forests

Communication

Restoring Degraded Forest Land with Native Tree Species: The Experience of "Bosques Amazónicos" in Ucayali, Peru

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Abstract: The case is a private initiative in Peruvian Amazon reforesting with native tree species on degraded lands for timber and carbon purposes. By 2018 around 870 hectares have been reforested and additionally 124 hectares are being restored through protection measures and assisted natural regeneration. The paper describes the local context and project design, the technical and social aspects of project implementation, the outcomes and challenges after 12 years, including some reflections on success factors, lessons learned and implications for other forest landscape restoration (FLR) projects.

Keywords: Peruvian Amazon; forest restoration; timber plantations; carbon certification

1. Introduction

A degraded forest land can be defined as "former forest land severely damaged by the excessive harvesting of wood and/or non-wood forest products, poor management, repeated fire, grazing or other disturbances or land-uses that damage soil and vegetation to a degree that inhibits or severely delays the re-establishment of forest after abandonment" [1]. As such, degraded forest lands are characterized by a lack of forest vegetation (though single or small groups of pioneer trees and/or shrubs may be present); low soil fertility; poor soil structure (including soil compaction, waterlogging, salinization or other physical and chemical limitations); soil erosion; recurrent fire and increased susceptibility to fire; severe competition especially from grasses and ferns; and a lack of suitable micro-habitants for seed germination or establishment [1,2].

Forest restoration is a management strategy applied in degraded forest areas [1]. The term forest landscape restoration (FLR) has gained global acceptance recognizing the need to have a landscape approach. FLR is broadly defined as "a planned process that aims to regain ecological integrity and enhance human wellbeing in deforested or degraded landscapes" [3,4].

Forest restoration can restore many ecosystem functions and recover many components of the original biodiversity. Approaches to restoring functionality in forest ecosystems depend strongly on the initial state of forest or land degradation and the desired outcome, time frame and financial constraints [5]. Tree planting is the most common active forest restoration strategy [6].

Forest restoration efforts in some tropical regions are experimenting with mixtures of native and non-native tree species with the goal of enhancing biodiversity and ecosystem services, including sustainable timber production [7].

The Amazon forest, with about 540 million hectares, represents 70% of the total forest area of the eight countries sharing the Amazon Basin. Between 2000 and 2015, the Amazon forest area decreased 0.28% per year (almost 1.6 million hectares); however, the rate of net loss during this period decreased

50%, from 0.46% to 0.23% [8]. Common causes of primary forest degradation in the region are agriculture, cattle ranching, the logging industry, mining and infrastructure expansion [9].

Past efforts to restore or rehabilitate degraded forest lands in the Amazon region date back to over half a century, mostly carried out at an experimental/demonstration scale and primarily focusing on plantations with commercial exotic and native timber species [10–14]. In the Peruvian Amazon, experiences with forest restoration/rehabilitation have been conducted by government agencies often with involvement of research institutions, and increasingly by smallholders and local communities using tree plantations, agroforestry systems and management of secondary forests [14–18].

The experience initiated in 2008 by the private company Bosques Amazónicos SAC (BAM—http://www.bosques-amazonicos.com/en) in Campo Verde, Ucayali (the Campo Verde Project); reforesting with native tree species on degraded lands for timber and carbon purposes is one of the most well-known projects in the Peruvian Amazon. It is considered a model of good reforestation practices in the Amazon and the first experience of reforestation with native species in receiving the VCS (verified carbon standard) certification [19].

2. Project Site, Structure and Support

The Campo Verde Project is implemented by BAM, a Peruvian private company founded in 2004 specializing in the conservation, protection, restoration and sustainable management of tropical forests. Its mission is to maximize the value of Latin American forests, helping to preserve the biodiversity and creating benefits for local communities and for its shareholders.

The project area is private property purchased by BAM in 2004 located on the Campo Verde to Tournavista road, around 34 km from the city of Pucallpa, which is the capital of the Ucayali Region of Peru (Figures 1 and 2).

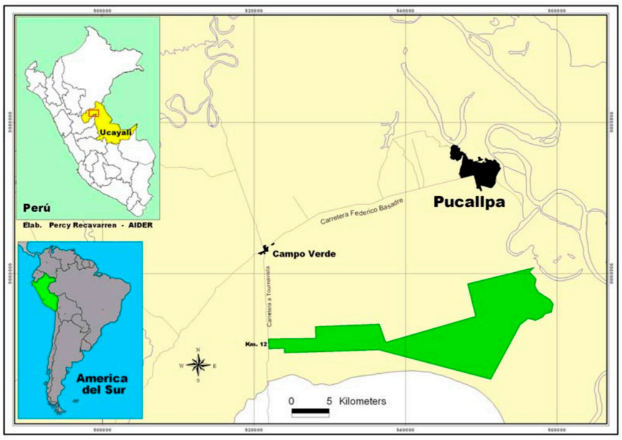

Figure 1. Location of the Campo Verde Project on the central eastern side of Peru.

