2015

Report ASEC-dryland-Forests

By Aida Cuni Sanchez
CMEC, University of Copenhagen,
Copenhagen, Denmark
aidacuni@hotmail.com
Kenyan phone number: 0739472763

1. Introduction

Tropical montane forests are important ecosystems, because 1) they are rich in animal and plant species found nowhere else in the world, 2) they maintain a special micro-climate with higher rainfall and fog, and therefore water, than lower altitudes or deforested areas, 3) they provide several services (water, firewood, medicine) to surrounding communities, which often depend on them for their livelihoods. In northern Kenya, tropical montane forests are also important habitats for some endangered species, such as the African elephant and the Grevy's zebra (Ngene et al. 2009).

Tropical montane forests, especially those found in drylands are known to be particularly sensitive to predicted changes in climate. Population growth and large infrastructure development projects are other challenges for these forests' conservation.

Despite their ecological and social importance at a local and regional level, little is known about them. This project named *ASEC-dryland-forests*, focused on Mt Marsabit, Mt Kulal and Mt Nyiro in northern Kenya aims at providing key scientific information that will help understand how these forests function, how local communities use them and what could be done to ensure their long-term existence.

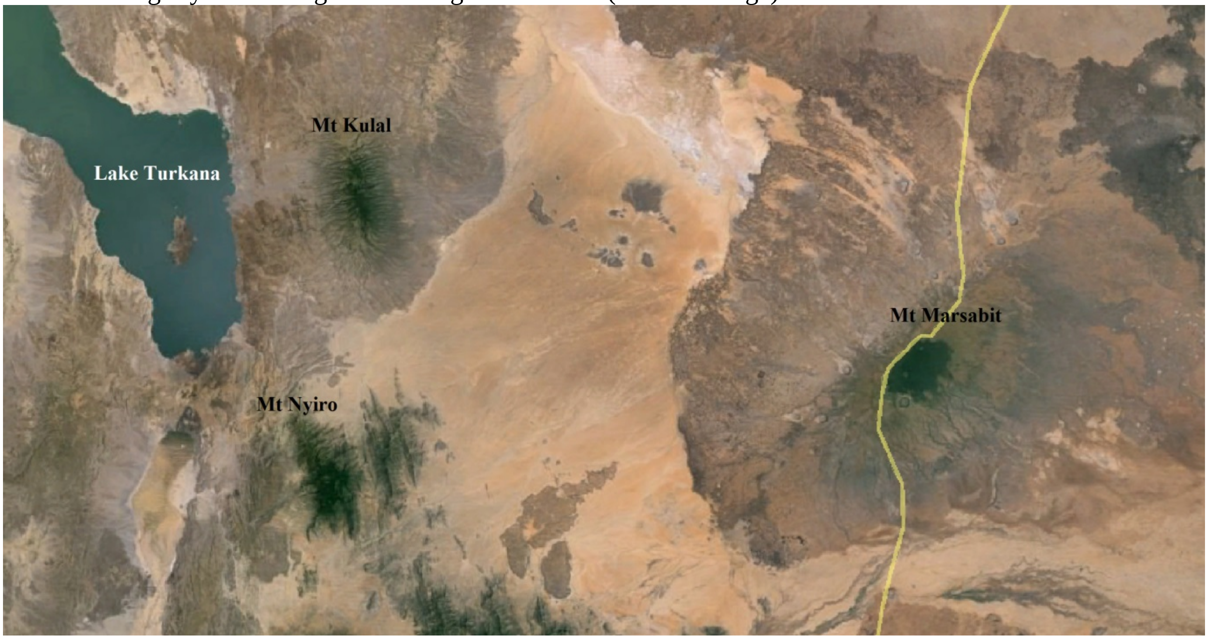
2. Study area

Northern Kenya is considered part of the Arid and Semi-Arid Lands (ASALs). Mt Nyiro (2752m), Mt Kulal (2285m) and Mt Marsabit (1707m) are the highest mountains in northern Kenya, the latter two being volcanic peaks. These mountains receive more rainfall than the lowlands (> 1000 mm yr^{-1}) and have high mist/fog condensation, which allows the existence of montane forests (Bussmann 2002). Rainfall is concentrated in two wet seasons, but inter-annual variation in rainfall is high, and droughts common. These three mountains have similar vegetation types, but Kulal and Nyiro also have *Juniperus procera* forest and Nyiro *Podocarpus* and elfin forests (Bussmann 2002). The protection status of these forests is different. Mt Nyiro is a Forest Reserve (FR), Mt Kulal designed as a UNESCO Man and the Biosphere (MAB) Reserve in 1978, is considered a community forest and Mt Marsabit is a FR, a National Park and a National Reserve at the same time.

Mt Nyiro and Mt Kulal are populated by Samburu pastoralists, while different ethnic groups inhabit Mt Marsabit: Borana and Gabbra dominate the villages on the north-eastern part, and Rendile and Samburu dominate on the south-western side. While residents in Mt Nyiro are strict pastoralists owning goats and cattle, some residents in Mt Kulal and most in Mt Marsabit are agro-pastoralists, cultivating beans and maize. Some families are still nomadic, but this is a decreasing trend. Access to health, education and urban markets is better around Mt Marsabit compared with the other two mountains, which are more isolated.

It should be noted that traditional pastoralism for these communities is typically a subsistence-level production system, with families relying more on milk than meat for nutrition, selling animals to get cash for other economic needs, and building herd sizes to accrue social status, wealth, and provide a buffer against risks such as severe droughts (Bussmann 2006). In northern Kenya rural livelihoods are particularly prone to uncertainties, mainly related to vagaries of climate such as drought events and conflict like cattle rustling.

Fig. 1. Mt Marsabit, Mt Kulal and Mt Nyiro in northern Kenya. Note the green colour of the montane forests in the contrasting drylands. Image from GoogleEarth 2015 (satellite image).



3. Forest use by local communities

Understanding how local communities use and value their forests is of great importance for both conservation purposes and for local development planning. Therefore, we assessed local communities use and perceptions of the forest near where they live, using focus-group discussions with village elders (see methods section).

In all villages and mountains it was mentioned that water availability was the most important service provided by the forest (linked with rain and mist attraction). Fodder during droughts, firewood, honey/fruits, medicine and poles for housebuilding were other services mentioned in all villages. 'Wildlife' was only mentioned around Marsabit, and 'place for hiding during conflict' around Kulal and Nyiro. 'Materials for plough' was only mentioned by Borana, 'forest is beautiful' and 'fresh/clean air' only by Samburu (see Table 1).

With regard to plant species, some differences were observed between mountains and ethnic groups. In Marsabit the most important species (with more uses) was *Olea europaea* (ngeriei, ejers) and in Kulal and Nyiro it was *Olea capensis* (loleontoi). *Coptosperma graveolens* (lmasei, korkore), *Drypetes gerrardii* (muhudima, lelei), *Strychnos henningsii* (njibiliua, karrah), *Dovyalis abyssinica* (elmoron, kurrah) and *Rinorea convallarioides* (nteroni) were also important useful species in Marsabit. *Dovyalis abyssinica*, *Juniperus procera* (Cedar, tarakwoi), *Podocarpus spp.* (biribiriti), *Myrsine africana* (lsegetet) and *Rhamnus prinoides* (ilkinyil) were important species in Kulal and Nyiro. In total 36 plant species were mentioned in Kulal, 27 species in Nyiro and 30 species in Marsabit. See Annex 1 for more information.

Overall, results indicate that these forests are extremely important for local communities in all three mountains and for all ethnic groups; water being a key service provided by these montane forests. Local communities have great knowledge of the plant species in the forest and use them often, on a daily basis in some cases.

