Combining Sustainable Land Management Technologies to Combat Land Degradation and Improve Rural...

Article *in* Environmental Management · July 2015

DOI: 10.1007/s00267-015-0579-9 · Source: PubMed

3 authors, including:

Kevin Mganga
South Eastern Kenya University

Nashon K R Musimba
South Eastern Kenya University

Combining Sustainable Land Management Technologies to Combat Land Degradation and Improve Rural Livelihoods in Semi-arid Lands in Kenya

K. Z. Mganga, N. K. R. Musimba & D. M. Nyariki

Environmental Management

ISSN 0364-152X

Environmental Management
DOI 10.1007/s00267-015-0579-9

Environmental Management
DOI 10.1007/s00267-015-0579-9

Combining Sustainable Land Management Technologies to Combat Land Degradation and Improve Rural Livelihoods in Semi-arid Lands in Kenya

K. Z. Mganga[1] · N. K. R. Musimba[1] · D. M. Nyariki[2]

Received: 6 August 2014 / Accepted: 3 July 2015

Abstract Drylands occupy more than 80 % of Kenya's total land mass and contribute immensely to the national economy and society through agriculture, livestock production, tourism, and wild product harvesting. Dryland ecosystems are areas of high climate variability making them vulnerable to the threats of land degradation. Consequently, agropastoralists inhabiting these ecosystems develop mechanisms and technologies to cope with the impacts of climate variability. This study is aimed to; (1) determine what agropastoralists inhabiting a semi-arid ecosystem in Kenya attribute to be the causes and indicators of land degradation, (2) document sustainable land management (SLM) technologies being undertaken to combat land degradation, and (3) identify the factors that influence the choice of these SLM technologies. Vegetation change from preferred indigenous forage grass species to woody vegetation was cited as the main indicator of land degradation. Land degradation was attributed to recurrent droughts and low amounts of rainfall, overgrazing, and unsustainable harvesting of trees for fuelwood production. However, despite the challenges posed by climate variability and recurrent droughts, the local community is engaging in simple SLM technologies including grass reseeding, rainwater harvesting and soil conservation, and dryland agroforestry as a holistic approach combating land degradation and improving their rural livelihoods. The choice of these SLM technologies was mainly driven by their additional benefits to combating land degradation. In conclusion, promoting such simple SLM technologies can help reverse the land degradation trend, improve agricultural production, food security including access to food, and subsequently improve livelihoods of communities inhabiting dryland ecosystems.

Keywords Adaptation · Diversification · Local knowledge · Holistic approach · Vegetation change

✉ K. Z. Mganga
kzowe@yahoo.com; kmganga@seku.ac.ke

[1] Department of Range and Wildlife Sciences, School of Agriculture and Veterinary Sciences, South Eastern Kenya University (SEKU), P.O. Box 170-90200, Kitui, Kenya

[2] Department of Agricultural Economics and Agribusiness, School of Agriculture and Veterinary Sciences, South Eastern Kenya University (SEKU), P.O. Box 170-90200, Kitui, Kenya

Introduction

Drylands cover approximately 5.17 billion hectares, which translates to nearly 41 % of the total earth's land surface (Biazin and Sterk 2013). They encompass rangelands, arable lands, forests and are a vital part of the earth's human and physical environment. Land degradation which is a major global problem, is widely recognized in the dryland ecosystems (Gisladottir and Stocking 2005) affecting a quarter of the earth's surface and more than 900 million people in over 100 countries (Bradley and Grainger 2004). Land degradation remains a central problem to the sustainable development of dryland ecosystems (Olukoye and Kinyamario 2009). Africa is particularly affected because land degradation principal processes affect about 46 % of its total land surface. Climatic conditions and intensive agriculture make many parts of Africa particularly vulnerable. The semi-arid to mildly arid areas of Africa are particularly more vulnerable as they have fragile soils, generally low input form of agriculture, scarce vegetation cover, and weak soil structure.

In Kenya, land degradation is widely regarded as a key environmental problem in the arid and semi-arid lands (ASALs). The ASALs in Kenya cover approximately 80 % of the total land area and support over 30 % of the Kenyan human population (Mganga et al. 2010a). Previous studies (e.g., Nyangito et al. 2008) have estimated that approximately 30–40 % of Kenya's ASALs are quickly being degraded and that another 2 % have completely been lost. Much of the soil erosion occurs when vegetation cover is removed, as this leaves soil unprotected from water and wind. Evidence of degradation in semi-arid ecosystems in Africa is evidenced by the decline in soil productivity, loss of soil biodiversity, increasing rate of soil erosion, and change in vegetation cover. Vegetation degradation is recognized as an important measure of degradation over different spatial and temporal scales in arid and semi-arid environments (Visser et al. 2007). Short-term indicators of degradation, which are reversible, include changes in the composition of grasses and herbs. However, a shift in state from grasslands to bushy and woody dominated vegetation types is indicative of severe degradation (Bennett et al. 2012).

Degradation of natural vegetation is a worldwide phenomenon (Visser et al. 2007) and is exemplified through loss in biodiversity, change in species composition, bush encroachment, and thickening. Degradation in the form of change of natural vegetation cover from 'excellent' to 'poor' in the arid and semi-arid ecosystems results in a subsequent but proportional increase in the dominance of unpalatable, undesirable (increaser), and invader species over the desirable (decreaser) vegetation types (Kassahun et al. 2008). Processes that lead to vegetation degradation involve complex interactions between societal factors e.g., poor land management and increasing population pressures, and natural climatic factors e.g., cyclical and short-term droughts.

