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Chapter

Applying Systems Analysis to Evaluate Options for Sustainable Use of Peatlands in Central Kalimantan in Indonesia

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Abstract

Peat fire and the consequent degradation of peatland have had significant negative environmental and economic consequences at national and global levels. A green economy transition path is seen as a socioeconomic solution to address peat degradation. Swamp agriculture, better known as paludiculture, is a green economy action holding promise. However, little knowledge exists on the socioeconomic outcomes of this option, vis à vis conventional development. This research is the first attempt to quantify the implications of a green economy strategy to the management of peatland, in a province where 30% of the land is peat. The research uses the system dynamics methodology to create a customized green economy assessment model, named the Central Kalimantan Green Economy model (KT-GEM). The model is used to assess how three different development scenarios perform against social, economic, and environmental indicators. The analysis shows that the business as usual (BAU) scenario leads to the highest profitability. On the other hand, positive economic performance is countered by unsustainable social and environmental outcomes. The paludiculture scenario instead curbs peat fires and externalities (e.g., cost of health) and results in the most sustainable societal outcome.

Keywords: system dynamics, sustainable land use, peat, climate adaptation

1. Introduction

Poor peatland management practices in Indonesia have led to large areas of degraded peatlands, which are causing increasing environmental and socioeconomic problems. Deforestation and canalization for agricultural development have drained the naturally water-logged peat swamps and have left behind dry, carbon-rich land that is extremely prone to fire [21, 52]. Recurrent fires on peatlands cause environmental destruction, greenhouse gas (GHG) emissions, and health impacts from toxic haze pollution, which translates into high socioeconomic costs [28, 53]. The 2015 fire episode has pushed Indonesia to the third place for global GHG emitters and led to an estimated damage of IDR 221 trillion [17, 53]. Besides fires, the decomposition

of stored organic matter in the drained peatlands also contributes substantially to Indonesia's total GHG emissions [21, 54] and leads to irreversible land subsidence [9, 20, 21, 33, 35]. As the majority of the underlying mineral soils are below sea level, this land subsidence will result in the future flooding of land [21]. Additionally, mineral soil contains acid sulfate soil, which turns acid when exposed and tends to be extremely infertile [34]. Thus, continuous peat degradation and subsequent flooding will prevent the productive use of land for agriculture or for other purposes.

As a result of the failed "Mega Rice Project" (MRP) that deforested and drained peat swamp forests to develop rice paddies, a large part of Central Kalimantan's peatlands is degraded.[1] This results in regular fires that are linked to the El Niño Southern Oscillation climate phenomenon (ENSO). In so far, a lack of anticipatory fire responses has made the province of Central Kalimantan one of the most affected by fire and haze [13, 24, 45]. The 2015 fire episode burnt an estimated 429,000 hectares and caused a financial loss of 233 million Indonesian rupiah [53]. Deforestation and canalization under the MRP have paved the way for further exploitation of the region and pressure on the peatlands is increasing as a result of migration to the area, the opening up of new land for smallholder and industrial plantations, and slash and burn farming practices [15, 42, 52]. Rapid agricultural development, in particular palm oil expansion, is one of the main drivers of deforestation and peatland degradation in Central Kalimantan and deforestation and palm oil expansion rates are now among the highest in Indonesia [1, 45, 48, 49]. As palm oil and other conventional cash crops require drainage for cultivation, the peatlands are continuously degrading, which leads to an increase in fire vulnerability and land subsidence in Central Kalimantan [13].

In light of the serious environmental, social, and economic impacts of degraded peatlands, restoration and sustainable peatland management is critical in order to reduce emissions, maintain biodiversity, and ensure a long-term solution to the recurring fire and haze problems in Indonesia [1, 9]. This requires a revision of land management policies and land use planning of these areas. The Indonesian government has taken up several regulations on peatland management and has committed to restore 2 million ha of peatlands [53].[2] Besides reducing social hazards and economic costs from peat fires, peatland restoration can lead to a large reduction of GHG emissions from fire and peat decomposition and in this way assist Indonesia in reaching its GHG emission reduction target of 29% compared to business as usual levels by 2030 [1, 9]. However, in addition to these policies, the government is also looking to expand its agricultural production and has pledged to double its palm oil production by 2020 [1]. Despite sustainability concerns, there is a large economic interest in the conversion of the degraded peatlands into plantations and large areas have already been licensed to pulp or palm oil companies [29]. Hence, the conflict between the social and environmental benefits of peatland restoration and