Table 1. Main services provided by Mt Nyiro, Mt Kulal and Mt Marsabit forests as reported by local communities. Values refer to percentage of villages studied in each mountain, * refers to most important service.

Service	Nyiro	Kulal	Marsabit Rendile/Samburu	Marsabit Borana/Gabbra
water	100*	100*	100*	100*
fuelwood	100	100	100	100
honey/fruits	100	100	100	100
medicine	100	100	100	100
poles	100	100	100	100
fodder during droughts	66	100	100	50
rain and fog attraction	50	92	67	83
wildlife			50	100
place for hiding during conflict	83	41		
shade	50		1	66
fresh and clean air	16	75	16	
forest is beautiful	8	25	16	
Fertile soil		16		33
plough				33
ceremonies			16	

4. Changes in forest cover over time

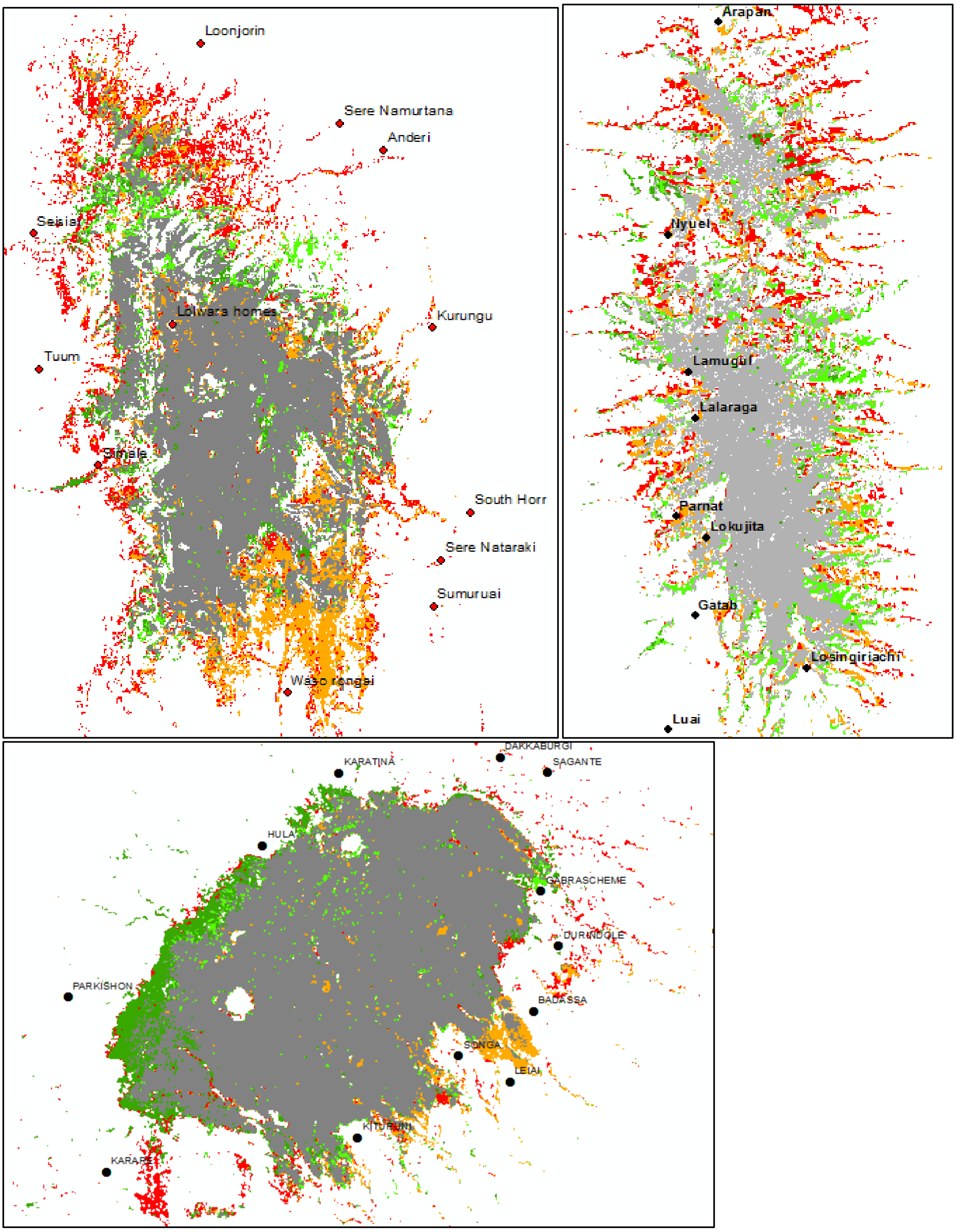
In order to determine how these forests might change in the future, it is important to understand how they have changed in the recent past, which factors might have caused these changes and how local communities have perceived these changes. We studied changes in forest cover (extension) over time using satellite images and also used focus-group discussions with village elders (see methods section).

Results from satellite image analysis revealed that Nyiro forest (13000hectares in 1986) lost 30% of its forest by year 2014, mainly at lower altitudes where the Cedar forest is located. Deforestation was greater for the period 2000-2014 than previously. Kulal forest (4000hectares in 1986) lost 20% of its forest by year 2014, mainly at lower altitudes near Arapan. Deforestation was greater for the period 1986-2000. Marsabit forest (13000hectares in 1986) lost 7% of its forest by year 2014, mainly near villages. Deforestation was greater for the period 1986-2000. Forest re-growth was important in Marsabit for the period 2000-2014. See Fig. 2.

In Nyiro, <u>some</u> villages reported that the forest had decreased in extension but some reported no change. Several villages reported the lack of regeneration of certain trees at higher altitudes and some also mentioned that the Cedar forest is now recovering as people had stopped cutting these trees. In Kulal <u>some</u> villages reported that the forest had decreased in extension and it was now less dense (degraded) but some reported no change. Several villages reported that Cedar trees have started to grow in the grasslands as people have stopped burning them. In Marsabit <u>all</u> villages reported that the forest had decreased in extension and all also said that it was now less dense (degraded) because of increased human and livestock in the area and more droughts. Land clearance for agriculture (Marsabit, some parts Kulal), use of fire to promote fresh pasture (Nyiro and some parts Kulal), firewood collection (mainly Marsabit) and tree cutting for fodder during droughts (everywhere) seem to be the main factors causing deforestation and forest degradation.

Overall, results indicate that there has been some deforestation and degradation in these forests, and that local communities perceive the changes in different ways, Marsabit communities being more aware of the changes.

Fig. 2. Forest cover in 1986 (grey) with forest loss (red) and gain (light green) for the period 1986-2000, and forest loss (orange) and gain (dark green) period 2000-2014 in Mt Nyiro (top left), Mt Kulal (top right) and Mt Marsabit (bottom). Maps obtained from the study of Landsat (satellite image), see methods section.



