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Feature article

RESTORATION OF NATIVE FOREST FLORA IN THE DEGRADED HIGHLANDS OF ETHIOPIA: CONSTRAINTS AND OPPORTUNITIES

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ABSTRACT: Wide spread deforestation and subsequent degradation is severely threatening the natural forest resources in Ethiopia. What is imperatively and urgently needed today is ecological restoration. In order for ecological restoration to be successful and cost effective, critical analyses of possible constraints and available opportunities are crucial. Such Knowledge increases our understandings of ecosystem responses and a more reasonable prediction of where and why restoration efforts will be difficult or possible. These understandings will also improve the decision-support systems for the kind of restoration strategies or tools to apply and what kind of management techniques to follow. Available literature indicated that scarcity or complete absence of viable soil seed banks under natural environments and in environments affected by humans, such as abandoned farmlands, poor seed rain/dispersal and site impoverishment would be severe limitations to ecological restoration in the country. On the other hand, land abandonment due to marginalization followed by the establishment of plantation forests as foster crops are opportunities that could be utilized for rapid and productive restoration of the vast degraded ecosystems in the country. Nevertheless, successful utilities of these management options certainly demand conservation of the remnant natural forests to serve as propagule donors. Hence, conservation of the scattered remnant forests in the country is the major prerequisite for successful future restoration ventures.

Key words/phrases: Land degradation, seedling bank, seed rain, soil seed bank, tree plantations

INTRODUCTION

Discussion about the alarming forest destruction in the highlands of Ethiopia has been in progress for some decades already. However, detailed analyses of the biodiversity crises associated with the destruction and practical solutions on how to effectively reverse the course of destruction in the country are generally scarce. Biodiversity management is not necessarily conservation over a future capital. Biodiversity is the resource from which several cereals, fruits, vegetables, quality firewood, quality lumber, palatable fodders, domesticated animals, etc. have been screened out through millennia. The high probability of global climate change and the increasing genetic manipulations of the limited number of presently used crops suggest that maintenance of biodiversity is probably the only insurance for humanity (Anonymous, 1992). This is particularly so for countries like Ethiopia, which is characterized by fragile ecosystems and recurrent drought. While humans have depended and will depend on biodiversity for food, medicine, income and industrial uses, roles of biodiversity in balancing ecosystem functions are unquestionable. We know that only properly functioning ecosystems are providing the most important anthropocentric functions, i.e. supplying air, water and soil, and that biodiversity is at the heart of such ecosystem health.

Situated in the northeastern highlands of tropical Africa, Ethiopia has unique geography with enormously diversified edaphic, climatic and biological resources. Ethiopian landmass covers a wide altitudinal variation ranging from 110 m below sea level to 4620 m above sea level. Furthermore, Ethiopia shares more than 50% of the

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Afromontane regions, lands above 1500 m, of Africa and 79.7 % of the lands above 3000 m (Yalden, 1983). This geographical diversity has yielded diversified flora and fauna rich with endemic elements (Sayer *et al*., 1992; Anonymous, 1992; Eshetu Yirdaw, 2001). The number of species of higher plants in Ethiopia is estimated at about 6,500 – 7000, of which 780 – 840 species are endemic to the country (IUCN, 1986; Demel Teketay, 2000). The floral endemism is also paralleled by faunal endemism (Anonymous, 1997). About 242 species of mammals and 847 species of birds exist in the country, of which 22 species of mammals, 16 species of birds, 5 species of reptiles and 30 species of amphibian are known to be endemic to the country (Sayer *et al*., 1992; Anonymous, 1997; Demel Teketay, 2000). This places Ethiopia in the fifth largest flora in tropical Africa (Eshetu Yirdaw, 2001), and the richest in avifauna in mainland Africa (Anonymous, 1997; Demel Teketay, 2000). Moreover, Ethiopia is one of the eight Vavilov's centers of crop diversity, which all together makes the country to be one among the most important international centers of biodiversity (Anonymous, 1992). Many of the genetic resources in this country are still unexplored. Little is known, for instance, about the insects and other groups of invertebrate species.

Unfortunately, these large biodiversity resources are under continuous and severe threats of destruction. Habitat loss/degradation and fragmentation due to agricultural land expansion is probably the major threats to the biodiversity resources of Ethiopia. A recent report on monitoring forest resources of Ethiopia (Reusing, 1998) showed that in the 1980s, only 0.2% of the originally assumed 40% cover of natural high forests remained in the country. This same source estimated the annual rate of deforestation to be 163,600 ha, which is within the range of a previous estimation of 150,000–200,000 ha (Anonymous, 1994). No doubt that such massive habitat loss or habitat degradation is accompanied with huge erosion of genetic resources of unprecedented rate, including the gene pool of wild populations of *Coffea arabica* L. (Tewolde Berhan Gebre-Egziabher, 1990; Demel Teketay, 1999; Tadesse W/Mariam and Demel Teketay, 2001; Tadesse W/Mariam *et al*., 2001; 2002). For instance, it has been reported that 129 plant species, which are endemic to Ethiopia and Eritrea, were threatened due to forest destruction (Ensermu Kelbessa *et al*., 1992). In this context, urgent actions are imperative not only for the sustainable management of the meager remnant natural forests but also for prompt ecological restoration management in order to preserve the rich biodiversity resources of the country from complete disappearance.

