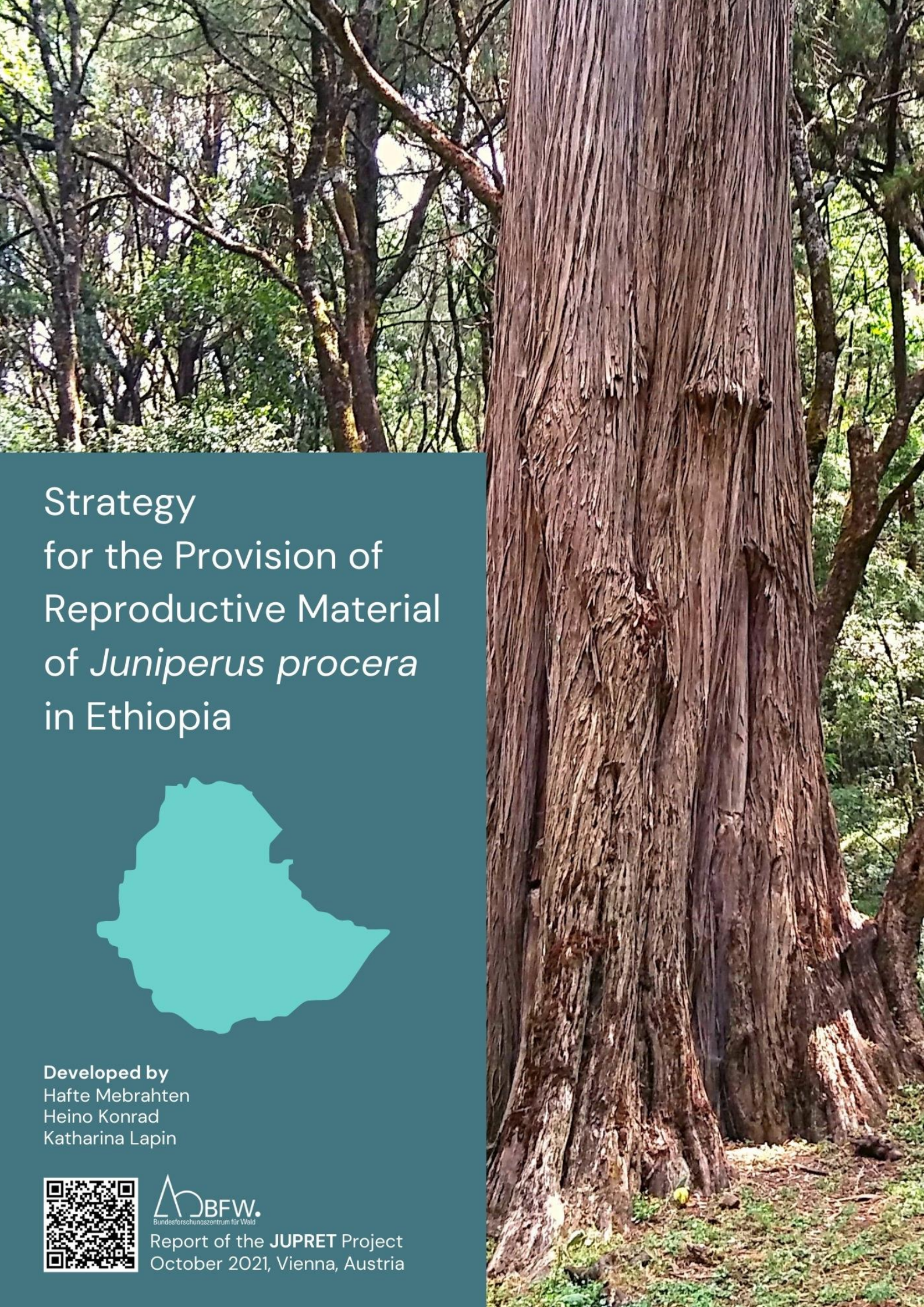

Strategy for the Provision of Reproductive Material of *Juniperus procera* in Ethiopia

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Executive Summary

Forests in Ethiopia are keys in supporting the livelihood of all Ethiopians by providing most of the energy consumed by the majority of the population, protecting soil erosion, conservation of water in watersheds and supplying other goods and ecological services in the entire landscape. *Juniperus procera* is one of the most important tree species that has the potential to provide numerous economic, social, and ecological services. However, due to anthropogenic influence that led to deforestation and forest degradation, and other natural hazards the tree is nowadays highly endangered and registered under the IUCN Red list.

The commitment and efforts to support the forestry sector by the government of Ethiopia has been increasing over time although the implementation of the reforestation and forest landscape restoration activities still needs to be improved. To that effect, the development of a strategy for the provision of reproductive material for the *Juniperus procera* was found to be relevant. The main goal of this strategy is to safeguard the provision of high-quality reproductive material for the sustainable use of the tree species and the maintenance of the ecological and socioeconomic benefits. Moreover, the strategy will help as a guide to conserve and attain sustainable utilization of the genetic material. Conserving and maintaining the genetic material will significantly contribute to the provision of adequate and high-quality reproductive material. In turn, the availability of adequate reproductive material for the species will help for successful reforestation and forest landscape restoration of *J. procera* populations.

Based on the findings of the project research work in JUPRET, the available literature, and our own knowledge the following 10 profound points of the strategy are included for effective provision of quality and adequate reproductive material of *J. procera* for the country. The points of the strategy are: (1) conducting an inventory for the species coverage, (2) enhancing the supply of genetically appropriate and adapted reproductive material, (3) the establishment of *ex situ* seed orchards, (4) establishment of a seed center, (5) importing viable *Juniperus procera* seeds from abroad, (6) capacity building for better provision of the reproductive material, (7) formation of task force to control pest and disease attack, (8) development and implementation of research programs for the production of adequate reproductive material, (9) establishing a strong partnership between government and other stakeholders/actors, (10) and extension, communication, and networking for better provision of reproductive material. In general, the strategy envisions building and strengthening linkages, collaboration, and partnerships among actors in the reproductive material supply chain and various stakeholders in forestry as drivers of successful implementation of this strategy.

African Pencil Cedar

Juniperus procera Hochst. ex Endl.

3%

J. procera forest cover was 3% out of the total forest area of Ethiopia during the 1950s. The population is decreasing since.

1. Introduction

Human life is highly dependent on the existence of plants. Numerous ecosystem services depend on plants. As a result, farming communities all over the world have been engaged in growing of multipurpose trees that provide nutrients, edible fruits, fodder for animals, timber, firewood, and contribute for climate change mitigation (Zomer *et al*., 2014).