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[1] The Mega Rice Project was a government project initiated in 1996 that aimed to convert 1.7Mha of unproductive and sparsely populated peat swamp forest into rice paddies by deforesting and canalizing the area. However, the project was unsuccessful and was eventually abandoned after severe environmental damage had already occurred. The deep drainage of the peatlands. Has resulted in annual fire hotspots during the dry season (see.e.g. [18, 19, 47]).

[2] For regulations on peatland see for example Government Regulation (Perpes) No. 71/2014 on the Protection and Management of Peatland Ecosystems and Presidential Instruction (Inpres) No.8/2015 on the postponement of the exisiting moratorium on the conversion of peatlands and primary forest. President Joko Widodo has also called for a moratorium on new peatland concessions and a cancelation of existing concessions that have not been developed, thereby halting the legal conversion of peatland and peat swamp forests into agricultural land ([53], 23 October Statement).

the economic benefits of industrial crops needs to be addressed in order to achieve effective peatland restoration.

An option that can offer a solution to this problem is paludiculture, which is the cultivation of native wetland crops on peatlands [13] and is currently being promoted by the Government of Indonesia [11]. Peatland restoration is not an easy process and requires careful consideration of the relationship between the native vegetation, hydrology, and peat soil [10]. Since paludiculture species can be commercially planted on rewetted peatlands, while maintaining the natural conditions of the peat, they can be effectively used in rehabilitation efforts and offer an alternative to the production of conventional commercial crops [13]. Restoring the peatlands this way is in line with Indonesia's ambitions to transit toward a "Green Economy," an economic framework that improves both human welfare and the environment by fully incorporating the value of natural capital [55]. In Indonesia, an estimated 60–80 species have been identified as having potential for paludiculture development, one of which is Jelutung (*Dyera* sp.), a native tree species that naturally grows in peatlands and can be used for latex and timber production [13, 56]. Over the last 20 years, planting Jelutung to rehabilitate peatlands has been tested by the Kalimantan Forests and Climate Partnership (KFCP) initiative, the Central Kalimantan Peatland Project (CKPP) of Wetlands International, and in ICRAF's Reducing Emissions from Land Use (REALU) in Sumatra [13].

While many small-scale efforts of paludiculture development have been implemented, no large scale attempts have been tried so far. This study aims to provide an initial investigation on the impacts of the large scale use of paludiculture development, as an effort to restore degraded peatlands. It will do so by modeling the impacts of jelutung development and other peatland management strategies in Central Kalimantan using an extended version of the Kalimantan Green Economy Model (KT-GEM) [3, 43, 44]. This model is a regional application of the Indonesia Green Economy Model (I-GEM) that was developed to inform, strengthen, and facilitate long-term policy planning and financing within the transition toward a Green Economy by evaluating the trade-offs between conservation and development scenarios [43, 44]. Central Kalimantan was chosen for this study because of its large areas of degraded peatlands, the existing fire and haze problems and the availability of the KT-GEM.

With the use of the KT-GEM, we review the outcomes of different policy scenarios for peatland use in order to assess whether the Jelutung approach of peatland restoration holds social, environmental, and economic benefits. This study further aims to provide a better understanding of the impacts of different policy decisions for peatland restoration, focusing on the most crucial issues of degraded peatlands: hotspots, GHG emissions, and economic development. Building on previous efforts of peatland restoration and paludiculture, the study provides a basis for further research into paludiculture development for peatland restoration in Indonesia.

