LAND TREATMENT EFFECTS ON MORPHOMETRIC CHARACTERS OF THREE GRASS SPECIES AND ECONOMIC RETURNS FROM RESEEDING IN KITUI DISTRICT, KENYA

BY

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DECLARATION AND APPROVAL

Declaration

I, Omondi Francis E. Opiyo, hereby declare that the work contained in this thesis is my original work and has never been submitted for a degree in any other University.

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Approval

This thesis has been submitted with our approval as University supervisors.

Signed---------------------------------------Date 17th MAY 2007..............................

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DEDICATION

This thesis is dedicated to
my parents
who raised and educated me under difficult conditions.

LIST OF ABBREVIATIONS AND SYMBOLS

^0C	-Degree Celsius
ACZ	-Agro-Climatic Zone
AM	-Annual Mean
ANOVA	-Analysis of Variance
ASAL	-Arid and Semi Arid Lands
C/B	-Cost Benefit ratio
cm	-Centimetre(s)
DHP	-Dryland Husbandry Project
DM	-Dry Matter
GoK	-Government of Kenya
Ha	-hectares
ICRISAT	-International Crops Research Institute for the Semi-arid Tropics
IRR	-Internal Rate of Return
Kg	-Kilogramme (s)
Km	-Kilometre(s)
Ksh	-Kenya Shillings
LSD	-Least Significance Difference
m	-meter (s)
MM	-Monthly Mean
NPV	-Net Present Value
OM	-Organic Matter
RBD	-Randomised Block Design
SD	-Standard Deviation
SE	-Standard Error
SPSS	-Statistical Package for Social Science
TLU	-Tropical Livestock Unit
USA	-United State of America

ABSTRACT

This study was conducted to determine the effects of tractor-ploughing and hand-clearing as land treatment methods on morphometric characters and aboveground biomass production of *Eragrostis superba*, *Cenchrus ciliaris* and *Enterepogon macrostachyus*. The study also evaluated the returns from range reseeding in eastern Kenyan rangelands of Kitui district.

Seed viability was tested under laboratory conditions following standard procedures using petri dishes over a period of 17 days. On-farm field trials involved broadcasting seeds of the grass species in two land treatments; namely, tractor-ploughing and hand-clearing. Each of the grass seeds were broadcasted randomly in six sub-plots (6 m x 6 m) in both treatments at a density of 100 grams m^{-2}. Thirty-five plants were randomly selected per sub-plot and tagged for sampling. Measurements of morphometric characters were taken weekly, whereas aboveground biomass was estimated by harvesting standing grasses in the sub-plots after three months of establishment. Data for economic analyses were generated from the costs of physical inputs used and costs incurred at the time reseeding was done.

After 17 days of laboratory observation, *C. ciliaris* had the highest percent germination of 28.4%, whereas *E. macrostachyus* and *E. superba* had percent germination of 20.1% and 8.6% respectively. These differences were attributed to the intrinsic properties of the grass seeds such as dormancy and tegumental hardness. To ensure successful reseeding in these ecosystems, it is necessary to determine that grass seeds are viable for rehabilitation. Results obtained showed that land treatment had a significant ($p<0.05$) effect on morphometric characters of grass species. Seedling mortality was found to be significantly higher in the hand-cleared than in the tractor-ploughed plots. In the tractor-ploughed plots, *C. ciliaris* (10.5%), *E. macrostachyus* (15.4%) and *E. superba* (24.8%) demonstrated lower percent seedling mortality than those in the hand-cleared plots. Percent mortality was relatively higher (*C. ciliaris* (20.5%), *E. macrostachyus* (18.2%) and *E. superba* (32.4%) in the hand-cleared plots than in the tractor-ploughed plots. Similarly, foliage cover, plant height, leaf and tiller numbers in the tractor-ploughed plots were significantly higher ($p<0.05$) than those in the hand-cleared plots. This scenario was

attributed to the opening-up of the soil surface, which might have increased capture of scarce rainfall water by the soil in the tractor-ploughed plots than in the hand-cleared plots. Aboveground biomass was also significantly higher ($p<0.05$) in the tractor-ploughed than in the hand-cleared plots at the milky stage of grass development. This ranged from; 3,682.5 kg ha^{-1} to 4,908.5 kg ha^{-1} DM, 2,734.0 kg ha^{-1} to 3,240.0 kg ha^{-1} DM and 1,899.5 kg ha^{-1} 2,434.5 to kg ha^{-1} DM for *E. macrostachyus*, *C. ciliaris* and *E. superba*, respectively, in hand-cleared and tractor-ploughed plots. Higher aboveground biomass in the opened-up plots than in the hard soil surface plots was also attributed to increased capture of scarce water by the soil. Of the three grass species tested, *E. macrostachyus* presented the best results for ecological rehabilitation for the area while *C. ciliaris* and *E. superba* were the medium and least suitable grasses, respectively.

An economic analysis demonstrated that investing in range reseeding using the two land treatment methods are both economically viable ventures. Computations based on the internal rate of return and benefit-cost ratio derived from the hypothetical sale of hay revealed that a net annual profit of about 15.4% and 26.4% could be obtained from the hand-cleared and tractor-ploughed investment respectively. This study also demonstrates that reseeding a similar area using these treatment methods can yield a benefit-cost ratio that is greater than one. Furthermore, *E. macrostachyus*, *C. ciliaris* and *E. superba* are all economically feasible species for reseeding in the eastern rangelands of Kenya. It is however recommended that, a study covering more than two seasons be carried out, as this would yield more information on the establishment of pastures under the two land treatment methods. Other potential species such as *Digitaria macroblephara*, *Cynodon dactylon*, *Chloris roxburghiana* and *Themeda triandra* should also be studied under different land treatment methods so as to increase knowledge on how to capture the scarce water by the soil which may be used to boost forage production and halt degradation in the rangelands.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The arid and semi-arid lands (ASALs) cover approximately 88% of Kenya's landmass, and support over 30% of Kenya's total human population, over 50% of cattle, 70% of sheep and goats and nearly 100% of camels and wild angulates (Hansen *et al.*, 1986; GoK, 2001). The ASALs of Kenya have undergone increasing land use pressure within the last 15 years, largely due to various factors that have caused a decline in forage resources and threatened the sustainability of land-based production systems (Jacobs and Coppock, 1999; Mnene *et al.*, 2000; Kitalyi *et al.*, 2002).

In the past, livestock production in Kenya's ASALs was sustainable due to low livestock and human populations, and was based on various forms of pastoralism as the main source of livelihood (Lesorogol, 1991; Mbogoh and Shaabani, 1999). However, over the years, land use systems have changed resulting in increased sedentarization and land subdivision, thereby impinging on pasture lands (Pagiola, 1994; Darkoh, 1996; Ego and Kibet, 2003). This encroachment into the grazing areas by cultivation and settlement has led to shrinking of pastoral production resource base, as pastoralists are increasingly confined to less productive ASALs (Wangoi, 1984; Keya, 1997; Ellis *et al.*, 1999; Alemu *et al.*, 2000). Similarly, effects of drought, termites, inappropriate cultivation and overgrazing have resulted in diminished or total loss of the population of some important forage species, especially grasses (Coppock 1994; Mbogoh and Shaabani, 1999; Mnene *et al.*, 2005).

Options for improving pasture cover and quantity where graminoid and non-graminoid plant species have disappeared have been limited to destocking, bush management, pitting and intermittent grazing (Pratt and Gwynne, 1977; Heady and Heady, 1982; Njenga, 1992; Musimba, 1998; Musyoka, 1999; Mnene *et al.*, 2000). However, Jordan (1957) and Bogdan and Pratt (1967) made some of the early re-seeding attempts as a means of rehabilitating degraded natural pasture with some encouraging success. Recently, the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) also carried out re-seeding trials in Makueni, Kajiado districts (Mnene and Mbakaya, 1997; Mnene *et al.*, 2000; Ego and Kibet, 2003). In all the four grasses used in the trials, it was suggested that for *Chloris roxburghiana*, *Eragrostis superba*, *Cenchrus ciliaris* and *Enteropogon macrostachyus* to establish, better knowledge of how these species should be applied under limiting and unstable environmental factors is a valuable information for range managers in their effort to improve forage production and halt degradation in the rangeland.

A review of ecological work undertaken in Kenya's grazing ecosystems by Owaga (1980), Gachimbi (1995), Keya (1997), Makokha *et al.* (1999), Ekaya *et al.* (2001), and Kitalyi *et al.* (2002) on the performance of indigenous African rangeland grasses shows that much work has been done. However, little has been done on how to improve the establishment success of grasses in arid and semi-arid areas (Njenga, 1992, Too, 1995; M'Seddi *et al.*, 2003). The knowledge on how to increase capture of scarce water by the soil and in turn meet germination, emergence and growth requirements of species is crucial. Further, economic benefits from range reseeding investments should also be evaluated before funds are expended (Godfrey and Sellassie, 1979; Workman, 1981; Ego and Kibet, 2003; Mnene, 2005). Therefore, there is need to intensify scientific research in the arid and semi-arid areas to make a contribution to this subject as well as provide data of more general relevance, as an important input to devising successful rehabilitation methods for possible up-scaling and adoption by communities.

It is thus of paramount importance to carry out on-farm evaluation of the effects of tractor-ploughing and hand-clearing as land treatment methods on pastures, particularly on the important range grasses such as *Eragrostis superba* Peyr, *Cenchrus ciliaris* L. and *Enteropogon macrostachyus* (Hochst. ex A. Rich.) Monro ex Benth. which have the potential to rehabilitate degraded grazing lands in Kenya (Pratt and Gwynne, 1977). In addition, an economic analysis of land treatment methods is important in determining whether to invest in a reseeding project or not.

1.1.1 Objectives

The specific objectives of the study were to:

1. Determine the effect of land treatment on seedling mortality, foliage cover, tillering and leaf production of *Enteropogon macrostachyus*, *Cenchrus ciliaris* and *Eragrostis superba*.
2. Evaluate the effect of land treatment on the biomass production of the three perennial grasses.
3. Determine the economic returns of range reseeding investment using tractor-ploughing and hand-clearing.

1.1.2 Hypotheses

The following hypotheses were tested:

a) Land treatment has no effect on morphometric characters and aboveground biomass production of *Enteropogon macrostachyus*, *Cenchrus ciliaris* and *Eragrostis superba*.

b) The use of tractor-ploughing and hand-clearing are not economically viable methods of land treatment for range reseeding.

CHAPTER TWO

LITERATURE REVIEW

2.1 RANGE RESEEDING

Rangeland climates are characterised by large spatial and temporal variations in rainfall. The moisture conditions suitable for active plant growth are usually short-lived, unpredictable and in many instances unreliable (Jordan, 1983; De Groot *et al.*, 1992; Keya, 1997). Opportunities for plant growth are therefore limited by a short rainy season, normally lasting few days. Even within-season rainfall distribution is often irregular, with long dry spells between rainy seasons. Frequent droughts are also a common feature of this environment. There is need to maximise the use of these spells of favourable plant growth. Thus only plants that can establish quickly to maturity have a good chance of surviving to the next generation. Therefore, plant establishment may be achieved through the use of land treatments that offer the best growth, survival and establishment within the moisture limit (Coyne and Bradford, 1985; Rosenschein *et al.*, 1999).

The primary purpose of reseeding is to improve existing ground cover and biomass to an extent or in a manner not possible by grazing management alone (Pratt and Gwynne, 1977; Makokha *et al.*, 1999). This can be accomplished by; 1) over-sowing into existing vegetation with a superior species: 2) establishing a completely new pasture, with or without the aid of irrigation, and 3) reseeding denuded land. The ecological stresses in these rangelands are so acute that ecosystem recovery through the process of natural secondary succession, even if provided in full protection, is likely to be very low. To accelerate the forage recovery process would require some external input such as reseeding of native grass species. However, abandoned areas where grazing and cultivation occurred can experience secondary succession so long as conditions are right. The original vegetation may re-establish if protected from further disturbances (Keya, 1997). Study undertaken else where shows that light grazing or no grazing of an area with less palatable perennial and annual grass promoted recovery of desirable grass species but did not lead to recruitment because of persistence of large bare patches. Over the years a number of techniques have been developed for rangeland rehabilitation; some of the options are pitting and re-seeding or over sowing (Pratt and Knight, 1964; Bogdan and Pratt, 1967). Range seeding involves reseeding of denudated land by the seeds of superior plants, or the establishment of completely new pastures, with or without the aid of irrigation (Bodgan and Pratt, 1967). Determining whether a range site can be restored by natural means or requires revegatation is a matter of judgement (Lusigi *et al.*, 1986). The decision is usually based on the kinds and amount of plants remaining, the expected rate of recovery, the cost of alternative approaches, climate, supplementary treatments that may be required to accelerate natural restoration and the suitability of the site to the present seeding techniques (Keya, 1998). These rangelands rehabilitation methods have been tried in many parts of Kenya rangelands. It was observed that the chance of establishment depend much on site conditions, soil type and rainfall amount (Jordan, 1957; Njenga, 1992; Gachimbi, 1995).

Plant establishment is a function of many factors, some of which are genotypic in origin while others are environmental in nature (Herriot, 1958, Sarukhan *et al.*, 1984). The manipulation of genetic factors takes a longer time to produce a plant that has the best establishment within the confines of climate Plant environment manipulations on the other hand are relatively easy and are the most widely employed in plant establishment. Of the environmental variables, the soil is the most widely manipulated. The soil condition dictates the ease of variability of moisture and nutrients to the growing plant. Rangelands reseeding in most cases require soil disturbances. This help in replenishing deficient plant species or introducing new ones by allowing seed penetration to the ground through provision of conditions suitable for germination, emergence and subsequent establishment of the species (Singh, 1987). Any reseeding operations, however carefully planned, can fail if insufficient rain falls at the right time. Nevertheless, proper appraisal of the situation and the correct choice of grasses and methods go a long way towards ensuring success (Bogdan and Pratt, 1967). From the many attempts that have been made in Kenya to restore grass cover by means of seeding, it has been learned that the fundamental requirements of success are: -

a) An appreciation of the ecological potential of the area concerned.
b) Grasses suitable for reseeding purposes and sufficient seed of adequate quality.
c) The integration of the seeding operation into an overall land-management policy, embracing grazing control and bush control where necessary.
d) Some form of seedbed preparation and a degree of seed protection in keeping with site requirements.
e) A period of complete rest from grazing after reseeding.
f) Reasonable rains during the establishment season.

It must be emphasised that failure in any one of these requirements can prove fatal, and every effort must be made to meet them all. Rainfall is beyond control, but species and techniques may nevertheless be so chosen that slightly below average rainfall will ensure success. Apart from soils and rainfall, other factors including human interventions (burning, cultivation and grazing) and individual species physiological differences affect germination and subsequent growth.

