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COMMUNITY PARTICIPATION IN THE REHABILITATION OF A SAND DUNE ENVIRONMENT IN KENYA

G. A. OLUKOYE[1]* AND J. I. KINYAMARIO[2]

[1]*Department of Environmental Sciences, Kenyatta University, PO Box 43844-00100, Nairobi, Kenya*
[2]*School of Biological Sciences, University of Nairobi, PO Box 30197-00100, Nairobi, Kenya*

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ABSTRACT

This study aims to document various community efforts in land rehabilitation and assess their potential. Data were captured using interviews and focus group with 150 community members. A public participation index was used to establish the extent of community efforts in land rehabilitation. The study revealed that in the absence of proper management and dune stabilisation, large areas covered with mobile sand dunes continue to be a threat to grazing lands in northern Kenya. In recognition of this threat, the people of North Horr have launched several initiatives to contain the problem. Environmental and non-environmental group members scored participation rates (PP) of 87·5 and 50%, respectively. These include tree planting on both communal and individual plots and the management of *Suaeda monoica* through natural regeneration. Although the survival rates of most planted trees on group plots were low, *Azadirachta indica* that were planted on individual homesteads appeared to be performing comparatively well. Natural regeneration of indigenous plant species such as *Suaeda monoica* has the potential to perform important economic and ecological functions. The study concludes that in order to effectively arrest the process of desertification on the pastoral drylands of northern Kenya and to restore productivity and biodiversity, it is important to take actions that incorporate both biophysical and human considerations. Linking sociology to ecology is thus paramount in any sustainable dune stabilisation (SDS) programme. Copyright © 2009 John Wiley & Sons, Ltd.

KEY WORDS: community participation; pastoral system; land rehabilitation; sand dune; Kenya

INTRODUCTION

Drylands are fragile ecosystems with unique features and resources. Most of these ecosystems transcend national boundaries and are therefore, regional in scope (UN, 1993). These ecosystems are, however, the most affected by desertification. Desertification defined as the degradation of land in arid, semi-arid and sub-humid environments through climatic variations and anthropogenic factors (UNEP, 1994) is a central problem in sustainable development of dryland ecosystems. Desertification affects about one sixth of the world's population, 70% of all drylands, amounting to 3·6 billion hectares and one third of the total land area of the world (UN, 1993). In Africa, past studies estimate that 75% of drylands are affected by desertification and land degradation of a moderate to high degree (Darkoh, 1994), while over 80% of Kenya's land is affected by the process (UND, 2002). Desertification results from the degradation of the dry lands production systems as a result of interactions between the human communities and their environments (Ibrahim, 1993). The process is characterised by a decrease in land productivity and biodiversity (Schlesinger *et al*., 1996; Ayoub, 1998). A sustainable response to desertification can be found in production systems that allow for a symbiosis of man and nature, guaranteeing the survival of both, not as separate entities, but as one integrated system (Ibrahim, 1993). The converse of land degradation is the process by which the biological and economic potential is conserved and/or improved, called sustainable resource management.

* Correspondence to: G. A. Olukoye, Department of Environmental Sciences, Kenyatta University, PO Box 43844-00100, Nairobi, Kenya.
E-mail: godfreyolukoye@yahoo.com

Desertification of land resources endangers basic production systems as well as natural ecosystems (Ayoub, 1998; Akuja *et al*., 2001; Okoti *et al*., 2006). In areas prone to desertification and drought, current resource-use systems are unable to maintain human livelihoods. Besides, effects of drought and increase in demographic pressures have threatened the traditional livelihood systems based on pastoralism (UN, 1993). Desertification, therefore, exacerbates poverty, which in turn exacerbates desertification because as the pressure increases, the inhabitants are forced to intensify over-utilisation of their land just to survive (Darkoh, 1993). Thus, the human impact of desertification is far greater on the inhabitants of arid and semi-arid areas who depend on land for their livelihoods. A major challenge today is to effectively arrest this process and restore productivity and biodiversity. This must be accompanied by actions to rehabilitate and improve the agropastoral and pastoral systems for sustainable management of drylands. To address these challenges, we need to understand the basic characteristics of semi-arid and arid landscape and the various interacting factors in desertification.

