

Review

Ecological restoration of pastoral landscapes in the drylands of East Africa

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Received 9 November, 2020; Accepted 26 January, 2021

The East African drylands cover about 47% of the land surface and host about 20 million people. Rural people living in the drylands are mainly pastoralists who depend on livestock for both economic and social well-being. During the dry season, pastoralists apply strategic mobility to access grazing resources efficiently. However, this strategy has experienced change and constraints due to various demographic- and climate-related challenges. Pastoral lands have been cleared for large-scale agriculture while pastoralists have shifted towards agro-pastoralism. This has eroded many dryland trees and forests leading to environmental degradation. This review discusses important indigenous trees that can be utilized in ecological restoration of drylands as well as providing ecosystem goods and services. These include trees for gums and resins (*Acacia*, *Commiphora* and *Boswellia*), indigenous fruit trees (IFTs) (*Adansonia digitata*, *Tamarindus indica* and *Balanites aegyptiaca*), trees for wood (*Melia volkensii* and *Terminalia brownie*) and fodder (*Acacia tortilis* and *Faidherbia albida*). They are not only drought-tolerant but also have minimal disruption to the ecosystem. Various dryland restoration strategies and constraints are also discussed. For successful establishment, seedling planting should be integrated with other appropriate practices such as natural regeneration, silviculture and enrichment planting for sustainable dryland management.

Key words: Ecological restoration, drylands, indigenous trees, pastoralism.

INTRODUCTION

Drylands cover 41% of the earth's land surface and are inhabited by about 40% of the world's population (Koochafkan and Stewart, 2008). Rural people living in the drylands are mainly pastoralists who depend on livestock for economic and social well-being. Pastoralism contributes 10 - 44% of the gross domestic product (GDP) of African countries and at least 50% of total value of production consumed by an average pastoralist household (African Union, 2013). Pastoralism is practiced

in an area of about 40% of Africa's land mass and covers 36 countries, stretching from the Sahelian West to the rangelands of Eastern Africa and the Horn and the nomadic populations of Southern Africa, with an estimate of 268 million pastoralists (FAO, 2018). In East Africa, drylands, commonly referred to as the Arid and Semi-Arid Lands (ASALs) cover 47% of the land hence representing about 5% of the global drylands (FAO, 2019). They are classified as semi-arid (37%), dry sub-humid (33%), arid

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(26%) and hyper-arid (4%) zones. Pastoralism in these areas is diverse and dynamic, integrating livestock production with other activities such as rain-fed agriculture and non-timber forest products. It offers direct support to an estimated 20 million people, accounting for 90% of the meat consumed in East Africa, and contributes 19, 13 and 8% of GDP in Ethiopia, Kenya and Uganda, respectively (Nyariki, 2017). Countries such as Ethiopia, Sudan and Somalia are major livestock exporters to the Gulf States (FAO, 2018). Livestock are raised not only for economic reasons but also for strong social, cultural and environmental services.

In Kenya, ASALs occupy more than 80% of the country's total land surface, support about 34% of the country's population and over 60% of the nation's livestock herd (Barrow and Mogaka, 2007). These regions are home to more than 90% of the wildlife that supports the tourism industry, contributing to 12% of Kenya's GDP (State Department for Arid and Semi Arid Lands, 2020). In Uganda, drylands cover about 42% of the country's total land area and hosts a population of around 6.6 million while in Ethiopia and Tanzania they cover about 63 and 51% of the countries, respectively (REGLAP, 2012). The ASALs of East Africa have enormous potential for renewable energy and other natural resources such as medicinal plants and high quality honey. They also have a great variety of biological diversity of plants, animals and habitats that play a vital role in the livelihoods of many dryland inhabitants (Davies et al., 2012). Sustainable management of these landscapes in East Africa is yet to be realized, and will help tackle global challenges such as poverty, climate change and desertification.

The East African drylands face numerous challenges linked to climate variability and change. The area is characterized by low erratic rainfall with as low as less than 200 mm per annum and frequent droughts and floods (Mati et al., 2006). Temperatures are high throughout the year resulting in high rates of evapotranspiration, while the soils are of low fertility and susceptible to erosion (Njoka et al., 2016). During the dry season pastoralists apply traditional management systems based on strategic mobility to access and use water and grazing resources efficiently. This system of mobility is flexible and responds quickly to changing environmental conditions, hence well suited to the ecological conditions of the drylands (FAO, 2018). However, pastoralists in East Africa has over the years experienced processes of change and constraints on pastoral mobility due to various social, economic and political challenges that are mainly intensified by encouraged privatization and individualization of formerly communally held resources (Fratkin, 2001). Mobility that has supported them for many years is now restricted due to inappropriate development practices that have resulted in rapid land use changes and diminished natural

resources (Norton-Griffiths and Said, 2010). The flexible rule of access to land and natural resources has been disrupted resulting in conflicts and contributing to the increasing vulnerability of pastoralists (FAO, 2018). Pastoral land is therefore shrinking and with it the opportunities for pastoral people to make a viable living. Many pastoralists in drylands of Eastern Africa have therefore shifted towards crop-livestock farming (agro-pastoralism) that is associated with environmental degradation and decreased access to pastures (Ekaya, 2005; Little et al., 2008). Unless appropriate action is taken to improve the sustainability of the new change, the livelihoods of millions of people will be at risk.

