Paludiculture in Indonesian Tropical Peatlands to Prevent Subsidence and Peat Fires

Ecological and Economic Aspects of Six Proposed Commodities

(Case Study in Central Kalimantan, Indonesia)

Dito Septiadi Marony Sitepu

MSc Thesis in Environmental Sciences

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Supervised by:
Dr. André van Amstel
Saritha K. Uda

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Supervisor(s):

1) Dr. André van Amstel
   Environmental Systems Analysis Group

2) Saritha K. Uda
   Ph.D. Candidate of Environmental Systems Analysis Group

Examiners

1st : Dr. André van Amstel

2nd : Dr. Sophie Rickebusch

WAGENINGEN UNIVERSITY & RESEARCH

Preface and Acknowledgement

This thesis is part of my master study at Wageningen University and Research Centre, the Netherlands. Besides the educational objective of my MSc study, this thesis is quite a challenge for myself. I focused on Sustainable Forest Management for my bachelor degree, but I am now working on Sustainable Peatland Management in this research. This six-months research took place in Pulang Pisau Regency, Central Kalimantan. This Regency was quite famous with the massive forest fires in 2015 and one of the ex-PLG project area. A Sustainable Peatland Management is urgently needed to prevent more fire events in this area. Paludiculture is a new concept in Indonesia. Thus my concern was to assess the possibility of the paludiculture plantation in peatland based on economic and ecological aspect. I also linked the paludiculture benefits with the on-going project such as Green Economy to increase the GDP of Pulang Pisau Regency.

I realized there were many difficult conditions in this research. Soon I learned many things about the environment of peatland in Indonesia. The peat areas were mostly too deep (between 4 to 20 meter) in Pulang Pisau, and I chose to rent a boat for field observation. It was quite difficult to collect secondary data from Indonesian Ministry of Environmental and Forestry due to big bureaucracy. On the other hand, BAPPEDA Pulang Pisau Regency fully supported this research; thus the secondary data was more accessible.

First of all, I gratefully acknowledge my supervisors. Dr. André van Amstel and Saritha K. Uda who were involved much during my thesis research in Wageningen University for giving many suggestions and recommendations. Next, I would like to express my gratitude to Mathieu Pinkers for giving feedback to my thesis proposal and start presentation. I want to also thank Dr. Suwarno, an expert in Land Use in Central Kalimantan who criticized my thesis draft and gave a recommendation about economic benefit of paludiculture commodities. I also would like to thank the Head of BAPPEDDA, Mr. Herson B. Aden, and his staff for the assistance and the guidance during the fieldwork period in the area.

Finally, I would like to acknowledge friends and family who supported me during my time in Wageningen. First and foremost I would like to thank Mom, Dad, Dion Sitepu, and Dirga Sitepu for their constant love and support. Amanda, Arti, Lugas, Ilham, Wildan, Dika, Bebel, mbak Zaidah, mas Andi, mas Arif, and mas Syukur made my time here at Hoevestein a lot more fun. I would like to thank to My GID group, Rony, Samaja, Markus, Edwin, Aftian, Thasia, Wikhen, Bebeth, Icha, and Susi. I owe a debt of gratitude to all the members of the Indonesian Student Organization in Wageningen. I would also like to thank all my friends in Netherlands, especially Cika, Maria, Mitra, Dyah, Priska, Nidhi, Davy, Twan, Guzal, Yui, Jessica, and Janine. Thank you for very much, everyone.

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Glossary

BAU	Business as Usual
BAPPEDA	Badan Perencanaan Pembangunan Daerah/ Regional body for planning and development
BPS	Badan Pusat Statistik/ Statistics
BRG	Badan Restorasi Gambut/ Peatland Restoration Agency
CBA	Cost Benefit Analysis
CO_2	Carbon Dioxide
FAO	Food and Agriculture Organization of the United Nations
FORDA	Forest Research and Development Agency
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IRR	Internal Rate of Return
NPV	Net Present Value
NTFP	Non-Timber Forest Product
PV	Present Value
SST	Sea Surface Temperature
TEV	Total Economic Value
WTD	Water Table Depth
1 Euro	IDR 14,330.19 (Live mid-market rate **2016-12-07 14:51 UTC)**

Summary

Peatlands hold as much carbon as the total of the other terrestrial biomass in the world. Tropical peatland has a rapid peat and carbon accumulation rate, thus it makes tropical peatland as important as carbon stocks in the boreal and temperate zones. These carbon stocks are important with respect to the climate change issue. Carbon stocks should be increased to reduce the carbon in the atmosphere. However, the degradation of peatland through lowering the groundwater table and El-Nino related droughts and resulting peat and forest fires has a major contribution to CO_2 emissions in Indonesia. Fire risks during El-Nino related droughts should be reduced. Therefore, paludiculture is developed for the peat areas. It is a new concept of peatland agriculture in Indonesia. By hydrology conservation through dams in the canals and planting paludiculture crops and trees in the peatland, it can rehydrate and maintain the peat body, and also facilitate peat accumulation within natural peatlands. This research compared six monoculture paludiculture (Chinese water chestnut, Sago, Jelutung, Tengkawang, Belangiran, and Gelam) and an agroforestry of the ensemble of paludiculture crops and trees in ecological and economic terms, plus their potential in the on-going Green Economy project in Pulang Pisau Regency. The objective of the research is to assess the total peatland CO_2 emissions from different paludicultures as alternatives for peatland degradation and to make recommendations which support sustainable peatland management. The ecological aspect was measured using total peatland emissions, peatland sequestration, flooding impacts, and historical emissions. The economic aspect was calculated using the CBA (Cost-Benefit Analysis). In the monocultures, Belangiran, Jelutung, Tengkawang, or Gelam generated the highest total peatland emissions with 21,467 tCO_2/ha (or around 14,000 $MtCO_2$ for total area) per type of commodity. On the other hand, agroforestry generated 14,474 tCO_2/ha (or around 9,500 $MtCO_2$ for total area) of total peatland emissions. Out of the commodities compared, Chinese water chestnut was the only one which contributed to peat formation. The highest total subsidence was found with Gelam, Tengkawang, Belangiran, Jelutung, and agroforestry with 10-meter depth. The total peatland loss due to the risk of flooding is around 166.5 ha and mostly affected the hardwood species (such as Jelutung, Belangiran, Tengkawang, and Gelam). Sago generated the lowest area lost with 161.5 ha. For the emission in 2050, Jelutung, Tengkawang, Belangiran, or Gelam obtained the highest total biological CO_2 emissions with 14,100 $MtCO_{2\text{-eq}}$, followed by Agroforestry with 9,500 $MtCO_{2\text{-eq}}$. The lowest total biological CO_2 emissions were found in Chinese water chestnut with 2,000 $MtCO_{2\text{-eq}}$. From an economic point of view, under the assumptions made, Jelutung generated the highest income with 5,710 euro/ha (or 3,800 million euro/total area), while Chinese water chestnut generated a loss of 1,493 euro/ha or (around 985 million euro/total area) by 2050. Agroforestry generated 2,222 euro/ha (or 1,500 million euro/total area) by the end 2050. In the Green Economy project, Jelutung generated the highest income with 67.7 billion euro, followed by Chinese water chestnut with 51.8 billion euro and Agroforestry with 51.6 billion euro. Although this concept of monoculture and agroforestry paludiculture is new in Indonesia, stakeholders had positive expectations about this concept overall. In Pulang Pisau Regency, paludiculture is more recommended than fallow land and palm oil plantation due to its ecological and economic potential. Among the monocultures, Chinese water chestnut is the most environmentally friendly scenario and Jelutung is the scenario with the highest profit. In the agroforestry system, paludiculture showed a balanced position between ecological and economic advantages. Agroforestry could therefore be the best option for paludiculture plantation in peatland. Jelutung and Chinese water chestnut monocultures could be alternatives for peatland management in Pulang Pisau Regency. Moreover, agroforestry, Jelutung, and Chinese water chestnut could contribute to increasing the Green GDP income.

Keywords: Agroforestry, CO_2 emissions, Green GDP, Indonesia, Monoculture, Paludiculture, Peatland

1. Introduction

Peatlands have an important role as sinks of atmospheric carbon dioxide (CO_2) for millennia (Limpens et al., 2008). According to Parish et al. (2008), peatlands cover only 3% of the world's land area. The global peatlands cover an estimated 4.26 M km^2 (Zinck, 2011). The largest proportions concentrate in the boreal (49%), temperate (42%) regions, and tropical (9%). Peatland can sequester carbon equal with all other terrestrial biomass in the World. It is nearly the same amount of carbon as contained in the atmosphere and twice as much carbon that stored in all remaining forest areas. Worldwide, peatlands can store almost 550 Gtonnes carbon (Joosten, 2009). Even though the greatest area of Peatlands was located in boreal and temperate zones, tropical peatlands also have an important role in terrestrial carbon storage. Tropical peatlands, which are located in Southeast Asia, South America, the Caribbean, and Africa, have a rapid peat and carbon accumulation rates, due to surplus rainfall and seasonal variations, that often exceed boreal and temperate peatlands.(Page et al.,2004). On the other hand, there is an on-going issue about the importance of carbon storage and carbon emissions from tropical peatlands. According to Page et al. (2002), the degraded peatland leads to the release of carbon emission and the reduction of peatland carbon pools.

According to Van Beukering (2008), Indonesia has roughly 50% by area of all tropical peatlands in the world. The total peatland area in Indonesia is approximately 265,500 km^2 (Zink, 2011). These peatlands contributed as the third highest source of CO_2 emissions in the world, mainly from peatland degradation, burning and deforestation (Silvius & Diemont, 2007; Hooijer et al., 2006. Due to El-Nino in 2015, the peatlands in Central Kalimantan suffered the most economic and ecological damage, compared to another province in Indonesia (World Bank, 2015). Slash-and-burn activities, palm oil plantation, and commercial tree plantations to make pulp and paper contribute to peatland degradation (Liu, 2015). Moreover, drainage canals for ex-irrigation and peat fires during drought periods are the leading causes of peatland degradation. Peatland drainage causes an irreversible process of drying, oxidation, flooding and fire which can release a large amount of CO_2 emission to the atmosphere (Law et al., 2015). Thus there is only a small amount of the undisturbed peatland that remains in Central Kalimantan.

Badan Restorasi Gambut (BRG) is an institution to coordinate and facilitate the peatland restoration in Indonesia. BRG has quite an important role in preventing peatland fires and subsidence. To prevent peatland fires and subsidence, BRG can perform peatland rewetting and hydrology conservation (e.g. blocking canal, water quality restoration, and reforestation) in protected zones. BRG also introduced paludiculture as the alternative agricultural crop in the peatland. One of the priority restoration areas that are chosen by BRG is located in Pulang Pisau, Central Kalimantan. This location has a history of burning. The area was a major “smoke-contributor” to Central Kalimantan (Fathurahman, 2016). According to Ekaputri (2016), there were at least 3,808 fire hotspots detected in this region in September 2015; it became the highest number of fire hotspots in Central Kalimantan. Besides, continuous peatland subsidence may eventually result in increased flooding and agricultural production loss in Pulang Pisau Regency (Hooijer et al., 2012). In 2016, Pulang Pisau Regency is flooded as high as one to two meters due to heavy rainfall and degraded peatland.

One way of utilizing peatland is by planting paludiculture commodities in the area. According to Wetlands International (2016a), paludiculture is a land use management system to sustain the ecosystem services, by rewetting peatlands under conditions that maintain the peat body, and to facilitate peat accumulation within natural peatlands. According to Wibisono et al. (2011), the environmental problems emerges mainly from drainage and peat fire due to agriculture on peatland. A shift from drainage-based agriculture to paludiculture is required to reduce environmental problems. The trials of paludiculture in Indonesia have been developed in the last ten years. However, there is still a lack of knowledge about the ecology and profitability of paludiculture commodities in Indonesia, e.g. Pulang Pisau. According to Tata and Susmianto (2016), there are six proposed commodities in Pulang Pisau Regency, namely Chinese Water Chestnut, Sago palm, Jelutung, Belangiran, Tengkawang, and Gelam. There are two options for paludiculture plantation in peatland, namely monoculture and agroforestry. The monoculture is a condition where the whole peatland area is only planted by one commodity. Besides, the agroforestry is a condition where the whole peatland area is planted by mixed paludiculture commodities.

This research illustrates the complexity of ecological and economic aspects of paludiculture on land use change in Pulang Pisau Regency, Central Kalimantan. Both aspects have high influenced to determine the most sustainable peatland land use. The ecological aspect can be determined from total CO_2 emissions and historical emission of the commodities. The most favourable peatland management can be generated using Vensim model. Vensim is an interactive software environment that can develop, explore, analyse, and optimize the simulation models. Vensim can address the complexity of environmental problem with simple modelling language (Eberlein & Peterson, 1992). This model helps to analyse the most sustainable peatland management by comparing the total CO_2 emissions and historical emission of paludiculture commodities. The economic aspect can be determined by using CBA (Cost-Benefit Analysis). CBA is a decision-making tool to evaluate and to compare two or more projects in terms of economic benefit. Moreover, CBA is used to analyse the costs and benefits of the investment, also to assess whether the investment is worth its costs. The valuation of CBA aims to attract the investors and developers for participating in this paludiculture by providing the economic value from each commodity of paludiculture (Johansson, 1993).

This peatland management can be integrated with other non-peat based economic activities such as Green Economy project to support the equitable development resulting in sustainable landscapes (Wetland International, 2016a). According to UNEP (n.d.), Green Economy concept can improve human well-being, social equity, and environmental quality. Green economy persuades the public and private investments to take participation in reducing carbon emission, improving energy efficiency, and maintaining biodiversity and ecosystem services. Central Kalimantan's Green Economy was developed in 2015 to support sustainable development in this province. This concept becomes a new issue for sustainable development in Central Kalimantan. According to Sukhdev et al., (2015a), Green economy can significantly help to reduce emission in the forestry and peatland as well as other economic sectors such as energy, industry process, and land conversion. Peatlands provide a reduction in CO2 emission service worth of 2.5 euro/ ton (Hamrick and Goldstein, 2016). The Green economy can ensure an increased revenue growth because this concept includes the economic value of ecosystem services and the value of natural capital. Therefore, this research is conducted to find out the most favourable paludiculture commodities to reduce peatland degradation particularly in Pulang Pisau, Central Kalimantan based on ecological and economic aspect. Furthermore, this research also discusses the potential impact of paludiculture on the Green Economy project and the possible recommendation for sustainable peatland management.

2. Research Objective

This section describes the objective and the sub-questions of this research. The objective and sub-questions will determine the research framework and the research method in the next sections. The objective of the research is to assess total peatland emissions from different paludicultures as alternatives for peatland degradation and to recommend and support sustainable peatland management. This research objective is analysed in sub-research questions:

- What is the carbon emission and sequestration of paludicultures from restoration area?
- What is the impact of paludicultures on the ecology and economy?
- How does paludiculture support the sustainable peatland management such as Green Economy?
- What is the best possible recommendation for sustainable peatland management in the restoration area?

3. Methodology and Literature review

This section describes the study site, framework, and method of the research. The study site discusses the characterization (e.g. total area, geographical location, climate, topographic condition, type of soil, slope level, and rivers) of the Pulang Pisau Regency, Central Kalimantan. The framework illustrates the process to achieve the research objective. Based on the framework, the research method describes the research tools and the required data to achieve the research objective.

3.1. Study Site

This study site is located in Pulang Pisau Regency, Central Kalimantan. This region has a total area of 899,700 hectares with 660,140 hectares of peatland area. This area is located on the equator, which is between 10-00 degree of southern latitude and 110-120 degree of eastern latitude. According to the Local Government of Pulang Pisau, this region has been designated and developed as the priority peatland restoration area in Indonesia. Figure 1 below presents the area of Pulang Pisau Regency.

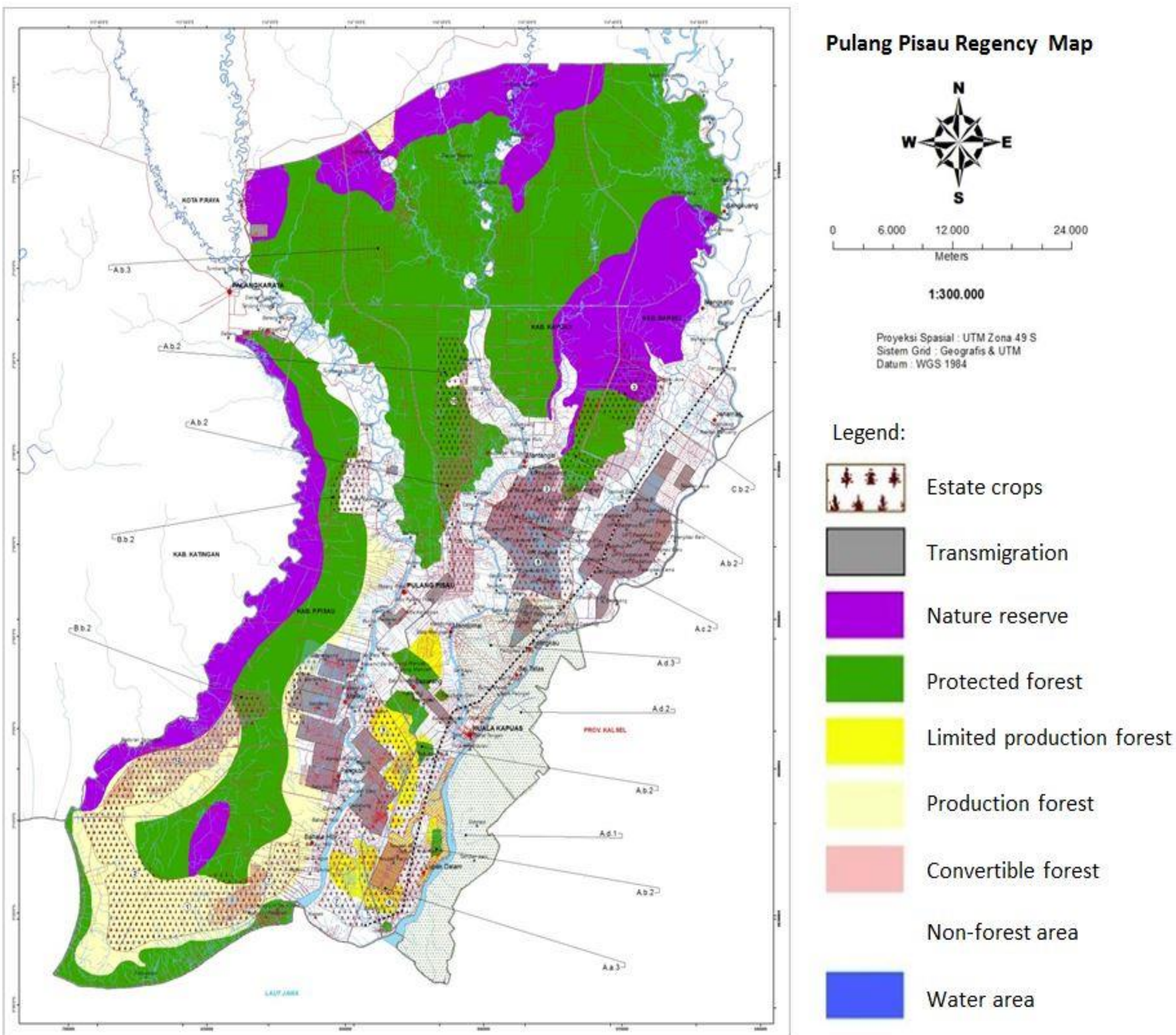


Figure 1. Pulang Pisau Regency map

This research is conducted in the block B and C of Pulang Pisau Regency (Figure 1). The climate in this Regency is humid tropical with annual temperature that varies between 22.5 to 38 degrees Celsius and annual precipitation can reach 224.50 mm (BPS, 2012). Evapotranspiration in this area exceeds precipitation in less than three months per year (Neuzil 1997).

