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Economic Feasibility of Tropical Forest Restoration Models Based on Non-Timber Forest Products in Brazil, Cambodia, Indonesia, and Peru

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Abstract: Mobilizing funds is a major challenge to achieve scalable Forest Landscape Restoration projects. While pure ecological restoration may not be a feasible investment from the private perspective, combining native species with non-timber forest products (NTFP) species may be a solution for reaching large scale and financially sustainable forest restoration. This study addresses potential species combinations for 12 restoration models, three models being based in pure ecological restoration and nine models being based on agroforests with NTFP, their economic costs, and benefits in tropical forests in Brazil, Peru, Cambodia, and Indonesia. A total of 12 semi-structured interviews were conducted to capture the models' productivity and prices. As for the prices that the producers did not know, specialized stores were consulted in the cities of the collection. The starting investment to restore 01 hectare (ha^{-1}) of tropical forest ranged between US $104 and $7736, with an average of $1963 ha^{-1} and a standard deviation of $2196 ha^{-1}, considering the 12 cases evaluated in 2018 and 2019. From nine restoration models that had economic purposes, financial indicators showed a median net present value (*NPV*) of $1548 ha^{-1}, and a median internal rate of return of 22%, considering a discount rate of 10%. The *NPV* varied between $−685 ha^{-1} and $55,531 ha^{-1}. Costs of pure ecological restoration were on average 42% lower than agroforestry systems, but did not produce direct income from NTFP, therefore yielding negative *NPV*. The study demonstrated the economic feasibility of seven of nine models that had economic objective, showing that there are promising business cases for private investment in tropical forest restoration.

Keywords: agroforestry; internal rate of return; net present value; sustainable development transformation; value chains

1. Introduction

Restoration of native vegetation is a nature-based solution for absorbing carbon dioxide from the atmosphere [1]. This is essential to keep global warming between 1.5 and 2.0 °C by 2100, compared to the pre-industrial period [2]. In addition, the recovery of native vegetation through the agroforestry system has been identified as an efficient way to generate social and economic benefits [3]. In fact, financial analysis by the International Monetary Fund suggests that investments to protect natural ecosystems have powerful positive effects on the local economy, proving that for every dollar invested in conservation, almost seven more dollars are generated in the global economy in the medium term [4]. Therefore, studies that examine the costs and profitability of agroforestry systems can contribute to the recovery of native vegetation essential for a sustainable economic transition [5].

Restoring degraded ecosystems is a proven measure to combat the climate crisis, improve food security, provide water, and decrease biodiversity loss [6,7]. Forest restoration models vary in terms of management standards and operating costs [8,9]. Planned ecological restoration interventions and natural regeneration are identified as the most efficient ways to act on a large scale to increase biodiversity and vegetation structures in deforested areas [10]. On the other hand, forest restoration with the planting of agroforestry and silvicultural systems that combine agricultural and native plants to recover altered areas have been highlighted for their capacity of generating positive economic returns and long-term financial sustainability [11–13]. Notwithstanding, only 2.5% of scientific studies have addressed the economic aspect of forest restoration [14], which points to a knowledge gap about potential investment returns (costs and revenues) from different restoration methods [15,16].

Depending on the local context, soil conditions, and value chain development, restoration models will have different productivities, implementation costs, and investment returns; items that should be carefully assessed in order to make large scale restoration feasible [17–19]. In addition, it is necessary to simulate and test how forest restoration systems can function at a large scale in a value chain perspective, considering their long-term financial sustainability [20]. The development of national Forest Landscape Restoration systems can be feasible if fundamentals in field observations and scenario building are used [6,21]. Without this knowledge, few producers and investors will take the risk of financing the restoration of degraded areas, especially in regions with high deforestation rates.

This study seeks to understand in which contexts forest restoration can be economically viable. The study analyzes 12 of the most promising ecological- and agroforestry-based restoration models that were found in the field in four countries with tropical forests. We compared the costs of pure ecological restoration with agroforestry based on non-timber forest products (NTFP) plant species restoration. The economic analysis presents cash flow models with results such as the internal return rate, net present value (NPV), investment cost per hectare, and benefit–cost ratio. The hypothesis tested by this study is that, with a proper species selection, investment level and technical assistance, restoration models can be financially sustainable (NPV greater than zero, considering a period of 30 years). The confirmation of this hypothesis would imply that these restoration models could attract and pay back private investors and landowners, therefore being able to be scaled up if market conditions remain constant.

Understanding economic aspects is important for planning investments and managing the post-implementation stages of forest restoration [14]. Approaches that consider a larger number of countries can provide a broader understanding of the factors associated with return of investments aimed at restoring tropical forests. Such studies are especially relevant because the availability of NTFP has been reduced as both deforestation and climate change advance on tropical forests [22] and compromise the productivity and geographic distribution of plants [23,24]. For this reason, studies like this can serve to assist forest dependent communities (for example: Indigenous Peoples, riverine community, smallholder farmers), companies, non-governmental and national organizations, in their efforts to restore tropical forests.