Although ecological restoration is viewed as second to the preservation of the original habitats, its potential as a management tool, or even as a means of preventing the continual loss of biodiversity, has been widely acknowledged (Wilson, 1992; Young, 2000; Muutka and Laasonen, 2002). This is particularly relevant in situations like Ethiopia where the original habitats are already at stake. Although little efforts are practically observable in the country at present, we hope that the next era would, definitely, be the era of restoration management for Ethiopia, like it is today in most parts of the world. If so, almost all ecological restorations will be expected to take place on abandoned farmlands and/or severely degraded sites. Consequently, critical assessments of possible limitations and responses of these ecosystems to restoration management would be a vital prerequisite.

Ecological vegetation restoration deals with nature management practices aimed at the reconstruction of a natural or semi-natural ecosystem on degraded or modified lands (Miller *et al*., 1995; Bakker *et al*., 1996a). The recovery of plant species, their composition, structure and function on restoration sites depend on three main factors: (i) the presence of persistent seeds in the soil ("seed bank") as a 'memory' of the past plant community; (ii) if seeds had disappeared from the soil seed banks, they have to be transported/dispersed to the restoration sites ("seed rain"); and (iii) the sites of restoration have to be proved "safe sites" to induce restoration (Harper, 1977). Without the presence or arrival of seeds, restoration of plant species would not be possible (Bakker *et al*., 1996a), and if restoration sites are not habitable, arriving seeds may not get the chance to germinate and grow. Knowledge on these factors will increase our understanding on ecosystem responses and to predict, more reasonably, where and why restoration efforts will be difficult or possible. These understandings will also improve the decision-support processes for the kind of restoration strategies or tools to apply, what kind of vegetation management and control mechanisms to follow.

Generally, restoration processes at a site may be fast or slow depending on the degrees of previous land use effects on the above mentioned three factors. It is true that most disturbances destroying a site often leave it with some self-regenerating potential. However, we could expect that most degraded lands are poor to very poor in many aspects of self-regenerating potentials, and these potentials are rarely strong enough to achieve the desired degree of rehabilitation within a desired 'time frame'. In fact, the time dimension needs to be focused in designing ecosystem rehabilitation projects. This, therefore, calls for some methods of speeding up the process, often called active restoration. In this paper we attempted to review available information on the constraints and opportunities for successful restoration of native forest flora on degraded lands in the highlands of Ethiopia.

CONSTRAINTS

Scarcity or complete absence of soil seed banks of woody species

Usually, disturbances do not destroy sites completely, and some plant propagules remain at degraded sites, in or on the soil, which are collectively called soil seed bank. Soil seed banks are aggregations of viable seeds accumulated in or on the soil over several years potentially capable of replacing adult plants (Baker, 1989). Seed banks are acknowledged as a low cost restoration technique since they often dispose of many of the problems associated with collecting, storing, sowing seeds and transplanting individual seedlings raised in a nursery (van der Valk and Pederson, 1989). However, the ability to restore native forest flora from soil seed banks depends primarily on the viability and composition of the soil seed banks at restoration sites. One of the major potential constraints related to restoration of native forest flora on degraded lands in the highlands of Ethiopia will be the scarcity or complete absence of long lived seeds, particularly of woody species, in the soils of both highland forests and abandoned degraded farmlands.

Soil seed banks in natural and plantation forests

Results from a number of studies on the soil seed banks of natural and plantation forests in the highlands of Ethiopia have shown that the proportion of viable seeds of woody species in the soil is extremely low (Table 1). For instance, viable seeds of native woody species are critically low in soils of mature natural forests (Demel Teketay and Granström, 1995; Demel Teketay, 1997a, 1998; Feyera Senbeta and Demel Teketay, 2001, 2002; Kebrom Tekle and Tesfaye Bekele, 2000; Feyera Senbeta *et al.*, 2002a) and plantation forests established on degraded natural forest sites (Feyera Senbeta and Demel Teketay, 2001, 2002; Feyera Senbeta *et al.*, 2002a; Mulugeta Lemenih and Demel Teketay, 2004a.). Most climax species possess large and often fleshy seeds (*e.g., Pouteria adolf-frederici*[1], *Ekebergia capensis, Prunus africana* and *Syzygium guineense*) that are recalcitrant, i.e. have short longevity (Harper, 1977; Leck *et al.*, 1989: Thompson *et al.*, 1993; Demel Teketay and Granström, 1997a, b; Demel Teketay, 1997b; Bekker *et al.*, 1998). Their large sizes also imply the less likely chance of finding their way passively down into cracks in the soil or being buried by soil animals. As long as they remain on the surface, they either get attacked by predators or immediately germinate. Several species in the Afromontane forests of Ethiopia are observed to germinate within a few days or weeks after dispersal (Demel Teketay, 1996, 1997b; Demel Teketay and Granström, 1997a, b). This means that most woody species in the dry Afromontane forests of Ethiopia store large seedling-sapling banks (Pohjonen, 1989; Demel Teketay, 1996; Demel Teketay, 1997b). Therefore, formation of seedling banks under the shade of mature forests appear to be the regeneration strategy of most climax woody species in the Afromontane forests of Ethiopia. This implies that mature forests should always be present not only to supply with fresh seeds but also to nurse juvenile seedlings under

