LAND DEGRADATION & DEVELOPMENT
Land Degrad. Develop. (2015)
Published online in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ldr.2341

BENEFITS DERIVED FROM REHABILITATING A DEGRADED SEMI-ARID RANGELAND IN COMMUNAL ENCLOSURES, KENYA

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Received: 26 March 2014; Revised: 15 September 2014; Accepted: 4 November 2014

ABSTRACT

Combating land degradation in the semi-arid rangeland of sub-Saharan Africa is essential to ensure the long-term productivity of these environments. In the Lake Baringo basin in Kenya, communities and individual farmers restored indigenous vegetation inside enclosures in an effort to combat severe land degradation and address their livelihood problems. This study quantified the benefits of rangeland rehabilitation using yearly communal enclosures' utilisation data compiled by Rehabilitation of Arid Environments (RAE) Trust over a 6-year period (2005–2010). Results showed that communal enclosures provide a source of income through the sale of fattened livestock, harvested grass seeds, hay, honey and charcoal, among other products. Regression analysis showed an increasing total enclosure income with time. The enclosures also provide grasses for thatching, livestock feed and dry season grazing. Indirect products like milk, blood and meat are essential for household nutrition and food security. These benefits reinforce the management through incentive to maintain existing enclosures and establish new ones and therefore the increasing trend in rangeland enclosure. Increased soil and biomass carbon storage could come with other indirect environmental benefits including improvement in soil quality, land productivity for pasture production and food security, and prevention of land degradation, thus leading to economic, environmental and social benefit for the local agropastoralist communities. Copyright © 2014 John Wiley & Sons, Ltd.

KEY WORDS: environmental services; Kenya; land management; pastoral livelihoods; reseeding; semi-arid rangeland

INTRODUCTION

The problem of land degradation in the semi-arid rangelands of sub-Saharan Africa is well documented (e.g. Oldeman *et al.,* 1991; FAO 1995; Barbier, 2000; UNEP, 2008; Mekuria & Aynekulu 2011; TerrAfrica.org, 2012). The climatic and environmental changes occurring during a land degradation process simultaneously take away the capacity of the land to provide regulating, socio-cultural and supporting services (Irwin & Ranganathan, 2007). Ultimately, the supply of provisioning services is also eroded resulting in livelihood crisis for the agropastoral communities dependent on these ecosystems (Kitalyi *et al*., 2002). The persistent menace of recurrent droughts, floods, disease outbreaks leading to large livestock losses, and dryland crop failure is commonplace (UNEP, 2000). Increasing food insecurity and poverty pose a major threat to the pastoral livelihoods and the local biodiversity.

Combating land degradation is essential to ensure long-term productivity of semi-arid environments. In most pastoral areas of sub-Saharan Africa, main options for improving pasture quantity and quality where graminoid and non-graminoid herbaceous plant species have disappeared have been limited to destocking, bush management, and intermittent grazing (Mnene *et al*., 2000; Opiyo *et al*., 2011; Mekuria & Aynekulu, 2011; Angassa, 2012). Other methods such as tilling, ripping and seeding are also practised but are not common in a pastoral setting because of their high capital requirements (van den Berg & Kellner, 2005; Opiyo *et al*., 2011). Revegetation through ripping and grass reseeding has the potential to restore degraded rangelands and improve their potential for livestock production and wildlife conservation. Revegetation also has potential to provide direct economic benefit as a source of income through the pasture-related income-generated activities (IGAs), and a balanced diet from milk especially for children (Makokha *et al*. 1999; Mekuria *et al.*, 2011b).

In Baringo, the Rehabilitation Arid Environments (RAE) Trust has for more than 29 years been training agropastoralists to restore and manage severely degraded areas in the Lake Baringo basin with some pragmatic outcomes. RAE implemented its first reseeding project in communal rangeland on the lake plain (Njemps Flats) in 1982, later expanding these efforts to upland sites (de Groot *et al.*, 1992). About 38 communal enclosures have been established since 1982, covering about 1,496 ha. During the last decade, attention has turned increasingly to private enclosures. Rehabilitation of private enclosures started in 1994, and up to 2010, RAE has established well over 700 private enclosures ranging in size from 0·5 to 20 ha in the

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whole lake basin following individual farmer's requests (RAE, 2010). This represents a rate of around 50 enclosures per year. This trend has given rise to two major categories of enclosures in terms of management and ownership (access and user rights). The first category is the reseeded, communally owned, and communally managed enclosure. This belongs to the community and is managed by a community group with back-stopping from RAE's extension. The second is the reseeded private enclosures established, owned and managed privately by individual farmers who exercise exclusive access and user rights. These farmers also receive extension services from RAE regarding enclosure establishment and extensions, choice of germplasm, management and marketing of enclosure products. A third category exists comprising of private naturally regenerated enclosures, but their success rate has been low in the Lake Basin (Mureithi *et al.,* 2010).