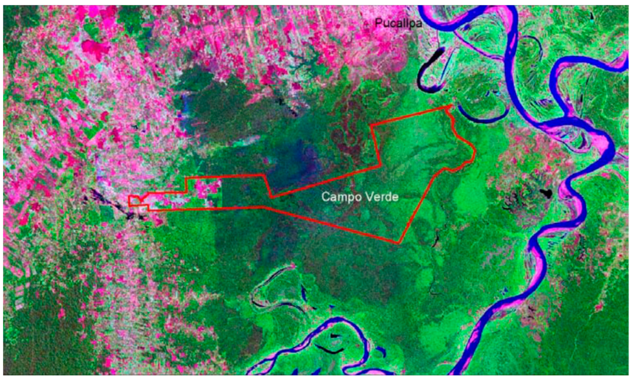

Figure 2. A Landsat image showing the locality of Campo Verde in relation to the town of Pucallpa. Note the deforestation surrounding the project (pink).

The total area of BAM's property in the Ucayali Region is around 18,000 hectares (area of influence of the project) comprising degraded pastureland, wetlands, grasslands and primary and secondary forests. The region is part of the Peruvian Amazon rainforest, with a temperature range between 33 °C (maximum) and 21.5 °C (minimum), average rainfall of 1862 mm per year and located at a maximum altitude of 220 m above sea level. No communities or people live within the project boundary.

The site history in the property reveals a pattern of unsustainable logging and farming since the 1960s. Since the 1980s, the area was cleared in successive stages for cattle ranching. By the mid-1990s, active production on the project land ceased. Continuous fires from neighbouring smallholding plots and soil degradation resulting from overgrazing and soil fragility typical of these areas precluded the natural regeneration of the original forest cover.

An area of 2040 hectares of degraded pastures were targeted for restoration (project area). A biophysical survey carried out in 2005 shows that a very significant loss of biodiversity has already taken place in this area. Eighty-six tree species were identified in the remaining primary and secondary forests, while in the pasture area no more than 15 grass and shrub species were identified and only a few remaining trees.

The total carbon stocks estimated in 2008 for the project area amounts to 4.61 tCO2e/ha, of which 3.87 tCO2e/ha corresponds to existing trees and 0.74 tCO2e/ha to shrubs.

Until reforestation activities commenced, the predominant vegetation cover consisted of various grasses, predominantly the invasive grass, *Brachiaria decumbens* Stapf., covering 62% of total area. Other invasive species include *Imperata brasiliensis* Trin., *Axonopus compressus* Rauh., *Paspalum conjugatum* Bergius., *Pteridium aquilinum* (L.) Kuhn., among others (Figure 3).

Figure 3. Degraded area before the start of the reforestation program.

There are seven small rural settlements neighbouring the property that predominantly work on agriculture and cattle raising activities to cover their subsistence needs. The average size of each family's plot is 28 hectares (a typically sized plot in the Peruvian Amazon), almost half of which is dedicated to agriculture or cattle raising and the remainder of the plot is covered by degraded or secondary forest, and degraded lands abandoned after a few years of intensive agriculture use or cattle ranching. On average, each family has a monthly income of US$40, which is just above the national poverty level.

2.1. Project Scope, Goal and Management Objective

The Campo Verde Project encompasses the reforestation of degraded pasture lands, rehabilitation of degraded areas and supporting biodiversity by connecting forest fragments and recreating habitats for wildlife. In addition, the project aims to build local capacity in sustainable forest management and low impact logging techniques and avoided deforestation as well as nursery and plantation management. The importance of developing the capacity of families neighbouring the project is not only to generate a more equitable economic development but also to change current unproductive agricultural practices.

The main goal of the project is to develop a forest management system that accelerates the natural successional stages of forest regeneration from pioneer to secondary and finally climax species. In line with this goal, all species chosen were native species, with a combination of fast-growth species and mid-growth hard wood species. The decision to use many species (instead of a monoculture plantation) and to use only native species (instead of exotic ones) has the goal of trying to replicate the original forest of the area in order to recover the original rainforest as much as possible and the fauna of the area (by attracting the fauna that had to migrate given the loss of their natural habitat).

BAM's management and business model considers a strategic planning process with baseline diagnostic studies and silvicultural operations to deliver the final products, community development activities and strategic alliances to improve or develop production protocols (such as the phytosanitary control) for basic studies of plant production (cloning, etc.), monitoring and research as well as product processing and commercialization (Figure 4).

