ISSN: 2310–3469 RNPS: 2347
Revista Cubana de Ciencias Forestales. 2019; septiembre-diciembre 7(3): 365-376

CFORES
REVISTA CUBANA DE CIENCIAS FORESTALES

Translated from the original in spanish

Forest seed production and conservation: current situation and perspectives in Ecuador

Producción y conservación de semillas forestales: situación actual y perspectivas en Ecuador

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Received: January 11th, 2019.
Approved: July 10th, 2019.

ABSTRACT

The objective of this paper is to assess the current situation of forest seed production and conservation in Ecuador, through the analysis of documents. It is noted that there are two strategies for the conservation and/or production of seeds in the country. In situ conservation shows results from the selection of seed sources from different actors: the EcoPAr foundation selected 20 in Andean forests in the Sierra, the Municipality of Quito identified 28, while Solidaridad Internacional installed 33 in Orellana, among others. Ex situ conservation developed alternatives such as: cryopreservation, long term, medium term, in vitro and field. The National Germplasm Bank of The National Autonomous Institute of Agro-Livestock Research has 72 species with 85 accessions, the Bank of the Private Technological University de Loja has 500 species in more than 800 accessions and there are also seven botanical gardens. The efforts made and the different experiences obtained are isolated. There are limitations of constructive and technological infrastructure, human resources, as well as deficiencies in the inter-institutional coordination of inventories and management plans of the forests that have seed sources.

Keywords: seed sources; germplasm bank; botanical garden; arboretum.

RESUMEN

El objetivo del presente trabajo es valorar la situación actual de la producción y conservación de semillas forestal en Ecuador, mediante el análisis de documentos. Se constata que existen dos estrategias para la conservación y/o producción de semillas en el país. La conservación *in situ* muestra resultados de selección de fuentes semilleras desde diferentes actores: la fundación EcoPAr seleccionó 20 en bosques andinos en la Sierra, el Municipio de Quito identificó 28, en tanto Solidaridad Internacional instaló 33 en Orellana, entre otras. La conservación *ex situ* desarrolló alternativas tales como: crioconservación, largo plazo, medio plazo, *in vitro* y campo. El Banco Nacional de Germoplasma del Instituto Nacional Autónomo de

Investigaciones Agropecuarias posee 72 especies con 85 accesiones, el Banco de la Universidad Tecnológica Particular de Loja tiene 500 especies en más de 800 accesiones y existen también siete jardines botánicos. Los esfuerzos realizados y las diferentes experiencias obtenidas resultan ser aislados. Existen limitantes de infraestructura constructiva y tecnológica, recursos humanos, así como carencias en la coordinación interinstitucional de inventarios y planes de manejos de los bosques que poseen fuentes semilleras.

Palabras clave: fuentes semilleras; banco de germoplasma; jardín botánico; arboreto.

INTRODUCTION

According to Romero (2018) and León *et al.,* (2014), the forest masses of the planet receive high pressure from the extension of the agricultural frontier, the change of land use to satisfy the growth of the urban and periurban population and the negative effects of climate change.

The most significant losses of tropical forest areas have occurred in recent years in Africa and Latin America (FAO, 2016). A total of 29.4 million hectares of forest have disappeared in 2017, the second worst year after 2016 with 29.7, where the record was reached, according to University of Maryland records since 2001. Tropical forests accounted for 63 percent of losses in 2017, with a total of 15.8 million hectares (Seymour, 2018).

In Ecuador, the trend of deforestation and its rate, since 1990, has the following behavior. According to MAE (2014), for the period 1990-2000, average deforestation was 89,944 ha/year for a deforestation rate of -0.71 %, while for the period 2000-2008 it was 77,647 ha/year for a rate of -0.66 %. On the other hand, during the period 2008-2012 deforestation was 65,880 ha/year for a rate of -0,54 %. The results obtained show that the gross deforestation values of continental Ecuador for the period 2014-2016 are lower than in the historical stages, maintaining the downward trend of gross deforestation, with an average gross annual deforestation of 94,353 ha/year and an annual gross deforestation rate of -0.74 % (MAE, 2017; 2018).

The response of governments, non-governmental organizations, associations, communities and other actors interested in slowing this situation, is to plan and implement plans for afforestation, reforestation, restoration and enrichment. For such purposes, large productions of seedlings of forest species are needed in the nurseries, which demands quality seeds.

Guaranteeing the quality of seeds to be used in afforestation and reforestation programs and plans in Ecuador is a social task of different public and private institutions. The National Agrarian Authority and the Consultative Council of Agrobiodiversity and Seeds National Assembly (2017), Ministry of Agriculture and Livestock (MAG), Ministry of Environment (MAE), National Autonomous Institute of Agricultural Research (INIAP), universities and forestry companies, among others, conform the system of entities with common purposes in relation to the achievement of quality of forest seeds and their certification.

