Reforestation and its role in sustainable development of one community of Luz de América, Ecuador, with eight subtropical plant species implemented

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Abstract. The objective of our social project was to improve agroforestry production systems through the reforestation of multipurpose plant species and to counteract the effects of climate change. Over the course of 24 months (2016–2018), 14,125 trees were planted, reforesting 50 farms in the Luz de América rural parish, Santo Domingo de los Tsáchilas province, Ecuador. The project became an activity integrated into rural communities where 25 community leaders were trained on establishing techniques, planting density, and forest management of several species, such as black and white guayacans, cedar, Honduran mahogany, dyer’s mulberry, Brazilian fern tree, laurel, and Colombian timber bamboo. The leaders were regarded as multipliers of the knowledge acquired on the farms and actively collaborated with the University of the Armed Forces (ESPE). A group of teachers of social engagement, 58 agricultural and livestock engineering students from ESPE, and 151 community beneficiaries carried out data collection and cultural work. At the end of the project, the survival rate of plants was 82.01%, and the total investment was USD 18 thousand. Among the project’s indirect benefits, we can mention an increase in water sources in the area, the control of erosion in degraded areas and steep slopes on farms, mitigation of climate change, and improvement of the economic conditions of the residents.

1 Introduction

Reforestation plays an important role in sustainable development. That is a green path to fight against desertification, reduce deforestation and slow down climate change. Reforestation provides in the same time a wide range of environmental, economic and social benefits. Reducing Emissions from Deforestation and Forest Degradation (REDD) in developing countries is today a fashionable abbreviation in environmental education classes and, of course, on the front pages of many newspapers worldwide (Angelsen and Wertz-Kahoun, 2008). It is not an easy task for developing countries to reduce carbon emissions caused by deforestation and pollution, all of which constantly influence climate change (Gibbs H., 2008).

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Deforestation, forest degradation, and environmental emissions are undoubtedly latent problems in South America (Bautista et al., 2023). Despite current regulations at the local and regional level, the average annual gross deforestation in Ecuador between 2008 and 2016 amounted to 96,135 ha/yr (MAE, 2015; Castillo-Vizuete and Chavez-Velasquez, 2022). The principal motivation for felling has been the expansion of the agricultural frontier (Wunder and Alban, 2008). The intensive production of commercial plant species, such as pineapple and African oil palm, has generated profound changes in the Ecuadorian ecosystem (Kovacic and Viteri, 2017). In the mid-19th century, African oil palm production deeply impacted agricultural production and land use in Santo Domingo de los Tsachilas province (Montufar et al., 2018). Cultivation of palm and other plant species employs intensive methods, which are the first cause of deforestation, biodiversity loss, soil erosion, high greenhouse gas emissions, and water pollution (Angelsen and Wertz-Kanounnikoff, 2008; Andrade et al., 2023).

Forest cultures, also called carbon sinks, have played a fundamental role in strategies and negotiations on climate change and are undoubtedly the axis of strategies to limit atmospheric concentrations causing the greenhouse effect, described in the Kyoto Protocol (Bäckstrand and Lövbrand, 2006). The ESPE social engagement projects not only help young students to get involved and generate an impact in the community; they are also a means for the creation of new jobs and the organization of educational seminars and workshops; they provide supplies and capital to farmers, connect community members and introduce new technologies (Bruning et al., 2006, Daneri et al., 2015).

Conservation and natural resource management activities led by the academy and executed jointly with indigenous groups substantially improve human and environmental rights (Castro and Nielsen, 2001; Wilson, 2002). The project described in this paper was carried out in the rural town of Congoma, on the Santo Domingo–Quevedo road, 14th km. The community members involved live on 50 farms in the region. Since its conception, the project has sought to generate scientific, social, economic, political and environmental impact (Tab. 1).

<table>
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<tr>
<th>Table 1.</th>
<th>Matrices of expected impact with the framework of the social engagement project</th>
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<tr>
<td><strong>1. Scientific impact</strong></td>
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<td><strong>2. Social impact</strong></td>
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3. Economic impact

Ecological economy. Energy, resources, waste, ecosystems, and biodiversity have an impact as well as an economic value (Rilovic et al., 2022). By diversifying farms with annual and perennial crops, productivity increases with different components and elements. Farmers’ economic income improves in medium, short, and long terms. Moreover, complementary activities such as buying and selling as well as processing make the regional and national economies more dynamic.

