The Desert Margins Programme Approaches in Upscaling Best-Bet Technologies in Arid and Semi-arid Lands in Kenya

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Abstract Kenya's land surface is primarily arid and semi-arid lands (ASALs) which account for 84% of the total land area. The Desert Margins Programme (DMP) in Kenya has made some contribution to understanding which technology options have potential in reducing land degradation in marginal areas and conserving biodiversity through demonstrations, testing of the most promising natural resource management options, developing sustainable alternative livelihoods and policy guidelines, and replicating successful models. In extension of sustainable natural resource management, two types of strategies were used: (i) strategies for the promotion of readily available technologies and (ii) approaches for participatory learning and action research. Thus DMP-Kenya initiated upscaling of four 'best-bet' technologies. Under the rangeland/livestock management options, scaling-up activities include improvement of rangeland productivity, rangeland resource management through community-based range resources monitoring/assessment, and fodder conservation for home-based herds. Restoration of degraded lands included rehabilitation of rangelands using the red paint approach in conservation of *Acacia tortilis*, control of *Prosopis*, planting of *Acacia senegal* trees in micro-catchments, and rehabilitation of degraded areas through community enclosures. Improved land, nutrient, and water management involved upscaling water harvesting and integrated nutrient management (INM) technologies. Activities under tree-crop/livestock interactions included upscaling of *Melia volkensii* and fruit trees (mangoes) and enhancing biodiversity conservation through support of beekeeping as a viable alternative livelihood. Participatory learning and action research (PLAR) was used for technology development and dissemination. Capacity building and training was a major component of upscaling of these best-bet technologies.

Keywords Approaches in upscaling technologies · Arid and semi-arid lands · Biodiversity · Kenya · Land degradation

Introduction

The problem of desertification and land degradation in Kenya presents a major threat to all facets of land productivity (Kilewe and Thomas, 1992). Land degradation, either natural or induced by humans, is a continuing process. It has become, however, an important issue through its adverse effects on national natural resources, food security, and livelihoods in sub-Saharan Africa (Nabhan et al., 1999). The potential scale of land degradation in Kenya is serious as 84% of the total land area is arid and semi-arid. Causes of land degradation are numerous and include decline of soil fertility, development of acidity, salinization, alkalization, deterioration of soil structure, accelerated wind and water erosion, loss of organic matter, and biodiversity (Nabhan et al., 1999). Kilewe and Thomas (1992) and Nandwa et al. (1999) reviewed the forms of soil degradation (both chemical and physical) occurring in Kenya. The absence of quantitative data necessary

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A. Bationo et al. (eds.), *Innovations as Key to the Green Revolution in Africa*,
DOI 10.1007/978-90-481-2543-2_120, © Springer Science+Business Media B.V. 2011

for predicting land degradation and detecting critical management alternatives has curtailed the development of conservation practices applicable to Kenyan conditions. This has also prevented objective evaluation and adaptation of models and experiences developed elsewhere and hindered the rehabilitation of degraded land.

The Desert Margins Programme (DMP) is a project in the Sub-Programme of Environmental Science and Research of the United Nations Environment Programme that covers nine countries in Africa (Burkina Faso, Botswana, Mali, Namibia, Niger, Senegal, Kenya, South Africa, and Zimbabwe). The DMP was developed in response to a recommendation made to the international research community at UNCED to consider specific contributions for implementation of the three international conventions on biodiversity, climate change, and desertification. The overall objective of the DMP is to arrest land degradation through demonstration and capacity-building activities developed through unravelling the complex causative factors of desertification and conservation and restoration of biodiversity through sustainable utilization in the desert margins in Africa. The Desert Margins Programme (DMP) in Kenya was implemented from 2003 to 2007 by the Kenya Agricultural Research Institute in collaboration with NARS [Kenya Forestry Research Institute (KEFRI), National Environment Management Authority (NEMA), the National Museums of Kenya (NMK), University of Nairobi (UoN), and extension agents], NGOs (ITDG and ELCI), and international institutions (ILRI, ICRISAT, TSBF, and ICRAF) resident in Kenya. DMP has local objectives of mitigating land degradation in the desert margins in Kenya. While addressing its primary objective of alleviating land degradation, DMP is expected to make a significant reduction in the negative impacts associated with other factors that cause degradation processes. During the past 4 years (2003–2006), the DMP project in Kenya has made some contribution to understanding which technology options have potential in reducing land degradation in marginal areas and conserving biodiversity through demonstrations, testing of the most promising natural resource management options, developing sustainable alternative livelihoods and policy guidelines, and replicating successful models. Thus DMP-Kenya has initiated upscaling of four 'best-bet' technologies that include various rangeland/livestock management options; restoration of degraded lands; improved land, nutrient, and water management; and tree-crop/livestock interactions.

Materials and Methods

Biophysical and Socioeconomic Characteristics of the Study Sites

The Kenyan component of DMP was implemented in three benchmark sites in Turkana/Turkwel, Marsabit, and the Southern Rangelands.

Turkana/Turkwel Site

The Turkana/Turkwel site is a river basin ecosystem in northwest Kenya. The ecosystem consists of the Turkwel riverine forest that supports hydropower production at the gorge, pastoralism, irrigated agriculture, production of Doum palms, fuel wood including charcoal production, and human settlements. Currently, *Prosopis juliflora* has become an obnoxious invasive weed within the Turkwel ecosystem and is also choking shores of Lake Turkana. Mean annual rainfall is approximately 500 mm in the upstream section and less than 200 mm downstream. Temperatures range between 24 and 38°C with a mean of 30°C. The forest is largely dominated by *Acacia tortilis* with *Faidherbia albida*, *Acacia elatior*, *Cordia sinensis*, and *Hyphaene compressa* as sub-dominants on the riverbanks and *Balanites pedicellaris*, *Boscia coriacea*, and *Acacia nubica* on the dry edge of the riverine zone. The soils are alluvial deposits of deep sandy or silty loams classified as calcaric Fluvisols (Van Bremen and Kinyanjui, 1992). The major source of livelihood is livestock sector, which contributes to 60% of the district population. However, crop production is mainly practised along major rivers and contributes to about 16% of the local economy. Despite the increasing dependency on agriculture most Turkana still keep herds of livestock (cattle, camels, goats, sheep, and donkeys) and are either nomadic pastoralists or agro-pastoralists. Poverty levels within this region are generally high with an overall poverty of 74% and food poverty of 81% (GOK, 2002).

Marsabit Site

Marsabit site is in northwest Kenya and comprises Kargi, Ngurunit, Korr, and Kalacha sub-sites. Pastoral livestock production with a bias on camels, sheep, and goats is the main livelihood, with settlement playing a significant role in degradation. Marsabit represents a gradient of ecological differentiation: from the oasis ecosystem in an otherwise desert zone at Kalacha through a very arid zone at Korr and Kargi to the montane semi-arid ecosystem at Ngurunit. The site has a diversity of plant species that are endemic.