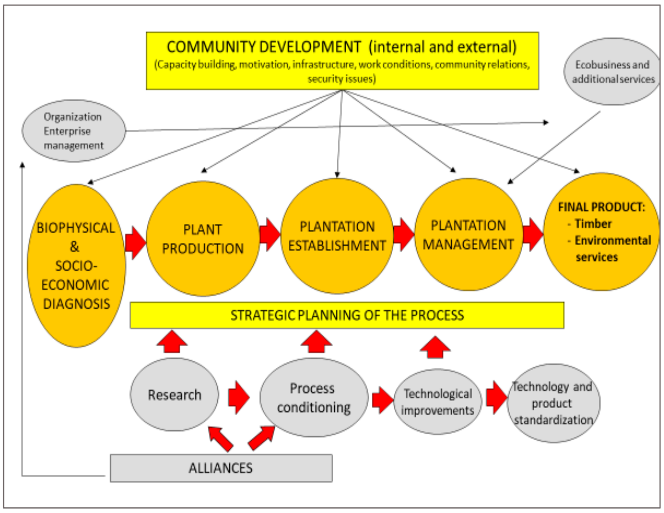

Figure 4. BAM's management and business.

The forest management plan prepared for the project area for the period 2008 to 2012 set the objective to reforest approximately 930 ha of degraded pasture and carry out enrichment plantings in approximately 268 ha of secondary forest in order to derive income from the sustainable harvest of timber for the domestic market and CO2 sequestration from these plantings. (In 2008 the project became a verified carbon standard (VCS) afforestation/reforestation (ARR) project under the CCBA—climate, community and biodiversity alliance [20]. The project achieves greenhouse gas emission reductions through reforestation of native tree species on land that was degraded due to cattle ranching, as well as through natural regeneration [21].).

At the start of the project in 2007, the project proponents were SFM-BAM (as BAM was originally called) as the owner of the land and the environmental rights; SFM Ltd (a British company that develop several projects of reforestation and forestry management around the world. In 2009, SFM Ltd transferred its position, rights and obligations to Asterix Ltd.) as a shareholder of BAM, the financier of the project and the carbon program manager; and AIDER (Asociación para la Investigación y Desarrollo Integral), a non-governmental organization hired to assess and develop the field activities. Since 2017 the funding for the project comes from private national and regional investors, including (more recently) Andean Crown (through the Andean Fund Sustainable Forest Management—http://www.andeancrown.com/fondo-forestal/).

In 2004 BAM set up an initial experiment in a highly degraded pilot area of 100 hectares covered with invasive vegetation (mainly exotic pasture grasses) to validate its recovery and commercial planting model in degraded areas. The financing for this pilot came from a Peruvian environmental fund—FONAM (Fondo Nacional del Ambiente—Perú.), the Regional Government of Ucayali (GOREU) (Gobierno Regional de Ucayali.) and BAM, with AIDER being the executing entity.

2.2. Project Design

The design and planning of the Campo Verde Project considered a sequence of assessments/studies and activities.

Biophysical assessment for the characterization of the (herbaceous, shrub and arboreal) vegetation, soils and fauna (with emphasis on entomological fauna).

a. Socioeconomic assessment of the zone of influence to gain knowledge and enhance the understanding of the core characteristics and aspirations of the villages and settlements located in the proximity of the project area.
b. Technical proposal design. Preparation of the main components of the proposal (species selection, soil preparation, quality of plants to use according to the dominant vegetation and planting design, spacing, management regimes, etc.) based upon the infield biophysical surveys and analyses, literature review and experts' opinion.
c. Establishment of a central nursery with a production capacity of one million plants per year in polyethylene bags from seed propagation (Figure 5). A traditional substrate of agricultural land in combination with organic fertilizer (compost posture hen excrement) and coarse river sand is used. An average of 35 local people—mostly female labour—were employed, and in some cases the production was outsourced to local producers and farmers' organizations under the protocol and supervision of the company. The irrigation system is by sprinkling with hose in a manual way with strategically located exit points; the shade is high shed or roof with raschell meshes. Seedlings have a traceability from their place of collection to the final planting point.
d. Establishment of the forest plantation. Planting of four native timber species combining fast (*Simarouba amara* Aubl., local name marupa), medium (*Dypterix ferrea* Ducke, shihuahuaco) and slow (*Tabebuia serratifolia* (Vahl) Nichols, tahuarí and *Swietenia macrophylla* King, caoba or mahogany) growing species. In addition, the planting of the nitrogen-fixing species *Inga edulis* Mart. (guaba) with the purpose of ameliorating the soil, suppressing weed growth and providing shade and protection for the timber species (Figure 6). The timber species were planted in various combinations or stand models (see next section).
e. Maintenance and silvicultural practices, designed to reduce the mortality level, maximise growth and yield and mitigate the risk of pests and diseases.
f. Research, carried out directly by BAM or through partnerships with acknowledged research organisations.
g. Monitoring, for carbon marketing purposes (carbon stocks, leakages, emissions) and for the company's management needs in order to assess in a timely way fundamental indicators such as survival, growth rates and unit costs. The monitoring also included environmental and social impacts of the project based on a set of key indicators.
h. Social issues, including the promotion of productive projects with neighbouring communities such as the replication of the plantation model in 20,000 hectares in plots of rural families, and other crops.

Figure 5. Lateral view of the central nursery.

Figure 6. Planting *Inga* sp. and timber species.

