Overview of restoration and management practices in the degraded landscapes of the Sahelian and dry land forests and woodlands of East and southern Africa

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Abstract

The highest deforestation and forest degradation rates in Africa occur in the dry forests and woodlands where pressure for land is increasing, poverty is rampant, livelihood options are few and climate change effects are severe. This paper examines factors that cause land and forest degradation in the Sahel and dry forests and woodlands of eastern and southern Africa and highlights some successful restoration practices, technologies and approaches. In the Sahel, enclosures are used to protect young growing trees while in East Africa are implemented on degraded, land as a mechanism for environmental rehabilitation with a clear biophysical impact. The choice of techniques for rehabilitating specific degraded areas depends first on the priorities and management objectives of stakeholders followed by the costs and benefits associated with available rehabilitation techniques and the economic, social, and environmental values of the land resources in their current and desired future states. In the Sahel, sustainable land management is considered as an imperative for their sustainable development and the practices include soil and water conservation activities and structures. In all regions, natural forest rehabilitation has used both natural and assisted

regeneration to promote the growth of especially indigenous species through coppice regrowth and root suckers rather than seeds. Assisted regeneration was especially prevalent in the Sahel where indigenous tree species have been identified to dominate the degraded sites during early stages of secondary forest succession. The success of any rehabilitation activities depends on community-based natural resources management. In addition, the forest policies and their related policies need to be enabling in order to address issues of concern including (i) the full participation of communities; (ii) clear land and tree tenure and (iii) equitable benefit sharing.

Keywords: Restoration, dry forests, woodlands, regeneration, policies

Introduction

The highest deforestation and forest degradation rates in Sub-Saharan Africa (SSA) occur in the dry forests and woodlands and Sahel where the pressure for land is continuously increasing due to rampant poverty and limited livelihood options (Maisharou et al. 2015; Chirwa et al. 2015a, Chirwa et al. 2015b). In addition, land and forest tenure and rights of access to forest and woodland resources are either not clearly defined or are non-existent to many people in many parts of SSA (FAO 2008). The vegetation types in these regions support the livelihoods of millions of both the rural and urban dwellers through the provision of non-wood products which include bees wax, honey, edible fruits, edible insects, mushrooms and traditional medicines (Bradley and Dewees 1993). They are also a source of agricultural land, firewood, charcoal and timber production (Luoga *et al.* 2000) upon which the rural economy is mainly based. As a result, these activities have greatly contributed to the degradation of woodlands and forests in the region creating characteristic rings of deforestation around cities and towns where forests and woodland are still available (Chirwa et al. 2015a). In addition, these activities contribute to the increased emission of carbon

dioxide into the atmosphere as the carbon sink is progressively reduced. Climate Change will further exacerbate the situation in all the regions, and species that will be more vulnerable are those with: limited geographical range and drought/heat intolerant; low germination rates; low survival rate of seedlings; and limited seed dispersal/migration capabilities (Chidumayo 2008, Chidumayo *et al.* 2011). On the other hand, the forestry sector has the greatest mitigation opportunities as net sinks of carbon dioxide through Reducing Emissions from Deforestation and forest Degradation (REDD).

Restoration of degraded forests, woodland areas and parklands of the Sahel region therefore may contribute to both peoples' livelihoods and environmental quality in SSA. However, if restoration of degraded forests, woodlands and parklands is to succeed, it is important to develop an understanding of the various factors that cause land and forest degradation. Furthermore, practices and technologies that are employed in addressing challenges of implementing restoration programs need to be identified. There are, however, recognized traditional forest management practices and new tree planting opportunities with associated socio-economic benefits that have the potential to promote both forest land and/or restoration provided proper institutional frameworks are in place including policies that address the problems highlighted.

This paper highlights restoration approaches in literature that is used in the dry forests and woodlands of eastern and southern Africa and parklands of the Sahel. It specifically presents (i) the ways and experiences of how farmers and other stakeholders are using to rehabilitate degraded lands and forest and tree resources; (ii) the technologies that have been very successful and conditions for their success; and (iii) the potential and conditions for up-scaling such experiences.

