PATSPO

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EFCC ETHIOPIA

Norway's International Climate and Forest Initiative (NICFI)

Status of tree improvement and gene conservation in Ethiopia

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TECHNICAL

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Provision of Adequate Tree Seed Portfolios (PATSPO)

Status of tree improvement and gene conservation in Ethiopia

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1. Introduction

The forest resources of Ethiopia have been, and still are, subject to indiscriminate destruction. Agricultural expansion and free grazing have been practiced for centuries in Ethiopia. These, and the relentless cutting for fuel and building needs by a dense and rapidly growing population, have led to an almost complete deforestation of the Ethiopian highlands today.

The forest and woody vegetation resources of Ethiopia had been estimated to cover more than 27.5 million ha of land in 1992 (EFAP, 1994). Currently (in 2016), Ethiopia has close to 17.35 million ha (15.7% of the country area) of forest resources, including bamboo, dense woodland, natural forests, and planted forests. Plantation forest also comprises public industrial plantations and private woodlots. Species wise, eucalyptus dominates the current plantation forests, covering more than 90%. Cupressus contributes 3.3% and other species cover a small fraction of the standing stock (MEFCC, 2017).

Table 1. ForestPlantation of Ethiopia by Ownership and Species

Regional state	Public/state owned (ha)	Private/ Community (ha)	Total	Area by species (ha)						
				Eucalyptus	Cupressus	Grevillea	Pinus	Acacia decurense	Euc+Cup mixed	Others
Oromiia	57739	27800	85539	56082	15898	472	1217	64		1032
Amhara	32093	639400	671493	653260	5809	432		593	5699	5699
Tigray	15000	23700	38700	38700						
Addis A	27000		27000	27000						
SNNPRS	57201	124157	181358	152757	11440	2860	1430		5720	7150
Total	**189033**	**815057**	**1004090**	**927800**	**33148**	**3764**	**2647**	**657**	**11419**	**13881**

Source (MEFCC, 2017)

Wood product demand is growing fast in Ethiopia due to population and economic growth. The construction sector boom, growth in urbanization and urban population, and growing middle class is driving a rapid increase in demand for wood and other forest products (MEFCC, 2017).

At the national level, there is a huge gap between demand and domestic sustainably produced supply of wood products (WBISPP, 2004). This has triggered two economically unfavorable outcomes. First, it is driving unsustainable extraction of wood from the natural forests, and hence the degradation and loss of biodiversity. Second, this forces the country to depend heavily on imported wood products for its wood-based industries. Unless actions are taken swiftly, the situation will drive further degradation of the natural stands and affect the economic growth of the country through competition for the scarce hard currency for importation of wood (MEFCC, 2017).

Indigenous timber species such as *Juniperus procera, Hagenia abyssinica, Cordia afrcana, Podocarpus falcatus, Olea europaea,* and *Pouteria adolfi-friederic*i once covering about 85% of the demand are now endangered and the first four were gazetted not to be harvested from both Regional and Federal Forests of the country (Gil et al., 2011).

The Forest Sector Review conducted in 2015 estimated that Ethiopia needs an additional plantation estate of around 7.2 M ha (MAI of 20 m³/ha/yr, 5-year rotation) to fulfill the wood fuel supply gap. Data obtained from the Oromia Forest and Wildlife Enterprise (OFWE) shows that firewood accounts on average for 20-25% of the total harvest of plantation stands of cypress, eucalyptus and indigenous species at the age of 21-25. As plantations become older, they produce less firewood and more timber. This indicates that establishing the forest and tree resources combined with the distribution of the energy saving cook stoves can address the existing wood fuel demand and supply gap by 2025. Additionally,

sustainable management of the existing natural forests and woodlands will contribute to closing the wood fuel supply gap (MEFCC, 2017).

The current state of knowledge indicates that Ethiopia should develop about 310,000 ha of well-managed new commercial forest plantation to satisfy its growing industrial wood demands, substitute imports and also engage in wood product exports in the decades to come. Development of the new commercial plantations calls for the involvement of various actors and diverse investment options, including the private sector, domestic and foreign institutional investors, state forest enterprises and smallholder woodlots.

2. History and status of Tree improvement programs in Ethiopia

2.1. History and general overview

Tree improvement programs in Ethiopia commenced with the introduction of several exotic species since the last decade of 20th century, to address the rapid deforestation and growing scarcity of fuel and construction wood in Addis Ababa and its surroundings.

Fast growing exotic tree species including the 15 *Eucalyptus* species Acacia and Pines were introduced from Australia, Portugal, Italy, Greece, etc in a form of seed to Ethiopia during 1895-1907 during the regime of Emperor Menelik II. Subsequently, large number of exotic species (About 60 eucalypts species) has been introduced and planted most species as trial research in the different regions of Ethiopia(Gil et al., 2011). The introduction was a success, and soon after the turn of the century, planting of Eucalyptus for fuel and other uses was expanding throughout Ethiopia. Farmers quickly accepted the new productive and useful exotic tree (Moges, 1997).

