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Economic comparison of reforestation alternatives in La Hesperia Biological Station & Reserve, Ecuador

Master thesis

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Motto

"La naturaleza o Pacha Mama, donde se reproduce y realiza la vida, tiene derecho a que se respete integralmente su existencia y el mantenimiento y regeneración de sus ciclos vitales, estructura, funciones y procesos evolutivos."

Constitución de la República del Ecuador, Capítulo séptimo,
Derechos de la naturaleza, Art. 71

"Nature or Pachamama, where life is reproduced and exists, has the right to exist, persist, maintain and regenerate its vital cycles, structures, functions and its processes in evolution."

Constitution of Republic of Ecuador, Chapter 7,
Rights of nature, Art. 71

Declaration

I hereby declare that this thesis entitled "*Economic comparison of reforestation alternatives in La Hesperia Biological Station & Reserve, Ecuador*" is my own work and all the sources have been quoted and acknowledged by means of complete references.

Prague, 16 April 2014

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Bc. Zuzana Nováková

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Abstract

The master thesis presented an economic comparison of three reforestation alternatives of private natural reserve La Hesperia Biological Station & Reserve, Pichincha province, Ecuador; as well as the identification of the suitable plants and design of plantations or agroforestry plot considering the economic, environmental and social context. Data were collected during the period from September to December 2012 in the natural reserve La Hesperia Biological Station & Reserve through semi-structured interviews, transect walks and direct observations. Following indicators, net present value (NPV), internal rate of return (IRR) and benefit-cost ratio (BCR) were calculated in order to estimate the economic efficiency of proposed alternatives. The data were calculated for the period of 20 years. Results showed that the highest NPV, considering the 10% discount rate, was performed by agroforestry model, followed by monoculture (*Alnus acuminate*) and intercropping model (*Alnus acuminata* and *Coffea Arabica*) showing values of 2,404 USD, 2,338 USD and 1,279 USD, respectively. Significant differences were observed among the alternatives in IRR, showing the values of 27.1%, 17.6% and 35.6%, for monoculture, intercropping and agroforestry model, respectively. There were not observed significant differences in BCR. The payback period (PBP) showed similar results among all alternatives, i.e. between 4.00 to 6.00 years, while the shortest PBP was represented by agroforestry model. Results confirmed the economic viability of all assumed alternatives. Furthermore, there were discussed the environmental and social benefits of proposed alternatives. As a most suitable and appropriate alternative was indicated the agroforestry model, that corresponds to the principles of sustainable practices combining economic, social and environmental benefits.

Key words:
reforestation, economic evaluation, cost-benefit analysis, natural reserve, Ecuador

Abstrakt

Diplomová práce přináší ekonomické srovnání tří postupů zalesňování v soukromé přírodní rezervaci La Hesperia Biological Station & Reserve, která se nachází v provincii Pichincha v Ekvádoru. Spolu s ekonomickým zhodnocením je prezentována též identifikace vhodných druhů dřevin a jejich skladba pro návrh nových zalesňovacích postupů zohledňujících ekonomický, krajinotvorný i sociální kontext. Sběr dat probíhal v období od září do prosince 2012 přímo v přírodní rezervaci La Hesperia Biological Station & Reserve prostřednictvím polo strukturovaných rozhovorů a přímého pozorování. Ekonomická analýza se opírá o ukazatele, jako jsou čistá současná hodnota (ČSH), vnitřní výnosové procento (VVP) a poměr nákladů a výnosů (BCR) a byla kalkulována na období 20 let. Studie prokázala, že nejvyšší ČSH (d=10 %) vykazuje agrolesnický model (2 404 USD), následovaný monokulturou druhu *Alnus acuminata* (2 338 USD) a intercropping modelem v kombinaci druhů *Alnus acuminata* a *Coffea arabica* (1 279 USD). Významných rozdílů dosahují jednotlivé varianty podle VVP: 27,1%, 17,6% a 35,6%, pro monokulturu, intercropping a agrolesnický model, respektivně. Naproti tomu poměr výnosů k nákladům byl u všech variant obdobný. Doba návratnosti se u všech alternativ pohybovala v rozmezí od 4.00 do 6.00 let. Výsledky potvrdily ekonomickou životaschopnost všech předpokládaných variant. Agrolesnictví lze doporučit jako nejvhodnější variantu, který odpovídá zásadám trvale udržitelného rozvoje kombinujícího ekonomické, sociální a environmentální přínosy.

Klíčová slova:
zalesňování, ekonomická analýza, analýza nákladů a přínosů, přírodní rezervace, Ekvádor

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List of Abbreviations

BCR	Benefit-cost ratio
CBA	Cost-benefit analysis
EAP	Economically active population
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GNP	Gross National Product
HDI	Human Development Index
IBAs	Important bird areas
INEC	Instituto de Estadística y Censo (Institute of Statistics and Census, Ecuador)
IRR	Internal rate of return
NPV	Net present value
OPEC	Organization of the Petroleum Exporting Countries
PBP	Payback period
PPP	Purchasing Power Parity
TMCF	Tropical mountain cloud forest
UNDP	United Nations Development Programme
UNFPA	United Nations Population Fund
USD	United States Dollar
WB	World Bank

1 INTRODUCTION

The deforestation trend occurs in many parts of the world (Chokkalingam et al., 2006). However, South America shows high numbers in forest loose, particularly in Amazon tropical forest. Ecuador is one of the 17 mega diverse countries in the world and is home of a huge number of species (UN-REDD, 2010). Unfortunately it also ranks the highest rate in deforestation among South America. According to Ecuador's Ministry of Environment (2013) the deforestation rate is over 61,000 hectares per year. In order to reverse forest loss, Ecuador is implementing many initiatives to reduce deforestation in the country as part of good governance of forest resources (UN-REDD, 2010). In addition, Ecuador is the first country in the world with codification of rights of nature in its constitution (Rights of Nature, 2013). Recently, new NGOs and private reserves focusing on reforestation and conservation activities were established. According to Günter et al. (2009), the successful reforestation of deforested tropical forest is reforestation with native species which meet the environmental needs of the forest as well as social needs of local communities, that were depended on them in past. Unfortunately there are limited studies of the reforestation by native species in Ecuador (Pedraza and Williams-Linera, 2003).

The deforestation activities are very frequent in tropical mountain cloud forest (TMCF) of Ecuador (Raberg and Rudel, 2007). According to Sierra and Stallings (1998), the deforestation is very common in Chocó region, one of two Ecuadorian biodiversity hotspots, where is located La Hesperia Biological Station & Reserve (further La Hesperia). The main income of La Hesperia is generated from the fees of volunteers from different countries, coming there to get experience in natural conservation and reforestation. Thus for the need of reforestation in Ecuadorian TMCF, limited studies on the topic of reforestation by native species; and diversification of income of La Hesperia, the investigation was carried out.

The master thesis analyses the three proposed alternatives of reforestation activity of the private reserve La Hesperia, particularly from the economic point of view. First chapter, the literature review, deals with the forest issue, deforestation trends and reforestation effort in the world and linked and focus deeper on the environment of Ecuador as it is a country with the highest deforestation rate among Latin America. Methodology used in this thesis was based on participatory techniques. Cost-benefit analysis (CBA) was applied in order to provide quantitative analysis of three proposed reforestation alternatives within the reserve. There were followed several studies on similar topics as Lojka et al., (2008) or Šálek and Sloup (2012) and modified to the environment of the TMCF of Ecuador and the environment of the private natural reserve. Results have brought an interesting insight into the different proposed reforestation alternatives of the private reserve in Mejia canton, Pichincha province, Ecuador.

2 LITERATURE REVIEW

2.1 Deforestation, reforestation and forest issue

The deforestation over the world is very high, the forested area decreased in last decade, from 31.4% to 30.9%. More alarming situation occurs in the region of Latin America and Caribbean, where the loss of the forested area dropped from 49.0% to 46.8% (WB, 2013). Before European settlement, Latin America was probably from 75% forested. However, nowadays around 50% is forested. The pace of deforestation activities has doubled in the 20th century compare to 18th and 19th century (FAO, 2012; Williams, 2002). While tropical deforestation continues at alarmingly high rates, the net loss of forest area globally has slowed (Le et al., 2014). This reduction in net loss happens particularly due to the increase of afforestation and natural forest regrowth. It appears that in number of tropical countries occurred the shift from deforestation to net reforestation (Meyfroidt and Lambin, 2011).

The term deforestation is nowadays very frequent word, at least in the environment of the forestry engineers or environmentalists. According to FAO (2001), deforestation is "*the conversion of forest to another land use or the long-term reduction of tree canopy cover below the 10% threshold*". It means the long-term or permanent loss of forest cover. Such a loss can be caused by natural destruction or human intervention. Deforestation includes areas of forest which are converted into pastures, agricultural land, water reservoirs or urban areas.

In the tropical forest, the first step in the destruction the forest is the over exploitation of the high value timber and reshaping the forest into the pastures leading to the degradation of the soil. This process is usually accompanied by loos of biodiversity, erosion or changes in hydrological system (Beck et al., 2008; Günter et al., 2008). Clearing the forest for agricultural (Walker, 2004; Brockerhoff et al., 2007, Šálek and Sloup, 2012), infrastructure or other purposes leads to the decrease of the land category "forest" and increase of the land category "other land use". The net change rate of forest takes account of four categories: i) decrease by deforestation, ii) decrease by natural disasters, iii) increase by reforestation and iv) increase by natural expansion (Beck et al., 2008).

Generally, there are three most common responses for the forest degradation. First represents the establishing of protected areas that would protect remaining biodiversity. Second accounted improving the agricultural productivity in abandoned land to increase the living standard of local communities; and third performs the reforestation activities (Lamb et al, 2005).

According to FAO (2001), afforestation is "*the conversion from other land uses into forest, or the increase of the canopy cover to above the 10% threshold. Afforestation is the reverse of deforestation and includes areas that are actively converted from other land uses into forest through silvicultural measures*." The term afforestation can be used as well as the term reforestation. Afforestation or reforestation include natural changeover of the land into the forest, for instance on abandoned agricultural land which has not been classified as forest for the period when it was abandoned. The same as for deforestation, the conversion should be long-term[1].

There are two alternatives how to make reforestation successful and sustainable; mitigate the causes of perturbation, as fire, cattle or crops; or plant seedlings of native species artificially (Murcia, 1997). The success of reforestation activities depends on appropriate selection of the native species which will fulfil the satisfaction rural population's needs as well (Günter et al., 2009). In cases, where the land is degraded and appear soil erosion, there is suitable to plant the fast growing trees, which firstly mitigate the erosion and in addition providing source of (fire) wood to the local communities (Harrell, 2014). Monoculture shows the higher risk of pests, hence there is recommended to plant mixed tree species to mitigate the risk mainly from pests and diseases (Nair, 2001). According to Le et al. (2012) the indicator of socio-economic success of reforestation project are increasing of local income, local employment opportunities, availability of food supply,

[1] The areas where the reforestation process should take less than 10 years should not be classified as reforestation areas. For instance, areas where is evidence of high number of fires or hurricanes. Thus the long-term is defined as 10 years at least.

stability of market prices, local empowerment and capacity building. Harrell (2014) stated that top-down programs or projects usually fail unless there is a meaningful role for local initiative.

Does tree planting really work? According to World Land Trust (2011) if there is used the appropriate mix of native species regarding to the ecology and environment of the area and the needs of the communities living close by, reforestation activities can be a powerful tool for restoring degraded forest as well as introduce the buffer zone around the biodiversity hotspot. Besides benefits as improving environment and conserve the biodiversity, other benefits include the reduced erosion, stabilisation of the slopes and improve the hydrological flow.

Unfortunately, mismatch between social and ecological goals of reforestation occur many times; either reforestation aimed to fulfil social or economic needs without taking in consideration the environment, or it aimed directly to the conservation goal without taking into account the social and economic needs of people living in the area (Le et al., 2014).

According to Šálek and Sloup (2012) the economic evaluation is one of the most important parts of forest planning to obtain the result which type of reforestation pattern will be used. Taking in consideration the time factor of the as some tree species need longer rotation period as well as environmental issue as biodiversity, native tree species etc.

2.2 Characteristics of tropical mountain cloud forest

Tropical mountain cloud forest (TMCF) usually occurs in narrow altitude belt on the ridge or peak of the mountains. The altitude of occurrence of TMCF shows considerable variation as it depends on the concentration of the moisture in the air, the velocity and direction of the wind, distance to the sea or cloud formation processes. However, the typical TMCF altitude is between 2,000 and 3,000 m. On the coastal or isolated mountains, as Hawaii or Fiji, TMCF can be found even lower than 500 m (Hamilton et al., 1995; Foster, 2001). Epiphytes are a defining characteristic of TMCF, where one fourth of all plant species may be epiphytes and they play a crucial role in the health of the TMCF (Foster, 2001).

TMCF of the Andes in Ecuador is known for its extraordinary biodiversity, but unfortunately either as the region with the highest deforestation rate (Günter et al., 2009). Although Ecuadorian TMCF are relatively small in size, they are considered as one of the richest hotspot on the planet, containing approximately 17% of the world's plant species and disposes with almost 20% of its bird diversity. The dry and moist forests of western Ecuador are some of the most threatened ecosystems in the world. With over 1,500 species of birds[2] it ranks fourth in avian diversity amongst all countries in the world. (Rainforest Rescue, 2008). In addition, many tree species in TMCF provide high-quality timber (Pedraza and Williams-Linera, 2003).