The forest resource

Eastern and southern Africa

The southern African vegetation is generally referred to the Zambezian Phytoregion (see Chirwa 2014). Miombo woodland is a significant biome covering about 10% of the African land masses (White 1983). A distinction is made between wetter miombo (rainfall>1,000 mm, canopy height>15 m, floristically rich) and drier miombo (rainfall<1,000 mm, canopy height<15 m, floristically poor) (Geldenhuys and Golding 2008).The dry miombo woodland occurs in Malawi, Mozambique and Zimbabwe (White 1983; Frost 1996). Parts of Tanzania are also covered by the miombo woodlands making up about 90% of all forested land in Tanzania, equivalent to 44.6 million ha, out of which 54% is under general lands (Abdallah and Monela 2007).

The other woodlands types in southern Africa are the undifferentiated woodlands of teak and *Acacia* (*Vachellia*) woodlands (Timberlake *et al.* 2010). The third types are the mopane woodland and semi-arid shrubland which have *Colophospermum mopane* as the dominant tree species (Timberlake *et al.* 2010). In East Africa, the most extensive dry woodland types are in the semi-arid zone, covering 1.6 million km^2 and comprise deciduous microphyllous bushland and thicket dominated by spiny species of Vachellia and *Commiphora*. Other common woody plants are said to include *Grewia* species, *Balanites aegyptiaca*, and various members of the Capparidaceae family such as *Boscia senegalensis* and *Cadaba*. The baobab tree (*Adansonia digitata*) is also characteristic at lower altitudes towards the coast and the environs of the Great Rift Valley.

The Sahel region

The Sahelian region is characterized by high climatic variations from 200 to 800 mm of rainfall per annum, the predominance of agriculture and livestock rearing, land degradation and overexploitation of natural resources by local communities, especially wood for energy (Larwanou 2011; Maisharou *et al.* 2015). According to Leonard *et al*. (1983) in Larwanou (2011), the Sahel covers approximately 2 million square kilometres comprising 27% of Senegal, 39% of Mauritania, 40% of Mali, 7% of Burkina Faso, 50% of Niger and 32% of Chad. Other authors have included the arid savanna zones as part of the Sahel covering especially most of northern Senegal from Dakar to just south of the Senegal River, and extending eastward across Africa, including large parts of central Mali, northern Burkina Faso, southern Niger, northern Nigeria, Chad, Sudan, and Ethiopia (Andrew 1995 in Larwanou 2011).

The woody biomass of forests in the Sahelian zone is said to be as low as 4 tonnes per ha with extraction often far exceeding natural productivity. The total land area in West Africa is 505.3 million ha with a forest land area of 72.2 million ha. This is 14.3% of the total land area in this region with an annual change of -1.26% as deforestation rate (FAO 2001). The Sahel vegetation is semi-desert grassland, thorn scrub and wooded grassland dominated by *Vachellia* (*Acacia)* spp. (White 1983; Wickens 1984). The Sahelo-Saharian zone in the northern fringe has relatively few trees including *Acacia ehrenbergiana, Acacia tortillis* and *Balanites aegyptiaca*. Sparse grass such as *Panicum turgidum* is found on sand dunes. South of the Sahelo-Saharian zone is more vegetated with characteristic species like: *Vachellia ehrenbergiana, Acacia nilotica, Vachellia Senegal, Vachellia tortillis, Balanites aegyptiaca, Maerua crassifolia, Salvadora persica, Ziziphus mauritiana,* etc. Annuals such as *Aristida asdscensionis, Aristida funiculata, Panicum laetum* and *Schoenefeldia gracilis* are found on

silty soils. *Aristida mutabilis*, *Cenchrus bifloris* and *Tribulus terrestris* are found on sandy soils. The vegetation cover increases in the Sudano-Sahelian zone, reaching 10–12 % on sandy soils and over 60% on silty soils. *Andropogon gayanus* and *Zornia glochidiata* are representative grasses of the Sudano-Sahelian zone; representative trees include *Faidherbia albida*, *Vachellia seyal*, *Adansonia digitata* and *Combretum glutinosum*. In the dry savanna part of the Sahel, the vegetation consists mainly of *Vachellia* spp., with *Vachellia senegal* (gum arabic), *Vachellia raddiana*, *Leptadenia pyrotechnica*, *Salvadora* spp., *Grewia* spp., *Vachellia seyal* in low areas liable to flooding, and grasses such as *Aristida* and *Chloris* spp. (Larwanou 2011).