Kargi is a Rendille settlement about 70 km northwest of Marsabit town at an altitude of approximately 600 m.a.s.l. with mean rainfall of 250 mm, mean monthly temperature of 27–29°C, and a mean annual potential evapotranspiration of about 2,500 mm. The vegetation is dominantly *Acacia* shrub land with *Duosperma*/*Indigofera* understory.

Ngurunit is an Ariaal/Rendille settlement situated at an altitude of approximately 700–800 m.a.s.l. The mean annual rainfall is about 600 mm and diurnal temperatures range between 22 and 27°C. The potential annual evapotranspiration is about 2,000 mm.

Korr is a Rendille settlement at an altitude of 500 m.a.s.l. The mean rainfall is 180 mm.

Kalacha is inhabited by the Gabbra pastoral community on the northern edge of the Chalbi desert. The settlement lies at an altitude of 386 m.a.s.l. The mean annual rainfall is less than 200 mm. The area surrounding the settlement is typical of most arid areas of Marsabit District except that there is an oasis with plenty of water and a big grove of Doum palms. The settled pastoralists do some irrigated farming using water from this oasis. The area is sparsely wooded with *A. tortilis* being the dominant species, sparsely interspersed by the salt-tolerant bush *Salsola dendroides*.

Southern Rangeland Site

This site is at the intersection of Kajiado, Makueni, and Taita-Taveta Districts with land degradation impacts emanating from farming, pastoralism, and wildlife conservation. The climate is semi-arid to arid with the mean annual rainfall ranging between about 600 and 750 mm as opposed to potential evaporation varying between 2,100 and 2,150 mm (Achieng and Muchena, 1979). In the national park, however, rainfall varies between 300 and about 900 mm and increases towards the south.

The altitude lies between 150 and 1,000 m.a.s.l. The natural vegetation is dominated by wooded bushland consisting of *Enteropogon macrostachyus* and *Chloris roxburghiana* (30% of grasses) with *Acacia brevispica*, *Combretum exallatum*, *Commiphora* spp. and grasses such as *Premma holstii*, *Ocinum basilicum*, and *Grewia* spp. plus other wooded species.

All soils in the district are developed on sandstones rich in ferro-magnesium minerals. They are well drained, deep to very deep, red to dusky red, and sandy clay to clay (Ekirapa and Muya, 1991). These are represented around Kiboko and west of Kibwezi by *chromic* Luvisols and interfluves of *orthic* and *xanthic* Ferralsols (Ministry of Agriculture, 1987). Soils are variable in depth depending on the parent material and slope and are generally low in organic matter and deficient in nitrogen, phosphorus, and potassium (Van Wijngaarden and van Engelen, 1985).

The population of Makueni District consists of some 43,377 households with a density of 10–150 people/km^2 and farm sizes averaging 3.5 ha per household (De Jager et al., 2006). Of the total farmland an average of 48.5% is under cultivation and up to 71% of the households live below poverty line.

Farm sizes are on average 3.3 ha per household of which about 1.8 ha is utilized to grow crops, with the rest of the land under pasture. Livestock are also kept but their quality is low due to poor breeds and poor feed supply and feed rations. Apart from rainfed agriculture there are extensive areas where irrigation is practised.

Methodologies/Approaches

Extension of the sustainable natural resource management (NRM) component of DMP was to foster improved and integrated soil, water, nutrient, vegetation, and livestock management technologies to achieve greater productivity of crops, trees, and animals to enhance food security and ecosystem resilience. In Kenya, extension of sustainable natural resource management was started in the second year of DMP. Two types of strategies were used: (i) strategies for the promotion of readily available technologies and

(ii) approaches for participatory learning and action research.

The research component started by developing inventories and characterizing available technologies ready for promotion, defining potential user groups/systems–farm typologies, and matching technologies with people. A bottom-up, social, and experiential learning approach was needed to foster technological change. Such a learning approach aimed at making the best use of locally available resources, knowledge, and decision making in combination with research-based understanding and analysis of the underlying processes, leading to technology adaptation, innovation, and change based on social interaction.

The methodologies/approaches used to implement DMP activities included reconnaissance surveys, diagnostic surveys, soil surveys, stakeholder workshops, on-farm trials/demonstrations, establishment of demonstration plots on forage germplasm, indigenous fruit trees, tree nurseries, medicinal plants, commercial fruit trees, multipurpose trees, woodlots, horticultural crops, drought-resistant crops, and other potential biodiversity activities and upscaling of 'best-bet' technologies. Best-bet technologies were upscaled through establishment of small-scale demonstration plots, on-farm trials, training and stakeholder workshops, information dissemination and exchange, and raising awareness to foster adoption of sustainable land use practices. The programme participated in a number of initiatives to generate a policy and regulatory environment to encourage sustainable use of natural resources. Community-based management of natural resources and monitoring and evaluation of the natural resource base with the pastoral communities was started in the DMP sites.

This was implemented in close collaboration with the relevant stakeholders involved in extension work. The existing and new farmer networks formed the basis for the set-up of stakeholder platforms for all relevant partners involved in research and development activities in the sites. They included extension services; international, national, and local non-governmental organizations (NGOs); and private sector who directly work with farmer groups and community-based organizations (CBOs) as primary beneficiaries. Detailed aspects of methods for each project in the programme are summarized under major activities for each project in the various DMP sites.

Results and Discussion

Rangeland/Livestock Management Options

Improvement of Rangeland Productivity

Range condition and trend assessments over the years have often pointed at worsening productivity of natural pastures in both the arid and semi-arid areas of East Africa (Coughenour et al., 1990; McPeak, 2003; Coughener, 2004). Wandera et al. (1996) highlighted the need for pasture improvement for greater meat production from indigenous livestock in pastoral areas of Kajiado and Baringo Districts in Kenya.

Range and livestock technologies can be used intensively to improve the productivity of the marginal areas in the rangelands of Kenya. Low levels of production in these areas are attributed not only to scarce and erratic rainfall but also to low levels of technical skills by farmers. Proper exploitation of the range resource potential through improved management can easily change the living standards of these farmers. The potential rangeland management practices that can be used to increase production in the semi-arid rangelands include range, plant, and livestock-related technologies.

Soils and soil moisture form the basis of rangeland productivity and therefore their conservation and management are of paramount importance. These can be achieved in grazing lands through pitting, contour terracing, and revegetation of watersheds and pastures. Forage species adapted to grazing and drought stress have been identified in ASALs of Kenya. Subsequently, field experiments were carried out to test and demonstrate the usefulness of the selected genotypes in the reclamation of degraded rangelands and production of good quality forages in the semi-arid zones.