The topographic condition of Pulang Pisau Regency can be divided into two parts, namely northern and southern part. In the northern part, the area is dominated by hills with an average altitude around 50-100 m above sea level and an average inclination of slopes around 8%-15%. Moreover, this area also has a highlands region with slope level about 15%-25%. In the southern part, the area is dominated by coastal, swamps with an altitude of 0-5 m above sea level and slopes from level 0% to 8%. This area is mainly influenced by the tides and has high intensity of floods.

Pulang Pisau is dissected by some well-known rivers, namely Kahayan River with 600 km length, Sebangau River with 200 km length, Anjir Kalampan with 14.5 km length, Anjir Basarang with 24 km length and Anjir/ Terusan Raya with 18 km length.

The type of soil in Pulang Pisau Regency is following the topographic pattern. In the southern part, the types of soil are dominated by peat and alluvial soil. This area doesn't have a good drainage. On the other hand, the types of soil in the northern part are dominated by podsols and alluvial soils. Moreover, the type of soil in the riverside areas is dominated by alluvial soil that is derived from sediment.

In this area, the construction of canal blocking dams already started on 12th October 2016. These canals are claimed to keep the water supply and to prevent the forest fire in this area effectively. The canals have 14 km length and connect to Kahayan River. Figure 2 below presents a blocking canal in this area. Moreover, the Pulang Pisau Government also installed 30 water pumps in this area to be able to extinguish the forest fires when they occur.

Figure 2. Wooden Blocking Canal

3.2. Research Framework

In this research, the peatland areas are assumed to be in two conditions. The first condition is when the peatland area is managed by monoculture system, where the total area will be planted with only one commodity. The second condition is when the peatland area is managed by agroforestry system, where the total area will be planted with six different commodities.

Figure 3 below illustrates the framework that will be followed in this research to achieve the research objectives in section 2. First, the formulation of the research proposal can be seen in section

1(Introduction) and section 2 (Research Objective). Second, the data will be collected from literature review and field observation. Third, data processing and analysis will be conducted by comparing all commodities with six criteria (output 1 and 2). In the end, the Green Economy valuation will be calculated (output 3).

To comprehend the objectives of this research, the framework will be conducted in eight major steps, namely:1. The determination of paludiculture scenarios, 2. Quantification of total peatland emissions, 3. Quantification of peatland formation, 4. Quantification of historical emissions, 5. Ecological Aspect, 6. Economic Aspect, 7. Valuation of Green Economy. These eight steps will be elaborated in the next section, the research method (see section 3.3).

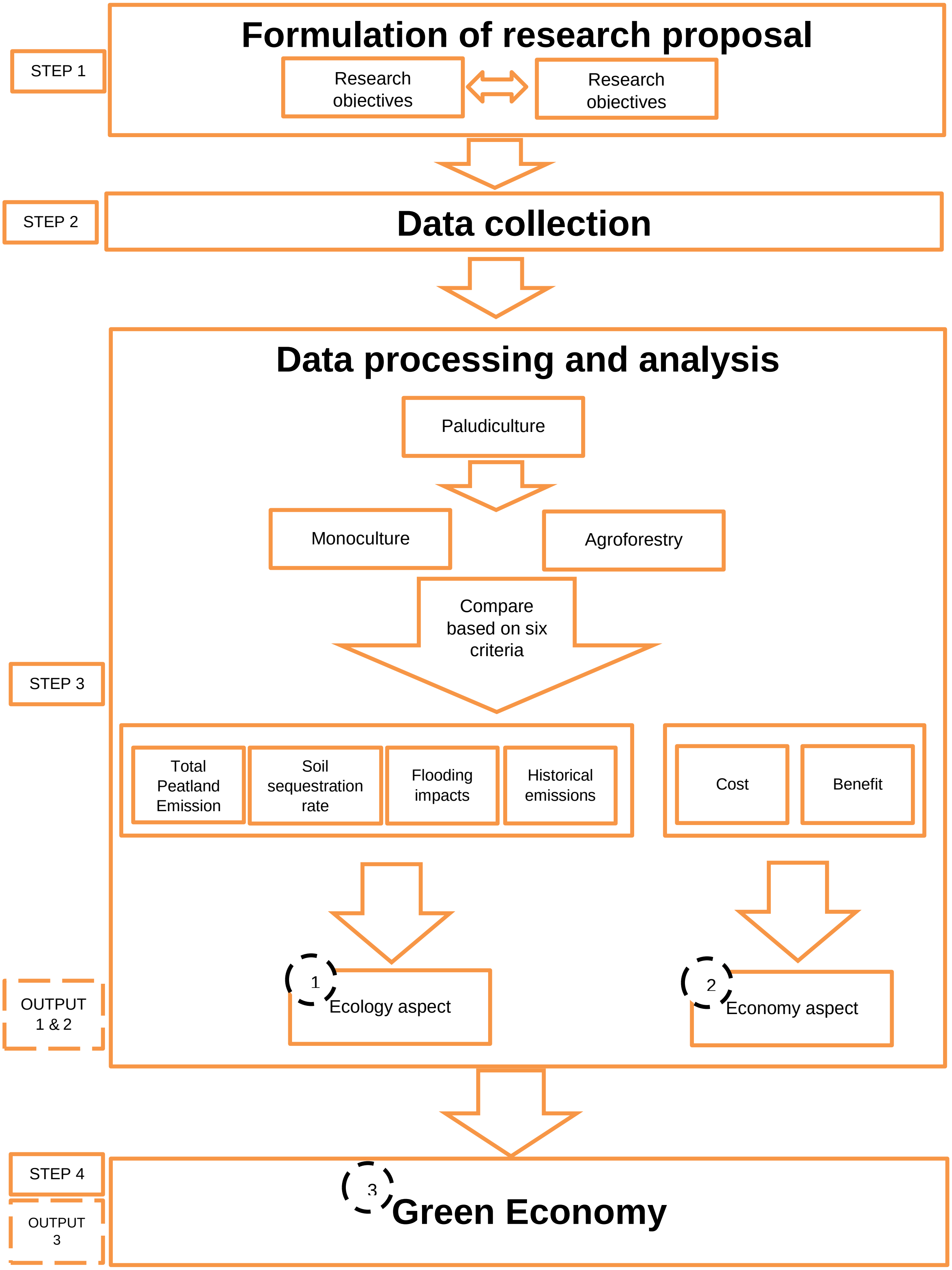


Figure 3. Research Framework

3.3. Research Method

This research took place in Pulang Pisau Regency, Indonesia due to the peatland fires within this area. In 1998, extremely dry El Nino conditions in Indonesia initiated a wave of large-scale uncontrolled burning that destroyed about five million hectares of tropical forest. Pulang Pisau Regency has a long history with peatland fires. Pulang Pisau also suffered peatland fires due to the latest El-Nino in 2015 that destroyed most of the peatland in this area. This event also led to the release of carbon dioxide into the atmosphere, and huge clouds of smoke and haze across the region. Moreover, this area is disrupted by the fallacious construction of drainage canals that are more harmful to local economies and global GHG emissions than anything else (USAID Lestari, 2016).

Paludiculture is one of the promising management systems to reverse these fire risks and to restore wetland ecosystems in Indonesia (Tata & Susmianto, 2016). Moreover, the BRG authority also considers paludiculture as the most promising management systems because it merges the forestry and agricultural use of peatland by cultivating convenient plants that can combine interests into both climate protection and agriculture. However, there is still a lack of knowledge of paludiculture in Indonesia, especially in Pulang Pisau Regency, i.e. the economic value of the paludiculture commodity and the impact to the ecology.

Therefore, this research analyses the economic and ecological aspects of paludiculture. Then, economic and ecologic aspects are integrated to find the Green Economy valuation. This research also conducts six scenarios based on six most promising paludiculture commodities.

3.3.1. Determination of paludicultures on peatland management scenarios

This research assumed six paludiculture commodities to predict the environmental impact of different commodities in Pulang Pisau peatland. These six commodities are already used traditionally in Central Kalimantan, so they have a high possibility to be cultivated in Pulang Pisau Regency. The paludiculture commodities that are analysed, namely Chinese water chestnut *(Eleocharis dulcis Hensch.*), Sago palm (*Metrioxylon sagu*), Jelutung (*Dyera sp.*), Belangiran (*Shorea balangeran*), Tengkawang (*Shorea spp.*), and Gelam (*Melaleuca cajuputi Powell*) (Tata & Susmianto, 2016).

Chinese water chestnut is a bio-control commodity, absorbs heavy metals, and acts as a bio-filter toxic substance (Asikin and Thamrin, 2012). Sago palm is a tree that needs periodical inundation for better performance, so it is highly suitable to be cultivated on tropical peatlands (FAO, 2015). Wetlands International (2016b) defined Jelutung as a latex-producing tree, a popular species that often is planted in reforestation attempts. Belangiran is a typical Indonesian tree species with valuable hardwood timber. Tengkawang produces seed that has a good price in the market, and also the seed can be used for reproduction. Gelam is a pioneer species in the ex-peat swamp forest that burned.

In ecological aspect, these six commodities were used to assess the peat sequestration, flooding impacts, and historical CO_2 emission in next sections. The peat sequestration could be either subsidence or formation of the peatland itself. According to Joosten and Clarke (2002), peat formation is defined as an accumulation of carbon surplus. This accumulation has a significant role in maintaining the existence of peatland. Peat subsidence is a reduction in the level of soil's surface. This subsidence leads to CO_2 emission due to a large extent by oxidation (D'cruz, 2014). This quantification of peatland sequestration is needed to find out the impact of the paludiculture plantation in this area. Flooding impacts would be calculated to determine the risk of peat subsidence in paludiculture area, especially agricultural commodities. Then, historical emission was measured to predict total biological CO_2 emissions until 2050.

In economic aspect, the six paludicultures were quantified to find the economic benefit from all commodities. The quantification of economic benefit from each commodity is explained below.

Chinese Water Chestnut

Chinese water chestnut is assumed to be planted from 2015, and it has a 6-months cutting cycle with a yield of more than 7 tons/ha per harvest time (Moore, 2008). According to Kleinhenz et al. (2000), Chinese water chestnut has an increasing demand in Australia, and thus it has a stable market for sales. Moreover, the price of this chestnut can be up to 3.8 euro/ton. This research assumed Chinese water chestnut products from Pulang Pisau Regency can be imported to Australia. The corms from Chinese water chestnut can be used for planting and replanting, so there is no additional cost to plant and replant this kind of chestnut.

Sago palm

Sago palm is assumed to be cultivated from 2015, and it has a 12-years cutting cycle (Tata & Susmianto, 2016). According to Bustaman (2015), there are approximately 82 palm trees to harvest in one hectare. In one hectare, sago palms can produce 8,076 liters bio-ethanol per year with market price around 0.35 euro/liter. Sago palm can reproduce vegetatively. Thus there is no cost for replanting. In this scenario, there is always a demand for sago palm in the market.

Jelutung

Jelutung is assumed to be planted from 2015 and it has a 35-years cutting cycle. Jelutung trees produce a type of white latex. Jelutung latex can already be harvested after the trees are seven years old. Jelutung tree can be tapped until 40 times a year, and it can produce around 0.4 kg/ tree. Based on Jambi Ministry of Forestry database, latex can be priced around 0.21 euro/kg with 200 trees per hectare. Therefore, the economic value of latex is approximately 700 euro/ha/year. However, latex only can be harvested until 25 years old According to Nugroho (2014), the cost of planting Jelutung is around 280 euro/ha. This scenario only assumes the latex production, and the demand of Jelutung is always stable from year to year.

Belangiran

Belangiran is assumed to be planted from 2015, in Pulang Pisau Regency. According to West Java Department of Forestry, Belangiran has a 20-years cutting cycle. Bahtimi (2009) assumed that hardwood usually has 15-meters of bole height with average volume about 3 m^3/ tree. Based on Indonesia Ministry of Forestry (2014), the wood from Belangiran tree has a market price of approximately 16.5 euro/m^3. The wood production from Belangiran is approximately 90 trees/ha. According to Nugroho (2014), the cost of planting and replanting of Belangiran is around 140 euro/ha. This scenario assumed that Belangiran wood is in stable demand on the market.

Tengkawang

According to Indonesia Ministry of Forestry, Tengkawang is categorized as hardwood, and it has a 35-years cutting cycle. This research assumed it to be planted in 2015. In Ministry of Forestry's database, Tengkawang produces seeds that can be used for reproduction or conservation. The tree produces the first seeds after 8 years of growth (Heri, 2013). Based on Indonesia Ministry of Forestry's website, it can produce seeds every three years. The seeds of Tengkawang can be priced at 0.21 euro/kg (Cholidatul, 2016). According to Fachrizal (2014), Tengkawang can produce seeds around 400 kg/hectare. Since the seed can be used to reproduce vegetatively, there is no additional cost for replanting. In this scenario, the research assumes that the demand and market price of seeds are stable every year.

Gelam

Gelam is assumed to be planted from 2015, and it has a 9-year cutting cycle. According to Giesen (2015), Gelam tree is normally used by local people for pole production and NTFP (such as oil). However, this research assumed there is no wood-cutting activity in Gelam peatland. Gelam leaves are extracted to make this oil. The oil can be harvested every year, and the price is up to 281 euro/ha per year. The cost for planting and replanting Gelam is about 280 euro/ha (Nugroho, 2014). In this scenario, it is assumed that there is a high demand of Gelam tree in the market.

3.3.2. Quantification of total peatland emissions (IPCC, 2007)

According to research framework in Figure 3, the total peatland emissions are quantified from biological and fire emissions. However, paludiculture can prevent forest fire in the peatlands, so the total peatland emissions are only measured from biological emissions. This research compared between monoculture and agroforestry paludiculture system in peatland. Monoculture assumed that the peatland is planted by only one commodity, and there is no forest fire in that area for a long time. Agroforestry assumed that the peatland is planted by six commodities and every commodity can be planted proportionally.

A. Monoculture paludiculture system

In the monoculture paludiculture system, the peatland emissions from each commodity are calculated separately. Monoculture paludiculture allows the rewetting of drained peatlands and keeps the peat fire as low as possible, and thus the peatland emissions should be only calculated from biological emissions. The emission quantification from this source is explained below.

In monoculture system, the measurement of peatland emissions were conducted to six commodities of paludiculture. In Table 1, the list of emission factors is shown. However, these emission factors were categorized by the type of vegetation due to lack of information about each specific commodity.

Table 1. List of emission factors based on vegetation type

Commodity	Vegetation	Emission Factor ($tCO_2\ ha^{-1}\ yr^{-1}$)	Source
Jelutung	Rubber plantation	36	Agus et al., 2013
Sago palm	Cropland	20	Couwenberg, 2011
Belangiran	Timber plantation	36	Agus et al., 2013
Tengkawang			
Gelam			
Chinese water chestnut	Grassland	5	Couwenberg, 2011

By multiplying the emission factor and total land use area, the peatland emissions can be obtained. The peatland emissions calculation can be shown in the Equation 1 (Hooijer et al., 2014).

$$\boldsymbol{PE_X = EF_X \times A_X} \quad \textbf{(1)}$$

Where:

PE_x : Peatland emissions X ($tCO_2\ yr^{-1}$)
EF_x : Emission factor X ($tCO_2\ ha^{-1}\ yr^{-1}$)
A_x : Total land use area X (ha)
X : Type of commodity

In this situation, total land use area is defined by the total peatland area in Pulang Pisau. The peatland area was estimated to be 660,140 ha. Then, land use change area from fallow land to paludiculture is also needed for calculating the peatland change emissions. Equation 2 (Hooijer et al., 2014) illustrates the calculation of land use change.

$$\boldsymbol{PcE_X = EF_{Fallow\ land} \times LUC} \quad \textbf{(2)}$$

Where:

PcE_x : Peatland change emissions X ($tCO_2\ yr^{-1}$)
$EF_{Fallow\ land}$: Emission Factor of fallow land ($tCO_2\ ha^{-1}\ yr^{-1}$)
LUC : Land use change area(ha)
X : Type of commodity

After conducting Equation 1 and 2, then total peatland emissions can be calculated by summing up peatland emissions and peatland change emissions. See Equation 3 (Hooijer et al., 2014) below.

$$\sum PE_X = PE_X + PcE_X \tag{3}$$

Where:

$\sum PE_X$: Total peatland emissions X (tCO_2)
PE_X : Peatland emissions X ($tCO_2\ yr^{-1}$)
PcE_X : Peatland change emissions X ($tCO_2\ yr^{-1}$)

B. Agroforestry paludiculture system

This agroforestry system divides peatland area for six commodities in Pulang Pisau to be planted based on the economic value of each commodity. The commodity with higher economic value has more proportion of area to be planted. The distribution of peatland is divided into six: the highest one with 0.3 ha per ha, 0.25 ha per ha, 0.2 ha per ha, 0.07 ha per ha, 0.05 ha per ha, and lowest one with 0.03 per ha. The same with monoculture system assumption, the agroforestry system also allows the rewetting of drained peatlands and keeps the peat fire low. Therefore, the peatland emissions should only be calculated from biological emissions.