Most importantly life in many drought-affected regions is challenging and communities are trying to seek ways to improve their livelihood and tackle environmental problems. Some of the profound challenges in management of natural resources in Ethiopia are deforestation and degradation of forests, woodlands, and agricultural lands. Those significant obstacles have a negative impact on the overall landscape productivity. To overcome these negative impacts effective biodiversity conservation activities should be implemented.

The conservation of the forest resource and its reproductive material could be handled either by *in situ* conservation method or *ex situ* or both ways. *In situ* conservation is the conservation of ecosystem and natural habitats, for maintenance and recovery of viable populations of species in their natural surroundings whereas *ex situ* conservation is the conservation of components of biological diversity outside their natural habitats.

1.1 Species description

The tree species, *Juniperus procera* Hochst. ex Endl., also known as African Pencil Cedar, is a coniferous tree species, which is adapted to grow in dry conditions and is believed the largest species of the genus *Juniper* in the world (Negash and Kagnew, 2013). The growth of the tree in general, is relatively slow but it can reach heights of 40m and diameter at breast height of up to over 200cm when it is growing naturally (Worku and Soromessa, 2015) and in plantation forests an average height of 35.5 m and diameter at breast height of 107 cm (at the age of 200 years) was reported in Ethiopia (Couralet and Bakamwesiga, 2007). The species is suited to grow mainly in highland areas with cold high ridges and distributed in altitudinal range of 1000-3500 m asl. The average annual temperature of the suited areas ranges from 5°C to 20°C (Pohjonen and Pukkala, 1992; Couralet, and Bakamwesiga, 2007). Forests stands dominated by *Juniperus procera* are mostly considered as important components of transitional zone between the dry forests, Afromontane forest and semi-evergreen forests (Sterck *et al*., 2010).

Juniperus procera which is among the drought-adapted tree species - plays a very important role for provisioning numerous ecosystem services and for adapting and mitigating to Climate change (Leipzig, 1996). For example, the species ensures various ecological benefits such as regulating the rainfall, improving infiltration, reducing water runoff and soil erosion in watersheds (Dallimore and Jackson, 1966).

The benefits of planting *J. procera* are not only restricted to the ecological aspect but also has wider the economic as well as medicinal plants' usage (Sterck *et al*., 2010). Chaffey (1982) reported, that the seasoned heartwood of *J. procera* is very stable and used for indoor and outdoor constructions (doors, windows, furniture, and poles) and additionally is used as source of fuel wood for house consumption. In addition, the bark strips are used for roofing huts, covering beehives and as pads to carry water jars (Negussie, 1995). The wood of *J. procera* is believed to be naturally hard with an average wood density of 0.62 g/cm3 (http://db.worldagroforestry.org/species/properties/Juniperus_procera). Because of less seasoning defect and high wood density the species has fulfilled acceptable timber properties and qualities. As a result, the timber is durable and is used for applications that do not need nailing (Desalegn *et al*., 2005).

The oil from the leaves, shoot, and berry, the resins from the woody part are some of the important ingredients used in different pharmaceutical applications. For instance, the cedar oil is used in microscopy, soap, perfumes and medicines and for abortions (Jansen, 1981), the oil from berries is used in pharmaceutical preparations, for flavouring alcoholic drinks and other food products (Zaman *et al*., 1968), oil from leaves and shoots is also used as ingredient in medicine, as incense in India, Iran, Afghanistan and Baluchistan (Dallimore and Jackson, 1966). Some communities tried to use them as traditional medicines to cure different diseases. For instance, chopped and finely ground leaves, mixed with water, are used as a drench for horses and mules suffering from stomach disorders; dry powdered leaves are used to cure wounds in animals. Jansen (1981) reported that a cold aqueous extract of the leaf is effective against Mycobacterium tuberculosis. The fruits of *J. procera* tree have also high potential of treating headaches and skin diseases. Generally, it is difficult to list all the economic, ecological, and medicinal benefits of the tree since it has wider application. The tree species is one of the most preferred multipurpose trees in Ethiopia (Coural *et al*., 2005) and is in a high demand always.

Figure 1

The native range of *Juniperus procera* extents across the countries Djibouti, Eritrea, Ethiopia, Kenya, Malawi, Saudi Arabia, Somalia, Sudan, Tanzania, Uganda, Yemen, Zaïre, and Zimbabwe.

1.2 The Ethiopian forest sector

Ethiopia is known for its diverse faunal and floral community. The vegetation of the country comprises more than 7000 plant species, of which, 1150 are endemic. The forest is also serving as a refugee for diverse and high number of Fauna. For instance, Ethiopian forest ecosystems are home to 240 mammalian species, of which, 22 species are endemic, and 845 bird species, of which, 24 species are endemic (Teketay *et al*., 2010). The diverse forest ecosystems of Ethiopia range from low altitudes in the northeastern lowlands to a chain of mountains in the northern highlands. The various parts of Ethiopia have different potential of accommodating forest resources. For instance, the northwestern part of the country mainly supports high forest ecosystems. The richest forest biodiversity is supported by the southwestern and central highlands of the country. The central highlands of the country also support the dry montane forests. In those ecosystems *J. procera* species is one of the economically important tree species.