Sustainable land management (SLM) practices described as measures of land and water conservation that support land-based production systems have been acknowledged, promoted, and used to mitigate land degradation. Combating land degradation in the drylands using SLM practices such as reseeding using adapted perennial grasses, agroforestry, or reforestation has been a global aim for over 70 years (Gisladottir and Stocking 2005; Schwilch et al. 2014). Key principles of such SLM practices are the productivity and protection of natural resources, coupled with economic viability, and social acceptability (Schwilch et al. 2014). Agroforestry systems and grass reseeding interventions are aimed at mitigating land degradation by increasing the area under vegetation cover, biodiversity, ecosystem functionality, and production potential.

Combining rainwater harvesting, multi-purpose tree species and native perennial grasses to mitigate land degradation in the Kenyan drylands has been made more attractive by their economic viability, decrease in individual farm-holdings, coupled with increased human population. Interestingly, to our knowledge, very few studies have been conducted to document how communities' inhabiting semi-arid lands in Kenya perceive and respond to land degradation. Furthermore, little is known about how the combination of the adopted SLM technologies improves their livelihoods. It is with this backdrop that the present study was undertaken (1) to determine what agropastoralists inhabiting semi-arid Kibwezi Sub-County, Kenya, attribute to be the causes and indicators of land degradation, (2) to document the SLM technologies being undertaken to combat land degradation, and (3) to identify the factors that influence the choice of these SLM technologies.

Study Location and Methodology

Description of Study Area

This study was conducted in Kibwezi, a semi-arid Sub-County in southeastern Kenya (Fig. 1). The largest ethnic group in the study area is the Akamba, who depend in part on pastoral and in part on agronomic economy to meet most of their needs. Other activities include beekeeping (Musimba et al. 2001). Kibwezi Sub-County is located between latitudes 2° 6′S and 3°S, and longitudes 37° 36′E and 38° 30′E, respectively, has a total area of 3400 km^2 (Mganga et al. 2010b). It lies in a region that has generally been classified as agro-ecological zone (AEZ) V i.e., it is semi-arid with average annual rainfall of 300–600 mm and % R/Eo ratio of 25–40. The climate is characterized by low and unreliable supply of enough moisture for plant growth. The average annual rainfall and temperatures are 600 mm and 23 °C, respectively. The effectiveness of the rainfall is much reduced by the high evaporation rates (averaging 2000 mm annually) which result from the high temperatures which occur throughout the year. The rainfall pattern is bimodal with the long rains from March to May and short rains from November to December. The average annual rainfall for the study area during the period 1977–2008 is given in Fig. 2. Temperatures are high in the wet season and low in the dry season.

The soils are of volcanic origin, shallow to very shallow, extremely stony to rocky, and are highly permeable, mainly Ferralsols, Cambisols, and Luvisols. Most of these soils are compact with strong surface sealing properties that reduce infiltration and cause much runoff. This can be attributed

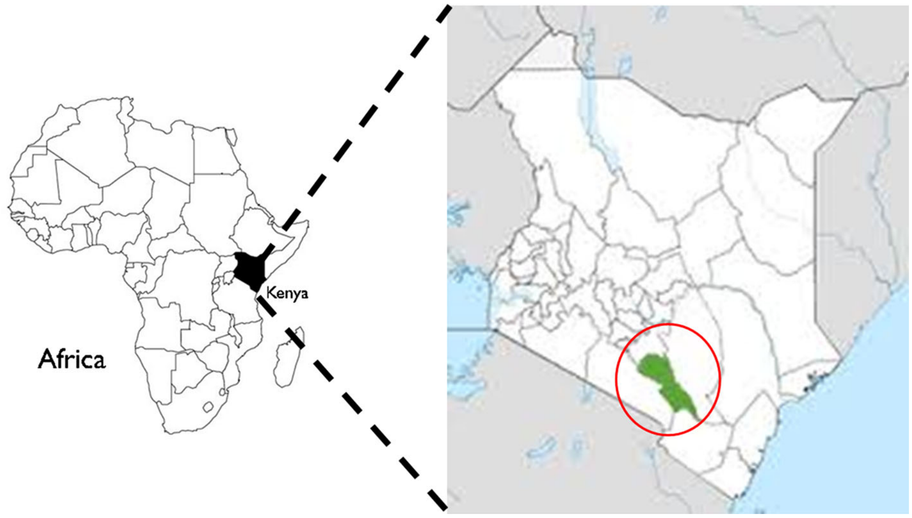

Fig. 1 Map of Africa and Kenya showing the location of the study area, Makueni County, Southeastern Kenya

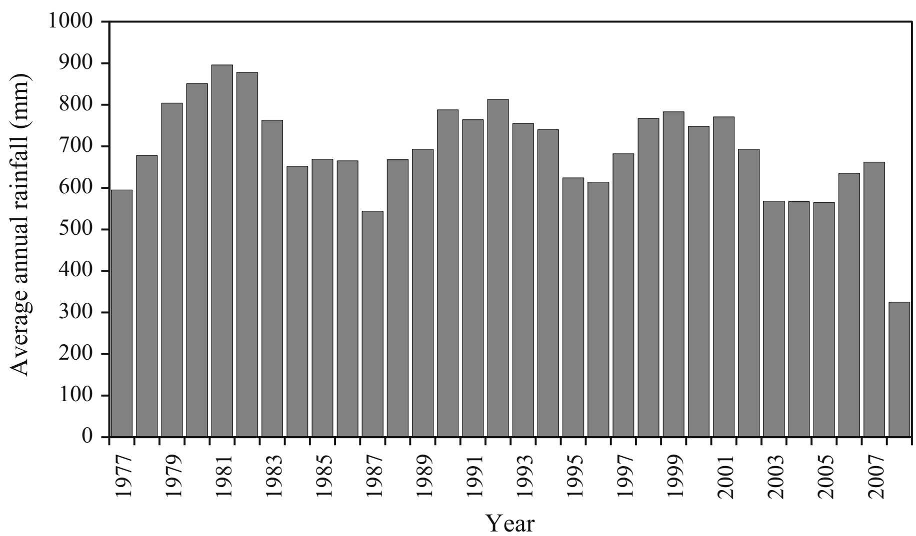

Fig. 2 Average annual rainfall for the study area (1977–2008) (Makindu Meteorological Station, Makueni County, Kenya)

mainly to the soils' low organic matter, with carbon content between 0.1 and 0.5 %.