Drivers of land degradation

Globally, direct drivers of change encompass habitat change and degradation; climate change and extreme weather events; over-exploitation of natural resources and; invasive species. Similar drivers are experienced in Sub-Saharan Africa (SSA) including the dry land forest and woodlands regions of the Sahel, eastern and southern Africa. The main drivers identified include population growth and demography, agricultural expansion and energy needs. These direct activities are closely linked to policy, market and institutional failures that undervalue forests and woodlands, and overvalue the benefits of destroying them to make way for other forms of land use. Land tenure arrangements and associated equity issues are a major threat to the sustainable use of land resources. The communal land tenure system is the most widespread, in which individual property rights are weak. Hence, this poor land and tree tenure in Africa is likely to have encouraged their over-exploitation. Consequently, the remaining forested areas face increasing pressure, particularly in response to high population growth rates and increasing poverty.

Forests and woodlands are the main source of fuel for the majority of the households and thus directly linked to the main threats of deforestation. In eastern Africa, about 173 million m^3 of fuelwood and about 5.2 million m^3 of industrial round wood is annually produced, most of which is consumed within the sub-region (FAO 2005). Throughout the sub-region, the rate of off-take from the forest is more than the natural regeneration capacity. There is very little investment in afforestation and reforestation (Chamshama et al. 2009). The main human-induced habitat changes in the dry regions of East Africa include low input agriculture and especially pastoralist practices (Chirwa et al. 2015a). In addition, topography is an important consideration, as many countries are mountainous. In order of magnitude, Rwanda, Burundi and Ethiopia encounter the highest potential erosion risk due to steep topography (Chirwa et al. 2015a). The areas with the most severe land degradation are also those with the highest population density such as in the central and northern highlands of Eritrea, Rwanda and Burundi (Chirwa et al. 2015a).

Similarly, southern African woodlands also support the livelihoods of millions of both the rural and urban dwellers through the provision of non-wood products (Bradley and Dewees 1993) and are also a source of agricultural land, firewood, charcoal and timber (Luoga *et al.* 2000). Impoverished subsistence communities often have no choice but to rely heavily on wood as fuel and on the wild plants, animals and other resources that natural forests and woodlands provide (see Kalumiana and Shakachite 2003; Falcão 2008; Kambewa *et al.* 2007). The status of the woodlands in southern Africa is therefore heavily disturbed, with very little old-regrowth woodland remaining, while forest cover continues to decline (Dewees *et al.* 2010; Syampungani *et al.* 2009).

In the Sahel, like in many parts of Africa in the past, land ownership was through traditional tenure and recent changes in Agrarian and Land Reform Law seem to be in conflict with customary authorities especially with nomadic pastoralism prevalent in the Sahel region. The traditional systems of rangeland which is characterized, to a large extent, by an open access and common property resources, of which the common management is guided by local traditions has virtually followed the path of the tragedy of the commons. However, recently, the introduction of forest and woodlands resources management by local communities to satisfy the demand of urban centres, has introduced the monetary value to wood – once free access and traditionally managed resource – to a commercial resource managed by local people based on sustainable management norms via rural wood markets. However, because of the monetary value attached to the business, the assigned wood cutters are not following the allowable cut leading to unsustainable management of the meagre woodlands resources, most especially in Niger.

Restoration approaches and practices in the dry forests, woodlands and Sahel parklands

Natural regeneration

The dry forest and woodlands are usually subjected to continued pressure as they provide a livelihood to the rural communities and in many cases the urban areas of many African cities as a source of energy. The management practices for dry forests and woodlands are designed to meet specific tangible products (Chidumayo *et al.* 1996; Dewees *et al.* 2010). In the Sahel, enclosures are used to protect young growing trees while in East Africa enclosures are implemented on degraded, generally open access land in many dryland areas, as a mechanism for environmental rehabilitation with a clear biophysical impact on large parts of the formerly degraded lands (Tucker and Murphy, 1997; Mekuria, 2007). It has been shown that

enclosures in Ethiopia resulted in high number of woody species at lower diameter classes showing the potential of the technique to restore degraded lands (Mekuria 2007). In eastern and southern Africa and to an extent the Sahel, natural forest rehabilitation has used both natural and assisted regeneration to promote the growth of especially indigenous species. Natural regeneration involves protecting rehabilitation sites from external interference, through enclosures, to facilitate natural regeneration. The technique is employed in situations where there are some trees left in the landscape to act as seed sources during secondary succession. Assisted or aided regeneration is especially prevalent in the Sahel where indigenous tree species are planted (enrichment planting) that have been identified to dominate the degraded sites during early stages of secondary forest succession. The trees planted are intended to act as nurse trees that provide shade, enrich the soil and the microhabitat for naturally recruiting woody species. The management activities in the protected (enclosed) areas in the Sahel include (i) seeding/planting of improved fodder species; and (ii) establishing stone lines and half-moons for erosion control and water harvesting, (iii) installing beehives for honey production; and (iv) fodder production: the grass is cut, tied and carried to feed livestock outside the regeneration area (Rinaudo 2008; Wocat/FAO 2011).