2. Method

2.1 Study area

Central Kalimantan is the third largest province in Indonesia and covers approximately 15.4 million hectares (Mha), of which around 3.47 Mha is peatland [27] and Government of Central Kalimantan [14]. The province has a tropical climate and its forests and peatlands are part of the biodiversity hotspot of Borneo that provides vital ecosystem services [48, 49]. Around 2.7 million ha is degraded in one form or the other. In 2015 alone over 429,000 ha burnt. In 2014, the province had a total population of 2.4 million inhabitants, with a population density of 16 inhabitants/

km^2 [7]. Agriculture is the main economic sector contributing to local GDP, with the most important crops being, rice, oil palm, and rubber [8, 45]. Other important sectors include mining and tourism and to a limited extend other sectors such as industries and transportations [7, 45].

2.2 KT-GEM and system dynamics modeling of peatland scenarios

Moving toward a greener economy involves the design and implementation of key interventions such as public expenditure, policy reforms, and regulation changes that aim to foster sustainable economic growth, employment generation, inclusive income opportunities, and environmental conservation. As a result, methodologies and models are needed in order to support policymakers in the assessment of cross-sectoral economic, social, and environmental impacts of green economy policies. In particular, methodological approaches and models should allow to quantitatively project and evaluate trends (for issue identification), identify entry points for interventions and set targets (for policy formulation), assess ex-ante the potential impact across sectors and the effectiveness in solving stated problems (or exploiting opportunities) of selected interventions (for policy assessment), as well as monitor and evaluate the impact of the interventions chosen against a baseline scenario (for policy monitoring and evaluation ex-post assessment/analysis).

Finding that most currently available national planning models are either too detailed or narrowly focused, this study proposes an approach that:
(a) extends and advances the policy analysis carried out with other tools by accounting for the dynamic complexity embedded in the systems studied and
(b) facilitates the investigation and understanding of the relations existing between natural capital, society, and the economy. The inclusion of cross-sectoral relations supports a wider analysis of the implication of alternative green economy policies, and the long-term perspective proposed allow for the identification of potential side effects and sustainability of different strategies.

The approach proposed uses the system dynamics (SD) methodology as its foundation, serving primarily as a knowledge integrator. System dynamics modeling is a form of computer simulation modeling designed to facilitate a comprehensive approach to development planning in the medium to long term [12, 30, 37]. A key characteristic of SD is that it allows to integrate the three spheres of sustainable development in its analytical process. SD operates by simulating historical data for a period of at least 1 decade and comparing simulation results with the available data. The purpose of such models is not to make precise predictions of the future; rather, they are a tool for exploring alternative policy scenarios in order to identify those policies which could improve conditions in the future and contribute to the achievement of desired goals and objectives [36, 39]. System dynamics allows to represent explicitly stocks and flows of human, built and natural capital, and to create linkages among them through the use of feedbacks, delays, and non-linearity.

The green economy model (GEM) is well suited to: (1) generate projections of future developments, though acknowledging that long-term accurate projection cannot easily be produced, even when simulating a large number of endogenous key variables; (2) provide an integrated analysis and evaluation of policy choices; and (3) increase the understanding of the relations underlying the system analyzed. The following paragraphs briefly describe the principal aspects of the GEM application customized to Mauritius.

- *Boundaries*: Variables that are considered an essential part of relevant development mechanisms are endogenously calculated. For example, GDP and its main determinants, population and its main determinants, and the demand

and supply of natural resources are endogenously determined. Variables that have an important influence on the issues analyzed, but which are only weakly influenced by the issues analyzed, are exogenously represented.

- *Time horizon*: GEM applications are built to analyze medium to long-term green economy scenarios. Also, simulations start in the past in order to allow validation against historical data. In the customization to Mauritius (M-GEM), the time horizon for simulation starts back in 1980 and extends up to 2030.

- *Structure*: despite the variety of green economy opportunities considered, GEM is a relatively small model. Its complexity lies in the high number of cross-sectoral linkages (dynamic complexity), but its vertical detail (within a sector, or detailed complexity) is far from overwhelming. This makes so that the model is fully tailored to a green economy analysis, being based on stakeholder inputs, and does not compete with the models already being used by the government and its partners. In fact, GEM is developed to fill a gap in the current modeling work in relation to the green economy, and to identify research needs to be addressed with more detailed sectoral models.

