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Review

Importance of non-timber forest production in sustainable forest management, and its implication on carbon storage and biodiversity conservation in Ethiopia

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Non-timber forest products (NTFPs) are biological resources of plant and animal origin, harvested from natural forests, manmade plantations, wooded land, farmlands and trees outside forests or domesticated. These products are vital sources of income, nutrition and sustenance for many forest-based communities around the world. This study tries to review available and accessible literatures on role of NTFPs in sustainable forest management including sociological approach, economic approach, ecosystem approach, technological approach and its related services (biodiversity conservation and carbon sequestration). The use of NTFPs has received attention in light of their perceived potential to address both poverty reduction and tropical forest conservation. It was suggested that better management and utilization method has to be set for diversifying products benefit for the local community.

Key words: NTFPs, sustainable, biodiversity, forest management.

INTRODUCTION

Non timber forest products (NTFPs) are, in broadest sense, any biological resources collected from wild by rural people for direct consumption/income generation on a small scale (Shackleton and Shackleton, 2004). They include wild edible foods, medicinal plants, floral greenery, horticultural stock, fiber of plants, fungi, resins, fuel wood, small diameter wood used for poles, carvings etc. (McLain and Jones, 2005). Interests in NTFPs was predicated upon a few assumptions these include: commercial exploitation of NTFPs is less ecologically destructive than timber harvesting, and thus has greater potential for sustainable forest management; local forest users exploit forest resources wisely and sustainably and NTFPs will more directly benefit people living near forest compared to timber harvesting (Ruiz Perez and Arnold, 1997).

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There has been increasing recognition of NTFPs contribution to household and national economies and environmental objectives including biodiversity conservation (Arnold and Perez, 2001). For example, a study by MEA (2005) estimated that up to 96% of the values of forest are derived from NTFPs and services. Also, they have been recognized internationally as an important element in sustainable forestry. The UNCED in 1992 identified sustainable forest management as a key element in sustainable economic development, and set out nonbinding guidelines for sustainable forest management with specific inclusion of NTFPs (Jones et al., 2004).

Similarly, Plotkin and Famolare (1992) ascertained it by stating that there was a big concern on how to address the increasing and expanding deforestation of tropical forests. At that time, ecologists tried to answer how to make forest resource economically attractive to local people to reduce deforestation. NTFPs were among options considered best strategies to raise income for local people from forest while addressing conservation bjectives (Ruiz Perez and Byron, 1999). Since then, sustainability of NTFPs extraction has been a topic of debate due to the underlying objective of development, and conservation are basically linked. For instance, EARO and IPGRI (2004) argued that contribution of NTFPs to livelihoods of rural communities is likely to persist as long as the resources are exploited on sustainable basis. This has led in a global move towards developing management of natural forest for the benefits of local communities (Hobley, 1996).

Biodiversity is the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This comprises diversity within species, between species and of ecosystems (Gillespie, 1997; Huston and Marland, 2002; Koziell, 2001; UNEP, 2007). Particularly NTFPs is one option for slowing the rise of GHGs concentrations in atmosphere which aims to increase the amount of carbon remove and what is stored in forests (Gorte, 2009). CS is defined as an increase in Carbon stocks other than in the atmosphere (Huston and Marland, 2002; Namayanga, 2002).

Objective

1. To know the importance of non-timber forest production in sustainable forest management.
2. To know the importance of non-timber forest product for carbon storage and biodiversity conservation.

BASICS OF NTFPS, SUSTAINABLE FOREST MANAGEMENT AND ITS RELATED SERVICES

Non timber forest products (NTFPs)

NTFPs have many definitions in the literature. Thus, it is hardly to encounter single definition of NTFPs in the existing literatures (Gary and Kristin, 2005). This is due to the fact that different individuals and/or organizations have modified the definition in different ways to suit their needs (Belcher, 2003; Rajesh, 2006). Accordingly, definition of NTFPs for this study is provided in the introduction section.

Sustainable forest management (SFM)

There is no standard definition of SFM. However, according to Chamberlain et al. (2002), SFM is built on the principle that forest management will meet current societal needs without affecting future generations, or the forests' abilities to rejuvenate. This concept holds three fundamental standards: forest management is socially acceptable and equitable; the impact is ecologically benign and the economic impact to local communities is positive. In similar fashion, it was stated that sustainable forest management is a type of management that maintains and enhances long-term health forest ecosystems, while providing economic, social and cultural opportunities for the benefit of present and future generations (Mulugeta, 2009).

Non-timber forest products in Africa

Although NTFPs play a major role in the rural economy of Africa, information on their overall contribution is patchy and incomplete at best, except for a few species and products of commercial importance (FAO, 2003). The lack of systematic efforts to conserve and manage resources is a major concern, and it is only in few cases that efforts have been made to cultivate species that yield NTFPs. African forests are a source of a variety of NTFPs such as fruits, gums and resins, honey and beeswax, medicinal and aromatic plants, dying and tanning materials, bamboo, and bush meat. These products are of critical importance to the livelihoods of rural communities and, in some situations, account for a significant share of household income (FAO, 2003) as a source of food.

Increased demand has not necessarily led to improved management including domestication, and a substantial proportion of products are collected from the wild, hence resource depletion is a major problem (FAO, 2003). Further, Africa has not been able to take advantage of its wealth of raw material and traditional knowledge and investing on processing—undermining opportunities for employment and income generation. Namkoong et al. (1996) concluded that the main effects of harvesting whole individuals would be via genetic drift and indirect selection. In contrast, harvesting only reproductive structures would most likely affect gene flow, the mating system and direct selection.

Throughout Africa, numerous medicinal plant species are becoming increasingly scarce due to a rise in trade to meet the demand from growing urban populations (Marshall, 1998). For example, favored species such as Dalbergiamelanoxylon have declined in Kenya and South Africa through harvesting to supply the woodcarving trade (Shackleton, 1993; Cunningham, 2000). Bark extraction has caused serious damage to wild populations of Prunusafricana, including trees inside forests of high conservation value (Cunningham et al., 2002). Warburgiaugandensis is another tree species threatened by exploitation of its roots, barks and shoots for medicinal purposes in East Africa. *Boswelliapapyrifera* is one of the threatened species in Ethiopia due to over exploitation or improper tapping of its frankincense, and lack of regeneration (Abeje, 2002).

Unless harvesting is controlled, some species will therefore become genetically impoverished or depleted more rapidly than others (Arnold and Perez, 2001). Exploitation of NTFPs from the wild in many respects and depending on the plant part harvested can help for sustainable utilization of the species. However, this requires understanding growth and reproductive characteristics of the plants and the application of harvesting practices that permit adequate reproduction or regeneration of the individual organism (Sunderland et al., 2004). Domestication of the species in question is another alternative in cases where exploitation of NTFPs from the wild cannot be sustainable.

Important NTFPs in Ethiopia

Due to its varied ecological and climatic conditions, Ethiopia is home to some of the most Diverse flora and fauna in Africa. NTFPs in Ethiopia cover a wide range of products, and are most extensively used to supplement diet and house hold income, notably during particular seasons in the year, and to help meet medicinal needs. They are largely important for subsistence and economic buffer in hard times.

These products contribute to the improvement of the livelihoods of rural communities by providing food, medicine, additional income, and employment opportunities and foreign exchange earnings of the country. In addition, by complementing wood-based management, they offer a basis for managing forests in a more sustainable way, thereby supporting biodiversity conservation. Historically, early forestry work tended to ignore this fact; it was mainly focused on managing forests for the continued supply of timber. The significant value and importance of NTFPs is felt more in dry land areas where few alternatives of resources exist for supporting the livelihoods of local communities because of difficult environmental conditions (EARO, Unpublished).

In Ethiopia, non-farm income represents an important element in the livelihoods of the poor. In several areas, where the population density and depletion of natural resources are high, agriculture cannot possibly remain the only source of income. Observations show that, in many areas, crop production is no longer the main source of income for poor rural households (RESAL, 2000). Therefore, it is essential for rural households to look for non-farm activities like productive exploitation of NTFPs to supplement agricultural production.

The most important NTFPs in Ethiopia include coffee; spices and condiments; honey and wax; bamboo; reeds; natural gums such as gum arabic, frankincense and myrrh; edible plant products like leaves and shoots, fruits, seeds, tubers, mushrooms, edible oil, and fat; fodder; fibers; bark, simple sugar products; essential oils; tannins and dyes; resins; latex; ornamental plants and giant/long grasses (EARO, Unpublished). Spices harvesting is practiced in many forest areas of southern Ethiopia, such as Sheka, Keffa, Bench Maji, South Omo and GamoGofa Zones (Jansen, 1981). Commercial spices such as Aframomumcorrorima (Korerima) and Piper capense (Timiz) are found as indigenous species in Shekicho-Keficho and Bench Maji forests and woodlands.

Beekeeping is an ancient tradition in Ethiopia with annual production of about 24,000 tons of honey. This is the third of the total honey production in Africa. The density of hives is estimated to be the highest in Africa. An estimated 4 to 10 million traditional beehives, and some 10 000 modern boxes exist in the country (Vivero, 2001). The main products of the beekeeping industry are honey and wax. Honey is almost exclusively consumed locally, while a considerable proportion of wax is exported.

Ethiopia is one of the few tropical countries well-endowed with diverse plant species that yield economically valuable gum and aromatic resins such as gum acacia, frankincense and myrrh (Wubalem et al., 2003). The commercial use of natural gums is an age-old activity in Ethiopia. Ethiopia has been one of the major producers and exporters of natural gums from different indigenous tree species of the genus Acacia, Boswellia and Commiphora, which are found in different agro-ecological zones of the country (Vollesen, 1989).

Ethiopia has 67% of Africa's bamboo resources which is about 7% of the world total (Kassahun, 2002). It has about 1 million ha (Luso Consult, 1997; Kassahun, 2002) of highland bamboo. Arundinariaalpina accounts 150, 000 ha, out of which 130, 000 ha is natural and 20, 000 ha human made bamboo plantations owned by framers. Lowland bamboo is dominant with coverage of 700,000 to 850,000 ha. Bamboo provides food, fodder, furniture and building materials (scaffoldings), industrial inputs, medicinal plants and fuel. Solid bamboo has been tested as a concrete reinforcement to substitute steel and the results have revealed success.

The overall socio-economic and ecological importance and contribution of NTFPs in Ethiopia is significant, diversified and valuable. The harvesting, commercialization and transformation of certain NTFPs by the rural poor can be a means of shifting efforts away from the unsustainable exploitation of ecologically sensitive forest products. The NTFPs are among the main coping mechanisms that poor households and the nation have. Thus, their importance should not be overlooked or underestimated.

The link between NTFPs and forest sustainability and its services

Forest biodiversity is being lost at an alarming rate. Publications of MEA (2005) indicate that a large and increasing number of forest ecosystems, populations and species are threatened globally or being lost due to the loss and degradation of forest habitats.

The link between NTFPs and forest sustainability and its services (biodiversity conservation &carbon storage) can be understood by taking into consideration of some cases. For example, in the Bio-Carbon fund project of CDM in Niger, *Acacia Senegal* Plantation aimed to reforest over 17,000 ha of degraded land, expected to sequester about 1.8 million tCO_2 in the nearfuture (2017). With strong local social and environmental benefits: income generation through carbon payments, gum production, rehabilitation of degraded land and biodiversity (NTF-PSI, 2008). Likewise, in case of Ethiopia, Humbo Assisted Regeneration Project is aimed to restore 2,728 ha of biodiversity natural forest and expected to sequester about 750,000 tCO_2in 30 years with benefits of improved community capacity to participate in carbon finance reforestation, and also to improve their livelihoods (NTF-PSI, 2008). Moreover, Mulugeta and Habtemariam (2007) discussed that vegetation of *Acacia, Boswellia and Commiphora*(ABC) which can be managed to provide many functions (economical andecological services). This will enable Ethiopia to fulfill international conventions (such asCBC, CCD and CCC) that Ethiopia has ratified. Some of the Potentials of the vegetation, ABC, for biodiversity conservation and carbon sequestration, are presented as follows:

ABC for biodiversity conservation: There are two possible states of affairs in that *Acacia, Boswellia and Commiphora* species can be managed to contribute to biodiversity (Mulugeta and Habtemariam, 2007). (a) Through gum and incense extraction, as NTFPs. Extraction of gum and incense, when appropriately conducted, is non-destructive and hence causes negligible damage to the biodiversity, this is in line with one of the few assumptions of NTFPs. For that reason, via proper gum and incense extraction for economic benefit, we can conserve the vegetation for their biodiversity value. (b) Through integration of the species into other economic sectors. *Acacia, Commiphora and Boswellia*species can be integrated with farming systems in different forms of agro forestry. Agro forestry, as one of integrated approaches to biodiversity conservation, is nowadays receiving considerable attention; since many species of *Acacia, Boswellia and Commiphora* have the necessary qualities to be integrated in agroforestry systems (Mulugeta and Habtemariam, 2007).

ABC for carbon sequestration: Forests involve largest carbon pool of all terrestrial ecosystems (Gibbs et al., 2007; Jandl et al., 2007). This was supported by the study of Von (2006) who stated that tree-based systems and carbon sequestered through process of photosynthesis remains fixed in wood and other organic matter in forests for a long period of time.

In Ethiopia, land use changes such as deforestation and conversion of forests into farm lands are the principal sources of carbon dioxide emission (Mulugeta and Habtemariam, 2007). As a signatory of the convention on climate change, Ethiopia has to work together in the ongoing efforts for carbon sequestration by making use of various sink potentials. In dry lands of Ethiopia, the most viable approach to achieve significant carbon sequestration is by means of productive vegetation management practices. The fact that Acacia, Boswellia and Commiphoracan grow under harsh environment, means that there is even a potential to sequester carbon in extreme environmental circumstances. These plants can also act as wind breaks and, thus, reduce loss of soil carbon by wind; and intercept rain drops by their widely spreading canopies, reduce speed of surface run off and thus reduce soil erosion effectively thereby stabilizing soils and protecting soil carbon (Mulugeta and Habtemariam, 2007). As per Table 1, it is clear that the existence and coverage of the vegetation is almost throughout the nation. This indicates that there is a possibility to develop strategy for these vegetation's to provide socio-economic and environmental goods and service, at regional and/or national level based on proper management of the vegetation.

NTFPs and community development

NTFPs were regarded as providing a very good opportunity for sustainable forest management and community development in the last two decades. There has been an increasing recognition of their contribution to household economies and food security, to some national economies and particularly to environmental objectives, including the conservation of biological diversity (Arnold and Perez, 2001). The role of NTFPs to the livelihoods of rural communities is likely to continue as long as the

Table 1. Estimated area coverage of vegetations with gum and resin bearing species in Ethiopia by region.

Region	Genus of vegetation	Estimated area (ha)
Afar	*Commiphora and Acacia*	65,000
Amhara	*Boswelia, Commiphora, Acacia and Sterculia*	680,000
Benshangul	*Boswelia, Acacia and Sterculia*	100,000
Gambela	*Commiphora, Acacia and Sterculia*	420,000
Oromia	*Boswelia, Commiphora, Acacia and Sterculia*	430,000
SNNP	*Boswelia, Acacia and Sterculia*	70,000
Somalia	*Boswelia, Sterculia, Commiphora and Acacia*	150,000-1, 500,000
Tigray	*Boswelia, Sterculia, Commiphora and Acacia*	940, 000
Total	-	2,855,000-4,355,000

Source:(Fitwi, 2000; Lemenih et al., 2003).

resources are exploited on a sustainable basis. This in itself is not likely to result in tremendous community development since these rural communities have been using these resources for centuries. On the other hand, exploitation of NTFPs for commercial purposes contributes to local economies—hence contributing to community development. The only drawback to this scenario is that commercialization also results in over-exploitation and depletion of the resources. Therefore, a balance has to be stricken between resource sustainability and benefits of exploitation of products, particularly for the export market.

Management of non-timber forest products

Theoretical concepts in NTFPs management

The process, by which resources are allocated, regenerated, managed and conserved over time and space to meet the needs of humankind has been termed as resource management (Karki, 2001). on the same document, resource management involves an interaction of three major elements. These are:

1. Physical resource base (land, water, forests, wildlife, etc.).
2. Production system (the mix of technologies and productive activities) and
3. Social regulation (laws, rules and principles).

NTFPs management encompasses ecological, technical, social, economic, legal and political aspects (Karki, 2001). As an ecological concept it deals with complex ecosystems that need to be monitored and maintained. Its technical aspect involves choice between different methods, techniques and development of appropriate harvesting and processing technologies. The social aspect of resource management also deals with people, cultures, belief systems, attitudes and behavior, ethics, aspirations and social values, and its economic aspect aims at maximizing benefits and efficiency from a resource and minimizing input costs.

In the case of NTFPs, the social aspect also entails dealing with competing and voracious demands of people invariably place on the shrinking resources. Finally, resource management is a political subject because it involves exercise of power and control over users of resources, and this raises issues of administration and decision making (Karki, 2001).

Management approaches of NTFPs

Non timber forest products management is a process involving harvesting, gathering, utilization and management of resources within a given ecological, economic, social, political, institutional and legal frameworks (Karki, 2001). Further, it was discussed that in past times, focus on forest resource management has been in sector and single purpose user centered, that was solely giving the responsibility of resource management to technical expert such as forester and biological scientists. This scientific approach has neglected, traditional resource management based on local people's knowledge, cultural values and needs. Moreover, the multidisciplinary and integrated nature of resource management in which inter sector a land synergistic linkages has often been ignored (Karki, 2001). With the increasing recognition of the limitations of such centralized approaches in recent years, a need has been felt for more holistic and integrated approaches for sustainable management of NTFPs resources.

Sociological approach

This approach emphasizes on significance of culture, ecological and social ethics, indigenous knowledge, the role of local people and social institutional arrangements in resource management. The sociological aspect of resource management has been the most neglected area in the resource management strategies of many countries until recently (Karki, 2001). For instance, Chambers (1991) examined that failure of a number of resource management programs was associated to the disregard of local culture and wisdom. This approach involves research methods such as participatory rural appraisal (PRA) and institutional arrangements including administrative structures and procedures, policies and laws and financial management (Karki, 2001).

Economic approach

This approach is based on the principle that there is a need to rationalize the allocation of natural resources, and optimize their use through competitive market economies to achieve maximum economic efficiency (Karki, 2001). However, this approach is limited as it assumes that firstly, cost and benefits from the use of natural resources must be known and quantifiable and secondly costs and benefits from one resource need to be isolated from those of another. But sometimes it is difficult to price/determine economic value of intangible benefits from natural resources such as ecological uniqueness, biodiversity, etc. Moreover, minimizing production costs and maximizing monetary benefits in order to strive for economic efficiency tends to increase pressure on some resources and neglect other resources for being of little/no significance in terms of economic development.

Ecosystem approach

This approach considers the whole ecological system, and the relationship among its various components (Karki, 2001; Pawlos, 2010). It recognizes the dynamics of the ecosystem as the basis for resource management. The approach aims at the rational allocation and management of resources based on ecological characteristics, component behavior, change processes and functional relationships among different components within ecosystems (Karki, 2001). The primary concern is to manage resources in a manner that minimizes ecological destruction. This approach involves practices such as; resource inventory, identification of natural processes that affect ecological stability; evaluation of functional significance of different components in an ecosystem and design of alternative management strategies to ensure ecological stability, productivity and sustainable development. Ecosystem approach is based on three perspectives represented as follows:

1. **Technological approach:** This approach comprises comprehensive land use or resource management plans and their implementation for rational allocation and utilization of natural resources based on the land capability classification. It is aimed at monitoring and mitigating environmental change using physical tools and modern technologies like mapping, geographic information system(GIS),remote sensing(RS) etc, environmental impact techniques, biotechnology and other techniques (Karki, 2001). Ecosystem approach is based on three perspectives represented on Figure1.

2. **The contribution of NTFPs extraction to forest conservation**: Some NTFPs enter into international market, even though most of them are locally used as food, medicine etc (Ros-Tonen, 2000). Among the NTFPs that inter the international markets are: honey, palm heart, plant and animal input to the pharmaceutical industry, bamboo, essential oils and gum arabic. In relation to this commercial extraction of NTFPs through adding value to the forest product it may provide an incentive to conservation and sustainable forest management. Similarly, Andel (2006) stated that commercial NTFP extraction may contribute to forest conservation because collectors often protect useful trees from being logged.

3. Moreover, if people can earn a living by selling NTFPs, they will not need to involve in other environmentally more destructive activities. Increased income from trade of NTFPs is thought to provide stimulus for local communities to protect their forest and manage sustainably (Ros-Tonen, 2000). Many NTFPs can be harvested without significantly changing the forest, hence maintaining the forest environmental services and biological diversity (Ros-Tonen, 2000). On the other hand, any harvesting of NTFPs have ecological impacts including, gradual reduction of vigor of harvested plant species, decreasing rate of seedling establishment (peters, 1996). However, comparing to that of logging and conversion of land to other land that use these ecological impact were viewed as minimal. Ros-Tonen (2000) stated that it is incorrect to suggest that NTFPs are harvested indefinitely without proper management practice to sustain their yield.