5. Observed changes in climate

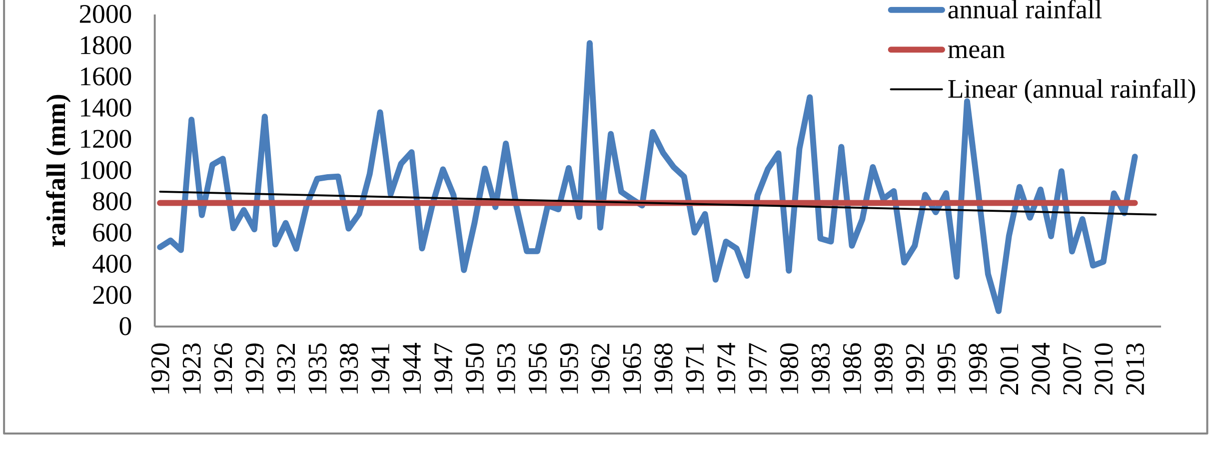
In order to better understand how these forests have changed in the past years and how they might change in the future, we also studied observed changes in climate. As previously mentioned, montane forests keep a special micro-climate, attracting rains and fog, and making the whole area more humid. We used local perceptions (focus-group discussions with village elders) and historical meteorological data from Marsabit Meteorological station (see methods section).

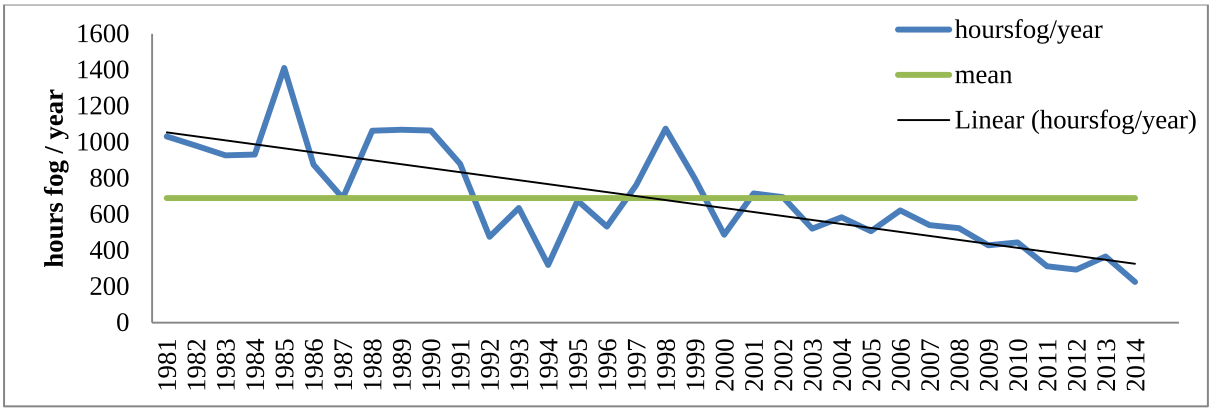
Results from the focus-group discussions indicated that all villages in all mountains reported a decrease in amount of rainfall, and reliability, with droughts becoming more common. For example, locals mentioned: '*before you would know when the rains would come, and how long they would last, now sometimes the rains skip (non-occurrence of rains), and even when it rains you cannot tell if they will be the long rains, the short ones, or useless rains*'. In most villages it was also reported that there had been a reduction in amount of fog, especially in Marsabit, where locals mentioned: '*before one could not see the sun for several days or even a whole week, and now you can only see fog around the rainy season, and even then, you see the sun every day*'. While in Nyiro they reported no changes in temperature, in Kulal and Marsabit it was mentioned that '*in general, now it is much hotter than before*'. It is important to highlight the consensus between villages, regardless of ethnic group or location (side of the mountain, altitude).

Historical rainfall data for Marsabit shows a general trend towards a decrease in annual rainfall (see Fig. 3). The number of years with annual rainfall below the average has increased in the past decade. Historical fog data indicates an important reduction in number of days and hours a day with fog per year. The reduction in fog is independent of the rainy or dry seasons; there has been a reduction in all months.

Considering the consensus between villages and mountains, and historical data from Marsabit, it seems that in these mountains there has been a general decrease in amount of rainfall, which is now less reliable, and also in amount of fog. This has important consequences for the forest itself and the people living around it.

Fig. 3. Annual rainfall (top) and hours of fog per year (bottom) for Marsabit Meteorological station.



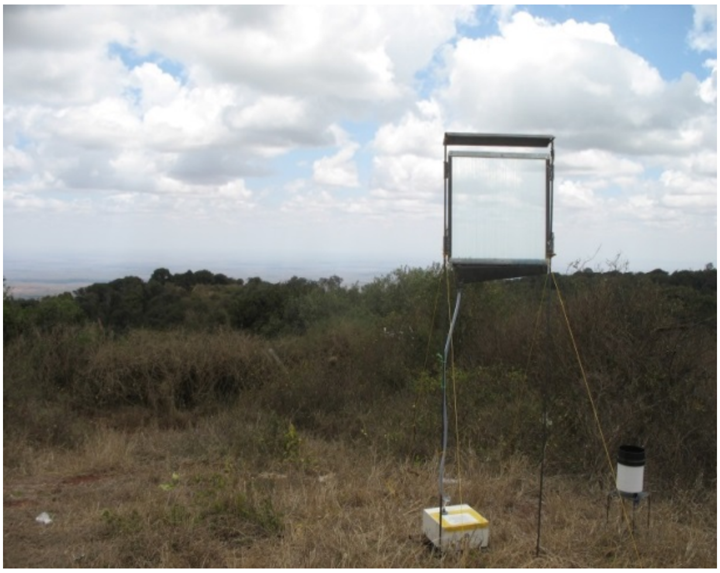


6. Water resources

As water is an important service provided by montane forests in drylands, we studied more in-depth the water resources of these mountains, to determine how much water comes from rainfall and fog and if aquifers are connected. We measured rainfall, fog and water dripping from trees in the forest using different equipment (see Fig. 4), we collected water samples and analysed their chemical properties, and we also discussed with village elders. Note that this part has not been completed yet.

Preliminary results indicate that fog is an important source of water for these forests, especially outside the rainy season. If there are fewer trees (due to deforestation), then less fog is captured by the forest and therefore, less water enters the soil, with important consequences for the aquifers in the area. Different aquifers can be found around these mountains, and it seems that most boreholes are exploiting old aquifers not being replenished by current rainfall or fog trapping by trees. Village elders around Marsabit mentioned that before there were more permanent streams around Mt Marsabit, and that Lake Paradise dried up in few occasions, mainly in the past 6 years. This part is still ongoing.

Fig. 4. Equipment used to measure fog (wire harp, square frame) and rainfall (HOBO, white cylinder).



7. The future of these forests

In order to ensure the long-term existence of these important forest ecosystems and the services they provide to people, we investigated which factors are likely to negatively affect these forests in the future, and discussed potential ways to deal with these challenges with local communities, NGOs and government organisations. This part has not been completed yet, and we only present preliminary findings.

7.1 The challenges

Several factors are likely to negatively affect tropical montane forests of northern Kenya:

a) Predicted changes in climate

Climatic Research Centers in different countries have created different models to predict future climate. These future climate predictions also depend on how much greenhouse gases such as carbon dioxide are produced in the world, which is determined by individual country future development pathways such as the use of green energy like solar energy, etc. Here we present the results of a combination of models for a potential future emission of moderate greenhouse gases, but if more greenhouse gases were produced, changes in temperature and rainfall would be even greater than described here (see methods section).