[1] The nomenclature of plant species in this paper follows Hedberg and Edwards (1989, 1995), Friis (1992) Edwards *et al.* (1995;1997;2000) and Hedberg *et al.* (2003). Hereafter, the species names appear in full when they are referred to for the first time but only their genus names will be used thereafter.

their shade for the continuous perpetuation of the tropical Afromontane forest biodiversity in Ethiopia.

Soil seed banks in degraded lands and agro-ecosystems

Ethiopia is an agrarian country, where agriculture is not only the backbone of the economy but also a major occupation for nearly 85% of the population. Consequently, agricultural land expansion is changing rapidly most rural landscapes in the country.

Unfortunately, results of a number of soil seed bank studies in agro-ecosystems converted from natural forest have shown the lack or scarcity of viable seeds of woody species as a common syndrome (Table 1). For instance, seeds of woody species in soil seed banks sampled from farmlands converted from dry Afromontane forest contributed to less than 1% of the soil seed flora in the Harerge highlands (Demel Teketay, 1996, 1997a). Similarly, woody species contributions to the soil seed flora dropped from 5.7% after 7 years to nil after 53 years of continuous cultivation of farmlands developed by clearing an Afromontane forest in the southern highlands of Ethiopia (Mulugeta Lemenih and Demel Teketay, 2004a). Soil seed bank investigation of degraded hill slopes in Welo also showed that only two woody species, about 3% of the whole soil seed flora, were recovered (Kebrom Tekele and Tesfaye Bekele, 2000). These studies clearly showed that degradation, conversion and subsequent cultivation of Afromontane forests diminish and, eventually, exhaust soil seed reserves of woody species, which will ultimately impose severe limitations on future native forest flora recovery following abandonment of agricultural activities. Major farm activities such as repeated plowing, weeding, burning, site preparation, stump splitting and digging out for firewood, animal trampling and, to some extent, the side effects of inputs, *e.g.*, pesticides, are mentioned responsible for the exhaustion of native woody species propagules from arable lands (Demel Teketay, 1996; Mulugeta Lemenih and Demel Teketay, 2004a).

Table 1. Native woody species (tree + shrub) recovered from soil seed banks of different sites in the Afromontane region of Ethiopia

Locality	Sampled Sites					References
	Farmlands	Natural forest	Plantation*[a]	Plantations*[a]	Degraed secondary forest	
Munessa-Shashemene	2	2	2	3	-	Mulugeta Lemenih and Demel Teketay (2004b)
Gara ades, Harerge	2	19	-	-	-	Demel Teketay and Granström (1995)
Welo	-	5	-	-	3	Kebrom Tekle and Tesfaye Bekele (2000)
Munessa-Shashemene	-	8	-	-	-	Demel Teketay and Granström (1995)
	-	5	9	-	-	Feyera Senbeta and Demel Teketay (2002)
Menagesha-Suba	-	10	-	-	-	Demel Teketay and Granström (1995)
	-	5	8	-	-	Feyera Senbeta and Demel Teketay (2002)
Wof-Washa	-	3	-	-	-	Demel Teketay and Granström (1995)

Furthermore, the maximum longevity of seeds is known to exceed 100 years for only few species (Thompson *et al.*, 1996). However, data from seed longevity studies made for longer periods, i.e. many decades or centuries, are very rare, and do not always seem to be reliable (Bakker *et al.*, 1996b). More specifically, most typical shade-tolerant forest plant species, like the climax tropical tree species in the dry Afromontane forests of Ethiopia, do not accumulate persistent seed banks (Thompson, 1992; Demel Teketay and Granström, 1995; Demel Teketay, 1996). Even those species with persistent soil seed banks do not survive a short period of other land uses after conversion (Bossuyt *et al.*, 1999). Due to the prolonged agricultural land use history of the country, particularly in the central and northern parts, it is possible to speculate that several indigenous plant species might have become locally extinct except those that have found refuges in the small patches of remnant forests in northern and central highlands (*e.g.*, Demel Teketay and Tamrat Bekele, 1995; Kibrom Tekele, 1998; Tesfaye Bekele, 2000; Alemnew Aleligne, 2001), including church, monastery and mosque compounds (Alemayehu Wassie, 2002; Alemayehu Wassie *et al.*, 2003a, b), where some remnant climax tree species are presently found. These forests have great potential as sites of *in situ* conservation of the woody plants, sources of propagules for natural and artificial restoration of the native woody flora in the degraded highlands and stands to provide timber and non-timber products as well as various environmental services (Alemayehu Wassie, 2002; Alemayehu Wassie *et al.*, 2003a, b).