Factors that hamper sustainable management of ntfps

Ecological factors

Ecological issues, if not addressed, could result in long-term and perhaps permanent decline in biological diversity (Chamberlain et al., 2002). The same document revealed that current scientific knowledge cannot adequately determine sustainable harvest levels of

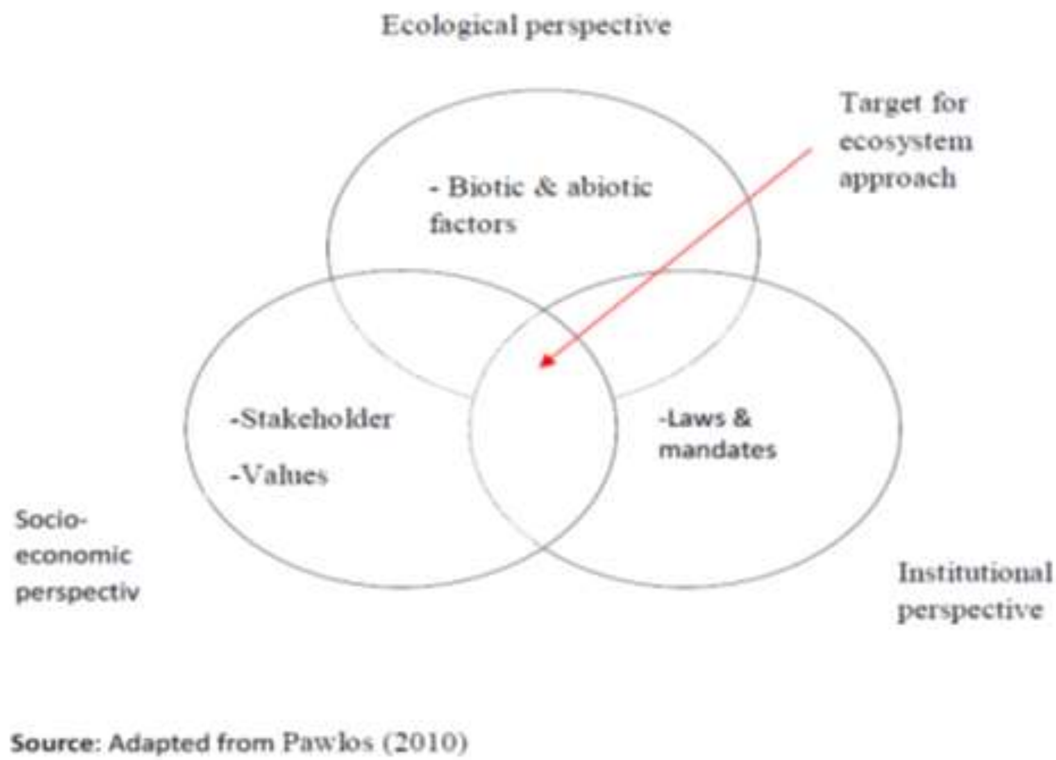

Figure 1. Ecosystem approach on different perspectives.

biological resource from which NTFPs is collected; research is needed to examine and determine effects of harvesting on plant populations, as well as the impact on associated forest ecosystems, and concluded that sustainable forest management will remain elusive until knowledge concerning NTFPs is developed. Neumann and Hirsch (2000) supported this idea by stating efforts to measure the direct ecological impacts in actual NTFPs harvesting systems is not easy since most real world situations are complex that other underlying factors are hard to filter out.

Nevertheless, many studies have tried to deal with it. For example, seventy studies have quantified ecological effects of harvesting NTFPs from plant species perspective, with aims of assessing current state of knowledge, and illustrated that NTFPs harvest can affect ecological processes at many levels, from individual to ecosystem (Ticktin, 2004). In this case, it was evidenced that intensive annual harvesting of a valuable market fruit or oil seed can gradually eliminate a species from a forest ecosystem (Ruiz and Arnold, 1997). Ecological impacts of NTFPs harvest is not only observed in plants but also in animals. For instance, Fitzgibbon et al. (1995) stated that bush meat harvesting has the potential to alter ecosystem structure and functioning where one/more important animal species are depleted.

Change in socio-economic and institutional aspects

It is clear that transport systems are reaching further into remote areas, catalyzing forest and woodland clearing for different purposes, and this result in the loss of supplies of wild harvested species as habitat declines. For this reasons, Wilkie et al. (2000) underlined the need, through co-ordinated land-use and infrastructure planning, to plan roads in a way that maximizes local and national economic benefits while minimizing the negative effects road construction has on biodiversity. Since the 1960's, growing demand from urban areas has catalyzed NTFPs trade, drawing resources from rural areas to towns and cities, for fuel wood, building materials, medicinal or edible wild fruit species (SCBD, 2001). Consequently, urbanisation has tended to increase rather than reduce the demand for wild plant resources that stimulates overexploitation.

According to Chamberlain et al. (2002) three major institutional weaknesses were important to have impact on sustainable forest management efforts. First, staff levels and expertise were inadequate to deal with non-timber forest products. Second, institutional impediment to sustainable management of NTFPs was that the biological materials from which these products originate are not recognized nor treated as other natural resources (such as timber and minerals) and third, lack of funding to support sustainable forest management activities.

Some suggested points concerning sustainable managements of NTFPs

Ticktin (2004) suggested that, so as to manage and conserve NTFPs populations effectively, at least three ecological questions must be addressed in addition to socio-economic issues; these were: what are the ecological impacts of NTFPs harvest? What are the mechanisms underlying these impacts? And what kinds of management practices mitigate negative impacts and promote positive impacts?

It was also recommended that, feasible strategies and continuous action plan should be developed for conservation and sustainable utilization of respective source of NTFPs species and their habitat (EARO and IPGRI, 2004). Similarly, Arnold and Perez (2001) recommended that approaches to conserve plant species that are source of NTFPs, need to be adapted to individual species and their habitat. Suggestion provided by SCBD (2001) also support the same idea, that if policy on sustainable management of NTFPs is to be implemented successfully, then policies and their implementation practice have to be tailored to local ecological, economic and socio-political circumstances.

Source of NTFPs populations managed by knowledgeable harvesters may show high growth rates under high harvest pressure, whereas populations of the same species managed by less knowledgeable harvesters may decline under much lower levels of harvest (Ticktin and Johns2002). It seems for this reason, EARO and IPGRI (2004) recommended that, public awareness needs to be created about the contribution of NTFPs at local and national level to promote sustainable utilization of products for economic and environmental benefits. On the other hand, Chamberlain et al. (2002) suggested a helpful thought that, many collectors can trace their heritage and relationship with NTFPs back to several generations, and this traditional ecological knowledge is critical in understanding the fundamentals of NTFPs management.

Thus, sustainable management strategies will require understanding and respecting people views and uses of the NTFPs resource. Biodiversity of tropical forests with its millions of species, which have not yet been scientifically described, might hold many NTFPs for future uses in different sectors, thus conserving this biodiversity is critical. Good forest governance and incorporation of NTFPs in relevant national strategies and action plans are important steps for conservation and sustainable use of NTFPs resources (SCBD, 2009). Furthermore, it was suggested that, it is indispensable to continue research on possibilities for NTFPs to contribute to sustainable forest management since NTFPs play important role in local forest use (Ros-Tonen, 2000).

CONCLUSION

Forest management is primarily for ameliorating climate, checking soil erosion and flood, protect biodiversity etc. Dry land forest management and silviculture incorporate a set of practices that can facilitate the expansion, regeneration, growth and functional utility of forests, and the human activities essential to the conservation and sustainable development of forest and woodland resources in drylands, helping these resources to become ecological and environmental buffers that tone down the often harsh climatic conditions and their impacts.

NTFPs have been increasingly recognized for their contribution to economic development and sustainable forestry management. The link between NTFPs and forest sustainability could be understood by taking some cases into consideration (for example, properly managed vegetation forgum and resin can store carbon and conserve biodiversity). This can led to sustainable forest resource management; since extraction of NTFPs can be conducted without significantly changing forest stands. However, sustainability in NTFPs resources management is questionable without giving considerable attention to ecological, social, and economic aspects. On the other hand, there are some obstacles that restrain sustainable management of NTFPs related to ecological change, socio-economic change and institutional factors.

Eventually, some suggestions regarding sustainable management of NTFPs were provided. These were linked to impact of NTFPs extraction on species and ecology; management approaches; knowledge of collectors, integration of NTFPs in national strategies and need of continuous research on NTFPs for forest sustainably.

Thus, based on the review, management approaches and practices of NTFPs in sustainable forest managements need to be adapted to local ecological, economic and social political circumstances. Responsibility of NTFPs management for forest sustainability should not be given only to an expert (forester) but also inclusion of traditional knowledge through involvement of stakeholders in management of forest resource is vital. Finally, further research on possibilities of NTFPs management for forest sustainability and its related services is needed.

Conflict of interest

The author has not declared any conflict of interest.

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Sorghum bicolor landraces: Selection criteria and diversity management in Ethiopia's East-Central Highlands, 1992-2012

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The dynamics of sorghum on-farm landrace diversity in five North-Eastern, Central Highlands communities in Ethiopia have been investigated through 300 farmer interviews and surveys of their fields in each of the 1992/1993, 2000/2001 and 2011/2012 cropping seasons. Over the 20-years, farmers' selection criteria increased from 10 to 28 and the landraces from 60 to 77. That 50 of the landraces were recorded in all the surveys, suggests that they were chosen for their acceptable performances over the various and variable climatic seasons and/or for their cultural values. Landraces grown in only one or two communities increased from 37 to 53, while landraces cultivated in three or more increased by 1 (23 to 24). These increases have occurred despite increased land fragmentation related to government land redistribution policies and population growth having decreased the average field area planted to sorghum landraces by 42% (1.97 to 1.14 ha). Despite the reduced land area cultivated, 56% of the farmers increased their on-farm sorghum landrace richness and 72% increased their selection criteria over the period. The implications of cultivating huge landrace diversity, using multiple selection criteria and increasing the practice of interplanting quick-maturing standby crops in a situation of shrinking and increasingly fragmented land areas for the feeding of a growing population in an area of recognizable climate uncertainty and extremes are discussed.

Key words: Agricultural landscape, agroclimatic variations, farmers' selection criteria, landrace richness, Spatio-temporal dynamics.

INTRODUCTION

Since the dawn of agriculture, landraces have served as the foundation for humanity's food and livelihood security. They emerged through intra-and inter-speciation processes in response to human and natural selection pressures. Landraces continue to be abundant, especially where unfavourable soil and/or climatic

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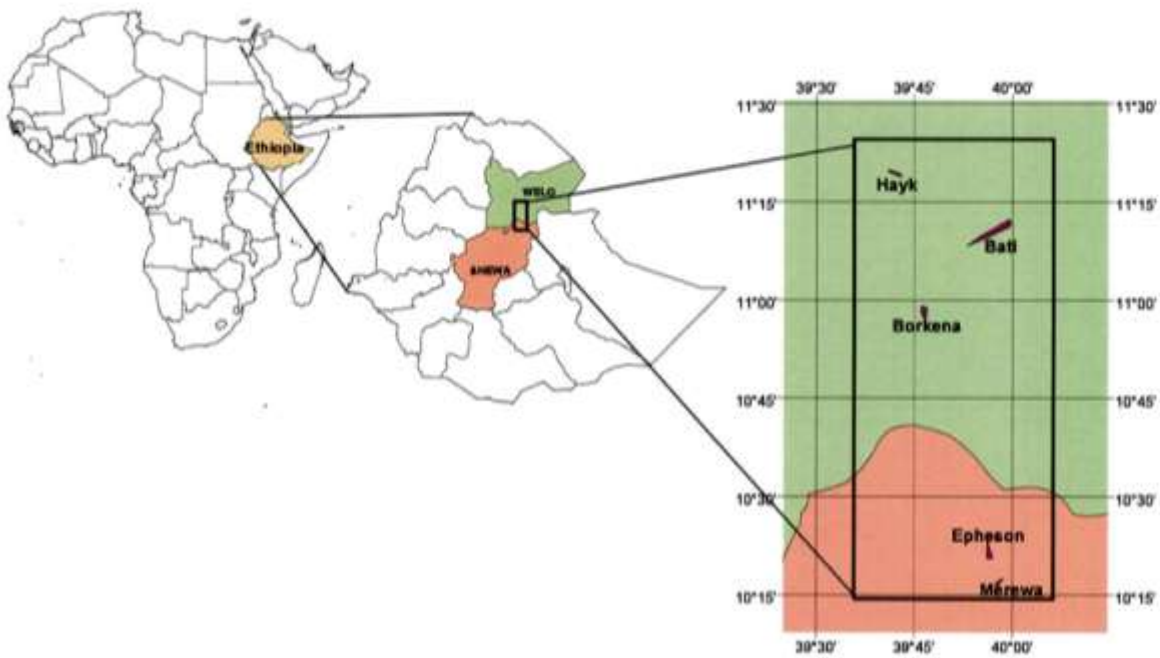

Figure 1. The research area: five agricultural landscapes in North Shewa and South Wollo, Ethiopia (Teshome et al. 2007).

conditions constrain the production systems of traditional farmers.

In Ethiopia, the centre of origin of sorghum (Vavilov, 1926), traditional farmers maintain a wealth of sorghum landraces and other locally, nationally, regionally and globally important crop species in their seed systems and agricultural fields. Sorghum [*Sorghum bicolor* (L.) Moench], which was domesticated (Vavilov, 1951; Dogget, 1988, 1991) and diversified in Ethiopia (Harlan, 1969), belongs to the elite cultivated crops that strongly dominate as sources of human energy. Indeed, sorghum is surpassed, only by rice, wheat, and maize in feeding the human race (National Academy of Sciences, 1996).

Of these crops, the untapped potential of sorghum is by far the greatest. The base of this potential resides in the genetic, morphological and physiological characteristics of the landraces selected and maintained by the traditional farmers. These characteristics have allowed sorghum to dominate in many drought-prone production systems. More than 90% of African sorghum production is from traditional-farmer-developed sorghum landraces (National Academy of Sciences, 1996). In Ethiopia, over 95% of sorghum fields are planted to sorghum landraces, and over 95% of the sorghum varieties cultivated are farmer-selected landraces (CSA, 2012). Intraspecific diversity and the farmers' knowledge and practices have worked together over climatic seasons (time) and across agricultural landscapes (space) to provide resilient and sustainable seed, food, and livelihood security and to reduce the risks of genetic erosion (Teshome et al., 2016).

Studies by Teshome (1996) to present in north Shewa and south Wollo, Ethiopia, where sorghum is the dietary staple and most important crop in production and acreage, have verified that human and natural factors interact to generate and expand the status and trends of landrace diversity in traditional farming systems at field, community and landscape levels. Surveys were conducted in five agricultural communities - Bati, Merewa Adere, Epheson, Borkena, and Hayk - by increasing altitude (Figure 1). A major south to north highway, with a link to Bati and the Rift Valley, links the communities. While the highway connects the communities, the farmers, by and large, use beasts of burden to transport agricultural produce to the nearest local market. Direct interactions with farmers of other than neighbouring communities are infrequent.

Three hundred randomly selected farmers were interviewed and their fields systematically surveyed in each of 1992/1993, 2000/2001 and 2011/2012 cropping seasons to determine if and how farmers' selection criteria and sorghum landrace diversity have changed, and to gain insight into the implications of the changes for seed, food and livelihood security. The major conclusions are that: (1) folk and numerical taxonomies for the landraces are consistent with one another (1997); (2) the landrace diversity at the field level is greater for farmers who apply more selection criteria to define their diverse needs and requirements (1999b); (3) the sorghum landraces vary in their levels of biological resistances to storage pests (1999a); (4) the farmers' knowledge of storability corresponds with laboratory tests of resistance to weevil infestations (1999a) and (5) both natural factors and farmers' selection criteria shape crop genetic diversity at the field and landscape levels (1996).

The farmers practice diversity-based agriculture in which a variety of crops and crop varieties are cultivated. Management choices are based on their knowledge of their fields in terms of size, soil variability, topography, altitudes, and microhabitats, and how these impose restrictions, or present opportunities. Recognition that climatic factors have degrees of unpredictability is always included. The farmers attempt to self-insure by choosing a sufficiently broad base of landraces to ensure at least the minimum essential degree of food and income security (Abdi et al., 2002; Dyer et al., 1992, 1993; Tunstall et al., 2001; Teshome et al., 1999b, 2007, 2016). Most of our study area experienced the severe droughts that afflicted much of East Africa in the late 1980s. As the drought abated, the farmers, in collaboration with the Seeds of Survival Program (SoS) of USC Canada, actively engaged in a major effort to rescue threatened landraces from extinction. The 1992/93 survey was undertaken to establish a benchmark, relatively early in the SoS program, against which to compare future developments.

The objective of this paper is to highlight and analyze the spatio-temporal changes of sorghum landraces, farmers' selection criteria and field sizes, as they evolved over this 20 year period. Readers are advised that, although the research for this study was conducted in five distinct agricultural communities, analysis and discussion will be conducted at the geographical scale of the whole study area. This broad landscape approach is employed to facilitate discussion of the opportunities and difficulties presented by nature's short- to medium-range changes, and the commonalities and differences in the ways that the farmers have responded to the natural and human constraints that they face as they react to agro-environmental, political and other opportunities and challenges (Manel et al., 2010; Schoville et al., 2012).

Study area

The study area (Figure 1) is dominated by steep slopes and undulating landforms with variable shapes and sizes of valley bottoms. Altitudes of the fields surveyed range from 1,200 to 2,500 m above sea level. Mountains and hills, ranging from 900 to 3000^{+}m, influence the agroclimatic patterns of the study area (Teshome, 1996). The major soil types are *Vertisols (in level valley bottoms), Alfisols (on undulating areas in valleys and on low slope and), Inceptisols (on modest slopes),* and *Entisols (on steeper slopes)* (Teshome, 1996).

Temperature and rainfall are highly heterogeneous and play deterministic roles in the crops and varieties cultivated. Mean monthly minimum and maximum temperatures range from 3-14°C and 18-30°C, respectively (EMA, 2012). The annual rainfall regime may be bimodal or unimodal. The bimodal rains come as short rains (*belg)* in February/March to April/May followed by long rains (*meher)* from May to September. The short rains (*belg)* may be adequate for quick-maturing sorghum and other fast-maturing crops, and support up to 30% of grain harvest. The long rains (*meher*) regularly support in excess of 70% of grain production. When the *belg and meher* rains overlap, a bountiful harvest may result. Even light, short rains make ploughing for the long season easier and facilitate planting. If the long rains are inadequate in the unimodal regime, severe shortfalls in grain production may result.

The agricultural system is a rain-fed, seed-farming complex, dominated by cereals, pulses and oil crops. The land is cultivated several times in preparation for planting. Seeds are broadcast over the field and then ploughed into the soil to facilitate germination. Stagger planting and crop diversification are ways of adapting to late or early onset and unpredictability of rainfalls. Nevertheless, undesirable timing and variability of rainfall can introduce serious challenges.

At harvest time, farmers fell each sorghum plant while the head is intact. The heads are removed using a sickle, collected in baskets and taken to the threshing ground. Threshing may be done as a bulk mixture or each landrace is separated by its phenotype and threshed separately. Livestock and human labour are used in threshing. The threshed grain is collected, taken home and stored.

METHODOLOGY

The sorghum landrace diversity measurements were conducted on-farm. For each survey, transect lines were set out 10 meters apart, and the owner of each field was asked to identify the landrace of the sorghum plant closest to each 5 m interval point; at least 200 plants were randomly sampled in each hectare of each field. During the field survey, individual farmers identified each sampled plant by landrace name, and identified the reasons for growing it. Farmers also were asked about the maintenance of sorghum wild relatives *in situ* and the sources of the seeds for their standing landrace populations.

Multiple samples of each landrace were selected in each field with no sample regeneration, purification or bulking being done. This sampling strategy allowed verification that the farmers' names for the sorghum landraces were consistent across the communities and consistent with scientific numerical taxonomy (Teshome et al., 1997). This strategy also facilitated the identification of new landraces. Landrace names are derived on the basis of distinctive agromorphological characteristics, use values and other criteria. The participating farmers all speak the Amharic language and are consistent in their use of sorghum landrace names; neither using the same name for different landraces nor using multiple names for a particular landrace. In Kenya, Labeyrie et al. (2014) also found that sorghum landrace names were consistent across all the farming communities within which a common language was spoken. They were followed in the 2000/2001 resurvey conducted by Teshome with collaboration of graduate students and their supervisors from Addis Abeba University (AAU) and research personnel from the Institute of Biodiversity Conservation (IBC), and in the 2011/2012 resurvey conducted by Teshome in collaboration with USC (Unitarian Services Committee of Canada), EOSA (Ethio-Organic Seed Action. The changes between the 1992/93 to 2000/01 and 2000/01 to 2011/12 surveys have been published in Teshome et al. (2007, 2016).

RESULTS

Changes in sorghum landrace richness

The distinct sorghum landraces recorded have increased from 60 in 1992/93 to 68 in 2000/01 and 77 in 2011/2012 (Table 1). The maximum landraces grown by an individual farmer was 24 in 1992/1993, 34 in 2000/2001 and 26 in the 2011/2012 cropping seasons. The sorghum landrace diversity differences across all the seasons were significant, except between 1992/1993 and 2000/2001 (Figure 2 and Table 2).

Of the 60 landraces recorded in 1992/1993, 9 (*Adow, Aeyfere, Borie, Jiru tinkish, Marchuke/Barchuke, Senklie, Wogere tinkish, Tuba tinkish, and Zengada tinkish)* were not recorded in 2000/2001 of which 4 (*Aeyfere, Marchuke/Barchuke, Senklie, Wogere tinkish,* were again recorded in 2011/2012; a net loss of 5 over 20 years. Over the same periods, 17 new sorghum landraces were recorded in 2000/2001 (total of 68); 13 of these were again recorded in 2011/2012. Only 13 of the 17 new landraces first recorded in 2000/2001 were again recorded in 2011/2012. *Jibo tinkish, Worebabo tinkish, Wotet-begunche, and Gebsitu* were the ones not re-recorded. Nine new landraces were recorded in 2011/2012 (total of 77). Those landraces that were recorded in the first two surveys, but not recorded in 2011/2012, cannot definitively be declared as 'lost'; they may have been at locations not captured by the survey, or they may remain in the local seed supply system but were not been chosen for planting that season by the farmers interviewed (Table 1).

The analysis to this point has been based on the accumulated data from all five communities. A few landraces were recorded in all the communities but the majority were in only one or two. This has caused us to divide the landraces into two categories: 'specialist' and 'generalist', in which 'specialists' are those recorded in only one or two of the agricultural landscapes, while 'generalists' are found in three or more. By this criterion, specialist landraces increased from 37 to 53 (by 43%) over the 20 years, accounting for 61% in 1992/93 and 69% in 2011/12. Over the same period, the generalist landraces increased from 23 to 24, accounting for 38% in 1992/1993, and 31% in 2011/2012.

A substantial proportion of the farmers have changed the number of sorghum landraces cultivated per field. By 2000/01, 39% had increased diversity, 18% had unchanged diversity and 43% had decreased diversity relative to 1992/93. By 2011/2012, 56% had increased, 30% had unchanged, and 14% had decreased the diversity relative to 1992/1993.

Changes in field sizes and farmer responses

Over the survey period, the average field size planted to sorghum landraces has changed from 1.97 ha (92/93) to 1.21 ha (00/01) to 1.14 ha in (11/12) (Figure 3 and Table 2). The average field size was 62% of the original by 2000/01 and only 58% of the original by the 2011/2012 cropping season. Despite these huge shrinkages, farmers have slightly increased the average landrace richness across the whole study area per field from 8.35 in 1992/93, to 8.63 in 2000/2001, and 9.39 in 2011/2012. The extremes of sorghum landraces planted per field were 2 and 24, 2 and 34, and 3 and 26 in 1992/1993, 2000/2001, and 2011/2012, respectively.