Forest seed requirements are essentially determined by afforestation and reforestation plans, while restoration and enrichment practices are at minimum levels in the country.

The incentive program for commercial reforestation, attached to the Ministry of Agriculture, Livestock, Aquaculture and Fisheries (MAGAP, 2016), defines 19 incentive species. This program requires seeds with quality and quantity for the achievement of its objectives, but although in quantity it approaches its fulfillment, it is far from its satisfaction in quality. It also serves as the basis for the project to establish 120,000 ha which, according to the technical file for monitoring it (MAG, 2017), the accumulated income from 2013 to 2017 is 67,664.67 hectares, representing 54 % of the total to be achieved.

The beginning of a forest genetic improvement program is fundamentally based on the selection and identification of high yield trees, according to the criteria of Vallejos *et al.,* (2010). According to Valladolid, León and Paredes (2017), they have already defined and identified the origins and sources of seeds, selected sites with high percentages of healthy trees and good phenotype.

At the level of Decentralized Autonomous Governments (GAD) some initiatives are being developed that seek to address the problem of obtaining quality seeds, such is the case of the Province of Orellana located in the Amazon where 140 forest species are harvested, being the most in demand *Cordia alliodora* Ruiz & Pav. (laurel), *Cedrelinga cateniformis* Duke (chuncho*), Ceiba pentandra* L. (ceibo), *Otoba spp*. (chicken blood), *Sterculia spp*. (sapote) and *Virola spp*. (coconut). The reproductive biology, phenology and production mechanisms of plants in nurseries are unknown for some of these species, making it difficult to develop forest promotion, planning and management actions (Fundación Española Solidaridad Internacional, 2011).

It is recognized in the report of the State of Forest Genetic Resources of Ecuador, according to Grijalva *et al.,* (2016), that there is no well-structured Genetic Improvement Program, but rather initiatives of private companies and universities. These social actors have conducted specific research studies, but they are far from sustaining and responding to a forest genetic improvement plan.

Grijalva *et al.,* (2016) also propose the use of seeds from imported genetic material, in forest plantations and agroforestry systems, as well as locally collected material that does not guarantee the phenotypic and less genotypic superiority of the seeds used. On the other hand, the storage and commercialization of forest seeds does not show a coherent and articulated system in the country.

In a characterization of seed sources in the south of the country, nurseries point out that obtaining seeds is so far very random, there is no technical evaluation of the trees to take as seed (Raurau, 2012). The current sources are trees isolated from farms, highways and/or city parks and avenues, which does not necessarily ensure that the seeds are in good condition. Therefore, the quality of the seedlings that are obtained later are not necessarily adequate, making it impossible later to develop clonal orchards to have guaranteed and registered seed sources. This situation is also evident in the Amazon Region (Barrera *et al.,* 2018).

The new Ecuadorian legislation, the Organic Environmental Code, establishes an important framework aimed at obtaining quality seeds, as Article 28, numeral 3, states: "Promote the formation of nurseries, seed and orchards, collection, conservation and supply of certified seeds" (National Assembly of Ecuador, 2017).

The objective of the following paper was to assess the current situation of forest seed production and conservation in Ecuador.

DEVELOPEMENT

Analysis in the Ecuadorian context

According to Nyoka *et al.,* (2015), germplasm supply systems do not efficiently meet farmers' demands and environmental expectations in terms of productivity, species and genetic diversity in countries in Africa, Asia and Latin America. They also state that, in some countries, the germplasm used comes mainly from undocumented sources and has often not been tested. All of which makes the appreciation of the value of high quality genetic tree germplasm low.

Similar criteria are presented by Atkinson *et al.,* (2018), when analyzing the situation of seed supply systems for specific restoration implementation purposes in Mexico, Guatemala, Costa Rica, Colombia, Peru, Chile and Argentina. They affirm that these countries have at least some aspects of the seed system for specific purposes, but there are two fundamental gaps common to all: a low diversity of native species is available and used in restoration projects and there is little consideration of the genetic origin and diversity of seeds used.

A successful experience in the field of forest seed production and certification in Latin America is the Forest Seed Bank (BSF) of the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in Costa Rica. They show an experience of about 50 years of different initiatives focused on restoration and forest genetic improvement. According to Mesén (2017), the "BSF is a self-sufficient marketing unit of high quality seeds, which annually distributes about 10 tons of seeds to about 20 countries. In Ecuador, the private company Profafor S. A. is the exclusive distributor in the country of CATIE.

At the end of the 1990s, the Andean Forest Seed Network (RASEFOR) was formed, integrated by Bolivia, Chile, Colombia, Ecuador and Peru, which promoted, from the physical and genetic point of view, a relative advance in the management of forest seeds.