The perspective for native vegetation recovery with NTFP can be approached in two ways: bioresources or bioecological visions [25]. Briefly: the bioresources vision seeks to ensure a source for sustainable raw materials for industrialized products, while the bioecological vision seeks mainly to act against the loss of biodiversity and climate change. Therefore, studies on the costs and benefits of recovering native vegetation with NTFP can benefit people and companies.

2. Materials and Methods

2.1. Study Area

The data used to analyze investments, productivity, and financial indicator initiatives to restore tropical forests were obtained in properties with areas currently undergoing restoration located in Brazil, Peru, Cambodia, and Indonesia (Figure 1). The rural properties were located approximately at the geographical coordinates 07° S and 59° W in Brazil, 11° N and 103° E in Cambodia, 01° N and 99° E in Indonesia, and 06° S and 77° W in Peru (Figure 1).

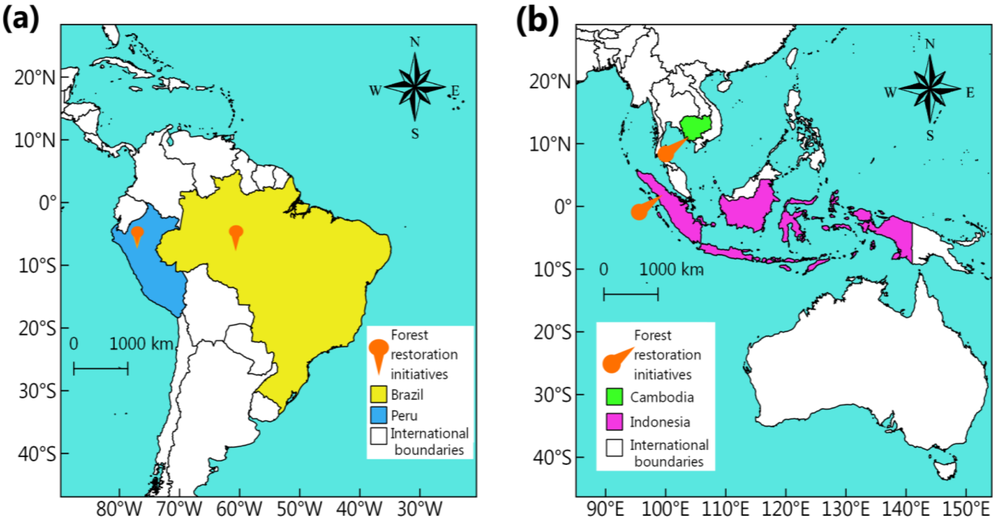

Figure 1. Representation of the study area. The orange pin symbols are close to the forest restoration initiatives visited in 2018 and 2019. (**a**) Brazil and Peru in South America. (**b**) Cambodia and Indonesia in Southeast Asia.

Area selection seeks to provide consistent data sets with information on tropical forest restoration. It is a first step in terms of providing a generalizable picture of this type of initiative's costs and benefits in tropical forests, while also addressing and discussing how local differences can affect species selection and market conditions.

A summary of local conditions, previous land use, original vegetation, soil characteristics, topography, and climate are presented in Table 1.

Table 1. Biophysical characteristics of studied areas.

Country	Region	Previous Use	Topography	Soil	Average Temperature	Average Precipitation (Annual)	Vegetation Type
Brazil	Apuí District (Amazonas)	Agriculture	Flat	Clayey	26.3 °C	2193 mm	Tropical rainforest
Cambodia	Ou Baktra	Forestry and agriculture	Flat-Gently rolling	Clayey	27.5 °C	1349 mm	Deciduous forest
	Sre Ambel District (Koh Kong)	Forestry	Flat-Gently rolling	Clayey	26 °C	3459 mm	Evergreen Forest
Indonesia	Tapanuli Selatan District (Peatland and Coastal)	Agriculture (Palm Oil)	Flat	Sandy	25.4 °C	3220 mm	Broadleaf evergreen forest
	Tapanuli Selatan District (Highlands)	Forestry and agriculture	Mountainous	Clayey	25.1 °C	2410 mm	Mangrove
Peru	Gepalacio District (Moyobamba Province)	Agriculture and Livestock	Inclined slope (45°)	Clayey	20.7 °C	2021 mm	Mountain rainforest
	Calzada District (Moyobamba Province)	Agriculture	Flat	Clayey	20.7 °C	2021 mm	Tropical rainforest

Deforestation in these different countries is caused mainly by: a demand in the global economy for protein of animal and plant origins, implementation of highways, illegal land tenure, and weakening of environmental governance in the Brazilian Amazon [26,27]; land concession followed by rapid conversion of forest to commercial agriculture and illegal wood in Cambodia [28]; large-scale oil palm, timber plantations, and conversion of forests to grasslands in Indonesia [29]; expansion of road infrastructure, gold mining, and agricultural production in Peru [30].

