Global Ecology and Conservation 14 (2018) e00402

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Original Research Article

Participatory scenario development process in addressing potential impacts of anthropogenic activities on the ecosystem services of Mt. Marsabit forest, Kenya

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A R T I C L E I N F O

Article history:
Received 13 March 2018
Received in revised form 19 May 2018
Accepted 19 May 2018

Keywords:
Land use change
Climate change
Ecosystem services
Marsabit forest
Participatory planning

A B S T R A C T

The Marsabit Forest Reserve (MFR), a green island in an arid environmental setting, generates multiple ecosystem goods and services (ES) to the local community critical for their livelihoods. The forest has been experiencing substantial land conversion for town expansion, agriculture production and settlements threatening long-term ES provision. Sustaining the forest ES under increasing anthropogenic pressures is one of the great challenges of the Marsabit forest community. We used focus group discussions in the thirteen locations around the forest and individual key informant's interviews in the identification of drivers of change and their potential impacts on ES in MFR. We used the scenario development process (SDP) in coming up with four divergent but plausible exploratory scenarios. The study established that the main ES provided by the forest was, water, fuelwood, forage (dry season grazing resource), medicinal plants and timber for construction. Stakeholders identified population pressure, unsustainable utilisation of forest resources, institutional barriers to effective resource management, land use and climate change as the main drivers impacting ES provision in the forest. Land use change and climate change were considered the most significant drivers yet the most uncertain in the future impacting ES provision in the MFR. The SDP identified four alternative future scenarios for the MFR by the year 2044 with the Marsabit we want scenario identified as the most desirable future for the sustainable supply of ES with adequate adaptation to observed changes. Stakeholders came up with a joint action plan implementation matrix for the identified scenario while mitigating the negative aspects of the alternative scenarios. The results support the need for participatory land use planning that takes into to account the growing threat of climate change to natural forest systems.

1. Introduction

The Millennium Ecosystem Assessment (MEA) defines ecosystem services (ES) as the goods and services local communities obtain from an ecological system for their wellbeing (Reid et al., 2005). These ES were further broken down into four distinct categories: provisioning services, regulating services, supporting services and cultural services (Díaz et al., 2006).

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https://doi.org/10.1016/j.gecco.2018.e00402
2351-9894/

Environmental stresses have caused untold deterioration of terrestrial, freshwater, and marine environments (Butchart et al., 2010). Anthropogenic intervention in various ecosystems causes habitat loss, degradation, and fragmentation, and is, therefore, a leading cause of terrestrial biodiversity loss, impairment of ecosystem functioning, and loss of ecosystem services (IPCC, 2007). According to most researchers, the assessment of ES demands an integrative approach that considers ecological, economic and social evaluation criteria (Burkhard et al., 2009).

The Marsabit Forest Reserve (MFR), a dry tropical forest in the middle of a semi-arid region, is of critical importance to sustaining life not only within the forest but also in the surrounding areas harbouring a diverse range of ecosystems and associated biodiversity. The forest is experiencing anthropogenic pressures through illegal extractive activities, increasing human population in the surrounding areas, conversion of lands around the forest to other land uses, and human encroachment from Marsabit town — all these threaten the sustainability of the forests' ES provision (Githae et al., 2008). Reid et al. (2005) recommend an integrated approach to establishing the status and threats to ES in different jurisdictions, factoring both scientific, economic and social aspects of ES assessment. The participatory scenario development process (SDP) which was used in this study is a systematic method for thinking creatively about dynamic, complex and uncertain futures, and identifying strategies to prepare for arranging of possible outcomes (IPCC, 2014). They can be used to (1) enable managers to understand better the forces driving landscape change and work with landscape stakeholders, as well as to (2) improve adaptive capacity, not only by responding to landscape changes but also by anticipating them. Scenarios may be developed with little participation from stakeholders but may be participatory, given their capacity to influence decisions that may have wide-reaching implications for a range of stakeholders (Reid et al., 2005). SDP has been applied to various issues including; community forest management (Wollenberg et al., 2000); rural funding policy in mountainous landscapes (Bayfield et al., 2008); deforestation in Brazil (Soler et al., 2012); forest management impacts on livelihoods (Kassa et al., 2009); future environmental changes Lake Victoria basin (Odada et al., 2009); management of natural parks (Daconto and Sherpa, 2010); and changes to freshwater resources (van Vliet et al., 2010). Given the dynamic complexity and unpredictability of socio-ecological systems, as they respond to drivers such as climate change, scenarios are increasingly being developed at various temporal and spatial scales to help people prepare for change (Eames and Skea, 2002).

It is, therefore, necessary to study how future anthropogenic pressures might affect human-environment interactions in the Marsabit Forest Reserve and the effects of forest destruction on ES provision. This will inform possible future interventions about mitigation and adaptation efforts for sustainable ES provision by the Marsabit forest. Our study aimed to (i) to identify ecosystem services and how they are perceived by local communities (ii) assess the impact of anthropogenic activities on ecosystem service provision (iii) identify through the scenario development process the most plausible outcome that will sustain ecosystems service provision and (iv) develop an action plan for the favored scenario outcome to build resilience to related changes in the Marsabit forest community.

2. Materials and methods

2.1. Study site

Mount Marsabit is a unique dry forest system in Kenya which is ecologically and socio-economically important to the people of Marsabit County (Githae et al., 2008). It is located between latitude 01°15′North and 04°27′ North and longitude 36°03′ East and 38°59′East (Fig. 1). It was established in 1948 (Synott, 1979) and is the only government gazetted forest in Marsabit County under the management of Kenya Wildlife Service and Kenya Forest Service (Kenya Wildlife Service, 2016).

The MFR covers approximately an area of 157 square kilometres with the highest point on the mountain at 1836 meters above the sea level. It is an isolated area in the semi-arid region of northern Kenya in Marsabit County, about 560 kilometres from Nairobi, Kenya's capital city. Being an extinct volcano, the MFR has rich and well developed volcanic soils (mainly Cambisols) which have a high-water retention capacity (KFWG, 2001). Some areas have moderately deep clay loams while others are stony or rocky. The soils are suitable for crop farming in areas of sufficient rainfall. It experiences a bimodal rainfall pattern with mean annual rainfall ranging between 600 and 1000 mm per year (Bake, 1984). The long rains (March—May) are brought by southeasterly winds. Most rainfall is experienced in the March to May and October to December rainy seasons. The intervening periods are dry. Highest temperatures usually are experienced in February, ranging between 30° and 35 °C while lowest temperatures are experienced in March and July and range between 22° and 25 °C.

The floristic composition of Marsabit forest is a mosaic of mature and transitional forest types, deciduous woody shrublands and wetland communities (Githae et al., 2008). The vegetation clusters depict a combination of climax, remnant and or regenerating and colonising species. There is an evergreen to semi-deciduous bushland type vegetation that is most extensive on the southern and southeast sides of the mountain. The evergreen forest is dominated by *Cassipourea malosana, Podocarpus gracilior, Olea africana, Juniperus procera* and, *Croton megalocarpus*. The MFR is located in Saku constituency with a population of 46,502 persons with a third (16,213) of them residing around the MFR (Wiesmann et al., 2014). It consists of thirteen locations namely, Hula Hula, Karare, Dirib-Gombo, Songa, Kituruni, Leyai, Sagante, Qilta-korma, Gabra Scheme, Dakabaricha, Nagayo, Jirime, and Mountain central in the urban set up (Fig. 2). The communities surrounding the study area are predominantly Rendille (in Karare, Hula Hula, Leyai, Kituruni and Songa locations) Gabbra (in Jaldesa location) and Borana (in Jirime, Jaldesa, Mountain central, Dakabaricha, Qilta-korma and Nagayo locations). The other smaller ethnic groups of Burji, Turkana, Samburu, Sakuye, Somali, Ameru and other migrants also occupy these locations around the MFR. Pastoralism is the main economic activity in the study area, accounting for 80% of the economic activities, while subsistence agriculture