By using Equation 1, 2, and 3, the total peatland emissions from each commodity is calculated. Then, the total peatland emissions from all commodities can be derived by using Equation 4.

$$\sum_{i=1}^{n} PE = PE_1 + PE_2 + \cdots + PE_n \tag{4}$$

Where:

$\sum PE$: Total peatland emissions from all commodities (tCO_2)
PE_n : Total peatland from each commodity ($tCO_2\ yr^{-1}$)
n : Number of commodities
i : Increment

3.3.3. Quantification of peatland sequestration and flooding impacts

A. Peatland Sequestration

<u>Formation</u>

Peat formation is essential for storing a huge amount of carbon. In the global discussions, tropical peatlands become an important issue due to their importance as carbon stores (Jaenicke et al., 2008). According to Page et al. (2004), the current average accumulation rate for Indonesian peatlands has been estimated to be between 1 and 2 mm yr^{-1}. However, it only can be applied on Chinese water chestnut.

<u>Subsidence</u>

In both monoculture and agroforestry paludiculture, the peat formation is assumed to be stable or less degraded. According to Wichtmann & Joosten (2007), paludiculture does not focus on peat formation because there is a lack of data about peat formation in paludiculture. Moreover, the organic geochemical research to this aspect of peat formation is still in its infancy. On the other hand, paludicultures can stop peat oxidation and sustainably provide harvests from peatland in economic perspective (Wetlands International, 2013).

Peat subsidence has an important role in peatland degradation. Land subsidence is the sudden sinking of the Earth’s surface owing to subsurface movement of earth materials. According to Hooijer et al. (2012), the peat subsidence is influenced by the Water Table Depth (WTD). Each commodity has their WTD that categorized by the type of vegetation (Agus et al., 2013). Table 2 presents the WTD of all commodities.

Table 2. WTD based on vegetation

Commodity	Vegetation	Water Table Depth (cm)
Jelutung	Rubber plantation	50
Sago palm	Cropland	30

Belangiran Tengkawang Gelam	Timber plantation	50

Therefore, Hooijer et al. (2012) formulated an equation to measure the relationship between subsidence level and WTD. The subsidence rate is shown in the Equation 5 below.

$$\boldsymbol{SR = 0.69 - 5.98 \times WTD} \qquad \textbf{(5)}$$

Where:
SR : Subsidence rate (cm/year)
WTD : Water table depth (cm)

B. Flooding Impacts

In this section, the flooding impacts are calculated from only agricultural peatland commodities, namely Jelutung, Sago, Belangiran, Tengkawang, and Gelam. On the other hand, Chinese water chestnut is counted as non-agricultural commodity, and it is assumed that this commodity will increase the peat formation.

The flooding impacts are highly depended on the subsidence rate from section 3.3.3.A. Equation 6 from Hooijer et al. (2015) displayed the relation between the amount of flooded agricultural peatland and the accumulated agricultural subsidence. Equation 6 is illustrated below.

$$\boldsymbol{FlAgPe = -0.0001 \times AgS^2 + 0.187 \times AgS + 27.8} \qquad \textbf{(6)}$$

Where:
FlAgPe : The amount of flooded agricultural peatlands (%)
AgS : The accumulated agricultural subsidence (cm)

After the amount of flooded agricultural peatlands were obtained, then these results are used to calculate the flooding agricultural peatland. Equation 7 displayed the amount of flooded agricultural peatlands and the inverted Nino4 SST Index. The Inverted Nino4 SST Index is defined as a condition where wet years are positive instead of the other way around. The equation 7 illustrates the quantification of flooded agricultural land.

$$\boldsymbol{FAL = FlAgPe \times Inv.Nino4\ SST \times AL} \qquad \textbf{(7)}$$

Where:
FAL : Flooded agricultural land (ha)
FlAgPe : The amount of flooded agricultural peatlands (%)
AL : Agricultural land area (ha)
Inv. Nino4 SST : Average inverted Nino4 SST Index (where wet years are positive instead of the other way around) is derived by comparing the relationship between El-Nino and Central Pacific anomalies (see Annex 1)

3.3.4. Quantification of historical emission

This section discusses the historical emission of the research area that starts from 2000. The historical emission from peatland biological oxidation was calculated by using average annual emission from 2000 to 2015. This quantification is used to find the trend of current biological emission and to predict the amount of biological emission in 2016. The peat biological oxidation in Pulang Pisau Regency is presented in Table 3.

Table 3. Annual Biological Oxidation

Year	Annual Biological Oxidation ($tCO_{2\text{-eq}}$)
2000	59,070,982
2003	47,907,819
2006	44,764,388
2009	39,988,098
2011	39,504,902
2012	38,155,160
2013	39,184,047
2014	39,184,047
2015	29,175,868

Source: Ministry of Forestry, 2016

Table 3 presents the prediction for historical emission in 2016-2050. This research uses the exponential trendline by using Microsoft Excel 2013. Eventually, the historical emission can be calculated by using Equation 8 below.

$$\boldsymbol{HE = -10^7 ln(x) + 6 \times 10^7} \qquad \textbf{(8)}$$

Where:

HE : historical emission ($tCO_2\ yr^{-1}$)

x : number of time period (year)

3.3.5. Vensim (Ventana Systems, Inc.)

Vensim is a system dynamics modelling that can solve and describe complex problems. Vensim can make model conceptualization and modification to analyse and perform using a graphical interface (Jennings et al., 2006). By using the simulation in Vensim model, a set of equations can represent the considered system with a chosen time resolution. This model was used to make the scenarios in ecological aspect until the end of 2050. For total peatland emissions, this model integrated the variables (the emission factor from each paludiculture commodity total land use area, total fallow land area) with the time until 2050. Thus the accumulation of total peatland emissions of each commodity could be generated. For peat sequestration, Vensim integrated the variables (peat formation rate, water table depth) with time to generate the accumulation of total peat sequestration of each commodity until 2050.

3.3.6. Ecological Aspect

In Ecological aspect, this research compared each commodity from monoculture and agroforestry paludiculture system to determine the most environmentally sound commodity. The most environmentally sound commodity is defined as the system with the lowest total peatland emissions in 2016. Each commodity is accumulated with the historical emission in section 3.3.4. The system with the lowest emissions will become a recommendation in the next climate convention. The calculation is illustrated in the Equation 8 below.

$$\boldsymbol{HPE_{2050} = PE_x + HE} \qquad \textbf{(9)}$$

Where:

PE_{2050} : Peatland emissions in 2050 (tCO_2)

PE_x : Total peatland emissions X (tCO_2)

HE : Historical emission (tCO_2)

3.3.7. Economic Aspect (TEV)

In economic aspect, this research compared six monocultures and an agroforestry paludiculture to determine the most profitable systems. According to Torras (2000), attaching a value to ecosystems services for instance of a forest is not always easy because of the various uncertainties surrounding the issue of its valuation. However, even if the monetization of the ecosystem services is associated with uncertainties, it is an important way of internalizing externalities and also facilitation of decision making (de Groot et al., 2010).

A. Cost-Benefit Analysis (CBA)

CBA is an analytical tool for economic evaluation of projects intention of identifying their consequences in monetary terms (Atkinson et al., 2008). In ecosystem service assessment, CBA helps to identify the economic outcomes (costs and benefits) of conserving/optimizing or converting ecosystems use (de Groot et al., 2010). This research considers the benefits and costs from paludiculture plantation.

Benefits

The benefits that human beings derive directly or indirectly from ecosystem functions (de Groot et al., 2010).

Costs

The cost refers to both the direct and the indirect cost of converting a certain ecosystem to other use or the cost maintaining /managing the ecosystem.

Net Present Value (NPV)

Net present value involves the discounting of the future flow of values which is the total of the Present values over time (Costanza, 1998). Therefore, in the calculation of NPV, this research uses the Equation 9 below, using a timescale of 35 years and a discount rate of 5 %.

$$\boldsymbol{NPV} = \sum_{\boldsymbol{t=0}}^{\boldsymbol{n}} (\boldsymbol{B} - \boldsymbol{C}) \times \frac{\boldsymbol{1}}{(\boldsymbol{1} + \boldsymbol{r})^{\boldsymbol{t}}} \qquad \textbf{(10)}$$

Where:

t : Number of time period (year)

r : Discount rate (%)

B : Benefits (euro)

C : Costs (euro)

B. Sensitivity Analysis

The sensitivity analysis is performed to determine the response of the NPV on the changing discount rates. In this analysis, a minimum, medium and maximum discount rates were used to show the influence of this factor on NPV of the commodities. Therefore, the discount rate is an important determinant of the value of different the NPV of commodities.

C. Internal Rate of Return

Internal Rate of Return (IRR) is one of the alternatives to the NPV criterion. The IRR is a measure frequently employed in financial investment appraisal (Hanley et al., 2009). According to Patrick et al. (2016), IRR is a condition when the NPV of a project is zero at selected discount rate. IRR is quite contrasting with the NPV; IRR is an indicator of the efficiency, quality, or yield of an investment.

The IRR formula is expressed in Equation 10 below.

$$IRR = r_1 + \frac{NPV_1 \times (r_2 - r_1)}{(NPV_1 - NPV_2)} \quad \textbf{(11)}$$

Where:

IRR	: Internal rate of return (%)
NPV	: Net present value (euro)
r	: Discount rate (%)

This research assumed the paludiculture should take at least 35 years to be planted in Pulang Pisau. Thus the paludicultures have time to gain the profit until 2050. Therefore, this research used 1% for r_1 and 5% for r_2.

3.3.8. Valuation of Green Economy (Sukhdev et al., 2015b)

Green Economy is one of the economic options to increase human well-being and social equity and to reduce environmental and ecological scarcities. It is an economic mechanism that designed for sustainable development. Moreover, Green Economy also become a central theme of Rio+ 20. In this Green Economy project, the peatland is assumed to generate income and to provide employment through public and private investments that supported by targeted policy reforms, regulation changes, and capacity building. Managing the peatlands are needed because the peatland is an asset class and important factor of production. In the Green Economy, government and the international community need to perform a policy reform to create incentives to manage and invest in the peatland. The indicator of Green Economy, namely Green GDP, Decent Green Jobs, and GDP of the Rural Poor.

In the research, the optimal commodity is partly analysed through the value of Green GDP, instead of GDP. Green GDP was chosen as it accounts for the value of natural capital loss as well as the benefits from green investments in the production sector of Pulang Pisau. The Green GDP was measured by using the Equation 11 below.

$$\textit{Green GDP} = \textit{Real GDP} + \textit{NPC} \quad \textbf{(12)}$$

Where:

Green GDP	: GDP that monetizes the loss of biodiversity, and accounts for costs caused by climate change (euro)
Real GDP	: GDP in a given year (euro)
NPC	: Natural capital change (euro)

According to Boyd (2007), real GDP is the most visible and influential of the national economic indicators. Real GDP also measures whether the economy is shrinking or growing. On the other side, green GDP measures nature's contribution to human welfare. NPC defines as a changing of the stock and variety of species, and the stock and variety of ecosystems, and their functions. Several output variables discussed in the previous sections were included in calculating the NPC, namely the economic benefit from commodity and total peatland emissions. From total peatland emissions, the carbon storage net can be derived for the benefit from carbon trading. Thus the Carbon storage in Pulang Pisau can be derived by converting the CO_2 emission to carbon emission. This carbon storage net change was later included in the total natural capital net change, which further included in the Green GDP calculation. The carbon storage net can be calculated by multiplying total carbon stock in Pulang Pisau with carbon price in the market. According to Hamrick and Goldstein (2016), the average price of carbon is 2.5 euro/ton in carbon market.

3.4. Data Collection Methods

Table 4. Data list and sources.

Context	Data/Equation	Source
Land-use management	Paludiculture (six species)	Tata & Susmianto, 2016

Biological Emission Quantification	Biological Emission Equation	Hooijer et al., 2014
Emission Factor	Sago palm	Couwenberg, 2011
	Jelutung	Agus et al., 2013
	Belangiran	Agus et al., 2013
	Tengkawang	Agus et al., 2013
	Gelam	Agus et al., 2013
Economic Value (Market Price)	Sago palm	Bustaman, 2015
	Jelutung	Jambi Ministry of Forestry, 2016
	Belangiran	Indonesia Ministry of Forestry 2014
	Tengkawang	Cholidatul, 2016
	Gelam	Giesen, 2015
Cost-benefit analysis	Benefit	Field observation (Contact: BAPPEDA and BRG)
	Cost	Field observation (Contact: BAPPEDA) *
Green Economy	CO_2 price	Hamrick and Goldstein, 2016
Total peatland area	Pulang Pisau peatland restoration area	Field observation (Contact: BAPPEDA) *

*List of contact person in Annex 2

4. Results

This section presents the key findings of this research. This section elaborates the findings to address the research objective and all sub-questions by following the steps in Methodology (section 3). This section includes the quantification results (i.e. total peatland emissions, peatland sequestration, and flooding impacts, and historical emissions), ecological and economic benefits of paludicultures, also the Green GDP income.

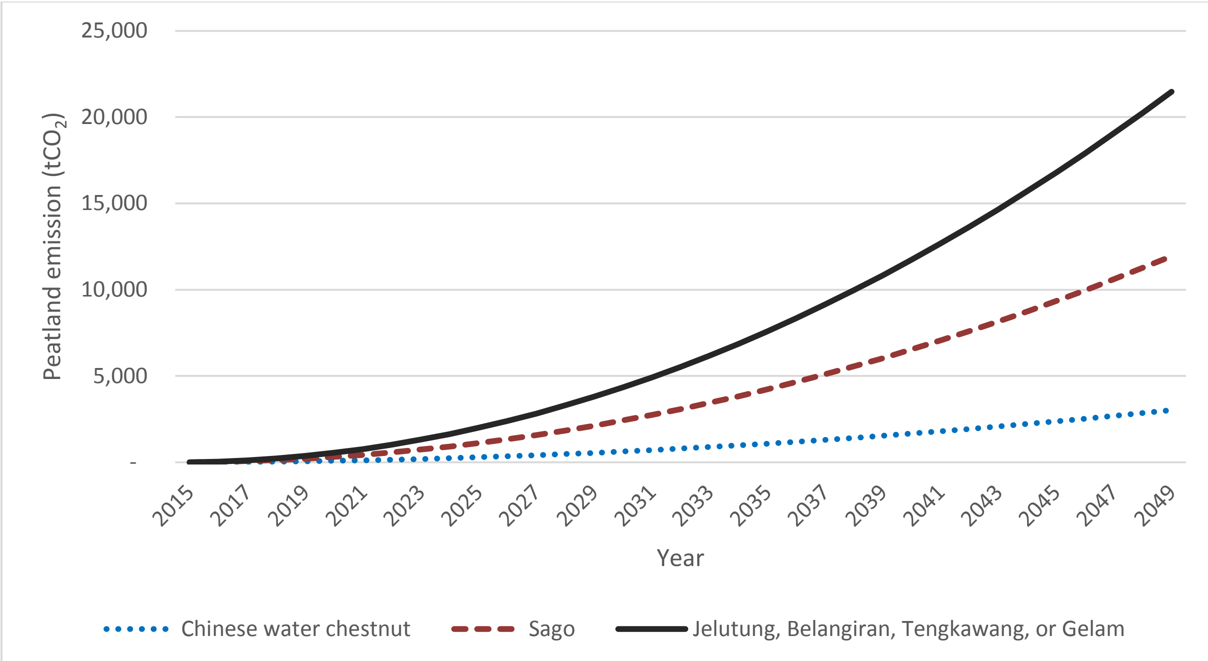
4.1. Quantification result of total peatland emissions

4.1.1. Monoculture

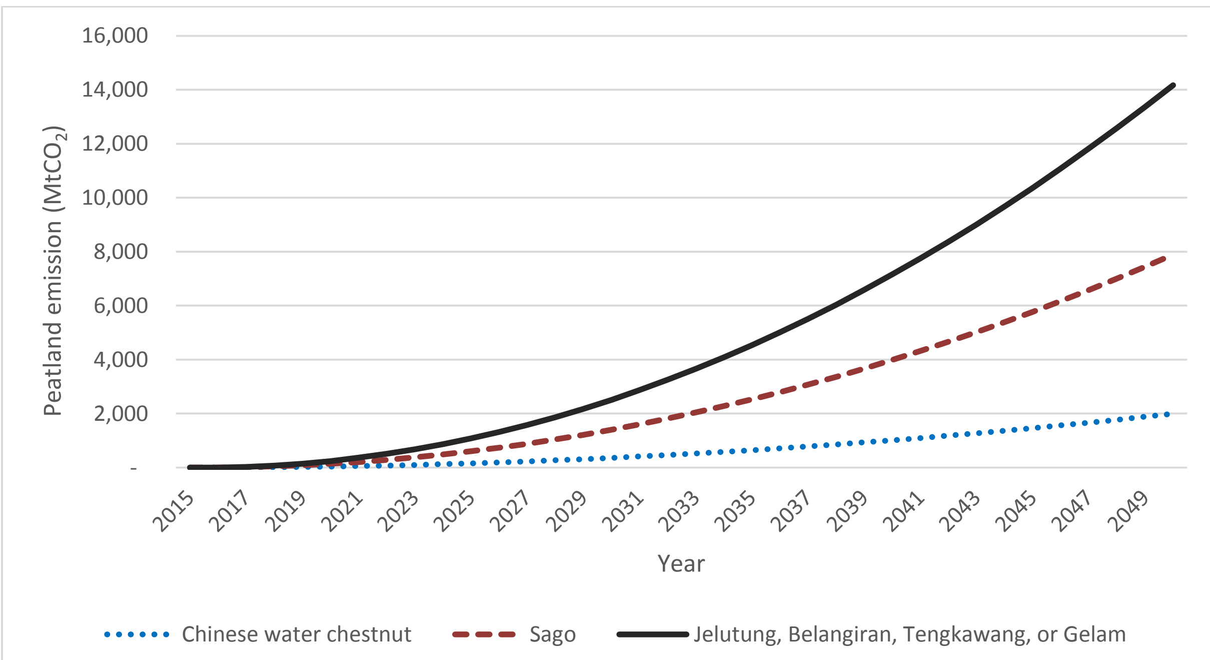
In monoculture, the paludiculture commodities reduce the chance of fire emission from peatland area. Therefore, the total peatland emissions were only generated from biological emissions. This monoculture system assumed that there is no fire emission in the peatland restoration area.