During the period under review, DMP worked in five farmer clusters in the Southern Rangelands. In each cluster, five farmers were selected as contact demonstration farmers representing each village composed of about 50–60 active farmers. The demonstrations were carried out at the village level where all the farmers participated through participatory adaptive research and development approaches. In each village one farm was identified where demonstrations were carried out. Three grass species (*Cenchrus ciliaris*, *Eragrostis superba*, *and E. macrostachyus*) were established on a 0.25 ha of land. Other farmers were each allowed to carry grass seeds of one species of their choice for establishment in their farms. At the end of the first season a total of 21 farmers from 2 villages had well-established pastures. Their pastures ranged from 0.1 to 0.3 ha and the demand for grass seeds had increased, with farmers who had harvested grass selling all their stocks. After seed harvesting about 40% of the farmers harvested and baled the grass as hay while the rest allowed animals to graze during the dry season. Those who baled later sold them at a profit.

Results from participatory evaluation of trials on pasture reseeding and related trials indicated that farmers were encouraged by the increased forage for their livestock. Farmers realized increased income from increased milk yield, hay, and sale of grass seeds. The hay and grass seed sale resulted in diversification of income sources to the community. Other sources of increased incomes were due to sale of animals as a result of improved livestock conditions with improved availability of pastures in restricted areas. Farmers have therefore expanded the areas under pastures and forages. A community-based seed multiplication approach has been adopted to meet the high demands for seed. This group approach to on-farm trials and demonstrations has resulted in more rapid scaling up of technologies in the DMP sites within the Southern Rangelands through promotion and support of farmer groups and community-based organizations (CBO) that were registered during the EU/ARSP and ARIDSAK projects.

With the adoption of improved range management technologies, it is expected that primary and secondary rangeland productivity and the living standards of the communities will be improved as well as reduction in rangeland degradation.

Improvement in Rangeland Resources Management Through Community-Based Range Resources Monitoring and Assessment in ASALs

Over the last two decades community-based natural resource management (CBNRM) has become an important strategy to conserve and sustainably use biodiversity in Africa. Community resource management institutions and organizations are now receiving greater attention as a viable alternative to regulation by the state or privatization as a means of rectifying inefficiencies caused by attenuated property right systems and externalities (Fabrius et al., 2005; Gemedo-Dalle et al., 2006). There is growing recognition that biodiversity and indigenous knowledge are interrelated phenomena (Balard and Platteau, 1996; Warren 1993). Once the diversity of floral and faunal resources disappears, the knowledge associated with these resources also disappears. It was with this background that the community, in collaboration with KARI-Marsabit research scientists, initiated a community-based range resources monitoring and assessment activity. This is expected to harmonize the traditional methods of range resources monitoring and assessment with the conventional methods.

The main objective was to actively involve the community in biodiversity conservation through jointly documenting changes in natural resources over time by using traditional and conventional methods of range resources monitoring and assessment. The community was involved in monitoring the state of resources within their area using traditional indicators in collaboration with the research scientists who used conventional methods.

Conventionally, the technical staff described the various resource attributes within established permanent transects and also clipped the herbaceous vegetation falling at specified intervals within transects. Data were collected along three 500 m long transects and at intervals of 100 m; grasses, herbs, forbs, shrubs, and trees were sampled using the nested quadrat method. Descriptions were also made of the vegetation species, and the soil conditions and the results were compared with the community description. Two transects fall within the community livestock home range and the third transect outside the livestock home range.

For the community, data collected gave a general/subjective description of the area from their traditional indigenous knowledge perspective. Their method of recording and analysis depended more on memory and discussion than on written records. They describe the environment and their observations which are documented in terms of vegetation suitability, cover, soil conditions, and general observations on use or misuse of resources.

This approach was received with enthusiasm by the community members and promises to yield great impact in enhancing environmental conservation efforts at the community level. To sensitize the wider community on the importance of biodiversity conservation, the results from the studies are continuously made available to the community through workshops and outreach to institutions like schools. Since the communities took the necessary initiatives, the results from these studies will feed back into the community policy structures for conservation of resources. Communities in other areas have requested that the same structures for conservation be introduced in their areas. Hence, collaboratively with the GEF-funded Indigenous Vegetation Project, six more transects have been established for monitoring natural resources dynamics.

The project goal of conserving and restoring biodiversity in the desert margins is being met since the project's aim was to create awareness on resource use dynamics and influence conservation policies at the grassroots level. The greatest impact will be improvement in biodiversity within the areas that are already under pressure due to resource over-utilization. Ecosystem products and services such as vegetation resources, reduction in soil erosion, and improved water infiltration will improve. The total area targeted is over 30,000 ha and this will benefit over 1,200 households.

Fodder Conservation for Home-Based Herds

Because of many factors, there are many changes that have taken place within the drylands of Kenya which have led to changes in the vegetation structure. Several communities in the northern part of Kenya point to a good past in terms of vegetation resources endowment (Milimo et al., 2002). However, they indicate that there has been a downward trend in vegetation attributes over the years. This has led to scarcity of forage to livestock, especially the home-based herds, since the other livestock species migrate in search of pasture when conditions allow. To minimize forage scarcity for the home-based herds, fodder bank technology was introduced to the community. The technology involves fodder establishment at the community level/individual farmer's plots. Interested farmers who demand for grass seeds for fodder establishment are given technical advice on fodder establishment and hay bulking. This is a community-driven initiative that receives given technical support from research and extension agents.

The challenges of the recent drought, that made the government provide hay as part of relief efforts, have made the community take the initiatives of fodder conservation more seriously. The only challenge will be provision of grass seeds, which imply timely harvesting of grass seeds or sourcing of fodder germplasm.

The direct benefit of the initiative was provision of fodder for the home-based herds and securing food security at the household level. By implication, the provision of fodder reduces the pressure on vegetation resources, hence allowing regeneration and conservation of biodiversity.

Restoration of Degraded Lands

Rehabilitation of Degraded Rangelands

Rangelands have a relatively low production potential, are fragile, and are easily degraded through over-utilization or use of inappropriate technologies (Herlocker, 1999). The most common types of degradation in the rangelands are degradation of the soil, vegetation, and animal species.

The demand on the rangelands is high due to increasing livestock and human populations. The pressure is from within the rangelands and immigration from neighbouring densely populated high-potential areas.

There is need therefore to develop and/or source, adapt, and upscale appropriate rangeland rehabilitation technologies and to support efforts by research and other development agencies in providing technologies that will sustainably improve rangeland productivity.

The technologies being upscaled were mainly in soil and water management and improvement of primary productivity. The soil and water management technologies are as follows:

(i) Runoff harvesting for improving soil moisture
(ii) Construction of water and soil micro-catchments
(iii) Construction of modified terraces
(iv) Restoration of gully eroded rangelands

Technologies for improvement of primary productivity are as follows:

(i) Plant species enrichment that involves introduction or increase of the germplasm to improve ground cover and production
(ii) Bush management technologies that involve reduction of the woody vegetation to allow for increased herbaceous production

The technologies were implemented using on-farm trials and demonstrations carried out at the village level where farmers were involved through participatory adaptive research and development approaches.