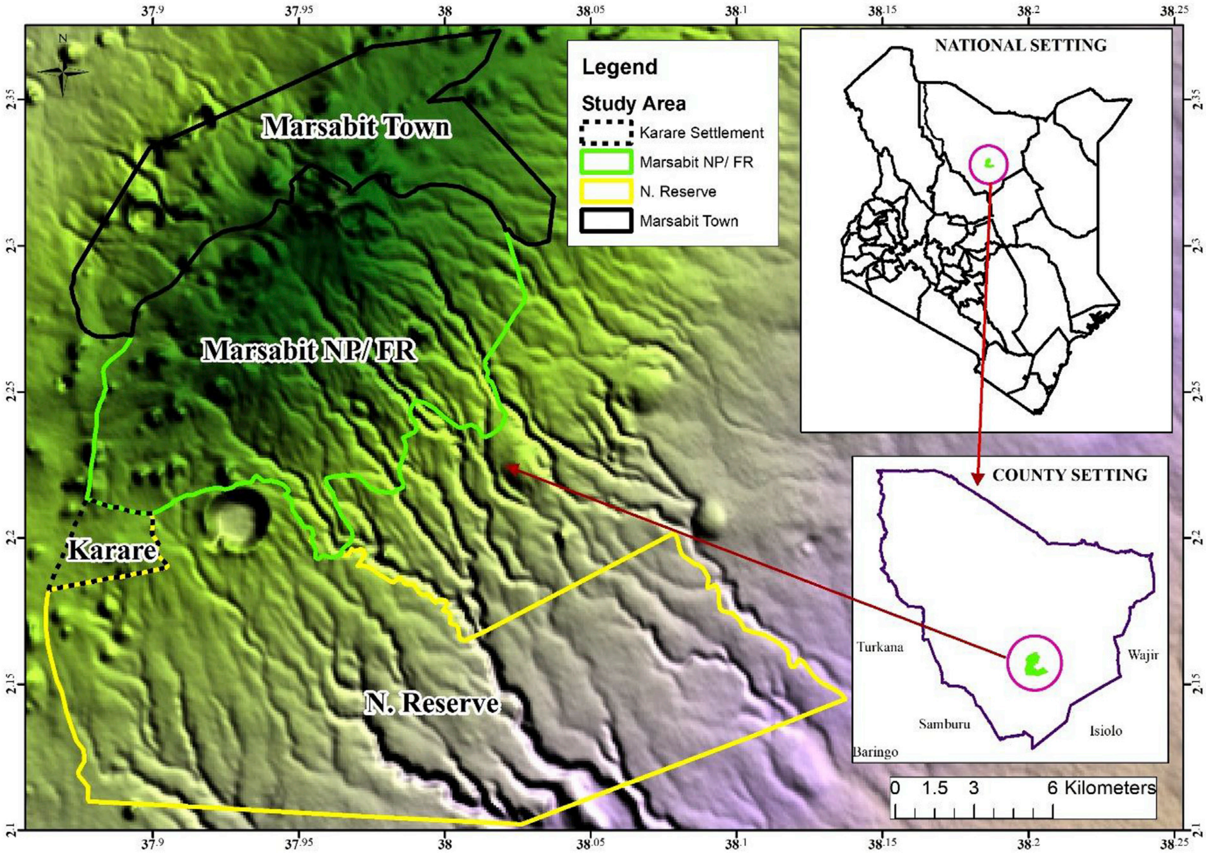

Fig. 1. Location of the study area in Kenya and the Marsabit County setting (Source: Muhati et al., 2018).

centred in food crops like maize, sorghum, millet, beans, fruits and vegetable crops grown is also practised in the eastern locations of Jaldesa and Songa which receive favourable rainfall.

The MFR provides ecosystem services i.e. provisioning services such as food, water, fuelwood, pasture, and medicinal plants, regulating services such as, climate regulation, natural hazard regulation, carbon storage, water purification, air quality regulation, climate regulation, erosion regulation, and cultural services such as spiritual enrichment, recreation and aesthetic values that are critical to the livelihood of the people of Marsabit town (Kenya Wildlife Service, 2016). Due to the sustained anthropogenic pressures, primarily through over-abstraction of water, selective logging, harvesting of fuelwood and over-grazing of livestock (Muhati et al., 2018), the role that MFR plays in the provision of ecosystem goods and services are under threat and therefore the wellbeing of its inhabitants.

2.2. Sampling framework and field data collection

Stakeholder defined scenarios usually have greater political plausibility and public acceptance than expert-driven scenarios because of the participatory engagement and planning approaches (Kassa et al., 2009). Stakeholder participation in the scenario development process in our study was considered key given the high stakes among the conservation interest groups, the fourteen different ethnic groupings, the County Government of Marsabit and other government institutions in the decision-making process and the future well-being of the MFR. Prior to the multi-stakeholder driven scenario-building process, twelve key informants representing key agencies in the area helped identify the focal issue of concern afflicting stakeholders around the MFR during a joint discussion workshop in January 2016. During the workshop, they responded to semi-structured questionnaires and also identified the drivers affecting the focal issue, their trends in the microenvironment, the ES provided by the MFR, and the potential effects of anthropogenic dynamics on ES provision (Supp. 1). The experts, who were considered to have firsthand knowledge of the challenges facing the MFR. were drawn from the following institutions that primarily deal with or are associated with the management of natural resources in Marsabit County:

1) Kenya Forest Service (KFS)
2) Kenya Wildlife Service (KWS)

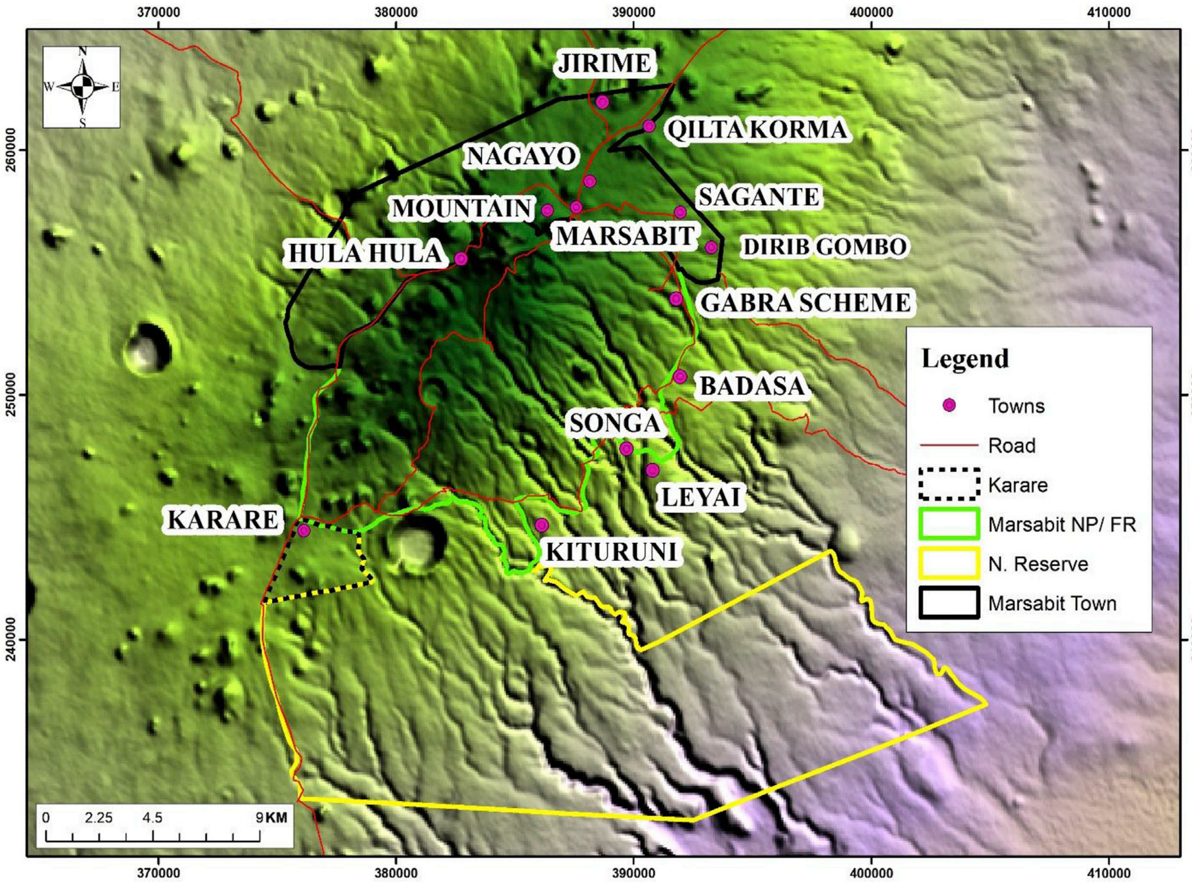

Fig. 2. The thirteen locations where focus group discussions were held around the Marsabit Forest Reserve.

3) Kenya Agricultural and Livestock Research Organization (KALRO)
4) Marsabit County Government (CGM)
5) Water Resources Authority (WRA)
6) National Drought Management Authority (NDMA)
7) National Environmental Management Authority (NEMA)
8) Food for the Hungry (FHI)
9) A representative of conservation NGOs (None governmental organizations)
10) Conservancy managers (Shurr, Songa and Jaldesa Conservancies)

Purposive sampling, a non-probability sample approach where FGD respondents were selected from the local population based on their unique utilisation of the forest, was used. Members of the community located within a five-kilometre belt from the MFR boundary where there were pronounced anthropogenic activities were targeted. These community members belonged to different ethnic and user groups that were utilising the MFR forest resources. A total of thirteen FGD meetings were held, one in each of the thirteen locations around the MFR in October 2015 (Fig. 2). Semi-structured questionnaires were administered to the FGDs targeting one hundred and thirty respondents representing six members of the forest user groups (i.e. firewood collectors, farmers, honey collectors, livestock herders, water users and herbalists) and four members who did not necessarily identify with any user group but had a stake in forest resource use.