Seed rains and seedling banks

In this paper, seed rain, is loosely used to include all modes of recent seed dispersal by wind, humans, animals, water, machinery, etc. Seed rains of individual plant species could be important for successful restoration of native forest flora, particularly under the condition where viable seeds of 'target species' are lacking in the soil seed bank. Knowledge about both temporal and spatial dispersal of seeds would, therefore, provide the best predictions of chances for restoration of native forest flora on degraded sites (Poschlod *et al.*, 1995).

Wind, animal hooks, animal body, water erosion and machineries are known to involve in different forms of seed dispersal. However, the significance of each of these mechanisms depends on the nature of the seeds to be dispersed and the spatial characteristics, such as distance, shape and area, of the restoration site with respect to the seed source (Honnay *et al.*, 2002). Wind dispersal is common to seeds with small sizes (Friis, 1992). Seeds weighing less than 5 X 10^{-5} gm were observed to be effectively dispersed by wind even if they lack dispersal appendages (Hughes *et al.*, 1994). Furthermore, winged seeds/seeds with dispersal appendages are dispersed far distances than unwinged seeds by wind. Larger seeds can only be effectively dispersed by wind if their shape reduces fall speed. Large seeds that lack dispersal devices can only be transported long distance by accident such as animal hooks, machines and attachments to animal bodies or by water transport. Possibly, herbivore mammals are among the most important seed movement vectors with respect to restoration management (Poschlod *et al.*, 1995). Animals transport seeds either by attachment to their body or by consuming as feed and passing them out with dung. Birds, mice, ants and beetles are also known seed dispersal agents, and most tropical seeds are animal dispersed (Cubina and Aide, 2001), especially birds (Hardwick *et al.*, 1997; Keenan *et al.*, 1997; Feyera Senbeta *et al.*, 2002b). However, many frugivorous birds and bats avoid large open areas that could expose them to predators, particularly if there are no perches or fruits (Howe and Smallwood, 1982). Therefore, animal dispersal to bare (abandoned) lands will always be with a minimum probability.

Experimental studies in several tropical conditions (Bakker *et al.*, 1996a; Lyaruu, 1998; Cubina and Aide, 2001) have shown that long-distance dispersal of large seeds of the climax tropical tree species is rare. Their sizes coupled with distance to the restoration site are major limiting factors for long-distance transport. A lot of forest plant species have substantial difficulties to bridge gaps between the seed source and seed destination or restoration site (Grasshof-Bokdam and Geertsema, 1998; Brunet *et al.*, 2000; Butaye *et al.*, 2001; Cubina and Aide, 2001). For instance, a seed rain experiment in Puerto Rico has shown that only 0.3 % seeds and three species were dispersed more than four meters from the forest edge out of 35 species that produced fruit in the forest (Cubina and Aide, 2001). This dispersal is not only a small sub-set of the complex natural forest community but also part of the dispersed seeds is likely to be subjected to predation. Overall, most dispersal agents are important within a community but not for restoration management unless restoration sites are adjacent to stands that still possess dispersible seeds of native woody species.

Studies on seed rain in particular and dispersal ecology in general are scanty in the Afromontane region of Ethiopia. However, a study on manure dispersion of seeds in Ghinchi highlands showed that manure seed banks contained more annuals than perennials (Zerihun Woldu and Salleem, 2000). The fact that most tree species in the Afromontane forests have relatively large seeds may imply poor long-distance dispersal of their seeds (Demel Teketay and Granström, 1995). Furthermore, experiences in several short- and long-term studies in Europe on restoration management aiming at the restoration of species-rich grassland types have shown that most of the 'target' species, which lacked persistent seed banks, did not establish still after years (Poschlod and Jordan, 1992) and decades (Bakker, 1989; Rosenthal, 1992). Therefore, the 'target' species have to be transported from outside by artificial means if rapid restorations are sought (Pywell *et al.*, 2002).