The government of Ecuador's National Development Plan 2017-2021 "Toda una Vida" (A Lifetime) declares the citizen and institutional priorities for the realization of Good Rural Living, where the diversification of seed banks is proposed, as stated in policy 6.2, Objective 6: To develop productive capacities and the environment to achieve food sovereignty and Good Rural Living. In order to comply with this plan, the Ecuador Green Program is created, which contains work objectives where reforestation is one of the most important, therefore, the need for seeds will increase. In the legal sphere, there is the Forest Seed Standard, which corresponds to Ministerial Agreement No. 003, with Official Gazette No. 269 (MAE, 2014). It contains the management of these, as well as technical, administrative and institutional aspects. The Regulations for the Registration of Seed Importers and Exporters (MAGAP, 2012) are also available.

Forest seed production systems are mainly composed of companies focused on meeting the needs of forest species of interest for commercial plantations. This is the reason why the production of these companies specialized in seed production is targeted at medium and large producers, according to Arenas *et al.,* (2015). They are governed by regulations on production, quality and marketing, which implies high costs of production, research and development (Neate and Guei, 2011).

It is an FAO criterion (2014) that for the improvement of *in situ* and *ex situ* conservation of forest genetic resources, in order to ensure the quantity, quality and timeliness of seed supply, becomes necessary:

- To strengthen the contribution of the main forests and protected areas to the *in situ* conservation of FGR.
- To promote the establishment and development of sustainable and effective *ex situ* conservation systems, including live collections and gene banks.
- To support and strengthen the role of local and indigenous communities in the sustainable management and conservation of FGRs.
- To identify priority species for action.
- To harmonize *in situ* and *ex situ* conservation measures, including through networking and regional cooperation.

According to Galindez *et al.,* (2015), land use change and climate change are negatively affecting natural ecosystems, so there is a need to carry out *in situ* and *ex situ* conservation and management programs for the species and communities of which they are part. They propose that, for this "it is essential to know the requirements of germination, the presence and type of dormancy and behavior during storage of seeds. They also agree with Hoyle *et al.,* (2014) and Hay and Probert (2013) that this knowledge serves as a basis for understanding and predicting the processes that occur in natural communities such as establishment, succession and natural regeneration, as well as for developing conservation protocols for species, respectively.

Romero and Pérez (2016) state that there is a lack of knowledge of the ecology, physiology and morphology of seeds, which makes it difficult to carry out this conservation strategy in the case of the dry forests of southwestern Ecuador and northwestern Peru. This statement is relevant if we consider that these ecosystems are included in a hotspot due to their high diversity and endemism. In order to be able to fulfill the country's aspiration of reforesting 220000 ha, which is in line with international commitments, it is necessary to have initial information about the ecology and biology of seeds, which is very limited for the tropical Andean region (Palomeque *et al.,* 2017).

In Ecuador there are two strategies for the conservation and/or production of seeds in the country, *in situ* and *ex situ* conservation.

The conservation and/or production of seeds in situ shows results from the selection of seed sources from different actors, where the following can be identified, according to Grijalva *et al.,* (2012; 2016):

EcoPAr Foundation selected 20 in Andean forests in the Sierra.

- Asociación de Agrónomos Indígenas de Cañar 13 de especies nativas en Cañar, Fundación Ecológica Arco Iris 14 de especies nativas en Lojas.
- Municipality of Quito identified 28.

- International Solidarity installed 33 in Orellana.

In this sense, Toro and Roldan (2018), in relation to the Juglans neotropica Diels species, propose the establishment of in situ conservation programs for seed trees to guarantee quality seeds for propagation in nurseries and higher quality seedlings for planting in the field. They also state that knowledge of the reproductive ecology and dynamics of seed tree populations is essential, especially on their phenology and productivity, as it allows the elaboration of forest calendars or schedules.

Ex situ conservation developed alternatives such as: cryopreservation, long term, medium term, in vitro and field and the following stand out (Grijalva *et al.,* 2012; 2016):

- Banco Nacional de Germoplasma del Instituto Nacional Autónomo de Investigaciones Agropecuarias has 72 species with 85 accessions.
- Banco de la Universidad Tecnológica Particular de Loja has 500 species in more than 800 accessions.
- La Represa" Experimental Farm of the Technical University of Quevedo has a collection of 50 species of tropical trees.
- Arboreto de la Universidad Nacional de Loja with species of nine families.
- Network of Jardin Botanico del Ecuador, recognized by the Ministry of the Environment, which registers seven units that contribute to the conservation of species and seeds, of which only three are recognized as Botanical Gardens.