One important aspect of the desertification debate is the interaction between pastoralism and overgrazing. Pastoral economies and their impact on land have been re-evaluated in the light of changing assumptions and foci of different studies. In the 1970s, for example, pastoral economies were seen as viable, healthy and environmentally sound. In the literature of 1980s on the other hand, issues such as drought, destitution and failure of pastoral economies dominated (McCabe, 1994). Niamir-Fuller and Turner (1999), for instance, concluded that the scale and magnitude of persistent environmental decline in dryland Africa and the role of livestock grazing in this decline had been overestimated. The authors noted that the appearance of land degradation caused by human impact is much more severe around permanent settlements than in open rangelands. More recent perspectives acknowledge that pastoral economies may after all not be responsible for land degradation and desertification (Oba *et al*., 2000b). Thus, there seem to be conflicting perspectives on the relationship between pastoral economies and land degradation and hence desertification.

In Kenya, the rate at which land degradation is occurring, the relationships between the various forms of land use and degradation hazards and the losses of productivity are not well characterised. This lack of precise information is felt most in the arid and semi-arid regions of Kenya where land is marginal for crop production and soil erosion has an immediate impact on human life. The absence of quantitative data necessary for predicting land degradation and detecting critical management alternatives, and the failure to genuinely involve local communities has curtailed the development of conservation practices applicable to Kenyan semi-desert conditions. This has also prevented objective evaluation and adaptation of models and experiences developed elsewhere. This dynamism appears to have hindered the rehabilitation of degraded land. North Horr, a semi-desert region of northern Kenya, is an area typical of drylands subject to pastoral land use and susceptible to degradation. This paper reports on interventions, associated issues and socio-ecological lessons learnt after involving local communities in efforts to rehabilitate the sand dune environment of North Horr in northern Kenya. An evaluation of this community's experience may be instructive for similar initiatives throughout rural regions of sub-Saharan Africa.

THE PROBLEM OF SAND DUNE ENCROACHMENT IN KENYA'S NORTH HORR REGION

North Horr is a classic example of how interactions between climatic and anthropogenic pressures can lead to land degradation. Decreased precipitation, lack of natural and cultivated vegetation cover, coupled with anthropogenic pressures resulting from sedentarisation have resulted in a dramatic increase in wind erosion on these pastoral lands. The geomorphic response to the increased aeolian activity associated with recent droughts in the area has been the development of plant-caused hillocks, referred to as *nebkha* dunes. These dunes have distinctive vegetation types, notably *Suaeda monoica*, *Hyphaena coriacea*, *Euphorbia cuneata*, *Sporobolus spicatus* and *Indigofera spinosa*. These form a perimeter around North Horr town settlement.

These once stable dunes have been reactivated, since 1992 when strong winds started to transport an increasing amount of sand in the dry season, which was in turn trapped by different vegetation types to form **nebkhas**. During the rainy season, sand is transported further by water. The resultant sand encroachment in the middle of North Horr settlement has created several problems which in extreme cases, has led to the burying of houses and roads (see Figure 1). The sand encroachment is also a potential health hazard and chronic annoyance to the residents.

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Figure 1. Currently mobile sand dune in North Horr settlement (foreground). This figure is available in colour online at www.interscience.wiley.com/journal/ldr

Sand has also covered existing seed banks of dwarf shrubs and grasses. This, coupled with the recurrent droughts has adversely affected the natural processes of regeneration of plant species, severely crippling their life pattern, reversing the natural successional trends and ultimately degrading vegetation substantially.

The indigenous plant community has, therefore, deteriorated and failed to maintain natural vegetation distribution and richness. Vegetation degradation contributes to human impoverishment as well. With less productive land, fewer livestock can be raised. This is exacerbated in cases where pastoral livestock production, a rational response to the existing harsh conditions, fails to function optimally due to the altered conditions and steady land degradation.

In summary, North Horr contains large areas that are covered with mobile sand dunes, often the result of erosion processes. This material may be deposited or moved to new locations along the path of the blowing wind. In the absence of proper management and stabilisation, these dunes pose a continued threat to the grazing lands of the area. Indeed, mobile sand has been shown to have a severe impact on dry season grazing (Omar and Abdal, 1994). Sand covers the dwarf shrubs and grasses, thus reducing grazing resources. Furthermore, **nebkha** dunes have been described as indicators of wind erosion and land degradation (Ibrahim, 1993; Tengberg, 1995) and consequently as indicators of ecological degradation.