Land degradation

Land degradation hampers vegetation restoration by changing several abiotic factors of a site such as soil, microclimate and seed sources (Hermy, 1994; Koerner *et al.*, 1997; Lugo, 1997; Bossuyt *et al.*, 1999; Honnay *et al.*, 1999; 2002). Site quality as affected by length of agricultural occupation, for instance, negatively affected native forest recovery in Belgium (Honnay *et al.*, 1999). Land degradation, due to soil erosion and loss of soil fertility, is one of the most visible phenomena on agricultural or deforested sites in Ethiopia (FAO, 1986; Hurni, 1988, 1993; Anonymous, 1994; Kebrom Tekle, 1999). It involves physical, chemical and biological degradation, i.e. loss of the overall productive capacity of a land. The most important soil chemical degradation involves plant nutrient depletion and loss of soil organic matter. Although, the soils of Ethiopia, like other tropical countries, are naturally poor in N and P, erosion induced losses are also tremendous. For instance, an agro-ecosystem nutrient balance study at a continental scale revealed that Ethiopia is one of the countries having the highest rate of the three macro-nutrient (N, P, K) depletion, with aggregated national scale nutrient balances of - 41 kg N, - 6 kg P and - 26 kg K per ha (Stoorvogel and Smaling, 1990). It is not hard to guess that these essential plant nutrients are at extremely low level when farmlands are abandoned due to marginalization. Soil loss due to erosion also reduces soil depth (Omita *et al.*, 1999), consequently, decreasing the amount of soil moisture content and rooting depth. Loss of soil organic matter (SOM) from the farmlands is also a severe phenomenon in the highlands of Ethiopia. The estimated soil loss, an average value of 7,800 million tons per year, causes a loss of about 1.17 – 7.8 million tons of SOM, 0.39 – 1.17 million tons of nitrogen and 1.17 – 3.9 million tons of phosphorus per year (Tamerie Hawando, 1995). Furthermore, SOM turnover studies following forest conversion to farmlands in the highlands of Ethiopia are rapid resulting in losses of over 60% just within 30 years after conversion (Dawit Solomon *et al.*, 2002). Changes in the quality and quantity of SOM have direct impact on soil physical, biological and chemical properties. Decreased SOM lowers soil water and nutrient-retention capacity, structural stability and infiltration rates, increases soil crusting/sealing and accelerates runoff and erosion. Thus, exhausted abandoned sites will be too marginal for seeds of rare incoming woody species to germinate, get easily established and colonize a site as they have to cope with the lack of nutrients and, often, poor water availability.

Inhospitable site

Most of the native climax species of the Afromontane forests are shade-tolerant and are nursed under the shade of mature forest canopy. As a result, the extreme environmental conditions of a bare soil such as high temperature, frost, low humidity and desiccating winds will be too hostile for the germination of seeds of climax species and establishment of seedlings in open sites. The severely impoverished soils of marginalized abandoned farmlands are also quite uninhabitable by young seedlings. Lastly, seed banks of abandoned sites are rich in competitive and aggressive weedy species and grasses (Demel Teketay, 1996; 1997a). These 'undesirable' species often quickly colonize sites following abandonment. The rapid establishment of adaptive competitive 'undesirable' species might further prevent the re-appearance of seedlings of the 'desirable' species that might have escaped soil-imposing limitations. Together or in isolation, these biotic factors would severely limit the chance of native forest flora to successfully re-appear on degraded and abandoned sites.

OPPORTUNITIES

Land abandonment

The greatest biodiversity losses in the world have occurred through habitat losses. Conversely, the greatest opportunities for ecological restoration will occur through land abandonment (Young, 2000). Studies have indicated that half of the arable lands in the highlands of Ethiopia (22 million hectares) are already seriously degraded, out of which 2 million hectares have degraded to the extent that they could not sustain crop production in the future (FAO, 1986; Anonymous, 1994). About 20,000 to 30,000 ha of croplands are also abandoned annually because cropping can no longer be supported by the soil (FAO, 1986; Anonymous, 1994). Indeed, significant areas of marginalized lands are abandoned annually in the country, which ecologists could exploit as an opportunity to catalyze restoration of native flora.

Plantation forestry

There are many approaches to land and vegetation rehabilitation/restoration (Brown and Lugo, 1994), each of which depending on the severity of damage to the land resource (Lugo, 1997). Lamb and Tomlinson (1994) believe that the first objective of degraded land rehabilitation should be the prevention of further degradation. Plantation forestry can be employed as a tool not only to arrest further site degradation but also to catalyze native forest flora restoration after prolonged anthropogenic disturbances. Tree plantations were initiated and rapidly expanded in the tropical world in the early 20th Century to meet the increasing demand for wood products and relieve the pressures on natural forests. Soon after wide scale plantation establishments, however, ecologists began to question about their stability and future sustainability. The concern stemmed partly from agricultural experience or traces back to historical misconceptions about the influence of plantations of conifers (usually monocultures, sometimes of exotic species) on soil and site processes (Powers, 1999). The questions that were raised against the use of tree plantations usually centre on the negative effects of monocultures, i.e. low stability, low resource use efficiency, low level of biodiversity, the tendency to use exotics that was believed to displace indigenous species and the effects of intensive land management on site conditions including soil and water (Lundgren, 1978; Evans, 1986; Ewel, 1986; Lugo *et al.*, 1988; Berger, 1993; Smith, 1994). These were all sound looking arguments for the denouncement of plantation expansions, particularly in tropical ecology where biologically rich tropical natural forests are replaced with biologically poor monocultures (Armstrong and van Hensbergen, 1996; Armstrong *et al.*, 1996).

