Baden Württemberg

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KEYWORDS:
Hyla arborea L., Species distribution modelling, DOMAIN, Habitat suitability, Conservation

ABSTRACT

Geographic Information Systems can be effectively used in the field of biodiversity research it manages large data sets for analysing and visualising the spatial distribution of species. The analysis of species–environment relationship has always been a core issue in species distribution studies. Species distributions modelling or habitat suitability mapping has lot of applications in ecology, evolutionary biology, and conservation science. An attempt had been made to model the potential distribution of Hylaarborea L. (European tree frog) which is found to be endangered in Germany and few other countries in the Western Europe. The core objective of the study involves mapping of current geographic distribution and the prediction of its potential distribution to produce a habitat suitability map. This attempt focused on species environment relationship analysis by collating environmental data, mainly climatic variables, with the species' geographic distribution with in the state of Baden Württemberg, Germany. A species environmental model called DOMAIN was adopted to predict the habitat suitability. Generally data availability on the terrestrial habitat of amphibians is unfortunately poor and the surveying methods are not cost effective. Species distributionmodelling using presence data is very helpful in identification of areas having higher biodiversity and it has momentous application in ecosystem conservation and management. Archival species data from herbaria, museums etc. could be used for this modelling and it will be eventually helped in biodiversity monitoring surveys and conservation activities

1 Introduction

Amphibians are among the most vulnerable animals of the world as nearly one-third of known amphibian species are currently threatened by extinction (Stuart et al., 2004).Studies showed that, nearly a quarter of amphibians are considered as threatened in Europe,of which 2.4% are Critically Endangered, 7.2% Endangered and 13.3% are Vulnerable(Temple and Cox, 2009), This study had focused on European tree frog Hylaarborea L. which is mainly found in Western Europe and it is one among the smallest anuranfound (Grosse &Nöllert 1993). This species is placed in least concern category of IUCN Red list,however the population trend is found to be declining (IUCN 2010) and its regional long term persistence is not guaranteed.Geographic Information System has lots of application in the field of ecological research as it helpful in visualising the spatial distribution of species and managing large data sets.The analysis of species–environment relationship has always been a core issue in species distribution studies. Hutchison (1957) introduced the concept of fundamental niche as an 'n dimensional hyper volume'. It explains the niche as a set of environmental variables within which an organism can persist and survive Species distributionmodelling (Habitat suitability mapping/Ecological Niche Modelling) is a GIS based application being increasingly adopted to assess the potential geographic distribution of the species based on species presence data and climatological data (Guisen and Thuiller 2005,Chen and Bi, 2007).Forthis study DOMAIN modelling algorithm had been adopted to predict the potential distribution of Hylaarborea L. Many previous studies have shown that the performance of DOMAIN is more reliable and outstanding in species distributionmodelling with presence records (Yun, 2006; Ward, 2007, Carpenter et al., 2003)..Data availability on the terrestrial habitat of amphibians is unfortunately poor and the surveying methods are not cost effective Understanding of the terrestrial autecology and the distribution of most amphibian species, including the European tree frog remains lacunar (Stumpel, 1993). The core objective of this study includes, mapping the distribution of Hylaarborea L. in Baden -Württemberg using species presence record, enabling spatial analysis and finally to model the habitat suitability of Hylaarborea L. using species - environment data

2 Methodology

Baden-Württemberg (Baden Wuerttemberg) is the third largest German federal state with an area of 35751 km2(www.baden-wuerttemberg.de)bounded between the coordinates of 7027′ 29″ E, 4705′N, and 10034′ 59″ E, 490.49′59″N. Among the 23 amphibian species reported in Germany about 13 amphibian species were reported in this stateThe most common strategy for estimating the actual or potential geographic distribution of a species is to characterize the environmental conditions that are suitable for the species, (correlative approach) and to then identify where suitable environments are distributed in space. That means, it's linking the geographical space with the environmental space (Pearson, 2007).Species presence records for Hylaarborea L. was obtained from the amphibian database provided by State Research Centre for Environment, Measurements and Nature conservation, Baden-Württemberg (LUBW) and the shape file of the Baden-Württemberg were downloaded from DIVA Website (www.diva-gis.org). Global Bioclimatic map for current climate at 2.5Arc minutes resolution, suitable for DIVA GIS application had been downloaded from Worldclim(www.worldclim.org, Hijman., et al, 2005). It contained the interpolated values of altitude, minimum temperature; maximum temperature and precipitation at global scale The 19 bioclimatic variable used in modelling were derived from this climatic map. These data setswere downscaled by assigning coordinates which coversthe study area.to create the regional climatic map

Habitat suitability was predicted with the help of the DOMAIN model (Carpenter et al., 1993) which was installedin DIVA GIS 5.2 version (www.diva-gis.org). Using the values of the 19 bioclimatic variables, it calculates the Gower distance statistics between each cell on the map and each point. Thereby it assessed new sites based on the environmental similarity. DOMAIN producedindices of habitat suitability on a continuous scale from 0-100 of which value greater than 90 is assumed to be suitable habitat for the species. Split sample approach (Guisan and Zimmerman, 2000) was applied for creating training and test datafor the modelling. Partition was created by randomly selecting 75% of the species record as training data set and the remaining 25% set aside for testing the resulting model. As the species data contain only presence records,it was generated some pseudo absence records to evaluate the model. Absence data were produced 1:1 proportion throughout the study area at random. The training data set had been used to predict the habitat suitability for the species. Ecological niche modelling tool implemented in DIVA GIS was used for prediction.The resulting model was evaluated with Kappa analysis and Receiver Operating Characteristics calculating area under the Curve (AUC).

3 Results and Discussions

According to the species presence records obtained, the southern part of the Baden-Württemberg comprising Konstanz, Bodenseekreis and Ravensburgas well as the border area of northwest region including Baden baden, Karslruhewerereported with abundantoccurrence of Hylaarborea. Towards the central part of the state and some eastern regions, more number of localities was reported with even distribution. But the south west part of the state comprising Lorrach, Waldshut,Breisgau-Hochschwazwarld, Freiburg, Ortenaukriesetc having very poor distribution and.many areas are even not. The terrain of the Baden Württemberg is found to be undulating with highlands, valleys, plateaus etc. The spatial analysis of the distribution revealed that this species mainly found in places with medium elevation.(Below 800 m).Generally Hylaarborea L.isassociated with open, well-illuminated broad-leaved and mixed forests and low riparian vegetation and even in anthropogenic landscapes and dense forests are preferably avoided. (Amphibiaweb, 2010, Kaya., et al., 2010). The temperature preference found to be in between 8-100C.and the species is very scarce or even not reported in the areas with high rainfall.

The modelled potential distribution delineated the suitable habitats where the species is likely to be occurred by calculating the suitability index for each grid rather than predicting the probability of species occurrence in those areas. The areas with grey coloured grids in the suitability map are not suitable for the species to survive at all. In Baden -Württemberg, those areas are found to be at the south west region comprising the boarders of the districts Waldshut. Lörrach and Breisgau-Hochschwarzwald with index value ranges from 14 to 50.The suitability of the dark green shaded areas with index value in between 50 and 90 is very low or even not. Mainly south west part of the state comprised with these grids. It is clearly visible that most of the places in Baden -Württemberg is suitable for Hylaarborea to survive. Considering the grids having index value higher than 95, red coloured grids (index value 100) represents Excellent suitability then orange (98-99) followed by yellow (95-97). The results explicitly show that North East, South East, North West, Northern and Central regions of the state have excellent suitability forHylaarborea L. to persist. The evaluation of the model using Kappa analysisgave a value of 0.939and likewise the ROC test generated a value of 0.969 which all indicates the good performance of the model.

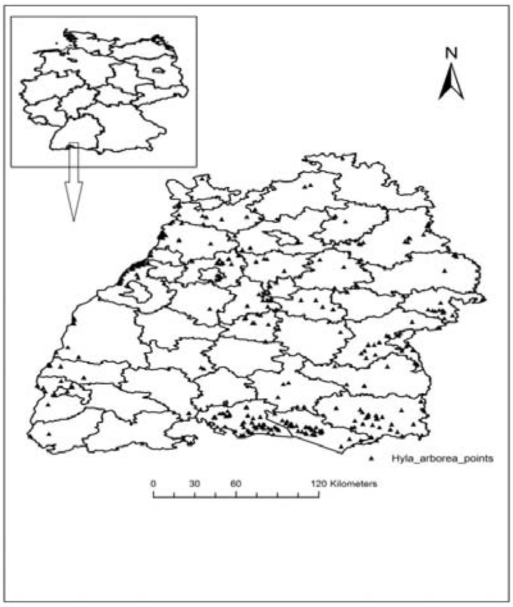

Fig. 5: Geographic Distribution of *Hylaarborea L*. in Baden-Württemberg

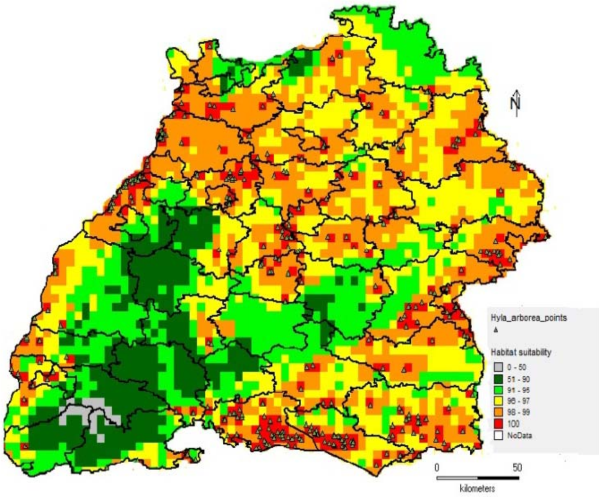

Fig. 2: Habitat Suitability (Potential distribution) of Hylaarborea L.in Baden-Württemberg

4 Conclusion

The study shows Baden-Württemberg, having favourable climatic conditions for the survival of HylaarboreaL. This modelled distribution range is not an ultimate one but it exposes the probable occurrence of the species. Since the external interferencesthreats species' existence, the real distribution of species may be distorted. Butthis work can be effectively applied in biodiversity monitoring, prioritising conservation efforts,and designingof protected area networks and also in gap analysis for assessing efficacy of the current protected networks. Since amphibians are among the most vulnerable species on the earth, it needs higher priority in the conservation efforts. There are various interferences and threats operating on the ecosystem making these species more vulnerable and bringing them at the edge of extinction. Climate change, habitat loss, fragmentation, invasive species spread, epidemic diseases are the distinct among the threats (Amphibiaweb.2010). Studying the impact of climate change on the distribution of the species and habitat range shift are the future scope of this work.

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Estimation of Non-Point Source Pollutants in Upper Mahaweli Catchment of Sri Lanka by using GIS

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KEYWORDS:

Catchment base, GIS, Non-Point Source (NPS), pollutants, Upper Mahaweli Catchment

ABSTRACT

Upper Mahaweli Catchment (UMC) is the upper portion of the Mahaweli watershed area, above the Rantembe dam and it covers an area of about 3118 km^2. Four hydro power plants located inside this catchment that contributes 60% of the hydro electricity supply in Sri Lanka. Therefore, this area is very vital to national economy. Qualities of the surface water of this catchment have been affected extensively due to increase of urban and sub-urban agglomeration along water bodies, wastes disposal by local authorities, soil erosion, and intensive agricultural activities. Identification and estimating point source have been properly done over the years due to simplicity of the process. Eventhough, assessment of Non-Point Source (NPS) is indispensable part of catchment base wastewater management; inadequate studies were done due to NPS pollution is highly correlated with specially oriented data and analysis. Geographical Information System (GIS) is popular for its capability to integrate and analysis layers of spatially oriented large amount of information. This study mainly focuses on assessment of average annual NPS pollutant load contributing from the sub-catchment area of UMC area. Surface runoff and the soil erosion process are two main transport agents of NPS pollutants. In this study, measurements were taken for pollutants in selected points inside the catchment and same points were used to demarcate micro catchments in ArcGIS Hydro Extension. Therefore, those micro-catchments are the contributed area for pollutant measurement points. Soil erosion was calculated by using Universal Soil Loss Equation (USLE) in GIS raster format and hydrological equations were used to calculate the surface runoff per year. Rate of erosion and pollutant concentration in the eroded soil used to estimate the pollutant transport with soil and annual surface runoff and pollutant concentration in water samples were used to estimate pollutant transport by surface runoff. Summation of above the estimated values considered as the amount of pollutant produced by NPS pollutes in the particular micro-catchment per year. Eventhough, the estimated loads might be not the absolute values, it can provide sufficient information to decision makers for implementing proper catchment base wastewater management system.

The REE-Mix toolset: A spatial decision support system to assess potentials for regional renewable energy supply

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KEY WORDS:
Renewable energy, SEAP, climate protection, DSS

ABSTRACT:

Regional renewable energy sources are getting increasingly important (IEA 2010). The promotion of sustainable energy supply is also political aim in many countries (Lund 2010). A large technological progress was achieved, but there is a lack of management of energy infrastructure to support further development. The members of the European Covenant of Mayors made commitments to provide Sustainable Energy Action Plans as key document in which the Covenant signatory outlines how it intends to reach its CO2 reduction target by 2020 (Covenant of Mayors 2011).

Renewable energy sources need more space than classical power plants, but the energy can be generated decentralized according to local needs (de Vries 2007, Angelis-Dimakis 2011). Land requirements for different types of renewable energy and efficiency of the resources can be analyzed using GIS.

A modular toolset within a decision support system (Sustainable Energy Action Plan DSS) is developed to assess those land requirements and potentials to support decision making of stakeholders such as local authorities, energy suppliers or banks (Figure 1: Modules A1-A3).

Main aim of this "mixture of Regional renewable energy (Ree-Mix) toolset" is the detection and prevention of potential ecological and social conflicts for the renewable energy sources wind, sun, water, biomass and geothermal energy. Possible solutions for conflicts can be achieved with spatial analysis as well as optimization of energy allocation and infrastructure. First modules were developed, assessing yield and feasibility and infrastructure of wind, geothermal and solar energy (A1 – A3). Other renewable energies and cogeneration of heat are implemented into the existing tools. First GIS analyses were performed to build the B and C modules.

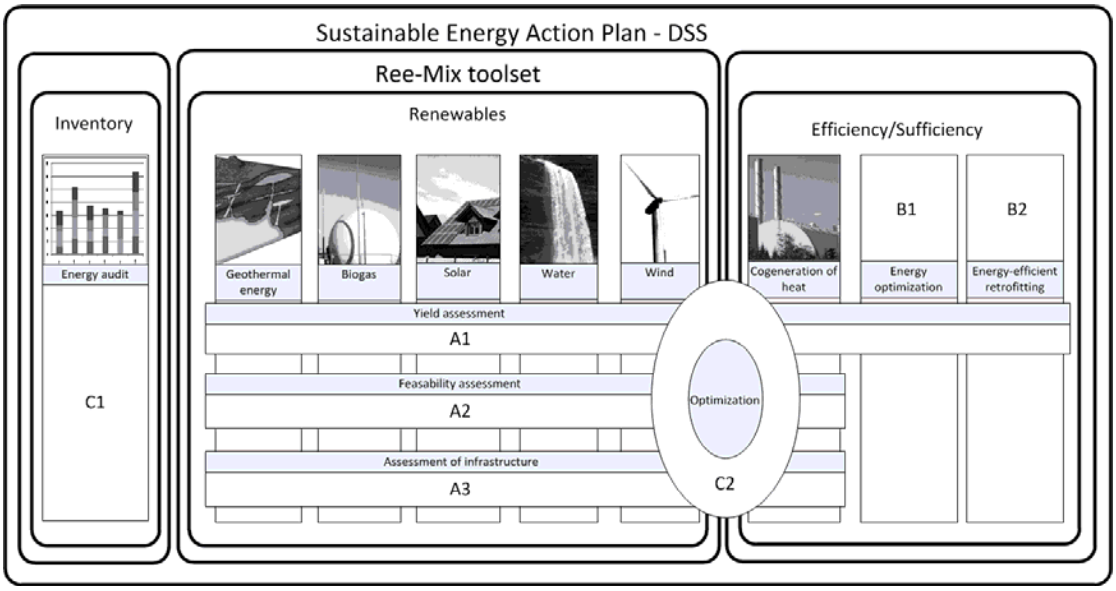

Figure 1: Modular structure of the Sustainable Energy Action Plan DSS with the central Ree-Mix toolset.

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Sustainability of Tourism in Kenya: Analysis of land use/cover changes and animal population dynamics in Masai Mara

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KEYWORDS

Masai Mara ecosystem, land use/cover, image classification, GIS, wildlife habitat

ABSTRACT

Land use/cover changes in wildlife conservation areas have serious implications for the ecological systems and distribution of wildlife species. Masai Mara was used as an example of an ecosystem rich in biodiversity but now under threat. Long-term land use/cover changes and wildlife population dynamics were analyzed in Masai Mara. Multi-temporal satellite images (1975, 1986, and 2007) together with physical and socio-economic data were employed in a post classification analysis with GIS to analyze outcomes of different land use practices and policies. The results show rapid land use/cover conversions and a drastic decline for a wide range of wildlife species. The changing habitat has led to loss of grazing and dispersal areas and could be responsible for the observed 60% wildlife decline in the 32-years study period. Integration of land use/cover monitoring data and wildlife resources data can allow for analysis of changes from past to present, and can be used to project trends into the future to provide knowledge about potential land use/cover change scenarios and ecological impacts in Masai Mara.

1. Introduction

Land use/cover changes occurring in areas surrounding protected animal parks may substantially influence the natural resources within these parks. As human population increases, biodiversity is facing widespread competition with humanity for space and resources and there is increasing conflict between the need for biodiversity conservation and economic development. The Masai Mara ecosystem comprising of Masai Mara National Reserve and the adjoining group ranches hold spectacular concentration of wildlife and is home to the iconic Masai pastoralists making it a popular international tourism destination.

The Masai Mara ecosystem however, embodies many issues in biodiversity conservation. Despite being a vast area incorporating a major protected area, its many wildlife species require access to large, unprotected dispersal ranges inhabited, and increasingly transformed, by agro-pastoral human communities. Sustainable coexistence of the regions pastoral people with the wildlife populations is being threatened by the increasing human activities. There are many variables at play in Masai Mara. The ecosystem has different land zones with different land uses. The national reserve, owned and controlled by two local governments is exclusively for wildlife tourism and conservation. The adjacent group ranches are owned privately or communally and have multiple land uses. This ecosystem also lies on the border with Tanzania, where socio-economic, political and land tenure systems are different. Wildlife movements across the border show that the protected areas are not adequate for the protection and viability of wildlife species in the ecosystem. What is happening in the adjoining group ranches therefore has a direct influence on the wildlife in the protected areas.

The objective of this study is to analyze the long-term land use/cover changes and wildlife population trends in Masai Mara ecosystem. The changes in land use/cover, wildlife, and livestock population were summarized and developed a conceptual model to explain the land use/cover change dynamics.

2 Study Area

Wild life movements in the study area are illustrated in Figure 1. The National reserve is unfenced and contiguous with the adjacent unprotected land and the Serengeti National Park in Tanzania to the south. The surrounding unprotected areas are a mixture of private and communally owned land. Recently, subdivisions of group ranches into parcels of privately owned land have been widely promoted resulting in significant land transformations including mechanized farming and tourism activities.

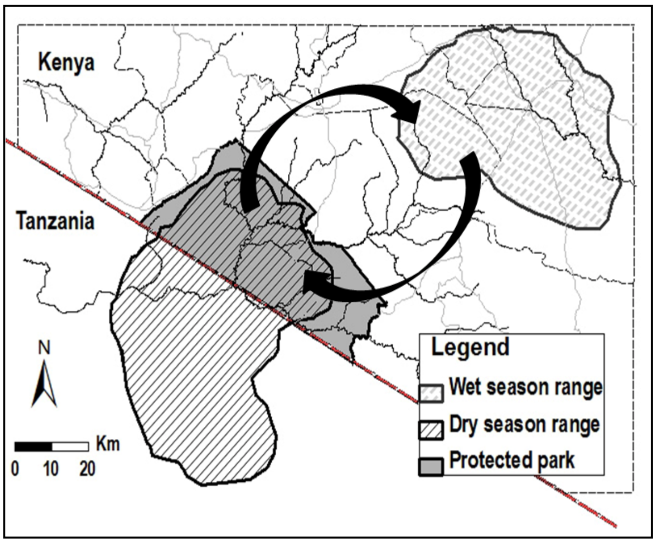

Figure 1: Wildlife movements in the study area.

3 Data and Methodology

This study integrates data from different sources, and uses different methods and approaches. To analyze wildlife and livestock population changes, animal counts were used from aerial census conducted by the Department of Resource Survey and Remote Sensing (DRSRS) between 1975 and 2007 using systematic reconnaissance flights fitted with GPS sets. To characterize land use/cover changes, satellite data was used as outlined in Table 1 below.

Table 1: Key characteristics of satellite data

Satellite	Sensor	Acquisition date	Resolution
Landsat MSS	Landsat 2	1975/02/11	75/120
Landsat TM	Landsat 4	1986/10/17	30/120
ALOS	AVNIR-2	2007/07/24	10

Our methodology is summarized in Figure 2. Based on the results of the unsupervised classification, ground data and authors knowledge of the study area, clusters of pixels representing various land use/cover categories were selected as training sets and their spectral response patterns were generated. Based on spectral separability, the training areas were suitably modified and the final spectral response patterns were generated, and used to classify the images using a Gaussian maximum likelihood per pixel classifier. The classification accuracies were then estimated following the procedure by Bishop et al (1975). Post classification analyses were performed to quantify and identify the changes that occurred over the study period. Further, using GIS techniques, qualitative interrelationships between various variables were analyzed and a conceptual model depicting land use dynamics developed and key relationships evaluated.

4 Results and Discussions

Classified results of land use/cover for 1975, 1986 and 2007 are presented in Figure 3 and the changes in Table 2.

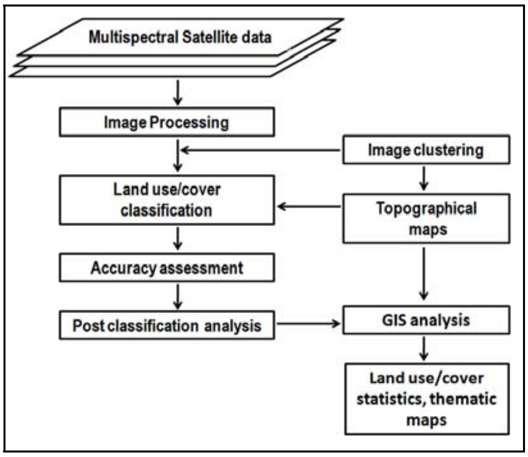

Table 2: The approach adopted for the analysis of land use/cover changes.

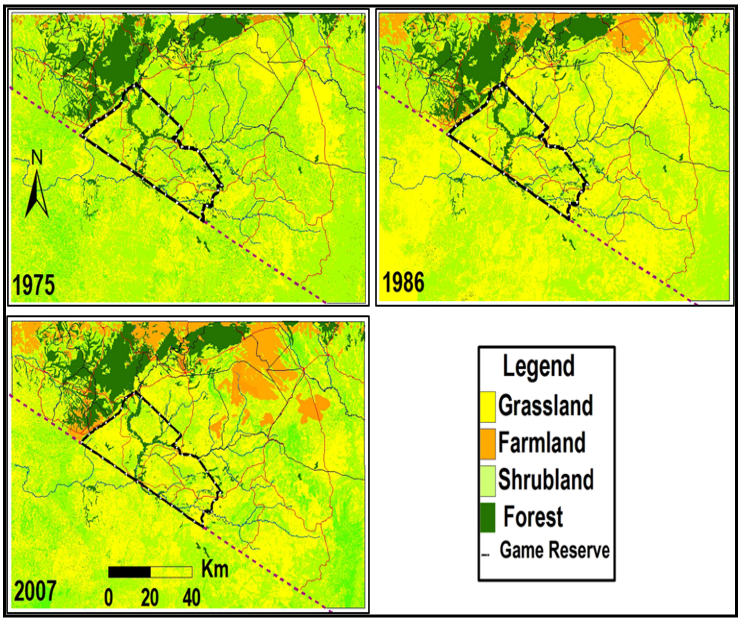

Figure 3 Land use/cover maps for Masai Mara ecosystem for 1975, 1986 and 2007 from multispectral satellite images.

Farmland, grassland, shrubland and forest area were the dominant land use/cover classes. Significant spatial expansion in farmland and the rapid decrease in forest cover within and close to the Masai Mara National Reserve were observed in the 1986 and 2007 land use/cover maps.

Table 2: Observed land use/cover changes for Masai Mara.

Land use/cover	1975		2007		% change
	Area (ha)	%	Area (ha)	%	1975-2007
Farmland	15,540	1.2	147,490	11.5	10.3
Grassland	243,940	18.9	191,070	14.9	- 4.0
Forest	138,430	10.8	123,600	9.6	-1.2
Shrubland	886,090	69.0	822,030	64.0	- 5.0
Total	1,284,000	100.0	1,284,000	100.0	

Analysis of long-term aerial census data show very rapid decline for most wildlife species. Population trends for the livestock and the three most abundant wildlife species in Masai Mara ecosystem are presented in Figure 4.

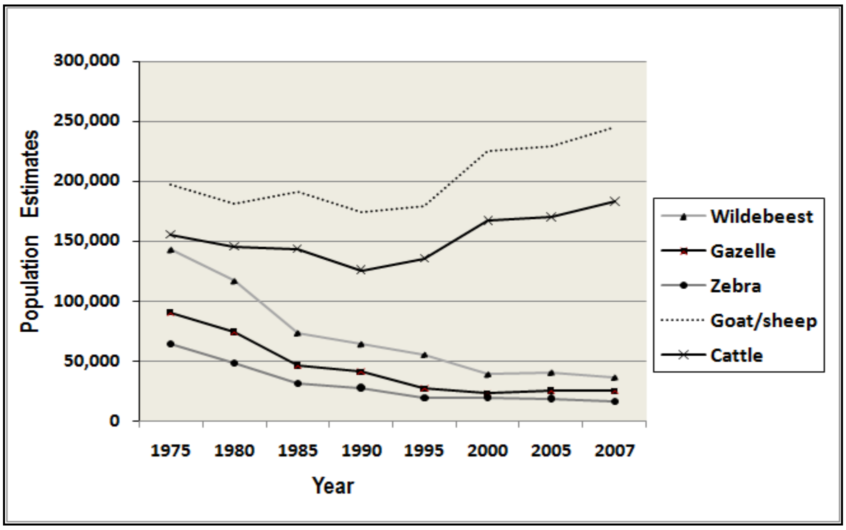

Figure 4: Population trends of wildlife and livestock in Masai Mara National Reserve and surrounding areas. Source: Department of Resource Survey and Remote Sensing (DRSRS).

Analysis of wildlife dynamics indicates that the wildebeest population decreased by 74% while the expansion of mechanized farming took place on the wet season rangelands, which were fenced off to exclude wildlife. Livestock population trends over the same period shows fluctuating patterns with an increase in recent years.

4.1 Conceptual model

Following remote sensing based analysis and extensive fieldwork assessment in Masai Mara, a conceptual model was developed and shown in Figure 5 that analyzes the dynamics of ecosystem change in terms of competition for land and competition for biomass. The total land area of the ecosystem is in demand for subsistence, tourism, mechanized cultivation, and for grazing both livestock and wildlife. These land demands are controlled by socio-economic factors but also compete for limited space.

The transitions while driven by many factors have underlying human drivers. Foremost among these is land conversion to agriculture especially the expansion of mechanized farming which is controlled by economic factors. Wildlife and livestock compete for biomass and the size of livestock is linked to pastoralist's decision and their wealth. Around the conservation areas, a significant portion of pastoralist wealth derives from wildlife related tourism activities. All these factors together with the tourism management style and the existing environmental conservation policies have contributed to the current scenario of rapid land use/cover changes and wildlife decline.

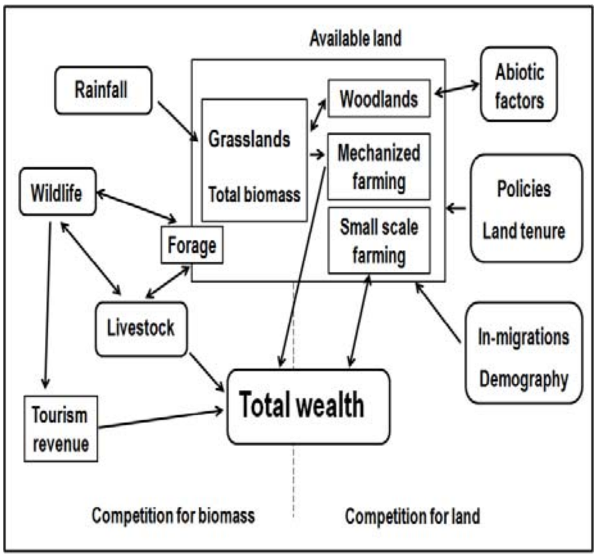

Figure 5: Conceptual model depicting the land use/cove dynamics in Masai Mara Ecosystem

4.2 Conclusions

Increasing land use/cover changes and the drastic decline in wildlife population have been observed in the Masai Mara ecosystem. Information about these changes is important for planning for sustainable utilization of resources. To study the long-term land use/cover changes and wildlife population trends, data was integrated from different sources and different methods were used and approaches including satellite remote sensing, field surveys and wildlife population trend analysis. Post classification analysis and integration of various data using GIS approach was adopted to examine changes and wildlife population dynamics.

The results show rapid land use/cover conversions and a drastic decline for a wide range of wildlife species. It is urgent that all necessary measures are taken in order to strike a balance between wildlife conservation and economic development. It is also important to revise and strengthen the wildlife policy so that wildlife species in private group ranches outside the Masai Mara National Reserve are protected and habitats are conserved to ensure sustainable tourism and balanced economic development.

Acknowledgement

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KEYWORDS:
Catchment base, GIS, Non-Point Source (NPS), pollutants, Upper Mahaweli Catchment

ABSTRACT

Upper Mahaweli Catchment (UMC) is the upper portion of the Mahaweli watershed area, above the Rantembe dam and it covers an area of about 3118 km^2. Four hydro power plants located inside this catchment that contributes 60% of the hydro electricity supply in Sri Lanka. Therefore, this area is very vital to national economy. Qualities of the surface water of this catchment have been affected extensively due to increase of urban and sub-urban agglomeration along water bodies, wastes disposal by local authorities, soil erosion, and intensive agricultural activities. Identification and estimating point source have been properly done over the years due to simplicity of the process. Eventhough, assessment of Non-Point Source (NPS) is indispensable part of catchment base wastewater management; inadequate studies were done due to NPS pollution is highly correlated with specially oriented data and analysis. Geographical Information System (GIS) is popular for its capability to integrate and analysis layers of spatially oriented large amount of information. This study mainly focuses on assessment of average annual NPS pollutant load contributing from the sub-catchment area of UMC area. Surface runoff and the soil erosion process are two main transport agents of NPS pollutants. In this study, measurements were taken for pollutants in selected points inside the catchment and same points were used to demarcate micro catchments in ArcGIS Hydro Extension. Therefore, those micro-catchments are the contributed area for pollutant measurement points. Soil erosion was calculated by using Universal Soil Loss Equation (USLE) in GIS raster format and hydrological equations were used to calculate the surface runoff per year. Rate of erosion and pollutant concentration in the eroded soil used to estimate the pollutant transport with soil and annual surface runoff and pollutant concentration in water samples were used to estimate pollutant transport by surface runoff. Summation of above the estimated values considered as the amount of pollutant produced by NPS pollutes in the particular micro-catchment per year. Eventhough, the estimated loads might be not the absolute values, it can provide sufficient information to decision makers for implementing proper catchment base wastewater management system.

Assessing Application of Markov Chain Analysis in Nakuru

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KEYWORDS:
GIS, Land cover, Markov modelling, Nakuru Municipality, Remote sensing, MSS, TM, and ETM

ABSTRACT

Land use/cover change is a major global environmental change issue and projecting these changes is essential for the assessment of environmental impacts. In this study, a combined use of satellite remote sensing, geographic information systems (GIS), and markov chains stochastic modelling techniques were employed in analysing and projecting land use/cover changes. The results indicate that there has been a notable and uneven urban growth with a substantial loss in forest land, and that the land use/cover change process has not stabilized. The study demonstrates that the integration of satellite remote sensing and GIS can be an effective approach for analyzing the spatio-temporal patterns of land use/cover change. Further integration of these two techniques with Markov modelling was found to be beneficial in describing, analysing and projecting land use/cover change process. The projected land use/cover for 2015 show substantial increase in urban and agricultural land uses in the study area to a depper extent.

1 Introduction

Urban expansion, particularly the movement of residential and commercial land use to rural areas at the periphery of cities and towns, has long been considered a sign of regional economic vitality. However, its benefits are increasingly balanced against ecosystems including degradation of environmental quality, especially loss of farmland and forests, and also socioeconomic effects (Squires, 2002). The land use/cover changes, associated with rapid expansion of low-density suburbs into formerly rural areas and creation of urban or suburban areas buffered from others by undeveloped land, have ramifications for the environmental and socio-economic sustainability of communities.

Many cities and towns in Africa have seen marked increases in urban growth and the associated impacts of environmental degradation (Kamusoko and Aniya, 2007; Braimoh and Onishi, 2007; Mundia and Aniya, 2005). These changes and their repercussions require careful consideration by local and regional land managers and policy makers in order to make informed decisions that effectively balance the positive aspects of development and its negative impacts in order to preserve environmental resources and increase socio-economic welfare. While regional planners and decision makers are in constant need of current geospatial information on patterns and trends in land use/cover, relatively little research has investigated the potential of satellite data for monitoring land use/cover changes in both rural and urban areas in Africa.

There are various ways of approaching the use of satellite imagery for resolving land use/cover changes. Yuan et al. (1998) divide the methods for change detection and categorization into pre-classification and post classification methods. The pre-classification methods apply a variety of algorithms, including image differencing and image ratioing, to single or multiple spectral bands, vegetation indices or principal components, directly to multiple dates of satellite imagery to create ‘‘change’’ vs. ‘‘no-change’’ maps (Yuan et al, 1998).

This paper describes the approach and results of classifications and post-classification analysis of multi-temporal Landsat data of Nakuru Municipality in Kenya for 1973, 1986 and 2000. The purpose of this study was to measure the land use/cover changes based on multispectral Landsat data and to test a Markov-based model to generate land use/cover change projections in Nakuru municipality, an area characterized by high rates of changes. The approach is based on the quantification of the course of land use/cover in addition to the projection of the process from these observations.

2 The study area

Nakuru municipality (Figure 1) lies approximately between 0° 15' and 0° 31' South, and 36° 00' and 36° 12' East, with averagel altitude of 1,859 meters above sea level, enveloping an area of 290 km². Nakuru town, found within this municipality is the fourth largest town in Kenya. It occupies a pre-eminent position as the administrative headquarters of the Rift Valley Province, and as an industrial, commercial and service centre for the surrounding agricultural hinterland (Odada, et al, 2004). Agriculture and manufacturing are the main economic activities in Nakuru municipality. The area surrounding Nakuru town has vast agricultural potential with numerous farms and many agricultural enterprises. The area is also endowed with vast tourism resources including Lake Nakuru National park. Population in Nakuru has grown substantially over the years from 38,181 in 1962, to 289,385 in 1999, growing at a rate of about 5.6 per annum (Republic of Kenya, 1999). By the year 2015, the population is projected to rise to 760,000, fifty percent above the present levels.

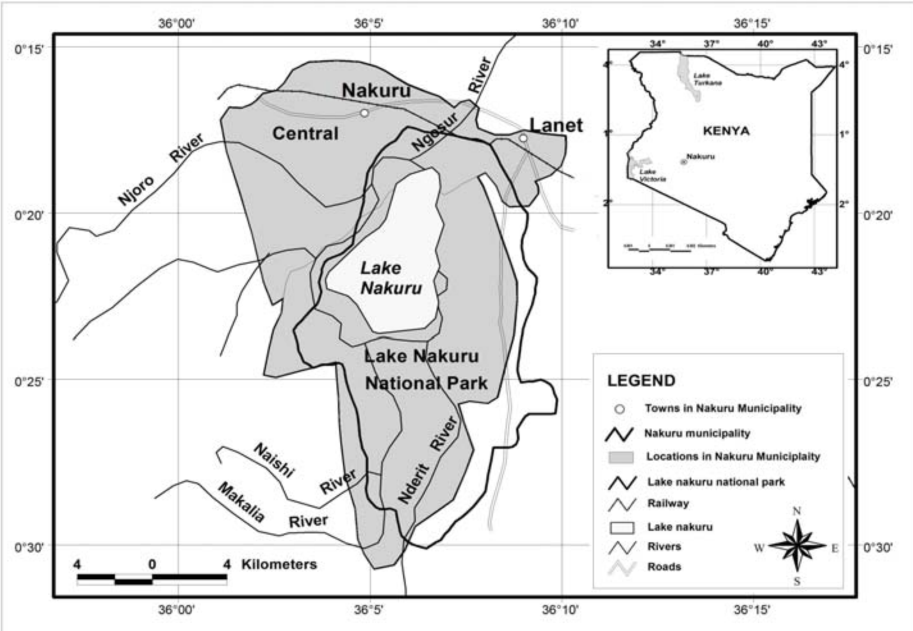

Figure 1: Map showing the extent of the study area

3 Methodology

3.1 Land Use/cover change analysis

The approach adopted for the analysis of land use/cover involved three sets of clear, cloud-free Landsat images for 1973, 1986 and 2000 where were selected to classify the study area. Nakuru municipality is entirely contained within Landsat TM path 169, rows 60. The data sets comprised of Landsat MSS, TM, and ETM+ images. The three images were rectified using at least 35 well distributed ground control points and nearest neighbour resampling. The root mean square errors were less than 0.5 pixels for each of the images. Reference data were developed for each of the three years and then randomly divided for classifier training and accuracy assessment.

Black and white aerial photos acquired in 1987 and 1995 were used as reference data for the 1986 and 2000 classifications while topographical maps were used as Reference data for the 1973 training and accuracy assessments. Stratified random sampling was adopted for selecting samples. Our classification scheme comprised of six classes namely forest, urban land, agriculture, water, rangeland, barren land, and vegetation, was based on the land use/cover classification system developed by Anderson et al. (1976) for interpretation of remote sensing data at various scales and resolutions.

Several of the factors mulled over during the design of categorization scheme incorporated: the major land use/cover groups within the study area, disparities in spatial decrees of the sensors which varied from 30 to 79 m, and the want to always discriminate land use/cover classes irrespective of seasonal disparities (Anderson et al, 1976). A combination of the reflective spectral bands from images (i.e., stacked vector) was used for classification of the 1973, 1986 and 2000 images. A hybrid supervised-unsupervised training approach referred to as ‘‘guided clustering’’ in which the classes are clustered into subclasses for classifier training was used with maximum likelihood classification (Bauer et al., 1994). Training samples of each class were clustered into 5–10 subclasses.

Class histograms were checked for normality and small classes were deleted. Following classifications, the subclasses were recorded to their respective classes. Post-classification refinements were enforced to diminish categorization errors that were a result of the similarities in spectral responses of certain classes such as bare fields and urban areas and some crop fields and wetlands. Spatial modeller and additional rule based procedures were adopted to overcome these classification challenges and differentiate between classes.

Independent samples of about 100 pixels for each class were randomly selected from each classification category to assess classification accuracies. Error matrices as cross-tabulations of the mapped class vs. the reference class were used to assess classification accuracies (Congalton & Green, 1999). Overall accuracy, user’s and producer’s accuracies, and the Kappa statistic were then derived from the error matrices. The Kappa statistic incorporates the off diagonal elements of the error matrices (i.e., classification errors) and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance. Following the classification of imagery from the individual years, a GIS based multi-date post-classification comparison change detection strategy was employed to determine changes in land use/cover.

3.2 Descriptive modelling of land use/cover change processes

Given the difficulties in designing deterministic models of land use/cover change processes, it is convenient to consider them as stochastic (Lambin 1994). For land use/cover change, one may formulate a principle analogous to one of classical physics: the possibility that the system will be in a given state at a given time t2 may be derived from the knowledge of its state at any earlier time t1, and does not depend on the history of the system before time t1—i.e. it is a first-order process (Parzen 1964, Bell). Stochastic processes which meet this condition are called Markov processes and if the Markov process can be treated as a series of transitions between certain values (i.e. the states of the process), it is called a Markov chain (Lambin, 1994).

The number of possible states is either definite or denumerable and for land use/cover change, the states of the system are defined as the amount of land occupied by various land use/covers. To model a process of land-cover change by a Markov chain, the land-cover distribution at t2 is calculated from the initial land use/cover distribution at t1 by means of a transition matrix (Lambin 1994). The Markov chain can be expressed as: $vt2 = M \times vt1$

Where vt1 is the input land use/cover proportion column vector, vt2 is the output land use/cover proportion column vector and M is an m×m transition matrix for the time interval $\Delta t = t2 - t1$.

When the transition probabilities depend only on the time interval t, and if the time period at which the process is examined is of no relevance, the Markov chain is said to be stationary or homogeneous in time (Karlin and Taylor 1975). If two estimates of the transition matrix of a land use/cover change process are available for two calibrations time intervals, these estimates must be adjusted to an equivalent calibration time period to allow for comparisons and to assess the stationarity of the process (Bell and Hinojosa 1977). This operation can be performed by using the matrix analogous of the exponential and logarithmic functions (Petit et al., 2000). For this study, the transition matrices were constructed from the change/no change matrices obtained in the change detection analysis and the modelling processes implemented using algorithms supplied with the Idrisi software.

Although the Markov chain analysis operates under fairly restrictive assumptions such as independence and stationarity, they are scientifically compact and easy to execute with empirical data such land use/cover. In addition, the land use/cover transition probability results can therefore serve as an indicator of the direction and magnitude of land use/cover process.

Markov models have several advantages. Firstly, they are relatively easy to derive from successional data. Secondly, the Markov model does not need deep insight into the system of dynamic change, but it can assist to specify areas where such insight would be important and therefore act as both a stimulant and guide to further research. Thirdly, the basic transition matrix summarises the fundamental parameter of vibrant change in a way that is accomplished by very few other kinds of models. Lastly, the computational requirements of Markov models are self-effacing, and can easily be met by small computers.

Markov models have several disadvantages. Firstly, there is removal from the simple suppositions of stationary, first-order Markov chains while, theoretically possible, results in analytical and computational difficulties. Secondly, in some areas, the data accessible will be inadequate to approximate consistent transfer or probability rates, especially for exceptional transitions. Lastly, the validation of Markov models depends on forecasts of system behaviour over time, and is as a result frequently hard, and may even be unattainable, for really long periods of time (Petit et al, 2000).

4 Results

4.1 Supervised land use/cover classifications

The three successive supervised land use/cover classifications discriminated six classes: urban land, water, forest land, agricultural land, rangelands and barren land. The accuracy assessment results are provided in Table 1. The overall accuracy of the January 1973 classification, assessed on the basis of topographical maps produced in 1970 was 85%, with a Kappa coefficient of 0.8, while the overall accuracies for the 1986 and 2000 classifications based on black and white aerial photographs were 86% and 92% respectively. These accuracy estimates met the minimum standards as stipulated under USGS classification scheme.

Table 2 : Statistics for Land use/cover for years 1973, 1986, 2000

Year	1973	1986	2000
Land use/cover	Area (km^2)	Area (km^2)	Area (km^2)
Water	39.9	35.0	39.2
Forest	21.1	20.3	19.0
Barren	8.4	2.4	1.9
Urban	19.0	23.5	37.3
Agriculture	71.7	61.1	83.2
Rangeland	131.7	149.3	110.8
Total	291.7	291.7	291.7

4.2 Land use/cover changes

The post-classification comparison approach was employed for detection of land use/cover changes, by comparing independently produced classified land use/cover maps. The main advantage of this method is its capability to provide descriptive information on the nature of changes that occurs. The change statistics are summarised in Table 1. The spatial distributions of each of the classes were extracted from each of the land use/cover maps by means of GIS functions. From these results, urban land covered 19 km2 in 1973 and increased to 24 km2 in 1988. These areas increased further to 37km2 by the year 2000. Forest land on the other hand has decreased from 21 km2 in 1973 to 19 km2 in year 2000. The agricultural fields occupied 72km2 in 1973, decreased to 61 km2 in 1986, but further increased to 83 km2 in 2000.

Rangelands, consisting of mixed rangeland and shrub/brush rangeland decreased from 131 km2 in 1973 to 110 km2 in 2000. These trends in land use/cover changes for Nakuru municipality are summarised in Table 1. The comparison of land use/cover classification results in Table 1 indicates that the rate of encroachment of urban land on other land uses has been rapid, with discontinuous patches of urban development characterizing the urban sprawl. Viewed as a time series, the land use/cover changes have varied substantially over the study period. Urban land in Nakuru Municipality expanded by 6% during the 13-year period from 1973 to 1986 compared to the 13% for about a similar time period between 1986 and 2000. Mundia et al (2008) report that the main driving force of land-cover changes in this region is the growing pressure of population which has more than doubled since 1960.

4.3 Land use/cover change projections

Representing the land use/cover change process by a Markov model allows us to address questions such as: How is the land use/cover change process likely to progress in the future? Is it possible to infer future evolutions from observations of recent changes? Land use/cover change projections were generated on the basis of the Markov chain. The transition probabilities produced the projection in Table 2.

In the absence of any major policy, socio-economic or climatic change, future land use/cover changes would continue to affect the natural vegetation, which would continue to decrease over the years by being converted to urban and agricultural lands. The Markov chain analysis for year 2000 and 2015 are summarized in Table 2. From these results, our model predicted that the urban land would increase by 45%; agricultural lands by 28% and the bare land by196%.

One suspects however that institutional and policy changes will intervene in the study area to modify these trends. Such projections rely strongly on the hypothesis of stationarity of the land use/cover change process. Results reveal that the change process is not stationary since the two projections, based on transition matrices from different time periods, provide divergent equilibrium distributions of land cover.

Table 3: Markov Chain Analysis for year 2000 and 2015

Year	2000	2015	Change (km2)	Change (%)
Land use/cover	Area (km2)	Area (km2)	Area (km2)	%
Water	26.7	46.6	19.9	74.7
Forest	22.5	21.7	-0.9	-3.9
Barren Land	2.9	8.7	5.8	196.9
Urban	35.5	51.6	16.1	45.4
Agriculture	74.8	95.8	21.0	28.1
Rangelands	168.6	101.6	-62.0	-37.9

5 Conclusion

Monitoring land use/cover changes is necessary for guiding decision making for resource management. We analyzed land use/cover changes between 1973 and 2000 and used the findings to produce a simulated result for Nakuru Municipality for 2015. To achieve this, multispectral Landsat images for 1973, 1988 and 2000 were used in a post-classification analysis with GIS. The Land use/cover results were then employed for predicting land use/cover changes for 2015 using Markov chains. Our results show that land use/cover in Nakuru Municipality has changed. In particular, the urban land has doubled over the period from 1973 to 2000. Loss of forest land and the problem of urban sprawl were noted as serious issues. Markov chains, applied to the remote sensing data by way of transition matrices generated projections of land-cover distributions for the year 2015. The projections of future land use/cover changes on the basis of a Markov chain showed a continuing trend of increase in urban and agriculture land, and the decline in forests and other natural vegetation covers. Our prediction however assumed that the transition probabilities would remain constant. This is unlikely to be the case as the process of land use/cover change does not generally conform to the hypothesis of stationarity and, therefore, Markov chain models may provide unreliable projections.

When facing such severe and rapid land use/cover changes, one requirement for decision-making is to be able project future changes under certain assumptions. Such projections also contribute to increased awareness of the ecological consequences of growing pressures. However, this study only used satellite data which is probably limited and not sufficient to grasp the land use/cover change process in all its complexity. Attempts need to be undertaken to incorporate socio-economic variables to improve the results. The information obtained however, is very useful for planning purposes and for the appropriate allocation of resources and demonstrate the potential of multi-temporal Landsat data to provide a precise and inexpensive means to analyze and map changes in land use/cover over time that can be used as inputs to policy decisions and land management.

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Simulating the impact of land use change on watershed services in Sasumua Watershed using SWAT

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KEYWORDS:

Base flow, land use change, runoff curve number, sediment yield, surface runoff, water yield

ABSTRACT:

Land use change has a major influence on the capacity of watersheds to produce watershed services such as improving water quality and flood mitigation. The objective of this study was to simulate the effect of land use change on the sediment and water yield in Sasumua watershed, Kenya using SWAT model. The SWAT model was calibrated and validated using recorded reservoir data. The validated model was then used to simulate water and sediment yield under three scenarios of runoff curve number CN (improved land surface condition CN-6, base case, degraded land surface condition CN+6). The CN was used as a surrogate to represent land surface treatments that influence generation of surface runoff following rain events. The coefficient of determination from the calibration of the model was 0.6 and 0.5 for the validation. An increase in CN by 6 (scenario CN+6) units in the agricultural part of the watershed, increased the sediment loading to the streams by 53.6% while a reduction by 6 units (scenario CN-6) reduced sediment loading by 34.3%. Scenario CN-6 resulted in a 28.5 % decrease in surface runoff, a 13.8% increase in base flow and a slight decrease in total water yield of 1.2%. On the other hand, scenario CN+6 increased the surface runoff by about 44%, reduced base flow by 10.5% and increased the water yield by 6.5%. Improvement in land surface condition that enhances infiltration is a feasible conservation measure to reduce soil erosion and subsequent sedimentation of the rivers and the reservoir. CN-6 can be achieved through terracing, contour farming, grass strips, better crop residue management and well managed grazing.

