Management and restoration practices in degraded landscapes of Southern Africa and requirements for up-scaling

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SUMMARY

Southern African woodlands support the livelihoods of millions of both the rural and urban dwellers through the provision of non-wood products including supply of energy and agricultural expansion thereby contributing to deforestation and woodland degradation. However, there are recognized traditional forest management practices and technologies that have potential to promote rehabilitation and/or restoration of degraded woodlands provided relevant policies and institutional frameworks are in place. This paper reviews the causal factors of land and forest woodland degradation in southern Africa and highlights some of the successful practices for their restoration. Natural regeneration of different forms, including complete coppice; coppice with standards and selective cutting; pollarding, pruning and lopping, was found to be the predominant form of restoration in dry forests and woodlands of southern Africa. However, while policies promoting participatory natural resource management are in place in most countries of the region, implementation of these have mostly taken pilot project based approach with no strategies for up scaling by the governments. In addition, enabling policies for community based approach including clear cut land tenure and equitable benefit sharing are still not operational in most countries of the region. The conditions for up-scaling successful restoration practices include: (i) recognition of local knowledge; (ii) institutional support for implementation of restoration activities; (iii) income generating initiatives through marketing and value adding of natural resources; (iv) taking on financial opportunities from CDM mechanism including REDD.

Keywords: restoration, dry woodlands, regeneration, policies, degradation

Gestion et pratiques de restauration dans les paysages dégradés du sud de l'Afrique et nécessité d'accroître leur envergure

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Les terres boisées du sud de l'Afrique soutiennent les revenus de millions d'autochtones ruraux et urbains de par leurs produits autres que le bois, tels que l'énergie et l'expansion de l'agriculture, aggravant la déforestation et la dégradation de la terre forestière. Toutefois, il existe des pratiques de gestion et des technologies traditionnelles reconnues ayant le potentiel de promouvoir la réhabilitation et/ou la restauration des terres forestières dégradées, si les cadres institutionnels et les politiques appropriées sont en place. Cet article examine les facteurs causant la dégradation de la terre et des terres forestières dans le sud de l'Afrique et souligne certaines des pratiques à même d'assurer leur restauration. Différentes formes de régénération naturelle telles que la coupe en taillis, celle en taillis à standards et coupe sélective, l'étêtage, l'élagage se sont trouvées être la forme prédominante de restauration dans les forêts et les terres forestières sèches du sud de l'Afrique. Cependant, bien que des politiques encourageant la gestion participative des ressources naturelles soient en place dans la plupart des pays de la région, la mise en pratique de ces dernières n'a été principalement effectuée que dans le cadre d'une approche basée sur des projets pilotes, sans stratégie d'accroissement par les gouvernements. De plus, la facilitation des politiques d'une approche à base communautaire incluant une propriété foncière clairement définie et un partage équitable des bénéfices n'est toujours pas opérationnelle dans la plupart des pays de la région. Les conditions pour tirer vers le haut de l'échelle les pratiques de restauration efficaces incluent : (i) une reconnaissance de la connaissance locale, (ii) un soutien institutionnel de la mise en pratique des activités de restauration, (iii) des initiatives créatrices de revenus, avec l'aide du marketing et de la valeur ajoutée aux ressource naturelles, et, (iv) une prise en compte des opportunités financières du mécanisme CDM, incluant la REDD.

Prácticas de gestión y restauración de paisajes degradados del sur de África y requisitos para la ampliación

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Los bosques del sur de África son la base de los medios de vida de millones de habitantes de zonas rurales y urbanas, gracias a la provisión de productos no maderables como el suministro de energía y la expansión agrícola que contribuyen a la deforestación y la degradación forestal. Sin embargo, existen prácticas de gestión forestal tradicional y tecnologías reconocidas con el potencial de fomentar la rehabilitación o la restauración de bosques degradados, siempre que estén presentes las políticas y los marcos institucionales adecuados. Este artículo revisa los factores causales de la degradación del suelo y del bosque en el sur de África y destaca algunas de las prácticas eficaces para su restauración. Se encontró que la regeneración natural por diferentes medios, como el monte bajo, el monte medio y cortas selectivas, y el trasmochado, podas y escamondas, fue la forma predominante de restauración en el bosque seco y otros bosques del sur de África. Sin embargo, aunque en la mayoría de países de la región existen políticas que promueven la gestión participativa de los recursos naturales, la implementación de éstas se ha realizado mayormente bajo un enfoque basado en proyectos piloto sin una estrategia de ampliación por parte de los gobiernos. Además, en la mayoría de los países de la región aun no están en funcionamiento las políticas favorables para los enfoques basados en la comunidad, como la tenencia de tierra para tala rasa y la distribución equitativa de beneficios. Las condiciones para la ampliación de las prácticas de restauración que han resultado exitosas incluyen: (i) el reconocimiento del conocimiento local; (ii) el apoyo institucional a la implementación de actividades de restauración; (iii) las iniciativas de generación de ingresos mediante la mercadotecnia y el valor agregado de los recursos naturales; y (iv) el aprovechamiento de las oportunidades económicas del MDL como REDD.