Paradoxical to most of the above negative speculations, today, plantation forestry is getting recognition not only from economic and local wood product supply point of view but also from ecological and biodiversity perspectives. Several recent studies have proven that plantation forests can assist ecological recovery from prolonged anthropogenic disturbances (Lugo, 1992a; Lugo *et al.*, 1993; Parrotta, 1993, 1995; Powers *et al.*, 1997;

Carnus *et al*., 2003). For example, tree plantations have been shown to improve soil conditions of degraded sites (Stone, 1975; Lundgren, 1978; Parotta, 1992, 1999; Fisher, 1995; Lugo, 1997; Islam and Weil, 2000; Carnus *et al*., 2003). Most efficacious influences of tree plantations are production of litter and thus improvement of soil organic matter, nutrient recycling, decrease of soil bulk density and increases of biological activities. For instance, Lugo (1992b) reported that tree plantations accumulated more mass and nutrients in litter than did secondary forests of a similar age.

Several other studies have also shown that plantation forests established on marginalized tropical sites are nursing rich number of native forest flora under their canopies (Lugo, 1992a; Lugo *et al*., 1993; Parrotta, 1992; 1993; 1995; 1999; Guarringuata *et al*., 1995; Fimbel and Fimbel, 1996; Parotta *et al*., 1997; Feyera Senbeta, 1998; Yitebitu Moges, 1998; Eshetu Yirdaw, 2001; Feyera Senbeta and Demel Teketay, 2001; Feyera Senbeta *et al*., 2002a; 2002b; Mulugeta Lemenih and Demel Teketay, 2004b; Mulugeta Lemenih *et al*., 2004; Carnus *et al*., 2003; see also Table 2). Studies made in the south central highlands of Ethiopia, for instance, showed that within 15–17 years of establishment on abandoned farmland, plantations assisted the restoration of 78% of native woody flora recorded from under an adjacent natural forest (Mulugeta Lemenih and Demel Teketay, 2004b; Mulugeta Lemenih *et al*., 2004). These studies revealed that plantation forestry could facilitate rapid succession of native forest flora on abandoned farmlands despite the absence of viable seeds of the woody species in the soil seed flora at the time of abandonment. Therefore, plantation forests could be employed as viable restoration management tools for rapid recovery of degraded landscapes as well as threatened biodiversity resources.

Table 2. Density and number of regenerating species under plantation forests established on degraded natural forests sites in the highlands of Ethiopia.

Locality	Plantation species	Total number of NRNWS	Density of NRNWS/ha	Reference
Wondo Genet	*Pinus patula*	30 (62.5%)	4500	Eshetu Yirdaw (2001)
	Cupressus lusitanica	34 (70.8%)	8225*	
	Juniperus procera	32 (66.7%)	5475	
	Grevillea robusta	29 (60.4%)	5500	
	Natural forest	48	7275	
Munessa-Shashamane	*C. lusitanica (9 yrs)*	30 (111.1%)*	7325	Feyera Senbeta *et al.* (2002a)
	C. lusitanica (17 yrs)	22 (81.5%)	7375	
	C. lusitanica (25 yrs)	16 (59.2%)	5950	
	E. globulus (13 yrs)	16 (59.2%)	6550	
	E. globulus (16 yrs)	13 (48.1 %)	2300	
	E. globulus (22 yrs)	17 (63%)	13400*	
	E. saligna (11 yrs)	18 (66.7%)	3575	
	E. saligna (22 yrs)	23 (85.2%)	10100*	
	E. saligna (27 yrs)	25 (92.6%)	18650*	
	P. patula (10 yrs)	18 (66.7%)	2325	
	P. patula (21 yrs)	16 (59.2%)	3750	
	P. patula (28 yrs)	15 (55.6%)	2525	
	Natural forest	27	9658	
Menagesha-Suba	*C. lusitanica (14 yrs)*	18 (69.2%)	5770	Feyera Senbeta and Demel Teketay (2001)
	E. globulus (17yrs)	27(103.8%)*	7730	
	C. lusitanica (24 yrs)	11 (42.3%)	1630	
	P. radiata (24 yrs)	15 (57.7%)	3130	
	P. patula (24 yrs)	17 (65.4%)	3940	
	J. procera (42 yrs)	27 (103.8%)*	18270*	
	Natural forest	26	11680	

* Plantations with density or species richness more than the natural forest; NRNWS, naturally regenerating native woody species.

Plantation forests facilitate recolonization of native forest flora by simulating environments that closely resemble the natural forests than does a bare soil. These conditions may include: (i) provision of habitat for seed dispersing animals, *e.g.*, roosting ground for birds and movement corridors for other animals; (ii) amelioration of the harsh micro-climatic condition of a bare soil by providing shade and moderate temperature for seeds and developing seedlings, and reducing wind desiccations, all of which are crucial for the regeneration of climax dry tropical woody species; (iii) improvement of the impoverished and, often, nutrient-poor soils of degraded farmlands through litter fall, nutrient recycling and improved activities of micro-organisms; and (iv) suppression of the potential competitive plant species. Indeed, plantation forests address two often-supplementary purposes: rapid restoration and productive restoration. These synchronized approaches are very fundamental in the highlands of Ethiopia where both land degradation and scarcity of wood products are chronically severe. Therefore, in the lights of the limitations that potentially hinder the restoration of naïve forest flora, plantation establishment will remain the main management tool for catalyzing succession even under the conditions where seeds of woody species are absent from the soil seed banks. They could also be exploited as an *in situ* protection tool for the rich biodiversity resources of the country. Supplementary advantage of plantation management is that managers have wide options to choose plantation species that successfully establish under the condition of the restoration/degraded sites (Lugo, 1997). Most plantation species available today, including those in the country, are shade intolerant that they easily grow in open sites provided that proper species-site matching is made.