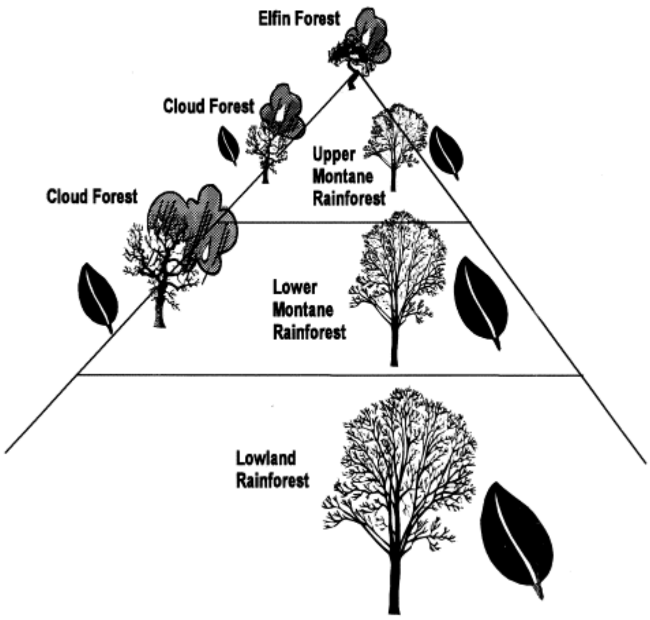

Figure 1 Classification of a forest in Ecuador. Source: Foster (2001)

[2] For comparison the size of Australia is 7,617,930 km2 (almost 27 times bigger than Ecuador in the area) and it counts only 800 species of birds (Rainforest Rescue, 2008).

2.3 Republic of Ecuador and its recent economic and social development

Ecuador, even small in size, covering the area of 256,370 km^2 (FAO, 2013a), 1.5% area of South America, is often called as a one of the most diverse countries in the world (Sierra et al., 2002) it is home to almost 50% of the bird species on the continent, 1,515 out of 3,100 (Rainforest Rescue, 2008). From the whole area, 38.9% is covered by forest, 28.7% is used as an agricultural land and 4.5% is an arable land (FAO, 2013a; WB, 2013a). With the total population of 15,490,000 inhabitants, it ranks Ecuador to countries with lower population density, about 60 persons per km^2. Moreover, the vast part of Ecuadorian Amazonia (called *El Oriente*) is sparsely populated by only by 3% of total population (Albright College, 2011). The urbanisation rate has been slightly increasing over last years, reaching 68% in 2012, compared to 62% in 2003 (WB, 2013a).

In Ecuador live many ethnic minorities. The composition is following; 71.9% are mestizos (mixed Amerindian and white), 7.4% Montubio, 7.2% Afroecuadorians, 7.0% Amerindian, 6.1% white and 0.4% others. The official languages are Spanish and also indigenous languages, particularly Quechua and Shuar. In terms of the religion, there is a strong Christian faith, as 95% belong among the Roman Catholics. Ecuador has a small but growing immigrant population and belongs to the top recipient of refugees among Latin America. Majority of refugees (98%) who are received in Ecuador are Colombians as a result of instability in their country (WB, 2013b; CIA, 2014).

Ecuador, as other Latin-American countries faced many problems. The national economy was affected by political instability within the country borders, which led to less international either domestic investment in Ecuador’s market and finally experienced higher interest rates. Ecuadorian inability to post continuous growth in production caused that 64.4% of the population lived below poverty line in 2000 and pushing unemployment rate to almost 15%. However the national policy implementation was successful as the poverty rapidly decreased up to 27.3% in 2012 and unemployment rate to around 4.1% (WB, 2013b; WB, 2014b). One of the main priorities for the government and the development plan in 2000-2003 was the poverty reduction, as the poverty rate remained huge number (UNFPA, 2013). The poverty has been reduced, but Ecuador still has the highest poverty rate for indigenous people in Latin America[3] (Escribano, 2013) as the most affected people by poverty are indigenous groups, mixed race and rural population (CIA, 2014). According to UNFPA (2013) poverty occurs in Ecuador mainly in the Quechua-speaking regions, where the indigenous communities have lack of access to infrastructure or basic services as sanitation, healthcare, clean water, electricity or education.

The HDI of Ecuador is 0.724, ranking the 89th post (Escribano, 2013; UNDP, 2013). In addition, as Ecuador is still a developing economy, it is facing another problem, inequality. The inequality index took the 83rd post with 0.442. Reducing inequality is one of the main economic challenges of present government. According to HDI ranking, Ecuador decreased in ten posts in terms of income inequality. However, even the country's Gini Index has been significantly reduced in last decade, from 54 to 48 between 2006 and 2012; it still remains high even for Latin American standards, particularly in urban areas (UNDP, 2013; WB, 2014b).

Ecuador has experienced rapid socio-economic development in the last several years. Tourism, mining and agriculture activities have expanded a lot and unfortunately have led to enormous ecological changes in the biodiversity 'hotspot' (Levin and Reenberg, 2002; Gamboa et al., 2010). Ecuador, the OPEC[4] member, with the smallest amount of proven oil reserves[5], gained attention in the debate about the future oil extraction in the amazon basin in Ecuador and it may play decisive role of the global tension between economic development and environmental conservation (Odell, 2013).

According to FAO (2013b) the most important produced crops in term of produced quantity are followings; sugarcane, bananas, rice, maize, plantains and potatoes (see Table 4). Ecuador is the 4th country in the world with highest production (as well as the value) of bananas[6], producing 7,427,776 million of tonnes in the value of 2,091,891 million USD.

[3] Data were available only in urban areas.

[4] Organization of the Petroleum Exporting Countries (OPEC) includes 12 members: Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabi, United Arab Emirates and Venezuela (OPEC, 2013).

[5] Proven crude oil reserves in Ecuador are 8.24 billion barrels (OPEC, 2013)

[6] After India, China and Philippines

In terms of export; oil, shrimp, and bananas are the Ecuadorian top 3 export products, while the manufacturing sector (including basic manufactured goods, machines, and transport equipment) accounts for less than 7% of all exports (FAO, 2013b).

Table 1 Top commodities produced in Ecuador by value and production volume

Commodity	Production ($1000)	Production (MT)
Sugar cane	263,084	8,131,819
Bananas	2,091,892	7,427,776
Milk, whole fresh cow	502,287	6,375,323
Rice, paddy	400,144	1,477,941
Maize	39,177	864,445
Plantains	103,887	591,984
Meat indigenous, chicken	489,811	343,870
Potatoes	42,230	339,038
Oil, palm	126,123	289,900
Meat indigenous, cattle	723,954	267,995

Source: FAO (2013b)

Since the new constitution was approved in 2008, the country is taking forward a ‘National Plan for Good Living’, which promotes economic growth and at the same time support strengthening of vulnerable economic sectors, agricultural sustainability, food security, and climate change adaptation (CDKN, 2013).

Economic growth, measured by GDP, had declined by 0.6% in 2009, particularly due to the impact of the world economic crises. However in 2010 the Ecuadorian economy started to recover, reaching almost 8% in 2011 (ranking the 3rd post in the region). Continuously, in 2012, the GDP growth slightly declined, however still remained over 5%. The actual GDP per capita (including PPP) is 9,490 USD (WB, 2014a; WB, 2014b).

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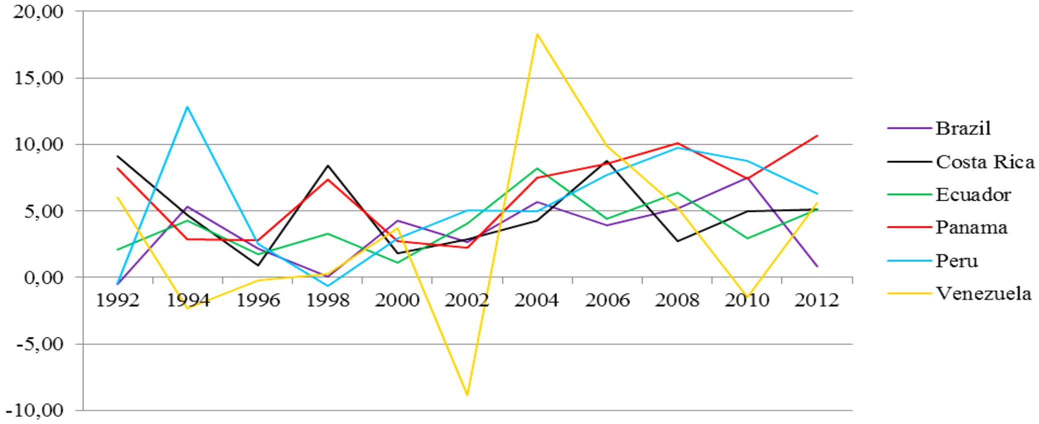

Figure 2 GDP annual change of selected countries from Latin America (1992-2012, in percentages); Source: WB (2014a)

Ecuador needs to, among other things, deal with the variation of landscapes. The country is divided into four natural regions: the coastal area along the Pacific Ocean, the highlands of the Andes (called *Sierra*), the Amazon Basin containing the spacious parts of the rainforest; and the Galapagos Islands (Profafor Face, 2005). The rugged mountainous landscape contains a large number of isolated valleys, giving the area a very high rate of endemism as well (Levin and Reenberg, 2002). The general ecosystems in the country are also diverse: humid forests (1,200 up to 3,600 m.a.s.l.) in the Andes, remarkable grasslands (3,200 up to 4,100 m.a.s.l.) in the Andes (*Páramo*), dry and humid tropical forests and mangrove areas. Noticeable fact is that Ecuadorian forest area covers 38.9% of the whole land surface and over 40% of this forested land has a protected status (Profafor Face, 2005; WB, 2013a).

2.4 Environmental issue, biodiversity and forestry in Ecuador

With the approval of the rewritten constitution in 2008, Ecuador became the first country in the world to codify the rights of nature (see Annex 1). The constitution was approved by 68% majority in the national referendum in 2008. "*Rather than treating nature as property under the law, rights for nature articles in the constitution acknowledged that nature in all its life forms has the right to exist, persist, maintain and regenerate its vital cycles*." (Rights of Nature, 2013).

Ecuador is a country that disposes of an extremely enormous biodiversity (Beck et al., 2008; Mosandl et al., 2008; Günter et al., 2009) and together with Costa Rica is considered as one of the countries with highest biodiversity in the whole world (Profafor Face, 2005). As it shows on the Figure 3, particularly Yasuni National Park located in the Amazon basin in East Ecuador belongs to the few biodiversity hotspots among whole South America, considering together amphibians, bird species, mammals and plants (Larrea and Warnars, 2009; Odell, 2013).

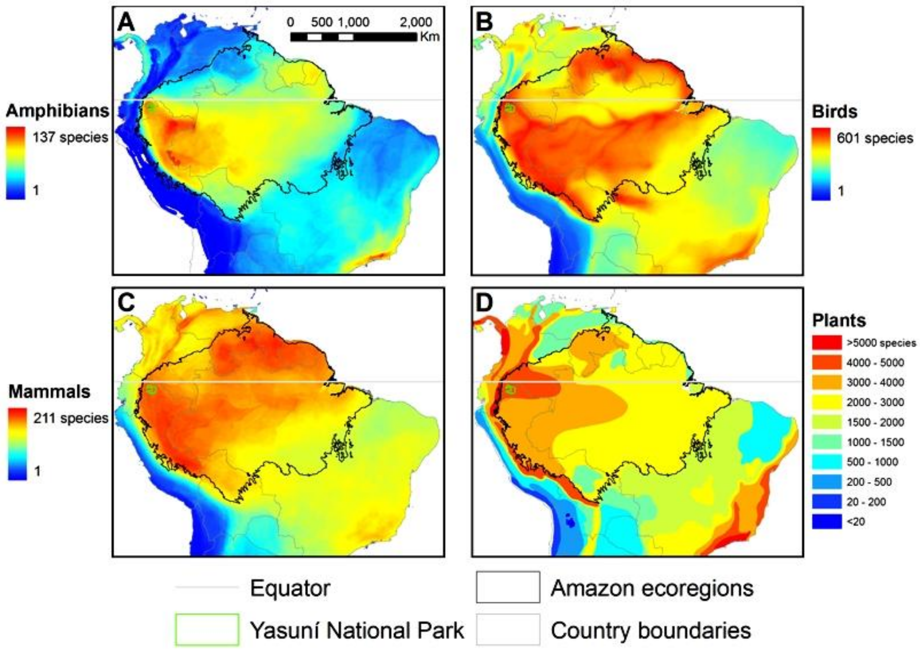

Figure 3 Biodiversity within the South America, Source: Odell (2013)

Even small in size, Ecuador belongs to the mega diverse countries in the world, both measured the absolute number of the species as well the number of species per km^2. This high biodiversity is caused by many factors, particularly different bioregions or ecoregions: Chocó, Tumbez, northern and southern central Andes and northern and western-southern Amazonia, and its environmental variability[7] of each mentioned (Sierra et al., 2002). Ecuador contains two biodiversity hotspots, one east and the other west of the Andes. The first mentioned, Choco, contains particularly large concentration of plants endemic to the

[7] For instance, the Anden region has several subregion, each characterized by different evolution history and climatic regimes (Sierra et al., 2002).

region. Unfortunately, particularly Choco region and north-east Amazonia suffers the rapid rates of deforestation (Sierra and Stalings, 1998; Raberg and Rudel, 2007). Concerned citizens, donors and scientist responded to the environmental crises by creating NGOs focusing on different reforestation and conservation activities (Raberg and Rudel, 2007).

There are different approaches to determine certain areas as a biodiversity hot spot. One of the globally identifies approach is Important Bird Areas (IBAs), key sites for conservation of threatened, restricted range and migratory bird species (Bertzsky et al., 2010). According to BirdLife International (2013), Ecuador has 107 IBAs.