2.2 EFFECTS OF LAND TREATMENT

In arid and semi-arid regions where water is scarce, plant establishment can only succeed only if the seedlings have access and contact with the supply of water during the growing seasons (Bogdan, 1958; Kitalyi *et al.*, 2002). These areas do not provide enough year-round distribution of precipitation to sustain the amount of water resources that will meet the primary productivity of most plants. Studies show that land treatments may increase the capture of scarce water by soil, and meet the germination, emergence and growth requirements of the species. Adams and Danckwerts (1993) reported that *Themeda triandra* seeds planted in burnt and tilled treatments perform differently in their morphological characteristics. According to their findings tillage not only produced most recruits at the end of the growing season, but had plants with greater numbers of tuft masses than on other land treatment. Proper site preparation is critical to the success of any planting. Further, existing information show that grasses differs markedly in their reaction to treatments such as cultivation, burning and seed dressing (Njenga, 1992).

Various land treatments have been evaluated over the years on their effectiveness in increasing capture of the scarce water by the soils and providing optimum grass growth conditions (Bogdan, 1977; Boonman, 1993). Jordan (1957) observed the importance of land treatment in establishment of grass species in Kitui district. Scratch ploughing on contour, in Kitui produced satisfactory grass establishments with respect to the seeds and biomass production from the species sown. A study by

Ruyle *et al.* (1998) compared seasonally burned and unburned as land treatments. Their work showed that burning was effective in increasing the germination of seeds, otherwise unburned treatments offered the worst result. On the other hand, cultivation has also shown to stimulate volunteer grasses and herbaceous plants. This confirmed earlier study by Cox *et al.* (1986), which observed the highest number of volunteer grasses on cultivated plots. Similarly, King *et al.* (1989) found the highest density of annual grasses on the tilled seedbed.

Further studies suggest that ox-ploughing treatments are better than burning for plant performance and establishments (Njenga, 1992). However, Ruyle *et al.* (1998) working with Lehmann lovegrass (*Eragrostis lehmanniana* Nees) found out that burning increases germination of this grass seed reserves, although burning did not improve establishment in absence of cultivation; this is in agreement with the findings of Owen and Bryzostowski (1967) and Marieta and Britton (1989). Musyoka (1999) records that there are a number of factors that influence or suppress germination and performance in range grasses, any land treatment, mechanical or otherwise which remove the stem apex destroy apical dominance and stimulate tillering or branching unless the level of cutting is below the auxiliary buds. Tiller is defined as a unit of vegetation that develops from specific auxiliary of basal bud prior to development of any roots from the node (Ries *et al.* 1991). However, promotion or inhibition of tillering vary from one grass species to another, largely dependent on defoliation severity, grass phonological stage when defoliation is imposed and other associated environmental factors such as land manipulations (Gardner *et al.*, 1985). Seedbeds that received a soil treatment were found to have a high grass population than those that receive none (Njenga, 1992). Humphreys

(1959) obtained similar results while working on *Cenchrus ciliaris*. In South Africa, Adams and Danckwerts (1993) reported that tilling had a significant effect on grass response compared to the non-tillage treatment, and that to re-establish *T. triandra* in degenerate swards in the area; some form of destruction of competition from the existing vegetation is essential. Owen and Bryzostowski (1967) also obtained similar results in central Tanzania. Conversely, Taylor *et al.* (1969) reported that the intensity of tillage has an effect on plant size. There was an increase in plant size with the intensity of tillage n Alfalfa and clover. This was probably due to better water penetration, aeration, mineralization and even exclusion of competing weeds with increase in cultivation. Establishment, however, depended more on species and to a less extent on the seedbed preparation method. On crusting soils, Karl *et al* (1982) observed that ploughing did increase seedling emergence, but tended to enhance seedling establishments. Lavin *et al* (1973) showed that ploughing excluded most competing weeds with the highest emergence and survival being recorded on ploughed plots. Further work revealed that seedbed preparation resulted in a large variation in the emergence of sown grasses. High survival rates were observed on cultivated treatments. Survival was found to be a function of the degree of competition at the seedling stage. Competition was a function of the intensity of cultivation and subsequent weather conditions. Similar results were obtained by Frischknecht (1983) who pointed out that weed control was important in grass establishment. Range grass plants react to unfavourable growth conditions by either varying growth rate or by dying if are unable to survive the stress. Their response to these stresses varies with plant species, metabolic activity, morphology and yield potential (Gardner *et al.*, 1985).

Rehabilitation of land therefore needs to be disturbed for successful grass establishment. Burning with no other disturbance failed to produce good establishment (Thomas *et al.*, 1983). Cultivation has also been shown to stimulate volunteer grasses and herbaceous plants. Highest number of volunteer grasses and highest density of annual grasses were on the tilled treatments (Cox *et al.*, 1986; King *et al.*, 1989). Too (1995), while over-sowing with perennial native grasses in order to increase primary productivity of different range sites at Kiboko had to scratch the soil surface so as to incorporate the seeds properly. The study showed positive results of reseeding and this has been demonstrated in other studies elsewhere (Mott *et al.*, 1976; Cook and Dolby, 1981). Breaking the hard soil surface allows better water infiltration and thus leads to a better seedbed for the seed, both for the naturally existing in the soil and the introduced ones (McIvoir and Gardener, 1981).

2.3 RANGE GRASSES FOR RESEEDING

Within the tropics, rainfall is the major hydrological input to soil moisture, its quality and availability to growing plants determine geographical distribution of plants species (Jones, 1988; Herlocker, 1999). Range grasses have evolved adaptive mechanisms of survival. Bogdan (1958) recommended that local grasses should always be used for reseeding in preference to introduced, exotic species. Based on this recommendation, several grass species have been tried for reseeding grazing lands in Kenya (e.g. *Eragrostis superba, Eragrostis trichodes, Eragrostis bicolour, Cenchrus ciliaris, Enteropogon macrostachyus, Chloris roxburghiana, Chloris gayana, Chloris virgata, Cymbopogon caesius, Dactyloctenium aegyptium, Panicum coloratum, Sorghum sudanensis* and *Sporobolus pryramidalis*). Only local species have proven to be the most successful (De Groot *et al.*, 1992; M'Seddi *et al.*, 2003). The suitability of these grass species depends on their life span (i.e. whether they are annuals or perennials) and according to their habit of growth. Whilst annual grasses last only one year or wet season and die when seed is formed, perennials have the ability to survive dry seasons and regenerate with each rain to produce fresh growth from the original rootstock. Although perennials may produce seed every season, they live for a few to several years. The diverse growth habits that occur are rhizomatous creepers, stoloniferous creepers and tufted or bunch grasses. In most grassland types, tufted species form the dominant component of the climax community (Bogdan, 1958).

Tolerance to grazing and drought and the stability to establish fast during spells of favourable climatic conditions are very important traits in choosing grass species for reseeding (Jordan, 1957; Njenga, 1992). Presently, utilization of East African rangelands by livestock and wildlife is confined almost entirely to natural vegetation where shrubs such as *Acacia* species are the major source of browse rich in protein during the dry periods of the year, while perennial grasses such as *Eragrostis superba* (Peyr) *Cenchrus ciliaris* (L.) and *Enteropogon macrostachyus* (Hochst and A Rich) Munro ex Benth. provide forage to grazing animals. It must be appreciated that the chemical composition of grasses is very dependent on environmental conditions (Bogdan, 1958, Bogdan and Pratt, 1967). In addition to the local effect of soil and season, there is a broad climatic influence that affects dry-season value.

The choice of grass for reseeding should be based on the following: it must be sufficiently drought tolerant to survive, perpetuate itself, and provide a good quantity of herbage of fair or good grazing value. It should also produce an adequate amount of viable seed, which can be easily harvested, and easy to establish (Farah, 1982; Musyoka, 1999). Local grass species have been used with good results in range reseeding in Kenya and other East African countries. Some examples of these species are discussed below.

2.3.1 *Eragrostis superba* Peyr.

This is a tufted perennial 20-120 cm high (family *Eragrostideae*) with narrow leafy herbage and wide spread in the semi arid areas of East Africa, particularly in eco-climatic zone VI where mean annual rainfall is about 500-900 mm. It is common in bush grassland, sandy and rocky grounds (Bogdan, 1958). Its distribution is perhaps restricted to the African savannah although other species of the same family occur widely in the tropics.

The grass is palatable when young but with age it becomes very stemmy. At early flowering stage, a crude protein content of 12% has been reported on dry matter basis (Bogdan and Pratt, 1967). Commonly referred, as Maasai love grass, it has spikelets flatly compressed from the sides, purple-tinted, 5-9 mm wide. It is of high grazing value in the dry areas. The grass has been used successfully for reseeding denuded lands (Bogdan, 1958). It has also been extensively used for reseeding denuded pastoral land in Kenya (Jordan, 1957; Narper, 1965; Pratt and Gwynne, 1977). This grass species has a high shoot/root ratio (Taerum, 1977) which is a disadvantage during drought periods but is advantaged by having deep root which go as far down as 2.2 m with 73% of the roots limited to the upper 0.4 m from the soil surface, which enable the grass to make full use of light showers of rain. Njenga (1992) reported highest yield of *Eragrostis superba* (Peyr), when reseeded on various land preparation methods compared to *Cenchrus ciliaris* (L.) and

Enteropogon macrostachyus (Hochst. ex A. Rich) Monro ex Benth. It is a moderate tiller and its regrowth ability is poor when compared to *Cenchrus ciliaris* (L) and *Chloris roxburghiana* (Schult) (Woie, 1984). Seeds of this species are in the form of a small, plump grain, which are particularly susceptible to insect damage.

2.3.2 *Cenchrus ciliaris* L.

Cenchrus ciliaris is a perennial grass belonging to the C_4 photosynthesis type (Bogdan, 1977; Heady and Heady, 1982). The grass is native to tropical and subtropical Africa (Bogdan, 1977), with a height of 20 – 110 cm, forming tufts; some forms produce short stout rhizomes grasslands in rocky places. The grass species exhibits drought resistance and tolerance due to its strong and deep rooting system. The species is well adapted to the hotter regions and enjoys wide distribution over the drier parts of India, Pakistan, and South Africa. In Australia it is considered among the best drought resistant grasses (Keya, 1998; M'Seddi *et al.*, 2003). It is also a major component of pasture for cattle in Southern U.S.A. and Eastern Africa (Cox *et al.*, 1988). It is cultivatable and has been used in reseeding denuded and pastoral land or for improving worn-out pastures. This grass has limited its adaptations to elevations less than 2000 m throughout the tropics (Bogdan, 1977; Heady and Heady, 1982; Boonman, 1993) in many distinct forms most of which are of high grazing value. The culms usually are branched and with linear left-blades, flat or having enrolled margins. False spikes usually purplish 2.5-15 cm. Long, dense, spiklets lanceolate bristles, the outer ones slender, the inner ones somewhat flattened and connate towards the base, ciliate above (Bodgan, 1958). *Cenchrus ciliaris* has been recommended for reseeding areas receiving 350-900 mm of rain per year. Whole seeds of this species have been shown to result in better grass stands than when hulled seeds are used (Chakravaty *et al.*, 1966; Martha *et al.*, 1995). Observations suggest that temperature has a major influence in seed viability and hence germination potential. *Cenchrus ciliaris* seeds have been reported to germinate better after pre-drying for 10 days at 40^0C than pre-chilling for the same period at 5^0C (Maze *et al.*, 1993; Hussey and Bashaw, 1996). Martha *et al.* (1995) reported that buffel grass annually produced three times more green forage than native grasses in the Sonoran Desert, Mexico.

2.3.3 *Enteropogon macrostachyus* (Hochst. ex A. Rich.) Monro ex Benth

Enteropogon macrostachyus is a widely distributed graminaceous species very common in arid areas where it grows in bush, in forest edges and to a lesser extent in open grassland (Jordan, 1957; Bogdan, 1958; Kitalyi *et al.*, 2002). It occurs from 300-1600 m above sea levels in semi-arid areas of tropical Africa. The species is a tufted perennial up to 1 m high with narrow flat leaves, which depending on the environment may be leafy or stemmy. Although stemmy it is drought resistant and provides useful grazing for herbivores. In the coastal areas it is replaced by an allied species, which differ in having smaller spikelets and slightly different habit. The grass is a good seed producer and is reported to have good seed quality and rapid germination (Pratt and Gwynne, 1977). It had been tried with moderate success for reseeding denudated pastoral land in Kenya (Kitalyi *et al.*, 2002) under annual rainfall of 550-800 mm. Because of its value to herbivores, its re-introduction in degenerated swards is of obvious value to grazers. Good seeding stands occur in *Acacia* or *Commiphora* bushland between Sultan Hamud and Voi, and locally throughout the dryland areas of Kenya.

2.4 ABOVEGROUND BIOMASS PRODUCTION

Most range management decisions are based on quantitative measurements of production and utilization of key range plant species. Understanding how much standing crop is available in a site is the first step in making informed decision on stocking rates. It forms the basis for estimating the area's carrying capacity since normally, there is marked variation in standing crop of plant biomass from site to site (Bogdan, 1977; Mnene, 2005). Although much work has been done on primary production in the tropics (Skerman and Rivieros, 1990; Boonman, 1993; Keya, 1998; Ekaya *et al.*, 2001) limited literature exists for species dominating arid and semi-arid lands.

Where forage is scarce and where efforts to re-establish are made, results tend to be influenced by prevailing environmental conditions, mostly soil moisture and rainfall. Boutton *et al.* (1988) observed that soil moisture and rainfall were significantly correlated with plant primary production in the Nairobi National Park. Soil moisture stress effects on grass tillering and regrowth rates reduce shoot development thereby reducing herbage yields (Taerum, 1970). Similar observation relating land condition and forage yields showed that land preparation methods affect forage biomass yields to a certain degree (Humphrey, 1981). Mott and McComb (1976) studying moisture effects on yield on *Helichrysum cassiniamum* (Gaud), *Helipterum craspedioides* (W.V. Fitzg) and *Aristida contorta* (F. Muell.) under 7%, 10% and field capacity soil moisture content reported reduced biomass dry weight in moisture stressed plants which was attributed to changes in both shoot and root growth. Similar observations were made by Musyoka (1999) on *Panicum maximum* Jacq and *Eragrostis Superba* Peyr under different moisture effects. However, forage grasses have their most favourable soil moisture levels at which they yield highest forage amount as was observed by Koshi *et al.* (1977) on *Bothriochloa barbinoides* (Hirter) which yield highest herbage under moderate levels of irrigation with no increase in yield with additional water. Some grasses grow in different associations on different soils (Bogdan, 1977; Boonman, 1993). Mnene (1997) reported results on work with seven grasses growing in a natural association at Bachuma Kenya, that showed variations between grass species in terms of on-set growth, flowering and eventual dieback.

Herbage yield vary in different land treatments. Friedel and Bastin (1988) working on *Eragrostis curvula* (Schrad) and *Hilaria mutica* (Buckl) found that fire intensity does not strongly affect herbage yield. M'Seddi *et al.* 2003 working with *Cenchrus ciliaris* observed mean phytomass production of 50.6 to 178 g DM plant^{-1}. Work at Kiboko (Woie, 1986), and Kitale (Boonman, 1993) in Kenya, demonstrated that grasses have different forage production capabilities and nutrient contents. They also differ in their ability to tolerate varied frequency and intensity of utilization. Further, large number of tillers and leaves produced by some grasses such as *C. ciliaris, P. maximum* and *Digitaria macroblephara* allow the grasses to attain maximum growth rate at an earlier age and recover sooner after defoliation (Woie, 1986). In savannah grassland, total aboveground biomass production declined with increasing frequencies of harvest or clipping (Leriche *et al.*, 2001). That is because, defoliation aimed at removing leaves as happens during grazing, retards tillering and results in a reduction in photosynthetically active tissue with a resulting reduction in carbon assimilation (Troughton, 1957). Therefore, in order to maintain a maximum rate of dry matter production, sufficient leaf area must be present to effectively intercept incoming radiation (Nobel *et al.*, 1993). Further, the hypothesis that grazing could stimulate the aboveground dry matter available to grazers has no blanket application in rangelands with a mosaic of plant associations.