Total Peatland Emissions

Total peatland emissions were derived by summing up the peatland emissions from each commodity and fallow land area (see section 3.3.2). The quantification results are illustrated below in Figure 4.



(a)



(b)

Figure 4. Total peatland emission of monocultures for (a) per hectare and (b) total area

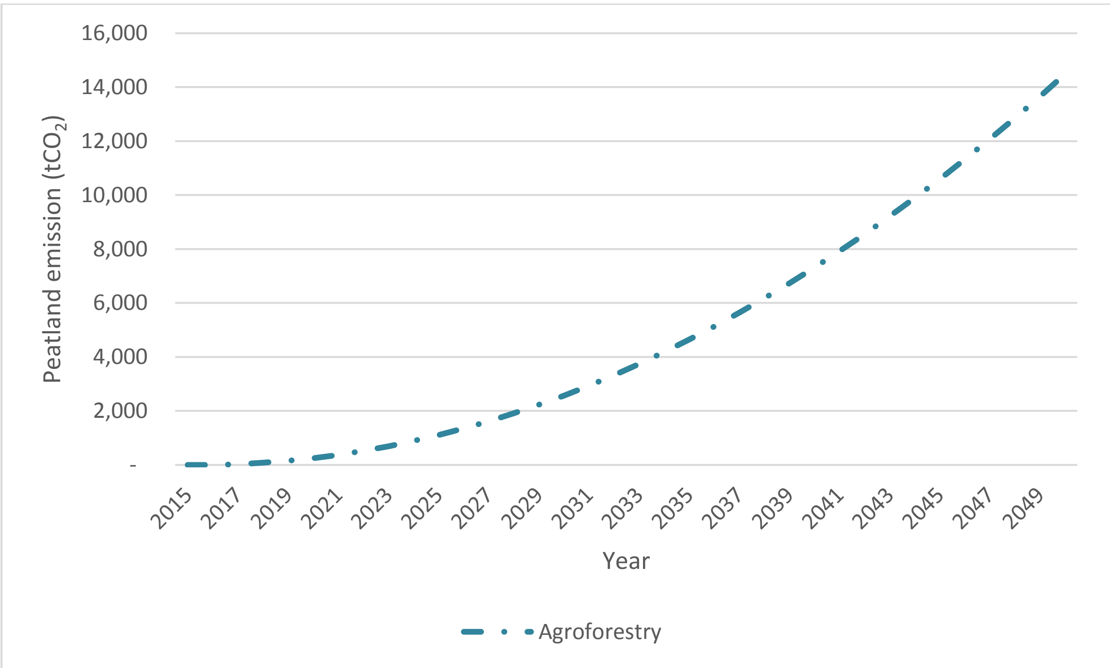
Belangiran, Jelutung, Tengkawang, or Gelam generated the highest total peatland emissions, followed by Sago and Chinese water chestnut consecutively (see Figure 4). Belangiran, Jelutung, Tengkawang, or Gelam generated 21,467 tCO_2/ha (or 14,000 $MtCO_2$ for total area), Sago generated 11,947 tCO2/ha (or 8,000 $MtCO_2$ for total area), and Chinese water chestnut generated 3,022 tCO_2/ha (or 2,000 $MtCO_2$ for total area). The monoculture system started in 2015 when the interventions were given. The interventions that were provided including the plantation of paludiculture commodities. The total peatland emissions from Belangiran, Jelutung, Tengkawang, and Gelam were quite similar because these commodities were categorized as hardwood species. The Vensim model of monoculture is presented in Annex 3.

4.1.2. Agroforestry

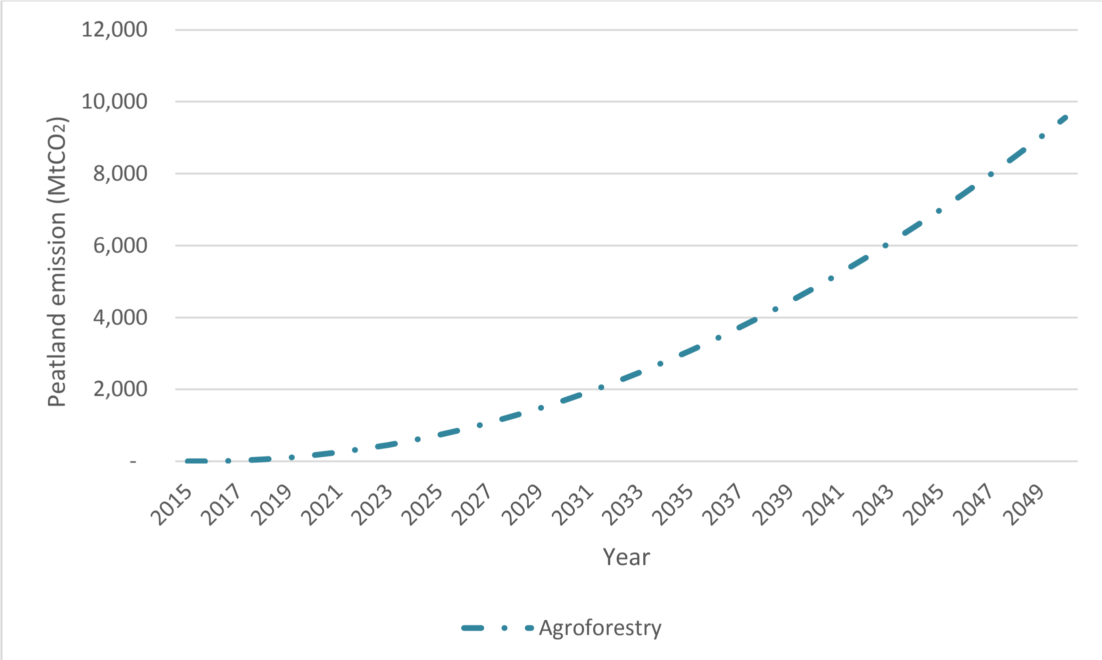
In this agroforestry paludiculture, it was also assumed there is no fire emission in the peatland. Therefore, the total peatland emissions were calculated by summing the biological emissions from all commodities. Due to the difference of economic value, the peatland area was divided differently for six commodities. Jelutung has the widest area in one hectare, followed by Gelam, Sago, Belangiran, Tengkawang, and Chinese water chestnut consecutively (see Section 3.3.2 part B).

<u>Total Peatland Emission</u>

Total peatland emissions were derived by summing up the total peatland emissions from six commodities (see section 3.3.2). The quantification results are given below in Figure 5.



(a)



(b)

Figure 5. Total peatland emission of agroforestry for (a) per hectare and (b) total area

Figure 5 illustrates that agroforestry paludiculture generated total peatland emissions around 14,474 tCO_2/ha or 9,500 MtCO2 for total area in 2050. This agroforestry system started in 2015 by planting all six commodities in total peatland area. The Vensim model of agroforestry is presented in Annex 4.

4.2. Quantification result of peatland sequestration and flooding impacts

A. Peatland Sequestration

Formation

Based on section 3.3.3, the formation rates were measured for only one monoculture commodity, namely Chinese water chestnut. In Figure 6 below shown that peat formation of Chinese water chestnut from 2015 until 2050. The peat formation could occur until 5.25 cm in 2050. This commodity helps to prevent peatland from degradation and to improve the thickness of peatland itself. In Figure 6, the peat formation increased linearly because the model only influenced by formation rate. The Vensim model of total peat formation is illustrated in Annex 5.

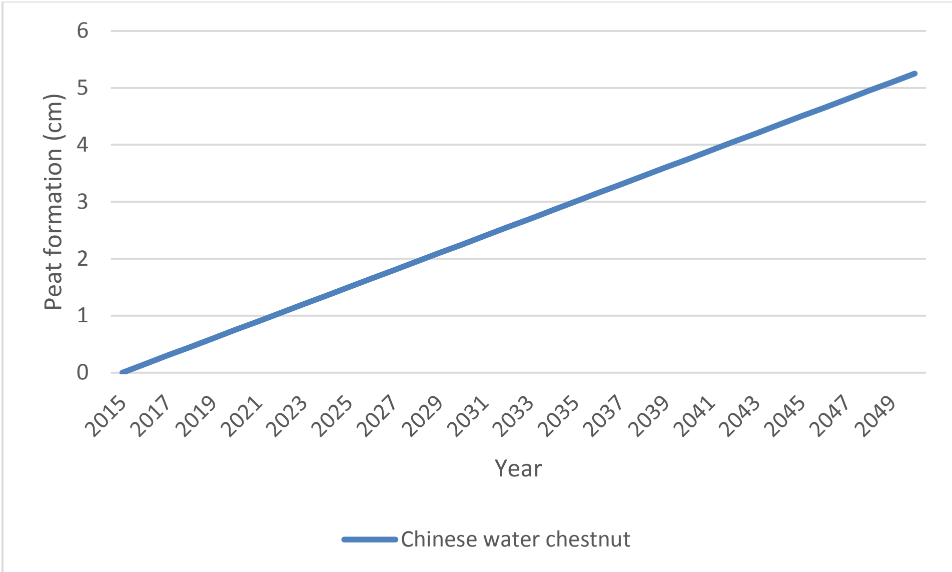


Figure 6. Peat formation of Chinese water chestnut

Subsidence

In this section, the total subsidence was measured from five different monoculture commodities (Sago, Jelutung, Belangiran, Tengkawang, and Gelam) and Agroforestry commodities. Figure 7 presents the total subsidence from these commodities. These commodities were calculated from 2015 until 2050 by using Equation 5 from Hooijer et al. (2012). As previously explained in section 3.3.3 part B, the equation of subsidence rate indicated that subsidence level was influenced by an independent variable, namely Water Table Depth (WTD). Agroforestry is a combination of six commodities, so this research assumed that Agroforestry also has the highest WTD as other commodities (Belangiran, Tengkawang, or Gelam). In Figure 7 below showed that Gelam, Tengkawang, Belangiran, Jelutung, and Agroforestry have the highest total subsidence around 10-meter depth, and followed by Sago palm with total subsidence around 6-meter depth. Based on these results, Sago palm is more environmental friendly than other commodities. In Figure 7, the curve of total subsidence increased linearly because the model only influenced by WTD. The Vensim model of total peat subsidence is illustrated in Annex 6.

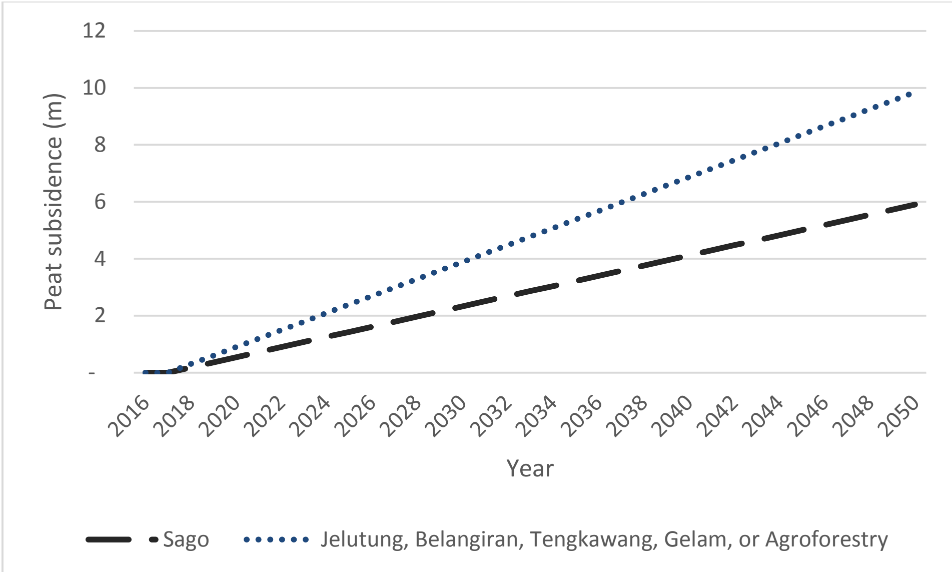


Figure 7. Total subsidence from monocultures and agroforestry

B. Flooding Impacts

The risk of flooded agricultural is affected by accumulated agricultural subsidence. By applying the accumulated agricultural subsidence to the Equation 6, the amount of flooded agricultural peatlands can be gained. The amount of flooded agricultural in 2015 is around 30%. Furthermore, by multiplying the amount of flooded agricultural peatlands with the accumulated agricultural subsidence and total peatland area, the flooded agricultural land can be gained. However, the accumulated agricultural subsidence is distinguished by the commodities (see section 4.2, part Subsidence). At the end of 2015, total peatland lost due to flooded risk is around 25.15% of total area for Jelutung, Gelam, Tengkawang, and Belangiran and 24.46% of total area for Sago (See Figure 8 below).

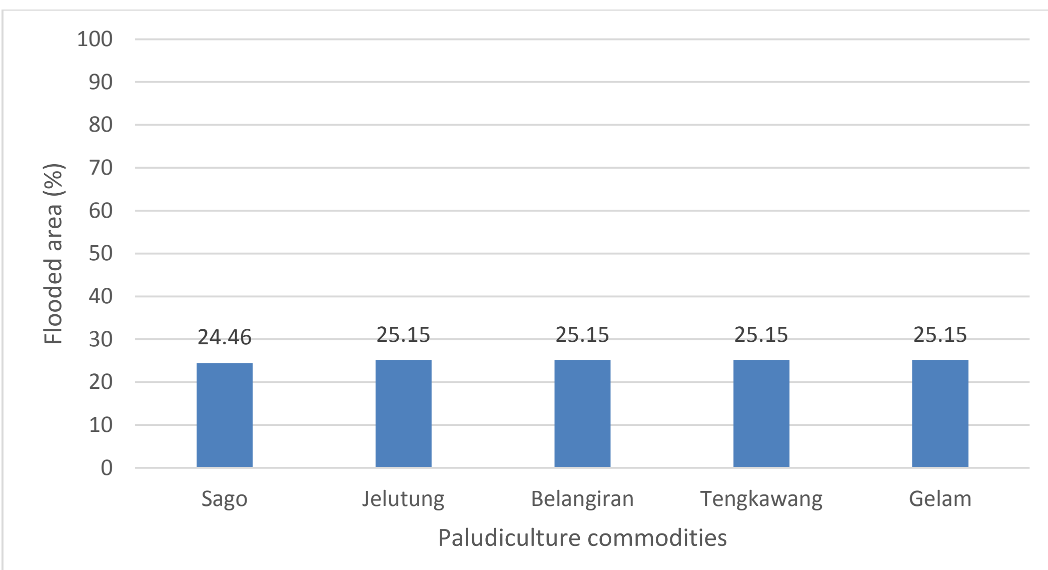


Figure 8. Flooded agricultural land from paludiculture commodities

4.3. Quantification result of historical emission

In this section, the historical emission from monoculture and agroforestry paludiculture were predicted from Ministry of Forestry database. The total biological CO_2 emissions were calculated until 2050 using Equation 8. Figure 9 illustrates that the biological CO_2 emission reduced until 2050. In the end of 2050, the biological CO_2 emission reduce to 22 $MtCO_{2-eq}$. The calculation of historical emission used the Business as Usual (BAU), it means that the current condition will be similar with the future condition.

