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Invasive and Exotic Species in the Restoration of Stochastic Agricultural Lands in Ethiopia

Sileshi Degefa Teshome Soromessa
Centre for Environmental Science, Addis Ababa University, P.O. Box 1176, Ethiopia

Abstract
Feeding inexorably increasing population is among the challenges confronting mankind. Marginal lands including mountainous and sloppy areas have been converted to agricultural land. The highland parts of Ethiopia (43% of the country's total size) have been highly degraded. About 4 % had reached a point of no return. This has diminished food crop production capacity of the country. In addition, there is not extra marginal or forest lands to be converted to farmland as before. Hence, restoration of agricultural land is an urgent matter. Restoration increases agricultural system stability. Restoration can be done in various ways such as area closure (in areas with relatively large landholding size), erosion protection using physical structure and restoration using tree planting or combination of two or more of the interventions. But rural Ethiopia cannot afford to put land aside for restoration due to scarcity of farmland. A key question, then, is how to successfully and quickly restore the degraded landscapes in the country. This review work, therefore, analyzes the merit and demerit of exotic and invasive plant species in the restoration of agricultural land in Ethiopia. Most Exotic species in Ethiopia are providing various socio-economic services. On the other hand, few are highly competitive and deny resources for native trees as well as for crops. Some of these invasive species have allelopathic characteristics and ooze inhibiting chemicals. They quickly colonize the area and deny the space for crops. The invasive species also lower the water table and also adversely affect the livestock sector however that agriculture and livestock sectors are complementary activities in Ethiopia. Absence of well-developed management techniques exacerbated the downside of invasive species. Many studies invigorate adverse impact of invasive species. The invasive plants use the opportunity of high disturbance of agricultural lands to outcompete with crops or co-existing native flora. Unless it is the last option using invasive species for restoration of agricultural land is not recommended. Regarding the exotic species such as Eucalyptus spp, Cuppressus lustanica, Gravillia robusta, Pinus radiata, there is mixed evidence on their role on restoration of agricultural land. The widely held negativity view of exotic plant species seems not right. The performance of exotic trees on the restoration of agricultural land varies from species to species. Some leguminous exotic species has a positive role in increasing soil nitrogen, moisture content, total SOC, physical property of soil, etc. Few such as eucalyptuses have over competing with crops and with co-existing native flora for the available water, nutrients, light, etc. Species such as Cuppressus lustanica has very high evapo-transpiration during wet season and suppress the growth of understory. As compared to the native trees exotic species have less efficiency on the restoration of agricultural lands. This does not mean that all native plants have good performance than exotic plants. In general, before embarking to agricultural land restoration species selection that exactly fits the required purpose must be done.
Keywords: Restoration, invasive species, Exotic, Agricultural land

INTRODUCTION

The most pressing issues facing mankind this day among the other is producing more food to feed inexorably increasing population. Food production is a major component of human disturbance of Earth's ecosystems (Perry, 1998). Modern, high-intensity agricultural practices generally exclude natural communities and can degrade adjacent areas by altering hydrology, increasing nutrient and chemical inputs, and providing sources of invasive species. It is exorbitant for developing countries such as Ethiopia to feed the nation in the face of agricultural land degradation and global warming. Thus, Ethiopia is on the frontline to face the challenge due to the fact that the economy is highly relied on agriculture. Productivity of the country has been set back by primitive way of cultivation and poor land management. In Ethiopia the livelihood of 85% of the population are directly depend on agriculture (Lemneh, 2006). The economic philosophy of the country is also agricultural led economy. Agriculture sector accounts for 50% of GDP, 85% of foreign exchange earnings and supports 85% of the workforce (Lemneh and Teketay, 2004; Bishaw, 2001).