Does choice of plantation species matter?

Both regeneration assessments and soil investigations under plantation forests of various species have indicated the existence of considerable differences between plantation species. While certain plantation species seem to have a high potential to facilitate more rapid restoration of a forest community, others have no effect of increasing richness above what might occur naturally on unplanted abandoned sites (Fimbel and Fimbel, 1996; Powers *et al.*, 1997; Mulugeta Lemenih and Demel Teketay, 2004b; Mulugeta Lemenih *et al.*, 2004; Tables 2 and 3). Species differences on understorey vegetation species richness are most likely a function of the individual characteristics such as branching habit, leaf area index, leaf orientation, etc. than variables related to landscape context, intrinsic site qualities, variable seed dispersals or relative distances to seed sources (Powers *et al.*, 1997; Mulugeta Lemenih *et al.*, 2004). Generally, broad-leaved species or open canopy conifers appear to facilitate more understorey vegetation recruitments and growth than dense canopy plantation species (Fimbel and Fimbel, 1996; Mulugeta Lemenih and Demel Teketay, 2004b; Mulugeta Lemenih *et al.*, 2004; Table 3).

Table 3. Example of effect of plantation species on density and growth of naturally regenerating native woody species.

Stand	Age (Years)	Canopy Closure (%)	Under canopy air temperature (°C)	Number of NRNWS/plot	Density of NRNWS/plot	DBH of NRNWS (cm)	Height of NRNWS (cm)
Natural forest	-	68.9	18.9	10.2	63.7	3.04	278
Cordia africana	28	54.	21.6	8.7	53.2	4.14	402
Eucalyptus saligna	31	67.8	19.7	8.6	62.8	2.40	218
Pinus patula	31	79.5	17.9	7.5	36.8	2.92	396
Cupressus lusitanica[*]	31	94.2	16.4	6.6	33.2	-	-

[*] *C. lusitanica* had no regeneration satisfying the lower size limit set for the investigation indicating its poor growth facilitation dense canopy density (Mulugeta Lemenih *et al.*, 2004); NRNWS = naturally regenerating native woody species

Several authors, including from Ethiopia, have also reported the significant differences of plantation species on the direction and rate of soil amelioration (Sanchez *et al.*, 1985; Binkely and Sollins, 1990; Parrota, 1992; Brown and Lugo, 1994; Smith, 1994; Fisher, 1995; Garcia-Montiel and Binkley 1998; Islam and Weil 2000). Major differences seem to originate from litter quality, litter decomposability, biomass production and immobilization of plant nutrients in biomass. Therefore, proper selection of plantation species is a very good start for efficient and successful restoration management whether for soil restoration or inducing plant regeneration.

Does origin of the plantation species matter?

Despite the merits of using indigenous species, the major pushes for choosing exotic species in the past were the readily available knowledge on their silvics, ecology, biology and seed supply. Probably their fast growth habit has also biased foresters to rapidly meet the acute demand of wood products. On the contrary, knowledge of the silvics, biology and ecology of native woody species were hardly available that they were grossly overlooked at the beginning. Nevertheless, comparison of exotics and indigenous species did not show a significant difference in terms of native woody species regeneration (Mulugeta Lemenih and Demel Teketay, 2004b; Mulugeta Lemenih *et al.*, 2004). The major plantation factor that mattered was their canopy architecture and associated under canopy microclimatic variables. Light and temperature fluctuations, climatic variables controlled by the amount of canopy openness of the overstorey plantation species, are important factors for germination and establishment of seedlings. Thus, whether exotic or indigenous, plantation species with open canopy induce diverse and vigorous understorey regeneration of native forest flora than plantation species with heavy and dense canopy that shade the forest floor (Table 3). Careful thinning of plantations with dense canopy could help to open up their canopies and induce regeneration (van Wyk *et al.*, 1995).

Furthermore, the studies have also indicated potential limiting factors other than plantation species for the full realization of the catalytic role of plantation forests. Some of these include stand age (Oberhauser, 1997; Feyer Senbeta, 1998), presence of competitive grasses in the understory (Powers *et al.* 1997), litter thickness/mass (Parrotta, 1995; Feyera Senbeta and Demel Teketay, 2001), fire, lack of protection, silvicultural management employed and substrate quality (Oberhauser, 1997; Parrotta and Knowles, 2001; Pywell *et al.*, 2002). As there have been rare experimental verifications on the importance of each one of these factors, it is recommended to conduct controlled experiments on these factors in order to promote the catalytic role of plantation forests for the rapid restoration of native forest flora.