Table 2 The biodiversity according to BirdLife International (2013).

Name of the country	**Ecuador**	**Costa Rica**	**Venezuela**
Area of the country (km^2)	283,561	51,100	912,050
Species			
Total number of birds	1,583	856	1,351
Globally threatened birds	95	22	40
Country endemics	35	5	37
Important Bird Areas (IBAs)			
Number of IBAs	107	21	72
Total IBAs area (km^2)	91,435	30,709	210,417
Total IBAs area (%)	32.3	60.1	23.1
Endemic Bird Areas (EBAs)			
Number of EBAs	9	5	7

It is estimated that more than half of the known terrestrial plant and animal species are living in forests. Regrettable, this outstanding richness is threatened by habitat loss due to the deforestation activities related to oil, gas and minerals exploitation that have devastating impact on the biodiversity as well (Bertzsky et al., 2010). The illegal timber logging and the conversion of partly-protected forests to pastures perform continuing challenges to the regional human-environment relationship (Gerique and Pohle, 2006).
Hence one of the major challenges performs decrease the deforestation rate and at the same time fosters the afforestation activities (Mosandl et al., 2008; Günter et al., 2009) and to establish appropriate forest management (Bergseng et al., 2012). According to Günter et al. (2008) the best solution how to protect biodiversity is to keep humans away. Unfortunately, humans have never stayed away from forest and they never will do so.

It is logical that higher protection of biodiversity leads to the reduction of income from timber both for society and forest owners, and consistent analysis of the relationships between biodiversity benefits and costs is important for forest managers as well as policy makers (Bergseng et al., 2012).

It is assumed, that originally there was 90% of the area of Ecuador covered by forest (Beck et al., 2008), whilst in 2012 it was just slightly below 39% (WB, 2013a). Land tenure plays an important role in affecting landholder's investment decisions on their property and forest use (Levin and Reenberg, 2002; Joppa and Pfaff, 2011; Holland et al., 2013). The impact of land tenure conditions on forest outcomes is difficult to predict and hence the recent research on land tenure and tropical forest conservation is limited (Joppa and Pfaff, 2011; Holland et al., 2013). According to the case study of Knapp (1991) from Ecuadorian highland, the majority of agricultural land is owned by large haciendas while indigenous, small scale farming is mostly restricted to small marginal plots. The agriculture of hacienda's owners is characterised by cattle husbandry; and indigenous households must adopt intensive cultivation in order to meet their needs from a limited land area. More than 26% of the Ecuadorian forest is owned by indigenous communities. Most of this land is located in Amazon basin in the East of the country (Bertzsky et al., 2010).

A considerable proportion of the region is still made up of relatively undisturbed natural land cover partly due to a poorly developed road network. However, during the last 50 years the region has been subject to an extensive infrastructural development. Since the exploitation of oil fields in the eastern Amazon lowlands beginning in the 1950s, several new roads have been built, connecting the densely populated highlands with Amazon provinces. Improved access has led to changes in market access and other socioeconomic conditions affecting agricultural strategies and results in tremendous land use and land cover changes (Levin and Reenberg, 2002).

2.4.1 Deforestation activities in Ecuador

Regrettably, Ecuadorian rainforests are being deforested at a very high rate (Brockerhoff et al., 2007; Mosandl et al., 2008; Günter et al., 2009), approximately 198,000 hectares per year, including large areas of TMCF. At this rate it is predicted that Ecuador will be completely deforested within the next 30 years (Rainforest Rescue, 2008). In comparison to the other countries of Latin America, Ecuadorian deforestation rate is one of the most quick within last decades (see Figure 4). Ecuador is often compared to Costa Rica, especially with the biodiversity and endemic rate, but it should definitely get some lessons from the Central American country that increased the reforestation area in the beginning of 2000s. As shows the Figure 4, in the end of 1990s there was an increased in the forest cover of Ecuador, which tends to think about implementing reforestation activities. Unfortunately, the percentage changed as Ecuador lost part of its territory as a result of conflict with Peru in 1990s. Thus, in fact, the forest cover has been continuously decreasing over last decades.

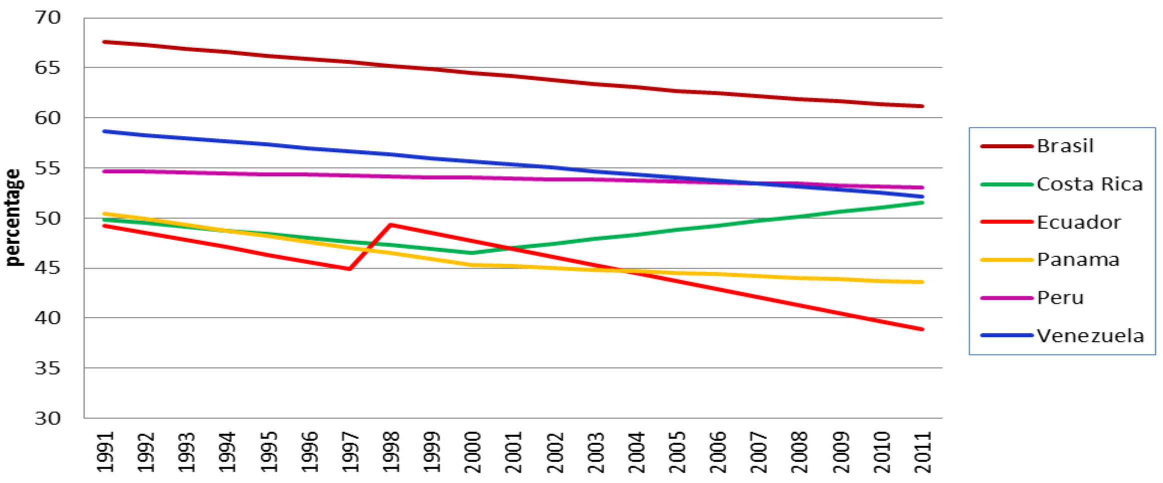

Figure 4 Forested area (% of a land area), Source: WB (2014a)

Nowadays the Andes are the most densely populated area of Ecuador and it leads to a significant pressure on the natural resources that lead to, among other things, a further reforestation. Main motives are: expansion of the agricultural land, need for firewood and the demand for wood for the construction of houses (Profafor Face, 2005). In addition, one the main causes of deforestation in Ecuador, besides the clearing of lowland forest in coastal area for agricultural purposes were the oil boom in 1970s (Mosandl et al., 2008). Recent research indicates that commercial and subsistence logging is implicated from local to global scale and nowhere is it as severe as in the tropics (Barraclough and Ghimire, 2000; Lopez et al. 2010). However, Ministry of Environment plans to implement managing the forest in the sustainable way. Furthermore it plans to implement the REDD+[8] mechanism that maximises benefits for environment, climate and people (Bertzsky et al., 2010). Considering the deforestation activities, Ecuadorian government has created a system of national parks and reserves since 1970s (Raberg and Rudel, 2007). However, the international awareness and attention of necessity of conservation is high, tropical forests have been still disappearing in enormous speed (Wunder, 2000).

2.4.2 Protected areas and reforestation activities in Ecuador

National System of Protected Areas (Sistema Nacional de Áreas Protegidas, or SNAP) was established in Ecuador, representing a major tool in the country's biodiversity conservation strategy. Nowadays it includes 48 conservation areas that are protected under eight[9] different management categories. All these natural areas cover up 18.7% of whole national territory (Himley, 2009; Bertzsky et al., 2010), whilst the world average is only about 6% (Raberg and Rudel, 2007; Freile et al. 2010). The careful location of protected areas ere is essential in order to conserve the biodiversity (Lamb et al., 2005). During last years the Ecuadorian *Sierra* has experiences many conservation projects, varying from preserving Ecuadorian biodiversity, over maintenance of watershed integrity to promoting ecotourism activities (Himley, 2009).

[8] REDD+ = Reducing Emissions from Deforestation and forest Degradation

[9] Management categories include: National Park (Parque Nacional), Biological Reserve (Reserva Biológica), Ecological Reserve (Reserva Ecológica), Geobotanical Reserve (Reserva Geobotánica), Fauna Production Reserve (Reserva de Producción Faunística), Wildlife Refuge (Refugio de Vida Silvestre), and Marine Biological Reserve (Reserva Biológica Marina) and National Recreation Area (Área Nacional de Recreación). Source: Ministry of Environment (2013).

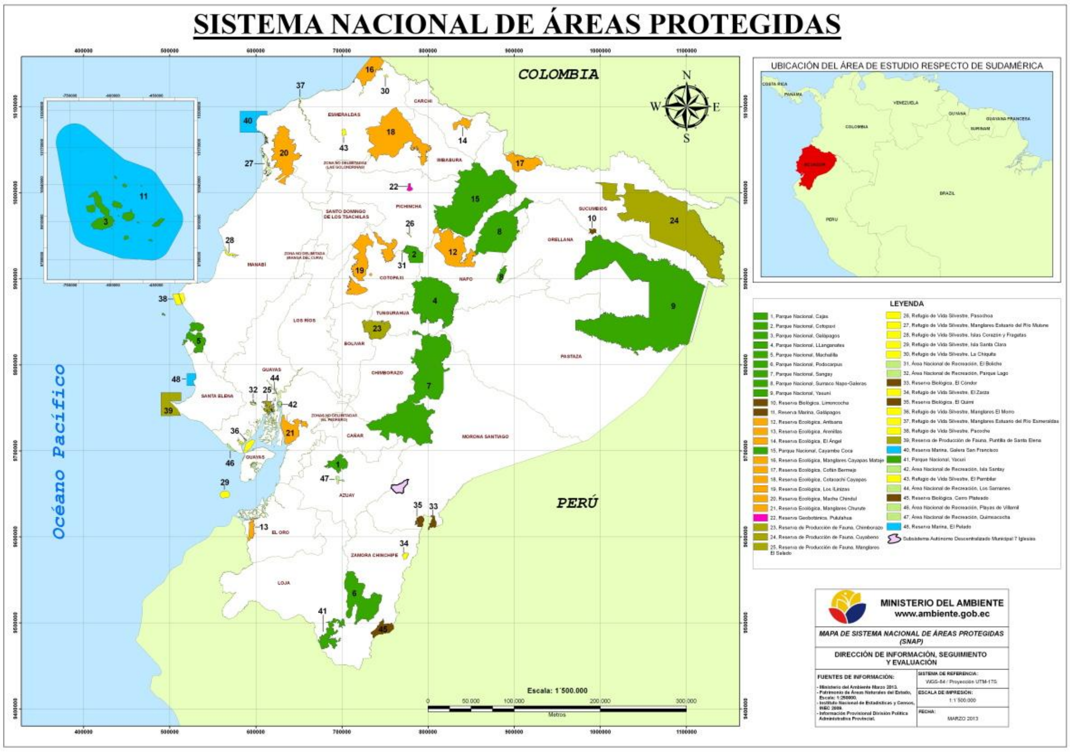

Figure 5 Map of National System of Protected Areas (Sistema Nacional de Áreas Protegidas, or SNAP) of Ecuador. Source: Ministry of Environment (2013)

According to Günter et al (2009) there is important to carry out the reforestation with native species. Unfortunately there are limited studies about reforestation activities with native species in Ecuador, especially in TMCF. However in other region, research and publications on tropical native tree species used in plantations and forest rehabilitation activities are increasing (Pedraza and Williams-Linera, 2003; Piotto et al., 2004; Günter et al., 2009). In last decade, there were tested new forms of reforestation as for instance improvements in management of secondary forests (Lamb et al., 2005).

2.4.3 Forest plantations in Ecuador

Forest plantations are at an increasing rate and according to FAO (2012) they cover nowadays more than 5% of global forest cover. Their importance in production is very significant as they provide around 40% of global wood supply (Kelty, 2006). However the ecological and conservation aspects are less positive, particularly where the natural forest has been deforested in purpose of plantation establishment. Fortunately this trend is becoming less popular as there are many abandoned areas available for planting (Evans and Turnbull, 2004; Kelty, 2006). There was reported, that 75% of timber used in industry in Venezuela, Colombia, Ecuador, Bolivia, and Peru was logged by small-scale producers, subsequently sold to medium and large-scale wood-processing firms. In these countries, forest plantations are very limited. However, the demand is met through the extracting the timber form natural forests (Sierra, 2001). It is promising that establishment of new plantations ensure demand for timber and hence alleviate the pressure on extracting natural forest (Šálek and Sloup, 2012).

Only about 2% of English-language literature on plantations deals with mixed-species plantations (Nichols et al., 2006). The majority of reforestation projects in Ecuador consist from the introduced monocultures with small variability (mainly *Pinus, Eucalyptus* and *Acacia*). Exotic species provided the goods for pulpwood production, but it did not provide the different variety of goods, as wood, medicines, food or fodder, which the native species in past provided to the local communities living nearby (Lamb et al., 2005). The reforestation by exotic species happens particularly due to the insufficient or lack of information about the native species (Günter et al., 2009), good availability of planting material or proven good productivity (Beck et al., 2008). Many of the tropical native tree species are valuable in commercial sense, hence besides the environmental and social benefits, the economic needs could be satisfied as well (Piotto et al., 2004). Mixed plantations planted by native species seem to be more appropriate to the wider range of options as protection, biodiversity, production, risk reduction, or restoration of degraded areas (Parotta and Knowles, 1999; Piotto et al., 2004).