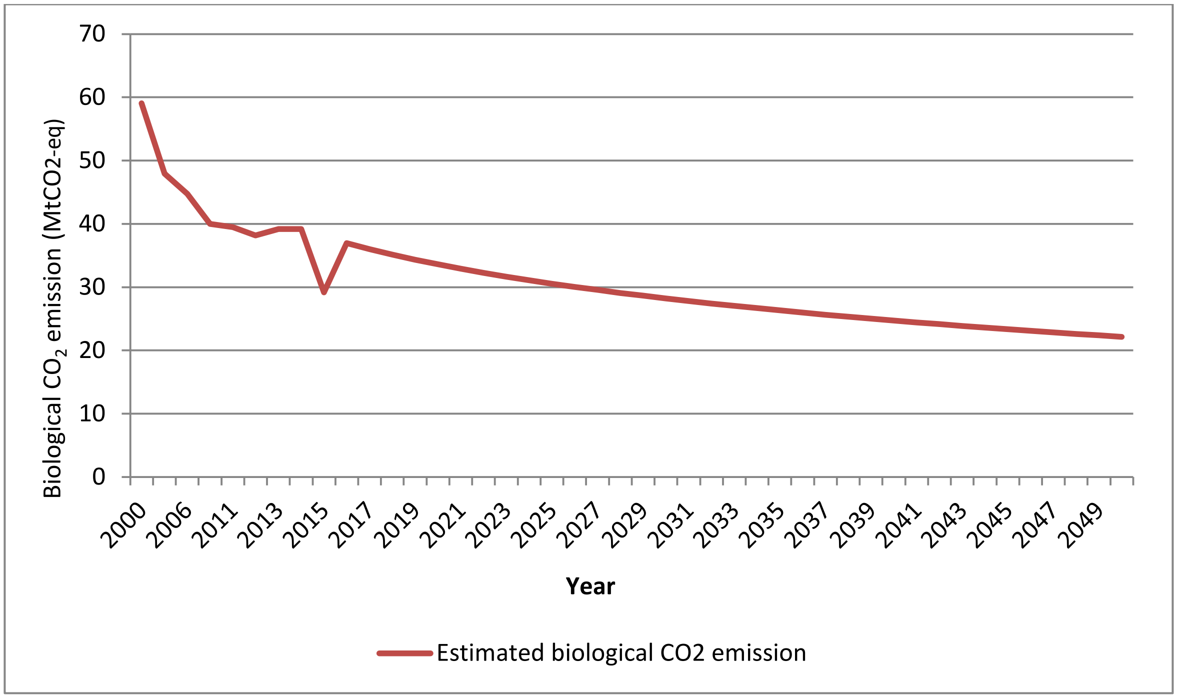


Figure 9. Estimation of biological CO_2 emission

4.4. Ecological Aspect

In this section, the estimation of biological CO_2 emission in 2050 (see section 4.3) is used to calculate the total biological CO_2 of monoculture and agroforestry paludiculture. By summing up the estimation biological CO_2 emission (see section 4.3) and the total peatland emissions from paludiculture (see section 4.1), the total biological CO_2 emissions from 2015 until 2050 can be gained. Figure 10 illustrates that Jelutung, Tengkawang, Belangiran, or Gelam had the highest total biological CO_2 emissions with 14,100 $MtCO_{2-eq}$, followed by Agroforestry with 9,500 $MtCO_{2-eq}$, Sago with 7,800 $MtCO_{2-eq}$, and Chinese water chestnut with 2,000 $MtCO_{2-eq}$ consecutively. Jelutung, Tengkawang, Belangiran, and Gelam had exactly the similar emission due to lack of data on these commodities. Thus these commodities were categorized as hardwood species and were assumed to have an equal emission. The emission of hardwood commodities is almost half of the agroforestry emission. Even though agroforestry also included these hardwood commodities, it still had emission from Sago and Chinese water chestnut. Sago emission is almost as high as Agroforestry emission, even the gap between these emissions were approximately 2 $MtCO_{2-eq}$. Chinese water chestnut has the lowest emissions as compared to other commodities. The gap between hardwood species and Chinese water chestnut were almost 12 $MtCO_{2-eq}$. Although it is compared with Sago emission, the gap between these commodities are still 6,000 $MtCO_{2-eq}$. In Figure 10, the number of biological CO_2 emission of all commodities are increasing from time to time. The increasing emission showed that the paludiculture plantation and its growth also release the CO_2 emission. This CO_2 emission came mainly from the respiration of commodities. Based on the ecological aspect, the lowest total biological CO_2 emission has the most promised commodity to be conducted. Therefore, Chinese water chestnut has the highest chance to be chosen because this commodity had the lowest emission.

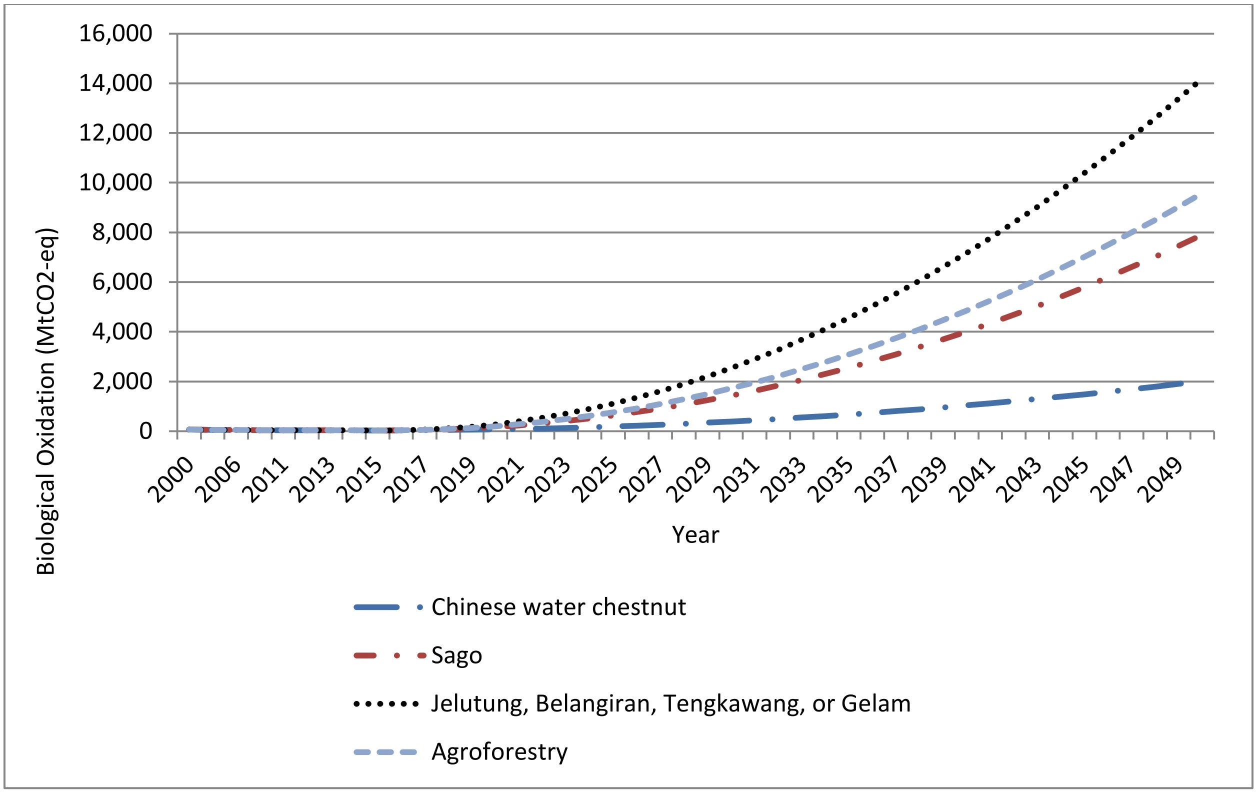


Figure 10. Total Biological CO_2 emission of Monoculture and Agroforestry

4.5. Economic Aspect

4.5.1. Cost-Benefit Analysis

<u>Cost</u>

In this section, the costs are mainly from the rehabilitation of the peatland and seedling of the paludiculture. In the rehabilitation cost, there are four main activities (i.e. Canal Blocking, peat rehabilitation intensive planting, enrichment planting, and monitoring. Table 6 shows that canal blocking was done only once (in the year 0); peatland rehabilitation intensive planting and enrichment planting were done in the year 0, 1, and 2; also monitoring activity was conducted every year.

In the seedling cost, the costs were distinguished by each commodity. According to Ministry of Forestry (2014), the cost for seedling one commodity is similar with other commodities, except Belangiran. Belangiran is an endemic vegetation in Kalimantan peatland and it can be found in many peatland areas. Thus the seedling cost is lower than other commodities. The average seedling cost is around 279.13 euro/ha, but the seedling cost for Belangiran is only 139.57/ha.

Table 5. Rehabilitation and seedling cost of paludiculture commodities

Item	**Cost (euro/ha)**
Rehabilitation cost	
Canal blocking (see Annex 7)	5.86
Peat rehabilitation intensive planting in year 0	627.07
Peat rehabilitation intensive planting in year 1	196.70
Peat rehabilitation intensive planting in year 2	83.38
Enrichment planting in year 0	303.55
Enrichment planting in year 1	111.90
Enrichment planting in year 2	61.86

Monitoring	12.56
Seedling cost	
Sago	279.13
Jelutung	279.13
Belangiran	139.57
Tengkawang	279.13
Gelam	279.13

Source: Nugroho, 2014

Benefit

In this section, the benefits were calculated based on monoculture and agroforestry system in section 3.3.1. Table 7 illustrates the benefits from each commodity. In this research, the benefits were mainly per harvest year. In the section 3.3.2, it is already explained that every commodity has their harvest cycle.

Table 6. Benefits from all commodities

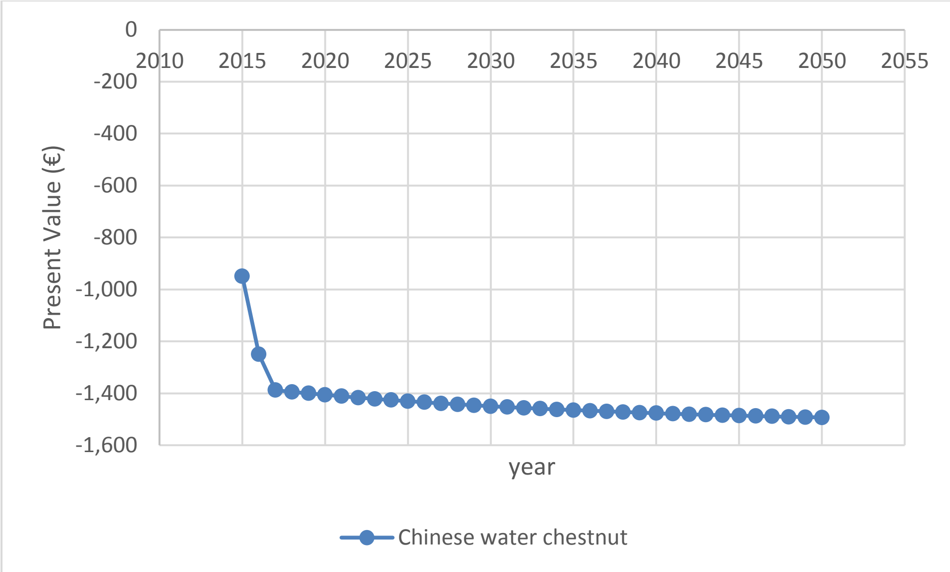
Item	Benefit (euro/ha/year)
Sago -Bioethanol	2,818
Jelutung -Latex	670
Belangiran -Wood	4,460
Tengkawang -Seed	52
Gelam -Oil	281

4.5.2. Net Present Value

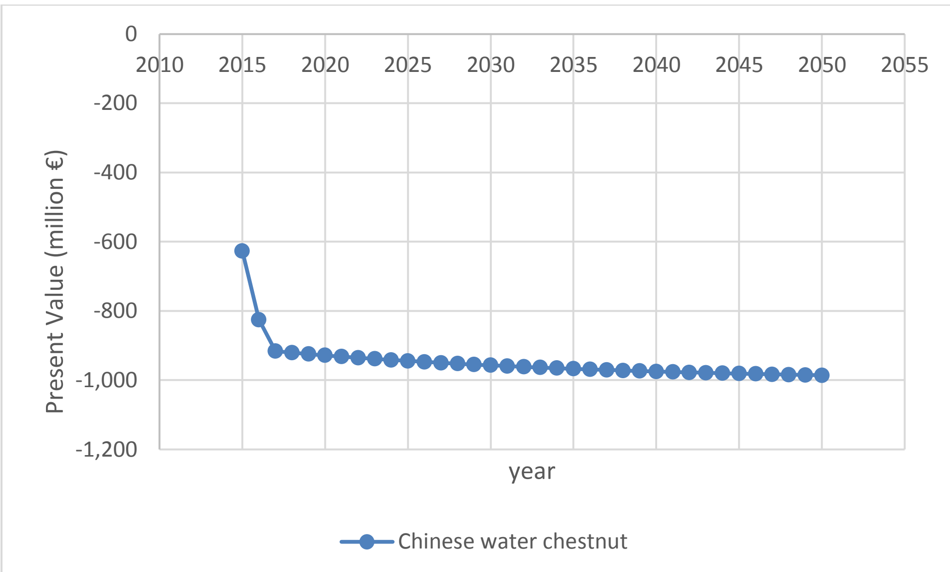
Net Present Value (NPV) involves the discounting of the future flow of values which is the total of the Present values over time (d'Arge, 1997). Equation 10 was conducted to calculate the NPV with a timescale of 35 years and a discount rate of 5 %. This research comparing the NPV from monoculture and agroforestry. The NPV was gained by accumulating the PV of commodities in monoculture and agroforestry system. Furthermore, The PV was gained by calculating the difference between benefits and costs. The result of NPV from monoculture and agroforestry is described more detail below.

Monoculture

The Present Value (PV) of all commodities decrease with time and the PV from each commodity in every year is different from others because the benefit from each commodity has different harvest year (see Figure 11-16 below). From the summary of NPV from six commodities, Jelutung generated the highest number of NPV, followed by Gelam, Sago, Belangiran, Chinese water chestnut, and Tengkawang consecutively. The NPV from all monoculture commodities explained more detail below.



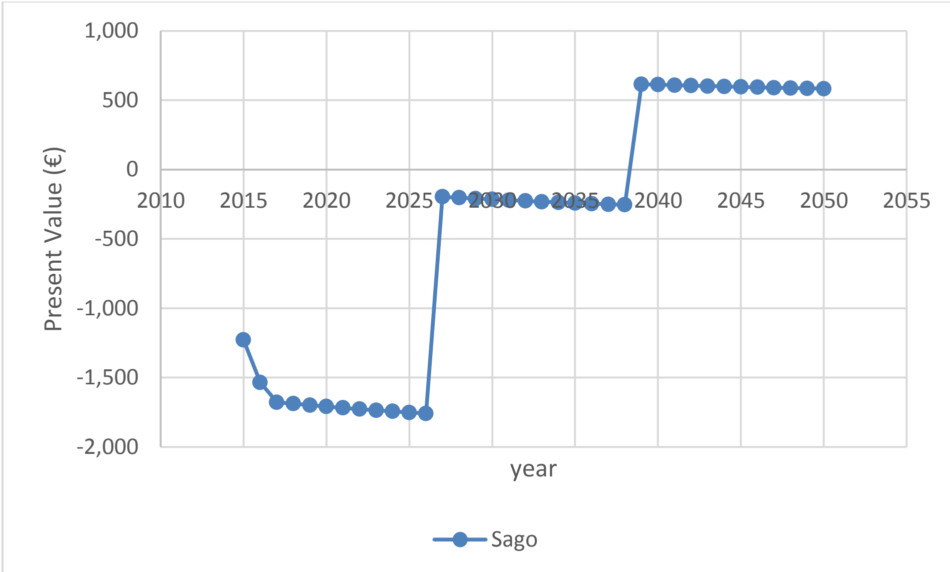
(a)



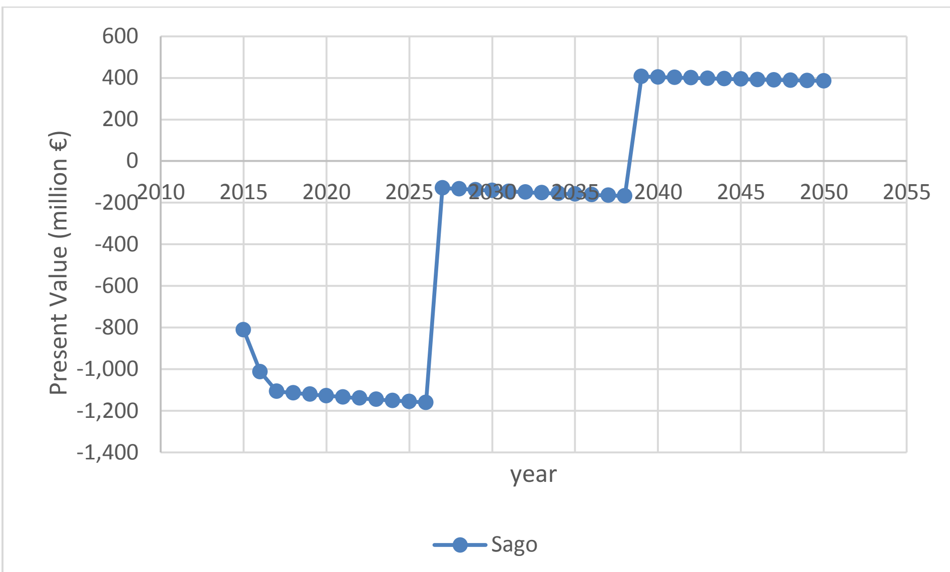
(b)

Figure 11. NPV of Chinese Water Chestnut for (a) per hectare and (b) total area

In Figure 11, the curve declined from 2015 to 2050 for 35 years. Even though the Chinese water chestnut gained the benefit every year, the benefit could not cover the rehabilitation cost in the early year. The NPV of Chinese water chestnut in 2050 is almost -1,500 euro per hectare (Figure 11a) or -985 million euro for total peatland area (Figure 11b). In economic aspect, this commodity has small chance to be chosen as the promising commodity, because it won't gain any benefit until the end of 2050.