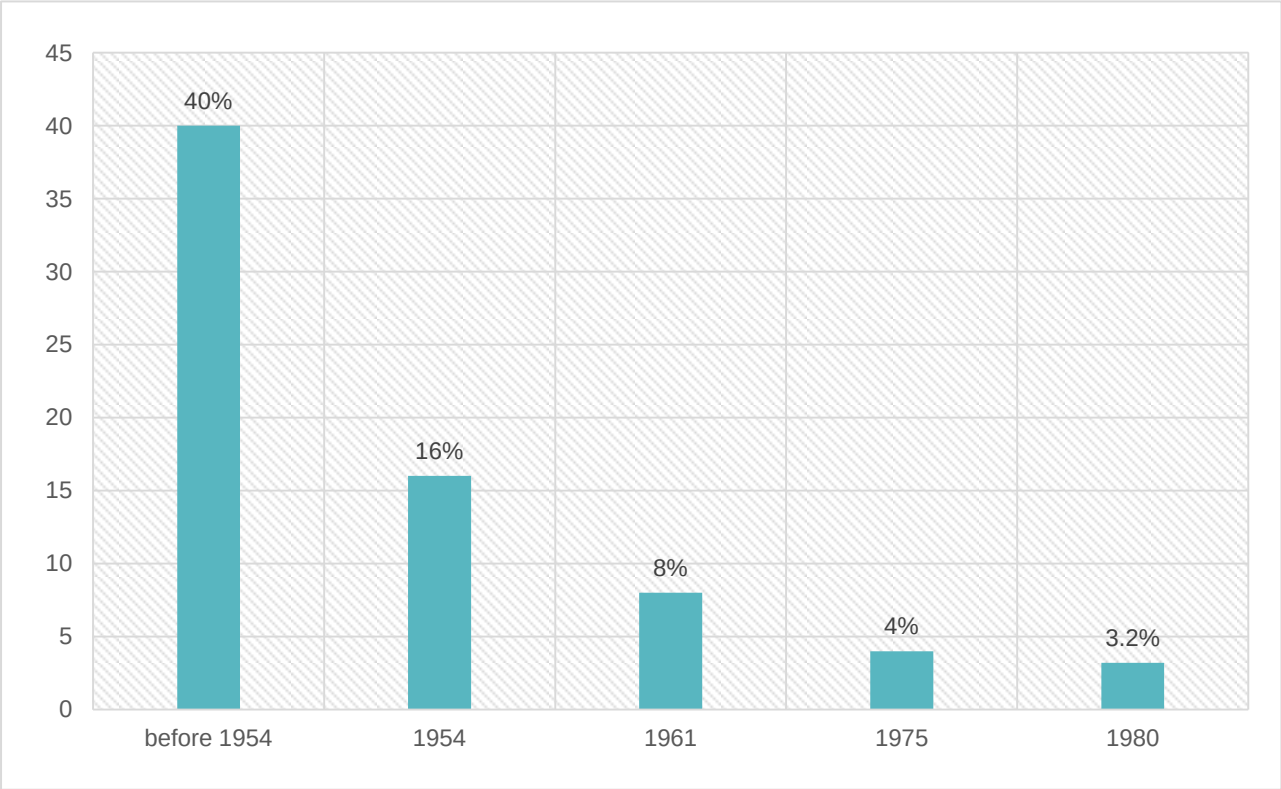

Figure 2 Trend of forest coverage in Ethiopia (Amogne, 2014).

The woody vegetation coverage of Ethiopia is about 53.1 million ha, of which, 12.5 million ha of forest land and 40.6 million ha of other woodland (FAO, 2015). Considering the total land area covered by forests Ethiopia is listed as one of the countries with the largest forest resources in the horn of Africa (FAO, 2015).

International reports revealed that about 40% of the country's land area was covered with dense forests in 1900 (EFAP, 1994). However, due to the anthropogenic and other factors the forest resources of the country have been overexploited (Demel, 2001). Within the last century the forest cover of Ethiopia showed a significant decrement in some intervals.

But since the last decade the forest coverage showed a slight increment. According to the national forest inventory report (2018) the forest cover is estimated 15.7%. This increment in forest cover is due to vast re-afforestation and forest land scape restoration activities undergoing by the government of Ethiopia (FAO, 2020).

According to the recent study and assessment on the forest resources of Ethiopia the contribution of the current forestry to the national GDP has grown from 8% to 12%. Such positive impact on the economy of the country motivates policy makers to become concerned and pay more attention to the development of the forestry sector (FAO, 2020).

The commitment and efforts to support the forestry sector by the government of Ethiopia is increasing over time. Several measures were taken to strengthen the forestry sector of Ethiopia, such as the launch of the Environment, Forest and Climate Change Commission (EFCCC) and an increase of subsidies. In addition, initiatives such as the “Green legacy” will have a significant effect in restoring and conserving the forest resource (https://www.pmo.gov.et/greenlegacy/). The “Green legacy” is one of the good initiatives and actively involved in the re-afforestation and forest landscape restoration activities. The commitment to increase the forest cover of the country and strengthen the contribution of the forestry sector to green economic growth is also very high. For instance, the sector is aiming to expand the forest cover from 17.35 million ha (15.7%) today to 30% by 2025. Furthermore, the forest sector is expected to reduce emissions by 255 Mt CO2e (which is 50% of the national goal) by 2030 (NFSDP, 2018).

Juniperus procera Hochst. Ex Endl. is one of the tree species growing in different forest areas of the country. As Teketay and Bekele (2002) reported the *J. procera* forests are part of the once covered some 200,000 ha in the highlands of Ethiopia. Some reports revealed that during the 1950s *J. procera* forest cover was 3% out of the total forest area of Ethiopia (Jansen, 1981; FAO, 1986). However, the *J. procera* forest coverage started to decrease rapidly after 1980s. The main reason for its high deterioration is because of multiple anthropogenic factors. Moreover, the exploitation got more intensified in the beginning of the 1900s following the high demand of this species for high-quality saw milling raw material (Veli and Timo, 1992). As a result, today, the species become threatened and only remnants of the old stands have been reserved in some natural forest reserves, around old churches, and monasteries in these highlands (Bongers *et al*., 2006).

1.3 Challenges in conservation and restoration of *Juniperus procera*

Deforestation and forest degradation are major threats to forest ecosystem biodiversity and ecosystem services in Ethiopia. Forests with stands of *J. procera* are affected by these threats and nowadays are very much reduced in population size and limited through fragmentation (FAO, 1986; Borghesio *et al*., 2004). The species is categorized as least concern under the IUCN Red List. The extreme reduction of their coverage in the country mainly associated with anthropogenic factors such as intensive utilization of the forest, intensive timber harvests and grazing by livestock (Teketay and Bekele, 2002; Burgess *et al*., 2004; Couralet *et al*., 2005). In addition, there are other factors that negatively affect the conservation and restoration of the species.

Low regeneration rate: the species is reported to have a low regeneration rate at forest level. Wassie *et al*. (2009a) reported that the regeneration rate of *J. procera* in church forests (collection of different trees and shrubs grown around Christian orthodox churches) and other parts of northern Ethiopia was low. This could be associated with different factors that inhibit the regeneration such as amount and thickness of litter in the ground, canopy cover, and crown density. The availability of sun light radiation in the forest floor can assist the regeneration of the species. Wassie *et al*. (2009a) observed a better regeneration rate in open areas than in the closed canopy of the protected forest, where the dense herb layer of grasses might prevent optimum radiation (Yirdaw and Leinonen 2002; Teketay 2005), which is negatively influencing the regeneration by hindering germination of the seeds of *J. procera* (Cabin *et al*., 2002). The regeneration rate could be also affected by the level of litter accumulated in the protected forest floor. For instance, thick and less decomposable litter of *J. procera* has high probability of preventing the seeds from contacting the soil (Prescott *et al.,* 2000). As a result, breaking of seed dormancy might be reduced, which is a limiting factor for the germination success (Rotundo and Aguiar 2005; Cierjacks *et al*., 2008). As Yirdaw and Leinonen (2002) and Teketay (2005) revealed that availability thick litter in the forest floor might also have influence on emergence of newly germinated seedlings by suppressing them.