Sadly, Ethiopia relies on long-established agricultural system which uses primitive technology, less or no agricultural input and poor land management. Thus, agricultural production is being seriously eroded. Unsustainable land management practice both in areas of food crops and in grazing lands is observed all over the country. Land degradation in Ethiopia has long history. Few studies show that ancient civilization such as Axumite Kingdom was failed due to land degradation. Currently, the highland parts of the country are severely eroded (El-Swaify and Hurni, 1996, cited in: Weldemlak Bewket, 2003). The average annual nationwide soil erosion rate was estimated at 12 tons per ha (Gessesse, 2010), while a total annual soil loss was 2 million tons (FAO, 1996; cited in: Bewket, 2003). The soil erosion hazard is much higher for land under annual crops as

compared to that under grazing, perennial crops, forest and bush. In spite of covering only 13% of the country's area, annual crop land contributes to about 45% of the estimated total soil loss (MoARD & WB, 2007; cited in: Gessesse, 2010; Hurni, 1993; cited in: Bewket, 2003). According to the Ethiopian Highlands Reclamation Study (1986), cited in: (Gessesse, 2010), about 130 tons of soil per hectare are lost from cropland; the average for the country as a whole is about 35 tons of soil per hectare. According to Gessesse (2010) 50% of the highlands were significantly eroded, 25% are seriously eroded and 4% had reached a point of no return. Ethiopia is also one of the countries with the highest rates of nutrient depletion with nutrient loss of 41 kg/ha/yr for Nitrogen, 6 kg/ha/yr for Phosphorous and 26 kg/ha/yr for potassium (Stoorvogel and Smaling, 1990; cited in: Tesfaye, 2011). Due to the land degradation over the last decade Ethiopia has been unable to feed its population (Bewket, 2003). Out of the total area of the country, the highland part accounts for 43% (McCornick *et al.,* 2003). From this, 25% are seriously eroded and 4% had reached a point of no return (Gessesse, 2010). On the other hand, the population of Ethiopia is steadfastly increasing with growth rate of 3.2% per annum (CSA, 2008; McCornick *et al.,* 2003). Acute shortage of land driven by population booming is compelled for agricultural land restoration.

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (Harris and Diggelen, 2006*).* It helps replacement of soil chemical, physical and biological state of affairs. There are diverse restoration mechanisms such as area closure in order for viable seeds from soil seed bank grown and subsequently fertility restored; constructing erosion control physical structure; planting trees or combination of two or more of the interventions. Agricultural land restoration can be done using indigenous as well as exotic plant species.

Some exotic plant species positively assist the restoration of agricultural land while others inhibit native species by outcompeting for nutrients, waters, light. Some have allelopathic (toxic producing tendency) and affects nearby plants by notorious toxic while other diminish the crop yield by replacing crop lands and affects the livestock production by inhibiting grass and palatable leave of native species and injuring cattle by thorn, etc. Therefore, this review work critically assesses the existing literature and compiles the role of exotic and invasive species in restoring stochastic agricultural land in Ethiopia.

METHODOLOGY

The methodology followed was mainly reviewing articles from known journals, books, reports and student thesis pertinent to the topic. More than 10 published articles were reviewed in the course of compiling this review work. The available materials were systematically selected on the basis of content, relevance and their publication time. Restoration ecology book was the base to evaluate stochastic agricultural land restoration in Ethiopia using exotic and invasive plant species.

RESULT AND DISCUSSION

Definitions

Exotic plant species are species that are new to the country or to some region which are unintentionally introduced through trade or aid shipment or deliberately introduced for their economic, aesthetic and conservation purposes without taking their ecology into consideration (Etana, 2013). Not all of them pose harm to the environment. Instead, most of them particularly the crop species that were naturalized long time ago in Ethiopia have immense socioeconomic importance. Many exotic tree species become dominant and also enormously supporting development in Ethiopia. Only few were turned invasive by outcompeting for resources.

Restoration involves reestablishment of the structure and function of an ecosystem to a historical or idealized state that is resilient, self-assembling, self-sustaining, and integrated into the surrounding landscape (Allen 1995; Bradshaw 1997; SERI 2004, cited in: Brown, *et al.,* 2008). Restoration of agricultural land using exotic plant species is assisting the rehabilitation of agricultural lands using human intervention by promoting their growth. Several recent studies have proven that plantation forests can assist ecological recovery from prolonged anthropogenic disturbances (Lugo, 1992; Lugo *et al.,* 1993; Parrotta, 1993, 1995; Powers *et al.,* 1997; cited in: Lemneh and Teketay, 2004). 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 (Lemneh and Teketay, 2004).