Plant biomass production is a function of species genetic potential that can only be fully expressed depending on the various environmental factors such as soil moisture, day length, air and temperature (Bade *et al.*, 1985). Soil moisture holding capacity varies with soil type (Herlocker, 1999; Ekaya *et al.*, 2001). Generally, sandy soils tend to allow fast water infiltration and percolation, but lose water rapidly through evaporation. Clay soils behave nearly the opposite. As a result, small rain showers may boost clay moisture content sufficiently to trigger and sustain plant growth while heavy rainstorm may lead to water logging (Nill *et al.*, 1996). These characteristics are part of what distinguishes soil types and for a plant to grow in any one kind of soil it would need the ability to adapt to the inherent characteristics.

The standing biomass yield inside the enclosures may be used to estimate the 'carrying capacity' which refers to the maximum number of livestock units that a given range area can support when forage is at its lowest. Grazing influences the structure and function of grasslands depending upon the vegetation type, rainfall, the type of grazing animal and the duration and intensity of grazing (Herlocker, 1999). Grazing creates relatively open canopies thus making the invasion of annuals and other alien plant possible (Pratt and Gwynne, 1977; Herlocker, 1999). Under heavy grazing, unpalatable plants of low successional order invade the open grasslands, eventually reducing the basal cover leading to greater chances of soil erosion while reducing the desirable standing crop. Similarly, at such high levels of utilization, biomass production is impaired because grazing targets leaves and it is leaf area that contributes to efficient biomass production (Briske and Heitschmidst, 1991).

2.5 ECONOMIC ASPECTS OF RANGE RESEEDING

Economic aspects of producing forage from range and pasture lands are concerned with obtaining optimum production (use) of forage at the minimum cost (Neilsen, 1967; Workman and Tanaka, 1991). The economics of range reseeding lead directly to the factors of input-output in production economics. The costs of improvement can be compared with the value of the forage or benefits produced, and an estimate made as to the benefit-cost ratio or balance (Kearl *et al.*, 1975; Clawson, 1983). Although range reseeding often increased forage production on rangelands, livestock producers have been reluctant to use them because of uncertainty about profitability. Reseeding is generally assumed to be costly in labour, land preparation, fertilizer, purchase of seed supply, and installation of fencing (Chileshe and Kitalyi, 2002). Similarly, it had been argued that using the established pasture is also costly in labour for cut-and-carry harvesting, controlling grazing time, preparing hay, and storing and maintaining the herbage (Chileshe and Kitalyi, 2002).

The initial costs in reseeding may be high, few published studies (Caton and Beringer, 1960; Kearl *et al.*, 1975; Godfrey and Sellassie, 1979) shows that the long-term benefit is high. However, the relation of benefits to costs may be expressed in benefit-cost ratio, or may be expressed as the amount of the net benefits (total benefits minus total costs). The two measures do not necessarily yield the same answer (Workman and Tanaka, 1991). The evaluation must be made at the optimum combination of inputs, which in turn depends on both physical and economic relationships (Clawson, 1983). For example, if one proposes to grow more grass, the more animals to consume it may be necessary, and this in turn means other adjustments in the production process. The costs involved are complex in benefit-cost ratio. for example what allowance should be made for the time and labour of the farmer who installs the practice? What interest rate should be charged on the investment of capital in the economic evaluation of range improvement? These are some of the questions that may arise in estimating the cost of range reseeding. Expected rates of return, risk of failure, and availability and source of capital must all be considered. However, the use of internal rates of return (IRR) is probably the most universally adapted method of determining the profitability of investing in range reseeding (Gardner, 1963; Prest and Ralph, 1975; Neilsen, 1977; Workman, 1981; Gittinger, 1982). The question of which of the three cost-benefit analysis (Benefit-cost ratio, internal rate of return and net present value) standard criteria to use in evaluating reseeding investment projects have long been a source of controversy among economists and range managers (Workman and Tanaka, 1991). The question of which criterion to rely on and which to disregard has come about simply because the three cost-benefit analysis criteria, as commonly calculated often produce contradictory results.

According to several study reviews of classic treatments of the problem of capital budgeting (Dean, 1954; Lorie and Savage, 1955), it has been recommended that IRR, rather than net present value (NPV), be used as the criterion for ranking range improvements projects that are mutually exclusive due to limited investment funds. Advantages claimed for IRR were (1) the calculated rate is directly comparable to the compound interest rate paid for borrowed capital, (2) it is not necessary to undertake the difficult task of selecting the 'correct' interest rate for NPV discounting calculations, and (3) IRR standardizes projects with respect to size and expected life. The listed advantages are based on the assumption that net cash flows to a short lived project can be reinvested at the IRR generated by the project to give a useful life equal to the longest lived project under consideration (Gardner, 1963; Workman, 1981). Workman (1981) did caution however, that the period of discounting should not exceed the expected life of the range improvement project. Even if the improvement has the potential of long-term benefits, this period should not normally be extended over a period of thirty years (Nielsen, 1977). Studies have shown that reseeded plots are only able to provide forage for livestock over a given period of time (Workman, 1981; Workman and Tanaka, 1991). On the other hand, the public land managers have long used benefit-cost ratio as the criterion for separating feasible and infeasible management alternatives. Benefit-cost ratio expresses the feasibility of a given project as a ratio of present value of gross project benefits to present value of project investment and operating costs. Some of the advantages of this method include: i) it considers the time value of money, ii) it accounts the cash flow over the entire project life, iii) can be used to show the level to which the costs could rise without making the project economically unattractive (Gittinger, 1982).

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

3.1.1 Location

This study was conducted in Endau hill escarpment, Mwitika division, Kitui District (Figure 1). Kitui District borders Machakos and Makueni districts to the west, Mwingi district to the north, Tana River district to the east and Taita district to the south. The study area lies between latitudes 0^0 3.7' and 3^0 0' south and longitudes 37^0 45' and 39^0 0' east.

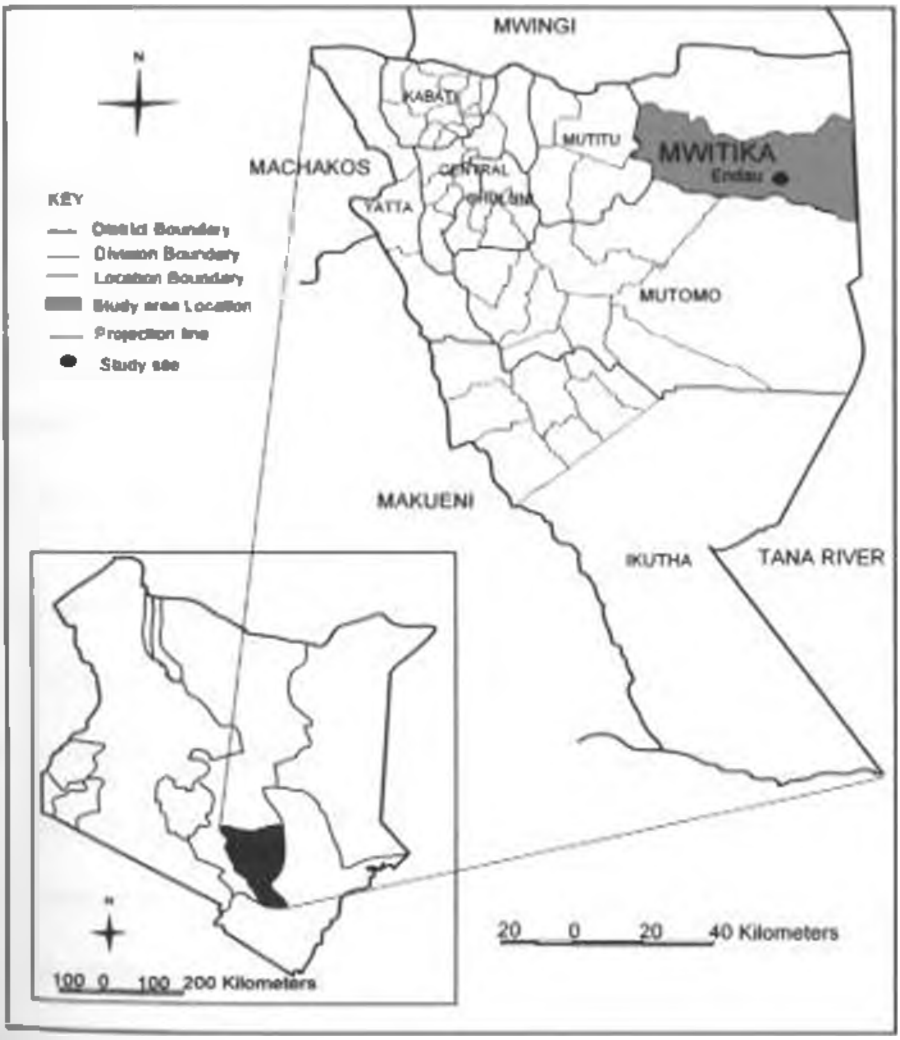

Figure 1: Location of study site

3.1.2 Topography and climate

Kitui District lies between 400 m and 1800 m above sea level. According to Pratt and Gwynne (1977) and Jaetzold (1991), the western parts fall under agro-climatic zone five (ACZ IV) while the eastern side falls under ACZ V. The study area is characterised by high temperature throughout the year, with the minimum and maximum temperatures ranging from 15°C to 18°C and 25°C to 28°C, respectively. The rains in the district are low, erratic and unpredictable in nature, ranging between 250 and 900 mm (GoK, 2002). Figure 2 represents eleven years mean monthly rainfall and coefficient of variation between 1990 and 2001. Monthly mean rainfall values in Figure 3 are attributed to random variability. The variation in rainfall amounts and distribution are normal characteristics of the semi-arid rangelands (Pratt and Gwynne, 1977; Gichuki, 2000; Ekaya *et al.*, 2001). The rainfall pattern is bimodal, with long rains expected between March and May and short rains from October to December. The rainfall distribution in the area is strongly influenced by the topography at the local scale, whereas the rainfall seasons are attributed to the influence of Inter-Tropical Convergence Zone (ITCZ) (Downing *et al.*, 1988).

3.1.3 Soils and vegetation

The soils of Kitui reflect the largely metamorphic parent material and the rainfall regimes that contribute to their formation (Michieka and Van der Pouw, 1977). They are generally of sandy-clay medium texture, shallow to moderate in depth, and greyish-brown in colour (Ojany and Ogendo, 1973; Thomas and Moore, 1981). The soils in the study site are well-drained sodic clay with whitish sandy tops. The landforms and geology of the study area have been described in detail by Jaetzold and Schmidt (1983), Jaetzold (1991) and Belkhodja *et al.* (2003).

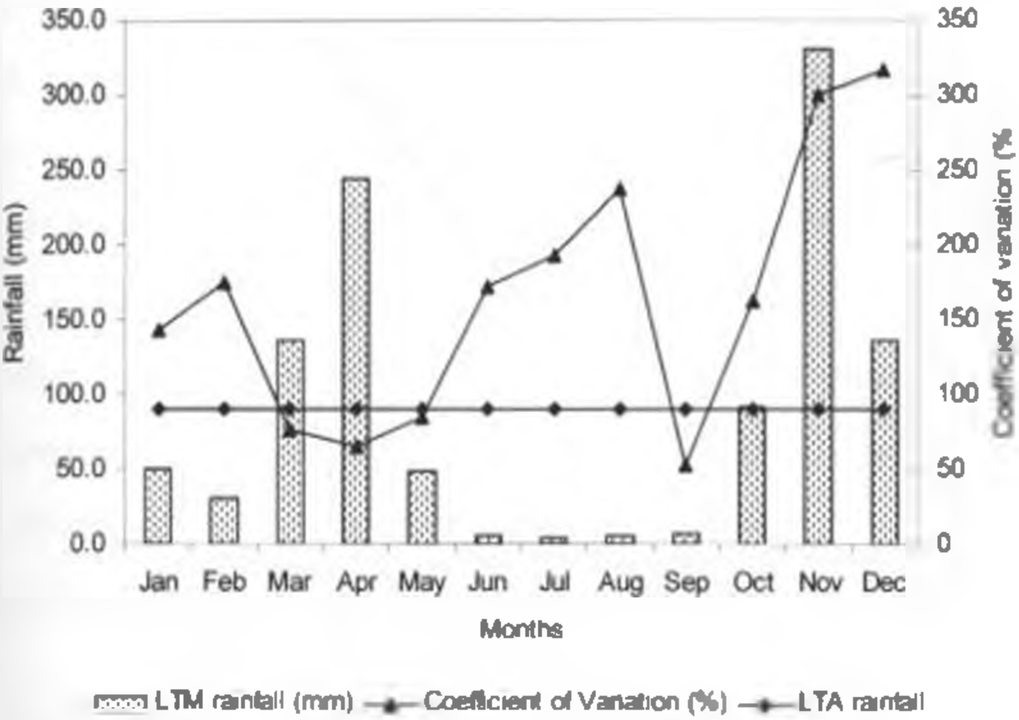

Figure 2: Monthly mean (MM) rainfall and annual mean (AM) rainfall and coefficient of variation at Endau (1990-2001)

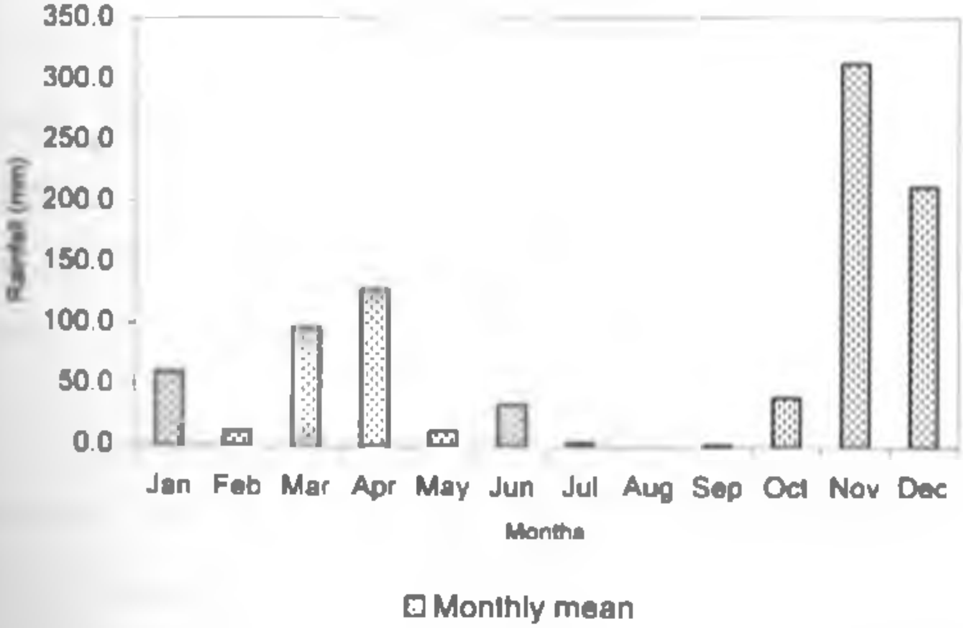

Figure 3: Monthly mean (mm) rainfall between January and December 2003 at Endau sub station *(Data Sources, Endau Sub-Metrological Station)*

The vegetation of the study site is highly heterogeneous probably due to variation in both soil type and history of land use (Jaetzold and Schmidt, 1983). The hills were once forested, but currently most of the desirable vegetation species have been cleared (Belkhodja *et al.*, 2003). The predominant woody species in the area include *Commiphora africana, Commiphora riparia, Acacia tortilis, Acacia mellifera, Acacia senegal, Acacia nilotica, Cordia ovalis, Combretum* spp, *Balanites aegyptiaca, Terminalia orbicularis,* and *Adansonia digitata.* The scattered woody trees along the seasonal rivers and highland reserve forests provide fuel, building materials and other wood products to the local people, besides being an important habitat for wildlife.