Low germination rate: The seeds of *J. procera* have very hard seed coats and always need effective pre-treatment to break the dormancy and achieve successful germination. According to our results from two *J. procera* populations

the germination rate is very low. This problem of germination could be associated with different factors. Weak pre-treatment (immersing in hot water, immersing in chemicals, scarification etc), poor seed viability, damage by seed predators and others could negatively affect the germination rate either at laboratory or field conditions. The need for additional manipulation of the seeds results in a poor germination capacity under field conditions (Mamo *et al*., 2006). Similarly, the sun light radiation affects the germination significantly. Mamo *et al*. (2006) reported that *J. procera* seeds incubated under continuous light showed higher overall germination performance than those seeds incubated in darkness.

Long generation time: naturally *Juniperus procera* flowers only periodically every several years (approximately every 10-15 years) (Orwa *et al*., 2009). Taking long time to flower could also significantly affect the possibility of producing seeds every time. Relatively slow growth of the species coupled with taking long time for flowering could is hampering the constant supply of adequate reproductive material for the current and future re-afforestation programs.

There are additional factors that affect the successful conservation and restoration of the species. For example, the species is susceptible to attacks by insect borers and heart rot (Champion and Brasnett, 1958) and the young trees are susceptible to fire (FAO, 1958). In general, the above-mentioned challenges and other factors forced us to develop a strategy for the provision of reproductive material for J. procera species. It is believed that an appropriate strategy will bring change in the provision of reproductive material and hence contribute to succeed re-afforestation and forest landscape restoration activities.

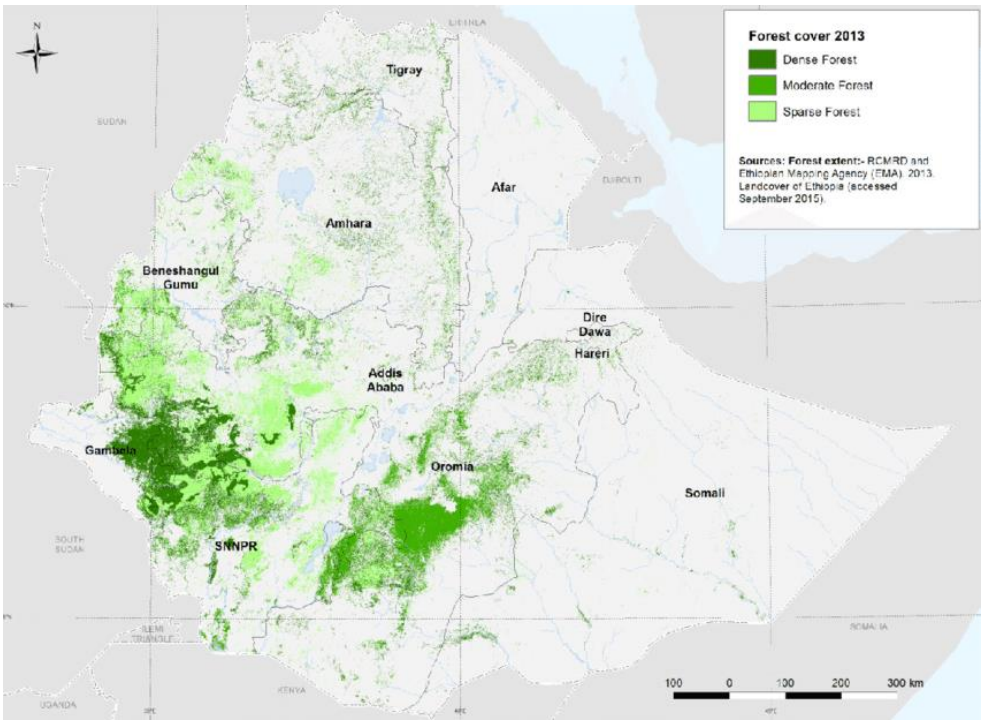

Figure 3

Forest cover of Ethiopia. (UNEP, 2016).

2. Background and needs for the strategy development

The development of a strategy for the provision of reproductive material of *J. procera* is contributing to one of the main contributors for the effective implementation of the reforestation and forest landscape restoration programs in Ethiopia. The application of the strategy depends on the existence of different forest restoration plans, biodiversity conservation policies and frameworks.

The presence of a defined national/international framework and government policies are a prerequisite to develop a strategy for the provision of reproductive material of *J. procera*. Moreover, the strategy supports the proper planning and implementation of reforestation and forest landscape restoration activities. One of the International frameworks which was ratified by Ethiopia is Convention on Biodiversity (CBD). This CBD is very relevant for the conservation of forest genetic resources, including the reproductive material for *J. procera.* The CBD employs a comprehensive approach to the conservation and sustainable use of biological resources. The convention includes a preamble 42 Articles and the six are particularly relevant for the endeavor of forest reproductive material conservation in Ethiopia. The six relevant and supportive articles for development of this strategy include a) Article 6. *General measures for conservation and sustainable*, b) Article 8. *In situ conservation*, c) Article 9. *Ex situ conservation*, d) Article 13. *Public Education and Awareness*, e) Article 14: *An Environmental Impact Assessment* (EIA) and f) Article 15: *Access to Genetic Resources*.

Furthermore, the conservation of forest genetic resources and provision of reproductive material for *J. procera* is of high relevance for national policies. The two main policies are: a) Environmental Policy of Ethiopia, which was issued in 1997, and b) the National Policy on Biodiversity Conservation and Research issued in 1998. Additionally, the strategy supports very relevant national programs: the Ethiopian Forestry Action Program issued in 1994, National Biodiversity Conservation and Research Program, and the seed zone system of the National Tree Seed Project.

Ethiopia has also ratified numerous international agreements related to forest landscape restoration and combatting climate change. For instance, in 2014,

Ethiopia declared its support for the New York Declaration on Forests and the Bonn Challenge by pledging to restore 15 million hectares of degraded and deforested lands by 2025. Promising to restore such a big area which is corresponding to nearly one seventh of Ethiopia's total area is a challenging goal. Ethiopia has developed a climate resilient green economy strategy in 2011 and later signed the Paris agreement on climate change in 2015. These promises and efforts indicate how Ethiopia is moving forward to achieve its forest landscape restoration objectives. It is also very supportive to the ongoing genetic diversity conservation activities and efforts on provision of reproductive material. In addition, Ethiopia is signatory to the Convention on International Trade in Endangered Species of Wild Fauna and Flora, the Convention to Combat Desertification, and other very important international conventions. Although there are some weaknesses in implementation Ethiopia already has proclamation (Pro. No. 94/1994) that prohibits the felling of *J. procera.*

Table 1 International targets of Convention on Biodiversity (CBD) and Sustainable development goals (SDGs) supported with the implementation of this strategy.