The distribution of vegetation is controlled by a number of complex interrelated factors, notably climate, geological formation, soil type, and the presence or absence of ground water. The natural vegetation is woodland and savannah (Nyangito et al. 2009). Woody species such as *Acacia tortilis* (Forsk), *Acacia senegal* (L. Willd), *Acacia mellifera* (Wahl) Benth and grass species, notably *Cenchrus ciliaris, Enteropogon macrostachyus, Eragrostis superba*, and *Chloris roxburghiana* are some of the important plant species native to the area.

Data Sources and Analysis

The study was carried out under the Dryland Husbandry Project (DHP), a larger project focusing on livelihood security, deteriorating socio-economic conditions, land degradation, inappropriate pastoral development, and drought vulnerability and risk in an agropastoral area in southeastern Kenya. The data were collected between 2007 and 2008 through 5 face-to-face interviews of key persons, questionnaire administration to 50 households and 2 group discussions.

In the first stage, data were collected through one-on-one interviews. Focus persons for the questionnaire administration were the household heads (male or female). Interviews were conducted in the national language, *Kiswahili*. The survey instrument was pre-tested in a non-sample community before the start of the study. Farmers preferentially and independently adopted some of the technologies introduced by the DHP, notably reseeding to combat desertification, water harvesting, and dryland agroforestry. The questionnaire included dichotomous, multi-choice, and open-ended questions to allow ease of capture of the diverse issues being investigated. Some of the open questions posed during the interviews include; (1) what are the general causes of land degradation? (2) what are the causes of land degradation in their area? (3) what are the indicators of land degradation? (4) when did these changes started to occur? (5) what reasons informed them to start practicing SLM strategies? and (6) what informed their choice to practice the selected SLM technologies?

In the second stage of data collection, two focused group discussions (FGDs) were conducted in two different locations within the study area. Each FGD had a total of 20 separate participants who were not part of the 50 households interviewed. The main objective of the FGDs was to validate the data obtained from the questionnaires. Furthermore, we used the FGDs to clarify aspects that were not captured well by questionnaires.

During the third stage, in-depth key informant consultations were conducted in *Kiswahili* with the local area chief, village elders, and older persons (>50 years old). These unstructured key informant interviews were designed to gather additional information and a broader understanding of the historical perspective of environmental and climate change. This is because it became evident during the group discussions and interviews that indigenous knowledge (IK) was directly related to the period of time a person has been living in an area, direct experience, and the socio-cultural embedment of the persons. The older persons were found to capture long-term direct experience and socio-cultural embedment, thus enabled us to collect additional data which might not have been captured using the other methods.

Annual rainfall data covering the period 1904–2008 were obtained from Makindu Meteorological Station and were analyzed during the final stage. We conducted simple descriptive statistics and Spearman correlation analysis between the sustainable land use practices and perception of land degradation in the study area using the Statistical Package for Social Sciences (SPSS) package (Einstein and Abernethy 2000) that were used to analyze the collected data.

Results

Causes and Indicators of Land Degradation

A high proportion of respondents (88 %) and (96 %) noted recurrent droughts to be the main cause of land degradation globally and in the study area, respectively (Tables 1 and 2). Recurrent drought as the main cause of land degradation was positively correlated with grass reseeding and water harvesting technology but negatively correlated with incorporation of multi-purpose trees in farmlands.

Table 1 Agropastoralists' opinion on the general causes of land degradation

General causes of land degradation	Respondents (%)
Recurrent droughts	88
Low amounts and variability of rainfall	64
Overgrazing	64
Soil erosion	46
Poor agricultural practices	32
Deforestation and charcoal burning	10

Table 2 Agropastoralists' opinion on the main causes of land degradation in the study area

Causes of land degradation in study area	Respondents (%)
Recurrent droughts	96
Overgrazing	78
Low amounts and variability of rainfall	64
Poor agricultural practices	42
Lack of government support	26
Charcoal burning	12
Unplanned human settlements	12

Overgrazing, low amount of rainfall, poor agricultural practices, deforestation, and charcoal burning were also cited as the other main contributors to land degradation both globally and in their environment. However, overgrazing was negatively correlated with the use of grass reseeding technology to combat desertification. These explanations showed the general awareness among the agropastoralists towards the causes of land degradation.

Majority of the respondents (76 %) cited change in vegetation, exemplified by the increase in woody species and the fast disappearance of preferred forage grass species notably *E. superba*, *C. ciliaris*, *E. macrostachyus*, and *C. roxburghiana* as the main indicator of land degradation in the area. Others (46 %) cited loss of soil fertility and soil erosion as the indicators of land degradation (Table 3). Overgrazing (40 %) and climatic factors (36 %) were cited to be the two main factors responsible for the changes in vegetation. A higher proportion of the agropastoralists (60 %) reported that these changes started occurring between 1961 and 1970, which corresponds to the period immediately after Kenya attained her independence in 1963 (Table 4).