CONCLUSIONS

A reality to be acknowledged in Ethiopia today is the fact that it might be already 'too late' to talk about saving the original forests, with only less than 3% of the land mass covered with forests, which are even under greatest and continuous pressure from exploitation. This is not to under-stress the urgent need for policy and legislation that protects the remnant patches, at least, as source of seeds for future restoration management. Since the dominant parts of our forests have already gone, we need to focus very much, now, on the possible solutions for the future. Indeed, the best that could be done would be to begin restoration programs on the vast degraded landmasses. This could be facilitated through the creation of new plantation forests.

Allegations about the adverse effects of plantation forests lack sound scientific ground to decline their potential uses as probably the best management tool not only for the restoration of the degraded ecology, but also for restoration of the rich biodiversity resources of the country. Several international symposia, conferences and meetings have been organized in the recent past solely related to ecology of plantation forests. Examples are United Nations Conference on Environment and Development (UNCED) in 1992 at Rio de Janeiro, the key outcome of which was the Forest Principles and Agenda 21 that endorsed increased use of planted forests in the world (Keating, 1993). Another example is the 'Planted Forest Symposium' held during June 1995 in Portland, Oregon, USA (Boyle *et al.*, 1997). Similarly, there was a symposium/workshop that was held in Washington DC by the IUFRO-World Band-USDA forest service on tropical forest rehabilitation (Parrotta *et al.*, 1997). These and similar others had looked critically into planted forest landscapes and ecology and did not find sound scientifically supported negative ecological effects of planted forests. Instead, they ended up with a conclusion that plantation programs enormously contribute to environmental quality, forest productivity and ecological restoration (Winjum and Schroeder, 1997; Parrotta *et al.*, 1997).

Furthermore, plantation forestry could be manipulated with scientifically designed silvicultural practices to address several of the ecological and economic problems prevailing today in the country similar to what is being done elsewhere in the world. Plantations could relieve the pressure from natural forests through provision of wood products. They could also be used to restore biodiversity. Plantations could be used to rapidly restore degraded lands much faster than either physical soil-water conservation measures or simple abandonment. They could also be used to contribute significantly to local and national economy through income diversification and wood industry expansions. What is required is a well-designed silvicultural management with strong research support. Good examples are the invasions of native forest flora under plantation forests, which in some cases were shown to comprise species richness of over 100% compared to the adjacent natural forest stands. Such invasions took place without deliberate management practices favoring them. It is not difficult to imagine significant improvements in the richness of plant diversity as well as growth of the naturally regenerated woody species if supported with purposely designed silvicultural management. Similarly, there is no reason why plantation forestry could not be used as source of raw materials for wood-based industries, particularly, given the conducive climatic and edaphic resources of the country for fast growth and wood volume accumulation. In conclusion, there is no doubt that plantation forestry will be Ethiopia's best hope not only for wood products supply but also for ecological restoration.

Finally, if plantations are to be employed as nurses, this role totally rests on fresh seeds transported into the plantations, since the propagules of native woody species are always lacking in the soil seed banks. Unless the remnant natural forests exist, there will be no sources of seeds to be dispersed into plantation stands. Experiences from other countries have shown that plantations established nearby natural relics quickly develop rich understorey than those located faraway (Honnay *et al.*, 1999). Therefore, prompt and strict protection of the scattered remnant forests existing today in the country is the very cornerstone of successful future restoration ventures. Otherwise, it may be in vain to think of other mechanisms, including the nurse plants advertised above, to save the rich biodiversity resources of the country from vanishing.

RECOMMENDATIONS FOR FUTURE RESEARCH

Although the number of studies carried out so far on restoration ecology in Ethiopia is encouraging, a lot remains to be investigated in the future. Thematic research topics that require future attention with regard to indigenous woody plants in all vegetation types of Ethiopia include phenology, ecology of flowering and fruiting, seed production and dispersal ecology, pre- and post-dispersal seed predation, seed rain, fate of dispersed seeds, dynamics of soil seed banks, ecophysiology of field seed germination, seedling establishment and growth, longevity of seeds once they are incorporated into the soil, seed dormancy and cues for seed germination, rate and processes of recruitment of seedlings from the soil seed bank, types and extent of natural and anthropogenic disturbances of different forests/vegetation types and sources of regrowth of woody plants after such disturbances, plant strategies used to detect gap formation or gap-phase dynamics.

With regard to plantation forests, research areas that need future attention include comparative study of indigenous and exotic plantation tree species in terms of their adaptability to different agro-ecological conditions in the country, including their rate of growth, and ability to foster the regeneration of indigenous woody species, seed dispersal and agents involved in the seed dispersal, eco-physiology of seed germination and seedling growth of naturally regenerating native woody species and successional processes in tree plantations, relationship between canopy architecture, microclimatic conditions and regeneration of indigenous woody species as well as management regimes aimed at manipulating plantation stands and the established native woody species to develop secondary forests over time.

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