STRATEGY	International targets of CBD and SDGs supported by the strategy	
	CBD target	SDGs target
STRATEGY FOR THE PROVISION OF REPRODUCTIVE MATERIAL FOR *JUNIPERUS PROCERA* IN ETHIOPIA	Strategic Goal A: Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society. This strategic goal includes targets 1,2,3, and 4	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture
	Strategic Goal B: Reduce the direct pressures on biodiversity and promote sustainable use. This strategic goal includes targets 5,6,7,8,9, and 10	Goal 3: Ensure healthy lives and promote well-being for all at all ages
	Strategic Goal C: To improve the status of biodiversity by safeguarding ecosystems, species, and genetic diversity. This strategic goal includes targets 11,12, and13	Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
	Strategic Goal D: Enhance the benefits to all from biodiversity and ecosystem services. This strategic goal includes targets 14,15, and 16	Goal 7: Ensure access to affordable, reliable, sustainable, and modern energy for all
	Strategic Goal E: Enhance implementation through participatory planning, knowledge management and capacity building. This strategic goal includes targets 17, 18, 19 and 20	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable
		Goal 12: Ensure sustainable consumption and production patterns
		Goal 13: Take urgent action to combat climate change and its impacts
		Goal 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
		Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development

3. Objectives of the strategy

The native tree species *Juniperus procera* is one of the most important tree species in Ethiopia. The goal of this strategy is to safeguard the provision of high-quality reproductive material for the sustainable use of the tree species and the maintenance of the ecological and socioeconomic benefits of *J. procera*. Therefore, the overall objective of this strategy is to conserve and attain sustainable utilization of the genetic material of *J. procera* trees. Conserving and maintaining the genetic material will significantly contribute for provision of adequate and high-quality reproductive material. As a result, availability of adequate reproductive material for the species will help for successful reforestation and forest landscape restoration of *J. procera* populations. Moreover, it is intended to contribute towards attaining a sustainable development through enhancement of the economic, socio-cultural, and ecological values of the forest ecosystems of Ethiopia. This strategy also focuses on ways and possibilities to enhance the provision of reproductive material and working with stakeholders for sustainable utilization of the resource. It is believed that this strategy can serve as a guide for the future to perform genetic resource conservation of *J. procera* population either at *in situ* or *ex situ* mechanisms. This strategy was developed based on the existing knowledge and scientific results. The strategy will be open for amendment when additional relevant information is acquired.

4. The Strategy`s Steps and Recommendations

The provision of the reproductive material for *Juniperus procera* is based on two important concepts of genetic conservation namely, the *in situ* and *ex situ* sources.

The prioritized concept is the availability of reproductive material from *in situ* sources. Reproductive material that is collected from *in situ* conserved area has the advantage of conserving a maximum of genetic diversity in a cost-efficient way and with research requirements under natural selection. This will help particularly for the conservation of ecosystem and natural habitats, for maintenance and recovery of viable populations of the *J. procera* in their natural surroundings. Using *in situ* as sources of the reproductive material includes the collection of germplasm from the natural *J. procera* stands and artificial regeneration with defined material (seeding and planting in situ). The artificial way of obtaining the reproductive material from *in situ* comprises the collection of germplasm from a given site, propagation of seedlings in a nursery and subsequent planting of the produced seedlings in a delineated area where the germplasm was obtained from.

The second concept refers to the production of reproductive material is from *ex situ* sources. This includes the collection of the germplasm outside their natural habitats. Generally, there are two possible methods for application of the *ex situ* concept: collection from naturally *J. procera* conserved sites (field conditions) and from artificial sites (controlled conditions). The implementation of artificial way of reproducing germplasm is mainly dependent on "gene banks". The gene bank particularly includes the storage of seed, pollen, plants, parts of plants and tissue. Since *J. procera* is one of the species listed under endangered species it is important to establish *ex situ* plantation stands to get more reproductive material for further propagation. For instance, establishment of seed orchards is one of the *ex situ* sources of reproductive material under natural condition. The seed orchards can be categorized as seedling seed orchard (a seed orchard established from the seedlings of superior mother trees) and clonal seed orchard (a seed orchard established by vegetatively propagated material in which the genetic material of the mother tree is identical to the offspring with the intention of duplicating a superior *J. procera* tree species.

For actual implementation of these conservation methods the formulation of a sound strategy that enables provision of quality and adequate reproductive material of *J. procera* for the country is needed. Based on our knowledge, the following parts of the strategy are listed for the time being.

10 Steps

1

Conducting an inventory for *Juniperus procera* coverage

2

Enhancing the supply of genetically appropriate and adapted reproductive material

3

The establishment of ex-situ seed orchards

4

Establishment of a seed center

5

Importing viable Juniperus procera seeds from abroad

6

Capacity building for better provision of the reproductive material

7

Formation of a task force to control pest and disease attack

8

Development and implementation of research programs

9

Establishing strong partnership between government and other stakeholders & actors

10

Extension, communication, and networking for better provision of reproductive material

4.1 Conducting an inventory for *Juniperus procera* coverage

To assess the status and trends of the species conducting detailed inventory at all levels is very important. The inventory will help practitioners to have a better overview about the distribution and area coverage of the species in different parts of the country and at national level. In addition, the information gathered from the inventory supports the planning for a maximized establishment and enrichment of *J. procera* forest sites across the country. Moreover, practitioners and decision makers will use the inventory data as an input to predict the future coverage of the species across the country and to look in which part of the country is severely degraded and in which part is in better condition. Availability of inventory data about the species will also help for future monitoring and to decide which measures could be implemented to protect the species from deterioration effectively and in a sustainable manner.

4.2 Enhancing the supply of genetically appropriate and adapted reproductive material

Productive re-afforestation, plantations, and restoration practices either at landscape level or farm level can be realized only when we use genetically appropriate and adapted reproductive material. A comprehensive and integrated reproductive material planning, production and storage systems is very important for successful restoration of deteriorated sites by planting *J. procera*. This is because it promotes the availability of sufficient quantities of suitable reproductive material when and where they are needed for specified purpose. In order to achieve the enhanced supply of genetically appropriate reproductive material for *J. procera* there are two important measures.

A - Focusing on needs and capacity assessment of high-quality reproductive material production and distribution.