Subsequently, several tree improvement programs have been conducted by different government and no government institutions. The former Forestry Research Center (FRC), now Central Ethiopia Environment and Forest Research Center (CEE-FRC) played a big role on the national tree improvement programs supported by international organizations (FAO, SIDA, UNDP, DANIDA, etc.).

A brief summary of Tree Improvement and Seed Source Development activities till 2000 are as follows (EARO, 2000):

- 288 candidate tree seed sources have been identified.
- 108 ha of seed production areas of *Pinus patula, Cupressus lusitanica, Eucalyptus camaldulensis, E. globulus, E. grandis, E. viminalis* and *Grevillea robusta* have been taken over from FRC, and management activities are underway.
- 4.4 ha of progeny trial for *Eucalyptus citriodora* has been established at Dembecha, East Gojam.
- 46 ha of provenance seed stand of *Grevillea robusta* originating from Australia has been established at Yirgalem, Bedele and Wondo Genet.
- 15.5 ha of provenance seed stands have been established from selected provenances of *Eucalyptus globulus, E. grandis* and *E. camaldulensis* at Yirgalem and Bedele.
- 54.6 ha of different seed sources from 4 indigenous species (*Cordia africana, Juniperus procera, P. falcatus* and *Hagenia abyssinica*) and 2 exotic species (*Sesbania aculeata* and *Albizia lebbeck*) have been established in different agro-ecological zones of the country, namely Bedele, Boter Becho, Menagesha, Arjo, Wondo Genet, Yirgalem, Wolaita and Wolkite.

- 27 different multi-purpose tree species have been established for species elimination trial at Melka Woba, Yirgalem, Geffersa and Bedele on a total area of 7.34 ha.
- 25 tree seed zones and 45 sub-zones have been identified (Aalbaek, 1993).

Over 70% of the seed collections of the Forestry Research Center come from planted forests and natural forests, and a quarter of the collection comes from trees planted in rows or irregularly in boundaries, as ornamental and shade trees, and natural regeneration or remnants found scattered in various compounds (Derero *et al*., 2011)

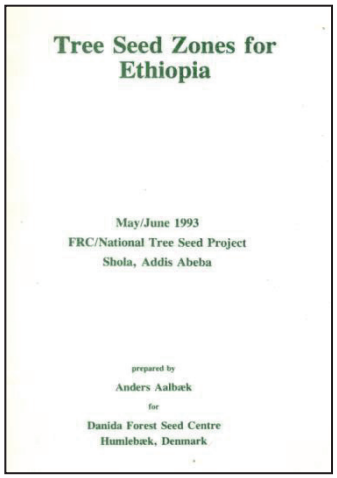
2.2. Tree seed zones for Ethiopia

A tree seed zonation system was developed for Ethiopia and Eritrea was prepared in 1993 by Danida Forest Seed Center (Aalbaek, 1993).A seed zoning system divides a country into ecological zones and gives a description of the zones. The main purposes of establishing a seed zoning system is to provide safe guidelines on transfer of tree seed and to provide a tool for evaluating current seed supply and identifying a new seed source.

A total of 25 tree seed zones and 45 sub-zones have been identified and a map showing the delineation of these zones with a corresponding memoir has been prepared and distributed to government and non-government organisations and higher learning institutions. The memoir provides the following information on each zone: name of zone, ID No., geographical location, boundaries, area, altitudinal range, rainfall range, frost hazard, vegetation types, selected species (both indigenous and exotic), selected literature, remarks and typical meteorological station (Aalbaek, 1993).

Identified seed stands:

The project has identified several seed sources for several indigenous and exotic species from both natural forests and plantation. The seed sources are distributed mainly in the following seed zones:



- Awash Semi-arid Woodland (6.1)
- Lake Area Semi-arid Woodland (10.1)
- Debre-Zeyit Slopes Semi-arid Woodland (10.2)
- Western Lowlands Broad-leaved Deciduous Woodland (11.3)
- Welo Dry Juniperus Forest (15.3)
- Northeastern Dry Afromontane Forest (20.2)
- Southeastern Shewa Dry Afromontane Forest (20.3)
- Western Dry Afromontane Forest (20.4)
- Arsi Western Escarpment Dry Afromontane Forest (21.1)
- Western Lower Broad-leaved Afromontane Rain Forest (23.1)
- Central Wet Broad-leaved Afromontane Rain Forest (23.2)
- Eastern Higher Broad-leaved Afromontane Rain Forest (23.3)
- Southeastern Upper Wet Broad-leaved Afromontane Rain Forest (24.1).

The Tree Seed Zone developed for Ethiopia is a general seed zonation and itself requires refinement. However, the public sector is following neither this zonation nor another strict guideline to transfer seeds (Derero, 2012).

2.3. Establishment of seed sources and provenance/progeny trials.

Large scale industrial plantations were started in the early 1960's in Ethiopia. In line with this different exotic tree species were introduced between 1956 and early 1970to support the large scale afforestation and reforestation efforts in the country. Consequently, provenance, adaptation and growth trials were established in Belete, Menagesha Suba, Hamulo, Yerer, and Bedele by different institutions notably Ministry of Agriculture (MOA), Forestry & Wildlife Development Authority (FAWDA), Alemaya College of Agriculture (Debre Zeit research station), Faculty of Science of Addis Ababa University and international forestry development partners.