4. Political impact

The production and protection systems implemented in the agroforestry area have political consequences since the opening and maintenance of roads for the transportation of supplies, the establishment of forest species, and harvesting their crops requires the involvement of the political system. The project implementation motivates the application of regulations for the protection of water sources, soil, flora, and fauna. It also generates an interest in training on sustainable management issues and international accreditation for farms and their owners.

5. Other: environmental impact

The implementation of forest species in different agroforestry arrangements or designs, along with those established in water sources and degraded lands, leads to tangible and intangible benefits from those species to improve the environment. Implementing native species in the project can mitigate the effects of climate change, capturing CO₂ and releasing oxygen, binding particles, stabilizing the soil, and enhancing the flora and fauna.

2 Materials and Methods

Fig. 1. The geographic location of the study area.

Elevation 327 MSL
HR 91%
T° annual average 24 C
Average annual precipitation 2518 mm

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Four teachers from the Life Sciences department and 58 fourth-year agricultural and livestock engineering students participated in the project on behalf of the ESPE. They spent a minimum of 160 hours of fieldwork per person in the whole project. Additionally, the ESPE contributed USD 16,500, invested over the 24-month period that the project lasted. The money was spent in transportation, farm equipment, theoretical and field training, laboratory analysis, field analysis, seedlings, and supplies.

One hundred and fifty-one people, both men and women, participated voluntarily in the Congoma commune. They live permanently in the area spread across 50 farms. The community members contributed USD 1,500 during the 24 months of the project. The money was spent in transportation, farm equipment, fertilizers, fungicides, farm work, and other expenses related to the project.

Species choice. The project work extended over 59.62 ha (50 farms). According to the literature, 24 species are reported to bear fruit between February and June (Ochoa-Gaona, 2008). Of these, 8 species were chosen after a closed survey conducted among the 50 farms, in which people were asked to rank 10 species by their relevance. To begin the reforestation, seedlings produced from cuttings were acquired at the ESPE facilities. The seedlings were of the following species: black guayacan, white guayacan, Honduran mahogany, dyer’s mulberry, Brazilian fern tree, laurel, cedar, and Colombian timber bamboo. These species have historically shown good adaptative abilities in this area. They provide a habitat for endemic animal species, which need them for their development and survival (GAD, 2018).

Depending on the dominant tree species, plantations were divided into five categories: boundary, forest, protection, agroforestry, and mixed.

Temporality. The purchase and shipment of seedlings from the ESPE Santo Domingo campus was authorized on February 5, 2016. They were transported to the collection center and Congoma community house. Before sowing, the soil was prepared by community members, and the seedlings were quarantined for 10 days. After this period, the seedlings that showed visible damage were rejected and sowing was carried out.

 Evaluated variables. The following variables were evaluated: average seedling growth rate (cm/week), annual difference in diameter (only in timber species), and percentage of seedling survival, following the recommendations of Pérez-Hernández (Pérez-Hernández et al., 2011).

3 Results

<table>
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<th>Planted Species</th>
<th>Common name</th>
<th>Scientific name</th>
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<tr>
<td><strong>White guayacan</strong></td>
<td>Tabebuia donnell-smithii rose</td>
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<tr>
<td><strong>Black guayacan</strong></td>
<td>Tabebuia billbergii</td>
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<td><strong>Cedar</strong></td>
<td>Cedrela odorata</td>
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<td><strong>Honduran mahogany</strong></td>
<td>Swietenia macrophylla</td>
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<td><strong>Dyer’s mulberry</strong></td>
<td>Macluratinctoria</td>
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<td><strong>Colombian timber bamboo</strong></td>
<td>Guadua angustifolia</td>
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<td><strong>Brazilian fern tree</strong></td>
<td>Schizolobiumparahyba</td>
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<tr>
<td><strong>Laurel</strong></td>
<td>Laurus nobilis</td>
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As for the type of plantation established, the main one is the boundary, with 50% of the total number. The reason is that community members usually rely on forest species to demarcate their properties. The second place corresponds to mixed plantations (28.13%), which are established as ornamental and forestry barriers, thus being of great importance for farmers. Also, 12.5% indicate that forest species are used as protection means to avoid erosion or other alterations in the ecosystem. The percentages for forest and agrosylviculture forestry (Agroforestry) were 1.56% and 3.13%, respectively.