The herbaceous layer comprises mainly annual forbs and grasses such as *Premna resinosa, Dobera glabra, Sporobolus pellucidus, Cenchrus ciliaris, Eragrostis superba, Enteropogon* spp. and *Pennisetum* spp. However, within the last decade, annual grasses and shrubs like *Brachiaria leersioides, Justicia exigua, Eragrostis cilianensis, Tetrapogon tenellus and Aristida adscensionis* have continued to dominate the non-cultivated areas, a phenomenon closely associated with overgrazing and land degradation (Michieka and Van der Pouw, 1977; Belkhodja *et al.*, 2003).

Generally, the rangelands in the study area have been assessed as being in poor condition due to degradation (Tiffen *et al.*, 1994; Nyariki and Abeele, 2004). The primary vegetation in the study site includes shrub vegetation and small patches of grass cover (Plate 1).

Plate 1: Scattered vegetation in Endau area

3.1.4 Population, settlement, and land-use practices

According to 1999 census, the population of Kitui District was approximately 515,422 with a population density of 25 people km^{-2} (GoK, 2002). The vast majority of the population (about 95%) live in rural villages and rely on a combination of subsistence and commercial agriculture, with some wage labour (GoK, 2002; Nyariki and Abeele, 2004). According to a 1999/2001 household survey of Kitui district, agriculture accounts for over 50 percent of income, off-farm enterprises for 17 percent, salaries and wages for 24 percent, and other sources for 9 percent (GoK, 2002; Institute of Economic Affairs, 2002). Field crop cultivation and livestock rearing are the two major components of the local subsistence economy (Nyariki and Abeele, 2004). Most households keep cattle, donkeys, goats and a few sheep, with an average of 10 cattle and 15 goats or sheep. The most common crops grown in the area are maize, beans, cowpeas, pigeon peas, pumpkins, green grams, and a variety of vegetable crops to supplement income from livestock.

The landholdings in the area range from 2 to 1,000 hectares, with most households in agro-ecological zone IV owning 2-10 hectares, and those in zone V owning 2-15 ha (Rocheleau, 1992). As human population increases, household land holding is decreasing.

3.2 EXPERIMENTAL DESIGN AND TREATMENTS

3.2.1 Land preparation and field layout

Two experimental plots each measuring 300 m x 30 m were established 10 m apart in the study site, which has been used for livestock grazing in the past 5 - 10 years. The plots were located in flat open grassland with very short shrubs of less than a metre. The land preparation methods were the main treatment in the experimental plots. These were tractor-ploughing and hand-clearing. Tractor-ploughing treatment operation involved minimum tillage of one run-over by 65-capacity tractor, whereas hand-clearing treatment involved hand slashing the experimental plots using a machete to ground stubble height. The slashing was done without disturbing the soil and litter were left on the surface to dry. The experimental plots were prepared during the dry season just before the onset of March-May rains of 2003.

The experimental layout used was randomised block design (RBD). Within each homogenous block, the treatments were assigned at random to each unit (Steel and Torrie, 1980). Six sub-plots measuring 6 m x 6 m were laid out within each treatment. The sub-plots were three in the tractor-ploughed and three in the hand-cleared treatment (Figure 4). The grass seeds were broadcast randomly within each sub-plot at a density of 100 grams m^{-2} on 3rd May 2003. The broadcasted seeds were not covered. The experimental sites chosen were initially fenced using live trees and shrubs to exclude both big and small livestock and wild herbivores from grazing on the reseeded plots.

Block 1 (Tractor-ploughing)	Block 2 (Hand-clearing)
Sub-plot 1 *Cenchrus ciliaris*	Sub-plot 4 *Eragrostis superba*
Sub-plot 2 *Enteropogon macrostachyus*	Sub-plot 5 *Cenchrus ciliaris*
Sub-plot 3 *Eragrostis superba*	Sub-plot 6 *Enteropogon macrostachyus*

Figure 4: Experimental layout

3.2.2 Seed viability tests

All the seeds used in the experiment were obtained from the University of Nairobi, Dryland Husbandry Project (DHP) site, in Makueni District. The seeds had been stored for over one year at the Kibwezi Research Station. The germination capacity of the grass seeds as a measure of seed quality was tested in the laboratory.

Germination test as described by Tarawali *et al* (1995) was used in the study. Random samples of 100 seeds obtained from bags of seeds collected were put on wet Whitman filter paper in a petri dish. Ten replicates were used for each grass species. The petri dishes were then placed in an incubator at 25^0C, and moistened everyday with 5 mm of water for 17 days. The grass seeds that germinated every day were counted and removed from the incubator. Germination was considered to have occurred when a clearly identifiable radicle emerged from the seed in the petri dish (HSU, 1994; Koning, 1994). At the end of the 17 days, all germinated seeds were expressed as a percentage of total seeds incubated.

Percent germination was calculated using the following formula:

$$\% \text{ Seed Germination} = \frac{\text{No. of seeds germinated}}{\text{Seeds per petri dish} \times \text{replicates}} \times 100$$

The mean daily germination rate was further expressed as the percent number of seeds that had germinated in a given day.

3.2.3 Morphometric characters

Thirty-five plants were randomly selected per sub-plot and tagged for sampling. A sample size chosen was an arbitrary representative of the plant population as used by Njenga (1992) in similar studies. The following parameters were monitored weekly between May and December 2003:

a.) Plant height (cm) was measured on the primary shoot from the soil surface to the base of the top-most leaf.

b.) The leaves on each primary plant shoot were counted on a weekly basis.

c.) The live tillers visible on each plant were counted weekly.

d.) The plants that withered or died were identified and recorded on a weekly basis.

e.) Plant foliage (downward projection of the actual foliage plant) cover was estimated using a 1 m^2 quadrat in each treatment sub-plot at the end of the 12^{th} week after sowing.

f.) The annual weeds in each sub-plot were identified, counted and recorded at the second week and the tenth week of the experiment.

3.2.4 Aboveground biomass production

The aboveground biomass production was estimated by harvesting all the plant material in each sub-plot, leaving a stubble height of 2.5 cm. Harvested materials for each grass species were weighed while fresh, using a one-kilogram triple beam balance. Thereafter, sub-samples of the harvested materials of each species were packed in paper bags, sun dried for five days, and weighed using a half-kilogram spring balance to derive average dry matter production. The sampling was done twice at the beginning of August and again at the end of December 2003 to obtain the mean biomass yield.

3.2.5 Benefit-cost analysis

Data on costs were obtained on land reseeding investment projects, physical inputs used, and costs at the time reseeding were done. Costs were then calculated using 2003 prices to give a standard base for reference and comparison. Indirect costs of reseeding included risk cost of reseeding failure and interest on direct costs. The fixed costs, including depreciation, interest on machinery investment, and taxes, were not estimated since the tractor was hired. The returns were computed based on the hypothetical sale of hay from the harvested biomass on the reseeded plots, using the market sale price of hay in the area.

The benefit-cost analysis was used to compare benefits with costs from the tractor-ploughed and hand-cleared reseeding investments. The commonly used benefit-cost analysis criteria in determining the profitability of investing in range reseeding projects were employed. The analysis methods included benefit-cost ratio and internal rate of return (Workman, 1981). Benefit-cost ratio (B/C) has long been used by the public land managers as a criterion for separating feasible and infeasible management alternatives. The B/C is the ratio obtained when the present value of the flow of benefits is divided by the present value of the flow of costs (Gittinger, 1982; Jenkins and Harberger, 1995). The selection criterion for the B/C ratio method is to accept reseeding investment with a ratio equal to or greater than 1, when the cost and benefit flows are discounted at the opportunity cost of capital (Jenkins and Harberger, 1995).

The mathematical expression of the benefit-cost ratio is given by:

$$B/C \text{ ratio} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

Where

B_t = benefit at time t
C_t = cost at time t
$t = 1,2,...,n$
n = number of years

The internal rate of return (IRR) method was also adopted for analyzing cash flows. In this study, the IRR is defined as the discount rate at which the net present value (NPV) is equal to zero (Gittinger, 1982). Neilsen (1967) defines this rate as the rate of return, which makes the discounted income stream over the life of the project equal to the rate at which money can be borrowed. The IRR method is used extensively despite the textbook criticism (LeBaron, 1963; Kearl and Cordingley, 1975). It is favoured because it is very good for screening investment projects (Neilsen, 1967; Gittinger, 1982).

The mathematical expression of the IRR is given by interest rate (i) in the following formula:

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0$$

Where

B_t = benefit at time t

C_t = cost at time t

$t = 1, 2, \ldots, n$

n = number of years

The expected economic life of range reseeding investment in this project was assumed to be 20 years ($t = 20$). Similar studies of reseeding indicate that this length of life is a reasonable expectation (Neilsen, 1967; Godfrey, 1979). Using the calculated table factor and estimated lifetime expectancy of the project, the appropriate rate of return was determined. The present worth of an annuity factor for computing percentage IRR was used (Gittinger, 1982). The calculated percentages of IRR were compared with the interest rates (16.6%) charged by commercial banks in Kenya on real estate loans by 2003 (World Bank, 2005).

$$\text{Table factor} = \frac{\text{Initial investment}}{\text{Net (additional) annual return}}$$

The decision on the profitable reseeding investment was determined based on a comparison between the internal rate of return and the lending rate charged by the banks on the real estate loans. Therefore, if the internal rate of return exceeds the lending rate, then the reseeding investment would be considered profitable. However, to eliminate project selection disagreements and the resulting confusion as to which criterion to follow, a 'normalization' procedure was used as suggested by Mishan (1976). This involves compounding project returns forward and discounting them back at the same interest rate, without changing the NPV.

3.3 STATISTICAL ANALYSIS

Statistical analyses were conducted using Statistical Package of Social Science (SPSS) packages (Cernea, 1985; Einstein and Abernethy, 2000). Differences in morphometric characters between treatments were analysed by analysis of variance (ANOVA), with treatment and species considered as main factors. The data values were log-transformed prior to statistical analyses to correct unequal variation and improve the fitness (R^2) of the relations. Mean separation tests were performed using least significant difference (LSD) (Steel and Torrie, 1980) at 5% level after significant *F* values were obtained.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 SEED VIABILITY TESTS UNDER LABORATORY CONDITIONS

The result showed that there was significant difference ($p<0.05$) in seed germination between the three grass species. Figure 5.1 presents percent seed germination for the grass species after 17 days. Seeds of *C. ciliaris* had the highest germination (28.4%). The percent seed germination for *E. macrostachyus* was 20.1% while *E. superba* had the lowest percent germination of 8.6%. The percent seed germination of *C. ciliaris* and *E. macrostachyus* increased up to the 14^{th} day, thereafter there was no percent germination increase. However, the percent seed germination of *E. superba* increased up to the 13^{th} day. The plateaus towards the end of percent seed germination curves were the time in which the seeds failed to germinate in consecutive days.

There was significant difference ($p<0.05$) in mean daily germination rate of the three grass species. The seeds of *C. ciliaris* had the highest mean daily germination rate of 2.9%, followed by *E. macrostachyus* (2.3%) and *E. superba* which had the lowest mean daily germination rate of 0.7% (Figure 5.2). Although the seed germination of *C. cilliaris* started a day after that of *E. macrostachyus*, it attained the highest germination rate on the fifth day. However, germination of *E. superba* seeds started on the sixth day and took seven days to attain maximum mean daily germination rate. According to this experiment, with greater percent seed germination the higher mean daily seed germination rate was obtained. A percent germination obtained implies that the grass seeds are viable and are capable of producing normal plants under suitable germination conditions.

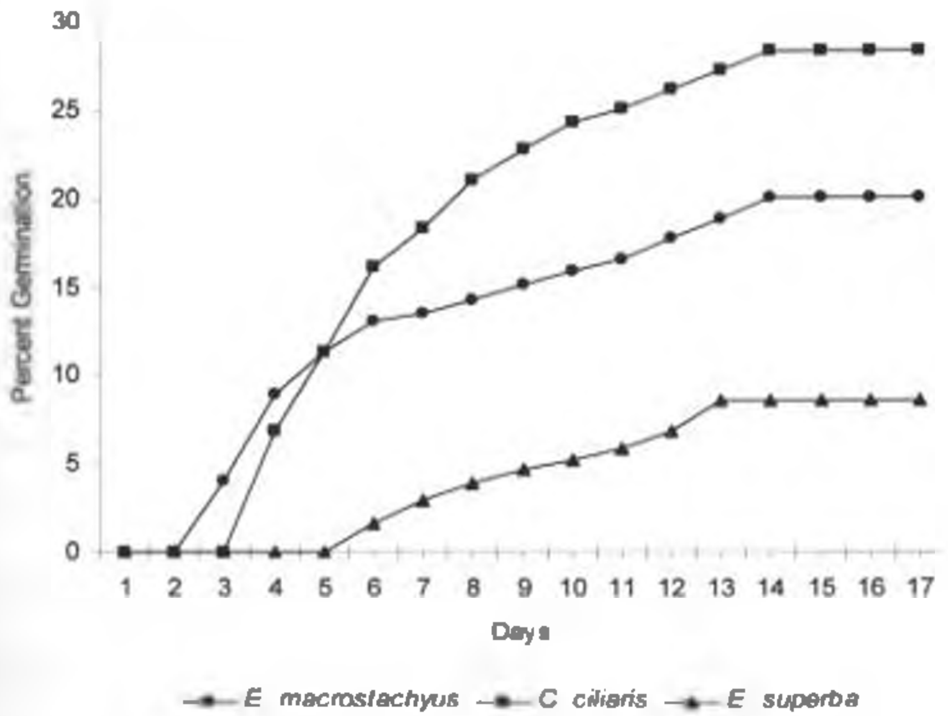

Figure 5.1: Percent seed germination of *E. macrostachyus*, *C. ciliaris* and *E. superba* under laboratory conditions