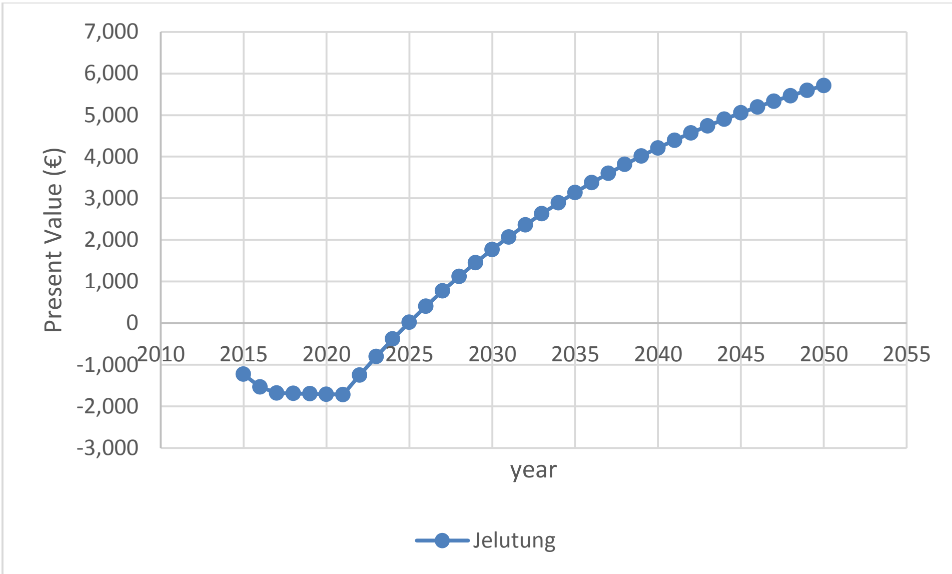
(a)



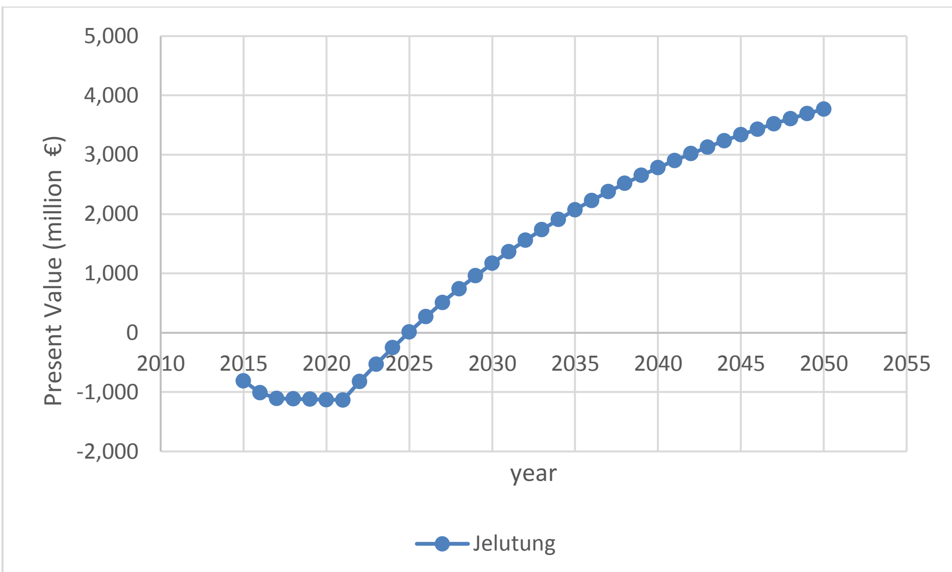
(b)

Figure 12. NPV of Sago for (a) per hectare and (b) total area

In Figure 12, the curve significantly declined in the first 3 years and then it steadily decreased until 2025. In 2027, Sago produced bioethanol with benefit 2,817 euro/ha (or 1,860 million euro for total peatland area) in one harvest season. Then, there was only monitoring cost in 2028 to 2038 so the curve declined again. In 2039, the Sago can be harvested again, thus the curve went up. After that, the curve slightly decreased due to monitoring cost until 2050. As overall, Sago could gain the profit in the end of 2050. This commodity is one of the recommended option for peatland land use. Sago profit is roughly 583 euro per hectare (Figure 12a) or approximately 385 million euro in 2050 for total peatland (Figure 12b).



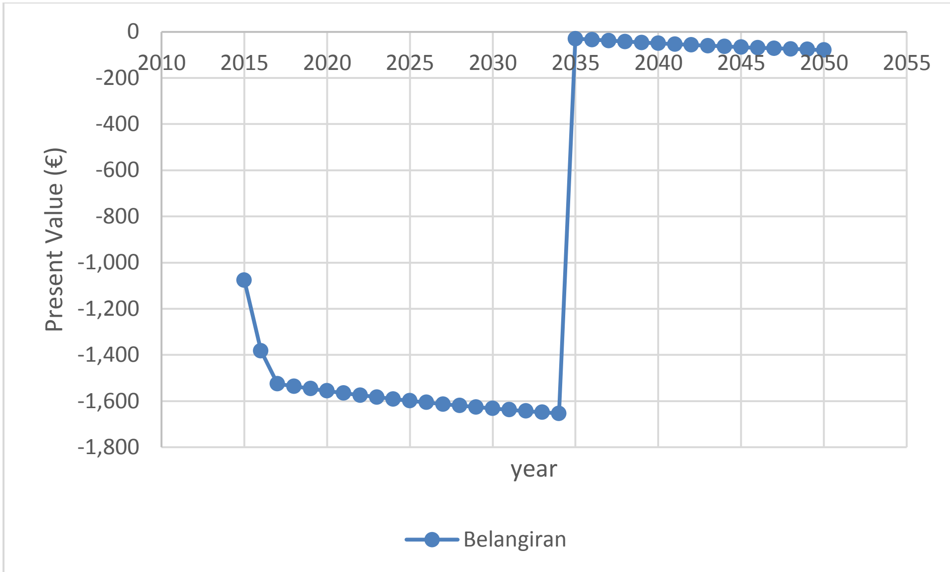
(a)



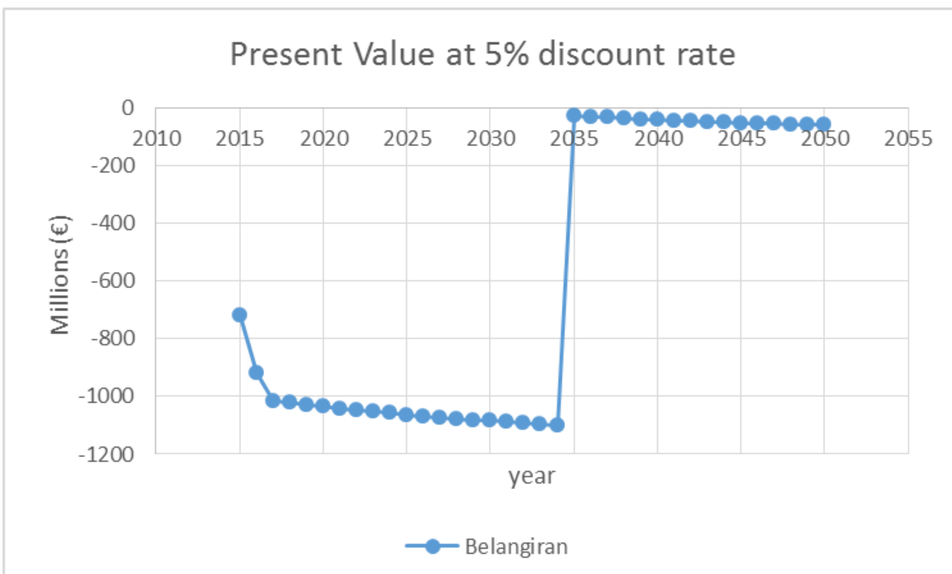
(b)

Figure 13. NPV of Jelutung for (a) per hectare and (b) total area

In Figure 13, the curve of Jelutung inclined up as overall. In 2025, Jelutung already gained profit from the latex production. In the end of 2050, the profit from latex production is around 5,710 euro/ha (Figure13a) or 3,800 million euro for total peatland area (Figure 13b). Jelutung is quite promising commodity because the latex production can be harvested every year. This commodity could be a recommended option for peatland land use. In economic aspect, Jelutung gained higher profit than other commodities.



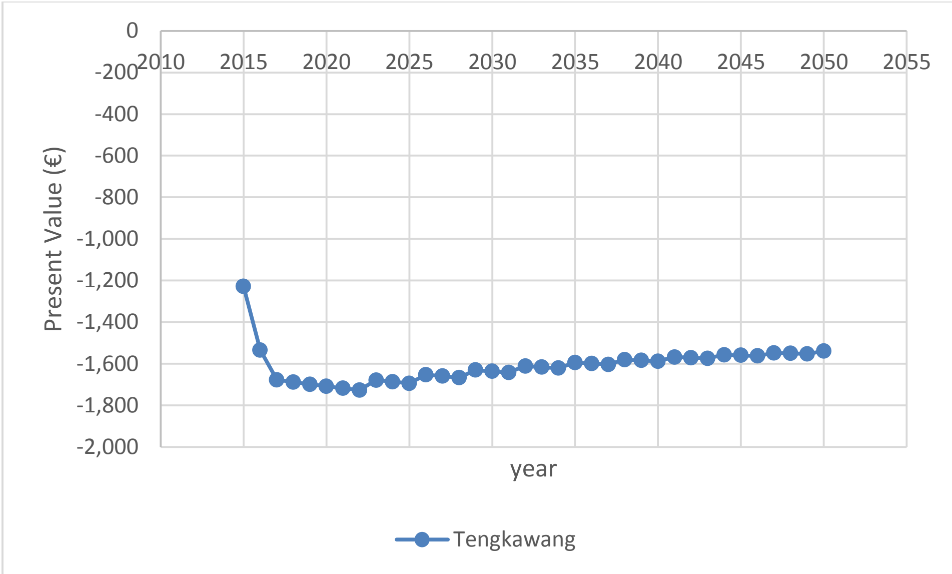
(a)



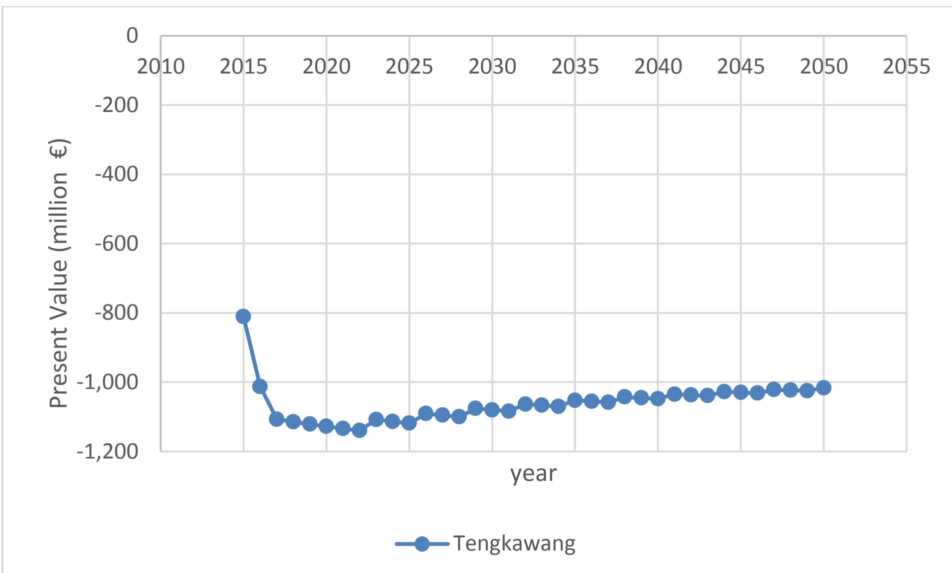
(b)

Figure 14. NPV of Belangiran for (a) per hectare and (b) total area

In Figure 14, Belangiran almost gained benefit in 2050. Even though the benefit from wood production is really high in one harvest year, it still could not cover all rehabilitation cost and seedling cost. In the end of 2050, this commodity still lost 79 euro/ha (Figure 14a) or around 60 million euro for total area (Figure 14b). In this research, this commodity had slight chance to be a recommended option for peatland land-use. However, Belangiran had potential to gain profit in the next harvest season.



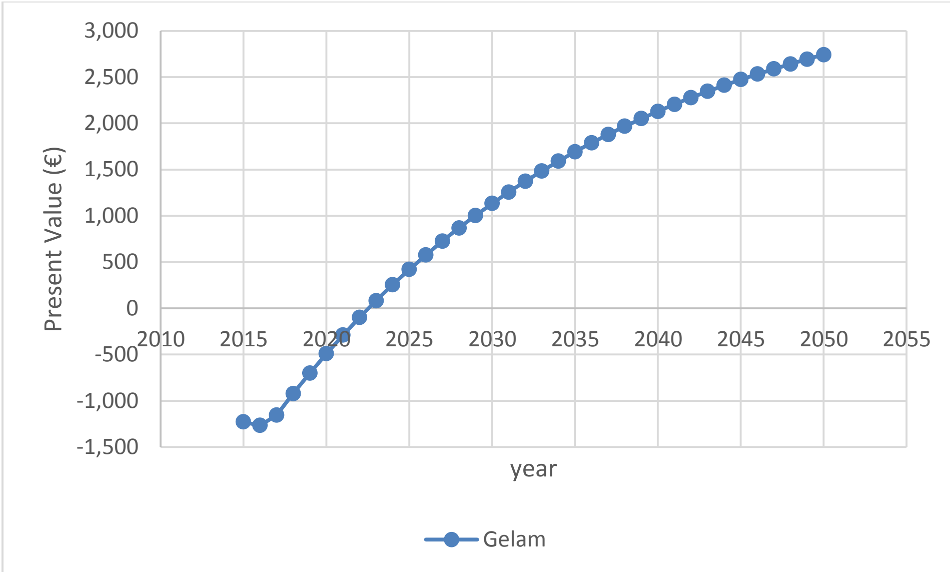
(a)



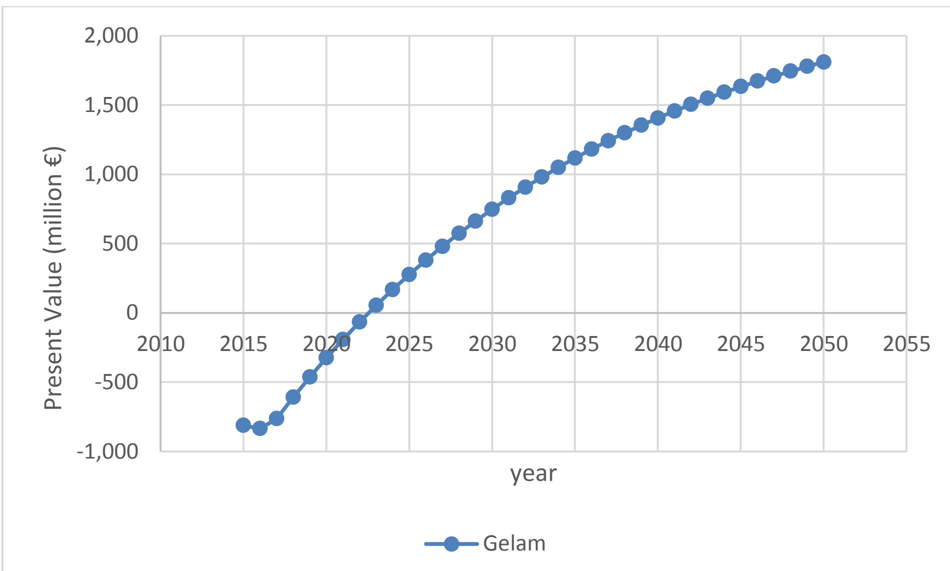
(b)

Figure 15. NPV of Tengkawang for (a) per hectare and (b) total area

In Figure 15, Tengkawang would not gain any profit in 2050. The price of Tengkawang seed was really low on the market in 2015. Thus it made this commodity only gain low profit. In the end of 2050, Tengkawang still lost 1,540 euro/ha (Figure 15a) or 1,000 million euro/total area (Figure 15b). This commodity had a little chance to be a recommended option for peatland land-use.



(a)



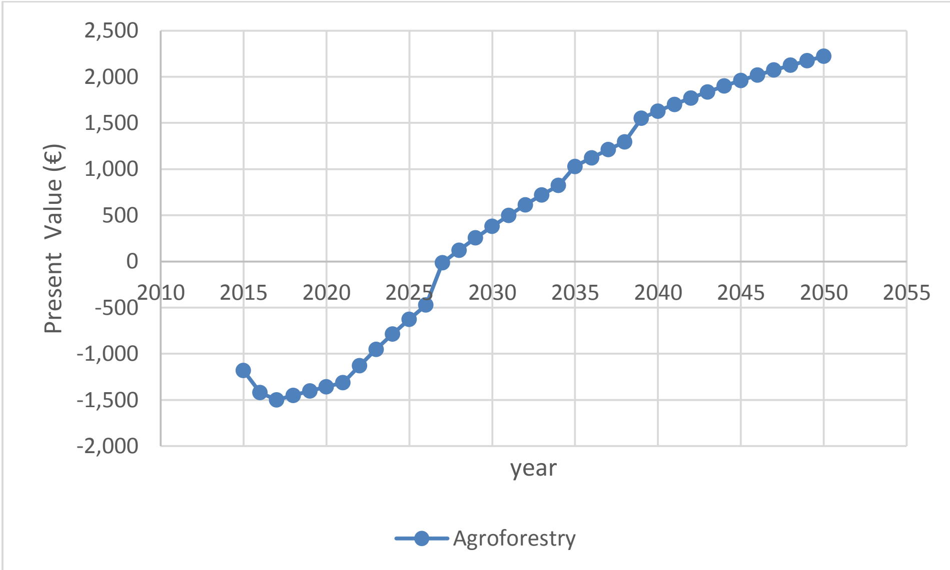
(b)

Figure 16. NPV of Gelam for (a) per hectare and (b) total area

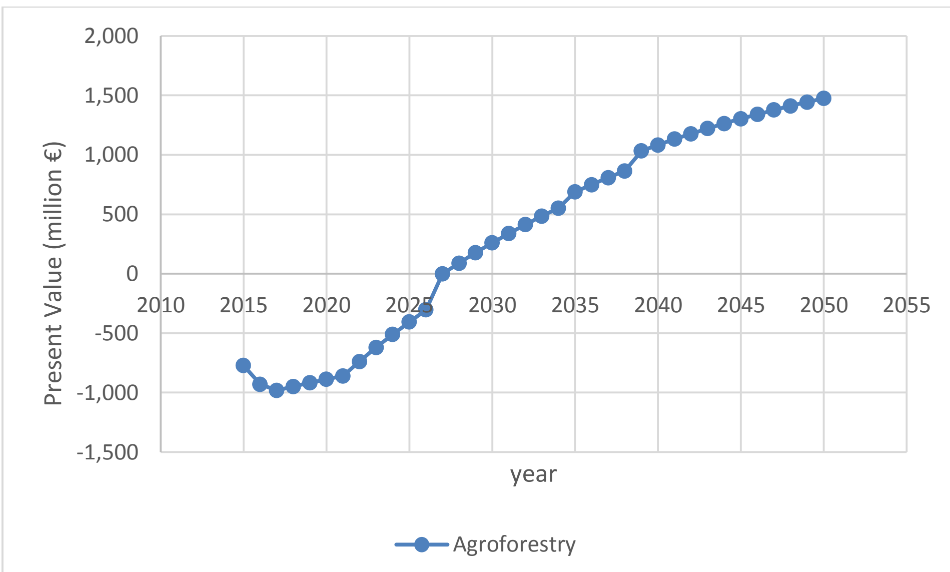
Gelam is also one of the recommended options for peatland land use. In Figure 16, Gelam already could gain profit since 2023. The price of oil production in the market was also good; the profit could cover all rehabilitation costs and seedling cost. In 2050, Gelam gained profit around 2,742 euro/ha (Figure 16a) or 1,800 million euro/total area (Figure 16b).