Due to the patriarchal cultural setup, the FGDs entailed holding separate discussions with representatives of women, youth and men and only converging during the plenary to share the findings. The local chiefs in every location assisted the community forest association officials in selecting the FGD members and facilitating the sessions due to their knowledge of the forest and the respect they command from the community. The local chiefs familiarised themselves with the various ES as defined by Díaz et al. (2006) and extensively interpreted to the community the ES terminology in the local (Borana and Rendille) language. The first section of the FGD questionnaire centred on the importance of the forest to the local communities, the ecosystem goods and services provided by the forest and the threats facing the forest. The second section centred on the ranking of plant species that were of importance to the livelihood of the communities and the potential impacts of anthropogenic threats to ecosystem services.

2.3. Stakeholder's workshops

Two stakeholder workshops attended by forty participants representing the different forest user groups around MFR and twelve members representing the natural resource management institutions were held in the month of February and March 2016 in Marsabit town. The objective of the first workshop was to assemble a multidisciplinary team from communities and natural resources managers to develop scenarios using the first four steps of the eight steps approach by (Lindgren and Bandhold, 2009) in the following sequence.

2.3.1. Identification of the focal issue of concern around MFR

To ensure that all participants started with a similar level of understanding on the focal issue and to prevent barriers to an effective discussion, relevant background material on the Marsabit Forest Reserve and its historical land use change perspective was prepared in collaboration with stakeholders and shared before the workshop. In the stakeholder's workshop, the FGD and KII representatives deliberated and agreed on the focal issue of concern afflicting the forest and the local communities based on a summary of their initial interview responses. Presentations by representatives of the FGD and KII groups were made on the results of their perception of the key ES provided by the forest, the drivers impacting the ES and the impacts of the driving forces on future ES provision. The experts in natural resource management (the key informant interviewees) assisted the FGD participants to strengthen their understanding of the key driving forces impacting the focal issue, their trends and their impact on ES sustenance in MFR based on available literature.

2.3.2. Identification of the driving forces affecting focal issue based on their importance and uncertainty

Based on the driving forces affecting the focal issue as perceived by the FGDs and KII, the stakeholders jointly assessed the responses and came up with a common set of drivers. Participants then ranked the key drivers based on their significance in impacting ES provision and the uncertainty of their trajectories in future. From the identified driving forces, participants identified the two most important but uncertain drivers creating divergent and relevant future conditions to be included in the scenario building. This was done by plotting the drivers on a matrix plot based on their importance and future uncertainty to the focal issue. Driving forces that were not considered critical for the development of scenarios were classified as supporting drivers to the focal issue to be addressed.

2.3.3. Hypothesizing the interactions of the two main driving forces with other driving forces

For each driving force, stakeholders identified two attributes representing two distinct but opposing scenarios and exploring the interaction of the two main drivers creating four divergent but plausible future scenarios for the MFR.

2.4. Second stakeholder workshop

The second stakeholder workshop was held in the month of March 2016 in the Marsabit town two weeks after the first stakeholder's workshop. The objective of the second workshop was to assess the scenarios using the following remaining steps (as per Lindgren and Bandhold, 2009) in scenario development.

2.4.1. Fleshing out the scenarios

Participants fleshed out the scenarios with each of the four proposed future scenarios given a name which was representative of the possible future outcome. Detailed narratives for the four alternative scenarios describing a future MFR were then written based on the logics from the previous steps.

2.4.2. Selecting indicators for monitoring

The stakeholders, using a matrix, identified salient sets of indicators for monitoring and measuring possible future change on the focal issue on each developed scenario. Once the sets of indicators were identified, the stakeholders used the indicators to assess how the focal issue was affected by the different scenario outlooks.

2.4.3. Evaluating impacts of scenarios and adoption of alternative strategies

Storylines were then developed as a set of exploratory and plausible trajectories for each distinct scenario outlook with the relevant monitoring indicators. Stakeholders then evaluated the alternative scenarios and adopted the most suitable scenario that represented the future that they desired. An action plan that stakeholders believed would lead them to that desired future was then developed. The action plan was developed with the focal issue as the objective to be achieved with the chosen scenario informing the activities to be included in the action planning framework (Fig. 3). The development of the plan was participatory with the stakeholders identifying the objective to be achieved, proposed interventions, verifiable indicators, the implementors, sources of funds and the timelines. The mode of facilitation in the scenario-building process in our study was a mixture of oral presentations, break out group sessions and written submissions.

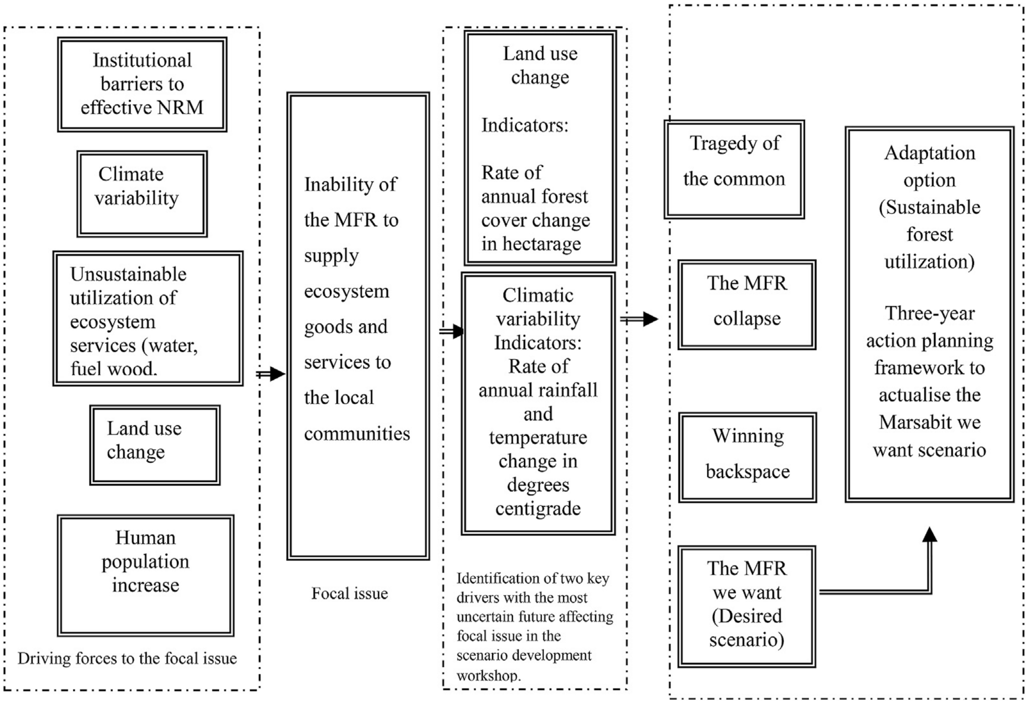

Fig. 3. Conceptual framework scenario development process. NRM – Natural Resources Management; MFR – Marsabit Forest Reserve.

2.5. Data analysis

Qualitative data from the scenario workshops, focus group discussions and key informant interviews were translated from the Rendille and Borana local languages to the English language. The identified forest services were then ranked into provisioning services, regulating services and cultural services similar to the categorization by Díaz et al. (2006). The data was analysed using the preference ranking approach by Martin (2004) and displayed in the form of tables. The ranking identified the most widely used tree species for livestock forage, medicinal uses and house construction per location as identified. The frequency of the most preferred species per location was then averaged and ranked to identify the ten most preferred species across the MFR. Responses from the FGD and the KII on the focal issue of concern, impacts of anthropogenic forces on ES and the most important driving forces affecting the forest were further ranked in the first workshops plenary to develop common rankings for scenario development.

3. Results

3.1. Ecosystem services as perceived by FGD and KII

All the one hundred and thirty respondents from the 13 locations in the FGD discussions were familiar with the different aspects of ES. The most significant ES provided by the MFR according to ranking were: water provision (for domestic use and livestock through wells), fuelwood provision, forage provision (dry season grazing resource), building materials, and climate regulation, with revenue generation through tourism ranked the least significant (Table 1).

Similarly, respondents from the KII considered rainfall provision, fuelwood provision, forage (dry season grazing resource) building materials, and water provision (for domestic use and livestock through wells) and water provision to the town (Bakuli springs) as the most significant ES provided by the MFR (Table 2). The KWS and the KFS officers, however, noted that there is currently a moratorium on the consumptive utilisation of all resources in the forest other than water which is permitted. However, due to the lack of alternatives for communities, and the lack of enforcement capacity, the utilisation of these resources is tolerated.