3. Project Implementation

3.1. Technical Aspects

3.1.1. Species Selection

The selection of the timber species for plantation was based on local consultation with technical specialists and as a result of site visits to surrounding areas. Information about successful tree species from these sources informed the company's decisions about which species to plant or favour in case of natural regeneration. The selection process was in a large part based on local knowledge about allelopathy, providing information on species interaction and the interplanting regime. Accordingly, information regarding growth rates, spacing, and other inputs were strongly influenced by local knowledge about behaviour of these species in local conditions.

The seeds were all sourced from the remnant native forests and forest reserves in Ucayali, except for mahogany, which was sourced from other areas because it was completely harvested from the region many years ago. Each tree from which seeds were collected was documented and geo-referenced using GPS. Additionally, arrangements were made with local communities living in the vicinity of these seed trees to ensure the seed trees are protected for subsequent seed harvest.

A critical aspect of the model is the use of *Inga edulis*, a leguminous fruit tree that produces guaba, a locally consumed fruit with high demand. This tree was included because of its nitrogen-fixing characteristic in order to enhance the soils in the highly degraded lands of the project area, suppress weed growth and provide initial shade and protection to the timber species. *Inga* is later eliminated from the system as it is outcompeted by the shade of subsequently planted timber species and incorporated as dead biomass adding more nutrients and organic matter to the soil. In the initial pilot experience *Inga* was planted from 6 to 9 months in advance of the establishment of the timber species plantation, but this changed with the first plantations. The results were similar in terms of survival and growth of the planted timber species and saved almost a year of time in the planting scheme.

3.1.2. Plantation Management System

The successful management of information and the scheduling of operations was deemed critical for the design of the plantation management system. Two key components of the plantation management system applied by BAM were:

- The spatial representation of the area using a geographical information system (GIS). The delineation of the management units for reforestation in GIS is illustrated in Figure 7; and

- an attribute database linked to the spatial database and where all information pertaining to particular management units is stored, e.g., species provenance, weed management, site preparation, fertilizer application, etc.

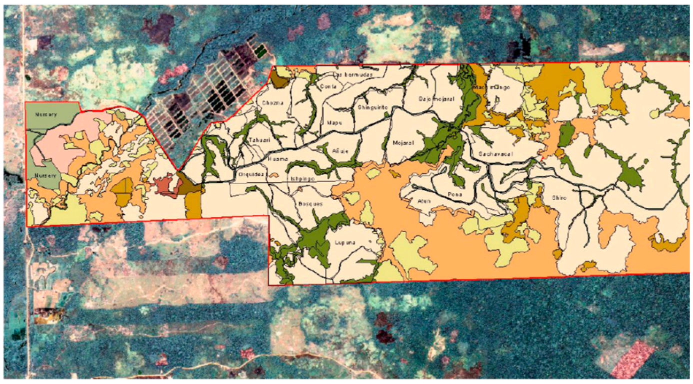

Figure 7. The western side of the Campo Verde Project showing the management units to be reforested.

3.1.3. Nursery Practice

Due to the large volume of seedlings required, the propagation of seedlings was initially carried out under contract to INIA as well as within BAM's nursery (annual production capacity of approximately 550,000 seedlings).

Seeds collected are cleaned, stratified and sown in germination beds. Fifteen days after germination the seedlings are transplanted into 25 × 15 cm polythene bags. The growing medium comprises a mixture of sand, loam and chicken litter. Depending upon the species, nursery duration from germination to seedlings ready for planting out in the field ranges from six to twelve months. Seedlings are graded and only those with a root collar diameter greater than 8 mm and height range 100 to 180 cm are dispatched from the nursery.

3.1.4. Planting Configurations and Regimes

The regimes for the reforestation of the pasture areas and the enrichment planting of the secondary forests are provided in Table 1. This regime is based upon results of the pilot trial as well as other trails carried out by INIA. *I. edulis* is planted at approximately 1111 stems/ha, the secondary forest species *S. amara* at approximately 555 stems/ha, while *D. ferrea* or *T. serratifolia*, both primary forest species, are planted at a stocking of approximately 539 stems/ha, together with a small amount of *S. macrophylla* at 17 stems/ha (this low density is due to the species susceptibility to attack by the shoot borer *Hypsipyla grandella*).

Table 1. The regimes for the reforestation of the pasture areas and the enrichment planting of the secondary forests.

Management Class	Species	Regime 1 (Stems/ha)	Regime 2 (Stems/ha)	Comments
Pasture	*I. edulis* *S. amara* *D. férrea* *T. serratifolia* *S. macrophylla*	1111 555 539 0 17 2222	1111 555 0 539 17 2222	*I. edulis* planted at 3 × 3 m spacing. Six to nine months later and within the rows of Inga the remaining species are planted. Final configuration is 3 × 1.5 m
Secondary forests (juvenile)	*D. ferrea* *T. serratifolia* *S. macrophylla* *C. odorata*	484 0 8 8 500	0 484 8 8 500	Strips 1.5 m wide made every 5 m and trees planted every 4 m
Secondary forests (juvenile)	*D. ferrea* *T. serratifolia* *S. macrophylla* *C. odorata*	296 0 8 8 312	0 296 8 8 312	Strips 1.5 m wide made every 8 m and trees planted every 4 m

In the case of the enrichment planting in secondary forests, in both forest types strips of 1.5 m are cut through the forest undergrowth and trees planted every 4 m. These strips are cut every 8 m for the mature secondary forest and every 4 m for the juvenile secondary forest.