1 Introduction

Watershed services are water related benefits that ecosystems provide for human wellbeing. Watershed services which primarily deal with provision of adequate amounts of good quality water is one of the main classes of ecosystem services. Others are carbon sequestration, biodiversity conservation and aesthetics features or landscape beauty. Watersheds are expected to offer enough amounts of water and the water should be of good quality. Human activities especially in agricultural watersheds affect the capacity of the watersheds to offer watershed services. Overexploitation of natural resources is one way that limits the provision of these services.

Population increase causes rise in demand for food, water and fibre. Where land is scarce, people tend to over utilize it to meet the food demand. In such cases poor management of land is common and the result is land degradation. Soil erosion is one form of land degradation that results from poor land management. Soil erosion is the process by which soil particles are detached from within the surface of a cohesive soil matrix and subsequently moved down slope by one or more transport agents. It can be caused by wind or water (Kinnell, 2010). The sediments which result from soil erosion become a source of pollution of the water bodies.

Proper land husbandry calls for better management of land where infiltration of water into the ground would be encouraged. Infiltration of water would reduce the volume and depth of the surface runoff and therefore its erosive power. The infiltrated water recharges the shallow aquifer and the ground water from the aquifer is slowly released to the streams as base flow. This means that the water which would otherwise have taken a short time to reach the streams as surface runoff will take a longer time as base flow. This phenomenon will reduce the incidences of flash floods and regulate the flows to the water bodies. Increased base flow will result in increased dry weather flows. Water related conflicts happen during the dry seasons when stream flows are minimal. Thus increase in dry weather flows will ensure that water is adequate (Cassman *et al*., 2007).

Changes in land use can positively or negatively affect the provision of watershed services. Land use change has direct effect on sediment yield and also affects how the water yield is portioned into surface runoff, lateral flow and base flow. Positive land use change which encourages infiltration and reduces soil erosion can be achieved through terracing, contour farming, grass strips, better crop residue management and well managed grazing. On the other hand, lack of soil conservation measures, poor crop residue management and soil compaction through practices such as overgrazing are negative land use changes that would limit provision of these watershed services.

In this study the impacts of land use change on sediment yield and water yield components were assessed. We used a computer model, Soil and Water Assessment Tool (SWAT) (Neistch *et al.*, 2005) to simulate the land use changes.

2 Materials and methods

The study was carried out in Sasumua watershed in Kenya. Soil and Water Assessment Tool (SWAT) was calibrated and validated using inflows into Sasumua reservoir which was calculated from the reservoir water balance. The validated model was then used to simulate the land use condition scenarios.

2.1 The study area

Sasumua watershed lies between longitudes 36.58°E and 36.68°E and latitudes 0.65°S and 0.78°S (Figure 1) and has an altitude of between 2200 m and 3850 m. The watershed has a reservoir (Sasumua) which receives water from three sub-catchments (Figure 1). Sasumua sub-catchment (67.44 km^2) which is seasonal in nature provides water only during the rainy season. Chania sub-catchment (20.23 km^2) and Kiburu sub-catchment (19.30 km^2) both of which are perennial and connected to Sasumua reservoir via tunnel and pipe diversions respectively provide water throughout the year. The total catchment area feeding the reservoir is therefore 107 km^2 about half of which is in the forest reserve. Sasumua sub-watershed is mainly agricultural, with only a small portion which is under forest. Measurements of sediment yield indicate that Sasumua sub-watershed is a major contributor of sediment reaching the reservoir. The reservoir design capacity is 16 million cubic meters and supplies about 64,000 cubic meters, at normal operating conditions, of water daily to Nairobi City which is about 20% of water used in Nairobi (Gathenya *et al.*, 2009). The mean annual rainfall in Sasumua ranges from 800- 1600 mm with two main rainfall seasons. Long rains occur from March to June and the short rains from October to December. The soils in Sasumua from the high mountainous Northeastern end are Teric Histosols (HSs), Humic Nitisols (NTu), Haplic Acrisols (Ach), Haplic Phaeozems (PHh), and Eutric Planosols (PLe) on the lower Southwestern plateau area (Figure 2). Mollic Andosols (ANm) are also present downstream of the dam. The main agricultural part of Sasumua sub-watershed is composed mainly of Planosols and Phaeozems. Planosols have low infiltration rates and have periodic stagnation of water. The low infiltration rates cause high erosion and runoff rates. The catchment is composed mainly of small farm sizes which are privately owned. Potato and cabbage are the major crops grown in the area. Peas and carrots are also grown. A land use map of the watershed is shown in Figure 3.

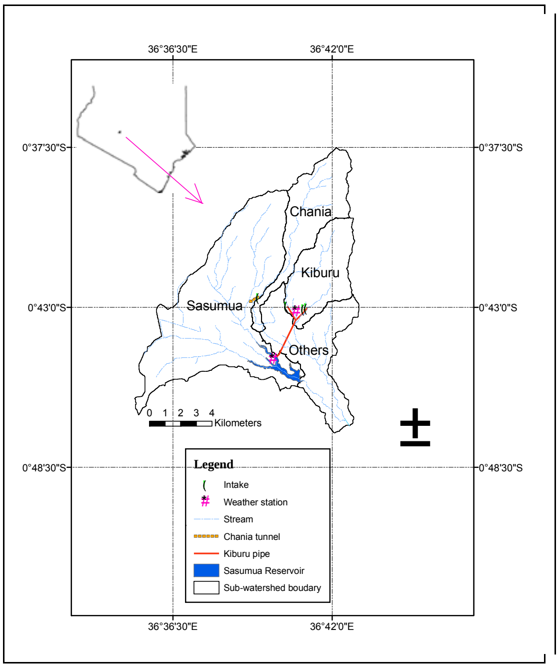

Figure 1: Sasumua watershed showing sub-watersheds (inset- location of Sasumua in map of Kenya)

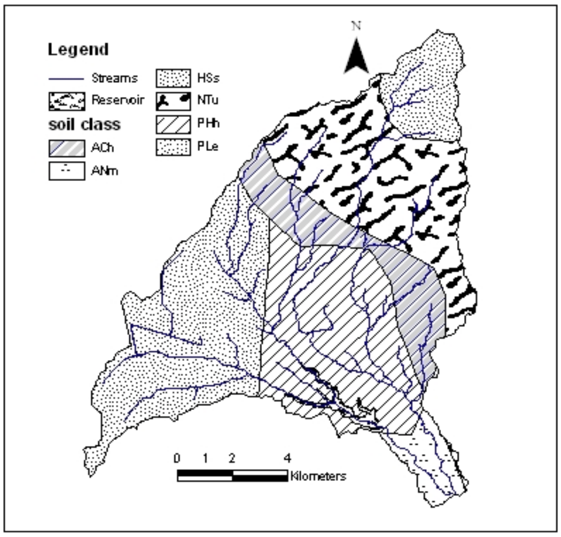

Figure 2: Soils in Sasumua watershed

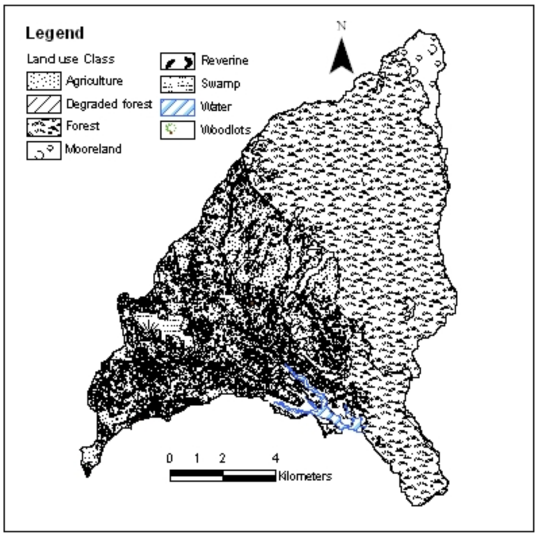

Figure 3 Land use/Land cover for Sasumua

2.2 SWAT Model

SWAT model is described in detail in Arnold *et al*. (1998), Neitsch *et al*. (2005) and Gassman *et al.* (2007). It is a physically based distributed parameter, continuous-time model that operates on a daily time step and is designed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex un-gauged watersheds with varying soils, land use and management conditions. Weather, hydrology, soil temperature and properties, plant growth, nutrients, pesticides, bacteria and pathogens, and land management are the major components in the model (Gassman *et al.*, 2007). The model partitions the watershed into a number of sub-basins depending on the critical source area specified by the user. The critical source area is required to initiate a channel flow (Arabi *et al.*, 2008). The sub-basins are further partitioned into Hydrologic Response Units (HRUs). A HRU has homogeneous soil properties, land use and land management. The model allows the user to define the HRU by either the dominant land use and soil type in which the HRU will be equal to the sub-basin or by percentage of the land use and soil type which will result into multiple HRUs in the same sub-basin.

2.3 Model setup

SWAT 2003 which runs on an interface of ArcView GIS was used for this study. SWAT model inputs for this study were a DEM with a spatial resolution of 10 m from World Agroforestry Center (ICRAF), a land use map generated using digital image classification of Aster satellite images of 2007 (from ICRAF) and soil data from SOTER database for East Africa.

Twenty seven years of climate data (1970-1996) from Kenya Meteorological Station number 9036188 in the dam site area and from South Kinangop forest rainfall station (9036164) (Figure 1) was used. The watershed was subdivided into 62 sub-basins with the same number of HRUs. Dominant land use and soil was used as the criteria for HRU definition such that the dominant land use and soil in each sub-basin were used to represent the sub-basin in the model. Management operations were scheduled by dates. In SWAT, operations can be scheduled either by heat units of by dates (Neitsch *et al*., 2005). Irish potato is the main crop grown in the area and is usually rotated with cabbages and there are on average three growing seasons in a year (Mwangi, 2011). One-year crop rotation was selected to be representative for Sasumua and was used in the model the operations in the agricultural land as shown in Table 1.

Table 1: Management operations modeled for the agricultural land.

Operation	**Date**
Planting POTA (potatoes)	1st March
Harvesting (harvest and kill)	31st May
Planting CABBAGE	15th June
Harvesting (harvest and kill)	15th September
Planting POTATO	1st October
Harvesting (harvest and kill)	31st December

2.4 Model Calibration

Water balance in the reservoir was used to calculate the inflow data which was then used for calibration and validation of the model. For sediments, proper parameterization guided by literature and field visits was carried out. For calibration purpose, a 'theoretical gauge' was put at the location of the dam. The inflow into the reservoir was used as to represent the measured stream flow at the 'theoretical gauging station'. The inflow was computed from the water balance of a reservoir .

where V_{inflow} is the volume of water entering the reservoir during the day (m3), V_{end} is volume of the water at the end of the day (m3), $V_{beginning}$ is volume of water in the reservoir at the beginning of the day (m3), $V_{flowout}$ is the volume of water flowing out of the reservoir during the day (m3), V_{pcp} is volume of precipitation falling on the reservoir during the day (m3), V_{evap} is volume of water removed from the reservoir by evaporation during the day (m3), V_{seep} is volume of water lost from the reservoir through seepage (m^3) this was assumed to be in significant and its value assumed to be zero.

The outflow data from the reservoir over the spillway was not available and therefore the outflow considered during the water balance was only the water abstracted from the reservoir for treatment. Therefore the accuracy of the inflow data calculated was high during the time periods when the reservoir was not full and low when the reservoir was full. When the reservoir was full the outflow over the spillway was not accounted in the water balance.

Calibration and validation was done using monthly data and therefore the daily reservoir inflows were converted to mean monthly inflows. The flow data for the period between 1988 and 1993 was used for calibration. The first two years were used as the warm up period. Manual calibration was carried out where after running the model, the simulated mean monthly flow was plotted along the observed (calculated) mean monthly flow. Both visual and statistical methods were used to assess the goodness of fit between the simulated and the observed stream flow. Coefficient of determination (R^2) was used to numerically test the model performance. R^2 varies between 0 and 1 with 1 being ideal for a perfect fit. An R^2 of 0.5 and above was considered reasonable for this study considering the accuracy of the data used. The mean monthly reservoir levels were also plotted on the same graph with the monthly simulated and measured hydrographs. The reservoir levels were used to show whether the reservoir was full or not for each month used in the calibration and validation. This was important to explain the fit between the simulated and the observed flows because when the reservoir was full, there was unaccounted water in the water balance which affected the fit between the simulated and the observed hydrographs.

2.5 Model Validation

To demonstrate that the calibrated model was capable of making accurate predictions, the model was validated. The reservoir inflow data was used for the validation just as in the case of calibration. The model was validated by data for the period between 1994 and 1997. Both calibration and validation periods were chosen to correspond to the time when there was relatively good data for calculation of the reservoir water balance components. During validation process, the model parameter values set during the calibration were maintained constant. The resulting stream flow (simulated) was compared visually with the observed stream flow in a graph. Coefficient of determination was also established.

2.6 Simulation of land condition Scenarios

Three scenarios were carried out namely, base, improved land surface condition and degraded land surface condition. Improved land surface condition scenario simulated less intensive cultivation and well managed grazing. This practice would encourage more infiltration of water into the ground and reduce both surface runoff and soil erosion. Degraded land surface condition scenario simulated the degradation of the watershed where intensive cultivation and overgrazing dominates. This practice would impede infiltration of water and increase surface runoff and subsequent soil erosion. Base scenario was the referenced land surface condition and simulated 'business as usual' condition.

For base simulation scenario, the parameter values obtained during calibration and used during validation were used without any adjustment. Improved land surface condition scenario was simulated by decreasing the Curve Number (CN) by 6 units (CN-6) from the base simulation case. The degraded land surface scenario was simulated by increasing the **CN** by 6 units (CN+6) from the base simulation scenario. CN-6 represents increase in infiltration and thus a decrease in the surface runoff whereas CN +6 represents low infiltration and high surface runoff (USDA-NRCS, 2004). CN-6 can be achieved through contour farming, terracing, addition of organic matter, better crop residue and surface roughness management. CN+6 will occur where there is soil compaction, poor management of crop residue and soil cover and where there is generally poor soil and water conservation (Gathenya *et al.,* 2011).

3 Results and discussions

3.1 Model Calibration

Figure 4 shows the calibration plot for stream flow. Monthly data was used for calibration. The figure shows the 'measured' (generated from the reservoir) and simulated stream flow in addition to mean monthly reservoir data for the same period. The fit between the simulated and 'measured' flow hydrographs with an R^2 of 0.6 was found satisfactory under the existing conditions considering that some water was not accounted for in the reservoir water balance which was used to generate the flow data. The reservoir capacity when full is 16 million cubic meters of water.

It can be seen that the reservoir was full during the periods April—July 1990 and 1993, during the rainy season. The overflowing water through the spillway is not gauged at the reservoir. This water was therefore not accounted for in the reservoir water balance which was used to calculate the inflow into the reservoir. The reservoir inflow was used as the 'measured' stream flow in the calibration and validation of the model. During the rainy season when the stream flow is high, the pipe from Kiburu sub-watershed can only carry a limited capacity and so when full, the rest of the water goes downstream through Kiburu stream and does not go to the reservoir. The simulated flow would however include this water. In 1991 and 1992, there is a relatively close agreement between the simulated and the 'measured' stream flows. Although April-July is a rainy season, the reservoir was not full during that period in 1991 and 1992. This means that little or no water was lost through the spillway during that period.

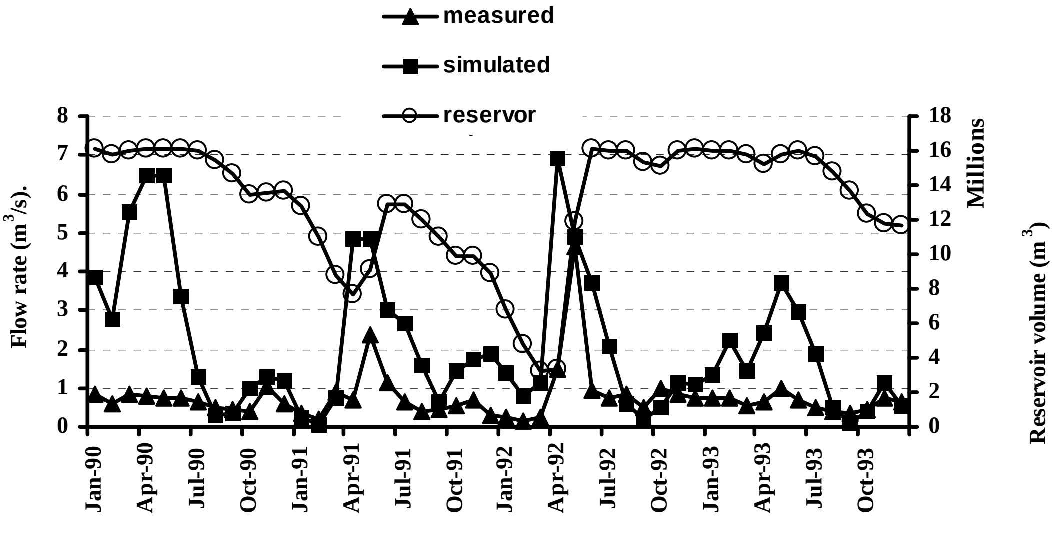

Figure 4 'Measured' and simulated stream flows comparison with mean monthly reservoir volumes

3.2 Model Validation

The validation period was from 1994 to 1997. On average, there was reasonable agreement between the 'measured' and the simulated stream flows with an R^2 of 0.5. Like in the case of the calibration, the simulated stream flows was slightly higher than the 'measured' flow during the rainy seasons of April-July of 1995, 1996 and 1997. Again, this is a wet season and there was unaccounted for water in the reservoir water balance. This is as shown in the Figure 5 which represents the mean monthly simulated and 'measured' steam flows together with the reservoir volumes. In April—July of 1994, the reservoir was not full and therefore little or no water was lost from the system and hence the close fit between the hydrographs.

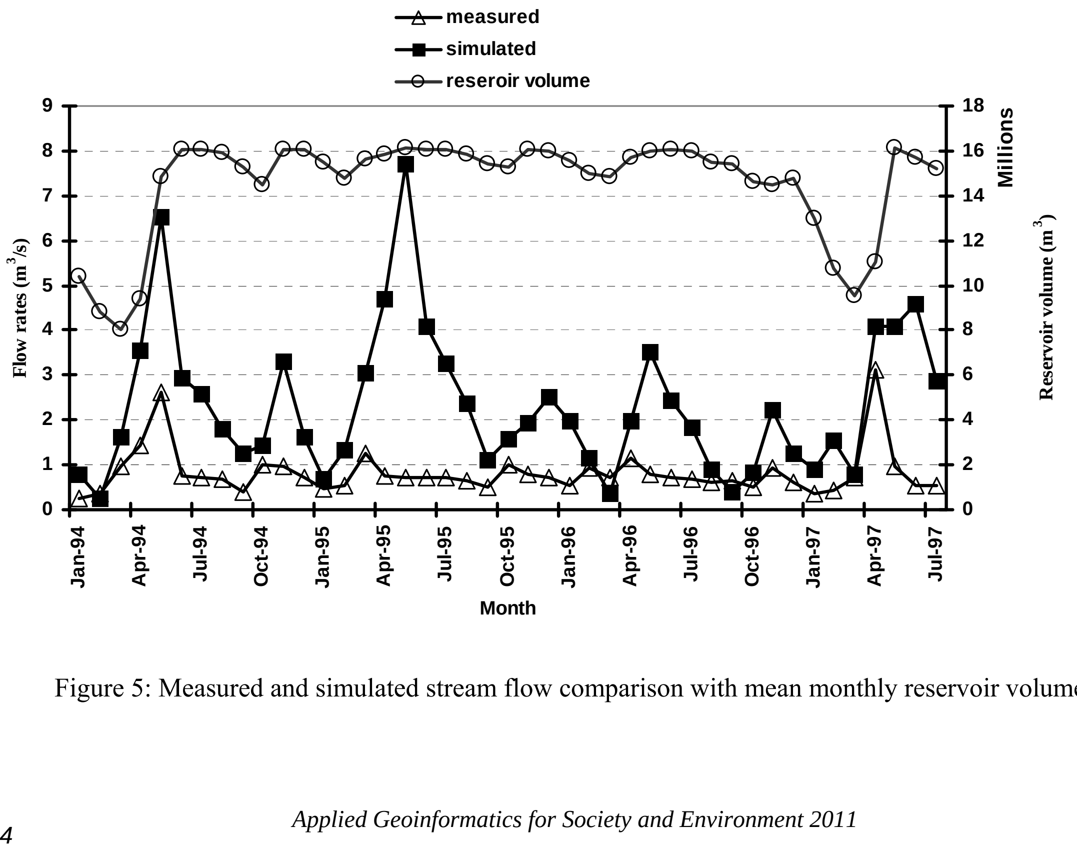

Figure 5: Measured and simulated stream flow comparison with mean monthly reservoir volumes

3.3 Land management scenario analysis

Model simulation results for degraded land surface conditions showed that sediment loading to the streams would increase by 53.6% while improved land surface condition would reduce the sediment loading by 34.3% in reference to the base simulation. (Table 2). This implies that measures need to be taken to avoid degradation of the watershed which if not controlled will limit the capacity of the watershed to produce good water quality. Degradation is more likely to happen with the increasing population in the watershed. If, however, soil and water conservation measures that will improve the land surface condition to allow more infiltration will be implemented, then soil erosion in the watershed will reduce and sediment loading will reduce by 34.3%. The sediment loading reduction will reduce the cost of treatment of water from the reservoir and siltation of the reservoir.

Table 2 also shows that surface runoff would decrease by 28.5% and base flow increase by 13.8% for improved land surface condition. This is the desired land management option that would enhance the capacity of the watershed to provide the watershed services i.e. reduce flooding and increase the quantity of flow during the dry weather. It is also worth noting that improved land management would only have a slight change in the total water yield. This means water will only be portioned in the different components without having a major change in the total available water in the watershed. If the watershed is degraded, then infiltration will be limited and surface runoff will increase by 44% and base flow reduce by 10.5%. Thus degradation of the watershed would increase the flash floods, reduce the dry weather flows and should therefore be avoided.

Positive land use change would therefore enhance the provision of the watershed services (improve water quality and increase dry weather flows) while negative land use change would cause degradation of the watershed and limit its capacity to produce the services.

Table 2: Sediment loading and water balance for base scenario, improved (CN-6) and degraded (CN+6) land surface conditions

	Sediment yield ($\times 10^3$ tons/year)	Surface runoff (mm)	Lateral flow (mm)	Base flow (mm)	Water yield (mm)
Base simulation	32.62	193	184	304	680
Degraded land surface condition scenario (CN+6)	50.11	278	176	272	724
% change	**+53.6**	**+44**	**-4.3**	**-10.5**	**+6.5**
Improved land surface condition scenario (CN-6)	21.43	138	190	346	672
% change	**-34.3**	**-28.5**	**+3.3**	**+13.8**	**-1.2**

4 Conclusions

SWAT model was calibrated and validated for Sasumua watershed using historical daily measurements of reservoir volume. It was then used to investigate the effect of land use changes on the provision of watershed services and in particular reduction in sedimentation and increase of dry weather flows. Positive land use change would enhance the capacity of the watershed to provide the watershed services while negative land use would limit its capacity.

Calibration of the SWAT model was done manually for flow. A coefficient of determination of 0.6 was achieved for calibration and 0.5 for validation. The coefficient of determination achieved was reasonable to represent the watershed in the model and therefore the SWAT model was successfully used to simulate watershed processes in Sasumua.

Land use change that would improve the land surface condition was found to reduce the sediment loading by 34.3%. It would also reduce the surface runoff by 28.5 % and increase the baseflow by 13.8 %. Land use change that would cause degradation of the watershed lead to increase in soil erosion and subsequent pollution of water by sediments. Degradation of the watershed would increase the sediment loading to the streams and the reservoir by 53.6%, increase the surface runoff by 44% and reduce the baseflow by 10.5 %. Positive land use change that would improve the condition of the land surface was recommended.

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Evaluation of the most Appropriate Method in Orographic Rainfall Data Reconstruction of Mbeere District of Kenya Using GIS Tools For Agricultural Development

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ABSTRACT

In most water resources management and agricultural production studies in sub-Saharan Africa, the predominant problem in analyzing hydro-meteorological events are occasioned by either lack of or inadequate and inconsistent meteorological data. Like in most other places, the rainfall data within the Mbeere district and neighboring stations are scarce with missing data making their utilization a challenge. Mbeere district represents a semi-arid region with low potential in terms of agricultural production. This study sought to determine the most appropriate geostatistical interpolation approach for spatial and temporal reconstruction of rainfall data in Mbeere based on the gauged data from the neighboring meteorological stations. Rainfall data of the neighboring stations were processed using Microsoft Excel spreadsheet where missing data gaps were filled through correlation functions derived from elevation versus recorded rainfall amounts. Linear functions were derived and fitted into the GIS environment tool combined with the Digital Elevation Model (DEM) for orographic construction of monthly average maps starting from January 2001 to December 2008 using various interpolation techniques. The performance of the various interpolation methods were assessed using Root Mean Square Errors (RMSE), Mean Absolute Errors (MAE) and correlation coefficient (R) statistics and utilizing rainfall data from specific research site for validation. Based on the study results, Kriging was identified as the most appropriate geostatistical and deterministic interpolation technique that can be used in spatial and temporal rainfall data reconstruction in the region. Finally, based on the constructed data, updated average monthly and annual rainfall maps of Mbeere district were produced.

1 Introduction

Geographic Information System (GIS) and modeling have become dominant tools in agricultural research and, Natural Resource Management (NRM). Thus, spatial and temporal estimates of climatic data are increasingly utilizing GIS modeling and applications (Collins & Bolstad, 1996) with prime intent of optimizing agricultural production. There is need for accurate and inexpensive quantitative approaches to spatial data acquisition and interpolation. In Kenya, small holder farmers in the densely populated central highlands are resource deprived operating below the agricultural potential. They have been experiencing declining crop yields due to low, erratic and unreliable rainfall (Mugwe et al, 2006). Reduced rainfall has led to low soil water availability for crop productivity. Although water is limiting, it is either the rainfall distribution or lack of it that affect crop growth and final yields. However, to optimally utilize rainfall in the rain-fed agricultural system in the study area, understanding its occurrence, patterns and distribution both temporally and spatially through hydrological and meteorological analysis is required. Thus, information on rainfall events (rainfall data and patterns), flow depths, discharges, evapo-transpiration, and other meteorological data for this region is required. However, most data in the meteorological stations in Mbeere are inconsistent, unrecorded or missing; leading to more discrete and unreliable data for analysis apart from the main stations themselves being several kilometers from the target area. Utilization of the spatial tools, Inverse Distance Weighted (IDW), Spline and Kriging interpolation techniques are some of the applications exhausted in the ArcGIS tool essential for data reconstruction. Kriging is a geostatistical gridding and flexible technique that has proven useful and popular in many fields and is supported by the ArcGIS software. This technique generates visually appealing maps from intermittently spaced data. Kriging attempts to convey the trends produced by data, so that, high points are joined along a ridge rather than be isolated by bull's-eye form of contours. This depends on the user-specified parameters during data input. It integrates anisotropy as well as the underlying trends in an efficient and natural way (Yang et al., 2006). Unlike the other interpolation techniques supported by the ArcGIS Spatial Analyst, Kriging utilizes an interactive analysis of the spatial trends of the events represented by the z-values before selecting the accurate estimation technique for spawning the output surface. IDW interpolation overtly implements the premise that things that are close to each other are more identical than those that are farther apart. Thus, predictably, values close to the gauged point have predominant influence on the generated value on assumption that the gauged value has a local influence which diminishes with distance. Spline technique estimates values via a mathematical function which minimizes general surface curvature, resulting into an even surface that interconnects all the input points. Conceptually, the gauged points are extruded up to the height of their magnitude. This study sought to utilize computer applications of ArcGIS tools to reconstruct rainfall data through appropriate and reliable techniques that employ geostatistical or deterministic interpolation techniques. To do this appropriately, homogeneity testing and frequency analysis were other objectives. The output of this study is invaluable to farmers, researchers and model users, for planning, designing and implementing effective and efficient agricultural programs and projects locally, regionally, and at national scale.

2 Materials and Methods

2.1 Selection of the Study Area

The study was conducted in Mbeere District in the Central Highlands of Kenya. Mbeere district lies in the Lower Midland 4 and 5 Agro-ecological zones (Jaetzold et al., 2007) on the Eastern slopes of Mount Kenya at an altitude between 700 and 1200 m above the sea level (asl). The mean annual temperature ranges from 20.7oC to 22.5oC with soaring evapotranspiration trends. The area receives an average annual rainfall between 700 and 900 mm. The rainfall received is bimodal with Long Rains (LR) from mid March to June and Short Rains (SR) from late October to December and hence two cropping seasons per year. The site soils are predominantly ferric in nature (Jaetzold et al., 2007). Various agriculture-based studies have been carried out in the region and that led to its selection. According to (Mugwe et al., 2006), the region has experienced drastic declines in its productivity potential rendering its populace resource poor. There is a secure tenure system on land ownership but underscore in productivity due to inadequate information on the rainfall patterns. The prime crop is maize intercropped with beans though livestock keeping is equally dominant. Some of the distinctive characteristics of this region are summarized in table 1.

2.2 Selection of study sites and data collection methods

Primary and secondary meteorological data from five gauging stations were collected. Much of the primary data was acquired from the ongoing recordings at Embu, Kamburu, Kindaruma, Machang'a and Kiritiri Meteorological stations. Additionally, long term secondary data was acquired from the Kenya Meteorological Department in Nairobi. Further, supportive analytical data was taken from published works.

3 Results

3.1 Rainfall Averages

The results for the rainfall averages indicate a correlated trend amid the generated and recorded data.

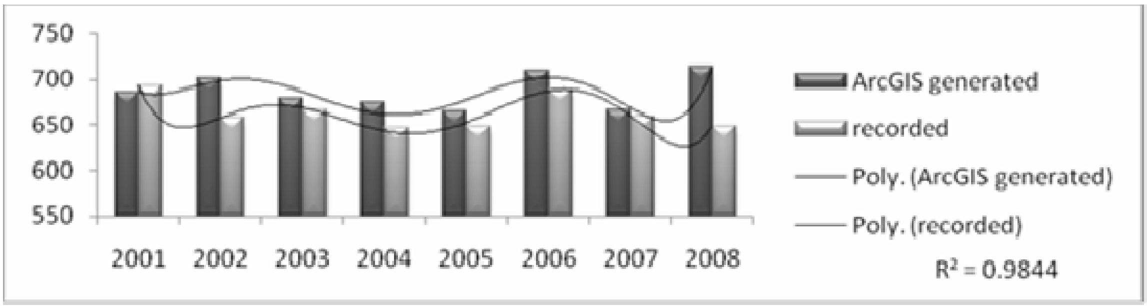

Fig 1 Comparative outlook of the generated and recorded amount of Mbeere District (Rainfall in mm Vs. Years)

3.2 Homogeneity Testing and Frequency Analysis (RAINBOW-IuPware)

The frequency analysis utilized normal probability distribution with various transformations for different months. Weibull method for estimating probabilities and Method of Moment (MOM) parameter estimation method were also utilized in all the analyses. The means, standard deviations, Kolmogorov-Smirnov Test and R-Square are shown in Table 1.

Table 1, Data transformations and distribution tests before frequency analysis

Month	**Transformation**	**Kolmogorov-Smirnov Test (K-S)**	**Non Nil values*(n)***	***Mean***	***Std Dev.***	**R^2 (%)**
Jan	cube root	0.1500	29	2.9	1.4	96
Feb	cube root	0.1146	22	2.7	1.2	97
Mar	square root	0.1557	32	10.1	3.3	96
Apr	square root	0.0560	32	17.2	3.9	98
May	square root	0.1457	32	12.4	4.2	94
Jun	log10	0.0797	32	1.3	0.3	98
Jul	square root	0.0620	32	5.1	1.4	99
Aug	log10	0.0805	32	1.5	0.3	98
Sep	square root	0.0826	32	5.2	2.3	98
Oct	square root	0.0817	32	12.2	4.6	98
Nov	square root	0.0961	32	15.4	3.3	98
Dec	square root	0.1240	32	8.0	3.6	96

Table 2: Frequency analysis results; Probability of exceedence and return periods of monthly rainfall events

Probability of exceedence (%)	Return period (year)	Magnitude (rainfall mm)											
		Jan	Feb	*Mar*	Apr	May	Jun	Jul	Aug	Sep	*Oct*	Nov	Dec
20	5	64	40	*164*	419	253	41	40	53	50	*258*	331	117
40	2.5	30	16	*118*	330	181	26	30	37	33	*179*	264	74

50	2	20	9	100	295	154	22	26	32	27	149	237	59
60	1.67	12	3	84	262	129	18	22	27	21	122	212	45
80	1.25	2	0	50	193	79	12	15	19	11	70	159	18

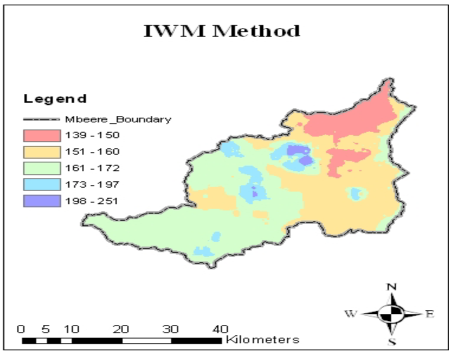

Figure 2, IWM Average Rainfall Map

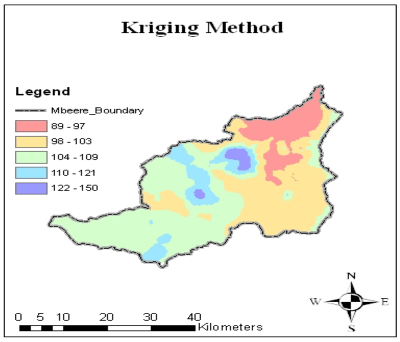

Figure 3, Kriging Average Rainfall Map

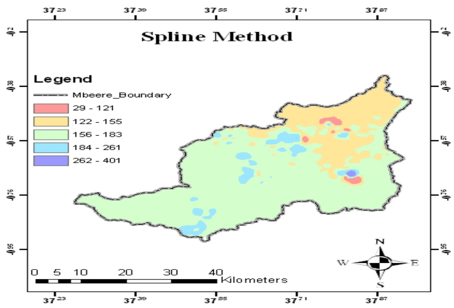

Figure 4, Spline Average Rainfall Map

4 Discussion

4.1 Homogeneity Test

This test was intended to establish whether the collected date came from the same population. From the results, the number of outliers (the values that were not considered) was zero. Similarly, the Number of NIL-values (values above threshold) was also zero. Thus, the cumulative deviation had to be rescaled by dividing the initial and last values of the standard deviation using equation 1:

$$S_k = \sum_{i=1}^{k}(X_i - \bar{X}) \qquad k = 1, \ldots, n \qquad (1).$$

Critical figures for the test-statistic that test the significance of the departures from homogeneity were also plotted in the Homogeneity plot menu as well (3 horizontal lines). None of the cumulative deviation crossed any one of the horizontal lines and hence no homogeneity of the data set was rejected at all the levels of probability.

4.2 Frequency Analysis

The frequency analysis utilized normal probability distribution with assorted transformations for different months (See Table 1 for results).

In this study, the probability of exceedence at 50% was considered for analysis (Table 2). The months of January, February, June, July, August and September are characterized with low rainfall averages of between 9 and 32mm. For any agricultural planning, these periods were considered dry season, while the remaining months as wet season. The region is thus characterized by two rainfall seasons; of short rains and long rains (Fig 1). Being a dry land region, maize, beans, are some of the crops that the study recommends for wet seasons. On the other hand, millet, and sorghum could do well during the dry season.

4.3 Interpolation

The resultant annual rainfall maps of various spatial interpolation methods are shown in figures 2, 3, & 4. The resultant patterns of spatial distribution for each map were an outcome of the generated patterns from the mapping of the index value (the mean annual precipitation). Besides, they were influenced by the spatial local conditions (elevation) including the nonexistence of altitudinal variability of the parameters of the distribution function and the interpolation methods used. From a statistical point of view, the spatial distribution of quantiles is theoretically better underpinned in the regional Kriging (Fig. 3) approach than in the other methods tested. For this study, Kriging was extended by the regional regression for each index value for areas whose terrain or other controls could have contributed to the spatial variability of the trends. Despite the fact that usual mapping methods like Spline and IDW are considered ample only for simple climate patterns, here, their application was considered justified both by the properties of the data and the respective maps generated. Both methods presume that the modeled value is not dependent on spatial location. Additionally, they premise that variance of the differences amid two values predominantly is dictated by the distance between them but not locational variability. On the other hand, this common feature showed that the results of both methods exhibit visually and numerically similar results (Fig. 2 and 4).

5 Conclusion and Recommendations

The study showed that the rainfall patterns of Mbeere are generally homogenous. Before frequency analysis of the rainfall data is done, various transformations are essential for the data to follow particular probability distribution patters. Weibull method for estimating probabilities and MOM parameter estimation methods proved to be sufficient for the task. The purpose of the study was to produce average maps of annual precipitation as rainfall indices which could be used in agricultural planning. In the follow up investigations, the mapped information could be further processed by different interpolation methods such as IDW, Spline and Kriging for temporal and spatial reconstruction of precipitation values. Kriging appeared to be the best technique despite showing high sensitivity to inconsistent density of the stations in the district, which was an initial limitation. However, it still has some limitations including the high amount of required calculations, the need for expert judgment and the impossibility of normalizing the indices for a few months.

Finally, it is recommended that within the month's rainfall frequency analysis might be essential in order to better understand rainfall characteristics such as onset and cessation. Understanding these patterns is crucial especially for better farm management practices by the small scale farmers of Mbeere district and in the Central Highlands at large.

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Rainfall Induced Landslide Probability Mapping for Central Province

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Landslides, hazards, weights of evidence, slope instability mapping

ABSTRACT

Rainfall induced landslide hazards in Kenya represents a major challenge and remain an important issue in disaster management especially in Kenya's central province where the effects are very common with the onset of El niño rains. The main aim of this study is to develop a rainfall induced landslide probability map for Kenya's central province. In order to achieve this, process based methods were used to map landslide areas using the following factors: slope, rainfall, land cover change, Normalized Difference Vegetation Index (NDVI) change, Curvature, watershed, and soil characteristic including: type, texture, soil bulk density, Base Saturation, and Total Water Available Distribution Map. The minimum conditions were set for each factor for landslide occurrence.

Slope stability mapping was done to determine the stable areas and thus derive the probability of landslide occurrence. Statistical methods were then employed by means of weights of evidence to achieve the probability weights for each factor considered to cause landslides. The factors were then overlaid using the probability weights to obtain the probability map for landslide occurrence in central province.

The results of the study were landslide areas, Maps showing the stable and unstable areas and probability maps of landslide occurrence for central province for two epochs i.e. October 1997 – May 1998, and October 2009-May 2010. The probability weights of a factor causing landslide, showed Land cover change, Rainfall and NDVI change factors as very important for this study. It was observed that the probability map of landslide occurrence had the same pattern as rainfall distribution and that probabilities of landslide occurrence were higher with more rainfall.

1 Introduction

Rainfall-induced landslides represent a major hazard not only in Kenya but also in other parts of the world. In Kenya, preliminary statistics show that most catastrophic landslide events have been associated with rainfall. Landslides drain years of economic gains and development through disruption of people's lives through displacements, destruction of livelihoods and property, deaths and injuries. Landslides are triggered by rapid saturation of the soil, which in turn reduces cohesion, surface tension and friction. The El Niño rains experienced in the epochs October 1997 to February 1998 and October 2009 to May 2010 exacerbated the landslide hazards, thus calling for an urgent need to set up early warning systems in Kenya.

This study therefore sought to develop a landslide probability map showing the probabilities of landslide occurrences in central province. Identification of areas prone to rainfall induced landslide is a fundamental component of disaster management and an important basis for promoting safe human occupation and infrastructure development in landslide prone areas considering the devastating impacts of such landslides. The study helped to investigate the characteristics, probabilities and intensity of rainfall induced landslide hazards and factors which determine the magnitude of a landslide disaster.

The main objective was to develop a rainfall induced landslide probability map for Kenya's central province. The specific objectives were: to identify areas susceptible to rainfall induced landslides; to find out if landslide activity in the study area is related to both intense, short duration precipitation events (1–30 days) and long-lasting rainfall episodes (1–6 months); to assess the dependency between rainfall induced landslide areas with respect to land use; generate probability maps of rainfall induced landslides in the study area; to familiarize the relationship of rainfall induced landslide hazard inducing factors.

2 Study area

The study area is central province which is one of Kenya's provinces and it ranges from longitude 36°15´00"E to 37°30´00"E and latitudes 0°7´00"N to 1°15´00"S. It has a highly rugged mountainous terrain with altitude varying from 1020m to 2890m above mean sea level. Kenya's major rivers originate in the study area and their major tributaries form a dendritic drainage pattern on the slopes of Mt Kenya and the Aberdare ranges. It has fairly reliable rainfall is fairly reliable, with two seasons, one from early March to May and a second during October and November. According to the 2009 population census results, the province had a total population of 4.4 million inhabitants for an area of 13,232 km^2.

According to The Kenya Natural Hazard Profile (2010), "in Murang'a district there are reports of whole families being buried in the long rains of April and May in 2002 and 2003". Some of the factors reported to aggravating landslides in this district include: the influence of topography, human activities i.e. cultivating, deforestation and construction which destabilize the already fragile slopes.

3 Slope Instability mapping

Approaches to assess susceptibility to landslides are either heuristic, deterministic (process based), or statistical (Regmi et al. 2010). Heuristic approaches require expert opinions/observations to estimate landslide potential from data on preparatory variables. Deterministic/ GIS process based approaches are based on slope stability analysis (Xie et al., 2004), and include the physical processes involved in landslides and therefore can often better pinpoint causes of mass movement (Miller, 1995). They usually provide the most detailed results, expressing the hazard in absolute values as safety factors, or a probability of failure given a set of conditions (Barredo et al., 2000).

This study used both process-based landslide models and statistical approaches. The boundary conditions for upper and lower thresholds for possible slope failures were used to define stable and unstable areas. Unconditionally stable areas are areas predicted to be stable even when saturated and satisfy:

$$tan\theta \leq \left(\frac{C}{cos\theta}\right) + \left(1 - \frac{\rho_w}{\rho_s}\right) tan\emptyset \qquad (1)$$

Unconditionally unstable areas are areas predicted to be unstable even when dry and satisfy:

$$tan\theta > tan\emptyset + \frac{C}{cos\theta} \qquad (2)$$

Where: θ the local slope angle [°]; ρ_s wet soil bulk density [g cm+^{3}]; ρ_w the density of water [g cm^{-3}]; ϕ the effective angle of internal friction of soil [°]; and C the combined cohesion term made dimensionless relative to perpendicular soil thickness and defined as:

$$C = \frac{C_r + C_s}{D\rho_s g} \qquad (3)$$

Where: C_r is root cohesion [N m^{-2}], C_s soil cohesion [N m^{-2}], D perpendicular soil thickness [L], and g the gravitational acceleration constant (9.81 m s^{-1}).

The susceptibility to landslides was assessed through GIS techniques using Bayesian theorem based on weights of evidence (WOE). For mapping susceptibility to landslides, the WOE method calculates the weight for each causative factor of a landslide based on the presence or absence of landslides within the area. It assumes that future landslides will occur under conditions similar to those contributing to previous landslides and that causative factors for the mapped landslides remain constant over time. It therefore has two probabilities i.e. the prior probability (which is the probability of an event, determined by the same types of events that occurred in the past, for a given period of time) and the posterior probability (which is the modified / revised prior probability using other sources of information or evidence).

Favourability of an incidence of landslide given the presence of the causative factor can be expressed by conditional probability (Bonham- Carter, 2002) as follows:

$$P\{L/F\} = \frac{P(L \cap F)}{P(F)} \quad (4)$$

Where: P (L/F) is the conditional probability of the presence of a landslide (L) given the presence of a causative factor, F.

Similarly, the conditional probability of landslides based on factor F is:

$$P\{F/L\} = \frac{P(L \cap F)}{P\{L\}} \quad (5)$$

Combining equations (4) and (5), we obtain equation 6 below:

$$P\{L/F\} = P\{L\}\frac{P\{F/L\}}{P\{F\}} \quad (6)$$

This states that the conditional (posterior) probability of a landslide, given the presence of the factor F, equals the prior probability of the landslide P{L} multiplied by the factor P{F|L}/P{F}.

Dividing both sides of the Equation (6) by $P\{\bar{L}/F\}$ i.e. the probability that there is no landslide but there is a factor that cause a landslide, we obtain

$$\frac{P\{L/F\}}{P\{\bar{L}/F\}} = \frac{P\{L\}P\{F/L\}}{P\{\bar{L}/F\}P\{F\}} \quad (7)$$

Similarly, the posterior probability of a landslide, given the absence of the factor, can be determined as:

$$P\{L/\bar{F}\} = P\{F\}\frac{P\{\bar{F}/L\}}{P\{\bar{F}\}} \quad (8)$$

Similar to Equations (5) and (6), from the definition of the conditional probability is:

$$P\{\bar{L}/F\} = \frac{P\{\bar{L} \cap F\}}{P\{F\}} = \frac{P\{F/\bar{L}\}P\{\bar{L}\}}{P\{F\}} \quad (9)$$

Substituting the value of P{L̄|F} in the right side of Equation (7), produces:

$$O(L/F) = \frac{P\{L/F\}}{P\{\bar{L}/F\}} = \frac{P\{L\}\,P\{F\}\,P\{F/L\}}{P\{\bar{L}\}P\{F\}\,P\{F/\bar{L}\}} \quad (10)$$

Where: O{L|F} is the conditional (posterior) odds of L given F.

$$But, \quad \frac{Probability\ that\ an\ event\ will\ occur}{Probability\ that\ an\ event\ will\ not\ occur} = \frac{P\{L\}}{P\{\bar{L}\}} = O\{L\} \quad (11)$$

From Equations, (10) and (11), it can be rewritten as:

$$O\{L/F\} = O\{L\}\frac{P\{F/L\}}{P\{F/\bar{L}\}} \quad (12)$$

Where: O{L} is the prior odds of F.

$\frac{P\{F/L\}}{P\{F/\bar{L}\}}$ is known as the sufficiency ratio abbreviated as LS (Bonham-Carter, 2002).

In WOE, the natural logarithm of the sufficiency ratio is W^+.

$$W_i^{+} = \log_e \frac{P\{F/L\}}{P\{F/\bar{L}\}} \qquad (13)$$

Thus, Similarly, taking the natural log of Equation (12) on both sides, produces:

$$W_i^{+} = \log_e \frac{O\{L/F\}}{O\{L\}} \qquad (eqn\ 14)$$

Similar algebraic manipulation leads to the derivation of an odds expression for the conditional probability of L given the absence of the factor. Thus,

$$O\{L/\bar{F}\} = O\{L\} \frac{P\{\bar{F}/L\}}{P\{\bar{F}/\bar{L}\}} \qquad (eqn\ 15)$$

The term $\frac{P\{\bar{F}|L\}}{P\{\bar{F}/\bar{L}\}}$ is known as the necessity ratio, LN (Bonham-Carter, 2002). W^{-} is the natural logarithm of LN. Thus,

$$W_i^{-} = \log_e \frac{P\{\bar{F}/L\}}{P\{\bar{F}/\bar{L}\}} \qquad (eqn\ 16)$$

Similarly, taking the natural log of Equation (15) on both sides gives:

$$W_i^{-} = \log_e \frac{O\{L/\bar{F}\}}{O\{L\}} \qquad (eqn\ 17)$$

LN and LS are also referred to as likelihood ratios. If the pattern is positively correlated, LS is greater than 1 (W^{+}=positive) and LN ranges from 0 to 1 (W^{-}=negative). If the pattern is negatively correlated, LN would be greater than 1 (W^{-}=positive) and LS ranges from 0 to 1 (W^{+}=negative). If the pattern is uncorrelated with a landslide, then LS=LN=1 ($W^{+}=W^{-}=0$) and the posterior probability would equal the prior probability, and the probability of a landslide would be unaffected by the presence or absence of the factor. When more than one factor occurs, it is necessary to combine weights of all the factors. For example, when two factors are present:

$$O\{L/_{F_1} \cap F_2\} = O\{L\} + LS_1 + LS_2 \qquad (eqn18).$$

$$Logit\{L/_{F_1} \cap F_2\} = Logit\{L\} + W_1^{+} + W_2^{+} \qquad (eqn\ 19)$$

Therefore, the general expression for combining i=1, 2, …, n maps containing data on factors is:

$$Logit\{L/_{F_1} \bigcap F_2 \bigcap F_3 \bigcap F_4 \ldots\ldots\ldots F_n\} = Logit\{L\} + \sum_{i=1}^{n} W^{+} \qquad (eqn\ 20)$$

4 Methodology

The methodology involves data collection, derivation of factors, determining and extracting conditions favourable for landslide event, overlaying and intersecting the dataset to map the areas, stability mapping, derivation of probability weights and their application to overlay the factors resulting in landslide probability maps.

4.1 Description of the Data and the derivation of factors

The following data was used: Rainfall data, Soil data, DEM / elevation, Land-cover change, NDVI change, Curvature, and Watershed. Landslide occurrence was observed under the following conditions: rainfall> 1160mm (in 8 months period), soil properties: soil texture= clayey & well drained, BULK[4] >1, TAWC >10 and BSAT >50, DEM derivatives: slope >60º, curvature >1 and watershed>128, Land-cover change >± 10% and NDVI change <0%.

[4] BULK – Bulk density (density of the soil) , TAWC- Total Available water capacity, BSAT- Base saturation

Landsat TM images for scenes: p168r060, p168r061& p169r060 taken in the month of February, for the years 1995, 2000 and 2002 were used. The scenes were mosaiced and subset for each year. Maximum likelihood supervised classification method was used to classify the Landsat images. The overall classification accuracy was 79%, 74% and 82% for the years 1995, 2000 and 2002 respectively.