3.2. Community water sources

Communities in the FGDs and KII identified eighteen water sources for use within and outside the MFR; they were broadly categorised as for domestic use, livestock watering, and wildlife (Table 3).

Table 1
ES provision as perceived by local communities in the FGD.

Ecosystem services from the Marsabit forest	HH	KA	DG	SO	KI	LE	Villages		JA	DA	NA	JE	MC	Total	Rank
							GS	QK							
Water provision	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	13	1
Fuel wood provision	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	13	1
Forage provision	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	13	1
Climate regulation/rainfall attraction	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	13	1
Building material	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x	11	2
Medicinal plants	x	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	x	10	3
Soil fertility provision	x	✓	✓	✓	x	x	✓	x	✓	x	x	✓	✓	7	4
Cultural site	✓	✓	x	x	✓	✓	x	✓	✓	x	x	x	✓	7	4
Honey harvesting	✓	✓	x	x	✓	x	✓	✓	x	✓	x	x	x	6	6
Habitat for wildlife	✓	✓	x	✓	✓	x	x	x	x	x	x	✓	✓	6	6
Wild fruits and root tubers for livestock	✓	✓	x	x	✓	✓	x	✓	x	x	x	x	x	5	8
Tourism	x	x	x	x	x	x	x	x	x	x	x	✓	✓	2	9

Note: HH=Hula Hula, KA=Karare, DG = Dirib Gombo, SO=Songa, KI=Kituruni, LE = Leyai, GS = Gabra Scheme, QK = Quilta Korma, JA = Jaldesa, Dk = Dakabaricha, NA=Nagayo, JE = Jerime, MC = Mountain central.

Table 2
Ecosystem service provision as perceived by the KII.

	KFS	KWS	KALRO	CGM	WRA	NDMA	NEMA	Conservancies	NGOs	Total	Rank
Water provision	✓	✓	✓	✓	✓	✓	✓	✓	✓	9	1
Rainfall attraction/climate regulation	✓	✓	✓	✓	✓	✓	✓	✓	✓	9	1
Fuel wood	✓	✓	✓	✓	✓	✓	✓	✓	✓	9	1
Forage provision	✓	✓	✓	✓	✓	✓	✓	✓	✓	9	1
Habitat for wildlife	✓	✓	✓	✓	x	✓	✓	✓	✓	8	5
Tourism revenue	✓	✓	x	x	✓	✓	x	✓	✓	6	6
Cultural site	✓	✓	x	✓	x	x	x	✓	x	4	7
Carbon sequestration	✓	✓	x	x	x	x	✓	x	x	3	8
Wild fruits and Root tubers for livestock	✓	x	x	✓	x	x	x	✓	x	3	8
Honey harvesting	✓	x	✓	x	x	x	x	✓	x	3	8
Medicinal plants	x	x	✓	✓	x	x	x	✓	x	3	8
Flood water control	✓	✓	x	x	x	x	x	x	x	2	12
Ground water recharge	✓	✓	x	x	x	x	x	x	x	1	13

Note: KFS=Kenya Forest Service, KWS=Kenya Wildlife Service, NDMA=National Drought Management Authority, WRA=Water Resources Authority, Conservancies = Songa, Shurr and Jaldesa community conservancies, NGOs = Non-governmental organizations in Marsabit, NEMA=National Environmental Management Authority, CGM=County Government of Marsabit.

Table 3
Community water sources and usage in MFR as perceived by KII and FGD.

Water source	Location	Usage
Fifty deep wells	Forest Reserve	Livestock watering
Aite well	Community land	Watering point for domestic use
Bakuli (dam 1)	Forest Reserve	Water extraction
Bakuli (dam 2)	Forest Reserve	Water extraction
Bakuli (spring 1)	Forest Reserve	Water extraction
Bakuli (spring 2)	Forest Reserve	Water extraction
Elephant pool	Forest Reserve	Livestock watering/wildlife use
Hulahula well	Community land	Livestock watering
Karsa wells	Forest Reserve	Livestock watering
Lagga Lchuta spring	Forest Reserve	Livestock watering
Lagga Lguru spring	Forest Reserve	Livestock watering
Lagga Mohammed spring	Forest Reserve	Livestock watering
Lagga Sirba spring	Forest Reserve	Livestock watering
Lake Bongole (Crater Lake)	Forest Reserve	Livestock watering/wildlife use
Ote wells 1	Community land	Livestock watering
Ote wells 2	Community land	Livestock watering
Songa spring	Forest Reserve	Livestock watering
Lake Paradise	Forest Reserve	Wildlife use
Songa spring	Forest Reserve	Livestock watering

3.3. Forage species in MFR

The FGDs identified ten forage species of high significance to the communities in the forest with *Olea europaea* ssp. *africana* as the most preferred while *Paspalidium desertorum* was the least preferred. Ranking of the forage identified both grasses and trees as a source of fodder for their livestock (Table 4).

3.4. Medicinal plants

The FGDs identified ten medicinal species of high significance to the communities in the forest with *Bothriochloa insculpta* as the most preferred and *Vangueria madagascariensis* the least preferred (Table 5).

3.5. Trees species for building purposes

Several tree species were used by the community for building purposes with *Olea europaea* ssp. *africana* being the most preferred timber species and *Vangueria madagascariensis* the least preferred (Table 6).

3.6. Threats to ES provision

The KII and the FGD members in the scenario workshop identified land use change, unsustainable utilisation of resources and climatic variability as the main threats faced by the local communities with regard to the sustenance of ES. Respondents

Table 4
Forage species as perceived by local communities in the FGD.

Common name	Scientific name	Frequency	Ranking
Ejersa	*Olea europaea* ssp. *africana*	11	1
Ntalaguani	*Aristida kenyensis*	10	2
Lperesi	*Themeda triandra*	9	3
Karra	*Strychnos henningsii*	9	3
Buyo	*Eragrostis caespitosa*	8	5
Qayyo	*Commelina benghalensis*	6	6
Lonoro	*Eragrostis ciliaris*	6	6
Maderr	*Cordia sinensis*	5	8
Baratt	*Blepharis* sp.	4	9
Idho	*Paspalidium desertorum*	4	9

Table 5
Medicinal species as perceived by local communities in the FGD.

Common name	Scientific name	Frequency	Ranking
Lkawa	*Bothriochloa insculpta*	13	1
Lperesi/lperesiwas	*Themeda triandra*	12	2
Ntalaguani	*Aristida kenyensis.*	11	3
Losau	*Boscia angustifolia*	10	4
Buyo	*Eragrostis caespitosa*	10	4
Lkurume	*Pennisetum mezianum*	9	6
Dekha	*Grewia tenax*	9	6
Idho	*Paspalidium desertorum*	8	8
Qayyo	*Commelina benghalensis*	8	8
Lkoromosio	*Vangueria madagascariensis*	5	10

Table 6
Trees species for building purposes as perceived by local communities in the FGD.

Common name	Scientific name	Frequency	Ranking
Ejersa	*Olea europaea* ssp. *africana*	13	1
Nchipiliwa	*Strychnos henningsii*	12	2
Lngeriyoi	*Olea europaea* ssp. *africana.*	12	2
Lokho	*Diospyros abyssinica*	12	2
Lecholo	*Bauhinia tomentosa*	12	2
Maderr	*Cordia sinensis*	11	6
Mukhdima	*Ochna insculpta*	11	6
Karra	*Strychnos henningsii*	10	8
Korkore	*Tarenna graveolens*	9	9
Bururi	*Vangueria madagascariensis*	8	10

felt that the impacts of the identified threats to the forest were mostly manifested in increased drought frequency, reduced forage, and reduced aquifer recharge. Loss of biodiversity was considered to be the least impacted by the forest threats (Table 7).

3.7. Scenario development process

3.7.1. Identification of the focal issue of concern for stakeholders around MFR

The first stakeholder's workshop in Marsabit town identified and defined the focal issue as: “establish the status of ecosystem goods and services in the MFR under the prevailing anthropogenic activities and determine the most appropriate adaptation options to sustain ecosystems service provision and build resilience in the forest community”.

3.7.2. Identification and ranking of the driving forces affecting focal issue based on their importance and uncertainty

Land use change was considered the most important driving force impacting the focal issue while population increase around the MFR considered the least significant. Land use change and climate change were considered the most significant drivers impacting ES provision in the MFR yet the most uncertain in the future (Table 8). In order of ES importance, water provision (for domestic use and livestock watering), fuelwood and forage provision (dry season grazing resource) and climate regulation were ranked the most important.

3.7.3. Hypothesizing the interaction of the two main driving forces with other driving forces in the development of scenario logics

The stakeholder workshops identified four alternative future scenarios for the MFR by the year 2044 (Fig. 4). The scenarios focused on two uncertain future trajectories for the two focal driving forces (climate change and land use change) with other support driving forces at play.

Table 7
Impact of forest threats to ES.