In general, all over the world in the tropical areas, monocultures, single-species or pure plantations prevail over the mixed ones. Majority of forest project use the small number of exotic species, which are easy to manage through lot of propagation methods (Piotto et al., 2004). Moreover there are implemented the large-scale plantation which can lead to the environmental difficulties as higher vulnerability to diseases and pests, soil degradation or low environmental stability (Lamb et al., 2005; Günter et al, 2009).

The establishment of forest plantation is considered as a tool for forest restoration with the effect of microclimate, vegetation structure and soils (Pedraza and Williams-Linera, 2003) as well as it acts as sinks of carbon dioxide and thus reducing greenhouse effects (Masera et al. 1997).

3 OBJECTIVE OF THE THESIS

An environmental issue is recently highly discussed and relevant in Ecuador, as from the total area more than 17% is under administration of national parks or natural reserves. High demand for timber and recently discovered oil supplies; put Ecuador to the front ranks of the Latin-American countries with the highest rate of deforestation activities per hectare. Therefore the reforestation based particularly on traditional plant species is very essential and appropriate. Thus the aim of the thesis was to identify the traditional plant species and crops, suitable for the designing and establishment of forest plantations or agroforestry plots, and, proposed three different reforestation alternatives particularly for the purpose of private natural reserve. The three reforestation alternatives were subsequently analysed particularly from the economic point of view, however environmental and social context were discussed as well.

4 MATERIALS AND METHODS

4.1 Study area description

The survey and data collection was conducted within La Hesperia Biological Station & Reserve (further La Hesperia), which is located in the canton Mejia, Pichincha province, approximately 90 km south west from the capital city, Quito.

Province Pichincha

The province of Pichincha is one of 24 provinces in Ecuador, covering up an area of 9,612 km^2 and inhabited by 2,576,000 inhabitants, including the province's as well as country's capital, Quito (INEC, 2013). Prior to 2008, the canton Santo Domingo de los Colorados was a part of the Pichincha Province. Since 2008 it has become its own province, Santo Domingo de los Tsáchilas. Pichincha province includes 8 cantons as well, whereas the study survey was conducted in the Mejia canton. The province of Pichincha is located in the central region of the *sierra* (local name for the mountain area), towards the north of the territor. Province of Pichincha crosses the Equator and is situated between two *cordilleras* of the Andes. It is situated in the Guayllabamba river basin and in the volcanic area. The main cultivated crops are coffee, rice, cocoa and there is widespread husbandry. The tourism is also very important source of income, as the main touristic attractions are the volcanos (Cotopaxi or Pichincha), hot springs as well as ecological tours within the cloud forest, particularly in Mindo area (Gobierno de Pichincha, 2013; INEC, 2013).

Province of Pichincha has a variety of climates due to the different altitude zones. From very cold weather on the Andean *paramos* (between 4°C and 8°C) to the subtropical zones on the flanks of the western *cordillera* close to Santo Domingo de Los Colorados, for instance, where the average temperatures range between 20°C and 22°C. In the upper plains and valleys the temperature ranges from 12°C to 15°C, sometimes with high humidity levels (up to 95% of humidity) (Hip Ecuador, 2013). The land in the valleys of the Andes contain fertile alluvial soils, which, when is irrigated, provide agricultural income for dense populations of smallholders (Raberg and Rudel, 2007).

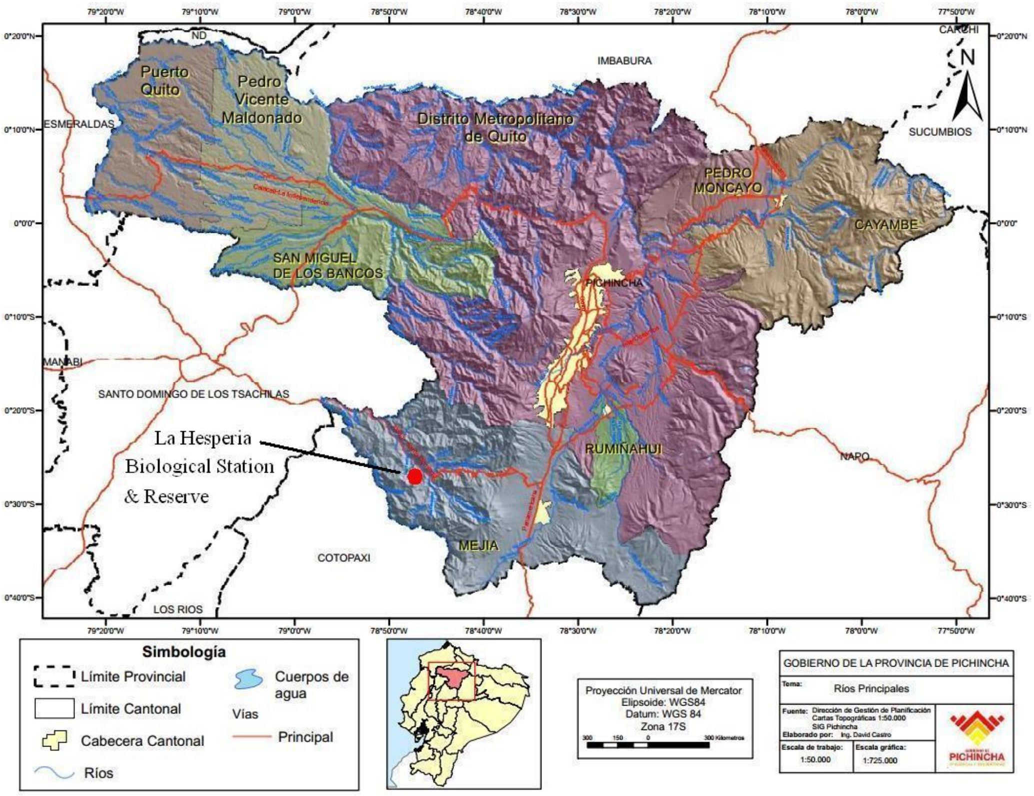

Figure 6 Map of the Pichincha province (Gobierno de Pichincha, 2013)

La Hesperia Biological Station & Reserve

La Hesperia Biological Station & Reserve (further La Hesperia) is a nature reserve located in the western range of the Andes at an altitude of 1100 – 2040 meters above the sea level. La Hesperia is situated in the slopes of the valley of watershed Tandapi, around 2 km far from the small community village La Esperie and about 10 km far from the town Tandapi. The area of watershed Tandapi was inhabited in 1958 by people who came from different parts of Ecuador. Before there was an area covered by lush vegetation, full of banana trees, sugarcane and wetland due to the watershed around (La Hesperia, 2012; Gobierno Parroquial de Tandapi, 2013;).

The reserve La Hesperia covers an area of 814 hectares and is part of the centre of the Rio Toachi-Chiriboga IBA (Important Bird Area, declared by Bird Life International and

Conservation International). Furthermore is a part of two important bioregions: The Tropical Andes and the Choco Darien – Western Ecuador, which is considered within the top five biodiversity hotspots on the Earth. Within the boundaries of the reserve there are 287 species of birds, 40 species of mammals, and 63 species of butterflies. The reserve encompasses three types of forest: pre-mountains evergreen, low mountains and high mountains, i.e. tropical mountain cloud forest (TMCF). The vegetation is typical of TMCF, which has the highest diversity of epiphytic plants. In the La Hesperia nursery several endangered and rare tree species are being produced such as: tangaré (*Carapa guianensis uubl*.), canelo (*Nectandra spp.*), colorado (*Guarea guentheri*), cedro (*Cedrela montana*) and aguacatillo (*Persea caerulea*) (Fundacion Tangaré, 2010; La Hesperia, 2012).

For the TMCF are characteristic the annual horizontal precipitations in range of 2,200 – 4,700 mm. In La Hesperia there is a distinct dry season for about 7 months (June through December) when rain is scarce and sporadic, but moisture levels are still maintained by mists that condense on the side of mountains. The rainy season usually starts in December through May, where the heaviest rain occurs in April and May. Rainfall is present especially during the afternoons and mostly in the months from February to April when we can expect rainfall most days. During the dry season occur many days with no rain. Day average temperature is 20°C and 25°C, during the rainy season and dry season, respectively (Bruinjzeel et al., 2010; El Monte, 2013).

Main tasks of La Hesperia reserve is a natural conservation, protection of existing forest, reforestation, restoration of degradarted areas and in addition work in a direction of sustainable activities, which positively affects not only people living within a reserve, but as well local community in La Esperie village. La Hesperia is also trying to become a model of integrated farming where agricultural practices complement the primary objective of preserving the natural forest. Combining conservation and agriculture activities will enable La Hesperia to achieve its goal of sustainability in the reserve and work to promote environmentally friendly economic activities for the surrounding area. (Silva et al., 1992; Fundacion Tangaré, 2010; La Hesperia, 2012).

This area was inhabited in 1958 by people who came from different parts of Ecuador. Before there was an area covered by lush vegetation, full of banana trees, sugarcane and wetland due to the watershed around (Gobierno Parroquial de Tandapi, 2013)

4.2 Data collection

Data were collected within the La Hesperia Biological Station & Reserve during the period from September to December 2012.

During the research period there were conducted three meetings with the director[10] and two meetings with the administrator[11] of the reserve La Hesperia. First meeting with the director aimed to obtain information for environmental, social and economic background of the reserve as well as the vision of the project. Afterwards there were discussed the possibilities, suggestions and constrains of the project. Study was in certain manner limited by the low number of potential stakeholders, which is usually required for participatory research.

Plant species identification and design of plantations

In order to suggest suitable and appropriate plants for the forest plantations and/or agroforestry plots, review of relevant scientific articles was carried out. Only scientific databases Thomson Reuters, ISI Web of Knowledge® and SciVerse Scopus® were considered. For identification of suitable species we followed already published studies on similar issue (Current et al., 1995; Gamboa et al., 2010; De Souza et al., 2012) and we modified them according to our situation (limited time, private natural reserve, climate conditions).

One transects walk and one semi-structured interview with local forestry engineer[12] were conducted to verify and discuss the suitability of the chosen plant species for local climate

[10] Mrs. Alexandra Hoenesein holding position of Director of the station and reserve La Hesperia since 2007

[11] Mr. Diego Pullugando holding the position of administrator of the reserve since 2012.

[12] Mr. Eduardo Aguilar Cueva, working as a forestry engineer for the project Proyecto Hidroeléctrico Toachi-Pilaton

and conditions. During the transect walk the demonstration farm and nursery was visited to observe different reforestation alternatives, particularly similar agroforestry plot and monoculture of *Alnus acuminata*, as finally were proposed. The transect walks and interview were held and supported together with Belgian volunteer[13] as he was experienced in forest management as well.

Consequently, total number of seven dwellers (two carpenters, one farmer, four workers of the reserve) from village La Esperie situated 1.5 km from the reserve were approached and direct observation together with undirected interviews were carried out in order to understand their attitudes towards their possible involvement in the project after implementation and their opinions about the project itself. Moreover they were interviewed to identify suitable native species and role of forest for their livelihood. The undirected interviews with local dwellers, forestry engineer and the administrator of the reserve were held in Spanish as the interviewees spoke Spanish only. However the meetings with director of the reserve were held mainly in English (Vlkova et al., 2011).

The three alternatives were considering the local conditions with emphasis on using of appropriate and particularly native species. Moreover economic profitability of the reforestation alternatives as well as sustainability was taking in account. There were proposed three various scenarios in order to find out the most economically profitable alternative, regarding to the environmental or social benefits (especially creating job opportunities as it is a private natural reserve) as well.

Economic evaluation

During the transect walks with the local forestry engineer the issue about the economic feasibility of forest plantation or agroforestry plot and potential financial costs and benefits of the proposed alternatives were discussed. With the director and administrator of the reserve was consulted the issue about salaries of the workers, prices for selling the harvested items, needed man-days for the certain operations during the establishment and maintenance of the plantations.

[13] Germain Castermanns, volunteer in La Hesperia, graduated from Forestry management at Université catholique de Louvain, Belgium.

Administration costs account for 5% of all costs. Other costs create additional 10% of total costs which includes occasional renting of machinery, fuel, taxes, electricity and unexpected expenses related to the maintenance of plantations.

4.3 Data processing

Finally, data were entered into MS Office Excel®. Cost-benefit analysis (CBA) was applied (Rasul and Thapa, 2006; Siregar et al., 2007; Lojka et al., 2008; Nuberg et al., 2009). There were used discounted methods as they include a time dimension in project appraisal. The designs of the plantations and agroforestry plot were processed via AutoCAD®.

Discounted methods

Discounted methods are based on the time factor consideration in order to evaluate future value of the money by determination of inflation rate, investment benefits or risk. There was applied 10% and 15% discount rate based on many studies e.g. Siregar et al., 2007; Rondon et al., 2010; Cañadas and Cadeño, 2011. In the study of Cañadas and Cadeño (2011) which was carried out in Ecuador, 10% discount rate was applied on the forest plantation project. This discount rate corresponds to the payment rate for the forest projects of Banco Nacional de Fomento (National Bank of Development). In the study of Dunn et al. (1990), there was applied discount rate of 15% in the planting pattern of *Alnus acuminats* as agroforestry component for 20 years rotation cycle.

Firstly, net present value (NPV) was applied in order to appraise future revenue and costs of forest plantation/agroforestry plots establishment and maintenance. Calculation formula for NPV is following (Siregar et al., 2007; Cañadas and Cadeño, 2011):

$$NPV = \sum_{t=1}^{n} \frac{B_t - C_t}{(1+i)^t}$$

where B is incremental benefits (cash inflows) in the year t, C is incremental costs (cash outflows) in the year t, n is number of periods (years) and i is the interest rate in percentages. NPV is the present worth of the net income stream generated by an investment.