By 2000/01, 62% of farmers had greatly reduced field sizes planted to sorghum compared to 1992/1993, 26% maintained the same field sizes, and 11% increased the field sizes. Despite the field size changes, there was almost no change of landrace richness per field. By 2011/2012, 19% of farmers had further decreased field sizes, 53% maintained the same field sizes, and 28% had increased the field sizes; surprisingly, the number of sorghum landraces per field increased significantly. What is of most interesting is that while the field size decreased, 56% of the farmers increased landrace richness and 72% used an increased number of selection criteria (Table 3).

Changes in selection criteria

The total number of selection criteria for choosing sorghum landraces has increased greatly with time (Table 2 and Figure 4) (Teshome et al., 2016). The number of selection criteria for individual landraces ranged from 2 to 6, 2 to 8, and 4 to 8 and the number of per field ranged from 2 to 10, 2 to 16, and 2 to 16 in the successive cropping seasons. Figure 4 presents the changes in the number of selection criteria used by the individual farmers across cropping seasons.

Between 1992/1993 and 2000/2001, 79% of farmers had increased their number of selection criteria; 7.3% decreased; and 13.5% had maintained the same number. Between 2000/2001 and 2011/2012, 85.9% of farmers had hugely increased; 4.5% decreased and 9.6% maintained the same number. Over the 20-year interval, 72% of the farmers increased; 11.5%; decreased and 16.5% maintained the same number of selection criteria (Figure 4 and Table 3).

DISCUSSION

This research commenced a few years after the easing of the severe droughts that caused famine and other severe hardships for the people of the area during the 1980s. The SoS (Seeds of Survival) program had been established to assist the communities in recovering and

Table 1. Landrace distributions (1992/1993, 2000/2001 and 2011/2012).

Sorghum landraces ('92/93)		Sorghum landraces ('00/01)		Sorghum landraces ('11/12)	
Abaerie	Killo	Abaerie	Jofa tinkish	Abaerie	Key ehel
Adow	Kumie	Abdoke	Keteto	Abdoke	Keyo tinkish
Aehyo	Megalie tinkish	Aehyo	Keyo tinkish	Aehyo	Killo
Aeyfere	Malie tinkish	Aehyo-Jamuye	Killo	Aehyo-Jamuye	Kumie
Afeso	Meltae	Afeso	Kumie	Aeyfere	Malie tinkish
Amelsi	Merabete	Ajaebe	Malie tinkish	Afeso	Megalie tinkish
Bakelo	Mogayefere	Amelsi tinkish	Megalie tinkish	Ajaebe	Meltae
Barchuke/Marchuke	Mognayakish tinkish	Aso tinkish	Meltae	Amelsi tinkish	Merabete
Basohe	Mokake	Atse-bayush	Merabete	Aso	Mogayefere
Betenie	Motie tinkish	Bakelo	Mogayefere	Atse-bayush	Mognayakish tinkish
Borie	Nchero	Basohe	Mognayakish tinkish	Bakelo	Mokake
Buskie	Necho tinkish	Betenie tinkish	Mokake	Barchuke	Motie tinkish
Cherekit	Rayo	Borshe	Motie tinkish	Basohe	Muzie tinkish
Chomogo	Senkle	Buskie	Nchero	Betenie tinkish	Nchero
Dekussie	Sererge tinkish	Cherekit	Necho tinkish	Borshe	Necho tinkish
Delgome	Tenglaye	Chomogo	Rayo	Buskie	Rayo
Dobie	Tuba	Dekussie tinkish	Sedecho tinkish	Cherekit	Sedecho tinkish
Ganeseber	Tuba tinkish	Delgome	Sererge tinkish	Chomogo	Senkle
Gedalit	Wanese	Dobie	Subahan	Dekussie tinkish	Sererge tinkish
Gegretie	Watigella	Dewoye	Tenglaye	Delgome	Serina
Gorad	Wogere tinkish	Ganeseber	Tuba	Dewoye	SoS-Aehyo
Goronjo	Wofe-aeybelash	Gebsitu	Wanese	Dobie	Subahan
Gubetie	Wogere	Gedalit	Watigella	Fereji	Tenglaye
Jamuye	Wuncho	Gegretie	Wofe-aeybelash	Ganeseber	Teshale
Jemaw	Yegenfoehel	Gomzazie	Wogere	Gedalit	Tuba
Jiru	Yekermindaye	Gorad	Worebabo tinkish	Gedido	Wanese
Jiru tinkish	Yekersolate	Goronjo	Wotet-begunche	Gegretie	Watigella
Jofa tinkish	Zengada	Gubetie	Wuncho	Gomzazie	Wofe-aeybelash
Keteto	Zengada tinkish	Humera	Yegenfoehel	Gorad	Wogere
Keyo tinkish	Zeterie	Ismael	Yekermindaye	Goronjo	Wogere tinkish
		Jamuye	Yekersolate	Gubetie	Worehimenu
Subtotal=30	**Subtotal=30**	Jemaw	Yifate tinkish	Humera	Wuncho
		Jibo tinkish	Zengada	Ismael	Yekermindaye
		Jiru	Zeterie	Jamuye	Yekersolate
				Jemaw	Yelem-deha
		Subtotal=34	**Subtotal=34**	Jiru	Yifate tinkish
				Jiru tinkish	Zengada
				Jofa tinkish	Zeterie
				Keteto	
				Subtotal=39	**Subtotal=38**
Grand Total= 30 + 30= 60		Grand Total= 34 + 34= 68		Grand Total= 39 + 38= 77	

regenerating the seed stock of their major crop, sorghum, which provided the people with food, feed, fibre, fuel, building material, income and more. Most of the initial seed stock was obtained within the communities and across the study area. The 1992/93 research established a baseline against which to measure subsequent changes (recovery). The relationships among landrace richness, farmers' selection criteria and field sizes through time and space over the subsequent twenty years period are discussed below.

Diversity changes

Traditional farmers, using their knowledge of the heterogeneity and adaptive responses of the landraces to

Table 2. Diversity, field size, and farmers' selection criteria changes in1992/1993, 2000/2001 and 2011/2012

Selection criteria	Mean 1992/93	Mean 2000/01	T-stat	P-value	Mean 2000/01	Mean 2011/12	T-stat	P-value	Mean 1992/93	Mean 2011/12	T-stat	P-value
Field size (ha)	1.97	1.21	16.22	<0.0001	1.21	1.14	2.1	0.035	1.97	1.14	16.15	<0.0001
Landrace diversity (numbers)	8.35	8.63	-1.02	0.30*	8.63	9.39	-3.2	0.0015	8.35	9.39	-3.41	0.0007
Farmers selection (numbers)	5.35	8.82	-20.43	<0.0001	8.82	9.21	-2.2	0.02	5.35	9.21	-23.72	<0.0001

Changes in 1992/93, 2000/01 and 2011/12 cropping seasons were tested for significance using matched pairs *t* test.
(*) = Not significant @ P≤0.05.

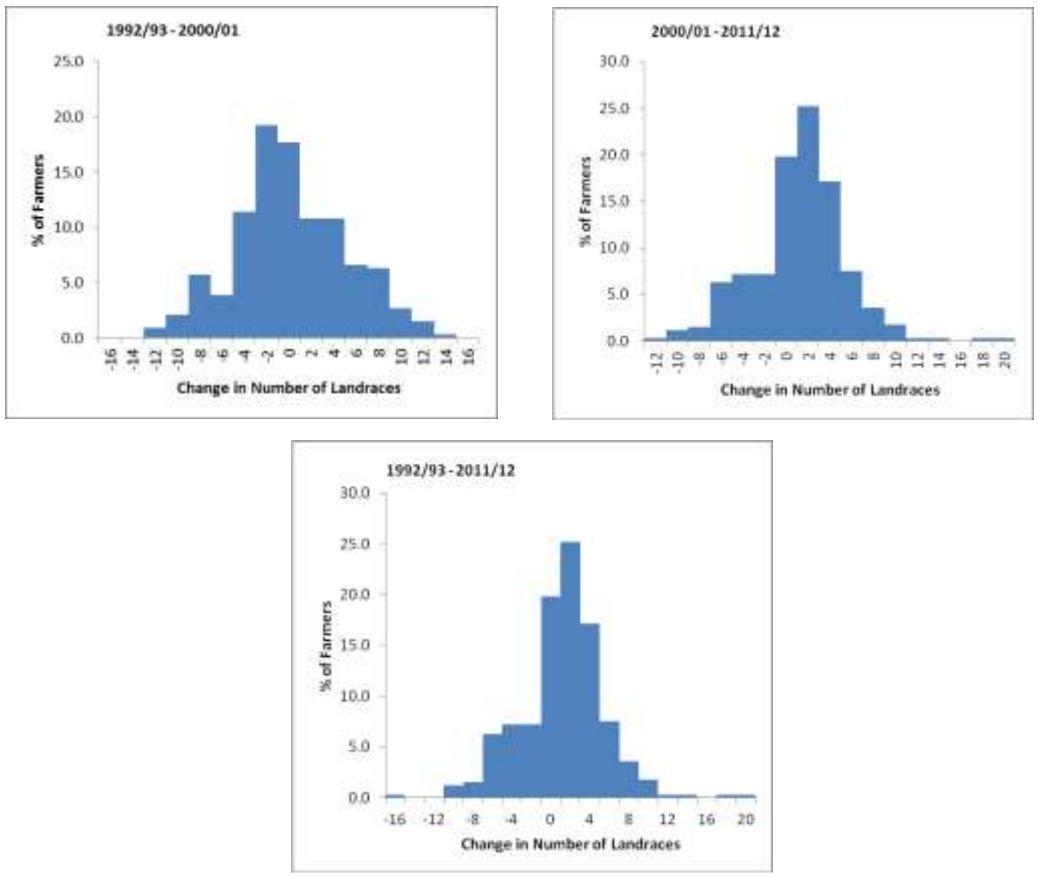

Figure 2. Landrace diversity change distributions.

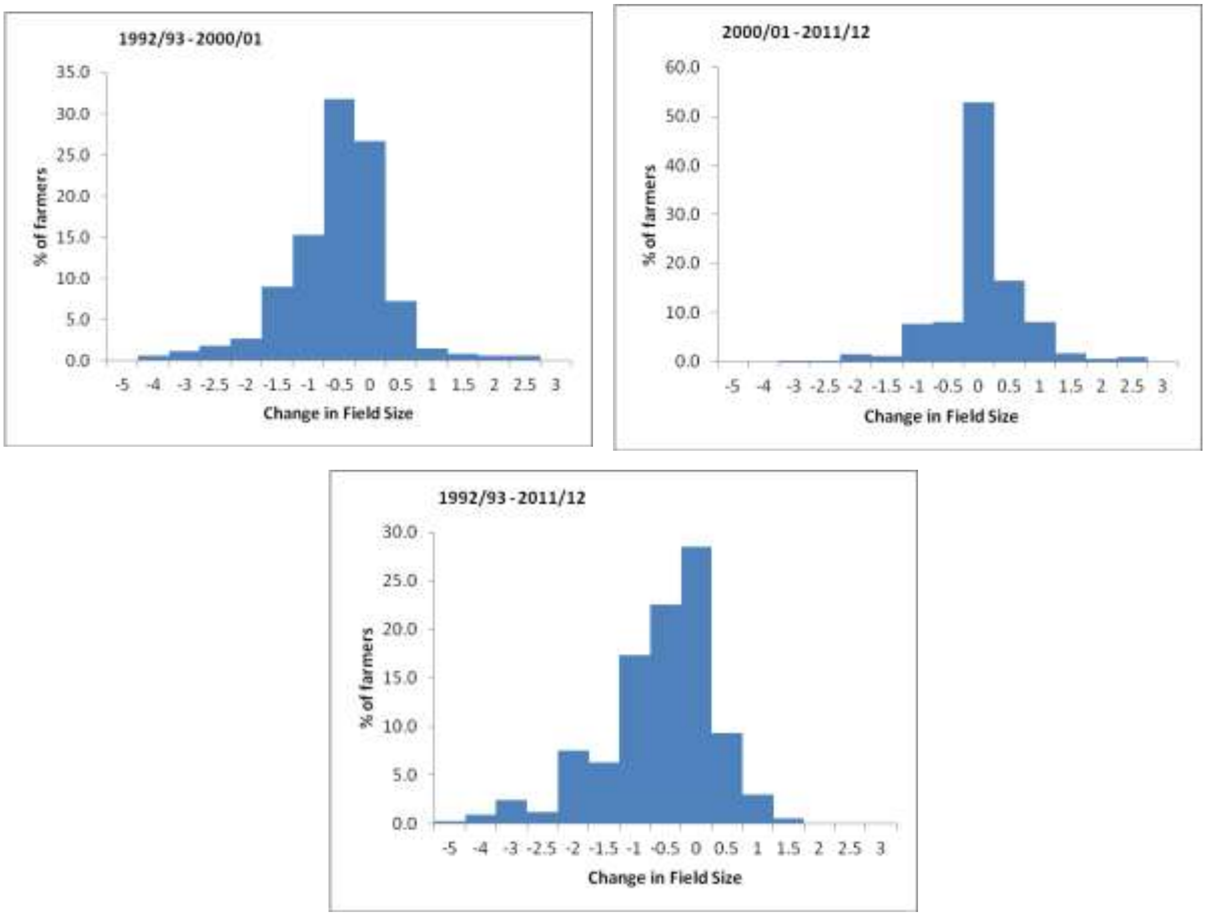

Figure 3. Field size change distributions.

Table 3. Percentages of farmers and changes in diversity, field sizes, and farmers' selection criteria (1992/1993 and 2011/2012).

Selection criteria	Increased (% farmers)	No change (% farmers)	Decreased (% farmers)
Field size changes	13.00	28.50	58.50
Diversity changes	55.90	14.10	30.00
Selection changes	72.05	16.50	11.45

variable agro-climatic conditions, cultivate a diversity of crops and crop varieties during each growing season. For the purposes of this analysis, we divide the landraces into two categories: 'generalist' and 'specialist', as defined earlier. The generalist landraces are deemed to have a broad adaptive range that allows them to perform over a substantial agro-climatic range. In contrast, the specialist landraces are deemed to be more narrowly adapted and niche-specific. Over the survey periods, the specialist landraces, grown in only one or two communities, increased from 37 to 46 to 53, while the generalists cultivated in three or more communities remained essentially constant at 23, 22 and 24, respectively in 1992/1993, 2000/2001 and 2011/2012 cropping seasons. A few landraces crossed the line from generalist to specialist, or vice-versa, during the study period (Teshome et al., 2016).

Although the absolute number of distinct sorghum landraces increased from 60 (1992/1993) to 77 (2011/2012), the number of sorghum landraces that were grown in 2 or less, 3 and 4 communities increased from 37 to 53, 6 to 9 and 9 to 10, respectively, while those in all five decreased from 8 to 3. While we anticipated an increase in 'niche-specific', specialist landraces, because the selection process starts with a single farmer with her/his family selecting adaptable landraces which might

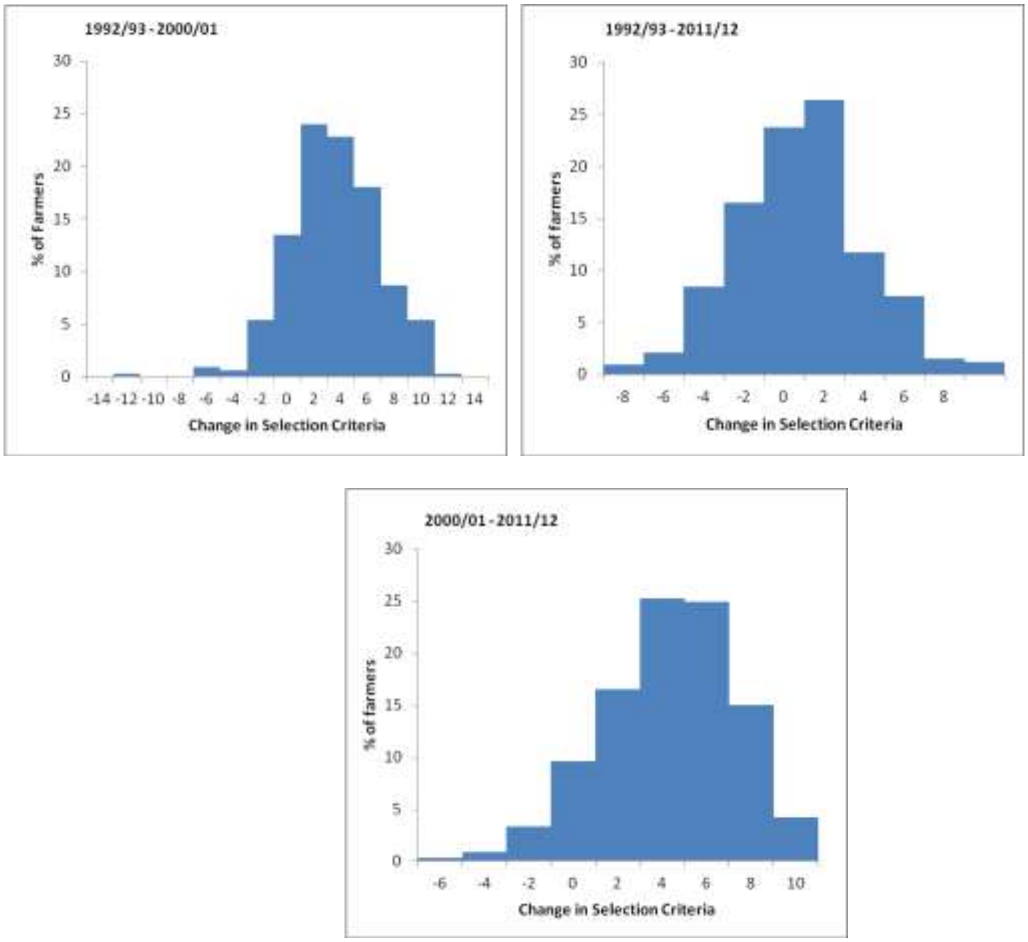

Figure 4. Selection criteria change distributions.

subsequently be adopted by neighbours, we had not expected to observe a decrease in the number of highly plastic and widely adapted landraces grown in more than three of the agricultural communities. The latter trend could, in the long term, have negative consequences for the sustainable cultivation of widely adapted landraces, especially in a context of future field-size reductions and increased fragmentation. As explained by Teshome et al., (2007, 2016), land fragmentation and field size shrinkage directly affect the viable population sizes of the landraces and the selection, amount, quality, quantity, diversity and availability of the desired seed stocks for sowing and re-sowing purposes. Should we be concerned? Should this abundance of both specialist and generalist landraces be monitored periodically? Our answer is 'Yes'.

This spatio-temporal sorghum study has demonstrated that sorghum landrace richness varies by farmer, field, and community, cropping season and agricultural landscape. These findings have commonalities with the changes of crop diversity over time as studied by Yemane et al. (2009) who reported an increment in the diversity of sorghum collections between 1997 and 2007 in northern Ethiopia and observed that sorghum landrace richness varied considerably across villages, districts and administrative regions. Their study did not directly assess whether or how the diversity changes might be related to changing farmers' selection criteria or field sizes.

Stable landraces

In our three surveys over the twenty-year period, 50 of the landraces were recorded somewhere within the study area during each survey (Table 4). We interpret this to mean that: 1) there are farmers who value these landraces; 2) the landraces satisfy a variety of their needs for seed, food, feed and livelihood security; and 3) the individual landraces, has a stable heterogeneity that is adapted to niches of soil conditions, climatic variability and socio-cultural environments found within the host communities. These landraces are, by and large, self-pollinated populations with distinctive and stable morphological characteristics that make selection, harvest, exchange, marketing and processing much

Table 4. Cultivated stable sorghum landraces (1992/1993, 2000/2001 and 2011/2012).

Landraces	Use*	Landraces	Use*	Landraces	Use*
Abaerie	DG	Goronjo	FG	Motie tinkish	SW
Aehyo	DG	Gubetie	FG	Nchero	DG
Afeso	DG	Jamuye	DG	Necho tinkish	SW
Amelsi tinkish	SW	Jemaw	DG	Rayo	DG
Bakelo	DG	Jiru	DG	Sererge tinkish	SW
Basohe	DG	Jofa tinkish	SW	Tenglaye	DG
Betenie tinkish	SW	Keteto	DG	Tuba	DG
Buskie	DG	Keyo tinkish	SW	Wanese	**FG**
Cherekit	DG	Killo	WR	Watigella	FG
Chomogo	DG	Kumie	DG	Wofe-aeybelash	DG
Dekussie tinkish	SW	Megalie tinkish	SW	Wogere	DG
Delgome	DG	Malie tinkish	SW	Wuncho	DG
Dobe	DG	Meltae	FG	Yekermindaye	SW
Ganeseber	DG	Merabete	DG	Yekersolate	SW
Gedalit	DG	Mogayefere	DG	Zengada	DG
Gegretie	FG	Mognayakish tinkish	SW	Zeterie	DG
Gorad	DG	Mokake	DG		

*Dry grain (DG), Fresh green grains (FG), Sweet stalk (SW), Wild Relative (WR).

easier for the farmers and other end users. They include broad generalists and speciality sorghum types endowed with desirable attributes, potentially including: quality protein, free threshing, storability, disease and pest resistance, popping capability, quick cooking, and short and long growing-season varieties. These 50 landraces are variously used as: dry grain [30/50 (60%)]; sweet stalk [13/50 (26%)]; fresh green immature grains [6/50 (12%)]; and a wild-relative for ecological and genetic benefits [1/50 (2%)] (Table 4). The farmers value them for their collective contributions to multiple livelihood aspects and for their survival through favourable and unfavourable conditions. Because of these desirable factors, these landraces should face very low risk of genetic erosion or displacement. They represented 83% (50/60), 73% (50/68), and 65% (50/77) of all the cultivated sorghum landraces, respectively, in 1992/93, 2000/01, and 2011/2012 cropping seasons (Table 1).

Field size and diversity

The relationship between on-farm sorghum diversity and field size is bimodal in all the surveys. Diversity tends to be high in small fields (especially those adjacent to homesteads), less in intermediate sized fields and again high in larger fields. Higher diversity in larger fields reflects both the availability of more space and the existence of a greater diversity of agroclimatic niches (Teshome et al., 1999b, 2007, 2016). In small fields near the homestead, farmers actively increase the niche diversity by using household refuse and family labour to grow preferred landraces for fresh green consumption during the growing season. Abdi and Asfaw (2005) found similar relationships between sorghum landrace richness and field sizes.

The number of landraces an individual farmer grows is influenced by many factors including: rainfall and temperature variations, seed availability, exchange mechanisms and decision making processes acting individually or collectively. Innovative individuals and groups of farmers with access to diverse and adaptable seed stocks may use a range of sowing, resowing after seedling failure and other strategies to get through dry-spells, drought and other challenging climatic conditions that may threaten to undermine their livelihood security.