For East Africa and Kenya, most models predict a general increase in temperature and rainfall. However, increased climate variability including more extreme events (droughts, floods) is also predicted. A report from Herrero (2010) already highlighted that increased drought frequencies to more than a drought every five years could cause significant irreversible decreases in livestock numbers in ASAL, and that cropping might no longer be possible in ASAL areas, such as northern Kenya.

A recent study which specifically considered mountain areas in Africa (Platts et al. 2015) indicates that most models show a general increase in temperatures and a decrease or no change in annual rainfall for our study area. The distribution of rains is also predicted to change, with more dry months and shorter major rains. Increased temperatures negatively affect the formation of fog, but no model has assessed fog occurrence. It should be noted that available data for the present assumes that there is more rainfall in Marsabit than in Kulal or Nyiro and ongoing field measurements indicate the contrary. Therefore, future changes in rainfall in Kulal and Nyiro might be even more severe than the models have predicted.

Fig. 5. Minimum temperature of the coldest month for the present (left figure) and the future (year 2055, right figure). Light blue refers to Lake Turkana, black dots refer to villages and grey lines major roads. Dark red: 20-25°C, light red: 15-20°C, yellow: 10-15°C, blue: 5-10°C (see methods section).

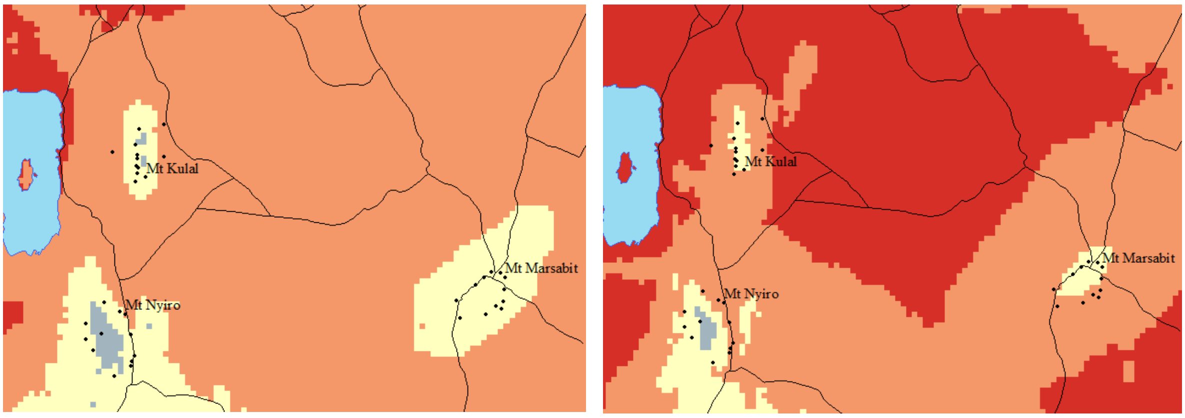


Fig. 6 Rainfall of the wettest month for the present (left figure) and the future (year 2055, right figure). Yellow: 0-50mm, light green: 50-100mm, dark green: 100-150mm, light blue: 150-200mm, dark blue: >200mm.

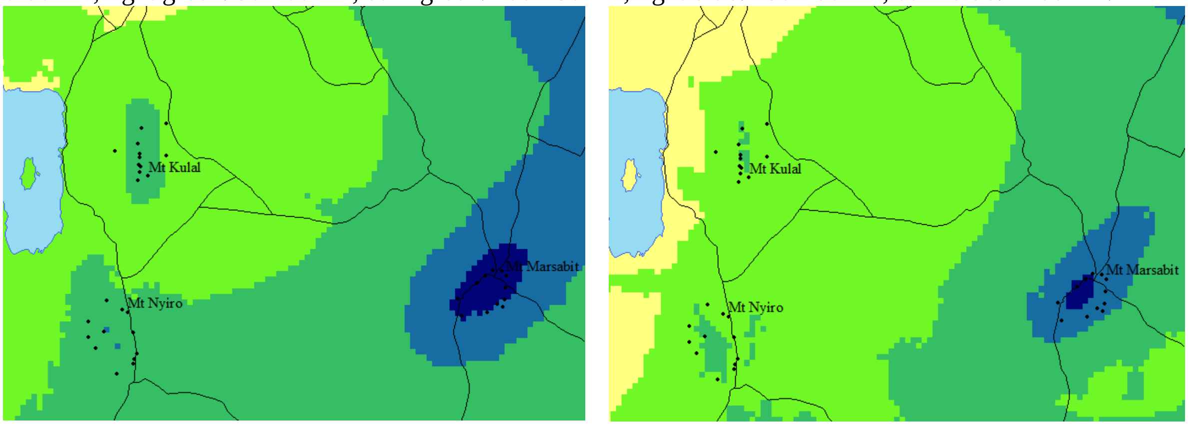


Fig. 7 Annual rainfall for the present (left figure) and the future (year 2055, right figure). Yellow: 0-200mm, orange: 200-400mm, dark pink: 400-600mm, light pink: 600-800mm, purple: 800-1000mm, blue: >1000mm.

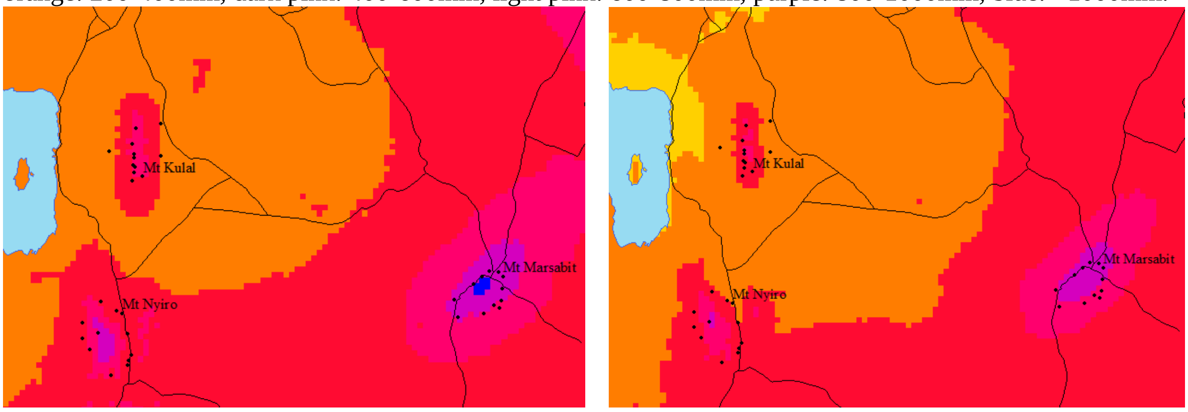
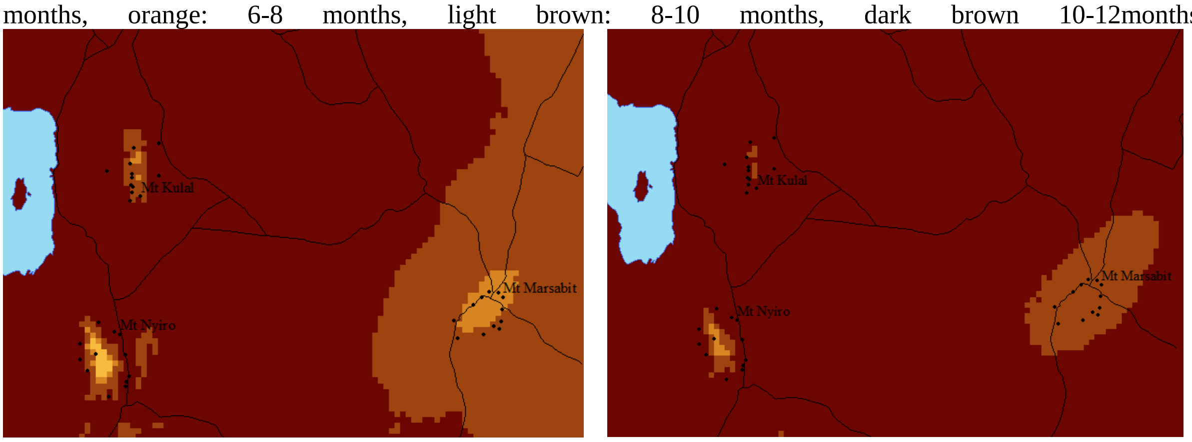