MATERIALS AND METHODS

The Study Area

North Horr settlement is situated in North Horr Division of Marsabit District at the north–western edge of the Chalbi Desert in northern Kenya (Figure 2). The area borders Ethiopia to the North. It covers an area of 18 401 km^2. According to the 1999 Kenya Government household and demographic survey, the Division had 6090 households and a population of 23 576 persons; 930 of the households were located in North Horr settlement.

Physical and biological factors

Climate. Most of North Horr is classified as semi-arid, falling in agro-ecological zone VI (Jätzold, 1991). The climate is characterised by high input of solar radiation through generally clear skies, high radiative heat losses at night, low precipitation, high evapotranspiration and prolonged water deficits. It receives an annual mean rainfall of 157 mm with a median of 200 mm (Schwartz *et al*., 1991) characterised by a high spatial and temporal variability (Figure 3). Drought occurs in 4 out of 10 years.

Soils. Soils in the study area are sandy loams, saline and sodic, calcareous, shallow to moderately deep and pale brown. The parent material is sand mixed with some volcanic ash. The soils are classified as Cambic Arenosols

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Figure 2. Location of North Horr in Kenya.

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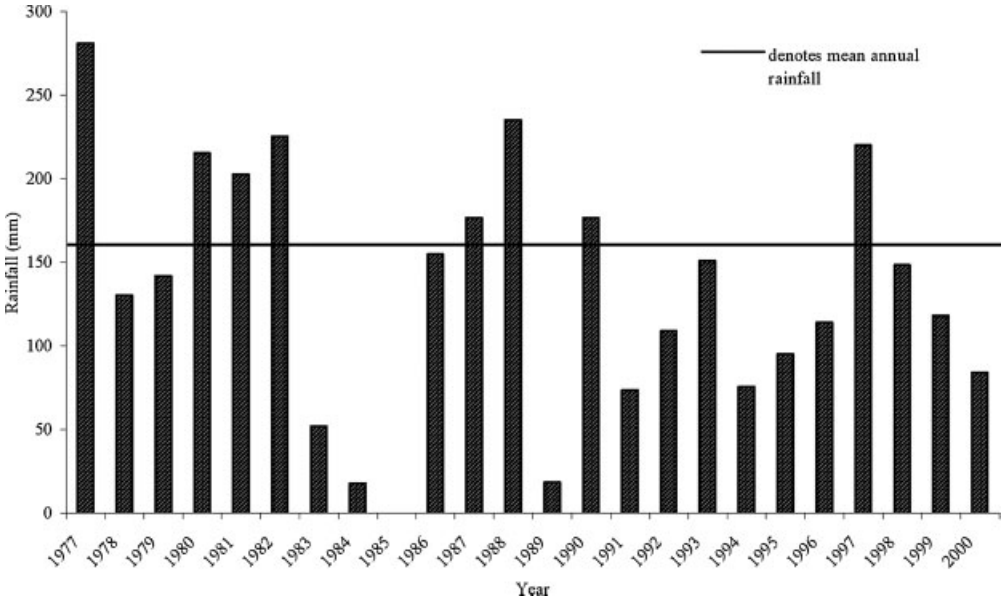

Figure 3. Total annual rainfall distribution in North Horr between 1977 and 2000.

(Aridosols and Solonchaks). These have low organic carbon content with less than 1% in the top 15 cm of soil (Olukoye *et al*., 2003). Infiltration capacity of the surface soil has been described as moderate (Touber, 1991). The interdunal flats have an imperfectly drained, very deep, friable to firm, strongly calcareous, strongly saline, strongly sodic, sandy clay loam to clay soil. The land's undulating relief gives rise to erosion hazards. The coarse texture limits water availability due to increased infiltration capacity, which in turn limits the growth of perennial vegetation. The high sodicity also limits potential vegetation production.

Vegetation. According to the older residents of North Horr, the vegetation three decades ago was characterised by a relatively dense bushland. On the topographic maps 1:250 000 of 1963 (compiled in 1960), the area of North Horr is described as 'open bushland'. By 1991, the physiognomic types in North Horr were classified as 50% barren land with dwarf shrub/annual grassland, 30% bush land to grassland on saline soils, 10% riparine woodland and 10% deciduous shrub land (Schwartz *et al*., 1991).