INTRODUCTION

The rate of forest loss within the past few decades is alarming globally (Lamb 2005). According to ITTO (2002), degraded primary forests and secondary forests cover about 500 million ha, while 350 million ha of formerly forested land was deforested between 1950 and 2000. Furthermore, annual loss of natural forests in 1990s was estimated at 15.2 million ha, out of which conversion to other land-uses took about 14.2 million ha (FAO 2001a). The highest deforestation and forest degradation rates in Sub-Saharan Africa (SSA) occur in the dry forests and woodlands where the pressure for land is continuously increasing due to rampant poverty and limited livelihood options. 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). Restoration of degraded forest and woodland areas therefore may contribute to both peoples' livelihoods and environmental quality in SSA, southern Africa inclusive.

The southern African vegetation is generally referred to as the Zambezian Phytoregion. The region covers over ten countries in central and southern Africa lying between latitudes 3° and 26° south with a total area of 377 million ha (White 1983). The major vegetation formation for this biome is Miombo woodlands which covers 10% of the African land masses (White 1983). In addition a number of other vegetation formations namely the undifferentiated woodlands (Zambezi teak and *Vachelia* woodlands), Mopane woodlands and semi-arid scrublands do occur within this Phytoregion (Timberlake *et al*. 2010). These vegetation formations 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. Typically, the vegetation formation of southern Africa ranges from tall to almost closed-canopy stands and many areas of cleared woodland arising from land clearing for agriculture and wood extraction for energy (Syampungani 2008, Syampungani *et al*. 2009, Dewee *et al*. 2010).

The management practices for the woodlands in southern Africa are designed to meet specific tangible products (see Chidumayo *et al.* 1996, Chirwa *et al.* 2008, Dewees *et al.* 2010). The productivity of Miombo woodland is influenced by the way Miombo tree species respond to both harvesting and the management practices. Most Miombo woodland species usually respond to wood harvesting by coppice regeneration while others respond to injury arising from cultivation through root suckering (Chirwa *et al.* 2008, Syampungani 2008). The best harvesting techniques and management practices in the post-harvest era are those that promote regeneration. For example, adhering to optimum diameter classes within which particular species have high coppicing effectiveness would provide for enhanced coppicing ability for many woodland species (Chirwa *et al.* 2008).

Forest and other related policies in most countries in southern Africa have been revised to address the access of the local communities to the resource with the hope that it will result in sustainable use and management. In addition, most of the countries in southern Africa have signed the SADC Forestry Protocol whose main objectives inadvertently address long term improvement of the forest condition (Ham and Chirwa 2011). Furthermore, the region has demonstrated strong commitment to implementing the UNCCD by ratifying it and by developing national and sub-regional programmes to combat desertification with collective response to problems of land degradation, drought and desertification thereby directly facilitating land and forest rehabilitation and restoration.

In addition to the foregoing, there are recognized traditional forest management practices and technologies and approaches 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 of forest and land degradation. This paper therefore reviews the factors that have caused land and forest degradation in southern Africa and documents some of the interventions through both traditional and other practices and technologies that are used to rehabilitate and/or restore degraded lands. In addition, the paper identifies some prerequisites that need to be in place in order to be able to up-scale the most successful restoration practices and technologies in southern Africa.

LAND USE CONVERSION AND DEGRADATION

Changes in dry land forest ecosystems and degradation in southern Africa are mostly driven by agricultural expansion and energy needs. These 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. As reported by FAO (2008), land tenure arrangements and associated equity issues were major threats to the sustainable use of land resources in southern Africa. The communal land tenure system is the most widespread, in which individual property rights are weak. Hence, this poor land and tree tenure in southern 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.

An average loss ranging from 0.2 to 1.9% of forest land attributed to unsustainable harvesting practices including expansion of agricultural land and use of fire for land clearing as well as the change in forest classification has been reported in the region. In addition, 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. For example, charcoal production and trade provide income generating opportunities for both the rural and the urban communities of southern Africa. In Zambia alone, the charcoal industry has been reported to generate and support about US$30 million and 60,000 Zambians, respectively (Kalumiana and Shakachite 2003). According to Falcão (2008), 150,000 families are employed in charcoal production in Mozambique and on average the annual income generated is about US$ 250–300 per family. In Malawi, estimates show that 92,800, people owe their livelihood to the charcoal industry (Kambewa *et al.* 2007).