Sustainable Land Management Technologies

This study revealed that 76 % of those interviewed practice grass reseeding technology. *Eragrostis superba* (74 %) is

Table 3 Agropastoralists' opinion on the main indicators of land degradation (% of respondents)

Main indicators of land degradation	
Vegetation degradation (increase in woody species replacing preferred grass species)	76
Loss of soil fertility and soil erosion	46

Table 4 Agropastoralists' opinion on the causes and onset of vegetation degradation in study area % of respondents

Causes of vegetation degradation in the study area	
Overgrazing	40
Climatic factors (rainfall and recurrent droughts)	36
Lack of bush control strategies	20
Uncontrolled burning	18
Poor agricultural practices	6
Lack of rehabilitation initiatives	6
Onset of vegetation degradation in the study area	
1950–1960	2
1961–1970	60
1971–1980	24
After 1980	14

the most popular grass species used to rehabilitate degraded semi-arid ecosystems in southeastern Kenya. *Cenchrus ciliaris* (48 %), *Chloris roxburghiana* (32 %), and *Enteropogon macrostachyus* (28 %) were ranked second, third, and fourth, respectively, which corresponds to their use as livestock feed. Other multiple uses of the grasses are soil conservation by supporting terraces, thatching houses and granaries, and as a source of income through the sale of seeds and hay to the neighbors (Table 5).

Although all the grasses used to rehabilitate degraded semi-arid lands in southeastern Kenya are adapted to harsh environmental conditions, their resilience varies. Drought tolerance was among the main characteristics considered by the community for selecting the grass species used for rehabilitation programs. 56 % of the respondents considered *E. superba* as the most drought-tolerant species. This result corresponds well to its popularity among the agropastoralists. Other key characteristics of the grass species considered include availability and quality of seed, grazing resistance, and biomass yields (Table 6).

To ensure sufficient moisture is available to support the growth of grass seedlings, the agropastoralists are also practicing in situ water harvesting technologies (ox-plowed micro-catchments and macro-catchments) to trap enough rain water. In addition to in situ water harvesting techniques, the agropastoralists also trap rain water using roof catchments in their homesteads. Water harvested by roof catchment is mostly (90 %) for domestic use especially during periods of drought. Additionally, the water can also be used to water livestock (52 %) and tree nurseries (14 %) especially during the dry season (Table 7). The main soil conservation strategy (98 % of respondents) in the study area is terracing. Micro-catchments (46 %), and mulching and macro-catchments (8 % each) were ranked second and third, respectively (Table 7).

Furthermore, agropastoralists in semi-arid southeastern Kenya are integrating multi-purpose tree species into their farms as a form of dryland agroforestry. Integration of multi-purpose trees in farmlands was positively and significantly correlated with grass reseeding technology, but was negatively correlated with recurrent droughts and overgrazing as the main contributors of land degradation in the area. *Azadirachta indica* (Neem tree), is the most popular tree species in the study area. This was mainly attributed to its multiple uses, notably high medicinal value (64 %). Interestingly, according to the respondents, provision of bee forage and shade both for humans and grazing animals, were among the most consistent characteristic features of almost all the tree species (Table 8). These characteristics correspond well to counteract the hot sun in the semi-arid environment and to support beekeeping as a key economic activity among the agropastoral Kamba community, respectively.

Table 5 Multiple uses of the grass species used for rehabilitating degraded semi-arid ecosystems in southeastern Kenya (% of respondents)

Grass species	Total	Main uses of the grasses by agropastoralists'			
		Livestock feed	Soil conservation	Thatching	Income
Eragrostis superba	74	74	44	48	34
Cenchrus ciliaris	48	48	34	34	20
Enteropogon macrostachyus	28	28	18	6	8
Chloris roxburghiana	32	30	22	16	6

Table 6 Key characteristics of the grass species considered by the agropastoralists for reseeding programs (% of respondents)

Grass species	Main characteristics considered for selection of species			
	Drought tolerance	Seed availability	Grazing resistance	Biomass yield
Eragrostis superba	56	36	48	2
Cenchrus ciliaris	34	30	28	8
Enteropogon macrostachyus	14	14	4	2
Chloris roxburghiana	24	10	20	2

Table 7 Water harvesting and soil moisture and conservation techniques practiced by agropastoralists in semi-arid southeastern Kenya (% of respondents)

Water harvesting	Total percent	Uses of harvested water
Micro-catchment	46	Grass reseeding and crop production (90 %)
Roof catchment	80	Domestic use (90 %), watering livestock (52 %), watering tree nurseries (14 %)
Macro-catchments	6	Grass reseeding and crop production (75 %)
Soil conservation	**Total percent**	**Method used**
Mulching	8	Hand-held hoes (*Jembe*)
Terracing	98	Hand-held hoes (*Jembe*)
Micro-catchments	46	Ox-driven plow
Macro-catchments	8	Ox-driven plow, hand-held hoes

Percentages in the right under the column 'Uses of harvested water' represents a proportion of the respondents practicing the water harvesting technique in the corresponding left column

Table 8 Multiple uses of the tree species incorporated in the farms as a form of dryland agroforestry in semi-arid southeastern Kenya (% of respondents)

Tree species	Multiple uses							
	Fodder	Fuel	Timber	Bee forage	Human food	Shade	Green manure	Medicinal
Leucaena leucocephala	56	38	22	46	–	34	–	–
Terminalia mentalis	–	2	–	2	–	6	–	–
Tamarindus indica	–	2	10	4	18	14	–	–
Mangifera indica	8	16	12	6	24	20	–	–
Azadirachta indica	4	8	10	22	–	56	–	64
Psidium guajava	–	2	–	8	32	–	–	–
Senna siamea	–	24	6	20	–	20	4	–
Citrus sinensis	2	–	–	22	50	2	–	–
Adansonia digitata	–	–	–	–	36	4	–	–
Melia volkensii	34	8	42	2	–	22	–	–

Discussions

Causes and Indicators of Land Degradation

Our results confirm that human-induced land degradation is prevalent in the semi-arid drylands (Mwang'ombe et al. 2011; Opiyo et al. 2011). In general, overgrazing contributes to the rapid disappearance of palatable forage species in semi-arid environments (Mnene et al. 2005). This is because increased grazing pressure offers woody species a competitive advantage over preferred grass species. This change in vegetation composition from preferred grass species to woody species is among the main indicators of land degradation in the semi-arid lands. Moreover, intensive grazing contributes about 34.5 % of total soil degradation and high rates of soil losses of up to 50 tons per hectare per year in the semi-arid Kenya (Nyangito et al. 2008). This has consequently resulted to the decline in soil fertility in the semi-arid lands.