Presently, large areas are completely bare and covered with desert pavement (*serir* desert type), underlain by fine to middle sand, an indicator of exposure to strong wind erosion. Dune fields of **nebkha** type surround the North Horr settlement. Hummocks with mostly *Suaeda monoica*, a salty shrub palatable to camels, *Euphorbia cuneata*, *Indogofera spinosa*, *Heliotropium species* and *Sporobolus spicatus* form a perimeter around the settlement. There are also scattered trees, mainly *Acacia tortilis*, *Boscia* spp, *Balanites orbicularis* and *Salvadora persica*. Groups of *Hyphaena coriacea* (doum palms) are found growing in areas of high ground water table around the springs near the settlement.

Land use. The main land use in the North Horr region is nomadic livestock production. The Gabra, who are the main inhabitants of North Horr, predominantly keep camels on this harsh, arid land. They also keep cattle, sheep and goats. The Gabra live with their herds and flocks, moving in search of fresh pastures whenever necessary (Tablino, 1999).

Trade in livestock and livestock products is the predominant economic activity in the area. The commercial animal trade is dominated by goats and sheep and to a small extent, includes cattle. The main livestock marketing channels are through producers (pastoralists), butcheries and live sales. During the dry season, most animals are in

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foora—grazing outside North Horr town. Traders, therefore, spend a lot of time looking for the animals to buy at this time.

Methodology

Data were collected using participatory methodologies, mainly interviews and focus group discussions (FGD) with representative community members. The ages of the sample population ranged between 17 and 94 years. Age distribution of the respondents was as follows: 15–34 years constituted 47·3%, 35–54 years were 36·7%, 55–74 years were 10·7% while 75–94 years constituted 5·3%. Hence the average respondent age was 40 years. Guidelines were used in most of the interviews while a semi-structured questionnaire, with questions targeted towards assessing the level of people's participation in project activities, was used to gather information on community efforts in environmental rehabilitation and natural resource management. The household head was the main respondent while the household was taken as the sampling unit. A sample of 150 respondents was randomly identified with size per cluster being dependent on the cluster population. Stratified random sampling was used with the main strata being Environment Management Committee (EMC) members ($n = 7$), Mazingira and the Catholic women's groups ($n = 13$ and 20, respectively), Catholic youth group ($n = 20$) and non-environmental group members ($n = 90$). These were used to provide in-depth understanding and analysis of the socio-ecological issues involved in rehabilitating the sand dune environment. The main thrust of the analysis considered the level of participation in dune stabilisation measures as well as activities involving restoration of biodiversity, best bet options, empowering of local communities, initiating a process for participation of vulnerable groups and establishing a permanent dialogue framework among the community.

To analyse people's participation in environmental rehabilitation, various answers by respondents to a set of questions were assigned numerical values of 1, 0·5 and 0. The sum of weights was 100 and the scale thus assumed values ranging from 0 to 100. Using this method, a score for each sample respondent was computed and all the scores were then added and divided by the number of sample respondents to get the average participation rate (PP) in any activity. The mean PP when expressed in percentage terms was the People's Participation Index (PPI), defined as:

$$P = \frac{P_i}{N},$$

where P is PPI, P_i is the participation score of the ith individual defined as $P_i = W_{ij}\, X_j$ where W_{ij} is the weight assigned to the jth factor (question asked of the ith beneficiary) with the condition that the sum of weights is equal to 100 and N is the number of respondents (Frankfort-Nachmias and Nachmias, 1996).

The parameters/indicators used to construct the PPI were based on project activities and included: involvement in tree planting especially at the individual and group level, knowledge of training being done within the settlement and responsible persons, attendance in training sessions, knowledge of groups participating in natural resource management and other related activities.

RESULTS AND DISCUSSION

Participation Levels in Environmental Rehabilitation

In recognition of the adverse impacts of sand encroachment, the people of North Horr set up several initiatives to contain the problem. For instance, parents of Ruso Primary School organised themselves into groups that scooped sand from the engulfed buildings every saturday. The community through 'food-for-work' programmes also participated in the removal of sand from the roads to improve accessibility. Three environmental groups in North Horr are actively involved in tree planting activities to minimise the effects of sand encroachment on the settlement. These are the Catholic Womens Group, Mazingira Womens Group and the Environmental Management Committee. The Catholic Youth Group is a recent formation that is involved in a variety of general environmental programmes, except tree planting.

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Other environmental improvement activities of the community include tree planting at personal and group level, afforestation on a food-for-work basis, nursery establishment and awareness creation. The involvement of the community in land rehabilitation activities is an indication of its recognition of the value of natural resources, the problems of environmental degradation, especially sand dune encroachment, and their willingness in helping in the resolution.