- NPV < 0; present value of the benefit stream is less than the present value of the cost stream (insufficient to cover the establishment costs)
- NPV ≥ 0; present value of the benefit stream is higher than/equal to the present value of the cost stream, i.e. yield from investment is higher.

Generally, projects where NPV is equal to zero or it shows positive values, should be considered as successful and supported.

Secondly, benefit-cost ratio (BCR) was applied, which expresses the benefits generated per unit of cost. BCR can be calculated using the following formula (Rasul and Thapa, 2006; Cañadas and Cadeño, 2011):

$$BCR = \frac{\sum_{t=1}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n} \frac{C_t}{(1+i)^t}}$$

where, B_t is incremental benefit in period t, C_t represents incremental cost in period t, i is the discount rate in percentage and n is the project duration in years.
Thirdly, internal rate of return (IRR) was applied in order to estimate the maximum interest rate that this project could pay for the resources used. Final IRR should exceed or at least to be equal to the opportunity cost of the capital (e.g. interest rate in the bank). IRR can be calculated through the following formula:

$$IRR = r_l + \frac{(r_h + r_l) \times |NPV(r_l)|}{|NPV(r_l)| + |NPV(r_h)|}$$

where, r_l is lower discount rate, r_h is higher discount rate.

While much attention is given to NPV results, which is hard to compare to the other studies, the IRR and BCR indicators are useful for forest managers and engineers as well. While the NPV requires an estimation of the discount rate, which can be very hard to predict for the long time period of a timber projects, the IRR would tell us the highest possible discount rate to accomplish the project profitable (Keefe et al., 2012).

For the purpose of the study, the life of the forest plantation/agroforestry plots was estimated for 20 years as a specific tree species need up to 20 years to be logged.

5 RESULTS

5.1 Identification of useful tree species

Based on the collected data, there were identified 13 traditional tree species belonging to nine different families (see Table 3), that are suitable for reforestation activities in La Hesperia Biological Station & Reserve (further La Hesperia). Following three species, *Alnus acuminata, Coffea arabica, var.catura rojo* and *Nectandra spp*. were chosen in order to propose the reforestation alternatives in different combinations, together with annual or perennial crops that are recognized as important and widely cultivated in the area of TMCF.

Table 3 Identified traditional tree species in La Hesperia Biological Station & Reserve

Species	**Family**	**Local name**
Alnus acuminata	Betulaceae	Aliso blanco
Carapa guianensis aubl.	Meliaceae	Tangaré
Cinchona pubescens	Rubiaceae	Cascarilla/chincona
Coffea arabica, var.catura rojo	Rubiaceae	Caffee
Cedrela montana	Meliaceae	Cedro
Cordia eriostigma	Boraginaceae	Balsa negra
Croton magdalinensis	Euphorbiaceae	Sangre de dragon
Guarea guentheri	Meliaceae	Colorado
Nectandra spp.	Lauraceae	Canelo
Ochroma pyramidea	Malvaceae	Balsa blanca
Persea caerulea	Lauraceae	Aquacatillo
Prunus salicifolia	Rosaceae	Capulin
Psidium guajaba	Myrtaceae	Guava

5.2 Forest plantation design

Based on the identified tree species, three different reforestation alternatives were proposed i) Monoculture, ii) Intercropping and iii) Agroforestry model with following tree species and/or crops; and their designs.

Table 4 Species used in the different reforestation alternatives

Planting pattern	Tree speceis/Crop	Plants per hectare
Monoculture	*Alnus acuminata*	400
Intercropping	*Alnus acuminata*	100
	Coffea arabica (var.caturo rojo)	1,200
Agroforestry	*Alnus acuminata*	28
	Nectandra spp.	16
	Coffea arabica (var.caturo rojo)	400
	Musa x paradisiaca	192
	Zea mays	0.4*

Note: *Musa x paradisiaca* = plantain, *Zea mays* = maize; *there is necessary 11 kg per hectare, however there is sowed by maize 0.4 hectare twice a year.

5.2.1 Monoculture model

As this model is a monoculture, there was chosen only one tree species, native to the humid TMCF of Ecuador, *Alnus acuminata*, locally known as Aliso blanco. This tree species is commonly logged after six years of growing. *Alnus acuminata* is known for fixing nitrogen from the air, which is beneficial for other plants. It is often cultivated in plantation as silvopastoralism, as the grass is taking the nutrients from the tree. However the cattle can be placed on the plantation after two years as earliest. The design of the monoculture plantation as a silvopastoralism was set in spacing of 5x5 m (see Figure 7), which resulted in 400 trees per one hectare.

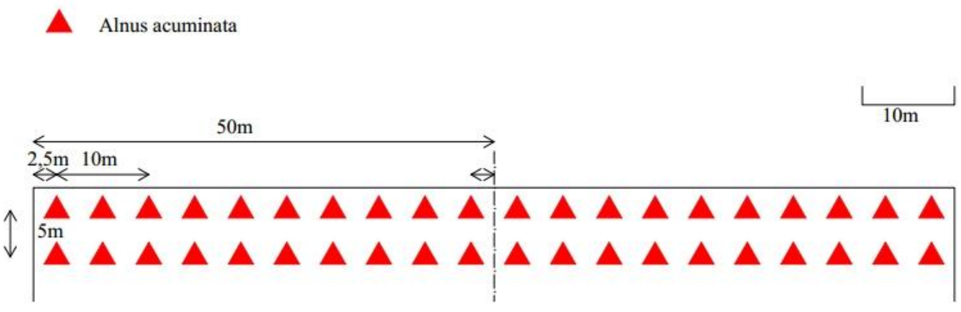

Figure 7 Planting pattern of Monoculture model

5.2.2 Intercropping model

There were proposed two traditional species in the region, *Alnus acuminata* and *Coffea arabica*, variation *Catura rojo*. The variety *Catura rojo* used to be planted in La Hesperia in past and thus there was verified its possibility and efficiency to cultivate it there. *Alnus acuminata* together with coffee can very well get along to each other and supply the nutrients. The design of *Alnus acuminata* was set as following, spacing of 10x10 m. In between planted *Alnus acuminate* two rows of coffee were intercropped in distance of 1.5 m apart (see Figure 8). According to this design, there were established 100 trees of *Alnus acuminata* and 1,200 coffee plants per one hectare.

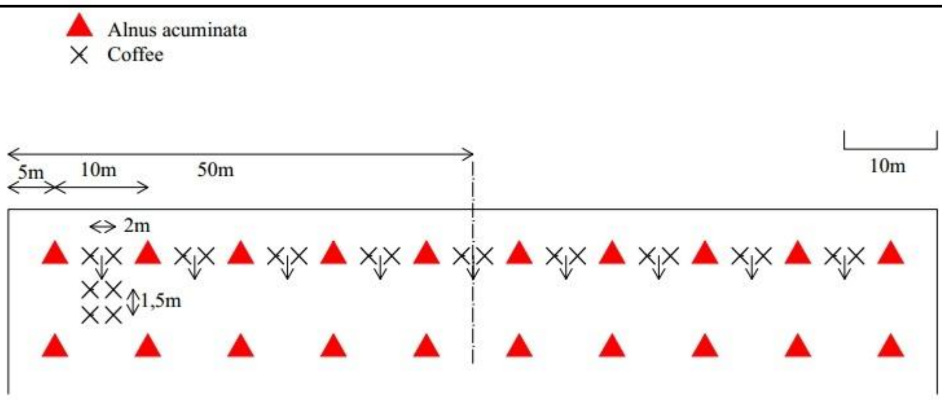

Figure 8 Planting pattern of Intercropping model

5.2.3 Agroforestry model

In agroforestry model two tree species were proposed, *Alnus acuminata* and *Nectandra spp*. The plantation was divided in two areas, where in the first area there were used two species as an intercropping, *Coffea arabica* and *Musa x paradisiaca*, known as plantains. The second half of the plantation was used for annual crops, while maize (*Zea mays*) was chosen as an example.

The design of the agroforestry model was following; the spaces between the two main tree species were 10 m and they were planted along the boundaries of the field. In the middle there was planted coffee (2x1.5 m), plantains (5x3 m) and it was intercropped by maize. Such agroforestry model resulted in 28 trees of *Alnus acuminata*, 16 trees of *Nectandra spp.*, 400 plants of *Coffea arabica* and 192 plants of plantains *(Musa x paradisiaca)* per hectare. In the rest of the area, approximately 0.4 of hectare, maize (*Zea mays*) was sowed. The design of the agroforestry plot is designed on the plan (see Figure 9) for better calculation of the profitability; however, the design can be done randomly. Nevertheless, there should be preserved that the plantains and subsequently trees provide shade for coffee. Maize can intercropped randomly between the single coffee plants.

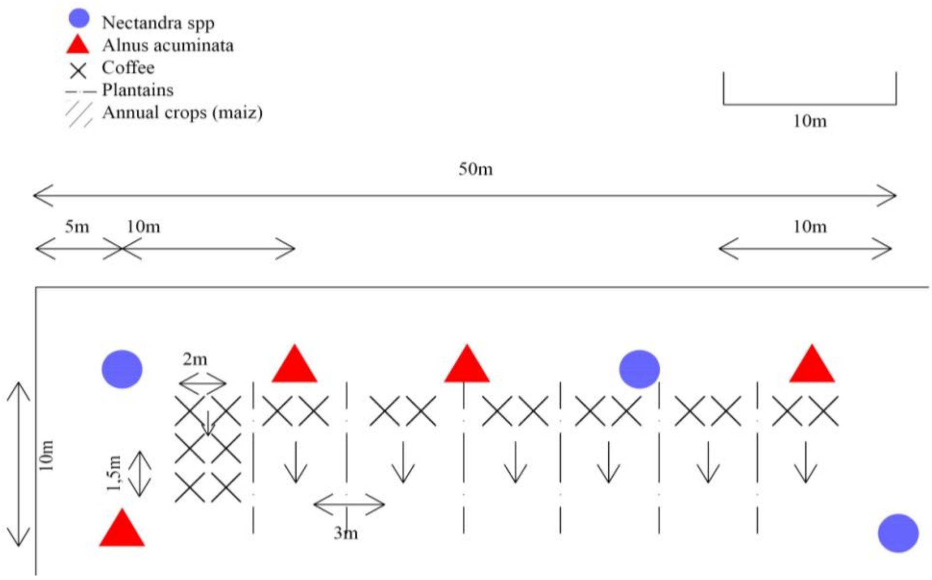

Figure 9 Planting pattern of Agroforestry model

5.3 Economic evaluation of reforestation alternatives

Evaluation of potential financial costs

Table 5 shows the detailed costs for the first year of Agroforestry model. The other alternatives are shown in Table 8 together with all costs for the period of first ten years. There was observed that costs during the first year of Monoculture are almost three times lower than costs of Agroforestry model as a result of lower number of practised activities.

Preparation of the land includes cleaning of the terrain before establishing plantation from shrubs, undesirable plants and weed. In addition, it includes an activity as marking the lines and signs where to make the holes and subsequently plant the plants. It includes tools as well. The terrain for planting only trees needs less cultivation than terrain for planting coffee and, much less than maize. Making holes varies a lot depending on the plant (trees or annual crops) and quantity.

In the model of Monoculture and Intercropping, there were not observed any costs for harvesting during the first year as trees are logged in the sixth year and coffee starts to be harvested in the third year after planting. Nevertheless, maize and plantains, in case of Agroforestry, are planted and/or sowed and harvested already during the first year of plantation. The transport includes the transportation of the plants from the nursery, about 12 km far from the reserve. The cost performs 1 USD per one km including the use of the car, fuel and driver. The harvest is transported to the town Tandapi (10 km far from the reserve) in case of maize and plantains. However, coffee has to be transported to the city of Santo Domingo in other province, approximately 60 km far.

Table 5 Costs during the first year (USD/ha) of Agroforestry

Activity	Unit	Cost per unit	Quantity	Total cost
Preparation of the land	man-days	16.00	21.00	336.00
Tools	number	10.00	20.00	200.00
Plants (trees)	number of plants	0.25	44.00	11.00
Plants (coffee)	number of plants	0.25	400.00	100.00
Plants (plantains)	number of plants	0.25	192.00	48.00
Seeds (maize)	kg	2.00	10.00	20.00
Transport	km	1.00	60.00	60.00
Planting	man-days	16.00	12.00	32.00

Sowing (maize)	man-days	16.00	4.00	64.00
Weed control	man-days	16.00	30.00	480.00
Herbicides	litres	7.00	2.00	14.00
Fertilizers (coffee)	kg	26.00	3.00	78.00
Fertilizers (trees)	kg	1.00	6.50	6.50
Fertilizing	man-days	16.00	3.50	32.00
Pruning	man-days	16.00	0.25	4.00
Maintenance of plantains	man-days	16.00	20.00	320.00
Harvest trees	man-days	25.00	0.00	0.00
Harvest coffee	man-days	16.00	0.00	0.00
Harvest plantains	man-days	16.00	8.00	128.00
Harvest maize	man-days	16.00	10.00	160.00
Transport of harvest	km	1.00	100.00	100.00
Administration	5 % of all costs	1.00	118.88	118.88
Others	10 % of all costs	1.00	249.64	249.64
Total costs				**2746.01**

Certain differences were observed between the three alternatives during the first year of plantations in terms of labour costs. It creates a significant share of total costs as Monoculture and Agroforestry model perform more than a half of all costs, 55% and 63% respectively. Surprisingly, Intercropping model shows the values of 36% only.

In case of Agroforestry, there is obvious the high demand of labour as there are many additional operations which has to be done at least once a year, for instance cleaning the terrain for sowing maize, sowing maize itself , harvesting maize and plantains or taking the harvest to the market in the town. Moreover, mentioned operations have to be done since the first year of plantation, unlikely in other alternatives, where coffee starts to produce in third year after plantation and trees can be logged after six years.