East Africa's dryland vegetation ranges from woodlands, where trees can reach up to 15 m in height to hyper-arid landscapes with few shrubs and denser shrubs occurring only along seasonal riverbeds (FAO, 2019). Dryland vegetation provides goods and services essential to the livelihoods and is the main source of nutrients for both livestock and wildlife. However, most of the vegetation is degraded either due to complex anthropogenic factors or heavily encroached by invasive alien species such as *Opuntia*, *Prosopis* and *Lantana camara* (Githae, 2018; Obiri, 2011). Dryland degradation associated with loss of vegetation is estimated to cost about 4-8% of GDP in developing countries (EMG, 2011). Urgent action is therefore needed to restore dryland ecosystems in order to combat land degradation, support livelihoods and conserve biodiversity. This should include promotion of sustainable land management practices that protect biodiversity and boost soil structure and function. This review discusses important indigenous trees that can be utilized in ecological restoration of drylands as well as providing ecosystem goods and services. These include trees for gums and resins, indigenous fruit trees (IFTs), and trees for durable wood and quality fodder.

MAINTAINING INDIGENOUS TREES ON FARM AND RANGELANDS

Investing in trees that survive well in harsh climatic conditions in the drylands is among the best options to restore the ecosystem. When crops fail during drought, communities resort to trees for food, fodder and other economic benefits that protect livelihoods against the extremely high drought-induced vulnerability (Wagner et al., 2013). Trees also aid in soil conservation, regulation of water cycle and local climate as well as contribute to soil formation and nutrient cycling. They also support both livestock and wildlife. Indigenous trees survive in the drylands by having two important adaptations: (i) deep roots to access deep ground water and (ii) longevity to enable reproduction during favourable environmental conditions (Davies et al., 2012). They form a safety net during dry seasons that mitigate climate-related risks in pastoral communities (Barrow and Mlengi, 2003).

Table 1. Drought-tolerant dryland trees with potential to restore degraded lands and improve pastoral livelihoods.

S/N	Tree species	Common name	Main source of income	Other uses
1.	<i>Acacia senegal</i> (L.) Willd. also known as <i>Senegalia senegal</i> (L.) Britton (Fabaceae)	Gum arabic/ Gum acacia	Gum Arabic	Fodder, shade, medicine, fuel, wood, dune stabilization and soil fertility improvement
2.	<i>Acacia tortilis</i> (Forssk.) Hayne also known as <i>Vachellia tortilis</i> (Forssk.) Galasso & Banfi (Fabaceae)	Umbrella thorn acacia	Commercial tannins and quality fodder	Food, mulch, medicine, fuel, timber, shade, erosion control, molluscicide and algicide.
3.	<i>Adansonia digitata</i> L. (Bombacaceae)	Baobab	Fruit	Medicine, fibre mulch, gum and resin, dyes and fodder
4.	<i>Balanites aegyptiaca</i> (Linn.) Del (Balanitaceae)	Desert date or Egyptian balsam	Fruit oil, Leaves (vegetables)	Fruits, medicine, durable and termite-resistant wood, fodder, bee forage, windbreak, mulch, fish poison and live fence
5.	<i>Boswellia neglecta</i> S. Moore (Burseraceae)	Frankincense tree	Frankincense	Traditional chewing gum, incense and medicine
6.	<i>Melia volkensii</i> Gürke (Meliaceae)	Melia	Durable and termite-resistant timber	Fodder, bee forage, insect repellent, medicine and mulch
7.	<i>Tamarindus indica</i> L. (Fabaceae)	Tamarind	Fruit	Medicine, timber, wood, fuel, fodder and soil fertility improvement

Appropriate tree management in the drylands can increase groundwater recharge and improve groundwater resources. Unfortunately, the richness and abundance of indigenous trees and shrubs in the drylands is being eroded, which leave the rural poor with fewer options to improve their health, nutrition and income (Kalinganire et al., 2007).