Change detection was then performed for the epochs 1995-2000 and 2000-2002. NDVI for each of the images was calculated and the NDVI values range is as follows: 0.98 to -1, 1 to -1, and 0.80 to -1 for the years 1995, 2000 and 2002 respectively. The NDVI change was as shown in Table 1. ***[Table 1 here]***

A 30m resolution DEM data from ASTER Data was used to derive slope, flow direction, curvature, upslope contributing area, flow accumulation, and watershed map. Slope angles ranged between 0^{o} to 88^{o}, curvature values ranged between -13 to 569, while watershed values ranged between 1 to 255. Rainfall data from 14 stations for the epochs October 1997 to May 1998 and October 2008 to May 2010 respectively were used. Kriging method was used with the rainfall data at the measured stations to interpolate the rainfall across the study area. The results are shown in figure 1. ***[Figure 1 here]*** Soil properties affect landsliding by determining how much water the soil can retain, the rate of permeability and its erodibility factor. BSAT values were ranging from 0 to 100, BULK values: 0 to 1.47 and TAWC: 0 to 35. Figure 2 shows the area that satisfies soil conditions for landslide occurrence.

4.2 Landslide areas and Results

The minimum condition for landslide occurrence for each of the factors described above in section 4.1 was applied on each of the factor by selection / extraction by SQL statements into a separate layer. Land-cover, NDVI and Rainfall factors were extracted for two epochs i.e. 1997/1998 and 2009/2010 and were overlaid with the other factors (with exception of Land-cover change) using equal weights. The result of this overlay is shown in figure 2a. ***[Figure 2a here]*** In order to test the effect of land-cover change on landslide occurrence, land-cover change factor was combined with the overlay in figure 5 to obtain figure 2b. ***[Figure 2b here]***

4.3 Stability mapping and Results

Stability mapping procedure was done considering equations1 & 2 and using the following factors: slope angle

θ, soil cohesion C, friction angle ϕ, bulk densityρ_s and water density ρ_w**.** To apply the two equations, all the

factors were required as single themes in raster format. The right and left hand side of equations 1and 2 were then executed separately. The areas returned as true for equation 1 were unconditionally stable areas while those that returned true for equation 2 were unconditionally unstable areas as shown in Figure 3. ***[Figure 3 here]***

4.4 Derivation of Probability weights for Factors

The results obtained in section 4.3 above were used to determine the probability of landslide occurrence P(L) and the probability of no landslides P($\bar{L}$) for the whole central province. From definition of probability, then P(L) =0.389 and P($\bar{L}$) =0.611 from equation 21 below.

$$P(L) = \frac{\textit{The number of unstable cells}}{\textit{Total number of cells}} \qquad P(\bar{L}) = \frac{\textit{the number of stable cells}}{\textit{Total number of cells}} \qquad (eqn\ 21)$$

For each factor deemed to cause landslide, as described in section 4.1, the probability was calculated as shown in table 2. ***[Table 2 here]*** Similar weights were also calculated for landslide causing factors in the year 2009/2010 as shown in Table 2. ***[Table 3 here]*** For the two epochs, the probability of landslide due to land cover and NDVI changes were much higher than other factors.

4.5 Application of the weights to overlay the factors and Results

The factors were overlaid using the scaled weights obtained in section 4.4 above. The result was then overlaid with the stable areas while applying P(L) and $P(\bar{L})$ respectively. The final result is shown in Figure 4. ***[Figure 4 here]***

5 Discussion

Epochs 1997/1998 and 2009/2010 had similar scale ranges for both landslide areas with and without land-cover change i.e. 0-70 to 0-99.7 respectively. There was more emphasis on man-made developments which disturbs the soil greatly, such that areas with such developments were at a higher scale value than areas with no developments. The effect of land-cover change on landslide probabilities may be explained in table 4. ***[Table 4 here]*** The landslide areas obtained were compared with OCHA landslide regions and approximately 62.3% of the mapped area was within the landslide zone by OCHA. Villages reported to have suffered landslides in the recent past in Mathira and Mukurweini divisions were well within the mapped areas.

It can be noted from the stable and unstable areas, Figure 3 (a) and (b), that the classification results are almost identical in both cases. However the slight difference can be attributed to the condition of instability even at dry levels when triggering factors of moving water are absent.

The probability of landslide occurrence, Figure 4, in the epoch 1997/98 ranges from zero to 99%, while that of 2009/10 ranges from zero to 62%. That remarkable difference can be induced from rainfall which was much higher in 97/98 period than in 2009/10 period, and NDVI changes where the 97/98 period recorded a general decrease in NDVI while there was a general increase in NDVI values towards the year 2002.

Conclusions

The landslide probability map for the two epochs displays a similar pattern to rainfall distribution. The difference in probability values for epoch 1997/98 (0-99%) and 2009/10 (0-62%) can be attributed to the rainfall difference in the two epochs. It can be noted that the most important factors for landslide occurrence in central province are the amount of continuous rainfall and decrease of NDVI as a result of decrease in agricultural areas and forests.

Areas susceptible to rainfall induced landslide were successfully mapped and validated against OCHA landslide prone areas, of which 62.3% of the mapped area was within the OCHA landslide prone areas. It was also noted that most landslide activity is associated with heavy rainfall as north-East parts of the central province had the lowest probability of landslide occurrence and they registered the least rainfall.

Application of the weights of evidence on the factors causing landslides shows the relationships between the factors and can be used as basis for modeling. By varying the application of land cover change in the factors to map landslide areas, the results showed a remarkable difference implementing that land cover change should not be ignored in landslide studies. Also during the weights of evidence Land-cover and NDVI changes had the greatest weights and therefore their importance in determining landslide occurrence in Central Province.

It was also observed that slope instability mapping conditions for unstable and stable areas resulted in slightly different values of stable and unstable areas. This can be attributed to the fact that unconditional instability condition predicts areas to be unstable even when it is dry. For the case of rainfall induced landslides, water flow facilitates movement of the land masses and therefore the difference between the values obtained using stable and unstable conditions.

Acknowledgments

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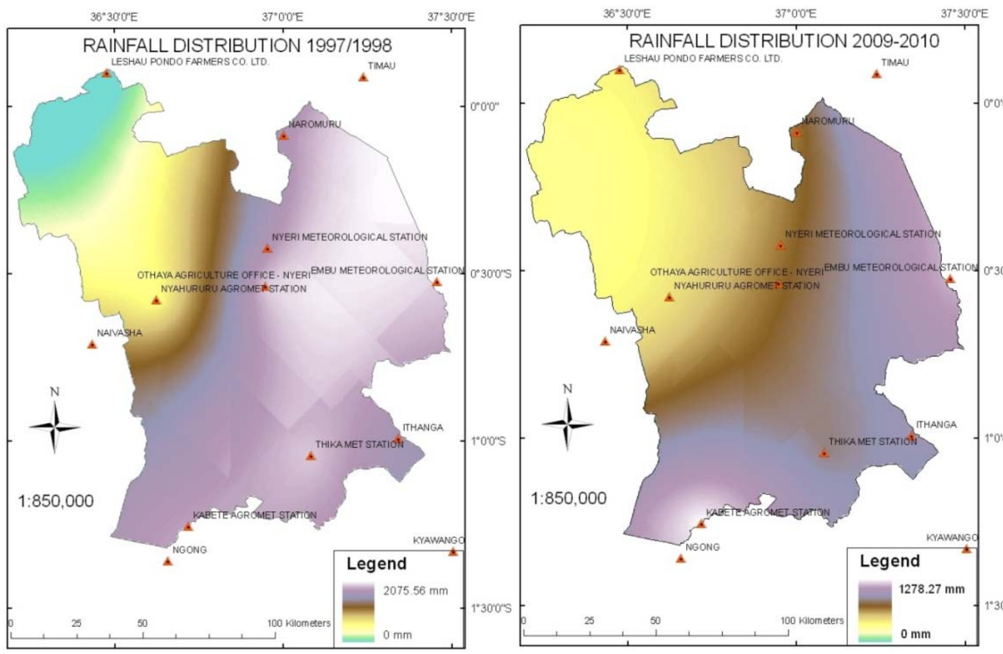

Figure 1: Rainfall distribution (a) October 1997- May 1998 and (b) October 2009- May 2010

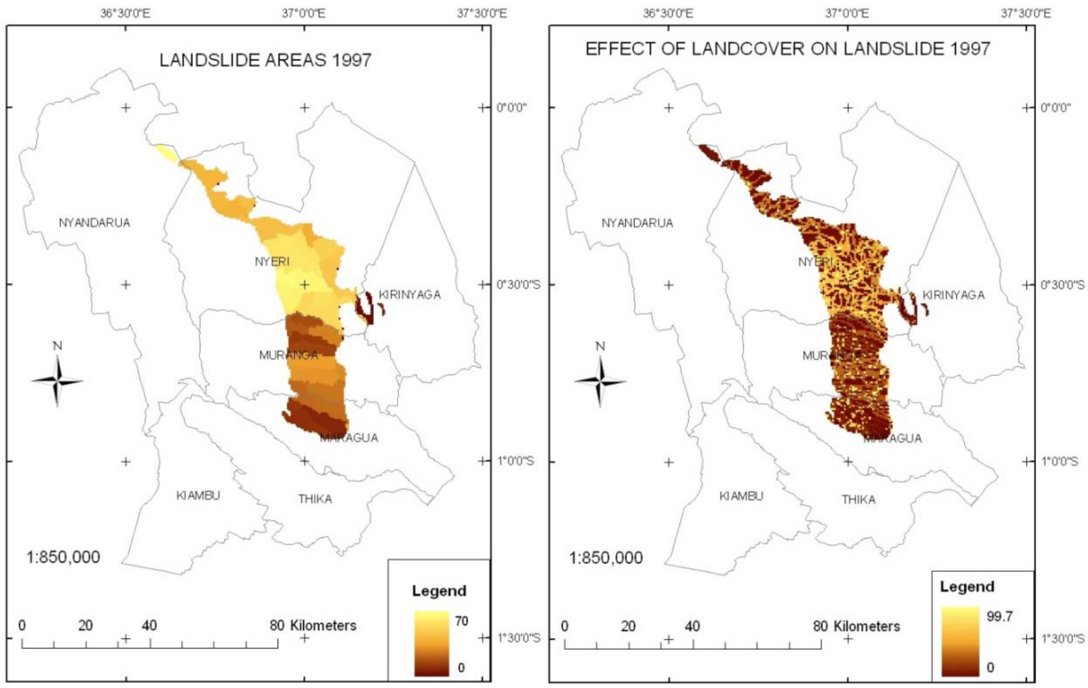

Figure 2: (a) Landslide areas (b) Landslide areas in relation to land-cover

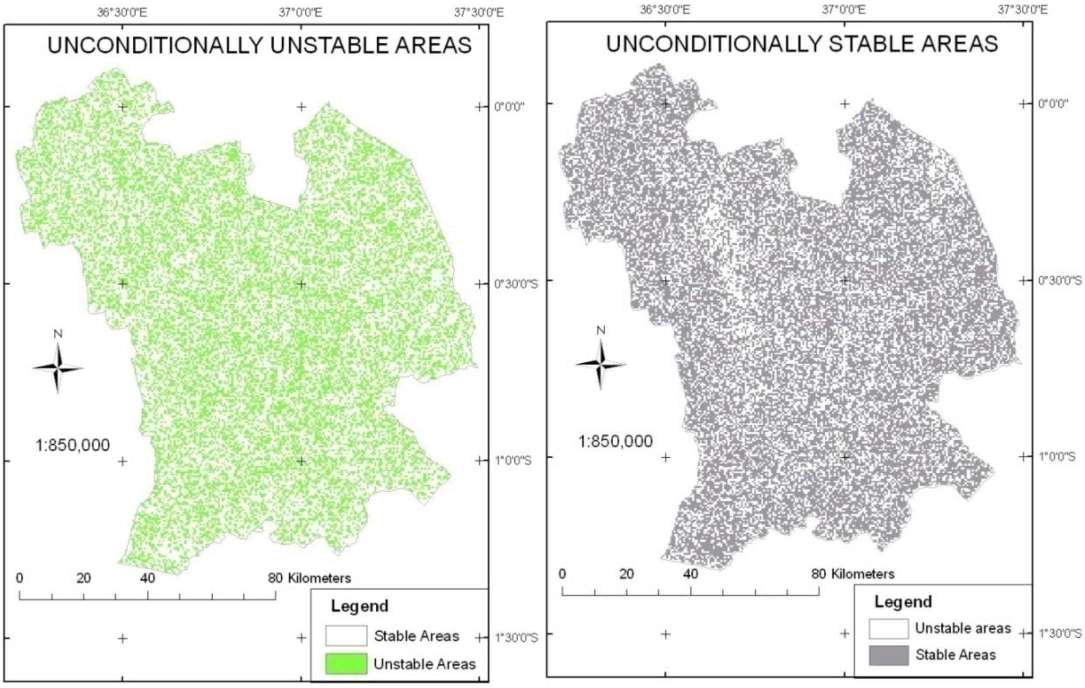

Figure 3: Unconditionally (a) stable areas and (b) Unstable areas

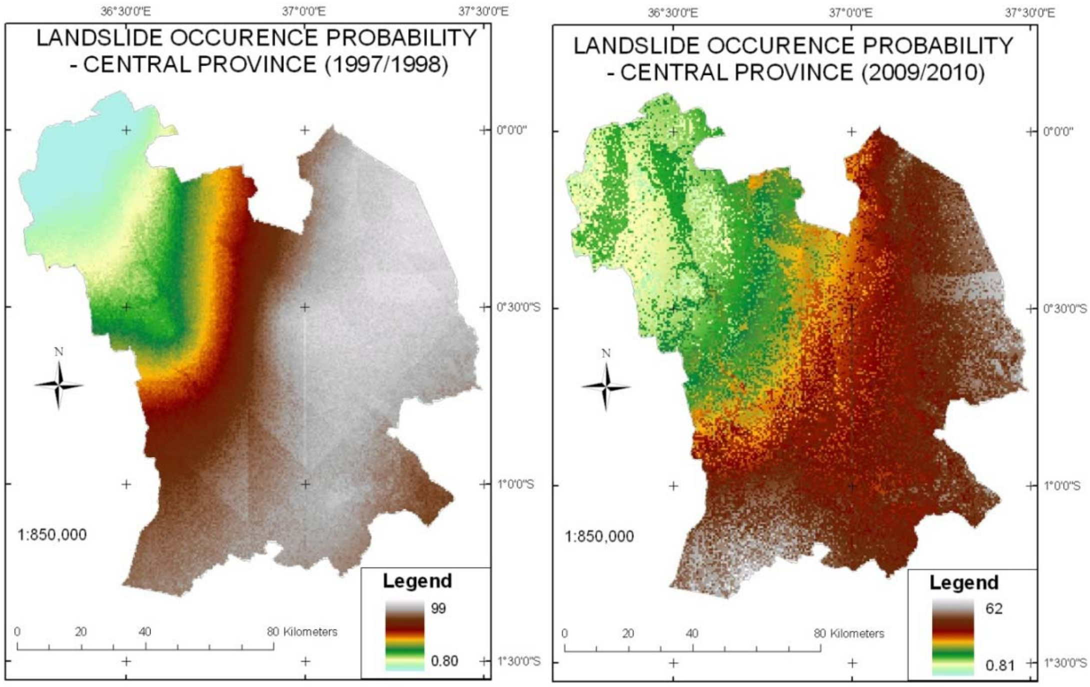

Figure 4: Landslide Probability Values for central province for (a) 1997/98 & (b) 2009/10

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Table 1: NDVI change

	1995-2000		2000-2002	
	Area in Km^2	Percent	Area in Km^2	Percent
Decreased	11712	88.4%	731.	5.5%
Some Decrease	1245	9.4%	3645	27.5%
Unchanged	6	0%	27	0.2%
Some Increase	211	1.6%	6818	51.5%
Increased	68	0.5%	2021	15.3%
Total	13242	100%	13242	100%

Table 2: Weight of evidence for factors contributing to landslides in 1997/98

$P(L)$ = 0.389			$P(\bar{L}) = 0.611$		W_i	
Factor	$P(F)$	$P(\bar{F})$	$P\left(\frac{F}{L}\right)$	$P\left(\frac{F}{\bar{L}}\right)$	$Log_e \frac{P(F/L)}{P(F/\bar{L})}$	**Scaled W$_i$**
Slope	0.0049	0.9951	0.9875	0.992	0.0046	0.0028
watershed	0.0128	0.9872	0.9681	0.9794	0.0117	0.0073
NDVI change	0.9995	0.0005	0.2802	0.3794	0.3032	0.1888
TAWC	0.1097	0.8903	0.78	0.8478	0.0833	0.0519
BSAT	0.1097	0.8903	0.78	0.8478	0.0833	0.0519
unstable	0.389	0.611	0.5	0.611	0.2005	0.1248
curvature	0.5383	0.4617	0.4195	0.5316	0.2369	0.1475
Rainfall 2009	0.9329	0.0671	0.2943	0.3958	0.2963	0.1845
Land Change	0.9967	0.0033	0.2807	0.3801	0.3029	0.1886
Bulk	0.1097	0.8903	0.78	0.8478	0.0833	0.0519
					1.6059	**1**

Table 3: Weight of evidence for factors contributing to landslides in 2009/10

$P(L)$ = 0.389			$P(L) = 0.611$		Wi	
Factor	$P(F)$	$P(\bar{F})$	$P\left(\frac{F}{L}\right)$	$P\left(\frac{F}{\bar{L}}\right)$	$Log_e \frac{P(F/L)}{P(F/\bar{L})}$	**Scaled W$_i$**
Slope	0.0049	0.9951	0.9875	0.992	0.0046	0.0029
watershed	0.0128	0.9872	0.9681	0.9794	0.0117	0.0075

NDVI change	0.9979	0.0021	0.2805	0.3798	0.303	0.1939
TAWC	0.1097	0.8903	0.78	0.8478	0.0833	0.0533
BSAT	0.1097	0.8903	0.78	0.8478	0.0833	0.0533
unstable	0.389	0.611	0.5	0.611	0.2005	0.1283
curvarture	0.5383	0.4617	0.4195	0.5316	0.2369	0.1516
Rainfall 1997	0.6264	0.3736	0.3831	0.4938	0.2538	0.1624
Land Change	0.9909	0.0091	0.2819	0.3814	0.3023	0.1935
Bulk	0.1097	0.8903	0.78	0.8478	0.0833	0.0533
					1.5627	**1**

Table 4: Effect of Land-cover change on landslides Probabilities

	Land cover probability change									
Year	Crop Field	Intensive Agricult.	Dense Forest	L. D Forest	Thick Shrubs	Grass land	Swampy veg	Rock/ Barren Land	Settle-ments	Water Bodies
1995-2000	3.3%	5.5%	3.2%	3.5%	0.5%	1.8%	0%	8.9%	2.4%	0.3%
2000-2002	4.1%	1.8%	1.6%	0.7%	8.7%	5.9%	2.9%	2.8%	0.3%	0.5%

Natural Resources Management and Monitoring

Determination of Safe Distances between Shallow-Wells and Soakpits within Plots in Juja, Kenya

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KEYWORDS:
Shallow wells, Soak pits, Aquifer and recharge zones, Safe distances

ABSTRACT

This project was a suitability study whose main aim was to assess sites for locating shallow wells and soak pits in order to avoid water pollution while maximizing utilisation of plots. It involved assessing the conditions of the existing shallow wells and soak pits and then assessing other potential sites. Factors that were considered in assessing existing shallow wells and soak pits include: zones of influence of the shallow wells, the shallow well spacing distances, the depth to the water table, soil type, area between the shallow wells and location of soak pits in reference to shallow wells. Darcy's principle was used to investigate the relations between zones of influence and depths to the water table, while GIS aided in analyzing the derived data.

Soak pits in the zones of influence of the shallow wells were found to be polluting the shallow wells and their aquifers. It was found that the zones of influence decreased with increase in depths to the water table and vice versa. Thus, the shallower the well was, the more the likelihood of being polluted especially during the wet seasons. The results included suitability maps of sites suitable for soak pits and shallow wells and susceptibility maps showing vulnerability to pollution in the plots. It was therefore recommended that shallow wells found to have high susceptibility levels be converted to boreholes to reduce the pollution. In the long run, there is need to adopt other wastewater treatment / disposal systems other than soak pits

1 Introduction

Water is a basic need for survival. Water has the capacity to dissolve numerous substances in large amounts and therefore pure water rarely occurs in nature. Soak pits are the most commonly used sewage treatment means for domestic wastes. A major cause of ground water contamination is effluent (outflow) from septic tanks and soakpits. Of particular concern to ground water quality is the locations of these soak pits with respect to shallow wells. The vulnerability potential of an aquifer to ground water contamination is in large part a function of the susceptibility of its recharge area to infiltration. Areas that are replenished at a high rate are generally more vulnerable to pollution than those replenished gradually by hydrological processes. Shallow wells that are close to soak pits are more susceptible to contamination, thus there is a need to maintain safe distance between a soak pit and a shallow well. Bedrock areas with large fractures are also susceptible by providing pathways for the contaminants.

Factors affecting the safe distance such as; a soil's permeability (determined by soil type), gradient of the water table at shallow well, the depth of the water table at a soak pit site, the gradient of the water table between the soak pit and the shallow well and the shape of the water table were considered in the study. To help protect water wells against contamination, it is important to use the natural protection that soil provides by maintaining adequate separation distances between shallow wells and potential sources of contamination such as soak pits. Prevention is the key and it includes determining the safe distances between soak pits and shallow wells and using this information to plan plots. Table 1 shows the minimum separation distances that should be maintained between wells and soak pits.

Table 1: Separation distances between septic tanks and shallow wells[5]

Separation distance in meters	*From the wells to:*
7.62	Septic tanks
15.24	Livestock yards, silos, septic leach fields
30.48	Petroleum tanks, Liquid-tight, manure storage, Pesticide and fertilizer storage and handling
76.2	Manure stacks

According to a study by Kamau (2004), Juja shallow well water is polluted by affluent material from soak pits and pit latrines. The water pollution has been attributed to failure to observe safe distances between shallow wells and soak pits. People consuming shallow wells water have suffered (or are prone to) water borne diseases (Kamau, 2004).

To solve this shallow well water pollution problem, there is need for proper planning of shallow wells and soak pits within plots. This requires analysis of the minimum safe distance between shallow wells and soak pits that must be maintained. This would help in making decisions that lead to controlling shallow water pollution. The results of the study would show the need for the respective town/municipal council to set the minimum plot sizes that enables proper planning to control water pollution. This would also act as a guide towards the management of water as a natural resource that demands environmental concern.

The objectives of this study were: to assess sites suitable for shallow wells and soak pits within plots in Juja so as to avoid water pollution; to investigate the relationships between safe distances versus water pollution, soak pits versus shallow wells, zone of influence of a shallow well versus the depth to the water table (J) and thus provide relevant information for the selection and location of shallow wells and soak pit sites; to determine distance to the water table and zones of influence for each shallow well; to provide insight for proper planning of their plots in order to avoid water pollution.

2 Study Area

The study area is Juja west and is located in Thika District, Central province, Kenya. It is about 40 km north of Nairobi. It extends 1º50'S to 1º60'30"S and 37º0'30"E to 37º01'30"E and about 1550 m above sea level. It covers an area of 192.5972 Ha.It is mainly dry most of the year with two wet seasons i.e. March- May and November-December. Waste water disposal is by pit latrines and septic tanks which drain into soak pits since the area is not served by sewer system. The area suffers flooding during the wet seasons and water shortage during the dry seasons which last most of the year. There are only three water kiosks supplying water from Juja Water and Sewerage Company. Therefore, residents supplement water from the water kiosks by water from wells.

The area is served by two types of wells i.e. shallow wells (less than 45 m deep) and deep wells (boreholes about 150 -220 m deep). Shallow wells are prone to pollution by infiltrating water from soak pits absorption areas. Boreholes are less prone to pollution because they are deep and all other openings are sealed in the process of drilling. Boreholes are sustained by water from the water table and are recharged by hydrological processes. But they are expensive to drill and residents opt to dig shallow wells.

3 Methodology

Sites suitable for shallow wells and soak pits were assessed in accordance with Darcy's principle and with the help of GIS in the following stages; data collection, data capture, creation of topologies, deriving of indices, modeling and analyzing to get results in form of suitability maps and digital elevation models (DEM).

[5] Modified from: http://www.purdue.edu/dp/envirosoft/groundwater/src/quality3c

3.1 Data Processing and Analysis

Topographic and soil maps and survey plans were scanned, loaded in ArcMap GIS software and georeferenced, after which they were used for digitizing contours, soil types, and plots respectively. The soil type did not vary much since the area of study was relatively small. The basis of classification was the soil texture which had the aspects of particle size and soil permeability. The permeability of a soil type determined its horizontal hydraulic conductivity (K¡) Table 2.

Table 2: Soil types and their permeability values (source: U.S. Bureau of soils)

Material	*Clay, %*	*Silt, %*	*Sand, %*	*Approx. permeability, m/day (K)*
Clay	30-100	0-50	0-50	0.4*10^-5
Silty clay	30-50	50-70	0-20	0.4*10^-4
Sandy clay	30-50	0-20	50-70	0.4*10^-4
Silty clay loam	20-30	50-80	0-30	0.4*10-^{3}
Clay loam	20-30	20-50	20-50	0.4*10-^{3}
Sandy clay loam	20-30	0-30	50-80	0.4*10-^{3}
Silty Loam	0-20	50-100	0-50	0.004
Loam	0-20	30-50	30-50	0.004
Sandy loam	0-20	0-50	50-80	0.04
sand	0-20	0-20	80-100	Over 0.4

The following parameters were obtained from the collected data: soil classification and their horizontal hydraulic conductivity, (K¡), plot sizes / areas (A¡) and distance between shallow wells (L¡).

Contours were used to model the ground surface and the water table. The area being modeled was deliberately big as compared to the study area to estimate the water table more accurately. The main aim of modeling was to obtain the exact elevations of shallow wells both at the surface and at the mean water table. Modeling was done using the 3D analyst tool in Arc map and Arc scene. Table 3 shows the various boreholes used and their attributes.

Table 3: Attributes of the boreholes used in the study

Borehole	*Northing*	*Easting*	*depth*	*Reduced level*	*Elevation*
Borehole no.1	9879145.65	278651.02	182.88	1367.12	1550
Borehole no.2	9879331.95	278957.26	182.88	1367.12	1550
Borehole no.3	9879584.37	279118.53	182.88	1367.12	1550
Borehole no.4	9879273.43	279302.93	182.88	1367.12	1550
Borehole no.5	9878916.96	279164.37	182.88	1367.12	1550
Juja farm	9872502.43	290146.70	198.2	1371.8	1570
Murera East	9876734.83	273990.21	131.1	1398.9	1530
Sukari	9867033.53	273772.19	150.3	1369.7	1520
Ruiru	9870269.59	277229.30	188.1	1311.9	1500
Juja	9877505.85	277615.85	155.6	1364.4	1520
Thiririka	9882188.31	274215.50	183.2	1376.8	1560

The contours digitized were at 20 m interval. A TIN (Triangulated Irregular Network) was created for the area covered by contours using the heights. More contours were interpolated at 10 m interval and added to the TIN which was used to create a digital terrain model (DTM).

To estimate the water table level accurately, widely spaced boreholes (whose depths and elevation values were known) were used. Any contour that coincided with the boreholes had their reduced levels at the water table assigned to the reduced value of that borehole at the water table. From the known reduced levels of a few contours, then the other contours' reduced levels were obtained by adding or subtracting 10 m interval from a successive contour. The TIN was created and used to create a DEM.

The shallow well spacing equation was used to determine the distance to the water table, J, and the zones of influence, Z, for each shallow well, water table gradient, δJ/δX, at a point X from the centre of the shallow well as in the following steps:

(i) the length, L in meters, was obtained by measuring the distance between the shallow wells;

(ii) the radius of influence of each shallow well Z, was determined from eqn 1 and was used for buffering the shallow wells;

$$Z = 0.57\,L \qquad (1)$$

where: Z radius of influence, L is the distance between soak pits and shallow wells

(iii) the apparent flow velocity V, was generated from eqn 2 ;

$$L = V\left(\frac{A}{N}\right) \qquad \Rightarrow V = L\left(\frac{N}{A}\right) \qquad (2)$$

where: A is the area served by N wells, and V is the velocity

(iv) the flow rate Q was determined from eqn 3;

$$V = \frac{Q}{A} \qquad (3)$$

(v) the long term average recharge R (m/day), was generated from eqn 4;

$$\pi(Z^2 - X^2)R = Q \qquad (4)$$

Where: X is the distance in horizontal direction from the well

(vi) depth of the water table J, was determined from eqn 5;

$$V_X = \frac{\pi(Z^2 - X^2)R}{2\pi XJ} \qquad (5)$$

(vii) the gradient of the water table (S) at a point X from the centre of the shallow well, was determined from the eqn 6,

$$\frac{\delta J}{\delta X} = \frac{V_X}{K_X} = S \qquad \Rightarrow V = KS \qquad (6)$$

To investigate the relationships between zones of influence of shallow wells versus the depth to the water table, the actual values of J to the water table, values of Z were determined which satisfied the values of J at the particular shallow wells. From the equation 5, X ranges from 0 to Z and thus X (maximum) = Z. Also from equation 4,

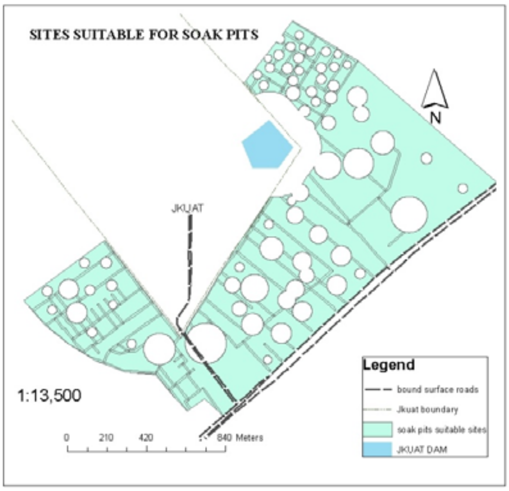
$$\Rightarrow X_{maximum} = \frac{A}{2\pi J} \qquad (7)$$

The values of X max were compared with the values of Z generated earlier. The existing soak pits were discriminated on the basis of whether they were within the zones of influence of the shallow wells. Figure 2 shows soak pits that were not within the zones of influence of the shallow wells.

Figure 2*:* Map showing soak pit not within shallow wells zones of influence; **Figure 3***:* Map showing zones suitable for shallow wells

4 Results

Figure 3 is the map showing zones suitable for shallow wells. The suitable zones were obtained by clipping out: zones of influence for existing shallow wells, sewerage dam and soak pits, buffered loose surface roads and bound surface roads from the study area



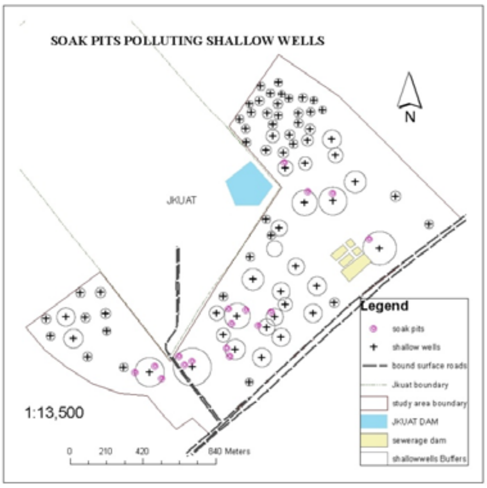


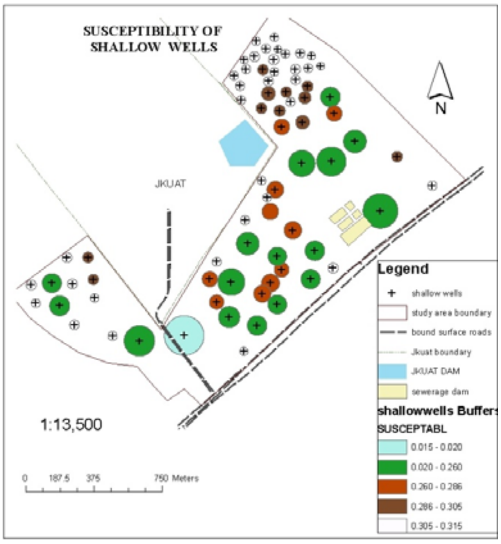
Figure 4*:* Map showing zones suitable for soak pits **Figure 5***:* Map showing soak pits polluting shallow wells

Figure 4 is the map showing zones suitable for soak pits. Zones suitable for soakpits were obtained by clipping out: zones of influence for existing shallow wells and clean water dam, loose and bound surface roads from the study area.

Figure 5 is the map showing soak pits polluting shallow wells i.e. the soak pits found within the buffered zones of influence of shallow wells.

Figure 6 is the map showing susceptibility levels for the zones of influence of shallow wells i.e. the likelihood of pollution which increases inversely with the presence of soak pits within the zones of influence of shallow wells.

Figure 7 is the map showing susceptibility levels of each plot i.e. plots where safe distances have not been observed between shallow wells and soak pits/pit latrines.



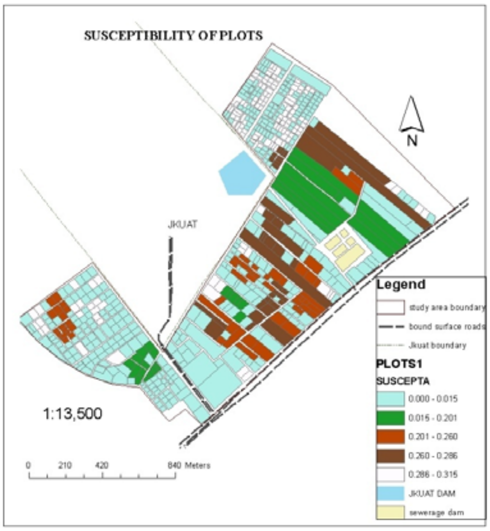


Figure 6: Map showing susceptibility levels for the buffered shallow wells; **Figure 7:** Map showing susceptibility levels of each plot

5 Discussions

The values of J obtained from the collected data differed greatly with those obtained from the difference in heights between DTM and DEM. This perhaps indicates the existence of aquifers at those values of J which supplied the shallow wells with water. Soak pits within the zones of influence, were found to be polluting these aquifers supplying water to the shallow wells. As the value of zones of influence increases the value of J decreased. The larger the values of the zone of influence, the more the surface area for infiltrating water to the aquifer and the higher the chances of pollution. This makes the shallow wells more susceptible to pollution especially during the wet season when the value of J decreases. Thus, less the value of J for a shallow well the more likely it was to be polluted.

The susceptibility to pollution decreased with increasing depths to the water table. However, at certain low values of J, the susceptibility ratio was high and remained constant. The behavior of L versus susceptibility also took the same form with a higher gradient. Therefore, there is need to maintain and ensure that the shallow wells have the maximum values of depth that qualifies them to be shallow wells. Thus the minimum safe distance is a function of the depth to aquifers for shallow wells.

The value of the apparent flow velocity in the horizontal direction (Vx) was found to increase with decreasing area between shallow wells. The apparent flow velocity increased not only due to shallow wells but also due soak pits. The values of Vx were found to be a function of susceptibility to pollution and soil type. Thus there is need to set the minimum plot sizes in the area if the shallow wells continue to be the main source of water.

6 Conclusions

The study was able to determine the safe distances between existing shallow wells and soak pits. Also, some shallow wells were found to be polluted by soak pits found within the zones of influence of the shallow wells. The study was also able to assess the existing shallow wells and proposed sites for both shallow wells and soak pits. Zones of influence and depths to the aquifers and water table were obtained at each shallow well.

Depth to the water table was found to vary inversely to the zone of influence i.e. as the value of J increases the value of the zone of influence decreases. To set out the minimum safe distance in the proposed suitable sites, the values of L (distance between shallow well and a soak pit) should be used to avoid chances of pollution.

Areas between shallow wells provide insight on the minimum plot sizes that should be maintained to avoid water pollution. However, for shallow wells the minimum area is a function of the soil type within the area. This calls for proper planning of the plots in order to minimize water pollution. Factors affecting suitability of a site for shallow well within a plot include: the safe distance, the depth to the aquifer, soil type, plot size, zones of influence of other wells and soak pits.

Susceptibility indices were derived to show potential of pollution of the shallow well water and the plots affected. Shallow wells situated on small area plots should be converted to boreholes. Also, there is a need to adopt sewerage treatment/ disposal systems other than soak pits.

Acknowledgments

We extend our gratitudes to the Estates department (JKUAT), Mr.Warui and Mr. Ben Kariuki of the Ministry of Water and Irrigation, Thika who assisted us with data.

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An Assessment of Climate Change Impact in Agricultural Sector in Khulna City, Bangladesh

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KEYWORDS:
Climate Change, Agriculture, Flood, Damages, Raster Data, Vector Data, GIS

ABSTRACT

Climate change is extremely important issue for Bangladesh. Economy of the county is still heavily dependent on agricultural production. Climate change causes to raise sea level, which ultimately inundates much more landmass intensifying the scarcity of agricultural land. The aforesaid phenomenon puts an extra momentum adversely on agriculture. The depth and duration of floodwater would also leave a devastating effect on infrastructures, industry, agriculture, socio-economic aspect and so on. This study has made an attempt to estimate damages of flood in agricultural sector in spatial extent. The techniques of geo-informatics are deployed to complete this study using a set of raster and vector data such as flood depth maps and landuse data. Inundation maps are used as input for the damage estimation due to excessive flooding in crop filed. In this case the damage in agriculture is directly related to the depth of flood water in each pixel with a scale from 0 to 1 where 0 represents no damages and 1 indicates full damage. With the result of this study it is possible to visualize scenario of climate change impact in agricultural sector in 2030 and 2050. The result of this study is presented as a whole for Khulna City and separate impact in each administrative ward. The outcome of the research can be utilized for other coastal cities in Bangladesh in order to initiate preventive measures to protect diminishing agriculture in urban areas from being adversely affected by climate change.

1 Introduction

Bangladesh is one of the countries feared to be affected heavily by the climate change impact. The risk is aggravated as the land is a member of Least Developed Countries (LDC) and over burdened with unusually high density of population. The study area is located in the southern part of the country. The land levels of the area is more or less flat which ranges from 0.45 m to 5.40 m from the mean sea level (MSL) (Ref). There are two main rivers flowing by eastern side of the city. The low topography and the rising sea level could obviously delay the discharge from the drainage system which could cause prolonged drainage congestion and flooding. The intensified flooding will play havoc on agriculture, infrastructure, trade and commerce. This particular incident made me interested to carry out the study.

2 Study Approach

The figure1 shows the different steps related to the study. The shape file of the landuse data is converted into raster one with spatial resolution of 30 x 30 m which is in conformity with the Flood Depth maps(FD) and Digital Elevation Map(DEM). As the study is focused only with the agricultural areas, the very type of the use is separated from the rest of the uses. The Flood Depth maps are used to locate the agricultural grid cells to be affected by the flooding. The identified grid cells are then reclassified according to the damage function values. A set of maps are prepared depicting damages occurred due to flooding in Base Case , in 2030 and in 2050 for agricultural landuse. Comparisons are made with statistical approaches for these scenarios. Finally some conclusions are drawn with remarks.

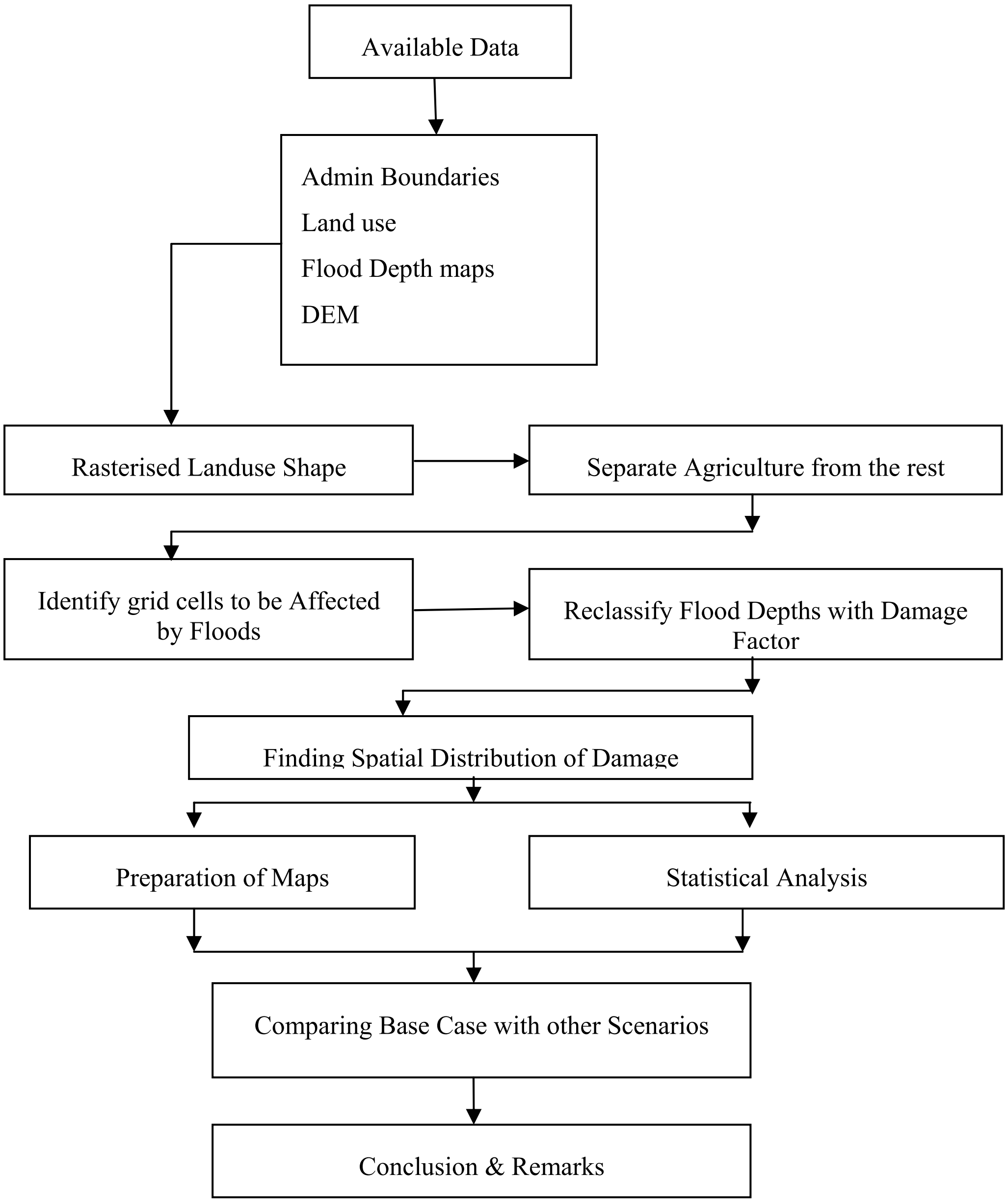


Figure 1: Methods & Approaches of the Study

3 Data and Software

Two different formats of data are used in this study such as raster and vector. The vector format includes Administrative Boundaries, Road Network, Water bodies, names of the important locations and landuses. The flood depth maps for 2010, 2030 and 2050 with DEM are in the raster format. The courtesy for three flood maps go to Water Resource Planning Division, Institute of Water Modelling which was prepared under the project Strengthening the Resilience of the Water Sector in Khulna to Climate Change

ArcGIS 9.3 is used for different types of data processing and analysis with a view to arrive at the final results. 3D analyst and Spatial Analyst are also used as tool at various stages. MS Excel helped a lot for statistical analysis.

4 Analysis

This section contains data preparation, analytical procedures, map preparation and result analysis

4.1 Data Preparation

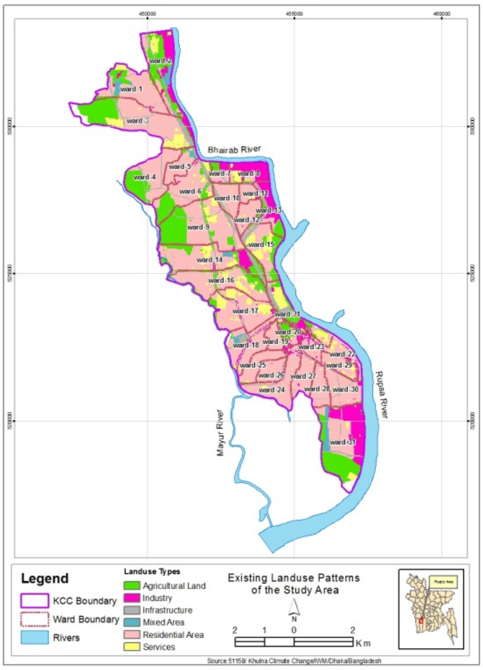
Digital Elevation Model and flood depth maps for 2010, 2030 and 2050 are readily available for analytical purposes. The spatial resolutions of these maps are 30 x 30 m. In order to make the landuse data compatible with the above stated types it is rasterised with the same spatial resolutions. The study is only concerned with agricultural areas so it is separated from the other types with queries. The Zonal Statistics as Table is utilized from the Spatial analyst tool for performing statistical analysis.

4.2 Analytical Procedures

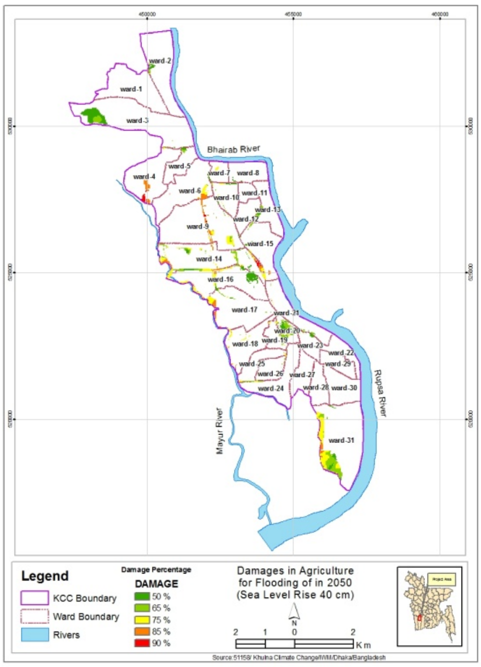
The flooding 2002 is considered as the base case. The spatial distribution of the flooding incident is found using Zonal Statistics as table in Spatial Analyst. The data is then analysed for mostly affected administrative units(Wards). The grid cells having agricultural landuse were separated earlier by spatial queries. This isolated landuse type is then used as mask for extracting grid cells affected by floods. At this stage cells of flood depths are reclassified using predefined adopted damage function for agricultural landuse from Deltares, Netherlands. The table shows the flood depth versus damage curve(ref). The result is used for calculating extent of damages in each grid cells. The total process is repeated for the year 2030 and 2050(Ref) with Plausible High Sea Level Rise of 25 cm and 40 cm accordingly.

4.3 Map Preparation

There are couple of maps prepared under this study. These are the landuse map(Map1), flood depth maps and damage maps for the base year, 2030 and 2050(Map 2). The flood depth maps depict the intensity of flood water all over the study area while the damage maps illustrate the pattern of damages.



Map 1 Showing Landuse Pattern



Map 2 Showing damage in agriculture in 2050

4.4 Result Analysis

4.4.1 Landuse of the Area

Landuse Type	Area(Ha)	Percentage
Mixed Area	59.49	1.34
Agricultural Land	828.27	18.72
Services	349.47	7.90
Industry	409.32	9.25
Infrastructure	283.86	6.42
Residential Area	2494.53	56.37
Total	4424.94	100.00

Table 1: The distribution of landuse pattern in the study area

The Table 1 above shows that the largest share of the project area is of residential uses while the second largest one is the agricultural landuse. The agricultural area is 18.72 % of the total study area. The areas are calculated here in hectares.

4.4.2 Damage Function

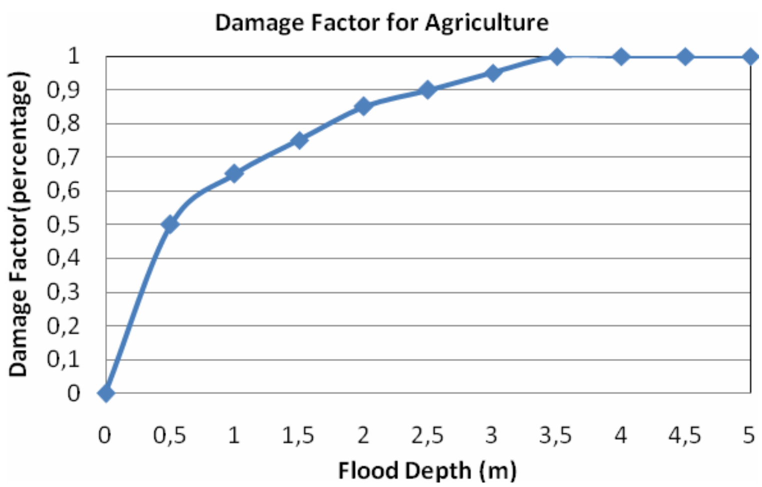


Figure 2 Damage function for Agricultural landuse

The chart(Figure 2) above tells the direct relationship between the flood depth and damages in each unit area such as when the flood level reaches at 1m the amount of damages should be as much as 65 percent of the cell.

4.4.3 Flooding as a whole

The table 2 bellow illustrates that the overall flooding is increasing from the base year to the projected years. Flood affected area increases 10.69 % from the base year in 2030 and 37.25 % in the year 2050. The average flooding condition rises with 56 cm in 2030 and 83 cm in 2050 while the values of 50 cm in base case. There is also an increase in the maximum flooding such as it is 185 cm in 2002, 210 cm in 2030 and 322 cm in 2050. The mostly affected administrative units(ward) are same in base case and in 2030 which is ward number 17 where the same incident happens in the ward number 14. The above all findings strongly support the intensification of adverse climate change impact in a coastal city like Khulna in Bangladesh.