The PPI aims to quantify the impact of various constructive anthropogenic factors affecting environmental rehabilitation, reflecting the extent of community participation. The people of North Horr participate in environmental rehabilitation activities at different levels. Results from the survey showed that environmental and non-environmental group members scored PP of 87·5 and 50%, respectively. Respondents' reports indicate that 73·3 and 26·7% of environmental and non-environmental group members, respectively, had *always* done something to improve the status of the environment. On the other hand, 20 and 61·1% of environmental and non-environmental group members reported *sometimes* doing something to improve the status of their environment.

Evaluating the Environmental Outcome of Community Efforts in Sand Dune Stabilisation in North Horr

The suitability of various indigenous and exotic tree and shrub species used in these rehabilitation programmes has not been comprehensively evaluated. Most of these community initiatives appear to only provide short-term remedies to the problem of sand encroachment. Through the FGD, it was apparent that the community has not tackled the root cause of the problem, primarily due to a lack of understanding of the exact mechanism of sand movement.

Further, the levels of tree and shrub performance in terms of growth rates have important implications for sand dune stabilisation with respect to the efforts of the three North Horr environmental management groups involved in tree and shrub planting. These groups have mainly planted *Hyphaene coriacea*, *Euphorbia cuneata*, *Commiphora africana*, *Suaeda monoica* and *Acacia goetzei*. *Azadirachta indica* and *Cocos nucifera* were introduced through the efforts of GTZ/ITFSP and GTZ/MDP. The trees were selected and planted due to their anticipated economic value. However, tree survival rates and their management strategies are of great relevance in sand dune stabilisation. Although the survival rates of most planted trees on group plots have been shown to be low (Olukoye *et al.*, 2003), *Azadirachta indica* that were planted on individual homesteads appeared to be performing comparatively well.

Thus, in North Horr town, growing trees on individual homesteads should be encouraged as this could afford better management of the trees and, hence, increase survival rates. Besides, the importance of indigenous vegetation for the rehabilitation of the degraded North Horr environment in general and sand dune stabilisation in particular has been demonstrated (Olukoye *et al*., 2003). The primary problem with indigenous plant species is their low growth rates (Sinha, 1997; Olukoye *et al.*, 2003) that discourage groups involved in tree planting activities. It should also be appreciated that there are difficulties in establishing trees in arid areas under communal land use. To successfully rehabilitate saline soils and stabilise the sand dunes in North Horr, greater emphasis should be placed on the use of indigenous tree and shrub species.

There is, therefore, a need to put in place an appropriate, systematic management programme for the indigenous vegetation regeneration and establishment. For instance, in the eastern periphery of North Horr, *Suaeda monoica* in combination with *Atriplex* spp is the main dune stabiliser (Figure 4) where it is used extensively for wood-fuel. *Suaeda monoica* is also an important dry season grazing reserve for the camels and therefore important for camel milk production. The socio-economic importance of *Suaeda monoica* might, therefore, jeopardise its ecological function of dune fixation in the long-term.

The Role of Vegetation Type and Pastoral Impacts: Towards Sustainability

It is often argued that pastoral rangelands are overstocked and that anthropogenic pastoral activities constitute a major contributory factor in vegetation degradation (Breman and de Wit, 1983; Sinclair and Fryxell, 1985; Niamir-Fuller, 1995). Sand encroachment in the present case requires re-examination in light of emerging perspectives on interactions among climate, plants and herbivory (Oba *et al*., 2000c). Impoverishment of vegetation and the selective elimination of soil fauna and the larger fauna, which live on the vegetation, affect the whole quality of the environment as well as land (Blaike and Brookfield, 1987). These changes, however, also have to be evaluated in

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Figure 4. Old **nebkha** dunes formed under Suaeda monoica (popular browse for camels) in the eastern part of North Horr settlement. This figure is available in colour online at www.interscience.wiley.com/journal/ldr

social terms, for instance, reductions in livestock yields and useful vegetation. For example, vegetation in North Horr performs both economic and ecological functions of providing fodder for livestock and in stabilising sand dunes.