In East Africa, many dryland trees play a significant role in conserving biodiversity and providing ecosystem goods and services that are essential for people's livelihoods and well-being (FAO, 2015). For centuries, the pastoral communities have depended on both wood and non-wood forest products as a source of livelihoods. Despite several challenges including moisture stress, successful establishment can be achieved by selection of appropriate tree species (Mwamburi and Musyoki, 2010). However, many restoration programmes in East Africa focus on addressing dryland degradation by planting trees that are drought tolerant with rapid growth establishment, but ignore the possibility of invasiveness (Reisman-Berman et al., 2019). If not properly managed, the introduced trees may later become invasive and harm the natural ecosystem. Selection of trees should therefore focus on species that are not only drought-resistant but also provide adequate ecosystem goods and services with minimal disruption to the ecosystem (Reisman-Berman et al., 2019). Some of the drought-tolerant dryland trees with the potential to restore degraded drylands of East Africa and improve pastoral livelihoods include trees for gums and resins (*Acacia*, *Commiphora* and *Boswellia*), indigenous fruit trees (*Adansonia digitata*, *Tamarindus indica* and *Balanites*

aegyptiaca) and many other economic important trees such as *Melia volkensii* and *Acacia tortilis* (Table 1). These trees are preferred by the rural communities since they produce well even during the dry seasons and contribute to food security and income generation.

While clearing land for agriculture or other activities, natural populations of these trees should be maintained in order to conserve their genetic resources.

TREES FOR GUMS AND RESINS

Dryland non-wood forest resources with the potential to improve rural communities' livelihoods in sub-Saharan Africa include gums (gum arabic) and resins (myrrh, hagar and frankincense), which are some of the known products that are used in many industries.

One advantage of these resources is their ability to produce during the dry season, hence an alternative source of income (Gachathi and Eriksen, 2011). In Ethiopia, they contribute about 33% of annual cash income generated per household and ranks second after livestock in the overall household livelihood (Lemenih et al., 2003; Hassan et al., 2011).

In Kenya, annual production estimates are 2,000 tonnes for gum Arabic, 900 tonnes for myrrh and 100 tonnes for frankincense with a gross income per household per month being USD 35, 72 and 28, respectively (Gachathi and Eriksen, 2011). The gums of commercial importance are collected from *Acacia* species (*Acacia senegal* and *Acacia seyal*), while commercial resins are obtained from trees such as *Commiphora* and *Boswellia* species.

***Acacia senegal* (L.) Willd. [Syn. *Senegalia senegal* (L.)]**

A. senegal (Fabaceae), also known as *Senegalia senegal* is a small thorny deciduous tree commonly known as gum arabic or gum acacia. The principal area of geographical distribution of *A. senegal* is the 'gum belt of Africa' which encompass Senegal, Mauritania, Sudan, Eritrea, Somalia, Kenya and Tanzania (United Nations, 2018). *A. senegal* is drought tolerant, has a wide climatic and altitudinal range and portray adaptive variation across its natural distribution range. The tree is known for its commercial gum that has been traded internationally for centuries. The gum is traditionally harvested by nomadic pastoralists in the course of their transhumance cycle and sold in the market for food, pharmaceuticals and cosmetic industries making it a very important economic resource in the drylands. In East Africa, Sudan is acknowledged as the world leader in gum arabic production, which covers 95% of the global gum arabic export market (United Nations, 2018). Furthermore, *A. senegal* also provides various key ecosystem services that include improving soil fertility through nitrogen fixation, fodder, shade, traditional medicine, fuel wood and dune stabilization (Fagg and Allison, 2004). Economically, the tree has high internal rate of return (IRR) of 61% and can save the cost of providing ammonia nitrate fertilizer equivalents to USD 78/hectare/annum (Taha et al., 2018).

***Boswellia neglecta* S. Moore**

B. neglecta (Burseraceae) commonly known as the frankincense tree is a frankincense-producing tree species dominantly found in the drylands of Africa. Frankincense is commercially used in the industrial production of perfumes, cosmetics and flavouring industries and is traditionally used as a chewing gum, incense and traditional medicine (FAO, 2010). It grows naturally in the dry areas of the Horn of Africa and southern Arabia. The species is drought tolerant and adapted to decreasing soil moisture deficits hence regarded as a key tree species for restoration of moisture-limited areas across the Horn of Africa (Mokria et al., 2017). The tree contributes significantly in providing goods and services and hence plays a major role in rural livelihood security and climate change adaptation (Hassan et al., 2011). Frankincense produced from *B. neglecta* is widely used for domestic consumption and contributes about one third of the annual household income in Ethiopia, hence making the species an economic priority for the country (Mokria et al., 2017).