Table 6 The labour costs during the first year in different alternatives (USD/ha)

			Monoculture		**Intercropping**		**Agroforestry**	
Activity	**Unit**	**Cost per unit**	Quantity	Total costs	Quantity	Total costs	Quantity	Total costs
Clean the terrain	M-D	16.00	3.00	48.00	5.00	80.00	7.00	112.00
Make spacing/signs	M-D	16.00	2.00	32.00	4.00	64.00	4.00	64.00
Make holes	M-D	16.00	5.00	80.00	10.00	160.00	10.00	160.00
Plant distribution	M-D	16.00	0.50	8.00	1.00	16.00	2.00	32.00
Planting the plants	M-D	16.00	3.00	48.00	8.00	128.00	10.00	160.00
Sowing maize	M-D	16.00	0.00	0.00	0.00	0.00	4.00	64.00
Weed control	M-D	16.00	18.00	288.00	5.00	80,00	30.00	480.00
Fertilizing (coffee)	M-D	16.00	0.00	0.00	1.00	16.00	1.50	24.00
Fertilizing (trees)	M-D	16.00	1.00	16.00	0.50	8.00	2.00	32.00

Pruning	M-D	16.00	0.00	0.00	1.00	16.00	0.25	4.00
Maintenance (plant.)*	M-D	16.00	0.00	0.00	0.00	0.00	20.00	320.00
Harvest plantains	M-D	16.00	0.00	0.00	0.00	0.00	8.00	128.00
Harvest maize	M-D	16.00	0.00	0.00	0.00	0.00	10.00	160.00
Total costs				**520.00**		**568.00**		**1740.00**

Note: M-D = man-days; *maintenance of plantains

Remarkable is the fact that costs for labour of Monoculture are slightly lower than Intercropping, 520 and 568 USD respectively; however the share of the total costs is much higher in case of Intercropping. In the Intercropping model there was planted less amount of tree plants per hectare, thus the labour significantly decrease. Even though there is an additional species, coffee, it does not require high maintenance during the first year as there is no harvest yet.

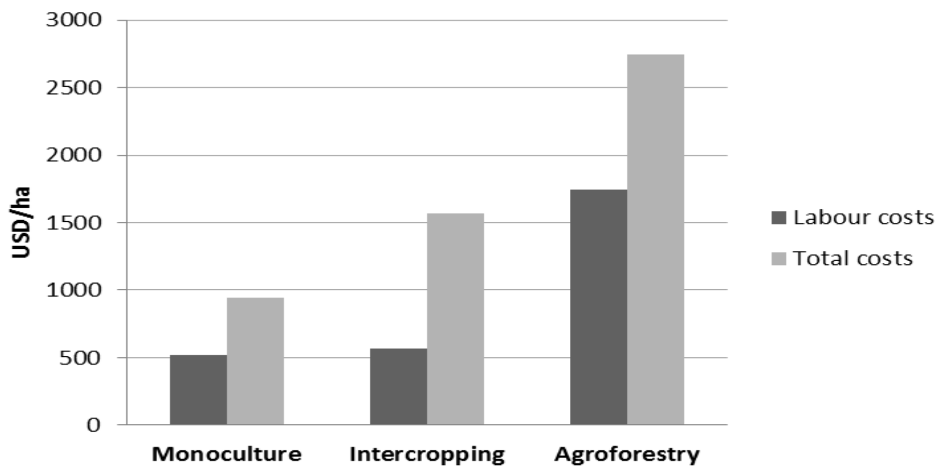

Figure 10 Proportion of labour costs and total costs

Table 8 shows the costs for each alternative during the period of ten years. The costs vary a lot according to different year and especially different alternative. In Monoculture and Intercropping model was observed that the costs for land preparation during the years 2 to 6 are basically zero, Agroforestry model performs significantly higher costs during this period due to the preparation of the terrain for the maize twice a year. Planting includes purchase of plants, transportation of the plants from the nursery to the farm, the distribution of plants and planting itself or sowing maize. In case of Monoculture and Intercropping model the planting is done just during the first year, in year 8 (as the trees are logged in year 6 and there is one gap year) and in year 15. In Agroforestry model, maize is sowed twice a year, thus the costs per planting during the years 2 to 7, 9 to 14 and 16 to 20 results in 124 USD per year (including the purchase of seeds, transportation and sowing of maize). In terms of planting itself and plant distribution, the highest costs perform Agroforestry model as there is necessary to plant, firstly, big amount of plants and secondly, many different species.

Maintenance includes activities as weed control, purchase of fertilizers or herbicides, fertilizing, maintenance of plantains or pruning of coffee. In terms of weed control, up to first two years of trees, there is necessary to carry out the weeding manually. The costs of pruning of the coffee varies among the years, as in Intercropping it takes one man-day in the first year, two man-days during the second year and three man-days since the third year on. Harvest includes the logging of the trees as well as harvesting coffee, plantains and maize. The logging of trees is carried out once in 6 years in case of *Alnus acuminata* and once in 20 years in case of *Nectandra spp*. Particularly in Monoculture; harvest creates a major part of the costs during the year six. It can be explained by two facts; firstly, there is necessary lot of labour force, it is estimated to work 0.2 of man-day for logging and facilitating one single tree. Secondly, there is necessary to hire a qualified person, who knows how to work with power saw and how to carry out the logging and its processing as the timber is sold in form of wood boards. The salary is 25 USD/man-day for the qualified person including renting the power saw and fuel; and 16 USD/man-day for non-qualified person (as they are used for other activities as planting, sowing or harvesting coffee).

The total potential financial costs cumulated for 20 years vary significantly among proposed alternatives. The lowest total costs per hectare for 20 years of plantation were observed in Monoculture, with a value of 14,366 USD. It is more than three times less than it was observed in Agroforestry model (47,298 USD). Intercropping model shows the value of 25,099 USD, almost two times less than Agroforestry model. Surprisingly, the highest costs of Monoculture occurred in the year of logging, year 6th (2,961 USD), 13th (2,961 USD) and 20th (3,016 USD) as there is needed a more qualified labour (see above). The costs for logging are more than three times higher than establishment costs in the first year, in case of Monoculture. Intercropping shows similar scenario; however the establishment costs are slightly less than costs for the years of logging. The highest costs in

Agroforestry were observed in the first year of plantation, including the establishment costs and maintenance during the first year. The costs per year do not fluctuate as much as in case of Monoculture.

There is important to mention, as the reserve is a private property, there is not necessary to rent a land, which usually creates a significant part of the costs as well as no irrigation system is needed as the reserve is located in the mountain cloud forest with relatively high precipitation and humidity.

Table 7 Cumulated costs for the period of 20 years (USD/ha)

Years	Monoculture	Intercropping	Agroforestry
1	947.10	1,563.87	2,746.01
2	1,367.52	1,927.70	4,667.78
3	1,621.62	2,874.80	6,827.89
4	1,709.40	3,992.84	9,072.00
5	1,797.18	5,110.88	11,316.11
6	4,758.02	7,037.42	13,823.78
7	4,813.46	8,173.94	16,061.06
8	5,723.60	9,641.94	18,780.83
9	6,144.02	10,759.98	21,192.94
10	6,398.12	11,878.02	23,437.05
11	6,485.90	12,996.06	25,702.16
12	6,573.68	14,114.10	27,946.28
13	9,534.53	16,059.12	30,453.94
14	9,589.97	17,177.16	32,699.63
15	10,500.11	18,645.17	35,415.19
16	10,920.53	19,763.21	37,827.30
17	11,174.63	20,881.25	40,071.41
18	11,262.41	21,999.29	42,336.53
19	11,350.19	23,117.33	44,580.64
20	14,366.47	25,099.31	47,298.30
Total costs	**14,366.47**	**25,099.31**	**47,298.30**

Table 8 Total costs for the first 10 years of plantations (USD/ha)

I. **Monoculture**	**Year**									
Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Preparation of the land	260.00	0.00	0.00	0.00	0.00	0.00	48,00	228,00	0.00	0.00
Planting	196.00	0.00	0.00	0.00	0.00	0.00	0.00	196,00	0.00	0.00
Maintenance	364.00	364.00	220.00	76.00	76.00	76.00	0.00	364.00	364.00	220.00
Harvest	0.00	0.00	0.00	0.00	0.00	2,487.50	0.00	0.00	0.00	0.00
Others	127.10	56.42	34.10	11.78	11.78	397.34	7.44	122.14	56.42	34.10
Total costs	947.10	420.42	254.10	87.78	87.78	2,960.84	55.44	910.14	420.42	254.10

II. **Intercropping**	**Year**									
Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Preparation of the land	454.00	0.00	0.00	0.00	0.00	0.00	16.00	206.00	0.00	0.00
Planting	549.00	0.00	0.00	0.00	0.00	0.00	0.00	97.00	0.00	0.00
Maintenance	351.00	315.00	256.00	256.00	256.00	256.00	256.00	256.00	256.00	256.00
Harvest	0.00	0.00	564.00	712.00	712.00	1412.00	712.00	712.00	712.00	712.00
Others	209.87	48.83	127.10	150.04	150.04	258.54	152.52	197.01	150.04	150.04
Total costs	1,563.87	363.83	947.10	1,118.04	1,118.04	1,926.54	1,136.52	1,468.01	1,118.04	1,118.04

III. **Agroforestry**	**Year**									
Activity	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Preparation of the land	536.00	32.00	32.00	32.00	32.00	48.00	32.00	262.00	32.00	32.00
Planting	495.00	124.00	124.00	124.00	124.00	124.00	124.00	187.00	124.00	124.00
Maintenance	958.50	920.50	747.50	747.50	747.50	747.50	741.00	907.50	907.50	747.50
Harvest	388.00	516.00	916.00	996.00	996,00	1,231.00	996.00	996.00	996.00	996,00
Others	368.51	329.26	340.61	344.61	344.61	357.16	344.29	367.26	352.61	344.61
Total costs	2,746.01	1,921.76	2,160.11	2,244.11	2,244.11	2,507.66	2,237.29	2,719.76	2,412.11	2,244.11

Evaluation of potential financial benefits

Benefits of plantations are created from different composition and proportional representation of items; i.e. wood (*Alnus acuminata* and *Nectandra spp*.), woody perennial (coffee beans), perennial crop as plantains and annual crop as maize.

In Monoculture model, timber (*Alnus acuminata*) creates the only source of financial benefits as it is a monoculture. According to the literature sources, *Alnus acuminata* is ideally to be logged after six years (see Table 9) as there is proved, that it provides enough amount of semi-hard timber regarding to the time of growing. After six years of growing, one tree produces approximately 0.4 m^3 of wood. The timber is sold in form of wood boards which are processed within the reserve immediately after logging by a qualified person with motor saw. One m^3 of wood board is sold for 50 USD. Within the village La Esperia, close to the reserve, there is small manufactory for producing the fruit boxes from *Alnus acuminata*, hence the major part of the harvest can be sold to the manufacturer. The harvest is done once in six years, which finally result in three harvests during the period of 20 years, creating total income of 24,000 USD per hectare.

As in the Intercropping model there is intercropped *Alnus acuminata* with coffee (*Caffee arabica, var. catura rojo)*, the income is more stable since the third year of plantation. In average, one plant produces 2 kg of coffee beans and it is harvested once a year. The price depends on the conditions of sold coffee; however in this case study, there is proposed to sell the raw, unprocessed (green) coffee, which can be sold for 0.62 USD per kg on the market in city of Santo Domingo, approximately 60 km far from La Hesperia. The income starts to be generated since the third year, where it results in 744 USD as coffee does not produce the maximal yield in the first year of production. However during the following year, there is a stable income from coffee 1,488 USD per year. The timber is logged three times during the period of 20 years, resulting in 6,000 USD, as there is a less density of planted trees compared to the Monoculture model. The total financial benefits after the estimated period result in 32,040 USD and coffee creates more than 80% of all financial benefits (26,040 USD).

In the Agroforestry model, four of five items can be harvested already in the sixth year, resulting in total financial benefits of 55,333 USD for all estimated period of 20 years. The highest benefit is generated from plantains (50.8%), followed by maize (29.6%) and coffee (15.7%). Timber creates minor part of financial benefits performing only 3.9% (3.0% by *Alnus acuminata* and 0.9% by *Nectandra spp*.). Similarly as *Alnus acuminata*, the price of *Nectandra spp*. is 50 USD per m^3 of wood board; however the logging is ideal after twenty years with production of 0.85 m^3 of wood. Both tree species are considered as semi-hard wood suitable mainly for furniture as well as sculpturing or production of decorative artefacts. The most valuable crops, plantains, are sold in Ecuador per "*rácima*" for 2.5 USD. *Rácima* is locally used expression performing a bunch of plantains, which weight approximately 30 kg. Plantains are usually harvested up to three times per year, which result in total 90 kg of plantains per year per one plant. The first year plantains do not produce the maximal potential production, hence the income is 720 USD in the first year, whilst in following years it performs 1440 USD per year. Since the first year, maize is sowed and thus harvested twice a year. The total yield per one year per 0.4 hectare is in average 1.24 tonne. One kg of maize is sold on the market in the town Tandapi (10 km far from the reserve) for 0.66 USD.