Impact of forest threats to ecosystem goods and services	Frequency	Ranking
Increased drought frequency	38	1
Reduced forage	36	2
Reduced aquifer recharge	34	3
Reduced climate regulation	24	4
Loss of building material	22	5
Biodiversity loss	19	6
Soil erosion	9	7
Loss of spiritual/cultural services	9	7

Table 8
Driving forces as ranked in the stakeholder's workshop.

Driver	Indicator	Total	Ranking
Land use change	The rate of forest loss in hectarage	38	1
Climate change	Variability in temperature and precipitation	36	2
The unsustainable utilisation of natural resources	The rate of utilisation of resources	34	3
Institutional barriers to effective natural resource management	Efficacy of natural resources management	33	4
Population increase	The rate of annual growth, per capita income	30	5

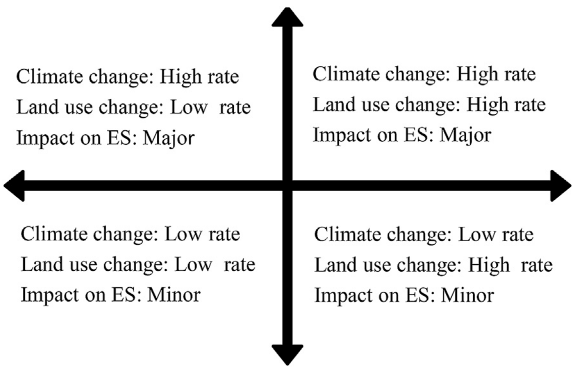

Fig. 4. Four alternative future scenarios for the MFR as identified in the stakeholder's workshop.

3.7.4. Fleshing out the scenarios

Stakeholders developed four scenario narratives by exploring the implications of alternative trajectories on the focal issue in MFR based on the interactions between the two key driving forces as follows,

i. The tragedy of the commons: A future where high rates of climate change coupled with a simultaneous increase in land use change have major impacts on ecosystem goods and services in MFR.
ii. The MFR we want: A future where low rates of climate change coupled with a simultaneous reduction in land use change have minor impacts on ecosystem goods and services in MFR.
iii. Winning backspace: A future where low rates of climate change coupled with a simultaneous increase in land use change have minor impacts on ecosystem goods and services in MFR.
iv. The MFR collapse: A future where a high rate of climate change coupled with a simultaneous reduction in land use change has major impacts on ecosystem goods and services in MFR.

3.7.5. Evaluating impacts of scenarios on selected indicators for monitoring

The stakeholder workshops identified scenario indicators based on the identified driving forces and assessed the impacts of the changing indicators against interacting driving forces and their impacts on the focal issue (Table 9) Four future scenario storylines were elaborated based on scenario narratives by exploring the implications of changing scenario indicators on the focal issue in MFR.

3.7.6. Development of an action plan

Following the description of alternative scenarios through the scenario matrix and storylines, stakeholders evaluated the efficacy of each scenario *vis à vis* the future they desired and identified the Marsabit Forest We Want scenario as the most plausible future they desired for the sustenance of ES. The other three scenarios were considered detrimental to the future wellbeing of the forest and by extension the livelihoods of the local communities. The five objectives underpinning this plan were: land use change mitigation around the forest, mitigation of the unsustainable utilisation of forest resources, climate change mitigation, ecological restoration and the local communities actively involved in forest conservation and management (Supp. 1).

4. Discussion

4.1. Ecosystem services as perceived by the FGD and KII

The ranking of water provision, fuelwood provision, forage provision, building materials, and climate regulation as the most significant ES both at the FGD and the KII levels underlines the importance of MFR in the community's livelihood provision. The high ranking placed on water as an ES may be explained as due to the semi-arid setting of the study area and consequent lack of reliable sources of water supply. The Marsabit County communities are predominantly agro-pastoralists (Githae et al., 2008), and as such depend on eighteen water sources from the forest to water their livestock, for domestic use as well crop production. Bakuli spring, with an estimated discharge of $108m^3$/day (Kenya Wildlife Service, 2016) is the main piped water supply for the Marsabit town with the other water sources supplementing the water requirements of the local communities. The additional water sources mentioned (Table 3) are neither connected to the piped water system nor chemically treated before domestic use. The water is collected in jerry cans and ferried to homesteads by women who carry the water on their back, or on donkeys. Respondents in the FGD were, however, concerned by the unchecked abstraction of water in boreholes in the lowlands and associated it with the lowering of the water table at higher altitude, arguing that this was the primary cause of the reported drying of boreholes around the Marsabit forest.

The FGD and the KII considered *forage provision* during the dry periods as an essential ES in sustaining livestock when pasture is depleted in the rangelands. MFR is regarded as a critical forest for its ecological functions and an important dry season pasture refuge for livestock and wildlife (Ministry of Environment and Natural Resources, 2016). Communities ranking of forage from both grasses and tree species was premised on its availability, accessibility, seasonality, nutritional value and palatability. The most palatable forage species that were in proximity and readily available for livestock were most preferred to species of nutritious value but further off community homesteads. When forage was limited due to drought, communities fed their livestock on the leaves of palatable trees species and reverted to the grasses when the conditions were favourable. The consumptive utilisation of tree fodder in the MFR is illegal with communities only allowed to water their livestock in the wells after foraging outside the forest. Respondents, however, admitted to occasionally using *pangas* (machetes) to trim the branches of palatable forage trees to feed their livestock during the drought season. This is one of the aspects of community access to the forest that Maina and Imwati (2015) thought exerted pressure on the regeneration of trees in MFR.

Fuelwood provision was also considered significant in all the 13 locations around the forest and was used by households on a daily basis for both cooking and lighting purposes. Fuelwood provision is a critical ES provided by forests in Kenya and is considered the principal form of biomass energy meeting the needs of over 64.5% of households, particularly in the rural set up (Wiesmann et al., 2014). Communities considered fuelwood a cheaper option to kerosene and charcoal which is imported

Table 9
Comparison of the four scenarios in MFR.

Alternative scenarios		Marsabit forest we want	The tragedy of the commons	Marsabit forest ecosystem collapse	Winning backspace
Key drivers and their impacts on ES	(i) Land use change Indicators: Annual rate of, • Closed forest cover change • Open forest cover change • Agriculture and settlement change.	Land use land cover change (LULCC) decrease with little impact on ES.	Major changes, significant impact.	Irreversible changes, unprecedented impact.	Minor changes, little impact.
	(ii) Climate change Indicators: Change in • Seasonal rainfall • Annual rainfall • Annual temperature • Decadal temperature • Modelled future temperature • Modelled future rainfall.	Minor changes, little impact.	Major changes, significant impact.	Irreversible changes, unprecedented impact.	Minor changes, little impact.
Other drivers and their trajectories	(iii) Human Perception and behaviour in the utilisation of natural resources Indicators: Change in • Stakeholders valuation of MFR. • Rates of utilisation of the forest resources. • Perception of ownership of the forest resources.	Stakeholder ownership of MFR, MFR a collective resource, long-term valuation of the forest, sustainable utilisation of forest resources.	Lack of stakeholder ownership, MFR a state resource, short-term valuation of the forest, individualism, unsustainable utilisation of forest resources.	Lack of stakeholder ownership, MFR a state resource, short-term valuation of the forest, individualism, unsustainable utilisation.	Stakeholder ownership of MFR, MFR a collective resource, long-term valuation of the forest, sustainable utilisation.
	(iv) Institutional arrangements to NRM (Natural resource management) Indicators: Change in • Responsive management of the MFR by KFS, KWS and CGM. • Local community participation in the MFR management.	A coordinated approach by KFS, KWS, CGM, and communities	Competing approaches between KFS, KWS, CGM, and communities.	Competing approaches between KFS, KWS, CGM, and communities.	KFS and KWS merged to form a single and more efficient entity to manage the Marsabit Forest Reserve.
	(v) Population growth rate and Socio-economic characteristics Indicators: Change in • Population growth • Per capita income • Infrastructural development • Social welfare • Technological innovations. • The adaptative capacity of local communities to climatic variability.	High population increase, population educated, skilled, middle-income levels, integrated.	Higher than projected, Population explosion, population poorly educated, non-skilled, poor, divided along ethnic enclaves.	High population increase, population poorly educated, non-skilled, poor, divided along ethnic enclaves.	A low rate of population increase, a population highly educated, highly skilled, middle class, high immigration rates.