Similarly, irregular climatic events such as recurrent droughts and low amounts of rainfall prevent the sustained growth of vegetation leading to eventual bare patches. Our results concur with those of Breshears et al. (2005) who found out that recurrent drought events in drylands can trigger large-scale landscape changes through vegetation mortality from water stress. Moreover, successive low annual rainfall events also lead to a shrinking livestock feed resource base. This eventually contributes immensely to overgrazed patches. Our findings confirm that interaction of heavy grazing and climatic variability causes dramatic ecological degradation in the semi-arid environments (Wessels et al. 2007). Additionally, crop failures and high livestock mortalities as a result of these irregular climatic events common in the drylands force the locals to engage in charcoal burning and trade. This further accelerates environmental degradation.

Our study confirms previous studies (Kituyi et al. 2001; Speranza et al. 2008) that charcoal burning and trade has become an important source of household income among communities inhabiting semi-arid lands in Kenya. Charcoal is a major source for cooking energy in most African countries (Naughton-Treves et al. 2007). Its market demand from an increasing human population has consequently led to the destruction of indigenous trees. Charcoal provides 82 % of the urban and 34 % of the rural domestic energy, representing an estimated national annual market value of 12 million USD. Unabated destruction of indigenous trees for charcoal burning has contributed immensely to environmental degradation in drylands. Furthermore, harvesting leguminous woody species e.g., *Acacia tortilis*, the most preferred species for charcoal burning in the area, depletes the drylands of its sources of forage. *Acacia* pods provide a rich and important source of forage especially during the dry season.

Additionally, the use of hand-held hoes and animal-driven plow for seed bed preparation, in situ water harvesting, and soil conservation is prevalent in the study area. Our findings compare well to those found by Mrabet (2002) who reported that 90 % of the farmers in Africa still use hand-held implements to till their land, 9 % use animal power and only 1 % use machinery. Repeated shallow plowing and livestock trampling compacts soil and significantly reduces water infiltration rate, thus promoting runoff and sheet erosion (Castellano and Valone 2007). Furthermore, soil compaction stunts root growth, reduces water storage, and stops the capillary rise of water from the subsoil. Poor and intensive agricultural practices also contribute to a progressive decline in soil fertility and organic matter (OM) content (Mganga and Kuzyakov 2014) consequently reducing the water-holding capacity. This eventually limits the availability of both water and nutrients for plant growth.

Human settlement schemes e.g., Masongaleni and Kiboko, in areas previously with relatively lower human populations have also contributed to land degradation. These settlement schemes have caused a large influx of people who generally invest minimal resources in land improvement and often engage in unsustainable farming practices, leading to rapid land cover changes and soil erosion. These results confirm that rural human migration is one of the key drivers of environmental degradation in tropical semi-arid regions (Wardell et al. 2003; Muriuki et al. 2011) and that rural migration is more important in global environmental change than previously thought (Carr 2009)

Sustainable Land Management Technologies

Maintenance of production, maintenance of quality of soil and water, risk reduction, and economically feasible and socially acceptable systems has been cited as criteria for SLM (Bouma 2002; Schwilch et al. 2009, 2011; Liniger et al. 2011). Despite the challenges posed by climate variability, agropastoralists in the area are maximizing production and combating land degradation by practicing and combining the following simple SLM technologies.

Grass Reseeding

High adoption rate of grass reseeding among the agropastoralists in the semi-arid Kenya is attributed to their indigenous knowledge of the grasses and their multiple benefits. Their higher preference to *E. superba* compared to *C. ciliaris, C. roxburghiana,* and *E. macrostachyus* demonstrate that the choice of grasses for reseeding is influenced by their forage value for livestock. Free-grazing animals show a higher preference for *E. superba* than the other species. This probably explains why *E. superba* forms part of the basal diet in many livestock feed trials in semi-arid Kenya (Nyambati et al. 2006; Koech et al. 2011). Pastoral communities e.g., the East Pokot and Il Chamus inhabiting semi-arid Lake Baringo Basin, Kenya have identified *E. superba* for fattening livestock (Wasonga et al. 2003).

Similarly, preference for *C. ciliaris* is attributed to its palatability and nutritional value (Farooq et al. 2003). Furthermore, *C. ciliaris* prolong grazing period, increases carrying capacity, and recovers well from grazing (Marshall et al. 2012). Similar to our study, Mnene et al. (2005) working in the same area observed *C. roxburghiana* to be highly palatable to cattle, sheep, and goats, especially during the early flowering stage. This coincides well with the high crude fiber content of 30 % of dry matter (DM) at this stage (Bogdan and Pratt 1967). Low preference for *E. macrostachyus* in the area is primarily attributed to its low forage value. Furthermore, it is easily uprooted by free-ranging animals in the rainy season and is prone to termite attacks in the dry season when livestock feed is scarce.

Grass seeds of *C. ciliaris*, *E. superba*, *C. roxburghiana*, and *E. macrostachyus* are sold both at the local and international market. The community-based forage seed system not only provides a gateway to reach the market to generate income, but also provides the local community with a reliable source of grass seed, which is otherwise not available in the formal pasture seed supply chain system. Income generated from the sale of the grass seeds are channeled to purchase food and for other social amenities such as health, education, and entertainment.