INDIGENOUS FRUITS TREES (IFTs)

Indigenous fruit trees (IFTs) contribute to food security

and income generation of rural communities in sub-Saharan Africa especially in drylands where cultivation of exotic fruit species is often not possible (Leakey and Ajayi, 2007). They are also well adapted to their local environments and hence used as emergency during times of food shortage (Stadlmayr et al., 2013). Inclusion of fruit trees in farming systems reduces the risks which are common in cultivated crops, and the source of income from indigenous fruits is much higher than that from traditional agriculture (Sidibé and Williams, 2002). A research study in Kenya documented 71 indigenous fruit species where 32% were sold in local markets while 55% were only for local consumption, and almost all of them had many other uses (Fukushima et al., 2010). However, the main factor contributing to the decrease of IFTs was the high logging pressure for wood products. Among the many utilized priority IFTs in sub-Saharan African include *Adansonia digitata*, *Tamarindus indica* and *Balanites aegyptiaca* (Kehlenbeck et al., 2013; Stadlmayr et al., 2013; Muok et al., 2000). These species are preferred by farmers because of their nutritional, medicinal and income-generating values. Domestication of IFTs can play an important role in poverty reduction by raising incomes for the rural poor as well as better nutrition and maintenance of biodiversity (Schreckenberget al., 2006). In addition, cultivation of IFTs on farms will contribute to climate change mitigation and adaptation as they also provide many other valuable environmental services (Kehlenbeck et al., 2013). With their wide role in the community and ecosystem, IFTs deserves greater attention in national planning processes.

***Balanites aegyptiaca* (Linn.) Del**

B. aegyptiaca (Balanitaceae) commonly known as Desert date or Egyptian balsam is an evergreen multipurpose tree species native to Africa and parts of the Middle East. It is widely distributed throughout the drier parts of Africa. It can be found in many kinds of habitat, tolerating a wide variety of soil types and climate (Maundu and Tengnäs, 2005). *B. aegyptiaca* is a very important species for drylands as it produces fruits even in very dry years. The fruits can be processed into a drink, while the young leaves, flowers and tender shoots are used as vegetable. The kernels produce oil that is used in cooking and has steroids that are used as raw materials for industrial production of contraceptives, beauty products and medicine (Okia et al., 2011).

A kilogram of partially cooked leaves in Uganda costs about USD 0.4 with a sale of USD 53 per leaf season. In addition, a kilogram of fruits in West Nile is sold at about USD 0.2 especially by women and children while a litre of balanites oil costs USD 2.0 in the market (Okia et al., 2011).

Besides, all parts of the plant have pharmacological properties and used in traditional medicines for the

treatment of different ailments and contraceptive activities (Yadav and Panghal, 2010). The tree is also valuable for its hard, durable and termite resistant wood as well as fuel, fodder, bee forage, shade, windbreak, mulch, fish poison and live fence (Maundu and Tengnäs, 2005).

***Adansonia digitata* L.**

A. digitata (Bombacaceae), commonly known as Baobab is one of the most characteristic species in the drylands because of its massive size and its importance in people's lives as the main sources of income, food and nutritional security during the dry season (Kalinganire et al., 2007). The tree occurs naturally in the drylands of most African countries. Although *A. digitata* is mostly regarded as an IFT, it is a multipurpose tree widely used in medicine, food and fibre industries (Sidibé and Williams, 2002). All parts of the tree are exploited for food and medicines. In Kenya, it is famous for the edible pulp-coated seeds (*mabuyu* in Swahili) that are coloured and sold as sweets (Maundu and Tengnäs, 2005). The fruits mature during the dry season while the leaves are harvested during the rainy season, sun-dried and stored for use during the dry season (Sidibé and Williams, 2002). Besides, the tree is fire resistant, fallen leaves improve soil quality and is also valued as a source of fibre, gum and resin, dyes and fodder (Maundu and Tengnäs, 2005).

***Tamarindus indica* L.**

T. indica (Fabaceae), commonly known as Tamarind is indigenous to tropical Africa and widely distributed in the Sahel, India, South East Asia, the Caribbean and Central America (Maundu and Tengnäs, 2005). The fruit pulp is nutritious, rich in tartaric acid and used as a seasoning or souring agent for sauces, porridge and juice, and as a natural preservative in the pickle industry (Kalinganire et al., 2007). Tamarind kernel powder is an important sizing material in textile, paper and jute industries while the leaves and flowers can be eaten as vegetables (De Caluwé et al., 2010). Roots, leaves, bark and fruit extracts are believed to have antimicrobial and anti-inflammatory activities hence used in pharmaceutical industries and herbal medicine (De Caluwé et al., 2010). Furthermore, the tree is valuable as a source of timber, wood, fuel and fodder. As a legume, *T. indica* has a symbiotic relationship with rhizobium bacteria that fix atmospheric nitrogen hence enhances soil fertility.

