UNIVERSITÀ DEGLI STUDI DI PADOVA
Dipartimento Territorio e Sistemi Agro-Forestali
Department of Land, Environment Agriculture and Forestry

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Forest regeneration after natural disturbance: an assessment of costs and benefits

Relatore/Supervisor:
Paola Gatto, Professoressa, University of Padova
Co-Supervisor:
Tom Beckley, Professor, University of New Brunswick

Submitted by:
Gillian Davis

Matricola n./Student n.

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ABSTRACT

Forests are important socioeconomically and environmentally but are increasingly vulnerable to natural disturbances. Windstorm damages, like those from Vaia in 2018, exemplify the growing risk to monocultural forest landscapes. There are debates about optimal forest management strategies for regeneration after damages and there are few studies that integrate both biophysical and socioeconomic strategies. This study aims at assessing the economic viability of artificial regeneration with objectives of providing both timber and non-timber forest products in 16 pilot sites located in Italy, France, and Spain. The project uses data referred to the initial two years of the LIFE VAIA project and projects the economic outcome at year 20 for a 100 hectare plot known as ES1. The analysis uses income from timber, non-timber forest products, and ecosystem services. The financial analysis yielded a negative NPV, but the NPV resulting from the extended economic analysis was positive. This indicates the influence inclusion or exclusion of ecosystem services valuation can have on Cost-Benefit Analyses. To demonstrate project resilience and framework robustness, sensitivity analyses were conducted and showed minimal impact on the economic analysis. The result is a framework design that is applicable across all LIFE VAIA pilot sites, and similar projects. The study illustrates the resiliency achieved when reforestation programs consider multiple goals and diversify income streams. Through the innovative methodology that considers agroforestry practices, the LIFE VAIA project acts as a model for adaptive reforestation programs.

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ABBREVIATIONS AND ACRONYMS

NTFP	Non-Timber Forest Product
FBI	Forest Based Industries
ES	Ecosystem Services
EU	European Union
CBA	Cost-benefit Analysis
RIGONI	Rigoni di Asiago srl
AFAF	Association Française d'Agroforesterie
ASIAGO	Comune Asiago
FEM	Fodazione Edmund Mach
GALLIO	Comune di Gallio
LFD	Longarone Fiere srl
TESAF	Università degli Studi di Padova – DIP. TERRITORIO E SISTEMI AGRO-FORESTALI
USC	Universidad de Santiago de Compostela
VENAGR	Agenzia Veneta per l'innovazione nel settore primario
TEV	Total Economic Value
MEA	Millennium Ecosystem Assessment
GVA	Gross Value Added

1. INTRODUCTION

Agroforestry methods can be used in forest management to help balance ecological and economic objectives through diversified production streams leading to more resilient environmental and economic systems (Długosiewicz et al., 2019; Huber et al., 2023; Quandt et al., 2023). With an increase in frequency in natural disturbances like windstorms, drought, forest fire, and pest outbreak, there is a need for development of adaptive forest management strategies (Intergovernmental Panel on Climate Change (IPCC), 2023; Romagnoli et al., 2023). Due to the multifunctionality of forests, it is essential to consider the biophysical and socioeconomic impacts of disturbances (Di Cori et al., 2022; Romagnoli et al., 2023). This thesis evaluates the economic sustainability of a forest regeneration project that aims to improve economic and ecological resilience through innovative agroforestry practices. This thesis contributes to the economic calculations necessary for market and cost-benefit analyses (CBA) for forest and secondary products exploited during forest regrowth. The analysis uses a pilot area of 100ha and a timeframe spanning 20 years.

The LIFE VAIA project is based on the two overarching objectives of achieving a more resilient and sustainable forest system. Forest degraded by natural disturbance after a reliance on monocultural practices can benefit from afforestation programs using natural and artificial regeneration and simultaneously gain a more diversified stream of income (Kurttila et al., 2018; Huber et al., 2019). This project introduces agroforestry as a dual-purpose strategy for financial sustainability and biodiversity conservation. Changing of long established forest management practices requires economic evidence to show long-term viability of these reforestation projects that require higher initial investments.

This thesis aims to economically assess the viability of the reforestation program by including financial elements like investment costs, maintenance costs, timber and NTFPs income, but also through the inclusion of non-market benefits like environmental services (ES). To build this study, primary data from project beneficiaries and expert opinion were used alongside secondary data sourced from literature. The data was used to estimate values and determine costs and benefits associated with the project. The findings of this research can be used as a framework for deeper economic analysis of the LIFE VAIA initiative, and other similar projects, and contribute to overall discourse on land management practices and decision making. The key focus of this research is to highlight the importance of integrating environmental and socioeconomic methods to achieve more holistic adaptation strategies and land management approaches.

1.1 BACKGROUND

Overview of LIFE VAIA Project

LIFE VAIA is a pilot program, funded by the European Union (EU), designed to address concerns associated with forest post-natural disturbance. The program aims to improve socioeconomic and ecological resilience of European forests and provide a methodology for afforestation after disturbance. This program is referred to as a "pilot" because the use of reforestation of species oriented by climate change has only been performed in experimental trials up until now.

There are eleven project beneficiaries associated with this project. Five beneficiaries are responsible for the facilitation of site preparation and management of sites they either own or have full availability provided by the owner for at least 20 years. The other five are expected to contribute to project organization, scientific information, and communication and dissemination. The list of beneficiaries include:

(1) Association Fraçaise d'Agroforesterie (AFAF)

(2) Comune di Asiago (ASIAGO)

(3) Fondazione Edmund Mach (FEM)

(4) Comune di Gallio (GALLIO)

(5) LONGARONE FIERE SRL (LFD)

(6) Rigoni di Asiago srl (RIGONI)

(7) Università degli Studi di Padova – DIP. TERRITORIO E SISTEMI AGRO FORESTALI (TESAF)

(8) Universitad de Santiago de Compostela (USC)

(9) Agenzia veneta per l'innovazione nel settore primario (VENAGR)

(10) Venetian Cluster srl (VHC)

(11) WBA Project srl Unipersonale Impresa Sociale Ex D.LGS 155/2006

The project is based on technical and scientific data and on knowledge already gained by the partners, such as, tests for bilberry cultivation carried out by RIGONI, experience with sustainable forest management by VENAGR, knowledge on beekeeping, berries genetic resources characterization and cultivation of edible plants by FEM, practical experiences in agroforestry by AFAF, public forest owners' experience by the community of Asiago and Gallio, scientific support by TESAF and USC, experience in biodiversity certification by WBA, competence on public-private partnerships and networking by VHC, and skills in communication and dissemination by LFD. Each pilot area included in LIFE VAIA is assigned to one of the following five beneficiaries. VENAGR is responsible for two areas in Foresta del Cansiglio (Italy), RIGONI has been assigned two areas in Asiago and Gallio (Italy), FEM has one area in

Trentino Alto Adige (Italy), AFAF is assigned one area in France, and USC has one area in Spain.

Due to the unique ecosystem needs in each pilot site, adaptations are made to the VAIA experiment, when necessary, specifically to aspects that are necessary to customize such as species selection. All pilot sites follow the same general actions:

- Preparatory work such as the eradication of potentially damaging or alien species including *Phytolacca americana L.* and *Acacia* through plant uprooting, digging, and cleaning.
- Planting of species based on site needs.
- Agricultural activities consisting of cultivated plants and introduction of bee apiaries.
- Fencing for protection from fauna grazing.
- And installation of water reservoirs and micro irrigation pipelines

LIFE VAIA Methodologies

The LIFE VAIA methodology can be described as temporary agroforestry in damaged forests used as a strategy to ensure economic survival of local communities and to increase forest adaptation for climate change. One of the goals being to improve European forest resilience in the face of climate change, led to species selection based upon the projected climate for the next 20, 50, and 100 years. The artificial regeneration used in this project based on these selected species, reduces the risks associated with solely relying on natural regeneration (Długosiewicz et al., 2019; Jonsson et al., 2022). The species selected to maximize genetic variability, the management procedures, and the natural evolution processes, are expected to steer the vegetal populations toward a final structure that is in line with the local environment.