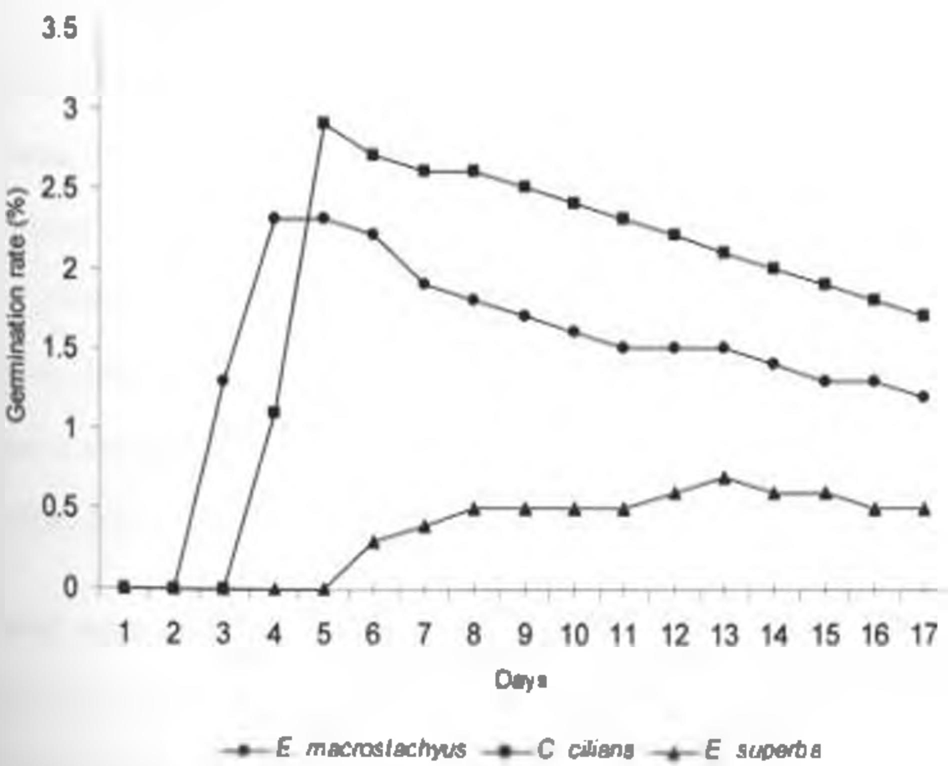

Figure 5.2: Germination rate of *E. macrostachyus*, *C. ciliaris* and *E. superba* seeds under laboratory conditions

The differences observed among the grass species in terms of percent seed germination and mean daily seed germination may be explained by the intrinsic properties of the seeds such as dormancy and tegumental hardness. The seeds morphology, for example the hairy bristle coat of the *C. ciliaris* fascicles is likely to have aided germination by maintaining a high humidity within the fascicle and thereby helps reduce water loss from the caryopsis thus enhancing germination (Cook and Dolby, 1981; Silcock and Smith, 1982; Sharif-Zadeh and Murdoch, 2001). These fascicles are known to contain more than one caryopsis (Winkworth, 1971; Daehler and Georgen, 2005). Further, it is likely that *C. ciliaris* seed dormancy mechanism involves only the integument which allows water and gaseous exchange between the embryo and the micro-environment with subsequent embryo growth, while *E. macrostachyus* and *E. superba* may have embryo or both the embryo and integument related dormancy (Simpson, 1990; Keya, 1997). In addition, dry seeds, particularly those of rangeland grasses are known to be highly hygroscopic (Ernest and Tolsma, 1988; Veenendaal, 1991) and exposure of dry seeds to moisture has been reported to worsen the dormancy and often leads to fungal infection (Chin and Hanson, 1999; Tweddle *et al.*, 2003). In this study, fungal growth was evident although no data was collected on grass seeds infestation. However, individual grass seed species ability to withstand moisture stress varies between species (Veenendaal, 1991; ISTA, 2001).

The results suggest that the grass seeds that failed to produce a clearly identifiable radicle over 17 days of the laboratory experiment were dormant. According to the results obtained, *C. ciliaris* is a fast-germinating tufted perennial grass compared to *E. macrostachyus* and *E. superba*. Under field conditions, faster germination is desirable since it will give the seedlings a head start in the normal plant competition (Baker and Abdi, 1987; Kadmon and Schimida, 1990; Keya, 1997). The faster a seed moves from the seed and seedling stages, the higher the chances for its survival and subsequent establishment if there is no selective predation (Ernest and Tolsma, 1988; Chin and Hanson, 1999). It was therefore expected that *C. ciliaris* to have the best seedling survival and establishment compared to *E. macrostachyus* and *E. superba*. The laboratory experiment implies that *E. macrostachyus* was to have higher survival and establishment than *E. superba*. However, others have argued that all grass seeds have the best germination results when planted into a well-prepared seedbed, since germination is usually spread over several rainfall events (Andrew and Mott, 1983; Fregeau and Burrow, 1989; Njenga, 1992). The results of mean daily germination rate and time taken for maximum germination to be attained could explain the performance of these grasses under field conditions.

4.2 LAND TREATMENT EFFECTS ON MORPHOMETRIC CHARACTERS

4.2.1 Effects of land treatment on seedling mortality and plant foliage cover

Land treatment had a significant ($p<0.05$) effect on seedling mortality of the three grass species. The seedling mortality was significantly higher ($p<0.05$) in the hand-cleared than tractor-ploughed plots (Table 1). In both treatment plots, seedling mortality was highest in *E. superba*, indicating its poorest adaptation to the two land treatments. For *C. ciliaris*, seedling mortality was the lowest, though not significantly lower than that of *E. macrostachyus*.

The results further revealed that the percent seedling mortality of *E. macrostachyus* and *C. ciliaris* within the same land treatment plots were quite similar. This implies that the species effect did not influence the survival of these grasses significantly.

However, mortality of *E. macrostachyus* and *C. ciliaris* was higher on hand-cleared than on tractor-ploughed.

Table 1: Percent seedling mortality of three grass species in two land treatments within a period of twelve weeks

Species	(%) Seedling mortality	
	Tractor-ploughed	Hand-cleared
E. macrostachyus	15.4[a]	20.5[b]
C. ciliaris	10.5[a]	18.2[b]
E. superba	24.8[b]	32.4[c]

Means followed by different letter superscripts in the same column, and those with different letter superscripts in the same row are significantly different at $p<0.05$ as determined by LSD test

The mean percent foliage cover was significantly ($p<0.05$) higher and almost twice in the tractor-ploughed than in the hand-cleared plots (Table 2). The highest percent foliage cover was observed in *C. ciliaris* followed by *E. macrostachyus* and *E. superba* had the lowest cover in both land treatments.

Table 2: Percent foliage cover of three grass species in two land treatments within a period of twelve weeks

Species	(%) Foliage cover	
	Tractor-ploughed	Hand-cleared
E. macrostachyus	46.2[a]	20.1[b]
C. ciliaris	65.8[b]	31.4[c]
E. superba	20.8[c]	8.4[d]

Means followed by different letter superscripts in the same column, and those with different letter superscripts in the same row are significantly different at $p<0.05$ as determined by LSD test

The relatively higher percent seedling mortality in the hand-cleared plots was attributed to the presence of a hard soil surface. The result suggests that the hard soil surface was not favourable for seedling survival. Adams and Danckwerts (1993), Oliver and Barapour (1996) reported higher grass seedling mortality in the hard soil surface than opened-loose soil surface. Hanselka *et al.* (1992) observed that opening-up the hard soil surface by ploughing allows roots to penetrate deeply and extensively, placing roots in greater contact with scarce water held by soil particles. However, Michelle de Chantal (2003) reported that seedling mortality of *Pinus sylvestris* L. (Scots pine) was not affected by site preparation in a Finland rangeland, unlike in this study, where seedling mortality was affected by the method of land treatment. This result further implies that seedling mortality in the hand-cleared plots could be a consequence of inaccessibility to scarce water held by the soil as reported else where by King *et al.* (1989).

The findings of this study are comparable to the results of Jordan (1957), Deshmukh and Baig (1983), Cook (1984), Boonman (1993) and Deleuran and Boelt (2005) who reported that some degree of site preparation or opening-up the compacted soil surface is necessary for successful survival and establishment of pasture in the arid and semi-arid lands. A study by Cook (1984) reported that ploughed seedbed produced the higher plants survival than herbicide and burnt plots with high seedling mortality. Njenga (1992) working on the southern rangelands of Makueni district, Kenya reported best plant performance in terms of survival in the oxen-ploughed plots than in the adjacent burned plots. A study by Too (1995) in the semi-arid area of Kiboko, Kenya, revealed better water infiltration rate in opened-up soil surface plots, leading to a better seedbed for seedling growth and survival. The improved seedling survival and higher foliage cover described by Adams and Danckwerts (1993) was attributed to the removal of competition from undesirable competitors. However, studies by Ego and Kibet (2003) in Makueni district, Kenya reported relatively higher foliage cover on *C. ciliaris* (79.6%) than those observed in the present study even though the same seed rate was used in both the experiments.

The findings suggest that opening-up the soil surface is necessary in providing the grass seedling with optimal growth requirements for survival. However, the significant difference in seedling mortality between *E. macrostachyus*, *C. ciliaris* and *E. superba* within the same treatment plots suggests that these species have different adaptation characteristics. Studies by Malan and Van Nickerk, (2005) showed that *C. ciliaris* exhibits drought resistance and tolerance as a result of its strong and deep rooting systems. This might have enhanced the survival and establishment of *C. ciliaris* compared to the other two species. Similarly, *E. macrostachyus* exhibits drought resistance characteristics (Kitalyi *et al.*, 2002), which might have favoured its survival. However, a high shoot/root ratio (Taerum, 1977), which is a disadvantage to E. superba, might have been the cause of high seedling mortality under this present study. The results further suggest that the prevailing weather conditions, especially the short rains during the months of October to December enhanced seedling survival and growth of the grass species.

4.2.2 Effects of land treatment on plant height

Land treatment had a significant ($p<0.05$) effect on the mean height of the three grass species (Table 3). Plant seedlings on the opened-up soil surface by tractor-ploughing were significantly taller ($p<0.05$) than seedlings on hand-cleared plots. At the end of 12^{th} week of the experiment, the tallest mean heights were for *E. macrostachyus*, followed by *C. ciliaris*, while *E. superba* was the shortest in both treatment plots. In the tractor-ploughed plots *C. ciliaris* and *E. macrostachyus*, *E. macrostachyus* and *E. superba* showed significant difference ($p<0.05$) between their mean plant heights.

However, there was no significant difference ($p>0.05$) in plant height between *C. ciliaris* and *E. superba*.

The mean plant height of grass species in the hand-cleared plots was significantly shorter ($p<0.05$) than those in tractor-ploughed plots (Figure 6.1). However, the mean height of *C. ciliaris* and *E. macrostachyus* were not significantly different within the tractor-ploughed plots (Figure 6.2). The results further showed that *C. ciliaris* and *E. superba*; *E. macrostachyus* and *E. superba* were significantly different ($p<0.05$) in the hand-cleared plots. The study also demonstrated that in both plants on treatments had a general increase of height with time during the 12 weeks of inventory.

Table 3: Mean plant heights (cm) for three grass species in tractor-ploughed and hand-cleared plots

Experimental species	Tractor-ploughed	Hand-cleared
	---------Mean (cm)---------	
E. macrostachyus	17.4 (10.7)^{a}	6.8 (5.4)[illegible]
C. ciliaris	10.2 (10.0)^{b}	6.4 (4.7)^{c}
E. superba	9.9 (14.1)^{b}	5.5 (6.1)^{d}

Means followed by different letter superscripts in the same column, and those with different letter superscripts in the same row are significantly different at $p<0.05$ as determined by LSD test
Values in parentheses () are standard deviations

The higher mean height for the plants in the tractor-ploughed than in the hand-cleared plots may be explained by the effect of opened-up soil surface on the seedling growth. The opening-up of hard soil surface might have enhanced rooting depth and increased the capture of rainfall water in the soil. As also shown in the study by King *et al.*, (1989), it is likely that opening-up of soil surface enhanced root penetration and improved water and nutrient uptake by grass species. Studies by

Humphreys (1959). Skerman and Riveros (1990) reported a higher plant height in the opened-up soil surface plots than in the burned plots. They attributed this to increased moisture retention, increased uptake of water and nutrients by plants, good aeration and easy root penetration by the seedlings.

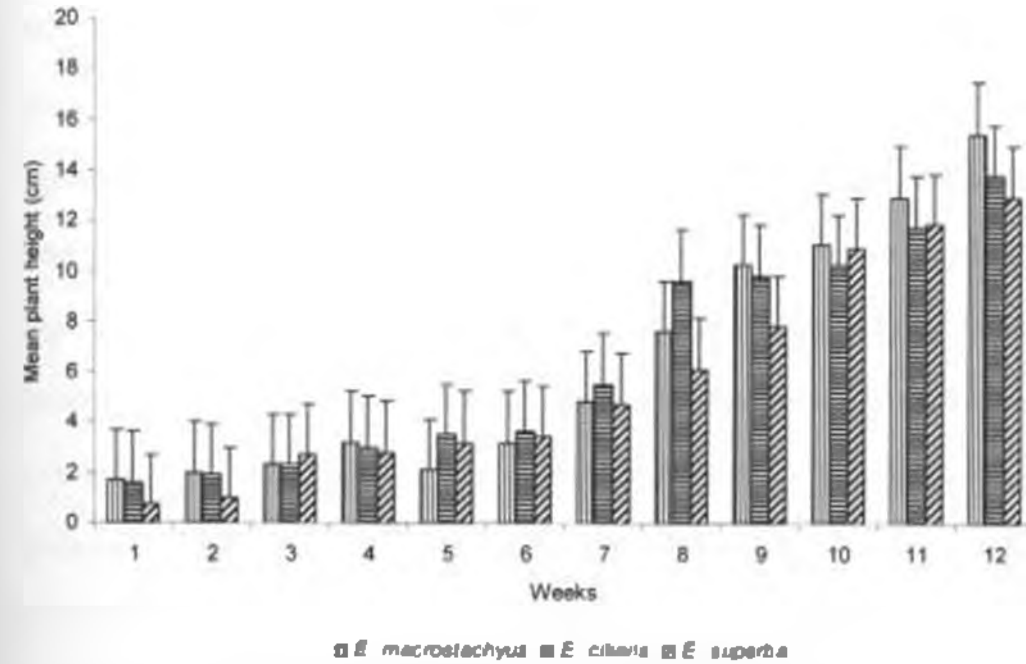

Figure 6.1: Mean plant height for three grass species in hand-cleared plots

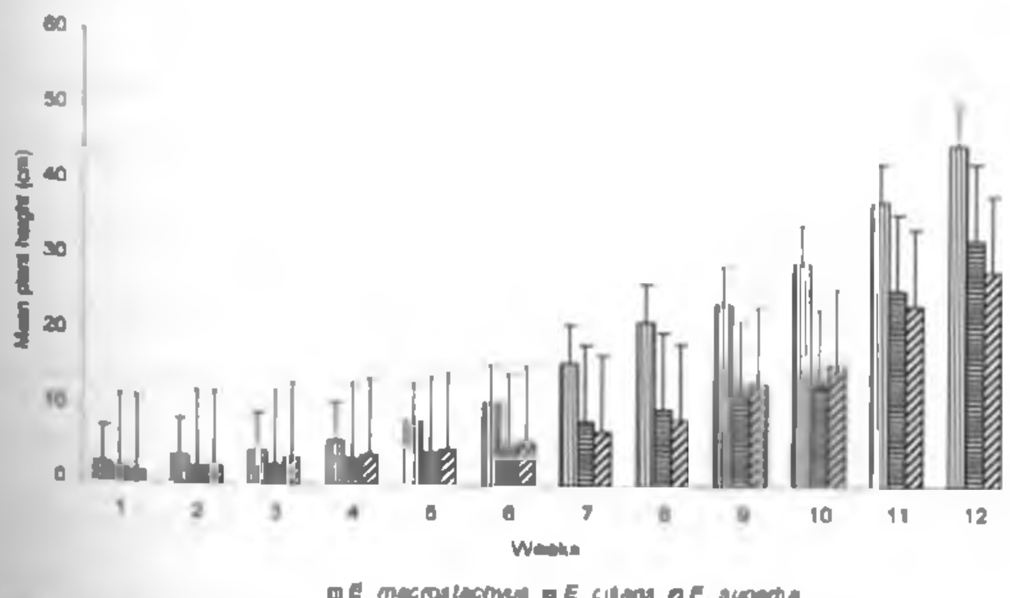

Figure 6.2: Mean plant height for three grass species in tractor-ploughed plots

This study just like other previous studies (Skerman and Riveros, 1990; Njenga, 1992; Mnene, 2005) demonstrated that plant height also varies between species. The grass species used differed in their mean heights throughout the twelve weeks of observation. The findings of this study are comparable to the results of Njenga (1992) working with *C. ciliaris, E. macrostachyus* and *E. superba* in Makueni District, who reported the best performance in mean plant heights in the tractor-ploughed and oxen-ploughed plots than in the burned plots. He observed that burning did not improve mean height of the three grass species in the absence of cultivation. Njenga (1992) suggested that higher mean height and grass population in the cultivated plots was due to exclusion of competing weeds previously existing in the site. Studies by Hacker (1989) and James *et al.* (2002) also emphasize the importance of opening-up the hard soil surface if the reseeded pastures are to benefit from the scarce water in the ASALs. Contrary to the hypothesis that land treatment would not affect the grasses height, the results demonstrated that opening-up the soil surface by tractor-ploughing enhances the growth of the grasses.