In the mid1970s and early 1980s Forestry Research Center had also introduced a number of exotic tree species and established experimental trials (e.g. screening, growth, provenance and progeny trials) under the technical, financial and material support of FAO/UNDP phase II project. Different international organizations and forest seed centers including common wealth Forestry Institute, University of Oxford, DANIDA and others were involved on the establishment of the experimental trials.

In general, comprehensive multi-location experimental trials were established at Aman, Bonga, Bebeka, Tole kobo and Gambella in South Western Ethiopia. Furthermore, the research center was entrusted to manage the previously established species trials in different parts of the country. In general, the study results from the experimental trials have shown that most of the introduced tree species have showed promising survival and early growth performance. In the course of time, a number of experimental trials were abandoned due to several reasons. Continuous follow up and growth data were collected until 17 years of age and report was produced for most of the experiments at different time by various authors(e.g. Mebrate, 2006, Mebrate et al., 2004, Mebrate et al., 2002, Negash, M. 1998) cited by Shimelis and Mindaye, 2015).

2.3.1. Provenance and progeny trials in South West Ethiopia

Large number of species have been introduced and planted in South and Sowthe western parts of the country. Different tree seed sources, provenance and progeny trials were established in Bench Maji zone, SNNP region and Belete Chaka in Jimma zone, Oromiya region.

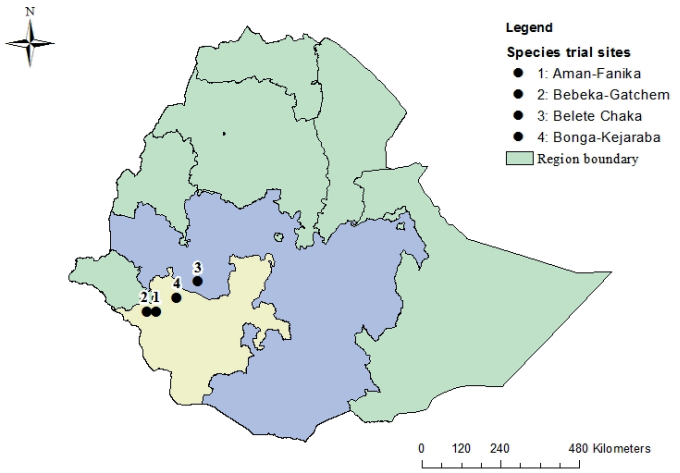


Figure 1: Map of the species trial sites in South Western Ethiopia.

Source: Shimelis and Mindaye (2015)

Tree seed sources have been established in different parts of the country starting from 1883 by the then National Tree Seed Project (Forestry Research Center). Tree seed sources were established in about six seed sites namely Agaro, Dembi, Arjo, Cherisie, Gemeda and Chora.

Table.2. General description of seeds stands and research stations

No	Site name	Tree species initially established	Area (ha)	Establishment year	Initial objective
1	Agaro	*Juniperus procera*	9	2000	Seed stands
2	Dembi	*Cordia africana*	6.1	2000	Seed stands
3	Arjo	*Eucalyptus globulus, Juniperus procera, and Podocarpus falcatus*	91	1996	Seed stands
4	Gemeda	*Pinus patula, Eucalyptus grandis,*	21	1985	Seed stands
5	Cherise	*Grevillea robusta, E. grandis, Podocarpus gracilior*	7.95 ha Eucalyptus, 6.13 Grevillea	1995	Seed stands
6	Chora	*Grevillea robusta*	21	1995	Seed stands
7	Aman-Fanika	*Cedrela odorata, Gmelina arborea, Tectona grandis, Pinus patula, E. saligna, E. grandis, Pinus taeda, P. gracilior, P. maximinoii*	15	1983	Species elimination trial
8	Bebeka_Gatchem and Abiy4	*G. arborea, C. alliodora, Tectona grandis, Terminalia ivorensis*	12	1984	Species elimination trial
9	BongaKeja	*Pinus patula, P. maximoini, P. teade, Gmelina arborea*	5	1983	Species elimination trial

Source: Alemu et al., (2017)

2.3.2. Different species provenance and progeny trials

Eucalyptus has been the dominant species in terms of introduction and establishment of seed sources and provenance trials more than 60 eucalyptus species have been introduced in different parts of the country by different institutions.

Although the first introductions of *E. globulus* to Ethiopia were successful, the provenance origins and genetic base of the introductions are unknown and probably sub-optimal, and there could be a high degree of inbreeding in the land races that have developed (EFAP, 1994; Davidson 1995).

Eucalyptus globulus

A tree improvement program for *E. globulus* in Ethiopia was initiated by FAO in 1990 in collaboration with the Forestry Research Centre. A provenance/progeny trial was established in the central highlands, testing progenies from an extensive range of provenances from across the natural range of *E. globulus* in Tasmania and Victoria.