Agroforestry

In Agroforestry, the commodities were planted with mixed combination of six commodities in total peatland area. This research assumed that the plantation had a well-managed agroforestry system. The distribution of each commodity area is presented in section 3.3.2. The distribution area for all commodities were 0.3 ha per ha for the highest value commodity, followed by 0.25 ha per ha, 0.2 ha per ha, 0.07 ha per ha, 0.05 ha per ha, and lowest one with 0.03 per ha consecutively. Due to this distribution area, Jelutung had the largest area, followed by Gelam, Sago, Belangiran, Chinese water chestnut, and Tengkawang consecutively. The result of agroforestry system is presented in Figure 16 below.



(a)



(b)

Figure 17. NPV of Agroforestry for (a) per hectare and (b) total area

Based on Figure 17, agroforestry already gained profit in 2027. Then, the profit raised consecutively until 2050. In the end of 2050, agroforestry gained 2,222 euro/ha (Figure 17a) or 1,500 million euro for total peatland area (Figure 17b).

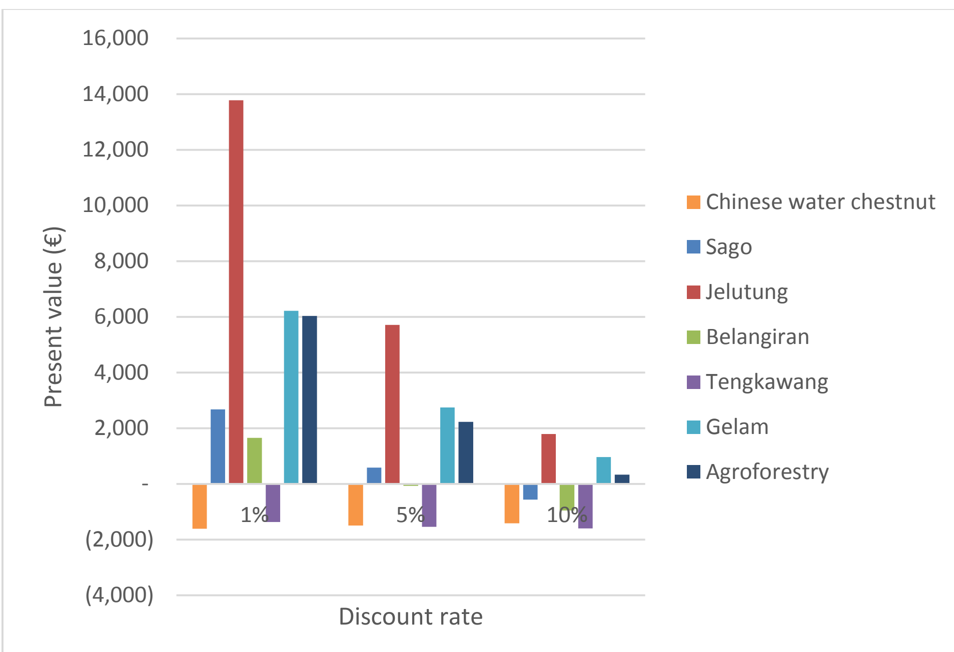
4.5.3. Sensitivity Analysis

The NPV was recalculated with changes to various key parameters for sensitivity analysis. Sensitivity analysis helps to determine on which parameters the NPV outcomes depend on the most (Hanley and Spash, 1993). This research uses only discount rate (R) as its parameter. Discount rates are modelled with 1%, 5%, and 10% as shown in Table 7. The NPV per hectare of all commodities was calculated for 35 years.

Table 7. Comparison of all monoculture and agroforestry commodities in sensitivity analysis

Commodities	NPV per hectare		
	1% (€)	5% (€)	10% (€)
Chinese water chestnut	-1,610	-1,493	-1,419
Sago	2,674	583	-566
Jelutung	13,773	5,710	1,793
Belangiran	1,648	-79	-956
Tengkawang	-1,367	-1,540	-1,602
Gelam	6,218	2,742	960
Agroforestry	6,028	2,222	325

Table 7 presents that four commodities of monoculture (Sago, Jelutung, Belangiran, and Gelam) and agroforestry still gained profits, but others (Chinese water chestnut and Tengkawang) declined when discount rate was 1%. When the discount rate was about 5%, there were Sago, Jelutung, Gelam, and Agroforestry that still remained profitable, and other commodities (Chinese water chestnut, Belangiran, Tengkawang) decreased. When the discount rate was about 10%, there were only Jelutung, Gelam, and Agroforestry still gained profit and other commodities (Chinese water chestnut, Sago, Belangiran, and Tengkawang) declined. Therefore, Jelutung, Gelam, and Agroforestry were the most recommended options for peatland land use (see Figure 18a and Figure18b).



(a)

Figure 18. Sensitivity Analysis Comparison of NPV per hectare

4.5.4. Internal Rate of Return (IRR)

By conducting Equation 11 to every commodity, the IRR from each commodity was generated. Table 8 displays the IRR from six commodities of monoculture and agroforestry. This research assumed the first discount rate (R1) with 1% and the second discount rate (R2) with 5% (see section 3.3.6, part D).

Table 8. IRR of all land use management commodities

Commodity	IRR (%)
Chinese water chestnut	56
Sago	6
Jelutung	8
Belangiran	4
Tengkawang	-31
Gelam	8
Agroforestry	7

The higher of a project's IRR, the more desirable it is to undertake the project. Moreover, the IRR of a project should be higher than discount rate to be valid (Patrick et al., 2016). Based on Table 8, the Chinese water chestnut had the highest IRR, followed by Jelutung, Gelam, Agroforestry, Sago, and Tengkawang consecutively. Chinese water chestnut had the highest IRR with 56% and Tengkawang has the lowest IRR with -31%. In Table 8, all commodities were favourable to be undertaken as a project, except Tengkawang. According to Clancy et al. (2009), negative IRR means the project should not be taken because the inflows would not cover the outflows.

4.5.5. Economic comparison between Monoculture and Agroforestry

This research also compared the economic benefits of monoculture and agroforestry. This comparison was between six commodities of monoculture and one agroforestry system based on sensitivity analysis and IRR results. Based on sensitivity analysis (see section 4.5.3), Jelutung monoculture, Gelam monoculture, and Agroforestry were the most recommended options for peatland land use. Thus Jelutung had biggest chance to be chosen for peatland land use from sensitivity analysis. On the other hand, Chinese water chestnut, Jelutung, Gelam, Agroforestry, Sago were the most recommended options for peatland use based on IRR result. By comparing both results from sensitivity analysis and IRR, Jelutung or Chinese water chestnut should become the most recommended option. However, Chinese water chestnut could not gain any profit based on sensitivity analysis. Therefore, Jelutung is the most recommended option for paludiculture in Pulang Pisau peatland based on economic aspect.

4.6. Comparison between ecological and economic aspects

This research compared the ecological and economic benefits of monoculture and agroforestry. The most promising peatland management system is obtained based on the result of Ecological aspect (section 4.4) and Economic aspect (section 4.5). Table 9 presents the comparison between ecological and economic benefits of monoculture and agroforestry.

Table 9. Summary of the ecological and economic aspects

Commodity	Ecological aspect	Economic aspect			
	Biological CO_2 emissions	IRR (%)	Sensitivity analysis		
			1%	5%	10%

	($MtCO_{2-eq}$)		(€/ha)	(€/ha)	(€/ha)
Chinese water chestnut	2,000	56	-1,610	-1,493	-1,419
Sago	7,800	6	2,674	583	-566
Jelutung	14,100	8	13,773	5,710	1,793
Belangiran	14,100	4	1,648	-79	-956
Tengkawang	14,100	-31	-1,367	-1,540	-1,602
Gelam	14,100	8	6,218	2,742	960
Agroforestry	9,500	7	6,028	2,222	325

Based on Table 9, the summary of the ecological and economic aspects provided the data to assess the most promising peatland management system. Table 9 presents the result overview of this research.

4.7. Quantification result of Green GDP

In this section, Green GDP calculation requires net natural capital consumption, including economic benefit and total carbon emission from commodities. According to Sukardi et al. (2015), the real GDP for mixed Agricultural, Forestry, and Fishing sector in Pulang Pisau Regency is 1,475 million euro in 2014. The quantification of Green GDP only calculated the most recommended option for peatland based on economic and ecological aspect. Therefore, Jelutung and Chinese water chestnut were chosen for monoculture to compare with agroforestry. The comparison between these commodities can be seen in Figure 19 below.

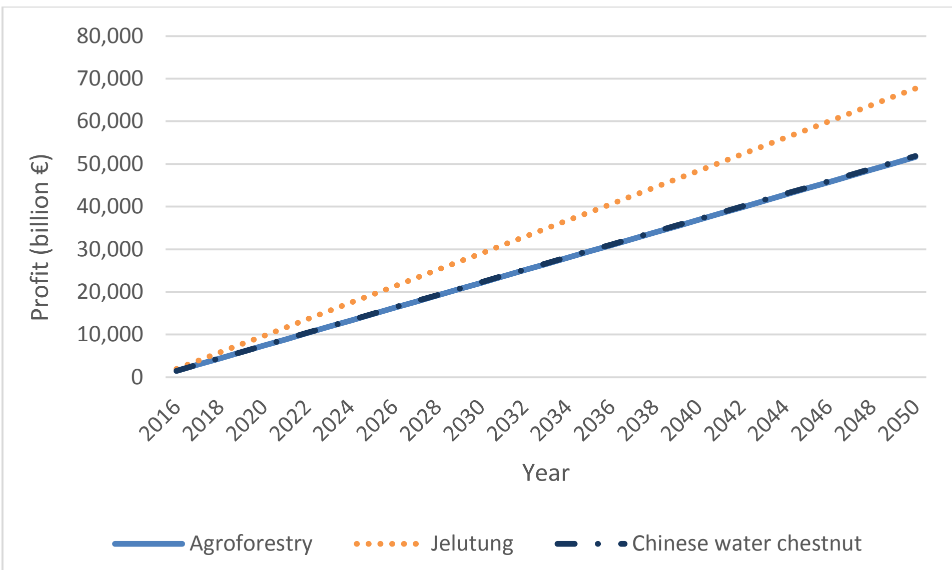


Figure 19. Green GDP calculation

In Figure 19, Green GDP calculation of Agroforestry, Jelutung monoculture, and Chinese water chestnut monoculture are illustrated. The result showed that Jelutung has the most income for Green GDP, followed by Chinese water chestnut and Agroforestry consecutively. In the end of 2050, Jelutung under the given assumptions will generate 67.7 billion euro, Chinese water chestnut will generate 51.8 billion euro, and Agroforestry will generate 51.6 billion euro. Jelutung was not environmental friendly due to total biological CO_2 emissions (see section 4.4), but this commodity has a high value for the farmers. Thus Jelutung could be the best option to be chosen for Green GDP.

Based on the Green GDP result, Jelutung was the most favourable option for peatland land use in Pulang Pisau Regency on Green Economy. Chinese water chestnut and Agroforestry could be the alternative options for peatland, but with lower income for Green GDP.

5. Discussion

This discussion section elaborates agroforestry paludiculture as the most sustainable peatland management in Pulang Pisau Regency. This section discusses the impact of assumptions and uncertainties to the results, the comparison between paludiculture and other land use (i.e. fallow land and palm oil), the comparison between monoculture and agroforestry of paludiculture, and the stakeholder perspectives on paludiculture.

5.1. Assumptions and uncertainties

This research involved some assumptions, which also led to particular levels of uncertainties. This research had some assumptions and uncertainties on quantification of ecological and economic aspect. First, this research assumed that paludiculture commodities have stable price and demand on the market. Thus, each commodity had stable income and benefits. This assumption is reliable because local and state government will collaborate to make a convenient and stable market for these paludiculture products. Second, there is no peat fire in Pulang Pisau Regency. The fire emission in this area remains zero until 2050 because paludiculture helps to prevent peat fires in this area. Third, the costs in CBA are only calculated from the major costs, such as rehabilitation, enrichment plantation, monitoring, and seedling cost. The major costs should be enough to represent the plantation cost of paludiculture commodities and these costs also are recommended by BAPPEDA. Fourth, there is no specific emission factor of paludiculture commodities; thus this research estimated the emission factor based on vegetation species. However, this uncertainty can be accepted because the commodities, that are classified into one vegetation species, still share similar characteristics. Last, this research assumed there is no clear-cutting in paludiculture commodities for more sustainable land use, except Belangiran. The other commodities, such as Chinese water chestnut, Sago, Jelutung, Tengkawang, Gelam, provide the benefits from Non-Timber Forest Product (NTFP). Belangiran was exception because it does not have any benefit from NTFP. Overall, the result of this research is reliable although there are some assumptions and uncertainties.

5.2. Why Paludiculture is more suitable than conventional agriculture, fallow land and palm oil for peatland management

This section discusses the advantage of paludiculture compared to fallow land and palm oil for peatland management. Paludiculture has already been introduced for ten years in Indonesia; thus this concept is relatively new in peatland agriculture. However, there is a great difference between paludiculture and conventional peatland agriculture. A conventional peatland agriculture uses a drainage system, that increases peat oxidation. The peat oxidation can potentially cause GHG emissions and destroy the existing peatland formation. In one side, paludiculture is designed for rewetting the peatlands and for maintaining the peat body. It also accumulates and provides natural peatland ecosystem services such as water, air filtration, non-timber forest product (Joosten, 2014).

Compared to fallow land, paludiculture can improve rural livelihood by providing sustainable income from abandoned area or other degraded peatlands. Paludiculture can also provide income from carbon credits and biomass production; thus paludiculture is one of the best recommended options for cost-effective climate change mitigation (Joosten, 2014).

Paludiculture can also be compared with palm oil plantation for economic benefit. One example of paludiculture is Jelutung. Jelutung does not gain benefit comparable to palm oil plantation, but its production is far more sustainable than palm oil. According to Sumarga (2016), palm oil plantations have a high profit in short term (±25 years), but its production in peatlands cannot be maintained in the medium (±50 years) and the long term (±100 years). Moreover, the incidence of flooding also affected the palm oil production in peatland area. Due to floods, palm oil production could only gain the benefit from 12% of total peatland.

5.3. Why agroforestry paludiculture is more recommended than monoculture paludiculture

This section discussion the comparison between monoculture and agroforestry paludiculture. Paludiculture plantation in peatland can be managed on 2 ways: monoculture and agroforestry system. These systems have their respective advantages and disadvantages. Monoculture of paludiculture commodity can be characterized as the cultivation of single commodity in whole peatland area. The main economic benefits of monoculture are the greatest quantity of timber production in shortest time and the cheapest way to gain the profit. Moreover, monoculture paludiculture also provides the greenhouse gases advantages over other food-based crops (Fargione, 2008). This monoculture usually cultivates the peatland with higher revenue crop (Hennessy, 2006). According to Birman and Fred (2009), the management system and the labour in monoculture are easier to understand than agroforestry. Furthermore, monoculture can create a suitable condition for native fauna, although the biodiversity is modest (Lamb, 2005). However, paludiculture with monoculture has some weaknesses in ecological aspect. According to Searle (2016), monoculture can induce species uniformity of nearly zero. Monoculture also leads to land subsidence, drainage, and water shortages. Drainage can reduce the capability of the entire hydrological system in terms of regulatory capacity (Evers, 2016).

On the other side, agroforestry can be considered as a better system than monoculture. Agroforestry has a good balance between economic and ecologic benefits. For economic benefits, paludiculture with agroforestry system can potentially accumulate more biomass and carbon than monoculture. The amount of carbon stored can be sold in carbon credit markets for profit (Schroth, 2002). Agroforestry also has some advantages in ecological aspect. Agroforestry provides habitat for many kind of species. It maintains the germplasm of sensitive species. Moreover, agroforestry reduces the traditional slash-and-burn by providing more productive sustainable alternative commodities; thus the rate of land conversion of natural habitat can be reduced. Agroforestry provides many ecosystem services such as erosion control, water filtration, and soil improvement. Paludiculture with agroforestry system can be a recommended land use option due to the integration of its economic and ecological aspects. Agroforestry provides a composition of trees and crops that are able to enrich the soil. By conducting an appropriate tree and crop management, the soil nutrient content can be richer than monoculture. Thus it can increase the production of trees and crops in the peatland area (Victoria et al., 2012). Even though agroforestry is a recommended land use option, it still has some weaknesses such as the limited farmer knowledge about agroforestry and insufficient extension services or government agencies to introduce agroforestry system to farmers. However, these weaknesses will be overcome in the next few years (Stainback, 2012).