Ultimately, it is critical to define the objectives of restoration activities when attempting to stabilise sand dune systems. The definition of sustainable sand dune stabilisation adopted in the present case is modified from Agenda 21(UN, 1993): thus, a system that aims at the conservation of biological diversity of the dune ecosystem through sustainable use of its components and ensures fair and equitable sharing of the benefits arising out of the utilisation of these components. Sustainable use in this case refers to the use of components of the dune ecosystem in a way and rate that does not lead to their long-term decline thereby maintaining their potential to meet the needs and aspirations of present and future generations. This definition takes cognisance of the fact that there is a close linkage between poverty and land degradation (Baas and Rouse, 1997; UNEP, 2004; Narain *et al*., 2005). Thus, sustainable **nebkha**-dune stabilisation can be realised only with adequate measures to eliminate or reduce poverty levels. Implied in this definition is the need, in the case of North Horr, to improve productivity of different components of the pastoral production system.

Sand encroachment is associated with vegetation degradation (Khalaf *et al*., 1995; Palmer and van Rooyen, 1998; Hesp and McLachlan, 2000), which is in turn associated with both abiotic and biotic factors. Thus, an understanding of the soil conditions, geomorphological factors and processes and the maintenance of a stable dune–vegetation equilibrium is essential in ensuring sustainable **nebkha**-dune stabilisation. Rather than the vegetation simply acting as an obstacle, a sustainable strategy needs to make it an integral part of the dune, growing as the sediments accumulate (Thomas and Dougil, 2001). Besides, the dune vegetation has to serve both the ecological and economic functions of dune stabilisation and livestock browsing, respectively, in a balanced fashion as illustrated in Figure 5.

Linking Ecology to Sociology in Sand Dune Stabilisation Measures

The starting point towards dune stabilisation is sustainable utilisation of the **nebkha**-dune vegetation resource. Sustainable dune stabilisation (SDS) in North Horr must incorporate appropriate pastoral livestock husbandry and vegetation management. Accordingly, SDS is locality and land use specific, and should rely on specific management options introduced by the local land users to ensure its success. For instance, in North Horr, this would be initiated through management interventions that address pastoral livestock grazing/browsing, recapitalisation of vegetation, provision of alternative sources of livelihood and participation of the local community.

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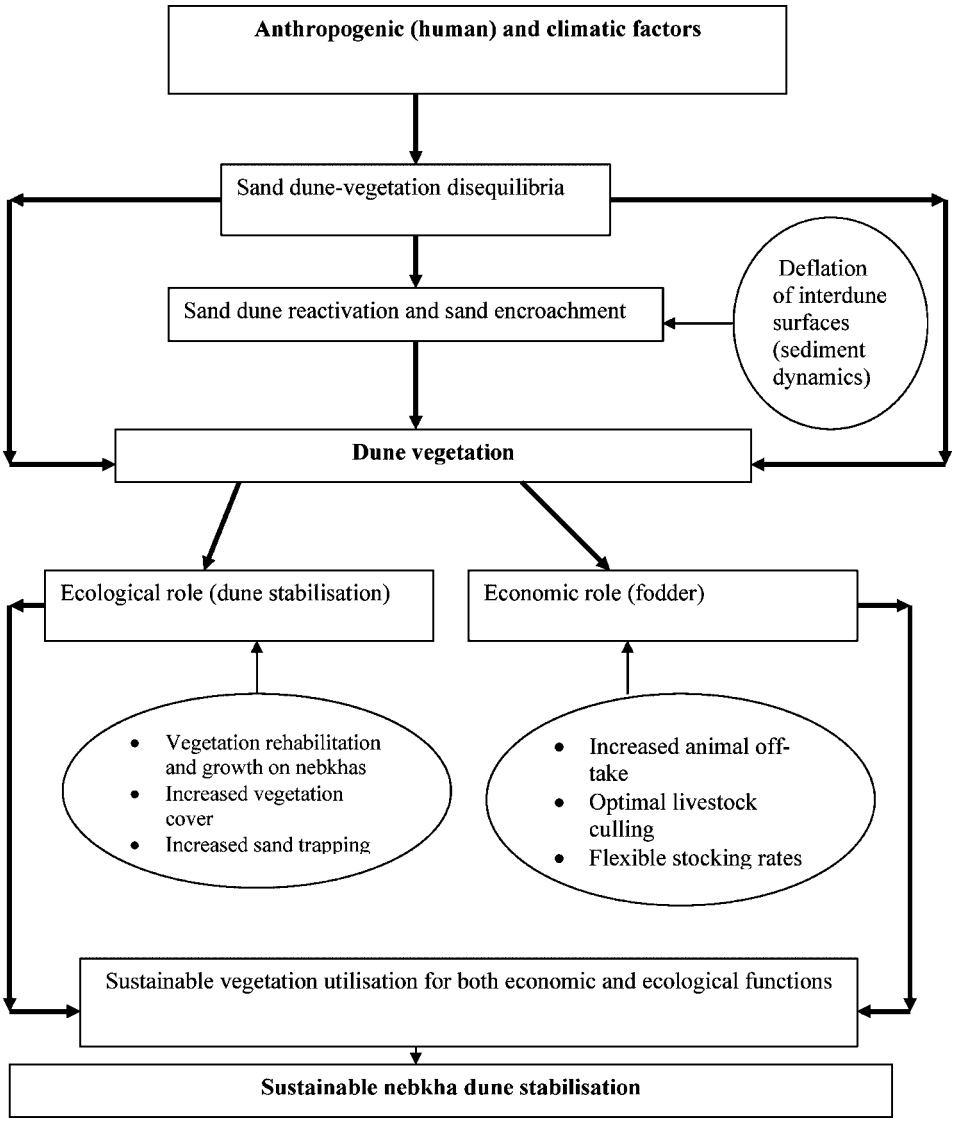