Fig. 8 Number of dry months for the present (left figure) and the future (year 2055, right figure). Yellow 4-6 months, orange: 6-8 months, light brown: 8-10 months, dark brown 10-12months.



b) Population growth

In Marsabit country, the population of 290000 people in 2009 is expected to rise to 375000 by 2017 because of the high annual population growth but also due to the high percentage of the population being 0-14 years (47 %) (see http://softkenya.com/marsabit-county/). An influx of people from other areas into the county following infrastructural development projects is also expected. Apart from more people, livestock numbers are likely to increase as well, linked to greater human population in the county, higher demand for meat in the county and elsewhere in Kenya and potential access to new international markets. However, droughts might reduce the rate of livestock increase.

c) *Planned infrastructural development projects*

In 2008 Kenya's government launched Kenya Vision 2030 which is designed to deliver a middle income country status to Kenya. This view for development has an inordinate urban focus. For northern Kenya development projects include (1) a livestock Disease Free Zone with an eye to international markets, (2) in the social sector, the construction of boarding primary schools and improved health care access (improved community health centres and expanded National Health Insurance Scheme), and (3) several large infrastructure projects. With regard to projects (1) and (2), it has been emphasized that these approaches follow one-size fits-all solution and they do not recognize the peculiar circumstances of pastoralists (Nyanjom 2014). For instance, they do not consider creating jobs for youth so that they do not need to leave the area and/or abandon pastoralism.

With regard to large infrastructure projects (3), their potential benefit for local communities has been questioned, because in the absence of an initial transformation in socio-economic values among local communities, these will not be able to participate in the modernising changes that result from the infrastructure investments. Instead, the anticipated changes might result in the further marginalization of the pastoralist communities, enhancing the scope for pastoralist conflict over their resources, especially pasture and water, which the proposed projects will diminish (Nyanjom 2014).

Example of large ongoing infrastructure projects:

- The Lamu Port Southern Sudan Ethiopia Corridor Project (LAPSSET) is a large transport and infrastructure project in Kenya (Sh3000 billion) which will connect Southern Sudan and Ethiopia with Lamu Port. It aims at building a new international port in Lamu, 1300 km of oil pipeline, 1600 km of railway, 1700 km highway, three new international airports and three new resort cities in Isiolo, Lamu and Lokichogio (see Fig. 9). Despite the projected development it will bring to the area, it should be noted that these utilities will excise over 100 km^2 of prime pastoralist land since they will go through existing settlements which often reflect the sites of best supplies of water and pasture.
- The Lake Turkana Wind Power Project near Loiangalani is the largest single wind power project in Africa and the largest private investment in the history of Kenya (Sh70 billion). It comprises 365 wind turbines over an area of 162 km^2 and it is expected to be fully operational by April 2017. Apart from improving road network and providing some new boreholes, this project (through Winds of Change Foundation) aims to uplift local communities through programs such as HIV awareness campaign, water, sanitation, electrification, sustainable development of agriculture and education. However, local communities' benefits to date are still marginal.
- Another relevant large infrastructure project is the construction of the controversial Sh2.4 billion Badasa Dam (which would serve 100000 residents around Marsabit). This started in 2009 and was expected to be completed by 2011 but it is still not finished yet (see Fig. 10). Now it is planned to be completed by late 2016.
- The Isiolo-Moyale road is being tarmacked, which will likely help market access but has already caused some conflicts over water resources (e.g. in Turbi).
- Apart from large infrastructure investments, activities designed to exploit the recently discovered initial oil deposits of Turkana, estimated at 250 million barrels worth

Sh3.2 billion (most likely to be exploited by international private investors), will also strongly affect the region.

Overall, it has been highlighted that local pastoralists are likely to be marginalized at a greater rate than before since the projects on their land (infrastructure, oil) will be comparatively greater than before. For instance, Bwanaadi (2013) relates LAPSSET to a tsunami that will eventually radically and adversely affect the livelihoods of the Rendile, Samburu, Borana, Gabbra, and Turkana pastoralist communities of northern Kenya.

Fig. 9. The alignments of the LAPSSET network. Source: Modified from Wikimedia Commons (2013).

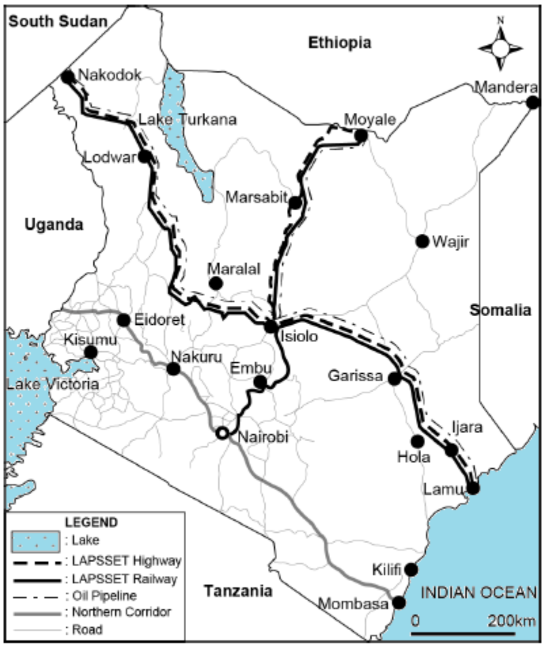


Fig. 10 The Badasa Dam in April 2015.

d) Other challenges

- Poverty: While the national human poverty index fell by seven points to 29.1 between 2005 and 2009, it rose five points to 51.3 for arid counties, such as Marsabit county (Fitzgibbon 2012)
- Illiteracy: While 41.2% of the men and 78.4% of the women cannot read, the respective national averages are 4.1% and 14.2% (KNBS and ICF Macro 2010). With lack of formal education, access to skilled (and better paid) jobs is limited.
- Lack of market access: despite accounting for 50% of Kenya's livestock valued at 10% of national Gross Domestic Product (GDP), these communities hold exceedingly large stocks of animals, whose sale is never a priority despite the ravage of perennial droughts (Nyanjom 2014).
- Food aid dependence: still high among local communities.
- Existing intra-pastoralist conflicts: since most of these conflicts relate to contest over diminishing resources (pasture and water), what has the national government done (or plans to do) to minimise the risk of further conflict that the alienation of land for the transnational infrastructure and oil extraction might occasion on these communities?
- Limited of social capital: Because of existing tension between ethnic groups and clans, social capital (institutions, relationships and norms that shape society's social interactions), critical for societies to prosper economically and for development to be sustainable, is currently limited in northern Kenya.