As presented by FAO (2011), Zambia has the largest (67%) of its land area covered with forest followed by Mozambique (50%) and Zimbabwe (40%). Deforestation varies across southern Africa with Zimbabwe having the highest rates (1.6%) between 1990–2000, as well as 2000–2010. On the other hand, Swaziland has the lowest deforestation rate at 0.9% and 0.8% in 1990–2000 and 2000–2010, respectively (Table 1). A number of factors may be attributed to the variation in deforestation rate from country to country namely; political instability affecting the economic wellbeing of the citizens, population increase, among others.

RESTORATION APPROACHES AND PRACTICES

Management systems

The management practices for the woodlands in southern Africa are designed to achieve specific objectives that are normally intended to produce a specific product such as poles, timber, etc (see Chidumayo *et al.* 1996, Chirwa *et al.* 2008, Dewees *et al.* 2010). This is possible because tree species respond differently to harvesting and management regimes. Responses are mainly dependent on a number of factors; phenological state, degree of resistance to disturbance mechanism such as fire, ability to re-sprout, seeding patterns, seed germination characteristics and seedling development

TABLE 1 *Annual rates of change of forests in southern African woodlands*

Country	Land area '000 ha	Extent of forest 2010: Forest area	% of land area	Area per 1,000 people	Annual change rate: 1990–2000		2000–2010	
		'000 ha	%	ha	'000 ha	%	'000 ha	%
Angola	124,670	58,480	47	3,245	–125	–0.2	–125	–0.2
Botswana	56,673	11,351	20	5,909	–118	–0.9	–118	–1.0
Lesotho	3,036	44	1	21	0	0.5	0	0.5
Malawi	9,408	3,237	34	218	–33	–0.9	–33	–1.0
Mozambique	78,638	39,022	50	1,743	–219	–0.5	–217	–0.5
Namibia	82,329	7,290	9	3,423	–73	–0.9	–74	–1.0
South Africa	121,447	9,241	8	186	0	0	0	0
Swaziland	1,720	563	33	482	5	0.9	5	0.8
Zambia	74,339	49,468	67	3,920	–167	–0.3	–167	–0.3
Zimbabwe	38,685	15,624	40	1,254	–327	–1.6	–327	–1.9

FAO, 2011

(Chidumayo *et al.* 1996). Miombo woodland usually responds to wood harvesting by coppice regeneration, but the rate of regeneration is affected by human activities (Chirwa *et al.* 2008). The best harvesting techniques and management practices in the post-harvest era are those that promote regeneration. Employing either of these systems requires that some management mechanisms are put in place to ensure high species and woodland productivity. For example, adhering to optimum diameter classes within which particular species have high coppicing effectiveness would provide for enhanced coppicing ability for many woodland species (Chirwa *et al.* 2008). Additionally, protection of young re-growths against fires would enhance their survival and consequently their establishment and development into adult trees.

Traditional management systems

Clarke *et al.* (1996) provided a review of some of the traditional practices and emphasized the inextricable link of the trees/woodlands and agricultural and livestock management systems in Africa. In some areas of Zimbabwe, local leaders control the felling of trees for small-scale use and permission may be sought for harvesting certain tree species. Traditionally, women would only be permitted to collect dead wood to be used as firewood. Environmental religion is believed to be at the centre stage of most of the traditional management systems in southern Africa. In some places, the bark may only be harvested on the west and east facing sides of the trunk, because it is believed that is where the most potent medicines are found. This was a way of preventing "ring barking". Control of use was also sometimes governed by traditional cultural practices. In Zimbabwe, Zambia, Tanzania and Mozambique, trees growing around sacred water sources may not be felled for fear of the water drying up (van Rijsoort 2000). Individual large trees are normally used for traditional ceremonies and therefore not felled as they are thought to have ties to the spirits (van Rijsoort 2000). Clarke *et al.* (1996) highlighted the wide spread importance of sacred groves as dwelling places for ancestral spirits, burial grounds, protection of springs and as sites for rainmaking ceremonies, in Zimbabwe, Zambia and Mozambique. Sacred groves are protected using religious sanction and/or through fines imposed on violators by the Chief Priest who is the custodian of the grove.