Red Paint Approach in Conservation of *A. tortilis*

This involves the painting of the stems of *A. tortilis* trees with red paint. Red paint within the Rendille and Samburu pastoral communities is revered and anything painted red is disused or used judiciously. By marking young tree seedlings with red paint, one marks them out for disuse by the community and with this they can be allowed to establish into mature trees.

The process of identifying the desirable areas/plants for conservation involved discussions with the community. Areas with high *A. tortilis* regeneration, especially in old abandoned bomas (Kraals), were identified and mapped out. Paint was then provided to the community members to paint tree stems of the identified trees. However, not all trees were painted, to allow access and use of some of the resources.

This technology or approach was tried by various projects including IPAL, GTZ, and the EU/ARSP II with very good success (Lusigi, 1981; Goldsmith, 2000; Ndung'u et al., 1999). It has worked with the community's approval since the costs involved are minimal.

Increased biodiversity will lead to improved ecosystem services to the community. The target species, *A. tortilis*, which is well adapted to this area, is of high value in terms of provision of livestock feed (pods are a main dry season feed source), wood fuel, building poles, and also fencing materials, among others. Hence the impact will be felt at the household level, with a total population of over 10,000 persons benefiting from the technology.

Rehabilitation of Deserts Through Planting of *Acacia senegal* Trees in Micro-catchments

The Acacia Operation Project (AOP) is a project supporting food security and rural development of gums and resins in sub-Saharan African countries (Burkina Faso, Chad, Kenya, Niger, Senegal, and Sudan). This project aims to rehabilitate degraded land by planting *A. senegal* using novel water harvesting technologies and improving livelihoods through promotion of gum and resin production.

Micro-catchments for water harvesting were made using a specially designed tractor and plough (Delphino plough) designed to make micro-catchments. *A. senegal* seeds are planted in the micro-catchments to utilize harvested runoff. Grasses were also planted on the micro-catchments for soil conservation and as a source of fodder.

The approach used created synergy between nature and modern technology in improving management of natural resources. The local communities were involved in the identification of potential sites for development of plantations for gum and resin production, before micro-catchments were ploughed. There was also capacity building on markets and income diversification as well as training in dryland food production and utilization to realize immediate benefits from the plantations.

The potential of production of gums and resins as alternative livelihoods and diversification of the production systems formed the basis for the success of these technologies. About 342.7 ha was planted by the AOP project with *A. senegal* seeds/seedlings and drought-tolerant crops at Serolipi, Laisamis, and Ngurunit in Marsabit and Samburu Districts. The results indicated that *A. senegal* can be successfully established in degraded sites. However, more trials need to be conducted before concrete recommendations on integration of crops with *A. senegal*. Challenges include a cultural bias towards pastoral livestock keeping as opposed to agro-silvopastoralism and communal land ownership. The technology will contribute to sustainable development, food security, and combating desertification through the promotion and integration of gums and resins in rural economies as an alternative livelihood.

Rehabilitation of Degraded Areas Through Community Enclosures

Community enclosures are ideal for improving the overall ecological conditions of degraded areas so that they can provide better socioeconomic benefits and environmental services to the local people. Previous studies in ASALs show that enclosing land with fencing had many benefits that included increased livestock feed, fuel wood, more water, higher land value, and increased livestock production. The method is cheap, quick, and cost friendly in this region. Due to low and unreliable rainfall, afforestation programmes and grass reseeding have resulted in low survival rates of germplasm. Reid and Ellis (1995) reported that *A. tortilis* was successfully recruited in South Turkana through abandoned livestock enclosures. Goats which form the majority of livestock population in the district normally eat the *A. tortilis* pods. However, the seeds are not digested but are excreted in the droppings which will later germinate, but if the young seedlings are not enclosed they will be browsed. Emiru et al. (undated) and Olukoye et al. (2003) demonstrated successful cases in Tigray in Ethiopia and Noth Horr in Kenya, respectively.

An evaluation of one successful case study of established community enclosure at Kalatum in Turkana was undertaken to assess the effectiveness of tested technologies, community mobilization approaches, and opportunities/challenges of upscaling this technology. The success of enclosures was tested by assessing the adoption of fencing technology by community members and comparison of vegetation status between the fenced and unfenced plots. Adoption of fencing technology entailed assessment of fence expansion, while impact of other range rehabilitation was undertaken by comparing vegetation variables between fenced and unfenced areas, using a total of 25 sample plots. Sampling was done during the wet and dry seasons because of variation of seasonal impacts on vegetation status. Results of this study showed an increase of the fenced area from the initial plot of 5 ha to an extensive area of about 25 ha. The community adopted the use of locally available plant materials and deterrent rules to keep off livestock from the areas earmarked for range regeneration. Ecological assessment of the impact of fencing and water harvesting on range resilience revealed a higher density of important fodder species such as *A. tortilis* of 124 trees and 14 trees per hectare in the fenced and unfenced areas, respectively. The average percentage cover of the dominant grass *Chrysopogon plumulosus* was 36 and 4% in the fenced and unfenced areas, respectively. In total, 15 plant species were recorded in the enclosures compared to only 7 in open rangelands.

The enclosure has been a model used by the DMP project for exposing more community members to this technology. This has been accomplished by community sensitization and formulation of community action plans which led to initiation of three more enclosures with a total area of 10 ha in different localities within the district. Increased vegetation cover through enhanced natural regeneration while conserving biodiversity will lead to improved standard of living of the target communities.

Improved Land, Nutrient, and Water Management

The current high population pressure on land necessitates exploitation of arid and semi-arid lands (ASALs) for crop production. However, agricultural production in ASALs is limited by low and erratic rainfall, high transpiration rates, and generally fragile ecosystems which are not suitable for rainfed agriculture (Jaetzold et al., 2006).

Rainwater harvesting using tied ridges and open ridges is one of the cheap methods of mitigating dry spells in areas where farmers have inadequate resources to invest in irrigation. On-farm trials in Makueni District and other studies in ASALs in Kenya and sub-Saharan Africa have indicated that tied ridges increase maize yields by more than 50% above the conventional flat tillage practised by farmers (Njihia, 1977; Kipserem, 1996; Ngoroi et al., 1994; Jensen et al., 2003; Itabari et al., 2004; Miriti et al., 2007; Itabari et al., 2007). There were significant increases in maize yield when tied ridges are combined with integrated nutrient management (Jensen et al., 2003; Miriti et al., 2007; Itabari et al., 2007). However, tied ridging has not been widely adopted by small-scale resource-poor famers in the semi-arid lands. There have been contradictory reports on the effects of tied ridging due to the variation in soil and climatic characteristics among sites and between years. In addition, the net effect of tied ridging includes both positive and negative effects (Hudson, 1987; Lal, 1995). The research hypothesis was that combining water harvesting techniques with improved soil fertility will result in higher efficiency of resources and increase in crop yields in the ASALs.