- Potential political exclusion: the influx of people into the county following infrastructural development projects might change localised electoral politics.
- Marginalisation by the government: For example, the National Dialogue on Water Towers, Forests and Green Economy, focused on the role of montane forests for water supply (UNEP 2012) does not consider northern Kenya important Water Towers (Mt Nyiro, Kulal and Marsabit). Kenya's NAPA (National Adaptation Plan of Action for Climate Change) which pays certain attention to ASAL pastoralists, does not mention northern Kenya montane forests (see NAPA 2013).

7.2 The way forward

Taking all these challenges into account, how can we ensure the long-term existence of these important forest ecosystems and the services they provide to people?

We would like to listen to your ideas.

For some preliminary information about our ideas, see ANNEX 2.

8. Preliminary conclusions

Our research highlights that:

- These forests are extremely important for local communities in all three mountains and for all ethnic groups. Water is the most important service provided by these montane forests.
- Local communities have great knowledge of the plant species in the forest.
- There has been some deforestation and degradation in these forests in the past 30 years.
- Available data shows that there has been a general decrease in amount of rainfall, which is now less reliable, and also in the amount of fog. This has important consequences for the forest itself and the people living around it.
- Fog is an important source of water for these forests, especially outside the rainy season. If there are fewer trees due to deforestation, less fog is captured by the forest and therefore, less water enters the soil, with important consequences for the aquifers in the area.
- It seems that most boreholes are exploiting old aquifers not being replenished by current rainfall or fog.
- Several factors are likely to negatively affect these forests in the future: predicted changes in climate, population growth, planned infrastructural development projects and other factors such as poverty and conflict.
- Ensuring the long-term existence of northern Kenya montane forests and the services they provide to people is challenging. We do not state that there is an easy solution, but possibly, a combination of actions could help mitigate the predicted negative changes in these forests. We should work together towards this goal.

9. Methodology

Methods section 3: Focus-group discussions were organised in twelve permanent villages located around each mountain studied. Each focus-group involved 5-10 male elders including the village chief, as it is a custom in the area. Informal discussions centred on (1) mentioning all services provided by the nearby forest and determining which are considered most important and why; and (2) establishing which plant species are considered the most important for firewood, poles, medicine, food and fodder. All plant species mentioned were collected for identification and verification of their local name at the Herbarium of University of Nairobi. Field observations were also made in each forest to determine if the plants mentioned in the discussions were present and how they were being harvested. For more information see Cuni-Sanchez et al. (submitted).

Methods section 4: Landsat satellite images of January 1986, 2000 and 2014 were used. Images were classified into several vegetation categories based on >300 gps locations (in each mountain) of known vegetation type based on field observations. Maximum likelihood classification from ENVI software was used to classify the images and ArcGIS software was used to estimate changes in forest extension over time. Field observations were also made to validate the forest cover maps. During the focus-group discussions organised, village elders were also questioned about changes they had observed during their lifetimes in forest extension, forest quality and factors which might explain these changes.

Methods section 5: During the focus-group discussions, village elders were also questioned about changes they had observed during their lifetimes in climate. Monthly rainfall (period 1920-2014) and fog data (period 1980-2014) were obtained from the Kenya Meteorological Department. No other historical meteorological data is available for northern Kenya.

Methods section 6: We set up several rain gauges (automatic), fog collectors (manual) and two throughfall experiments (water drip from the trees) for 12 months (October 2014-2015) at different altitudes in Marsabit and Kulal. We collected water samples of rain, fog, several springs, wells and boreholes around each mountain (>150 samples) and analysed their chemical properties. During the focus-group discussions, village elders were also questioned about the changes they had observed during their lifetimes in water resources (streams and wells that dried up etc).

Methods section 7: First we gathered information from several sources about potential future threats to these forests. We downloaded predicted future climate from Africlim data version 3 (Platts et al. 2015), which includes ten general circulation models (GCMs) of different Climate Research Centers downscaled using five regional climate models (RCMs), under two representative concentration pathways of the IPCC-AR5 (RCP4.5 and RCP8.5) (related to two potential greenhouse gases emission scenarios) (http://www.worldclim.org/). We plotted WorldClim Baseline (average 1950-2000) and RCP4.5 for year 2055. We investigated all models but we plotted the most extreme GCM model result for 2055. Number of dry months refer to months where mean annual rainfall / potential evapotranspiration is <0.5. Then we discussed potential ways to deal with these future threats with local communities, NGOs and government organisations using both focus-group discussions and interviews.

ANNEX 1

Useful plant species and their uses

Latin name	Local name (Samburu)	Local name (Boran)	Observations	Uses
Albizia grandibracteata	regit		tree by stream only	fodder
Apodytes dimidiata	rakaoulu		medium tree in forest	poles, firewood
Bauhinia tomentosa	ikerisoi	abartapat	medium tree Olea forest	firewood, fodder
Brucea antidysenterica	songoroi		large tree in forest	poles, medicine, fodder cows
Cadia purpurea	ilkikgueriai		small tree edge forest	poles
Carissa spinarum(=Carissa edulis)	lamuriei	dagams	bush in Olea forest	edible, medicine, fodder goat
Casearia battiscombei	genebor		medium tree in forest	
Cassipourea malosana	lberlait		large tree in elfin forest	medicine
Celtis africana	lestet		large tree in forest	poles, fodder
Chrysophyllum viridifolium		kolati	large tree Olea forest	medicine, edible, poles
Coptosperma graveolens (=Tarenna graveolens)	lmasei	korkore	medium tree forest	firewood, poles
Croton megalocarpus	ilmarguet	ngabo	large tree Olea forest	firewood, medicine
Diospyros abyssinica	lindunduri	loho	medium to large tree forest	firewood, poles
Dombeya torrida (=goetzenii)	baraguai		medium tree in forest gap	firewood, built houses
Dovyalis abyssinica	elmoron	kurrah	large tree open areas	edible, fodder goat, hoxe
Drypetes gerrardii	lelei (Marsabit area)	muhudima	medium tree forest	firewood, poles, fodder
Ehretia cymosa	lechuchuri		large tree in forest	poles
Erythrococca bongensis	Irri		medium tree in forest gap	
Euclea racemosa (=E. shimperi)	ilchingei	miesa	medium tree Olea forest	poles, medicine, ceremony
Euphorbiaceae	lasan		small herb open areas	medicine
Ficus sp.	lngabolo		large tree in forest	edible
Flueggea virosa	ilguerepuk	tchalanchalu	bush open areas	edible
Grewia arborea (= fallax)	domok	deka	bush in Olea forest	edible, fodder, firewood
Grewia damine (=bicolor)	Seteti		bush open areas, lowlands	poles
Grewia similis	Irri		large bush edge forest	edible, goat eat fruits
Grewia trichocarpa		arores	medium tree lowlands	fodder, sticks, ceremony
Grewia villosa	ilpupoi	dogondi	small tree in open areas	edible, ceremonies
Harrisonia abyssinica	lasaramai		bush in open areas	medicine
Heinsenia diervilleoides	Ilturural		small tree forest	fodder, flowers for bees
Juniperus procera	tarakwoi		large tree grassland/forest edge	poles, firewood
Maytenus undata	sagumai		small tree forest/open	fodder goat
Myrsine africana	lsegetet		bush in grassland	medicine
Nuxia congesta	musungash		large tree in elfin forest	fodder, flowers for bees
Olea capensis	loleontoi		large tree forest	fodder, poles, firewood