A provenance/progeny trial of *Eucalyptus globulus* ssp. globulus was established at Ilalaa Gojo in the central highlands of Ethiopia (about 20 km from Addis Ababa) in 1990 to identify superior provenances and establish a breeding population for genetic improvement programs. The trial tested a total of 299

open-pollinated families from 52 localities within 17 natural sub-races in Australia, and one local landrace from Ethiopia (Hunde *et al*., 2007). It is believed that the introduction provides substantial potential for genetic improvement of *E. globulus* in Ethiopia.

FRC have conducted silvicultural management practices, mainly thinning to induce seed production in the research trial. However, until now trees in the provenance trial doesn't set seeds and this requires further research to identify the real problem.

E. globulus clones and seeds from Spain

Two *E. globulus* clones (234 –Sancho–, 231 –Tinto–) from Huelva landrace (Spain) were selected for establishing clonal seed orchard. Clones were obtained within the *E. globulus* breeding program developed by the forest company ENCE since early 1990s.

Both clones are planted in Amhara Region of North Showa Zone, "Basona Worana" Wereda. Both clones were introduced from ENCE (Ence is one of the main European producers of eucalyptus pulp).

Eucalyptus camaldulensis

Eucalyptus camaldulensis was introduced into Ethiopia in 1895. It is regarded as the reliable eucalyptus for planting in the lowland and drier parts of Ethiopia. The original introduction and many additional imports were poorly documented as to its exact identity and origin. In the absence of reliable information, the current land race of the species is Ethiopia is assumed to have a very narrow genetic base. Given the suspected poor genetic quality of seed being obtained, it was important to start any new seed production effort with a new and wide range base population of *E. camaldulensis*.

E. camaldulensis Petford provenance base population progeny trial was established in Mankusa (Amhara Region) on 10.97 ha having stock of 9768 seedlings. The seeds of Petford provenance were provided from common Wealth Scientific and Industrial Research Organization (CSIRO). There were 407 progenies comprising of Petford introduced and 2 progenies of local land race collected from Iteya seed stand (Moges, 1997).

In March 1997 (5.75 years old), a complete measurement of all trees of the progeny trial was carried out. The progenies differed significantly for all traits and high levels of variability were observed within the progenies, which indicated that scope for selection exists for these traits. The existence of trait variations between these progenies is assumed to allow for making selections of the best progenies for the growth of *E. camaldulensis* Petford provenance in Ethiopia (Moges, 1997).

Eucalyptus grandis

Eucalyptus grandis is among 10 of the 70 eucalypt species introduced to Ethiopia which have been reasonably well tested in suitable ecological zones (Davidson, 1995).

Twelve provenances of *Eucalyptus grandis* from a wide range of localities in Australia, and one from a planted stand in Zambia, were established in 1991 in a trial at Wondo Genet, southern Ethiopia. The overall volume production (mean annual increment 25-41 m3 ha-1) was well above the minimum acceptable growth observed on good sites elsewhere. Differences between provenances were small and mostly not statistically significant, and no pattern of geographic variation was detected. No single provenance stood out as being much superior to the others. Hence all provenances should be maintained for further selection and breeding and to maximize genetic diversity of the species in Ethiopia (Hunde et al.. 2002).

Grevilea robusta

G. robusta provenances were introduced from Australia and planted in FRC, Bedele Sub center sites of Chora and Cherise in 1995. The initial spacing of 2 m spacing was widened to average 6 m by selective thinning. *G. robusta* stands started bearing flower at the age of 15 years but seed yield is very low, below acceptable level.

The stand commenced seed bearing at 14. Many of the individual trees were not bearing seeds. Those bearing seed were individuals at the periphery of the stands and those located at wider spacing. That poor seed bearing potential indicated that early thinning or wider spacing is essential for *G. robusta* seed stand establishment. Whereas *G. robusta* trees planted by the community in the surrounding are giving seed (Shimelis and Mindaye, 2015).Therefore, further research to determine the possible reasons of low seed bearing potential of the seed stand is required.

Pinus patula

The Gemeda plantation site (altitude 1983 masl) had 21 ha area and is planted with 2 blocks of *E. grandis* and 4 blocks of *Pinus patula*. *E. grandis* was planted in 1985 while *P. patula* is planted in 2012 after replacing the previous *P. patula* seed stand that was established in 1985 and thinned with low intensity and applied late.

Thinning *P. patula* is undergoing five years after planting. The thinning was made by removing the lower five branches. But such pruning may damage the photosynthetic and encourage apical growth, thus in the long run in may negatively influence seed and flower bearing. Thus only access pruning (removing to three branches starting from the base was advised to be followed during the side pruning operation (Alemu *et al*., 2017).