OTHER ECONOMIC IMPORTANT TREES FOR THE DRYLANDS

Most of the fuel-wood and charcoal in the East African region comes from the arid and semi-arid lands (FAO,

2019). The most valued trees for wood are *Melia volkensii* and *Terminalia brownie* while the most valued fodder trees are *Acacia tortilis* and *Faidherbia albida*. Fodder trees and shrubs constitute an essential component in livestock productivity in the arid and semi-arid zones especially during the dry season.

***Melia volkensii* Gürke**

M. volkensii (Meliaceae), commonly known as Melia is a fast-growing multipurpose drought-tolerant tree that is endemic to drylands of Eastern Africa with natural distribution range in Ethiopia, Somalia, Kenya and Tanzania (CADEP-SFM, 2018). The species is regarded as the ideal timber tree because it thrives well in harsh climatic conditions and produces very high-quality termite-resistant timber within a period of 10 to 15 years (Maundu and Tengnäs, 2005). In Kenya, *M. volkensii* is cultivated by farmers to provide durable and termite resistant timber and poles. The tree has been researched by the Kenya Forestry Research Institute's (KEFRI) especially on germination improvement, silvicultural aspects and breeding systems and was found to perform better than most of the other dryland species (Luvanda et al., 2015). Besides wood, *M. volkensii* provides other products such as high quality fodder, bee forage and hives, insect repellent and traditional medicine (Maundu and Tengnäs, 2005). It also improves soil through mulch and intercropping.

***Acacia tortilis* (Forssk.) [Syn. *Vachellia tortilis* (Forssk.) Galasso & Banfi]**

A. tortilis (Fabaceae) is currently recognized as *Vachellia tortilis* and commonly known as Umbrella thorn acacia. It is widely distributed in most of dry Africa from North and West Africa to South Africa (Maundu and Tengnäs, 2005). *Acacia tortilis* is among the most drought-resistant of the acacias and tolerates a wide range of soil with annual precipitation of less than 100 mm. Various parts of *Acacia tortilis* are used to improve the livelihoods of pastoral communities. For instance, commercial tannins derived from the bark are used as dye, pods are edible, and leaves are used as mulch and fodder. Medicinally, all parts of the plant are useful in the treatment of various human and livestock diseases (Yadav et al., 2013). The pods are very popular quality feed for livestock; they are collected and stored for use during the dry season. A 10 year old *A. tortilis* yields about 4-6 kg dry leaf and 10- 12 kg pods per year with a crude protein and digestibility coefficients of 18 and 46.2%, respectively (Orwa et al., 2009). The tree is also valued for fuel, timber, shade, erosion control and as a powerful molluscicide and algicide. The tree is able to reallocate carbon from the shoots to the roots as a hydration postponement strategy

Table 2. Land restoration interventions in the drylands.

Land type	Restoration options	Description
Land without trees	Planting of suitable trees	Stocking the area by direct planting
	Natural regeneration	Restocking the area by allowing the trees to develop from seeds, shoots or root suckers that germinate in situ.
Land with trees	Silviculture	Controlling the establishment, growth, composition, health, and quality of woodlands to meet the diverse needs and values of landowners and society.
	Enrichment planting	Introduction of valuable species to degraded forests without the elimination of valuable individual which already existed at that particular site
Land under agriculture	Agroforestry	Management and integration of trees with crops and/or livestock on the same land.
	Improved fallow	The targeted use of planted species in order to achieve the aims of natural fallow within a shorter time e.g. retaining rows of leguminous trees along the contours of sloping land in order to improve soil stability
Watershed	Watershed protection and erosion control	Establishing trees and enhancing forests along water courses, in areas that naturally flood, and around critical water bodies.

that is a survival mechanism during drought (Otieno et al., 2001).

IDENTIFYING POTENTIAL LAND RESTORATION OPTIONS

Ecological restoration is a way of reversing degradation processes and increasing the contributions of ecosystems to livelihoods and the environment (FAO, 2015). It is recognized by several international organizations and treaties as a wide range of practices that provide opportunities for environmental and socioeconomic gains. Severely degraded drylands can be restored through active restoration measures such as reseeding, planting and assisting natural regeneration of native species, and the success depends on the type of species planted (Yirdaw et al., 2017; Wagner et al., 2013). Many restoration projects in East Africa focus on tree seedling production and planting of both exotic and indigenous trees.

Other strategies applicable in the drylands such as natural regeneration, silviculture and enrichment planting should be included together with sustainable tree management practices (Barrow and Mogaka, 2007). This should incorporate the local people and their knowledge on what is socially acceptable and useful to them.

The Global Partnership on Forest Landscape Restoration (GPFLR) produced a framework of general categories of forest land restoration (FLR) interventions (IUCN and WRI, 2014) that can also be applied in the drylands (Table 2).