2.2. Forest Restoration Initiatives

Forest restoration initiatives studied were implemented with both ecological and economic purposes (Figure 2). For the sake of comparison, pure ecological restoration initiatives were also assessed, such as introducing seeds of native species to sow the soil and promote the revival of the forest, which yielded no positive economic return for the restorer. Therefore, the productivity and financial results of these initiatives were not presented in this study. On the other hand, some forest restoration initiatives have combined native tropical species with other fruit, timber, herbaceous, vegetable, or agricultural species to harvest roots, leaves, stems, fruits, and seeds with economic value (Table 2). In both situations, the forest restoration initiatives changed physical aspects of the area, filled with vegetation vertical strata of managed forests in areas that were abandoned or underutilized, serving to protect the soil from erosion and desiccation. Thus, twelve initiatives were analyzed, nine aimed to generate positive financial returns, and three had no economic expectations. The list of the main species found in the forest restoration initiatives studied is presented in Table 2.

Information on the main species found in forest restoration models (Table 2) was obtained from specialized sources [31–33]. Plants such as acai berry, banana, coffee, cocoa, coconut, ginger, and mangosteen, for example, provide important agricultural products with benefits for human health [34–40].

Table 2. Information relevant plant species in forest restoration initiatives surveyed in four rainforest countries in 2018 and 2019.

Country	Popular Name	Scientific Name	Botanic Families	Characteristics	Height (Meters)
Brazil	Acai berry	*Euterpe oleracea* Mart.	Arecaceae	Palm	3–20
	Banana	Musa X paradisiaca L.	Musaceae	Arboreal herbaceous	3–7
	Cocoa	*Theobroma cacao* L.	Malvaceae	Tree	4–6
	Coffee	*Coffea canephora* Pierre	Rubiaceae	Large shrub or shrub	1–4
	Guarana	*Paulinia cupana* Kunth	Sapindaceae	Scandant or climbing shrub	1–10
Cambodia	Bamboo	*Bambusa* sp.	Poaceae	Tufted tinyculms	2–3
	Ginger	*Zingiber officinale* Roscoe	Zingiberaceae	Rhizomatoza herb	0.5
	Lemon grass	*Cymbopogon citratus* (D.C.) Stapf	Poaceae	Herb	0.6–1.2
	Peanuts	*Arachis hypogaea* L.	Fabaceae	Herb	0.5
	Rattan	*Calamus rotang* L.	Arecaceae	Climbing palm	10
	Turmeric	*Curcuma longa* L.	Zingiberaceae	Rhizomatous herbaceous	0.4–0.8
Indonesia	Coconut	*Cocos nucifera* L	Arecaceae	Palm	30
	Durian	*Durio zibethinus* L.	Malvaceae	Tree	12–28
	Ketapang	*Terminalia catappa* L.	Combretaceae	Tree	15–25
	Mangosteen	*Garcinia mangostana* L.	Clusiaceae	Tree	10–20
	Sea cypress	*Casuarina equisetifolia* L.	Casuarinaceae	Tree	10–20
Peru	Cocoa	*Theobroma cacao* L.	Malvaceae	Tree	4–6
	Coffee	*Coffea arabica* L.	Rubiaceae	Large shrub or shrub	1–4
	Guaba	*Inga edulis* Mart.	Fabaceae	Tree	10–15
	Jacaranda	*Jacaranda copaia* (Aubl.) D. Don	Bignoniaceae	Tree	20–30

Figure 2. Examples from studied areas: (**a**) Cambodia; (**b**) Peru; (**c**) Indonesia; (**d**) Brazil.

2.3. Data Collection and Analysis

Field data collection took place in August 2018 in Brazil and August 2019 in Cambodia, Indonesia, and Peru. Data were collected through semi-structured interviews with landowners and farmers. Additional cost information, such as technical assistance and specific costs related to restoration inputs, such as fence installation, were collected through semi-structured interviews with local forest technical assistance, local agricultural equipment companies, and specialized stores in the cities. To demonstrate this, a questionnaire applied in data collection is presented in the Supplementary Materials (Table S1).

The interviews were conducted in 1 h, and additional data were collected in guided visits to the restoration sites, which took 3 h. Also, one producer was interviewed for each model, totaling 12 interviews. The interview data were used to capture the farmers' expected productivity and price changes over time. In cases where producers were unable to determine prices, specialized stores in the cities were consulted.

Information on the productivity, income, production costs and price of roots, leaves, seeds, and fruits of the species used in the forest restoration models was obtained from farmers and local markets. Furthermore, survey data were compared with real market data.

As the current restoration initiatives were younger than 30 years, the average productivities and prices were extrapolated and then used to calculate the financial indicators. Finally, the interview data were organized in spreadsheets, which were used as input for the cost-benefit analysis, as similar economic feasibility studies of agroforestry systems [41,42].