Rainwater Harvesting and Soil Conservation

The notable in situ rainwater harvesting technologies being practiced by the local community as a mitigation strategy against rainfall scarcity are micro-catchments and macro-catchments. Additionally they also direct surface runoff into their farms using shallow farrows constructed along the roads. These simple rainwater harvesting technologies increase rainwater infiltration, reduce surface runoff, promote better root growth, enhance germination and establishment of seedlings, and increase the soil's water retaining capacity. Micro-catchments e.g., half-moon and ox-driven plowed V-shaped micro-catchments and macro-catchments ensure that the seeds trap enough water prolonging the availability of enough moisture, thus improving the chances of the seeds to germinate and establish.

Terraces are highly regarded as a best practice for soil conservation in the area. These results compare well with previous studies which have demonstrated terraces as worthwhile investment in semi-arid landscapes (Kiome and Stocking, 1995; Zaal and Oostendorp 2002; Liniger and Mekdaschi Studer 2011). This is because they increase the value of land, raise and stabilize yields, and reduce erosion and fertilizer use (Tiffen and Mortimore 2002). Terraces in the area are of the *'Fanya Juu'* type, where a trench is dug along the contour and the soil is thrown uphill to form the start of the terrace. Interestingly, in the dry ecosystems, terraces are ranked even higher than trees (Tiffen and Mortimore 2002).

Dryland Agroforestry

Agroforestry is an ancient practice in sub-Saharan Africa (Liniger and Mekdaschi Studer 2011; Bucagu et al. 2013) widely promoted as a sustainability-enhancing practice combining the benefits of both forestry and agriculture (Young 1988). Farmers in the study area are incorporating economically important multi-purpose trees in their farms. These tree species are well adapted to high temperatures and low amounts of rainfall. Specific characteristics and uses of the tree species incorporated in the farmlands are briefly discussed in Table 8. The most preferred tree species among the farmers are discussed below.

Azadirachta indica (Neem tree) is the most popular multi-purpose tree in the area mainly because of its high medicinal value. Farmers in the area mainly use it as an ingredient for many home remedies e.g., mosquito repellant against malaria and headaches. According to Ahmed and Grainge (1986) its various plant parts have been used for headaches and ulcers. Additionally, the neem bears masses of honey-scented white flowers, making it a popular species among the beekeepers in the area. Furthermore, the local community in the area uses it as a source of timber because termites will not attack it. On the farm and homesteads, it is used as a windbreak and welcome source of shade. These results agree with previous findings (e.g., Young 1988) citing the neem tree as a valuable windbreak and source of dense shade in semi-arid zones.

Our study revealed that incorporation of *Leucaena leucocephala* (Wild Tamarind, the Miracle Tree) in croplands is mainly aimed at providing forage for both livestock and bees. These results strongly suggest that the high quality of fodder from *L. leucocephala* is known among the agropastoral farmers in the area. Leaves of tree legumes such as *L. leucocephala* are known to have medium to high *N* contents (15–30 % of DM) making them a valuable source of protein for livestock (Saha et al. 2008). *L. leucocephala* also has the added advantage of producing flowers adequate for foraging activities by the honeybees. As well as forage, *L. leucocephala* is also an important source of firewood and timber.

However, our findings show that *Melia volkensii* (Melia) is the most popular species for timber. Melia is highly preferred because it has a fast growth rate and exerts minimal competition to cultivated crops (Wekesa et al. 2012). This can be linked to its deep rooting system (Mulatya et al. 2002). Moreover, it fetches premium price owing to its high termite resistance (Runo et al. 2004). Additionally, the wood is easily worked and shaped, making it a popular tree species to make traditional log hives common in the area. Apart from timber, Melia is also an important source of fodder. The agropastoral farmers in the area use its twigs, leaves, and fruits as fodder for goats, cattle, and sheep, especially during periods of forage scarcity in the dry season. These results agree with those of Mulatya et al. (2002) who cited *M. volkensii* as an important source of animal fodder in semi-arid drylands in Kenya.

Multi-purpose fruit trees such as *Psidium guajava* (Guava), *Mangifera indica* (Mango), and *Citrus sinensis* (Orange) are the most common in the area. Additionally, they provide fuelwood, timber, shade, and bee forage. *P. guajava* is popular among the beekeepers because its white fragrant flowers secrete nectar in excess all day attracting bees. Moreover, the bees also collect juice from the fruits damaged by birds. Additionally, *P. guajava* is a source of fuelwood in the area. These results confirm that *P. guajava* wood is excellent for firewood and charcoal (Somarriba 1988).

In semi-arid southeastern Kenya, just like in other regions, *M. indica* is primarily planted for its fruits. However, farmers in the study area also utilize the tree as a source of firewood. Previous studies in Kenya (Kituyi et al. 2001) have also reported *M. indica* to be an excellent source of wood energy due to its high calorific value. Additionally, during the dry season, free-ranging domestic livestock in the area fed on *M. indica* leaves. *C. sinensis* is an important bee forage species (Yirga et al. 2012). Its white flowers are very useful as bee forage, often yielding good quantities of nectar and pollen. Honey collected from bee hive colonies foraging on *C. sinensis* flowers has a tangy sweet orange taste.

Impact of SLM Technologies to the Local Community

Agropastoralists inhabiting dryland ecosystems in Kenya depend on cultivation of crops and their animals—cows, goats, and sheep and camels—for both food and income. During drought periods crop failures are common, pasture and water become much harder to find, resulting in high livestock mortalities. Despite the challenges posed by climate uncertainties, farmers practicing the SLM technologies in the semi-arid lands in Kenya are better cushioned against vagaries of nature. For example, traditionally, farmers would keep livestock and sell them during dry spells. However, farmers currently practicing grass reseeding have enough quality forage that meets the nutritional value demands of their livestock.