Successful production and distribution of high-quality reproductive material of *J. procera* for the current and future has a strong implication for the economic development and ecological importance. Moreover, having such high-quality reproductive material has also a great

advantage for enhanced land restoration and genetic conservation in the short, medium, and long terms. The assessment of high-quality reproductive material should include identifying infrastructure assets, staffing, and training needs. Conducting the need and capacity assessment will help to identify who are the potential and accredited dealers for reproductive material, researchers, and other stakeholders engaged as accredited service providers at national and international level.

B - Assisting improvement and expansion of the production capacity of reproductive material sources.

The more there are reproductive sources the higher possibility of getting adequate reproductive material for the *J. procera*. This could be realized by cooperation and partnership within and among public and private sectors.

4.2 - Recommendations

- The supply of the reproductive material(seed) either from breeding seed orchard or seedling seed orchard should be from *J. procera* populations which perform very well in terms of morphological traits and adaptation to sites.

- The results of the JUPRET project research study showed that *J. procera* populations collected from Asebot monastery (ASEB) exhibited better in stable carbon isotope, less in aridity index, high in moisture index and high in biomass. Therefore, it is suggested that the supply of reproductive material from this population could resist drought and grow better. This in turn could help for successful re-afforestation and forest landscape restoration programs in the country.

- For adequate and adapted supply of reproductive material it is advisable to use other additional sources (populations) which perform well next to Asebot monastery (ASEB). For instance, supply of reproductive material from Gullele Botanical Garden (GULL), Gara ades (GARA) and Kahatasa forest (KATA).

4.3 The establishment of *ex-situ* seed orchards

It is evident that the flowering and producing of seeds in *J. procera* trees happens once every several years (averagely 10-15 years). This makes it to have slow production of seeds for further reproduction and less probability of restoring previously degraded *J. procera* stands in different landscapes. Some authors also mentioned that the reason for degradation of the species' populations in many areas of the country is due to low regeneration rate. The weak regeneration rate might be due to more shade to the underneath seedlings and thicker litter accumulation that hinders germination of the seeds. Not only the above mentioned two main factors for less restoration of the species but also the seeds of *J. procera* showed very weak germination rate under laboratory trial. For instance, the germination trial was conducted at Ethiopia Environment and Forest Research Institute (EEFRI) laboratory for seeds collected from two *J. procera* populations (Yabello-Konso forest and Gulelle botanical garden). The result of this trial showed the germination rate was very low with values 10.7% and 5% for Yabello-Konso forest and Gulelle Botanical Garden respectively.

Therefore, to overcome the above challenges and successful restoration of the *J. procera* populations in the Ethiopian landscapes, establishment of breeding seedling orchard, seedling seed orchards and if possible clonal seed orchards is very crucial. The establishment of seed orchards is done under natural condition and known site suitability. As the report from Provision of Adequate Tree Seed Portfolios" (PATSPO) project showed, two breeding seed orchards and one seedling seed orchard have already been established in the last two years in different regions of the country. For example, one breeding seed orchard (**BSO**) in Debremarkos of Amhara region having 120 *J. procera* plants with 47 rows (5640 plants in total), one breeding seed orchard (BSO) in Menagesha of Oromia region having 120 *J. procera* plants with 68 rows (8160 plants in total), and one seedling seed orchard (**SSO**) in Awada site of Sidama region. The *J. procera* plants in both **BSO** sites (13800) are expected to produce 345 million seeds (average of 25,000 viable seeds per tree) per year. The expected seedling to be produced will be 27.6 million (average of 8% germination rate) and will cover an area of 11,040 hectares by using 2 meters spacing between the trees. The material used is the same for all the three **BSOs/SSOs**: Dodola (Bale area), Yegof (Wello area), Menagesha (Suba area), Wof Washa (Shewa area).

4.3 - Recommendations

- Establishment of further breeding seed orchards and seedling seed orchards in additional regions. To re-afforest 40,000 hectares of land in the Afromontane landscapes of Ethiopia at least 7 breeding seed orchards (with 7000 plants each site) should be established in Oromia, Amhara, Tigray and Southern regions. The re-afforestation and forest landscape restoration of the above planned land area will be implemented in the next 20 years.

- To re-afforest additional 1600 hectares of land in the Afromontane landscapes of Ethiopia at least 20 seedling seed orchards should be established across the country. The SSOs are expected to produce 4 million seedlings in the next consecutive 20 years (200, 000 seedlings in each year).

- In general, about 52,640 hectare of land is suggested to be covered by *J. procera* by producing reproductive material in the already established and the coming BSO/SSOs sites.

- Proper fertilization, protection and tending should be done to the orchards. This activity improves survival of the growing species

- Protection against fire hazard and other disturbances should be done properly and effectively.

4.4 Establishment of a seed center

To respond the on-going and future reforestation and forest landscape restoration *with J. procera* reliable availability of genetically appropriate reproductive materials is needed. Establishment of a seed center for this species is one of the critical measures to be done before the species goes to genetic loss and high chance of extinction. To put this strategy into effect a proactive planning that includes capacitating the seed centers with adequate infrastructure, materials and technical capacities is very important. The arrangement of sufficient infrastructure will help for proper storage and handling of the reproductive material (seeds, tissues, etc.) in different seed centers. In addition, guidelines and protocols that describe how seed collection, testing and storage should be done will also be included. This will enable practitioners, scientists, and other stakeholders to have better understanding on how to utilize and reproduce these reproductive materials for further landscape restoration activities. The establishment of seed center should also include for other main tree species in the country and should be integrated in existing institutions, e.g. EEFRI.

4.4 - Recommendations

- Seed centers for *J. procera* should be established at federal and regional level for sustainable provision of the reproductive material
- Allocation of budget and other required infrastructures should be arranged by the responsible institutions. Establishment of the seed centers could be implemented and realized by the support of governmental and non-governmental funds
- Ethiopian Environment and Forest Research Institute, Environment, Forest and Climate Change Commission, and the regional Environment and Forest Research centers should take the responsibility
- The seed centers for this species in Ethiopia should have a good connection and collaboration with seed centers in other countries for sustainable provision of the reproductive material.

4.5 Importing viable *Juniperus procera* seeds from abroad

The adequate provision of reproductive material is the key factor for successful restoration of degraded *J. procera* forest sites. In a situation where there is scarcity of seed source to produce seedlings for the vast restoration activities it is advised to look other alternative sources. For instance, importing viable *J. procera* seeds from near-neighboring countries, which have similar agroclimatic setting and high probability of the reproductive material to show better success in germination, could be considered the best strategy. This will be implemented by respecting the standards, rules and regulations set by the government for importing biological materials from abroad. Therefore, for effective and smooth implementation of the importing system creating collaboration with international organization is very important. This collaboration and partnership will help to solve the challenges related to identifying potential providing countries, selection of the quality seeds, purchasing and shipping. This action is particularly important in the light of climate change, when local seed sources may not be best adapted to the future climate (cf. assisted migration).