4.2.3 Effects of land treatment on number of tillers

Land treatment had a significant ($p<0.05$) effect on mean number of tillers per plant shoot (Table 4). The tractor-ploughed plots had significantly higher ($p<0.05$) number of tillers than the hand-cleared plots for each grass species. Further tests showed that the mean number of tillers within the tractor-ploughed plots differed ($p<0.05$) significantly between species. Similarly, in the hand-cleared plots, the tiller production between species was significantly different. In both land treatments, *C. ciliaris* had the highest number of tillers followed by *E. macrostachyus* and *E. superba* had the lowest.

Table 4: Mean number of tillers per shoot for three grass species in tractor-ploughed and hand-cleared plots

Experimental species	Tractor-ploughed	Hand-cleared
	----------Mean number of tillers per shoot ----------	
E. macrostachyus	3.3 (2.0)[a]	2.3 (0.6)[b]
C. ciliaris	4.6 (1.1)[b]	3.7 (1.0)[c]
E. superba	2.2 (0.8)[c]	1.5 (0.7)[d]

Means followed by different letter superscripts in the same row, and those with different letter superscripts in the same column are significantly different at $p<0.05$ as determined by LSD test
Values in parentheses () are standard deviations

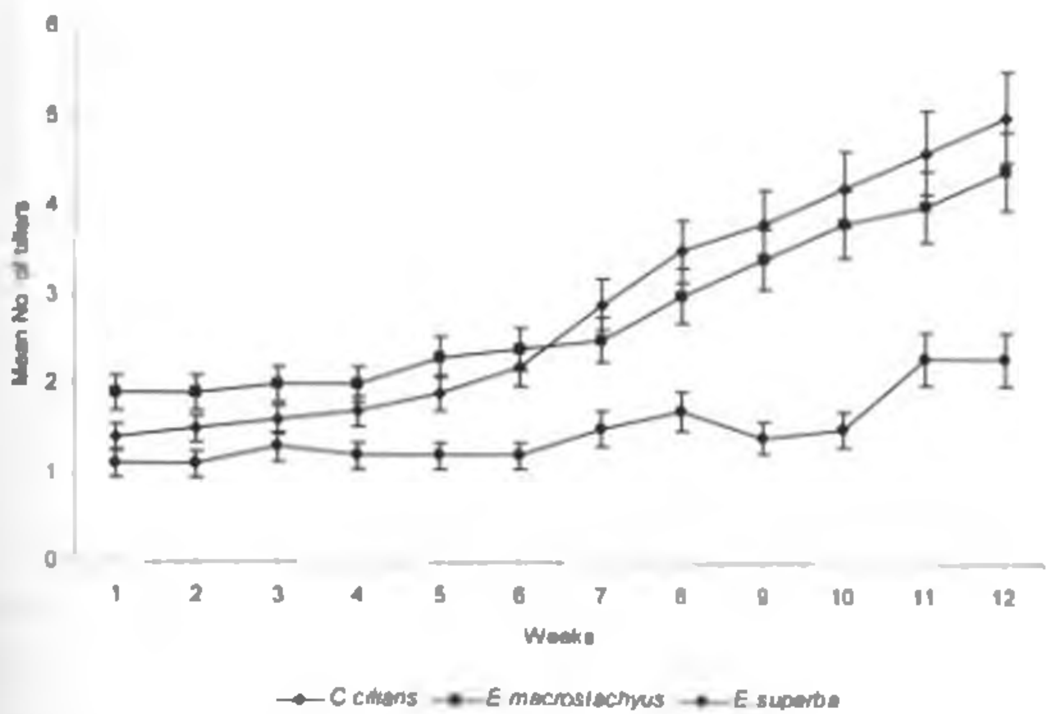

Figure 7.1: Mean number of tillers for three grass species in hand-cleared plots

Plants on the hand-cleared plots had the least number of tillers throughout the period of observation. Results further showed that the differences in the number of tillers between species were statistically significant ($p<0.05$) within the treatment plots. The production of tillers under the two land treatments showed a general increase with time except between the eighth and ninth week (Figure 7.1 and 7.2). This may have been due to the prevailing weather conditions since in all plots the trend was the same. However, in both land treatments *E. superba* maintained a relatively low number of tillers throughout the period of observation.

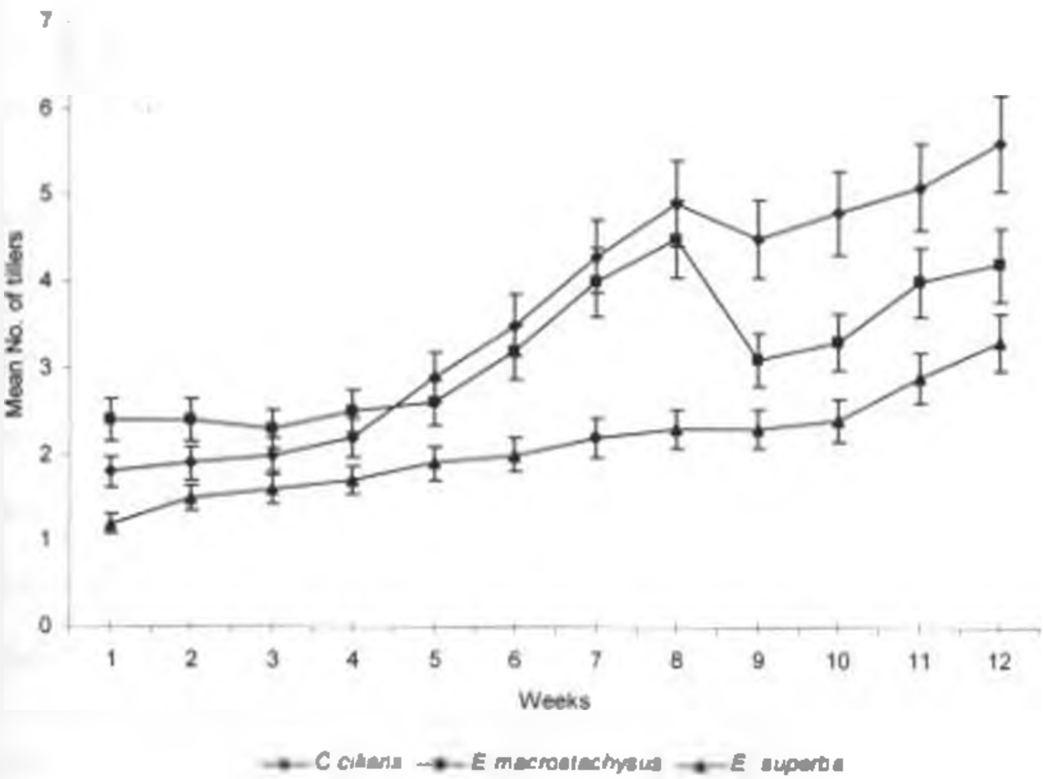

Figure 7.2: Mean number of tillers for three grass species in tractor-ploughed plots

Results of this present study concur with those of Langer (1963), Neuteboom and Lantinga (1989), Adams and Danckwerts (1993) which showed that when hard soil surface is opened-up by ploughing, grasses respond by producing a higher number of tillers than in compact soils. Langer (1963) working on the physiology of pasture growth in New Zealand argued that other than the genotype, seedbed preparation may explain in part the higher or lower number of tillers in species. Further, Neuteboom and Lantinga (1989) reported that due to environmental factors, tiller formation from leaf auxiliary buds could be delayed or suppressed entirely. Similarly, in an on-station experiment in the southern rangelands of Kenya, Njenga (1992) observed that *C. cliiaris*, *E. macrostachyus* and *E. superba* seedlings on hard soil surface plots had low number of tillers. Adams and Danckwerts (1993) advanced the argument that opened up soil surface produce more tillers with greater mass than hard soil surface.

In this study, *C. ciliaris* would be at an advantage than *E. macrostachyus* and *E. superba*. Further, large numbers of tillers and leaves produced by some grasses such as *P. maximum* and *Digitaria macroblephara* allow the grasses to attain a maximum growth rate at an earlier age and recover sooner after defoliation (Woie, 1986; Skerman and Riveros, 1990). Briske and Heitschmidt (1991) observed that tillers are formed from auxiliary buds of ontogenetically older parental phytomers at the nodes where leaves emerged.

Studies by Hacker (1989), Skerman and Riveros (1990) and Laidlaw (2005) showed that tillers are known to increases plant's chances of survival and amount of foliage cover. This concurs with the findings of this study, that grass species with highest number of tillers had also the highest percent foliage cover. Similarly, *E. superba* had the highest seedling mortality, lowest percent foliage and the least number of tillers. However, *E. macrostachyus* and *C. ciliaris* had relatively lower percent seedling mortality and higher number of tillers. The results suggest that seedling mortality may have some relation with number of tillers in a plant.

4.2.4 Effects of land treatment on number of leaves

Land treatment had a significant ($p<0.05$) effect on the mean number of leaves per plant shoot. The tractor-ploughed plots had significantly higher number of leaves per plant shoot than the hand-cleared plots (Table 5).

Figure 8.1 and 8.2 presents the mean number of leaves per shoot by the three grass species in the hand-cleared and tractor-ploughed plots respectively, observed for 12 weeks. It was observed that the three grass species growing in the tractor-ploughed plots had more leaves than the same species in the hand-cleared plots. In both land treatments, *C. ciliaris* had the highest number of leaves, followed by *E. macrostachyus* and the lowest was *E. superba*. Although *E. superba* was leafy for the first four weeks, with time it became stemmy, which could make it less palatable to most grazers.

Table 5: Mean number of leaves per shoot for three grass species in tractor-ploughed and hand-cleared plots

Experimental species	Tractor-ploughed	Hand-cleared
	----------Mean number of leaves per shoot ----------	
C. ciliaris	5.0 (1.2)^{a}	4.8 (1.1)^{a}
E. macrostachyus	4.6 (1.3)^{b}	4.1 (1.2)^{c}
E. superba	3.4 (1.2)^{c}	2.8 (1.2)^{d}

Figures followed by different letter superscripts in the same row, and those with different letter superscript in the same column are significantly different at $p<0.05$ as determined by LSD test values in parentheses () are standard deviation

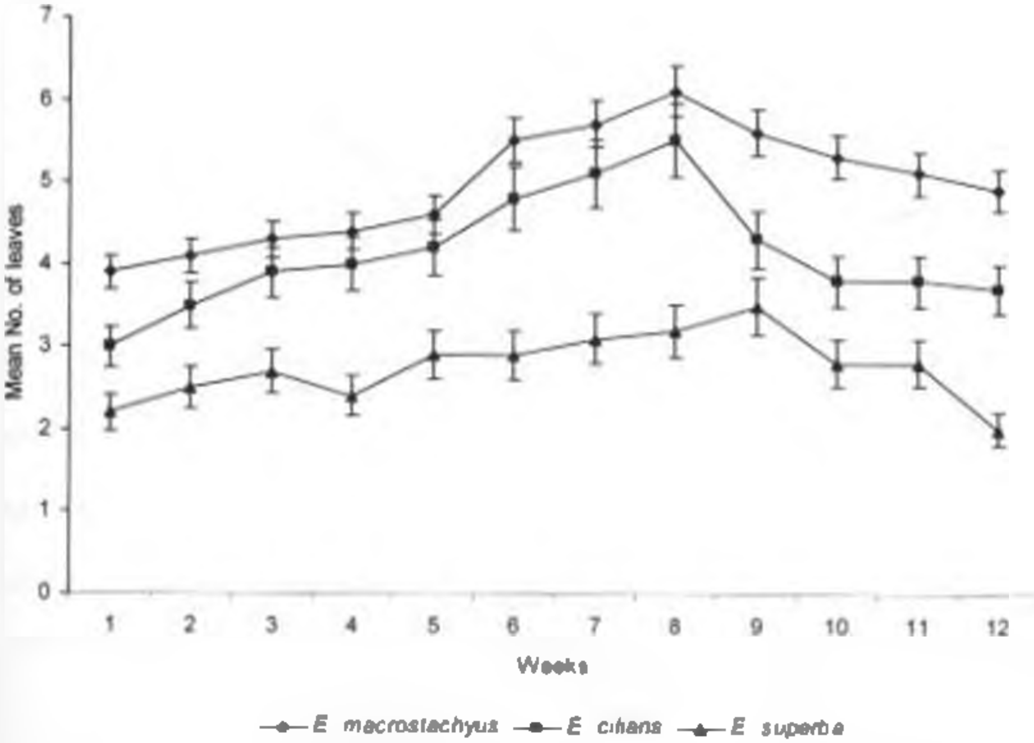

Figure 8.1: Mean number of leaves for three grass species in hand-cleared plots

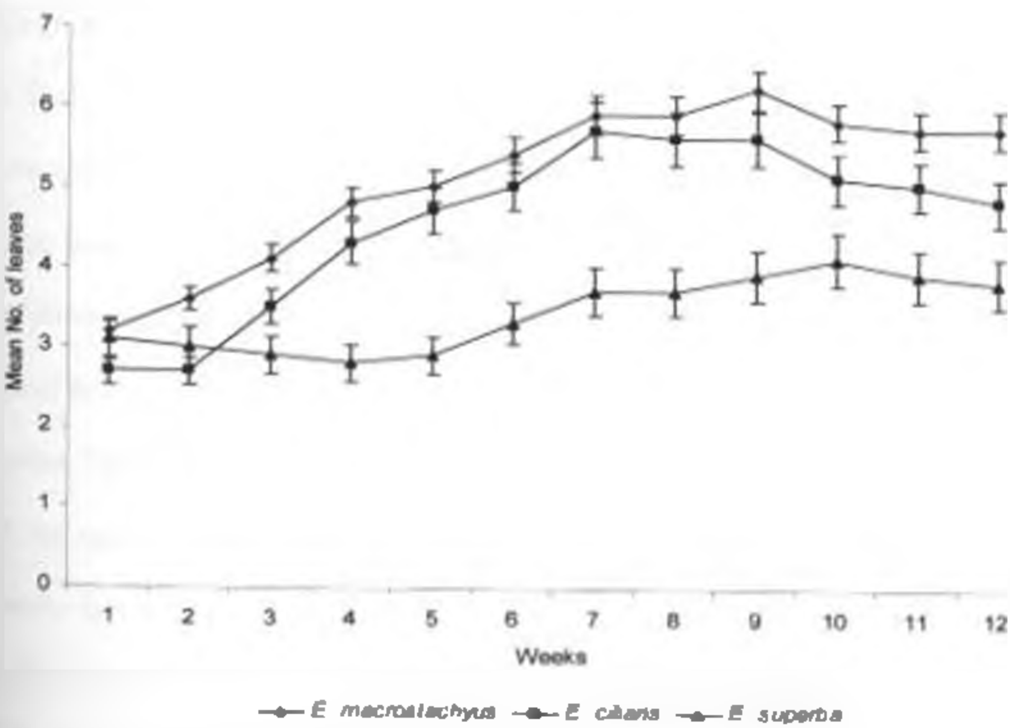

Figure 8.2: Mean number of leaves for three grass species in tractor-ploughed plots