This trend has resulted from the realisation by agropastoral communities that rangeland rehabilitation through reseeding has the potential to address their food insecurity, alleviate poverty and restore rangeland productivity (Kitalyi *et al*., 2002; Beyene, 2009; Mekuria *et al.*, 2011b). The general increase in acquiring exclusive property rights through enclosing the commons may also be driven by the pastoralist's need to diversify asset portfolios in response to declining pasture and other common resources (Beyene, 2009). For the gains in the fight against land degradation to be sustained, the physical and technical interventions must have a socio-economic and cultural dimension that addresses the needs and priorities of the local communities (Li et al., 2011; Mureithi *et al*., 2010; Martínez *et al.*, 2013). Understanding the socio-economic impacts of rangeland rehabilitation is essential to the management and planning of similar initiatives. This study aimed to quantify the benefits derived from the rehabilitated semi-arid rangeland in communal enclosures of the Lake Baringo basin.

MATERIALS AND METHODS

Study Area and Communal and Private Enclosures

The Njemps Flats (1°45′ and 0°15′N latitude; 35°45′ and 36°30′E longitude) covers approximately 305 km^2 and is one of 11 range units in Baringo County in Kenya (Figure 1). This flat to slightly undulating plain has an average altitude of 900 masl. and is surrounded by high-altitude hills, ridges and plateaus, having peaks over 2,300 m (Thom & Martin, 1983). The semi-arid lowlands receive a total annual rainfall varying between 300 to 700 mm (Kipkorir, 2002) and are characterised by a bimodal rainfall distribution with two peaks in April and November. The temperature in Njemps Flats shows little variation throughout the year with mean monthly temperatures ranging from 24 to 26°C (Ekaya *et al*., 2001; Kipkorir, 2002).

The dominant soils in the Njemps Flats, according to a reconnaissance soil survey (USDA-SCS/GoK, 1978), are well drained, silt loam to clay loam, Eutric and Calcaric Fluvisols (FAO, 2006a, 2006b). They are developed on alluvium from various Tertiary and Quaternary volcanic rocks and on sediments from basic igneous rocks. The main vegetation classes include acacia woodland (80%), permanent swamp and seasonally flooded grassland (15%) and shrub grassland (5%). Livestock production by the 'Il Chamus' agropastoralist community is the dominant land use. Availability of fresh water in the flat terrain and an increasing human and livestock population pressure encouraged

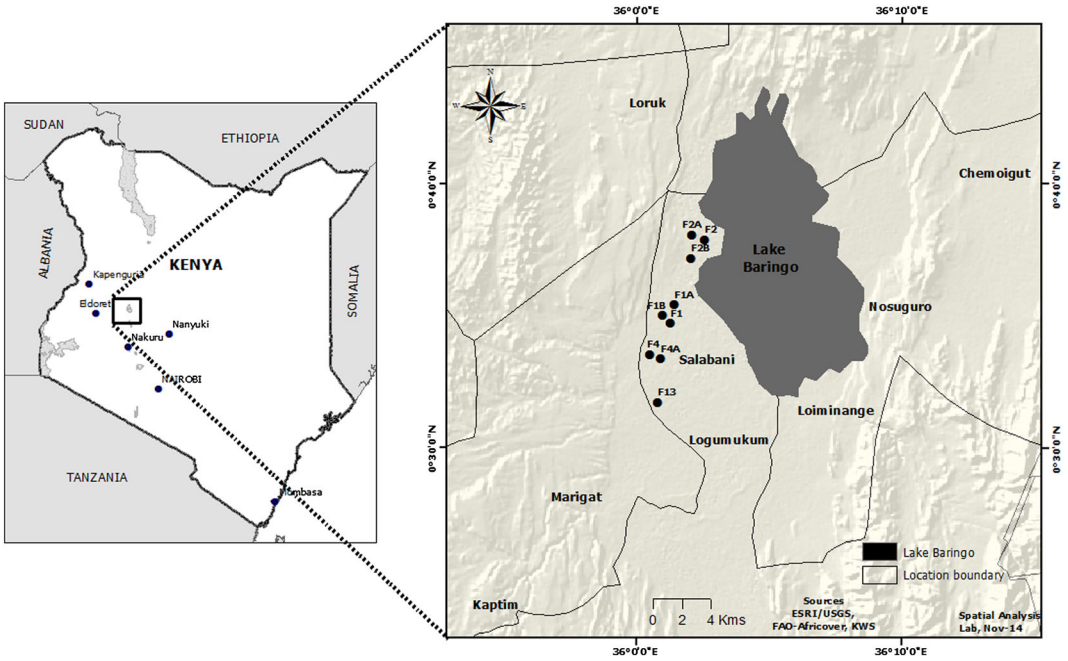

Figure 1. The study area (not to scale). Dots are the studied communal enclosures in Njemps Flats. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr

Table I. General characterisation of the selected enclosures

Local ID	Local name	Sub-location	Area (ha)	Age (year) as at 2010	Utilisation
F1	Meisori	Salabani	9·3	28	LF–G–GC–BK–GS–WC–CB
F1A	Meisori	Salabani	6·6	27	LF–G–GC–BK–GS–WC–CB
F1B	Meisori	Salabani	16·7	23	LF–G–GC–BK–GS–WC–CB
F2	Kapkoror	Kipcherere	5·3	28	LF–G–GC–GS–WC
F2A	Kapkoror	Kipcherere	7·8	27	LF–G–GC–GS–WC
F2B	KYS School	Kipcherere	6·0	23	LF–G–GC–GS
F4	Ongata-Mara	Salabani	22·4	25	LF–G–GC–GS
F4A	Ongata-Mara	Salabani	102·3	21	LF–G–GC–GS
F13	Lamalok	Salabani	140·0	19	LF–G–GC–GS

LF, livestock fattening; G, grazing; GC, grass cutting; GS, harvesting grass seed; BK, bee keeping; WC, wood cutting; CB, charcoal burning.

overgrazing. At present, severe land degradation is exacerbated by highly erodible soils in combination with erratic rainfall, in addition to intensive grazing pressure that has led to large-scale disappearance of perennial grasses. Ground cover is almost non-existent particularly during the dry seasons and droughts (Mureithi *et al.,* 2010). Encroachment by *Prosopis juliflora* in the communal rangelands has also become a great concern to the local communities and the planners (Mwangi & Swallow, 2008).