(*continued on next page*)

Table 9 (*continued*)

Alternative scenarios	Marsabit forest we want	The tragedy of the commons	Marsabit forest ecosystem collapse	Winning backspace
Storylines/impacts	Low rates of LULCC and climate change has little impact on ES under sustainable utilisation of forest resources. A responsive institutional management framework coupled with adequate adaptation/mitigation measures to observed changes by all stakeholders ensures sustainable provision of ES.	High rates of LULCC and climate variability has a significant impact on ES under unsustainable utilisation of forest resources, with a poor forest management regime with a reactive adaptation/ mitigation strategy to observed changes.	Low rates of LULCC and climate change has little impact on ES under sustainable utilisation of Forest resources, with a clear institutional management framework with adequate adaptation/mitigation measures to observed changes.	Low rates of LULCC and climate change has little impact on ES under sustainable utilisation of forest resources, with a clear institutional management framework with adequate adaptation/mitigation measures to observed changes.
Ecosystem state	Resilient, high state of community adaptation to impacts of perturbation to ES.	Vulnerable, a low state of community adaptation to impacts of perturbation to ES.	Ecosystem collapse and in an irreversible state, low state of community adaptation to impacts of perturbation to ES.	Resilient, high state of community adaptation to impacts of perturbation to ES.
Future ecosystem outlook	Positive	Negative	Negative	Positive

from the neighbouring Moyale town, as well as from the adjacent Samburu and Meru Counties. However, while respondents from Jerime and Mountain Central locations (which are in the urban areas) considered fuelwood provision as a critical ES, they viewed it from a commercial perspective whereby the product is sold in the local market after collection from the forest. Marsabit town provides a ready market for fuelwood which is used by 92.6% of the residents for their fuel needs (Kenya Wildlife Service, 2016). The firewood is supplied by groups of women who mostly illegally extract dry, dead wood from the forest floor. All the FGD locations did not have a particular preference for the wood fuel species but instead collected what was available in the forest for both domestic use and commercial purposes.

Jerime and Mountain Central locations did not consider *timber provision* a significant ES because they were either living in permanent houses or sourced timber from the timber yards which sold timber that had been imported from neighbouring counties. Several tree species were used by the community for the building of traditional houses through roofing, the framing of the housing structures, and fencing of the homesteads (Table 4). *Olea europaea* ssp. *africana* was the most preferred timber species for construction purposes because of its resistance to termite infestation according to the respondents.

While the provision of *biodiversity* is considered one of the important features of an ecological system (Reid et al., 2005), respondents were more concerned about the high rate of human-wildlife conflict primarily caused by elephants which destroyed crops and property and depredation from the hyenas. This, therefore, may have influenced their perception of the forest and hence negatively viewed the forest *vis à vis* biodiversity conservation in seven of the thirteen communities interviewed. The respondents, however, appreciated the role the forest played as a habitat for wildlife conservation.

While *tourism and habitat for wildlife* ranked poorly in the FGD, they ranked better in the KII. This may be attributed to the Government agencies tasked with forest and wildlife management attaching a high value to the forest as a wildlife habitat and for tourism revenue generation compared to the local communities. Tourism was considered the least significant ES in all the locations where FGDs were held, save for Jerime and Mountain central location that considered tourism as an important economic catalyst in the town. They noted that tourism contributed to the local economy through revenues from hotel occupancy and sale of curios crafted from the local traditional cultural centres. The other locations raised concern that financial benefits accruing from tourist visitation only served to benefit KWS and KFS and as such was not useful to the community.

The FGDs and the KIIs considered *climate regulation* a critical ES sustaining livelihoods in the forest area. Respondents attributed the favourable climatic conditions for agro-pastoralism around the forest to the existence of the MFR which regulates the microclimate of the area compared to the surrounding semi-arid region. This response corroborates, UNEP (2016) observation that regulating services such as local climate regulation are some of the critical ES provided by the montane forests in Kenya.

Carbon sequestration did not feature as a significant ES to local communities despite its significant role in carbon dioxide removal from the atmosphere and climate stabilisation (IPCC, 2014). Most of the participants were unfamiliar with this ES which they attributed to the low literacy levels as well as the fact that this ES is yet to be exploited in MFR under the REDD + framework and thus not considered immediately significant. It, however, featured in the KII with respondents familiar with this ES through literature and government institutional policies and programmes. This ES was, however, still not very well understood by the KIIs, which suggests that their capacity needs to be built if information on the importance of this critical ES is to be cascaded to the local communities.

The FGD and KII considered *medicinal plants* a critical ES provision though not as prominent as water, forage, fuelwood, and climate regulation. The communities collect traditional medicine in the form of roots, bulbs, tubers, tree bark, leaves and seeds using them for treatment of various ailments. The FGD ranked medicinal plant species based on their availability, location and the type of illness to be treated. Medicinal plants in Kenya's forests offer important alternatives to conventional medicine to the poor communities in rural areas (Ministry of Environment and Natural Resources, 2016). Some of the medical conditions treated using the traditional plants are malaria, snake bites, fever, pneumonia, coughs, sexually transmitted diseases, stomach upsets and infertility. The medicine is administered by traditional practitioners who take up this profession from their family lineage. Due to limited access to health facilities as a result of high poverty levels, poor infrastructure and long distances, respondents alluded to the significance of this ES in the rural areas.

The respondents indicated that the MFR not only provides provisioning ES but also regulating services (microclimate regulation) and cultural and supporting services. The diverse ES provided by MFR are similar to those provided by other dry forests in Africa (Chidumayo and Gumbo, 2010) as well as the dry island forests in northern Kenya like Mt Nyiru and Mathews ranges (Bussmann, 2006), and Mt Kulal (Watkins and Imbumi, 2007).

Responses to the threats to the MFR existence through land use change and unsustainable utilisation of resources may be explained as due to the encroachment of the forest, observed from the early 1990s. The MFR has experienced sustained land use change related to settlements, harvesting and utilisation of forest products, agriculture, and urban expansion between the 1990s to date which has reduced the forest hectarage from 11,020 to 7123 (Githae et al., 2008); (Maina and Imwati, 2015). Responses on the impacts of forest threats through increased drought frequency, reduced forage and reduced aquifer recharge may be attributed to climatic variability and environmental degradation observed in MFR over the years. According to Kenya Wildlife Service (2016), Marsabit County has experienced an increased number of drought occurrences between 2000 and 2010, to an almost two-year cycle adversely affecting livestock and agricultural production. The responses on impacts of anthropogenic activities on ES are similar to those of Reid et al. (2005) and Giupponi et al. (2014) who reported the consequences of land use change amid climatic uncertainty in forest systems as habitat loss, reduced biodiversity levels, reduced provision of ES and a lower quality of the landscape image.

From the FGD and KII responses, it was clear that local communities and stakeholders in different locations viewed ES uniquely dependent on the immediate benefits they accrued from the resource. However, responses to the universal benefits of ES, such as climate regulation, water provision, forage provision and rainfall attraction, were similar across all the locations. Respondents attributed the ranking of ES to the ease of its access relative to their homesteads, its significance to their daily livelihood and the availability of the service over the seasons. Various authors have suggested that the choice of ES to various beneficiaries varies according to the length of stay in an area (Gould et al., 2014) as well as availability, location, abundance and replaceability of the preferred species (Cuni-Sanchez et al., 2016).

4.2. Scenarios elaboration

The participatory scenario stakeholders workshop elaborated the four scenario narratives based on critical indicators and developed distinct storylines that represent four plausible futures that stakeholders will be faced with in MFR. In the following section, the scenarios are briefly introduced, with the storylines expounding how the different driving forces interact at different trajectories to impact the focal issue (see Figs. 5–8).

4.2.1. The "Tragedy of the Commons"

A future where a high rate of climate change coupled with a simultaneous increase in land use change has major impacts on ecosystem goods and services in the Marsabit Forest Reserve.

This scenario depicts the communities and state actors in forest conservation in MFR as reactive in light of climate variability. The MFR is considered the region's most important water tower and an important source of ES and a dry season refuge for pasture. There is increased economic expansion with investment in infrastructure and social amenities through the CGM with reduced levels of poverty and an increase in the population of the larger Marsabit County. Under this scenario projection (RCP 8.5), the rainfall levels have been increasing annually at a rate of 0.08 mm with a cumulative increase of 2.37 mm statistically insignificant by 2044 with a net increase in seasonal rainfall. The MFR is also experiencing an annual

Fig. 5. The "Tragedy of the Commons" summary diagram.

Fig. 6. The "Marsabit Forest We Want" summary diagram.

temperature increase of 0.04 °C with a mean temperature increase of 1.32 °C by 2044 higher than was anticipated as a result of an increase in global GHG levels. Incidences of heatwaves and episodic extreme rainfall events are more frequent with more warmer days than cold.

Land use change is the hallmark of this scenario with the illegal encroachment of the Marsabit National Reserve in the areas of Songa, Karare, Segel, and areas adjacent to the Marsabit town. KFS and KWS while still in charge of forest management lack the capacity and goodwill of stakeholders in securing the forest resources. The combination of a growing population increased livestock numbers and a growing per capita consumption rate leads to unsustainable demands for ES over the years for their daily needs.