WARD	ZONE_CODE	Base Case 2002				Scenarion 2030				Scenarion 2050			
		AREA(Ha)	MIN	MAX	MEAN	AREA(Ha)	MIN	MAX	MEAN	AREA(Ha)	MIN	MAX	MEAN
ward-2	1	6.3	22	85	47	3.96	10	40	32	7.83	22	93	52
ward-1	2	3.51	10	86	26	6.57	10	35	20	20.79	10	93	39
ward-3	3	85.95	10	170	43	127.53	10	174	44	157.68	10	226	75
ward-4	4	83.25	10	105	48	95.76	10	114	55	114.12	15	229	140
ward-5	5	**2.7**	29	69	52	**3.87**	14	82	55	54.9	12	169	65
ward-6	6	38.52	10	91	36	54.81	10	108	47	103.23	10	209	109
ward-7	7	24.84	19	139	69	24.03	17	135	74	25.02	18	158	88
ward-8	8	6.21	18	68	46	7.74	37	74	58	**7.02**	10	55	22
ward-10	9	47.07	10	116	67	49.95	19	170	94	77.04	11	156	83
ward-11	10	9.54	10	80	40	14.49	24	135	58	17.46	10	118	55
ward-12	11	57.87	15	109	47	58.77	19	104	50	64.89	30	136	78
ward-13	12	8.64	12	51	32	8.37	13	47	32	14.94	28	77	53
ward-9	13	138.51	10	177	48	157.95	10	202	67	198.54	13	322	137
ward-14	14	100.71	10	159	51	123.66	10	199	61	**232.92**	10	249	103
ward-15	15	52.02	10	185	64	57.06	11	210	93	76.59	10	260	103
ward-21	16	10.44	17	161	73	12.24	16	180	87	18.54	12	209	93
ward-16	17	133.74	10	118	47	128.88	10	109	60	200.88	10	195	106
ward-17	18	**158.67**	10	129	61	**173.07**	10	128	63	221.4	11	224	119
ward-18	19	122.94	10	149	67	136.44	10	148	69	156.33	13	246	114
ward-19	20	44.37	10	128	56	47.34	10	126	64	49.5	21	156	93
ward-20	21	30.33	10	123	43	32.4	10	125	44	45.54	13	178	66
ward-23	22	40.14	10	113	57	35.46	10	102	56	45.99	11	137	70
ward-25	23	67.68	12	159	49	72.72	10	180	69	77.22	40	250	116
ward-26	24	25.02	10	97	51	31.41	12	115	66	66.06	12	163	85
ward-24	25	55.98	10	125	54	67.59	10	121	60	151.56	27	198	92
ward-27	26	58.95	10	136	59	55.98	10	136	63	82.98	24	173	89
ward-29	27	44.91	13	80	42	53.64	11	101	35	47.7	15	104	57
ward-22	28	6.66	12	69	37	8.01	11	85	30	10.89	10	72	39
ward-28	29	53.01	10	104	38	43.74	10	109	41	72.18	13	164	79
ward-30	30	23.4	11	93	65	28.35	13	86	55	34.83	12	119	77
ward-31	31	67.32	10	91	38	80.19	10	105	44	110.07	10	183	89
		1609.2	**10**	**185**	**50**	**1801.98**	**10**	**210**	**56**	**2564.64**	**10**	**322**	**83**

Table 2 shows the distribution landuse pattern in the study area

4.4.4 Flooding in Agriculture

Damage (%)	Base Case 2002		Scenario 2030		Scenario 2050	
	Area(Ha)	% of Total	Area(Ha)	% of Total	Area(Ha)	% of Total
50	100.08	62.33	113.85	54.53	69.48	25.96
65	54.99	34.25	79.56	38.10	74.43	27.81
75	5.4	3.36	10.44	5.00	77.67	29.02
85	0.09	0.06	4.95	2.37	38.97	14.56
90	0	0.00	0	0.00	7.11	2.66
100	0	0.00	0	0.00	0	0.00
	160.56	100.00	208.8	100.00	267.66	100.00

Table 3 shows the impact of flooding on Agriculture

Table 3 shows that areas affected by flood are gradually increasing in spatial extent. In the year 2030 the flood affected area is increased by 23 % while in the year 2050 it is 40 % from the base case. There is another interesting finding that the largest areas fall under the first category of damages(50 % damage) in 2002 and 2030 while it moves on 3rd category of damages(75 % damage) in the year 2050. This is a clear indication of adverse climate change impact on agriculture in the study area.

5 Limitations

The study is based on a number of assumptions such as there is no landuse pattern change in 2030 and in 2050 which is not compatible with the reality. This is assumed due to the unavailability of landuse data in those years. The damage function for agriculture used in this study is adopted from a study made by Deltares, Netherlands which roughly fits in with scenario of our study area. But further study on this particular topic can make the damage function more pragmatic.

6 Conclusions

It is very clear from the analysis above that flooding event due to climate change is increasing in Khulna City as a whole. This is found in the area coverage, average and maximum flood depth. The impact of this phenomenon also leaves an adverse effect on agricultural sector of the city which is represented in the statement with an increment of flood affected areas by 23 % in 2030 and 40 % in 2050 in comparison to the base case in 2002.

Acknowledgement

The analysis of the study is greatly dependent on the flood depth maps of base year 2002, 2030 and 2050. I obtained these maps from Water Resource Planning Division, Institute of Water Modelling, Dhaka, Bangladesh. I would like to thank Mr. S. M. Mahbubur Rahman, Director, WRP, IWM for granting me the permission to use these maps. I also thank urban drainage modeler Mr. David Mohammad Khan and Ismat Ara Parvin for their support. Last but not least I would like to thank for all kind of supports from AGSE team and DAAD.

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Solar Potential Estimation - A case study of Kenya

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KEYWORDS:
Image Matching, Digital Elevation Model (DEM), GIS, Radiation, Solar Potential Estimation.

ABSTRACT

In an attempt to mitigate global warming, nations are turning to renewable energies with solar as a popular option. It is no different in Kenya whose location guarantees her of high insolation throughout the year. Government-led initiatives, growing public interest and new laws for solar technologies form a big source of motivation. As an aid to controlled adoption of solar technologies, this research explores the use of imagery-derived data such as digital elevation models and 3D building models for solar potential estimation. Two selected raster and model-based tools employing different approaches are used and a comparison of the results is made. Seasonal variations in the energy potential are additionally investigated. The output 2D and 3D solar atlases show the estimated annual energy potential, initial cost of investment, carbon dioxide emission savings and payback period for each building unit.

Modeling Mt. Kenya Forest Cover Change

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KEYWORDS:
Change detection, Modeling, Simulation, GIS and Remote Sensing

ABSTRACT

Forest cover prediction is vital in management and planning of the natural resource. Modeling forest cover aids in better use of forests while at the same time averting degradation of the forests and biodiversity reliant on the resource. Change detection and predictive modeling using GIS and Remote Sensing technology, involves the application of multi-temporal datasets to analyse the temporal effects of the phenomenon and predict the future. The Mt Kenya ecosystem is located along Latitude 0' 10'S and longitude 37' 20'E. The ecosystem is situated in two provinces and five districts of Kenya. Mt Kenya is an island of indigenous forest surrounded by densely populated small farming areas and is the scene of a battle between man and nature. It plays a critical role in water catchment for the country and is one of the five main 'water towers'. To model forest cover changes in the ecosystem, three year interval Landsat images from the 1980s to 2010 during the dry season from the months of January to end of March will be used, with GIS data derived from topographical maps as model inputs. The Landsat images will be classified to delineate forest cover. Change detection analysis will be carried out to help identify changes in forest cover. Through regression analysis, the relationship between forest cover and the identified model inputs will be highlighted. The results from the analysis will depict the factors that contribute most significantly to degradation therefore requiring immediate mitigation measures. From this analysis, Markov Chain predictive modelling and sensitivity analysis using Monte Carlo simulation will be applied to generate predictive maps.

1 Introduction

1.1 Background Information

Kenya has experienced a steady population expansion since independence in 1964. As well, many development activities have taken place including human settlements, agriculture and road construction. Growing human populations exert increasing pressure on the landscape as demands multiply for resources such as food, water, shelter and fuel. This has resulted in increased alterations in terms of land cover (Brandon, 2000).

Most of the natural disasters that occur in Kenya are weather related (Muchemi, 2003). Unpredicted climate events such as high frequency of flooding similar to that observed during the 1997-98 El Nino rains may still occur (Kabubo & Karanja , 2007).

Locating, characterizing and quantifying areas of significant change is one of the most important applications of remote sensing as well as land use/cover change analysis, assessment of deforestation, damage assessment, disaster monitoring and development of accurate change detection maps (Ayman et al., 2009). Models that simulate possible spatial developments are vital for the formulation of adequate spatial policies for they can support the analysis of the causes and consequences of land-use change (Verburg et al., 2004). Trend analysis can be used to simulate the possible future state of land-use systems on the basis of observed, past spatial developments (Koomen et al., 2007).

[*] Corresponding author.

Mt Kenya is considered one of the key conservation areas in the country (Emerton, 1999). It is widely accepted that forest resources and associated lands should be managed to meet the social, economic, cultural and spiritual needs of present and future generations (Naftal, 2008).The continued deforestation and forest degradation in Kenya has not only contributed to loss of biodiversity and wildlife habitat but has also negatively impacted on the environment and the economy. It causes the release of carbon which contributes to the atmospheric burden of greenhouse gases (NEMA, 2006). Conserving carbon stored in biomass could be a cost-effective strategy to mitigate future climate change impacts (Stern, 2007; Chomitz et al., 2006).

This research study seeks to model forest cover change and predict threatened areas in due time through the use of GIS and remote sensing technology. Specifically, identify factors that contribute to forest cover change, establish the role of GIS and remote sensing in modeling forest cover change, identify suitable remote sensing data to map forest cover change, model and validate forest cover change, create predictive maps and forecast the future pattern of land cover in Kenya. This will facilitate strategic planning of forest reserves.

2 Methodology

2.1 Study Area

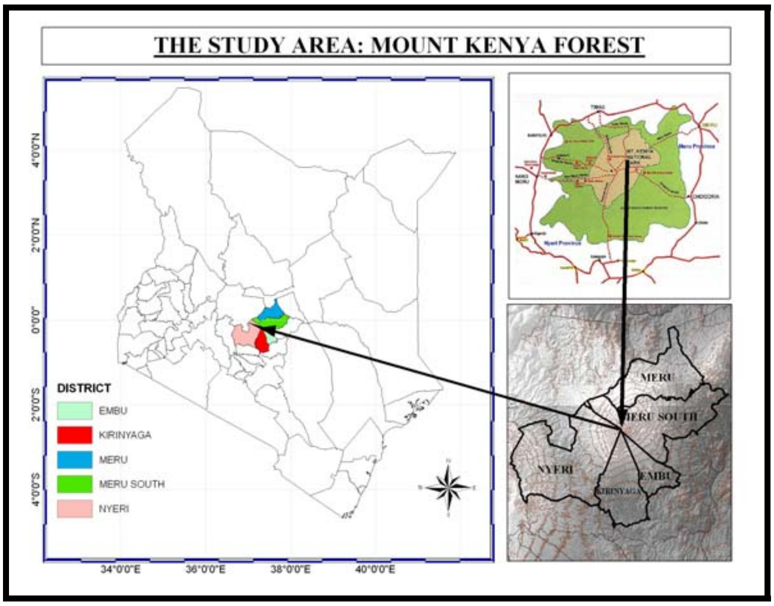

Figure 1: The study area

The Mt Kenya ecosystem is located to the east of the Great Rift Valley, along Latitude 0' 10'S and longitude 37' 20'E. It bestrides the equator in the central highland zones of Kenya (KWS, 2010). Due to the wide range in altitude and amount in rainfall, the mountain has a rich biological biodiversity. Mt. Kenya has eight different natural forest types and a variety of wildlife (EEIU Mt. Kenya, 2004). The foothills of Mt. Kenya are (or at least were originally) covered by dense evergreen forests (Tuomo & Petri, 2004). There are eleven remnant glaciers on the mountain, all receding rapidly (UNEP & WCMC, 1997).

2.2 Data capture and collection

The base map to be used for the study is a topomap of Kenya at a scale of 1:50,000, sourced from the Survey of Kenya, SoK. The road network and the boundaries of the Mt. Kenya Forest reserve will be digitized from the topomap. A handheld Global Positioning System receiver will be used to pick the positions of point features of concern to the study. Earlier Landsat images with 30x30 m resolution will either be downloaded or purchased for the case of latter year’s images. Soil data is available at the Kenya Agricultural Research Institute. Though inadequate, population data depicting density and distribution is available at the Central Bureau of Statistics. Elevation data will be downloaded from the USGS website.

2.3 Method

A three year epoch (interval) of Landsat data covering a sample of the Mt Kenya Forest would be collected from the 80s to 2011. The dates (epochs) of the satellite images to form the time series maps will be those acquired during the dry season in Kenya that occurs in Kenya from the months of January to end of March. These are the times that Kenya has the lowest cloud cover. The years to be considered will be 1773, 1976, 1979, 1982, 1985, 1988, 1991, 1994, 1997, 2003, 2007 and 2010. The 2000 image would be used validate the modeling process. From the digital elevation model, three maps would be obtained: altitude, slope gradient and aspect. The digital materials about the anthropogenic factors will be resampled to the UTM Zone 37 coordinate system and converted from vector data to raster data. From road maps, the map of distance from the road would be created.

The forest boundaries shapefile would be used to clip the landsat and the study area would be depicted in the same projection. The Landsat images will be geo-referenced against the topographic maps by using a number of ground control points.

A number of key features, such as roads and rivers will be digitized from the scanned topographic maps. The boundaries of the protected forests would be obtained from the Forest Department. The layers would be overlaid.

2.4 Change detection

NDVI transformation is computed as the ratio of the measured intensities in the red (R) and near infrared (NIR) spectral bands;

NDVI = (NIR - red) / (NIR + red)   [1]

The Red and NIR images will be obtained and used to calculate an NDVI value for each pixel. The NDVI equation produces values in the range of -1.0 to 1.0, where vegetated areas typically have values greater than zero and negative values indicate non-vegetated surface features.

Three years interval Landsat images will be used for the detection of changes in the Mt. Kenya forests. The bands of the selected images will enable the detection of critical changes in the forests, such as clear-felling of forest, illegal settlements and the conversion of forest land into agricultural land.

Preprocessing seeks to minimize data acquisition errors and mask contaminated scene fragments. Because analysis will be performed on a pixel-by-pixel basis, any mis-registration greater than one pixel will provide a false result for that pixel. This will be accomplished on the basis of uniformly well-distributed ground control points located on both the images and the maps. Image registration will be done to ensure that multidate images are registered to each other within one pixel by on-screen identification of common features, such as road intersections. To correct differences in atmospheric conditions, one image will be radiometrically corrected, or normalized to the other. Once the Imagery has been registered, normalized and subset into processing areas, it will be ready for input into the change detection process.

The change detection method to be used for the study will be at information level due to the low resolution of satellite imagery. Each image of multi-temporal images would be classified separately and then the classification result images will be compared. The type of change of each changed pixel will be determined by the change detection matrix.

Postclassification comparison will be used to find general categories of land use change. This implies finding the amount of forest area cleared or converted to other land uses such as agriculture. Trend analysis of forest cover (1980s-2011) on a three year epoch will then be analysed.

Then, a standard accuracy assessment analysis using the ground-truthing samples will be carried out at this stage using IDRISI. The accuracy assessment will be done by generating a random set of locations to visit on the ground for verification of the true land cover type. An error matrix will give the errors of omission and the errors of commission expressed as proportions.

2.5 Forest cover prediction

Vector data will be transformed to raster data in order to suit the modeling process. Before a modeling tool is chosen, two major steps will be considered ie determining what the output of the modeling process should be (both spatially explicit such as resultant GIS layers and spatially aggregated results such as the calculated total area of forest cover loss by the year 2030) and the identification of possible inputs now that the outputs of the modeling process are known. In this research study the possible inputs will be forest boundaries layer, the landsat image and the parameters.

Regression analysis will be used to examine the relationship between forest cover change and explanatory variables:

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots b_nX_n + e \quad [2]$$

Where Y denotes the dependent variable

X_1 $X2$ $X_{3.......,}$ X_n are the independent variables (soil, settlement, census, slope, aspect and proximity to roads

b0 represents the Y intercept

$b_{1,}$ $b_{2,}$ $b_{3,.....}$ b_n denotes the unknown coefficients

e is the randomly distributed error term

Soil data will be categorized into four categories in terms of their density and filtration rates. The classified soil categories and forest cover change detection images will be used to determine the relationship between deforestation trends and soil category. ArcGIS 9.2 geoprocessing (Intersect) would be used to extract the Euclidean distances of roads and settlements to the forest boundaries. Two major classes of land cover would be delimited ie forests and non-forested (Bare land, Cultivated). The relation between the variables would be calculated using regression analysis and analyzed using favourable methods eg Anova (Analysis of variance) test. ANOVA tests will be conducted to determine the most important variables determining forest cover change.

Land Change Modeller arcGIS extension will be used for analyzing and predicting land cover change. Trend analysis of forest cover (1980s – 2011) will be used to model and simulate the future state forest cover upto the year 2030. Validating the forest cover predictive model by the year 2030 will be done using the IDRISI Validate module. This would allow assessing the success with which one will be able to specify the location of change versus the quantity of change. Markov Chain predictive modelling and sensitivity analysis using Monte Carlo simulation will be applied. The accuracies of the transition (probability) such as the kappa coefficient and overall accuracies should meet the minimum standards as stipulated under the USGS classification scheme.

3 Expected results

The main methods of data analysis that will be adopted in this study include calculation of the area in hectares, change prediction, spatial overlay and image thinning. The results will be presented in form of maps, charts and statistical tables. They will include the static, change and projected forested zones. The results will explain statistically the relation between the forest cover change and elevation, slope gradient, distance from the road and the size of population.

The expected results, with accompanying statistics, will depict Mt. Kenya forest cover change from 1980s to the present day, a model of the Mt. Kenya forest cover to the year 2030 and the simulation maps of Mt. Kenya forest cover by the year 2030 in the event that certain mitigations are undertaken promptly. This research study seeks to cover only the extensive Mt. Kenya forest. However, similar studies can be carried out elsewhere but with special care on the parameters.

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District-Wise Forest Cover Assessment of Pakistan

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KEYWORDS:
Forest cover mapping, Remote Sensing, GIS

ABSTRACT:

Pakistan has a total land area of 87.980 million ha which includes 4.570 million ha of forests. Thus the country has a meagre forest cover of 4.8 % rating it as one of the low forest cover countries with only 0.03 ha of forest per capita of population compared to the world average of 1.0 ha (MoE 2010). The annual rate of change of forest cover during 1990 – 2000 was -1.8 % while during 2000 – 2005 it was -2.1 %. No other country in the Asia/Pacific region has a higher rate of deforestation (FAO, 2009)

GIS and Remote Sensing based tools and technologies are in use to assess forest cover for the last two decades in Pakistan. The national level forest cover studies based upon satellite images include the Forestry Sector Master Plan (1992) and National Forest & Range Resources Study (2004). Aim of these mapping activities conducted at 1:250,000 scale was to estimate national forest cover disintegrated at provincial level. The results of such, relatively coarser detail studies provide concise baseline information for policy level awareness and decision making. However, no systematic baseline data disintegrated at local administration boundaries (e.g., District and Tehsil), is available to accurately measure either the current extent of forest cover or the deforestation rate of a particular district (Qamer et al., 2010).

In this context, a comprehensive forest cover inventory primarily focused at district level, ultimately leading towards national scale mapping of forest resources in Pakistan is being developed. Through this project one of the most important environmental inventory in the form of national forest cover will be completed which will enable Ministry of Environment to meet the national obligations under the CBD (Convention on Biological Diversity), UNCCD (United Nations Convention to Combat Desertification) and UNFCCC (United Nations Framework Convention on Climatic Change) by developing reliable and comprehensive databases and reporting to international bodies including FAO (Food and Agriculture Organization), and UNFF (United Nations Forum on Forests).

A collaboration between World Wide Fund for nature – Pakistan, Pakistan Forest Institute and International Centre for Integrated Mountain Development is formed to jointly conduct the study. National Consultative Workshop on "District-wise Forest Cover Assessment of Pakistan" was held from 31st May to 4th June, 2010 in Islamabad. Twenty five professionals from the Ministry of Environment, provincial Planning & Development Departments, provincial Forest Departments, national space applications agency, and NGO's participated in the training. A collaborative framework of the study was prepared and documented in the proceedings of the workshop.

So far forest cover maps of most of the selected districts have been prepared which include the whole province of Gilgit-Baltistan (districts: Skardu, Ghanche, Diamir, Astor, Ghizer, Gilgit, and Hunza-Nagar), two districts from Punjab (Muazaffargarh and Rawalpindi), four districts from Sindh (Sh. Benazirabad, Thatta, Naushehro Feroz, and Sukkur), one district from Balochistan (district Ziarat), and two districts from Khyber-Pakhtunkhwa (Swat and Shangla).

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Rapid Replacement of Farmland with Settlement Areas in Kwale District, Kenya: Implications for future forest conservation

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KEYWORDS:
Agricultural expansion; Landsat; ASTER; image classification; settlement areas; population expansion

ABSTRACT

Intense growth in population coupled with agricultural expansion is causing serious concerns to forest conservation globally. Kenya's population has been growing at an increasing rate, causing serious forest encroachment and fragmentation. We used Landsat and ASTER remotely sensed imagery to analyze landuse interactions and their implications to forest conservation in 1986, 2003 and 2008 in Kwale District of Coast Province, Kenya. Satellite imageries were analysed with Idrisi Kilimanjaro software using supervised and unsupervised classification to determine landuse type in each of the three image sets. The area of each landuse category was calculated in hectares and compared across the three time periods. A total of seven landuse categories were isolated. Overall, farmlands increased between 1986 and 2003, but decreased rapidly between 2003 and 2008 as they were replaced by settlement areas as a result of an expanding human population. Forests also decreased between 1986 and 2003, but increased between 2003 and 2008 as a result of increased conservation action. It is anticipated that demand for more settlement areas and agriculture will increase and therefore exert pressure on forests, including the protected ones. A landscape approach to managing land resources is identified as a suitable alternative to sustainable use of land resources and forests.

Exploring Local Relationships between Vegetation Cover and Quality of Life Indicators Using an Exploratory Spatial Regression Approach: Gauteng Province, South Africa

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KEYWORDS:
Vegetation cover, quality of life, geographically weighted regression modeling, ordinary least squares, ndvi imagery, census data

ABSTRACT

This study investigates the relationship between quality of life indicators and vegetation cover. It follows an exploratory approach to research using the spatial statistical tools Ordinary Least Squares (OLS) and Geographically Weighted Regression (GWR) in ArcGIS to reveal the existing relationships between vegetation cover and Quality of life indicators. The vegetation indicator used was NDVI satellite imagery with 250 meter resolution. Quality of life was broadly defined by the indicators viz., household income, education levels, and population density, which correlate well with barriers to improved life quality standards. The outcome of this study revealed that for the Gauteng Province in South Africa, there is a positive correlation between greenness and increased quality of life, as defined by the variables used in the study. Noting that the interest of the study was in the application of GWR and OLS, comparisons were made between the outcomes of both methods and a discussion on possible applications of this kind of geostatistical analysis with regard to greening initiatives have been made. The discussions further consider the issues of data quality, time lags in the growth of trees, community involvement at a grassroots level, and the suitability of vegetation whose planting that will have direct positive benefits which impact the success of greening projects.

1 Introduction

Quantifying natural environment value in urban and rural settings is difficult and too often over looked. 'We value what we price, but nature's services – providing clean air, fresh water, soil fertility, flood prevention and drought control [are] not priced', describes the economic invisibility of nature (Sukhdev 2010). An inherently dependant relationship exists between humans and the environment as they are part of one self-contained ecosystem in which cause and effect interactions continually shape its development. One means to model, visualise and analyse natural processes is by making use of Geographic Information Systems (GIS) tools to understand what happens. The tools that this research will employ include spatial auto-correlation techniques in regression modelling for spatial statistics and data exploration (Smith et al. 2007). In particular this study seeks to explore the spatial relationship between quality of life indicators and vegetation of the greater Gauteng Province.

2 Background Information

2.1 Statistical Analysis

New knowledge in analytical methodologies in the last decade allowed geostatistical methods such as Geographically Weighted Regression (GWR) to contribute to the field of limited spatially varying parameter models. GWR is an advancement of the global linear regression methodologies like Ordinary Least Squares (OLS). The global application for this study uses OLS to estimate unknown parameters by using the sum of squared difference between known values and the estimated values. It emphasizes the similarities across space in an attempt to quantify the observation in a single common value (Fortheringham et al. 2002). GWR on the other hand, "extends this traditional regression framework by allowing local rather than global parameters to be estimated ... [thus allowing] a continuous surface of parameter values and measurements to denote the spatial variability of the surface (Fortheringham et al. 2002). As a local statistical method, GWR quantifies what happens throughout different parts of the region, and crucially highlights differences across space. The method has advanced the idea of estimating local models using a subset of observations, centred at a focal point. GWR has been instrumental in highlighting the existence of potentially complex spatial relationships by enabling the modelling of data sets that vary over space . GWR's accepting of non-stationarity of most spatial data sets and creation of models with improved information characteristics and amenability to statistics make it superior in some ways to other alternative methods including Kriging and Bayesian models (Páez & Wheeler 2009; Young et al. 2009). Nonetheless, it is crucial to verify relationships between the dependant and explanatory variables such as spatial variance or stationarity (Charlton et al. 2002).

2.2 Vegetation cover and urban ecologies

One possible explanation to the pattern in the formation of urban ecologies can be thought to emerge through Marxist Urban Political Ecologies, an organized system through which the commoditization of urban nature and green environments occurs (Heynen et al. 2006). Seemingly, social processes have manifested social inequalities into the content and distribution of vegetation over landscapes. Effectively, beyond the rich and poor divide, a divide forms that deprives the less privileged access to green spaces and vegetation cover. International research has examined the relationship between vegetation cover and socio-demographic information of populations and found in several places that there is a positive correlation between quantified vegetation features and wealthy social location and property prices. Contrary situations to such global norms like the occurrence of overgrowth in abandoned housing plots of low-income neighbourhoods do exist (Grove et al. 2006). Structurally, poverty landscapes in Africa are likely to be diverse and extreme in contrast to western urban landscapes. This is why it is important to examine the local context of this relationship.

An increase in urban environmental creation (urban greening) or urban environmental conservation is a prevalent occurrence in many cities. Urban forests are suggested to provide positive externalities for persons that live within urban environments. The benefits of urban greening and urban forests include climate amelioration, natural windbreakers, soil reclamation, noise reduction, waste land reclamation, income generation through tourism, wood products, waste water treatment , conservation and environmental education. This highlights the potential benefits that can be achieved through urban forests and better integration of natural ecologies in urban settings.

In South Africa, urban greening strategies are certainly not new. The planting of Jacaranda trees in central Pretoria or 200-year-old Quercus trees that line many Boland town streets indicate a long history of greening (Meyer, 2001). More recently, a move towards Eco City Planning is advocated as a means to countering increasing poverty in both urban and peri-urban areas (Meyer, 2001). Local authorities at different levels in South Africa have applied greening initiatives in townships and informal settlements as an intervention towards addressing prevalent environmental injustices. A current example leading up to the 2010 Soccer World Cup is the Soweto Greening tree planting campaign (Johannesburg City Parks, 2010). The project aims to plant 200,000 trees in marginalised neighbourhoods including Soweto, Alexandria, and their major road arteries as a means of improving environmental quality (Visser, 2008).

3 Focus and extent of this paper

The recent study by Ogneva-Himmelberger et al. (2009) used OLS and GWR to explore the nature of global and local variations in the relationship between wealth and Normalized Difference Vegetation Index (NDVI). Focusing on the state of Massachusetts in the United States of America, they found a positive correlation between wealth and vegetation coverage. This provided the basis for interest in testing this correlation in South Africa to compare international trends to local patterns but with focus more on poverty.

The Department of Agriculture Forestry and Fisheries (DAFF) has indicated that local research activities in the field of urban forestry and the local spatial temporal patterns suffer from under-funding, lack of co-ordination and a declining skills base and declining interest in forestry (Shackleton, 2006; South Africa (Republic of), 2010). This research can play an important role in supporting the cause for urban greening initiatives by applying GIS tools to statistically explore local relationships of vegetation cover to socio-economic indicators of well-being. The exploratory approach means an array of socio-economic spatial variables can be examined and regressed in comparison to the presence or/ lack of vegetation in the environment. This approach to enquiry facilitates synthesis of local knowledge on existing correlations specific to the area. With limited use of GWR in local studies, the method will compare local and global regression modelling and show the nature of spatial consistency; how the relationship between the dependant variable and explanatory factors change over different places. Calculation of the joint probability distribution of all the variables under examination, conditional on location is possible from this approach (Fortheringham et al. 2002).

Vegetation cover plays an important role in urban ecologies that commonly is overlooked. Current South African research has shown that there are benefits of forests on local livelihoods including energy saving from micro climate regulation, natural resource capital sales from non timber forest products to increased property valuation on account of tree cover (De Sousa, 2003; Long & Nair 1999). Still, there is far too little research and development in the sector over the benefits of green urban environment (Shackleton, 2006). Thus this study will explore the nature in which incomes, education levels, and crowdedness of a give population contribute to vegetation coverage over an area.

4 Methodology

Data from the last National Census of South Africa in 2001, and MODIS NDVI imagery for the same year is used. The NDVI imagery with a resolution of 250 meters covered the months of January and July; periods of the highest and lowest annual rainfall, an environmental factor that would strongly influence the NDVI values over the study area. The Census data was enumerated down to the level of small areas across the study which covered the whole of Gauteng province. The Census variables that were considered focused on the income, education and population data as indicators of the standards of living or quality of life. These variables form the explanatory factors to be used in the regression analysis. The analysis was carried out using ArcGIS v9.3 that for the first time includes the spatial regression technique GWR and the older OLS regression modelling. As a guide the ArcGIS regression analysis Tutorial was used, along with the documentation of regression analysis basics (ArcGIS Help 2009,) and extended materials by Charlton and Fotheringham (2007).

Support for the use of these variables is based on Ogneva-Himmelberger et al.(2009) who applied OLS and GWR in determining the relationship between wealth and vegetation cover. In their study, median income levels and population density were also used as explanatory variables. Luck et al. (2009) explained income as having a direct effect on households' ability to move to greener areas or maintain green spaces at home or in their neighbourhood. Population density on the other hand has negative correlation with vegetation cover, since high population density requires the clearing of land for settlement, and infrastructure (Luck, 2007; Jenerette et al. 2007).

The level of education of the population is considered to enable educated persons access to higher incomes and thus mobility and choice over the quality of their environment (Grove & Burch 1997). Educated people are also more likely to have a greater appreciation for the environment leading to greater conservation or movement into greener neighbourhoods. Locally the education system is supportive of conservation and protection of natural biomes particularly because South Africa has very rich biodiversity. Organisations like Schools Environmental Education and Development (SEED) and the South African National Biodiversity Institute (SANBI) provide support for greening initiatives as well as facilitate Environmental education (EE) and permaculture programs at a school curriculum level and the greater community (SANBI 2010). A positive relationship is therefore assumed between highly educated populations, quality of life and vegetation cover (Luck et al. 2009). It is from these viewpoints that the variables chosen to quantify standards of living are suitable measures through which the relationship to vegetation cover is explored.

5 Results

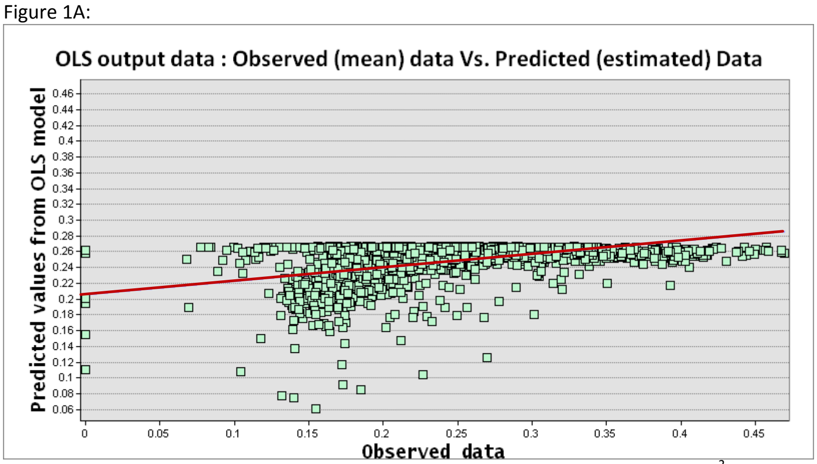
5.1 Identified relationship between Quality of life and Vegetation

The final correlations determined from running the global and local regression models have been graphed to visually illustrate the relationship and also show the improvements of the local model in comparison to the global model. The charts plot the values predicted by the model (y) against the actual values / real observations (x). A linear regression is then done to determine R^2 values of each model.

Figure 1 illustrates the correlation performance of each model separately. Figure 1A considers the OLS output data which has a weak correlation between the actual values and those generated through the ordinary least squares. The overlaid linear regression is determined at an R^2 value = 0.5241 . In comparison the strength of the relationship between greenness and the variables; average household income, population density and tertiary education (Figure 1B) shows significant improvement in the result when using GWR as opposed to the OLS. The included linear regression measures the performance of the GWR's predictions against actual observed values to be R^2 value = 0.806.

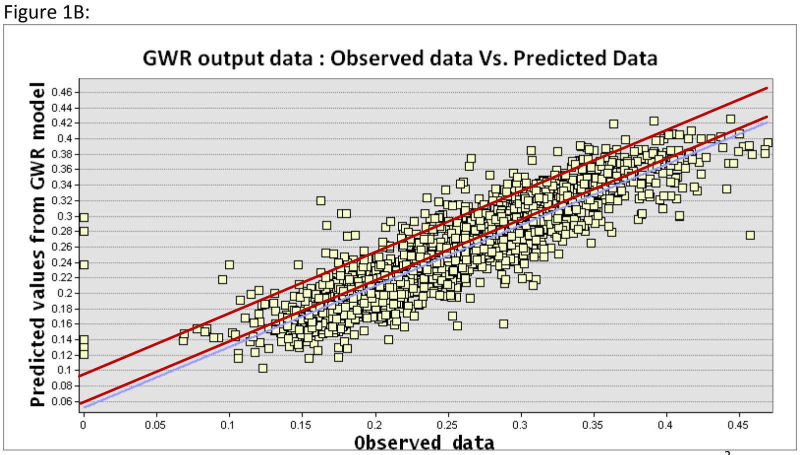
In addition the Global Moran's I test, which showed that clustering in the data was found in the OLS model suggests the findings of the OLS regression are unreliable. GWR on the other hand surpassed this challenge and did not exhibit statistically significant clustering in the data, therefore qualifying it as a reliable model. As a test of the validity of the model, an overlay analysis was additionally carried out to examine the relationship between NDVI (greenness) to the average household incomes. This analysis sampled 50% of all the data used in the study, and it also revealed supportive evidence of a positive correlation between household incomes and vegetation cover. 65% of the high income locations had the highest NDVI values while the lowest income locations had the least vegetation coverage. On testing a negative relationship, only a mere 2% of the data supported such a conclusion. Therefore the results significantly support the findings of an existing positive correlation between quality of life and vegetation cover in the study area.

Figure 1A:



OLS R^2 value = 0.5241

Figure 1B:



GWR R^2 value = 0.806

Figure 1: Charts of the estimated and predicted values as produced by the output tables of OLS and GWR regressions

5.2 The Global and Local models

The results of both the global and local regression model are displayed in Figure 2. The standard residual value that has been mapped is a measurement of the prediction quality of the analyse. High standard residuals indicate that the values at those specific locations have been over predicted, while lower values indicate that the model under predicts those values to a lesser degree (ArcGIS 2009). It is apparent from the figure that there is a greater degree of over prediction (reds/ warm colours) along the northwestern tracts in a W to NNE direction on the map. Under predictions (blues) are mostly clustered in the centre extending out to the East for the most part.

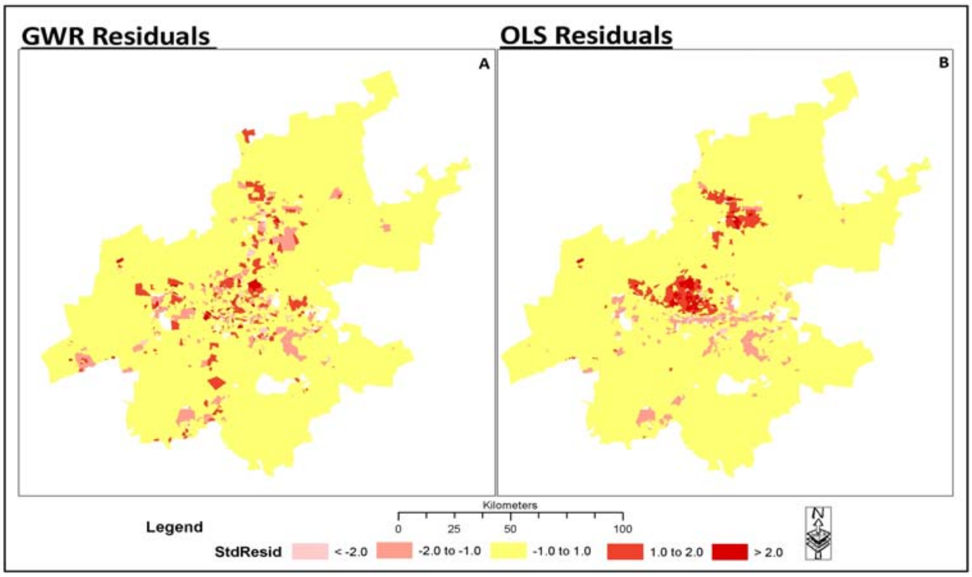


Figure 2: OLS and GWR Standard residuals output.

The GWR residual Map (Figure 2-B) shows a relatively scattered pattern of both over predictions and under predictions intermittently occurring amongst each other. The Moran's analysis of these residuals showed that the over predictions and under predictions occurred in a random pattern. This is a sign of a good weighted regression model (ArcGIS 2009). If there was clustering or dispersions in the standard residuals like the global model it would mean that a key explanatory variable is missing. This means that for the scope of this study the GWR model sufficiently represents the relationship between vegetation cover and quality of life.

6 Discussion

Significant factors that can alter the findings of this research are those of scale and modifiable areal unit problem (MAUP). This concept with specific regard to GWR is highlighted by Fortheringham et al. (2002). Essentially, the MAUP problem occurs from the aggregation of census tracts into larger areal units. For example, aggregation of census data from the individual to enumerated areas (between 100 – 130 households), sub place demarcations and then districts has a zoning effect that has been observed to increase the strength of observed relationships. The zoning effect of MAUP means that different results are obtainable due to the regrouping of zones at a given scale. This aspect can have significant influence in the findings around settlements that varied in size significantly. The effect leads to higher coefficient results (coefficient results refer to the raster surfaces created by GWR to better understand regional variation in the model explanatory variables) produced from the GWR.

At a broad regional scale, the data used was suitable enough to identify the broad relationships and trends that occur in the study area. Analysis at a different scale such as for suburban/neighbourhood analysis requires finer resolution data for both the NDVI imagery and the census data. The high resolution imagery would make it possible to clearly identify greening zones such as those along road networks, or in community public spaces to a greater degree. At present, the resolution of the data was at an actual resolution of 230 meters. However, in order to be able to analyse local changes at a small scale, high resolution imagery would be far more useful. Future studies that truly want to quantify changes in vegetation cover should seek better quality imagery. To put this in context the 200,000 trees planted in and around Soweto under the Soweto Greening Initiative (Johannesburg City Parks, 2010) would be most visible with improved imagery. With more detailed census tracts, the scale and resolution of data that the regression model uses and subsequently the trends and patterns produced in the GWR coefficient raster's would be more accurate to local patterns and changes in the environment.

Even as the findings suggest that there is a positive correlation between the quality of life indicators and vegetation cover, the actual human social processes are more complicated than what the method suggests. The impacts of greening initiatives on individual lives differs with various levels of success depending on the individual needs and the direct impact the trees will have on improving people's lives and therefore the standards of living. Tree planting can lead to economic returns through eco tourism projects based on the unique biodiversity of South Africa (TEEB, 2010). Tree planting in the Cape Flats by SEED (2010) aims to provide a natural windbreaker, shade and food security that leads to better quality of life for those individuals. The approach and choice of greening initiative needs to be considered carefully in order for the benefits to lead to improvements in people's quality of life. At a broader scale, better ecosystems management and integration of natural environments into urban environments particularly and the conservation of the environments in the rural goes a long way to benefiting the population at large, in numerous ways (TEEB, 2010)

Additional factors to consider include very importantly the time factor. There is a natural lag between the start of an initiative and when the actual benefits are felt. It often takes several years for a tree to reach full maturity. The success of any greening project is pegged on a joint bottom up and top down approach to the issue. Community involvement and buying into the idea is essential particularly in providing after care support (i.e. weeding, pruning) during the first 5-7 years when the trees are young. Communities would need to be educated but further to that appreciate the value of trees. A top down approach happens when government enables conducive environments for conservation. For example, governments particularly in East Africa have criminalised the cutting down of trees even on private lots (City Council of Nairobi, 2010; African Conservation, 2009). Such policies safeguard vegetation cover particularly in poor communities where livelihoods are a big challenge, and the conversion of trees into charcoal as a source of income and energy is rampant (Mawiyoo, pers comm. 2010).

To improve this type of study and modelling in general, rather then creating a snapshot in time, which this study attempts, better insight is possible through a longitudinal study that collects information on how living things and their environments interact. (Dean, 2007) This incorporates the time lag factor mentioned earlier. The exclusion of temporal considerations in the modelling of this study is perhaps its greatest limitation. Luck et al. (2009) point out that 'Regression models that explicitly accounted for a time lag between neighbourhood socio-economic characteristics and vegetation response explained more variation in vegetation cover than models that ignored the effects of time.' The changes in both vegetation cover and economic conditions over time is a noteworthy area of research.

Additional indicators could further improve the regression models, for example poverty indicators and other quality of life indicators. At the same time, this also cues in on a natural problem of modelling nature and humans, the processes involved are numerous and complex so it is likely that the model only represents a part of the big picture. The literature provided a solution to the poor performance of the global model by using a local model instead. While this worked particularly well, the local model could also be improved with the addition of key variables, identifying key excluded explanatory variables should be a focus of further research in order to produce the best representative model of reality.

7 Conclusion

This study set out to explore the relationship between quality of life indicators and vegetation cover through the application of considerably new geostatistical methods in a GIS. The findings of this study support the existence of a positive relationship between vegetation and the socio-demographic information in the Gauteng Province of South Africa, thus Vegetation cover (greenness) correlates positively with quality of life as described by the indicators used. The regression modelling showed that in most cases, using a local model (GWR) yielded better findings than that of the global model (OSL) particularly because GWR quantified the relationship in accordance to more accurately informed local relevance. A refinement and advancement of the modelling is crucial as has been discussed. Further research could explore if local models can go as far as predicting the type of vegetation in different kinds of neighbourhoods or even identifying locations that could benefit directly from modern incorporative urban planning and urban redevelopment which strongly accommodates urban greening. The link between global variables and local variables is very important in terms of predictive applications that can advise policy. Charlton & Fortheringham (2007) suggest that statistically significant global variables that exhibit strong regional variation can inform local policy while if the global variables exhibit weaker regional variations then GWR's predictive applications informs regional policy.

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Disaster and Risk Management

Use of Satellite Rainfall Estimates in Flood Early-Warning in the Nyando Basin, Kenya

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KEY WORDS:
Rainfall estimates (RFE), flood forecasting, hydrologic modelling, GIS

ABSTRACT:

Floods are considered one of the most common natural hazards in the Lake Victoria basin. However, significant delays in ground data availability have made it infeasible to use traditional flood forecasting systems. Satellite rainfall estimates have therefore been identified as readily and economically available data that can be used as input to run hydrologic models and produce flood-warning systems.

In this paper, historical rainfall data for the Nyando basin are used to validate the satellite-derived rainfall estimates (RFE). The RFE raster dataset and the point feature class of gauging stations were overlaid in a GIS to extract the cell values of rainfall estimates at the positions of the gauging stations for the period 1995 to 2005 corresponding to the locations of 35 gauging stations in the basin. The values were compared with the observed gauge data for the same period. A simple hydrologic model, developed for use as a GIS user-interface and integrated with a geospatial database of the area is then tested on its capabilities as a flood early-warning system by comparing it with historical streamflow.

The results for comparisons at daily accumulations of satellite-estimated rainfall when forced against observed rain gauge data are not so good but they performed reasonably well in detecting the occurrence of rainfall. The products show good results for 10-day accumulation where regression analysis yielded an average correlation coefficient (R^2) of 0.78. The simulated runoff is reasonably indicative of the variation in the stream level. Thus when there is forecast of a drastic surge in the runoff volume, a rise in the river level is to be expected and this enables the prediction of the occurrence of floods and the issue of early warnings.

1 Introduction

Frequent flooding has emerged as the greatest challenge to most developing countries particularly in Africa and Asia, leading to loss of lives, livestock and property. In the recent past, Nyando River Basin and its environs has witnessed rapid surge in flooding during most of the rainy seasons resulting in a myriad of problems and environmental risks.

Modern flood forecasting methods are increasingly being used as a strategy for mitigation of flood hazards worldwide and spatially distributed rainfall is an important input for accurate flood forecasting. Conventional rain gauge estimation of rainfall requires a dense network of many gauges to accurately characterize precipitation over an area such as a watershed. But the insufficient number of gauges cause gaps in continuous data collection hindering this method. In the developing nations accurate data is very often either not readily available or is expensive to obtain. In most of Africa, ground-based information is in short supply. Rain gauge networks are sparse with vast areas remaining non-gauged, while radar is not a feasible proposition on the grounds of cost, technical infrastructure and topography (Grimes and Diop, 2003). Satellite rainfall estimation becomes an attractive option. Thus the main challenge is to identify and use readily and economically available information to produce a flood warning system.

A technique for estimation of precipitation over Africa was developed to augment the rainfall data available from the relatively sparse observational network of rain gauge stations over this region. The method utilizes

Meteosat satellite data, Global Telecommunication System (GTS) rain gauge reports, model analyses of wind and relative humidity, and orography for the computation of estimates of accumulated rainfall (Herman *et al.*, 1997). The U.S. Agency for International Development (USAID) Famine Early Warning System (FEWS) has been supporting the production of 10-day Rainfall Estimate (RFE) data for Africa since 1995. The RFE 1.0 algorithm, implemented from 1995 to 2000, uses an interpolation method to combine Meteosat and GTS data, and warm cloud information for the 10-day estimations. The RFE 2.0 algorithm, implemented as of January 1, 2001 uses additional techniques to better estimate precipitation while continuing the use of cold cloud duration and station rainfall data. The RFE subsets are flat binary images of 8 km square pixels, with the cell value rainfall units in millimetres.

Satellite rainfall estimates have been found useful in characterizing flood hazards, in both simple indices and stream flow models (Verdin *et al.*, 2005).

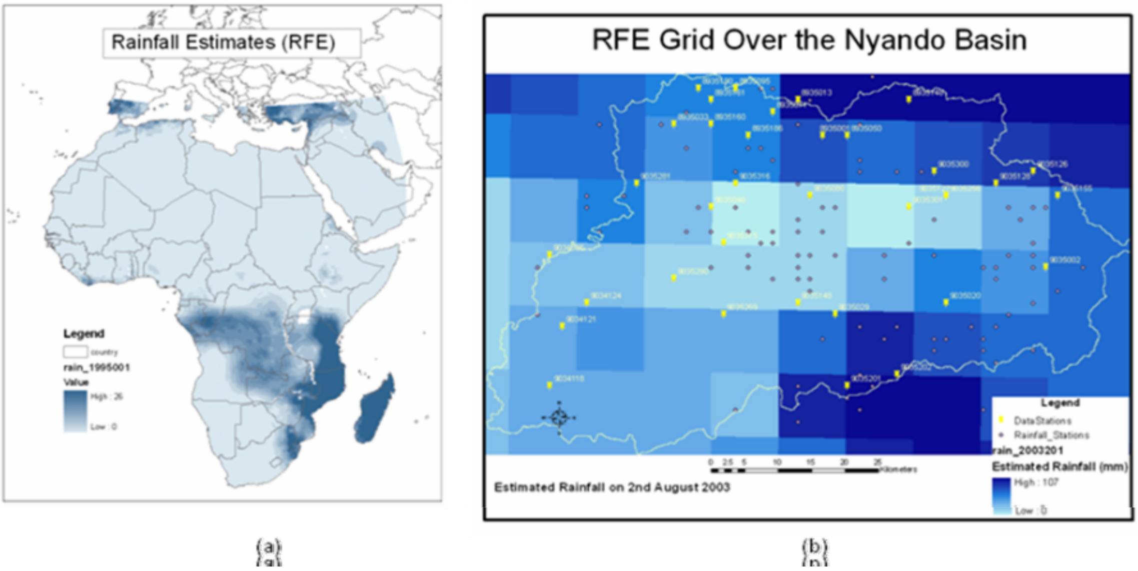

Figure 1: (a) Satellite rainfall estimates (RFE) over Africa on 1st January 1995 and (b) RFE grid for 2nd August 2003 overlaid with gauging stations over the Nyando Basin.

The main problem in this part of the world is that accurate data is very often either not readily available or is expensive to obtain. This paper seeks to demonstrate that RFE data, which is readily and economically available, can be used to produce a flood warning system. GIS tools are used to compare RFE with rain station data over the Nyando basin in western Kenya. The RFE data is then used to run a simple GIS-based hydrologic model for the Nyando basin that uses a GIS user-interface and is integrated with a geospatial database of the area so that it can be used as a flood management tool and early-warning system. The database includes a Digital Elevation Model (DEM) of the area together with the soil types, land use and the daily satellite-derived rainfall estimation. The system can be used in determining the areas affected by floods and forecasting areas likely to be flooded.