The project uses agroforestry approaches to regenerate damaged forests. The pilot sites include forest gardens used to produce Non Timber Forest Products (NTFPs), water reservoirs, and beekeeping. Each of these practices are anticipated to help generate economic resources for beneficiaries and improve forest productivity. Forest gardens contain edible plant species like blueberries, aromatics and medicinal herbs. In addition to productivity, it is anticipated that the presence of edible plants will increase the presence of fauna including birds and small mammals, improving the overall diversity of the ecosystem.

Aside from the ecological benefits of the innovative agroforestry practices selected, there is the addition of new economic chains based on NTFPs, that compensate for the loss of timber in the short-medium time and support local economy preventing depopulation. While LIFE VAIA is a project that aims to increase forest resilience and adaptation to climate change, it uses strategies that also ensure economic survival of local communities. This is achieved through the implementation of transitional agroforestry concepts as an ecosystem-based solution for promoting the fast regeneration of damaged forests, that also allows for supplement income in the interim through NTFPs like honey. In total there are 16 pilot sites (total surface area of 615 ha) and 7 larger areas previously devastated by storms (in Italy and France) or fire (in Spain).

1.3 Study Sites

Geographic overview

The project encompasses 16 pilot sites (of about 2.5ha each) in Italy, France, and Spain distributed across 7 pilot areas. Pilot sites are mainly in forests initially (pre-event) characterized by low biodiversity levels populated by monospecific and coetaneous woods originated by artificial reforestation initiatives carried out in the past. For example, Asiago and Cansiglio are dominated by Picea Abies with minimal undergrowth species and very low natural regeneration.

Each area consists of about 100 ha, aside from Trentino that consists of 191 ha. Large pilot areas are selected for bee keeping activities to ensure a vast enough space for bees to exist within pilot sites. Pilot sites are made up of diffused cultivation areas of about 0.8 ha and the exact shape and surface is adapted to the existing situations and needs in individual forest sites.

The pilot area located in Italy was damaged by an atmospheric event named the "Vaia Storm" in 2018, the area in Spain was devastated by fire in 2017, and 2021, and the area in France has faced damages from fire, storms, and bark beetle. Located in alpine environments, the Italian sites are described as having a long history of forest management dating back to the Middle Ages. Due to the Vaia Storm of 2018, the area was left with significant damages. Damages in the area include decrease in carbon sink, exposed soil with risk of erosion, and loss of biodiversity and timber (Antonetti et al., 2022; Pilli et al., 2021). The storm mainly impacted Norway Spruce, Silver Fir, and European Beech stands, but even so, "the calculated total damaged growing stock volume corresponded to more than 0.6% of the total volume of growing stock of all Italian forests" and twice as much as the timber extracted each year by Italian forests (Pettenella et al., n.d.; Pilli et al., 2021). The pilot area in France is in the Landes de Gascogne National Park. This forest has faced various disturbances including bark beetle *Ips sexdentatus*, windstorms, and fire (J. P. Rossi et al., 2009; Sergent et al., 2013). The forest cover is dominated by cultivated maritime pine (*Pinus pinaster*), and forestry activities play a significant role in the local economy (Sergent et al., 2013). The third pilot area is positioned in Galicia, Spain, a region considered to be "one of the most severely affected by forest fires in Europe" (Girona-García et al., 2023). About 70% of the Galician region is covered by wooded and open lands and nearly half are forest plantations or non-native species (Núñez-Delgado et al., 2023).

Individual site characteristics

***Table 1**: Pilot areas locations, codes, and names*

Country	Region	Code	Number of Pilot Sites	Total Hectares	Name
France	Nouvelle Aquitaine	FR1	2	84	Hop'Land
Italy	Veneto	IT1	2	100	Val Menera
		IT2	2	100	Val Piccola
		IT3	4	100	Calcara della Nasa-Croce di Sant'Antonio
		IT4	2	100	Val di Nos
	Trentino	IT5	2	191	Predolci-Grave Alte
Spain	Galicia	ES1	2	100	Piornedo

Pilot area FR1 includes two pilot sites totalling 84 ha. The area is in Lipsothey in the south-west of France, near the Landes de Gascogne Natural Park. The Landes Forest, maritime pine forest (*Pinus pinaster*), covers approximately 1,300,000 ha, and contains approximately 25,000 ha of firewalls. The pilot area is a monocultural forest, regularly divided by some fallow firebreaks consisting of 50m-wide corridors with no trees. The goal here is to reintroduce a diversity of crops (starting with hop and hemp) and other species (hedges, cover crops, etc.) to create ecological corridors and biodiversity habitats and thus enhance the resilience of the forest ecosystem.

The Veneto Region, pilot areas IT1, IT2, IT3, IT4, consists of two pilot sites in Gallio totalling about 100 ha and four pilot sites in Asiago totalling 100 ha. In Foresta del Cansiglio, there are four pilot sites totalling 200 ha. In Trentino, pilot area IT5, there are two pilot sites in Tressilla totalling 191 ha. These areas were damaged by the Vaia windstorm in 2018 and will undergo natural and artificial reforestation using forest species (*Fagus sylvatica, Acer pseudoplatanus, Fraxinus excelsior, Acer platanoides, Betula pendula, Sorbus aucuparia, Salix appendiculata, Picea alba, Larix decidua, Abies alba)*, forest gardens consisting of edible and medicinal plants, and apiaries used for honey and enhanced pollination.

Located in Navia de Suarna, Lugo, Spain the Galician pilot area occupies 100 ha with two pilot sites. In the pilot sites, at the beginning of 2023, a set of perennial and non-perennial forest trees and medicinal/aromatic/melliferous plant experiments were established. In total, eleven forest species adapted to the Atlantic and Mediterranean areas were planted. Part of the species are perennial and part are not perennial. The trees were intercropped to increase the landscape value of the species when the leaves fall. The chestnut plantation is enhanced with tree protectors to prevent damage to the trees by wild animals. Dead trees are replaced with new trees in both pilot sites. Medicinal/aromatic/melliferous plants best adapted to the area conditions are intercropped in the Castanea sativa plantation. Finally, a set of apiaries will be established after the vegetation recovery. Pilot area ES1 was most recently destroyed by a forest fire in August 2021. Therefore, the main objective is to carry out the restoration of this area of high natural value.

1.2 Problem Statement

Regeneration of damaged forests is often assessed from either a biophysical or socioeconomic perspective and rarely from a perspective that combines the two (Quandt et al., 2023; Romagnoli et al., 2023). To properly assess regenerative and adaptive potential of reforestation methods, an interdisciplinary approach is recommended that combines ecological, economic, and social considerations (Quandt et al., 2023; Romagnoli et al., 2023).

Artificial regeneration can reforest damaged areas while providing new resources with plants that are more resistant to disturbances, but the socioeconomic viability of this assumption must be assessed (César et al., 2021).

Based upon this literature review strategies in reforestation projects that aim to make ecological and socioeconomic improvements should ensure a diversity of species and economic resources, carefully selected species that are anticipated to be successful in projected climate, a combined use of natural and artificial regeneration, and agroforestry methods.

1.3 Objectives

General Objective

Contribute to the CBA of a forest regeneration project of damaged forests in the Mediterranean.

Specific Objectives

1. Assess the costs versus income associated with LIFE VAIA project activities
2. Develop and test a theoretical framework featuring ES benefits
3. Draw conclusions about the sustainability of the project

1.4 Research Questions and Hypotheses

Research Questions

1. What forest management strategies influence economic sustainability?
2. Will innovative agroforestry initiatives supplement income?
3. Are these agroforestry practices sustainable?

Hypothesis

The LIFE Vaia project will generate a positive Net Present Value (NPV) over the 20 year timeframe. The inclusion of ecosystem services will contribute to a more robust framework and lead to an increase in benefits. The key factors for profitability will be timber and NTFP production and this can be demonstrated through sensitivity analysis.