The water stress levels in this scenario are unprecedented due to the shear rate, scope and impact of climate change on ES. Bakuli springs and Badassa dam the main sources of water for Marsabit town have reduced yield due to catchment degradation, climate change coupled with over-abstraction of boreholes downstream. Communities in the eastern side of the forest (Songa Baddasa, Gabbra scheme and Karare) who are primarily agriculturalists are affected by climatic variability through low seasonal rainfall, a shift in planting seasons, increased incidences of pest and diseases leading to low yields and crop failures. In the absence of alternative energy-saving technologies coupled with land use change and climate change, the primary productivity of the forest is reduced with the ability of the forest to regenerate and provide fuelwood reduced precipitating an energy crisis.

Due to escalating climatic impacts coupled with sustained land use change patterns over the decades, the MFR is not resilient enough to withstand these abrupt changes with species already endangered and vulnerable at the risk of local extinctions. This leads to a loss of species diversity, changes in species distributions, abundance and movement with species like the *Loxodonta africana* unable to move from the forest to other dispersal areas of Mathew Ranges, Losai National Reserve, Mt Nyiro and Mt Kulal. The quantity and quality of ES in MFR changes dramatically with the inability of the forest to meet the demands of the growing population under a rapidly changing climate coupled with sustained land use change patterns.

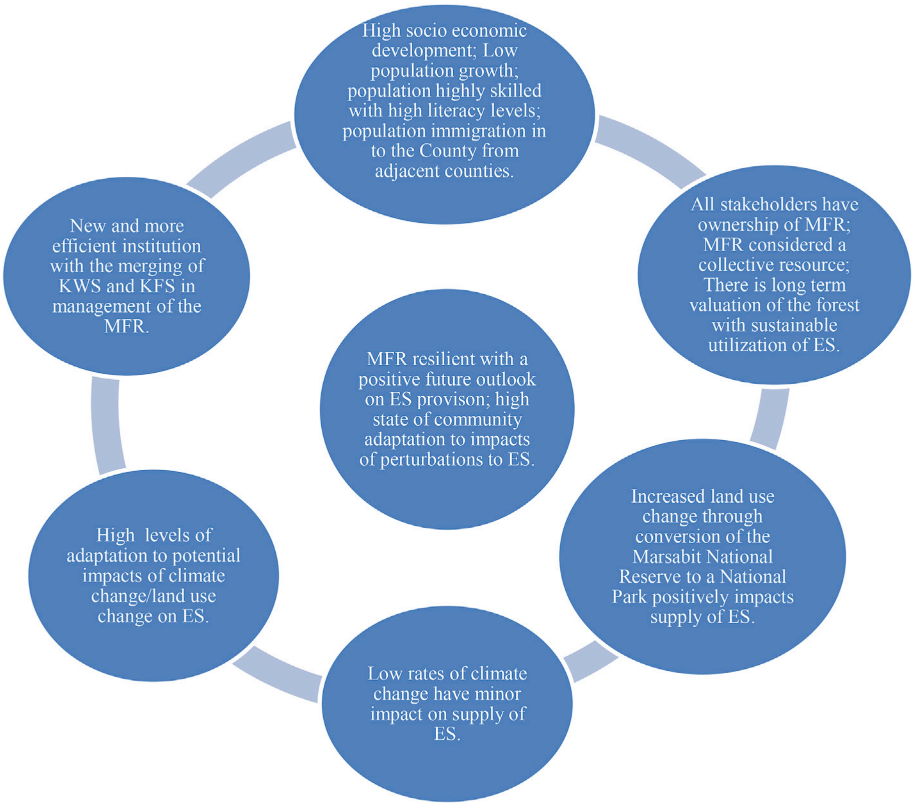

Fig. 7. “Winning Back Space” scenario summary diagram.

4.2.2. *The “Marsabit Forest We Want”*

A future where low rates of climate change combined with a simultaneous reduction in land use change have minor impacts on ecosystem goods and services in the Marsabit Forest Reserve.

This scenario depicts the communities and state actors in forest conservation in MFR as proactive in light of climate variability. There is a rapid expansion of social amenities with economic growth in Marsabit inextricably linked with sustainable environmental management. While there is a population increase due to better health facilities and an improved infrastructure network, there is also a commensurate increase in income levels. Under this scenario projection (RCP 4.5), the rainfall levels have been increasing annually at a rate of 0.05 mm with a cumulative increase of 1.5 mm statistically insignificant by 2044, with a shift in seasonal rainfall. The MFR is also experiencing an annual temperature increase of 0.03 °C with a mean temperature increase of 0.52 °C by 2044. There are increased incidences of drought to an average of a two-year cycle with incidences of heatwaves and heavy rainfall events more frequent though not higher than was envisaged. KFS and KWS the state agents in forest management are well equipped with effective and modernised operational capacity, to adequately manage the MFR through the implementation of integrated ecosystem management plans.

Despite the combination of growing populations, increasing livestock numbers and demand for ES, there is sustainable utilisation of forest resources. The need for more ecological resources for the communities is counterbalanced with ecologically compatible consumption patterns in households reflected by significant changes toward fuel-efficient technologies. Despite low yields in Bakuli springs due to reduced precipitation, its ability to supply water to the town dwellers is restored with the construction of check dams in the forest which recharge the aquifer with surplus water piped outside the forest. Communities have adopted water harvesting techniques with roof catchment harvesting and building of underground water reservoirs to store water and augment water sources.

Communities have invested in alternative energy-saving technologies with clay cladded *jikos*, embraced biogas production, adopted the use of efficient charcoal making kilns, solar energy, wind energy and energy saving bulbs to light their homes. Local communities through the CFAs have adopted agroforestry practices with the planting of trees species that, are non-palatable to wildlife reducing conflict, ameliorate soil fertility and are drought resistant providing a good source of fuelwood.

Communities in the eastern side of the Forest (Songa Baddasa, Gabbra scheme and Karare) who are primarily agriculturalists and affected by climatic variability practice integrated crop management where the use of crop rotation,

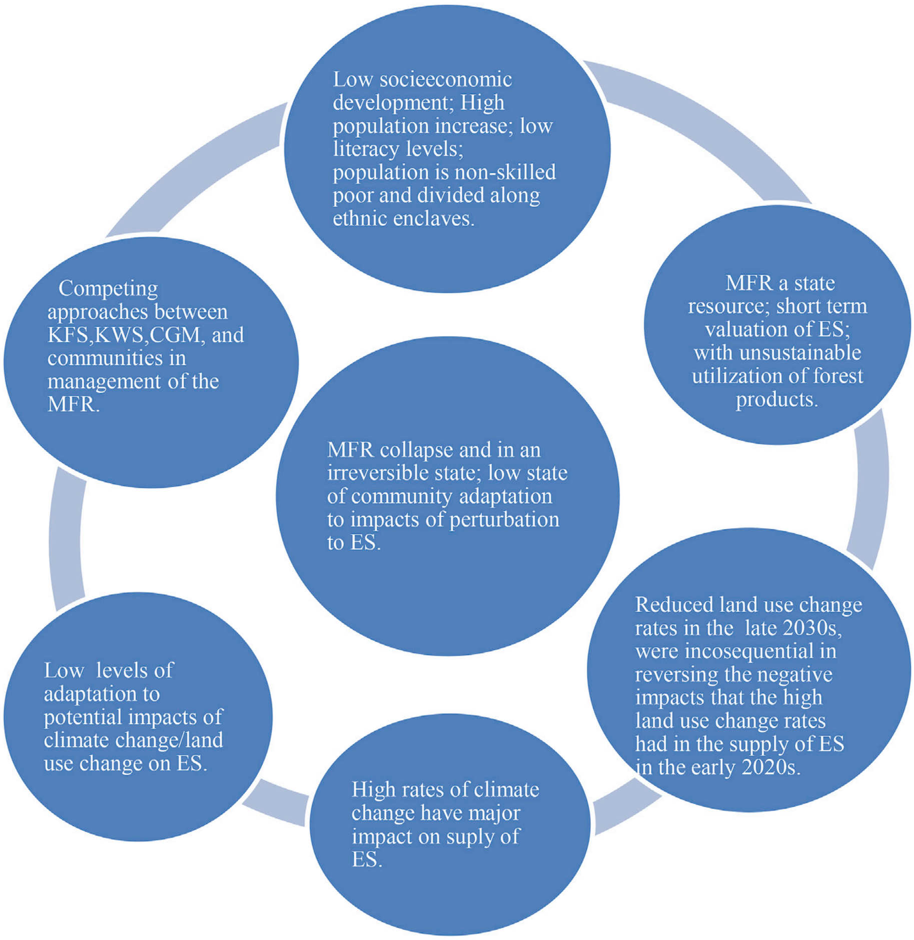

Fig. 8. The "Marsabit Forest Reserve Collapse" summary diagram.

intercropping, conservation agriculture and planting of drought-resistant crops increases yields, reduces soil erosion, and plant diseases.