Based on the above evidence from the ASALs in Kenya, DMP initiated upscaling water harvesting and INM in the benchmark sites in the Southern Rangelands and Marsabit District in northern Kenya. Researcher-farmer managed mother–baby on-farm trials and demonstrations were conducted to study the effect of different water harvesting technologies and integrated nutrient management practices on crop yields. The trial treatments included three water harvesting techniques [farmers' practice (flat tillage), contour furrows, and tied ridging] and five integrated nutrient management practices [control (without fertilizers), farmyard manure at 5 t/ha, farmyard manure at 5 t/ha + 20 kg N/ha + 20 kg P/ha, farmyard manure at 10 t/ha, and farmyard manure at 10 t/ha + 20 kg N/ha + 20 kg P/ha]. The treatment arrangement was split-plot and each treatment was replicated four times in a randomized complete block design (RCBD). Trials were established in five clusters in the Southern Rangelands. These clusters were at Kimana in Kajiado District, Kambu, Kamboo, Kathyaka, and Kalii in Makueni District. During the long rains in 2006 there were 5 mother trials and 15 baby trials, whereas during the short rains these were 4 and 18, respectively. Cowpeas K80 and green grams N26 were used as the test crops during the long rains and short rains, respectively. In Marsabit District four trial sites were selected in four different sub-locations [Songa, Galqasa/Goro Rukesa, Dirib Gombo, and KARI Marsabit (Majengo sub-location)]. Partners in the establishment of the trials were DMP research scientists from collaborating institutions that included the TSBF Institute of CIAT, KEFRI, KARI, extension staff from the line ministries, NGOs, and community-based organizations from the DMP sites.

Preliminary results indicated that there were differences between the tillage treatments at Katumani but not at Kiboko and Marsabit, and integration of manure and inorganic fertilizers within the treatments increased maize yields (Table 1). Application of manure 10 t/ha plus 20 kg N plus 20 kg P_2O_5/ha had the highest yields under tied ridging. The highest yield under contour furrows was at 5 t/ha with 20 kg N+20 kg P_2O_5/ha manure whereas under the farmers practice it was at 10 t/ha manure. The results show that tied ridging and contour furrows coupled with integrated nutrient management have potential as a viable option for improved crop production in arid and semi-arid lands. However, there is need for long-term trials as well as economic analysis prior to making any concrete recommendations.

Table 1 Preliminary results on the effect of water harvesting and INM on maize grain yields on farmers' fields in the Southern Rangelands (Katumani and Kiboko)

Treatments	Tied ridging	Contour furrows	Farmers' practice
Control	983	1,036	903
Manure 5 t/ha	1,194	1,123	963
Manure 5 t/ha + 20 kg N+20 kg P_2O_5/ha	1,139	1,180	1,018
Manure 10 t/ha	1,211	1,170	1,065
Manure 10 t/ha + 20 kg N+20 kg P_2O_5/ha	1,375	1,054	1,046
Mean	1,180	1,133	999
LSD (P< 0.05)	489	509	566

Tree-Crop/Livestock Interactions

Tree-crop/livestock integration offers a promising opportunity for intensifying agricultural production and increasing ecological integrity so as to have a positive impact on livelihoods and NRM in mixed farming systems (Karugu, 2004). For smallholders who have limited access to external inputs, research has documented that introduction of rotations of various crops, forage legumes, trees and use of manure help maintain soil biodiversity, minimize soil erosion, and conserve water. Activities under tree-crop/livestock interactions include upscaling of *Melia volkensii* and mangoes and enhancing biodiversity conservation through support of beekeeping as a viable alternative livelihood.

Upscaling of M. volkensii in the Southern Rangelands

M. volkensii Gürke has received significant research attention because of its socioeconomic importance in the drylands. *Melia* is a multipurpose tree species endemic in arid and semi-arid lands of eastern Africa. It is used as construction timber, fuel wood, fodder (fruit and leaves), medicine (bark), bee forage, mulch, and green leaf manure (Kamondo et al., 2006).

The Southern Rangelands located in the semi-arid areas of southeast Kenya form part of the drylands where *Melia* is endemic. The tree is heavily exploited in the region and very little remains in nature, calling for concerted efforts to conserve the natural stands as well as encourage farmers to plant *Melia* on their farms. In this region, DMP has responded to these needs and is currently upscaling *Melia* through the following:

(a) Capacity building on seedling production for farmers: The technology developed by KEFRI to raise *Melia* seedlings is an elaborate process that involves seed extraction from the nut, pre-treatments, and management of the seedlings. Capacity building is necessary for farmers' adoption and adaptation of the technology. Therefore, through support of DMP, KEFRI staff conducts on-station and on-farm training on requisite processes for successful seedling production through seeds. The training focuses on timing of seed maturity, depulping of *Melia* fruits, seed extraction, seed pre-treatment, sowing, pricking out, and tending of pricked out seedlings. Training is necessary because the species is highly sensitive to weather and environmental conditions.

During 2005–2006, members of four group nurseries were trained and they raised over 20,000 *Melia* seedlings that were either planted on their farms or sold off (Table 2).

In addition, over 200 farmers were trained in their individual capacity in raising *Melia* seedlings.

(b) Silvicultural management: Over 50 farmers supported to establish *Melia* woodlots in the Southern Rangelands site were trained on tree management to improve production of various *Melia* products. For timber production, pruning and spacing were the major training aspects. Tree-crop interactions/competition was also addressed through appropriate farm planning for optimum land productivity.

(c) On-station seedling production: On-station seedling production was initiated during phase II to meet the rising demand for *Melia* seedlings. This will be scaled down as farmers are trained to produce seedlings on farm. Over the past 3 years about 20,000 *Melia* seedlings were raised for out-planting (Table 3).

Therefore DMP is upscaling M*elia* through capacity building on seedling production and silvicultural management. By providing alternative source of forestry products like timber, the pressure on highland forests is expected to reduce in the long term, and this contributes to biodiversity conservation since highland forests are more endowed with biological diversity. The gains from increased *Melia* hectarage and conservation of ASALs will eventually lead to increased carbon sequestration. In addition to the above benefits, the

Table 2 Farmer groups trained on *Melia* seedlings production

Name of group	Number of members trained	Number of seedlings raised
Utheu wa Aka	21	4,500
Kituku's group	5	6,000
Nzonkolo group	15	1,500
Masongaleni group	5	5,000
DWA Sisal plantation	1	5,000

Table 3 Out-planted *Melia* seedlings

Division	No. of farmers	No. supplied	Farmers' own supplies	No. surviving	Average height (m)
Kibwezi	50	9,054	1,164	8,570	2.3
Kajiado	1	200	–	192	3.5
Marsabit	–	4,500	–	2,500	–
Makindu	2	2,000	–	1,600	3.0
Mtito Andei	3	3,720	–	1,970	2.2
Total	56	19,474	1,164	14,832	–

sale of its raw and processed products will contribute to household incomes as an alternative livelihood for local communities.