The priority areas in each country were selected based on interviews with experts. The selection of restoration models and species were based on interviews with experts and local restorers, following criteria for ecological restoration combined with the perception of most promising sets of species with economic potential given current market conditions. For the analysis, we considered "ideal average conditions", which means the price and productivity data refers to averages found on the field: if one producer on the field had abnormal problems, we did not directly include this in the analysis. As several current models are being improved in a learn-by-doing basis, if an interviewed producer learned that a new species was economically interesting only after some years of trials, we included this species as if it was implemented in the beginning of the model, as soon as ecologically feasible, as an "improved model". The productivity uncertainty was considered in the analysis by asking the amount and the chance to have a high and low productivity for each species.

For each model, we present the species with economic potential of restoration, and a schematic drawing detailing the number of trees and space between them (Supplementary Materials). The economic analysis presents a cash flow for a 30-year period (Tables S2–S13), when all the species' productivities are stabilized, and the forest value is expressed as the NTFP and crops sales in this time frame. Since the data were collected using local currency, the values of the parameters were converted into Dollars considering the 2018 average for Brazil and 2019 average for Peru, Cambodia, and Indonesia. In the Brazil cases, values were adjusted for inflation, using the Extended National Consumer Price Index (IPCA), used by the Brazilian Central Bank and provided by the Brazilian Institute of Geography and Statistics (IBGE), with 1 January 2019 as the reference date [43]. Also, the benefit/cost analysis used a fixed time horizon of 30 years, as used in similar studies [44,45] The financial results are presented using the following indicators:

- The Discount rate refers to the opportunity cost of capital and the investor's intertemporal preferences. It is composed by the sum of a risk-free rate and a risk premium rate—the remuneration that an investor would demand to risk its capital in a business. Therefore, future costs and benefits have a discounted weight in comparison to present costs and benefits in the economic analysis. The discount rate adopted for Brazil, Peru, Cambodia, and Indonesia is a real discount rate of 10%, kept equal for the sake of comparison—even though we recognize that different discount rates may be more appropriate to reflect specific countries' risk rates and market structure. The discount rate adopted was estimated by the WACC (Weighted Average Cost of Capital) for the forest sector in Brazil, which suggests values for the forest sector ranging from 7% to 11% [46,47]. Conservatively, we adopted a 10% discount rate.
- Net Present Value (*NPV*): *NPV* is the sum of discounted cash flows (costs and benefits) of the project over time. The *NPV* represents the net financial surplus after remunerating labor and capital opportunity costs. The equation used was (1):

$$NPV = \sum_{t=0}^{T} \frac{Ct}{(1+r)^t} \tag{1}$$

  where:
  C_t: Net cash flow from $t = 0$ to $t = T$;
  r: Discount rate;
  t: Time periods;

- Internal Return Rate (*IRR*): The *IRR* is a rate that, when applied to a cash flow, makes the sum of costs and benefits to be equal to zero when brought to present value. The equation used to calculate the *IRR* was (2):

$$IRR = \sum_{t=0}^{T} \frac{C_t}{(1+r)^t} = 0 \tag{2}$$

  where:
  C_t: Net cash flow from t = 0 to t = T;
  r: Discount rate;
  t: Time periods;

- Benefit/Cost Ratio: Is the ratio among the total benefits and total costs when brought to a present value. The equation used was (3):

$$B/C = \frac{\sum_{t=0}^{T} \frac{C_t[Benefits]}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t[Costs]}{(1+r)^t}} \tag{3}$$

  where:
  $C_t[Benefits]$: Net income (benefits) from t = 0 to t = T;
  $C_t[Costs]$: Net outcome (costs) from t = 0 to t = T;
  r: Discount rate;
  t: Time periods;

The cost comparison between the ecological restoration models and the agroforestry models was made based on the average results of the models. The results of costs and financial indicators are presented in their original values according to the data and models evaluated. In addition, statistics are presented in terms of mean, standard deviation, and amplitude of results, with the exception of statistics referring to *NPV* and *IRR*, due to the presence of one outlier. For this reason, the overall *NPV* and *IRR* are presented in terms of medians.

3. Results

3.1. Investment to Restore 01 Hectare of Tropical Forest

The investment to restore 01 hectare (ha^{-1}) of tropical forest in Brazil consists of fence installation, specialized technical assistance for planting, and acquisition of seedlings. Investment in fences to isolate the area from cattle in neighboring areas was $1202, considering 400 linear meters of installed structure. The specialized technical assistance was priced at $414 ha^{-1} as the initial cost in year one. Investment in native species seedling was $1000 ha^{-1}. Other costs include acquisition limestone to correct soil acidity and tractor rentals to assist with planting. Starting investments in Brazil ranged from $3041 ha^{-1} to $3365 ha^{-1} depending on the combination of species and planting density (Table 3). The average cost to manage and sell fruit species like acai berry, cocoa, and guarana introduced to restore the forest ranged between $897 and $1229 per year ($yr^{-1}$) (Table 3).