Selection criteria and diversity

Farmers' selection criteria are as old as agriculture itself. Farming commenced with the selection and domestication of wild plants which had served as food sources and for other purposes. Although farmers' have used selection criteria for millennia, they have not attracted the attention from researchers and breeders that they deserve. They have rarely been described in the literature (Zeven, 2000) and little scientific data is available on the selection and maintenance of landraces by farmers (Cleveland et al., 1994). This study and others by Abdi and Asfaw (2005) and Teshome et al. (1999b, 2007, 2016) have established that dynamic relationships exist between crop diversity and traditional farmers.

Farmers' crop selection criteria reflect the range of socioeconomic, cultural, agronomic, ecological, biological, and dietary needs each farmer desires to obtain from available resources. They result from deliberate application of women's and men's selection criteria, sophisticated naming systems and environmentally friendly farming and exchange mechanisms. The selection criteria vary according to each practising farmer's desires, the crop genetic resources available and the agroclimatic environment(s). There are multiple criteria because farmers recognize that multiple crops and crop varieties are essential to meeting their livelihood requirements. The extent to which farmers have periodically increased (or decreased) their selection criteria during the twenty-year period of our surveys demonstrates their dynamic nature.

The mixtures of crops and crop varieties nurtured by current farmers, in favourable and unfavourable agroclimatic environments, provide the choices to meet the challenges of feeding present and future generations. The farmers' selection criteria are the *de facto* sources of information on the agronomic performance and adaptive responses of sorghum landraces in highly variable agroclimatic environments. The varietal names, as chosen by farmers, often provide information on how the landrace is adapted to environmental conditions and cultural preferences.

Landrace usage

Sorghum landraces are rich with nutritional, dietary and sustenance qualities. Appropriate sorghum landraces are used for dry grain products, fresh green immature grain consumption and sweet stalk consumption. The percentages of landraces used primarily for human consumption have been relatively stable over the twenty-year period.

Landraces grown for dry grain production constitute nearly 60% of the sorghum population. They are selected for their yield, marketability, and beverage and milling qualities. They are the staple for family consumption and are the most important contributor to household income generation. The dry grain sorghums are milled into flour for baking or the grain is fermented, roasted and ground for beverage production. The solid stem residue is commonly used as fuel and the leaves as livestock feed. They constituted 35/60 (58%), 38/68 (56%), and 47/77 (61%), respectively, of the sorghum landrace populations measured in 1992/1993, 2000/2001, and 2011/2012. Their dominance in all the communities confirms their vital role in meeting the livelihood needs of all farming communities.

The sweet stalk landraces are cultivated for home consumption and income generation during the bridging months between the planting and harvesting periods. Sweet stalk sorghum landraces are popular for their chewable, green, sugar-rich stems. They constitute 27% of the landraces and are sparingly planted among the other sorghum landraces and maize. Their grains can be fermented to make beer for home consumption. The stems are sold in the local market for consumption by chewing, like sugar cane. Sweet stalk sorghum landraces are adapted to a range of soil and climatic constraints. Their drought tolerance and quick maturing helps the farmers go through the food scarcity months. Sweet stalk landraces have increased from 17 (92/93) to 20 in 2011/2012.

The fresh, green, immature sorghum landraces are also cultivated for home consumption and income generation during the bridging months between the planting and harvesting periods. They constitute less than 15% of the landraces. They are quick maturing and are consumed, either roasted or boiled, during the food scarcity months between grain-filling and harvest. The peduncled head is harvested intact from the standing plant while the grain is still sufficiently soft for consumption after roasting on an open fire or pan or after boiling in a pot. They have superior nutrition quality and palatability. The soft sweet grains are free of phenolic compounds that affect the palatability of most sorghum grains. Farmers generate income by selling them in the local market. Two of these sorghum landraces, *Wotet-begunche (milk in my mouth)* and *Marchuke/Barchuke (honey oozing)*, that have been identified to contain 30% more quality protein, and twice the normal level of lysine, an amino acid critical to nutritional quality (National Academy of Sciences, 1996), are widely grown. These unique sorghum landraces would appear to have potential for enhancement and wider use within the farming communities and for sale to other end users.

Sorghum wild-relative management

As with the cultivated landraces, the wild relatives that were at a 5 m interval point on the transect lines were identified and recorded. Their abundance has remained relatively stable at <2% over the 20 years. Almost all farmers tolerate some presence of sorghum wild-relatives. Intercropping, stagger planting, non-clean cultivation, and relaxed weeding are the major farming practices by which farmers intentionally tolerate wild- and weedy-relatives of sorghum, including *S. aethiopicum* and *S. arundinacium*. They are used primarily as livestock fodder and as mulch to minimize land degradation by protecting the soil surface from wind and water erosion. Their presence encourages gene flow, enhances organic matter accumulation, soil conservation and nutrient cycling, and increases the natural enemies of crop pests.

An educational experience during one of the surveys occurred when a group of farmer experts proudly lined up, for the benefit of the research team, freshly sampled sorghum populations, in order, from wild sorghum, through the weedy- and wild-relatives (grains with total glume cover and long awns) to the highly selected, cultivated, sorghum landraces (naked grains with no

Table 5. Temporal seed sources and percentages of farmers.

Seed sources	1992/1993 % of farmers	2000/2001 % of farmers	2011/2012 % of farmers
Home Saved	50.51	53.30	60.20
Market	16.72	14.20	13.01
Exchange	03.07	05.60	01.49
Community seed bank	02.39	00.48	00.80
Home-saved + Market	00.00	03.24	12.60
Market + Home	09.89	08.09	03.23
Home-saved + Exchange	00.00	01.75	04.25
Exchange +Home	02.39	03.52	02.60
Exchange +Market	01.71	00.85	00.60
Home- saved + Community seed bank	08.19	03.57	00.76
Home + Gift	00.68	00.55	00.00
Gift +Market	01.02	00.60	00.00
Gift + Market + Home saved	00.34	O0.75	00.00
Home + Exchange + Market	01.71	01.25	00.00
Home + Exchange + Community seed bank	00.34	00.75	00.00
Home + Market + Community seed bank	01.02	01.00	00.46
Total (%)	99.98	99.50	100.00

glumes and awns) that have been developed over the ages by the farming community. The sorghum populations along this spectrum differ hugely in the agro-morphological characteristics that farmers use to distinguish their adaptive capacities and performance superiorities.

Seed source management

The availability of seeds and the nature of seed sources affect the richness and on-farm distribution of the sorghum landraces. For the most part, the seed-supply system is stocked with locally grown seeds. Both women and men participate in the decisions as to the type of landraces and the amounts of seeds to save. The dynamics of the home-saved seed system include the selection of seed stocks from the standing crop populations, the elimination of pests and their safe storage under home conditions until required for planting (Teshome et al., 2016).

Home-saved seeds that are surplus to the farmer's needs may be made available through combinations of the Market, Exchange, and Community Seed Banks (CSB) and as Gifts. Table 5, in each line, presents the primary, secondary, and tertiary sources of the seeds that individual farmers have planted. The multiple, local seed sources, centered on local knowledge and practices, reflect the socioeconomic, cultural, genetic and agroclimatic heterogeneity of the production system and are integral components of the local harvest security. Changes in rank order of the sources that have occurred through time (Table 5) show that the percentage of farmers relying exclusively on their home-saved seeds increased from 50% in 1992/1993 to 60% in 2011/2012; the proportion of farmers who primarily used the local market only decreased from 16% (1992/1993) to 13% (2011/2012).

The local markets are critical components of the secured seed system. Besides serving as sources of the desired seed stocks, they are forces of differentiation and diversification that sometimes cross topographic, ethnic, cultural and socioeconomic barriers and introduce different genotypes, possibly leading to the generation of new varieties (Teshome et al., 2016). It is not unusual for farmers who obtained seeds from local markets to report the appearance of unexpected varieties, and weedy- and wild-relatives of sorghum landraces in their fields. Augmentation of home-saved seeds with desired seeds from local Markets increased from 3% in 2000/2001 to 12% in 2011/2012.

Some farmers, who grow a large number of distinct sorghum landraces every year, have found it challenging to maintain the desired seed stocks for all their preferred landraces. A few farmers have made arrangements to co-operate with each other in the exchange and storage of home-grown seed stocks. In the highland landscape of Hayk, 20% of the farmers used such exchange arrangements as the primary source to obtain sorghum seed in 2000/01 (Teshome et al., 2007). Seed exchange mechanisms are also employed by some farmers to test the performance of new crop varieties. Across the whole study area, the farmers employing exchange increased from 3 to 6% between 1992/1993 and 2000/2001, but declined to 2% in 2011/2012.

The security of the farmer-based seed system is built on the selection and inter-mixed cultivation of many different landraces at field and landscape levels over long time periods and various weather conditions. Indeed, security requires the collective efforts of the farming communities to ensure the diversity, equity, efficiency and resiliency of the farmers' seed systems. The cooperation in the seed system is also a reflection of the social network operating in the production system (McGuire, 2008).

IMPLICATIONS AND CONCLUSION

In the process of conducting the field surveys and through other interactions, the research team has developed a great deal of respect for the farmers (male and female) throughout the research area. We have been in the position of observing their practices and accomplishments. They (and their ancestors), as the primary domesticators, users, and engines of diversifications, have established an intimate relationship with the crops and landraces they select, cultivate and conserve. Based on their time-tested, experiential knowledge and keen observation, the farmers use the environmental heterogeneity to meet their multiple social, cultural, economic and ecological needs. The human selection process, superimposed on the environmental and agro-climatic heterogeneity, has had a major role in generating and maintaining the intraspecific diversity now observed at field and landscape levels. Because substantial discussion of the results has occurred in the various subsections of this paper, we have chosen to present of terse summary of the major findings of this research project.

Lessons learnt

We have learned many things about the farmers and the landraces: 1) The farmers know the characteristics of the landraces that they grow and they know why they grow each one of them; 2) The farmers have developed sound management practices relating to seed selection, seed storage, and marketing; 3) The farmers have used the inherent heterogeneity of the landraces and the agro-climatic environments to develop a mixture of high yielding, pest and disease resistant, cold and heat tolerant, quick and long maturing landraces; 4) The farmers use the whole plant - there is no such thing as waste. If it cannot be used otherwise, the plant or, more likely, the plant part goes back into the soil; 5) The most wide-spread generalist landraces across the communities are high-yield, dry-grain landraces, or wild relatives of sorghum; 6) The traditional farmers and landraces have maintained a faithful relationship since the beginning of crop domestication and agriculture – the farmers recognize that the intraspecific diversity of crops is the foundation for resilient seed, food and livelihood systems - they need each other for mutual survival.

Reflection

This study has gone beyond the identification of variations and the assessment of diversity by examining and establishing the critical role of farmers' selection criteria in the generation, diversification, maintenance and use of sorghum landraces. Farmers' skilful management strategies applied to genetic diversity, agro-climatic diversity, agricultural seasons, and agricultural fields and landscapes have strengthened the resilience and adaptive capacities of the farmers by spreading the risks and opportunities across socio-cultural networks, agricultural landscapes and climatic seasons. Such strategic management of genetic diversity needs to be constantly adjusted to increase food production while reducing societal vulnerability. Farmers, through farmer-scientist collaborations, can play a major role in leading the scientific community to recognize the importance of the generation, selection and maintenance of on-farm diversity and the enhancement of seed, food, livelihood and environmental security. Respect for the traditional farmers and increased recognition of their roles and self-interest in the generation and maintenance of genetic diversity will, hopefully, inspire them to continue with further diversification in order to maximize and stabilize diversity-based production, especially in highly vulnerable production systems.

The farmers of the study area have enthusiastically cooperated with our team of 'outsiders' each time we came asking many (repetitive) questions. We cannot measure the degree to which our curiosity has influenced them, but we know we have. The question as to 'Why do you grow this landrace?' (asked in Amharic) had not been systematically asked before. We are confident that the simple asking of that question during our first survey set their minds in action such that when asked again in the each subsequent survey, the list was longer. We doubt that our other queries had such dramatic effects, but we acknowledge that they most probably had some influence.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Distribution of Lichens on few ancient monuments of Sonitpur district, Assam, North East India

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This preliminary investigation describes the diversity and distribution of lichens from the different archaeological monuments of Sonitpur district, located in the Eastern Himalayan region of India, which is a part of Indo-Burma biodiversity hotspot. It is a land of natural beauty and rich cultural heritage and it is well reflected in the number of archaeological sites and monuments of ancient time at this region. Enumerations of 38 species of lichen belonging to 21 genera and 15 families have been reported from the archaeological monuments of Sonitpur district. 6 species are new records for this state. Members of Physciaceae showed higher dominance with 11 species followed by Teloschistaceae with 4 species and Lecanoraceae and Verrucariaceae each containing 3 species, respectively. *Cryptothecia subnidulans* is the most widespread species, reported from 7 study sites.

Key words: Diversity, Eastern Himalayan, heritage, hot spot, species.

INTRODUCTION

Lichens are a stable self-supporting association of a mycobiont and a phycobiont in which the mycobiont is the inhabitant (Hawksworth, 1988). They are known to occur on various substrates including barren rocks, mainly for their resistance to desiccation at extreme temperature and efficiency in accumulating nutrients (Martin, 1985; Chaffer, 1972; Seaward, 1979, 1988). As the earliest colonizers of terrestrial habitats on the earth, lichens are amongst the most successful forms of symbiosis (Galloway, 1994). These symbiotic thallophytic hardy plants can grow and thrive under extreme conditions and can withstand xeric conditions which other plants find unfavourable for their growth and survival. The colonisation of monuments by lichens is a universal and well established fact and is greatly influenced by climatic and micro-climatic condition (mainly temperature and relative humidity), type of substratum, architectural design as well as the anthropogenic disturbances. Bare and exposed monuments, ruins of ancient archeaelogical sites provide an ideal place for invasion and colonisation of different groups of lichens. The colonization of lichens on building material and biodeterioration are usually

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Table 1. List of study sites with their coordinates.

S/N	Study Site	Coordinates	Type of material	Periods of construction
1	Temple Ruins of Bamuni Hill	26° 37' 01” N 92° 48' 57” E	Rock, Brick	10th to 12th century AD
2	Temple ruins of Da-Parbatia	26° 37 ´ 52” N 92° 45 ´ 27 ” E	Rock, Brick	6th century AD
3	Ruins of Singri Hill	26° 36 ´ 53” N 92° 29 ´ 55 ”E	Rock	11th to 12th century AD
4	Rock inscription on the Bhomoraguri hill	26° 36 ´ 41” N 92° 51 ´ 13” E	Rock	18th century AD
5	Garh Doul	26° 38 ´ 46” N 92° 46 ´ 19” E	Brick	7th and 8th century AD
6	Sakraswari on the island Umatumuni	26° 39 ´ 42” N 93° 10 ´ 36” E	Rock	18th century AD
7	Biswanath Siva Linga	26° 39 ´ 41” N 93° 10 ´ 20” E	Rock	17th century AD
8	Bamgaon ruin	26° 73 ´ 73” N 93° 16 ´ 34” E	Brick	7th and 8th century AD
9	Bordol Temple	26° 39 ´ 35” N 93° 10 ´ 19” E	Rock, Brick	17th century AD
10	Dhandi Ruin	26° 51 ´ 90” N 93° 41 ´ 55” E	Brick	18th century AD
11	Basudev Doul	26° 51 ´ 46” N 93° 45 ´ 15 ”E	Rock, Brick	16th century AD
12	Nandikeshar Dewaloya	26° 73 ´ 80” N 92° 91 ´ 43” E	Rock, Brick	16th century AD
13	Mahabhairab Temple	26° 64 ´41” N 92° 79 ´ 64” E	Rock	10th century AD
14	Sculptures of Chummery Compound	26° 61 ´ 84” N 92° 79 ´ 49” E	Rock	10th to 12th centuries AD

linked to environmental conditions (Bajpai et al., 2012). The lichens on Indian monuments were previously described and reported in several literatures (Upreti, 2002; Upreti et al., 2004; Bajpai, 2008; Bajpai et al., 2008; Singh and Upreti, 1991; Chatterjee et al., 1995; Singh et al., 1999).

Sonitpur district of Assam is located on the Northern bank of River Brahmaputra, covering an area of about 5324 km^2 expanding from Singri to Hawajan, Sonitpur district with a large expanse of land lying scattered numerous archaeological remains showing a glorious civilisation in this region as old as six century A.D. There are many central government as well as state protected archaeological sites and monuments within the Sonitpur district which include remain of temple, rock inscription, sculptures, structural remains of ancient period and a few temples of Ahom destiny which are covered by enormous groups of lichens. Despite harbouring rich lichen diversity, these monuments are not being explored. The aim of the current study was to explore the distribution and diversity of lichen’s colonisation in the hitherto monuments of Sonitpur district.

MATERIALS AND METHODS

Lichens were carefully removed and collected from the monuments by avoiding any damage to these monuments. They were immediately wrapped in tissue paper and then transferred to lichen herbarium packets. The collected specimens were investigated morphologically, anatomically and chemically in the laboratory. The colour tests were performed with the following reagents; K (5% potassium hydroxide), C (aqueous solution of calcium hypochlorite), P (paraphenylene diamine) and I (iodine solution). Lichen’s substances were identified with thin layer chromatography (TLC) in solvent system A (toluene : dioxane : acetic acid; 180:60:8 ml).The lichen’s substances were identified with the help of table given by Orange et al. (2001). The identities of different specimen were confirmed by matching them with well identified specimen preserved in the herbarium of CSIR-NBRI, Lucknow. The nomenclature and classification of lichens were updated following Lumbsch and Huhndorf (2007).

RESULTS AND DISCUSSION

The different monuments of Sonitpur district harbour many lichen species and represented by 38 species belonging to 21 genera under 15 families (Table 2).

Table 2. List of lichens from the historical monuments of Sonitpur district, Assam.

Species name	Family	Type	*Study site	Secondary metabolites
Bacidea rubella (Hoffm.) Massal.	Bacidiaceae	Crustose	3	No secondary metabolites
Caloplaca bassiae (Wild. Ex Ach.) Zahlbr.	Teloschistaceae	Crustose	1,13,14	Parietin
C. cinnabariana (Ach.) Zahlbr.	Teloschistaceae	Crustose	6	Parietin, Xanthorin
C. cupilifera (Vain.) Zahlbr.	Teloschistaceae	Crustose	1	Parietin
C. subsoluta (Nyl.) Zahlbr	Teloschistaceae	Crustose	7,11	Parietin
Cryptothecia scripta G.Thor	Arthoniaceae	Crustose	11	Gyrophoric acid
C. subnidulans Stirton.	Arthoniaceae	Crustose	1,2,5,7,10,11,12	Gyrophoric acid
Chrysothrix candelaris (L.) J.R. Laundon	Chrysotrichaceae	Leprose	3	Calycin
C. chlorine (Ach.) J.R. Laundon	Chrysotrichaceae	Leprose	4,12,14	Calycin, Vulpinic acid
Dirinaria aegialita (Afz.in Ach.) Moore	Physciaceae	Foliose	1,4, 14	Divaricatic acid
D. applanata (Fee) D.D.Awasthi	Physciaceae	Foliose	2,10	Divaricatic acid
D. confluens (Fr.)D.D.Awasthi	Physciaceae	Foliose	1,2,6	Atranorin, Divaricatic acid
D. consimilis (Stirton) D.D.Awasthi	Physciaceae	Foliose	1, 12,14	Atranorin, Sekikaic acid
Endocarpon sp.	Verrucariaceae	Squamulose	1,5,8	No secondary metabolites
Heterodermia diademata (Taylor) D.D. Awasthi.	Physiaceae	Foliose	9	Atranorin, Zeorin
H. microphylla (Kurok) Skorepa.	Physiaceae	Foliose	3	Zeorin
Lecanora pseudistera Nyl.	Lecanoraceae	Crustose	1,3	Atranorin, 2-0-methylperlatolic acid
L. subimmersa (Fee) Vain.	Lecanoraceae	Crustose	1,14	Atranorin, Zeorin
Lecanora sp.	Lecanoraceae	Crustose	2,14	Atranorin, gangaleodin
Lepraria coriensis (Hue) Sipman	Stereocaulaceae	Leprose	14	Atranorin, Constipatic Acid
Micarea sp.	Pilocarpaceae	Crustose	5	Gyrophoric acid
Mycobilimbia hunana (Zahlbr.) Awasthi	Porpidiaceae	Crustose	1,5,8	Atranorin
Parmotrema presorediasum (Nyl.) Hale	Parmeliaceae	Foliose	1,3	Atranorin
P. reticulatum (Taylor) Choisy	Parmeliaceae	Foliose	9	Salazinic acid
P. saccatilobum (Taylor) Hale	Parmeliaceae	Foliose	7,10,11,14	Atranorin, protocetraric acid
P. tinctorum (Despr.ex Nyl.) Hale	Parmeliaceae	Foliose	1,12	Atranorin, Lecanoric acid
Peltula obscurans (Nyl.) Gyelnik	Peltulaceae	Squamulose	4	No secondary metabolites
P. tortuosa (Nees) Wetmore	Peltulaceae	Squamulose	3	No secondary metabolites
Phyllopsora furfuracea (Pers.) Zahlbr.	Ramalinaceae	Squamulose	2	Furfuraceic acid
Physia dimidiate (Arn.) Nyl.	Physiaceae	Foliose	2	Atranorin
Porina sp.	Porinaceae	Crustose	14	No secondary metabolites
Pyxine cocoes (Sw.) Nyl.	Physciaceae	Foliose	1,10,11	Lichenoxanthane, Triterpene
P. meissnerina Nyl.	Physciaceae	Foliose	6,14	Triterpenoides
P. subcinerea Stirt.	Physciaceae	Foliose	1,11	Lichenoxanthane
Rinodina oxydata (A.Massal.) A.Massal	Physciaceae	Crustose	1,2,4,11,14	Atranorin
Staurothele sp.	Verrucariaceae	Crustose	3	No secondary metabolites
Trapelia sp.	Trapeliaceae	Crustose	1	No secondary metabolites
Verrcuaria sp.	Verrucariaceae	Crustose	5	No secondary metabolites

*1. Temple Ruins of Bamuni Hill, 2.Temple ruins of Da-Parbatia, 3. Ruins of Singri Hill, 4. Rock inscription on the Bhomoraguri hill, 5. Garh Doul, 6. Sakraswari on the island Umatumuni, 7. Biswanath Siva Linga,8. Bamgaon ruin, 9. Bordol Temple, 10. Dhandi Ruin, 11. Basudev Doul, 12. Nandikeshar Dewaloya 13. Mahabhairab Temple 14. Sculptures of Chummery compound.

