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Full Length Research Paper

The challenges of rehabilitating denuded patches of a semi-arid environment in Kenya

Kevin Z. Mganga[1]*, Moses M. Nyangito[1], Nashon K. R. Musimba[1], Dickson M. Nyariki[1], Agnes W. Mwangombe[2], Wellington N. Ekaya[3], William M. Muiru[2], Daniele Clavel[4], Judith Francis[5], Ralph von Kaufmann[6] and Jan Verhagen[7]

[1]Department of Land Resource Management and Agricultural Technology University of Nairobi, P. O. Box 29053-00625, Nairobi, Kenya
[2]Department of Plant Science and Crop Protection, University of Nairobi, Kenya.
[3]RUFORUM, Uganda.
[4]CIRAD, France.
[5]CTA, Netherlands.
[6]FARA
[7]Wagengen University, Netherlands.

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Land degradation is a major problem in the semi-arid environments of Sub-Saharan Africa. Fighting land degradation is essential to ensure the sustainable and long-term productivity of the habited semi-arid lands. In Kenya, grass reseeding technology has been used to combat land degradation. However, despite the use of locally adapted perennial grass species namely *Cenchrus ciliaris* (African foxtail grass), *Eragrostis superba* (Maasai love grass) and *Enteropogon macrostachyus* (Bush rye) failure still abound. Therefore, more land is still being degraded. The aim of this study was to determine the main factors which contribute to failures in rehabilitating denuded patches in semi-arid lands of Kenya. A questionnaire was administered to capture farmer perceptions on failures on rangeland rehabilitation using grass reseeding technology. Rainfall data was collected during the study period. Moreover, rehabilitation trials using the three grasses were done under natural rainfall. Results from this study show that climatic factors mainly low amounts of rainfall to be the main contributor to rehabilitation failures. 92% of the respondents asserted that reseeding fails because of low rainfall amounts received in the area. The study area received a total of 324 mm of rainfall which was low compared to the average annual mean of 600mm. Reseeded trial plots also failed to establish due to the low amounts of rainfall received. This showed how low rainfall is unreliable for reseeding. Other factors namely destruction by the grazing animals, pests and rodents, flush floods, poor sowing time, poor seed quality, lack of enough seed and weeds also contribute to rehabilitation failures in semi-arid lands of Kenya.

Key words: Land degradation, grass reseeding, rehabilitation failures, low rainfall.

INTRODUCTION

Land degradation is a global problem facing us today. The United Nations Convention to Combat Desertification (UNCCD, 2003) defines desertification as a process of land degradation in the arid, semi-arid and dry sub-humid areas, resulting from various factors including both climatic variation and change in human activities. Land degradation manifests in forms of impoverishment and depletion of vegetative cover, loss of biological and economic productivity, wind and water erosion, salinization and deterioration of physical, chemical and biological soil properties. The drylands of the world, comprising the hyper-arid, arid, and semi-arid regions with annual

*Corresponding author. E-mail: kzowe@yahoo.com.

Table 1. Agro-climatic zones of Kenya, excluding areas above 3000m altitude (Biamah, 2005).

Zone	R/E_o* (%)	Classification	R (mm)	E_o (mm)
I	> 80	Humid	1100 - 2700	1200 - 2000
II	65-80	Sub-humid	1000 - 1600	1300 - 2100
III	50-65	Semi-humid	800 - 1400	1450 - 2200
IV	40-50	S.humid - S.arid	600 - 1100	1500 - 2200
V	25-40	Semi-arid	450 - 900	1650 - 2300
VI	15-25	Arid	300 - 560	1900 - 2400
VII	< 15	Very arid	150 - 350	2100 - 2500

Notes: * R – Average rainfall; E_o- Average annual evaporation.

moisture deficits greater than 50% are considered the most threatened by land degradation.

These drylands are estimated to cover 47% of the earth's surface (GEF/IFAD, 2002). In these areas, land degradation of which desert encroachment is only a small part is widespread and thus very important.