The investment to restore 01 hectare of forest in Cambodia ranged between $1494 and $7736. Technical assistance was priced at $267 ha^{-1} yr^{-1}. The main costs to restore were related with opening holes, technical assistance and acquisition of herbaceous plants (*C. longa*) and rhizomatous herb (*Z. officinale*). Digging holes to plant seedlings involves costs of labor, energy, and equipment rental. These costs have been estimated at $4167 ha^{-1} for the hole for planting turmeric and ginger (model 4). The average cost to manage model 4 was $1420 ha^{-1} yr^{-1}, with the average cost higher to maintain the productivity of species with economic value among the 12 studied initiatives (Table 3). The investment for planting turmeric and ginger were estimated at $1875 ha^{-1} yr^{-1}. On the other hand, the costs of bamboo, rattan, peanuts, and native tree species seedlings ranged from $200 ha^{-1} to $500 ha^{-1}.

Table 3. Investments for 12 tropical forest restoration models found in 2018 and 2019 in four countries.

Country	Models	Popular Name Species	Size (ha^{-1})	Investment (USD)	Investment Per Hectare (USD)	Average Annual Operating Cost Per Hectare in 29 Years after the Starting Investment (USD)
Brazil	1	Guarana	1.0	3365	3365	1229
	2	Coffee, cocoa and guarana	3.0	9124	3041	897
	3	Coffee, cocoa, guarana, acai berry and banana	1.5	5029	3353	863
Cambodia	4	Turmeric, ginger and lemon grass	1.0	7736	7736	1420
	5	Rattan and Bamboo	1.0	1548	1548	224
	6	Seed dispersal (Taungya)	6.0	8965	1494	320
Indonesia	7	Sea cypress and ketapang	2.0	208	104	0
	8	Durian, mangosteen and coconut	2.0	434	217	63
	9	Seed dispersal	1.0	1600	1600	0
Peru	10	Cacao and silvopastoral trees	5.8	2600	448	255
	11	Coffee, cacao, guaba and jacaranda	3.0	620	207	419
	12	Seed dispersal	5.0	2240	448	8

The investment to restore 01 hectare of forest in Indonesia ranged between \$104 and \$1600. Research in the field indicated planting costs of bone cypress and ketapang at \$104 ha^{-1} (model 7) and coconut, durian, and mangosteen at \$207 ha^{-1} (model 8). These tropical species of economic value are intercropped with other native species. The investment for model 9 (seed dispersal) was \$1600 ha^{-1}. This model requires investment of \$1331 for seeds of native species and about \$300 to plant 01 hectare of forest degraded or underutilized.

The main costs to restore forests in Peru were associated with the preparation of the area and technical assistance. The investment to restore 01 hectare of forest in Peru ranged between \$207 and \$448. Model 10 with cacao and native species to restore degraded pastures was priced at \$448 ha^{-1}. Model 11 with cacao and coffee intercropped with native species such as guaba and jacaranda was priced at \$207 ha^{-1}. Finally, model 12 seed dispersal without economic purpose was \$448 ha^{-1} (Table 3).

The pure ecological restoration models without economic purposes were demanding lower investments when compared to models that insert species and techniques to generate economic value to forest restoration (Table 3). Models 6, 9, and 12 were implanted with native seed dispersion (9 and 12) with native planting and sowing legumes (peanuts) to fertilize the soil (6). These models required an average investment of \$1181 ha^{-1} (n = 3). On the other hand, the restoration models with economic purposes based on agroforestry systems (models 1, 2, 3, 4, 5, 7, 8, 10, and 11) had an average cost of \$2024 ha^{-1} (n = 9).

Results showed that the average investment found necessary to restore 01 hectare of tropical forest was \$1963. Costs were higher than the overall average in Brazil and Cambodia, averaging \$3253 and \$3609, respectively. On the other hand, the costs to restore forests in Indonesia and Peru were smaller, \$640 and \$367 on average, respectively. The variation around the mean was high, with an average standard deviation of \$2196. The mean and standard deviation estimates were obtained considering 12 real cases analyzed as restoration methods. Finally, post-implementation costs were lower compared to investments to implement forest restoration. Analyses showed a variation between \$0 yr^{-1} and \$1420 yr^{-1} with an average of \$243 yr^{-1} and \$501 yr^{-1} of standard deviation.

3.2. Productivity of the Main Species of Economic Value in Forest Restoration Initiatives in 2018 and 2019

Among the species studied in Brazil (Figure S1), acai berry presented the highest productivity in the field (Table 4), with estimates of 14 kg of fruit per year, per palm, inserted in the forest restoration. The productivity of guarana was lower, varying between 0.200 and 1.200 kg of dry seeds per year, per bush. Coffee (*C. canephora*) varied between 1.44 and 4.29 kg of dry seeds per tree in its most productive period. Bananas produced an average of 24 kg of fruit in five years after the starting investment. The market prices of NTFP of these species surveyed in Brazil in 2018 ranged between $0.49 and $4.78 per kg (Table 4).