Chidumayo *et al.* (1996) have provided an extensive review of the harvesting practices in southern Africa which are usually dependent on end use. Pollarding is practised throughout the Miombo region, to a greater or lesser extent. In Zambia, mature woodlands are still pollarded and lopped in the preparation of ash gardens in the traditional *chitemene* shifting cultivation system. In Zimbabwe, branches are lopped for a variety of reasons: for fuelwood, browse, fibre, fruit harvest and Mopane worms in areas where trees are scarce and felling of whole trees is prohibited (Chidumayo *et al.* 1996). In areas where clear cutting is for permanent agriculture, tree regeneration is through root or coppice. Subsequent management would be through selective thinning for poles and timber in the long term. The 'nicking' of the cut edge will encourage sprouting from stump (Lowore and Abbot 1995), while deep ploughing is said to increase the stocking rate by causing root suckers to develop (see Chidumayo *et al.* 1996).

Silvicultural systems

Some basic silvicultural systems have been employed in harvesting Miombo woodland products in southern Africa namely; coppice with standard, selective cutting, clear felling, Harvesting of non-timber forest products, and fire management.

Coppice with standard

The system involves leaving behind few trees over a harvested area. The high value species are left until maturity whilst the other species are clear cut and the regeneration is managed to produce a range of small dimension wood products such as firewood and poles (Shackleton and Clarke 2007). The trees that are left may be important for timber, fruit, or fodder. For example, in Zambia most of the trees that are left over a cut area are timber species (Syampungani *et al.* 2011). However, the system has been proposed for use by small scale farmers in Malawi as a means of maximizing the production of firewood and poles whilst retaining high value species that produce non-wood products and other services, such as fruit trees with spiritual significance (Lowore and Abbot 1995). The system has the advantage of retaining a portion of tree cover and protecting site from erosion and sun scorch.

Selective cutting

Selective cutting is the cutting down of selected trees in a forest according to criteria regarding minimum tree size for harvesting so that growth of other trees is not affected. In Zambia, for example, as many trees as possible were cut for timber and poles and the stumps trimmed (see Lees 1962). The selection varied from tree to tree and species to species because the selection was dependent on size and suitability for intended product (Chidumayo *et al.* 1996). Branches were then piled away from live trees and stumps or sold as firewood or converted to charcoal. The cut-over area was early burnt for up to 10 years in order to encourage and protect regeneration in groups occurring in canopy gaps. However, Hosier (1993) views selective harvesting negatively in that an increase in the net price of a wood product, improvement in the harvesting or processing technology or increased poverty among harvesters tend to reduce selectivity and may cause over exploitation of the harvested species. It has been suggested that shading by canopy trees contributes to slow shoot growth of suppressed saplings in Miombo woodland (Werren *et al.* 1995).

Clear felling

Clear felling is appropriate when harvesting firewood for the charcoal industries (Shackleton& Clarke 2007). Since a large area is cleared the system results in the highest rate of regrowth of the three systems. This is because the stumps of most Miombo trees have the ability to produce coppice shoots once they are cut (Strang 1974, Chidumayo 1993). It tends to produce rapid regeneration which can be managed according to the product requirement.

Harvesting of non-timber forest products

While traditionally emphasis of silvicultural systems was on wood products such as timber, recently this has been extended to incorporate other wood products such as firewood and poles of various sizes (Lowore and Abbot 1995). However, very little research has been done on harvesting rates and designing management systems for non-wood products. The argument has been that products which are seasonally available such as fruits do not require harvesting limits, and that provided no damage is done to the trees during harvesting, the impact of fruit removal is minimal (Shackleton and Clarke 2007). For example, Emanuel *et al*. (2005) demonstrated that 92% of fruits of *Sclerocarya birrea* subsp. *caffra* could be harvested without impacting the population's size class profile. However, harvesting of bark for various products including medicine, rope fibre and for making beehives can be highly destructive and result in increased tree mortality (Chidumayo *et al*. 1996). A number of methods for reducing the negative impacts of bark harvesting have been proposed and tested, notably by using improved harvesting methods that prevent ring barking and reduce fungal infestation and the use of leaves to obtain medicinal products instead of bark (see Geldenhuys *et al*. 2006).

Fire management

Much of the current knowledge of fire and its effects on Miombo woodland structure and functioning has come from general observation supplemented by information derived from a limited number of experiments. The area of focus among the early researchers has been more on changes in species composition with emphasis on different ecological groups that tend to develop over time (Trapnell and Langdale-Brown 1962, Lawton 1978). However, several studies attempted to determine the effects of fire frequency and burning period on the structure and function of the Miombo woodlands in general (Trapnell 1959, Kikula 1986, Chidumayo 1988, Zolho 2005). These studies demonstrated that species dominance and coppice effectiveness can be influenced by fire frequency and intensity. This is because different Miombo species respond differently to fire attack (Lawton 1978). But high intensity fires on perennating organs and food reserves generally results in die-back of shoots as a result of depletion of root food reserve of parent plants due to the systematic and continuous effects of fire (Kennard *et al*. 2002).