2 Methodology

2.1 Study Area

The area of interest is the Nyando river basin where perennial floods in the lower Kano plains have been causing a lot of human suffering. The Nyando River is located in western Kenya and drains into Lake Victoria. The basin covers an area of approximately 2,646 km². The Nyando River basin is bounded by latitude 0^0 7' 8"N and 0^0 24' 36"S and longitude 34^0 51'E and 35^0 43' 12"E. Lake Victoria is to the west, Tinderet Hills in the east, Nandi Escarpment to the north and Mau Escarpment to the south east. The basin mainly lies in Kisumu, Nyando, Nandi South and Kericho districts. The Basin has a total population of about 750,000 based on the 1999 census. The mean annual rainfall varies from 1200 mm close to Lake Victoria to 1500 mm at the foot of the Nandi Escarpment. The annual rainfall pattern shows no distinct dry season; it is bi-modal with peaks during the long rainy season of the region (March–May) and during the short rainy season (October– December).

2.2 Validation of Satellite Rainfall Estimates

As the RFE raster divides the ground area into square cells on a regular grid, each cell is assumed to be homogenous. Any gauging station falling within a particular cell is expected to have recorded rainfall that is representative of the cell value for comparison with the uniform RFE value for that cell for that particular day. This comparison is only possible for cells that have gauging stations. A few cells have more than one station but all the stations that have data were used in the comparison.

ArcGIS was used to extract the values of the satellite rainfall estimates (RFE) at the positions of the gauging stations. The stations are first displayed in the GIS user interface. A Visual Basic for Applications (VBA) program was developed in ArcGIS to extract the values of the rainfall estimates at the positions of the gauging stations. The stations are first displayed in the GIS user interface. The custom tool imports each day's RFE raster dataset in turn and loops through each station in the point feature class to obtain the cell value of the raster on that point. This routine was used to obtain the RFE data for the period 1995 to 2005 corresponding to the locations of 35 gauging stations in the basin. The values were compared with the observed gauge data for the same period.

Observed data for 35 stations were obtained from the Kenya Meteorological Department. The stations used in the analysis are those with no missing days in observed data for any full year between 1995 and 2005. Though RFE data were obtained for the years 1995 to 2005, some years were left out of the analysis due to lack of concurrent RFE and station data. There was no station without gaps in 1995 while the RFE data in 2004 and 2005 had gaps. The RFE data for 2000 had unrealistic values for day 305 (ranging from 0 to 14848, in multiples of 256). Consequently, the years used in this study are 1997, 1998, 1999, 2001, 2002 and 2003. The number of stations used in the particular years ranged from 2 to 12 gap-free stations. A total of 18 stations were used.

Time-series graphs were plotted for each station for daily, 10-day (dekadal) and monthly rainfall. Histograms were plotted of the annual rainfall for each year at each available station by summing the daily precipitation from both sets of data for a graphical comparison. Daily precipitation fields were then summed up into dekadal fields for both sets of data for each station. The arithmetic average of the included stations was then calculated for each dekad in both sets.

Simple regression analysis was used to measure the degree of agreement between the observed rainfall and the satellite RFE. Time series traces (Figure 5) and scatter plots (Figure 6) of the data were prepared to illustrate the results. The root mean square error (RMSE) was also calculated to quantify the amount by which the satellite-derived rainfall estimates differ from the rain gauge-observed values for the 10-day accumulations.

2.3 Flood Modelling

The storage capacity (infiltration) was estimated through GIS analysis of existing digital soil maps and land cover map overlaid with the elevation layer. Surface runoff was generated as infiltration excess. For modelling purposes, the infinite variability of the parameters was averaged to a degree of finite elements (20 m square grids), which was then assumed to have uniform parameters (elevation, land cover, soils etc). These were based on the 20 m resolution of the DEM; generated from contour lines and spot heights of existing topographic maps of the area.

The soil types were classified from their attributes according to the Soil Conservation Service (SCS) of the United States into four hydrologic soil groups according to their infiltration rate (Maidment, 1993). Group "A" consists of soils that have low runoff potential and high infiltration rates. Group "B" consists of soils that have moderate infiltration rates. Group "C" consists of soils that have low infiltration rates. Group "D" consists of soils that have very low infiltration rates.

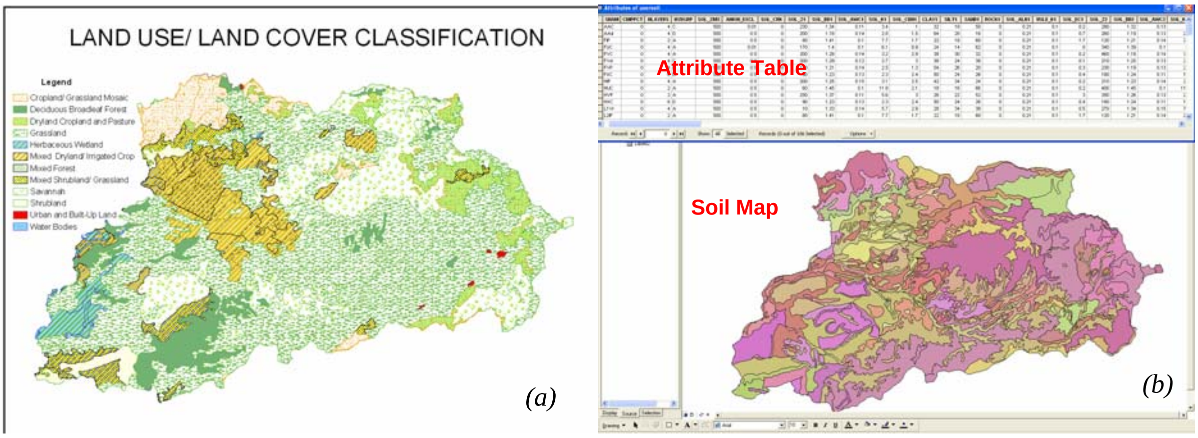

Figure 2: Classification into the major land use/ land cover groups (a), and a GIS display of soil data (b) for the Nyando basin

With the grids of soil hydraulic groups, land cover and rainfall estimates, surface runoff from each cell was estimated by the Curve Number method of the Soil Conservation Service. The runoff depth was calculated for each cell for each day to produce a continuous raster representing surface runoff from rainfall estimates (RFE), for the basin for each day. The approach estimates direct runoff Q in inches from rainfall P in inches and watershed storage S by:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (1)$$

The parameter S is defined by:

$$S = \left(\frac{1000}{CN} - 10 \right) \qquad (2)$$

Where CN the runoff curve number ranging from 0 to 100, dependent on the ground cover type and the hydrologic condition.

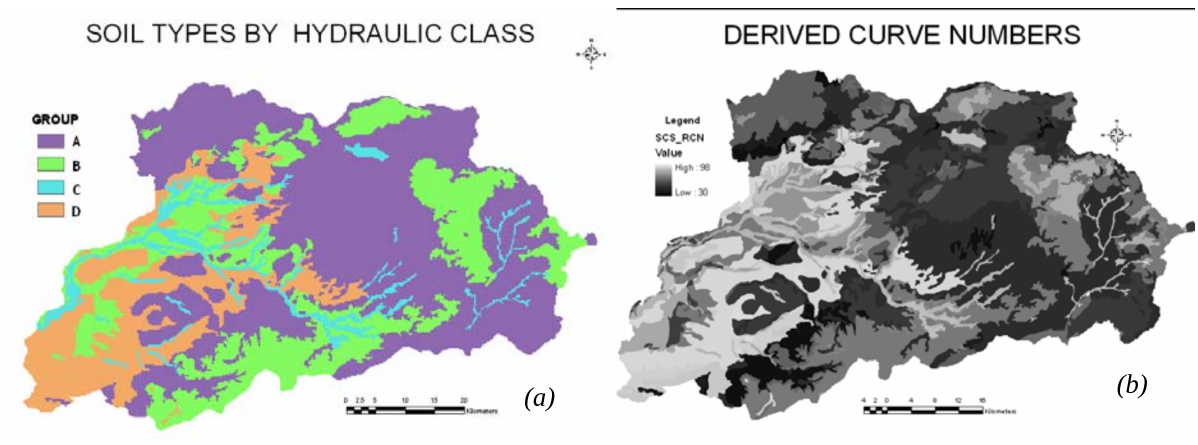

Figure 3: This illustration shows a grid of soil hydraulic groups (a), and a grid of the derived curve numbers (b) for the Nyando basin.

This grid is used to weight the flow accumulation grid of the Basin to estimate the amount of surface runoff that is incident on the surface, upslope from each cell. The simulated accumulations of surface runoff volumes driven by the daily rainfall estimates were compared with previous stream level records obtained from existing river gauging stations placed at sub-basin outlets.

3 Results and Discussions

Though visual examination of the time-series graphical pictures of superimposed RFE and observed daily rainfall over each station does not show good agreement on the amount of rainfall, it shows some reasonable concurrence on the occurrence of rainfall. When summed into 10-day accumulations, better agreement can be seen on both the amount and occurrence of rainfall. However in some cases the RFEs underestimated or overestimated the observed rainfall. The erratic pattern was not only seasonal as one half of the year could be mostly overestimated while the other half is underestimated (as could be seen on statistical plots of the monthly rainfall), but also spatial. On the annual scale, some stations were overestimated while others were underestimated as shown in Figure 4. Also, some years' totals showed a similar trend.

Table 1 summarizes the results of a comparison of the satellite rainfall estimates with the observed station data as the reference standard. Table 2 ranks the rainfall stations according to the correlation between the observed data and the satellite rainfall estimates at each station.

Figure 5 shows a good agreement between the arithmetic averages of the two sets of data from dekadal accumulations. Regression analysis yielded on average a correlation coefficient (R^2) of 0.78. Table 2 illustrates that the two years that showed the best match in this sample were 2003 and 1997; incidentally these two years saw some of the most extreme flood events of recent times in this region. Even for the year 2000 where Day 305 RFE data was suspicious, an arbitrary division of the cell values by 256 yielded a correlation factor of 0.74. The RMSE was on the order of 21 mm per dekad.

Most stations showed a high degree of association between and RFE and gauge data. Apart from Stations 9034121 and 8935148 that had moderate positive correlations, all other stations illustrate very strong positive correlations (Table 2). The results from the graphical comparison of the satellite estimates with observed rainfall show that the RFE underestimates rainfall in some stations but overestimates in some. This may have been due to the topography of the region that may have resulted in orographic precipitation (Ouma *et al,* 2008). Some stations had only moderate correlation. Overall, as much as the estimates are constrained with gauge data, gauge errors cause uncertainty too (Vieux, 2004). Errors in gauge accumulations may be caused by wind effects and tipping of bucket gauges during heavy rainfall rates.

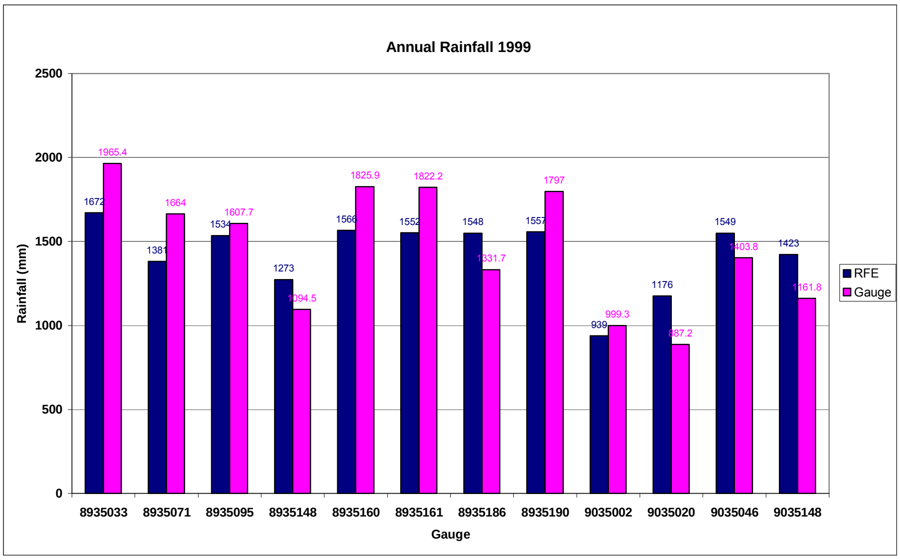

Figure 4: Comparison of annual rainfall between observed and satellite-derived estimates at the positions of 12 stations for the year 1999

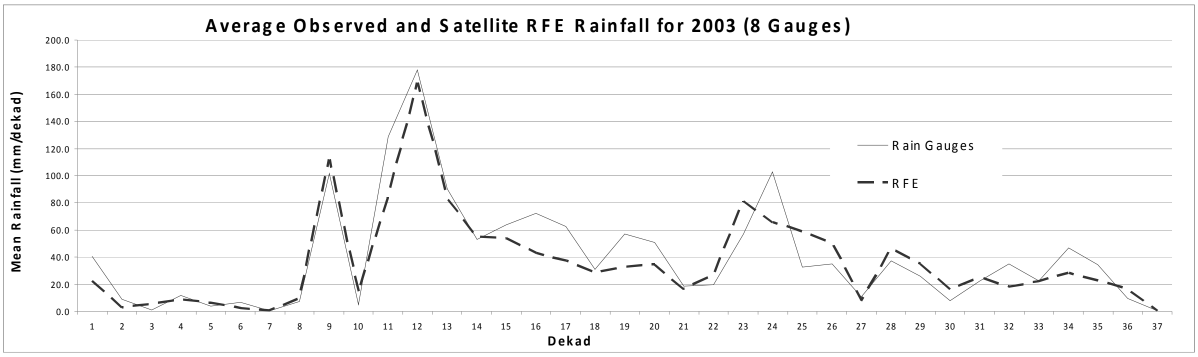

Figure 5: Time series plot of average study area rainfall (millimetres per dekad) for the 37 dekads of 2003 for the rain gauges (observed) and satellite RFE

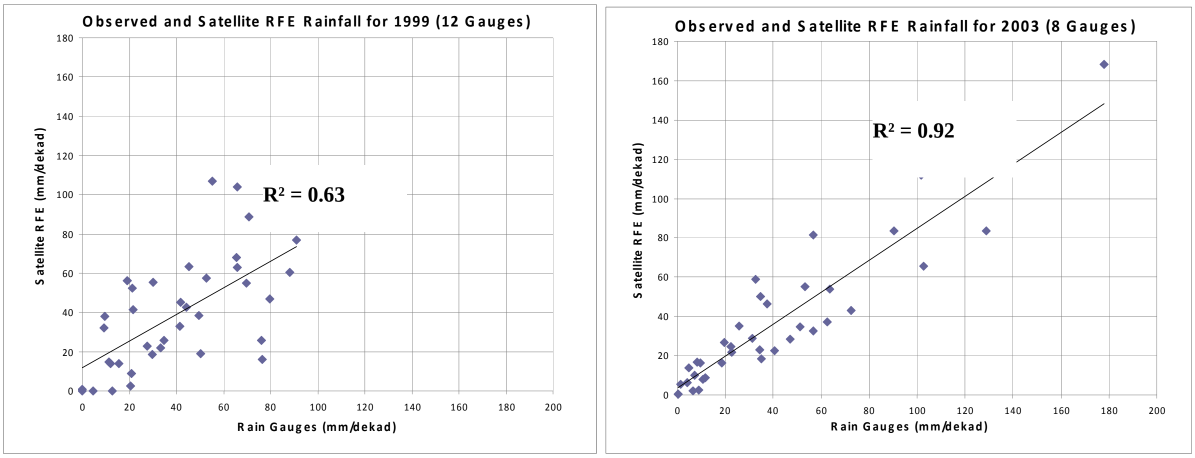

Figure 6: Scatter plots of dekadal average rain gauges (observed) rainfall versus satellite RFE for 1999 and 2003 with coefficients of correlation of 0.63 and 0.92, respectively.

Table 1: Results of the correlation analysis between the satellite rainfall estimates and the observed station data for the selected period.

Year	Correlation coefficient	No. of Gauges	RMSE (mm/Dekad)
1996	0.774	9	21.79
1997	0.903	11	16.79
1998	0.771	10	20.27
1999	0.629	12	23.37
2001	0.714	6	22.64
2002	0.775	4	25.11
2003	0.920	8	15.89

Table 2: Degree of association between the observed data and the satellite rainfall estimates at each station:

Station_ID	***Station_Name***	***Mean Correlation Coefficient***	***No. of years used***	***Station_ID***	***Station_Name***	***Mean Correlation Coefficient***	***No. of years used***
9035127	*P.B.K Londiani Pyrethrum Office Nursery*	*0.848*	*2*	***8935161***	*Nandi Hills - Kibweri Tea*	*0.623*	*12*
9035126	*P B.K Olenguruone Field Office*	*0.801*	*4*	***8935033***	*Nandi Hills - Savani*	*0.609*	*6*

					Estate		
9035080	*Kamarero - Songhor*	*0.799*	*2*	***8935190***	*Sitoti Estate*	*0.549*	*10*
8935071	*Siret Tea Co. Ltd. - Nandi*	*0.727*	*10*	***8935160***	*Kapsimotwa Tea Estate*	*0.525*	*12*
9035148	*Koru Bible School*	*0.681*	*6*	***9034086***	*Ahero Irrig. Research Station*	*0.524*	*4*
8935095	*Nandi Tea Factory*	*0.64*	*6*	***9035020***	*Kipkelion Railway Station*	*0.483*	*6*
9035046	*Chemelil Plantation*	*0.637*	*12*	***9035002***	*Londiani Forest Station*	*0.467*	*6*
9034124	*Masaka Apundo's Farm*	*0.632*	*10*	***9034121***	*Rae Girls' Secondary School*	*0.37*	*2*
8935186	*Kimwani A.D.C. Farm*	*0.632*	*10*	***8935148***	*Kipkurere Forest Station*	*0.279*	*2*

The results suggest that the satellite rainfall estimates can be a source of rainfall data for modelling processes for 10-day and longer periods. The RFE data can thus be used as the rainfall input in the flood forecasting system. Satellite rainfall estimates (RFE) fill in gaps in station observations. The gridded rainfall time-series give historical context, and provide a basis for quantitative interpretation of seasonal precipitation forecasts. It was noticeable from graphical comparison between simulated runoff volume and observed streamflow that whenever the simulated runoff volume at the gauging position increased significantly, there was, in most cases, a similar incremental trend in the observed level of the river on the same day or one day later.

4 Conclusion

The results suggest that the satellite rainfall estimates can be a source of rainfall data for modelling processes for 10-day and longer periods. The RFE data can thus be used as the rainfall input in the flood forecasting system. Satellite rainfall estimates (RFE) fill in gaps in station observations. The gridded rainfall time-series give historical context, and provide a basis for quantitative interpretation of seasonal precipitation forecasts. It was noticeable from graphical comparison between simulated runoff volume and observed streamflow that whenever the simulated runoff volume at the gauging position increased significantly, there was, in most cases, a similar incremental trend in the observed level of the river on the same day or one day later.

Satellite rainfall estimation is an attractive option in most of Africa, where rain gauge networks are sparse with vast areas un-gauged, while radar is not a feasible proposition on the grounds of cost, technical infrastructure and topography (Grimes and Diop, 2003). The validation results show that RFE; with operational estimates every 10 days, can provide a sufficiently reliable prediction of precipitation over the basin for flood forecasting purposes.

A simple spatial analysis of the basin drainage parameters integrated with RFE estimates over the basin can be used to predict the increase in stream levels that may lead to occurrence of floods. On daily time scales, the satellite rainfall estimates were weakly correlated with the gauge data, whereas the match between dekadal accumulated rainfall values was good. This implies that, in the absence of more accurate methods of estimation of precipitation such as ground-based radar, RFE input into a hydrologic model can be used to simulate the hydrologic process for a 10-day period in order to forecast flooding in the Nyando basin and other basins in the Lake Victoria region.

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Integrated Water Management Strategies through Drought Hazard Mapping and Water Quality Modelling Using GIS

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KEYWORDS:
GIS, Drought, Water Quality Index, Hazard, ground water

ABSTRACT

Drought is one of the most common climate related natural disaster in the world. Droughts have disastrous impacts on the economy and can affect the largest segment of the society. Drought by nature is a result of inter-related parameters. This study is based on the concept that the severity of the drought is a function of rainfall, hydrological and physical aspects of the landscape, leading to meteorological, hydrological and physical drought. In the present study a GIS-based tool for drought vulnerability assessment at a microlevel has been developed. Groundwater is an integral part of the environment, and hence cannot be looked upon in isolation. There has been a lack of adequate attention to water conservation, efficiency in water use, water re-use, groundwater recharge, and ecosystem sustainability. The study area, the Palakkad district in Kerala, is noted for its rice cultivation, as well as its industries and is known world-wide for its sustained opposition to Pepsi and Coca-Cola plants extracting large quantities of groundwater. The present study aims to identify the water quality, drought hazard prone areas of different time periods and also predict the drought vulnerable area to the next season using the present data and mathematical models. The drought vulnerable area map and water quality index map can be used by the public for the better management of water resources and drought management.

1 Introduction

Drought is a recurring natural phenomenon that has overwhelmed civilization throughout its history. It affects the ecosystem and all the sectors of society from agriculture to transportation and event to modern industries. Drought has long been accepted as one of the most dangerous cause of human misery (Wilhite, 2000). It has today become the worst natural disaster that annually claims billions of dollars of loss to affected communities. Its ability to cause widespread misery is actually increasing day by day. Drought hazard is known as a 'creeping hazard' (Coppola, 2007) and results in serious economic, social, and environmental impacts. Dynamic nature of drought with complex phenomenon having multiple effects form a major challenge in planning, monitoring, predicting, assessing impacts and offering solutions to drought hit areas. Because of these complexities, high quality data and improved tools to capture the spatial and temporal dimensions of drought, integrative tools like global positioning systems and GIS are needed. Satellite derived drought indicators calculated from satellite-derived surface parameters have been widely used to study droughts. Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), and Temperature Condition Index (TCI) are some of the extensively used vegetation indices (Zhao, 2008).

The chemical composition of groundwater is a measure of its suitability as a source of water for human and animal consumption, irrigation, and for industrial and other purposes. The groundwater resources are under great risk due to the drastic increases in population, modern land use applications (agricultural and industrial) and demands for water supply, which endanger both water quality and quantity (Babiker, 2007). The definition of water quality is therefore not objective, but is socially defined depending on the desired use of water. Different uses require different standards of water quality. Therefore, assessing and monitoring the quality of groundwater is important to ensure sustainable and safe use of these resources for the various purposes. Many researches in India and abroad have assessed the groundwater quality to find its suitability for drinking and irrigation purposes (Melian, 1999; Hrkal, 2001; Srinivas, 2005; Babiker, 2007.). When water comes down to the earth as rain it begins its journey in a highly pure form but as it falls through the air it begins dissolving gases and entrapping particulate matter present in the air. The nature and concentration of the constituents that the water acquire determine the quality of water (Reza, 2010).

2 Methodology

GIS and field-based methodology were adopted. It includes collection of spatial data layers, field verification, analysis and satellite data interpretation. The different layers used for the analysis of drought hazard map include land use and NDVI (Normalised Difference Vegetation Index) prepared from LISS IV satellite image (May 2010), geology map, soil map, geomorphology map, rainfall map (rainfall data is spatially interpolated by using geostatistical analyst to prepare rainfall map), depth to ground water map (depths to ground water level are analysed in the field in different stations and the data are interpolated using Inverse distance function of Spatial analyst extension of Arc GIS), drainage density map, Geohydrology map, rocks & minerals and slope map was prepared. These different layers are used for the analysis. Weighted overlay analysis technique was employed to determine the drought prone area. The weightages of individual themes and feature score were fixed and added to the layers depending upon their role in drought. Higher values of scores indicate higher possibilities. Spatial Analyst extension of ArcGIS 9.3 was used for converting the features to raster and also for final analysis.

The various physico-chemicals attributes of water samples such as pH, Electrical Conductivity (EC), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Carbonates (CO3), Bicarbonates (HCO3), Sodium (Na), Potassium (K), Chloride (Cl), Nitrate (NO3), Sulphates (SO4), Fluoride (F) etc were collected from the Central Ground Water Board, Trivandrum (CGWB). The different locations of sampling stations with its corresponding physico-chemical analysis values were imported into GIS as point layer. All the three years of data are imported like this. The spatial distribution of each water quality parameters are generated by using the 'Inverse Distance Weighted' tool in the spatial analyst toolbox of Arc. Map. This spatial distribution of the selected water quality parameters are used to generate water quality index (WQI) of the study area. Water quality index (WQI) is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water. WQI turns the complex water quality data into information that is understandable and usable by public. The BIS and WHO standards for drinking have been considered for calculation of WQI. The calculation of WQI is with the help of raster calculator (Kavitha et al., 2010)

The Water Quality Index (WQI) is calculated as follows:

$$WQI= \sum^{n}_{i=1} (Qi\ Wi) / \sum_{i=1} Wi$$

where, Qi is the sub index of ith parameter. Wi is the unit weightage for ith parameter, n is the number of parameters considered. Spatial distribution of each parameter generated. All such maps were integrated and generate water quality index map of the study area for three years.

3 Result and discussion

The drought severity maps of 2008, 2009 and 2010 are generated which gives a clear understanding of the spatial changes of drought and its extremely close link with the water level depth and rainfall. The drought severity maps of 2008, 2009 and 2010 are represented in Fig 2, 3 and 4 respectively. Careful analysis of the three year drought analysis shows an increasing pattern of drought in the district. This may be due to the changing climatic parameters, land use pattern and human exploitation. Based on these result prediction map of 2010 was prepared (Fig. 5). On analysis this drought vulnerable maps help to identify the drought hit areas in the district. The map shows four different classes as low, moderate, high and severe. The reason for the increase in drought is mainly the changing cropping pattern, over dependence on groundwater for domestic, industrial and irrigation purposes also exacerbate the drought condition in the district. The temperature in the region is also ever increasing.

The values of selected parameters of groundwater quality data in pre, syn, and post monsoon seasons and BIS and WHO water quality standards were used for calculating water quality indices. Quality status is assigned on the basis of calculated values of water quality indices to include the collective role of various physicochemical parameters on the overall quality of drinking water. WQI computations were made from the equations. The spatial distribution of the WQI map generated for the study area during, pre, syn and post monsoon seasons are presented in Fig.6, 7, and 8 respectively. The water quality map show four classes like very poor, poor, moderate and good quality areas. The analysis of the three years of WQI map shows that in 2009 water quality of the district is comparatively not suitable than in 2008 and 2010. This may be due to the climatic as well as human activities.

4 Conclusion

Water is a finite and vulnerable resources essential for the sustain of life, development and the environment. The increasing demand on water creates conflicts all around the world. As the drought is dynamic in nature, which builds over a time, timely and reliable information is essential for effective drought monitoring and management. Satellite remote sensing provides multi-spectral, multi spatial and multi temporal data useful for drought monitoring, assessment and management. The present study is a comprehensive evaluation and integrated analysis of drought, which has been carried out by using satellite based remote sensing and GIS techniques. Adverse climatic conditions may further convert these high drought prone areas to severe drought areas. Some action plans comprising of drought proofing works, employment generation programmes and social security programs were discussed for managing the drought prone areas. GIS based methodological framework developed as part of this study can be effectively used elsewhere in groundwater quality monitoring and their management. Spatial interpolation maps are used for the water quality monitoring process of the area and it is useful for the decision makers to take better decision for the water quality management. The present water quality index map and water quality data will serve as a baseline data for the future development and management of water use strategies in the area.

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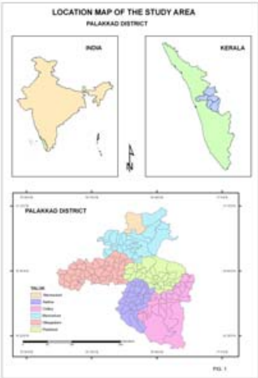

FIG.1

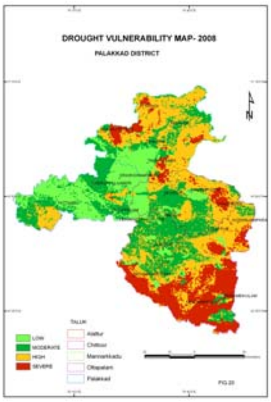

FIG.2

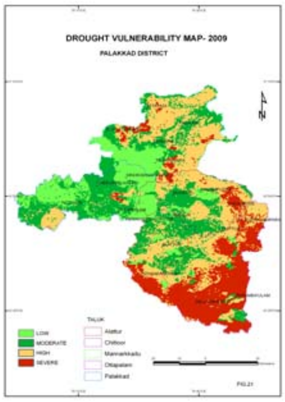

FIG.3

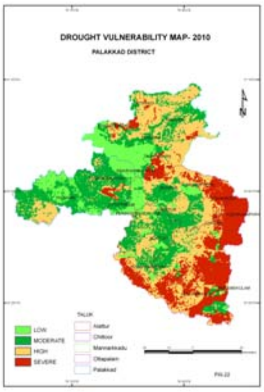

FIG.4

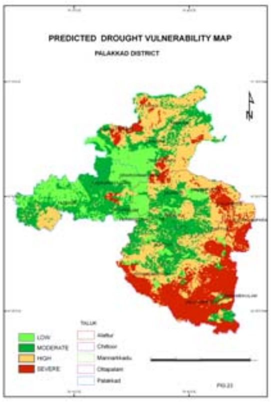

FIG.5

FIG.6

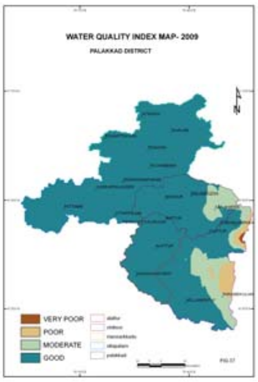

FIG.7

FIG.8

Optimum DTM Resolution for Flood Hazard Mapping: an example from Waiblingen, Germany

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KEYWORDS:
DTM, Flood, Simulation, Kalypso, Gaja3D

ABSTRACT

Water is one of the key natural resources that make earth liveable. Every living thing on earth directly or indirectly depends on water. Excessive availability of water resources (flooding) can create hazardous situations for life on earth. Accurate prediction of these disaster situations will help to reduce damages. Prediction of floods can be done by using computer simulation models. Digital Terrain Models (DTM) play a major role in flood modelling since it represents the ground surface, and high resolution DTM can even represent tiny details of the land surface. Although, detailed DTM provides more accurate prediction, availability and the cost of data as well as the processing power is important in determining the optimum resolution for a particular DTM.

Waiblingen in Germany, the study area, is characterized with high flood risk. A 2D mesh was developed by integrating DTM data into river profile data and then it was used for the 2D flow simulation. The model was calibrated for 10, 50 and 100-year recurrence intervals. The generated models were then used to simulate flood risk and damage. Kalypso, an open source modelling software, was used for the simulation. Different DTM resolutions were evaluated for the flood modelling and the developed flood grids were compared. The results indicate that high resolution grids gave the more accurate output since they covered smaller areas. However, when considering the processing speed, accuracy and cost of the data, middle level resolution grid is the best solution for flood modelling.

1 Introduction

As a natural resource, water plays a major role in ecosystem functioning. The majority of water on the Earth's surface is saline and the rest fresh water. Though water sustains life, its excessive availability leads to natural hazards like flooding, which can cause immense damage to the environment and its inhabitants. According to Knight and Shamseldin (2006), floods account for about a third of all natural disasters by number as well as economic losses and is responsible for over half of the deaths due to natural disasters worldwide. Therefore it is important to design settlements to reduce the impact of flooding.

Flood modelling can be used to predict flood situations. For the simulation spatial and nonspatial data are required. Most of the high resolution data are very costly and they need high processing power. On the other hand low resolution data can give under or over estimation affecting the accuracy of the prediction. Therefore it is important to find the optimum level of resolution for the flood simulation.

1.1 1D and 2D simulation

The 1D model is based on the stream cross-sectional data. It is capable of measuring the velocity of water flow and the model calculates water flow parallel to the main channel. The 2D model provides the horizontal and vertical spread of water flow. The 2D model requires surface information as a mesh. Surface parameter calculates velocity of the water in each direction and extent of the flood over the land. Land surface roughness value is one of the important parameters which retain a uniform value for different land use patterns. But most of the 1D models have different roughness values which can be applied according to the floodplain.

1.2 Boundary Conditions

Hydrological models are limited for some particular part or section of the real world. There should be a connection between real world and model. It is the boundary conditions that makes the linkage between real world and model possible. In 1D simulation, the boundary condition applies for one node while in 2D simulation it applies for several nodes which cross the river channel. In the upper reaches of the stream, boundary condition should have positive flow, which means flow into the model and downstream should have negative flow rate.

1.3 Roughness

River channels have different roughness values and flow velocity depends on the roughness, which is unique for the different surfaces. Manning's formula expresses the relationship between velocity and other factors.

1.4 About Kalypso

Kalypso is hydrological modelling software, which also has GIS functionality. Besides, the software aids flood risk mapping. The tool consists of six modules (Belger 2009).

6. Kalypso Hydrology
7. Kalypso WSPM
8. Kalypso 1D/2D
9. Kalypso Flood
10. Kalypso Risk
11. Kalypso Evacuation

2 Methodology

2.1 Data Preparation

2.1.1 Generation of Digital Elevation Model (DEM)

5 m resolution DTM was generated from the 1m LiDAR source data. Original LiDAR data was in point (X, Y) and it was converted to the ASCII file and used to generate raster surface.

2.1.2 Cross section data

Cross section data was entered manually into ArcGIS. Those data was entered perpendicular to the river band. Linear measurements were entered as polylines and those lines were used to extract vertices as a point on the line using "Feature Vertices to Point Tool" in ArcGIS. Figure 1 shows the original paper-based data sheet, which contained the profile values.

Kalypso is capable of using CSV file system to enter profile information. All the input cross-sections were sorted according to the Easting coordinates and width of the cross-sections and heights were modified in each model. According to the Kalypso manual, the constructed structure needs two supporting cross-sections to simulate the model. Due to limitation of data availability, the supporting cross-sections were measured using image and the depth of the channel was estimated according to the upper or lower cross-section parameters.

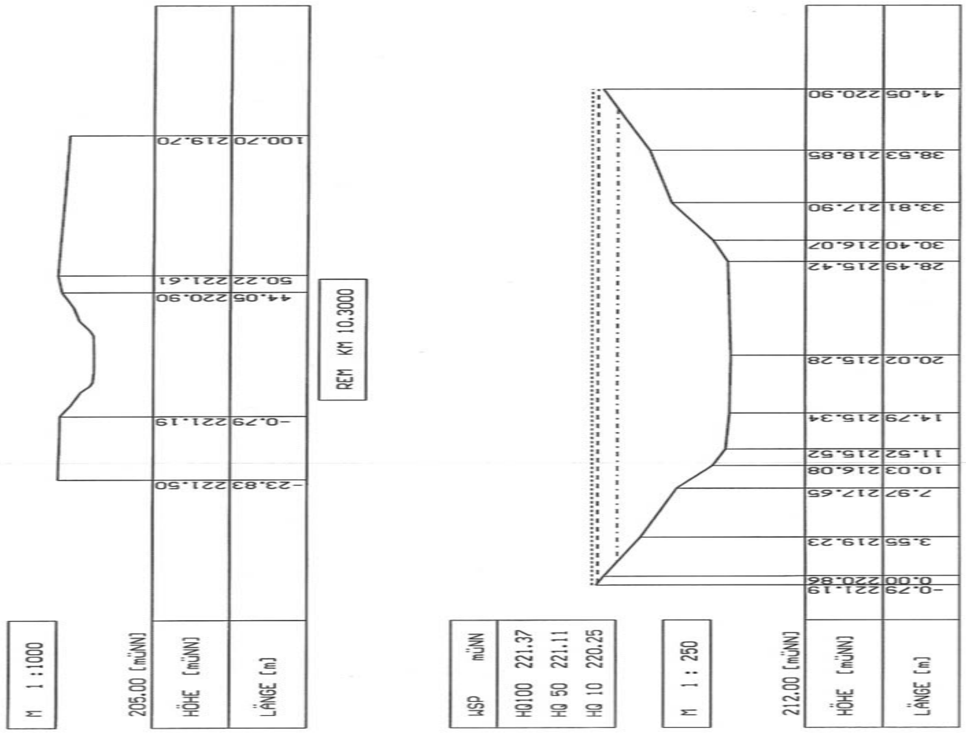


Figure 1. Paper-based cross-section data

2.1.3 2D River mesh generation

Using river channel generator tool in the Kalypso 1D/2D module, 2D river network was generated. It facilitates river channel generation using profiles. It interpolates the profiles between major profiles. Tool assigns height value according to the profile heights. Figure 2 shows the interpolated profiles and intermediate nodes.

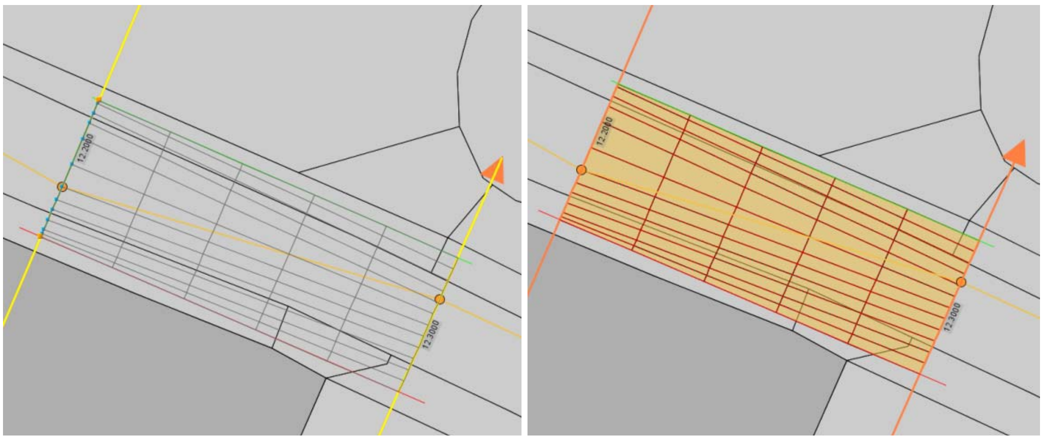


Figure 2: River channel generation in Kalypso 1D/2D module

Floodplain and rest of the mesh was generated using Gaga3D software. The Gaja3D was developed in the Hamburg University of Technology (TUHH). 5 m resolution DTM was used to generate the 2D nodes which were limited to 15000 due to limitations of RAM. The developed mesh from Gaja3D has different coordinate values and those values were corrected using Microsoft Excel and rewritten onto the 2D mesh file, which was developed using Gaja3D.

The mesh developed was imported into Kalypso as two files, because of the java heap error (large files). River channel was joined inside the Kalypso 1D/2D module. Height for the nodes was assigned by using 5m DTM.

2.1.4 Assigning of roughness values

Roughness values were assigned according to the landuse/coverage. Before import into Kalypso, the data was rechecked for the geometry, because overlapping and missing areas generates error during 2D simulation.

3 Results and discussion

Figure 3 shows the river profile from the Kalypso WSMP module. It contains the roughness value for each sections as well as the river tube section and floodplain.

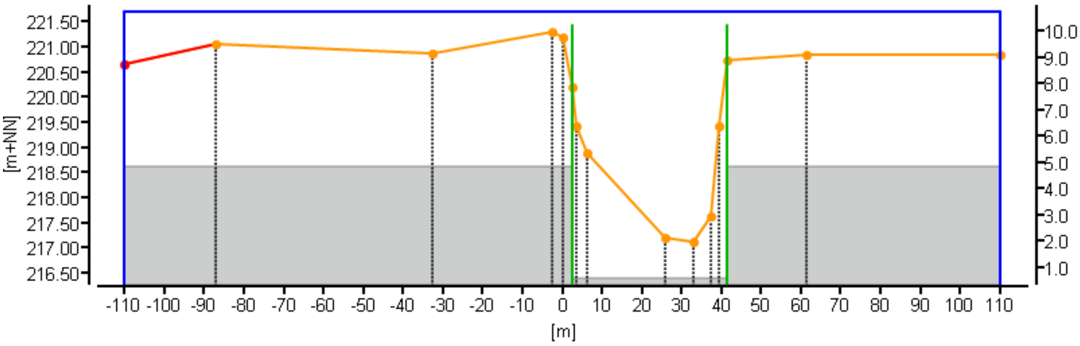


Figure 3. Cross-section in Kalypso

The 2D hydrological simulation basically depends on the 2D mesh. Mesh can be generated using Kalypso 1D/2D module itself. Generated 2D model is shown in the figure 6 and it is a compound output of Kalypso river channel generator and Gaja3dD. The mesh generated using Gaja3D tool has most of the break lines and topological variation. The tool generates mesh according to the topological variation that was taken from the DTM. The river channel section contains all interpolated cross sections and it refers to the cross section height information. This combination contains all the topological data as well as the river information. The DTM does not contain any river information, because the DTM source is from LiDAR data and LiDAR is not capable of penetrating water. Therefore a combination of this gives good mesh for 2D hydrological simulation.

The 2D simulation generates the water height as well as the water spreading over the ground. It basically depends on the generated 2D mesh. Figure 7 shows the setup model with the two boundaries and two boundary conditions. Boundary and boundary conditions were applied to the stations of 14 km and 10.3 km.

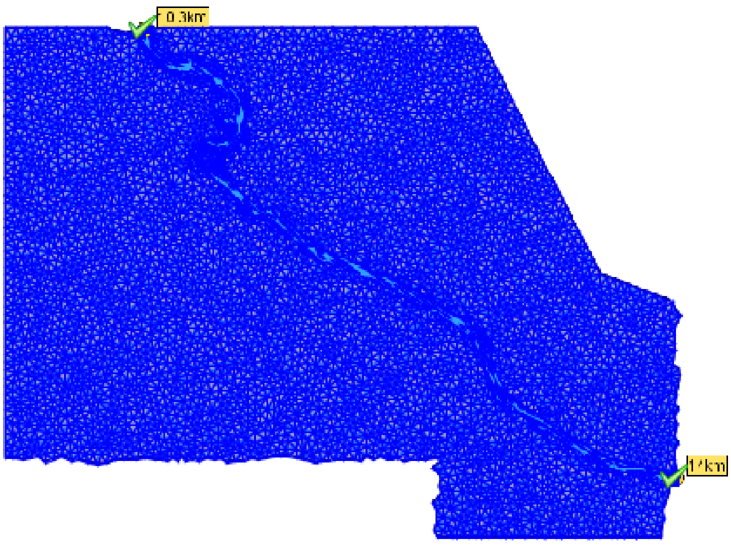


Figure 4: Boundaries and 2D mesh

2D simulation generates the water height values and those water height values and DTM together generates the water depth values. Figure 5 shows water depth grid that was generated by the Kalypso flood (10 year recurrence interval).

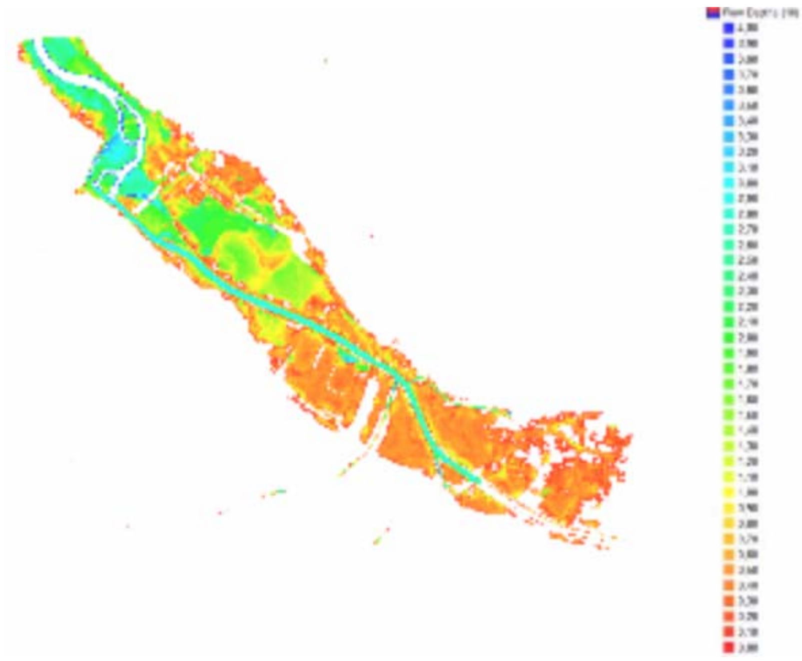
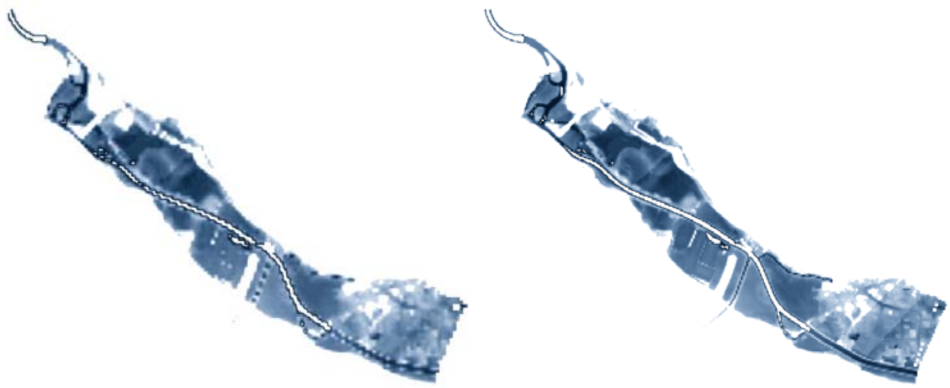


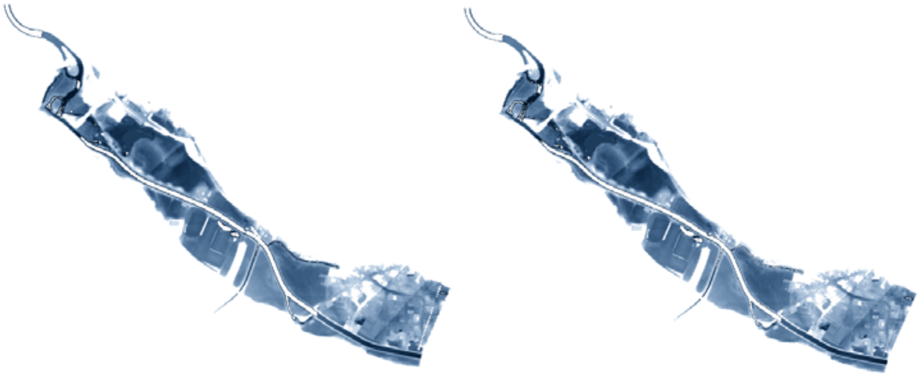
Figure 5: Water height values (10 year recurrence interval)

3.1 Resolution of DEM for flood modelling

The DTM resolution is one of the important factors for flood risk modelling. Figure 6 shows flood grids, which were created by using 20 m, 10 m, 5 m and 2 m DTM. The grid value indicates the water depth in a particular location. Figure 6(a) shows the low resolution (20 m) flood cover and figure 6(d) shows the high resolution (2 m) flood cover grid. They show clear differences and high-resolution grid covers more surface than low-resolution grid.



a. b.



c. d.

Figure 06: Water levels in different grid resolution *a)* 20 m resolution *b)* 10 m resolution *c)* 5 m resolution *d)* 2 m resolution

The effective DTM resolution can be distinguished by the risk zone analysis as well as damage analysis. Figure 7 shows the estimated damage according to the land values.

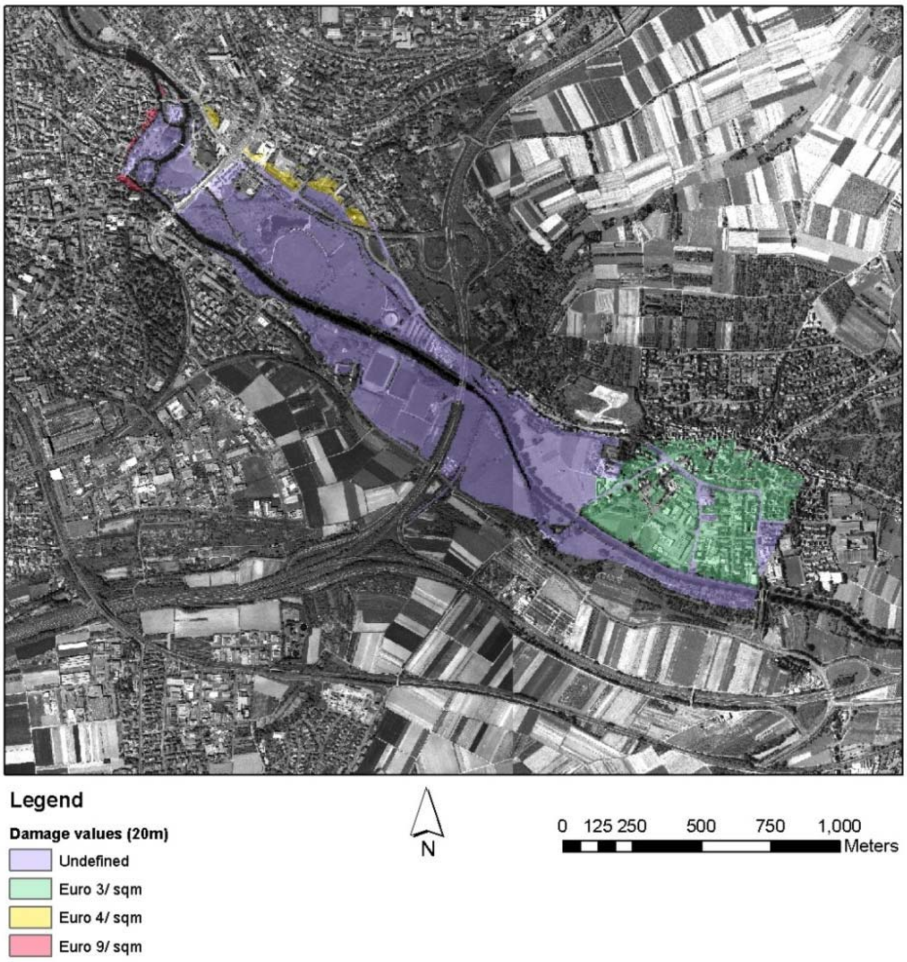


Figure 7. Damage according to the land values

Figure 8 shows the 20 m grid resolution flood damage and 2 m resolution flood damage, but they are not clearly visible in graphical mode. Table 1 shows the number of pixels per area with respect to the different damage value. It clearly indicates the affect of the resolution.