Table 4. Information on plant species with economic value in forest restoration models, with density, type of commercial product, productivity in 30 years, and prices raised in the field 2018 and 2019.

Country	Species (Models)	Plants Per Hectare	Type Forest Product with Economic Value	Average Annual Productivity over 30 Years				Prices in USD (Per Indicated Measure)
				1st to 5th	6th to 10th	11th to 20th	21th to 30th	
Brazil	Acai berry (3)	240	Fruits	970	3400	3400	3400	0.49 (kg) [1]
	Banana (3)	20	Fruits	480	-	-	-	0.62 (kg)
	Cocoa (2)	625	Seeds	240	580	625	625	1.72 (kg)
	Coffee (2)	1666	Seeds	1236	2400	1818	2400	1.34 (kg)
	Coffee (3)	140	Seeds	120	264	171	600	1.51(kg)
	Guarana (1)	667	Seeds	240	400	400	400	4.78 (kg)
	Guarana (2)	333	Seeds	24	60	60	60	4.78 (kg)
	Guarana (3)	417	Seeds	33	120	120	120	4.78 (kg)
Cambodia	Bamboo (5)	356	Canes	0	356	445	445	0.08 (pkg) [2]
	Ginger (4)	27,778	Roots	2812	2812	2812	2812	0.40 (kg)
	Lemon grass (4)	27,778	Leaves	1050	1050	1050	1050	0.28 (kg)
	Rattan (5)	356	Poles/Culms	0	40	40	40	0.28 (pkg)
	Turmeric (4)	27,778	Roots	675	675	675	675	0.40 (kg)
Indonesia	Coconut (8)	16	Fruits	92	405	440	356	0.14 (ud) [3]
	Durian (8)	25	Fruits	0	75	644	0	0.53 (kg)
	Mangosteen (8)	25	Fruits	0	25	329	187	0.36 (kg)
Peru	Cocoa (10)	1111	Seeds	64	650	750	750	2.12 (kg)
	Coffee (11)	2500	Seeds	800	1400	700	700	0.73 (kg)

[1] Kilogram. [2] Package. [3] Unidad.

In Cambodia (Figure S2), model 4, with ginger, turmeric, and lemon grass, required annual plantings to extract roots and leaves with economic value. The yield of ginger roots was estimated at 101 g per herb inserted in the model, being higher than the production of turmeric roots, 24 g, and the production of dry lemon glass leaves, 37 g, per individual, per year. The annual revenue by holes with ginger, turmeric, and lemon grass was estimated at $0.04, $0.01, and $0.01, respectively. The models using bamboo and rattan had low profitability due to low market prices.

In Indonesia (Figure S3), the restoration models with ketapang and sea cypress were not analyzed as species of economic interest due to the low market value of these species in Indonesia. On the other hand, information on the annual productivity of the species coconut, durian, and mangosteen and the prices of NTFP in the local market are presented in Table 4. In the most productive period, annual revenues obtained per plant were $3.85 for coconut fruits, $13.65 for durian fruits, and $4.74 for mango fruits.

In Peru (Figure S4), the selected plant species with economic potential were cocoa and coffea (*C. arabica*). In the period of greatest dry seed production, productivity was estimated at 675 g for cocoa and 560 g per bush per year for coffee. Considering the price of dried seeds in the local market, the revenue generated for each bush was estimated at $1.43 and for each coffee bush it was estimated at $0.41. For the species guaba and jacaranda, information on productivity was not collected, due to the low value of the fruits in the local market.

Field observations indicated that past use of the area under restoration and the experience of the restorer influenced plant productivity. For example, the cases with cocoa and coffee plantations in Peru indicated that the previous presence of cattle, herbicides, and the little experience of farmers with the management of the species may have contributed to lower productivity compared to cases in Brazil. In Peru, the average production of dry cocoa and coffee seeds was 0.67 and 1.26 kg per tree, respectively, while in Brazil the averages were 1.00 and 1.44 kg per tree per year. In all 12 cases analyzed, we included technical assistance costs, given that restorers were inexperienced with forest restoration, being a key element to scale-up these initiatives.

3.3. Income from Forest Restoration Initiatives

Financial indicators for the forest restoration models were generated considering nine of the twelve initiatives studied (Table 5), given that seed dispersal models 6, 9, and 12 had no economic goals. The investments required to implement the restoration methods were shown in Table 3, ranging between \$104 and \$7736 ha^{-1}.

Table 5. Financial indicators generated from investment costs to restore tropical forests in four countries in 2018 and 2019.