Mortality percentage for transplanted species Fig. 3.

The incidence of light encourages the vegetative growth of newly planted seedlings. Efforts should be made to remove pernicious weeds and select places without secondary vegetation (Bäckstrand and Lövbrand, 2006).
The mortality total by plant development was significantly different ($f=5.04$, $p<0.21$). Regarding the mortality variable, cedar was the forest species with the highest percentage of mortality, namely, 89.8%. This occurred due to a lack of care for this species, which was mostly overgrown with pernicious weeds. Weeds compete with the young plant for nutrients, water, and sunlight, which can hinder its growth and eventually cause its death. Another factor that contributed to cedar's high mortality rate was the lack of concern on the part of farmers; some plants they had requested were not transplanted and were left somewhere on their properties. Dyer’s mulberry showed the lowest mortality, with 18.2%. The average mortality for all the species was 35.9%, which we considered acceptable.

The average height and diameter of plants

![Height of assessed plants (m)](image)

**Fig. 4.** Figure 4 depicts the growth in height achieved by different forest species delivered to farmers of Middle and Small Congoma. Honduran mahogany was the species with the largest height value, namely, 4.06 m, followed by the black guayacan with 3.70 m and white guayacan with 3.20 m. The least developed plants, with heights less than two meters, were cedar (1.93 m) and Colombian timber bamboo (1.87 m).

![Diameter of assessed plants (cm)](image)

**Fig. 5.** Figure 5 shows the growth trend of each forest species from the first data collection, which was from October 16, 2017, to April 3, 2018. Laurel, with an average diameter of 0.95 cm in 2024, is depicted.
Causes of plant death

Fig. 6. Causes of death of plants delivered to beneficiaries.

According to Figure 6, the main cause of death was attack by cutting insects (ants), which amounted to 24% of dead plants. The second cause, with 16%, was lack of care, which caused dehydration of plants by the time they were planted in the field. The third cause of death, with 12%, was underwatering. The fourth cause, with 8%, were overwatering, herbicide damage, animal damage, fertilizer issues. The following cause of death, with 4%, were planting errors, fungi attack, bacterial pathogens and nematodes that attacked plant roots. These were the most significant causes of death.

4 Conclusions

Ecuador has a long history of forest clearing. On a national scale, some environmental institutions have doubts about where Ecuadorian official greenhouse accounts accurately show the impact of forest clearing until 2023 (Kleemann et al., 2022). That’s why it is necessary to introduce an international wide monitoring system based on research field and satellite systems.

In order to improve socio-economic conditions of the rural population, focus of reforestation must be on restoring critical ecosystem functions and services, rather than attempting to restore the forest structure to some historical point (Ivetić V., 2019).

Much of the Luz de América area has never been reforested before, but a significant minority is intact forest, which is a deeper store of CO2. It is obviously that we need to protect this region and the full province to avoid an unfolding environmental crisis.

The reforestation project in the Congoma rural parish has enjoyed remarkable acceptance, with around 34 families participating in it. They received the plants, planted them and, for the most part, have taken good care of them, which is reflected in plant growth, diameter, and survival rate. Dyer’s blueberry and white guayacan showed the best adaptation in the area, while cedar was the species with the highest mortality rate.
experience to respond to concerns of all kinds, not only in matters of reforestation and forest management but also of a humanistic nature, serving in a special way to vulnerable groups such as the disabled and the elderly.

During 160 hours of internship, the participating ESPE students (58 in total) strengthened their knowledge in the field, solved technical and personal problems, and had an opportunity to socialize with rural communities. They learned and shared cultural works altruistically from the beginning of the project and have undoubtedly acquired a pre-professional experience that will mark their future as national leaders.

We recommend increasing the area of influence of the ESPE project by inviting other rural farms of Luz de América to participate and signing agreements with the Decentralized Autonomous Government of Ecuador (GAD) of Santo Domingo to propagate reforestation strategies in the Tsáchila province.

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