Despite the low rates of climate change, the implementation of astute land use change practices and forest management have resulted in a resilient forest with an increasingly healthy population of threatened animals and plant species with the forest able to perform its ecological functions, such as climate regulation, flood water and soil erosion control.

4.2.3. "Winning Back Space"

A future where low rates of climate change coupled with a simultaneous increase in land use change have minor impacts on ecosystem goods and services in the Marsabit Forest Reserve.

This scenario depicts the Marsabit County as highly developed and mechanised with a high per capita income. The local population is more focused on harnessing the tourism potential thanks to the emerging touristic boom after the opening of the northern frontier counties through the Isiolo - Moyale road, the Marsabit Airport, and Isiolo Airport which was part of the Government of Kenya's vision 2030 blue print to improve connectivity. By 2044 the temperature increase is below the projected 0.52 °C in the GCM models with the number of extreme weather events decreasing steadily compared to historical patterns. The rainfall projections (RCP 4.5) have also been increasing annually though at a higher rate than the projected rate of 0.05 mm with a shift in seasonal rainfall. This is attributed to the implementation of the ratified Paris climate change accord in 2016 by world leaders which saw a substantial decrease in greenhouse gases globally over the decades.

Land use change has been curtailed with KFS and KWS merged to form a parastatal which is more responsive and effective to changing dynamics in conservation. The Marsabit National Reserve has been gazetted to a National Park augmenting the role of the MFR in biodiversity conservation with community land around the forest converted to wildlife conservancies increasing protected area land. There is a marked decrease in demand for ES due to a decreasing human population, and per capita consumption rates with the availability of alternatives sources of income through tourism development. The societal valuation of the MFR and the ES it provides is long term with greater community ownership.

Agriculture in this scenario is highly mechanised with farmers adopting irrigation technologies having planted drought resistant forage to feed their animals in periods of drought. Farmers have adopted greenhouse farming, use high yielding crops that are genetically modified, fast-growing and resilient to climate variability. Due to the mechanised nature of livestock production with the adoption of zero grazing technology and grazing management initiatives, less pressure is exerted on the forest during the dry season, with fewer impacts of climate change on livestock and the quality of pasture.

The impacts of climate change on the water levels in Bakuli springs and the Badassa dam have been mitigated by the adoption of more efficient water supply technologies and availability of alternative water harvesting initiatives by the communities. The impact of climate change on fuelwood supply to the local community is mitigated by investing in alternative sources of energy in the form of gas cookers, biogas production, solar energy, wind power energy and energy saving bulbs to light homes. Large-scale fuel consumers like Government institutions use both Bio-latrines for production of biogas and use of natural gas cutting down their fuelwood requirements.

The impact of this scenario on conservation is positive with an increased hectarage of protected area for biodiversity conservation. Despite the low rates of climate change, integrated forest management practices have resulted in a resilient forest with an increasingly healthy population of threatened animals and plant species with the forest able to supply the community required ecosystem goods and services.

4.2.4. The "Marsabit Forest Reserve Collapse"

A future where high rates of climate change coupled with a simultaneous reduction in land use change have major impacts on ecosystem goods and services in the Marsabit Forest Reserve.

This scenario depicts the Marsabit County economy as poorly developed and suffering from an economic recession with a low per capita. There is a total economic collapse triggered by the global economic recession following the collapse of the financial markets and global trade imbalances. Increased climatic variability in Kenya has an impact on agricultural production with the main cash crops like tea and coffee recording reduced yield, with the tourism sector affected by low tourist numbers. By 2044, the MFR was the target of high climatic impacts similar to experienced global averages. Over the last three decades, the mean surface temperature has risen to levels higher than was projected in the GCM models. Escalating climate change provided little warning to the residents of Marsabit County before impacts were felt. The ratified climate change agreement in Paris in 2016 failed to be implemented efficiently with countries failing to hit their GHG emission reduction targets.

An increase in the human population in the early 2020s led to a business as usual attitude where forest land was degraded and destroyed to satisfy human needs leading to the forest almost disappearing in the early 2030s. Despite stakeholders attempting to reduce the land use change rates in late 2030s, the levels of degradation over the decades had significantly impacted the ecological stability of the forest with the inability of the forest to absorb the impacts of climate change. Reduced income per capita rates means more dependence on ES from the forest with an individualistic clamour for forest resources. Systemic destruction of the forest over the earlier decades means that ES provision is at its lowest level.

Agricultural production in this scenario has collapsed with the areas of Songa, Karare, Kituruni and Gabbra scheme which were predominantly crop growing areas impacted by reduced episodic rainfall, an increased drought cycle, with the crops initially grown unable to cope with the increasing rates of a changing climate. Due to the lack of adaptation capacity by locals to the unprecedented climate change, there is a massive loss of livestock herds succumbing to water stress, lack of pasture and increased livestock diseases. Both the larger County of Marsabit and Saku Constituency suffer from acute water stress with Bakuli springs, and the Baddasa dam the main sources of water from the forest registering poor yields. The lack of adaptation to water harvesting and storage initiatives in light of unprecedented rainfall decrease occasioned by high water runoff means that communities lack alternatives sources of water for both livestock and household needs.

The rate of innovation and adoption of new fuel-efficient technologies in this scenario is none existent despite the unprecedented impacts of climate change. The impact of climate change on the productivity of the forest means that the available firewood for communities is less than can meet the population demands. The continued degradation of the forest over the decades and the unprecedented impacts of climate change raises genuine concerns that the MFR is potentially irreversibly damaged with the extinction of plants and animals critical to the forest ecology. Despite the renewed commitment by stakeholders to restore the forest, it lacks the resilience to absorb impacts of external perturbations and thus unable to perform its ecological functions.

4.3. Establishing scenario outcomes

The participatory scenario workshop identified and adopted the Marsabit we want scenario, as the most desired future stakeholders aspired for with regard to the sustenance of ES. This scenario presents a future where there are low rates of land use change with low impacts of climate change on ES under sustainable utilisation of forest resources. A responsive institutional management framework coupled with adequate adaptation/mitigation measures to observed changes by all stakeholders ensures sustainable provision of ES. The gazetted Marsabit Forest Ecosystem Management Plan 2015–2025 (Kenya Wildlife Service, 2016), was unanimously approved as the guiding blueprint to guide the forest community towards their desired future. In view of this, the scenario workshop developed a three-year action planning framework to implement key aspects of the desired scenario while mitigating undesired aspects of the three alternative scenarios. The framework identified the driving forces to be mitigated, the approach to be adopted and the specific activities to be undertaken to implement key aspects of the desired scenario. The action plan framework centred on forest resource management purposed to “conserve and protect the Mount Marsabit forest water catchment for sustained provision of environmental and socio-economic goods and services”. The five objectives identified to coordinate this plan were: land use change mitigation around the forest; mitigation of the unsustainable utilisation of forest resources, climate change mitigation, ecological restoration and the local communities actively being involved in forest conservation and management. An action plan implementation committee with stakeholders drawn from various sectors was constituted to spearhead the implementation of the framework (Supp. 1).

5. Conclusion and recommendations

The study established that the MFR is a critical habitat for wildlife and represents a vital source of ecosystem services to the local community of Marsabit County. Of particular importance are water provision, dry season forage provision and fuelwood provision for household energy needs. The continued provision of ES by the forest is under threat from anthropogenic threats principally among them land use change, climate change, population pressure, unsustainable utilisation of forest products and forest degradation. The impacts of forest threats to ES was manifested in increased drought frequency, reduced forage provision and the reduced ability of the forest to recharge the aquifer necessary for water provision. Four alternative future scenarios for the MFR by the year 2044 were developed by stakeholders. Participants identified the Marsabit we want scenario as the most desired future to sustaining of ecosystem services. In this scenario, stakeholders will have adopted land use policies that will conserve the Marsabit forest while adapting to effects of climate change. This will be achieved through behavioural changes in utilisation of forest products, participatory forest management regimes, adopting alternative sources of energy provision and embracing climate resilient livestock and agricultural practices. Stakeholders developed a three-year action plan framework 2017–2020 in line with the gazetted Marsabit forest ecosystem management plan 2015–2025 the blueprint for the conservation of the forest. Of immediate importance to the stakeholders would be the provision of (i) alternative sources of energy to reduce overdependence on firewood (ii) grazing management to avoid the influx of cattle during the dry season and (iii) the piping of water from the forest to community land to reduce forest encroachment. Cooperation between KWS, KFS and the local communities particularly the CFAs in forest management will be central in the MFR restoration. The results support the need for participatory land use planning that takes into to account the growing threat of climate change to natural forest systems.

Acknowledgement

This study was supported financially by the French development agency (AFD) Agreement No. CKE 1036 01H. We wish to thank the management of Marsabit Forest Reserve for providing the access and necessary logistical support to facilitate the field work.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.gecco.2018.e00403.

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