1.5 Limitations

This study is subject to several limitations that can influence precision and overall interpretation of findings.

1. Data Accuracy and Availability: The analysis uses primary data that relies on accurate reporting from beneficiaries. Secondary data was used to supplement any data that could not be gathered firsthand. While efforts were made to ensure reliability and compatibility with sources, there is still potential for human error, and possible unaddressed site specific nuances that are not fully captured in the benefit transfer. Some benefits could not be quantified in this study, including cultural benefits, and their exclusion may result in an underestimation of LIFE VAIA benefits. The study was limited to testing one of the seven pilot areas but is intended to be applicable for all seven. Due to limited testing, not all site nuances could be considered including differing investment costs, species composition, and climate. Testing across all pilot areas may change study findings.
2. Timeframe: The selected timeframe of 20 years cannot account for all felt benefits that will be ongoing for longer than this timeframe. The timeframe was selected due to the inclusion of the forest garden, that can only be in operation for the initial 20 years of the project due to the eventual shade from canopy density that is anticipated to limit forest garden productivity. Even so, the timeframe may be too short to quantify longer-term benefits such as chestnuts that will continue producing and benefits from ES.
3. Unexpected Costs: there is a possibility of unexpected costs that cannot be predicted. These costs may be caused by fencing failures (ungulate browsing) or unforeseen natural disturbances.

Further research should consider addressing these limitations to enhance overall robustness and applicability of study.

2 LITERATURE REVIEW

2.1 Contributions of Forest Ecosystems

There are a wide variety of forest-based industries (FBIs) in Europe and these industries employ approximately 3.6 million people and generated 25 billion€ in total gross value added (GVA) (Gardiner et al., 2013). This means it is essential to pursue forest management strategies focused on sustaining these forest-based economies. Regeneration activities, post disturbance, can alleviate economic strain through increased investments and job opportunities and this is especially beneficial for communities suffering depopulation (Gromko et al., 2019; Kettley, n.d.). According to López-Penabad et al. (2022), rural areas in Europe are experiencing population decline, especially in mountainous regions, and this is largely driven by socioeconomic factors including a lack of economic development. Loss of rural population can have negative implications for the local environment and culture (López-Penabad et al., 2022).

2.2 Climate Change and Natural Disturbance

Climate change has vast implications for forest ecosystems and therefore the communities and industries that rely on them. Natural disturbances in the form of windstorms, floods, and fires are becoming increasingly prevalent and increasingly damaging (Romagnoli et al, 2023). Gregow (2017) identified statistically significant change in storm intensity in Western, Central, and Northern Europe. Disturbance to forest ecosystems has economic, social, and ecological consequences. Forest ecosystems in Europe are vulnerable to disturbances, especially increased storm intensity (Romagnoli et al., 2023). Forest damages resulting from wind damages are predicted to be the primary cause for most stand damages (Samariks, 2020). This vulnerability is amplified by the increase of both growing stock and average forest age across Europe in the last 60 years (Gardiner et al., 2013). The current stock in Europe has experienced an increase in age proportional to increased volume of storm damages (Gardiner et al., 2013). Additional to risks associated with stock age, there are thawing soils resulting in further decreased resilience to wind damages (Gardiner et al., 2013). These disturbances have the potential to decrease Ecosystem Services (ES). ES commonly associated with forests include CO2 sequestration, water regulation, and erosion control. It is recommended that ES are protected or enhanced as a method for climate change mitigation (Reid, 2005).

With fast moving climatic changes, species are unable to evolve at a rate necessary to successfully adapt, ultimately shifting species suitability (IPPC, 2023). It is necessary to select species for regeneration that are predicted to persist despite anticipated changes (IPPC, 2023). Additionally, there are challenges associated with forest planting selections that are lacking genetic diversity (IPPC, 2023). While monocultures provide predictable yields, they're also more susceptible to damages associated with wind, insect outbreaks, and drought (Dymond et al., 2014). Therefore, improved forest resilience requires diversity of species selected for planting (Dymond et al., 2014). According to César et al. (2021), forest and land regeneration initiatives may help to alleviate climate change effects on biodiversity and ES provision.

2.3 Innovative Agroforestry and Regeneration Practices for Forest System Resilience

Agroforestry has been identified as a potential ecological and socioeconomic generator that provides ES, environmental benefits, and economic production (Satish et al., 2024). Agroforestry is an agroecological strategy that combines the use of woody species and cultivated plants (Young, 2017). Forest gardens are an example of an agroforestry method that involves the integration of agricultural systems in existing forest stands (Belcher et al., 2004). Ecologically, these techniques can be used to establish a more productive forest ecosystem (Young, 2017). Agroforestry systems can successfully mimic natural ecosystems with careful selection of species based on models (Young, 2017). Successful implementation of agroforestry requires extensive knowledge of species-specific traits to ensure appropriate selection and planting. Restoration through agroforestry can also be used to overcome socioeconomic challenges (Young, 2017). When used during the transitional periods post-disturbance, regeneration of degraded lands through agroforestry techniques can supplement income (Young, 2017). According to Young (2017), the creation of agroforests improves wildlife habitat, ES, economic opportunities from both timber and NTFPs, and contributes to social benefits like knowledge dissemination.

According to Dymond et. al. (2014), species diversity in forest stands can lead to higher harvest rates due to the diverse range of harvestable species, and a higher and more consistent net revenue overtime. This study in Canada shows that forest management strategies aiming to improve forest resilience do not need to compromise economic viability (Dymond et al., 2014). Forest and land regeneration programs should also focus on economic diversification meaning a diversity of land uses and economic activities providing different sources of income (César et al., 2021). Transitioning to diversified economic systems has the potential to improve climate change mitigation, adaptation, and resilience capacities (Dymond et al., 2014; César et al., 2021). Simulations by Jonsson et al. (2022) show that artificial forest regeneration, when compared to natural regeneration, has the potential to increase volume production and growth, and reduce the uncertainty of regeneration success. Plant species selected for forest regeneration can include plants that are used for NTFPs. NTFPs have the potential to strengthen economic viability especially when combined with wood resources (Huber et al., 2019). According to Sheppard et al. (2020), a transition to a “sustainable co-production management of timber and NTFPs” is essential for forest resilience. Artificial regeneration can reforest damaged areas while providing new resources with plants that are more resistant to disturbances

2.3 Cost-Benefit Analysis (CBA): Framework and Relevance

To properly assess the economic sustainability of this project we must determine both the costs, and the benefits associated with its implementation. Projects associated with the environment can be assessed using a cost-benefit analysis (CBA) (Alounsavath Master & Kim, 2021; Corradi et al., 2013; Gromko et al., 2019; Verdone, 2015; Wainaina et al., 2020). This type of assessment is suitable for projects that include non-market costs and benefits and therefore is suitable to this project due to the presence of ES (Gatto et al., 2009). CBA is the identification, quantification, and comparison of all relevant costs and benefits associated with a project (Wainaina, Gituku, et al., 2020). Due to its inclusion of all possible costs and benefits, CBA can help to determine financial viability and to aid in forest management decision making. Developing a robust CBA requires determining the scope and stakeholders, identification and categorization of costs, identification and categorization of benefits, monetization of costs and benefits, determining discount rate, and identification of economic indicators used to determine economic viability (Alounsavath Master & Kim, 2021; Corradi et al., 2013; Gromko et al., 2019; Verdone, 2015; Wainaina, Gituku, et al., 2020).

The initial phases require definition of study objectives, geographical area, time frame, and the inclusion of beneficiaries (Gromko et al., 2019). Identification of costs include considering categories like investment costs, maintenance costs, and opportunity costs (Gromko et al., 2019; Wainaina, Gituku, et al., 2020). The investment costs include any initial expenditures in the beginning stage of the project and oftentimes are associated with preparation. Examples of investment costs include land acquisition, purchasing of seedlings, establishment of infrastructure such as fencing and irrigation, purchases or rentals for tools and machinery, and the wage for labour associated with site preparation (Gromko et al., 2019; Kettley, 2024; Schwartz et al., 2016; Wainaina et al., 2020).