Nine communal enclosures were systematically selected across the Njemps Flats for this study (Table I). The selection criteria—similarity of terrain, soil, and land use—aimed at minimising variability in the abiotic determinants of rangeland vegetation composition and functioning and hence productivity. The selected communal enclosure's ages ranged from 19 to 28 years in the year 2010. The subsequent section details the monitoring and collection of utilisation (off-take) data in the communal enclosures.

Enclosure Utilisation and Benefit Monitoring Data

Rehabilitation Arid Environments keeps a record of all maintenance and utilisation activities carried out in all the communal enclosures and a number of private enclosures. When a field management committee decides to open up their enclosure for utilisation (Verdoodt *et al*., 2010), they liaise with RAE to send field recorders to be present during the field utilisation days. The field recorders use simple measurement yardsticks and terminologies to collect valuable ecological and enclosure utilisation data (Table II). The costs of a product bought for resale after value addition (e.g. livestock fattening) are also recorded for the determination of profits. Through education and extension, RAE has made an effort to standardise prices of enclosure products with time, in an effort to curtail the exploitation of farmers by middlemen who buy for sale in secondary markets. Monitoring provides data of ecological and socio-economic importance besides informing RAE and the local community on the productivity of the restored areas and the impact of rangeland rehabilitation to livelihoods. Detailed monitoring began in 1992 in the framework of a project and stopped in 1996 because of logistical reasons (Rosenschein *et al*., 1999), before resuming in 2001 to present, after RAE incorporated it as one of the continuous activities. New data entry formats were adopted from year 2005, making a comprehensive benefit database available. These quantitative and qualitative data (2005–2010) were used to quantify the benefits of rangeland rehabilitation through communal enclosure.

Data Analysis

Analysis of data combined both qualitative and quantitative approaches. First, the analysis began from revising detailed field notes and consolidating similar information from RAE's field reports with the use of a summary table. Second, data from the RAE field monitoring database was sorted out for the selected enclosures. The results were categorised into two: the quantitative [tangible product or

Table II. Quantitative and qualitative data recorded during the enclosure utilisation days

Income generating activity (IGA)	Parameter recorded[a]	Product sold	Sale price (USD)[a]
Livestock fattening	No. of bull days	Fattened bull/steer	$118{\cdot}2\,\text{head}^{-1}$
Dry season grazing	No. of grazing days[b]	—	—
Grass seed harvesting	Weight by species	Grass seed by species	$1{\cdot}3\,\text{kg}^{-1}$
Hay baling	No. of bales	Hay	$1{\cdot}3\,\text{bale}^{-1}$
Thatching grass	No. of backloads	Cut grass	$0{\cdot}12\,\text{backload}^{-1}$
Wood cutting	Tree species cut	Building poles/ fencing posts	$0{\cdot}12\,\text{piece}^{-1}$
Firewood	Shrub species cut/no. of backloads	Firewood	$0{\cdot}12\,\text{backload}^{-1}$
Honey	Gross weight	Unpurified honey	$1{\cdot}54\,\text{kg}^{-1}$
Charcoal	Woody plant species cut/ no. of bags	Charcoal	$3{\cdot}9\,\text{bag}^{-1}$

[a]Approximate minimum sale price in US dollars at an enclosure gate. The exchange rate as of 31 December 2010 was 1 USD ~KES 78.
[b]Per day grazing fees are chargeable per livestock head. Records include all known illegal grazing days and specify livestock species by age, for example, cattle or calf days.

good that had immediate economic value (Figure 2)] and qualitative (those that improved the welfare of the individual household, communities or overall society and the environment but could not be converted immediately into cash).

RESULTS

Within the period studied (2005–2010), enclosures F1, F1a and F1b at Meisori generated the highest per hectare income and had the highest number of income generating activities (IGAs; Table III). However, it was the second most diversified in terms of income portfolio after enclosures F2, F2a and F2b at Kapkoror. Enclosures F2, F2a and F2b were the most diversified in terms of income with 37% coming from grass seed sales (Table III). The total income of enclosures F2, F2a and F2b and F4 and F4a showed an increasing trend with time (Figure 3). The former had a strong positive coefficient of determination of 0·796.