WOODLAND RESTORATION PRACTICES

The choice of practices and/or 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. While other interventions are not discussed specifically, it is important to look beyond the forest rehabilitation and consider other socio-economic and ecological interventions. Some of the rehabilitation techniques identified as playing a role in rehabilitation in the southern Africa dryland forest ecosystems include: (i) Natural Regeneration, (ii) Artificial Regeneration/Seedlings and (iii) Traditional Agroecosystems.

Natural Regeneration

Most of the woodlands across southern Africa are capable of recovering following disturbance cessation (Geldenhuys 2005, Chirwa *et al.* 2008, Syampungani 2008). The re-growth may be from either coppices of stumps or root origin or stunted seedlings present in the herbal layer at the time of clearing (Chidumayo and Frost 1996). Savanna woodland species generally have both vertically and horizontally extensive root systems which facilitate recuperation after cutting (Mistry 2000). These extensive root systems tend to produce root suckers and coppices once the above-ground parts are removed. Syampungani (2008) observed that a number of species tend to coppice namely; *Brachystegia* spp., *Isoberlinia angolensis*, *Julbernardia paniculata*, *Pseudolachnostylis maprouneifolia*, among others in stands that were previously under charcoal production and slash and burn agriculture. Natural regeneration including assisted natural regeneration and coppicing has been reported in Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe (Table 2). Pollarding is also a common practice in most countries especially for trees on the farmland. Although fire as a management tool has been tried in some countries (Namibia, Swaziland and Zambia), literature indicates that it is mostly used to manage grazing areas (Scott 1970, Forbes and Trollope 1991, Archibald *et al.* 2010, McGranahan and Kirkman 2013).

The differences in regeneration mechanisms among the various vegetation formations of Southern Africa are as a result of inherent climatic and edaphic variation across the southern African vegetation and to an extent the resultant land use. The various regeneration mechanisms tend to influence the restoration technique that have to be employed in the rehabilitation of the degraded woodland/forest type. For example, management of coppices of most of the species such as protection against fires and herbivory in most of the vegetation have been used as a tool for increasing their survival rates. The inherent nature and response of various species to various disturbance factors provides a guide on how such species and their associated vegetation could be restored; species with extensive root systems are easily managed through suckering and coppicing in the restoration of degraded vegetation.

Stocking and basal area: productivity potential from restoration in natural woodland systems

Stem densities and basal area vary considerably across various vegetation type of the Miombo ecoregion. These parameters may be used to express the productive and recovery potential of the vegetation. Woodland type, recovery stage and the age of the woodland have direct implication on the stocking and therefore the restoration of southern African woodlands. Environmental factors (e.g. soil depth and rainfall pattern) and anthropogenic factors may also influence the

TABLE 2 *Some natural regeneration techniques practiced in in some countries of southern Africa*

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

NR = natural regeneration

stocking and restoration of the various vegetation formations within the Miombo ecoregion.

A number of studies indicate that stem density vary from one vegetation formation to another. For example, density has been observed to range from 837 to 1131 stems per hectare in old growth Kalahari woodlands of the undifferentiated woodland while in Miombo old growth, the stocking was reported to be between 2434 and 2773 stems for stems of ≥1 cm diameter at breast height per hectare (Syampungani 2008). Higher variations in stocking (stems per hectare) have also been observed in mesic, semiarid and arid localities in central lowveld of the South African savannas. Shackleton and Scholes (2011) recorded higher values in mesic (18530 stems per hectare) compared to semi-arid (3996 stems per hectare) and arid (3978 stems per hectare) localities. A comparison of regrowth stand densities between Kalahari woodlands and Miombo woodlands indicated a significant variation from 1131 to 6685 stems per hectare in Miombo woodland to 7264 to 9700 stems per hectare in Kalahari woodlands (Table 3). This may be attributed to differences in species and environmental factors between these vegetation types. A variation in stocking per recovery stage/disturbance factor was reported by Strang (1974) in the Zimbabwean Highveld which was protected against fires. Initially, a steady increase in stocking from 925 to 5810 stems per hectare was observed between 1.5 and 18 years since cutting. However, lower stocking levels were observed in the same locality which was constantly experiencing fires (Strang 1974).