3.1.5. Site Preparation and Establishment

The management regime for the site preparation and establishment of the pasture areas includes the following activities:

Area stratification and delimitation of management units to facilitate management and monitoring of activities (Figure 8). The management units in the project area were connected by a road network duly planned, including bridges and observation towers for fire control.

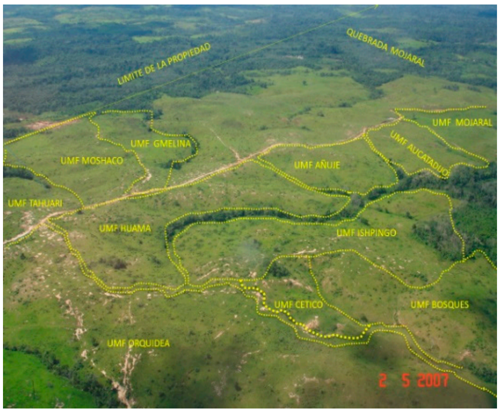

Figure 8. Delimitation of the project area in management units.

Land classification and evaluation. All pasture areas were classified according to various soil types, slope classes, terrain features and levels of weed competition. Based upon this classification the sites were evaluated to optimize silvicultural regimes in terms of soil preparation, weed management, soil nutrition and species choice.

Weed management. The dominant weed that occurs in the pastures is the perennial grass *Brachiaria decumbens*, a particularly aggressive grass. Weed control is carried out using tractor-mounted sprayers (Figure 9). The chemical used is glyphosate and depending on the level of infestation it is applied at a rate of between 4 and 6 L/ha. Up to three treatments may be required to successfully suppress *B. decumbens* competition. The application of the herbicide is done on a "green carpet" of pastures, preventing the product from contacting the soil and impacting the waters.

Figure 9. Application of herbicide in the *Brachiaria decumbens* dominated grass.

Soil cultivation. Once *B. ducumbens* has been killed, the sites are strip-ploughed (approximately 1 m width) using an offset disc plough to form contours or "fish spine" furrows (Figures 10 and 11). The objective of ploughing is to break through any stone lines or compacted soil horizons as well as to promote an even tilth to facilitate planting. In certain instances, because the *B. ducumbens* is so dense, the plough discs get clogged with the grass and cannot penetrate the soil. In these instances, the grass is burnt prior to ploughing. Ploughing is carried out along the contours to retain surface runoff of rain water and prevent soil erosion. Where there is no soil compaction or impedance to root growth, only planting pits are prepared.

Figure 10. Offset disc ploughing of 1 m wide strips along the contour.

Figure 11. Area prepared for plantation using the "fish spine" variation of soil cultivation.

Plant nutrition. Soils are dystrophic, with pHs ranging from less than 4.5 to 5.5 and have high levels of Al, high P-fixation capacity and low organic C content (1.5%). The current fertilizer regime prescribes the application of 1 kg of chicken manure and 100 g of dolomite lime per tree. Based on the best available information and trials with a range of fertilizers, the practice is to add super phosphate (10.5% P) fertilizer at rates of approximately 15 g P (elemental) per tree.

Planting. The dimensions of the planting pits are 20 × 40 cm and are prepared by hand along the plough line. Where no ploughing occurs, pits are 30 × 40 cm in dimension. Trees are removed from the polythene bags and planted in these holes.

3.1.6. Maintenance

Pruning. In order to maximize the value of the high value timber species, green pruning to eliminate lateral branching and corrective pruning to maintain stem form and apical dominance were implemented (Figure 12). Investigations carried out to determine the optimum pruning regime recommended to prune at a frequency that will maintain a knotty core of no greater than 15 cm in diameter and to a maximum height of 5 m, which ensured that two knot-free and consequent high value peeler veneer logs of approximately 2.3 m each can be obtained from each tree.

Figure 12. Pruning equipment to form crown.

Phytosanitary control. To maintain a high phytosanitary standard, the nursery layout was designed to minimize the risk of fungal diseases by ensuring the adequate throughflow of air and rapid drainage of the site. In addition, to avoid contamination, only borehole water is used for the irrigation of seedlings. Daily inspections of seedlings are carried out to ensure a rapid response to any pest or disease.

In the plantation areas, the mixed-species planting configuration is designed to minimize the risk of insect and fungal attack so often experienced in monoculture hardwood plantations in the tropics. In this respect, *S. macrophylla* is planted at a low density to minimize the risk from the shoot tip borer, *Hypsipyla grandella*. Regular phytosanitary evaluations are carried out to determine the presence of key pests and diseases. Plant protection is done using an integrated pest management approach. Native viruses are multiplied in the laboratory for larvae control. Entomopathogenic fungi and bacteria (*Metarhizium anisopliae*, *Beauveria bassiana*, *Isaria fumosorosea*, *Bacillus thuringiensis*) are used as agents for biological control of insects attacking *S. amara* and *D. ferrea* in particular (Figure 13).