Quantitative Benefits

Livestock fattening was the leading IGA netting in over 70% of the total income in all the selected enclosures (Table III), except for F2, 2a and 2b. Fattening of bulls in particular was the most profitable activity and relied solely on pasture in the enclosures, and no other feeds were supplied. Livestock fattening involved buying thin livestock from the local auctions during the dry season when prices were low and grazing within the enclosures for 3 to 4 months before selling at a profit. The average buying price for a thin stock was USD 90 translating to a profit of USD 39 after 3 months. At times, group members contributed one head of cattle to the fattening herd and were paid back the principal, while the profit was retained by the group. Such retained earnings were shared as group dividends at the end of the accounting year. This, however, excluded operational costs such as veterinary drugs and herder's wage. The activity was mostly carried out by groups that have management mandate over a communal enclosure or tenant groups that leased the enclosures over the fattening period. Examples of such groups are Naitemu Women's Group of Fields 1, 1a and 1b; Ngenyin Women's Group of Field 2; Namayana Self-Help Group of Field 4 and 4a; and Saruni Self-Help Group of Field 13.

Grass seed harvesting was the second highest IGA after livestock fattening in all the selected enclosures (Table III).

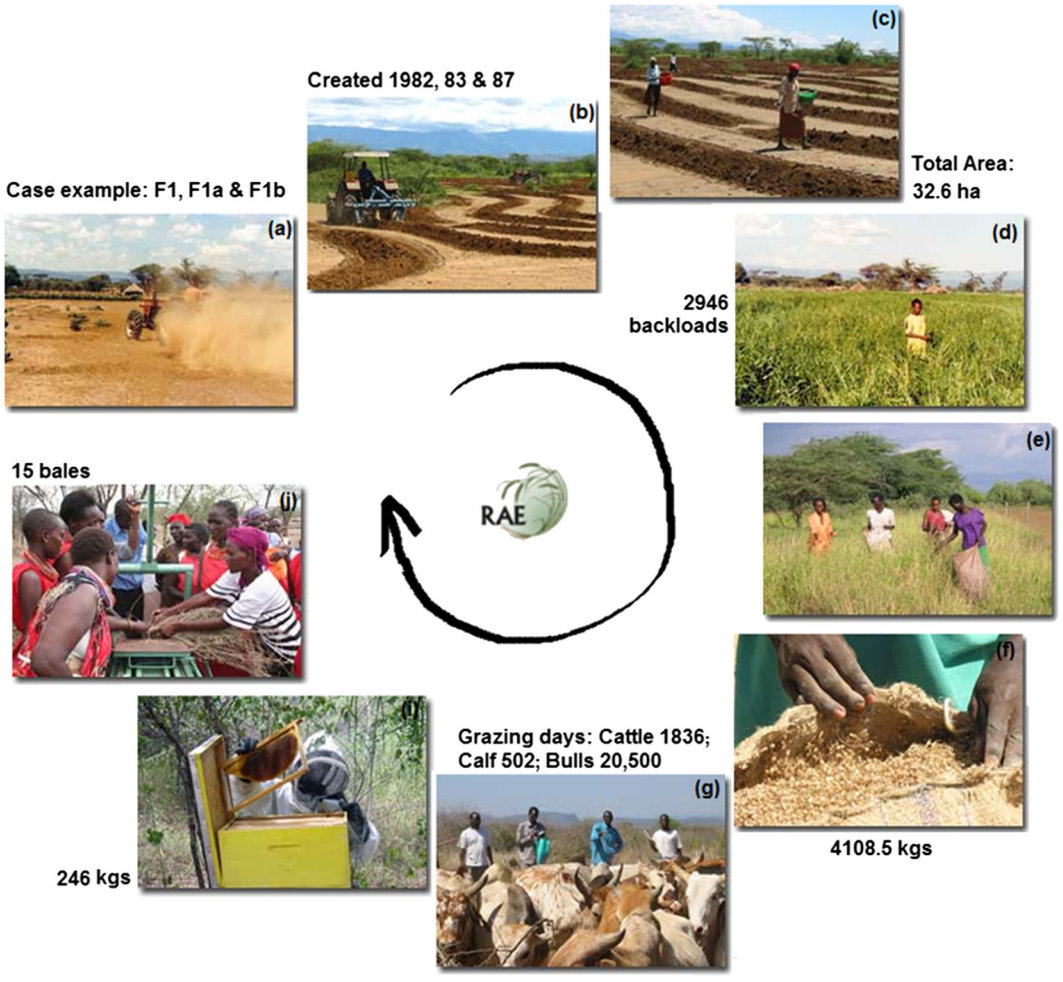

Figure 2. Pictorial viewing of rangeland rehabilitation benefits for enclosures F1, F1a and F1b during 2005–2010. They include reduced soil erosion (a–e), pasture for livestock, thatching grass and hay (d, e, g and j), grass seed (e and f), honey (i), wood (not shown), and pleasant views of grass-covered fields, among others (photos courtesy of RAE Trust). This figure is available in colour online at wileyonlinelibrary.com/journal/ldr