The higher leaf numbers in the tractor-ploughed than in the hand-cleared plots may was attributed to the opening-up of the soil surface. It is likely that the opening-up of soil surface by ploughing enhanced plant roots penetration, placing roots in greater contact with scarce water held by soil particles. The findings concur with those of other studies (Woie, 1986; Hanselka *et al.*, 1992; Njenga, 1992) that some degree of opening-up the hard soil surface by ploughing is required for successful establishment of pastures. Njenga (1992) working in eastern rangelands of Makueni District, Kenya argued that other than the species type, favourable site conditions for seedling growth could explain in part the higher leaf number from the grass species. The results, further attest the observation by Taylor *et al* (1969) that plant leaf numbers is either high or low depending on the method of land tillage/preparation.

The high leaf numbers is an important criterion for agronomists since it indicates high growth rate. In addition, plants with high leaf numbers and more pigmentation are likely to achieve a greater photosynthetic capacity resulting in fast growth of plants (McNaughton, 1983; Briske, 1991; Nobel *et al.*, 1993). The leafy structure of plants, though suited for photosynthesis, is also conducive for a high water loss via transpiration (Pratt and Gwynne, 1977; Mnene, 2005). Leaves develop from nodes formed below the meristematic apices and normally continue progressively as tillers develop. The findings show that *C. ciliaris*, which had the highest number of leaves had the second highest number of tillers after *E. macrostachyus*. In contrasts, *E. superba* had the shortest plants and lowest number of tillers and leaves throughout the 12 weeks of observation. The study suggests that *E. superba* was not favored by both land treatments compared to *C. ciliaris* and *E. macrostachyus*.

4.2.5 Densities of annual grass weeds

Land treatment had a significant ($p<0.05$) effect on the density of annual grasses. Mean annual density was significantly higher in the tractor-ploughed than in the hand-cleared plots (Table 6). Tractor-ploughed plots had mean annuals density of 138 plants m^{-2}. The annuals included *Aristida* species, *Rottboelia exaltata* and *Tetrapogon tenellus* (Roxb), Chiov. The *Aristida* spp had the highest density of 80 plants m^{-2}, *R. exaltata* had 50 plants m^{-2} and *T. tenellus* had the least density of 8 plants m^{-2}.

The hand-cleared plots had a mean annuals density of 103 plants m^{-2}. The dominant species were *Aristida* species with a density of 66 plants m^{-2}. *R. exaltata* had a density of 35 plants m^{-2}, and *T. tenellus* had the lowest density of 3 plants m^{-2}. It was also observed that the density of annual species differs significantly ($p < 0.05$) within the treatment plots.

Table 6: Density of volunteer annuals grasses (plants m^{-2}) under two land treatments

Land treatment	*Rottboelia exaltata*	*Aristida* species	*Tetrapogon tenellus*	Mean density
Tractor-ploughed	50	80	8	138^{a}
Hand-cleared	35	66	3	103^{b}
$LSD_{0.05}$				0.015

Means followed by different letter superscripts in the same column are significantly different at $p<0.05$ as determined by LSD test

The higher mean annual weed density in the tractor-ploughed than in the hand-cleared plots may be attributed to the opening-up of the hard soil surface by tractor-ploughing. Opening-up the hard soil surface may have promoted faster growth of these annual species. Although not investigated, increased capture of scarce water in the soil may also explain, in part, the higher annual species in the tractor-ploughed plots than in the hand-cleared plots. It was also argued that the removal of previously existing plant vegetations by ploughing might have reduced competition in the plots thereby enhancing the growth of annuals. Despite the high density of *Aristida* species, *R. exaltata* and *T. tenellus*, tractor-ploughed plots had the best performing species in terms of seedling survival, foliage cover, plants height, tillers and leaves number.

The results concur with previous research studies of Njenga (1992) who reported that land treatment had a significant effect on the density of annuals grasses. In contrast to this study finding, other researchers have demonstrated that opening-up the hard soil surface do not affect annual weed density (Mott, 1982; Renner and Woods, 1999). Renner and Woods (1999) observed that the difference in annual species density between the tractor-ploughed and non-ploughed plots was due to other factors such as moisture levels modified by the prevailing weather conditions rather than land treatment effect.

4.2.6 Effects of land treatment on aboveground biomass production

Table 7 presents aboveground biomass of the three grasses harvested from the two land treatment plots. There was significantly higher ($p>0.05$) grass aboveground biomass in the tractor-ploughed than in the hand-cleared plots. Although the tiller and leaf numbers of *C. ciliaris* were far above those of *E. macrostachyus* and *E. superba*, its aboveground biomass was significantly lower than that of *E. macrostachyus*. The results show that grass species depicted significant differences within each land treatment. In both treatments, *E. macrostachyus* had the highest mean biomass production, followed by *C. ciliaris* while *E. superba* had the lowest.

Table 7: Aboveground biomass production (Kg ha^{-1}) of three grasses in tractor-ploughed and hand-cleared plots harvested 12 weeks after planting

Species	Tractor-ploughed	Hand-cleared
	----Kg per ha----	
E. macrostachyus	4,908.5[a]	3,682.5[b]
C. ciliaris	3,734.0[b]	2,213.0[c]
E. superba	2,434.5[c]	1,899.5[d]

Means followed by different letter superscripts in the same row, and those with different letter superscripts in the same column are significantly different at $p<0.05$ as determined by LSD test

The relatively higher grass biomass production in the tractor-ploughed may be attributed to the opening-up of the hard soil surface. The opening-up of the hard soil surface most likely allow roots to penetrate deeply and extensively, placing roots in greater contact with water and nutrients held by soil particles. It is likely that the elongation of the plant roots into the soil eventually resulted into better plant growth and subsequently high biomass. Hanselka *et al.* (1992) working in the south Texas rangeland reported that yield of buffel grass increased by 100 percent in the disc-ploughed plots compared to the non-ploughed plots. They attributed this to the ability of the plough to remove hard surface soil and reduce the weeds to a manageable level in the ploughed than in the non-ploughed plots. Too (1995) while over-sowing with perennial native grasses in order to increase primary productivity of different range sites at Kiboko had to scratch the soil. The study showed positive results of reseeding and this has been demonstrated in other studies elsewhere (Mott et al., 1976; Cook and Dolby, 1981). The findings of this study suggest that hard soil surface for reseeding should be avoided, as they may have a negative effect on grass establishment.

The results showed that aboveground biomass production of the three grass species used were statistically different. This is comparable to the results of Chileshe and Kitalyi (2002) who reported that these grass species have different aboveground biomass yields. According to this present study, the aboveground biomass yield of *E. macrostachyus* was significantly higher than those of *C. ciliaris* and *E. superba*. That of *C.ciliaris* was significantly higher than that of *E. superba*. This confirms what Taylor *et al.* (1969). Reichenberger and Pyke (1990) earlier observed that rangeland grasses are known to yield various quantity of fodder depending on the prevailing environmental conditions.

Based on the aboveground biomass results, it was argued that the prevailing weather conditions, especially the short rains during the months of October to December created conducive microclimate for pasture establishments in the two land treatment plots. However, the study suggests that a land treatment method that opens-up or scratch the hard soil surface should be encouraged when regenerating sites by direct reseeding, especially on hard soil surface of the rangelands. The findings further suggest that opening-up the hard soil surface is effective to the species growth and yield in the eastern rangelands. In addition, opening-up the hard soil surface should be indispensable in order to promote the growth of plants in the degraded sites. The use of readily available land treatment methods such as ox-plough to scratch the soil is more advisable in the rangelands.

This study suggest that if the three grass species were to be sown at a seeding rate of 100 grams m^{-2} in the two land treatments, with an expectation of higher biomass yield, then scratch ploughing is a good land management alternative method for pasture improvement. An economic analysis follows in the subsequent section to test for economic viability of the range reseeding methods used.

4.3 COSTS AND RETURNS FROM RANGE RESEEDING

Two range reseeding methods (tractor-ploughing and hand-clearing) used and data on inputs required and costs of reseeding in this investment projects are presented in Table 8. The direct costs of range reseeding for the two investments which included the costs of clearing the plots, planting, fencing, harvesting, seeds, seed transportation, tractor hire, repairs and costs of tools were estimated at Ksh 23,525 and 19,565 in the tractor-ploughed and hand-cleared investments respectively. Indirect costs included risk cost of seeding failure at 20% (see Vallentine, 1980) and interest on direct costs at a lending rate of 16.6% (World Bank, 2005). The total initial investment costs in the tractor-ploughed and hand-cleared investments were Ksh 32,135 and 26,726, respectively.

The computations in Table 9 were based on a 20-year project life for the tractor-ploughed and hand-cleared investments. The additional annual costs were estimated at Ksh 8,212 and 6,900 in the tractor-ploughed and hand-cleared investments respectively. The annual returns from the hypothetical sale of hay were determined based on the aboveground biomass harvested from reseeded plots.

Table 8: Summary of input requirements and costs of reseeding a hectare of land

Item	Unit cost (Ksh)	Cost of tractor-ploughing (Ksh)	Cost of hand-clearing (Ksh)
Direct costs			
Man-days, average ha^{-1}			
Clearing (4 men)	@135	0	540
Planting (1 man)	@135	135	135
Fencing (6 men for 1 day)	@135	810	810
Harvesting (4 men for 2 days)	@135	1,080	1,080
Costs ha^{-1}			
Seeds (1,000 kg)	@10	10,000	10,000
Seeds transportation		6,000	6,000
Tractor hire (1 ha)	@ 4500	4,500	0
Repairs (1 ha)	@ 1,000	1,000	0
Machete (4)	@ 250	0	1,000
Sub-total		23,525	19,565
Indirect costs			
[1]Risk of failure		4,705	3,913
[2]Interest on direct costs		3,905	3,248
Sub-total		8,610	7,161
Total costs		32,135	26,726

[1]Risk of failure was 20% of initial investment costs, as used by Vallentine (1980) under similar conditions

[2] Interest is based on lending rate of 16.6% charged by commercial banks in 2003 on real estate loans (World Bank, 2005)

The results showed that *E. macrostachyus* had more returns in both range reseeding investments than *C. ciliaris* and *E. superba* in the same reseeding investment. In addition, reseeding an area using *E. macrostachyus, C. ciliaris* and *E. superba* for biomass was economically feasible. NPV indicates that all the grass species yield a net profit. B/C ratio reveals that each Ksh 1 invested produces more that Ksh 1, and IRR shows that all species yield an annually compounded rate of interest greater than the 16.6% cost of borrowing and the opportunity cost. Therefore, for rare situations where capital is unlimited, the farmer can invest in both methods using *E. macrostachyus, C. ciliaris* and *E. superba*. But in virtually all management situations, capital is limited and an optimum combination of investments that maximise NPV while staying within the limited budget should be selected. Thus, *E. superba* is the least cost-effective grass species for reseeding because it had the least NPV, and the B/C ratio was only slightly above one.

Table 9: Comparison of two range reseeding investments using benefit-cost ratio and internal rate of return methods for three grass species

Item	Project	
	Tractor-ploughed	Hand-cleared
Project life (years)	20	20
Initial cost of reseeding (Ksh)	32,135	26,726
Additional annual cost (using costs)[1]	8,212	6,900
E. macrostachyus		
Total annual return (Ksh)[2]	29,460	22,110
Net (additional) annual income (Ksh)	21,248	15,210
NPV at 16.6% discount rate	983.7	704.2
B/C at 16.6% discount rate	3.5	3.2
IRR (%)	51	50
C. ciliaris		
Total annual return (Ksh)[2]	22,410	13,290
Net (additional) annual income (Ksh)	14,198	6,390
NPV at 16.6% discount rate	657.3	295.8
B/C at 16.6% discount rate	2.7	1.9
IRR (%)	44	24
E. superba		
Total annual return (Ksh)[2]	14,610	11,400
Net (additional) annual income (Ksh)	6,398	4,500
NPV at 16.6% discount rate	296.2	208.3
B/C at 16.6% discount rate	1.8	1.7
IRR (%)	19	17

[1]Additional annual costs include additional fence maintenance, biomass harvesting and risk of failure (20%) of total annual return

[2]A bale of hay weighs 50 kg valued at a prevailing local market price of Ksh 150 bale^{-1} (personal observation)

From the results, an average return of Ksh 22,160 and 15,600 could be fetched from a hectare of land in the area using the three grass species (Table 9). The estimated net annual income was Ksh 13,948 in the tractor-ploughed and Ksh 8,700 in the hand-cleared investments. For the tractor-ploughed investment, the present value of an annual net return of Ksh 13,948 for 20 years was Ksh 645.70. Similarly, the calculated NPV in the hand-cleared investment was Ksh 402.80 within the same economic life of the project. As shown in Table 10, by the standard calculation method both range reseeding investments appear economically feasible based on both B/C ratio and IRR criteria. The B/C ratio reveals that each Ksh 1 invested produces more than Ksh 1 in return, and IRR shows that both investments yield an annually compounded rate of interest greater than the 16.6% cost of borrowing from the commercial banks in Kenya.