Figure 13. Application of entomopathogens in the planted timber species.

Forest protection. Protection measures include the application of environmental strategies for the prevention and control of pests and diseases, the compliance with legal and technical regulations on industrial safety and hygiene, and the involvement of the neighbouring population through good coexistence relations (Figure 14).

Figure 14. Villagers participating in a field visit and demonstration of practices adopted by BAM.

Fire protection. The high relative humidity and rainfall in the Pucallpa area implies that the relative risk of fires and consequent damage to the reforested areas is low. Most of these fires are likely to occur as a result of the burning of pasture areas on neighbouring properties. Nevertheless, the following precautions were taken to minimize the risk:

- Maintenance of 20 to 30 m wide firebreaks along the borders of Campo Verde where pastures occur
- Design of road infrastructure to act as firebreaks
- Maintenance of cordial and co-operative relationships with neighbouring communities
- Training of personnel in firefighting techniques (Figures 15 and 16)
- Provision of firefighting equipment
- Construction of water point s for fire tenders

Figure 15. Organization for fire control.

Figure 16. Participants in a training on control and prevention of forest fires

3.2. *Social Aspects*

BAN runs a community development program with neighbouring villagers to prevent encroachment and contribute to local livelihoods. Neighbouring communities have participated in different training opportunities organized by BAM on topics such as reforestation, integrated pest management, fire control and soil recovery. As part of its commitment to local development, the company has also been active in awareness-raising activities in schools.

Communities surrounding the project are given preference in labour contracting. BAM has provided employment to more than 400 residents in the area in the peak years of plantation. Women made up up to 40% of the labour force in the first two years at the time of the nursery production, decreasing this percentage to around 20% in the years after. Workers benefit from a permanent program set up by the company which includes activities for the integration of personnel and their families.

BAM staff provide on-the-site training and technical assistance to a farmers' organization interested in replicating the experience. The company has also trained an organic producers association providing *I. edulis* plants.

3.3. *Economic Aspects*

The reforestation of degraded pastures in the local conditions at Campo Verde is an expensive business, amounting to around US$7000 per hectare (including all direct and indirect costs). Half of the total cost goes to plant production, site preparation and planting. According to BAM managers, this drops ostensibly with economies of scale and mechanization.

The expected internal rate of return (IRR) for the project is 16% considering the harvesting of *S. amara* at year 12 and the selective harvesting of *D. ferrea* at year 18. When carbon is included, the IRR improves by 1.5%–2.0%.

4. Project Outcomes, Impacts and Monitoring

4.1. *Outcomes*

The project restoration interventions have contributed to the valorisation of 2040 hectares of degraded land through forest plantations and assisted natural regeneration. By 2018 around 870 hectares have been reforested with almost two million valuable native trees (an average plantation rate of

270 hectares/year) (Figure 17). Additionally, 124 hectares are being restored through protection measures and assisted natural regeneration.

Figure 17. *Dipteryx ferrea* and *Simarouba amara* in one of the management units planted in 2008/2009.

The project has achieved greenhouse gas emission reductions through the planting of native tree species on degraded land as well as through natural regeneration (Figure 18). By 2016, 169,000 carbon credits were generated in the carbon market. The price for the first sale of carbon—obtained up to the moment of its evaluation and verification—was US$8 per metric ton and later it was valued at US$9/ton. (There is a projected volume calculation for the life cycle of the plantation of 170,000 tons, which was placed in the national market on two occasions. The first purchase of 10,000 tons was made by aviation company LAN PERU at US$8/ton, while the second purchase of 36,000 tons was made by cosmetics company NATURA at US$9/ton. The balance (124,000 tons) is pending evaluation and verification in the following years.)

Figure 18. Visitors in one of the guided tours to the Campo Verde Project.

The project has fundamentally contributed to reverse a typical pattern of habitat loss, soil degradation and biodiversity impacts with a management regime that recovers soil physical, chemical and biological characteristics and regenerates forest habitats and enhances biological corridors, thus improving the overall biodiversity conditions of the region. Furthermore, the project intends to establish mahogany which is under serious risk of extinction (included in CITES list) because of its over exploitation for many years. An additional benefit is the improvement of water quality and quantity in the Agua Blanca river and other tributaries of the local water system.

The project is generating interest for ecotourism as evidenced by the many visitors to the area (over 2000 people annually), including professionals, producers (small- and medium landholders), interns and students from national and foreign universities.

The Campo Verde Project is currently considered a reference for other companies and landholders interested in the business of planting native tree species in deforested/degraded forest lands. In that sense, BAM has created the building blocks for an "Amazon forestry" through:

- Research work in alliance with universities and public and private institutions;
- training opportunities offered for near 3000 undergraduate students through pre-professional practices, internships and thesis preparation;
- the development of plant material for technological and genetic improvement of future native tree plantations; and
- professional specialization in new areas of forest restoration such as: Weed management, integrated pest management, pruning, fertilization and environmental services (carbon credits).