Table III. Selected enclosures' benefit summaries in US dollars for 2005–2010

	F1, F1a and F1b			F2, F2a and F2b			F4 and F4a			F13		
Income generating activity (IGA)	Total income (USD[a])	Income (USD) ha^{-1}	% income	Total income (USD)	Income (USD) ha^{-1}	% income	Total income (USD)	Income (USD) ha^{-1}	% income	Total income (USD)	Income (USD) ha^{-1}	% income
Livestock fattening—bulls	23 993·6	736	74	4,856·4	254·3	52	10 318·6	82·7	97	34 002·6	242·9	81
Grass seed harvesting[b]	5,341	87·1	17	3,490·3	182·7	37	293·5	2·4	3	4,240·5	30·3	10
Dry season grazing[c]	55·8	1·7	0	606·3	31·7	8	—	—	—	2,619·4	18·7	6
Cattle days												
Calf days	1·3	0[d]	0	14·1	0·7	0	—	—	—	55·7	—	0
Bull days	191·4	5·9	1	45	2·4	1	22·1	0·2	0	1·3	0,0	0
Goat days	3·6	0·1	0	19·5	—	—	0	0	0	857	6·1	2
Sheep days	4·6	0·1	0	10	0·5	0	0	0	0	2·6	0·0	0
Lamb days	—	—	—	3·2	0·2	0	—	—	—	—	—	—
Thatching grass	353·6	10·8	1	79·9	4·2	0	1·2	0	0	5·6	0·0	0
Hay baling	19·2	0·6	0	21·8	1·1	1	—	—	—	—	—	—
Honey (gross wt)	315·4	9·7	1	—	—	—	—	—	—	—	—	—
Building poles/ fencing posts	1,103·5	33·8	3	—	—	—	—	—	—	—	—	—
Firewood (bundles)	14·1	0·4	0	—	—	—	—	—	—	—	—	—
Charcoal (bags)	829·5	25·4	3	—	—	—	—	—	—	2·2	0·0	0
Research fees[e]	25·6	0·8	0	—	—	—	—	—	—	—	—	—
Total: ten activities	32 252	7,783	100	9,147	7,271	100	10 635	6,879	100	41 787	7,091	100
Total income rank		2			4			3			1	
Income per hectare rank		1			2			4			3	
Number of activities		10			5			3			3	
Total area (ha)		32·6			19·1			124·7			140	

[a]Exchange rate as of 31 December 2010: 1 USD ~KES 78.
[b]The main species harvested are *Cenchrus ciliaris* and *Eragrostis superba*.
[c]Includes known illegal grazing days.
[d]Value less than 0·1%.
[e]Fees charged to researchers by the respective enclosure's field management committee.

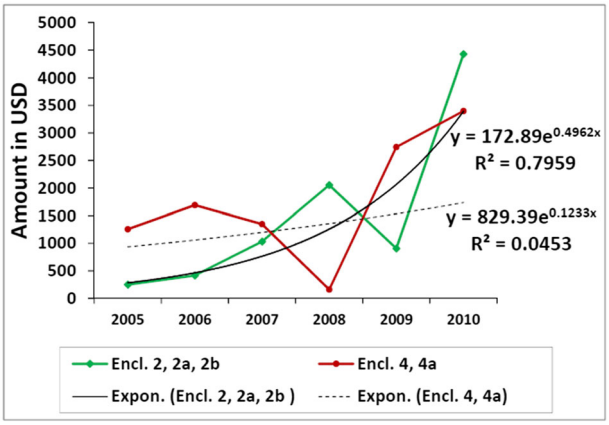

Figure 3. Increasing total income trends (2005–2010) in USD for enclosures 2, 2a and 2b, and 4 and 4a respectively.

The IGA contributed to at least 10% of the total income for all the enclosures sampled, except F4 and F4a. The dominant species harvested in the selected enclosures were *Cenchrus ciliaris* L. and *Eragrostis superba* Peyr. Other main species encountered in communal fields include *Enteropogon macrostachyus* (Hochst. ex A. Rich.) Monro ex Benth, *Cymbopogon pospischilii* (K.Schum.) C.E.Hubb. and *Sehima nervosum* (Willd.) Stapf. Harvested grass seed was transported to RAE Trust for processing (removing chaff and packaging), storage and sale at an average retail price of USD 6·4 per kilogram. Grass seed was packaged in jute gunny bags of 10 kg each and stored in a dry well-aerated store raised from the ground to avoid termite and rodent infestation. The grass seed finds ready market in Baringo and other dryland districts in Kenya. RAE is recognised by the Kenya Plant Health Inspectorate and government ministries (Livestock and Fisheries Development, Development of Northern Kenya and Other Arid Lands) as a source of grass seed for pasture improvement and reseeding degraded rangelands.

Dry season grazing was key utilisation of the enclosures and generated an income for all the enclosures except F4 and F4a (Table III). The main category of the livestock grazed indicated the priority of the groups managing the particular enclosure. For instance, Naitemu Women's Group who managed enclosures F1, F1a and F1b largely practiced livestock fattening and grass seed harvesting (Table II). On the other hand, Saruni Self-Help Group of enclosure F13 utilised their enclosure in grazing and fattening bulls during the dry season (Table III). In enclosures F2, F2a and F2b, Ngenyin Women's Group of enclosures utilised their field mostly for cattle and sheep dry season grazing. Dry season grazing mainly sustains the livestock through the dry season and drought. During the wet season, livestock graze in the communal open rangeland; thus, the enclosures serve as a buffer against dry season pasture scarcity and accompanied livestock losses.

Grass cutting for thatch was carried out in all the selected enclosures (Table III). Grass in the enclosures is usually cut after seed harvest for thatch or hay baling or cut and carried for livestock feeding at individual homes. The locals prefer *Cynodon plectostachyus* species for thatching, found in patches within the enclosures dominated by *C. ciliaris*. Cutting activity in these patches while the background is grazed maintains the homogeneity of the patches, while it promotes the overall enclosure heterogeneity (Mureithi, unpublished data). Baling for pasture preservation is preformed using a box manual baler provided by RAE (Figure 2j). In enclosures F1, 1a and 1b, thatch grass contributed to 1% of the total income over the period studied.