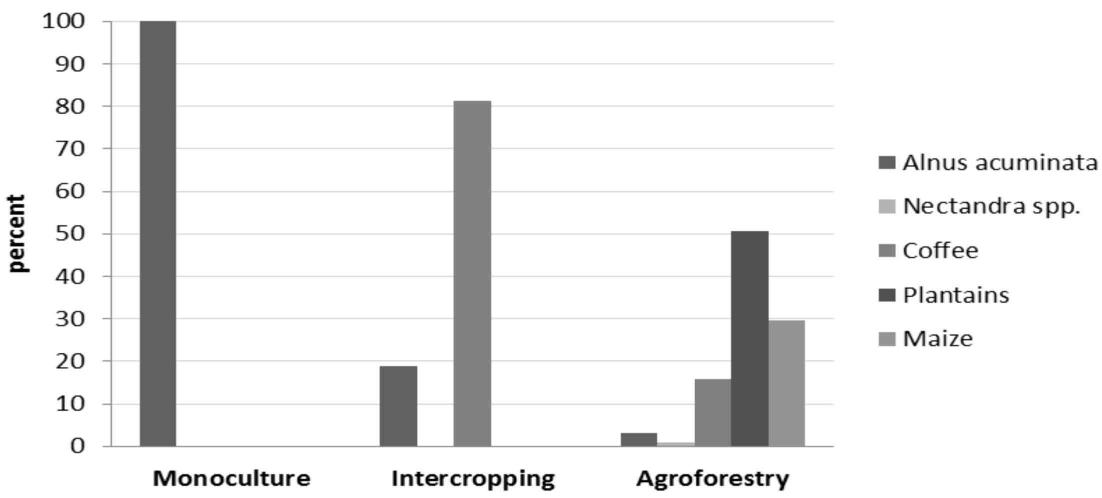

Figure 11 Diversification of produced items of proposed alternatives

As there can be seen on the Figure 11, there is a significant difference in terms of species diversification. The most diversified model is Agroforestry where the risk is spread to five different items and thus reduced. Tha major part is created by annual or perrenial crops (plantains, maize and coffee), creating more than 96% of total income. Monoculture has the only benefit, timber. For that reason risk of Monoculture model is very high. Intercropping is diversified with coffee, which perform the major part of income.

Table 9 Potential financial benefits of proposed alternatives (USD/ha)

Monoculture	**Year**								
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7 to 19**	**20**	**Total costs**
Alnus acuminata	0.00	0.00	0.00	0.00	0.00	8,000.00	8,000.00	8,000.00	**24,000.00**
Nectandra spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Coffee	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Plantains	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
	0.00	0.00	0.00	0.00	0.00	8,000.00	8,000.00	8,000.00	**24,000.00**

Intercropping	**Year**								
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7 to 19**	**20**	**Total costs**
Alnus acuminata	0.00	0.00	0.00	0.00	0.00	2,000.00	2,000.00	2,000.00	**6,000.00**
Nectandra spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Coffee	0.00	0.00	744.00	1,488.00	1,488.00	0.00	19,344.00	1,488.00	**26,040.00**
Plantains	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Maize	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Subtotal	0.00	0.00	744.00	1,488.00	1,488.00	3,488.00	21,344.00	3,488.00	**32,040.00**

Agroforestry	**Year**								
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7 to 19**	**20**	**Total costs**
Alnus acuminata	0.00	0.00	0.00	0.00	0.00	560.00	560.00	560.00	**1,680.00**
Nectandra spp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	525.00	**525.00**
Coffee	0.00	0.00	248.00	496.00	496.00	496.00	6,448.00	496.00	**8,680.00**
Plantains	720.00	1,440.00	1,440.00	1,440.00	1,440.00	1,440.00	18720,00	1,440.00	**28,080.00**
Maize	818.40	818.40	818.40	818.40	818.40	818.40	10639,20	818.40	**16,368.00**
Subtotal	1,538.40	2,258.40	2,506.40	2,754.40	2,754.40	3,314.40	36,367.20	3,839.40	**55,333.00**

Cost-benefit analysis (CBA)

To evaluate the feasibility of investment in plantation production and economic viability, the criteria such as Net Present Value (NPV), Internal Rate of Return (IRR), Benefit Cost Ratio (BCR) and Pay Back Period (PBP) were calculated.

The table 11 shows CBA in terms of NPV for each of proposed alternatives. There were applied two discount rates, 10% and 15%. In both considered discount rate, the reforestation alternatives are economically viable. Considering the discount rate of 10%, the highest NPV showed Agroforestry model, followed by Monoculture and Intercropping model, showing values of 2,409 USD; 2,339 USD and 1,279 USD respectively. There is no significant difference between the NPV of Agroforestry and Monoculture model. Taking in account the discount rate 15%, there was observed similar scenario, resulting in values of 1,392 USD, 1,062 USD and 313 USD for Agroforestry, Monoculture and Intercropping model respectively. Remarkable is the fact that the NPV of Intercropping is more than four times lower than the Agroforestry model (considering the 15% discount rate). However, if there is considered 20% discount rate, only Monoculture and Agroforestry model is profitable, showing values of 508 USD and 796 USD respectively. Intercropping model shows the value of -220 USD (see Table 10).

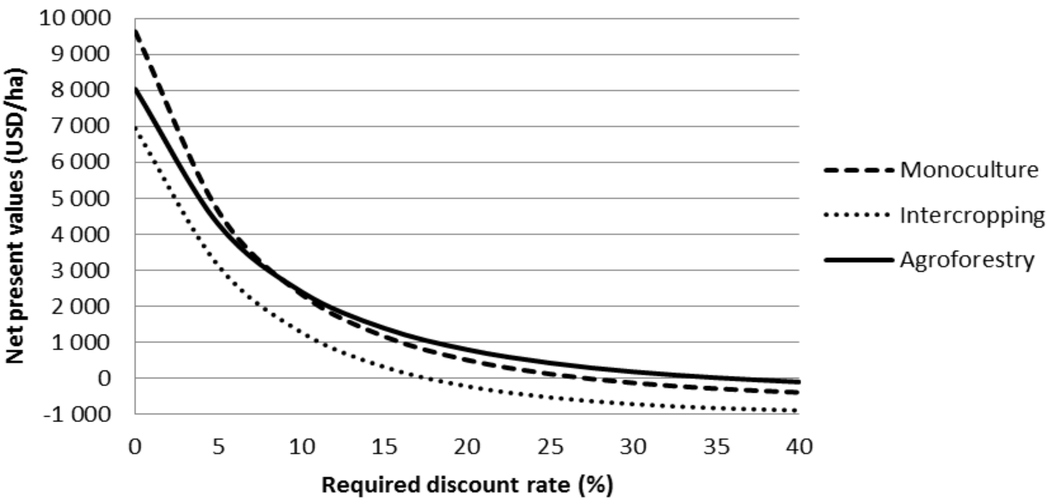

Figure 12 Net present values within changes of discount rates of three different reforestation alternatives

On the Figure 12 the changes in the NPV of all proposed alternatives are shown. The curves follow similar scenarios. Remarkable is the fact, that if we do not consider any discount rate (discount rate 0%) Monoculture shows much higher values than other alternatives. There is the switch of leading positions (Monoculture and Agroforestry) in discount rate of approximately 7%.

The highest IRR was observed for Agroforestry model with 35.6% (see Table 10), followed by Monoculture (27.1%) and Intercropping (17.6%) model. There was calculated BCR as well, which shows similar values among proposed alternatives, 1.67 (Monoculture), 1.28 (Intercropping) and 1.17 (Agroforestry). It proves that investment in all alternatives can be considered substantial and economically justifiable. The payback period (PBP) favours the Agroforestry model as the break-even point is between 4.00 and 5.00 years. However PBP of Monoculture and Intercropping model is around six years, which is slightly more than in Agroforestry model.

Table 10 Cost-benefit analysis of proposed alternatives

	Monoculture	Intercropping	Agroforestry
Total net benefits (USD/ha)	9,633.53	6,940.70	8,034.70
NPV, i = 10 % (USD/ha)	2,338.69	1,279.37	2,409.39
NPV, i = 15 % (USD/ha)	1,162.26	313.29	1,391.79
NPV, i = 20 % (USD/ha)	507.76	-222.14	796.04
IRR (%)	27.12	17.58	35.56
BCR	1.67	1.28	1.17
PBP (years)	6.00	5.00-6.00	4.00-5.00

If there are compared the three reforestation alternatives, the most economically beneficial and thus the most suitable for reforestation from the economic point of view is definitely Agroforestry model, as it has the highest NPV considering discount rates of 10%, 15% even 20%. Moreover, the IRR is the highest among all alternatives and the PBP is also the shortest as the reserve prefers the return of invested money as soon as possible. Another fact which favours Agroforestry model is the risk reduction through crop diversification. The only bottle-neck where the Agroforestry model is not ranking the best results is the BCR, which is the lowest among all alternatives. The Agroforestry model is followed by Monoculture as it shows the second highest NPV as well as IRR and is ranking in BCR. However PBP is lower than in Intercropping, difference is not significant. Diversification of crops performs very important, which Monoculture model does not fulfil.

Table 11 Net present values of the three reforestation alternatives during the period of 20 years (USD/ha)

	Monoculture			Intercropping			Agroforestry		
Years	**Net benefits**	**NPV df=10 %**	**NPV df=15 %**	**Net benefits**	**NPV df=10 %**	**NPV df=0,15 %**	**Net benefits**	**NPV df=10 %**	**NPV df=0,15 %**
1	-947.10	-861.00	-823.57	-1,563.87	-1,421.70	-1,359.89	-1,207.61	-1,097.83	-1,050.10
2	-420.42	-347.45	-317.90	-363.83	-300.68	-275.10	336.64	278.21	254.55
3	-254.10	-190.91	-167.07	-203.10	-152.59	-133.54	346.29	260.17	227.69
4	-87.78	-59.95	-50.19	369.96	252.69	211.53	510.29	348.53	291.76
5	-87.78	-54.50	-43.64	369.96	229.72	183.94	510.29	316.85	253.70
6	5,039.16	2,844.47	2,178.57	1,561.46	881.40	675.06	806.74	455.38	348.77
7	-55.44	-28.45	-20.84	351.48	180.36	132.13	517.11	265.36	194.40
8	-910.14	-424.59	-297.53	19.99	9.33	6.54	34.64	16.16	11.32
9	-420.42	-178.30	-119.51	369.96	156.90	105.17	342.29	145.16	97.30
10	-254.10	-97.97	-62.81	369.96	142.64	91.45	510.29	196.74	126.14
11	-87.78	-30.77	-18.87	369.96	129.67	79.52	489.29	171.49	105.17
12	-87.78	-27.97	-16.41	369.96	117.88	69.15	510.29	162.59	95.38
13	5,039.16	1,459.66	819.00	1,542.98	446.95	250.78	806.74	233.68	131.12
14	-55.44	-14.60	-7.84	369.96	97.42	52.29	508.71	133.96	71.90
15	-910.14	-217.88	-111.85	19.99	4.79	2.46	38.84	9.30	4.77
16	-420.42	-91.50	-44.93	369.96	80.51	39.54	342.29	74.49	36.58
17	-254.10	-50.27	-23.61	369.96	73.19	34.38	510.29	100.96	47.42
18	-87.78	-15.79	-7.09	369.96	66.54	29.89	489.29	88.00	39.54
19	-87.78	-14.35	-6.17	369.96	60.49	26.00	510.29	83.44	35.86
20	4,983.72	740.80	304.51	1,506.02	223.86	92.02	1,121.74	166.74	68.54
Total	**9,633.53**	**2,338.69**	**1,162.26**	**6,940.70**	**1,279.37**	**313.29**	**8,034.70**	**2,409.39**	**1,391.79**

6 DISCUSSION

Species selection and planting pattern design

Our study follows other studies on reforestation and native species growing wildly in Ecuador was preferred for scenarios modelling (Carpenter et al., 2004; Günter et al., 2009; Schiappacasse, 2012). The reason for that was that the indigenous species are more suitable for reforestation activities in the buffer zones, within the conservation areas or natural reserves (Butterfield, 1995). Unfortunately, native species are remained often overlooked in reforestation programmes, mainly due to the insufficient knowledge or lack of information about the native species by implementers of the projects (Günter et al., 2009), availability of planting material (in the case of exotic species) or proven good productivity (Beck et al., 2008). Traditional or native species are important from the socio-economic point of view, especially where the local households depend upon them for different modes of uses (Butterfield, 1995). For this reason traditional species were proposed for reforestation activities which are widely used in for instance carpentry sector close to La Hesperia reserve. All of crop species identified in La Hesperia were useful for reforestation purpose and grows wildly in Ecuador, mainly in the TMCF (Holdrige et al., 1947; NFTA, 1997; Nair, 2010).

The monoculture of *Alnus acuminata* can be planted as a silvopastoralism, which brings many other benefits apart from timber, such as forage or organic matter (Current et al., 1995). Additionally, *Alnus acuminata* has an ability to fix the nitrogen from the air and enrich the soil. Based on this, *Alnus acuminata* belongs to the prominent component of silvopastoral systems in mountainous farming systems in South America (Dunn et al., 1990; Kass et al., 1997; Gamboa et al. 2010). According to Budowski (1983), cows grazed on the pastures forested by *Alnus acuminata* produce higher quantity of milk. Moreover, 33% increase in weight gain of cattle grazing under *Alnus acuminata* has been reported compared to open pastures (PROTA, 2014). This could represent a positive benefit for La Hesperia reserve as there are 21 cows breaded entirely for milk production.