The basal area ranged from 7 to 22 meter cube per hectare in old uneven aged stands of various woodland types (Table 3) with the lowest being recorded on lithosols in southern Malawi at about 650 mm mean annual precipitation and the highest being recorded in wet Miombo woodland deep soils of the Democratic Republic of Congo at 1270 mm rainfall (Lowore *et al.* 1994, Freson *et al.* 1974). Lower basal area (e.g. 9.81 meter cube per hectare) was mostly associated with young regrowth stands of up to 20 years old since cutting (Chidumayo 1987). However, higher values of stand basal areas of between 30 and 50 meter cube per hectare have been recorded in wet Miombo and dry Miombo of Zambia and Zimbabwe respectively, in small sized plots (Chidumayo 1985, Grundy 1995).

TABLE 3 *Growth parameters of some southern Africa woodlands*

Range of variables		Vegetation type	Authors
Density (stems/ha)	1121-6926	Re-growth (Miombo)	Syampungani *et al*. 2010; Strang 1974
	2434-2773	Uneven aged mature woodland(Miombo)	Syampungani 2008
	3978-18530	Uneven aged mature woodland (South African Central lowveld)	Shackleton and Scholes 2011
	837-1131	Uneven aged mature woodland (Kalahari)	Timberlake *et al*. 2010
	7264-9700	Regrowth (Kalahari)	Timberlake *et al*. 2010
Basal area (m^2)	7-22	Uneven aged mature woodland (Miombo)	Lowore *et al*. 1994; Freson *et al*. 1994
	7.12-12.44	Uneven aged mature woodland (South African Central lowveld)	Shackleton and Scholes 2011.
Mean biomass ($Mg\ ha^{-1}$)	1.5-90	Uneven aged mature woodland (Miombo and Mopane woodland)	Chidumayo 1991 Tietema 1989.
	22-44.47	Uneven aged mature woodland	Guy 1981; Martin 1974
	18.41-37.9	Uneven aged mature woodland (South African Central lowveld)	Shackleton and Scholes 2011.
Growth rate (Mean annual ring width, mm)	4.4-5.6	Regrowth (Miombo)	Syampungani *et al*. 2010
	2.3-4.8	Uneven aged mature woodland (Miombo& South African savannas)	Shackleton 2002; von Maltiz *et al*., 1999; Chidumayo 1988

Source: Chirwa *et al.* (2014)

Artificial Regeneration / Seedlings (Plantations and Woodlots)

The success of seedling establishment in natural forests and woodlands is low due to moisture and heat stress. The majority of Miombo woodland tree seedlings, notably *Brachystegia* and *Julbernardia*, have non-foliaceous and non-chlorophyllous cotyledons with a short life span. In addition, Chidumayo *et al.* (1996) indicated that both *Brachystegia* and *Julbernardia* have ectomycorrhizae and it is also possible that the early death of some seedlings may be because these seedlings fail to establish an association with mycorrhizae by the time they shed their cotyledons. Mortality of young seedlings is also due to uncontrolled fires and grazing by the animals. Chidumayo *et al.* (1996) showed that stem mortality under late burning was 5–6 times higher than under early burning but mortality varied among species.

On the other hand, tree planting through woodlots and/or plantations is a viable option to increasing woody biomass and tree products to meet the long-term needs of the people. Trees have also been planted to produce environmental services, such as soil stabilization and amelioration, windbreaks and shade and carbon sequestration (Chamshama *et al*. 2010). Southern Africa currently has about 2 200 000 ha of forest plantations, which accounts for about 28% of total African plantations (Table 4). Almost two thirds of this, about 1 500 000 ha, are in South Africa. The plantations consist of fast growing exotic species, such as *Pinus patula*, *Cupressus lusitanica* and *Eucalyptus* spp. which were established mainly for the production of industrial roundwood for export and in some cases for wood fuel. Only in the case of South Africa, Swaziland and Zimbabwe have plantation programmes been strongly linked to industrial utilisation. Limited markets and accessibility undermined the industrial use of Malawi's plantations, while the civil wars in the past affected the management of plantations in Angola and Mozambique. However, there is a rapid expansion of forest plantations in Northern Mozambique (Landry and Chirwa 2011).

Traditional Agroecosystems

Farming systems in southern Africa have largely remained subsistence in practice on ever-decreasing plots of lands with declining soil fertility. These farming systems have become inadequate to cope with population growth explosions that are experienced in the region. The general agroecosystem / farming system in Zambia and Malawi is the *maize mixed farming* but Zambia also has the *forest based farming and root crop farming systems* (Musinguzi 2011). The *Forest based farming system* is practiced characteristically in humid forests in the region and farmers practice shifting cultivation by clearing a new plot in the forest every 3–5 years and then in the past allowed a fallow period of 7 up to 20 years. This is the basis of the Chitemene system in Zambia and the Machambas that are used to cultivate crops such as cassava, maize, beans, and potatoes in Niassa Province of Mozambique (Chidumayo 1987, Landry and Chirwa 2011).