Olea europaea subsp. cuspidata (=Olea africana)	ngeriei	ejers	medium tree in forest	firewood, fodder, poles, medicine, food
Pavetta gardeniifolia	lelei (Kulal area)		medium tree in sunny areas forest	
Pavonia urens	sulubei	gurbinhola	bush in open areas	fodder
Peponium vogelii	laragui/lalarak		liana in forest	edible
Podocarpus spp.	biribiriti		large tree in forest	poles
Prunus africana	malaan		large tree in elfin forest	medicine, fodder
Rapanea melanophloeos	sutoi		bush open areas	medicine
Rhamnus prinoides	lkinyil		bush in grassland	medicine, poles
Rhamnus staddo	lkokolai		bush in grassland	medicine
Rinorea convallarioides	nteroni	dalachibatah	medium undestory tree,wetter parts forest	fodder
Rotheca myricoides	makutikuti		bush in grassland	medicine
Rubus apetalus	lkaramule/garamulei		bush near water	edible
Rytigynia neglecta	lekipiria		medium tree in elfin forest	poles
Schrebera alata	lekuruki		medium tree in forest	fodder, medicine
Scuria myrthina	sanagork		small tree forest/open	edible
Searsia natalensis (= Rhus natalensis)	misigio		bush open areas	edible, medicine
Strychnos henningsii	njibiliua (Marsabit name)	karrah	medium tree	firewood, poles
Strychnos usambarensis	njibiliua (Kulal name)			firewood, poles, fodder
Toddalia asiatica	leparmunyo	egerra	liana in forest	medicine
Trema orientalis		dokonu	bush in open areas	fodder, medicine
Trichilia dregeana	elberi		large tree forest, streams	firewood
Vangueria madagascariensis	nkurumusi	bururi	bush edge forest	edible, firewood
Vepris nobilis (=Teclea nobilis)	lgelai	mikke	large tree forest	firewood, poles, fodder, medicine
Xymalos monospora	ilkukut		large tree in elfin forest	poles, fodder

ANNEX 2

Some preliminary information about our ideas for a brighter future

Ensuring the long-term existence of northern Kenya montane forests and the services they provide to people is challenging. We do not state that there is an easy solution, but possibly, a combination of actions could help mitigate the predicted changes in these forests. We considered several possibilities:

Establish a REDD project:

Establishing a REDD project could help provide funds for these forests' conservation. Reducing Emissions from Deforestation and Forest Degradation (REDD) is a climate change mitigation strategy introduced by the United Nations to help stop the destruction of forests in developing countries (for more information see http://www.un-redd.org/). Setting up a REDD project to get money from 'protecting a forest from its potential destruction' is not a quick or easy process. It requires a substantial initial investment to organise the documentation, planning and scientific information needed (e.g. how large is the forest and how much carbon dioxide do the trees store). However, some organisations help local communities set up REDD projects and some REDD projects are already set up in Kenya (e.g. http://www.v-c-s.org/). In order to determine if these montane forests store enough carbon dioxide to make them a potential site for a REDD project, we measured trees (diameter, height and species) in several parts of Mt Kulal and Mt Nyiro. Together with the satellite images we analysed for objective 2, we will make the calculations. This part has not been completed yet.

Tree planting:

Considering observed deforestation and forest degradation, and the importance of trees for maintaining the local climate (fog trapping), one option could be to plant more trees. Kenya's NAPA (National Adaptation Plan of Action for Climate Change) also considers tree planting in degraded lands, but not in our study area (NAPA 2013). KFS nursery already grows several canopy trees used by local communities such as *Olea europaea* (ngeriei, ejers) seedlings. We investigated the potential cultivation from seed of two interesting species: *Rinorea convallarioides* (nteroni) and *Prunus africana* (malaan). The first one is an abundant tree in the wettest parts of Marsabit forest highly appreciated by locals for its use as fodder during droughts, and the second one is a large tree with medicinal properties and high commercial value internationally for its use against prostate cancer. This part has not been completed yet, but seedlings are growing, slowly (Fig. 11). An important challenge to large scale tree planting is that most species need to be watered and grown in the shade (and protected from livestock and goats) when young.

Fig. 11. *Rinorea convallarioides* (nteroni) seedlings.

Alternative livelihoods for forest edge communities:
Following focus-group discussions with village elders we also considered what could be promoted as alternative livelihood. In general, in remote areas with limited access to markets and few tourists (e.g. to sell hand-made baskets), products with high value per weight unit (small volumes) such as medicinal plants, indigenous fruit trees and honey are the best options. Because of the limited number of tasty wild fruits in these forests, this possibility was discarded. Honey production is already being studied by KALRO (before named KARI) in Mt Kulal and Nyiro. We investigated medicinal plant trade (see Annex 3), and indeed, some plants if sustainably harvested could be further promoted or even be cultivated (e.g. *Myrsine africana* Lsegetet in Mt Kulal and Nyiro). For more information see Delbanco et al. (submitted).

Agroforestry:
Agroforestry is a land use management system in which trees or shrubs are grown around or among crops. Agroforestry is known to help increase crop yields, especially in nutrient poor soils and drier areas. Often, the trees planted have other uses such as medicinal or edible fruits. In some parts of Africa local communities have long been practicing agroforestry. Kenya's NAPA (National Adaptation Plan of Action for Climate Change) also considers agroforestry (NAPA 2013). Although this could be a solution, it should be noted that crops and trees can compete for water and predicted changes in climate (more droughts) might worsen this situation. We also realised that most agro-pastoralists in the area have no tradition of planting trees.

Eco-tourism:
Although eco-tourism can provide funds for forest conservation, the remoteness of the area and lack of infrastructure challenges it. Even in Marsabit, the number of tourists visiting the National Park is small. Although this does not seem to a short-term viable solution, if the roads and accommodation and other facilities are improved, tourists might start to flow to visit these beautiful forests.

Improved management:
This is definitely a key point. Greater involvement of local communities and greater agreement among and between different ethnic groups is needed. Although this seems challenging, it is not impossible. We hope this document provides some key information to help us all develop a better management approach which can ensure the long term existence of these forests and the services they provide to their neighbouring communities.

ANNEX 3- Medicinal plant species and their uses ADD as reported by AS Delbanco Master Thesis (ongoing). All local names are spelled as in accordance to Beentje (1994) and Latin names according to The Plant List 2013 (http://www.theplantlist.org/).

Latin name	Local name	Traded in (town)	Plant part(s)	Locality	Habitat	Relative abundance	Plant type	Diseases (vendors)	Diseases (literature)
Acacia brevispica Harms	Amarich	Marsabit	Root/stem	Marsabit	Bushland	High	Tree	Malaria, stomach ache, women's health	Aphrodisiac, itching, snake bites
Albizia anthelmintica Brongn.	Hawacho	Marsabit, Moyale	Bark	Marsabit	Bushland	High	Tree	Bone and joint pain, headache, stomach ache, stomach infections and worms, women's health	Gonorrhea, malaria, veterinary diseases
Allium sativum L.	Garlic	Marsabit	Fruits	Moyale	Cultivated	---	Herb	High blood pressure, respiratory diseases, stomach ache	Anti-cancer, general cardiovascular diseases, diabetes, general bacterial, fungal and viral infections
Carissa spinarum L.	Dagams	Marsabit	Root	Marsabit	Bushland	High	Bush	Bone and joint pain, stomach ache, tooth ache, women's health	Epilepsy, gonorrhea, kidney diseases, malaria, yellow fever
Croton dichogamus Pax	Mokorf	Moyale	Root	Moyale	Bushland	High	Bush	Bone and joint pain, respiratory diseases	na
Euphorbia heterochroma Pax	Arken	Marsabit, Moyale	Root/stem	Marsabit	Bushland	Low	Small succulent plant	Fever, gland complications, respiratory diseases	Diarrhea, fever, sexually transmitted diseases
Euphorbia tirucalli L.	Anon	Moyale	Bark	Moyale	Cultivated	---	Tree	Women’s health	Snake bites, stomach ache, throat infections
Lepidium sativum L.	Fito	Marsabit, Moyale	Seeds	Moyale	Cultivated	---	Herb	Bone and joint pain, fever, respiratory diseases, stomach ache	na
Lycium europaeum L.	Bursh	Marsabit, Moyale	Root/stem	Sololo	Bushland	Low	Bush	Headache, respiratory diseases	Women's health
Maerua subcordata (Gilg) DeWolf	Hagar nyab	Marsabit, Moyale	Root	Sololo	Bushland	Low	Shrub	Bone and joint pain, gland complications, stomach ache, tooth ache, women's health	na
Momordica spinosa Chiov.	Walda	Marsabit, Moyale	Root	Sololo	Bushland	Low	Shrub	Respiratory diseases, fever, headache, malaria	na
Myrsine africana L.	Angu	Marsabit	Seeds	Mt Kulal	Forest	Medium	Bush	Bone and joint pain, gonorrhea, kidney diseases, women's health	Diarrhea, respiratory diseases, rheumatic diseases, tooth ache, veterinary diseases