Maintenance costs occur after the initial preparatory stages of the project. Maintenance activities include pruning, weeding, plant and infrastructure replacements, and monitoring. Maintenance costs are all expenditures stemming from maintenance activities (Gromko et al., 2019; Schwartz et al., 2016; Wainaina, Gituku, et al., 2020). Costs often include wage for labour and costs for equipment rental, purchase, and replacement (Gromko et al., 2019; Schwartz et al., 2016; Wainaina, Gituku, et al., 2020). Opportunity costs are the benefits associated with alternative projects if the selected course of action was not chosen (Dymond et al., 2014; Gang et al., 2023; Gromko et al., 2019; Kettley, n.d.; Verdone, 2015). Some examples of opportunity costs include income from alternative land uses and foregone timber harvests (Gang et al., 2023; Gromko et al., 2019; Kettley, n.d.; Verdone, 2015). Selecting other land use options could have resulted in income from farming, grazing land for pastoralists, and additionally, delaying planting for installation of infrastructure like fencing and forest gardens also can delay income from timber harvesting (Dymond et al., 2014; Gang et al., 2023; Gromko et al., 2019; Kettley, n.d.; Verdone, 2015). It is important to ensure that all costs are accounted for, even benefits foregone, to accurately account for all costs associated with the project (Wainaina, Gituku, et al., 2020).

When identifying benefits, one can categorize them based upon a Total Economic Value (TEV) framework that values based upon human use (Figure 1). The categories are direct use, indirect use, and non-use values (Verdone, 2015; Wainaina, Gituku, et al., 2020). Direct use values are those obtained directly from the resource such as fuelwood and timber (Wainaina, Gituku, et al., 2020). Direct use values are generally easier to monetize due to the existence of market prices

(Wainaina, Gituku, et al., 2020). Indirect use values are benefits that support human activity, often stemming from ES like water purification, pollination, and erosion control (Wainaina, Gituku, et al., 2020). These use values are more complex to monetize, similarly to non-use values. Non-use values may not be directly related to the resource but are a reflection of how they are perceived. Non-use values include existence, bequest, and altruistic values. Existence values obtain their value from the knowledge that the resource exists and can be used if ever necessary, bequest value is based upon preservation for future generations, and altruistic value is due to the satisfaction of its preservation. Non-use values can be further categorized using the Millenium Ecosystem Assessment (MEA) framework (Figure 2). This framework classifies ES into supporting, provisioning, regulating, and cultural categories based upon its socio-environmental role (Reid, 2005; Wainaina, Gituku, et al., 2020).

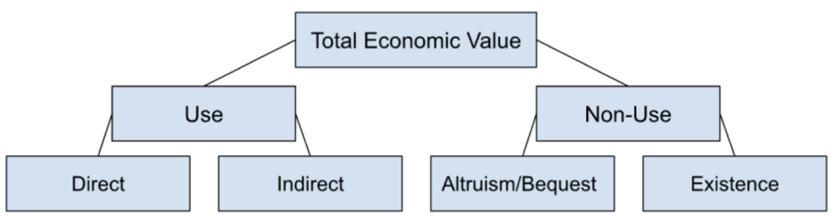

Figure 1: *Total Economic Value (TEV) framework.*
Adapted from *Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation* by R. de Groot, B. Fisher, M. Christie, J. Aronson, L. Braat, J. Gowdy, R. Haines-Young, E. Maltby, A. Neuville, S. Polasky, R Portela, I. Ring, J. Blignaut, E. Brondizio, R. Costanza, K. Jax, G. Kadekodi, P. May, J. Mcneely, S. Shmelev, 2010, Earthscan.

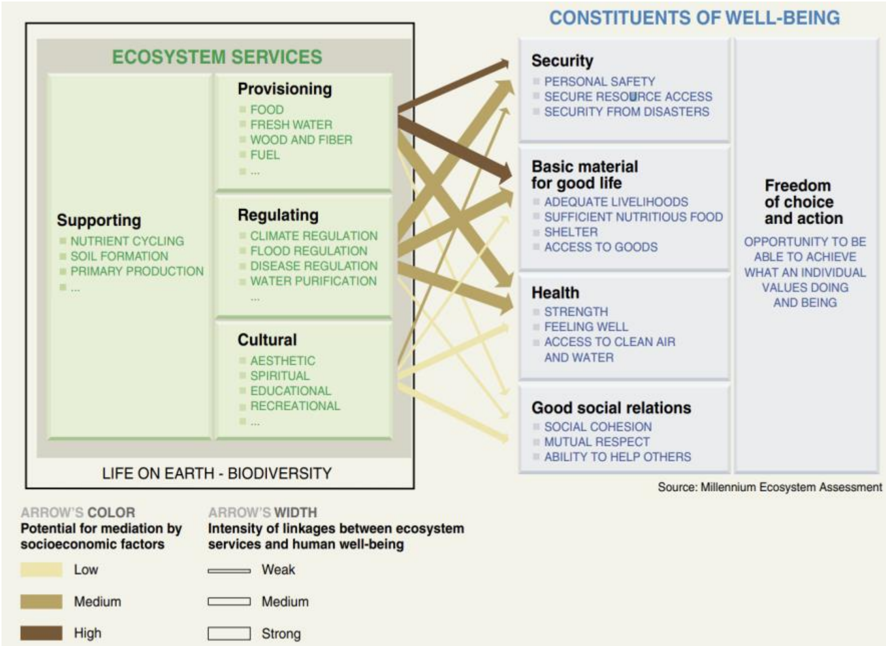

***Figure 2**: MEA Framework for Categorizing Ecosystem Services*
Retrieved from "Ecosystems and human well-being: synthesis: a report of the Millennium Ecosystem Assessment" by W. Reid, 2005, Millenium Ecosystem Assessment, 137

Monetizing in a CBA involves the prediction of inputs and outputs every year over a period (Verdone, 2015). The value associated with the input or output equals the price per quantity and can be expressed as: Value = Price * Quantity (Gromko et al., 2019). In an economic analysis, market prices may require adjustments due to taxes and subsidies, these are known as shadow prices (Gromko et al., 2019). Monetization can be complex when assessing social and environmental benefits that cannot be valued in the market, but various methods can be used to assess these elements. These methods include revealed preference, stated preference, and benefit transfer (Gromko et al., 2019; Verdone, 2015). For revealed preferences, the researcher infers value based upon travel costs and hedonic pricing. Stated preference methods directly assess a consumer's willingness to pay through techniques like contingent valuation. Benefit transfer involves using values already determined in similar projects and research (Gromko et al., 2019). A choice of discount rate is necessary as it helps to account for time value of money (Verdone, 2015). Finally, a sensitivity test is used to determine if the CBA is robust (Verdone, 2015).

CBA have been conducted and applied in forest and land management to evaluate the economic viability of activities. Activities are often cross evaluated to compare strategies to select the most cost-effective scenario and to support decision making. Economic valuation of NTFPs in Europe have assessed value of collected mushrooms and berries in the Czech Republic, harvested bilberries in Slovakia, and cranberries and blueberries in Finland (Kovalčík, 2014; Sisak et al., 2016). The techniques in these studies used to value the NTFPs include using market prices and non-market valuation. The market techniques consist of collecting data on quantities sold and price associated. The studies emphasize the inclusion of not just harvesting costs, but also costs associated with processing and transportation (Kovalčík, 2014; Sisak et al., 2016; Wollenberg, 2000). Kovalčík (2014), used interviews focused on forest berries and mushrooms picked for either consumption or sale, to determine the value of forest berries in Slovakia. Using surveys to assess frequency, quantity, and price per kg, Sisak et al. (2016) determined that collected NTFPs in the Czech Republic had a value equal to 18% of the annual value associated with timber production in the country (Sisak et al., 2016).