The semi-arid to weakly arid areas of Africa are particularly vulnerable as they have fragile soils, localized high population densities and generally a low input form of agriculture. Degradation is evident in a decline in soil productivity, loss of biodiversity and increasing rate of soil erosion (Beukes and Cowling, 2003; van den Berg and Kellner, 2005; Visser et al., 2007). Africa is particularly threatened because the land degradation process affects about 46% of the land surface area of the continent (WMO, 2005). It has been estimated that approximately 30-40% of Kenya's arid and semi-arid lands are quickly degrading and that another 2% has completely been lost through this process (Keya, 1991). In Kenya, high rates of soil loss of up to 50 tonnes per hectare per year from degraded grazing lands in semi arid areas are common (Nyangito et al., 2009). According to Graetz and Tongway (1986) grazing contributes about 34.5% of the total soil degradation. High rates of degradation can partly be attributed to the nature of the soils in the arid and semi-arid lands of Kenya. The main problems associated with these soils are high levels of salinity and sodicity, poor drainage, soil erosion, soil compaction, soil crusting and low fertility. Surface crusting properties are enhanced by rainfall of high intensity and short duration that is common in semi-arid areas (Biamah, 2005). The problem of land degradation is difficult to grasp in its totality. The use of indicators of degradation is more appropriate in trying to understand the land degradation problem. Indicators are variables and only show that land degradation has taken place. According to the United States Climate Change Technology Program, USCCTP (2005), the indicators of land degradation include poor soil cover, dominance of undesirable plant species, low soil quality, or in the extreme, erosion of top soil. According to Snel and Bot (2005), the indicators of land degradation can be grouped into three broad categories; biophysical indicators (degradation of soil, water and vegetation cover), socio-economic indicators (poverty and food insecurity) and institutional indicators (failures in the public/government, private/market, civil/community sectors and civil strife).

The problem of land degradation can partly be reversed through revegetation. Grass reseeding technology has been used successfully as a means of rehabilitating degraded rangelands in East Africa (Jordan, 1957; Bogdan and Pratt, 1967; Musimba et al., 2004). Despite the widespread success of grass reseeding technologies in combating land degradation in the semi-arid environment of East Africa, failure still abounds. The aim of this study was to determine the main factors which contributing to rehabilitation failures using grass reseeding technology in a semi-arid environment in south eastern Kenya.

MATERIALS AND METHODS

Study area

This study was carried out in the semi-arid district of Kibwezi of Kenya located about 200 km southeast of the capital city Nairobi, along the Nairobi-Mombasa highway. The Kamba agropastoralists are the main ethnic inhabitants in the study area (Nyangito et al. 2009). The district lies between the latitudes 2º 6¹ S and 3ºS, and longitude 37º36¹ E and 38º30¹E, respectively and has a total area of 3400 km² (CBS, 2000). The most dominant soils in the semi-arid area are Luvisols, Lixisols, Acrisols, Alisols, Ferralsols, Planosols, Solonchaks, Solonetz, Vertisols and Fluvisols (Biamah, 2005). These semi-arid soils are considered problematic because of their physico-chemical properties limit that their use for agriculture (Biamah, 2005). They generally have low organic matter content and an unstable structure.

The climate is typical semi-arid and the district is representative of many other zones with similar ecological conditions throughout Kenya, characterized by low and unreliable supply of soil moisture for plant growth. The semi-arid lands of Kenya occupy approximately 30% of the total land area and are classified into two agro-climatic zones (ACZ), IV and V, on the basis of the ratio of rainfall to open water evaporation (R/Eo) (Table 1) (Biamah, 2005). These areas have average annual rainfall, evaporation and temperatures of 600, 2000 mm and 23°C respectively (Michieka and van der Pouw, 1977; Braunn, 1977). Rainfall comes in high intensities and is usually concentrated at the beginning of the long or short rains. The natural vegetation in the area is woodland and savanna, with several tree species, mainly *Acacia* sp (A) such as *Acacia tortilis* (Forsk) Hayne and *Acacia mellifera* (Vahl) Benth, *Commiphora africana* (A. Rich) Engl, *Adansonia digitata* Linn and *Tamarindus indica* L. Shrubs include *Apis mellifera, Apis senegal* (L) willd and *Grewia* spp. (Nyangito et al., 2009). Perennial grasses such as *Cenchrus ciliaris, Enteropogon macrostachyus* and *Chloris roxburghiana* can dominate but many succumb to continuous abuse over long periods. *Eragrostis superba* is also commonly found in the district (Musimba et al. 2004).