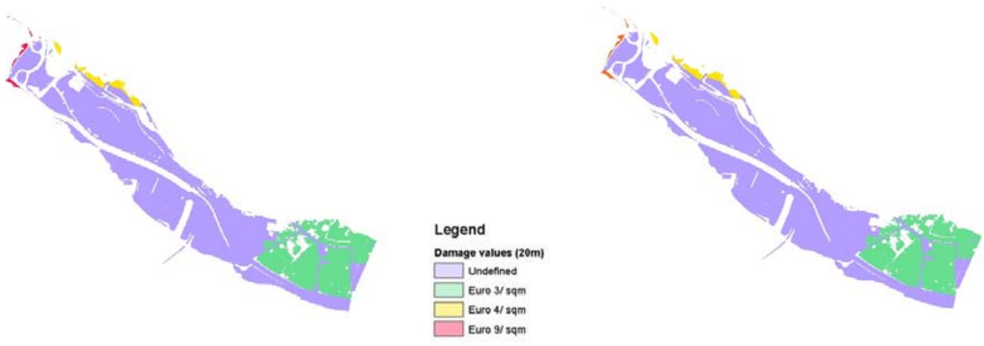


Figure 8. Damage according to the land values a) 20 m resolution a) 2 m resolution

Table 1: Comparison of 20 m and 2 m grid

Estimated losses	20 m resolution (m2)	2 m resolution (m2)
Euro 3/ m^2	177560	111064
Euro 4/ m^2	13800	8584
Euro 9/ m^2	3940	2472

4 Conclusions

High resolution grids consume more RAM space as well as time. With increase in resolution, processing time increases and RAM space becomes limited. Accuracy of the output increases with resolution but 5 m and 2 m does not show much difference. Because of those analysis 5 m grid level is chosen as the best resolution for flood modelling.

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Detecting and Quantifying Land Degradation and its Impact on Food Security in Ghana. A Case Study of the Upper East Region, Ghana

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KEYWORDS:
Land degradation, Ghana

ABSTRACT

Remote sensing techniques based on multispectral satellite-acquired data have demonstrated an unequalled potential to detect, quantify, monitor and map land degradation. However, remote sensing data alone do not provide information on how land degradation affects the socio-political aspects and the economics of the population living in the Upper East Region. We developed the Continuous Cycle of Land Degradation (CCoLD) to quantify the severity of the land degradation in the UER using a combination of remote sensing, ground data, and the additional evidence markers discussed.

We performed a field study in the UER of Ghana, a semi-arid transitional region which plays an important role for the economics of the country, and compared the results with multi-temporal remote sensing imagery. In additional to general ground measurements, the field studied included a questionnaire, asking local residents to assess the impact of land degradation on their quality of life.

The remote sensing data show widespread localized degradation. The field study conducted, supported by crop production data, also suggests overall extensive land degradation. However, field evidence suggests that improvements occurred where locally adapted horsetail grasses were displaced by environmentally efficient, short-lived, quick maturing and dense grasses.

Convergence of evidence suggests that desertification is in the advanced stage and that more focused, community-based effort would be needed to combat desertification and restore the ecosystems integrity.

Spatial Information in Environmental Impact Assessments: Experiences in Kenya

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KEYWORDS:
Environment, Environmental Impact Assessment (EIA), Kenya, spatial information

ABSTRACT

Environmental Impact Assessment (EIA) has been widely recognized as being beneficial to various stakeholders during the development of a variety of projects. In Kenya, the legal framework for EIA was set out in 1999 following enactment of the Environmental Management and Coordination Act (EMCA), and further formalized in 2003 through the Environmental (Impact Assessment and Audit) Regulations. These two legislations make EIA a legal requirement for specified projects in Kenya. Spatial information, on the other hand, due to its ability to illustrate the relationship between objects and their physical location, has been used within EIA to demonstrate the interaction between project components and specific aspects of the environment, hence enabling the establishment of potential project impacts on the environment, and the formulation of adequate mitigation measures. Using proportionate sampling, a review of EIA study reports submitted between 2002 and 2010 to Kenya's environment agency, the National Environment Management Authority (NEMA), was carried out to establish whether spatial information was used. Numerous types of spatial information were used in 93% of the EIA studies reviewed, and included photographs, plans, maps, satellite images and sketches among others. Suggestions are thereafter made regarding the use of spatial information within the EIA process in Kenya.

1 Introduction

Spatial information has been defined as that which identifies the geographic location of features and boundaries on Earth, as well as describes the physical location of objects, and the relationship between objects (Uttal *et al.*, 2006). As such, its qualities have been applied to aid in the understanding of environmental issues, and consequently, decision-making (Bacic *et al.*, 2006; Lewis and Sheppard, 2006). On the other hand, Environmental Impact Assessment (EIA), defined by the International Association for Impact Assessment (IAIA) as 'the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made' (IAIA, 2009) is a well recognized tool in environmental decision making (Haughton, 1999). In Kenya, EIA was established following the enactment of the Environmental Management and Coordination Act – EMCA (Republic of Kenya, 1999) and further elaborated in the Environmental (Impact Assessment and Audit) Regulations (Republic of Kenya, 2003). Consequently, EIA became a legal requirement for specified projects in the country.

Spatial information has been utilized within the different phases of EIA, including screening, scoping, public consultation and impact identification to demonstrate the interaction between project components and specific aspects of the environment. An improved understanding of environmental issues by communities, as well as increased and deeper discussions between project teams and the host community are some of the advantages associated with use of spatial information in EIA (Bacic *et al.*, 2006; Lewis & Sheppard, 2006).

The importance of this study is its contribution to the application of spatial information to environmental management, specifically EIA, as well as presentation of data that would form the basis for further study in this area. Further, spatial information within EIA has been in use in Kenya, but which types and to what extent, over time, has not been previously known. The overall objective of the study was to establish whether spatial information was used within EIAs in Kenya, using EIA Study Reports (EIASRs) submitted to the National Environment Management Authority (NEMA) between 2002 and 2010. The next section of this paper will present the methods used during the study followed by a presentation of results, and a discussion on the same. The final section of this paper will consist of conclusions made, and recommendations for further study.

2 Methods

The methodology consisted of an analysis of EIA Study Reports (EIASRs) submitted to the National Environment Management Authority (NEMA). An EIASR has been defined as 'the report produced at the end of the EIA Study process' (Republic of Kenya, 2003), and was selected for this study because it is prepared when NEMA finds that the proposed project will have a significant impact on the environment (Republic of Kenya, 2003).

To begin with, an inventory of all EIASRs submitted to NEMA was undertaken. The oldest EIA study report submitted to NEMA was dated 2002, hence the use of this year as a start for the analysis. It is also the same year that specific guidelines were prepared for the EIA process by NEMA, thereby making the process executable solely under Kenyan guidelines (NEMA, 2002). Following the inventory, EIASRs submitted to NEMA between 2002 and 2010 were analysed. Records at NEMA for EIASRs are categorized under date, sector represented (Republic of Kenya, 1999) and province of proposed project. These 3 criteria formed the basis for which a 50% proportionate sampling was followed.

3 Results and Discussion

The main objective of this study was to establish whether spatial information was used within EIA in Kenya, through an analysis of EIASRs submitted to NEMA between 2002 and 2010.

3.1 Study population

235 EIASRs were analysed, representing approximately 50% of all EIASRs submitted to NEMA between 2002 and 2010.

3.2 Use of spatial information within EIA

Spatial information was evidenced in 93% of EIASRs analyzed, indicating that it is commonly used during EIA in Kenya (Figure 1).

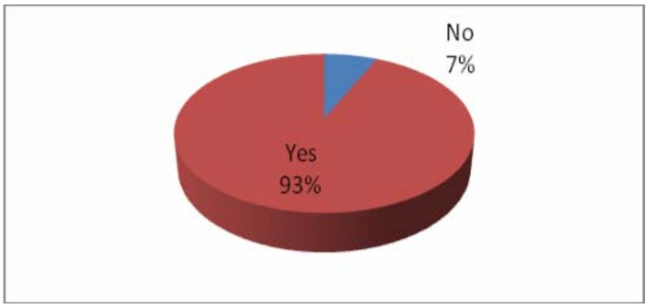

Figure 1: Proportion of EIAs in which spatial information used

Further, it was possible to establish trends indicating the use of spatial information during the study period of 2002 – 2010. Overall, there has been a general increase over time in use of spatial information during EIA (Figure 2). 2 dips occurred in 2006, and 2008, with the dip in 2006 possibly being the result of a constitutional referendum in 2005 (ILEG, 2007), and a catastrophic drought in 2006 (Kandji, 2006). The dip in 2008 was most likely the result of the previous year's post-election violence (UNHCHR, 2008) and the world economic recession (KNBS, 2010).

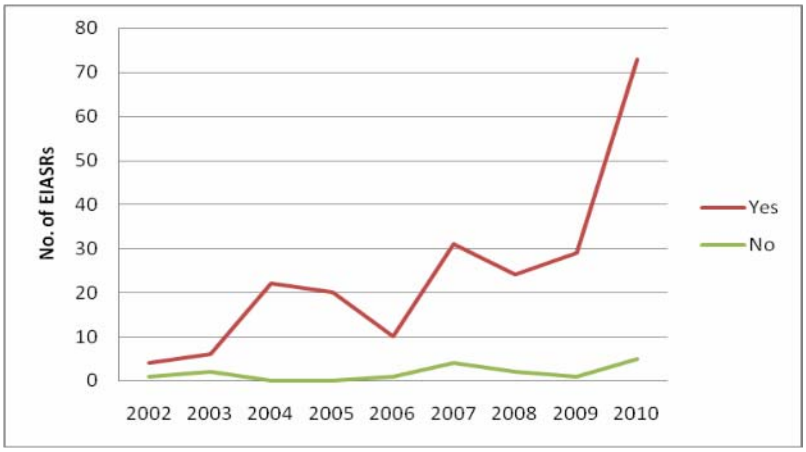

Figure 2: Trends in use of spatial information within EIA

3.3 Types of Spatial information used in EIA

Numerous types of spatial information are used during EIA in Kenya, and include maps, photographs, plans and architectural designs (Table 1).

Table 1: Summary of spatial information used in EIA

Types of Spatial Information	Examples
Maps	• Sketch • Route/road • Location • GIS data • Satellite images • Thematic maps (topography, soil, geology, economic activities, climate, population)
Photographs	• Ground • Aerial
Plans	• Site • Layout • Building • Deed/land title
Architectural designs	• Floor plan • Cross section • Elevation

Following a documentation of the types of spatial information used during EIA in Kenya, ranking was undertaken based on popularity of methods (Figure 3). Maps and photos (used in combination) were seen to be the most commonly used (31%), followed by architectural designs (19%), plans (17%) and photographs (15%).

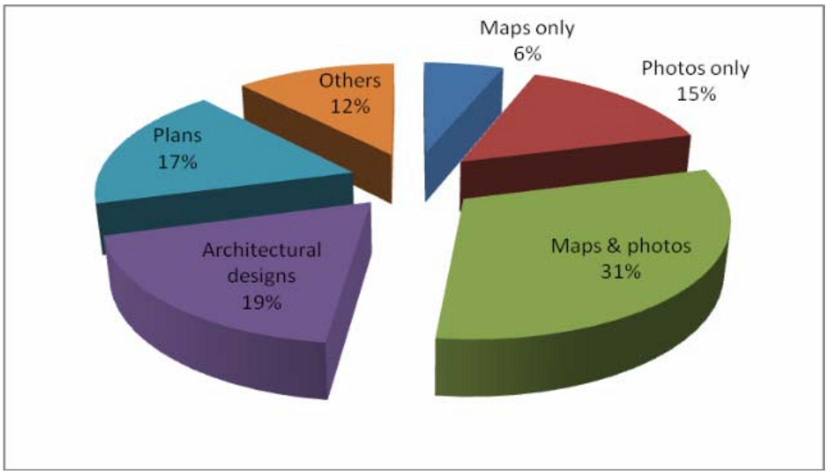

Figure 3: Spatial information used during EIA

Further, it was observed that the different types of spatial information mentioned above were used singly or in combination with others (Figure 4). Thus, it was noted that a combination of 2 types of spatial information was most common (47%), followed by the use of a single type (25%). An example of a popular combination of 2 types of spatial information is maps and photographs, which were the most popular (Figure 3). The use of more than 2 types of spatial information ranked third in popularity (21%). The combination of more than one type of spatial information is an innovative way of reducing the disadvantages associated with any one type, and increasing the effectiveness of spatial information (Medyckyj-Scott, 1992). For example, the combined use of maps and photographs enables the technical nature of maps to be ameliorated by the visual impact of photographs.

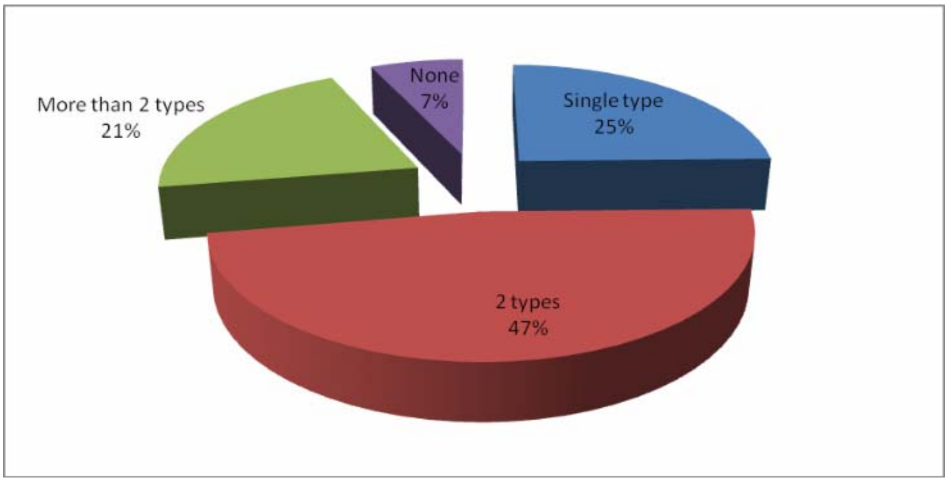

Figure 4: Combinations in use of spatial information

4 Conclusions and Recommendations

Overall, the use of spatial information with EIA in Kenya has been increasing over time, with the combined use of maps and photographs being most popular. Maps and photographs have their advantages and disadvantages, and a keen knowledge of this would enhance their contribution to the EIA process in Kenya. Notably, spatial information has in some cases been associated with improvement of participatory processes, hence its potential contribution to EIA (González *et al.*, 2008).

Further study on the types of spatial information used within EIA and more specifically, their use within the phases of EIA (screening, scoping, public consultation, impact identification) should be considered. It would also be worthy to investigate the contribution of spatial information to the EIA process in Kenya.

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Detecting and Quantifying Land Degradation and its Impact on Food Security in Ghana. A Case Study of the Upper East Region, Ghana

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KEY WORDS:

ABSTRACT:

Remote sensing techniques based on multispectral satellite-acquired data have demonstrated an unequalled potential to detect, quantify, monitor and map land degradation. However, remote sensing data alone do not provide information on how land degradation affects the socio-political aspects and the economics of the population living in the Upper East Region. We developed the Continuous Cycle of Land Degradation (CCoLD) to quantify the severity of the land degradation in the UER using a combination of remote sensing, ground data, and the additional evidence markers discussed.

We performed a field study in the UER of Ghana, a semi-arid transitional region which plays an important role for the economics of the country, and compared the results with multi-temporal remote sensing imagery. In additional to general ground measurements, the field studied included a questionnaire, asking local residents to assess the impact of land degradation on their quality of life.

The remote sensing data show widespread localized degradation. The field study conducted, supported by crop production data, also suggests overall extensive land degradation. However, field evidence suggests that improvements occurred where locally adapted horsetail grasses were displaced by environmentally efficient, short-lived, quick maturing and dense grasses.

Convergence of evidence suggests that desertification is in the advanced stage and that more focused, community-based effort would be needed to combat desertification and restore the ecosystems integrity.

Geoinformatics and Health

Understanding the Spatial Prevalence of Cervical Cancer Using GIS in Nairobi, Kenya

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KEYWORDS:
Cervical Cancer, GIS, Spatial Prevalence

ABSTRACT:

Cancer is characterized by excessive, uncontrolled growth of abnormal cells that invade and destroy other tissues. It can develop in almost any organ or tissue of the body, however certain types of cancer are more life threatening than others. In Kenya, cancer ranks third as a killer disease, with an estimated 18,000 deaths reported annually and 82,000 new cases diagnosed every year. Indeed it has been established that the chance of dying of cancer today is higher compared to HIV, Tuberculosis and Malaria 20 years ago. Cancer rates vary by gender, race, age and geographic region. For instance more men than women develop cancer whereas breast cancer is more common in wealthy countries compared to cervical cancer which is more prevalent in poor countries. Further, some types of cancers are more common in people over the age of 50. The spatial distribution of cancer mortality varies non-uniformly in Kenya. This study focuses on cancer of the cervix. This type of cancer has been found to be one of the most common causes of death among women in developing countries unlike in the developed ones. This has been attributed to several factors like poverty, lack of appropriate resource distribution and screening programs. Previous studies have concentrated on statistical techniques to establish the correlation between cancer prevalence and the risk factors. However, in order to enable appropriate mitigation there is need to localize and quantify the prevalence. In this regard, this study explored the use of GIS in highlighting the spatial prevalence of cervical cancer based on available four epochs of datasets namely 2003, 2004, 2005 and 2006 in Nairobi, Kenya. Specifically, the spatial trends, influence of age and poverty levels on the prevalence have been demonstrated. The results emanating from this study are useful in appreciating the magnitude and location of the problem thereby facilitating mitigation measures in terms of where to allocate and optimize proper screening programs for prevention.

1 Introduction

1.1 Background

More than 100 types of cancer develop in the various organs in the body. Cancers are described according to where in the body the cancer originated, what type of tissue it originated in, and what type of cell it started in. Based on the most complete and current data available, cancer accounts for one out of every eight deaths annually (Mathers & Loncar, 2006). More people die from cancer every year around the world compared to AIDS, tuberculosis and malaria combined. Cancer deaths occur with nearly six times the frequency of traffic fatalities on an annual basis, and 42 times the frequency of deaths from injuries suffered in war. While at one time the disease was widely thought to afflict only the elderly in affluent countries—where it was seen as a death sentence—cancer has now moved beyond high income countries of the developed world. Indeed today, more than 50% of new cancer cases and nearly two-thirds of cancer deaths occur in the low income, lower middle income and upper middle income countries of the developing world. By comparison, in 1970, the developing world accounted for 15% of newly reported cancers (Boyle & Levin, 2008). By 2030, the

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developing world is expected to bear 70% of the global cancer burden. Since cancer remains predominantly an illness for which the risk increases with age, as populations' age cancer incidence and deaths also rise.

Cancer of the cervix is most common among poor communities with limited facilities for screening (Rengaswamy et al. 2001). Worldwide it is estimated that over 493,000 new cases and 273,000 deaths annually are due to cervical cancer. Cancer of the cervix is the second most common cause of death in women globally. The majority of the cancer burden occurs among women living in developing countries where approximately 83% of new cases occur each year and cervical cancer surpasses breast-cancer as the leading cause of cancer deaths in women (Ferlay et al. 2005). On the other hand, the incidence of cervical cancer has declined in both North America and Europe (Parkin et al. 1993). In the developing countries a full understanding of the burden of cervical cancer is limited by scarce national registry data. However, it is clear that high level of exposure to HPV, absence of screening programs and poor access to appropriate treatment have resulted in the highest cervical cancer rates in the world among sub-Saharan African women. East Africa has notably high rates of cervical cancer incidence (20.1/100000 compared to 15.8/100000 for the world), as well as mortality rates (13.6 compared to 8.2/100000 for the world), and also has the highest cumulative risk (3 compared to 9 for world) (IARC, Globocan, 2008). The need therefore to localize and quantify the prevalence of cervical cancer is vital in informing policy making and programs thus necessitating a spatial approach.

1.2 Cancer Burden in Kenya

In Kenya cancer ranks as the Number Three killer in the country, with an estimated 18,000 deaths reported annually and 82,000 infections diagnosed every year. The top six sites of cancer include the breast, the cervix, the esophagus, the stomach, the prostate and the liver. The mortality rate from cancer of cervix creates a heavy burden for women in the prime of life, their families, and for the health care system. The international agency for Research on cancer (IARC) estimated the age-standardized incidence of cervical cancer in Kenya as 23.4 per 100,000 women. It is estimated that 2454 new cases per year in Kenya are reported (IARC, Globocan, 2008). Due to the high incidence, the crude mortality rate for Kenya is very high with up to 8.6 women per 100000 dying every year of cancer of cervix compared to 7.7 for breast cancer. Age-standardized death rates for Eastern Africa are among the highest in the world (25.3 compared to 7.8 for the world). These are more than three times the rates in Europe and North America, where intensive screening programs and readily available treatment have brought cervical cancer incidence down from similarly high levels nearly a century ago. The Kenya Age-standardized rates are 17.3 with annual number of deaths being at 1676 (IARC, Globocan, 2008). Poor health imposes a heavy burden on society and slows down economic growth. Illness in the family is one of the major causes in the reduction of incomes and assets of poor Kenyans. Cancer, for instance, has had a demonstrated negative impact on households, their education, as well as in their workforce productivity.

1.3 The Role of GIS in Cancer Management

Apart from analyzing disease data, GIS has also been used to develop applications that monitor population health. Applications in this regard range from the use of a GIS as a standalone computer application to more widely accessible web-based applications. Gossellin et al. (2005) and Shuai et al. (2006) report the development of a real-time GIS application for public health surveillance of West Nile virus in Canada. This system facilitates the collection, localization, management and analysis of monitoring data; display of the results of analysis on maps, tables, and statistical diagrams. In the area of cancer research, GIS has previously been used to estimate exposure of environmental toxins (Schreinemachers, 2000), statistical analysis incorporating spatial information, and to create maps for effective communication of the distribution of cancer (Brewer & Pickle, 2002; Brewer, 2006). Long Island Breast Cancer Study project is an example of a complex GIS developed at the National Cancer Institute of U.S.A.

2 Methodology

2.1 Data Sources and Tools

The data used in this study consisted of the administrative boundaries in shape file covering the area of study, the location of Health Facilities captured using GPS, cervical cancer data from the Nairobi Cancer Registry. The cancer data contained both spatial and non-spatial data. The spatial component pertained to the home location of the patient whereas the non-spatial referred to the patients profile age, gender, tribe, incidence date, hospital, status, and stage at which the cancer was diagnosed for the years 2003 to 2006. In addition poverty Index maps were also obtained from the Kenya National Bureau of Statistics as well as the spatial location of the hospitals visited by the patients.

2.2 Database Development

Data preparation which entailed clipping, reformatting, geo-referencing was done to ensure harmonization of the data sets. The population data obtained was for 1999. This formed the basis for the computation of population projections to cover the years of interest namely from 2003 to 2006. The population data was used for classifying into age cohorts specifically 0-4, 5-9, ... , 80-84 and 85+ to facilitate analysis of prevalence of cervix cancer.

After the data was prepared a Cervical Cancer Spatial database was developed through a personal database in Arc Catalog, and the edited Nairobi County and Hospital shape files imported. The prevalence table created in spread sheets were also imported into the database and linked with digital maps in Arc Map software. Once all the relevant spatial and non-spatial datasets were captured into the database, validation was done to ensure completeness and integrity.

2.3 Spatial Analysis of Cervical Cancer prevalence

This involved identifying the cancer trend from 2003 to 2006 for the eight divisions in Nairobi and their spatial distribution, the prevalence of cancer by age group, prevalence on the basis of poverty, cases reported to the various hospitals as well as available services and personnel for three main hospitals. The GIS analytic capabilities employed included exploratory and overlay operators (Longley et. al. 2005).

3 Results

3.1 Prevalence of Cervical Cancer

3.1.1 Cervical Cancer Spatial Distribution and Trend

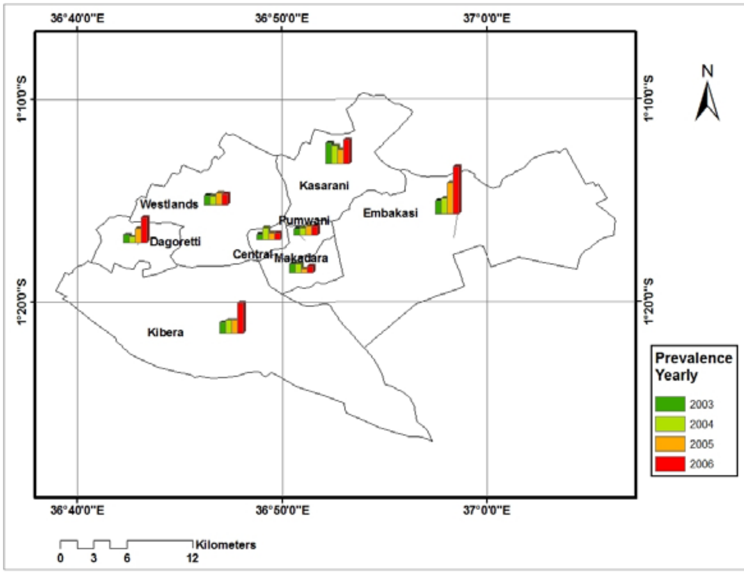

Figure 1: Spatial Distribution of Cervical Cancer Prevalence

The spatial prevalence of Cervix Cancer for the three years namely from 2003 to 2006 is depicted in Figure 1. Embakasi reported high prevalence, whereas Makadara, Central, Pumwani, Makadara and Westlands have low prevalence. Some of the reasons that can be associated with this trend could be population and awareness for screening services. Awareness of screening services for Cervix Cancer enables more women to go for screening and hence this is captured. In general, cervix cancer incidences revealed an upward trend with exceptions from Central and Makadara.

3.1.2 Prevalence of Cervical Cancer by Age groups

It is evident that the age group that is affected more by Cervix Cancer is in the range of 35-39, 40-44, 45-49 and 50-54 range as shown in figure 2. The risk of cancer increases as individuals age because genetic mutations accumulate slowly over many years, and the older a person is, the more likely that she will have accumulated the collection of mutations necessary to turn an otherwise healthy cell into a cancerous cell. It was also observed that cancer was more prevalent in 35-39 age group in female.

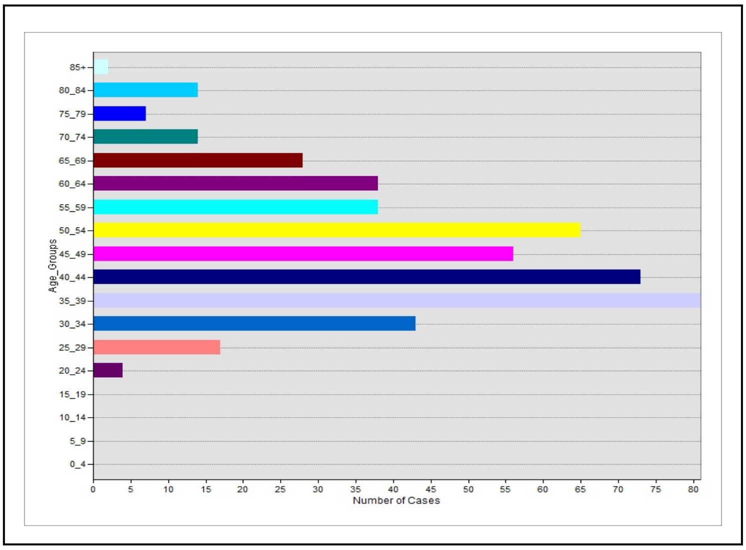

Figure 2: Cervix Cancer Prevalence in different Age Groups (Aggregated)

3.1.3 Prevalence on the basis of Poverty

An overlay of poverty incidence and Cervix Cancer prevalence is shown in figure 3. The Poverty Incidence and Cancer Prevalence maps were converted into raster format where poverty incidence and Cervix Cancer prevalence fields were used in respective layers. Poverty incidence layer was classified from low incidence to higher incidence rate and given weights from 1 to 8. Similarly the Cervix Cancer prevalence layer was also classified from low incidence to higher incidence rate and given weights from 1 to 8. After overlay Makadara division had the highest score of 7 showing the higher relationship between poverty incidence and Cervix Cancer prevalence.

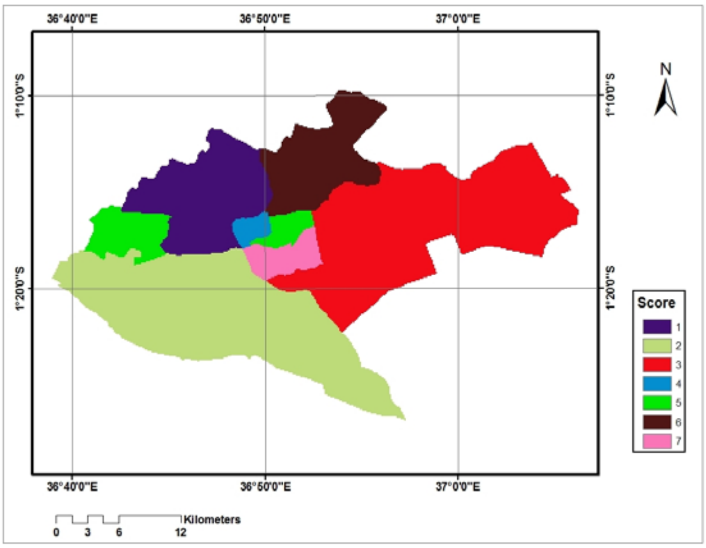

Figure 3: Prevalence on the basis of poverty

3.2 Management of Cervical Cancer

3.2.1 Reported Cases per hospital

The aggregated Cervix Cancer for the years 2003 to 2007 show that Kenyatta National Hospital had the highest number of cases reported with 205 (73.5%), followed by MP SHAH 26 (9.3%), Nairobi Hospital 15 (5.4%) and Aga Khan 13 (4.7%) as shown in table 1. The rest had less than 10 cases. The high number witnessed in Kenyatta National Hospital is due to the fact that it is a referral hospital and being a government hospital treatment costs are highly subsided. The other three hospitals namely MP SHAH, Nairobi Hospital and Aga Khan are private hospitals whose treatment costs are highly prohibitive.

Table 1. Reported Cases per Hospital

Hospital								
KNH	Aga Khan	MP Shah	Nairobi	Mater	Forces	Avenue	Equator	Total
205	13	26	15	10	2	3	5	279
73.5	4.7	9.3	5.4	3.6	0.7	1.1	1.8	100

3.2.2 Type of Treatment

The types of treatment offered to patients suffering from Cervix Cancer are mainly Radio-Therapy, Chemo-Therapy and Surgery. These are shown in proportion for the three main hospitals in figure 4. Kenyatta National Hospital is well known for Radio-Therapy, followed by Chemo-Therapy and very little surgery. Aga Khan and MP Shah concentrate more on Chemo-Therapy for treatment.

3.3 Discussion of the Results

Combining epidemiology and mapping creates the ability to identify, locate and group health status with people, places and activities. The health system can then use this information to develop policies and programs to control and manage the spread. The results obtained from this study revealed that cancer of the cervix had in general increased from the year 2003 to 2006. Kasarani, Kibera and Embakasi divisions which were observed to have a high total prevalence of more than 50% and Westlands was observed to have a lesser increase of 17%. This is attributed to the fact that Westlands is a relatively wealthier division compared to other divisions, hence most of the residents can afford regular medical checkup and have healthy eating habits.

The risk of cancer increases as individuals age because genetic mutations accumulate slowly over many years, and the older a person is, the more likely that he or she will have accumulated the collection of mutations necessary to turn an otherwise healthy cell into a cancerous cell. It was observed that cervix cancer was more prevalent in 40-44 age group in females. After overlay poverty incidence and Cancer prevalence it was observed that there was high relationship between poverty incidence and Cancer prevalence. It was evident that in Makadara division which is the poorest had 90.97% of cancer incidence rate that caused death, compared to Westlands which was relatively wealthier and had only 58.66% cancer incidence rate that caused death. This can be associated with high poverty levels in Makadara division, hence the residents cannot afford high cost of treatment.

It was observed that most hospitals had less capacity to handle cancer cases with MP Shah hospital having more human resource than other hospitals in the area of study with six Histo-pathologists, five Radio-onchologists and three Medical Oncologists. Kenyatta National Hospital had five Histo-pathologists, four Radio-chologists and two Medical Oncologists, and Aga Khan Hospital had five Histo-pathologists, one Radio-chologist and one Medical Oncologist.Three type of treatments were shown including Radio-therapy, Chemo-therapy and Surgery. It can be observed that Radio-therapy is mostly done in Kenyatta National Hospital. This was attributed to the availability of two Cobalt-60 machines that is used for radio-therapy. The available radio-therapy centres (Kenyatta National Hospital, Aga Khan and MP Shah) handle 3,800 patients a year which is way below the needs of the Nairobi residents. Patients refered from other hospitals have to wait for months before they can access services at the national referral hospital leading to a majority of patients presenting themselves at the late stage.

4 Conclusions

The main objective of this study was to demonstrate how GIS can be used for the localization and understanding of the cervix cancer prevalence using Nairobi County with Division level data, as a case study. For the four epochs of data namely 2003 to 2006, the spatial distribution and trend of the cervix cancer was mapped for the eight divisions. Another important output from this study is the influence of age on the prevalence and subsequently the most affected age group. Similarly the relationship between poverty and the prevalence of cervix cancer was generated. In general the study revealed that there is a general increase in the spread of cervix cancer. In addition, the two main factors considered did indicate a high influence on the prevalence amongst the most affected groups in the 35-39 (81) and 40-44 (73) age brackets. In terms of poverty, it was established that poverty does have an influence on prevalence of cervix cancer. For instance, in this study Makadara having the highest poverty index of 59 had a score of 7 which confirms a correlation between poverty and prevalence.

For the management of Cervix Cancer both facilities and trained personnel are necessary. It was established that for Nairobi there are four main hospitals with facilities for cancer treatment which include radio-therapy, chemo-therapy and surgery. Among the four hospitals only one is state owned whereas the others are private. This implies that there is need to have more hospitals equipped with adequate facilities for screening and treatment. This problem has been compounded by the scarcity of trained personnel available to handle cervix cancer cases reported in the hospitals.

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GIS in healthcare planning and provision: A case study of Homa-Bay district, Kenya

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KEY WORDS:
Healthcare planning and provision, inventory mapping, enhanced two step floating catchment area method, spatial accessibility, GIS

ABSTRACT:

The healthcare system in Kenya faces numerous problems such as lack of coordination in infrastructural and human resource investments, mismatch between demand and supply of available resources, poor accessibility, underfunding, political interference and high number of home deliveries among others. The purpose of this research work was to illustrate how healthcare planning and provision problems, which characterise the health sector in developing countries, can be addressed with the aid of geographical information systems. Through a case study of health facilities in Homa-Bay District in Kenya, an inventory mapping of the health facilities was undertaken, and the enhanced two step floating catchment area method was applied to analyse their spatial accessibility. The spatial accessibility map was integrated with poverty map through overlay to provide a healthcare accessibility index map. The problems of lack of coordination and mismatch of demand and supply were found to be easily solvable through inventory mapping of health facilities, while low or poor accessibility could be addressed by the analysis of spatial accessibility through enhanced two step floating catchment area method. The integration of non-spatial factors was utilised to improve the analyses of accessibility. Almost all the facilities within the study area were found to be ill equipped and understaffed. Both the eastern and western parts of the district were found to have relatively lower levels of accessibility in comparison with the northern and southern parts. A high correlation between poverty and spatial accessibility patterns was also elucidated in the area.

1 Introduction

Healthcare planning and provision is a very critical issue to the well-being of the population. Population subgroups differ in terms of healthcare needs and accessibility according to their age, sex, social class, ethnicity, and other non-spatial characteristics. Healthcare planning involves mostly accessibility to, and location of health facilities; it is in most cases measured by level of accessibility, which is in turn ensured by optimum distribution of health facilities. The levels of accessibility also take into account the necessary human resource and equipment. Healthcare provision on the other hand deals with optimal utilization of the available medical facilities and services; it involves attempts to strike a balance between available medical facilities, resources, personnel and the population demand for the respective facilities.

Access to healthcare varies across space because of uneven distribution of healthcare providers and consumers (spatial factors); it also varies among population groups because of their different socioeconomic and demographic characteristics (non-spatial factors). Accordingly, spatial access emphasizes the importance of geographic barriers such as distance or time between consumer and provider, whereas non-spatial access stresses non-geographic barriers or facilitators such as social class, income, ethnicity, age, sex, etc. (Joseph and Phillips, 1984).

The Government of Kenya, together with various donors, spend a lot of money in building hospitals and provision of medical services when addressing its mandate to provide health care to its citizens. The health care system consists of facilities categorized into five major levels of institutions each having distinct functions and characteristics. The categories include: dispensaries, health centres, district hospitals, provincial hospitals and teaching and referral hospitals. The level of service and demand expected of these facilities are dictated by norms and standards for service delivery which is a policy document by the Ministry of Health. It also details the level of investment expected over a given period of time.

The health care system faces myriad of problems which among them are related to the location of these facilities in relation to the population they are expected to serve. Lack of coordination in investments, especially in infrastructural and human resource allocation, result in inequitable and imbalanced distribution within and across facilities. Other problems in the health sector include high infant mortality rates, delay in procurement and delivery of drugs, lack of funding and political interference.

The main objective of the research was to demonstrate how geographical information systems GIS) could be utilised in analysing healthcare planning and provision problems, especially the locational and coordination related ones. Specifically it sought to undertake an inventory mapping of health facilities based on serviceable areas, and then analyze accessibility to the health facilities as influenced by their capacity, the level of demand, and impedance to its accessibility; the enhanced two step floating catchment area method was applied to achieve this.

Homa-Bay, an administrative district in the Nyanza Province, lying in the western part of Kenya and located along the shores of Lake Victoria was the case study. The district falls between 0° 21’ 27.9” S, 34° 11’ 30.3” E and 0° 52’ 46.4” S, 34° 39’ 14.6” E. It is characterised by high levels of disease incidences, with the common diseases being malaria, pneumonia, diarrhoea diseases and respiratory infections. The district has also had high HIV/AIDS levels, with a reported prevalence of 13.9% in 1998--99 against the national prevalence of 7.1% (KDHS, 2009). According to the 2009 population and housing census, the district had 963,794 people. The area is served by a single district hospital, several sub-district hospitals, health centres and dispensaries. The population mainly engages in subsistence farming and fishing.

2 GIS in healthcare planning and provision

Birkin et al.(1996) looks at the spatial change of health status as elucidated through the comparison of actual number of mortalities in an area with the national average; Nicol (1991), Brown et al (1991) and Wrigley (1991) delve into spatial epidemiology where the spatial incidences of diseases and environmental relationship are tackled. Healthcare facilities accessibility and utilization researches, strengthen the usefulness of GIS in addressing answering critical questions like optimal location of facilities such as the location of healthcare facilities, especially in the evaluation of accessibility and optimal demand of a given facility (Gatrell and Senior,1999: Jones and Bentham, 1995, and Forbers and Todd, 1995).

In Kenya, the application of GIS in healthcare system is still in its infancy compared to other fields and other countries like United Kingdom and United States which have made tremendous progress in this area. Notable contributions include Noor et al. (2004), who created a health service provider database and analyzed their relationships; others studies have looked at GIS applications to analyzing specific diseases. A comprehensive literature review related to GIS in health applications can be found in Rushton and Armstrong (1997).

2.1 Spatial accessibility

Most issues of healthcare planning and provision revolve around spatial accessibility to the health facilities. Spatial accessibility comprises two components, namely availability and proximity; both of which need to be measured together to define spatial accessibility (Joseph and Phillips, 1984; Luo & Wang, 2003). The high availability of services does not guarantee high accessibility because it depends on the proximity of the population to those services. Similarly, close proximity does not also guarantee high accessibility as it depends on the size of the population competing for the available services. Historically, three approaches namely distance/time to nearest service, gravity models, and population-to-provider ratios, dominated measures of spatial accessibility.

The ***distance/time to nearest service*** method, which uses travel impedance (distance or time) to the nearest service, is a simple and the most commonly used measure of spatial accessibility (Fortney et al., 2000; Hewko et. al, 2002; Rosero-Bixby, 2004). However, nearest service impedance only captures proximity between population and service locations with no account taken of availability (either the capacity of the service provider or the size of the population). Additionally, bypassing the nearest service is frequently observed where populations commonly have more than one health service to choose from (Fryer, et al., 1999; Goodman et al., 2003; Hyndman et al. 2003). Thus, the nearest service is an ineffective measure of spatial accessibility where overlapping catchments exist such as for primary care services.

The ***gravity model*** provides a measure that accounts for both proximity and availability (Joseph & Phillips, 1984; Weibull, 1976). This model assumes that the attractiveness of a service diminishes with distance and associated increasing travel impedance. Unlike nearest service, the gravity model does capture bypassing whereby the closest service is most likely to be chosen. Additionally, both supply and demand are captured within the gravity model. Most criticism of the gravity model has concentrated on the difficulty in selecting or empirically determining the distance-decay function (Guagliardo, 2004; Joseph & Phillips, 1984; Luo& Wang, 2003).

An extension of the population-to-provider ratios is ***floating catchment areas*** (FCAs) (McGrail, 2008; Luo, 2004; Talen, 2003, and Peng, 1997). The key difference between population-to-provider ratios and the FCA method is the use of floating catchment areas or ‘windows’ rather than set boundaries. In general, this method better meets the assumption that populations will only use services within their catchment area. The size of the window is determined by a choice of maximum travel impedance, where all services contained within that window are considered accessible to the population, and all other services are not accessible. This process creates as many catchments as there are defined populations, the boundaries for which ‘float’ and overlap. The significant problem with the FCA was that it was only the supply but not demand that was accounted for (Luo & Wang, 2003). Radke and Mu (2000) were able to address the supply demand issue with the development of a spatial decomposition method, which Luo and Wang (2003) then incorporated and referred to as *a two-step floating catchment area (2SFCA) method.*

2.2 The two-step floating catchment area (2SFCA) method

The first step of the 2SFCA is to determine what population falls within the catchment of each service provider (that is, potential population size being ‘served’). The second step of the 2SFCA is to allocate available services to populations, by determining what services fall within the catchment of each population. Calculation of both steps gives a familiar population-to-provider ratio. In the studies it has been used, the 2SFCA method is found to have two major limitations: (1) it does not differentiate distance impedance within the catchment (i.e., all population locations within the catchment are assumed to have equal access to physicians) and (2) it is a dichotomous measure (i.e., all locations outside the catchment have no access at all).

Wei Luo& Yi Qi (2009), applied weights to 2SFCA method in both first and second steps to differentiate travel time zones, thereby coming up with Enhanced 2SFCA (E2SFCA), which is implemented in two steps as follows:

Step1: The catchment of physician location j is defined and a search conducted on all population locations (k) that are within a threshold travel time zone (Dr) from location j (this is catchment area j), and then the weighted physician-to- population ratio, Rj, within the catchment area is computed as:

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_r\}} P_k W_r} = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_1\}} P_k W_1 + \sum_{k\in\{d_{kj}\in D_2\}} P_k W_2 + \sum_{k\in\{d_{kj}\in D_3\}} P_k W_3} \quad (1)$$

where P_k is the population of grid cell k falling within the catchment j ($d_{kj} \in D_r$), S_j the number of physicians at location j, d_{kj} the travel time between k and j, and D_r the r^{th} travel time zone (r = 1–3) within the catchment. W_r is the distance weight for the r^{th} travel time zone calculated from the Gaussian function, capturing the distance decay of access to the physician j.

Step2: For each population location i, search all physician locations (j) that are within the thresh hold travel time zone from location i (that is, catchment area i), and sum up the physician-to- population ratios (calculated in step1), Rj, at these locations as follows:

$$R_j = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_r\}} P_k W_r} = \frac{S_j}{\sum_{k\in\{d_{kj}\in D_1\}} P_k W_1 + \sum_{k\in\{d_{kj}\in D_2\}} P_k W_2 + \sum_{k\in\{d_{kj}\in D_3\}} P_k W_3} \quad (1)$$

Where A_i^F represents the accessibility of population at location i to physicians, R_j the physician-to-population ratio at physician location j that falls within the catchment centred at population i (that is, $d_{kj} \in D_r$), and d_{ij} the travel time between i and j. The same distance weights derived from the Gaussian function used in step1 are applied to different travel time zones to account for distance decay (Wei Luo and Yi Qi, 2009). Just as 2SFCA has proven to be a special case of the gravity model, where the friction-of-distance exponent equals 1 in the catchment and 0 outside (Luo and Wang, 2003b), E2SFCA is also a special case of gravity model. The Gaussian weight used in E2SFCA is away to implement the distance decay term in gravity model.

The advantage of E2SFCA is that multiple distance decay weights substitute the dichotomous 0 and 1 in 2SFCA; so it solves the problem of not differentiating accessibility within the catchment and thus is theoretically more analogous to the gravity model. The discretized consideration of distance decay (by travel time zones) in E2SFCA is a reasonable approximation to the continuous gravity model because, in reality, people would not mind a few minutes of difference in travel time to seek care. This approximation makes the result of E2SFCA straightforward to interpret and easy to use, because it is essentially a weighted physician-to-population ratio. This project applied the E2SFCA due to its numerous advantages as highlighted above.

3 Methodology

The methodology used involved healthcare provision data collection, inventory mapping, and accessibility analysis. Spatial accessibility was mainly based on straight line distances and the ability of the population to pay for the health services. Two-step floating catchment area method was used to generate spatial accessibility indices which were then overlaid onto poverty-based accessibility index map to provide an overall health facility accessibility index map. Most of the data processing was achieved through ArcGIS suite. However, the two-step floating catchment computations were formulated in Microsoft Excel®, while the necessary interpolations were carried out in ArcScene® of ArcGIS® software suite.

The data used included administrative boundaries, roads and towns, administrative sub-location centroids (used to represent village point data), health facilities location and their attribute data, and poverty data. The location of the health facilities and their attribute data were obtained from district health records office. A visit to each of the health facilities, provided the opportunity to verify their spatial location using hand held GPS, while additional attributes such as the number of staff manning a facility, level of service provided, source of water used, availability of laboratory, availability of maternity, source of power, bed capacity, among other attributes were verified or collected. Poverty mapping data, described as percentage of population living below the poverty line, was obtained the Kenya National Bureau of Statistics' district offices.

3.1 Data pre-processing and inventory mapping

As each data set was obtained from different sources, some pre-processing was necessary to enable them be in one platform / system while others needed to be cleaned or converted to digital form. The facility spatial location (x, y) data from the hand-held GPS was cleaned and integrated with the non- spatial attribute data for each facility in a table form ready for use in ArcGIS® software. The administrative boundaries data, as well as other geographical data such as towns and roads had to be converted from geographic coordinate system to projected coordinate system, so as to be in the same system as the health facility location data. For each administrative sub-location, the polygon centroid was determined in ArcGIS® suit, and used to serve as population points. The poverty data, available at the sub-location level, was added as an extra field and linked as attribute to the sub-location shape files. The facilities location data together with the other geographical data were assembled together in the ArcGIS® environment. The descriptive data for the health facilities included information such as the number of staff, level of service provided by the facility, availability and condition of the laboratories, sources of power available to the facility, availability of maternity services among others.

3.2 Accessibility analysis

Based on the government requirement of health provision that people should be within an average distance of 2.5 km of a health facility, two floating buffers were generated at 2.5 and 5.0 km to help in determining the demand side for the smaller facilities. For the district hospital it was necessary to have more floating buffers at intervals of 2.5 km as in reality it caters for all the residents of the district and thereby requiring their input with appropriate impedances depending on the distance from the facility. Anybody within the 2.5 km buffer is assumed to have absolute accessibility. Straight line distances were used as the area of study was basically rural area with not much road network. Village points falling within the first and the second 2.5 km were then found. These were then used to compute the ratio of number of medical workers at the facility to the number of population being served with those falling in the second 2.5 km buffer attracting impedance factor of 0.5.For the district hospital, a series of floating buffers were generated each at 2.5 km interval up to the furthest village point and impedances of 1, 0.875, 0.75, 0.625, 0.5, 0.375, 0.25, 0.125 applied from the innermost floating buffer. This was to take care of all the demand from the district, as in essence it is the referral hospital of all the other smaller health centres and facilities.

For each village point, two rings of floating buffers were generated at 0 – 2.5 km and 2.5 – 5.0 km, and health facilities falling within these buffers found. The ratios from above for each facility was summed with impedances applied to those ratios falling on the 2.5 -5.0 km buffer. The total sum of these ratios per facility formed the spatial accessibility index. The accessibility indexes at each village point were then used in ArcScene® together with the boundaries to produce a surface of accessibility index through Kriging, and the resulting surface reclassified to give them meaningful values. Poverty values were also used together with the boundary to generate a poverty surface of the district and the resultant surface reclassified to give it meaningful values.The two surfaces were then overlaid with spatial accessibility surface given a weight of 70%, while the poverty based given 30%, resulting into final health accessibility index map for the whole district.