The species we use might be native species or exotic species. In most cases the exotic species used for construction and fuel wood than for restoration purposes. Restoration using exotic trees has both merit and demerit. According to (Brown, *et al.,* 2008) in the initial phases of a restoration, the site potential must be assessed. This includes the edaphic conditions, topography, climate, disturbance regime, and availability of native, nonnative, and invasive species propagation at the site. Unsuitable or improper plant materials can cause catastrophic failures, waste tremendous amounts of time and money, and reduce the credibility of the restoration practitioner. This review work looked at three types of exotic plants: Naturalized and diversified plants (mainly crops) which were originated long time ago outside of Ethiopia; Non-invasive fast growing exotic plants and invasive exotic plants.

Naturalized and Diversified Exotic Species in Ethiopia

Large numbers of cultivated plants and their wild relatives were naturalized or originated in Ethiopia. Coffee (*Coffea arabica*), teff (*Eragrostis tef*), enset (*Ensete ventricosum*), and anchote (*Coccinea abyssinica*) are some of the species originated in Ethiopia. The country is also one of the main centers of diversity for a number of crops e.g. sorghum (*Sorghum bicolor*), finger millet (*Eleusine coracana*), field pea (*Pisum sativum*), lentil (*Lens culinaris*), chick pea (*Cicer arietinum*), perennial cotton (*Gossypium arboreum*), safflower (*Carthamus tinctorius*), castor oil bean (*Ricinus communis*) and sesame (*Sesamum indicum*) for which center of origin is somewhere on the world. The country is also an important center for linseed (*Linum usitatissimum*), durum wheat (*Triticum durum)* and barley (*Hordeum vulgare*) and potential industrial crops such as *Cordeuxia edulis* and *Vernonia galamensis*. Ethiopia is one of the 12 Vavilov Centers of crop genetic diversity. These exotic crop species have highly contributed to the socio-economic development of Ethiopian.

Invasive Species in Ethiopia

In Ethiopia, there are about 22 invasive alien species (McGinley, 2007; Etana, 2013). Among these invasive alien species Mesquites (*Prosopis juliflora*), parthenium weed (*Parthenium hysterophorus*), water hyacinth (*Eichhornia crassipes*), *Lantana camara*, and Acacia species are causing major problems in the country (Etana, 2013; Tesema *et al.,* 2003). *Prosopis juliflora* was intentionally introduced as an agro-forestry species in the Awash Basin. *Parthenium hysterophorus* was introduced accidentally through aid shipments. *Eichhornia crassipes* is most serious in the White Nile watershed and the Awash River system. *Striga spp,* is also an invasive species found in Ethiopia.

Limitation of invasive species in agricultural restoration

Restoration of agricultural land using invasive species has adverse impact than its ecological and its economic importance in Ethiopia. Invasive species take the scarce agricultural land and displace crops (Farm Africa, 2008). For instance, in contrary to its purpose of introduction, *Prosopis juliflora* escaped out of control and has invaded farmlands, pasture lands, rangelands, and irrigation schemes and has caused many land cover changes in Ethiopia. In the Middle Awash, about 30,000 hectare of grass land, rangelands, water points and croplands are estimated to be occupied by *P. juliflora* (Mehari, 2008; cited in: Getachew *et al.,* 2012). *P. juliflora* show a great depressive effect on the number, density, and frequency of native vegetation.

Prosopis juliflora is one of the invasive and a problematic tree heavily infests most agricultural as well as potential rangelands in Afar Region as well as in other parts of the country (Etana, 2013). Invasive species pose a depressive effect on the number, density, and frequency of native vegetation which has a positive impact for agricultural yield. Most of the invasive species have releases inhibiting chemicals to the surrounding. *Prosopis jiliflora* for instance, possesses allelochemicals that inhibit germination, growth and survival of other species (Etana, 2013). On the other hand, *Prosopis juliflora* proved to be effective in improving soil fertility and is useful for reclaiming moderately saline soils and degraded lands (Abebe, 2012).

Invasive species create further damage to agricultural land by altering habitat and modify hydrology, nutrient cycling and other ecosystem processes (Etana, 2013). They reduce agricultural yields, grazing areas, water availabilities, and contribute to spread of vector borne diseases (Getachew *et al.,* 2012; Etana, 2013). It has been estimated that weeds in general cause a yield loss of about 10% in less developed countries and 25% in the least developed countries (Akobundu, 1987; cited in: Etana, 2013). Few invasive plant species are weeds. In developing country in general and in Ethiopia in particular hand weeding are the dominant mode of weeding. Hand weeding accounts for up to 60% of pre-harvest labor in the developing world (Webb and Conroy, 1995; cited in: Etana, 2013).