Juniperus procera

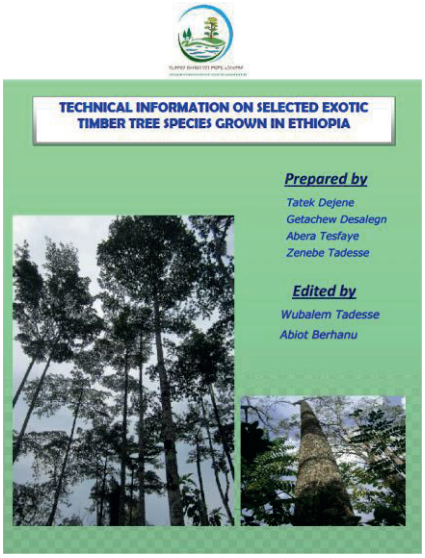
Juniperus procera seed stand site was planted in 2000 in Agaro (45 km from Jimma to Bedele) within 9.6 ha of land. Biting up was conducted to replace the dead seedlings at earlier stages. From randomly measured 10 trees, the average diameter growth of the stand was found to be 16.5 cm (range from 11 to 22.5 cm indicating high variability) at the age of 17 years. Thinning was conducted 10 years after planting (late thinning), but still the stand is crowded to be considered as a seed source.

Further thinning is recommended till the maximum number of trees per ha for J. procera seed sources reaches, by selecting specially crowded, and poor trees in growth performance is required this year (2017/18). The thinning intensity to be applied may be about 20% of the standing trees (Alemu *et al*, 2017).

2.4. Selected exotic species for promotion in Ethiopia

Aomong the several exotic species introduced to Ethipia, EEFRI has selected 13 well adapted exotic tree species to be promoted for large-scale commercial plantations, and rational utilization. Therefore, booklet entitled "TECHNICAL INFORMATION ON SELECTED EXOTIC TIMBER TREE SPECIES GROWN IN ETHIOPIA" is under preparation (Dejene *et al*., 2018).

1. *Cordia alliodora*
2. *Cedrela odorata*
3. *Cupressus torulosa*
4. *Eucalyptus degulpta*
5. *Eucalyptus grandis*
6. *Eucalyptus saligna*
7. *Eucalyptus viminalis*
8. *Gmelina arborea*
9. *Pinus caribaea*
10. *Pinus maximinoi*
11. *Pinus kesiya*
12. *Tectona grandis*
13. *Terminalia ivorensis*



Other well adapted exotic species not included in the booklet are:

- *Pinus michocana*
- *Pinus taeda*
- *Eucalyptus pilularis*
- *Eucalyptus maculate*

Tree improvement in Indigenous species

Podocarpus gracilior and *Juniperus procera, Acrocarpus frxinifolius* and *Ekebergia, Aningeria, Polyscius fulva* provenance trails were established in South Western research stations. *P. gracilior* and *J. procera* tree species showed remarkable growth performance at Aman and Belete Chaka. The species trials were among the few plantations on wider areas with complete background information (seed source, spacing, density and age).

There were several attempts to establish progeny trials of *C. africana* and *Hagenia abyssinica* in different locations by FRC. Phonotypically superior trees were selected and plantations were established. However, because of climate problems (mainly draught and freezing temperatures after plantations) the trials have failed.

3. Current status of research in tree improvement and seed projects in EEFRI

The Ethiopian Environment and Forest Research Institute (EEFRI) conducts tree improvement and seed sources establishment and seed procurement programs coordinated by two directorates and implemented in different research centers. Currently, the following four research projects are underway:

Project 1: Multi-location Seed Source Trial for Selected Introduced Timber Species in Ethiopia

General objective: To conserve and widen the genetic resources thereby increase seed production from introduced timber species that have shown best growth performance and adaptability in west Ethiopia by establishing SPAs

Specific objectives

- Study the phenology of the target species (*Teminalia ivorensis, C. torulosa, Cederela odorata, Gmelina arboria, Pinus maximonii, E. deglupta, Tectonia grandis. E. deglupta*);
- Characterize seeds of the target species and determine their physical and physiological quality;
- Determining optimum storage conditions and seed-pre-treatment techniques;
- To compare the species, as to seed source quality, under different locations;
- To establish and manage seed production areas for the target species.

Duration: Five years (2016-2020) and management of SPA extends to many years that will be determine by the length of time the SPA remains under seed production.

Project 2: Domestication and Seed Production Area Establishment for selected indigenous timber tree species in west and south-western Ethiopia

General objective: The general objective of this project is to domesticate and integrate selected timber species into the wider farming system (wider ecological and social environment), and sustain the seed system by developing Seed Production Area (SPA) in western and south western Ethiopia; *Antiaris toxicaria, Milicia exelsa*, *Trichilia emetic/Trichilia dergena and Pouteria adolfifridercii.*

Specific objectives

- Assess the population of the targeted species and describe ecological conditions (at original site) of the species;
- Study the phenology (flowering, fruiting calendar and seed yield potentials) of the species under their natural environment;
- Characterize seeds of the target species and determine their physical and physiological quality;
- Determining optimum storage conditions and seed-pre-treatment techniques;
- To study seedling growth performance under nursery conditions;
- To study the adaptability and growth performance of species under field conditions;
- Establish and manage Seed Production Area (SPA) for the targeted species in natural forests.