4.5 - Recommendations

- The Ethiopian Environment and Forest Research Institute and the Ethiopian Environment, Forest, and Climate Change Commission and Ethiopian institute of biodiversity should take the responsibility to import the reproductive material from abroad when it is needed
- Non-governmental organizations should also work closely and involved in importing seeds with the permission of the legal body
- Individual legal dealers who have a license in importing seeds should participate in this task by complying all the standards and full permission of Ethiopian institute of biodiversity
- All forest enterprises and private nursery owners should work closely with the federal Environment and Forest Research Institute and the Ethiopian Environment, Forest, and Climate Change Commission for fast and successful importation of the seeds
- Due attention should be given during the importation for *J. procera* seeds in order to control the importation of seeds of invasive species
- The government should allow tax free importation scheme for the seeds of species with high conservation concern like *J. procera*

4.6 Capacity building for better provision of the reproductive material

The production and supply of high-quality reproductive material used for restoration of *J. procera* suited areas demands trained staff. Providing training opportunities to experts, practitioners and other stakeholders will improve the capability of producing quality reproductive material. The capacity development includes training based on well-defined required skills and staffing the institutions with well-trained human resources. These efforts and investments for expanding and improving facilities will enhance the production capacity of reproductive materials. Additionally, the processing, testing, storage, and research conducted on the reproductive material will be improved.

Capacity building related to management, production, distribution, and other quality improving activities of the reproductive material should be tailored for the public sectors as well as private actors. The trainings should be given to breeders and forest experts working on public institutions such as Ethiopian Biodiversity Institute, Ethiopian Environment and Forest Research Institute, Environment, Forest and Climate Change Commission, Ministry of Agriculture and Natural Resources, all Environment and Forest Research centers, and people engaged in the private sector such as forest enterprises, timber factories and companies, cooperatives, enterprises, and individuals engaged in seed collection, seedling production and forest development.

Briefing and awareness creation on the status, the need to conserve for *J. procera* populations should be done by organizing different conferences, workshops, seminars, and meetings. This is mainly to make the government representatives, politicians, policy makers, decision makers and other concerned stakeholders aware to work closely with the institutions and give them due attention. Informing and encompassing of the above parties, strengthening the capacity of public and private actors will help for effective and smooth implementation of *J. procera* restoration projects across the country.

4.6 - Recommendation

- Production of bachelor/master's graduates with the specialization of tree breeding and ecological genetics
- Giving short-term trainings for forest practitioners and forest experts either in country or abroad
- Arranging experience sharing and sensitization visits for different actors, experts at all levels hence they will get more knowledge about provision of quality reproductive material
- Organizing conferences and seminars to share research findings with forest professionals, practitioners, and other different actors

4.7 Formation of task force to control pest and disease attack

One of the big challenges in re-afforestation and forest landscape restoration is trees/shrubs always suffer from pest and disease attack. These effects of the attack mostly happen if there are some climatic changes either with temperature extremes or rainfall shortages. For instance, *Juniperus procera* stands are attacked by borers and the cypress aphid (*Cinara cuppressii*) and older trees are susceptible to heart rot fungus (*Fomes juniperinus*) (Orwa *et al*., 2009). The trees could be both planted as plantation and natural forests. Therefore, for successful re-afforestation and forest landscape restoration the formulation of a task force which is responsible for controlling of the pest and disease infestation at all levels is suggeste. It should be formed in such a way that the Ethiopian Environment, Forest and Climate Change Commission (EFCCC) and Ethiopian Environment and Forest Research Institute (EEFRI) take the lead and other very close institutions such as Ethiopian Biodiversity Institute, Ministry of Agriculture and Natural Resources, Ethiopian Wildlife Conservation Authority, Environment and Forest Research Centre, International Centre for Research in Agroforestry (ICRAF), Centre for International Forestry Research (CIFOR) and International Livestock Research Institute (ILRI) work together at the federal level. The same way of forming a task force group should be implemented at regional, zonal and district level. This kind of linked coordination and integrity from the federal until the district level helps for effective and efficient control of pest disease attack in *J. procera* forest stands and mobilize more manpower during the campaign.

4.8 Development and implementation of research programs that improve the availability of adequate and quality reproductive material

Science based production of seedlings either at nurseries or individual homestead would help for provision of quality and healthy reproductive material that is going to be used in re-afforestation and forest landscape restoration programs. Implementation of research supported with high biotechnology could help for adequate and more adapted production of the genetic material.

Further research is needed to identify and select which populations of *J. procera* stands are performing well by withstanding the different climatic challenges. This will help forest practitioners to develop better know how in choosing the best quality and more adaptive reproductive material for successful implementation of the conservation programs. In addition, results of the conducted research can be used to develop guidelines for the selection of reproductive material which are adapted to different agroecological zones. In addition, research outputs should be used to develop manuals and protocols which are used to train forest practitioners and other actors engaged in provision of reproductive material for this species.

4.8 - Recommendation

- Collecting seeds from many *J. procera* populations and checking the germination rate at both laboratory and field conditions
- Incorporation of additional seedling production technologies like tissue culture is very important since there is a clear need for quantitavie increase in seedling production of good quality and then implementing plantation programs in the country.
- Research trials on clonal propagation of *J. procera* should be conducted as alternative method to maximize the provision of reproductive material in the country

4.9 Establishing strong partnership between government and other stakeholders/actors

Enhanced government/public-private partnerships have a great role in facilitating the production and distribution of reproductive material for the species. A greater collaboration between the government/public and the private sector is expected for attracting private investment and strengthening the production of high-quality reproductive materials while respecting the standards, rules, and regulations. This will give opportunity for private operators to participate, some of which have shown interest due to the market prospects. The strong collaboration and linkages between the different actors will help to develop a system with consistent and sustainable reproductive material supply. For successful *J. procera* restoration activities undergoing by the government of Ethiopia the collaboration should include governmental and non-governmental organization. Accordingly, the following parties should work integrately to bring the expected result.