Miombo woodland species regenerate largely through coppice regrowth and root suckers rather than seeds. Chidumayo (1988) observed that stumps of almost all miombo woodland trees have the ability to produce sucker shoots. This is especially important to understand in restoration programmes since the majority of seedlings of miombo trees experience a prolonged period of successive shoot dieback during their development phase in order to cater for water stress and/or fire during the dry season. In addition, fire has been reported to be the major ecological factor, which leads to the development of the savanna forest

ecosystems especially in the miombo woodland (Lawton, 1978). The impact of fire depends on time and frequency of burning and on the flammable biomass. Trapnell (1959) reported that repeated late and hot fires may destroy the woodland while early burning maintained regeneration, On the other hand, complete protection for a few years leads to an accumulation of fuel which is more detrimental to tree biomass if a fire occurs.

The choice of techniques for rehabilitating specific degraded areas depends first on the priorities and management objectives of stakeholders followed by the costs and benefits associated with available rehabilitation techniques and the economic, social, and environmental values of the land resources in their current and desired future states. Some of the rehabilitation techniques identified (see Tables 1 & 2) as playing a role in rehabilitation include (i) natural regeneration; (ii) assisted natural regeneration; (iii) fire as a management tool; (iv) enrichment planting; (v) artificial tree planting; and (vi) agroforestry.

Table1*: Some natural regeneration techniques practiced in in some countries of East Africa (Chirwa et al. 2015a)*

Country/	NR	ANR	Coppice	Pollarding	Fire
			√	√	
Burundi			√	√	
Djibouti			√	√	
Ethiopia	√	√	√	√	√
Eritrea			√	√	
Kenya		√	√	√	
Rwanda			√	√	
Somalia			√	√	
Tanzania	√	√	√	√	
Uganda	√	√	√	√	

N = natural regeneration; ANR = assisted natural regeneration

***Table 2**: Some natural regeneration techniques practiced in some countries of southern Africa (Chirwa et al. 2015b)*

Country/	NR	ANR	Coppice	Pollarding	Fire
Angola				√	
Botswana				√	
Lesotho				√	
Malawi	√	√	√	√	
Mozambique	√		√	√	
Namibia	√		√	√	√
South Africa		√			
Swaziland		√		√	√
Zambia	√	√	√	√	√
Zimbabwe	√	√	√	√	

N = natural regeneration; ANR = assisted natural regeneration

Forest management in the form of coppicing and pollarding is practiced in almost all the countries of eastern Africa (Monela *et al.* 2005; Mekuria, 2007; MNRT, 2008; Zeleke, 2009). With the exception of Kenya, both natural and assisted natural regeneration have been reported to be used in forest restoration in Ethiopia, Tanzania and Uganda (Chirwa *et al.* 2015a). Fire as a management tool has only been reported in Ethiopia while other countries like Tanzania have acknowledged prevalence of fires especially in the miombo as part of the ecological dynamics. In southern Africa, natural regeneration associated with coppicing has also been reported mostly in Malawi, Mozambique, Namibia, Zambia and Zimbabwe. Assisted natural regeneration is also used in forest restoration in Malawi, South Africa, Swaziland, Zambia and Zimbabwe (Chirwa et al. 2015b). Pollarding is also a common practice in most countries especially for trees on the farmland.