For instance, farmer-managed natural regeneration (FMNR) is a quick, affordable and easy-to-replicate way of restoring and improving degraded lands. The FMNR intervention has been successfully implemented for agroforestry systems in West African Counties (Niger, Burkina Faso, Mali, Senegal and Malawi) while in Ethiopia

it has been of large-scale natural regeneration (Reij and Garrity, 2016). In 2018, the World Vision Australia carried out a study in Kenyan drylands with the aim of improving food security for climate resilience and carbon sequestration. More than 7,700 farmers adopted the project and reaped various benefits and approximately 1,000 ha of degraded farmlands were restored with trees (Rinaudo et al., 2019). This clearly indicates that the aim of dryland restoration should not only be for dryland rehabilitation purposes but also to contribute to climate change adaptation and mitigation.

POLICY IMPLICATIONS

The drylands of East Africa present many opportunities that improve rural pastoralists. Pastoralism in these lands requires rangelands that can support them even during the dry-season drought. National policies have promoted individualization of commonly used pastoral land and this has promoted changes in land use leading to environmental degradation (Damonte et al., 2019). With the high rate of sedentarization and privatization of pastoral lands, environmental degradation may persist and become irreversible and regeneration impossible if no measures are put into place. This is worsened by various constraints that face ecological restoration of drylands (Table 3).

ACKNOWLEDGEMENT

The authors appreciate Chuka University for the technological support.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

Table 3. Constraints that face ecological restoration of drylands and possible solution.

S/N	Constraints	Possible solutions
	Preference for exotic tree species	Some exotic tree species become invasive and harm the natural environment. This can be prevented by awareness creation and enhancement of regulations to prevent introductions.
1.	Demand for wood and fuel	Many indigenous trees have durable wood and other valuable products hence a target for extraction that can lead to erosion of genetic resources. These trees should be protected for sustainable utilization and conservation of genetic resources.
2.	Insecure land tenure	Community land tenure is positively correlated with the sustainability of pastoral production systems. Adoption of better options is slow where land tenure is uncertain. Lack of land tenure can also lead to conflict of resources. Appropriate policies that favour dryland environments are therefore necessary to safeguard dryland communities and their environment. Where there are land rights, the owners should be enlightened on appropriate land restoration practices.
3.	Poor markets	Greater recognition of dryland tree products is required for both local and international markets in order to improve food security in the drylands.
4.	Poor investment in land restoration practices	Many forestry interventions focus on tree planting, and the success is measured by the numbers of trees planted and the area planted. This ignores the fact that the users are more knowledgeable on the type of species that are socially acceptable and useful. The approach should therefore incorporate other strategies that are applicable in the drylands while having the pastoral communities in mind.
5.	Unimplemented policies	Implementation of policies requires comprehensive legislative and coordination for cost effective delivery of services in drylands development. The policies should encourage the use of drylands as a renewable economic resource. Policies should assist pastoral communities to adapt to the changes and strengthen their governance to manage their land sustainably.