Seed viability estimation in the laboratory

Seed viability of perennial grasses commonly used for reseeding was estimated. Viability tests of freshly harvested and two year old seeds were determined as described by Tarawali et al. (1995). Random samples of 100 seeds of each set of the three grass species used; *Cenchrus ciliaris, Enteropogon macrostachyus* and *Eragrostis superba* were put on wet Whitman filter paper in a Petri dish. The Petri dishes were then placed at room temperature (30℃) in the study area. The seeds were monitored for a period of 14 days. All germinated seeds were expressed as a percentage of total number of seeds at the end of this period. Seeds which did not germinate within this period were dimmed dormant.

Site preparation and experimental design of reseeded plots

Land preparation involved the creation of micro-catchments. The micro-catchments were done using an ox-driven plough in rows across the slope. Each micro-catchment measured approximately 15cm deep. Spacing between micro-catchments was 30 cm. The micro-catchments were created to promote better germination of seeds and establishment of seedlings (van der Merwe and Kellner, 1999; Snyman, 2003; Visser et al., 2007). Slope (%) was estimated using the dumpy level and stuff method (Mnene, 2006) and was found to be 1.5% (range 0.00 - 2.11).

The plots were arranged in a Complete Block Design (CBD). Three blocks measuring 15 x 10 m were demarcated in the site. Fencing was done using locally available *Acacia* branches and *Commiphora* poles to keep of grazers from trampling over the grass seedlings, with a buffer zone of 3m around the perimeter as recommended by Ekaya et al. (2001) to minimize external influence. The 3 blocks were laid horizontally next to each other separated by 5 m spacing. Each block was further divided into 6 plots each 5 x 5 m. The seeds of the grasses were sown along the created micro-catchments as pure stands; *Cenchrus ciliaris, Enteropogon macrostachyus* and *Eragrostis superba* and as two grass mixtures; *Cenchrus ciliaris-Enteropogon macrostachyus, Cenchrus ciliaris-Eragrostis superba* and *Enteropogon macrostachyus-Eragrostis superba.* The seeds were covered with light amount of soil. The whole process; site preparation and sowing was completed before the on-set of the rainy season. .

Data collection and statistical analysis

Data was collected from a total of 50 agro-pastoralists using semi-structured questionnaires. A draft questionnaire taking into account the objective of the study was constructed before carrying out the field survey. Questions were dichotomous, multi-choice and open ended to allow ease of capture of the diverse issues that were being investigated, with necessary detail. The questionnaire was pre-tested in a pilot survey involving 20 households, before it was used in the main survey. The households belonged to the same area of study but were not included in the actual survey.

Rainfall data for the study area during the study period was also collected using a rain gauge set up at the experimental site. Disturbed soil samples were taken from the top soil of 0 - 20 cm to determine soil moisture. Soil moisture content was determined by the gravimetric method as explained by Rowell (1994). Statistical analyses were done using Statistical Package for Social Sciences (SPSS) packages (Einstein and Abernethy, 2000). Descriptive statistics were used to analyze data on the problems of rehabilitating denuded patches in the semi-arid environment.

RESULTS AND DISCUSSION

Seed viability tests of the two year old set of seeds showed that there was a difference in seed germination between the three grass species tested. Seeds of *Enteropogon macrostachyus* (under room conditions at an average of 30℃) had the highest germination percentage (53%). Percent germination for *Cenchrus ciliaris* and *Eragrostis superba* was 12 and 10%, respectively. Trends in germination percentage of the tested grasses are illustrated in Figure 1. Percent germination was an indicator of grass seeds viability and capability of producing normal plants under suitable germination conditions. The differences observed among the grass species in terms of percent seed germination can be explained by the intrinsic properties of the seeds such as dormancy and integumental hardness. Seed dormancy varies between species Veenendaal (1991). Higher percent seed germination of *Enteropogon macrostachyus* may be explained by its dormancy mechanism which involves only the integument while the other two species may have both the embryo and/or the integument related dormancy (Bryant, 1985). The hairy bristle coat of the *Cenchrus ciliaris* fascicles is likely to have aided its higher germination by maintaining a high humidity within the fascicle and thereby help reduce water loss from the caryopsis (Sharif-Zadeh and Murdoch, 2001) compared to that of *Eragrostis superba.* The freshly harvested seeds of all the three grasses used did not germinate. This was primarily attributed to seed dormancy.