Sustainable land management (SLM) in the Sahel

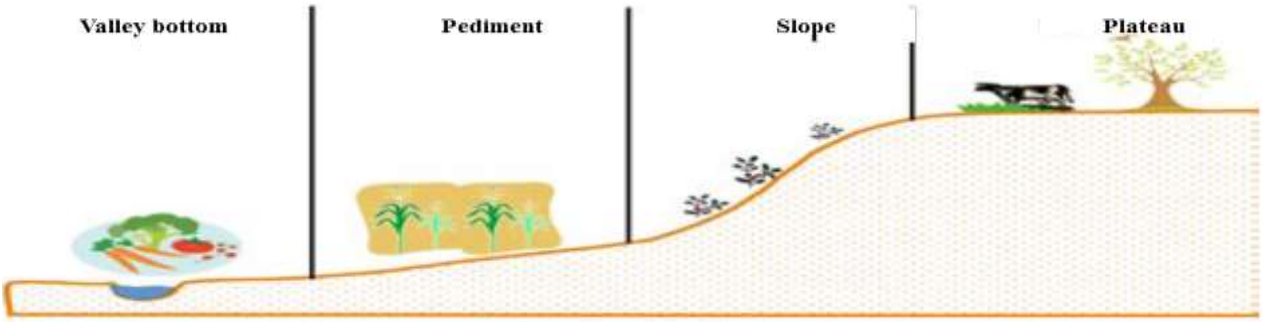
In the Sahel Region, the restoration approaches and practices (also termed the Sustainable Land Management (SLM) practices (Maisharou *et al.* 2015) are a function of land/soil, water conservation and management and as means to improving productivity of cropland, forestland and rangeland. The SLM practices, techniques and technologies used could be

categorized based on the toposequence position in relation to the associated activities for rehabilitation (Figure 1). Thus, the main categorization includes:

(i) Improvement of plateau: Semi-circular bunds, Nardi/Vallerani trenches, Contour bunds, firebreaks;

(ii) Improvement of slopes: Hand-dug trenches, Permeable rock dams, Dune stabilization;

(iii) Improvement of pediments: Contour stone bunds, Permeable rock dikes, Zai planting pits, Use of manure and compost, Mulching, Farmers' assisted natural regeneration; Sand dunes stabilization, firebreaks;



f soil	Fertile alluvial soil	Deep, fairly fertile colluvial soil	Shallow stony soil (or sandy soil in the case of dune stabilisation)	Shallow, infertile soil, duricrust outcrops, barren areas with hardened soil crust
Use	Individual plots with: irrigated crops market gardens Communal grazing and watering areas	Individual plots with rain-fed crops	Communal land with some grazing areas	Communal land for: grazing collection of wood and other products (fruits, medicinal plants)
Risks	Gully erosion Siltation Flooding	Gully erosion Sheet erosion	Gully erosion Landslides	Sheet erosion Gully erosion Wind erosion
SLM Practices	Water-spreading weirs Small-scale dams Village irrigation schemes Assisted natural regeneration Permeable rock dams Contour stone bunds	Contour stone bunds Permeable rock dikes Zai planting pits, manure/ compost Mulching Grass strips Permeable rock dams	Hand-dug trenches Permeable rock dams Contour stone bunds Dune stabilisation	Semi-circular bunds Nardi/Vallerani trenches Contour bunds (Firebreaks)

Source: Maisharou, 2015

Figure1*: Schematic representation of the toposequence of a watershed and SLM Practices*

(iv) Improvement of valley bottoms: Water-spreading weirs, Small-scale dams, Village irrigation schemes.

The most commonly used SLM practices, techniques and technologies in different Sahelian countries are summarized in Table 3. The associated activities in rehabilitation include the following:

- Biological farming practices or crop management techniques such as conservation agriculture with crop rotation and intercropping, integrated pest management, tree planting and agroforestry, mulching and crop residue management;
- Improved pastures and rangelands techniques including planned grazing combined with water holes establishment, seeding grasses and woody species, control of invasive non palatable plants species, and control of bush fires through fire breaks establishment;
- Improvement of forest management with practices such as afforestation, farmers' assisted natural regeneration, shelter belts establishment, protection against wild fires and reforestation, sustainable conservation of plant diversity;
- Improved soil fertility management including utilization of crop residues, organic and humus amendment (compost, manure and green manure), integrated management of soil nutrients, environmentally friendly farming techniques;
- Water harvesting techniques for the recharge of groundwater table or improved rain water management practices through techniques as zaï (tassa), half-moon, stony bunds, ripping and sub-soiling, grass strips establishment, rehabilitation of wasteland with benches and trenches, drainage techniques;
- Erosion control using mechanical methods or structures which serve as barriers using stones or vegetation installed along contour lines, ridging/ridge tying, minimum tillage

for the management of water erosion; and sand dunes stabilization/fixation for the control of wind erosion.