Ex situ conservation programmes continue to be limited to certain species of economic importance, which coincide with intensive genetic improvement or which are seriously threatened, with the serious financial consequences that this entails.

The efforts made and the different experiences obtained turn out to be isolated, in the absence of a national system. In particular, there is a lack of a National Forest Seed Bank for the production and conservation of forest seed that is structured, functional and with concrete results at the country level.

It is Romero's criterion (2018) that the main reasons for the scarce development of ex situ conservation alternatives in Ecuador are the following

- Lack of economic resources.
- Lack of trained personnel.
- Scarce scientific production on seeds.
- Ignorance of phenological periods.
- Lack of physiological information on seeds.
- Difficulty and limitations in the in situ collection of seeds.

Prado *et al.,* (2010) state that "the informal sale of seeds persists and there are not enough installed seed sources to supply seeds of known provenance and quality to plans and programmes".

On the other hand, Grijalva *et al.,* (2016) states that "the sale of seeds and seedlings of forest species in the country is carried out by private companies, foundations and research centers, which, in one way or another, have information on origins, protocols for acquisition and/or collection of germplasm, infrastructure and multiplication processes. These authors then refer to the existence of "informal

centers for the multiplication and sale of forest germplasm, which do not have the necessary information, protocols and infrastructure to guarantee the quality of the plant material". Genetically, there are some isolated advances such as: identification of phenotypically superior trees, establishment of progeny trials, installation of germplasm conservation plots, some of which are led by the private sector.

The quality of locally collected genetic material is considered to be of low quality, as seed sources do not guarantee genetic superiority, even phenotypic. FAO (2014) and Grijalva *et al.,* (2012; 2016) agree on the following challenges.

- Develop systematic national strategies for in situ and ex situ conservation and production of certified seeds, developing collaborative relationships and promoting coordination of national FGR-related programmes and institutions.
- Establish and strengthen educational and research capacities in in situ and ex situ conservation and certified seed production.
- Promote the participation of local and indigenous communities in in situ and ex situ conservation and certified seed production, within the framework of decentralization.
- Promote and implement mechanisms for regional exchange of germplasm for research and development, in accordance with international conventions.
- Strengthen international and regional cooperation, together with networking, to support education, knowledge dissemination, research, in situ and ex situ conservation and certified seed production.
- Reinforce measures to mobilise the necessary resources, including funding for in situ and ex situ conservation and certified seed production.

There are experiences in Ecuador regarding in vitro tissue culture of Cinchona officinalis L. focused on mass propagation from seeds, analysis of genetic fidelity and tissue conservation alternatives, as Armijos (2016), obtained relevant results such as:

- The development of efficient protocols to improve the germination percentages and the proliferation of shoots in explants cultivated in vitro.
- The evaluation of the genetic fidelity of explants obtained with different combinations of plant growth regulators and different subcultures.
- The establishment of in vitro conservation protocols and cryopreservation of nodal segments and buds.

The experience of Lima *et al.,* (2018), also in Cinchona officinalis L., offers a high rate of germination and formation of shoots, knots and leaves in the in vitro multiplication phase of explants (caulinary apexes and nodal segments).

Cryopreservation is a novel technique with broad potential to be applied in the country's forest resources. The reports of its use in Ecuador are minimal, therefore it constitutes a great challenge for scientists, professionals, businessmen and directors who are related or linked to the management and conservation of forest biodiversity, to act and comply with public policies, as demanded by the Constitution of 2018, Section Three: Natural Heritage and Ecosystems, Art. 404.- "The natural heritage of Ecuador unique and invaluable includes, among others, the physical, biological and geological formations whose value from the environmental, scientific, cultural or landscape point of view requires its protection, conservation, recovery and promotion. Its management shall be subject to the principles and guarantees enshrined in the Constitution and shall be carried out in accordance with the territorial ordering and ecological zoning, in accordance with the law.

The perspectives in the medium and long term must be:

- Constitution of the National Network of Germplasm Banks.
- Creation of the National Forest Seed Bank.
- Expansion and consolidation of the Network of Botanical Gardens of Ecuador, with international accreditation.
- Expansion of the production of Certified Seeds, with the aspiration of becoming an export item.
- To have a system of updated maps of the diverse seed sources of the country, its technical, climatological and edaphological characterization.
- Sufficiency of financing, via governmental, non-governmental budget and/or self-financing, to the system of production and conservation of forest seeds.
- Installation of orchards and/or seed stands in strategic places in the country.
- To design training strategies for the management of quality forest seeds, aimed at professionals, producers, forest operators and members of university communities.

CONCLUSIONS

In short, the structuring and operation of a national system for the conservation and production of forest seeds lacks a systemic and integrated character and the production and commercialization of forest seeds, by national entities in the country, is insufficient in quality, quantity and supply opportunity.

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