Peura et al. (2016) assessed the economic impact of forest management for the production of timber and NTFPs. The study used growth simulations and timber revenues, and then estimated yields and calculated the yearly economic value. Peura et al. (2016) used average market prices and used Net Present Value (NPV) that is based off the following equation:

$$Collectable\ good\ NPV = \sum_{t=0}^{50} y_{it} v_i e^{-rt}$$

An explanation of the equation described as "where a collectable good was denoted by *i*; years across the 50 year planning horizon by *t*; yields by *y*; their prices by *v*; and discount rate by *r*. NPV for collectable goods includes their value for the 50 year period only, and ignores any later yields" (Peura et al., 2016).

To determine economic value of different services in forests in Spain that included erosion, and CO_2 sequestration, Brey et al. (2007), used choice experiment. In choice experiment, participants select the preferred option from provided sets of alternatives with varying levels (Brey et al., 2007). The value in this study is based on participant Willingness to Pay (WtP). The study found that “respondents show positive preferences regarding the two environmental forest functions considered, CO_2 sequestration and erosion prevention. On average, they would be willing to pay 1.22€ per year to delay for a period of a hundred years the loss of land productivity caused by erosion, and 11.79€ per year for the CO_2 sequestered annually by the new forests, when this is equivalent to the emissions from a city of 100,000 inhabitants” (Brey et al., 2007).

3. METHODOLOGY

The methodology used for this thesis was developed to assess the economic sustainability of the LIFE VAIA project through a CBA that includes NTFP and timber production income and costs, and ES valuation. Additionally, I have performed a sensitivity analysis to assess the overall robustness of the CBA framework. The analysis is based on a pilot site of 100ha and a time frame of 20 years. The number of hectares was selected because nearly all pilot areas are measure 100ha. The analysis is based on two assumptions, stable market prices and yields, and no major climate impacts. Due to time limitation and data availability, one pilot area was analyzed in this report. The area and beneficiaries included in this test are:

(1) USC – ES1

3.1 Data Collection

The analysis integrates primary and secondary data. Management practices from preparation and maintenance that occur in site ES1are tracked by the corresponding site manager and beneficiary, USC, and communicated to me through data submission. Data was collected between July 1st, 2024, and October 18th, 2024. Additional data required for valuation was gathered using scientific literature and through communication with experts. Data was recorded and calculated via Microsoft Excel.

Costs

I developed a framework for the data collection of costs that is broken down into investment costs, maintenance costs, crops, and site description sections. The cost data is provided by the site manager that is responsible for the pilot area. After attending a presentation by me that introduced the framework, the representative from USC filled out the excel file and submitted it to me for analysis (Appendix A).

Income

Income is determined based on farmer gate pricing and expert opinion. To calculate the income from timber and NTFPs I developed a framework that considers the expected yield per species (kg/individual) and price (€/kg). Data was provided by the site manager such as the species lists, chestnut production, and honey production. Some data needed for this framework was unavailable to the manager and in these instances, I used existing literature and expert opinion to fill gaps. For example, this was especially necessary for ecosystem service provision which required the use of benefit transfer.

Benefit Transfer

Benefit transfer is a method of monetary valuation for non-market and non-use values like ES. The values transferred into my study come from an analysis of ES in the North of Italy. The study's site, being near many of the pilot areas associated with the LIFE VAIA project is comparable geographically, consisting of similar management practices, plant species, precipitation, geographic features, and average temperatures. All the pilot areas and this study's area are located in the Mediterranean. The study uses the valuation technique, replacement cost, to estimate the value of hydrogeological protection and calculates carbon sequestration and assigns value using carbon credits (Häyhä et al., 2015). Replacement cost is a valuation technique that considers the economic impact of substituting the asset and Häyhä et al. (2015) used the prices of bioengineering technologies to do this. Importantly for cost considerations, the most cost effective solutions were selected for stabilization of the landscape. This includes the palisade, terrace cutting, snow fences, and snow stands. The amount of carbon sequestered in the study area was calculated using an equation that includes wood biomass, wood density, dry mass, and roots. To assign the value to the amount sequestered, Häyhä et al. (2015) used the price associated with EU emissions permits at 15€/t. To calculate inflation, the time of the study and location had to be considered. In 2015 the GDP deflator index in Italy was 100 and the current GDP deflator index in Spain is 120 (Inflation, 2024). Inflation was calculated using the following formula:

"New Value" = "Old Value" ("New Index #" / "Old Index Number")

***Table 2**: Valuation of Ecosystem Services (ES) in Article and Inflation Adjustment Used for this Study.*
Retrieved from Assessing, Valuing, and Mapping Ecosystem Services in Alpine Forests by T. Häyhä, P. Franzese, A. Paletto, B. Fath, 2015, Ecosystem Services

ES	Valuation Technique	Substitutes	Article Value (€)	Value with Inflation (€)
Climate Regulation	Replacement Cost	Carbon Sequestration and Carbon Pricing	77	91.2
Hydrogeological Protection	Replacement Cost	Bioengineering Technology	328	393.6

3.2 Analytical Framework

The Analytical Framework follows components associated with an extended CBA.

Extended Cost-Benefit Analysis Design

The stepwise procedure developed by Cesaro et al. (1998) includes with five levels for the extended CBA. Elements like externalities, distributional effects, social costs and benefits, also known as welfare gain, are all considered in this form of analysis (Gatto et al., 2009). For a study conducted on pine processionary moths in Italy, Gatto et al. (2009) used an extended CBA using the following four levels: Financial analysis, conventional economic analysis, extended economic analysis 1, and extended economic analysis 2 (Cesaro et al., 1998; Gatto et al., 2009).

(1) Financial analysis is strictly the monetary flows of expenditures and revenues (Gatto, 2009; Gromko et al., 2019). Here, market prices are considered. In this study we use

market prices to determine cost of material purchases and market value of goods produced.

(2) Conventional Economic Analysis involves the conversion of market costs and prices to shadow prices to better understand the true value of the resource through elimination of distortions, market failures, and transfer payments (Gatto, 2009).

(3) Extended economic analysis 1 accounts for the external effects internalized in the market. This includes indirect market effects and site damages (Gatto, 2009).

(4) Extended economic analysis 2: uses the effects that are external to the market like intangibles, externalities, public goods etc. This step requires estimation of non-market values. Ecosystem benefits are considered non-market. These types of benefits require different valuing methods than simply assessing through market price (Gatto, 2009).

Due to the nature of this project, step 2; the conventional economic analysis, and step 4; extended economic analysis 2 are not included. This is because there are no shadow prices and due to time constraints and available data, I was unable to determine the cultural service benefits necessary for the fourth step.

To test the developed framework, pilot area ES1 is used, however it is designed to be applicable across sites. The data used is acquired from source (expert or literature) and calculated through Excel. The framework uses the items, benefit or cost categories, valuation techniques, physical indicators, and monetary indicators. Monetary indicators require the use of GDP deflators to adjust for inflation if the numbers are from previous years.

Financial Analysis

Activities resulting in incurred financial costs include site preparation, seedlings, planting, installation of fencing, removal of alien/invasive species, irrigation, pruning, road repairs, seedling replacements, and infrastructure repair. The specific costs associated with these activities include labour, machinery and tool purchases or rentals, and materials purchases. Each of these costs vary across sites due to differing needs. Benefits come from timber and NTFP production and ES provision. Values obtained from literature require the use of GDP deflators to adjust for inflation.

Chestnut Production

Estimations for chestnut production were provided by the beneficiary USC. Revenue from the chestnut trees is expected after 5 years. Projections are based off 15 year old chestnut trees in 1 ha. Production per year is expected to be 1250kg/ha. The revenue associated with each kilogram is 1,25€.

The costs from producing chestnuts stem from the labor needed for maintenance activities. These activities include pruning, understory clearing, grafting, and replacements. The approximate hourly wage is 14€ and hour and in the second year of planting there are 8 hours of work and after the second year there are 12 hours of work.