Country	Popular Name Species	Models	Size (ha^{-1})	Investment/ha^{-1} (USD)	*IRR* (%)	*NPV*/ha^{-1} (USD)	Benefit/Cost ratio
Brazil	Guarana	1	1.0	3365	10	−78	1.0
	Coffee, cocoa, and guarana	2	3.0	3041	10	113	1.1
	Coffee, cocoa, guarana, acai berry, and banana	3	1.5	3353	15.5	2271	1.29
Cambodia	Turmeric, ginger, and lemon grass	4	1.0	7736	11	497	1.0
	Rattan and bamboo	5	2.0	1548	6.1	−685	0.77
Indonesia	Sea cypress and ketapang	7	2.0	104	22	449	1.66
	Durian, mangosteen and coconut	8	2.0	217	27	1820	3.71
Peru	Cocoa and silvopastoral trees	10	5.8	448	39.6	5261	3,2
	Coffee, cocoa, guaba, and jacaranda	11	3.0	207	206	55,531	5.3

The *IRR* of restoration models varied between 6.1% and 206%, with median of 22%. In a scenario without model 11, which presented the highest value, this median would be 16.5%. In general, *IRR* were lower in Cambodia and the highest in Peru. The models (1 and 6) with guarana in Brazil and rattan and bamboo in Cambodia were the lowest *IRR* among those evaluated. On the other hand, the *IRR* of the models (2, 3, 10 and 11) that included cocoa and coffee among the species were higher, the highest being the forest restoration model with coffee in Peru (Table 5).

The *NPV* per hectare varied between \$−685 and \$55,531. The restoration models with highest *NPV* were those with combinations of acai berry, cocoa, coffee, durian, guarana, mangosteen, and coconut species (Table 5). Regarding the hypothesis tested in this study, 7 of the 9 models assessed presented *NPV* greater than zero (Table 5). Therefore, results corroborate the hypothesis that forest restoration models can be economically feasible in tropical regions.

The benefit/cost ratio of forest restoration models with economic objectives ranged between 0.77 and 3.71 (Table 5). The restoration model 5, which includes the species rattan and bamboo, was less than 1. The benefit/cost ratio indicators were higher for model 8 which used durian, mangosteen, and coconut in Indonesia and coffee, cocoa, guaba, and jacaranda in Peru (model 11). Considering the nine initiatives with economic purposes, the average benefit/cost ratio was 2.1 and the standard deviation was 1.58.

4. Discussion

The forest restoration initiatives evaluated were developed in different contexts, using different methods. Studies show that the costs of forest restoration projects depend on soil, topography, equipment, and available inputs, labor, personal options, legal restrictions, and vegetation management after implementation [9,48] and can reach up to \$10,000 ha^{-1} with planting in areas of degraded soil [48]. In the cases evaluated in the present study, higher investments to restore and maintain these areas were associated with intensified soil management, as happened in Cambodia, with a starting investment of \$7736 ha^{-1} and average annual operational costs of \$1420 ha^{-1} (Table 3). The high variation in investment to restore tropical forests was evidenced in this study by the standard deviation of \$2196 ha^{-1} and an average of \$1963 ha^{-1}, considering the 12 cases evaluated in 2018 and 2019.

The average investment to restore tropical forests with no direct economic purpose was \$1181 ha^{-1} (n = 3), 42% lower than the average investment of restoration models with economic purposes based on agroforest with NTFP (n = 9). The pure ecological restoration may favor projects that aim to increase structure and biodiversity in comparison to planting methods such as agroforestry systems [10]. However, as pure ecological projects do not generate direct financial returns, their *NPV* is negative as no other form of revenue is granted. Therefore, the agroforests with NTFP species may be the only economically feasible restoration alternative if no other incentive financial is provided.

Results also show that the number of hectares that can be restored with a given amount of investment depends on the local context. For example, \$1 million of investment in the field would be able to restore an average of 509 hectares, considering the average cost per hectare found in this study (\$1963). From a country perspective, with this investment level, it would be possible to restore 277 hectares in Cambodia, 307 hectares in Brazil, 1562 hectares in Indonesia, or 2725 hectares in Peru. This reinforces the understanding that assessment of different areas is essential to the success of restoration projects [9,49]. These results can serve to support international and large-scale projects such as Bonn Challenge, Initiative 20 × 20, and the AFR100 Africa Forest Landscape Restoration Initiative [50]. However, the present study did not analyze costs considering projects with larger quantities, such as 100,000 hectares, which can have a different cost structure, gains of scale, and generate changes in NTFP market conditions.

The literature review conducted did not identify studies on the costs of forest restoration in Cambodia, Indonesia, and Peru. This indicates that this study may be the first, to the best of our knowledge, to address this question in these countries. Thus, further studies will be important to increase knowledge about the costs of forest restoration in these countries and in regions with tropical forests. The literature review of restoration in Brazil showed that implementation costs of forest restoration in the Brazilian Amazon ranged between \$50 and \$5921 per hectare [51]. This shows that the investment values found to restore areas in Brazil are within the values detected in other studies [51–53]. In general, the present study detected a cost variation to restore tropical forests between \$104 ha^{-1} and \$7736 ha^{-1} using empirical data. Investment levels close to \$10,000 ha^{-1} and \$30,000 ha^{-1} found in the literature were not corroborated by the present study, but are cited as extremes in the scientific literature [10,48].