Figure 5. A conceptualised model for sustainable **nebkha**-dune stabilisation in North Horr, Kenya.

Most biological and physical efforts to combat desertification, especially in Africa have failed (Ibrahim, 1993): '*...desertification continues to spread and intensify despite efforts undertaken during fourteen years of implementing the Plan of Action to Combat Desertification...The inevitable conclusion is that the efforts were too modest and grossly inadequate to be effective. There is no evidence that the situation has improved appreciably any where in the world...*' (Dregne *et al.*, 1991).

UNEP (1992) concluded that the problem of land degradation in arid and semi-arid lands had intensified and new approaches were needed and stated that 'Success in combating desertification will require an improved understanding of its causes and impact'.

Ibrahim (1993) described the measures taken against desertification in the Sudan and showed how futile the strategies were because they did not build on the existing indigenous knowledge for coping with drought and desertification. As had been observed by Critchley *et al.* (1994), many projects had ignored local traditions and

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knowledge to their detriment. More recently, Stringer and Reed (2007) reported a significant overlap in local and scientific knowledge bases in most instances when assessing land degradation in southern Africa. This clearly underscores the importance of integrating both the biophysical and human aspects in any dune stabilisation programme.

By working with the local North Horr community through selected biophysical measures for dune stabilisation, this work attempted to correct this scenario to enable the formulation of a sustainable **nebkha**-dune stabilisation programme. Indigenous or local pastoralists' knowledge about production systems has often been overlooked despite the fact that indigenous people are often partners in the conservation and management of land and biodiversity whether for nature reserves or the improvement of crops and livestock yield (Lee and Zhang, 2004). Indeed it has been shown that local knowledge systems, traditions, institutions and environmental conditions are fundamental to biodiversity conservation and management (Okoti *et al*., 2006). Involving the community in assessing the condition of their own resources will not only help them to own the initiatives of biodiversity conservation but also increase awareness on the various issues that affect biodiversity. This approach commonly known as community based natural resources management (CBNRM) is aimed at empowering the community to take the lead role in sustainable utilisation and conservation of their resources.

CBNRM has become an important strategy to conserve and sustainably use land resources in Africa. It is argued that the solution to the problem of resource degradation in developing countries depends not only on appropriate technologies and efficient market prices, but also on local institutions, an effective approach to resource management and the existence of organisations to enforce them (Rasmussen and Meinzen-Dick, 1995; Ballard and Plateau, 1996). Community resource management institutions and organisations are now receiving greater attention as a viable alternative to regulation by the state or privatisation as a means of rectifying inefficiencies caused by attenuated property right systems and externalities. However, devolving rights to local communities to help build institutions for common property management may not be a sufficient condition for sustainable use of such resources. Effectiveness in internal governance is needed for the effective application of community rules (Turner *et al*., 1994; Swallow and Bromley, 1995).

Assessing Specific Strategies for Sand Dune Stabilisation

Institutional and normative capacity building alone appears to be insufficient. There is a need to understand the ecological processes and possible management strategies in desertified shrub lands. To meet the challenge of improving the efficient use of natural resources for sustainable sand dune stabilisation, an ecological perspective must be incorporated into land management decisions. An ecological basis for sound land management for the rehabilitation of moderately to severely desertified rangelands for productive utilisation and sustained productivity for pastoral development is necessary. This would, in addition, strengthen the ability of both local and national institutions to monitor ecological change and incorporate results of such studies into desertification and land degradation assessment practices. Besides, this information would help decision makers and change agents, for example community based organisations involved in rangeland development, to make rational and informed policy decisions.