Among the different growth forms, crustose lichens exhibit the maximum diversity with 17 (44.73%) species followed by foliose lichen with 13 (34.21%) species. 4 species of squamulose lichens (10.52%) and 3 species of leprose (7.89%) are also reported. Physciaceae dominates with 4 genera and 11 species. *Cryptothecia subnidulans* is the most common and well distributed species reported from 7 study sites followed by *Parmotrema saccatilobum* and *Rinodina oxydata* each from 4 study sites, respectively. The ruins of Bamuni hills exhibited the maximum diversity of lichens represented by 16 species followed by Sculptures of Chummery Compound with 11 species and Temple ruins of Da-Parbatia with 7 species respectively. Two lichen genera, *Caloplaca* and *Dirinaria* with 4 species each, dominants the study areas and grows luxuriantly in different

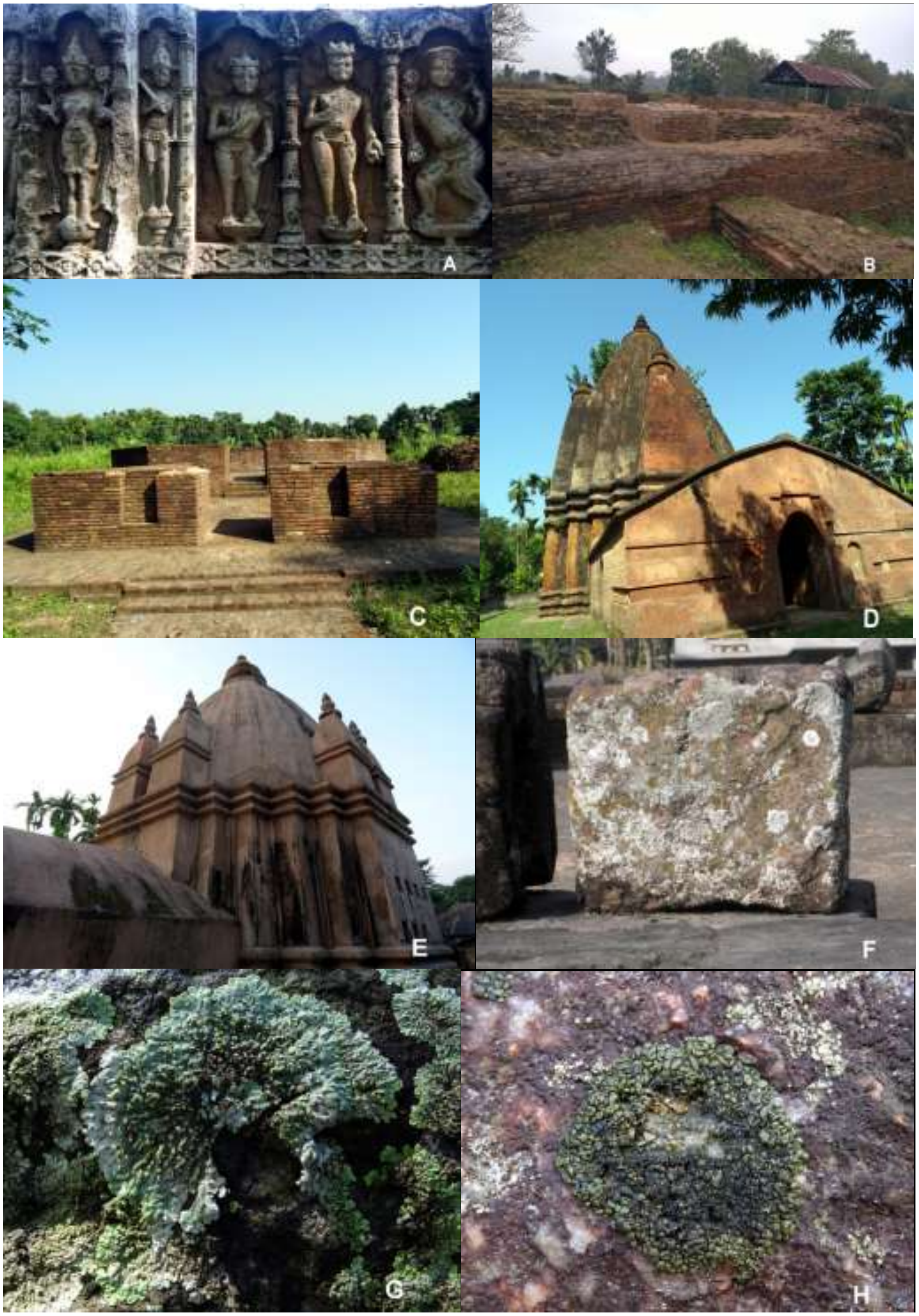

Figure 1. (A) Sculptures of Chummery Compound, (B) Garh Doul, (C) Bamgaon ruin, (D) Basudev Temple, (E) Bordle temple, (F) Da-Parbatia, (G*) Pyxine meissnerina,* (H) *Peltula tortusa.*

substrata in different conditions.

Due to lack of anthropogenic activities and lack of maintenances in terms of remedial measure, the different ruins exhibit high lichen diversity as compared to the other maintained sites. The geographical location, microclimatic condition and the presence of porous, rough and exposed rocks of Bamuni Hills provide ideal condition for the colonization of different groups of

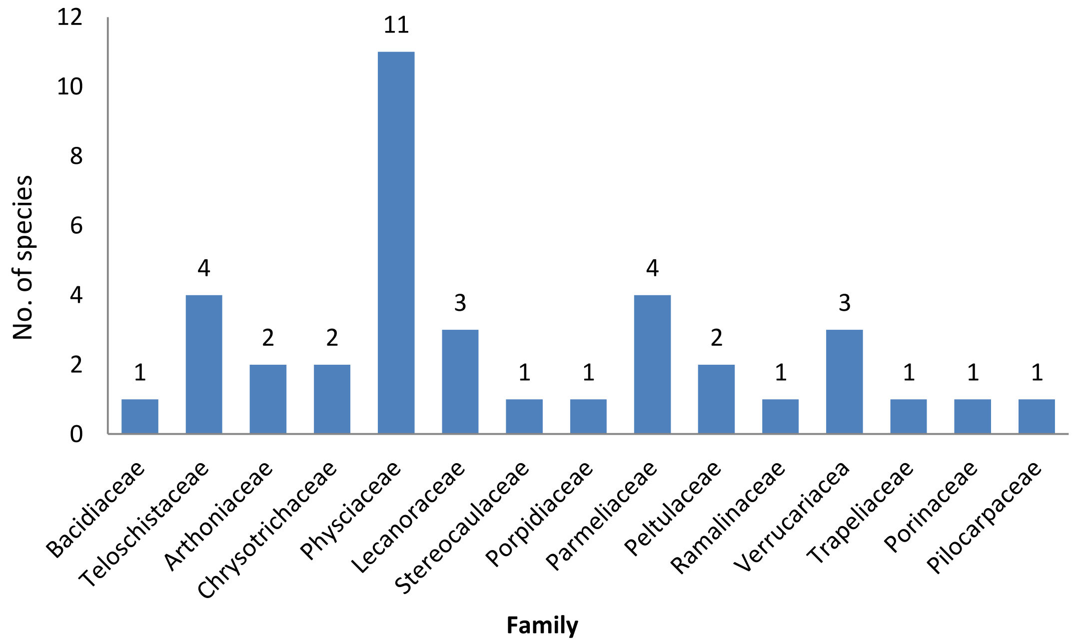

Figure 2. Representation of different lichen families in the monuments of Sonitpur district.

lichens. On the other hand, Biswanath Siva Linga, Bamgaon ruin and Bordol Temple are well maintained by both local authorities as well as by ASI, resulting in decreasing lichen's diversity. The excessive use of iron brushes for eradication of lichens resulted in the formation of irregularity of rock's surface morphology at several sites which in turn physically deteriorate the monument. These irregular lines are clearly seen in the different substrata of ruins of Da-Parbatia. In Bordol Temple, recent renovation work by lime concrete finishing to the mandapa and lime surkhi plastering to the cracks as well as on the exterior old decayed plaster of the monument were executed. During the renovation process *P. reticulatum* and *Heterodermia diademata* were completely eliminated from the Bordol Temple.

The lower strata of these monuments hardly receive strong light during the day time and remain shaded and moist, show dominance of some moisture loving species, *Mycobilimbia hunana*. In these strata of Garaha Dol brick built ruin *Mycobilimbia hunana* grows luxuriantly and occupy the whole strata. As the height from the base of the plinth increase the moisture content start to decrease and comparatively more exposed to sunlight and wind and shows dominance of genera *Cryptothecia, Caloplaca, Lecanora* and *Parmotrema*. The middle and the uppermost strata of the monument mainly composed of rock made vertical walls firmly joint by lime plaster and lime surkhi plastering to the exterior surface facing different directions and expose to different degrees of light, wind and moisture. The middle strata hold more and dense lichen's diversity and comprise different lichen's community. The uppermost stratum receives maximum amount of sunlight during the day time and provide xeric habitat for lichen genera, *Endocarpon* and *Peltula. Cryptothecia subnidulans* and *Dirinaria confluens* also grows abundantly in these faces. Presence of large woody vascular plant vegetation around and near these monuments also changes the microclimatic conditions of these faces, alter the niche and promote the growth of shade loving lichens genera *Heterodermia, Physia* and *Chrysothrix.* Shading tends to alter the microclimatic condition by reducing the hot day temperature, proving shade and slowing down the moisture evaporation process. In the roofs and terraces lichen genera, *Endocarpon, Dirinaria, Peltula* and *Cryptothecia* show abundance in the exposed horizontal floor of ruins of Da-Parbatia species *of Cryptothecia, Caloplaca, Dirinaria* and *Lecanora* grows abundantly. *Physia* and *Heterodermia* mostly occur in the vertical walls in association with *Cryptothecia.*

On the brick made monuments of Garhadol and Bamgaon ruin *Endocarpon pallidum* and *Mycobilimbia hunana* shows their dominance. *Cryptothecia subnidulans, D. consimilis* and *Pyxine meissnerina* are also found to grow in different brick made monuments.

Seasonal variation influences the visibility, texture, contrast of colours and appearance of fruiting bodies of the lichens on the monuments. During monsoon season, with increase in atmospheric humidity and abundant rainfall, species of *Endocarpon* and *Peltula* assume their natural characteristic colour, swell up and attain their normal dimension, and grow vigorously in different substrata. *Endocarpon* exhibits preference to colonize more rapidly in the monsoon season in the bricks.

Conclusion

The present investigation supports the lichen richness in the archaeological sites of Sonitpur district of Assam. Most of the archaeological monuments are constructed with sandstone and brick firmly cemented by lime plaster, which in turn provide an excellent substratum for colonization of different groups of lichens together with mosses and other vascular plants. This North East part of India is shared by well distributed and heavy rainfall that supports an excellent condition for the rapid growth and distribution of lichens. This present enumeration of lichens and their distribution pattern will act as baseline data which will be helpful in future for conducting bio-monitoring as well as bio-deterioration studies in this area of investigation area.

Conflict of Interests

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENT

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Cowpea (*Vigna unguiculata* (L.) Walp.) (Fabaceae) landrace diversity in Northern Ethiopia

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This study was carried out to identify and document the landrace (farmers' variety) diversity and ethnobotany of cowpea (*Vigna unguiculata* (L.) Walp.) (Fabaceae) in Northern Ethiopia. A total of 54 germplasm accessions and six representative voucher specimens of cowpea were collected from different geographical locations of Ethiopia ranging from 1260–2140 m a.s.l. within the grid references of 10° 00' to 14° 00' N and 38° 00' to 40° 00' E. Of these, 45 (83%) were local farmers' varieties and 9 (17%) were commercial varieties introduced by the Ethiopian Ministry of Agriculture and the Melkassa Agricultural Research Center (MARC). The majority of farmers (60) (75%) preferred the erect type of cowpea (*Vigna unguiculata* subsp. *cylindrica* (L.) Verdc. farmers' variety locally named KIMITE (short drought resistant) and subsp. *cylindrica* (L.) Verdc. farmers' variety CHEKELE (dry season crop). The spreading type of cowpea (subsp. *unguiculata* farmers' variety JERGADIE - stretched type) produces much more vegetative parts than grains. Farmers mainly used it for improving soil fertility and for animal feed. In Amhara Region, cowpea is mainly used for human food in the form of boiled grains (NIFRO), bread (KITA) and as ingredient for various sauces (SHIRO WET). There are high potential areas for cowpea production; but the actual production by local farmers is restricted to only few areas. Given the current paucity in making use of the locally available germplasm by farmers, the responsible body (MARC) for cowpea research and development would need to mount an aggressive enhancement and/or distribution of the important cowpea landraces to the areas where the crop can be suitably grown by local small scale farmers.

Key words: Cowpea, Ethiopia, ethnobotany, farmers' knowledge, farmers' variety, landrace.

INTRODUCTION

Pulses have been recognized as a major source of proteins (20 - 35%) with essential minerals and vitamins (Abebe et al., 2005). Among the pulses, cowpea (*Vigna unguiculata* (L.) Walp.) (Fabaceae) is an important food legume growing in tropical and subtropical regions of Africa, Asia, and Central and South America Lemma et al., 2009; Singh et al., 1997). According to Thulin (1989), in Ethiopia, cowpea is cultivated primarily for its edible seeds and the leaves that are sometimes used as human food in the form of cooked leafy vegetables. In Southern Ethiopia, cowpea young leaves, pods and seeds are used for human consumption and animal feed (Westphal 1974); and this was confirmed in a recent work (Sisay, 2015).

In addition to its importance for human food, the crop is also useful to enhance soil fertility through symbiotic nitrogen fixation and it also substantially contributes as a major source of animal feed due to the feed quality of the leaves. The species has a unique capacity to fix atmospheric nitrogen with its nodules and performs well even in poor soils with more than 85% sand, less than 0.2% organic matter and low levels of phosphorus (Bilatu Agza et al., 2012). Its world annual production is estimated at 5,249,571 tons of dried grains of which over 64% is produced in Africa. On the African continent, West Africa represents the largest production zone (Gbaguidi et al., 2013). Nigeria produces about 850,000 tons and is reputed as the highest producer of cowpea in the world (Ogbemudia et al., 2010).

Cowpea is an important grain legume in East Africa (Sariah, 2010). Pottorff et al. (2012) disclosed that cowpea is a multipurpose crop; the entire plant can be used for either human or livestock consumption while Islam et al. (2006) emphasized that all parts of the plant are used as food being nutritious as they provide protein and vitamins. Immature pods and seeds are used as vegetables while several snacks and main dishes are prepared from the grains (Agbogidi and Egho, 2012). Cowpea young leaves, pods and seeds contain vitamins and minerals which have popularized its usage for human consumption and animal feeding; and the scorched seeds are occasionally used as a coffee substitute (Ogbemudia et al., 2010).

Pulses as a group in Ethiopia constitute considerable number and diversity of crop species (Million Fikreselassie, 2012). The Ethiopian Biodiversity Institute has a total of 94 germplasm accessions of cowpea at the gene bank (EBI, 2014). Although Vavilov (1951) as cited in Westphal (1974) indicated that Ethiopia is a secondary center of diversity for cowpea, there is limited information regarding the genetic resource, there are major production challenges and social factors related to cowpea production in the country. In addition, there is no published document regarding cowpea landraces, the status of diversity and ethnobotany in Ethiopia.

Therefore, collecting and documenting cowpea landraces with the associated ethnobotanical information and landrace diversity are fundamental and urgent tasks. Hence, a study of cowpea landrace diversity and ethnobotany in northern Ethiopia, where it is an important component of the agricultural system and the food culture of the society, is crucial for better understanding, utilization, conservation and improvement of the crop. This study was initiated to gather, record and document the landrace diversity and ethnobotanical information of cowpea in its production range in northern Ethiopia, covering parts of the Amhara and Tigray regions.

MATERIALS AND METHODS

Materials

Representative cowpea voucher specimens and seed accessions were collected from different geographical provenances in northern Ethiopia. These materials were used for determinations of identities based on morphological characters, for germination tests and storage as gemplasm. Plant press, GPS, plastic bags, notebook, secateurs and a digital photo camera were used during the field-work.

Site selection

Based on the ecological requirements of the crop, assistance of district agricultural office workers, accessibility of the area and the availability of time, a total of five administrative zones comprising eight districts and 16 villages were purposively sampled for the study. Samples were collected from villages where cowpea is highly produced in order to obtain valuable information on landrace diversity together with the associated use values and the traditional production and management systems.

Informant selection

After selection of the study sites, a total of 80 informants (61 males and 19 females) aged 21 to 71 were randomly selected. Ten individuals from each wereda (district), that is, from each kebele 4-6 informants were interviewed using pre-prepared semi-structured interview guide. The selection of key informants and information regarding the knowledge of local farmers about cowpea was first gathered with the local guide and local agricultural extension experts of each wereda. Additionally, a total of 40 informants (five from each wereda local market place) were randomly selected for gathering information on the market value of cowpea.

Ethnobotanical data collection

Data were collected from September 2014 – January 2015. Semi structured interview, direct field observations and market surveys as described by Martin (1995) and Alexiades (1996) were conducted to collect both botanical and ethnobotanical data. Voucher specimens were collected from farmers' fields as described in IBPGR (1983) descriptor list for cowpea. The botanical information (passport data) of the crop was collected using GPS. Colored

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photos of cowpea accessions were also used to ease communication with farmers and local guides regarding the identity, distribution and local names of cowpea landraces before starting the interview. Both primary and secondary data were retrieved from the field. A total of 54 seed samples, six voucher plant specimens, and ethnobotanical information were collected from farmers' fields, threshing grounds, home gardens and local market places.

Official research permit was sought from the relevant local administrative offices and each informant gave free verbal consent to provide information upon providing the full details of the research (purpose, objectives and data utilization) to the local administration, the concerned community and the informants. Subsequently, verbal ethical clearance was secured in the traditional way where elders announced honoring the research through their blessings and the identified informants individually consented to provide information, all in the usual manner of traditional ethical clearance.

Sources for secondary data were both from offices of governmental and non-governmental organizations including agriculture and rural development offices and the National Meteorological Service Agency. Additional data were sourced from local communities and researchers. Voucher specimens were stored at the National Herbarium, Addis Ababa University while the seed samples were deposited at Melkassa Agricultural Research Center and at the completion of the research work, it was agreed, to be eventually transferred to the Ethiopian Biodiversity Institute (EBI) for proper conservation.

The collected ethnobotanical data were summarized in tables and figures and analyzed using both quantitative and qualitative approaches as recommended by Martin (1995), Cotton (1996) and Phillips (1996). Descriptive statistics, preference ranking and informant consensus tools were used to analyze the quantitative data. MS Excel 2010 was used to quantify and sort data, determine proportions, and draw bar graphs and tables.

RESULTS

Cowpea Landrace Diversity in Northern Ethiopia

A total of 54 cowpea germplasm accessions were collected (Table 1) in the 16 surveyed villages (Figure 1). Among these, 45 (83%) were local varieties and 9 (17%) were commercial varieties introduced by the Federal Ministry of Agriculture of Ethiopia, the Melkassa Agricultural Research Center (MARC) and the Sirinka Agricultural Research Center (SARC). Phenotypic diversity was observed in terms of growth habit, seed color, size and shape (Table 2).

Vernacular names of cowpea

Local farmers are generators and information base for modern taxonomy since indigenous knowledge is adaptive skill of the local farmers acquired informally through interaction with the natural environment. Accordingly, cowpea has different names in different areas of northern Ethiopia by local farmers based on the multiple purposes of the crop and the unique characteristics of each landrace type (Table 2) and information on morphological diversity of the landraces is given in Table 3.

Farmers' knowledge and utilization of cowpea

All the eighty farmers interviewed claimed to know modern agricultural production system especially in pre- and post-harvest technology. The majority of the farmers interviewed (75%) cultivated the erect type of cowpea in North Wello, Central Tigray and Waghimra zones. A reasonable number of farmers (25%) grew both the erect and prostrate or spreading types of cowpea mainly in Kalu and Bati districts. This is because in Bati and Kalu, local farmers grew cowpea when the soils are more degraded and/or where livestock are more important components of the farming system. The majority of farmers (60- 75%) preferred the erect type because they perceived that the ability to produce grains during famine season is due to its early maturing habit. Furthermore, local farmers preferred the erect types of cowpea for a variety of reasons such as high grain and straw yield, disease resistance, drought tolerance, adaptability to all types of soil, early maturity, market value, food quality, feed value and its multiple purposes. The spreading type of cowpea produced much more vegetative parts than grains and farmers mainly used this type for improving soil fertility and as animal feed. Grains, fresh vegetative parts and straw are the desired products of cowpea for all of the farmers who participated in the interview.

Based on results of the primary data, cowpea contributes to smallholders' income and to diet as a cost-effective source of protein intake especially in Central Tigray, South Wello and Oromia Special zones found in Amhara Region. On the other hand, in Amhara Region, cowpea is mainly used for human food in the form of boiled grains (NIFRO), baked as thin bread (KITA) mixed with other cereals and prepared into various sauces (SHIRO WET). The seeds are a major source of plant proteins and vitamins for humans, feed for livestock and also a source of income. The immature pods are occasionally eaten as raw vegetables in South Wello and Oromia Special zones. It is traditionally important as a source of protein especially in the leant (fasting) season of Christians in the northern part of the country. Moreover, cowpea also plays an important role in improving soil fertility in cereal crops (such as sorghum and maize) farming system when grown via intercropping and crop rotation. Informants, explanations about the use of cowpea as food, income source, forage, medicinal The best use of cowpea for a given wereda received the highest ranking value (5), while the least useful is assigned a ranking value of two (2) in this exercise.

Farming system and practices

The farmers in northern Ethiopia gave a description of the farming system and practices. They underlined that the rainy season commences in May and ends in October. They prepare the land between the months of March and May. Land preparation is mainly done by oxen plough

Table 1. Cowpea germplasm collected from northern Ethiopia.