Wood cutting was carried out only in enclosures F1, 1a and 1b, and F13 (Table II). Wood cutting is carried out mainly for maintaining the enclosures as productive grass fields and to avert bush encroachment. The main species targeted include *Acacia nubica* Benth, *Acacia reficiens*, *Acacia melliferra* and *P. juliflora*, which are all invasive and suppress grass growth making them not suitable for pasture fields. The cut wood is used for building poles, fencing posts, firewood and charcoal (Table II). Over the period studied, building poles and fencing posts and charcoal contributed 4 and 3% of the total income generated by enclosures F1, 1a and 1b respectively (Table III).

Bee keeping is an additional IGA carried out within the well-established enclosures. Honey was harvested in enclosures F1, 1a and 1b yielding 246-kg gross weight of *honey* (Table III). About 70% of the Langstroth hives mounted within the enclosures were colonised by bees. Bees (both stinging and stingless types) are also commonly found in old hollow tree trunks and deserted epigeal termite mounds within the enclosures. However, they are hardly seen in the degraded open rangeland indicating that the enclosures are biodiversity hubs. Harvested honey was pooled at RAE Headquarters and sold to a private company, Honey Care Africa (Kenya) Limited, at USD 1·54 per kg gross weight. The proceeds were remitted directly to the individual farmers or community group's kitty according to the kilograms of honey supplied.

Qualitative Benefits

The cumulative 6-year data (Table III) showed that restored areas have also other non-tangible benefits. These include as follows:

Successful rangeland rehabilitation: Owing to RAE's cumulative experience and plugging in lessons learnt since 1982, appropriate rehabilitation techniques and water harvesting methods have been defined and tested, making it easier to replicate them in other drylands. Ecological field monitoring exercises carried out in the restored sites show high biodiversity of flora and fauna compared with the open grazing areas. Rehabilitated areas in the Lake Baringo basin present a good example of tackling land degradation problems in arid and semi-arid rangelands (Figure 4).

Improved livelihoods: RAE's long-term benefit data on both private and communal enclosures indicate that rangeland rehabilitation has improved pastoral livelihoods in the Lake Baringo basin in various ways. These include

Figure 4. Wet season vigorous grass growth in a communal enclosure (F1) after a dry season controlled burn in early 2011. Adjacent degraded rangeland in the foreground (photo courtesy of RAE Trust). This figure is available in colour online at wileyonlinelibrary.com/journal/ldr

being a source of good-quality feed for livestock, income through the sale of grass seeds, hay and a balanced diet from milk especially for children. The money generated from sales of these products is channelled to other social amenities like health, education and entertainment. Moreover, grasses provide a ready source of thatching materials for houses and granaries. This boosts the longevity of the harvested grass seed and other stored crops, thereby boosting overall food and financial security for specific households. It has also been observed that water pans and dams within the established enclosures keep water longer than the ones in the open rangeland. This reduces time spent and distance covered searching for water for livestock and domestic uses.

Improved land and livestock management: Through extension, RAE has trained many agropastoralists on rangeland rehabilitation, grazing management, sustainable enclosure utilisation practices, and diversification of IGAs and opportunities. The efforts are based on realisation that rangeland rehabilitation provides alternative food security in drylands, in addition to improving communities' adaptive capacity against land degradation and climatic change.

Volunteers gains: Individuals or community groups came together to work in the communal enclosures in the spirit of *harambee* (meaning 'all pull together' in *Swahili*), a Kenyan tradition of community self-help events. The benefits were quantified in terms of *harambee* days, and the volunteers involved were compensated with free grazing days or at times direct cash compensation per *harambee* day per individual. Ultimately, it led to increased sustainability of the rangeland rehabilitation initiatives as a result of the occasional maintenance of the communal enclosures. Over the period studied, such maintenance work included uprooting *A. reficiens*, *A. nubica* and *P. juliflora* seedlings to prevent bush encroachment, weeding fence lines, dipping, vaccination, de-worming, and castration of bulls and fencing of bulls' *boma* (cattle corral) during fattening periods.

Capacity building for women and reproductive health care: The majority of communal enclosures in the Lake Baringo basin are managed by the community, especially women groups. RAE trains individual women and community groups as environmental managers, and many have benefited directly from restored areas and enclosure products. Alongside the environmental and financial skill capacity building, RAE also offers health care services and reproductive health education to men and women, through a RAE clinic at Kampi ya Samaki.

DISCUSSION

The main rationale behind the establishment of communal enclosures in the Lake Baringo basin was to demonstrate that severely degraded rangeland can be restored and, in so doing, address food insecurity, poverty and other livelihood problems plaguing the agropastoral households (Meyerhoff, 1991; de Groot *et al.*, 1992). The realisation of tangible benefits from the restored areas by community groups (Table III; Figures 2 and 3) justifies this initiative. Rehabilitation of degraded rangelands using enclosures in the Tigray region of northern Ethiopia has also been shown to be beneficial to the communities (Beyene, 2009; Mekuria *et al.*, 2011a).