Duration: Five years (2016-2020) and management of SPA extends to many years that will be determine by the length of time the SPA stays under seed production.

Project 3: Evaluation, promotion and management of industrial plantation

General objective: The general objective of this study is to evaluate, promote and manage participation of different stakeholders.

Specific objectives:

- Promote stakeholder-based tree planting activity for sources of seed, construction wood, fuel wood and food;
- To evaluate the impact of different spacing and fertilizer treatment along different altitudinal gradient on growth performance and productivity of *P. canariensis* and *P. pinea* in the study sites;
- To evaluate optimum rootability period of Populus cutting;
- To determine nursery life span of Populus;
- To determine optimum spacing level (1m, 1.5m 2m and 3m) for populus planting in the field;
- To evaluate the impact of different pruning levels on biomass and seed production capacity of existing *Pinus patula* plantation in Galama area;
- Estimate growth rate of *Juniperus procera* using tree ring analysis.

Duration: Seven years (2013-2019)

Project 4: Tree genetic resources selection for productivity gains and climate change mitigation

General objective: The overall objective of the project is to select best performing tree genetic resources in different climatic conditions for productivity gains and climate change mitigation in Ethiopia.

Specific objectives:

- To select best performing provenances of *Cordia africana* and *Juniperus procera* that are suitable for different locations;
- To select best performing progenies in *Cordia africana* and *Juniperus procera* for genetic gains;
- To determine above-and below-ground biomass accumulation in selected species/provenances in areas with various climatic conditions.

Expected outputs:

- The growth performance and biomass determined and best performing provenances identified for *Cordia africana.*
- The growth performance and biomass determined and best performing individuals/provenances identified for *Juniperus procera*.
- The growth performance and biomass of *Cederela odorata, Cordia africana, C. alliodora, Cupressus torulosa, Eucalyptus deglupta, E. grandis, E. saligna, E. viminalis, Juniperus procera, Pinus kesiya, P. maximinoii, P. patula ssp tecunumanii, P. radiata, Tectona grandis* and *Terminalia ivorensis* over various sites determined.

Duration: Five years (2015-2019)

4. Forest biodiversity and gene conservation efforts in Ethiopia

Ethiopia has defined 58 National Priority Forest Areas and five classes of vegetation containing priority species; in conjunction with other protected areas, these are the basis for the in situ conservation programme, which covers about 14 percent of the country's area. Ethiopia's Forest Genetic Resources Conservation Strategy sets general criteria for establishment of in situ conservation sites, including (FAO, 2014):

- the number of priority species in the forest;
- the presence of unique, endangered and endemic species within the population;
- the accessibility of the forest;
- the degree or threat of forest disturbance;
- the species richness of the site or population;
- the attitude of the local people or community towards conservation.

In Ethiopia, 92 native species and one exotic are conserved in multiple field and seed bank collections. The accessions from all native species include one or more field stand and ex situ seed bank collections (FAO, 2014).

Phytolaca dodecandra is the native species with the largest number of collections – 59 accessions over 19 field stands and 59 accessions represented in three seed banks. Five native species are represented by more than 20 accessions over multiple field stands: *Acacia etbaica, Cordia africana, Morinaga stenopetala, Oxytenanthera abyssinica* and *Phytolaca dodecandra*. The only exotic species conserved ex situ, *Eucalyptus globulus*, is represented by ten accessions available from one stand; these ten accessions are also conserved in one seed bank.

Ethiopia recognizes that "the most important threats to genetic diversity come from deforestation and forest fragmentation, which can result in total loss of genetic information and disturbance in the genetic structure".

Ethiopian Biodiversity Institute (EBI) is mandated for Gene conservation in Ethiopia and their main Duties and responsibilities are:

- Collection of forest and range land plant species.
- Conservation of forest and range land plant species in situ (mainly in natural high forests and dry woodlands), and ex situ (gene bank, field gene banks and botanic gardens).
- Characterization of forest and range land plant species and accessions for their desirable traits
- Restoration of degraded forest and range land ecosystems and threatened species.
- Distribution of forest and range land plant accessions for research and development purposes.
- Research on various aspects of conservation and sustainable use of forest and range land plants including forest vegetation inventories, and species diversity dynamics.
- Establishment of national herbarium.

Gulele Botanical Garden

The Gullele Botanical Garden (GBG) is a newly established conservation initiative located at the northwestern tip of the Addis Ababa City Administration. The site covers an area of 1000 ha which is representative of the central plateau of Ethiopia.

The main objectives of the botanical garden are to safeguard the future survival of adiverse set of species, conduct plant research, create an urban park for recreation, and improve the practical

knowledge of students and the general public in the fields of sustainable gardening, horticulture, floriculture, urban agriculture and forestry.