Reforestation model of trees in the coffee systems is one of the traditional agroforestry practises. Preferred species in such model were *Cedrela odorata, Diphysa Americana, Nectandra spp.,* but farmers plant also citruses, bananas or plantains (Current et al., 1995). Important fact is that the combination of *Alnus acuminata* with different kinds of coffee is also common (Gamboa et al., 1993). Beside timber, *Alnus acuminata* also provides other services and products such as supply of nutrients for coffee, providing shade for coffee plants as well as producing organic matter useful for preparation of compost or fodder (Current et al., 1995; Parrotta and Roshetko, 1997; PROTA, 2014). According to Parrotta and Roshetko (1997) the planting patterns in the intercropping model results in 100 trees per one hectare, same as it was designed in the study.

Designing of agroforestry system follows traditional design as the trees are established along the field boundaries generally in a single line at different distances (Current et al., 1995). Native species were preferred in the system design as is seems to be more of multi-task character, e.g. restoration of degraded areas, biodiversity conservation or increase, production of timber or risk reduction of pests and diseases (Parrotta and Knowles, 1999; Piotto et al., 2004).

Regarding to the mixed plantation, it was reforested by native species as they seem to be more appropriate to the wider range of options as protection, biodiversity, production, risk reduction, or restoration of degraded areas (Parotta and Knowles, 1999; Piotto et al., 2004). Our proposed tree species *Alnus acuminata* and *Nectandara spp* were also recommended by other studies focused on reforestation of degraded lands (Gamboa et al., 2010; Keefe et al., 2012).

Financial costs and benefits of plantations and agroforestry plots

The cultivation of mixed forests corresponds to the principles of sustainable forestry. Moreover it generates a good economical profit at the same time maintaining biodiversity (Šálek and Sloup, 2012).

The IRR of our study shows similar or higher values compared to other studies in similar environment of tropical forest in Latin America (Wunder and Alban, 2008; Open Forest, 2014). However it is necessary to mention that our results did not add forest land prices into calculations because the land is owned by the reserve (Šálek and Sloup, 2012). However there were included in the 10% other costs the taxes for the land. For this reason comparison of the results with other studies have to be seen with certain limitations.

Current et al. (1995) documented that a tree *Cedrela odorata* that is planted in Ecuador as well has a higher economic efficiency in monoculture (IRR=19.8%), than in intercropping with coffee (IRR=24.6%). However, our designed patters shown completely different efficiency, i.e. IRR of monoculture was higher than of intercropping model, 27.1% and 17.6% respectively. This could be explained by difference in the climate, natural conditions (TMCF), maintenance and particularly by the different tree species. Similarly to our study, the pure plantation shows higher IRR than the mixed one (Šálek and Sloup, 2012). Our monoculture model based on *Alnus acuminata* shows slightly higher economic efficiency (IRR=27%) than the monoculture based on introduced tree species as *Eucalyptus spp.* (IRR=25%) and higher than *Tectona grandis* (IRR=15%) as reported by Niskanen (1998). However, the native tree plantations reach IRR between 5% and 13% (Cubbage et al., 2007), which is significantly less than in our proposed designs.

In terms of BCR, there was observed higher ratio in monoculture compared to the mixed plantations, which is in correspondence to the study of Peiris et al. (2003). Correspondingly, PBP is similar to the situation observed in Central Vietnam of monoculture and mixed plantations (Šálek and Sloup, 2012).

Furthermore, the financial risk is higher if it is less diversified as in case of Monoculture. Only one final harvest operation was assumed and there was excluded the thinning condition, similarly as in case study of Günter et al. (2011). Hence there is no compensation effect of the market-price volatility.

The highest labour costs were performed by Agroforestry model. It is obvious, that more crop or tree diversification require higher demand on labour. However higher demand of labour should be compensated by higher yields (Lojka et al., 2008).

Non-financial benefits of plantations and agroforestry plots

There is a significant increase in biomass production as fodder, fuel, timber etc. with the adoption of agroforestry scenario. Additionally, reduction of dependency on the natural forest is another benefit for local households as agroforestry could supply their needs (Gangadharappa et al., 2003; Piotto et al., 2004). Moreover, the mixed stands can capture more solar energy as each plant has different requirements and crowns are distributed widely (Guariguata et al., 1995). This possibility also brings the benefits in risk reduction of insects, pests or disease issue (Gangadharappa et al., 2003; Lamb et al., 2005) or of the uncertainty of future market (Lamb et al., 2005). On the contrary, monoculture shows higher risk linked to the pests and disease incidence (Evans and Med, 2001). Additionally, in terms of monoculture and short-rotation cycles, the lower biodiversity richness is usually reported compare to plantation with long rotation cycle (McNamara et al., 2006). From the socio-economic point of view, Ianni and Geneletti (2010) observed that farmers in different regions of Latin America were highly influenced by timber industry and forestry advisors, who support the forest plantations of introduced species with better compare to native ones as it is expected that farmers and local dwellers would reduce the illegal extraction of timber and, at the same time, their income would increase via working for/in the reserve (Gamboa et al., 2010). In Ecuador, 8.4% of economically active population is involved in the forest and timber industry (UN-REDD, 2011), which makes this sector attractive. Reforestation activities have a potential to generate a significant amount of employment for local communities (Smith, 2002). In this regards, agroforestry pattern, and in a certain manner intercropping scenario as well, provides higher number of job opportunities then other scenarios as is more labour-intensive. For example in the case of monoculture, labour force will be hired particularly for planting and harvesting period.

Recommendations

Local communities should be more involved in the decision making and particularly their opinions should be taken in consideration in all further strategies related to environmental and social issues linked to reforestation of the reserve and it management in general. Local households should be provided with knowledge of the most suitable conservation practices and suitable livelihood strategies that are based on mutual interaction with local forest.

Furthermore the collection of forest products and timber logging has to be regulated as well as appropriate technologies and farming systems have to be introduced in order to ensure sustainable development (Banout et al. 2009). Some studies have pointed out the potential failure of sustainable forestry on private lands, including those controlled by local communities, if technologies are not correctly transferred and adopted or commercial interests prevail over conservation objectives (Lopéz et al., 2010).

Limitation

Our study should be viewed with certain limitations. Firstly, as almost the entire stakeholders spoke only Spanish and any translator was not available, some misinterpretation due to the language barrier could affect our results (Lohman, 2011). This could be example of particularly gathering data on livelihood strategies of local households and future expectations. Secondly, our study is designed for the purpose of the private natural reserve and to the environment of the TMCF, thus it cannot be generalized for any environment.

7 CONCLUSION

This master thesis documented three different reforestation alternatives: monoculture, intercropping and agroforestry model. For the each of proposed alternative, the most appropriate crop species were chosen considering the local conditions, while the traditional species were preferred. Results proved that all three alternatives, monoculture of *Alnus acuminata*, intercropping of *Alnus acuminata* and *Coffea Arabica*, and agroforestry model are economically viable (considering both 10% and 15% discount rate), however they differ in economic efficiency. Considering discount rate of 20%, only monoculture and agroforestry model are economically viable. The internal rate of return represents 27.1%, 17.6% and 35.6% for monoculture, intercropping and agroforestry model, respectively. The payback period showed similar values of all three alternatives, namely 6.00, 5.00-6.00 and 4.00-5.00. The highest NPV (d=10%) was observed in agroforestry model (2,404 USD), followed by monoculture (2,338 USD) and intercropping (1,279 USD) model. Environment and social benefits were considered as well, and, due to contributing specifically to the environment conservation, reaching higher economic profitability and having positive social impact, agroforestry model was recommended as the most suitable and appropriate alternative.

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ANNEXES

List of annexes

Rights of Nature Articles in Ecuador's Constitution

Title II
Fundamental Rights

Chapter 1
Entitlement, Application and Interpretation Principles of the Fundamental Rights

Art.10 Rights Entitlement.- Persons and people have the fundamental rights guaranteed in this Constitution and in the international human rights instruments.

Nature is subject to those rights given by this Constitution and Law.

Chapter 7th: Rights for Nature

Art. 71. Nature or Pachamama, where life is reproduced and exists, has the right to exist, persist, maintain and regenerate its vital cycles, structure, functions and its processes in evolution.

Every person, people, community or nationality, will be able to demand the recognitions of rights for nature before the public organisms. The application and interpretation of these rights will follow the related principles established in the Constitution.

The State will motivate natural and juridical persons as well as collectives to protect nature; it will promote respect towards all the elements that form an ecosystem.

Art. 72. Nature has the right to restoration. This integral restoration is independent of the obligation on natural and juridical persons or the State to indemnify the people and the collectives that depend on the natural systems.

In the cases of severe or permanent environmental impact, including the ones caused by the exploitation on non renewable natural resources, the State will establish the most efficient mechanisms for the restoration, and will adopt the adequate measures to eliminate or mitigate the harmful environmental consequences.

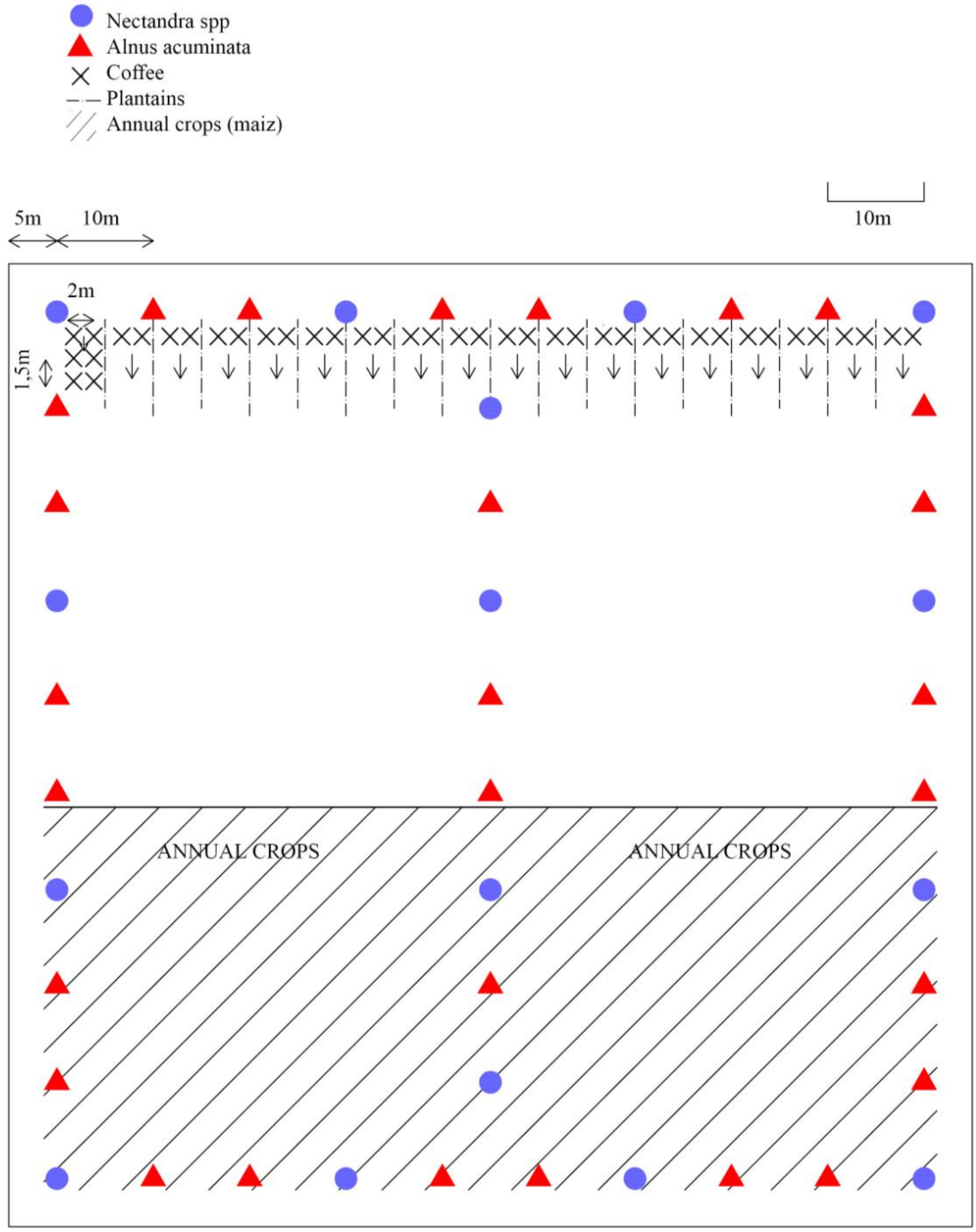
Art. 73. The State will apply precaution and restriction measures in all the activities that can lead to the extinction of species, the destruction of the ecosystems or the permanent alteration of the natural cycles.

The introduction of organisms and organic and inorganic material that can alter in a definitive way the national genetic patrimony is prohibited.

Art. 74. The persons, people, communities and nationalities will have the right to benefit from the environment and form natural wealth that will allow wellbeing.

The environmental services are cannot be appropriated; its production, provision, use and exploitation, will be regulated by the State.

Annex 1 The Constitution of the Republic of Ecuador (in English translation), including codification of rights of nature as a first country in the world. Source: Rights of Nature (2013)



Annex 2 Planting pattern of agroforestry plot (timber, plantains, coffee and maize)

Annex 3 La Hesperia Biological Station & Reserve. Pichincha province, Ecuador

Annex 4 The main building of La Hesperia Biological Station & Reserve. Pichincha province, Ecuador

Annex 5 Typical view on a tropical mountain cloud forest (TMCF). La Hesperia Biological Station & Reserve, Pichincha province, Ecuador

Annex 6 Transect walk with the forestry engineer (left) and the volunteer. Behind them there is visible the agroforestry plot. Las Palmas, Pichincha province, Ecuador

Annex 7 The forestry engineer and an example of agroforestry plot. Las Palmas, Pichincha province, Ecuador

Annex 8 Model of agroforestry plot (coffee, plantains and timber). Popayan, Colombia