Rainfall total in the study area for the year 2008 was 324mm. However, most of the rain came as short lived flushes, which lasted for a maximum of 10 days at the beginning of the rainy season, followed by long spells of dry periods for the remaining days of the month. The area received a total of 39 rainy days in the whole year. This rainfall regime resulted in initial good germination of seeds in all the plots, but farther establishment of grass seedling was truncated by the lack of enough moisture. Rainfall together with soil moisture balance has an overwhelming effect on vegetation structure, composition and productivity. The rainfall regime witnessed during the study period suggests that the rains in the semi-arid lands of south eastern Kenya are usually low, erratic and unpredictable in space and time. High variability in rainfall amounts and distribution are common characteristics of semi-arid rangelands (Pratt and Gwynne, 1977; Ekaya et al., 2001), leading to low soil moisture deficits. Rainfall trends in the study areas are illustrated in Figure 2. According to the Kamba agro-pastoralists living in Kibwezi district, climatic factors, namely low amounts of

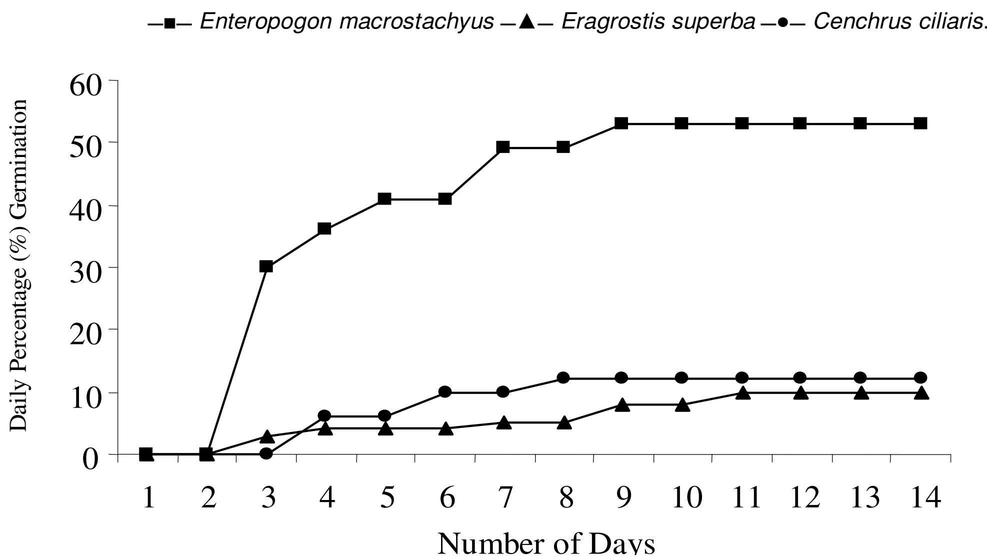

Figure 1. Daily percentage seed germination of *Enteropogon macrostachyus, Eragrostis superba* and *Cenchrus ciliaris,* under room conditions (30º C) in the study area (Set of two year old seeds).

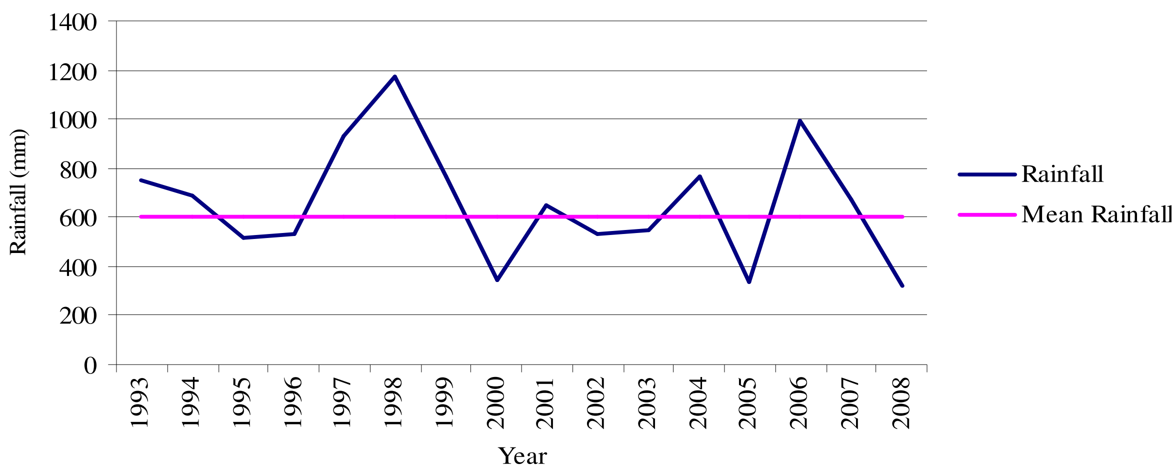

Figure 2. Annual rainfall in the study area (1993-2008).