The traditional tree legume-based system (Faidherbia albida *parklands*)

For centuries farmers have retained a low density of trees in the parkland or two-tiered systems in the tropics, especially in the semi-arid areas in order to improve the yield of understorey crops (Akinnifesi *et al.* 2008). In southern Africa, traditionally farmers grow crops under scattered trees including the *Faidherbia albida*/maize system in southern and central Malawi. *F. albida* has a unique characteristic of shedding most of its leaves during the wet season and resuming leaf growth during the dry season. This makes it possible to cultivate under its canopy with minimum shading effect on

TABLE 4 *Extent of forest plantations in southern African countries*

Country	Land area	Total forest area	Plantation forest	% area of Plantation forest area
	000 ha	000 ha	000 ha	%
Botswana	56,673	12 427	1	0.01
Lesotho	3,036	14	14	100
Malawi	9,408	2 562	112	4.4
Mauritius	202	16	13	81.3
Mozambique	78 638	30 601	50	0.2
Namibia	82,329	8 040	0	0
South Africa	121,447	8 917	1 554	17.4
Swaziland	1,720	523	161	30.8
Tanzania	88 359	38 811	135	0.3
Zambia	74,339	31 246	75	0.2
Zimbabwe	38,685	19 040	141	0.7
SADC	554 919	152 195	2 256	1.5

Source: FAO (2001b; 2011)

the companion crop. Substantial benefits are realized from these practices as resource-use by trees and associated crop components rarely overlap. The cultivation of crops under canopies of *F. albida* is the most notable of such traditional agroforestry practices in southern Africa (Khumalo *et al.* 2012).

Dambo land ecosystems (Dimba cultivation and pastures)
Smallholder farmers cultivate uplands as well as wetlands (Khumalo *et al.* 2012). The dambo is cultivated in the dry season intensively utilising both mono-cropping system as well as mixed cropping patterns also known as intercropping dominated by maize, beans, sugarcane and green vegetables. Apart from such intensive dry-season cultivation, dambo are a source of green grazing pastures when the uplands have dry grass. Such practices of cultivation and grazing result in vegetation degradation as invaders such as *Cynodon, Urochloa* and *Sporobolus* grass species become dominant.

Transhumance grazing systems
Seasonality is considered to be an important factor in the agricultural systems of the southern African agroecosystems. It revolves around the very distinct wet and dry seasons. The availability of pasture in the late dry season is of particular importance in the management of the agroecosystems (Clarke *et al.* 1994). In Zambia, transhumance grazing is still practised on the Kafue flats, where livestock graze in woodlands in the wet season and on the low-lying flood plains in the dry season (Sørensen 1993). Scoones (1990) also reported this pattern of grazing in Zimbabwe. This is important in the restoration of degraded land in that it allows the trees to recover through vegetative-coppice regrowth just before the start of the wet season.

AGROFORESTRY PRACTICES AND TECHNOLOGIES

In Africa, and particularly southern Africa, the main constraint to agricultural productivity, apart from rainfall variability, is soil nutrient deficiency. For this reason, agroforestry research in the region has focused on soil fertility replenishment (SFR) technologies over the years and the adoption and scaling-up of these practices is the main thrust of the ongoing on farm research (Akinnifesi *et al*. 2008; Akinnifesi *et al.* 2010). Table 7 gives the extent of use of different Agroforestry systems and/or technologies in southern Africa. SFR encompasses a range of agroforestry practices aimed at increasing crop productivity through growing trees (usually nitrogen-fixing), popularized as *fertilizer tree* systems, directly on agricultural land. Fertiliser tree systems involve soil fertility replenishment through on-farm management of nitrogen-fixing trees (Akinnifesi *et al.* 2010, Mafongoya *et al.* 2006).

The different fertiliser tree systems that have been developed and promoted in southern Africa (Akinnifesi *et al.* 2008, 2010) over the last two decades include:

Intercropping
This is the simultaneous cultivation of two or more crops on the same field; usually, involving maize as the main crop in southern Africa and other agronomic crops as risk crops. In agroforestry based intercropping systems, species such as pigeon pea (*Cajanus cajan*), *Tephrosia vogelii, Faidherbia albida, Leucaena leucocephala,* and *Gliricidia sepium* are prominent. *Gliricidia* is a coppicing exotic species that is being used in the intercropping technologies throughout southern Africa.

Relay Cropping: is a system whereby nitrogen-fixing trees, shrubs, or legumes such as *Sesbania sesban, Tephrosia vogelii, S. macrantha, Crotalaria spp.,* or perennial pigeon pea (*Cajanus cajan*), are grown as annuals and planted 3 to 5 weeks after the food crop.