5.4. Stakeholder perspectives on paludiculture for peatland management

This section discusses the acceptance of important stakeholders on paludiculture implementation in peatland. Since the paludiculture will be planted in this area, it is important to analyse the interest and influence of stakeholders. Thus, this paludiculture plantation can be accepted as the best possible recommendation for sustainable peatland management. In Pulang Pisau regency, the local Pulang Pisau government has high influence to implement the paludiculture. However, Regency government is the less affected stakeholder; thus imposed less understanding about peatland management and less necessity for solving economic and ecological problems. In practice, Pulang Pisau government supported the rehabilitation and restoration of degraded peatland ecosystems in some places by implementing paludiculture (Tata & Susmianto, 2016). State government, represented by BRG, has high influence to implement the paludiculture, but it is the least affected stakeholder; thus this stakeholder has an important role to develop regulation, policy, and strategy in peatland. BRG supported paludiculture practice as an option to design NAMA (National Appropriate Mitigation Action) and Greenhouse Gases reduction strategy. In Indonesia, paludiculture practices have been implemented in three provinces (East Kalimantan, West Kalimantan, and Riau) by BRG (FAO, 2016). Private actors such as pulp companies also supported the development of paludiculture concept. Moreover, the paludiculture concept included alternative pulp species that have high economic value such as Jelutung (Giesen and van der meer, 2009). Other private companies such as Oil palm companies (GAR, Wilmar, etc.) were not interested in the paludiculture concept. These companies only have committed to no peatland conversion due to RSPO (Roundtable for Sustainable Palm Oil (Kurniasari, 2014). Local farmers have no power to influence the development of the paludiculture concept in peatland. However, they were directly affected by the paludiculture implementation in peatland. According to Afriyanti (2011), the farmers would agree with the paludiculture concept when there is a practical feasibility and availability of financial support. Environmental NGOs have high interest on paludiculture implementation, however NGOs did not have enough power to influence the implementation. The NGOs had an important role to assess the options and recommendations for wet-peatland culture (Wardhana, 2016).

From these stakeholder perspectives, paludiculture in peatland area had positive impacts overall. The supports from stakeholders would help the implementation of paludiculture in this Pulang Pisau Regency.

6. Conclusion and Recommendation

These sections describe the conclusion of the research and the recommendation for further research. The conclusion sections summarizes all findings of this research. These findings address the objective and sub-question of this research (see section 2). Moreover, the recommendation section suggests further actions to be taken in response to the findings of this research.

6.1. Conclusion

Six monoculture commodities of paludiculture (Chinese water chestnut, Sago, Jelutung, Belangiran, Tengkawang, Gelam) and agroforestry paludiculture were evaluated to assess total peatland emissions from different paludiculture commodities as alternatives for peatland degradation and to recommend and support sustainable peatland management. This research evaluated monoculture and agroforestry paludiculture in terms of ecological and economic aspects. In ecological aspect, the total peatland emissions of each commodity were estimated until 2050 to find the most environmental friendly scenario with minimal environmental impact. In economic aspect, the economic benefits from of all commodities were calculated to find the highest economic value commodity to be planted. By integrating the ecological and economic aspects, Agroforestry was found to be the most sustainable form of peatland management.

The total peatland emissions from each commodity were derived from carbon and land use change emissions. The result showed that Belangiran, Jelutung, Tengkawang, or Gelam accumulates the highest emission up to 21,467 tCO_2/ha (or 14,000 $MtCO_2$ for total area) in 2050, followed by Sago and Chinese water chestnut consecutively. Compared to Agroforestry system, the total peatland emissions were about 14,474 tCO_2/ha or 9,500 $MtCO_2$ for total area. This research also calculated carbon sequestration of each commodity to determine the total peat subsidence or formation in 2050. Chinese water chestnut improved the peat formation with a growth until 5.25 cm of peat in 2050. However, other commodities still contributed to peat subsidence. The highest total subsidence was found on hardwood species (such as Belangiran, Tengkawang and Gelam with 10 cm, followed by Sago with 6 cm. Agroforestry was assumed to have the similar total subsidence with other hardwood species.

In terms of ecological aspect, the most environmental friendly scenario was selected based on the biological CO_2 emission in 2050. Chinese water chestnut was chosen as most environmental friendly scenario with the lowest biological CO_2 emissions of 2,000 $MtCO_{2\text{-eq}}$. Sago generated 8,000 $MtCO_{2\text{-eq}}$ of biological CO_2 emissions and agroforestry generated 9,500 $MtCO_{2\text{-eq}}$ of biological CO_2 emissions. These scenarios still could be alternatives for sustainable peatland management.

In terms of economic aspect, Jelutung was the most economically benefit scenario with a total profit of 5,710 euro/ha or 3,800 million euro/total area in 2050. Moreover, Gelam monoculture generated 2,742 euro/ha (or around 1,800 million euro/total area) and agroforestry generated profit around 2,222 euro/ha (or around 1,475 million euro/total area). These scenarios still could be alternatives for sustainable peatland management.

By integrating the ecological and economic aspects, there were three most recommended land use options, namely Jelutung and Chinese water chestnut for monoculture, also agroforestry. Jelutung was a high economic value commodity, but it was the lowest environmental friendly scenario. Chinese water chestnut was the most environmental friendly scenario, but it did not have high economic value.

Agroforestry had the medium economic value, and it also did not cause environmental damage as high as Jelutung. Agroforestry could be the recommended land use option in Pulang Pisau Regency. Agroforestry is the win-win solution for economic and ecological concern in this peatland area. Therefore, agroforestry is a better option than monoculture in this paludiculture plantation.

Paludiculture could support the current sustainable peatland management such as Green Economy. From three recommended land use options, Jelutung gained the most income for Green GDP, followed by Chinese water chestnut and Agroforestry sequentially. These three scenario could increase the income of Pulang Pisau Regency from Green Economy project. Jelutung could gain 67.7 billion euro, Chinese water chestnut could gain 51.8 billion euro, and agroforestry could gain 51.6 billion euro.

To summarize, agroforestry paludiculture is the most promising sustainable peatland management in terms of ecological and economic aspect. Jelutung and Chinese water chestnut of monoculture can be the alternatives for paludiculture plantation. Paludiculture plantation in peatland area had positive impacts overall from stakeholder perspectives. These paludiculture commodities can also increase the current Green Economy income. Paludiculture is the possible recommendation for sustainable peatland management in Pulang Pisau Regency.

6.2. Recommendation

In short term, more detailed study about the combination of agroforestry commodities is needed to investigate the possibility of agroforestry plantation in the peatland area. Moreover, further study is needed to assess the social impact of paludiculture plantation on the society welfare in Pulang Pisau Regency. It is also recommended to conduct more study in emission factor from these paludiculture commodities.

In the medium and long term, BRG (Peat Restoration Agency) should invite private companies and local society to participate in peatland rehabilitation. Private companies can also incorporate this participation as their CSR (Corporate Social Responsibility) program. Therefore, the cost for rehabilitation and enrichment plantation can be covered by private companies, also the peat monitoring system should include local society to be more effective. Furthermore, Indonesian government and Pulang Pisau government should collaborate more to make a convenient and stable market for these paludiculture products.

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ANNEX

Annex 1. Nino4 SST Index

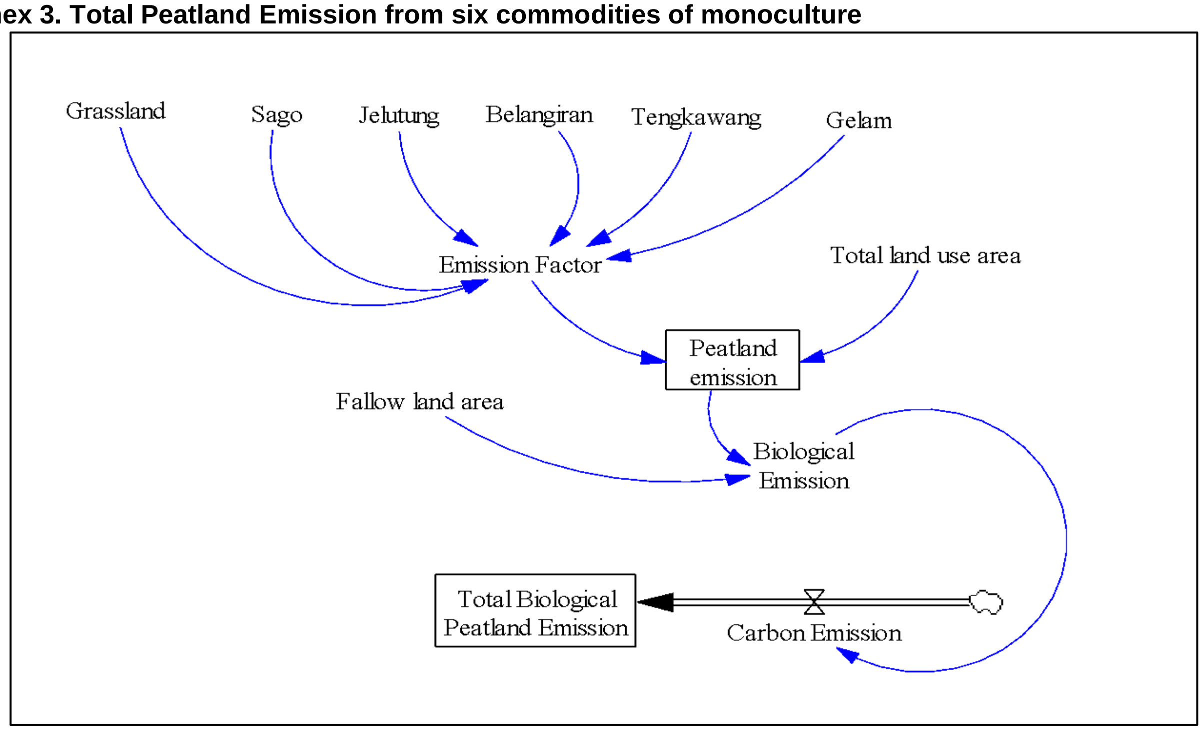
Time (Month in 2015)	Inverted Nino4 SST Index
January	1.013662
February	1.136007
March	1.229683
April	1.339692
May	1.242942
June	1.309883
July	1.23445
August	1.232991
September	1.264487
October	1.424868
November	1.960353
December	1.857406
Average	**1.353869**

Source: https://iridl.ldeo.columbia.edu/SOURCES/.Indices/.nino/.NCEP_OIv2/.NINO4/datatables.html

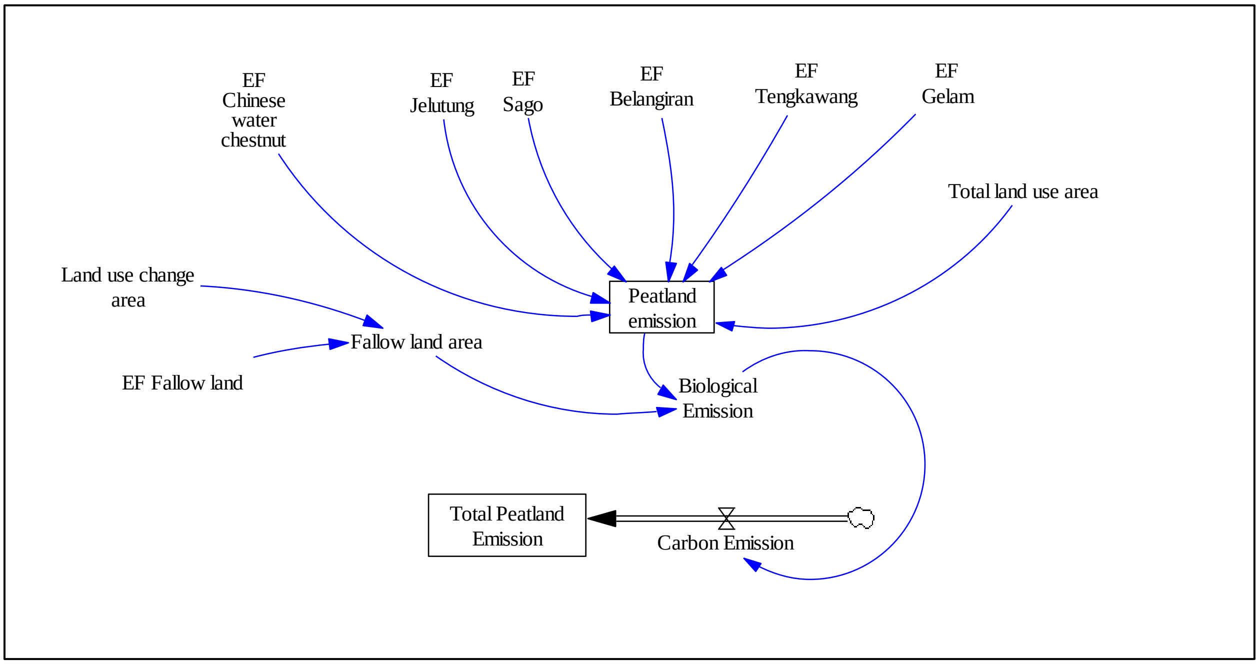
Annex 2. List of Contact Person

Type of company	Name of company	Address	Contact
BRG	BRG Indonesia	Gedung Sekretariat Negara, Jl Teuku Umar 10, 10350 Jakarta	Email: alue.dohong@gambut.id
BAPPEDA	BAPPEDA Provinsi Kalimantan Tengah	Jl. Diponegoro No. 60, Palangka Raya	Tel: +62 536 3231542

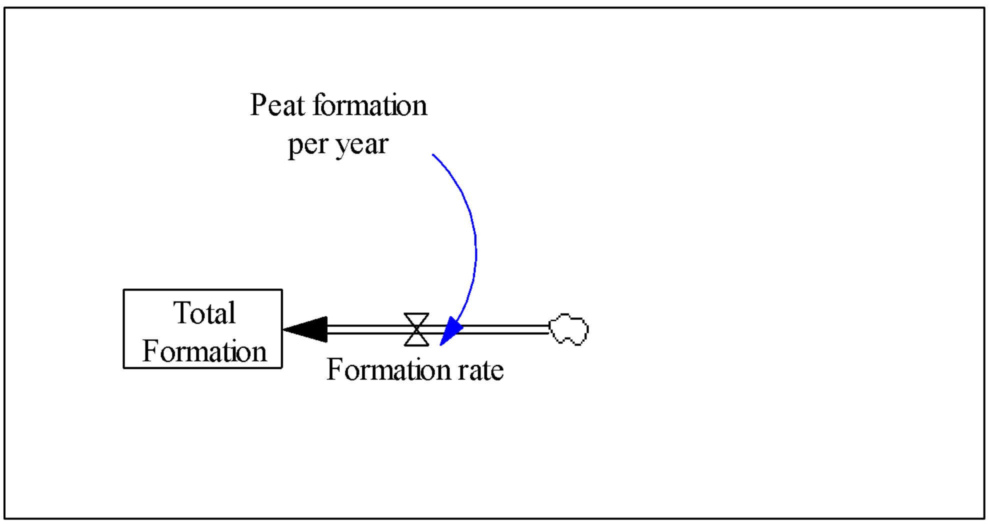
Annex 3. Total Peatland Emission from six commodities of monoculture



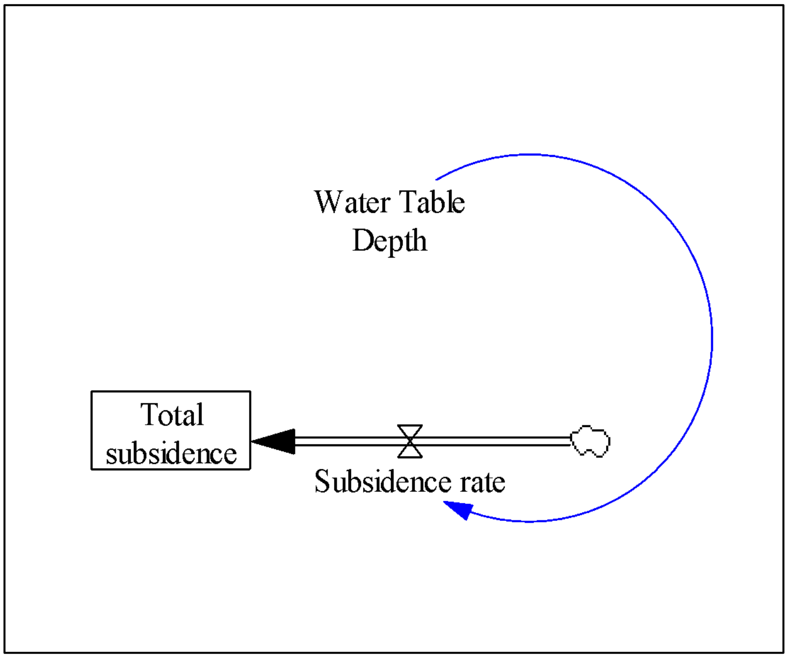
Annex 4. Total Peatland Emission from Agroforestry



Annex 5. Total Peat Formation



Annex 6. Total Peat Subsidence



Annex 7. Detail of Canal Blocking cost

Canal Blocking Cost	Volume per unit	Cost per unit (euro)	Project volume	Total cost (euro)
Compacted peat dams				
- Dam 3x10 m	10	586.90	23	13,498.77
- Dam 15x15 m	15	5,226.38	8	41.811,03
- Dam 15x30 m	30	12,527.40	2	25,054.80
- Dam 30x20 m	20	18,401.71	2	36,803.42
Spillway				
- Spillway 60x120 m	120	4,070.78	8	32,566.21
- Spillway 100x135 m	135	7,720.76	1	7,720.76
Palisade	15	5,385.75	12	64,628.94
Partial canal infilling				
- Canal infilling 1 m from both side of canal	1	1.69	12,000	20,239.79
- Canal infilling from excavation 20 m	1	4.83	12,000	57,989.46
Revegetation	1	1.21	6,000	7,244.84
Log wood transportation	206	22,641.01	2	45,282.02
Excavator operational	206	3,905.42	2	7,810.85
Excavator mobilization and demobilization	4	0.69	30,000	20,753.39
Monitoring	1	139.57	121	16,887.42
Unexpected cost	1	1,395.65	1	1,395.65
Cost				399,687.37
Tax 10%				39,968.74
Total cost				439,656.11
Cost per meter				43.97
Cost per hectare				5.86