The productivity of native species is directly related to the economic results of forest restoration. For example, the productivity of the guarana used in the three evaluated cases in Brazil varied between 0.290 and 1.200 kg of dry seeds per bush, per year, in the most productive period of the plant's lifespan (Table 4). These values are above the region's average, which is considered to be 0.200 kg per bush, but below the potential of genetically selected varieties that can produce 2.5 kg of dry seeds per plant [54]. This indicates that the restoration systems that use guarana can be more productive and, consequently, more economically attractive when the plants are selected and managed [54].

The *NPV* was positive in seven of the nine cases studied. The highest *NPV*s were found in Peru, using coffee and cocoa as economics species. The lowest *NPV* was found in Cambodia with rattan and bamboo (model 5), due to low product prices and revenue generated by the model. The *NPV* of models 1, 2, 4, and 7 were the lowest among those evaluated, varying between $−78 and $536. The explanation for the low *NPV* for models 1 and 2 may be due to low productivity of the guarana specie, as indicated in Table 4. For model 4, the low *NPV* can be related to the annual maintenance cost of species with economic value (turmeric, ginger, and lemon grass). The low *NPV* for the sea cypress and ketapang species used in model 7 is associated with the small market size and price of products of these species in Indonesia.

We acknowledge that the high return rate from model 11 in Peru is an outlier in comparison to other models, which can be attributable to a combination of several factors related to low implementation costs, and high productivity and prices found in the field. In our methodology, we considered the market value of goods and services that, in rural areas, often do not have prices, such as family labor—which we valued as being equivalent to the wage of hired agricultural labor. However, some inputs may have undervalued prices from activities prior to those carried out on the properties. One typical example is the seedlings that may have been sold at a lower price because the seller often did not consider the labor cost of collecting the seeds in the price formation. Therefore, we understand that in some regions, input prices may have been undervalued, which resulted in high financial indicators. A second reason for the discrepancy that we recognize is that the productivity may be higher than the average in the Peruvian region due to prior soil conditions and characteristics, which we have not explicitly evaluated in the analysis. Lastly, a larger sample of cases would provide a better sense of these variations, but the current sample of 12 cases was enough to highlight that this result from model 11 is an outlier and should be seen with caution.

In the case of places where forest restoration is obligatory for landowners with conservation deficit and other legal liabilities, such as in Brazil [55], our findings may incentivize landowners to restore, given that in the long term it will not be an expense, but will even generate income, therefore increasing law compliance. New studies on forest restoration costs and economic returns are relevant for years 2021–2030, as they can contribute to projects to remove greenhouse gases from the atmosphere [50]. These initiatives can even be combined with economic incentives, such as payments for ecosystem services to guarantee positive incentives and returns for those engaged in those initiatives.

5. Conclusions

The assessment of several forest restoration initiatives selected in the four tropical regions confirmed that models with NTFP can achieve both ecological and economical objectives if carefully designed. Ecological restoration models require less implementation and post-implementation investments compared to agroforestry models; however, they do not generate incomes in terms of NTFP. Results confirmed our hypothesis that, with a proper species selection, investment level, and technical assistance, forest restoration models can yield positive *NPV*. Therefore, we provide evidence that forest restoration should not be seen as a sunk cost, but as an investment that can produce NTFP, sequester carbon, and pay back its investors. Consequently, these positive results show that scaling up these initiatives can be feasible, given its potential to overcome one of its main bottlenecks, attracting private capital and being able to remunerate both capital and labor, including technical assistance.

As a recommendation for future research, it will be important to assess how forest restoration systems can function on a large scale, from a value chain perspective, considering that market conditions may change in the long term. For example, assessing the long term price effects of a large increase in NTFP supply. Another important question to be addressed is the relationship between soil degradation prior to restoration and the project's investment returns. In the current analysis, we could note this relationship, even though we did not carry out a statistical analysis between quantitative indicators on soil degradation and expected *NPV*. Lastly, a series of co-benefits could be explored in a future economic analysis, such as carbon sequestration and the provision of water regulation, biodiversity, and other ecosystem services. Given the current scenario of rising carbon prices, the financial results of agroforestry restoration could be greatly improved by the certification and accreditation of these initiatives as a generator of premium-quality carbon credits, which could also generate biodiversity and social co-benefits.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/f13111878/s1, Figure S1: Sketches of forest restoration models studied in Brazil: (A) model 1, (B) model 2 and (C) model 3; Figure S2: Sketches of forest restoration models studied in Cambodia: (D) model 4, (E) model 5 and (F) model 6; Figure S3: Sketches of forest restoration models studied in Indonesia: (G) model 7 and (H) model 8; Figure S4: Sketches of forest restoration models studied in Peru: (I) model 10 and (J) model 11; Table S1: Example of questionnaire applied in data collection; Tables S2-S13: Tables to enhance the reader's understanding of cash flow, gross income, costs and investments are presented, in 2019 US $ dollars.

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