Plant Collections

- Accession Number: 900
- Cultivation Taxa Num: 40
- Special Collections: We collect plants from different parts of the country by giving priority for Native, Endemic, Threatened and Economical.
- Invasive Species Monitoring: Yes
- Invasive Species Policy: Yes
- ABS Policy: Yes
- Plant Collection Policy: No

Source: https://www.bgci.org/garden.php?id=4538

Forest biodiversity conservation and development

Ethiopia is one of the top 25 biodiversity-rich countries in the world, and forests are the major source of biodiversity and ecosystem services on which the Ethiopian economy is based. However, the Protected Areas (PAs) network in Ethiopia is neither proportionally large enough related to the country's land mass nor are the existing PAs representative of the country's ecosystems. Therefore, there is an urgent need to expand the PA network from 14% to 20% by 2025, while ensuring the proper management of these areas through registration, demarcation and legal accreditation, amongst others. Further, to better ensure the maintenance of forest biodiversity in the future, it is important to develop strategies for the sustainable use of biodiversity. To ensure ex-situ conservation, the NFSDP also proposes the establishment of seven new botanical gardens (NFSDP).

Status of important indigenous tree species

- *Hagenia abyssinica* is becoming locally rare in some areas. This species is noted as being of serious conservation concern within Ethiopia in the 2005 Red List publication. *H. abyssinica* is used locally in Ethiopia for timber and as a source of medicine. There is a great need to increase conservation work of this important species to support wild populations and provide material for reintroduction and restoration projects in future.
- *Juniperus procera* is assessed as Least Concern on the IUCN Red List due to a current wide distribution; however the population is reported to be declining due to continuing exploitation and deforestation. The species is noted to be at particular risk in Ethiopia and Kenya, due to depletion of old growth forest groves of this species. As the only juniper species occurring in Sub-Saharan Africa, *J. procera* should be an important conservation priority for countries within its range.
- *Cordia africana* is an indigenous, multipurpose tree species that is found in the montane forest ecosystems of Ethiopia. However, serious deforestation coupled with the extensive exploitation of the species for furniture, charcoal and construction materials, has led to its depletion, and *Cordia* is now a highly endangered indigenous tree in Ethiopia. Measures to conserve the genetic resources of *Cordia africana* in Ethiopia are urgent and, as shown by the genetic diversity patterns, still feasible (Derero et al., 2011).

- *Podocarpus falcatus*, despite its great importance, the species is on the verge of local extermination because of its unsustainable exploitation over the last several decades. Even after it has been banned from harvesting/cutting, its illegal exploitation continues unabated. Unfortunately, owing to a number of factors, there are neither large-scale plantations nor future planned plantation establishment programs of the species. This implies that urgent actions are required to address its unsustainable exploitation.

4. The contribution of PATSPO for Ethiopian Tree improvement

4.1. The contribution of PATSPO

In Ethiopia, tree improvement and forest genetic research and establishment of seed orchards are in its infant stage. Early establishment efforts of progeny/ provenance trails supported by international partners were not sustainably managed to upgrade the progeny trials. Hence, Ethiopian afforestation and reforestation programs faced critical challenge on the provision of seed in terms of quality (physical and genetic) and quantity.

Therefore, PATSPO appeared to fill the missing link of the previous tree improvement efforts and re-initiate to modern tree improvement programs by strengthening and capacitating national tree seed programs as indicated in the following project objectives.

PATSPO addresses this major challenge by providing a multiple tree species programme able to provide:

- organizational setup of the tree seed sector, including stakeholder identification and roles and responsibilities, - based on a sector analysis
- species specific knowledge for most priority tree species, including: o the plant ecological base line for restoration o the potential natural distribution of multiple species and how they may be affected by climate change o DNA-based genetic variation patterns for priority tree species o an interactive knowledge and information portal for users
- a built up and establishment of the tree genetic resources for the future, comprising exploration, mobilisation, conservation, establishment, management and improvement
- capacity to monitor and deliver quality seed and seedlings of multiple species required for large scale restoration.

Output III. Existing seed sources upgraded and new seed sources established (tree genetic resources for the future mobilised and developed)

The Major Activities for Output III are:

3.1 Design of a national breeding programme: Design a national breeding programme for more than 50 priority species, including identification of distribution and deployment zones - also considering climate change aspects.

3.2 Range wide collections of priority species: Make range wide collections of plus tree families (from natural stands as well as possible landraces) complementing existing collections.

3.3 Establishment of breeding seedling orchards (BSOs): Design and establishment of breeding seedling orchards (BSOs – combined provenance/progeny testing and seed production / multiplication / conservation) in relevant deployment zones.

3.4 Assess, manage and use the BSOs for research, breeding and seed procurement.

Therefore, the above mentioned expected PATSPO project outputs are in line with government afforestation and reforestation strategy. The government has very ambitious tree planting programs. For example, the Forest Sector Review conducted in 2015 estimated that Ethiopia needs an additional plantation estate of around 7.2 M ha (MAI of 20 m³/ha/yr, 5-year rotation) to fulfill the wood fuel supply gap (MEFCC 2017).

All forestry development programs demand seed in required quantity and certified genetic quality to ensure the supply of national forest seed demand.