- Ethiopian Biodiversity Institute
- Ethiopian Environment and Forest Research Institute
- Ethiopian Environment, Forest, and Climate Change Commission
- Ministry of Agriculture and Natural Resources
- Ethiopian Wildlife Conservation Authority
- All public higher institutions
- All Environment and Forest Research Centers
- International organizations such as International Centre for Research in Agroforestry (ICRAF), Center for International Forestry Research (CIFOR), International Livestock Research Institute (ILRI), The Alliance of Biodiversity International and CIAT etc.
- All forest enterprises,
- All timber factories and companies
- Religious Institutions (The Ethiopia Orthodox Churches, Monasteries and mosques
- All cooperatives engaged in seed collection, seedling production and forest development
- All enterprises and individuals engaged in seed collection, seedling production, and forest development
- All national and international authorized seed dealers

4.10 Extension, communication, and networking for better provision of reproductive material

Advocating the benefits of conserving and restoring *J. procera* forest land scape in different circumstances is a crucial step to be done. Efforts to strengthen the management, extension, and communication services for public as well as for private actors should get due attention by the central government and other responsible organizations at all levels. Poor management, inefficient extension system, limited communication and collaboration among stakeholders could lead to weak and inefficient provision of reproductive material. Those short comings could reduce the provision of adequate and quality reproductive material and consequently hamper the re-afforestation and forest landscape restoration programs for *J. procera* in the country. Therefore, to overcome the problems related to extension there is a need to work in maximizing extension services to forest practitioners, seed collectors, seedling producers and other actors.

Dissemination of research findings, conducting of trainings, awareness campaigns and various communication tools and networking are some of the extension services that should be given to actors involved in the provision of reproductive material. Development of website for the national reproductive material register and data base is also part of the extension. The register system should be computerized and accessible to provide regularly up-dated information on the status of the reproductive material across the country, inventory data and other related information. In addition, important documents such as working manuals, guidelines, and protocols should be included in the system. For instance, guidelines for seed collection, storage, pre-treatment, germination test, clonal propagation, and others. Provision of such important documents helps researchers, forest practitioners, and other actors to have clear information regarding the status of *J. procera* in terms of availability of the reproductive material and methods to conserve it.

The role of communication in implementation of the re-afforestation and forest landscape restoration activities is very vital. This in turn affects the provision of reproductive material for the species positively. Therefore, development and implementation of different types of efficient and interconnected communication systems should get due attention. An efficient communication creates more trust and transparency among and within people who are engaged in provision of the reproductive material.

Development of mass communication such as media and broadcasted

information through TVs and Radio is very relevant. Because it helps to raise awareness the creation on stakeholders and disseminate important information on how to conserve and provide adequate and quality reproductive material for users. For instance, focusing on the dissemination of information on the importance of protecting the seed stands, seed orchards, will create market linkage for the seed sector and foster conditions for research in reproductive material. Information and other scientific results could be also disseminated through newsletter, magazines, leaflets, pamphlets etc.

Networking among and between the different actors, clients, stakeholders who are actively engaged in the provision of reproductive material for this species is indispensable. For instance, the networking could help to make a link between the private sectors which provides seed and the financial institutions. This linkage is aiming to provide financial support and hence helps to obtain the required infrastructure for seed production, collection, processing, storage, conservation, and quality assurance.

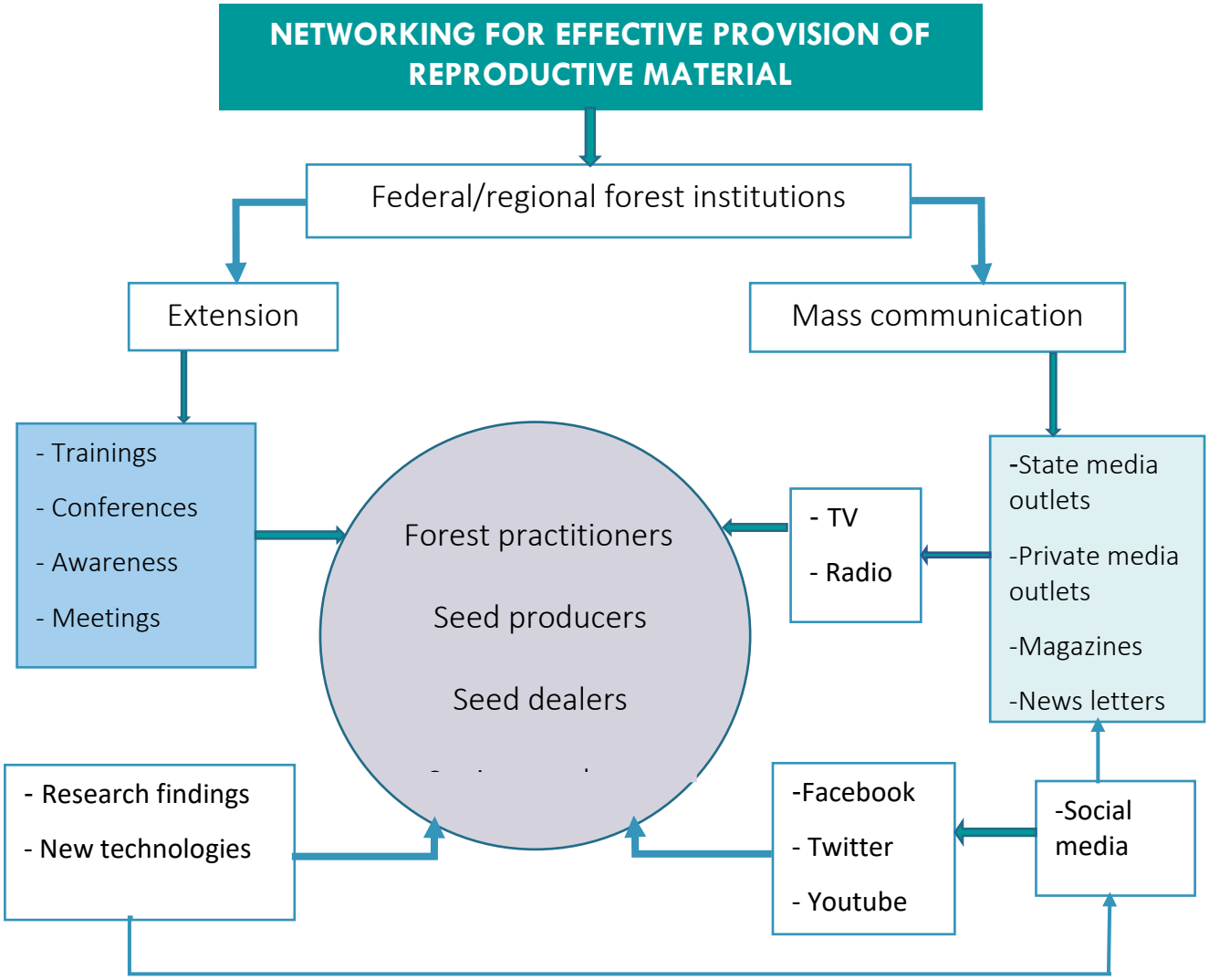

Figure 3 The role of extension and communication for different stakeholders

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Conelets and cleaned seeds of *Juniperus procera (c) BFW, 2021.*

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