Honey Production

Honey production estimates were provided by expert beneficiaries USC and FEM. Each hive is expected to produce around 15 kilograms of honey. Each kilogram is sold for 10€, therefore, each hive is initially valued at 150€.

The costs associated with honey production include baroque treatment for 2.85€ per hive, food for bees costing 3€ per hive, wax totaling 3.25€, material replacements totaling 20€, labour totaling 35€, kilogram jars for 0.75€ per kilogram, labels for 0.40€ per kilogram, and a yearly sanitary registration fee of 20€. All these elements were summed to glean the overall yearly cost.

Forest Garden

Forest garden production is based upon expert opinions and literature. Revenues from the forest garden occur in the second year. The plants included are *Thymus vulgaris*, *Lavandula hybrida*, *Rosmarinus*, *Salvia officianalis*, and *Origanum vulgaris*. Due to a lack of available data *Laurus nobilis* and *Vaccinium corymbosum* were removed from this study, but they will also be planted at the site. Each of species has their own cost and revenues and the data was located from different sources detailed below (Table 3). The costs and revenues are based upon market prices. The plant with the lowest cost per individual is *Lavandula hybrida* at 3.50€. The plants with the highest costs per individual are *Laurus nobilis* and *Origanum vulgaris* at 6€ each. Prices and yield were determined using literature.

- Thyme (*Thymus vulgaris*): within ES1 there were 96 individuals planted each costing 4€. The yield rate (kilogram per individual) of thyme was found in a doctoral thesis that determined the rate in a Mediterranean region (De Nadai, 2008). The price per kilogram was determined using the rates made available in the "Osservatorio Economico
- del settore delle piante officinali" report from Istituto di servizi per il mercato agricolo alimentare. (ISMEA) (2023). The price was then adjusted using the GDP deflator index to account for inflation.
- Lavender (*Lavandula hybrida*): within ES1 there were 96 individuals planted that cost 3.50€ each. The yield rate (kilogram per individual) of lavender was found using the same resource used for thyme where it was determined the yield per individual was 0.03 kg/individual (De Nadai, 2008). The price per kilogram was determined using the rates made available in the "Osservatorio Economico del settore delle piante officinali" report

from ISMEA (2023). The price was then adjusted using the GDP deflator index to account for inflation. The price was determined to be 4.78€/kg.

- Rosemary (*Salvia rosmarinus*): within ES1 there were 96 individuals planted that cost 4€ each. The yield rate of 0.61kg/individual was found through literature review (Ortiz de Elguea-Culebras et al., 2024). The price of 1.59€/kg was determined using the rates made available "Osservatorio Economico del settore delle piante officinali" report from ISMEA (2023). The price was then adjusted using the GDP deflator index to account for inflation. (Ortiz de Elguea-Culebras et al., 2024)
- Sage (*Salvia officinalis*): within ES1 there are 96 individuals planted that cost 4€ each. The yield rate of 0.3kg/individual was found through literature review ((Bahtiyarca Bagdat et al., 2017).The price of 4.62€/kg was determined using the numbers made available "Osservatorio Economico del settore delle piante officinali" report from ISMEA (2023). The price was then adjusted using the GDP deflator index to account for inflation. (Bahtiyarca Bagdat et al., 2017)
- Oregano (*Origanum vulgaris):* within ES1 there are 96 individuals planted that cost 6€ each. The yield rate of 0.3kg/individual was found through literature review (Sivicka et al., 2015).The price of 3.98€/kg was determined using the numbers made available in the "Osservatorio Economico del settore delle piante officinali" report from ISMEA (2023). The price was then adjusted using the GDP deflator index to account for inflation. (Sivicka et al., 2015)

Table 3 *Aromatic Plant Values.*

Species	# of Individuals	Cost (€/individual)	Yield (kg/individual)	Price (€/kg)
Thyme	96	4	0.32	3.5
Lavender	96	3.5	0.03	4.78

Rosemary	96	4	0.61	1.59
Sage	96	4	0.3	4.62
Oregano	96	6	0.3	3.98

Timber

Timber was assigned a yield rate of 6 m^3 /ha/yr. Using expert opinion, each m^3 of timber is priced at 50€ in this study (Table 4).

Table 4 *Timber Yield*

Item	Yield (m^3/ha)	Price (€/m^3)
Timber	6	50

3.3 Extended Economic Analysis 1

To select which ecosystem services to consider in this framework, I conducted a literature review to identify what ecosystem services were associated with the tree species selected for the LIFE VAIA project and then the other two elements, forest gardens and honey production (Tables 5 and 6). Services are then organized based upon the MEA framework so, provisioning, regulating, and cultural (Tables 6).

(1) Provisioning Services – Provisioning services are based upon medicinal, aromatic, and edible herbs located in the forest garden, the regenerated tree stands, and bee apiaries. Each service is quantified using a selected indicator. Indicators for food, honey, and medicine are yield (Table . Yield is weight (kg) per hectare per year ear and the price is determined by retail price or expert opinion. Indicator for timber is also yield, but instead of weight I use volume (m3) per hectare per year. The price for timber was assigned using expert opinion.

(2) Regulating Services – For this project I have selected climate regulation and hydrogeological protection. The indicators for these services are ton of CO_2 per hectare per year for climate regulation, and (Table 7). According to the literature review, habitat and pollination are services that are likely occurring in these sites but are not quantified in this study due to time constraint and readily available data. C02 is removed from the atmosphere by trees and stored in biomass (Schön et al., 2024).

(3) Cultural Services – Regeneration of study sites can benefit recreation and ecotourism through improved aesthetic. Additionally, there is the benefit of knowledge sharing between project beneficiaries. Indicators for this benefit include number of tourists per year in these site areas and number of participating beneficiaries. This category of ES was not included in my study due to time constraint and available data.

***Table 5**: Ecosystem Service identification using selected forest species present in LIFE VAIA*

Species Name	**Common**	**Ecosystems Service**							**Lit. Rev.**
		Timber products	Non-Timber Products	Climate Regulation	Pollination	Hydrogeological protection	habitat	Air quality Regulation	
Abies alba	Silver Fir	X				X			Selkimäki et al., 2020
Acer pseudoplatanus	Sycamore Maple			X				X	Maňák et al., 2024
Betula pendula	Silver Birch	X	X	X	X	X		X	Maňák et al., 2024
Betula pubescens	Downy Birch		X	X	X	X		X	Maňák et al., 2024
Corylus avellana	Common Hazel				X	X		X	Maňák et al., 2024
Fagus sylvatica	European Beech		X	X	X	X		X	Maňák et al., 2024
Fraxinus excelsior	European Ash			X	X	X		X	Maňák et al., 2024
Larix decidua	European Larch	X		X				X	Fontana et al., 2013
Ostrya carpinifolia	Hop Hornbeam			X					Tardella et al., 2019
Picea abies	Norway Spruce	X	X	X	X	X		X	Maňák et al., 2024
Pinus sylvestris	Scots Pine	X	X	X	X	X		X	Maňák et al., 2024
Populus alba	White poplar			X		X	X	X	Avram et al., 2023;

Populus tremula	European Aspen			X	X	X		X	Rossi et al., 2022 Maňák et al., 2024
Quercus petraea	Sessile Oak			X	X	X		X	Maňák et al., 2024
Quercus pubescens	Italian Oak			X		X		X	Rossi et al., 2022
Salix alba	White Willow			X	X		X		Avram et al., 2023; Ganatsas et al., 2022
Salix caprea	Goat Willow		X		X	X		X	Maňák et al., 2024
Sambucus nigra	Elderberry				X	X			Maňák et al., 2024
Sorbus aucuparia	Mountain Ash				X	X		X	Maňák et al., 2024
Sorbus domestica	Service Tree	X			X				Schmucker et al., 2024