rainfall and recurrent droughts common in the study area are the main factors which contribute immensely to rangeland rehabilitation failures. Out of all the farmers who practice reseeding, 92% have experienced rehabilitation failures and attributed this to low amounts of rainfall received during the respective year. Results from the questionnaire mirrored the results on site where there was poor establishment despite initial good germination. Low amounts of rainfall reflected by the soil moisture deficits hinder seed germination. Soil analysis results showed the soil moisture content in the study area to be as low as 6.87%. Similarly Mnene (2006) noted that when a seed stock is healthy, the main environmental factors that will stop seeds from germinating and establishing in the semi-arid rangelands are soil type and moisture. 24% of the agropastoral farmers practicing reseeding asserted that flush floods and soil erosion contribute to rehabilitation failures. Rainfall in semi-arid Kenya is often of high intensity and lasts within a very short period of time, that is, flush floods. This coupled with the problematic nature of the semi-arid soils characterized by high levels of salinity and sodicity, poor drainage, soil erosion, soil compaction, soil crusting and low soil fertility (Biamah, 2005) exposes the sown grass seeds to agents of erosion notably water and wind. The water often transports the sown grass seeds as it flows along the gradient. Heavy storms also destroy the shallow microcatchments meant to trap the water. Soil crusting farther hinders seedling emergence from the soil. This combination of climatic and edaphic factors leads to poor rates of germination and thus poor rates of establishment. Apart from soils and rainfall, other factors including human interventions (burning and grazing) and individual species physiological differences affect germination and subsequent growth (Mnene, 2006).

In the study area, grazing animals are kept under free range/herding in defined household grazing areas (Nyangito et al. 2009). This form of grazing system has also contributed immensely to rehabilitation failures since free grazing of livestock often cause destruction to young grass seedlings. Results from the survey showed that 50% of the farmers who have experienced rehabilitation failures blame it on livestock destruction. Free grazing animals often trample on newly established grass stands thus hindering their development to seed setting stage. Destruction of grass seedling before seed setting leads to the continual deprivation of the seed bank in the soil which in the long-run leads to bare patches. Improper stocking rates were also recognized to be a major contributor to rehabilitation failures. This anthropogenic influence was exacerbated by abiotic factors such as drought. Fencing is very expensive but is often the only way of excluding both domestic and wild herbivores from improved pastures. 95% of the agro-pastoralists who practice reseeding in the study area fence their rehabilitation plots and grass enclosures using cheap and locally available materials. However, the use of these locally available and cheap materials notably branches and poles of *Acacia* and *Commiphora* to keep free roaming herbivores out of reach increases the vulnerability of the grass seedlings to destruction in the long run. Such materials only provide a short term solution, since they are easily destroyed by livestock. Continued exposure of the fence to moisture farther weakens the fence. Moreover, some herders easily remove the fences to allow their animals graze the newly established seedlings and later replace it. As a rule of thumb, to ensure successful establishment, newly established grass stands should be protected from grazing animals for at least two growing seasons. However, with such prevailing conditions, this is hardly possible in agro-pastoral production areas. Majority of the farmers, (82%), who practice grass reseeding prepare their rehabilitation plots and sow the grass seeds prior to the rainy season. This ensures that the rain finds the sown seeds in the ground. In addition, the grass seeds are normally sown at a shallow depth and covered with minimal amounts of soil. This guarantees that the sown seeds get enough moisture for germination and consequent establishment. However, 3% of the farmers interviewed asserted that pests and rodents pose a great challenge to this form of dry planting.