Table 3: *Common SLM practices in the Sahelian countries*

Common SLM practice	Country					
	Niger	Burkina Faso	Mali	Mauritania	Senegal	Nigeria
Semi-circular bunds/ Half moon	X	X	X	X	X	X
Zai/Tassa	X	X	X	O	X	X
Stony /Vegetation bunds	X	X	X	X	X	X
Benches/banquettes	X	X	X	O	X	
Trenches	X	X	X	O	X	
Subsoiling		X	X	O	X	X
Mulching	X	X	X	X	X	X
Composting	X	X	X	X	X	X
River banks stabilization (Dikes, Gully plugging)	X	X	X	X	X	X
FMNR/RNA	X	X	X	X	X	X
Vallerani trenches	X	X	X	X	X	x
Windbreaks/hedgerows	X			X		X
Intercropping/ Mix cropping		X	X	X	X	X
Rural Territory Management approach	X	X		O	O	O
Rural wood market Approach	X	X	X	O	O	X
Sand dune stabilization	X		X	X	X	X
Fire breaks	X	X	X	X	X	X
Direct seeding	X	X	X	X	X	X
Aerial seeding	O	O	O	X	O	x
Liming	O	O	O	O	X	X
Minimum/Zero tillage	O	O	O	O	O	X
Cover cropping	O	O	O	O	O	X
Improved fallow	O	O	O	O	O	X
Contour ploughing	O	O	O	O	O	X
Terracing	O	O	O	O	O	X

X= Reported used practice; O = Not used practice
Source: Maisharou, 2015

In Burkina Faso, Mali and Niger the most practices, techniques, technologies, and approaches applied are for water harvesting and soil conservation, sand dune stabilization and soil fertility improvement (Table 3). This is most likely due to less rainfall received in these countries and the intense sand storms that erode away the fertile topsoil at the onset of the rainy season, creating large tracks of hardpans and sand dunes.

In Nigeria and to a lesser extent Senegal, the application of SLM practices are mainly related to soil fertility management due to the amount of high rainfall received in these countries which significantly results in the leaching of soil nutrients. In Mauritania the most important SLM applied includes a combination of water harvesting techniques, sand dunes stabilization, pasture management and gully plugging.

Conditions and prerequisites for up-scaling

The most promising adaptation strategies to declining tree resources in SSA countries include natural regeneration of local species, sustainable forest management and community based natural resources management (Desanker and Magadza 2001). However, the success of such strategies generally depends on the ability of local people to exercise power to inventory and manage local resources in systems of community-based natural resources management. Most of the mitigation activities to climate change in SSA have identified population pressure, agricultural expansion, overgrazing as some of the causes of deforestation. The most cross cutting conditions for up-scaling that have been identified in the Sahel, Eastern and southern Africa (see Chirwa *et al.* 2015a, 2015b; Maisharou *et al.* 2015) include the following:

- ✓ Enabling policies for community based approach including clear cut land tenure and equitable benefit sharing
- ✓ Recognition of local knowledge
- ✓ Capacity building at the local and professional level
- ✓ Institutional support for implementation of restoration activities
- ✓ Improved extension services
- ✓ Private sectors participation
- ✓ Financial/material support
- ✓ Participatory monitoring and evaluation of the natural resource use and management

- ✓ Alternative sources of energy
- ✓ Income generating initiatives through marketing and value adding of natural resources
- ✓ Taking on financial opportunities from clean development mechanism (CDM) including REDD.

Conclusion and recommendations

The main drivers of land degradation identified in this study include population growth and demography, agricultural expansion, climate variability and drought and energy needs. In addition, unclear policies on land tenure and associated benefit sharing are major threats resulting in the unsustainable use of land resources. Management practices for dry forests and woodlands in the study area are designed to meet specific tangible products. In the Sahel, enclosures together with different SLM practices are used to protect young growing trees while in East Africa enclosures are implemented on degraded, generally open access land in many dryland areas, as a mechanism to promote natural regeneration for environmental rehabilitation with a clear biophysical impact on large parts of the formerly degraded lands. In eastern and southern Africa and to an extent the Sahel, natural forest rehabilitation has used both natural and assisted regeneration to promote the growth of especially indigenous species. Assisted or aided regeneration is especially prevalent in the Sahel where indigenous tree species are planted (enrichment planting).

The success of such strategies generally depends on the ability of local people to exercise power to inventory and manage local resources in systems of community-based natural resources management. In addition, the forest policies and their related policies need to be enabling in order to address issues of concern including (i) the full participation of communities; (ii) clear land and tree tenure and (iii) equitable benefit sharing.

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