4 Results and analysis

The data collected from the field described the individual facilities in their entirety, with an up-to-date situation of the facility. This data was used to produce an inventory database that could be used to display any queried information and produce required maps as need arose. Visual inspection of spatial distribution of health facilities in relation to population distribution showed that all the village points (sub-location centroids) were within 2.5 km of a health facility except for the village of North-Kanyabala. A skewed distribution of health centres was also clearly visible. Most of the health facilities were located on the northern part of the district around the largest town, Homa-bay town, while the eastern and western parts had fewer or no health centres.

All the facilities except Homa–Bay DH were found to be understaffed with most of the centres serving a population approximately double the recommended.The District Hospital had uncharacteristically high number of medical staff in comparison with the other health centres; some for instance had a staff of two serving a population of over 2500 people. Querying the created inventory could reveal other areas that needed to be addressed, such as which facility was in bad state and required attention.

1.3 Health facility accessibility analysis

Accessibility indexes derived for the area could not on their own, in tabular format, give much meaning and had to be mapped in order to see how they compare spatially. On plotting them, a surface was generated by Kriging. To enhance interpretation and visualisation, a six-category classification was adopted to enable quick visual comparison, with the lowest class index showing lower accessibility, while the highest showed the best accessibility (see Figure 1).Accessibility is seen to vary radially from Homa-Bay town, the largest town in the district, and reducing as one moved further away. The eastern side is seen to have lowest accessibility.

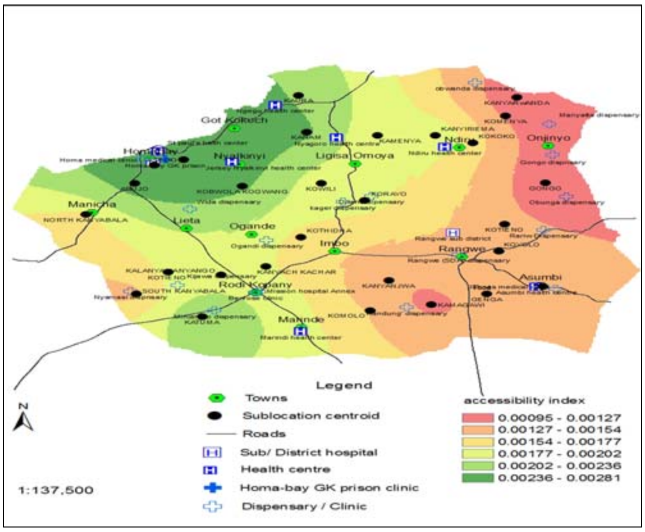

Fig. 6: Spatial accessibility index map from E2SFCA method

The poverty data showing percentages living below poverty line was also Krigged to produce a poverty surface of the district. The data was also reclassification into six categories to match the six categories used in the accessibility map. The scale represented the ability to afford healthcare, therefore places where 37% of the population lived below poverty was allocated higher ability i.e. six (6) as compared to areas where 74% lived below the poverty level which were allocated the lowest rank of one, with the other areas in between being fitted within this scaling. In overlaying the two data sets, spatial accessibility was given more weight than poverty index as spatial accessibility is taken as the primary factor in this analysis. This is due to the fact that cost increases with increase in distances irrespective of the facility charges. This was in tandem with other research such as Luo& Wang (2003b) who noted that in integrating spatial and nonspatial factors in accessibility studies, spatial factors are usually given higher weighting with nonspatial factors allocated a maximum of 30%. In line with this argument, spatial accessibility was allocated 70% while poverty was allocated 30% in this research, resulting into a final accessibility shown in Figure 2.

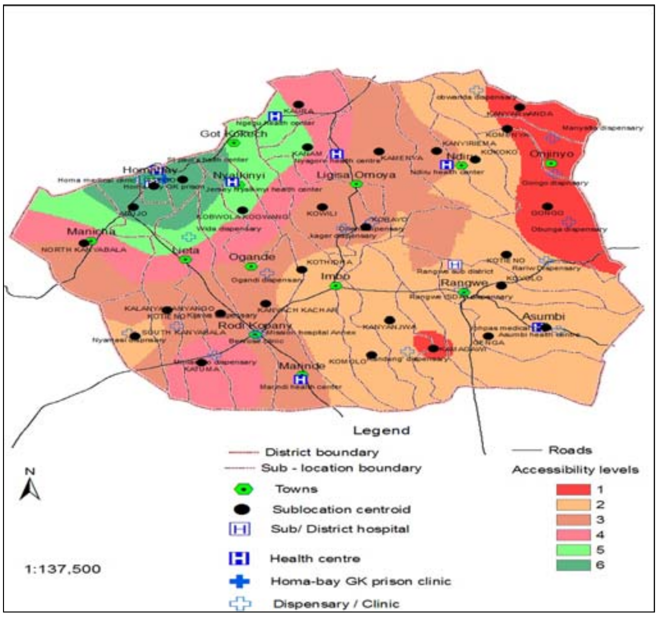

Fig. 7: Healthcare accessibility index map

The accessibility index map shows two sub locations, Homa-Bay town and Asegoto have the highest level of accessibility to healthcare, with a number of highly staffed facilities including the district hospital located there. On the eastern side of the district there is a comparatively low level of accessibility due to high population (high demand) and low number of staff manning the facilities. Integration of poverty with spatial accessibility is also seen to alter the pattern slightly since, with only distance, any one close to a facility is assumed to have accessibility but with purchasing power introduced; this complicates the situation as you can be near but cannot afford. The overall accessibility pattern between spatial accessibility and health accessibility with poverty integrated however does not change much, but on closer examination is found to have reassigned some areas from higher accessibility to relatively lower accessibility and vice versa. This redistribution effect maintains the overall pattern but changes the internal dynamics.

5 Conclusion and recommendations

The research demonstrated the power of GIS in analyzing positional related data and its enormous potential in solving healthcare planning and provisional problems. GIS provide simple tools like selection by attribute and location that were seen to solve the coordination and mismatch problems of healthcare systems based on the inventory map. Also, the visual display provides a powerful focus to aid decision making on what should happen where e.g. from the inventory mapping it was clear that there is imbalance in staffing. A very high percentage if not all the facilities are ill equipped to provide the level of service expected from them, when compared against those provided by norms and standards for health service delivery. Some dispensaries like Oneno and Kijawa have no water storage facility and power; this substantially reduces the services that can be offered from these facilities. Visual inspection also showed a very high correlation between the poverty patterns of the district and the spatial accessibility patterns. The relationship is an inverse relation where the higher the poverty the lower the accessibility.

The results of accessibility analysis is in line with other researches elsewhere that accessibility will generally be higher in town/urban centres and tends to be lower in rural areas due to fewer facilities and lower staffing coupled with relatively high population. Accessibility to healthcare was also seen to be influenced by the number of people in a given area (demand), available health facility and medical staff (supply) and socioeconomic status of the people.

Based on the inventory map, an upgrade of some dispensaries on both eastern and western part of the district would greatly improve accessibility. The government should either build many more facilities or increase medical staffing in the existing facilities in order to match supply with the demand. Elevating Nyamasi and Rariw dispensaries to health centres would greatly improve the situation.

The research could be improved by incorporating larger areas for the variations in healthcare accessibility to be appreciated much more clearly. Other non spatial factors like literacy, age, sex and ethnicity could also be incorporated to check their influence on healthcare.

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Urban and Regional Planning

Location Optimization To Establishment Of Clustered Treatment Plants In "Kandy Lake" Watershed Area

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Grey water, GIS, Kandy, location optimization, treatment plant

ABSTRACT

Kandy Lake is situated in Kandy district in Sri Lanka. It is one of the tourist attract cities in Sri Lanka. Kandy Lake is highly contributed for the aesthetic appearance in Kandy city. Unfortunately Kandy Lake is polluted mainly due to domestic, agricultural, auto mobile and tourist industries. Since it has both aesthetic value and economical value, protection of this watershed is important and it enhances the eco-tourism. Most of the hotels and guest houses do not have grey water treatment plants and send effluent directly to the Lake and it contributes highly to the pollution of the Kandy Lake.

This case study was conducted in order to find suitable locations to establish clustered treatment plants for the grey water effluent from the hotels and guest houses. Instead of locating one place, here it is encouraged to find different places to get the effluent through the gravity. It will reduce the pumping cost especially in this hilly area. Localized treatment plants will not function well without having good individual maintenance knowledge of the treatment plants.

ArcGIS was used as a tool to perform the task of optimization of suitable lands for the clustered treatment plants for the hotels and guest houses in Kandy Lake watershed area. As input layers 10 m contour map and land use map which was downloaded from the Google earth were used. Flow direction was simulated and flow accumulation was calculated. From that two sub watersheds were developed. Slope map also was created. From the land use map, all hotels and guest house layer and building layer as well as bare land layer was digitized and was rasterised. After overlaying the slope map with 15 % slope and bare lands map, suitable areas were created. Opening with hotel and guest house layer suitable area optimization was done. Two clustered were selected for the 25 number of hotels and guest houses in the watershed. Cluster one consists with 15 hotels and guest house and the land area is 1.17 km^2. Cluster two consists with 10 hotels and guest houses and land area was 1 km^2. These results will be beneficial to establish clustered waste water treatment plants and enhance the tourist industry in order to reducing the pollution in the Kandy Lake

1 Introduction

Water is a vital resource for the human as well as for all other living beings. Water plays a major role in the human life. Human use water for agriculture, industry, house hold, recreational activities and environmental activities also. Without water the life forms in the world is impossible. Clean water is essential resource for the human beings. World's supply of clean fresh water is steadily decreasing because of demand exceeds due to population pressure. Worldwide growing demand of water supply, combined with limited water deposits and their irregular spatial and temporal distribution often lead to serious problems with social and economical consequences. At the same time, the degradation of the water quality by human activities makes these problems more difficult. The pollution of the water bodies is a main reason to reduce the quality of the water, different types of wastewater are directly discharge to the water bodies by anthropogenic activities.

Sewage is the subset of wastewater that is contaminated with feces or urine, but is often used to mean any waste water. That contains a broad spectrum of contaminants resulting from the mixing of wastewaters from different sources. Black water is a type of waste water that used to describe wastewater containing fecal matter and urine. It is also known as brown water that comes from the toilet and garbage disposal. Grey water is another type of waste water which is originated from the laundry, kitchen & sinks. This grey water can be recycled and used for another purposes. Total waste water produced by a person is 120 Liter per a day (Fane, 2008). From this 120 liter, 20 liter is black water, it is mainly come from toilets. The total grey water produced by a person is high; it is about 84 liter per a day. Other 17 liter of waste water originated by kitchen taps and dish washing.

There are different types of wastewater treatment are present to treat this black water and grey water. Waste-water treatment is becoming more critical due to diminishing water resources and increasing waste-water disposal costs. According to the waste water types there are different treatment methods available. Most grey water is easier to treat and recycle than black water, because of lower levels of contaminants (Fane, 2008). Grey water may contain nutrients, pathogens, and is often discharged warm. It is very important not to store it before use in irrigation purposes, unless it is properly treated (Duttle, 1994).

Since Kandy is hilly area, clustered treatment plants were proposed to treat grey water. Grey water is the major contaminant from the surrounding hotels and guest houses to the Kandy Lake. Therefore the main objective of the case study is to find suitable locations to establish clustered treatment plants for the hotels and guest houses in the watershed area of the Kandy Lake. From that gravity can be used to deliver the waste water to the treatment plant.

2 Methodology

2.1 Study Area

Kandy Lake watershed area was selected for the case study. Normally Kandy temperature ranges from 21 to 26 °C, but in dry periods the temperature of the city area rises up to 29-30 °C. Land use of the area mainly consists of home gardens, commercial activity areas, public institutions, forests, markets etc. The total Area of the Kandy City is 1,940 km^2. From this total area land area is 1,917 km^2, Water bodies are 23 km^2. Kandy city is 500m above the mean sea level. Kandy Lake is surrounded by Kandy city. The population density is 57 persons per km^2. This manmade freshwater ecosystem was made in 1807. Figure 01 shows the location of the study area in Sri Lanka.

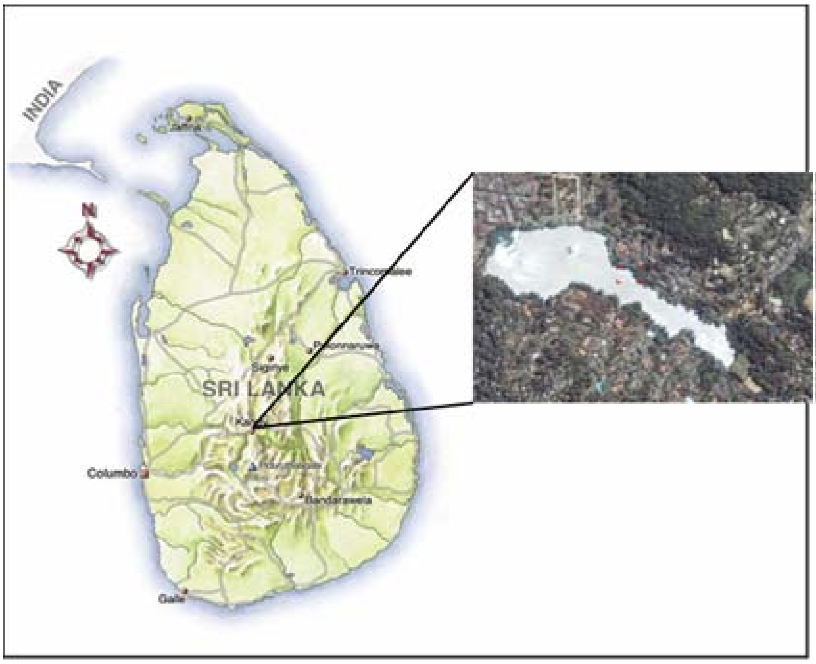

Fig. 1: Study area-Watershed of the Kandy Lake

2.2 GIS procedure

The following schematic diagram (Fig.02) was used to identify the GIS steps in our case study.

After site visit, final clustered treatment plants location optimization is confirmed as treatment plant cluster one and treatment plant cluster two shown in the Figure 03. This map will be useful for the local authorities in Sri Lanka as well as Tourist Board in Sri Lanka to improve the situation in Kandy Lake.

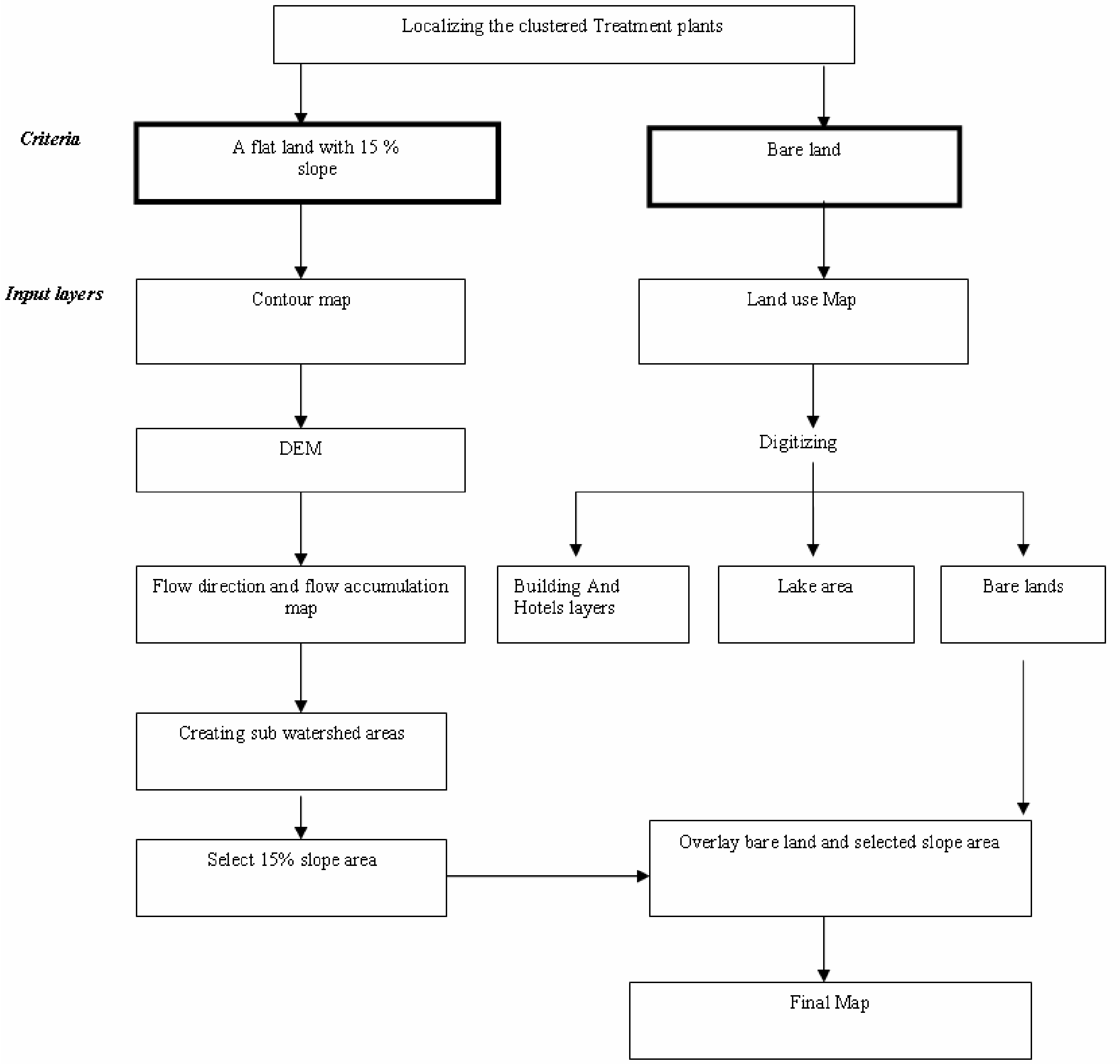

Fig. 2: Schematic diagram of GIS procedure

Location of the treatment site needs to fit with the overall physical plan of the development. Areas reserved for future development need to be clearly identified. And the proposed site needs to fit with existing plans for open space and buffers around a development's residences (Jones, et. al. 2001). There are many GIS applications to find optimum locations for treatment plants in Sri Lanka. Factor criteria are changing according to the purpose and the study area. There is a completed case study which used GIS for the location optimization of waste water treatment plant in the Upper Mahaweli Watershed. In that case study as factor criteria thematic maps of stream characteristics, land use and vegetation cover and socio-economic characteristics with DEM were used to determine the most suitable locations for putting up the treatment plants for non-point source pollutants. (Ratnapriya, 2009). But for this study as factor criteria, slope of the land (less than 15 %) and the land use (bare land) were selected. There are no any surface water bodies within the watershed area and there was no any flood history for the study area. Therefore water table fluctuations did not take into account in the study.

Contour map (20 m interval) was collected from UDA (Urban Development Authority) and corrections were made for missing lines and missing values. DEM was created by using fill tool in ArcGIS. It was important to develop good quality elevation model which was used to develop flow directions, flow accumulation and slope map for the study area. Flow accumulation map was used to create two (02) sub watersheds for the study area

(Fig.03). Slope map (Fig. 04) was created by using 20 m contour map. Above procedures were followed by using spatial analyst extension of the ArcGIS software. Different slopes were encountered and select only less than 15 % slope area as suitable for the treatment plant to minimize the unnecessary cost to establish the waste water treatment plants. Building layer was digitized from the available Google earth image of the study area. Then available land use map was used to get the bare lands to make no any disturbances to any eco systems in the study area. . Then 15% slope map and the bare land map were overlaid to get the suitable area for the treatment plants. After that two (02) sub watersheds and hotels and guest houses were overlaid to have final map.

2.3 Field Survey

Field survey was conducted to gather information about existing grey water and black water treatment plants (if available), number of rooms available and the number of staff in the hotels. Thirty four hotels and restaurants were selected for the field survey. Amount of grey water and black water volume were calculated by using surveying data.

Sri Lanka Standards (SLS) 2003 were used to calculate theoretical effluent by assuming maximum number of guests occupied all the rooms and whole hotel or guest house staff is working. This calculated value was used to determine the number of clustered treatment plants will be enough for the watershed.

3 Results and discussion

3.1 GIS procedure

Using ArcGIS, location optimization was done for the grey water clustered treatment plants. Figure 05 shows the final results with whole hotels and guest houses in the watershed area. Because of the volume of the grey water amount and the slope of the land, it was decided to establish two clustered treatment plants. Therefore whole watershed divided into two (02) sub watersheds and hotels and guest houses were located in two (02) sub watersheds as shown in the Figure 05. Final map shows the hotels and guest houses in sub watershed one (Black color) and the sub watershed two (Green color). Other than those, suitable areas for the clustered treatment plants are shown. Suitable areas for cluster treatment plant in sub watershed one shows in pink color and suitable areas for cluster treatment plant in sub watershed two shows in blue color. Cluster one consists with 15 hotels and guest house and the land area is 1.17 km2. Cluster two consists with 10 hotels and guest houses and land area was 1 km2.

Since selected locations for waste treatment plants are below the hetels, there will be no any pumping cost of waste water to the waste water treatment plant. Because of the gravity, waste water flows to the treatment plants.

3.2 Field Survey

Grey water volume from the hotels and guest houses is calculated as 250,860 l/day of the Kandy Lake watershed area. Calculations are based on Sri Lankan Standards (SLS) in 2003.

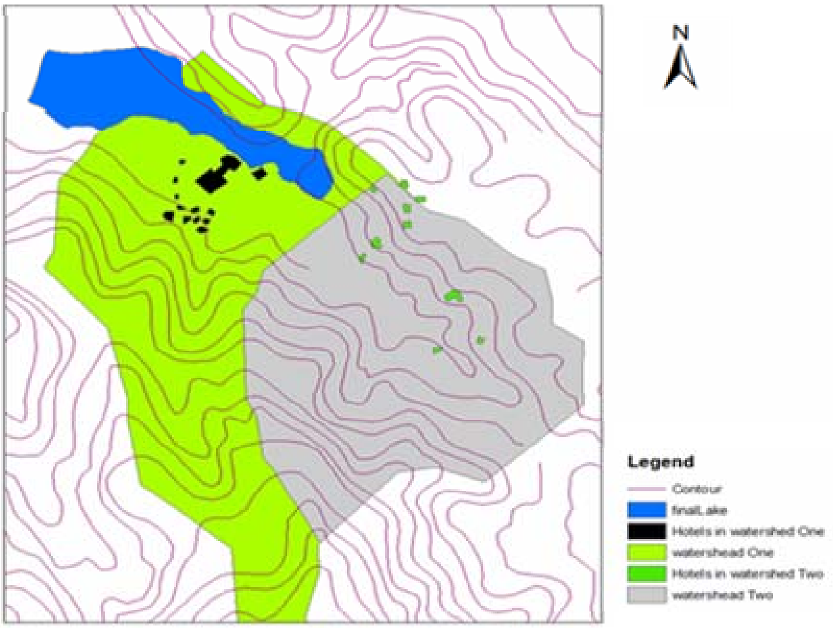

Figure 03: Two sub watersheds

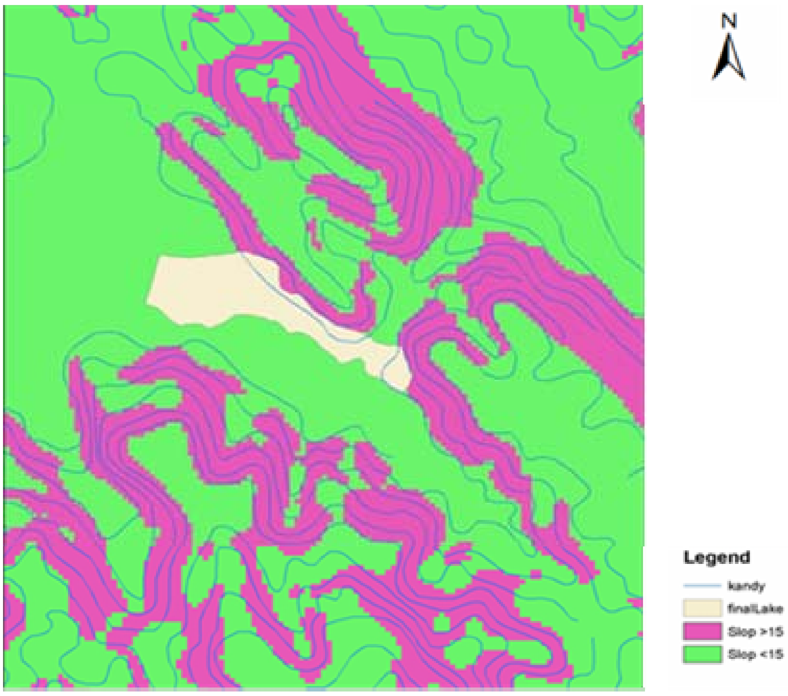

Figure 04: Slope less than 15%

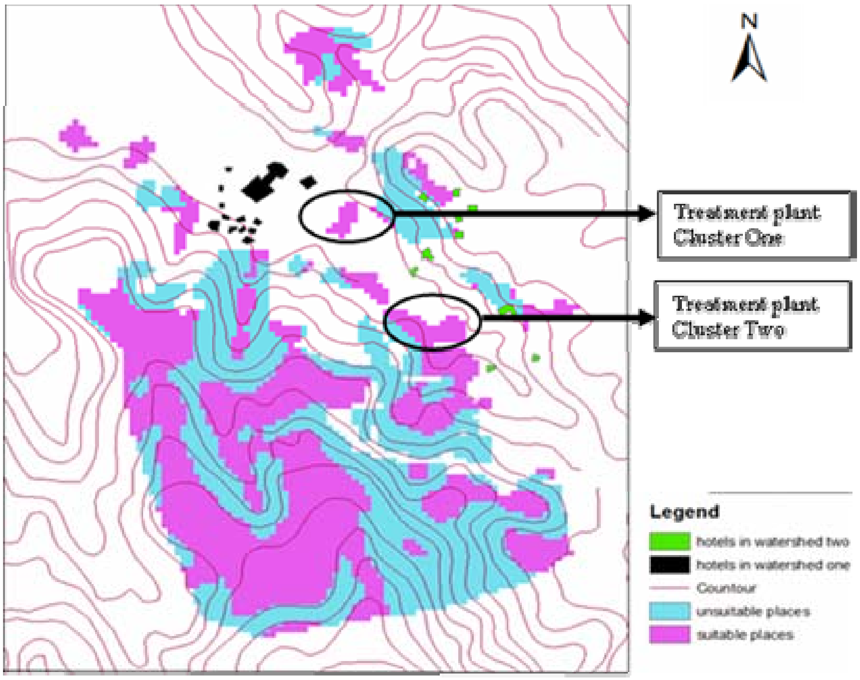

Figure 05:Final Map

4 Conclusion and recommendations

4.1 Conclusion

Two clustered grey water treatment plants have to be established in the Kandy Lake watershed area in particular places as shown in Fig.05.

4.2 Recommendations

1) GIS can be used as an effective tool for the multivariable analysis

2) Treatment plants have to be constructed for the maximum volume of grey water effluent.

3) Effluent drainage system has to be closed system in order to prevent contamination of rain water and other water borne diseases.

4) Better to have continuous maintaining plan for effluent delivery system of the treatment plants

5) Increase awareness of reducing Kandy Lake pollution level from the household level.

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Developing a sustainable land utilization model (SLUM) for urban planning – the case of Kisumu municipality

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KEYWORDS:
Decision support systems, Multi-criteria evaluation, Multi-objective land allocation, land use model

ABSTRACT

Urban land use planning in today's competitive world requires exploitation of spatial information for effective management of land resources if sustainable development is to be realized. This research developed a land use model for urban planning using multi-criteria/multi-objective decision support systems for Kisumu municipality. The study sought to establish and recommend the kind of land use model that urban planners can use as a planning tool for the provision of utilities and services with the aim of fostering sustainable development. This was in view of the fact that planners are faced with a diversity of land use objectives but their synthesis and wholesome consideration in the decision making process has been a formidable challenge to them. Solutions based on decision support systems integrated into planning schemes will therefore enable urban planners provide more rational, objective and non-biased approach to planning while embracing the ideals of environmental conservation. Both spatial and non-spatial data was analysed systematically through criteria formulation, multi-criteria evaluation and multi-objective land allocation processes to derive a land use model. The model can be manipulated by planning authorities and generate more information to guide their planning work. This in turn will enhance decision making in land use planning and foster sustainable land utilization and management in urban areas.

GIS for sustainable urban planning: Irbid governorate experience

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KEYWORDS:
GIS, Urban Planning, Irbid Governorate, Situation Analysis, Growth Plan

ABSTRACT

Planning requires a huge set of data related to the city's past, present and future. Traditional methods of managing, analyzing, querying and displaying information are hard to use in the planning process, especially for big dynamic, problematic urban areas. GIS become an essential tool for planning. Urban planning was completed for large portion of Irbid Governorate/Jordan using GIS to manage, store and analyze data and various growth scenarios, present the existing situation and the future plan. It was accomplished by Greater Irbid Municipality (GIM), Ministry of Municipal Affairs (MOMA), Amman Institute for Urban Development (AI) and Planning Alliance (PA) in two phases: situation analysis and growth plan. The first phase outlined different levels of growth. The second phase established urban and rural growth concept.

This paper demonstrates how effectively GIS was used in Irbid urban planning and highlights GIS role and application in the project.

1 Introduction

Planning requires a huge bulk of data related to the city where planners have to deal with land-use, transportation, infrastructure, and environment data, etc. Traditional methods of information management are hard to use in the planning process of large and problematic areas.

"Drawing boards and T-Squares were the main tools used in every planning office and information is kept in paper files and sometimes went missing without notice. Although it takes considerable time and efforts, it is not a problem because data can be collected again and again since it is part of the planning routines. However the process has changed and planning have to faced with complex urban problems due to rapid development of the country." (Kassim N.)

GIS is a powerful tool to create and maintain large quantities of data about a city .The capability of GIS in integrating the spatial and non-spatial data and analyzing them, provide the planners with variety of scenarios and approaches to choose from.

Irbid urban planning project was implemented by highly professional local and international experts, consisting of GIM, MOMA, AI and PA. The objective of the project was to create a vision for Irbid for 2030 with intensive public participation in forms of forums, committee workshop and focus group. The vision will help configure directives and needed polices to manage the growth in the study area. The urban planning was accomplished in two phases: the situation analysis and the growth plan.

This paper emphasizes the directions and promoting the use of GIS in urban planning and how it improves the efficiency of data compilation and analysis required in various phases of the project.

2 Study area

The study area was 669.40 Km2, defined by administrative and natural determiners. It includes Greater Irbid Municipality, Ramtha Municipality, West Irbid Municipality, part of Al Mazar Municipality and some land within Irbid Governorate. Figure 1 shows the study area with the different municipalities' boundaries.

Irbid is one of the 12 governorates in Jordan. It is located north of the capital, Amman. MOMA divides Irbid Governorate into 18 municipalities. The capital of Irbid governorate is Irbid City

"Irbid City, the bride of the north, is considered as one of the most beautiful Jordanian cities. It's situated on a plain land, 65 km. and surrounded by fertile agricultural lands from north, east and south, Irbid governorate is characterized by its strategic site, its historical and archaeological significance and the economic role that it plays. Irbid is at the top of the Jordanian agricultural regions especially in the production of citrus, olives, wheat and bee-honey" (GIM website)

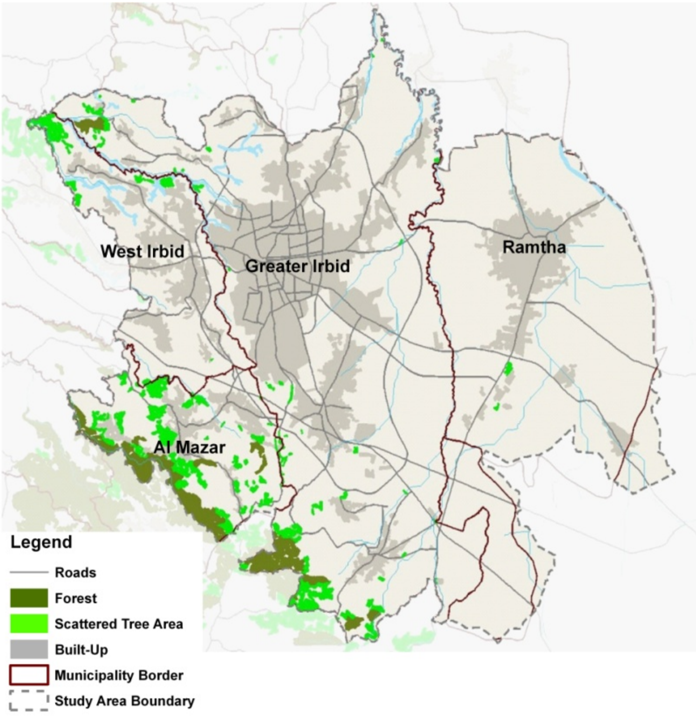


Figure 1: Study Area

3 Data and Methodology

ArcGIS 9.3 software was used to perform the spatial data analysis, conversion and mapping. GIS Data covering the study area was compiled, managed and analyzed according to the following methodology diagram:

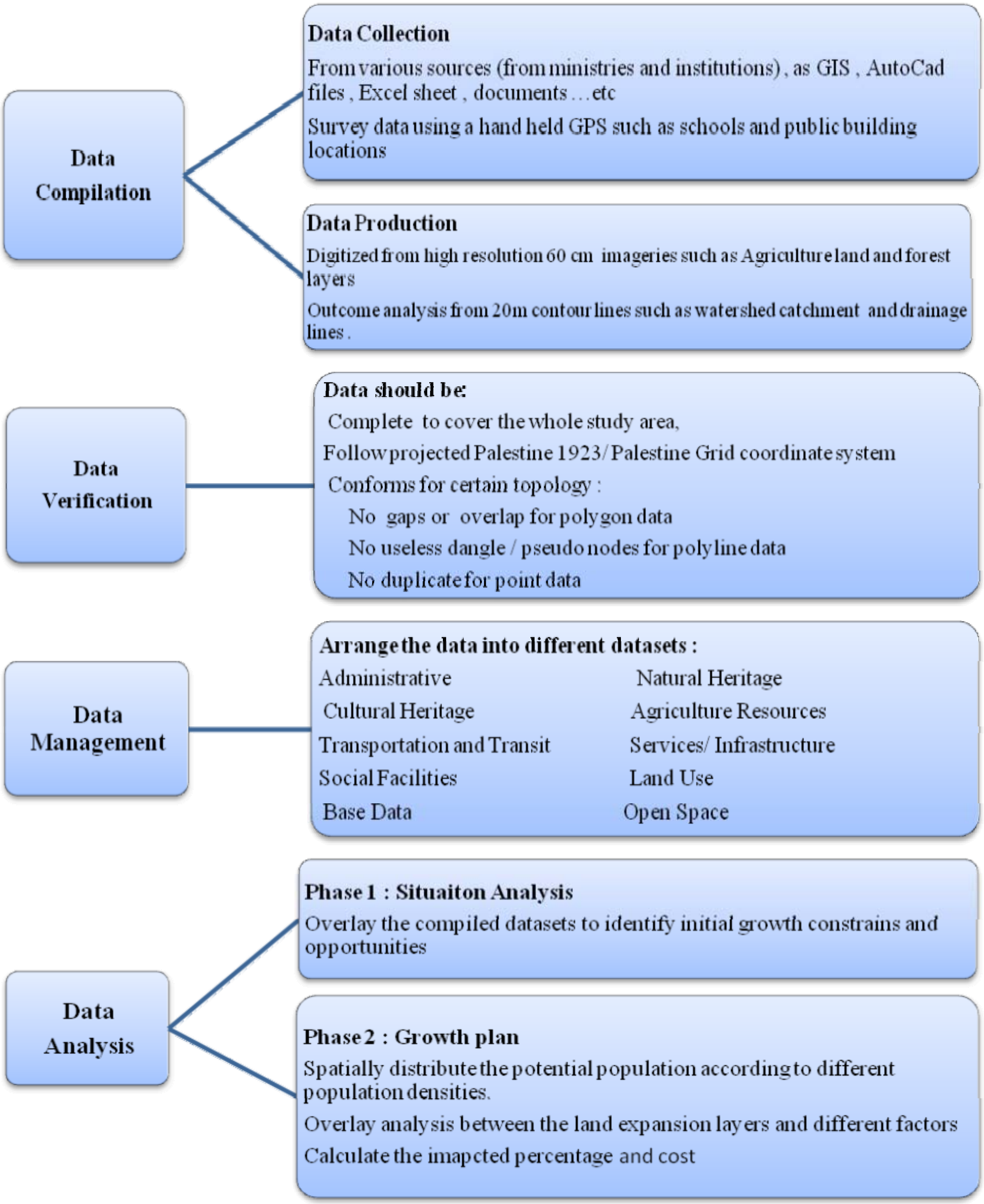


Figure 2: GIS Data Methodology diagram

4 Situation Analysis

Situation analysis phase presents the study area current situation and will be a guide to the growth plan.

After datasets were compiled, the next step was to identify initial growth constrains and opportunities. The growth constraints delineated areas where growth will need to be limited or restricted, while growth opportunities identified areas where growth will need to be allowed and encouraged.

The No Growth areas consist of areas where physical resources and culture heritage features, such as wadis, forests, reserved areas, antiques sites and heritage zones. Growth areas include the primary existing settlements, housing projects, major employment and industry areas, roads and infrastructure. Limited Growth areas fall in between the two categories, they consist of agriculture areas, rangelands, semi built/ built wadis, quarries and mining sites. Figure 3 shows the growth opportunities and constrains in the study area.

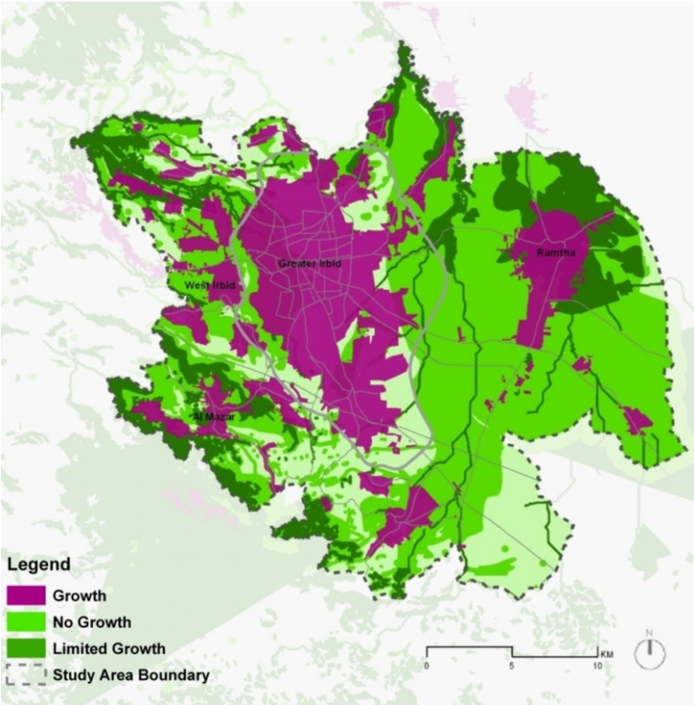


Figure 3: Growth constrains and opportunities overlay

5 Growth Plan

Growth plan provide future strategy in where the city will grow, and how it will accommodate the increase in the population. Having a defined growth plan will help control urban sprawl, protect environmental and agricultural resources and decrease the funding cost of infrastructure and services.

Irbid Growth Plan provides a spatial guide to development within the study area. It provides an urban and rural growth concept to control the growth in the region.

5.1 Vision

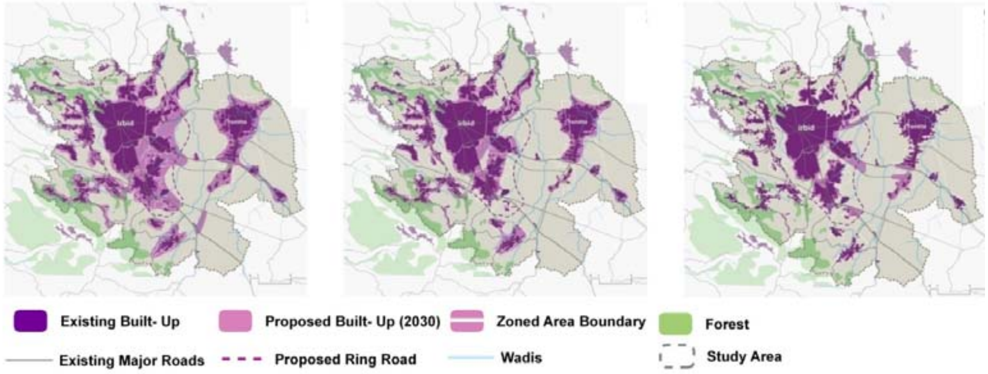
Irbid Vision is derived from the aspirations of the community. It reflects the needs and ambitions of many stakeholders and community sectors such as children, businessmen and carpenters.

"Irbid is a modern, sustainable, knowledge city that maintains its originality, a city that is prosperous economically, and invests effectively in its natural, human resources and strategic location" (GIM, AI and MOMA team, 2009)

5.2 Growth Scenarios

According to the Department of Statistics (DOS) in Jordan, the population projection indicates that the number of residents in the study area in 2004 will almost double and reach up to one million in 2030 (GIM, AI and MOMA team, 2009) correspondingly there will be increase in housing, investment and employment demands. A series of sessions were held to review and assess the different growth plans, to evaluates the population growth and corresponding land demand, plus the impact of different factors such as shrinkage of agriculture land and funding cost for the infrastructure and services**.**

Planners use GIS to distribute spatially the potential population within the study area according to different population densities: 5, 10, and 15 person per dunum (ppd) existing settlements, existing infrastructure, investment land and areas that should be protected as shown in Figure 3.



Scenario1 : 5 ppd Scenario2 : 10 ppd Scenario3: 15 ppd

Figure 4: Growth Plan scenarios

For each density the impact of proposed built up area (the land expansion) in 2030 on different factors was studied. Factors include percentage of impact on agriculture land, rangeland and environmental areas such as forest, and the estimated cost for infrastructure services such as roads, water supply, sewers, and electrical network as shown in Table 1

Table 1: Growth Scenarios Evaluation

Future Estimated Impacted Percentage/ Cost Length of	**Scenario 1 (5ppd)**	**Estimated Cost (JD)**	**Scenario 2 (10ppd)**	**Estimated Cost (JD)**	**Scenario 3 (15ppd)**	**Estimated Cost (JD)**
Agriculture Land	24	-	14	-	6	-
Rangeland	6	-	3	-	0	-
Natural Heritage Areas impacted	31	-	24	-	6	-
Road length (Km)	322	120,000,000	121	70,000,000	75	43,000,000
Water Network Length (Km)	1926	81,000,000	1122	47,000,000	460	19,000,000
Sewage Network Length (Km)	678	-	395	-	162	-
Electrical Line Length (Km	795	-	464	-	190	-

Based on the evaluation, practical ability, growth principals and focus group recommendations to allocate growth, Scenario 2 (10 ppd) was selected as the recommended scenario.

5.3 Growth Concept

Irbid Growth Plan is a guide for the City's development. It presents spatially an urban and rural land use concept in order to manage the growth in the region.

Urban growth Areas are the areas to be focused on where the development will reside. They include urban settlements, centers and corridors as well as major employment areas. An Urban fringe exists which is transition zone between urban and rural areas.

Rural areas will have less focus on development than urban ones. They fall within the limited growth areas with other component plans and include rural settlements, rural corridors and centers, agricultural areas, mining and quarrying sites, heritage centers and landscapes. Finally, core natural heritage areas are identified where growth is to be strictly limited (no growth areas). Figure 5 shows the different growth areas.

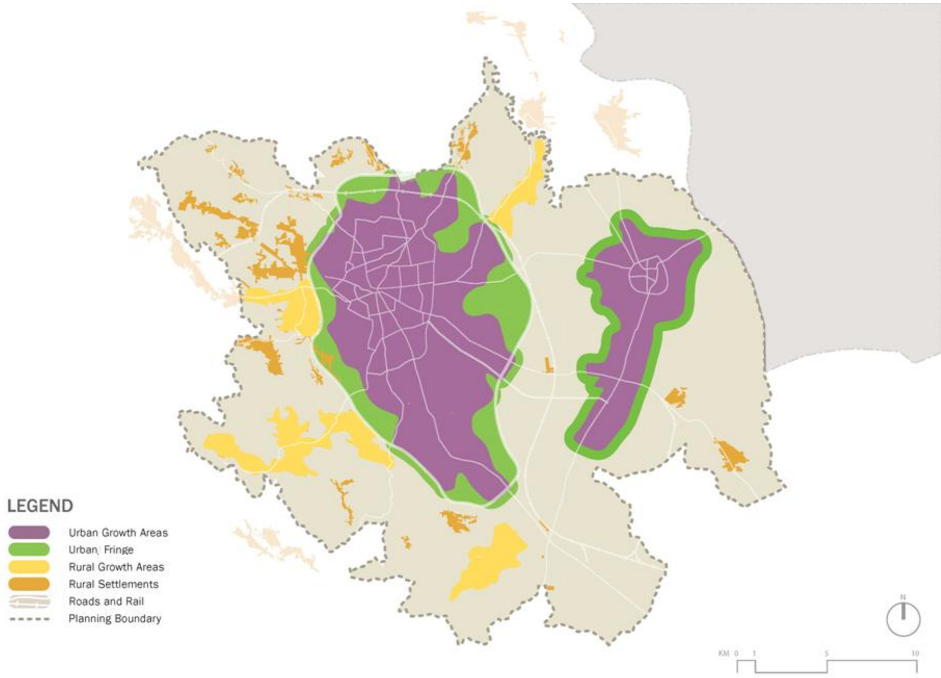


Figure 5: Growth Concept - Growth areas

6 Conclusions and discussion

This paper has presented the integration of GIS in urban planning for Irbid Governorate project and how it helped to define the current and the future plan. It has also highlighted some guidelines for GIS data compilation, management, analysis and some principals for an urban planning project.

GIS has provided an excellent platform for the planners and decision makers in this project. GIS has increased the work efficiency and the analysis accuracy.

GIS significantly reduced the amount of time it took to explore or query the huge amount of data related to the city such as accessing information about a specific parcel in the land use or land parcel layer.

GIS analyzed and assessed the different scenarios of urban growth that seek to present and predict changes in the project area in 2030, it has been successfully able to produce the results in spatial and numeric formats and help the planners and decision makers to choose the most preferable one.

GIS presented comprehensively by mapping the future plan and the current situation of the study area which are an integral part of the master planning process. GIS also allowed exchanging the data in different ways and formats such as maps, tables and geo-database.

GIS helps maintain a level of continuity throughout the life of a project and can even be used to tweak a project because of changes in the surrounding urban fabric or changing strategies.

A huge bulk of information related to different field were collected and verified within the study area. For further use, this information can be published on the web to be accessed by the community, and also it is a first step toward GIS hub for all Jordan.

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Acknowledgement

A special thanks for all the professional team consists of managers, planners, surveyors, etc. who worked or participated in this project from Greater Irbid Municipality (GIM), Ministry of Municipal Affairs (MOMA), Amman Institute for Urban Development (AI) and Planning Alliance (PA).

Using GIS for Village Level Planning for Agricultural Productivity through Water Harvesting in Semi- Arid Areas of Kitui District

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KEYWORDS:
GIS, Sand dams, Agricultural productivity, mapping, Spatial analysis and Expert Approach

ABSTRACT

A study was carried out to investigate the use of Geographic Information Systems in village Level planning in order to improve agricultural productivity through water harvesting in the semi-arid areas of Kitui district. The study considered sub-location, the lowest administrative boundary in Kenya and selected Mbusyani sub-location that has sand dams in comparison to other villages with no water structures constructed. The key factors affecting agricultural productivity were put into consideration in developing maps using the expert approach to analyze them. These key factors are namely location of rivers with existing water harvesting structures, agro-diversity, village population, soil suitability and land resource for irrigation. The analysis involved identifying areas where water harvesting structures would fit best in terms of availing water for irrigation in order to improve agricultural productivity. The population density is being served by the water source in relation to water for irrigation. To finally check the soil suitability for agricultural production and how close it is to the water source. The water harvesting structure used in the study is a sand dam since it is located on the river bed. Maps for the various factors were developed and spatial analysis carried out to identify and develop spatial relationships through overlays and combinations. Finally a suitability village level map built for improved agricultural productivity through water harvesting developed for use in planning.

1 Background

Agriculture is a key sector for people resident in the rural areas of Kenya. Water plays a fundamental role in agriculture: it is essential for livestock and it forms a large part of all plant tissues. For successful agricultural activity there has to be adequate water available on a timely basis and in reliable amounts as well as good soil that can support the growth of these crops. For farming systems in semi-arid areas erratic rainfall causes seasonal dry spells and periodic droughts. For these farming systems increased water infiltration in good soils can improve yields, reduce risk of yield losses as well as increase the recharge of ground water.

Farming under erratic rainfall conditions is pervasive in Kenya: 82 per cent of the land area is designated as semi-arid, holding in excess of one-third of the population [12]. Shortage of water resources and poor soils possess a threat to the economic potential of such areas especially as pertain crop production. The possibility to further agricultural development with such constraints is a key challenge for viable dry land farming. There is a need for a comprehensive, integrated approach to unlock the full potential of sustainable irrigated agriculture for poverty reduction and economic growth in the semi-arid areas. Sand dams shall be used as water harvesting structures in this research. Sand dams are impermeable structures constructed across ephemeral rivers. Their construction substitute for the natural subsurface aquifers that have in antiquity enabled the storage of water in some parts of the river channels.

Expert approach was applied in mapping the potential area where irrigation agriculture can be practiced by coming up with the proper characteristics for sustainable crop production under irrigation. These areas were mapped using GIS enabling identification of areas where water resources can be constructed for full potential agricultural production through irrigation. Suitability maps were generated for irrigation agriculture.

Crops success depends on many things including abiotic, biotic and economic conditions. Suitability is a relative measure of all locations to meet crops abiotic environmental requirements [1]. Considering crops suitability to basic climate and soil traits is an important initial step in identifying potential new crops. Potential irrigated crops that can be of economic value would include vegetables such as tomatoes, kales, cabbages, carrots, capsicum and onions. Irrigated crop performance = abiotic factors + biotic factors+ economic factors. These factors can be summarized by looking at soil suitability, water availability and land availability/ degraded land, [7].