The invasive plant species poses unpleasant impact on range land and subsequently on the livestock. In addition, some pose health risks to livestock and humans in the invaded areas by impairing mobility or causing injuries (Farm Africa, 2008). Apparently livestock and crop production in Ethiopia is two complementary activities. In terms of soil fertility and in terms of labor on agricultural activity livestock plays a linchpin role. Some invasive species serve as secondary hosts for crop pests including pathogens, nematodes, mites, and insects.

Invasive alien species are the second leading cause of biodiversity loss in the world today (Gichua *et al.,* 2013). There are about 22 invasive species in Ethiopia. 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 (Lemneh and Teketay, 2004).

Non-invasive Exotic Species

Ethiopia is endowed with many exotic wood species. These tree species become dominant in the country due to their socio-economic importance. There are various reasons for wide area colonization of these species. The first cause is the deforestation and clearing of indigenous tree species created shortage of construction and fuel wood in most part of the country. The species were highly proliferate and distributed in order to solve the repetitive problem. The second reason is the fast growth of these species than the indigenous one. Among the prominent exotic species are eucalyptus, *Gravillia robuta, Pinus radiata, Cuppressus lustanica,* etc.

Merit and demerit of Non-invasive exotic species on agricultural land restoration

Restoration efforts are required to recuperate degraded farmlands. Restoration of degraded lands is a subject that is receiving considerable attention today in many parts of the world. Restoration can be done using indigenous tree species or with the exotic trees. One of the major potential constraints related to restoration of native flora on degraded lands in the highlands of Ethiopia is the scarcity or complete absence viable seeds. According to Lemneh and Teketay (2004), the agricultural activities such as continuous plowing, site preparation, weeding, burning reduces the native flora seed bank. As a result most often farmers use exotic and sometimes invasive species on degraded agricultural land. With the objectives of satisfying the increasing demand of wood, relieving the pressure from natural forests and rehabilitating degraded lands in Ethiopia, non-invasive exotic tree plantations have been initiated since the turn of this century, mainly with introduced (exotic) species of *Eucalyptus, Cuppressus, Acacia, Pinus, Casuarina,* etc (Amare *et al.,* 1990; cited in: Senbeta *et al.,* 2002). But restoration of agricultural land using exotic trees would have both merit and demerit. The performance of non-invasive exotic species in restoring degraded land depends on the type of the species used. All species do not have uniform impact on the soil fertility, water use and interaction with co-occurring native plants. The evidence from previous studies on restoration of agricultural land with fast growing exotic plants is mixed. According to (Kindu *et al.,* 2005) in comparative study of seven tree species: (i) *Acacia decurrens, (ii) Chamaecytisus palmensis, (iii) C. proliferus, (iv) Eucalyptus globulus, (v) E. camaldulensis, (vi) Grevillea robusta and (vii) Hagenia abyssinica* Foliar N levels in *A. decurrens, C. palmensis and C. ploriferus* were significantly higher than those in the other four tree species, because *Acacia decurrens, C. palmensis and C. ploriferus* are N-fixing tree species. *Hagenia abyssinica* had higher K levels in the foliage and wood. Eucalyptus species tended to deplete soil fertility whereas *C. palmensis* and *C. ploriferus* improved soil fertility. *Chamaecytisus species and A. decurrens* can be short-term options for soil fertility improvement. Study by (Bekele *et al.,* 2006; Lemenhi *et al.,* 2005) were reported the positive impacts of fast growing exotic trees including eucalypts species on organic carbon and total nitrogen. Similarly (Birru *et al.,* 2013; Yitaferu *et al.,* 2013; Holden *et al.,* 2003) also found no significant negative impacts on soil of eucalyptus plantation following re-conversion form eucalyptus plantation to crop land in Ethiopia. In contrary to common belief of Eucalyptus impact on crop yield study (Tadele *et al,* 2014) the growth and yield of maize grown on the clear-felled eucalyptus stands were better than those grown on continuously cultivated farms. According to (Haile, *et al.,* 2014) eucalyptus woodlots land had higher OC, TN, SOC and TN stock as compared to cereal lands (Fritzsche *et al.,* 2006) added that Eucalyptus deep taproot deplete the underground water but crop root zone water which helps for crops and understory native species regeneration. On the other hand, soil was generally driest under *C. lusitanica* with its dense canopy and shallow root system, particularly following a relatively low rainfall wet season, with the wettest soil under *E. globulus.* Wet season transpiration of *C. lusitanica* was twice that of the other species.