Dry season planting coincides with a period of food scarcity for the pests and rodents. 3% of the agropastoral farmers emphasized that rats, squirrels and other small rodents and insects often feed on the sown seeds. Additionally, termites often transport the seeds long distances and store them in their food stores. Damage by termites is a general concern in the study area since they also affect crops and farm structures (Mnene, 2006). Furthermore, the *Quelea quelea* birds common in the study area often invade the rehabilitation plots in hundreds and feed on the sown grass seeds, especially those of *Eragrostis superba* which is mostly preferred by farmers because of its role in improving milk production (Wasonga et al., 2003). This leads to poor rates of initial germination in some patches, which often prompts the farmers to repeat the same process, and thus waste their time and money. That not withstanding, seedbed preparation is important in removing soil capping, enhance soil water infiltration and incorporate seeds into the soil (Mnene, 2006). 29% of the farmers interviewed cited inadequate supply of seeds of the locally adapted species commonly used for reseeding in the study area; *Enteropogon macrostachyus, Eragrostis superba, Cenchrus ciliaris* and *Chloris roxburghiana*. These findings agrees with that of Griffiths (1993) who reported that by the 1990s only 20% of farmers needs for herbage seeds could be met by formal seed production and marketing system in sub-Saharan Africa. This can also be attributed to degradation of natural vegetation whereby the more preferred vegetation type, grassland is steadily being replaced by a more woody vegetation type. As a result there is a shortage of supply of grass seeds commonly harvested in the forests and open grazing areas by the farmers. Proper seed technology is therefore necessary at harvesting, processing and storage, especially where communities are expected to undertake pasture seed multiplication to meet the current shortage (Mnene, 2006).

Poor storage methods, skills and facilities to store harvested seeds and use of poor quality seeds also contribute to poor establishment. 29% of the agropastoral farmers affirmed poor storage methods, skills and facilities as a contributor to rehabilitation failures. Majority of the farmers store their seeds in gunny bags and place them in grass thatched granaries which are sometimes not well done or poorly maintained. Seed quality of domestic species is highly variable and poor in the tropics as a result of poor harvesting and storage technology. Dry seeds, particularly those of rangeland grasses are known to be highly hygroscopic (Veenendaal, 1991; Opiyo, 2007), and exposure of dry seeds to moisture has been reported to worsen seed dormancy and often leads to fungal infection (Chin and Hanson, 1999; Tweddle et al., 2003). However, individual grass seed species ability to withstand moisture varies between species. During incidences of heavy storms, these granaries allow some rain water to penetrate thus contaminate the stored grass seeds. This leads to spoilage. Additionally, some of the farmers use dormant grass seeds to reseed their denuded patches. The seeds are either too old or too fresh, that is, immature or not yet broken dormancy. In this study, freshly harvested grass seeds of *Enteropogon* *macrostachyus, Cenchrus ciliaris* and *Eragrostis superba* failed to germinate under laboratory conditions. However, two year old seeds of the same grasses germinated under the same laboratory conditions. Competition from weed seedlings which germinate on established sown grass pastures can be very severe. All the farmers interviewed cited the problem of weeds in their individual rehabilitation plots. Semi-arid rangeland soils may contain 3,000 -15,000 viable seeds/m^2 of soil (Hodgkinson et al., 1980). This far exceeds the recommended sowing rates of rangeland pasture species usually at 30 - 500 viable seeds/m^2 (Heady, 1975). The common weeds in the study area included; *Solanum incanum, Lactuca capensis, Ipomoea kituensis, Digitaria scalarum, Eragrostis curvula, Datura stramonium, Tridax procumbens, Barleria taitensis* and *Commelina bengalensis.* Results showed that out of all the mentioned weeds, only *Ipomoea kituensis* greatly affected established grass stands. *Ipomoea kituensis* is a very common and notorious weed in the semi-arid districts of southern Kenya. It spreads very fast and thus colonizes a wide area within a very short period, making it difficult to eradicate. Its creeping nature engulfs the newly established grass seedlings. *Ipomoea kituensis* suppresses the growth and development of the grasses by covering the grass seedlings and depriving them of sunlight necessary for normal photosynthetic function. Furthermore, the weed out-competes the grass seedlings for nutrients and water from soil due to its aggressive growth nature.

Conclusion

The challenges facing agro-pastoralist farmers in semi-arid Kenya, who practice grass reseeding as a means of restoring denuded patches, are diverse. Insufficient amount of rainfall is the main contributing factor. Low amounts of rainfall and high rates of evapotranspiration result into soil moisture deficits, which subjects the grass seedlings to water stress leading to seedling mortality. Other factors, notably destruction by grazing animals, pests and rodents, flush floods, poor sowing time, poor seed quality, lack of enough seed and weeds also contribute to rehabilitation failures in semi-arid lands of Kenya.

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