2 Study area

The study area was 20 sub-locations in central division of Kitui District, figure 1.0. The District is in the Eastern Province of Kenya is a semi-arid region under agro-ecological zone iv and v situated 150 km East of Nairobi. The total land area is approximately 20,402km^2 and is characterized by hilly ridges, separated by low lying areas between 600 and 900 metres above sea level, about 1^o 22' south and 38^{o}1'East. The rainfall amount is (450-900) mm on average. Soils in these areas are sandy, dry and therefore prone to soil erosion by wind and sporadic torrential rains.

Figure 10: Sub-locations in Kitui Central

Farming in Kitui is majorly rainfed with crops such as green grams, cowpeas, pigeon pea, millet, common bean and sorghum grown. There is also agro-pastoral where crops together with animals such as small herds of cows (Boran cattle) and goats are kept. An indicator of the nature (type) and intensity of agricultural activities is the agricultural possessions in the various households. Irrigation of vegetable is carried out along large streams that take a longer period to dry. These vegetables include onions, tomatoes and kales. Land availability is characterized by large parcel of land that is usually cultivated during the rain season and yielding below average [12].

3 Methodology

3.1 Data sources and specification

There are various data sources used in the research, the GPS location of sand dams obtained from the field, digital topographical map of the scale 1:50,000 for Kitui area from the department of Geomatic Engineering at Jomo Kenyatta University of Science and Technology. Finally sub location and soil shape files obtained from the International Livestock Research Institute Website.

3.2 Tools used for data capture

The field data was collected from the field by use of a GPS (Global Positioning System). The field data was significant in the identification of sand dams. Other tools involved in data capture were computer software's such as Arc GIS 9.3 and Arc Hydro extension tool for ArcGis. A field survey carried out to establish highly demanded crops that can be irrigated and whose supply was low

3.3 Data preparation/geo-referencing

Digital topographical map of the scale 1:50,000 were projected to clarke 1880 UTM zone 37 south and used for digitizing the rivers used for the study. The shape files were also projected to above mentioned projections.

3.4 Data processing

Digitization of the field data using Arc GIS 9.3 was done in order to identification of area where sand dams have been constructed. Clipping of sub-locations from the Kenya sub-locations shape file was done to identify area of study. Using the clipped sub-locations, the soil map for the study area was extracted. The soil map generated was used in extracting the soil PH and soil drainage maps. Digitization of rivers from the 1:50,000 scale topo sheets was done to delineate rivers that were within the areas of study. The rivers were used in extracting the water flow accumulation map. Finally a 30m DEM (Digital Elevation Model) was used to extract DEM for the study area. The DEM was used in generating the watershed and flow accumulation map.

3.5 Data analysis

The first involved establishing suitable soils for irrigation crops such as vegetables i.e. kales, spinach, tomatoes, cabbages, carrots and capsicum. Soil suitability in this case involved ensuring the correct PH and drainage that would enable the crop grow well. From experts knowledge the PH and drainage requirements of the mentioned crops are known. The soil PH map was overlayed onto the soil drainage map to establish good soil for the irrigated crops. Figure 2.0 and 3.0 are the soil Ph and Soil drainage maps respectively and figure 4.0 the result of the intersection between the two maps done using ArcGIS.

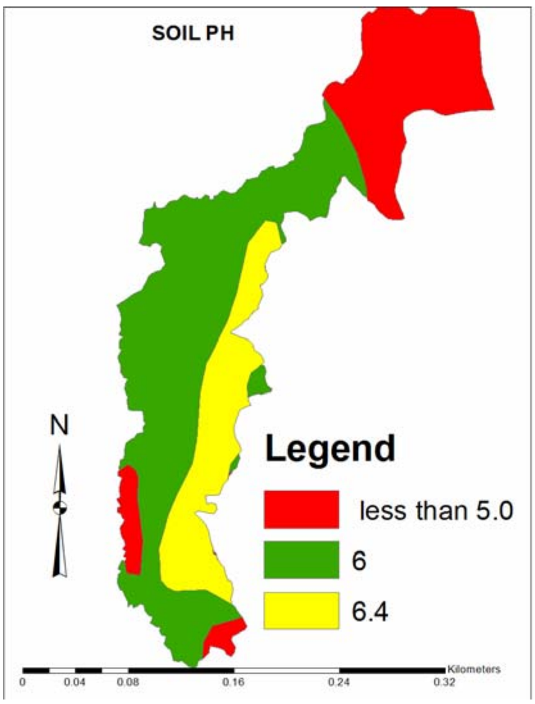


Figure 2.0: Soil PH map

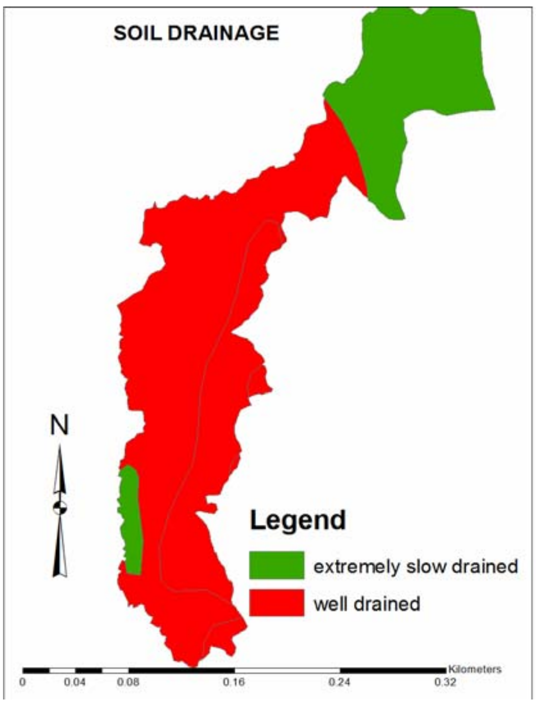


Figure 3.0: Soil drainage map

The results was four classes namely; PH of 6.4/ well drained soils, 6.0 /well drained soils, 0/well drained soils and finally 0/extremely slow draining soils.

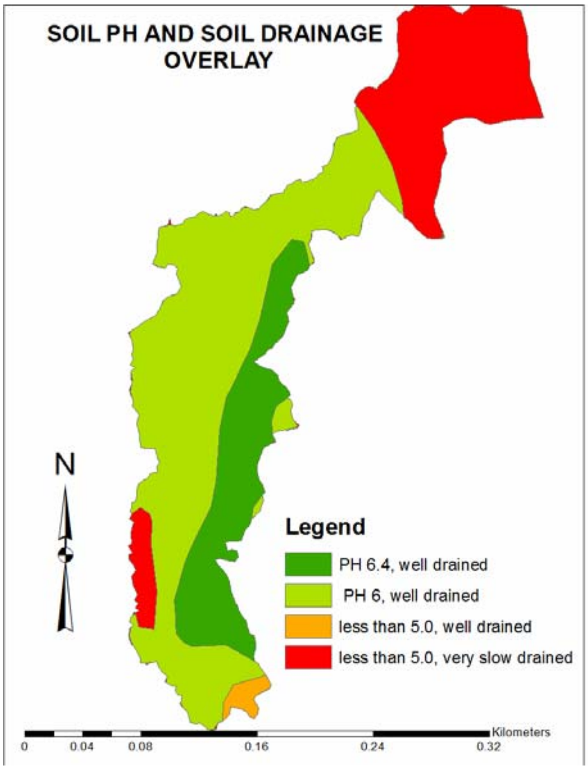


Figure 4.0: Soil PH and Soil drainage overlay

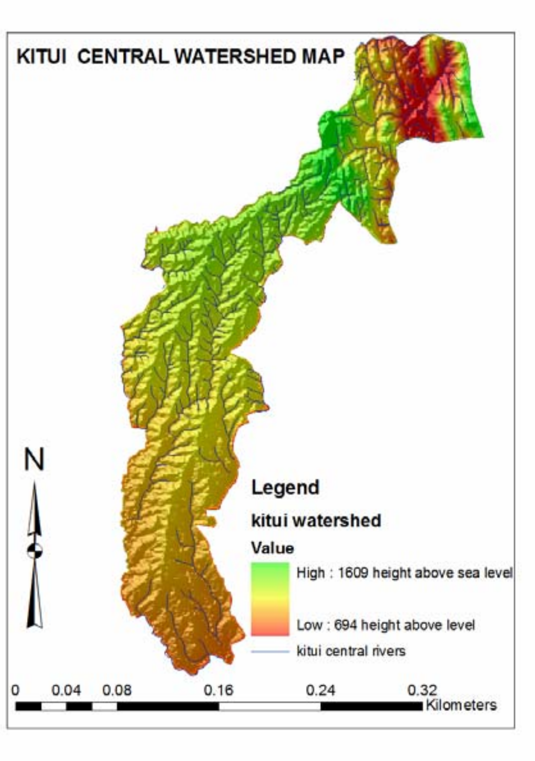


Figure 5.0: Kitui Central

Using the 30m DEM (Digital Elevation Model) map for the study area, a watershed was processed to show the drainage of the study area. Processing of hill shade was also done to enhance visualization of the area. The process for watershed generation involved;

DEM → FLOW DIRECTION → SINK → FILL → DEPRESSIONLESS DEM →

FLOW LENGHT → SNAP POUR → WATERSHED

The result was a watershed map showing the highest to the lowest point of drainage with rivers within the study area also overlayed, figure 5.0 above.

The depressionless DEM was also used in processing the flow accumulation using the Arc hydro tool extension for ArcGIS. The result was water flow accumulation for the study area as shown in figure 6.0. The maps processed i.e. the soil map and the water accumulation maps were compared in order to establish areas where water is available and the soils are also suitable for irrigated crops mentioned previously. The results showed that on areas where the soils were suitable, there were water channels of high water accumulation, figure 6.0.

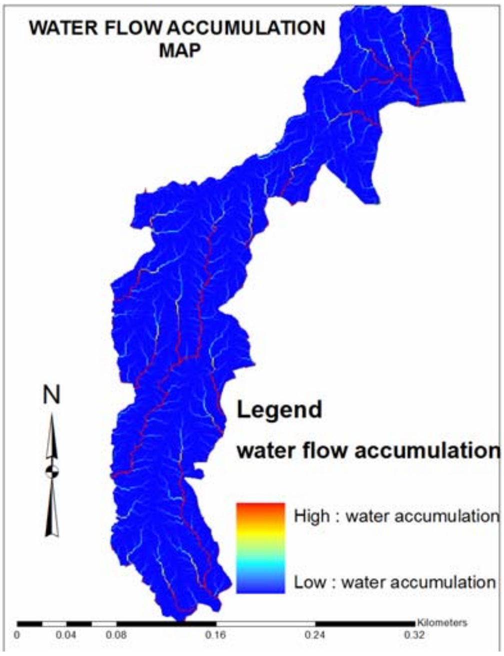
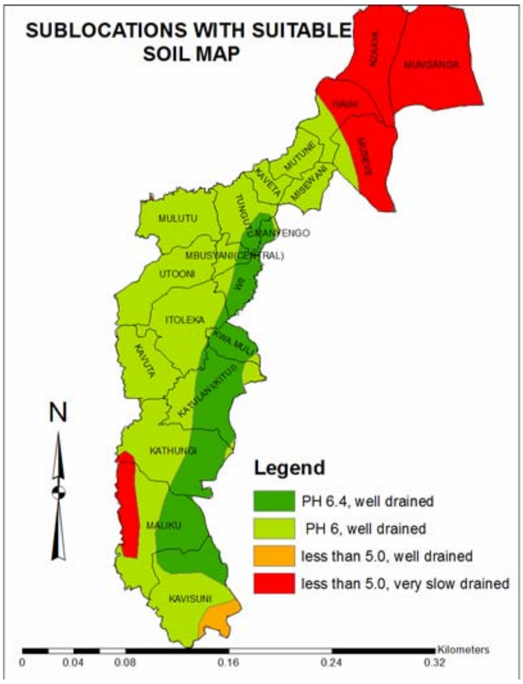


Figure 6.0 Water flow accumulation map

These results were then compared to the sub-location map to establish the number of sub-locations where crop irrigation was possible. 16 sub-locations out of the 20 had suitable soils for irrigation see figure 7.0 below. Out of the 16 sub-location, 13 had high water flow accumulation and hence suitable for crop irrigation for the mentioned crops due to the good soils and water a due to the good soils and water availability see figure 8.0 below.



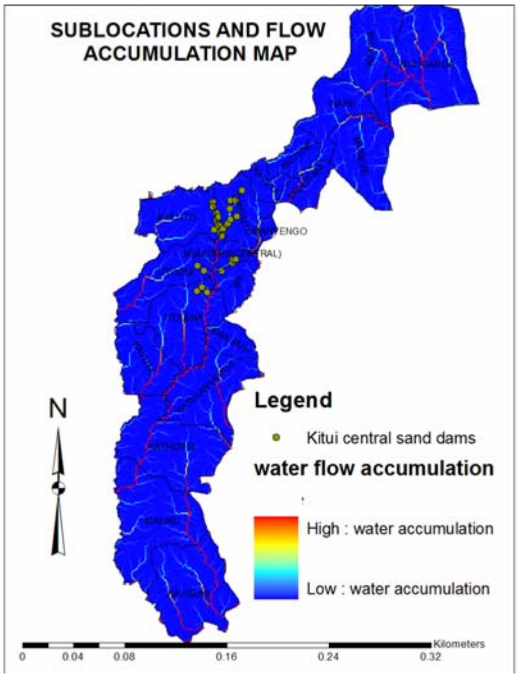


Figure 7.0: Water flow accumulation map

Figure 8.0: Water flow accumulation map

Finally established water structures such as sand dams were overlayed to confirm whether some of them could be utilized for crop irrigation, (figure 8.0). Out the 13 sub-location that were suitable for crop irrigation, 6 had sand dam constructed along the streams. 28 sand dams were considered in the study and 6 were lying in streams of high water accumulation. These 6 sand dams are more likely to sustain multiple uses i.e. irrigation alongside other uses such as livestock watering and domestic use compared to the other dams.

4 Discussion

The data analysis was able to identify the sub-locations that have good soils for the irrigation crops mentioned earlier in terms of soil pH and soil drainage. Soil forms the most important non-renewable natural resource determining the success of agriculture in any tract. It was, therefore, essential to make a scientific appraisal of soil resources, especially for their potential and constraints, so that sustainable production is planned. 16 of the sub-location out of 20 were found with good soils for irrigation. The soil PH and drainage for the irrigable crops mentioned earlier are in table 1.0 below;

Table 1.0: crops soil PH and drainage characteristics

Crop	Soil PH	Soil drainage
Kales	6 to 7.0	Well drained soil
Cabbage	6 to 7.0	Well drained soil
Onions	5.8 to 7.0	Well drained soil
Carrots	5.5 to 6.0	Well drained soil
Capsicums	5.5 to 7.5	Well drained soil
Tomatoes	6.0 to 6.8	Well drained soil

[14], specifies the importance of proper soil PH and soil drainage in dry land farming. Sustainable crop production is possible where suitable soils for the various crops are understood and identified before production can commence. The table above confirms the 16 sub- locations were suitable for crop production. Soil drainage addressed also the ability of the land to become irrigable. 13 of the 16 sub-location had area of high water accumulation and hence availability of water for irrigation. These are streams that can be exploited for irrigation of the crops mentioned above alongside other uses such as domestic use and livestock watering. Construction of water structures such as sand dams that improve ground water recharge would improve on the use of these streams for irrigation [2], discusses on the ability of a sand dam to improve water recharge along streams.

The population of the sub-locations in the study were evaluated and found to fall within the same range and the population density (2009 census) not high enough to put a constrain on water use and land available for cultivation. 6 out of the 28 sand dams were found to be on streams of high water accumulation ad hence likely to function better in terms of ground water recharge compared to the other dams. [8], in the principles of storage dams indicate the importance of the location of the dam especially the ability of that water structure to provide water.

5 Conclusion

Proper planning and management of the available resources is key towards addressing food security in the semi-arid areas [4]. The use of geographically referenced data and analysis of factors affecting agricultural productivity is key towards solving agricultural challenges in the semi-arid areas. The results from this research show that the creation simulation planning maps at small scale village level for use in addressing agricultural challenges in the semi arid areas is possible. This information can be integrated into a database that can be retrieved when development issues of the area are being discussed. Farmers and land resource professionals can assess the options that optimize the productivity and sustainable land use.

6 Recommendation

A land cover analysis of the study area would have been able to confirm in ha the land available that can be used for irrigation. A developed database of such analysis would be useful for future reference.

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GIS in Education

GIS education in Zambia

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ABSTRACT

Geographical Information System (GIS) technology has developed to such an extent that it has penetrated a number of academic subjects and has integrated further into mainstream business. There has been a gradual increase in human activity dependency on GIS and Geographical Information (GI). GIS application in our everyday life has also increased as is evidenced by its application in the many services we rely on. Researchers, scientists and administrators are increasingly using GIS as a decision making tool to inform about real issues. The areas and scales of application of GIS technology are so numerous and keep on increasing.

There is therefore a greater need for academic institutions to introduce GIS education as a matter of urgency. This paper seeks to highlight how Zambia has fared in this area of GIS education, what interventions are currently underway towards GIS education and also the challenges that remain to be addressed. This paper uses University of Zambia and Copperbelt University as case studies. The two universities, being the main universities in Zambia, are in the forefront of GIS education provision.

Lessons Learned Teaching the Kenya Free of AIDS (KeFA) GIS/GIA Course

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KEYWORDS:
GIS; Education; Kenya; Spatial Data; Computing

ABSTRACT

The Kenya Free of AIDS (KeFA) project, funded through the U.S. National Institute of Health, is a partnership between the University of Washington, U.S. (UW), and the University of Nairobi, Kenya (UoN). The project aims to 1) Build capacity for rigorous social and behavioural science research on HIV/AIDS at the UoN Centre for HIV Prevention and Research, and 2) Conduct foundational interdisciplinary research projects in HIV prevention. To further these aims, KeFA hosts an annual Advanced Research Methodology Workshop at the UoN, providing training and forums for discussion on topics requested by local population scientists. For the past two years, the KeFA workshop has included week-long courses on Geographic Information Systems (GIS) and Geographic Information Analysis (GIA). This presentation will discuss lessoned learned in three key areas related to the GIS/GIA courses: 1) subject matter, 2) spatial data resources, and 3) hardware and software infrastructure. Recommendations about course content will include understanding the spatial applications of researchers in this environment, striking the right balance between theory and methods, and developing exercises to show immediate results while leaving long-lasting understanding. Suggestions about data resources will consider the related issues of teaching a data-centric discipline, such as GIS, in a data-poor environment, using non-local data in the classroom (U.S. data in Kenyan workshop), and establishing a community forum for sharing data resources. Finally, we will demonstrate how the KeFA project established GIS computing resources for a 40-person workshop in a resource-limited environment by implementation a remote computing infrastructure.

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Experiences and Business Development

Hand in Hand for Benefits of All

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KEYWORDS:
Dissemination of information, access to benefits, cooperation, professional organisation, Open Source, capacity building

ABSTRACT

As we look at the Millenium Development Goals that were implaced since 2000, it is obvious that many of Stuttgart University of Applied Science alumni will be involved in one or more goals, deliberately or without realising it. These goals are commitments that are not just related to the governments but also to anyone with common sense and sense of belonging to a place. Improvement and develeopment are essences of human tale on earth.

In many developing countries as in Indonesia, dissemination of information and access to benefits of new technologies are, in some places, almost absent or at minimum level. For example the more eastern and / or remote area in Indonesia, the lesser it is for the above mentioned topic/benefits. In some cases, this can be caused by what seems to be "ego" of a department or institution which tend to "protect" the information / technology to its own benefits. Sharing of it seems to be the last thing on the list. This appears to be caused by fear of loosing investment, project or allocated budget. The other players such as private sector/industry in many instances are more advanced in technologies but can be reluctant to share the benefits of them as it may be viewed as unneccessary, unprofitable or even reduce its competitiveness. The importance of the corporation is highlighted in the MDG's #8; in particular Goal 8F. Only when the corporation is encouraged, nurtured and cultured amongst the stakeholders such as government, private sector and community, then the benefits of information and new technologies can be made readily available and can have wide impact to all.

The example from sharing of knowledge and experience in GIS/spatial data management between local government in Maluku and a private company has contributed to accelertion in GIS works for example data acquisition, management, analysis and data presentation. Some approaches are in place such as set of protocols, introduction of Open Source softwares, regular communication, info update and links.

Professional organisations are also another stakeholder that can care to contribute for a good and improved corporation. Spatial data user professionals in applied sectors such as mining and forestry are those who can share knowledge and experience to enhance capacity building and to share the benefits of expertise and new technologies to others. This is another niche for alumni to make their mark.

Some of lessons learnt so far in this tale are the importance of good will, openess, positive feedback and simplified bureaucracy.

GIS Supported Bank Collateral Mapping: A Case Study of Cooperative Bank of Kenya, Thika District

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KEYWORDS
Banking processes, loan facility, collateral

ABSTRACT:

The cooperative Bank of Kenya is one of the leading financial institutions in the country providing credit to its customers. The existing system entails filling of application forms which are then vetted through a grueling and error prone process. The bank needs to verify the authenticity of documents submitted as collateral, evaluate the credit worthiness of the client and establish that the client does not have huge outstanding loans with other financial institutions.

In this study both spatial and non-spatial information on all securities owed to the bank was collected and stored in a spatially aware database. From this databank, a solution was developed that allowed customer information to be interrogated prior to processing his/her application. This solution will minimize human error, reduce fraud in the banking sector and provide a spatial representation of all property used as loan security

The solution features an array of functionality to support loan appraisal, ensure security of access to the system via a logging in interface and prepare reports and maps about customer information held by the bank. These can be used to inform the customers why their applications were rejected. This solution largely automates the process of loan appraisal to the point of award or rejection.

1 Introduction

Recently, Kenyans have increased their investments by embarking on new projects. Investments range from single businesses, agriculture, corporations, to larger empires such as the shipping industry, security firms and real estate. Over the years banks have reduced their lending rates and this, coupled with the improving Kenyan economy owing to tighter security has led to increased consumer spending and investment (Kuria et al, 2009). The Kenyan economy maintained a rapid growth between 2005-2007 of 5.9% and 7.0%. However, the growth recorded a major decline in 2008 of 1.6% owing to the global recession and the 2007 post-election violence. In response, the government put up measures to stimulate growth including, restoring investor confidence and expansionary fiscal policy such as the economic stimulus package (ODI, 2010).

The financial sector expanded by 4.6% in 2009 compared to 2.7% in 2008. This was mainly caused by increased profitability by banks, and attributable to the reduction of the minimum cash ratio requirement from 6.0% in December 2008 to 4.5% by July 2009 (CBK, 2009). This in turn has increased the money in circulation availing more money to the banks to lend out to the general public at lower rates, with more people signing up for loans. With so many loan applications to be processed using manual verification and checking, there is an attendant risk of losing documents or misplacing files and possibilities of double allocation. This creates an avenue for fraud in the banking sector leading to loss of millions of shillings in revenue.

In the past banks kept their records in files but currently loan requests are persisted in computerized databases. However, spatial data is still kept in hardcopy form making it difficult to verify availability of spatial entities used as collateral to the loan application. When one puts up collateral, the bank uses a surveyor, to verify the

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record, and an appraiser, to conduct the valuation of the property, to ascertain the true value of the property. This process typically takes a minimum of three weeks.

A Geospatial Information System is a unique geographic database that can provide a great deal more problem solving capabilities than using a simple mapping or adding data to an online mapping tool (Kuria *et al*, 2009a). Some of the benefits such a system offers include: increased efficiency, increased revenue, better communication within the organization, better decision making, better storage and updating of data, efficient information retrieval and the ability to trade in the data collected.

The main objective of the research was to create an efficient bank security banking system to display the location of bank assets and attach the value of the security and aid in the processing of loans. This will be accomplished through (i) showing the distribution of the Bank securities, (ii) showing the location of bank securities and the value attached to the property, (iii) countering fraud in the banking sector in the office by connecting land parcels with customer information, (iv) minimizing human error during data entry by maintaining a single database and putting in place mechanisms to validate data entry and assigning responsibility for database modification.

2 The study area

The study area is Thika district which lies between 0° 45’ S - 1° 00’ S and 37° 00’ E and 37° 15’ E.

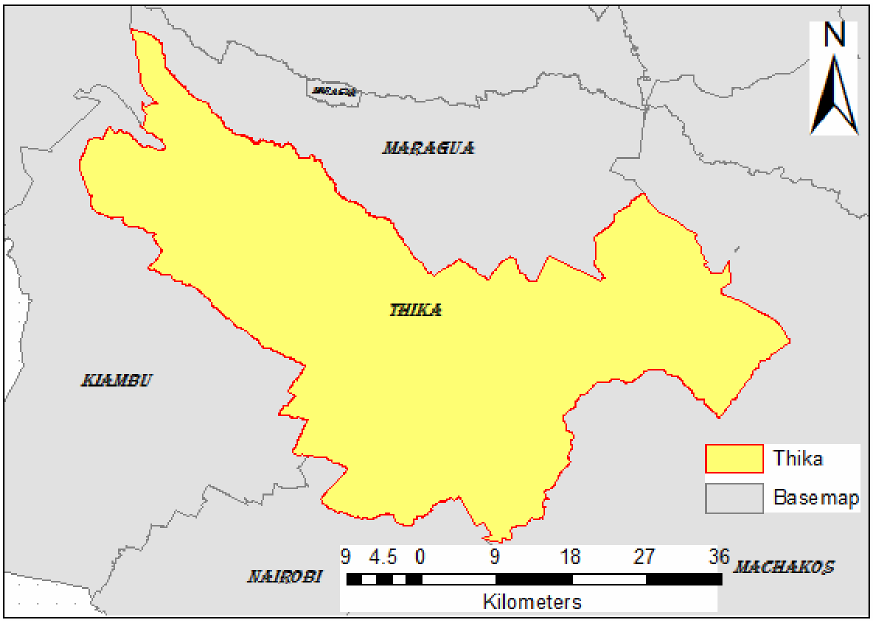

Figure 1 Study area Thika District

Figure 1 show the area extent of the study area. This work was carried out for the Cooperative Bank of Kenya, Thika District. The bank has various branches within the district, it has a substantial customer base in the area and it has been dispatching various financial products for its customers among which are loan facilities.

2.1 Process of loan taking

When taking up loans there are two major players involved, the lenders and the borrowers. The lenders in a loan syndication have the responsibility of conducting due diligence with regard to the borrower. The borrower may provide relevant information (e.g., organisational documents, annual reports) to the lenders through the arranger or agent, and the lender could use such documents for due diligence purposes (including customer identification) as appropriate. Identity may, however, be verified on a non-documentary basis, and lenders may obtain relevant information from other sources. The lenders do not have a due diligence obligation with respect to each other, nor does the arranger or agent have such an obligation with respect to the borrower solely by virtue of its capacity as arranger of, or agent under, the credit facility.

GIS can be a useful tool for decision making supporting verification as it makes location related decisions and analysis very easy. It makes the analysis simple and precise if the inputs are correct. Thus one can have the benefits of analysing spatial data as well as socio-economic data from within a GIS platform.

In secured loans where the borrower pledges some asset such as plots and buildings, the use of GIS can be very instrumental since the assets are positioned on the surface of the earth and therefore possess spatial qualities which can be used to accurately locate the asset and all the available information on it. GIS can be used in the form of an Land Information System (LIS) which contains parcel information such as owner information, parcel size, parcel definition, land use and administrative information. This information can prove imperative to lending institutions when assessing the collateral offered by borrowers and ascertaining their legitimacy and nature and condition of the asset. The LIS may also be used to get legal information such as if there are any charges on a parcel put up as collateral and save the institution a lot of money and time (Khan, 2006)

3 Materials and methodology

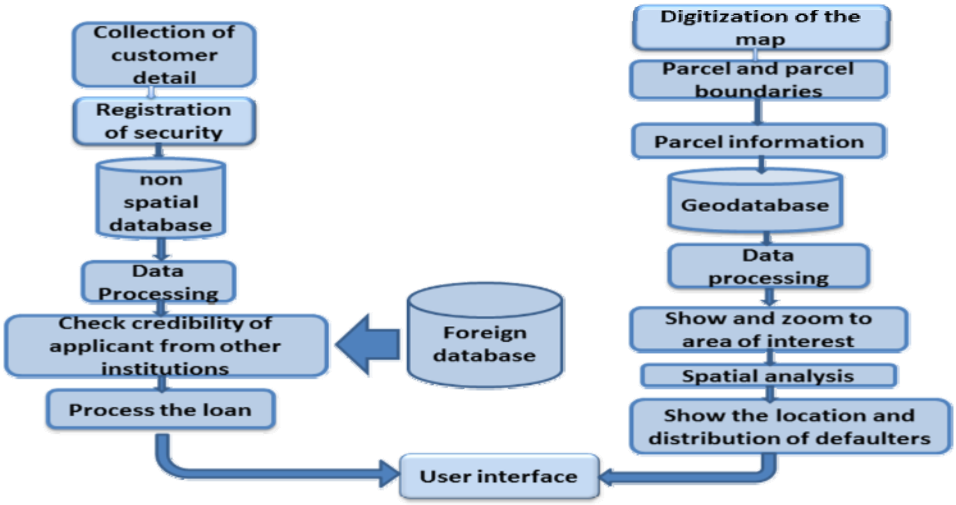

Figure 2 Methodology flowchart

Figure 2 show the steps taken to realise the solution developed in this work.

3.1 System design

An analysis of the existing system was made and the following are the main details that the bank collects: full names, gender, date of birth, marital status, nationality, postal address, plot number, number of dependents.

The above information is collected on a form and the details are filed pending approval and later fed into a digital database with all the details of the customer. Before approval a search is carried out to ascertain the legality of the title holder and find out is the land is charged by another institution.

The following shortcomings of the current mode of operation were identified: (a) it is a tedious process and time consuming for a search to be conducted, (b) there is no immediate confirmation to the legality of the parcel ownership (establishing if the customer is who he/she says he/she is), (c) there is no way the bank can know the credibility of the customer from other institutions and (d) no spatial queries can be made to ascertain the authenticity of the plot (its location in space)

3.2 Collection of data

The cadastral data used was provided by Survey of Kenya and it included Thika parcels and roads as well streets. The parcel data contained information such as the owner, postal address and price of the parcel.

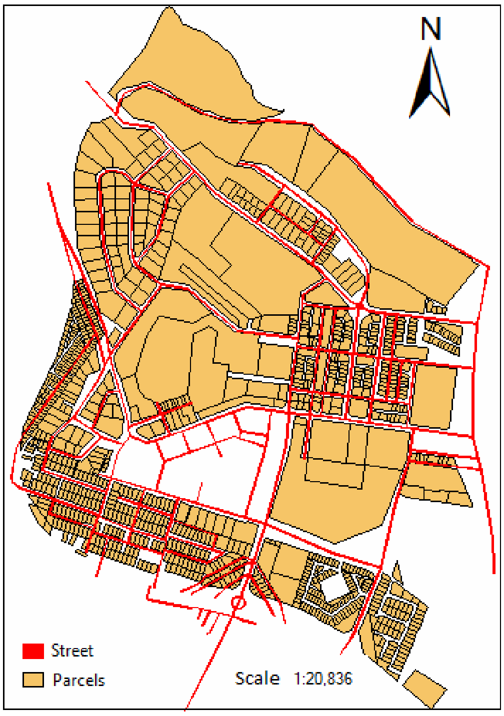

Figure 3 Topo-cadastral data

Figure 3 shows these topo-cadastral data digitized from the topo-cadastral sheets. These data were in UTM coordinate system zone 36 and arc 1960 reference ellipsoid.

All the non-spatial entities required for the system were stored in a MySQL database, with spatial entities stored in a separate Environmental Systems Research Institute (ESRI) geodatabase. The non-spatial database in MySQLwas used to store the account information such as applicants' names, loan information such as amount of loan applied for, the location of a clients assets. The spatial database can be used to show the security location of the loan applicant, zoom to it and show the distribution of the parcels of interest to the bank and flag defaulters.

The tables which were identified and created are:

Employees: - This table contains information on the list of authorised operators of the system including the administrators of the system.

Customers:-This table contains a list of all customers that have applied for a loan using land and business premises as collateral.

Security:-This table contains a list of all the security collateral owned by loan applicants.

4 Results and analysis

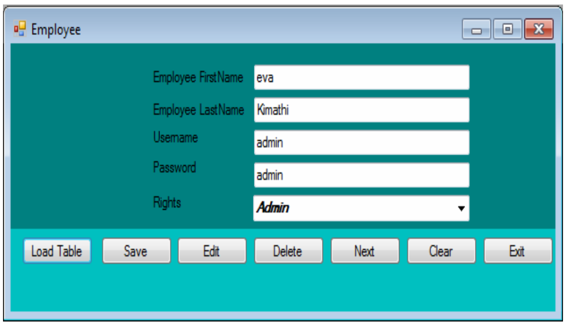

Figure 4 User assignment form only accessible by the administrator

To enhance security a safe login system was created giving users access according to their clearance level and the highest of the clearance level being an administrator. To log in the user has to supply the correct login credentials. The administrator has the ultimate rights in relation to the system. He has access to all the functions offered by the system Figure 4 shows the interface used by the administrator in case modifying users' information is required.

Figure 5 shows the interface to retrieve customer information. These include textual information and images from the owner and the parcel. The system has the ability of querying an external database such as a database shared by other financial institutions flagging defaulters and delivering a message either passing of failing the applicants.

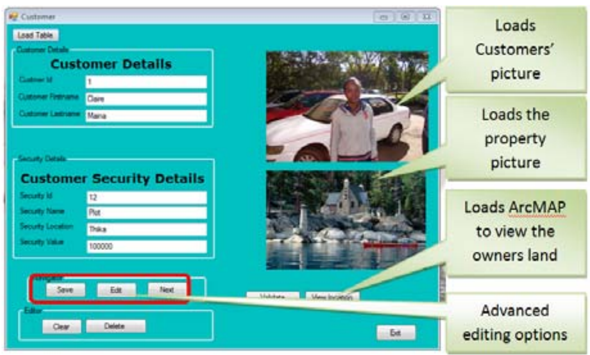

Figure 5 Customer details

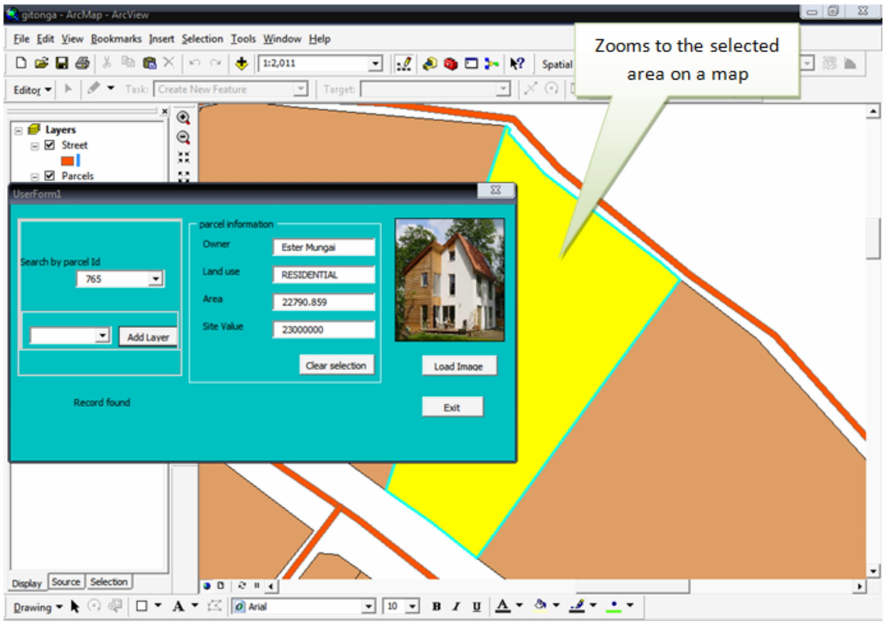

Figure 6 Connection of customer information with the spatial parcel information

Figure 6 shows the connection between non spatial customer information with the spatial information about the parcels. Through this connection, it is therefore possible to identify properties that may already be charged (there are un-cleared loans for which it was used as collateral). The system provides a graphical representation of all loan securities showing their spatial location, distribution and the value attached to the property, showing the location of the assets and their access to roads. It can also provide reports on all customers servicing loans, location and value of the property used as collateral and generally can be used to view all parcel of interest to the bank

5 Conclusion

A system has been developed which allows saving, editing and loading customers of a bank with user restrictions which can be used in order to flag customers and users who may be involved in fraudulent allocation of loan facilities. This system has the capability of viewing the client as well as the security offered by the client in a pictorial representation for better identification. It also has the capability of creating and viewing reports which could be used to support decision making and may inform such strategies to increase market penetration.

This solution addresses the objectives of the research and it is recommended that it be considered for adoption by the Cooperative Bank of Kenya for all its branches as it has been demonstrated as being capable of reducing data entry errors, greatly minimizing opportunities for fraudulent transactions and also ensures speedy and efficient processing of loan applications and appraisal of property values.

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Workshops

Because the main business of government - to make decisions in the public interest - involves geographically related issues, Geographic Information Systems (GIS) provide incomparable power that can play critical roles in all dimensions of good governance.

Peter Kuntu-Mensah, Accra, Ghana, 2006

Workshop on Quantum GIS

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ABSTRACT

Quantum GIS (QGIS, http://www.qgis.org/) is the most popular open source desktop GIS software which is driven by a very active community of developers, documenters, translators and users. QGIS is developed in C++ and distributed under GPL open source license which allows users to freely distribute and modify the features of the software. QGIS can handle almost all the vector and raster data formats including the spatial databases like PostgreSQL, SpatiaLite etc. Additional functionalities to QGIS are offered by plugins which is developed in Python programming language. There are hundreds of plugins available for QGIS free to all downloadable from different repositories. Some of the interesting plugins are:

- *fTools: Vector geo processing*
- *GDAL tools: Raster processing*
- *OGR converter: Conversion between different data formats*
- *Open layers plugin: Adding Different API's like Google Maps , Yahoo Maps*
- *OGR2Layers: converting from a OGR format layer to OpenLayers page –creating a simple webGIS based on OpenLayers.*
- *WFS layer: support according to OGC WFS specification*
- *PostGIS manger: extract data from PostGIS with SQL queries*
- *Open street map plugin: Download and upload data to OSM*
- *Mapserver export: exporting an OGR layer to map file to be used in UMN mapserver.*

In this workshop we will be focusing on some of the exotic plugins and functionalities of QuantumGIS giving an emphasis to accessing different webservices like OSM, OGC services, spatial databases, SLD creation and creating a simple openlayers page with controls etc.

From GPS-geodata collection to Web based visualization

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KEYWORDS:
GPS, WMS, Web Mapping

ABSTRACT

The GPS-space segment is currently in a renewing process, the first generation satellites will be replaced until 2012 with remodeled satellites providing advanced technical features and an increased reliability in terms of the on board clocks. This will increase the geo-location accuracy for all GPS signal users. The ground segment, e.g. handheld receivers, public navigation tools and professional surveying equipment benefits from newly designed GPS-receiving chips. An important public and scientific task is the mapping of objects in a scale range according to the typical GPS accuracy, which is usually about +- 5m. Openstreetmap data collection and medium scale geodata mapping (~ 1:10.000) for land use land cover documentation and as a digital planning source, are typical applications. Using the new GPS chips, a more accurate and an increased reliability of the GPS signal can be achieved. SirfStar III (http://www.csr.com/products/27/sirfstariii-gsc3elpx-gsc3flpx), a 20 channel, low cost chip has been introduced in 2006 and lead to a push especially for the sector of public handheld receivers. Recently presented multi-channel chips now offer the ability to receive the GPS signal with 50+ bands. With more satellite signals available for the calculation of the geo-position, the precise determination of the actual position is possible. A dense forest canopy layer or urban canyons for example affect the GPS signal negatively.

In this workshop several brand new, low cost GPS receivers will be introduced, ranging from blue tooth GPS mice in combination with smartphones (Android; Windows Mobile OS) to classical handheld receivers (Garmin). Those are all low cost developments and have been proofed intensely for field geo-data collection. Within this workshop we will perform a field campaign, collecting our own geodata in the Kenyatta University surroundings. Later we will transfer the geodata and we will store it in an internet-based geo-db. Finally the geodata will be prepared with a special set of programs for the presentation as an OGC conform Web Map Service with appropriate symbolization.

Above Ground Biomass Estimation, based on Remote Sensing Methods for CDM and REDD

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KEYWORDS:
REDD, tropical deforestation, land use change, greenhouse gas emissions, Forest Degradation, CDM

ABSTRACT

The UNFCCC Conference in Bali in 2007 established the political framework for the policy process "Reducing emissions from deforestation and degradation in developing countries" (REDD). Participating parties confirmed the urgent need to take further action to reduce emissions from deforestation and forest degradation and adopted a work program for further methodological work. That program focuses on assessments of changes in forest cover and associated greenhouse gas emissions, methods to demonstrate reductions of emissions from deforestation and the estimation of the amount of emission reductions from deforestation. REDD itself is considered to be an important component of a future climate change regime beyond 2012, in terms of mitigation and adaptation. In this way, REDD can be seen as a tool not just for mitigating climate change, but also for conserving biodiversity and a range of ecosystem services of global and local interest.

The objective of the proposed workshop is to get familiar with remote sensing based methods, which are suitable to assess and monitor deforestation and forest degradation and correlate it with biomass measurements on the ground. The method proposed in this workshop, delivers statistics and maps on forest area, forest area changes, biomass, carbon stock and their respective changes on multi-temporal basis applying optical data such as Landsat-7 ETM+, SPOT or others. Results generated by this method can serve as a basis for the baseline assessment required by REDD. The proposed workshop will include a brief introduction of LCCS (Land Cover Classification System), developed by the FAO as an appropriate classification scheme for REDD. Alternative remote sensing approaches of direct biomass assessment for REDD by applying Synthetic Aperture Radar (SAR) should be discussed in this context as well.

Python in three hours

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Stuttgart University of Applied Sciences

ABSTRACT

The use of Python as a programming language is increasing rapidly. With the release of ESRI's latest ArcGIS version (ArcGIS 10), customizing with VB.NET is gradually giving way to Python. The present add-on option for VB will end with this release; it will not be available in ArcGIS 11. But there is no need to worry; Python offers a perfect replacement with added advantage! It is not only stable and independent from the operating system used, it is also a dynamic and flexible programming language. Additionally, Python can be used for web-programming, programming of Graphical User Interfaces as well as for complex programming and geoprocessing tasks.

How useful this relatively new programming language can be, shall be demonstrated using different examples; one of them being customizing ArcGIS.

Note: A basic understanding of programming is assumed. If any special help is required, this can be given in a general lecture in the morning

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Using Web Services in Desktop-GIS - Requirements for Replacing Local Data

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ABSTRACT

Sandards are necessary for using geodetic data interoperably in heterogeneous environments. Such standards are developed and published by the Open Geospatial Consortium (OGC), e.g. Web Map service (WMS) and Web Feature Service (WFS). These standards are integrated in existing GIS software. In commercial software the standards are add ons and competing with the industries own developments. In open source products, they are used in general for accessing and sharing data.

Spatial data infrastructures (SDI) are in development in many countries and regions. Their definitions are widely based on standards of ISO (International Standardization Organization) and OGC as key definitions for data interoperability. Examples are the European INSPRE directive (Infrastructure for Spatial Information in the European Community) and the Spatial Data Infrastructure Germany (GDI-DE) which cramps spatial data infrastructures of states and local administrations. The author is member of the committee for the SDI of the German state Baden-Württemberg (GDI-BW).

Working with web services shows that all the standards are necessary but not sufficient for efficient daily use. Problems still occur when data from various vendors has to be integrated into existing workflows or combined for individual purposes. This is especially the case when web services are used in desktop GIS.

The workshop will show how easy WMS and WFS can be set up and integrated in desktop GIS, but this is not its main focus. The main focus will be set on additional needs for controlling data access and data harmonization. These two factors can not be covered by general standards. They have to be worked out within a community of data providers and users.

Introduction to ILWIS

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KEYWORDS:
IWIS, GIS, Spatial Modeling

ABSTRACT

ILWIS stands for "Integrated Land and Water Information System" which is a free open source GIS software .This one is the world's most user-friendly integrated software with raster processing capabilities to work on remotely sensed satellite images as well as vector data processing capabilities for making vector maps. There are also numerous spatial modeling abilities of this software. It's fully integrated raster and vector approach with user-friendliness that makes it particularly suitable for GIS Professionals,Urban Planners, Natural Resources Managers, Field Scientists, Biologists, Ecologists, and so on.

The workshop will be a session of 2/3 hours accompanied by lectures and exercises. The successful participants would be acquainted with basic tools and techniques of geo-processing through hands on training with this powerful software.

Key Features of the Software:

1. *Free open source software available for downloading by anyone*
2. *Vector and Raster data processing are integrated into one package with very rich documentation and tutorial data*
3. *Some of the greatest selections of import and export modules of widely used data formats*
4. *Comprehensive set of image processing tools*
5. *Advanced modeling and spatial data analysis*
6. *3D visualization with interactive editing for optimal view findings*
7. *Rich projection and coordinate system library*
8. *Geo-statistical analyses, with Kriging for improved interpolation.*

Strategic process management for introducing GIS

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Strategic Planning, Management, GIS introduction, System evaluation, Cost-Benefit-Analysis

ABSTRACT

In this workshop a concrete path for the introduction of Geographical Information Systems (GIS) in public agencies or private companies will be intrduced.

The whole process consists of ten different phases, starting with the initalization and ending with the productive usage of the system. Aspects of the strategic planning of the institution are presented, as well as requirement analysis, and conceptual database modelling and conceptualization of the IT infrastructure. Based on these findings information products are described and assigned to specific organisational units. In a cost-benefit-analysis different categories of benefits which can be accrued by introducing GIS are taken into account. A methodology of assessing monetary benefits for all information products is presented.

By a call for tender the system introduction is announced to possible vendors. Further steps like evaluation of submitted offers and testing of offered systems prepare the final decision.

By data import and usage of interoperable services the GIS starts its operational use.

References

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Poster

We believe that the central challenge we face today is to ensure that globalization becomes a positive force for all the world's people.

United Nations Millennium Declaration, 2000

Yield Estimation by Using GPS and Sensor Technology

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KEYWORDS:
Precision Farming, GPS, GIS, SMS, Sensor Technologies

ABSTRACT

or many years variations in yield is estimated within management units of farming operations and this variation has caused in losses in both farm profits and efficiencies. These variations in yield happen due to variations in drainage, slope, fertility, water supply, acidity, and soil type. Since this occur within a block of 1000fd, it is impossible to adjust management and farming practices with these variations using traditional farming systems.

However with the recent development of the technology of Global Positioning System (GPS), Geographic Information System (GIS) and Sensor Technology (ST), farming practices can be adjusted within a management block and thus even show the variations in yield.

Further to these one can also record yields per square meter, and with the use of GIS systems, maps for each land that indicates yield problem areas can be obtained. A simple soil and leaf analysis in problem areas can solve the yield problems and within a short period the block can be yielding evenly.

The objective of this study was to define the precision farming application in Sudan as a new economically current technology for farm management.

Multi-criteria suitability modelling for geothermal exploration well siting: a case study of the Silali geothermal prospect, northern Kenya Rift

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KEYWORDS:
Multi-criteria suitability modeling, weighted linear combination, Boolean integration model, Environmental suitability analysis

ABSTRACT

Models are used in many different ways, from simulations of how the world works, to evaluations of planning scenarios, to the creation of indicators of suitability or vulnerability. In geothermal resource exploration, GIS based Multi criteria suitability modeling was applied in the Silali geothermal prospect and it involved assigning weights to locations relative to each other based on given geo-scientific criteria to find favorable locations for siting exploration wells in the prospect. Geothermal well site selection is a spatial problem which involves the evaluation of data samples collected over a prospect area by different geo-scientific teams which include Geophysicist, Geochemists, Geologists, Reservoir Engineers, Environmentalists and GIS Analysts using varied spatial sampling methods and techniques. This multi-disciplinary approach of geothermal exploration therefore necessitates for multi criteria analysis. Weighted linear combination (WLC) model and Boolean integration modes were utilized towards eventual suitability modeling in GIS. This approach has produced posteriori maps identifying favorable areas for drilling exploration wells. The results of the weighted linear combination analysis and the Boolean integration model were combined with those of an environmental suitability analysis for final selection of well sites.

Geospatially-based Flood Risk Vulnerability Mapping: A Case Study of Budalangi plains, Lower River Nzoia Basin in Western Kenya

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KEYWORDS:
Flood risk vulnerability mapping

ABSTRACT

This research was aimed at estimating flood inundated areas and population and settlements vulnerable to floods under different levels of water flow depth in river Nzoia, western Kenya. To achieve the aims of the research, two applications were used; Arg Gis 9.3 and Geographic Information System Flood tool (GFT Flood Tools)-an hydrologic model attachable to Arc Gis 9.3. Data used included; flow volume data, mass points data and Population and Housing Census data 2009. The Digital Elevation Model (DEM) was first generated from mass point data collected by Lidar. The DEM was then used to generate; hydrologic properties of the area study area. Using the GFT flood Tools, the hydro-properties and DEM were used to evaluate the river cross sections and stage discharge curves for 3 points along the channel. With input of known flow volume data at a known point along the channel (Rwambwa)- the discharge impact was evaluated and the inundation areas for four different water levels scenarios above the bankful level of up to 7 meters level (1, 3, 5 and 7 meters intervals) were generated.. The final raster layers for inundated areas were overlaid with Census data. The final output was area inundated and the number of persons and settlements vulnerable under the four different water depth levels.