BAM has received a number of awards:

- Gold level certification by the Climate, Community and Biodiversity Alliance (CCBA), in recognition of its effectiveness in mitigating climate change and promoting biodiversity and sustainable development
- 2010 National Renewable Natural Resources Eco-Efficiency Business Award by Peru's Ministry for the Environment and Universidad Científica del Sur (Figure 19)
- First place at the National Contest "Good Practices on Restoration of Degraded Areas" organized by the Peruvian Forest Service (SERFOR) and the FAO in 2016

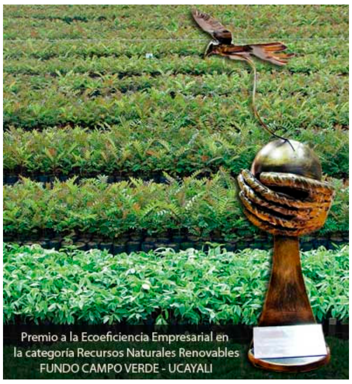

Figure 19. Eco-Efficiency Business Award.

4.2. Monitoring

BAM is implementing a monitoring plan directly and through its relationship with AIDER. The monitoring system developed by AIDER includes the following components and issues: Carbon stocks (removals, emissions, boundaries, leakages), nursery, plantation (costs), labour and environmental and socioeconomic impacts. The monitoring proposal also describes the flow of information between different areas of the involved institutions. The results of monitoring are used to adjust project research and development priorities and action.

As part of the environmental monitoring in the baseline it was possible to determine: (i) An increase in the water flow of courses that come from the plantation; (ii) the improvement of soil layers in horizon 0; (iii) an increase in soil macro fauna; and (iv) abundance of wildlife in the plantation.

BAM has developed standard operating manuals for all components that require monitoring over time. These manuals inform newer team members of the procedures required for implementation of all project activities. Where needed, the manuals will be updated based on lessons learned during the project.

To monitor tree growth and yield as well as to develop growth and yield models, permanent sample plots (PSPs) have been laid out in the management units.

4.3. Knowledge Dissemination

There is an organized flow of information and feedback that guarantees that relevant information is being documented completely and permanently, and guarantees this information is known in a timely manner and communicated to the decision levels required.

Periodical internal workshops are convened to discuss issues that arise during the implementation of the project. These workshops allow knowledge dissemination and "lessons learned" from on the ground experience in the project and are used to introduce changes in project implementation.

5. Challenges

During the development of the project some drawbacks occurred, e.g.:

- Difficulties in following an orderly and sequential establishment of the plantations due to encroachment by some villagers from neighbouring settlements;
- low availability of planting material with known origin (seed trees);
- low supply of skilled human resources;
- poor availability of machinery for land preparation; and
- high costs for the control of invasive weed species.

Thinnings were not foreseen in the contractual arrangement with CCBA project documents and therefore were not allowed (this problem has not been overcome yet). However, thinning is badly needed. BAM plans the following regime for the two leading timber species:

- For *S. amara*: Thinning at year 4 and harvesting at year 12
- For *D. ferrea*: Thinning at year 8 (to a spacing of 6 × 6 m or 8 × 8 m if it was planted at 4 × 3 m) and harvesting at year 18 or being left until year 30, depending on the wood quality at that age

In site preparation work was done on level curves leaving pastures in strips and applying the herbicide before the grass came to fruition. Today BAM has ruled out the contour lines because it makes the operation of the machinery very difficult and generates problems for the light management of the species to be planted, according to the design. Instead, a "fish spine" form was adopted (Figure 11).

The application of integrated pest management practices is limited by the lack of a market chain with the local suppliers in the region.

The choice of *T. serratifolia* was not suitable for the expectations in terms of growth rate and is now discarded, at least as part of the plans for further plantations.

There were some problems due to the increase of fauna in the area, mainly añuje (*Agouti paca*) (Figure 20) and carachupa (*Dasypus novemcinctus*) as it attracts trappers from the communities. BAM is offering them a quota to extract fruits from the palm *Mauritia flexuosa* (aguaje) in exchange for helping protect the fauna.

Figure 20. *Agouti paca* populations have increased in the project area.

Water monitoring has not been able to continue due to recent financial restrictions.

A restriction for the efficient and sustainable management of commercial-scale plantations is the limited offer of professionals willing to work under the prevailing conditions in the region (e.g., job stability, education).

In the past two years BAM has faced financial constraints which are about to be partially solved thanks to the incoming of a new financial partner.

Another challenge being faced by BAM's project is the near lack of support from regional (the Government of Ucayali—GOREU) and national (the Wildlife National Service—SERFOR) government authorities.