Table 6: *Ecosystem Services present in LIFE VAIA project*

Ecosystem Services in LIFE VAIA					
MEA Category	ES	Subservice	Element		
			Tree Stands	Forest Garden	Honey Production
Provisioning					
	Food	Crop Yield		X	X
	Genetic Resources	Genetic Diversity	X	X	
	Medicinal Resources	Crop Yield		X	
Regulating					
	Air Quality	C02 Sequestration	X	X	
	Climate Regulation	C02 Sequestration	X	X	
	Erosion Control	Erosion Control	X		
	Water Regulation		X	X	
	Pollination	Pollination		X	X
	Habitat	Habitat Diversity	X	X	
Cultural					
	Aesthetic		X	X	
	Recreation	Tourism	X	X	
	Education	Dissemination	X	X	X

Table 7*: Cost-benefit Analysis Framework.*
Adopted From P. Gatto 2009

Item	Benefit (+), Cost (-)	Valuation Technique	Physical Indicator	Monetary Indicator	Monetary Value	Source
Financial Analysis						
Timber Revenues	+	Market Price	Yield (m^3/ha/yr)	Stumpage Price (€/m^3)	50€/m^3	Expert Opinion
Chestnut (Scientific Name)	+	Market Price	Yield (kg/ha/yr)	Weight Price (€/kg)	1.25€/kg	Expert Opinion
Honey	+	Market Price	Yield (kg/ha/yr)	Weight Price (€/kg)	10€/kg	Expert Opinion
Thyme (*Thymus vulgaris)*	+	Market Price	Yield (kg/ha/yr)	Weight Price (€/kg)	2.86€/kg	Literature
Lavender (*Lavandula hybrida)*	+	Market Price	Yield (kg/ha/yr)	Weight Price (€/kg)	3.90€/kg	Literature
Rosemary (*Rosmarinus)*	+	Market Price	Yield (kg/ha/yr)	Weight Price (€/kg)	4€/kg	Literature
Sage (*Salvia officinalis)*	+	Market Price	Yield (kg/ha/yr)	Weight Price (€/kg)	1.30€/kg	Literature
Oregano *(Origanum vulgaris)*	+	Market Price	Yield (kg/ha/yr)	Weight Price (€/kg)	3.77€/kg	Literature
Forest Investment Costs	-	Market Price	€/ha	€		Site Managers
Forest Management Costs	-	Market Price	€/ha	euro		Site Managers
Extended Economic Analysis 1						
Climate Regulation	+	Benefit Transfer	Sequestered Carbon t/ha/yr	Carbon Pricing (€/tC)	89€/ha/yr	Literature
Hydrogeological Protection	+	Benefit Transfer	Replacement cost (€/ha/yr)	Replacement Cost (€/ha/yr)	383.76€/ha/yr	Literature

3.4 Net Present Value Calculation

Net Present Value (NPV) expresses the difference between the present value of future costs and benefits. It is commonly used in sustainability and environmental studies to aid in the evaluation of economic viability of a project. For this study 2 discount rates were used. 1% and 2% were selected based on the analysis by Dymond et al. (2014) that selected discount rates of less than

5%. Discount rate is added to account for the time value added of money. The calculation of NPV can be represented with the following equation (Alounsavath Master & Kim, 2021):

$$NPV = \sum_{t=0}^{n} \frac{B_t - C_t}{(1+r)^t}$$

Where (Wainaina, Minang, et al., 2020):

- Bt = Benefits in year t
- Ct = Costs in year t
- R = Discount Rate
- t = Year
- n = Timeframe

3.5 Sensitivity Analysis Calculation

To assess the robustness of the analytical framework, I used two sensitivity analyses. Sensitivity analysis 1 reduced the yearly chestnut yield (kg/ha) by half. The chestnut production was selected to see if there was significant impact on profitability due to its large revenue. Sensitivity analysis 2 was alters the discount rate to 0%. This was done to see what the NPV would be without consideration of time value of money.

4 Results

The economic sustainability of investment for the 100 hectare pilot area, ES1, was analyzed over the 20-year timeframe. The main feature of this study includes net revenues, ecosystem services, costs, and net present value. Net revenues come from timber and forest garden production, ecosystem services benefits come from carbon sequestration and hydrogeological protection, and costs come from investment and maintenance activities.

4.1 Financial Analysis Results

Net Revenue

The overall net revenue per hectare per year is 50,618€/ha/yr by year 20. This income stabilizes by year 6, once all contributing elements are steadily producing. For example, the overall highest yearly contributor income are chestnuts, but they are not produced until after the first five years and aromatic plants begin producing in the second year (Table 8).

- NTFPs
    - Chestnut: Due to the differing activities, in the second year the costs associated with chestnut production is 112€ and after the second year is 252€/yr. Therefore, the net revenue from chestnut production is 1311€/ha/yr after the initial 5 years (the estimated amount of time it will take to see revenue). The chestnut production represents the greatest overall contributor to the net revenue.
    - Honey: Hives are initially valued at 150€/yr, but with a cost of about 85.20€/yr, it is calculated that the total net revenue from honey production is 65€ a year per hive.
    - Aromatics: forest garden production, after the initial purchasing costs, contribute a net income come 462.25€/yr after the fourth year.
- Timber
    - Timber production contributes 300€ annually per hectare.

Costs

- Investment costs: in the initial year of activities in area ES1, the total impact of investment costs is 12678€/ha/yr (Table 8).
    - Removal of alien species cost 1000€/ha/yr, fences for pilot areas cost 80€/ha/yr
    - Soil preparation activities cost 4658€/ha/yr
    - Planting activities cost 6940euo/ha/yr.
- Maintenance costs: maintenance costs, occurring every year after the first year, total 3422€/ha/yr (Table 8).
    - Removal of alien species costs€/ha/yr
    - Seedling replacements costs 1070 a year/ha

Table 8 *Annual Cash Flow at Year 20*

Source	Revenue (€/ha)	Cost (€/ha)
	Net Revenue	
Chestnut	1563	252
Honey	150	85.20
Forest Garden	462.25	Included in maintenance cost calculation
Timber	300	Included in maintenance cost calculation
	Maintenance	
Removal of Alien Species		2352
Seedling Replacements		1070

4.2 Extended Economic Analysis 1 Results

This analysis included the addition of ES that used the following values:

- Climate Mitigation: Carbon sequestration is valued at 91€/ha/yr (Table 9)
- Hydrogeological Protection: avoidance of natural disaster is valued at 393.6€/ha/yr (Table 9)

***Table 9**: Annual Costs and Benefits at Year 20*

Source	Revenue (€/ha)	Cost (€/ha)
	Net Revenue	
Chestnut	1563	252
Honey	150	85.20
Forest Garden	462.25	Included in maintenance cost calculation
Timber	300	Included in maintenance cost calculation
	Maintenance	
Removal of Alien Species		2352
Seedling Replacements		1070
	Ecosystem Services	
Climate Mitigation	91	
Hydrogeological Protection	393.6	

4.3 Net Present Value Results

The NPV in the financial analysis is negative, but positive in extended economic analysis 1. provides two different NPV rates with the differing corresponding discount rates. By year 20, the rate of 1% achieves a NPV of -30,020 in the financial analysis and 834,787 in the extended economic analysis 1 (Table 10). With a 2% discount rate, the NPV is -27,634 in the financial analysis and 755,140 in the extended economic analysis 1 in year 20 (Table 10).

***Table 10**: NPV in Financial and Extended Economic Analysis 1 at year 20*

NPV	Financial Analysis	Extended Economic Analysis 1
1% Discount Rate	-30,020	834,787
2% Discount Rate	-27,634	755,140

4.4 Sensitivity Analysis Results

Two sensitivity analyses were conducted to test the overall robustness of extended economic analysis 1. The first altered the discount rate to 0% and the second halved the yield rate of the chestnut trees.

Sensitivity Analysis 1

For sensitivity analysis 1, I decided to alter the discount rate, because it greatly influences the outcome of NPV and doing so allows for understanding of project viability under differing monetary time values. I selected a discount rate of 0% and this was compared against the rate of 2%. Selecting 0% discount rate shows the cash flow without accounting for time value of money. Using a discount rate of 0% resulting in a NPV of 926,707 by year 20 (Table 11).