Collection code	Latitude (dd mm ss)	Longitude (dd mm ss)	Altitude (m.a.s.l.)	Sources of collection	Status of collection
MAARC 19	N13 37 32.7	E38 59 59.0	1650 m	AARC (Abi Adi)	Improved
MAARC 20	N13 37 32.7	E38 59 59.0	1650 m	AARC (Abi Adi)	Improved
MAARC 21	N13 37 32.7	E38 59 59.0	1650 m	AARC (Abi Adi)	Improved
MAARC 22	N13 37 32.7	E38 59 59.0	1650 m	AARC (Abi Adi)	Improved
MAARC 23	N13 37 32.7	E38 59 59.0	1650 m	AARC (Abi Adi)	Improved
MAS 42	N12 58 38.7	E38 57 37.6	1260 m	Saka (Abergelle)	Landrace
MBB 35	N11 14 28.5	E40 00 27.4	1770 m	Bira (Bati)	Landrace
MBB 35A	N11 14 28.5	E40 00 27.4	1770 m	Bira (Bati)	Landrace
MBB 35B	N11 14 28.5	E40 00 27.4	1770 m	Bira (Bati)	Landrace
MD 04	N11 08 58.4	E39 54 30.0	1460 m	Arabu or Degan (Kalu)	Landrace
MD 05	N11 08 58.4	E39 54 30.0	1460 m	Arabu or Degan (Kalu)	Landrace
MDRM 07	N11 08 09.1	E39 38 27.5	Unknown	Desse Robit Market	Landrace
MDT 29	N13 42 57.2	E38 47 10.9	2130 m	Derene Tseb (Kola Temben)	Landrace
MEA 37	N10 20 25.9	E39 57 51.4	1420 m	Ataye (Efratanagidem)	Landrace
MEG 38	N10 56 41.0	E38 20 56.1	2000 m	Enebse Sarmidir (East Gojam)	Landrace
MEG 38A	N10 56 41.0	E38 20 56.1	2000 m	Enebse Sarmidir (East Gojam)	Landrace
MH 27	N13 13 56.9	E38 59 34.7	1633 m	Hadnet (Tanqua Abergelle)	Landrace
MH 06	N11 16 48.8	E39 40 51.0	2050 m	Haik (North Wello)	Improved
MHT 24	N13 31 09.7	E39 01 49.6	1490 m	Hadash Tekli (Tanqua Abergelle)	Landrace
MHT 24A	N13 31 09.7	E39 01 49.6	1490 m	Hadash Tekli (Tanqua Abergelle)	Landrace
MKA 36	N11 09 31.2	E39 53 23.9	1580 m	Abecho (Kalu)	Landrace
MKA 36A	N11 09 31.2	E39 53 23.9	1580 m	Abecho (Kalu)	Landrace
MLB 15	N12 10 02.4	E38 59 06.4	1990 m	Bilbala (Lasta Lalibela)	Landrace
MLG 18	N11 56 33.2	E38 53 21.6	2050 m	Gelesot (Lasta Lalibela)	Landrace
MLM 17	N12 03 18.6	E39 02 05.9	2040 m	Medage (Lasta Lalibela)	Landrace
MLS 08	N11 58 48.8	E38 58 53.1	1960 m	Shumshuha (Lasta Lalibela)	Landrace
MLS 09	N11 58 23.4	E39 03 08.5	2070 m	Berta (Lasta Lalibela)	Landrace
MLS 10	N11 59 25.4	E39 00 57.9	2140 m	Godu Memder (Lasta Lalibela)	Landrace
MLS 11	N11 59 21.5	E38 59 11.0	2000 m	Tinchoy (Lasta Lalibela)	Landrace
MLS 12	N12 00 37.4	E39 00 08.8	2090 m	Lawober (Lasta Lalibela)	Landrace
MLS 13	N12 00 54.1	E39 01 38.7	2100 m	Yohans Amba (Lasta Lalibela)	Landrace
MLS 14	N11 59 53.6	E38 58 01.1	2000 m	Enkuay Beret (Lasta Lalibela)	Landrace
MLSM 16	N12 03 30.3	E38 58 19.0	2030 m	Segno Gebeya (Lasta Lalibela)	Landrace
MM 25	N13 16 11.7	E38 59 47.7	1560 m	Maerey (Tanqua Abergelle)	Landrace
MM 25A	N13 16 11.7	E38 59 47.7	1560 m	Maerey (Tanqua Abergelle)	Landrace
MML 34	N11 14 04.6	E39 58 47.3	1750 m	Melka Lugo (Bati)	Landrace
MML 34A	N11 14 04.6	E39 58 47.3	1750 m	Melka Lugo (Bati)	Landrace
MML 34B	N11 14 04.6	E39 58 47.3	1750 m	Melka Lugo (Bati)	Landrace
MN 29A	N13 42 37.9	E38 45 28.8	2100 m	Newi (Kola Temben)	Landrace
MRKA 28	N12 04 09.2	E39 37 48.2	1470 m	Aradum (Raya Kobo)	Landrace
MSAN 33	N13 02 33.9	E38 59 01.7	1350 m	Maernet (Abergelle)	Landrace
MSH 32	N12 27 31.8	E39 09 08.1	2030 m	Hamusit (Sekota)	Landrace
MSRC 01	N10 00 22.5	E39 53 42.7	1290 m	Shewarobit	Improved
MSRC 01A	N10 00 22.5	E39 53 42.7	1290 m	Shewarobit	Improved
MSRC 01B	N10 00 22.5	E39 53 42.7	1290 m	Shewarobit	Improved
MSRM 02	N10 00 04.0	E39 54 09.5	1270 m	Shewarobit	Landrace
MSRM 02A	N10 00 04.0	E39 54 09.5	1270 m	Shewarobit	Landrace
MST 31	N12 31 13.0	E39 04 43.1	2110 m	Tiya (Sekota)	Landrace

Table 1. Contd.

Collection code	Latitude (dd mm ss)	Longitude (dd mm ss)	Altitude (m.a.s.l.)	Sources of collection	Status of collection
MSW 30	N12 32 56.7	E39 03 19.5	2040 m	Weleh (Sekota)	Landrace
MTAL 41	N13 14 39.3	E39 02 36.3	1610 m	Lemlem (Tanqua Abergelle)	Landrace
MWEC 39	N14 03 59.6	E39 01 33.4	2070 m	Enda Chewa (Werie Leke)	Landrace
MWZ 40	N14 01 45.0	E39 01 37.4	2020 m	Zongi (Werie Leke)	Landrace
MY 26	N13 17 13.1	E38 59 39.6	1560 m	Yechilla (Tanqua Abergelle)	Landrace
MY 26A	N13 17 13.1	E38 59 39.6	1560 m	Yechilla (Tanqua Abergelle)	Landrace

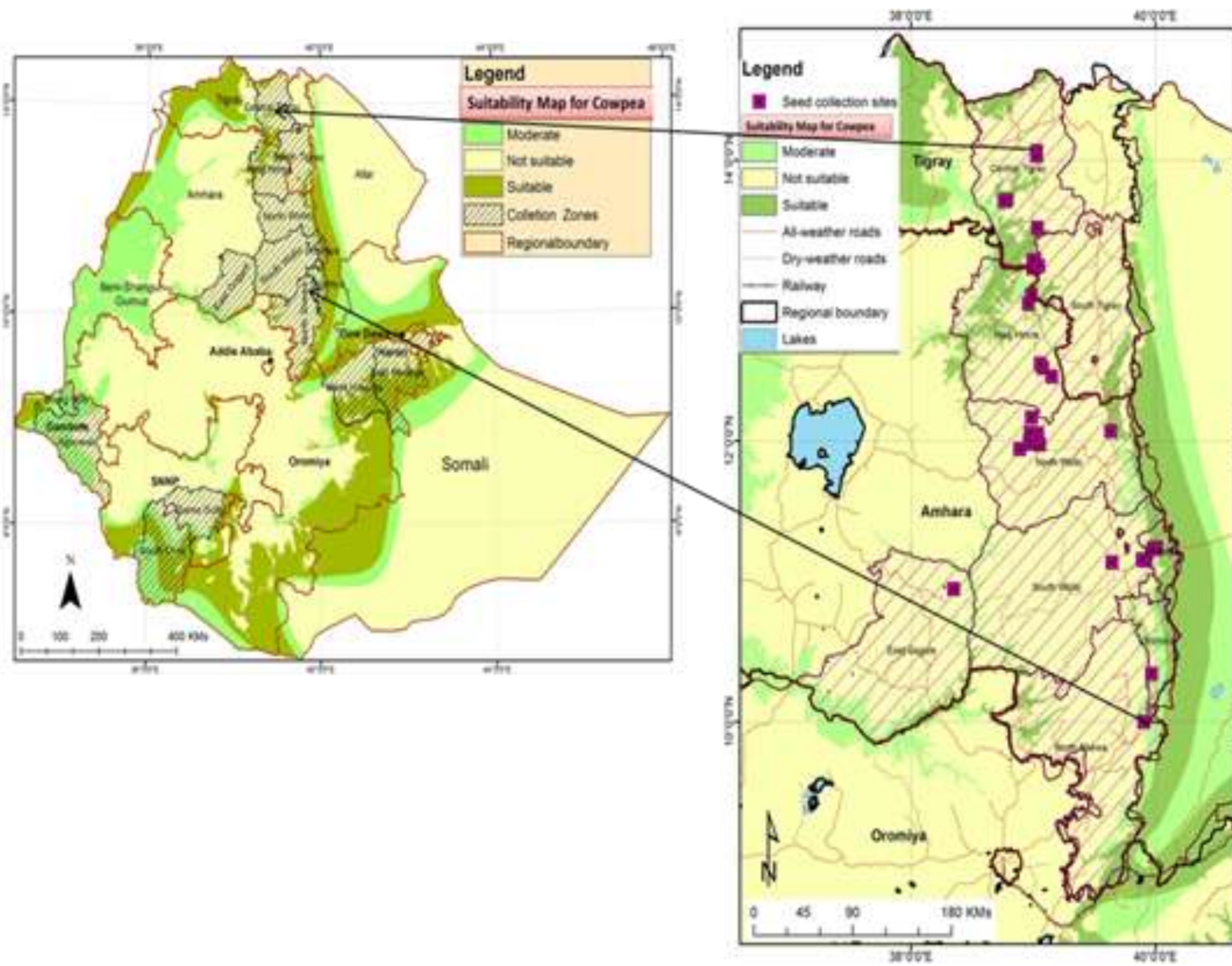

Figure 1. Map of Ethiopia showing Regional States and collection zones and districts for cowpea landraces (Map credit: Demeke Nigusse, GIS specialist, EIAR).

and weeding activity is done by manual hand-weeding and handheld hoeing. Planting commences towards the end of May, right after the first substantial rains have been received through to July and early August. By the end of November, all farmers harvested cowpea from the field.

The result of this study revealed that, cowpea is predominantly grown as a sole crop (48.75%) and followed by intercropping (35%) (Figure2).

Traditional cropping systems reported by farmers showed that farmers' perceptions was found cowpea is mostly intercropped with cereals.

Table 2. Diversity of cowpea landraces cultivated in northern Ethiopia as revealed by seed morphology (size, color, shape).

Seed sample of cowpea landraces with code	Local names (scientific name)	Language	Meaning of the name	Agroecology (Traditional zone)	Place of collection
A 	Adengor, Adagura, Dekak Adagura, adenguarie, Dekak Adagura *(Vigna unguiculata* Subsp. *unguiculata*)	Tigregna	A pulse crop with small seed size mainly used for animal feeding Green pulse crop	Woina Dega (midlands) Kolla (lowlands)	Tanqua Abergelle and Kola Temben
B 	Tekemiche, Kimite, serekula *(Vigna unguiculata* Subsp. cylindrical)	Amharic	Drought resistant herb	Woina Dega and (midlands)	Bati and Kalu
C 	Tekemiche, Kimite, serekula *(Vigna unguiculata* Subsp. cylindrical)	Amharic	Drought resistant herb	Woina Dega and (midlands)	Bati and Kalu
D 	Chekele, Egoyla *(Vigna unguiculata* Subsp. cylindrical)	Amharic and Agewgna	Drought tolerant herb grown in the dry season A crop mainly used when food in short supply	Woina Dega (midlands) and Dega (highlands)	Lasta Lalibela, Sekota, Abergelle and Enebse Sarmidir
E 	Adengor, Adagura, Dekak Adagura, adenguarie, Dekak Adagura *(Vigna unguiculata* Subsp. *unguiculata*)	Tigregna	A pulse crop with small seed size mainly used for animal feeding	Woina Dega (midlands)	Tanqua Abergelle, Kola Temben and Werie Leke
F 	Jergadie *(Vigna unguiculata* Subsp. unguiculata)	Amharic	A climber with large seed size	Woina Dega and (midlands)	Bati and Kalu
G 	Adengor, Adagura, Dekak Adagura, adenguarie, Dekak Adagura *(Vigna unguiculata* Subsp. *unguiculata*)	Tigregna	A pulse crop with small seed size mainly used for animal feeding	Woina Dega (midlands)	Werie Leke
H 	Chekele, Kimite *(Vigna unguiculata* Subsp. cylindrical)	Amharic	Drought tolerant herb grown in the dry season	Woina Dega (midlands) and Dega (highlands)	Bati and Enebse Sarmidir
I 	Jergadie *(Vigna unguiculata* Subsp. unguiculata)	Amharic	A climber with large seed size	Woina Dega and (midlands)	Bati and Kalu

Table 3. Morphological diversity of collected cowpea landraces in northern Ethiopia (qualitative and quantitative traits).

Qualitative and quantitative traits	Collected voucher specimens of cowpea landraces					
	Vigna unguiculata Subsp. unguiculata farmers' variety JERGADIE, collected from Bati (Table 2, Code F)	*Vigna unguiculata* Subsp. unguiculata farmers' variety JERGADIE, collected from Kalu (Table 2, Code I)	*Vigna unguiculata* Subsp. cylindrica farmers' variety KIMITE, collected from Kalu (Table 2, Code B)	*Vigna unguiculata* Subsp. cylindrica farmers' variety KIMITE, collected from Kalu (Table 2, Code C)	*Vigna unguiculata* Subsp. cylindrica farmers' variety CHEKELE, collected from Lasta Lalibela (Table 2, Code D)	*Vigna unguiculata* Subsp. cylindrica farmers' variety CHEKELE, collected from Sekota (Table 2 Code D)
Growth habit	Climbing	Climbing	Erect	Erect	Erect	Erect
Growth pattern	Determinate	Determinate	Determinate	Determinate	Determinate	Determinate
Twinning tendency	Intermediate	Intermediate	None	None	None	None
Terminal leaflet shape	Sub-globose	Sub-globose	Globose	Globose	Hastate	Hastate
Plant hairiness	Glabrescent	Glabrescent	Glabrescent	Glabrescent	Glabrescent	Glabrescent
Raceme position	Throughout canopy	Throughout canopy	In upper canopy	In upper canopy	In upper canopy	In upper canopy
Pod attachment to peduncle	30-90^0 down from erect	30-90^0 down from erect	Erect	Erect	Erect	Erect
Pod curvature	Straight	Straight	Slightly curved	Slightly curved	Straight	Straight
Seed shape	Ovoid	Ovoid	Rhomboid	Rhomboid	Rhomboid	Rhomboid
Testa texture	Smooth	Smooth	Smooth to rough	Smooth to rough	Smooth	Smooth
Leaf color	Intermediate green	Intermediate green	Pale green	Pale green	Pale green	Pale green
Leaf marking	Absent	Absent	Absent	Absent	Absent	Absent
Splitting of testa	Absent	Absent	Absent	Absent	Absent	Absent
Terminal leaflet length (mm)	90	87	72	76	74	76
Terminal leaflet width (mm)	54	58	48	44	30	33
Number of pods per peduncle	2	2	3	3	3	3
Number of seeds (locules) per pod	18	17	12	13	10	10
Seed length (mm)	8	8	5	5	6	5
Seed width (mm)	6	5	2	3	3	3
Pod length (cm)	18	19	9.5	7.4	8.1	8.5
Pod width (mm)	9	8	5	4	5	5

Common combinations are sorghum with cowpea and maize with cowpea using different planting methods mainly broadcasting (85%) and row planting (13.75%) (Figure 2). Furthermore, farmers produce cowpea in sandy and marginal soil conditions since the crop has the ability to with-stand drought and poor soil fertility conditions. Farmers produce this crop in their entire farms (main field, 60%; home garden, 8.75% and at borders of farm fields, 31.25%) during the rainy season except farmers from Central Tigray (Wereie Leke) where they use irrigation. The majority of farmers (60%) used their home saved seed (Figure 3) for the next growing season except in Werie Leke District where they use mostly seed obtained from agricultural office and sometimes they used their own home saved seed for the next growing season. The secondary seed

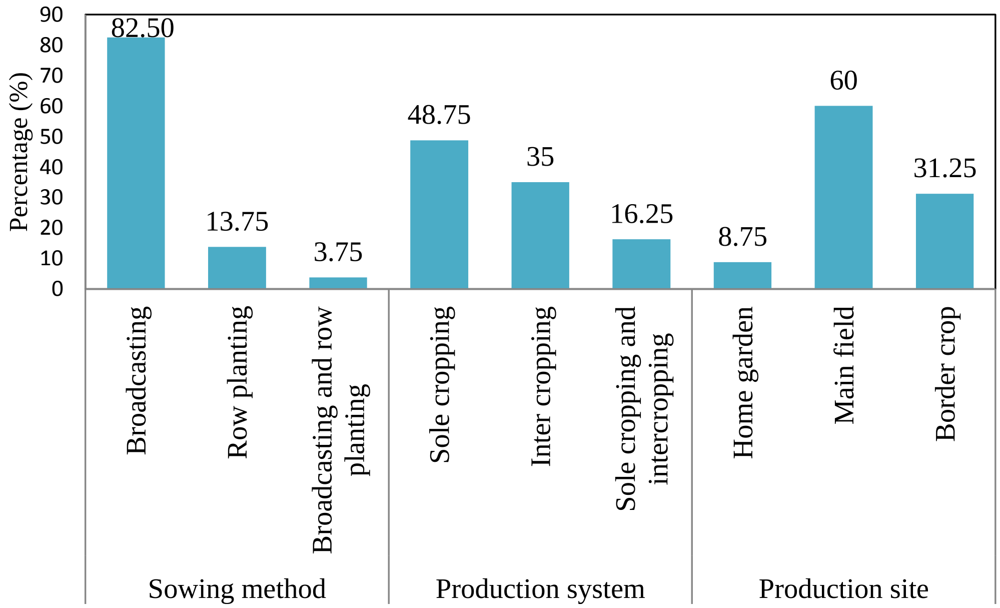

Figure 2. Agronomic practices for cowpea production in Northern Ethiopia.

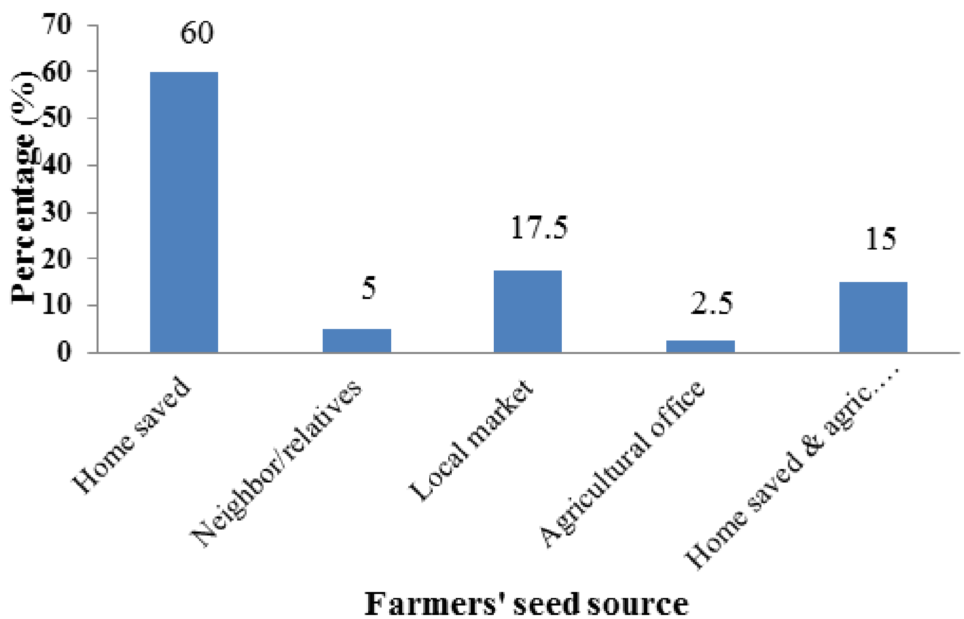

Figure 2. Farmers' seed source.

source for cowpea production has been found to be local market (17.5%) (Figure 3).

Gender roles for maintaining the landrace diversity of cowpea

Traditionally, in northern Ethiopia cowpea cropping is mostly done by men including the agronomic activities such as land preparation, planting, weeding, harvesting, threshing and drying. The major responsibilities of women are preparing processed the products of cowpea in the form of local recipes. Women also participate in many activities, together with their children, to support their husbands, including in weeding and harvesting. Women are also especially involved in variety selection, post-harvest treatment (during storage), marketing of the grain and processing for animal feed.

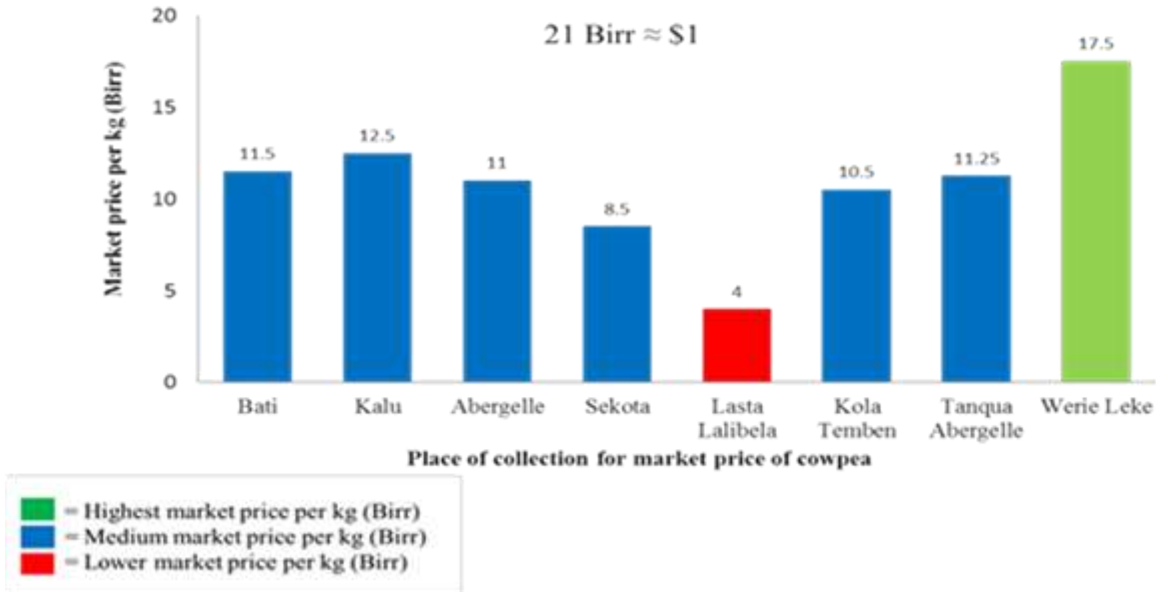

Figure 4. Market price of cowpea landrace varieties in localities within the study area.