6. Reflections on Success Factors, Lessons Learned and Implications for Other FLR Projects

6.1. Reflections on Success Factors

The Campo Verde Project is a successful case in the prevailing context of the Peruvian Amazon, constituting a replicable reforestation model for its use of local valuable species, intermediate technology, simplicity of operations, integrated pest management program and compatibility of integral systems. The use of local knowledge about soils, species interactions and the appropriateness of species selection as well as the institutional alliances (with AIDER, INIA, SENASA) were also important for the success of the experience

Other companies and producers in the Ucayali region are replicating the model based on their interests. BAM generated expectations with the species used, allowing the regional government, NGOs, companies and small-scale forest producers to replicate the project. While the local government failed in its attempts due to deficiencies in producing quality plants suitable for the targeted degraded areas, large companies with their own investment were in general successful, though some experienced phytosanitary problems which caused them to stop working with *Simarouba amara*. The NGO Plant Your Future has improved the replication considering all the social and technical components.

Key factors that appeared to have contribute to the success of the Campo Verde Project include:

- Private investors' decisions in a high-risk activity.
- Efficient plant production in nursery. (This is exemplified with the case of *Inga edulis*. Instead of the pre-plantation of *I. edulis* and having to wait a year to plant the timber species, both are planted at the same time. With that, *I. edulis* can stay more time in the nursery (up to nine months), so taking more robust plants to plantations which can quickly occupy the area and provide the desired growing conditions for the timber species. The best nursery production reduces planting density—by one third, from 1111 to 832 plants/ha—and reduces one year of operation.)
- Continuous improvement of the technology for soil preparation, plant production and plantation management based on strategic alliances.
- Adoption of a working schedule geared to reduce costs and be sustainable.
- Development of skills based on in-service knowledge transfer from senior professional staff to junior professionals selected from pre-professional practices performed in the company
- Effective monitoring and evaluation system.
- Constructive relations with local communities.

6.2. Lessons Learned

The continuous research and knowledge management that are part of the company's operation has helped the project to learn lessons, such as:

- ◦ The choice of species should be made on the basis of a biophysical diagnosis.
- ◦ The use of *Inga edulis* to recover degraded areas has proved to be a success in the plantation model.
- ◦ The accompaniment to the planted species through the regrowth or natural regeneration left on site is critical. (It remains to compare the accompaniment of natural regeneration with plantation

areas where such accompaniment is not present. The reduction in volume per area can be compensated with a reduction of the investment in weeding, pruning and control of pests and diseases, ensuring the sustainability of the plantation over time.)

- The cutting of lianas or other creeping plants is essential.
- To ensure quality final products from the forest plantation the origin of the planting material and its traceability is of utmost importance.
- Soil cover with legumes has proved to be an efficient way of biological control of weeds, notably with *Desmodium ovalifolium* (Figure 21) (low-cost establishment, persistent, non-aggressive, supporting shade in plantations, lignified stem and high contribution of biomass) to be introduced in the system at the third year.
- The best method of pest control in a mixed native species forest plantation is biological control with the use of entomopathogens.
- The establishment of biological corridors that provide alternate hosts and shelters to parasitoids is a good option to maintain the balance of harmful insect populations.
- Local participation should be promoted at two levels: Internally, to maintain well trained and motivated human resources, and externally as part of a community development program to approach and raise awareness with neighbouring villagers and communities.

Figure 21. *Desmodium ovalifolium*.

6.3. Prospects

The initial objective of the Campo Verde Project (Figure 22), to produce wood and commercialize carbon, was changed to just focus on the production of wood with native species of fast and slow growth. The sale of carbon was discontinued due to the heavy burden of prerequisites demanded; for that was not compensated by the income received. The company is also considering the processing and commercialization of value-added products from the plantations and the residual forests under management.

Figure 22. View of the Campo Verde reforestation on degraded areas.

Once the area with degraded soils has been restored through tree plantations, BAM plans to carry out inventories of the area covered by remnant high forests and secondary forests, prepare the operational management plans, taking advantage of what can be sold of residual trees and secondary forest trees (such as *Croton matourensis*—auca atadijo) and then enrich it by 40% of the area using strips 30 m wide.

There are important gaps of information on taxonomy, silviculture and technological properties of several forest species that need to be prioritized to maximize the efficiency, yield and impact of forest plantations and remnant primary and secondary forests. The genetic improvement of the planted timber species is also an area in need of attention, particularly for *D. ferrea*. The increasing interest in reforesting with native timber species experienced in the Ucayali region and elsewhere in the Peruvian Amazon will demand large amounts of quality seeds which will be a most critical limiting factor for upscaling.

A much-needed policy and institutional intervention to scale-up the restoration of degraded areas, in particular by smallholders, is the granting of start-up incentives mainly by ensuring reliable technical assistance with well-trained personnel, and by providing good quality planting material as a credit to be paid with timber sales. The replication of the BAM model in small-scale producers requires working under the agroforestry model and with farmers who directly cultivate their plots. Producers evidencing good results with their restoration interventions could be encouraged, for example, by reducing their taxes or helping them formalize their land rights.

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