Upscaling Mango (Mangifera indica) Production and Marketing in the Arid and Semi-arid Lands in Kenya

Mango is the most important fruit in the tropics. The fruit marketability, especially for the export market, is high where the fruit fetches high prices. Mango which has been naturalized in Kenya grows well from sea level up to an altitude of 1,800 m and requires mean annual temperatures between 20 and 30°C. Once established the plant can tolerate a wide range of soils but prefers deep fertile well-drained soils with pH ranging from 5.5 to 7.5.

The Kenya Forestry Research Institute (KEFRI) and KARI through the ARIDSAK project were involved in the promotion of mango orchard establishment as a sustainable alternative livelihood source for the communities in the drylands. The key challenge to mango production is timely production of quality fruits in quantities that justify selling in lucrative markets located far away from the drylands. In addressing production and marketing challenges, different techniques and methodologies have been identified. Suitable types and varieties of mangoes for each region, grafting techniques, integrated soil water and fertility management practices, and pest and disease management options have been identified. In addition, there have been proposals by stakeholders on marketing and value added strategies through collective action, networking, packaging, and transportation of the fruits.

Promotion of mango production has been constrained by lack of quality planting materials. This is further exacerbated by lack of know-how by farmers on appropriate production and marketing practices. During 2003–2006, DMP responded to these needs in the Southern Rangeland site by the following:

(a) Raising and provision of quality germplasm and capacity building of farmers.

During 2005–2006, 57 farmers were provided with 5,308 mango seedlings and trained on planting and management, acquisition/production, and distribution of germplasm materials; formation of mango farmers' associations; and networking with potential marketing agencies (Table 4). After identification of farmers for mango orchard establishment, suitability of the site is assessed and field training of the targeted farmers undertaken on their farms. The farmers are given briefing on different mango types, grafting techniques, pitting, spacing, planting, and management of the orchard. They are also introduced to book-keeping and enterprise development as a complementary activity.

Table 4 Mango seedlings supplied and out-planted on farmers' fields

District	Division	Farmers recruited	Seedlings planted
Makueni	Kibwezi	43	3,898
	Mtito Andei	6	550
	Makindu	1	60
	Kathonzweni	5	500
Kajiado	Mashuru	2	300
Total		57	5,308

To produce quality germplasm materials, private nurseries were supported through training and provision of nursery materials. On-station seedlings production was done on a very low scale to complement the private nurseries.

(b) Improvement of mango fruit quality and quantity. Studies done by KEFRI show that better mango establishment is achieved when grafting is done in the field rather than in the nursery. During 2005–2006, DMP supported project staff to carry out grafting of mangoes on 30 farms. Farmers were trained on how to carry out grafting. To improve fruit quantity, production, and timeliness, DMP commenced a field study on nutrient management, watering, and pesticide application under a strict annual schedule. The study that commenced in 2005 has demonstrated that physiological manipulation of the mango tree through nutrient management and watering could alter its flowering pattern that impacts on the marketability of the fruits. Under treatment, mangoes flowered and yielded fruits 2 months earlier than those under normal conditions. The study is being documented and guidelines developed for dissemination to mango producers.

(c) Networking and marketing of products in the mango products value chain. Linkages were established by networking farmers with exporters and other marketers in potential outlets with better prices for products. The targeted ones were producers and traders of quality germplasm and buyers of the fruits. The mango seedlings' producers were linked up to Horticultural Development Authority (HCDA) for certification and cataloguing. The key buyers of the fruits from the site were the exporters and supermarkets mostly located in major urban centres and institutions and retail traders located in all marketing centres. All these were linked up by encouraging dialogue between them and farmers.

Empirical evidence has shown that mango production is highly profitable. The prices in the international market are highly competitive. Thus through capacity building, provision of quality germplasm, value adding, and improved marketing strategies, incomes of dryland communities will improve. This will help divert the farmers' focus from destructive and environmentally unfriendly practices such as charcoal production. Increased incomes will also help reduce over-reliance on livestock keeping, thus lessening pressure on the environment due to overstocking in ASALs.

Enhancing Biodiversity Conservation Through Support of Beekeeping as a Viable Alternative Livelihood

Beekeeping has several potential impacts and is particularly appropriate in the resource-poor ASALs because it does not compete directly for resources with other agricultural activities; it requires little space (50 hives can be accommodated in a tenth of a hectare) and land can be of poor quality. Thus, beekeeping is a viable and sustainable income generating activity in the drylands and has enormous environmental, social, and economic benefits for the ASALs in Kenya. Kenya's ASALs have a potential to produce between 80,000 and 100,000 t of pure honey per year, earning 20 billion shillings from the domestic and foreign markets (Nyariki et al., 2005).

To broaden their livestock base and diversify livelihood sources and income generation, settled pastoralists in ASAL ranges practise traditional beekeeping as an alternative livelihood source, which is highly compatible with biodiversity conservation. About 20% of pastoral households residing near the Ndotto Mountain ranges in Marsabit District rely on bees as a source of livelihood (Lengarite and Okoti, 2004). Traditional beekeeping is compatible with natural resource conservation since beekeepers strictly utilize fallen dead wood from 12 different woody species for making hives. C*ommiphora* and *Euphorbia* spp. are the best preferred plants which have an average life span of over 10 years. Traditions discourage beekeepers from cutting down live trees for log hives and harvesting of wood products on trees bearing hives. In the upper slopes, families and clans control the use of resources in the apiary site and through routine surveillance control fire outbreaks and harvesting of woodland resources in the apiary sites. The increased interest in beekeeping has meant that many areas have been put under natural resource conservation, which contributes to biodiversity conservation.

The purpose of the project was to establish the potential of beekeeping in the Ndotto Mountain ranges and to describe development within the sector with a view to optimally exploit beekeeping as a sustainable livelihood strategy and for biodiversity conservation in this fragile ecosystem. Priority areas for training and appropriate beekeeping technologies were identified in collaboration with target communities. To improve the traditional system, several interventions were initiated that included capacity building of traditional beekeepers blending modern beekeeping technologies with indigenous skills to sustainably manage bees and hive products, social control measures to curb hive pillaging, and integrating women in beekeeping production. To improve the quality of hive products, simple and low-cost technologies on harvesting and post-harvest handling of hive products were initiated. To refine the results and discuss on survey findings, feedback workshops were conducted. Traditional beekeepers and representatives of women groups and local traders were taken for an external study tour to visit and learn from other beekeepers and create market linkages. The introduction of modern beekeeping technologies was carried out through participatory trainings and demonstrations.