Drought-tolerant indigenous grasses used for rehabilitating degraded lands such as *C. ciliaris, E. superba, E. macrostachyus*, and *C. roxburghiana* provide forage for their livestock and source of income through sale as hay. Farmers are also benefiting from the sale of grass seeds which fetches a good price, approximately 10 Euros per kilo, at the local and international market. Food and Agriculture Organization of the United Nations (FAO) (Kenya and Somalia), African Wildlife Foundation (AWF), Care International, and Germany Agro Action (GAA) are some of the ready markets for the grass seeds. Interestingly, when livestock feed is scarce elsewhere, these farmers have abundant standing hay. This enables them to allow animals from neighboring farmers to graze on the grass at a minimal fee, thus generating some income. Money generated from the sale of grass seeds and hay is channeled to cater for other basic needs notably purchase of food, health care, and paying education fees.

Conclusions

Land degradation is a serious problem in semi-arid lands in Kenya, threatening the livelihoods of agropastoralist communities. Change in vegetation cover composition from the preferred grass forage species to more woody species and the loss of soil fertility due to erosion are the two main indicators of land degradation in semi-arid environments in Kenya. These environmental changes have been attributed to both human factors such as overgrazing, charcoal production, unplanned human settlements, and poor agricultural practices, and irregular climatic events notably low amounts of annual rainfall and recurrent drought. In response to this, agropastoral communities in semi-arid Kenya are practicing simple sustainable land management (SLM) strategies notably grass reseeding technology, rainwater harvesting and soil conservation, and dryland agroforestry using multi-purpose tree species to mitigate the impacts of climate variability and combat environmental degradation. In addition to combating degradation, these simple technological strategies are improving the livelihoods of the agropastoralists in semi-arid environments in Kenya by cushioning them against the vagaries of nature. These simple technologies provide a reliable source of human food, livestock feed, and income through the production and sale of e.g., timber, honey, and grass seeds. Findings from this research work clearly demonstrate that combining sustainable land management strategies has a great potential to improve ecosystem functionality and resilience, alleviate pasture scarcity, and create alternative income generating activities for the agropastoral communities in semi-arid Kenya.

Acknowledgments Funds for this research were provided by the European Commission under the Agricultural Innovations for Drylands Africa (AIDA), Grant Number 043863-SSA Africa (2006). The lead author would also like to sincerely thank the Tropical Biology Association (TBA) for English editing and inviting him to participate in the TBA-NK-NMK DRECA Specialist Training Workshop on Communicating and Disseminating Research Results (2011) where the motivation and drive to write this paper was drawn.

References

Ahmed S, Grainge M (1986) Potential of the Neem Tree (*Azadirachta indica*) for pest control and rural development. Econ Bot 40(2):201–209

Bennett JE, Palmer AR, Blackett MA (2012) Range degradation and land tenure change: insights from a 'released' communal area of eastern Cape Province, South Africa. Land Degrad Dev 23:557–568

Biazin B, Sterk G (2013) Drought vulnerability drives land-use and land cover changes in the Rift Valley dry lands of Ethiopia. Agric Ecosyst Environ 164:100–113

Bogdan AV, Pratt DJ (1967) Reseeding denuded pastoral land in Kenya. Republic of Kenya, Ministry of Agriculture and Animal Husbandry, Government Printers, pp 1–46

Bouma J (2002) Land quality indicators of sustainable land management across scales. Agric Ecosyst Environ 88:129–136

Bradley D, Grainger A (2004) Social resilience as a controlling influence on desertification in Senegal. Land Degrad Dev 15:451–470

Breshears DD, Cobb NS et al (2005) Regional vegetation die-off in response to global-change-type drought. PNAS 102:15144–15148

Bucagu C, Vanlauwe B et al (2013) Assessing farmers' interest in agroforestry in two contrasting agro-ecological zones of Rwanda. Agrofor Syst 87:141–158

Carr DL (2009) Population and deforestation: why rural migration matters. Prog Hum Geogr 33:355–378

Castellano MJ, Valone TJ (2007) Livestock, soil compaction and water infiltration rate: evaluating a potential desertification recovery mechanism. J Arid Environ 71:97–108

Einstein G, Abernethy K (2000) Statistical package for the social sciences (SPSS) Version 12.0. Furman University, Greenville

Farooq MU, Saleem R et al (2003) Estimation of root and shoot biomass of *Cenchrus ciliaris* (Dhaman) under Barani conditions. Pak J Biol Sci 6:1808–1813

Gisladottir G, Stocking M (2005) Land degradation control and its global environmental benefits. Land Degrad Dev 16:99–112

Kassahun A, Snyman HA et al (2008) Livestock grazing behaviour along a degradation gradient in the Somali region of eastern Ethiopia. Afr J Range Forage Sci 25(1):1–9

Kiome RM, Stocking M (1995) Rationality of farmer perception of soil erosion: the effectiveness of soil conservation in semi-arid Kenya. Glob Environ Change 5(4):281–295

Kituyi E, Marufu L et al (2001) Biofuel availability and domestic use patterns in Kenya. Biomass Bioenergy 20(2):71–82

Koech OK, Kinuthia RN et al (2011) Use of dryland tree species (*Prosopis juliflora*) seed pods as supplement feed for goats in the arid and semi-arid lands of Kenya. Environ Res J 5(2):66–73

Liniger HP, Mekdaschi Studer R et al (2011) Sustainable land management in practice—guidelines and best-practices for sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO)

Marshall VM, Lewis MM et al (2012) Buffel grass (*Cenchrus ciliaris*) as an invader and threat to biodiversity in arid environments: a review. J Arid Environ 78:1–12