Nigella sativa L.	Kimami gurati	Marsabit, Moyale	Seeds	Moyale	Cultivated	---	Herb	Headache, high blood pressure, stomach ache	na
Platycelyphium voense (Engl.) Wild	Sottawesa	Marsabit, Moyale	Bark	Marsabit	Bushland	High	Tree	Bone and joint pain, yellow fever	na
Rotheca myricoides (Hochst.) Steane & Mabb.	Mara sisa	Marsabit, Moyale	Root	Marsabit	Bushland	High	Bush	Bone and joint pain, gland complications, malaria, respiratory diseases, stomach ache	Aphrodisiac, gonorrhea, itching, tooth ache
Tamarindus indica L.	Groha	Marsabit, Moyale	Fruits	Moyale	Cultivated	---	Tree	Stomach ache, throat infections, women's health	Anti-cancer, diabetes, eye diseases, general infections, gonorrhea high blood pressure, malaria
Terminalia brownii Fresen.	Biress	Marsabit, Moyale	Bark	Marsabit	Bushland	Low	Tree	Yellow fever	Stomach ache, women's health
Terminalia orbicularis Engl. & Wild	Bissik	Marsabit	Bark	Marsabit	Bushland	Low	Tree	Bone and joint pain	na
Nicotiana tabacum L.	Geise/Tobacco	Marsabit	Leaves	Moyale	Cultivated	---	Herb	Stomach infections	na
Turraea sp.	Injirmocho	Marsabit	Root	Marsabit	Bushland	Low	Bush	Women's health	na
Zanthoxylum usambarense (Engl.) Kokwaro	Gadah	Marsabit	Bark	Marsabit	Bushland	High	Tree	Throat infections	na
Zingiber officinale Roscoe	Tangawizi/ginger	Marsabit	Rhizome	Moyale	Cultivated	---	Herb	Respiratory diseases, throat infections	Alzheimers/dementia, bone and joint pain (osteoarthritis)
Indet.	Araq	Marsabit	Root	Marsabit	Bushland	---	---	Fever, respiratory diseases	na
Indet.	Arsa	Marsabit	Stem	Marsabit	Bushland	---	---	Malaria, respiratory diseases	na
Indet.	Gis	Moyale	Gum/root	Moyale	Bushland	---	---	Bone and joint pain, stomach infections, women's health	na
Indet.	Gororsa	Marsabit	Root	Marsabit	Bushland	---	---	Throat infections	na
Indet.	Idjujumma	Moyale	Root	Moyale	Bushland	---	---	Women's health	na
Indet.	Kumbi	Marsabit	Gum	Moyale	Bushland	---	---	Epilepsy, itching, throat infections	na
Indet.	Natura	Marsabit	Leaves	Marsabit	Cultivated	---	---	Stomach infections	na
Indet.	Safara	Moyale	Root	Moyale	Bushland	---	---	Bone and joint pain, high blood pressure, respiratory diseases	na

References

Beentje, H.J., 1994. Kenya Trees, Shrubs and Lianas. National Museums of Kenya, Nairobi.

Bussmann RW, 2002. Islands in the desert-a synopsis of the forest vegetation of Kenya's northern, central and southern mountains and highlands. Journal of East African Natural History 91(1), 27-79.

Bussmann RW, 2006. Ethnobotany of the Samburu of Mt. Nyiru, South Turkana, Kenya. Journal of Ethnobiology and Ethnomedicine 2:35.

Bwanaadi H, 2013. LAPSSET will bring a tsunami, government says; people of Lamu react with shock and dismay (July 27, 2013). The East African, Nairobi. see Nyanjom O, 2014.

Cuni-Sanchez A, *et al.*, submitted. Ethnic and locational differences in ecosystem service values: insights from the communities in forest islands in the desert. Ecosystem services

Delbanco A-S, *et al.*, submitted. Medicinal plant trade in northern Kenya and its implications for conservation. Journal of Ethnopharmacology

Fitzgibbon C, 2012. Economics of Resiliense Study: Kenya Country Report. see Nyanjom O, 2014.

Herrero M, *et al.*, 2010. Climate variability and climate change and their impacts on Kenya's agricultural sector. Nairobi, Kenya. ILRI.

KNBS (Kenya National Bureau of Statistics) and ICF Macro 2010. Kenya Demographic and Health Survey 2008–09. KNBS and ICF Macro, Calverton, Maryland.

NAPA (National Adaptation Plan of Action for Climate Change, 2013. Government of Kenya, available at http://unfccc.int/

Ngene SM, *et al.*, 2009. The ranging patterns of elephants in Marsabit protected area, Kenya: the use of satellite-linked GPS collars. Afr. J. Ecol., 48, 386–400.

Nyanjom O, 2014. Remarginalising Kenyan pastoralists: the hidden curse of national growth and development. African Study Monographs 50, 43-72.

Platts PJ, Omeny PA, Marchant R, 2015. AFRICLIM: high-resolution climate projections for ecological applications in Africa. African Journal of Ecology 53, 103-108.

United Nations Environment Programme (UNEP), 2012. The role and contribution of montane forests and related ecosystem services to the Kenyan economy. UNON/Publishing Services Section/Nairobi, Kenya.

Wikimedia Commons 2013. Map Showing the Scope of the LAPSSET Project within Kenya. see Nyanjom O, 2014.

Also:
Kenya Vision 2030 see www.vision2030.go.ke
LAPSSET project see http://www.lapsset.go.ke/
Lake Turkana Wind Power Project see http://www.ltwp.co.ke/

Acknowledgements

We are deeply grateful to our study participants, who graciously shared their time, energy, and stories. We are thankful to all village chiefs, our field assistants and translators A.M. Aide, H. Lerapo, J. Harugura, M. Galgalo, R.A. Wamuro, S. Wasapicho, J. Lekatap and L. Lemooli for making this research possible, and to P.Ch. Mutiso at the School of Biological Sciences, University of Nairobi, for helping with plant identification. We also thank the kind support given by M. Kirimania, L. Olaka, B. Mamo and NEMA Marsabit Office, T. Kinyua and WARMA Marsabit Office, H.K. Walaga and KALRO-Marsabit, KWS Marsabit Office, S. Rucina and NMK, A-S. Delbanco and the British Institute in Eastern Africa (BIEA). This research was funded by Marie Curie Actions Intra-European Fellowships (IEF), number 328075. My supervisors and collaborators substantially improved this work Neil D. Burgess (CMEC, University of Copenhagen), Rob Marchant (University of York) and Marion Pfeifer (Imperial College London).

Knowledge is power…
Make good use of it.