Improved Fallow
This emerged as a promising alternative to traditional fallows. In an improved fallow, fast-growing, nitrogen fixing species such as *Sesbania sesban, Tephrosia vogelii, Gliricidia sepium,* and *Leucaena leucocephala* are grown for 2 to 3 years in the fallow plot after which, they are felled. The most widely tried system in Eastern Zambia is the improved fallow system while different forms of conservation agriculture are being promoted in Malawi, Zambia and Zimbabwe. The most common traditional systems are common in Malawi, Mozambique and Zambia (Table 5).

CONTRIBUTING FACTORS TO UP-SCALING RESTORATION PRACTICES

There are very few areas of the natural forests and woodlands in the sub-region that could be described as pristine woodlands or forests. In fact, most of the forest areas have been associated with human activities and have been transformed to secondary forests. The main forest restoration practices advocated in natural forests and woodlands in all the countries in southern Africa is mostly through coppice natural regeneration because of the associated benefits of better rates of growth due to the already established root system (Chirwa *et al.* 2014). However, other forms of natural regeneration in the form of associated natural regeneration have been advocated by some development projects where the main objective was the rehabilitation of watershed management areas; and in South Africa in areas where removal of invasive alien species (Australian Acacias, Pines, etc.) is the main objective (see Chamier *et al*. 2012).

While forest policies and their related policies have been revised in line with the SADC forestry protocol and therefore incorporate the participation of local communities in natural resource management of the natural resource, there is still a problem of full scale implementation due to questions of land and/or tree tenure; and in cases of joint/co-management the benefit sharing mechanism are still not satisfactory to the communities (see Ham and Chirwa, 2011).

Addressing the linkages between Agriculture, Forest, and Land Use (AFOLU) and Reduced Emissions from Deforestation and Degradation (REDD) is being advanced under the

TABLE 5 *Some Agroforestry Systems and Technologies in southern Africa*

Country/	Improved Fallows	Contour Hedgerows	Conservation Agriculture	Boundary planting	Farm Forestry/ Woodlots	Traditional Systems
Angola						
Botswana						
Lesotho						
Malawi		√	√	√	√	√
Mozambique						√
Namibia						
South Africa				√	√	
Swaziland						
Zambia	√		√	√		√
Zimbabwe			√	√		

African Climate Solution (COMESA-EAC-SADC 2011). According to the Intergovernmental Panel on Climate Change (IPCC, 2014), carbon sequestration through the increase of carbon stocks, and particularly the conversion of unproductive croplands and grasslands to agroforestry, has the highest potential to soak up atmospheric carbon at rates of the order of three tonnes per hectare per year. The promotion of and/or up scaling of Climate Smart Agriculture through conservation agriculture, which is widely promoted in the region, fits into both the AFOLU agenda as it is fully incorporated in national development plans and/or strategic agricultural programmes for Malawi, Mozambique, Zambia and Zimbabwe.

CONCLUSIONS

It is clear from the review that natural regeneration of different forms especially through coppicing is the predominant form of restoration in dry forests and woodlands of southern Africa. This may carry different forms of silvicultural management practices (complete coppice; coppice with standards and selective cutting; pollarding, pruning and lopping) depending on the end products.

While the review shows promotion of participatory natural resource management are in place in most countries of the region, implementation of this has mostly taken pilot project based approach with no strategies for up scaling by the governments. However, opportunities exist where dry forests and woodlands can be sustainably managed provided tenure and benefits are clearly outlined and through promotion of income generating activities that are beyond tree utilization/ harvesting. For example, Zambia has well established Game Management Authority that seems to have some form of positive sharing of benefits (see Phiri *et al*. 2012).

There is also need to take cognisance of the linkage of the livelihoods needs of local people and global environmental requirements. Therefore multifunctional approach to land use management augers well with the current agro-ecosystems of southern Africa. In addition, most of the development strategies in the region highlight the need for sustainable management of the land resource. For example, climate smart agriculture such as conservation agriculture, agroforestry and indeed re-afforestation have been highlighted as the way of addressing climate change by agricultural sector plans in most countries in the region. The conditions for up-scaling successful restoration practices identified in southern Africa include the following:

- ✓ Enabling policies for community based approach including clear cut land tenure and equitable benefit sharing
- ✓ Recognition of local knowledge
- ✓ Institutional support for implementation of restoration activities
- ✓ Income generating initiatives through marketing and value adding of natural resources
- ✓ Taking on financial opportunities from CDM mechanism including REDD

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