Market value of cowpea

In addition to its food, soil improvement and forage values, cowpea has economic importance as income source; farmers often sell the grain in the local markets. The market price varied in the different districts of the study area (Figure 4). In Lasta Lalibela District, cowpea seed/grain had lower value, about Birr four per kg. Farmers in this area mostly use it as ground cover rather than for income generation. This is because farmers primarily focus on other legumes including: faba bean (*Vicia faba*), chickpea (*Cicer aritienum*) and field pea (*Pisum sativum*), which have higher demand than cowpea. They also mentioned some unpleasant organoleptic characters of cowpea as a factor discouraging its consumption by people. In Werie Leke District, cowpea has higher market price (Birr 17.5 per kg) than in other districts. This is because, in Werie Leke there is scarcity of livestock forage and the local farmers grew cowpea via intercropping with maize for livestock feed and for marketing.

The cowpea value chain consists of local exchanges and markets that ensure a movement of grain from producers to consumers. Therefore, exchange begins with the production of cowpea by small scale farmers. In northern Ethiopia, farmers typically sell their cowpea grains directly to consumers or some times to rural assemblers, who in turn sell it directly to consumers and bigger merchants.

Production constraints

In Northern Ethiopia, small holder farmers are facing different constraints on cropping, storage and consumption of cowpea including storage pests, field insects, parasitic weeds and diseases. However, farmers were unable to identify the names of insect pests and diseases. Nonetheless, according to the descriptions they provided aphids and pod borers were the most important insect pest problems for farmers. The primary insect pest causing losses to stored cowpea in northern Ethiopia according to the local farmers is storage weevil (*Callosobruchus maculatus*) locally called NEKEZ. Another menace is parasitic plant, locally called AKANCHIRA, a parasitic weed typically found in the study area causing yield losses as a root parasite.

DISCUSSION

Cowpea landrace diversity in northern Ethiopia

Landraces, also called farmers' varieties are the result of several years of natural and artificial selections by farmers for better adaptation to local growing conditions (Hegde and Mishra, 2009). Cowpea landraces collected from northern Ethiopia did not show much variation for plant growth pattern and growth habit. All local farmers grew determinate types with prostrate to erect growth habit. Such types are preferred by farmers because of their better performance under marginal conditions of rain fed environments where cowpea is commonly grown. Thulin (1989) reported that *Vigna unguiculata* subsp. *Sesquipedalis* and subsp. *dekindtiana* are mainly cultivated in northern Ethiopia. In the present study, landraces belonging to *Vigna unguiculata* subsp. *unguiculata* and *Vigna unguiculata* subsp. *cylindrica* were found under cultivation as components of different cropping systems under marginal rain fed conditions. The local landraces (83%) are more popular than the released commercial varieties because of farmers' preference owing mainly to their multi-purpose nature, organoleptic characters and higher market prices. The majority of landraces collected from Bati and Kalu districts of Amhara Region belonged to *Vigna unguiculata* subsp. *unguiculata* farmers' variety JERGADIE having prostrate (climbing) nature with higher vegetative growth and long pods in contrast to the erect type of cowpea. The collected landrace accessions were found both in mixed and uniform seed colors. Similar results were reported by Sariah (2010) where landrace accessions are mostly found both in mixed and uniform seed colors. From it that they grow cowpea for home consumption, livestock feed, income source and improving soil fertility. Thus, almost all collections from each district were found to be uniform in seed color except in some areas where accessions with mixed seed colors were found ranging from white to black, with cream and light red colors dominating mainly in Bati and Kalu districts and these were described as large seeded JERGADIE. This landrace type is mainly produced in Tanqua Abergelle and Bati as a major crop.

Cowpea is an important component of diets in northern Ethiopia, thus widely cultivated in Central Tigray (Tanqua Abergelle, Kola Temben and Werie Leke), Waghimra (Abergelle), South Wello (Kalu) and Oromiya Special zones (Bati). This is not the case in North Wello Zone (Lasta Lalibela), farmers said cowpea is predominantly grown for income generation, contingency of land use (ground cover) and sometimes for food. The reverse is true for Central Tigray local farmers where cowpea has an equal value with sorghum in terms of price value and major uses for home consumption primarily grown for food, income generation and forage.

Farmers' knowledge and perceptions

Cowpea is a versatile food crop that contributes to food culture in many parts of Africa (Timko and Singh, 2008) and referred to as the "hungry-season crop" given that it is the first crop to be harvested before the cereal crops are ready (Carlos, 2004). The same is true for Waghimra and Central Tigray zones where the crop is used as hungry-season crop and obviously known and grown by all farmers. This reflects the importance of cowpea in the day-to-day life of farmers in northern Ethiopia, which might probably be due to the fact that cowpea has the ability to withstand the existing dry conditions in the study areas. In every growing season, almost all farmers grow cowpea by intercropping with sorghum and maize except in Sekota and Lasta Lalibela districts where the farmers mainly use sole cropping system at their main and boarder farm fields as minor cropping. Both climbing and erect types of cowpea were grown in northern Ethiopia to exploit the advantages provided by each type. As described by Carlos (2004), the fast growth and spreading habit of traditional cowpea farmers' varieties suppress weeds, and soil nitrogen is increased which improves cereal growth. Farmers' responses on the selection criteria were based on the crop's multipurpose nature being used for human consumption, animal feed, income source and improving soil fertility. Cowpea also contributes to the sustainability of cropping systems and soil fertility improvement on marginal lands through nitrogen fixation, provision of ground cover and plant residues, which minimize erosion and subsequent land deterioration.

Crop uses and purpose of production

As indicated by Westphal (1974), Thulin (1989) and Gbaguidi et al. (2013), vernacular names traditionally attributed to crop varieties vary more often across administrative districts and villages even sometimes between farmers within a single village. Similar results were reported by Singh et al. (2003) and Timko and Singh (2008). As reported by Phillips et al. (2003) and Timko et al. (2008) cowpea is a multi-purpose crop and it is used for food, forage, income generation and improving soil fertility as asserted by all respondents of the present study. In addition, Megersa et al. (2013) reported that, cowpea is traditionally used by smashing and rubbing on affected part of body to treat the disease known as Tinea Corporis. The present study results did not indicate the use of cowpea as a medicine. Almost all parts of the crop such as seeds, pods, leaves/stems and straw are used for various purposes as reported by Singh et al. (2003); Pottorff et al. (2012) and the present study. As reported by Carlos (2004), in southern Africa, cowpea is grown primarily for fodder, although it is also used for grain production, green manure, and weed control in forestry plantations and as a ground cover to prevent soil erosion. In this study, cowpea uses varied considerably between regions and some uses reported from other countries were not recorded in northern Ethiopia. As reported by Timko et al. (2007), the tender green leaves are an important food source in Africa and are prepared as a pot herb, like spinach. Cowpea green leaves and immature pods are consumed as green vegetables in southern and eastern Ethiopia (Westphal, 1974). Immature green pods are used in the same way as snap beans, often being mixed with cooked dry cowpea or with other foods. The consumption of nearly mature cowpea grains shelled and boiled as a fresh vegetable reported in other parts of Africa is recorded in the present study in Ethiopia. The study results further showed that the seed is a highly valued part of the crop for home consumption in the form of NIFRO, KITA and WET. Sometimes, the green mature pods were eaten by children in Bati and

Kalu districts. As stated by Singh and Tarawali (1997), in northern Ethiopia cowpea foliage is an important source of high-quality hay for livestock feed.

Cropping systems and management practices

As reported by Blade et al. (1997) and Timko et al. (2007), cowpea is usually grown as an intercrop with sorghum (*Sorghum bicolor* (L.) Moench) and less frequently as a sole crop or intercropped with maize (*Zea mays* L.), cassava (*Manihot esculenta* Crantz), or cotton (*Gossypium* sp.). In the present study, cowpea is mainly grown as a rain fed crop and sorghum is the major cereal crop with which cowpea is intercropped (95%) in all surveyed areas, except in Werie Leke District where maize is the major cereal in which cowpea is intercropped (5%) along irrigation channels. Carlos (2004) and Dugje et al. (2009) described a similar intercropping system in West and Central Africa under similar semi-arid conditions, where cowpea was also intercropped with cereal crops (maize and sorghum) with the recommended spacing of 75 cm x 50 cm. Dugje et al. (2009) and AFF (2011) reported that fertilizer application in cowpea production depends on anticipated yield and soil fertility. As a legume, cowpea does not require much nitrogen because of the symbiotic nitrogen fixation. Based on the results, the majority of farmers (60%) indicated that they never used fertilizer and/or chemicals in the surveyed areas especially in Tanqua Abergelle, Abergelle, Sekota and Lasta Lalibela districts. On the other hand, reasonable number of the farmers (40%) used compost to improve soil fertility and chemical pesticides for plant protection in Bati, Kalu, Kola Temben and Werie Leke districts.

Seed supply, selection and storage

The reliance of local farmers mainly on sources of home saved seed and exchanging with their neighbors is a good support in maintaining and conserving the distinct types, but at the same time there is little driving force to create new types and maintain a high level of diversity (Munisse et al., 2011). The present study result also showed that, the majority of farmers relied on their own home saved seeds, buying from local market, exchanging with neighbors or relatives, buying from agricultural office (only landraces) and sourced from both home saved and agricultural office. The most important farmers' criteria for selection are tolerance to drought, good taste, high grain yield, early maturity, feed value and market value of grain. For example, some farmers in Bati and Kalu districts preferred cowpea landrace having the climbing habit (JERGADIE) due to its leafy nature that improves soil fertility via nitrogen fixation and livestock feed value as compared to cowpea types with erect growth nature (KIMITE and CHEKELE).

Cowpea is highly vulnerable to insect attacks and damage due to storage pests. There are published data (Carlos, 2004; Dugje et al., 2009) providing evidence that insect pests cause devastating losses in cowpea yields and weevils (post-harvest pest) can destroy a granary full of cowpea grains within two or three months. In northern Ethiopia, some farmers stored the seed with special treatment using chemicals (malatine), botanicals and ash for the next growing season to escape storage pest problem. As a result, all farmers reported that storage pests are the major causes of post-harvest losses. As reported by Dugje et al. (2009), insect pests are major constraints to cowpea production in West Africa and damage by insect pests on cowpea can be as high as 80–100% if not effectively controlled. The most important storage pest of cowpea is the weevil (*Callosobruchus maculatus*) and severe infestation can lead to total grain loss in storage (Carlos, 2004; Dugje et al., 2009; Sariah, 2010). The storage life of cowpea depends on its moisture content before storage; and the lower it is the better the quality of seeds for storage (AFF, 2011). In developed countries, one alternative is the use of cold storage and that exposure to minus 18^0C during 6 to 24 h reduced pest numbers by more than 99% (Carlos, 2004).

Qualitative and quantitative traits

Earlier studies on cowpea showed that morphological traits were of great importance to distinguish genetic variability. As in previous studies (Hegde and Mishra, 2009; Sariah, 2010; Gbaguidi et al., 2013), this study also found that morphological traits (quantitative and qualitative) are valuable tools for cowpea genetic diversity studies. For example, some of the morphological traits such as growth habit, terminal leaflet length, terminal leaflet width, seed length, twining tendency, terminal leaflet shape, pod length, number of seeds per pod and seed shape had the uses for morphological identification and characterization. The results showed that landraces collected in Bati and Lasta Lalibela locally called CHEKELE and KIMITE were similar. Similarities of some characters were also observed between JERGADIE on the one hand and KIMITE and CHEKELE on the other. As for the qualitative traits, the existence of genetic diversity among the collections for most of the morphological traits studied, CHEKELE and KIMITE were more varied than JERGADIE. A high level of similarity was also observed among the collection of CHEKELE and KIMITE for most of the traits studied.

Conclusion

Traditional knowledge related to the cultivation and use of cowpea, particularly on the local landraces, still persists in northern Ethiopia. There is great diversity in cowpea landraces in many traits. Local farmers' uses and value of different landraces according to their contexts and interests. Any cowpea development program should aim at maintaining its landrace diversity as a national and global germplasm pool. There is probably much more cowpea diversity to sample, collect and understand. This study has contributed to generation of general information about cowpea landraces as it occurs in the northern portion of Ethiopia and also supplied cowpea germplasm for conservation and future varietal improvement works. Hence, it will be of interest to study the diversity of the landraces further to be able to apply the local conservation strategies in a modern context and to identify potential genetic resources, to enhance food and nutrition security, and income generation. This study further indicates that integration of cowpea with the prevailing farming systems using native cowpea varieties could have significant importance in improving soil fertility and productivity, improving feed quality and withstands the impacts of climate change.

Conflict of interests

The authors have not declared any conflict of interests

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Propagule emergence in topsoil from a high-altitude field and implications for bauxite mining area restoration

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The identification of factors that influence the timing of seedling emergence in topsoil is important to improve restoration strategies in former mining areas. The aim of this study was to determine the time of emergence of seedlings present in the topsoil of high fields in the Atlantic Forest on bauxite mines in the plateau region of Poços de Caldas, Minas Gerais, in both the dry and rainy seasons. The surface layer soil (top 5 cm) and litter were collected in August 2011 and March 2012. We collected 12 samples, consisting of 6 subsamples distributed in 3 sites (4 samples/site), from both the dry and wet periods (n = 24). The collected contents were placed in plastic trays and germination was evaluated in the greenhouse. The seedling emergence curve was adjusted. The values were submitted to analysis of variance associated with the Scott-Knott test ($p < 0.05$). The number of emerged seedlings and the time required for emergence to stop were lower in the rainy season than the dry season. The results show that the best time for the storage of the topsoil layer is the dry season, since it prolongs the viability of propagules and improves the success of recovery activities on mined areas.

Key words: Atlantic forest, environmental restoration, emergence time, degraded areas, bauxite mining.

INTRODUCTION

Fields Plateaus in southeast Brazil contain rare vegetation and are considered areas of great environmental importance due to their high level of endemism (Caiafa and Silva, 2005). This plant communities occurs in open areas (Vasconcelos, 2011) covered by bunchgrass matrixes and some pteridophytes (Safford, 1999), and is usually found at an altitude of around 1,500 m (Vasconcelos, 2011). The plateaus deserve attention for their scenic beauty, biological importance, and geological particularities, standing out as sources of primary water capture, supplying water to approximately 25% of the Brazilian population (Safford, 1999).

The Poços de Caldas Plateaus are located within the Atlantic Forest ecosystem (Veloso et al., 1991) with a rich biodiversity and high level of endemism, where large deposits of bauxite are being mined in areas of typical regional vegetation. The knowledge and awareness of the impacts generated by mining in the region, as well as its importance for the national and international economies, motivate practices related to the conservation and recovery of these environments (Barros et al., 2012). The topsoil seed bank may be an indicator of the behavior of the species in areas subjected to mining (Martins et al., 2008; Machado et al., 2013), thus studying it provides important information for the development of conservation plans (Adams et al., 2005). Therefore, the evaluation of the emergence time of propagules in certain environments, taking into account spatial and temporal patterns (Ceccon and Hernández, 2009), allows for the identification of periods of higher propagule emergence, as well as periods with greater plant species diversity. This information can improve the expected results of environmental restoration plans that, among other factors, also include indicators of plant performance, physical and chemical aspects of the soil, and the impact on the fauna (Almeida and Sánchez, 2005; Mensah, 2015). Studies making use of this approach are important to gather cumulative data about the timing and plant diversity of propagule emergence, allowing inferences about the optimal periods to implement restoration practices in altered environments. Analysis of the propagule emergence time under controlled conditions is widely used for species of commercial interest to address the needs of seed and grain producers (Caldeira et al., 2015). However, few studies have been developed using this analysis for plant conservation in natural environments (Machado et al., 2013).

The removal, stocking, and returning of topsoil are used to promote environmental recovery after mining activities (Hall et al., 2010; Barros et al., 2012; Jaunatre et al., 2014). The topsoil, the layer that includes the surface horizons of the soil, is rich in organic matter, autochthonous seeds, and microorganisms, and is considered to be of the utmost importance in the restoration of altered environments (Koch, 2007). The knowledge of the wealth of plant species that make up the soil seed bank provides information on the conservation status of the area and will certainly contribute to the development of appropriate management protocols for vegetation condition (Fisher et al., 2009).

The returning of this surface layer is also recommended to maintain the physical characteristics of soil as close as possible to the existing prior to mining (Barros et al., 2013), since it must be considered the influence of storage time on the longevity of the existing propagules and their influence on the quality of soil and seeds bank. Therefore, this study aimed to determine the duration and timing of emergence of propagules collected in two periods (dry and rainy seasons) to optimize techniques for restoring bauxite mining areas in the Poços de Caldas Plateaus region of Minas Gerais, Brazil.

MATERIALS AND METHODS

The study area is located in the Poços de Caldas Plateaus, at an altitude of around 1,300 m, where the forest formations are classified as High-mountain Semi-deciduous Seasonal Forest (Oliveira Filho and Fontes, 2000), surrounded by native fields. The climate in this region is mesothermic, of the Cwb type (Alvares et al., 2013) with an annual average precipitation of 1,300 to 1,600 mm for the rainy season (October to March) and 300 mm for the dry season (April to September) (Guimarães et al., 2013). The collection of potential propagative material for restoration activities was carried out in August 2011 (winter dry season) and March 2012 (summer rainy season). The upper 5 cm of the topsoil was collected after removing the vegetation (Araújo et al., 2004). Soils classified as dystrophic Red Nitosol predominate in the study area (Embrapa, 2006), it is characterized as typically porous, high acidity, and in the case of the study area of large amounts of clay, gravel and strongly undulating terrain. The study area was divided into 3 sites: (A) close to a eucalyptus stand, (B) in the center of the field, and (C) in the field close to the native forest (Figure 1). The sampling was comprised of a total of 12 samples that included 6 subsamples (Souza et al., 2006), with 4 samples being collected per site for each period (N = 24). Immediately after collection, the samples were sent to a greenhouse at the forestry nursery of the Department of Forest Sciences (DCF) of the Federal University of Lavras (UFLA) and placed under a shade cloth at 50% luminosity. Each soil sample was spread over a 1.5 cm sterilized sand bed, autoclaved (120°C for 1 h), and placed in 33.00 × 44.00 × 8.00 cm plastic trays according to the methodologies proposed by Araújo et al. (2004) and Zhang et al. (2001). The soil samples collected were approximately 0.012 m^3.

The method used to quantify the individuals present in the topsoil was counting the daily emergence of propagules (Gross, 1990). The plants were identified and removed from the trays after reaching the adult stage (flowering, when possible), with proper care to avoid contamination of the propagules. The evaluations were performed for 11 weeks, until the emergence of new individuals ended. The maximum average temperature during the rainy season was 27.1°C and the minimum was 16.66°C, with an average relative humidity of around 75%. On the other hand, in the dry season, the maximum average temperature was 28.3°C and the minimum was 14°C, with an average relative humidity of around 58.7%. The propagules presents in the substrate were

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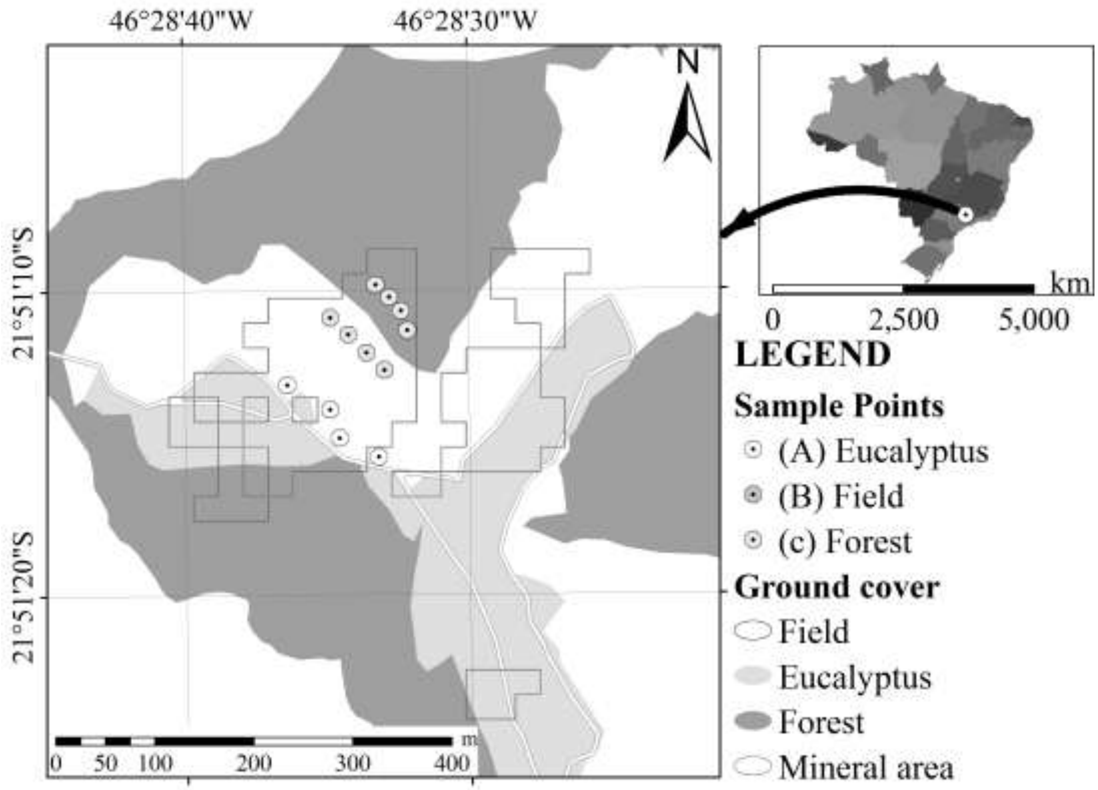

Figure 1. Experimental layout for studying propagule emergence in topsoil from the Poços de Caldas Plateaus, MG. (A) field area near the eucalyptus plantation, (B) center of the field, (C) field area close to the native forest.