Table 11: *NPV with differing discount rates and sensitivity analysis 1 (SA1)*

Discount Rate of 1%	Discount Rate of 2%	Discount Rate of 0% (SA1)
834,787	755,140	926,707

Sensitivity Analysis 2

For sensitivity analysis 2 I reduced the yield rate of chestnuts to half, to visualize a scenario where production was impacted. This could occur for a variety of reasons including pest outbreaks and climatic changes. Once reduced, the net revenue in year 20 is reduced from 50,618€/ha/yr to 49,836€/ha/yr (Table 12). This is a reduction of about 0.015%. The NPV with a discount rate of 2% changes from 755,140€ to 746,048€ by year 20 (Table 12). This is a reduction of 0.012%. While the chestnut production is the largest contributor to net revenue in the financial analysis, the reduction of yield to half per year creates insignificant impacts on the overall economic viability of the project, when ecosystem service provisions are considered.

Table 12: *Chestnut yield and revenue, NPV (1%), and NPV (2%), before and after sensitivity analysis 2 (SA2)*

Chestnut Yield (kg/ha)	Chestnut Revenue (€)	NPV (discount rate of 1%)	NPV (discount rate of 2%)

1250	1311	755,140	834,787
625	529	746,048	824,480

5 DISCUSSION

5.1 Interpreted Economic Sustainability

Based on the positive NPV result in my analysis, I interpret this project as sustainable, but only with the inclusion of authority subsidies and grants. My conclusion stems from the difference between the NPV results of the financial analysis and the extended economic analysis 1. NPV represents the net benefits that can be anticipated from implementation of the project (Gromko et al., 2019). To determine if a project is economically viable the NPV is used. If positive, the project is considered viable, if negative it's not (Gromko et al., 2019). In the financial analysis the result was negative, but in the extended economic analysis 1 the result was positive. Additionally, both SAs performed on economic analysis 1 resulted in a positive NPV. SA1 altered the discount rate, an element of NPV calculations, and it made minimal changes to the outcome. SA2 halved the yield of the highest producing asset in the financial analysis and still the NPV remained positive. It is important to recognize the impact of SA on the NPV as this confirms long-term viability of the project and therefore, I interpret the results as confirming that LIFE VAIA is a sustainable project as long as initial costs are subsidized by government entities (Wainaina, Minang, et al., 2020).

5.2 Role of Ecosystem Services

Ecosystem service provision contribute a significant amount to the overall net revenue of this project. This highlights the importance of provision activities as its inclusion in the analysis has the greatest impact on the total NPV. Based on this result, I think it is essential to include some form of ES valuation in the economic study as it ensures the consideration of the services in policy and decision making. Additionally, without the inclusion of ES valuation, the project is determined to be unprofitable. This is likely due to the high investment costs that are commonly associated with forest regeneration and these costs can act as a barrier to private entities attempting these projects (Gromko et al., 2019). To mitigate the initial costs, I think it is essential for governments to consider implementing subsidies and grant programs to encourage private entities to pursue these regeneration methods especially considering the overall socioeconomic benefit associated with the ES.

5.3 Implications

This study acts as the primary economic analysis of the LIFE VAIA project since its implementation. Specifically, through ES provision and inclusion of NTFP as economic resource, the analysis can be used as evidence to support the idea found in Dymond et al. (2014), that diversifying forest management practices can be profitable. Additionally, the diversity of income made the project less sensitive to a reduction in yield from one of the economic producers (chestnuts). This also confirms that a diversified income can improve forest biophysical and economic resilience. This confirms that integration of economic and ecological goals can result in benefits that achieve both environmental protection and financial income.

5.4 Limitations

It is important to consider the elements that were removed from this study due to lack of data and time constraint. It is likely the addition of more data, such as cultural ES, would have made the overall analysis more robust. Additionally, there will be fluctuations in costs and benefits due to the nature of the environment and unforeseen circumstances. New costs could arise from a variety of sources like fence damages from storms or plant damages from ungulate browsing. While the discount rate in this study was selected using recommendations in the literature, it is possible there will be a different time value of money in the selected 20 year time frame. Lastly, data quality and selection could pose as a challenge in this study due to a limited source of similar studies and possible human error. This is especially relevant when considering the use of benefit transfer. It is impossible to ensure complete compatibility of the characteristics of this study and those used, despite additional calculations to adjust for differences between location and time. It is possible there are other costs or benefits that may not have been identified throughout this study.

5.5 Recommendations for Future Research

To analyze the effect of income and cost fluctuations, I recommend updating and using this framework to compare and analyze this study's projections with the real, future returns. To produce a similar study, I recommend developing models for carbon sequestration based on each pilot area to get a more accurate value to use in this framework. Benefit transfer could be used to add an extended economic analysis 2. I would consider using studies that analysed tourism and valued through contingent valuation. Additionally, I recommend using this framework to test all pilot areas included in the LIFE VAIA project.

6 CONCLUSION

This thesis contributed to the extended Cost-Benefit Analysis (CBA) of the LIFE VAIA project by assessing cost flows and ecosystem services (ES). LIFE VAIA is an initiative that uses innovated practices that integrate agroforestry, artificial and natural regeneration, and diversified income streams, to achieve more resilient forest systems. This study considered value generated by non-timber forest products (NTFPS), timber, and ES to calculate benefits, and costs associated with project investment, production, and maintenance. Overall, the purpose of this study is to contribute to the understanding of forest management strategies that based on environmental and socioeconomic goals.

The financial analysis yielded a negative net present value (NPV), but the extended economic analysis 1 resulted in a positive NPV. This analysis reveals that the inclusion of ES can significantly enhance project economic viability and the extended economic analysis in combination with both sensitivity analyses (SA1 & SA2) confirms that the project is economically sustainable and resilient. The difference between the financial and extended economic analyses show the need for inclusion of ES in economic assessments and justifies the creation of subsidies for the initiation of these projects.

Despite all attempts to create a robust and accurate framework it is essential to consider the analysis for big picture patterns and not precise numbers. As the LIFE VAIA project progresses numbers can be updated to more accurately account for profitability. It is recommended that future analyses consider the inclusion of extended economic analysis 2 and refine data included through primary research. This will improve overall accuracy and act as further evidence for decision makers.

In conclusion, my study confirms the LIFE VAIA methodology can be a sustainable on for forest regeneration that balances both biophysical restoration and economic viability. It is a valuable demonstration that diversification of species planted, and income streams can create a more resilient regeneration effort. It is my hope that private entities, through the support of governments, pursue management practices that have the dual benefit of ecological and socioeconomic resilience.

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Appendices

Appendix A Data Calculation Instruments

Investment Cost

Site investment costs	*Date (mm/yr)*	**Purchases**	
		description	*Cost (€)*
Site preparation/cleaning			
Forest Restoration Lump Sum			
Seedlings			
Planting			
Hollowed out to plant the trees			
Tree protectors			

Disaggregated cost categories							
Machines		**Labour**		**Land acquisition**		**Other**	
description	*Cost (€)*	*description*	*Cost (€)*	*description*	*Cost (€)*	*description*	*Cost (€)*

Forest Restoration Item Examples:

- Forest Restoration Lump Sum
- Seedlings
- Seeds
- Fences
- Shelters
- Planting
- Roads

Maintenance Cost

Site management costs	*Date (mm/yr)*	**Purchases**	
		description	*Cost (€)*
Removal of alien species			
Irrigation			
Pruning			
Road repairs			
Fencing replacements			
Seedling replacements			
...add and delete items as necessary			

Disaggregated cost categories							
Machines		**Labour**		**Land acquisition**		**Other**	
description	*Cost (€)*	*description*	*Cost (€)*	*description*	*Cost (€)*	*description*	*Cost (€)*

Lump Sum	
description	*Cost (€)*

Source of data