Table 10: Average returns for three grass species using benefit-cost ratio and internal rate of return methods for comparing two range reseeding investments

Species	Project	
	Tractor-ploughed	Hand-cleared
Average annual return (Ksh)[1]	22,160	15,600
Net (additional) annual income (Ksh)	13,948	8,700
NPV at 16.6% discount rate	645.7	402.8
B/C at 16.6% discount rate	2.7	2.3
IRR (%)	43	32

[1]Average annual return from hypothetical sale of hay from the three grass species

The results confirm what many range managers (Pingrey and Dortignac, 1959; Neilsen, 1967; Sneva, 1970; Godfrey, 1979) have come to realize; that range reseedings are economically feasible projects based on B/C ratio and IRR. The computations demonstrated that both range reseeding investments are feasible and profitable. Therefore, the null hypothesis that tractor-ploughing and hand-clearing are not economically viable as land treatment methods for range reseeding is rejected. It was verified that opening-up surface soil by tractor-ploughing, and preparing the plots by hand-clearing are both economically viable investments for pasture production in the eastern rangelands of Kenya.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The results of this study have significant implication for dryland rehabilitation. In general, seed viability of *C. ciliaris* was greater than that of *E. macrostachyus*. However, *E. macrostachyus* had percent seed germination value intermediate between *C. ciliaris* and *E. superba*. These differences were attributed to the intrinsic properties of the grass seeds such as dormancy and tegumental hardness. To ensure successful reseeding in these ecosystems, it was necessary to determine whether the grass seeds ware viable for range rehabilitation.

This study shows that morphometric characters are affected by the land treatment methods used. Seedling survival was higher in the opened-up surface soil than in the hard surface soil. Despite the sprouting of annual grasses, the reseeded species in the opened-up surface soil plots had higher foliage cover, taller plants, and higher number of tillers and leaves than those in the hand-cleared plots. Opening-up the surface soil by tractor-ploughing therefore produced better results than hand clearing the plots with machette. It is likely that tractor-ploughing modified soil structure, thereby increasing capture of scarce rainfall water by the soil. In contrast, plants in the hand-cleared plots were found to have lower performance in terms of morphometric characters than those in the tractor-ploughed plots. This was attributed to the failure of the hard surface soil to capture the scarce water for plant proper establishment.

The grass species responses to both land treatments were significantly different as exhibited by differences in their morphometric characters. This implies therefore that, the three species have different potentials in pasture establishment as dictated by their genetic constitution. For example, *E. macrostachyus* produced taller plants, which had more tillers, higher number of leaves and high percent seedling survival than the rest regardless of the land treatment methods. This may have been a survival strategy and a fitness-enhancing mechanism of the specie in the ASALs. Of the three species tested, *E. macrostachyus* showed better performance in terms of pasture production in the area than *C. ciliaris*, which nevertheless produced more aboveground biomass than *E. superba*.

An economic analysis showed that both reseeding investment methods when properly done are profitable for reintroducing these grasses for pasture production. Computations based on the internal rate of return and benefit-cost ratio derived from the hypothetical sale of hay revealed that a net annual profit of about 26.4% and 15.4% could be obtained from the tractor-ploughed and hand-cleared investments, respectively. If the investment projects are mutually exclusive and the manager's goal is to maximize profit, then opening-up the soil surface would be the most preferred reseeding investment than hand-clearing method. However, the use of *E. macrostachyus*, *C. ciliaris* and *E. superba* on either hand-cleared or tractor-ploughed methods are economically feasible alternatives for pasture production in the area. Nonetheless, opening the soil surface by tractor-ploughing is a relatively costly approach, which the agro-pastoral communities find easier to substitute with ox-plough, especially where the slope is gentle.

5.2 RECOMMENDATIONS

The findings of this study only act as a pointer on the expected performance, and establishment of pasture grasses in the eastern rangelands of Kenya. In this study, besides the study period being very short, the study use only one site, and was not replicated in different ecological environments. Such studies require long-term monitoring of the reseeded plots for comprehensive conclusions and recommendations to be made. In addition, it is recommended that, a study covering more than two seasons be carried out, as this would yield more information on the morphometric characters of the grass species under the two land treatment methods. However, results obtained can be compared with those of other studies within the East African rangelands.

Generally, using adapted land treatment methods such as pitting and ox-plough instead of tractors is advisable for opening-up hard soil surface. This is because most agro-pastoral communities find it easier to open-up soil surface to increase capture of scarce rainfall water by the soil for reseeding with ox-plough, which is a relatively affordable approach. Other potential species such as *Digitaria macroblephara, Cynodon dactylon, Chloris roxburghiana* and *Themeda triandra* should also be studied under different land treatment methods so as to increase knowledge of the plant resources which may be used to boost forage production and halt degradation in the rangelands.

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APPENDICES

Appendix Table 1.1: ANOVA of mean daily seed germination of three grass species for seed viability test in the laboratory

Source	df	Mean Square	F Value	Sig.
Species	2	602.642	33.446*	< 0.05
Error	32	18.018		
Total	50			

*Significant at $p<0.05$

Appendix Table 2.1: ANOVA of mean mortality *of E. macrostachyus* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	5.833E-02	5.527*	.019
Error	838	1.056E-02		
Total	840			

*Significant at $p<0.05$

Appendix Table 2.2: ANOVA of mean mortality of *C. ciliaris* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	.344	11.180	.001
Error	838	3.077E-02		
Total	840			

*Significant at $p<0.05$

Appendix Table 2.3: ANOVA of mean mortality of *E. superba* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	9.011	59.373*	<0.05
Error	838	.152		
Total	840			

*Significant at $p<0.05$

Appendix Table 3.1: ANOVA of mean plant height of *E. macrostachyus* in the land treatment plots

Source	df	Mean Square	F Value	Sig
Land treatment	1	28411.974	211.377*	<0.05
Error	816	134.414		
Total	840			

*Significant at $p<0.05$

Appendix Table 3.2: ANOVA of mean plant height of *C. ciliaris* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	2132.071	87.771*	<0.05
Error	816	24.291		
Total	840			

*Significant at p<0.05

Appendix Table 3.3: ANOVA of mean plant height of *E. superba* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	1417.911	59.952*	<0.05
Error	816	23.651		
Total	840			

*Significant at p<0.05

Appendix Table 4.1: ANOVA of tiller numbers of *E. macrostachyus* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	197.003	69.511*	<0.05
Error	814	2.834		
Total	838			

*Significant at p<0.05

Appendix Table 4.2: ANOVA of tiller numbers of C. ciliaris in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	36.852	25.008*	<0.05
Error	813	1.474		
Total	837			

R Squared = .529

Appendix Table 4.3: ANOVA of tiller numbers of *E. superba* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	93.333	160.947*	<0.05
Error	816	.580		
Total	840			

*Significant at p<0.05

Appendix Table 5.1: ANOVA of leaves number of *E. macrostachyus* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	28302.831	210.059*	<0.05
Error	814	1.426		
Total	838			

*Significant at p< 0.05

Appendix Table 5.2: ANOVA of leaves number of *C. ciliaris* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	5.442	3.679*	<0.05
Error	813	1.479		
Total	837			

*Significant at p< 0.05

Appendix Table 5.3: ANOVA of leaves number of *E. superba* in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	112.933	69.110*	<0.05
Error	816	1.634		
Total	840			

*Significant at p< 0.05

Appendix Table 6.1: ANOVA table showing F values for volunteer annual weeds and their significance in the two land treatments

Source	df	Mean Square	F Value	Sig.
Land treatment	1	171.735	0.153*	0.015
Error	4	1121.018		
Total	5			

*Significant at p< 0.05

Appendix Table 7.1: Mean % foliage cover of the three grasses used for reseeding in the hand-cleared plots

Sampling number	*C. ciliaris*	*E. macrostachyus*	*E. superba*
1	21.4	16.2	6.4
2	41.4	24.0	10.4
Mean	31.4	20.1	8.4

Appendix Table 7.2: Mean % foliage cover of the three grasses used for reseeding in the tractor-ploughed plots

Sampling number	*C. ciliaris*	*E. macrostachyus*	*E. superba*
1	61.3	31.0	11.4
2	70.3	61.4	30.2
Mean	65.8	46.2	20.8

Appendix Table 8.1: ANOVA of aboveground biomass production in the land treatment plots

Source	df	Mean Square	F Value	Sig.
Land treatment	1	1051.906	2.887*	<0.05
Error	100	364.379		
Total	106			

*Significant at $p < 0.05$

Appendix Table 9.1: Compounding and Discounting Tables

PRESENT WORTH OF AN ANNUITY FACTORS

How much 1 received or paid annually for X years is worth today

YEAR	1%	3%	5%	6%	8%	10%	12%	14%	15%	16%	18%	20%	25%	26%	28%	30%	35%	40%	45%	50%	YEAR
2	1.9704	1.9135	1.8594	1.8334	1.7833	1.7355	1.6901	1.6467	1.6257	1.6052	1.5656	1.5278	1.44	1.424	1.392	1.3609	1.2894	1.2245	1.165	1.111	2
3	2.941	2.8286	2.7232	2.673	2.5771	2.4869	2.4018	2.3216	2.2832	2.2459	2.1743	2.1065	1.952	1.923	1.868	1.8161	1.6959	1.5889	1.493	1.407	3
4	3.902	3.7171	3.546	3.4651	3.3121	3.1699	3.0373	2.9137	2.855	2.7982	2.6901	2.5887	2.3616	2.320	2.241	2.1662	1.9969	1.8492	1.720	1.605	4
5	4.8534	4.5797	4.3295	4.2124	3.9927	3.7908	3.6048	3.4331	3.3522	3.2743	3.1272	2.9906	2.6893	2.635	2.532	2.4356	2.22	2.0352	1.876	1.737	5
6	5.7955	5.4172	5.0757	4.9173	4.6229	4.3553	4.1114	3.8887	3.7845	3.6847	3.4976	3.3255	2.9514	2.885	2.759	2.6427	2.3852	2.168	1.983	1.824	6
7	6.7282	6.2303	5.7864	5.5824	5.2064	4.8684	4.5638	4.2883	4.1604	4.0386	3.8115	3.6046	3.1611	3.083	2.937	2.8021	2.5075	2.2628	2.057	1.883	7
8	7.6517	7.0197	6.4632	6.2098	5.7466	5.3349	4.9676	4.6389	4.4873	4.3436	4.0776	3.8372	3.3289	3.241	3.076	2.9247	2.5982	2.3306	2.108	1.922	8
9	8.566	7.7861	7.1078	6.8017	6.2469	5.759	5.3282	4.9464	4.7716	4.6065	4.303	4.031	3.4631	3.366	3.184	3.019	2.6653	2.379	2.144	1.948	9
10	9.4713	8.5302	7.7217	7.3601	6.7101	6.1446	5.6502	5.2161	5.0188	4.8332	4.4941	4.1925	3.5705	3.465	3.269	3.0915	2.715	2.4136	2.168	1.965	10
11	10.3676	9.2526	8.3064	7.8869	7.139	6.4951	5.9377	5.4527	5.2337	5.0286	4.656	4.3271	3.6564	3.543	3.335	3.1473	2.7519	2.4383	2.185	1.977	11
12	11.2551	9.954	8.8633	8.3838	7.5361	6.8137	6.1944	5.6603	5.4206	5.1971	4.7932	4.4392	3.7251	3.606	3.387	3.1903	2.7792	2.4559	2.196	1.985	12
13	12.1337	10.635	9.3936	8.8527	7.9038	7.1034	6.4235	5.8424	5.5831	5.3423	4.9095	4.5327	3.7801	3.656	3.427	3.2233	2.7994	2.4685	2.204	1.990	13
14	13.0037	11.2961	9.8986	9.295	8.2442	7.3667	6.6282	6.0021	5.7245	5.4675	5.0081	4.6106	3.8241	3.695	3.459	3.2487	2.8144	2.4775	2.210	1.993	14
15	13.8651	11.9379	10.3797	9.7122	8.5595	7.6061	6.8109	6.1422	5.8474	5.5755	5.0916	4.6755	3.8593	3.726	3.483	3.2682	2.8255	2.4839	2.214	1.995	15
16	14.7179	12.5611	10.8378	10.1059	8.8514	7.8237	6.974	6.2651	5.9542	5.6685	5.1624	4.7296	3.8874	3.751	3.503	3.2832	2.8337	2.4885	2.216	1.997	16
17	15.5623	13.1661	11.2741	10.4773	9.1216	8.0216	7.1196	6.3729	6.0472	5.7487	5.2223	4.7746	3.9099	3.771	3.518	3.2948	2.8398	2.4918	2.218	1.998	17
18	16.3983	13.7535	11.6896	10.8276	9.3719	8.2014	7.2497	6.4674	6.128	5.8178	5.2732	4.8122	3.9279	3.786	3.529	3.3037	2.8443	2.4941	2.219	1.999	18
19	17.226	14.3238	12.0853	11.1581	9.6036	8.3649	7.3658	6.5504	6.1982	5.8775	5.3162	4.8435	3.9424	3.799	3.539	3.3105	2.8476	2.4958	2.220	1.999	19
20	18.0456	14.8775	12.4622	11.4699	9.8181	8.5136	7.4694	6.6231	6.2593	5.9288	5.3527	4.8696	3.9539	3.808	3.546	3.3158	2.8501	2.497	2.221	1.999	20
21	18.857	15.415	12.8212	11.7641	10.0168	8.6487	7.562	6.687	6.3125	5.9731	5.3837	4.8913	3.9631	3.816	3.551	3.3198	2.8519	2.4979	2.221	2.000	21
22	19.6604	15.9369	13.163	12.0416	10.2007	8.7715	7.6446	6.7429	6.3587	6.0113	5.4099	4.9094	3.9705	3.822	3.556	3.323	2.8533	2.4985	2.222	2.000	22
23	20.4558	16.4436	13.4886	12.3034	10.3711	8.8832	7.7184	6.7921	6.3988	6.0442	5.4321	4.9245	3.9764	3.827	3.559	3.3254	2.8543	2.4989	2.222	2.000	23
24	21.2434	16.9355	13.7986	12.5504	10.5288	8.9847	7.7843	6.8351	6.4338	6.0726	5.4509	4.9371	3.9811	3.831	3.562	3.3272	2.855	2.4992	2.222	2.000	24
25	22.0232	17.4131	14.0939	12.7834	10.6748	9.077	7.8431	6.8729	6.4641	6.0971	5.4669	4.9476	3.9849	3.834	3.564	3.3286	2.8556	2.4994	2.222	2.000	25
30	25.8077	19.6004	15.3725	13.7648	11.2578	9.4269	8.0552	7.0027	6.566	6.1772	5.5168	4.9789	3.995	3.842	3.569	3.3321	2.8568	2.4999	2.222	2.000	30
40	32.8347	23.1148	17.1591	15.0463	11.9246	9.7791	8.2438	7.105	6.6418	6.2335	5.5482	4.9966	3.9995	3.846	3.571	3.3332	2.8571	2.5	2.221	2.000	40
50	39.1961	25.7298	18.2559	15.7619	12.2335	9.9148	8.3045	7.1327	6.6605	6.2463	5.5541	4.9995	3.9999	3.846	3.571	3.3333	2.8571	2.5	2.221	2.000	50

Source: Gittinger (1973, pp. 104-09)