The overall sustainability of the enclosures is determined by an interaction of three key factors: productivity, management and benefits (Figure 5). The subsequent discussion takes these factors into consideration. For the enclosure system to be sustainable, the determining factors themselves need to be sustainable. Holding the abiotic and climatic controls constant, the management (enclosure establishment, maintenance and utilisation) is the main factor that determines the productivity of the enclosures and therefore the benefits (Figure 5). The benefits, in turn, reinforce the management through incentive to maintain existing enclosures or establishing new ones and the cycle goes on. These two are regulated by the abiotic (e.g. site edaphic characteristics according to Verdoodt *et al.*, 2009, 2010) and climatic (e.g. rainfall patterns) controls. A chronosequence carried out by Verdoodt *et al.* (2009) showed that some much older enclosures had a lower biomass production than some younger ones. They concluded that the grass cutting and grazing (management) activities must have a significant effect, in addition to specific site soil factors (e.g. high sodicity). Sustainable enclosure management can improve ecosystem health (both biotic and abiotic) and productivity over the long term and hence the benefits. Long-term monitoring of the management factor could allow better interpretation of both ecologic and benefit factors and the feedback loops within them.

Across the study sites, livestock fattening programmes (particularly bulls) generated the highest per hectare incomes among IGAs (Table III), followed by grass seed harvesting and dry season grazing (wood harvesting in F1, F1a

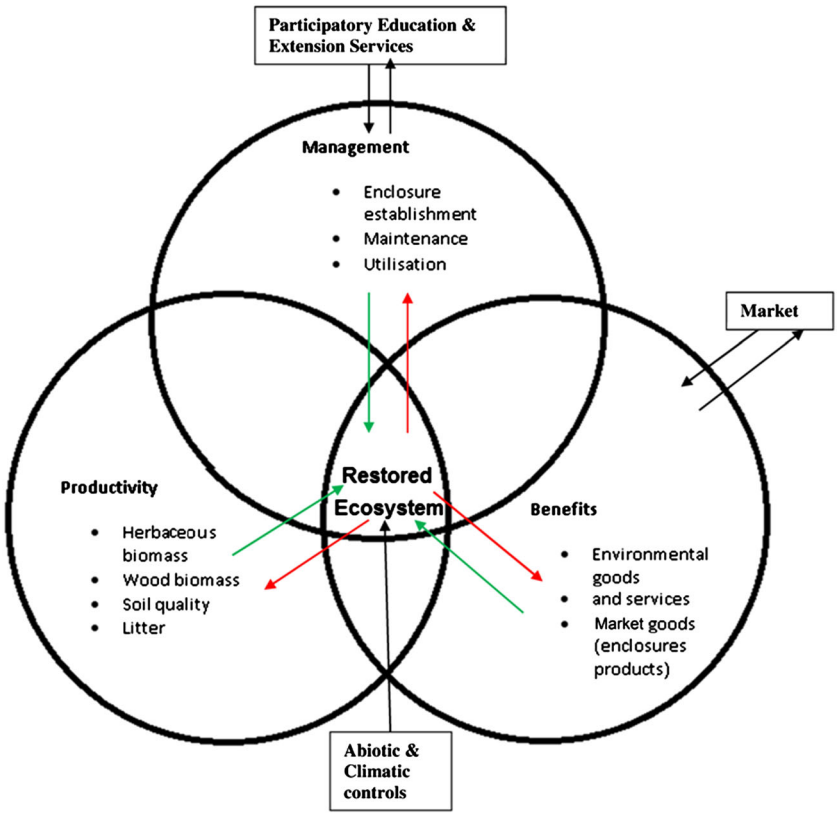

Figure 5. A conceptual figure showing the factors determining rangeland enclosures' sustainability and their feedback loops. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr

and F1b). Livestock fattening is purely a commercial activity practiced by enclosures' owners and community groups. Grasses cut from the enclosures provide a readily available source of thatching materials for houses and granaries, which augments the longevity of the harvested grass seed and other stored crops, thereby improving overall food security for specific households. For optimal benefits of rangeland rehabilitation, multiple IGAs could be carried out within the enclosures, for instance, by paddocking the large enclosures, where sequential activities were carried out in various paddocks. The utilisation sequence of an enclosure can be as follows: grass seed harvesting, thatch grass cutting from the *C. plectostachyus* patches within the enclosures, livestock fattening and lastly dry season grazing. With time, diversification has become a necessity because reliance on livestock keeping only as an income and food source does not meet subsistence requirements (Little *et al*., 2001).

Rangeland enclosure is itself a form of diversification to an alternative livelihood source and a coping mechanism for the pastoralists, for instance, the Borana in southern Ethiopia enclosures as dry season grazing reserves for milking cows around sedentary homesteads and for seasonal grazing by calves and sick/weak animals (Angassa & Oba, 2008). According to Angassa & Oba (2008), there is a high prevalence of enclosures among the Borana, and the trend towards a set-up of new ones is increasing. The sociocultural and ecological changes in the common grazing areas are the main drivers forcing the pastoralist to adapt to new ways of life. Sociocultural changes include shifts in tenure and access structures, social organisation and gender norms and relations (Angassa & Oba, 2008). In the Lake Baringo basin, notable ecological changes are characterised by increasing bare ground cover and bush encroachment (mostly by *P. juliflora*) and decreased plant diversity and forage production (Mwangi & Swallow, 2008; Wasonga *et al*., 2011). It is noted that specialisation in terms of IGAs does not necessarily lead to more income. For example, Namayana Self-Help Group who manage enclosures F4 and F4a specialise in livestock fattening that accounted for 97% of their total income during the sample period. However, they trailed all other groups in per hectare incomes (Table III). This may point to some management problems within the group. On the other hand, Naitemu Women's Group that manages enclosures F1, F1a and F1b were the most diversified with a total of ten IGAs carried out within the study period and were also the leading group in per hectare income (Tables II and III). The variation in per hectare income between groups was used to gauge the capacity of the management to optimise income generation.