Irrigated every 24 hours using 500 mL of water in each tray.Data on the number of propagules that emerged in the samples were used to adjust the emergence curve of plateau plants using the software Germinator (Joosen et al., 2010), as described by El-Kassaby et al. (2008), using the parameters of the Hill function (4PHF):

$$y = y_o + \frac{ax^b}{c^b + x^b}$$

Where: y = percentage of cumulative emergence in x time; y_0 = y-axis intercept; b = exponent that controls the form and degree of inclination in the curve; c = time necessary for 50% of viable propagules to emerge (t50); x = assessment time; and a = maximum cumulative emergence percentage.

The adjustment of the cumulative emergence curves indicates the biological behavior before specific environmental conditions (Joosen et al., 2010). In this study, the values found for the adjustment of the emergence time were subjected to variance analysis, having as variables: t50 (necessary time for 50% of the viable propagules to emerge) and u7525 (time interval between the emergence of 25 and 75% of propagules). The design used was completely randomized, in a 3 × 2 factorial scheme (3 areas and 2 periods) with 4 replicates (n = 24). To compare averages, an analysis of variance was performed in association with a Scott-Knott test with $p < 0.05$ using the programming language medium R (R, 2009). After Shapiro Wilk's and Levene's tests, it was found that the data were normally distributed ($p > 0.05$) and with homogeneous variances ($p > 0.05$), respectively, thus enabling us to submit them to variance analysis with $p < 0.05$.

RESULTS

The first propagules emerged in the first week during the rainy season and ended during the fifth week, whereas in the dry season, seedling emergence began in the third week and ended during the tenth week. In total, 585 individuals emerged in the rainy period, and 777 in the dry period. Seven botanical families were identified during the rainy period, comprising 34 species (Table 1). Among these, 5 were identified only at the genus level, and 14 were classified as morphospecies. Among the identified families, Asteraceae showed the greatest species richness in this period, (7 species, 20.59%), followed by Poaceae (6 species, 17.65%), and Rubiaceae and Melastomataceae, both with 2 species (5.88%). In the dry period, 50 species from 14 botanical families were identified. Among the species, 10 were identified only at the genus level and 11 as morphospecies. Among the families identified, Poaceae showed the highest richness

Table 1. Plant species germinated in samples collected from topsoil in altitude fields vegetation on the plateau of Poços de Caldas, Minas Gerais.

Plant species	Botanical family	Period	Eucalyptus plantation	Field strict sense	Forest vegetation
Achyrocline alata (Kunth) DC.	Asteraceae	S/C	+/+	+/+	+/+
Achyrocline satureioides (Lam.) DC.	Asteraceae	S/C	+/+	+/+	+/+
Ageratum fastigiatum (Gardner) R.M.King & H.Rob.	Asteraceae	S/C	+/+	+/+	+/+
Alternanthera sp.	Amaranthaceae	S	-	-	+
Andropogon bicornis L.	Poaceae	S/C	-/-	+/-	-/+
Andropogon sp.	Poaceae	S/C	-/+	+/-	+/+
Baccharis dracunculifolia DC.	Asteraceae	S	+	+	+
Bacharis sp.	Asteraceae	S	-	+	-
Borreria capitata (Ruiz & Pav.) DC.	Rubiaceae	S/C	+/+	+/+	+/+
Borreria latifolia (Aubl.) K.Schum.	Rubiaceae	S/C	+/+	+/+	+/+
Borreria verticillata (L.) G.Mey.	Rubiaceae	S	-	+	-
Bulbostylis capillaris (L.) Kunth ex C.B. Clarke	Cyperaceae	S/C	+/+	-/-	-/+
Cenchrus echinatus L.	Poaceae	S	-	+	-
Chamaecrista flexuosa (L.) Greene	Leguminosae	S/C	-/-	-/-	+/+
Conyza bonariensis (L.) Cronquist	Asteraceae	S/C	-/+	-/-	+/+
Cyperus aggregatus (Willd.) Endl.	Cyperaceae	S	+	-	-
Digitaria corynotricha (Hack.) Henrard	Poaceae	S	-	+	+
Echinolaena inflexa (Poir.) Chase	Poaceae	S/C	+/+	+/+	+/+
Eragrostis rufescens Schult.	Poaceae	S	-	-	+
Galinsoga sp.	Asteraceae	C	-	-	+
Gamochaeta americana (Mill.) Wedd.	Asteraceae	S/C	+/+	+/+	+/+
Gamochaeta coarctata (Willd.) Kerguélen	Asteraceae	C	+	+	+
Gymnopogon spicatus (Spreng.) Kuntze	Poaceae	S	+	+	-
Hyptis sp.	Lamiaceae	S	-	-	+
Lantana sp.	Verbenaceae	S	-	+	-
Leandra sp.	Melastomataceae	S/C	+/+	+/-	+/+
Lippia sp.	Verbenaceae	S	-	-	+
Melinis minutiflora P.Beauv.	Poaceae	S/C	+/-	+/+	+/+
Miconia cinnamomifolia (DC.) Naudin	Melastomataceae	S	+	+	-
Panicum campestre Nees ex Trin.	Poaceae	S	+	-	+
Paspalum pilosum Lam.	Poaceae	S	+	+	+
Paspalum polyphyllum Nees ex Trin.	Poaceae	S	+	-	+
Paspalum sp.	Poaceae	C	+	+	+
Phyllanthus niruri L.	Phyllanthaceae	S/C	-/+	-/+	+/+
Rhynchospora sp.	Cyperaceae	S	-	+	-
Schizachyrium tenerum Nees	Poaceae	S/C	+/+	+/+	+/+
Scoparia dulcis L.	Plantaginaceae	S	-	+	+
Setaria parviflora (Poir.) M.Kerguelen	Poaceae	S	+	-	-
Solanum palinacanthum Dunal	Solanaceae	S	+	-	-
sp. 1	-	S	+	+	-
sp. 2	-	S	-	+	+
sp. 3	-	S	-	+	+
sp. 4	-	S	+	-	-
sp. 5	Euphorbiaceae	S	-	+	-
sp. 6	-	S	-	+	-
sp. 7	-	S	+	-	-
sp. 8	Fabaceae	S	-	+	-
sp. 9	-	S	+	-	-

Table 1. Cont'd

sp. 10	-	S	-	-	+
sp. 11	-	S	-	+	-
sp. 12	-	C	-	+	+
sp. 13	-	C	-	+	-
sp. 14	-	C	-	-	+
sp. 15	-	C	-	+	-
sp. 16	-	C	+	-	-
sp. 17	-	C	+	-	-
sp. 18	-	C	+	-	-
sp. 19	-	C	-	+	-
sp. 20	-	C	-	+	-
sp. 21	-	C	-	-	+
sp. 22	-	C	-	-	+
sp. 23	-	C	-	-	+
sp. 24	-	C	-	-	+
sp. 25	-	C	+	-	-
Trembleya sp. 1	Melastomataceae	S/C	+/+	+/+	+/+
Trembleya sp. 2	Melastomataceae	S	-	+	-
Zornia reticulata Sm.	Fabaceae	S	-	+	+

* S/C: occurrence of the species in the dry and rainy season; S: occurrence of the species in the dry season; C: occurrence of the species in the rainy season; +: confirms the occurrence of the species in a given collection site; -: absence of species in a given collection site.

(13 species, 26.00%),followed by Asteraceae (7 species, 14.00%) and Melastomataceae with 4 species (8.00%). These plant families predominate in altitude fields, suggesting great ecological importance in studies of restoration areas under the influence of bauxite mining. There was a predominance of plant species classified as herbaceous. The abundance of individuals in dry season, there was a predominance of the family Asteraceae, primarily related to the abundance of *Ageratum fastigiatum* (163 individuals), which stands out for its representation of the herbaceous habit in grassland vegetation types. Other species of large occurrence in this period were: *Achyrocline satureioides* (121 individuals), followed by *Echinolaena inflexa* (90 individuals) *Achyrocline alata* (87 individuals), *Borreria latifolia* (43 individuals) and *Melinis minutiflora* (22 individuals). In rainy season prevailed also Asteraceae family. Again the patterns abundance of *A. fastigiatum* (225 individuals) in rainy season were higher. Other species of large occurrence in rainy season were: *Gamochaeta americana* (71 individuals), followed by *Borreria latifolia* (75 individuals), *Paspalum* sp. (38 individuals), *Phyllanthus niruri* (37 individuals) and *Echinolaena inflexa* (31 individuals). We highlighted the occurrence of two endemic species from Brazil: *Panicum campestre* and *Miconia cinnamomifolia*, suggesting greater concern for conservation of open fields. The total species richness was 77 species. Regarding species richness that occurred in each area investigated there was a higher occurrence of species in propagules bank of samples collected in the field strictu sensu and forest environment (40 species), followed by eucalyptus plantation (34 species) and 17 species shared in the three areas covered in this study, equivalent to 23.37% of total species richness (Table 1). Some species occurred mainly in a period or specific collection site. Among these species there are *A. fastigiatum*, *A. satureoides*, *B. latifolia*, *E. inflexa* and *Melinis minutiflora* as the most frequent occurrence, the latter being an exotic species of high fields from the Atlantic forest.

We found a significant difference only for the period (dry and wet) ($p < 0.01$), which suggests a low contribution of the surrounding areas (field area near the eucalyptus plantation and field area close to the native forest) ($p > 0.05$) for the restoration of the studied field area. Considering the periods, it was found that dry period showed higher plant species richness when compared to the rainy season (Figure 2). There were distinct differences in the time of emergence between the dry and rainy seasons; propagule emergence ended sooner in the rainy season (Figure 3). In the rainy season, the propagules germinated more quickly, which would cause significant losses if topsoil stocking was carried out during this period. On the other hand, a longer period of propagule emergence was observed in the dry period, in addition to a higher number and richness of species, suggesting a greater viability of propagules, and, possibly, better environmental recovery after mining

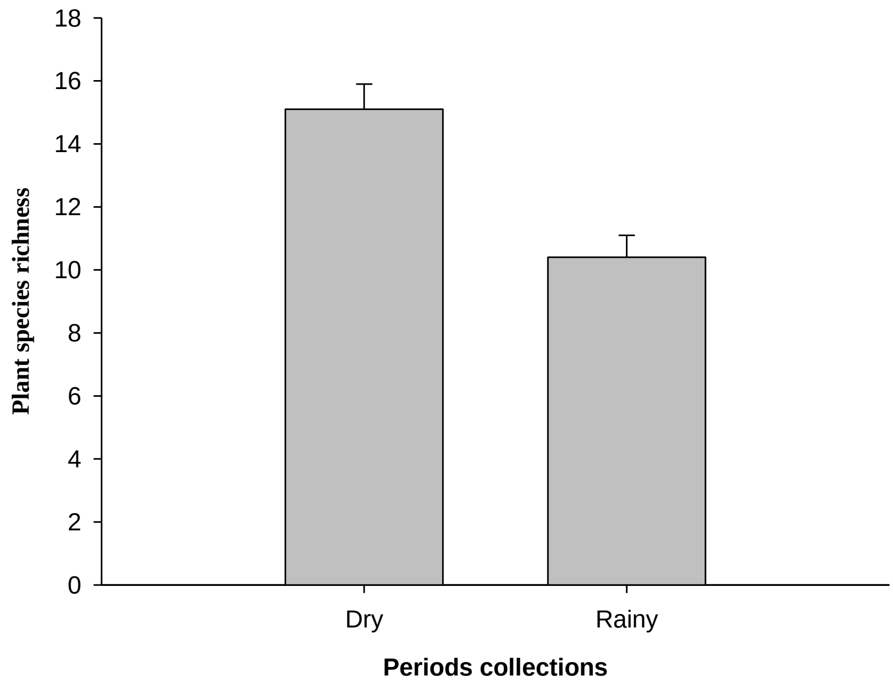

Figure 2. Species richness collected in different periods (dry and rainy) in altitude fields vegetation on the plateau of Pocos de Caldas, Minas Gerais.

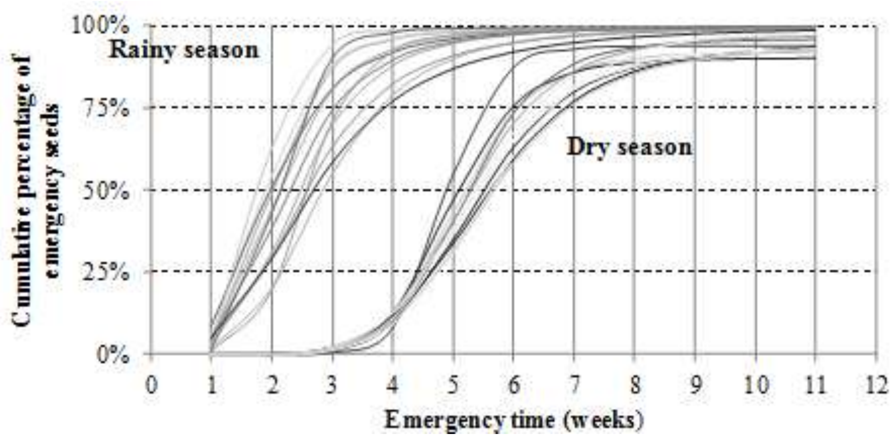

Figure 3. Emergence of propagules during the assessment periods for the collected topsoil from plateaus on bauxite bodies at Poços de Caldas, Minas Gerais. The lines represent the adjusted curves for each of the replicates in different environments and collection periods. $R^2 = 0.9$.

activities. As expected, the sooner the initial emergence, the shorter the time to reach 50% of the total emergence (t50) was. In this work, the greater propagule emergence speed was during the rainy period. Both t50 and u7525 were lower for this period (Figure 4), indicating that less time was needed for the stabilization of the cumulative emergence curve ($p < 0.05$). The variable t(50), was not significantly different between the center of the field area and the area close to the native forest. However, both were significantly different from the area close to the eucalyptus stand ($p < 0.01$) (Figure 4). In addition, there was a shorter interval of time between the emergence of 25 and 75% of propagules for the samples collected in the area close to the eucalyptus stand than for the other

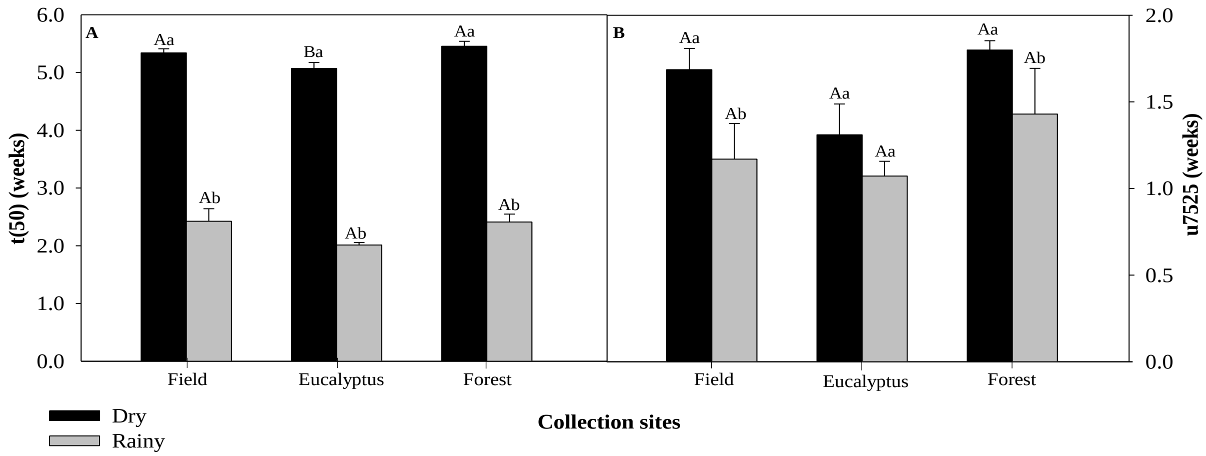

Figure 4. Dynamics of the emergence of propagules present in the topsoil in different collection sites in the plateaus of Poços de Caldas, Minas Gerais. (A) time needed for 50% of the viable propagules (t50) to emerge, and (B) uniformity of emergence (u7525), in different collection periods (dry and rainy); p = 0.00001 and 0.01329, respectively. Uppercase letters compare different sites within the same period and lowercase letters compare different periods within each site.

areas; however, there was no statistical difference in the u7525 variable among the areas analyzed during the dry and rainy seasons with $p > 0.05$ (Figure 4).

DISCUSSION

The emergence performance of propagules in an environment can be characterized through 3 parameters: the time of first emergence and the speed and duration of emergence (El-Kassaby et al., 2008). The early emergence of propagules from the plateau topsoil during the rainy season is related to the higher likelihood of appropriate conditions for germination due to higher humidity. This reflects synchrony between the reproductive strategy, which is concomitant with the dispersion of diaspores at the end of the dry season and emergence right at the beginning of the rainy season (Munhoz and Felfili, 2006). The composition of plant species is also important and should be considered in restoration studies on degraded areas, since restoration success is directly related to the favorableness of a period for a higher diversity of species, along with information of the impact on the soil and fauna (Almeida and Sánchez, 2005). In the case of the field environment under study, we identified more plant families and species during the dry season. In addition, the use of topsoil stock in this season allowed for greater time for the beginning of emergence of propagules, avoiding important losses of plant species and total individuals after restoration of the area. Studies on the speed and uniformity of emergence are useful not only to estimate the conversion of propagules into seedlings (Joosen et al., 2010), but also to direct management practices for minimizing the impact of mining and conserving the diversity of plant species (Kolotelo et al., 2001; Sheoran et al., 2010). From this perspective, the stocking of topsoil for restoring mining areas should be performed during periods of lower physiological activity of the seeds and greater longevity of propagule emergence. The viability of propagules in the long-term has been related to environmental parameters, such as humidity and temperature (Fenner and Thompson, 2005). The early emergence of seedlings during the rainy season in this study indicated a shorter propagule viability time when stocked in the form of static piles, increasing the possibility of losing propagation material (Golos and Dixon, 2014), since, in tropical regions, where up to 90% of rain is concentrated in the 3-month rainy period, storing at the soil level becomes a problematic activity (Sheoran et al., 2010). Seedling emergence and establishment are regulated by diverse factors, including abiotic conditions like humidity and temperature that influence the propagation of species (Eliud et al., 2009; Lebrija-Trejos et al., 2011). The first manifestations of emergence are characterized by the swelling of the propagules and the emergence of the radicle and cotyledon (Rosa et al., 2005). Overall, more propagules from recalcitrant species, which do not show strategies for early emergence, occur in dispersed areas during the rainy period, since their seeds do not dry at the end of maturation but are dispersed during elevated humidity, remaining metabolically active and germinating immediately after dispersion (Hong and Ellis, 1996;

Carvalho et al., 2006). Recalcitrant species are more sensitive to drying, and their propagules cannot be stored for long periods (Barbedo and Bilia, 1998; Carvalho et al., 2006), indicating that some of the propagules from the Poços de Caldas Plateaus that emerged during the rainy season share this reproductive strategy. Some species of botany family Asteraceae, Poaceae, Rubiaceae and Melastomataceae are classified as recalcitrant (Farnsworth, 2000), and scatter seeds with high humidity can begin the process of germination quickly (Nery et al., 2014).

During the dry period, more propagules of orthodox species occur (Chazdon et al., 2003), which indicates greater tolerance to dryness when stored (Hong and Ellis, 1996; Barbedo and Bilia, 1998) in the topsoil, which makes them more efficient to use for restoration. On the other hand, seeds from recalcitrant species easily lose viability when subjected to unfavorable circumstances (Nazário et al., 2008), thus storing the upper level of soil for long periods may reduce the number of species restored (Barbedo and Bilia, 1998; Sheoran et al., 2010). According to what was observed in the present work, the rainy season is not the best period for stocking topsoil, based on the speed (t50) and uniformity of emergence (u7525) of the propagules ($p < 0.05$) (Figure 4). On the other hand, propagules emerged more persistently in the dry period, that is, for a longer period. Seed longevity increases in colder and less rainy conditions, whereas the loss of viability is increased under hot and humid conditions (Pakeman et al., 2012). In addition, excessive humidity accelerates seed germination and induces overcoming dormancy (Golos and Dixon, 2014). When mining work is planned for the rainy season, it is recommended that material removed from the station be quickly used to restore another area, reducing the possibility of propagule loss. Propagule dispersion and germination are important for the establishment and maintenance of plant species, and are important in natural regeneration (Harper, 1977; Deminicis et al., 2009), with the success of the recomposition being related to the type and quantity of seeds produced, size of seeds, maturation period, and environmental conditions (Lebrija-Trejos et al., 2011; Marini et al., 2012). In this study, faster propagule emergence and fewer individuals were observed in the rainy season, which suggest that topsoil stocking should be performed in the dry season to extend the stocking time and, possibly, promote the efficiency of the restoration of mined areas.

The time of emergence of the samples collected in the site near the eucalyptus area was different from the others, reaching its maximum accumulated germination more quickly, possibly because these samples feature the best conditions of humidity for germination. This suggests that areas of the same region with a different land-use history have different propagule emergence dynamics, which should be considered when planning restoration activities in degraded areas. However, richness and dispersion strategies, relief conditions, distance area after forests fragments, surrounding cultures and content moisture of propagules should be considered for activities recovery of high field in the Atlantic forest. The simulation of the propagule emergence time curve under controlled conditions may contribute to understanding the biological responses in the process of plant recolonization (Ikeda et al., 2008), and thus improve the practicality of techniques used in the restoration of mining areas, taking advantage of the best time for the beginning of the restoration process in the local community after the stocking period and topsoil return. After bauxite mining activities in the plateaus in Poços de Caldas, we did not observe significant variations in the main physical characteristics of the soil after returning the upper level of the soil (Barros et al., 2013). This indicates that the stocking period and topsoil return are of great importance and should be taken into account to avoid irreversible modifications in the soil structure that could affect plant establishment. An efficient model of restoration for a degraded system should consider the space (limits of the system), the subsystems (its components), and the time interval to be considered (Aumond and Maçaneiro, 2014).Thus, the planning of restoration activities is fundamental and must include considerations of the favorable periods for the establishment of plant species, especially in regard to the stocking time and the quantity of topsoil to be returned to the upper level during the post-mining restoration process (Salomão et al., 2014). The restoration activities of degraded environments need a systemic, multidisciplinary approach, supported by an ecological model that involves more information on the abiotic and biotic components of the altered ecosystem (Aumond and Maçaneiro, 2014).

Conclusion

Based on the conditions used in this work, it is possible to state that the dry season is better for restoration activities in plateau areas affected by bauxite mining, since the speed and time of emergence, as well as the richness of plant species were greater in this period, indicating a longer propagule viability time. From this work, we suggest that special attention should be given to the areas surrounding the plateau fields, as well as the plant community history, as part of considering the local characteristics, and, consequently increasing the possibility of success during restoration on mining areas.

Conflict of Interests

The authors have not declared any conflict of interests.

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