REFERENCES

- African Union (2013). Policy framework for pastoralism in Africa: Securing, protecting and improving the lives, livelihoods and rights of pastoralist communities. African Union, Addis Ababa, Ethiopia
- Barrow E, Mogaka H (2007). Kenya's drylands-wastelands or an undervalued national economic resource. IUCN (International Union for Conservation of Nature), Nairobi.
- Barrow E, Mlengi W (2003). Trees as key to pastoralist risk management in semi-arid landscapes in Shinyanga, Tanzania and Turkana, Kenya. In International Conference on Rural Livelihoods, Forests and Biodiversity, pp. 19-23.
- CADEP-SFM (2018). Guidelines to Growing *Melia volkensii* in the Dryland Areas of Kenya. Nairobi, Kenya.
- Damonte G, Njagi T, Kirimi L, Glave M, Rodríguez S (2019). Land tenure and the sustainability of pastoral production systems: a comparative analysis of the Andean Altiplano and the East African savannah. *Nomadic Peoples* 23(1):28-54.
- Davies J, Poulsen L, Schulte-Herbrüggen B, Mackinnon K, Crawhall N, Henwood WD, Gudka M (2012). *Conserving Dryland Biodiversity*. xiii+84p.
- De Caluwé E, Halamová K, Van Damme P (2010). *Tamarindus indica* L. a review of traditional uses, phytochemistry and pharmacology. *Afrika Focus* 23(1):53-83.
- Ekaya WN (2005). The shift from mobile pastoralism to sedentary crop-livestock farming in the drylands of eastern Africa: Some issues and challenges for research. In African Crop Science Conference Proceedings 7(3):1513-1519.
- Environment Management Group (EMG) (2011). *Global drylands: a UN system-wide response*. Geneva, Switzerland.
- Fagg CW, Allison GE (2004). *Acacia Senegal and the gum arabic trade: monograph and annotated bibliography*. Oxford Forestry Institute, University of Oxford.
- Food and Agriculture Organization (FAO) (2010). *Guidelines on sustainable forest management in drylands of sub-Saharan Africa. Arid Zone Forests and Forestry Working Paper No. 1*. Rome.
- Food and Agriculture Organization (FAO) (2015). *Global guidelines for the restoration of degraded forests and landscapes in drylands: building resilience and benefiting livelihoods*, by Berrahmouni N, Regato P, Parfondry M. Forestry Paper No. 175. Rome, Food and Agriculture Organization of the United Nations
- Food and Agriculture Organization (FAO) (2018). *Pastoralism in Africa's drylands*. Rome. 52 pp. License: CC BY-NC-SA 3.0 IGO.
- Food and Agriculture Organization (FAO) (2019). *Trees, forests and land use in drylands: the first global assessment – Full report*. FAO Forestry Paper No. 184. Rome.
- Fratkin E (2001). East African pastoralism in transition: Maasai, Boran, and Rendille cases. *African Studies Review* 44(3):1-25.
- Fukushima T, Morimoto Y, Maundu P, Kahindi B, Fondo J (2010). Local preference of indigenous fruit trees in Coast Province, Kenya. *African Journal of Environmental Science and Technology* 4(12):872-885.
- Gachathi FN, Eriksen S (2011). Gums and resins: The potential for supporting sustainable adaptation in Kenya's drylands. *Climate and Development* 3(1):59-70.
- Githae EW (2018). Status of *Opuntia* invasions in the arid and semi-arid lands of Kenya. *CAB Reviews* 13(3):1-7.
- Hassan B, Glover EK, Luukkanen O, Chikamai B, Jamnadass R, Iiyama M, Kanninen M (2011). The Role of *Boswellia* and *Commiphora* species in Rural Livelihood Security and Climate change adaptation in the Horn of Africa: case study of northeastern Kenya. *International Journal of Social Forestry* 4(1):86-112.
- IUCN and WRI (2014). *A guide to the Restoration Opportunities Assessment Methodology (ROAM): Assessing forest landscape restoration opportunities at the national or sub-national level*. Working Paper (Road-test edition). Gland, Switzerland: IUCN 125 p.
- Kalinganire A, Weber JC, Uwamariya A, Kone B (2007). Improving rural livelihoods through domestication of indigenous fruit trees in the parklands of the Sahel. *Fruit trees* 10:186-203.
- Kehlenbeck K, Asaah E, Jamnadass R (2013). Diversity of indigenous fruit trees and their contribution to nutrition and livelihoods in sub-Saharan Africa: examples from Kenya and Cameroon. *Diversifying food and diets: using agricultural biodiversity to improve nutrition and health* pp. 257-269. https://www.researchgate.net/profile/Teresa_Borelli/publication/236605246_Diversifying_Food_and_Diets_Using_Agricultural_Biodiversity_to_Improve_Nutrition_and_Health/links/0c96052cea5a6a51d7000000/Diversifying-Food-and-Diets-Using-Agricultural-Biodiversity-to-Improve-Nutrition-and-Health.pdf#page=290