On the other hand, fast growing nature of species like eucalyptus species may negatively affects soil reaction and moisture. Planting eucalyptus also negatively affects the crop yield of adjacent farmlands due to root competition and shading effects (Haile, *et al.,* 2014). Eucalyptus decimates land and water while *Prosopis juliflora* detrimental effects to local plant species richness at high densities (Neville *et al.,* 2003, cited in: Gichua *et al.,* 2013). Based on research outcomes by different scholars restoration using fast growing agricultural land has both harmful and beneficial sides. Therefore, future restoration of soil should focus on strategies that improving the soil nutrient and carbon storage under cereal land for enhancing sustainable agricultural landscape management, thereby improving the livelihood of agrarian community. Thus, current strategies of planting fast growing eucalyptus woodlots in response to scarcity of forest products and economic benefits should be considered the negative impacts on soil and crop yields of neighboring farmlands. Tree crown and root management, design the spacing and orientation in such a way that the competition of fast growing trees will be minimized should be explored.

CONCLUSIONS

Long time cultivation and lack of proper agricultural land management has led to soil degradation and subsequent reduction in crop yield. As a result Ethiopia remains food aid receiving country. The highlands part of the country on which overwhelming population reside are highly degraded and large hectares of land had reached a point of no return. Farmers have been encroached marginal lands and converted forest lands to

agricultural land as adaptation mechanism. But this could no longer be an option due to lack of any remaining marginal or forest lands to be converted. The best countermeasure is therefore restoration of the degraded agricultural land.

There are different restoration mechanisms. Restoration can be done by enclosing the area (avoid the land) from cultivation or grazing in areas of large landholding size, implementing different physical SWC measures, tree planting or the combination of these interventions. It is very exorbitant to use area closure due to scarcity of agricultural land in Ethiopia. Restoration using tree planting in combination with physical SWC measures is a viable option. Restoration using re-vegetation can be done by planting trees. It can be exotic or native trees. This review work focused on merit and demerit of using exotic and invasive plant species for agricultural land restoration in Ethiopia. It is possible to categorize exotic plants into three based on their behavior. The first is exotic plants species mainly crop species introduced, naturalized and diversified in Ethiopia long time ago; non-invasive fast growing species (mainly trees) and invasive species (herbs, shrubs or trees).

The naturalized and diversified plants become part of Ethiopia agricultural. They have immense socio-economic importance. The second group of exotic species is invasive species. The adverse impacts of the invasive species such as (*Prosopis juliflora*), parthenium weed (*Parthenium hysterophorus*), water hyacinth (*Eichhornia crassipes*), *Lantana camara*, and Acacia species outweigh their beneficial role. The lack of proper management techniques has worsened the situation of agricultural land colonized by these species.

On the other hand there are high numbers of fast growing non-invasive exotic species in Ethiopia. These plants have multifaceted socio-economic importance. They are used for fuel wood, construction material, timber, etc. They also help for conservation purposes or for land restoration, however all the exotic species do not have similar behavior. Their performance also varies on the site condition. There are leguminous exotic plants which help the restoration of soil fertility; there are also species which suits local flora. On the other hand there are species which affects water availability, outcompete with co-existing native species by their root structure near crop root zone. In general merit and demerit of fast growing exotic species vary from species to species. The generalization or old view on the devastating behavior of all exotic species is not right as some studies confirm their positive role. Therefore, while selecting exotic plant species for agricultural land restoration, their compatibility should be assessed in advance. Otherwise, their weaknesses mask their benefits. In general, restoration is a complex process that is further complicated by invasive plants. More-sophisticated methods to selectively control invasive plants while promoting the establishment of desired species are needed to overcome obstacle to restoration success. If possible good trait of invasive species should also be used to facilitate restoration.

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