Table 3: Action programs that contribute to increased forest cover (millions of hectares)

Action Programs	**Contribution to forest cover in GTP2**		**Contribution to forest cover in 2025**	
Establishing new commercial plantations including bamboo	0.18	0.16	0.6	0.5
Afforestation/reforestation	0.9	0.81	3	2.7
Forest and Landscape Restoration	2.5	2.25	7.5	6.75
Purposeful tree planting in the form of wood-lots	1.25	1.13	5	4.5
Total	**4.83**	**20**	**16.1**	**30**

To advance forest sector development and ensure the development and uptake of forestry innovation adapted to Ethiopia's diverse contexts, the NFSDP will establish modern laboratory facilities to support research related to genetic improvements such as cloning. This includes the introduction of laboratories for modern wood and non-wood products, clonal nurseries and green houses, seed centers with modern facilities and seed orchards to facilitate distribution. Focus will also be placed on improving the linkage between research and extension and public private research partnerships to ensure the uptake of innovation (MEFCC, 2017).

4.2. The contribution of previous Tree improvement efforts

The already established and tested exotic and indigenous species progeny/provenance trails will facilitate to PATSPO project by providing seeds for future seed source establishment programs and make available information about the adaptation performance of each introduced species.

Besides, the existing federal (EEFRI centers), universities, EBI and regional seed centers through their facilities and human resources are assets for PATSPO project.

Table 4: Selected EEFRI research sites that can be managed by PATSPO

No	Species	Site	Area (ha)	Establishment year	Fruit setting capacity	Suggested Management intervention	Expected purpose	Remark
1	*Pinus patula*	Gemeda (Jimma)	21 (with other species)	2012	Yes	Pruning and thinning	Seed source	
2	*Juniperus procera*	Agaro (jimma)	9.6	2000	Yes	Pruning and thinning	Seed source	average DBH was 16.5 cm at the age of 17 years
3	*Grevillea robusta*	Bedele (Chorra)	21	1995	Poor	Pollarding/thinning	Seed source	**Note 1:**
		Bedele (Cherise)	6.13	1995				
4	*Eucalyptus globulus*	Illala Gojo		1990	No	Cutting for vegetative propagation to be planted in other sites and establish clonal seed orchard		
5	*Eucalyptus globulus (two clones)*	Debre Birhan	0.5	2006	Yes			
6	*Eucalyptus grandis*	Gemeda (Jimma)	21	1985	Yes			
7	*Eucalyptus camaldulensis*	Mankusa	10.97	1991	Yes	Thinning	Seed source	

- **Note 1**: fruit bearing of the seed stand is very low hence it is not used for seed collection, wheras seed bearing potential of some trees outside the seed stand, from same origin, are giving more seed and even farmers are collecting and sellig *G. robusta* seeds.

5. Conclusion

The current state of knowledge indicates that Ethiopia should develop about 310,000 ha of well-managed new commercial forest plantation to satisfy its growing industrial wood demands, substitute imports and also engage in wood product exports in the decades to come. Development of the new commercial plantations calls for the involvement of various actors and diverse investment options, including the private sector, domestic and foreign institutional investors, state forest enterprises and smallholder woodlots. To properly achieve planned forestry programs provision of seed in quality and quantity has paramount importance.

While eucalypts will continue to play an important role in Ethiopian forestry, there is a need to embark on similar tree improvement and breeding programmes for non-eucalypt indigenous and exotic species. The genus Acacia should receive high priority, both in the moist and dry zones of the country, Much more attention must be given to the indigenous highlands forest species. With rapid disappearance of closed natural forests in Ethiopia, in situ and ex situ forest genetic resources conservation must be given High priority (Davidson, 1995).

Major challenges in tree improvement

- Lack of proper scientific management to convert the progeny and provenance trials later to seed orchards. Hence, best families are not selected and as a result orchards (seed and clonal) are not established yet.
- Lack of qualified professionals in tree improvement and forest genetics in the countries. The existing very few professionals are graduated from foreign universities.
- Frequent structuring in forestry sector in the country, and low attention to forestry sector.
- Lack of knowledge and laboratory infrastructure for Eucalyptus and other species clonal propagation.
- Lack of appropriate silvicultural management i.e. weeding and slashing of the under growth, thinning of the trials and weak follow up and regular monitoring might end up with the loss of experimental sites.
- Weak forestry research extension system motivated the well adapted exotic tree species stay in the research plots. Since 2015, seed collection for evaluating and promoting of selected species in other sites and for multi-location seed source establishment purposes is conducted by EEFRI in relatively good state as compared to previous years.

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7. Annex

Terms of reference

- Compile data and information on the past and present tree improvement and gene resource conservation in Ethiopia, in form of overall plans as well as specific trial reports.
- Assess the compiled data and their present value and relevance for present and future tree improvement and gene conservation activities in Ethiopia.
- Assess and describe how the ongoing and planned BSO establishment programme under PATSPO possible can contribute – and compliment ongoing tree improvement and gene conservation activities/programmes in Ethiopia.

PATSPO
Provision of adequate tree seed portfolios

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