- Koohafkan P, Stewart BA (2008). Drylands, people and land use. Water and cereals in drylands FAO pp. 5-15. <http://www.fao.org/3/i0372e/i0372e00.pdf>
- Leakey RRB, Ajayi OC (2007). Indigenous fruit trees in the tropics: domestication, utilization and commercialization. CABI.
- Lemenih M, Abebe T, Olsson M (2003). Gum and resin resources from some Acacia, Boswellia and Commiphora species and their economic contributions in Liban, south-east Ethiopia. Journal of Arid Environments 55(3):465-482.
- Little PD, McPeak J, Barrett CB, Kristjanson P (2008). Challenging orthodoxies: understanding poverty in pastoral areas of East Africa. Development and Change 39(4):587-611.
- Luvanda AM, Musyoki J, Cheboiwo J, Wekesa L, Ozawa, M (2015). An assessment of the socio-economic importance of Melia volkensii based enterprises in Kenya. Kenya Forestry Research Institute.
- Mati BM, Muchiri JM, Njenga K, de Vries FP, Merrey DJ (2006). Assessing Water Availability under Pastoral Livestock Systems in Drought-prone Isiolo District, Kenya. Working Paper 106. Colombo: IWMI
- Maundu P, Tengnäs BO (2005). Useful trees and shrubs for Kenya. ICRAF Technical handbook series.
- Mokria M, Tolera M, Sterck FJ, Gebrekirstos A, Bongers F, Decuyper M, Sass-Klaassen U (2017). The frankincense tree Boswellia neglecta reveals high potential for restoration of woodlands in the Horn of Africa. Forest Ecology and Management 385:16-24.
- Muok BO, Owuor B, Dawson I, Were J (2000). The potential of indigenous fruit trees: results of a survey in Kitui District, Kenya. Agroforestry Today 12(1):13-16.
- Mwamburi A, Musyoki J (2010). Improving tree survival in the dry lands of Kenya: A guide for farmers and tree growers in the dry lands. Kenya Forestry Research Institute.
- Njoka JT, Yanda P, Maganga F, Liwenga E, Kateka A, Henku A, Mabhuye E, Malik N, Bavo C (2016). Kenya: Country situation assessment. PRISE working paper.
- Norton-Griffiths M, Said MY (2010). The future for wildlife on Kenya's rangelands: an economic perspective. Wild rangelands: conserving wildlife while maintaining livestock in semi-arid ecosystems. Blackwell Publishing Ltd.
- Nyariki DM (2017). Assessment of the economic valuation of pastoralism in Kenya. A report for IGAD, Nairobi, Kenya.
- Obiri JF (2011). Invasive plant species and their disaster-effects in dry tropical forests and rangelands of Kenya and Tanzania. Journal of Disaster Risk Studies 3(2):417-428.
- Okia CA, Agea JG, Kimondo JM, Abohassan RAA, Okiror P, Obua J, Teklehaimanot Z (2011). Use and Management of Balanites aegyptiaca in Drylands of Uganda. Research Journal of Biological Sciences 6(1):15-24.
- Orwa C, Mutua A, Kindt R, Jamnadass R, Anthony S (2009). Agroforestry Database: a tree reference and selection guide version 4.0 (<http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp>)
- Otieno DO, Kinyamario JI, Omenda TO (2001). Growth features of Acacia tortilis and Acacia xanthophloea seedlings and their response to cyclic soil drought stress. African Journal of Ecology 39(2):126-132.
- REGLAP (2012). Key Statistics on the Drylands of Kenya, Uganda and Ethiopia. Regional Learning Advocacy Programme for Vulnerable Dryland Communities. REGLAP.
- Reij C, Garrity D (2016). Scaling up farmer-managed natural regeneration in Africa to restore degraded landscapes. Biotropica 48(6):834-843.
- Reisman-Berman O, Keasar T, Tel-Zur N (2019). Native and non-native species for dryland afforestation: bridging ecosystem integrity and livelihood support. Annals of Forest Science 76(4):114.
- Rinaudo T, Muller A, Morris M (2019). Farmer Managed Natural Regeneration (FMNR) Manual. A resource for project managers, practitioners and all who are interested in better understanding and supporting the FMNR movement. World Vision Australia
- Schreckenber K, Awono A, Degrande A, Mbossso C, Ndoye O, Tchoundjeu Z (2006). Domesticating indigenous fruit trees as a contribution to poverty reduction. Forests, Trees and Livelihoods 16(1):35-51.
- Sidibé M, Williams JT (2002). Baobab. Adansonia digitata. International Centre for Underutilized Crops, Southampton, UK.
- Stadlmayr B, Charrondiere UR, Eisenwagen S, Jamnadass R, Kehlenbeck K (2013). Nutrient composition of selected indigenous fruits from sub-Saharan Africa. Journal of the Science of Food and Agriculture 93(11):2627-2636.
- State Department for Arid and Semi-Arid Lands (2020). Ministry of Devolution and the ASALS. <http://www.asals.go.ke/>
- Taha MEN, Pretzsch J, Siddig ME, Deafalla TH, Elamin, HM (2018). Valuation of the Environmental Role of Acacia senegal Tree in the Gum Belt of Kordofan and the Blue Nile Sectors, Sudan. Gum Arabic. Academic Press pp. 23-28.
- United Nation (2018). Commodities at a glance, special issue on gum Arabic, special issue no. 8, United Nations, Geneva-UNCTAD/SUC/2017/4
- Wagner B, Leeuw J, Njenga M, Liyama M, Jamnadass R (2013). Towards greater resilience in the drylands: trees are the key. World Agroforestry Centre Policy Brief No. 18
- Yadav JP, Panghal M (2010). Balanites aegyptiaca (L.) Del. (Hingot): A review of its traditional uses, phytochemistry and pharmacological properties. International Journal of Green Pharmacy 4(3).
- Yadav P, Kant R, Kothiyal P (2013). A Review on Acacia tortilis. International Journal of Pharmaceutical and Phytopharmacological Research 3(2):93-96
- Yirdaw E, Tigabu M, Monge A (2017). Rehabilitation of degraded dryland ecosystems—review. Silva Fennica 51(1B):1673.