The impact of beekeeping interventions in the study area showed that log hive population had increased by 12% and the volume of crude honey traded in the local market had increased by 20%. The increase in the amount of crude honey delivered to the market was attributed to more pastoralists venturing into beekeeping. The improved capacity of local markets to buy honey also stimulated many beekeepers in the Ndotto ranges to deliver honey to the local market, including

Marsabit town. The quality (absence of impurities) and shelf life of processed honey by the women groups have improved, due to better processing techniques and women now process strictly ripe honey for the market. Since hive products were less perishable, more women groups are investing on hive products like making of wax. This diversification of products has meant increased incomes to the various households.

Conclusions

The main conclusions from the implementation of best-bet technologies in ASALs in Kenya are that the Desert Margins Programme (DMP) in Kenya has made some contribution to understanding which technology options have potential in reducing land degradation in marginal areas and conserving biodiversity that will benefit ASAL communities. Several hectares of degraded lands and rangelands have been reclaimed through various land degradation control technologies. However, land ownership is critical to farmers' investment in land degradation control and better rangeland management strategies. Policy advocacy will be necessary to promote appropriate land ownership by rural communities hoping that this will lead to greater adoption of some of the best-bet technologies that address land degradation control. Good policies will promote sustainable livelihoods, while bad policies will discourage local initiatives and result in resource degradation, poverty, and conflict (Munyasi et al., 2007: IIRR, 2002).

Combating land degradation and conserving biodiversity in the ASALs require diversification of production and cropping systems. Hence, technologies that provide alternative livelihood options to the local communities are essential to the success of land degradation control measures. Technologies that have obvious and immediate benefits to communities are more readily accepted and adopted. This is illustrated by the increased income generation from technologies such as beekeeping and honey production and fodder conservation for sedentary livestock herds in Kenya. Thus community-based natural resources management is key to sustainable resource use and derivation of benefits by the local community.

Training of stakeholders is an important component of upscaling; therefore, many stakeholders (farmers, women, and technicians) have been trained during the implementation of the best-bet technologies. Training provided included grafting techniques, use of drip irrigation, and community-based monitoring and assessment of rangelands. However, the high cost of scaling up of some of the technologies, especially those that concern rehabilitation of degraded lands, is a major constraint to large-scale dissemination of these technologies. Another constraint to rehabilitation of degraded lands by tree planting and pasture production is protection of the land being reclaimed from livestock grazing, especially if it is communally owned. Moreover, sustainability of some of the technologies, especially tree planting and reseeding of rangelands, depends heavily on rainfall, which is often erratic.

Generally many of the technologies implemented have great potential to arrest land degradation and biodiversity loss in ASALs. However, larger scale upscaling of these technologies will necessitate influencing a change in policy.

Acknowledgements We acknowledge the financial support from the Desert Margins Programme for Africa that is funded by GEF, implemented by UNEP, and executed by ICRISAT in collaboration with NARS in Africa. We thank the various collaborative partners in Kenya [KARI, KEFRI, University of Nairobi, NMK, NEMA, ITDG (Practical Action–East Africa), Government of Kenya extension services and other extension agents, etc.] for their technical support and the Director, Kenya Agricultural Research Institute (KARI), for permission to publish this chapter.

References

Achieng NJM, Muchena FN (1979) Land utilisation types of the Makueni area. Miscellaneous Soil Paper no. M20. Kenya Soil Survey, Kabete Nairobi

Ballard JM, Plateau JP (1996) Halting degradation of natural resources: Is there a role for rural communities? Clarendon Press, Oxford

Coughener MB (2004) The Ellis paradigm – humans, herbivores and rangeland systems. Afr J Range Forage Sci 21(3): 191–200

Coughenour MB, Coppock DL, Ellis JL (1990) Herbaceous forage variability in an arid pastoral region of Kenya: importance of topographic and rainfall gradients. J Arid Environ 19:147–159

De Jager A, van Keulen H, Maina F, Gachimbi LN, Itabari JK, Thuranira EG, Karuku AM (2006) Attaining sustainable farm management systems in semi-arid areas in Kenya. Few technical options, many policy challenges. Int J Agric Sustainabil 3(3):189–205

Ekirapa AE, Muya EM (1991) Detailed soil survey of part of the University of Nairobi Dryland Field Station, Kibwezi. Machakos District. Detailed Soil Survey Report No. D75. Kenya Soil Survey

Emiru B, Demel T, Pia B (Undated) Contribution of enclosures to rehabilitate degraded drylands of Northern Ethiopia

Fabrius C, Koch E, Magome H, Turner S (eds) (2005) Rights, resources and rural development: community-based natural resources management in Southern Africa. Earthscan, London

Gemedo-Dalle, Mass B L, Isselstein J (2006) Rangeland condition and trend in the semi-arid Borana lowlands, southern Oromia, Ethiopia. Afr J Range Forage Sci 23(1):49–58

Goldsmith P (2000) Natural resource management in Marsabit District. Case studies of pastoral settlements. Analysis and recommendations. Project No. ACP. KE.061 – Kenya Agricultural Research Institute (KARI) Report. Kenya Agricultural Research Institute, Nairobi, Kenya

Government of Kenya (GOK). (2002) National Development Plan (2002–2008). Ministry of Planning and Development, Government Printer, Nairobi

Herlocker D (ed) (1999) Rangeland resources in Eastern Africa: their ecology and development. GTZ, German Technical Cooperation, Nairobi

Hudson NW (1987) Soil and water conservation in semi-arid areas. FAO Soils Bulletin No. 57. Food and Agriculture Organization of the United Nations (FAO), Rome

IIRR (2002) Managing dryland resources-An extension manual for eastern and southern Africa. International Institute of Rural Re-construction (IIRR), Nairobi

Itabari JK, Kwena K, Esilaba AO, Kathuku AN, Mohammad L, Mangale N, Kathuli P (2007) Land and water management research and development in arid and semi-arid lands of Kenya. A paper presented at an International Symposium on Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts. African Network for Soil Biology and Fertility (AfNet) of TSBF-CIAT in collaboration with the Soil Fertility Consortium for Southern Africa (SOFECSA), Arusha, Tanzania, 17–21st Sept 2007

Itabari JK, Nguluu SN, Gichangi EM, Karuku AM, Njiru EN, Wambua JM, Maina JN, Gachimbi LN (2004) Managing land and water resources for sustainable crop production in dry areas: a case study of small-scale farms in semi-arid areas of Eastern, Central and Rift Valley Provinces of Kenya. In: Crissman L (ed) Agricultural Research and development for sustainable resource management and food security in Kenya. Proceedings of the agriculture/livestock research support programme, Phase II. End of programme conference. Kenya Agricultural Research Institute (KARI): Nairobi, Kenya. pp 31–42, 11–12 Nov 2003