Mganga KZ, Kuzyakov Y (2014) Glucose decomposition and its incorporation into soil microbial biomass depending on land use in Mt. Kilimanjaro ecosystems. Eur J Soil Biol 62:1–9

Mganga KZ, Musimba NKR et al (2010a) Improving hydrological properties of degraded soils in semi-arid Kenya. J Environ Sci Technol 3(4):217–225

Mganga KZ, Nyangito MM et al (2010b) The challenges of rehabilitating denuded patches of a semi-arid environment in Kenya. Afr J Environ Sci Technol 4(7):430–436

Mnene WN, Hanson J et al (2005) Genetic variation between ecotypic populations of *Chloris roxburghiana* grass detected through RAPD analysis. Afr J Range Forage Sci 22(2):107–115

Mrabet R (2002) Stratification of soil aggregation and soil organic matter under conservation tillage systems in Africa. Soil Tillage Res 66:119–128

Mulatya JM, Wilson J et al (2002) Root architecture of provenances, seedlings and cuttings of *Melia volkensii*: implications for crop yield in dryland agroforestry. Agrofor Syst 56:65–72

Muriuki G, Seabrook L et al (2011) Land cover change under unplanned human settlements: a study of the Chyulu Hills squatters, Kenya. Landsc Urban Plan 99:154–165

Musimba NKR, Nyariki DM et al (2001) The socio-economic, ecology and culture of bee-keeping among the Akamba community of southern Kenya. J Hum Ecol 12(3):207–216

Mwang'ombe AW, Ekaya WN et al (2011) Livelihoods under climate variability and change: an analysis of the adaptive capacity of rural poor to water scarcity in Kenya's drylands. J Environ Sci Technol 4:403–410

Naughton-Treves L, Kammen DM et al (2007) Burning biodiversity: woody biomass use by commercial and subsistence groups in western Uganda's forests. Conserv Areas High Popul Density Sub-Sahar Afr 134(2):232–241

Nyambati EM, Sollenberger LE et al (2006) The value of *Acacia brevispica* and *Leucaena leucocephala* seedpods as dry season supplements for claves in dry areas of Kenya. Afr J Agric Res 1(4):118–124

Nyangito MM, Musimba NKR et al (2008) Range use and dynamics in the agropastoral system of southeastern Kenya. Afr J Environ Sci Technol 2(8):222–230

Nyangito MM, Musimba NKR et al (2009) Hydrological properties of grazed perennial swards in semiarid Southeastern Kenya. Afr J Environ Sci Technol 3(2):026–033

Olukoye GA, Kinyamario JI (2009) Community participation in the rehabilitation of a sand dune environment in Kenya. Land Degrad Dev 20:397–409

Opiyo FEO, Ekaya WN et al (2011) Seedbed preparation influence on morphometric characteristics of perennial grasses of a semi-arid rangeland in Kenya. Afr J Plant Sci 5(8):460–468

Runo MS, Muluvi GM et al (2004) Analysis of genetic structure in *Melia volkensii* (Gurke) populations using random amplified polymorphic DNA. Afr J Biotechnol 3(8):421–425

Saha HM, Kahindi RK et al (2008) Evaluation of manure from goats fed Panicum basal diet and supplemented with Madras thorn, Leucaena or Gliricidia. Trop Subtrop Agroecosyst 8:251–257

Schwilch G, Bachmann F, Liniger HP (2009) Appraising and selecting conservation measures to mitigate desertification and land degradation based on stakeholder participation and global practices. Land Degrad Dev 20:308–326

Schwilch G, Bestelmeyer B, Bunning S et al (2011) Experiences in monitoring and assessment of sustainable land management. Land Degrad Dev 22:214–225

Schwilch G, Liniger HP, Hurni H (2014) Sustainable land management (SLM) practices in drylands: how do they address desertification threats? Environ Manage 54:983–1004

Somarriba E (1988) Pasture growth and floristic composition under the shade of guava (*Psidium guajava* L.) trees in Costa Rica. Agrofor Syst 6:153–162

Speranza CI, Kiteme B, Wiesmann U (2008) Droughts and famine: the underlying factors and the causal links among agro-pastoral households in semi-arid Makueni district, Kenya. Glob Environ Change 18:220–233

Tiffen M, Mortimore M (2002) Questioning desertification in dryland sub-Saharan Africa. Nat Resour Forum 26:218–233

Visser N, Morris C et al (2007) Restoring bare patches in the Nama-Karoo of South Africa. Afr J Range Forage Sci 24(2):87–96

Wardell DA, Reenberg A, Tøttrup C (2003) Historical footprints in contemporary land use systems: forest cover changes in savannah woodlands in the Sudano-Sahelian zone. Glob Environ Change 13(4):235–254

Wasonga VO, Ngugi RK et al (2003) Traditional range condition and trend assessment: lessons from Pokot and Il Chamus pastoralists of Kenya. Anthropologist 5(2):79–88

Wekesa L, Muturi G et al (2012) Economic viability of *Melia volkensii* (Gurkii) production on smallholdings in drylands of Kenya. Int Res J Agric Sci Soil Sci 2(8):364–369

Wessels KJ, Prince SD et al (2007) Relevance of rangeland degradation in semi-arid northeartern South Africa to the non-equilibrium theory. Ecol Appl 17:815–827

Yirga G, Koru B et al (2012) Assessment of beekeeping practices in Asgede Tsimbla district, Northern Ethiopia: absconding, bee forage and bee pests. Afr J Agric Res 7(1):1–5

Young A (1988) Agroforestry and its potential to contribute to land development in the tropics. J Biogeogr 15:19–30

Zaal F, Oostendorp RH (2002) Explaining a miracle: intensification and the transition towards sustainable small-scale agriculture in dryland Machakos and Kitui districts, Kenya. World Dev 30(7):1271–1287