Diversification of enclosure utilisation and income sources cushions the enclosure owners to periodic climatic or market shocks and gives the possibility of realising alternative benefits during harsh times. For instance, the long rains for the year 2005 and 2006 were both late and erratic in the arid and semi-arid areas of the county, resulting to low revenue from grass seed harvesting and grass-cutting

activities, by, for example, Ngenyin Women's Group who manage enclosures F2, F2a and F2b (Figure 3). Ngenyin Women's Group relies heavily on grass seed harvesting and livestock fattening, which accounted for 37 and 52% of the total income during the sample period respectively. During a severe drought experienced in Kenya in 2009, the group was still able to make good revenue from the two main IGAs (Figure 3).

In emulation of the communal enclosures, the private enclosure owners in the lowlands have commercialised their enclosures. Their main IGAs include fattening of bulls, grass seed harvesting and hay baling using a box although in small scales depending on the enclosure size. From 1994 to 2010, RAE has established well over 700 private enclosures in the whole lake basin following individual farmer's requests (RAE, 2010), representing a rate of just about 50 enclosures per year. A similar trend is picking up the neighbouring West Pokot County (Makokha *et al.,* 1999; Kitalyi *et al.,* 2002). Enclosures are also common in south-eastern Kenya (Macharia and Ekaya, 2005; Ngugi & Nyariki 2005; Opiyo *et al.*, 2011), in Tanzania (Mwilawa *et al.,* 2008), and in northern and southern Ethiopia where economic benefits have been reported as key drivers of their establishment, among others (Angassa & Oba, 2008; Beyene, 2009).

In Baringo, the urgent task facing RAE and other rangeland rehabilitation players is to carry out stepwise community mobilisation and education to enable the resource users to embrace sustainable natural resource management both within and outside the fence. This includes making the right choices on germplasm for restoration and fencing to avoid using invasive species like *Prosopis* (*P. juliflora*) and cactus (*Opuntia elatior*) that are invasive. Regular enclosure maintenance practices (e.g. uprooting invading weeds and maintaining the fence) and sustainable utilisation (e.g. stocking density and number of grazing days) are a prerequisite to optimising the potential environmental goods and services from the restored areas. Therefore, continued extension services and participatory education on management of the enclosures for owners and community groups are vital for the sustainability of the achievements attained so far. As shown in Figure 4, a well-maintained enclosure is a 'resource-rich island' or key resource area relative to the resource-depleted background (Ngugi & Conant, 2008). Similarly, strengthening the existing market linkages and seeking new market linkages for the enclosure products are also recommended. Establishment of microfinance options (e.g. community banks and savings and credit cooperative, where one can borrow against enclosure products such as bags of grass seed delivered or steers being fattened or be guaranteed by a fellow enclosure owner) is necessary as well. This calls for committed capacity building to unlock the potential of rangeland rehabilitation to transform impoverished pastoral communities, improve quality of life, and accumulate wealth for pastoral households making them better prepared to manage risk (Coppock *et al.,* 2011).

According to Wasonga *et al*. (2011), pastoralism in Baringo is a system in transition, attempting to maintain itself while at the same time trying to adapt progressively to a continuously shrinking resource base. Most people in the Lake Baringo basin indicated that they would care more for the land if they owned it, contrasting the present scenario where they own it communally and the free access of the commons persists (Mureithi *et al*., 2010). Thus, the sustainability of the positive rehabilitation work achieved so far also lies in a land policy and tenure reform addressing the needs and priorities of agropastoral communities. This has partly been addressed in the Kenya's New Constitution, Land Act 2012 (Kenyalaw.org, 2012a) and the Land Registration Act 2012 (Kenyalaw.org, 2012b).

CONCLUSION

Across the study sites, the livestock fattening programme (particularly bulls) generated the highest per hectare income, averaging at 80%, followed by grass seed harvesting (15%) and dry season grazing (4%). Other tangible benefits included income from sale of hay, honey, building poles and fencing posts, firewood and charcoal from thinned woody plants. Moreover, grasses provide a readily available source of thatching materials for houses and granaries, which boosts the longevity of the harvested grass seed and other stored crops, thereby boosting overall food security for the household. Diversification of IGAs cushions the enclosure owners against periodic climatic or market shocks and gives the possibility of realising alternative benefits during harsh times. Thus, there is a need to enhance market linkages for restored rangeland products that would then drive the adoption of rangeland restoration initiatives. Continued participatory education, capacity building and extension services for the enclosure owners and community groups are highly recommended.

ACKNOWLEDGEMENTS

This study was made possible through the financial support provided by Special Research Fund (BOF Grant No 01W01510) of Ghent University, Belgium, in favour of the first author. We are grateful to Rehabilitation of Arid Environments (RAE) Trust for sharing socioeconomic data used in this study.

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