Jaetzold R, Schmidt H, Hornet ZB, Shisanya CA (2006) Farm management handbook of Kenya, vol II. Natural Conditions and Farm Information, 2nd edn, vol II/ Part C Eastern Province. Ministry of Agriculture/German Agency for Technical Cooperation (GTZ), Nairobi

Jensen JR, Bernhard RH, Hansen S, McDonagh J, MØberg JP, Nielsen NE, Nordbo E (2003) Productivity in maize based cropping systems under various soil-water-nutrient management strategies in semi-arid alfisol environment in East Africa. Agric Water Manage 59:217–237

Kamondo BM, Kimondo JM, Mulatya JM, Muturi GM (eds) (2006) Recent Mukau (*Melia volkensii* Gurke) research and development. Proceedings of the First National Workshop, KEFRI Kitui Regional Research Centre. Kenya Forestry Research Institute, Nairobi, Kenya

Karugu WN (2004) The potential of agroforestry for subsistence farming in arid and semi-arid areas of Kenya. In: Temu AB et al (eds) Rebuilding Africa's capacity for agricultural development: the role of tertiary education. World Agroforestry Centre: Nairobi, Kenya, pp 170–175

Kilewe AM, Thomas DB (1992). Land degradation in Kenya. A framework for policy and planning. Food production and Rural Development Division, Commonwealth Secretariat, Marlborough House, Pall Mall, London SWIY 5HX

Kipserem LK (1996) Water harvesting on entric Fluvisols of Njemps Flats of Baringo district. A paper presented at the Dryland applied Research and Extension Project (DAREP) workshop at Embu from 4–6th June 1996

Lal R (1995) Tillage systems in the tropics. Management options and sustainability implications. FAO Soils Bulletin No. 71. Food and Agriculture Organization of the United Nations (FAO), Rome

Lengarite MI, Okoti M (2004) Survey report on the potential of honey production and marketing in Ngurunit and East of Ndoto Mountain ranges. Desert Margins Programme (DMP) Report. Kenya Agricultural Research Institute, Nairobi, Kenya

Lusigi WJ (1981) Combating desertification and rehabilitating degraded production systems in Northern Kenya. Integrated Project for Arid Lands (IPAL) Tech. Rep. A–4

McPeak JG (2003) Analyzing and addressing localized degradation in the commons. Land Econ 78(4):515–536

Milimo B, Olukoye GA, Moindi D (2002) The human dimension of desertification with special reference to people's participation in dune stabilisation measures in North Horr, Northern Kenya. Deutsche gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, TOB Publication No: TOB F-1/8e ISBN: 3-9801067-14-1, Eschborn 2002

Ministry of Agriculture (MoA) (1987) Description of the first priority sites in the various districts. Fertilizer use Recommendation Project (FURP) 26, Machakos District., NARL-Kabete

Miriti JM, Esilaba AO, Kihumba J, Bationo A (2007) Tied-ridging and integrated nutrient management options for sustainable crop production in semi-arid eastern Kenya. In: Bationo A, Waswa B, Kihara J, Kimetu J (eds) Advances in integrated soil fertility management in sub-Saharan Africa: challenges and opportunities. Springer, Netherlands, pp 434–441

Munyasi J, Esilaba AO, Wekesa L, Ego W (2007) Policy issues affecting integrated resource management and utilization in ASALS. A paper presented at an International Symposium on Innovations as Key to the Green Revolution in Africa: Exploring the Scientific Facts. Organized by AfNet of TSBF-CIAT in collaboration SOFECSA, Arusha, Tanzania, 17–21 Sept 2007

Nabhan H, Mashali AM, Mermut AR (1999) Integrated soil management for sustainable agriculture and food security in southern and east Africa. Proceedings of the Expert Consultation, Harare, Zimbabwe, 8–12 Dec 1997. Agricultural Technical and Extension Services (Agritex) and

Food and Agriculture Organization of the United Nations (FAO), Rome
Nandwa SM, Gicheru PT, Qureshi JN, Kibunja C, Makokha S (1999) Kenya country report. In: Nabhan H, Mashali AM, Mermut AR (eds) Integrated soil management for sustainable agriculture and food security in southern and east Africa. Proceedings of the Expert Consultation, Harare, Zimbabwe, 8–12 Dec 1997. Agricultural Technical and Extension Services (Agritex) and Food and Agriculture Organization of the United Nations (FAO), Rome
Ndung'u JN, Nyamori BO, Kuria SG, Njanja JC (1999) Participatory rural appraisal on livestock management practices of the Rendille pastoral community at Korr in Marsabit District. Kenya Agricultural Research Institute, (KARI) Report. Kenya Agricultural Research Institute, Nairobi, Kenya
Ngoroi EH, Gitari J, Njiru EN, Njakuthi N, Mwangi I, Muriithi C (1994) Effect of moisture conservation methods and fertilizer/FYM combinations on grain yield of maize in low rainfall areas. Annual Report, KARI Regional Research Centre, Embu
Njihia CM (1977) The effect of tied ridges, stover mulch and farmyard manure on rainfall abstraction in a medium potential area, Katumani, Kenya. Paper presented at the International Conference on role of soil physical properties, December 1977. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria
Nyariki D, Ikutwa C, Musimba N (2005)Capacity building through training of beekeepers in the southern rangelands of Kenya. Desert Margins Programme (DMP) Report. Kenya Agricultural Research Institute, Nairobi
Olukoye GA, Wamicha WN, Kinyamario JI (2003) Assessment of the performance of exotic and indigenous tree and shrub species for rehabilitating saline soils of Northern Kenya. Afr J Ecol 41(2):164–170
Reid RE, Ellis JE (1995) Impacts of pastoralism on woodlands in South Turkana, Kenya: Livestock Mediated Tree Recruitment. Ecological Appl 5:978–992
Van Bremen H, Kinyanjui HCK (1992) Soils of the Lodwar area: An inventory of soils, an evaluation of present land use and recommendation for future land use Reconnaissance Soil survey Report No R17. Kenya Soil Survey, Nairobi
Van Wijngaarden W, van Engelen VWP (1985) Soils and vegetation of the Tsavo area (Mtitu andei-Voi). Reconnaissance soil survey report no. R7. Kenya Soil Survey, Nairobi, Kenya
Wandera FP, Sitienei J, Mnene WN, Ahuya CO (1996). PRA report for Kajiado and Baringo Districts
Warren DM (1993) The role of indigenous knowledge in adaptation and development. Background paper for keynote address 'Pithecanthropus Centennial 1893–1993: human evolution in its ecological context'. University of Leiden, Leiden, The Netherlands