Among the Gabra of North Horr, the dominant production system is camel nomadism (Simpkin, 1995; Tablino, 1999) that is dependent on shrubs like *Suaeda monoica* and *Indigofera spinosa*. Thus, strengthening the pastoral production system presents the most sustainable option from both a socio-economic and ecological perspective in North Horr (Keya, 1998). Policy measures that ensure socio-economic and ecological viability of pastoral production systems must be predicted on an understanding of the multiple functions of the existing environmental resources. Failure to recognise the ecological implications of policy measures can lead to unintended consequences (McPeak, 1999).

In the present case, the North Horr, sand dune vegetation is an important component in the Gabra livestock production system. For instance, *Suaeda monoica* is important in the pastoral economy, yet it is one of the least understood plants (Barrow, personal communication). Studies on *Suaeda monoica* are virtually non-existent. The few studies have mainly focused on *Indigofera spinosa*, another camel fodder (Oba *et al*., 2000a, b). Thus, an understanding of the links between the pastoral livestock production system and the sand dune vegetation would

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ensure a balance in these dual functions of vegetation through sustainable utilisation and thus ensure dune stabilisation. This would in turn contribute to a better analysis and understanding of the biophysical aspects of ecosystem rehabilitation on degraded lands.

In the present context, it is well to consider the potential of fencing and natural regeneration for dune stabilisation in the North Horr region. Results from previous long-term fencing trials in Kargi and Korr of Marsabit District, Kenya, demonstrate the natural potential of vegetation to recover given temporary protection (Lusigi, 1984). From these trials, it was concluded that natural regeneration might be more cost effective than tree planting or reseeding, although manipulation of the soil to improve soil water may be necessary. Thus, fencing and enclosures that encourage natural regeneration of vegetation could play a very important role in dune stabilisation. However, the viability of fencing for large-scale land rehabilitation in a nomadic pastoral production system is questionable: fencing interferes with the animal movement, and therefore, there is a need to develop other management strategies to ensure the natural regeneration of important dune stabilising plants such as *Suaeda monoica*.

The management of *Suaeda monoica* through natural regeneration could, therefore, be significant in ensuring that it performs both the economic and ecological functions. Natural regeneration is easier, cheaper and quicker (Misak and Draz, 1997). To this end, the North Horr EMC emphasises the rotation of camel **bomas** (night enclosures). A sub-committee of the EMC was, therefore, formed to popularise this strategy among the larger North Horr community. This management strategy is based on the fact that camels aid in natural regeneration of *Suaeda monoica* through their dung (Father Richard, personal communication). Its seeds are scarified by the camel's digestive system as they pass through the dung hence enabling a wider dispersal and faster regeneration.

Just as with Sahelian vegetation, *Suaeda monoica* appears to be very resilient to natural and pastoral stresses because of the strong dynamism of its seed production, dispersion and germination cycle (Hiernaux, 1992). This option is compatible with the land use system and appears to be the most viable and sustainable for dune stabilisation in North Horr. Natural vegetation colonises and grows preferentially on the dunes and in some cases may completely cover and stabilise the dunes if precipitation levels are sufficiently high (Nickling and Wolfe, 1994). Management of natural *Suaeda monoica* regeneration may, however, be more effective if it is based on empirical information on the impacts of camel herbivory on browse production and growth of young *Suaeda monoica* seedlings. This management strategy should also encompass other areas neighbouring North Horr. This is because what goes on in these surrounding areas impacts on the environmental resources in the North Horr settlement.

CONCLUSION

To effectively arrest the process of desertification in the pastoral drylands of North Horr and to restore productivity and biodiversity, it is important to take actions that incorporate both biophysical and socio-economic considerations. This would rehabilitate and improve the pastoral systems for sustainable management of these drylands. The management of *Suaeda monoica* through natural regeneration, that takes advantage of the symbiotic association between the plant and camels, should be promoted on a continuous basis by the local environmental management committee through the rotation of camel *bomas* (night enclosures). A blend of modern science and indigenous technical knowledge is required to face the challenges of managing the environment on a sustainable basis in the dry lands. It is also important to ensure that the relevant local communities are given management responsibility for the natural areas upon which their continued prosperity depends. Linking sociology to ecology is thus paramount in any SDS programme.

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