The main outputs of GEM, and of the green economy analysis carried out with it, include the investment required to implement the intervention desired, added benefits, and avoided costs. Among the benefits, indicators include sectoral value added (as driven by natural resources stocks and flows, e.g., sustainable agriculture yield and production), direct employment creation, and relative income generated, for example, additional employment in public transport or energy efficiency sectors. Avoided costs include savings from avoided consumption (e.g., water, through resource efficiency interventions), and potential avoided ecosystem restoration costs. These are compared with costs, and potential damages created by the business as usual case and by the policy implemented, to estimate the economy-wide annual cash flow, as well as the break-even point, and the return on investment (and, for instance, the return on employment, and emissions).

By generating systemic, broad, and cross-sectoral scenarios over time that address environmental, economic, and social issues in a single coherent framework, the GEM simulates the main short, medium, and long-term impacts of investing in a greener economy. The most important contribution of this model is its systemic structure that includes endogenous links within and across the economic, social, and environmental sectors through a variety of feedback loops. Most existing models focus on one or two sectors and make exogenous assumptions about other sectors that affect and are affected by the sector under consideration. Using endogenous formulations instead improves consistency over time and across sectors, because changes in the main drivers of the system analyzed are reflected throughout the model and analysis through feedback loops. While detailed sectoral analysis is very important, it is not adequate to demonstrate the whole set of relations and feedback loops that properly represent the functioning of the real world and that must be taken into account in making the necessary transitions to greener economic and social structures.

The study uses different indicators that capture the value of natural capital in order to represent a green economy, which are green GDP and GDP of the poor. These indicators were developed in the I-GEM as an alternative to conventional GDP, which only captures a small portion of nature's contribution to people's livelihoods [43, 44]. The model mainly used Green GDP as an indicator of the Green Economy, which is an alternative measurement of GDP growth that accounts for
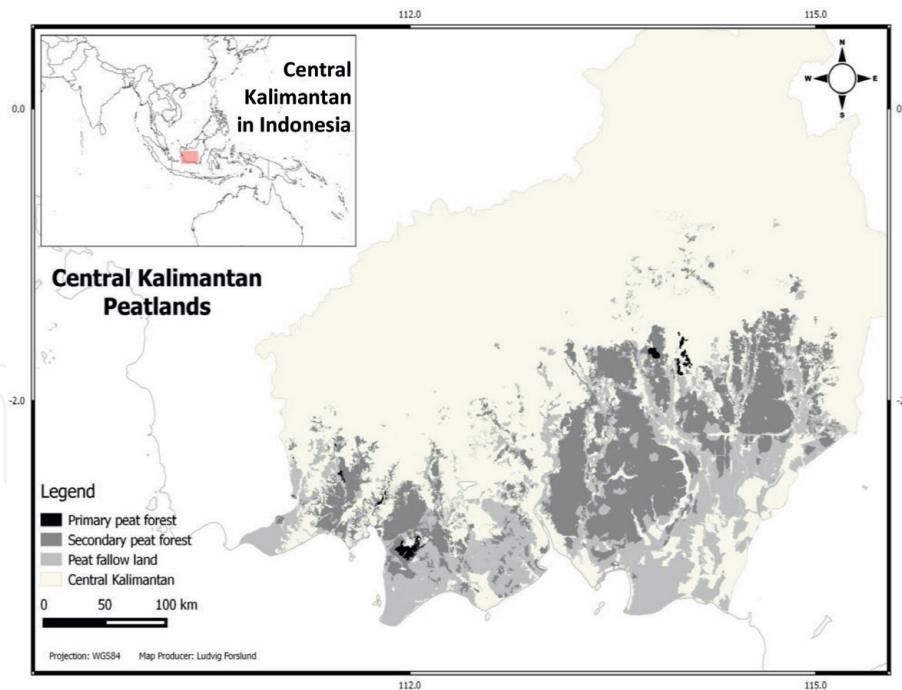
Figure 1.
Extent of peatland and the land use on peatland in Central Kalimantan.Data source: The Ministry of Forestry Republic of Indonesia. [57].

natural capital depreciation and changes in the value of human capital. The GDP of the Poor indicator measures the contribution of nature and environmental services to the household incomes of poor communities **Figure 1** [43, 44].

2.3 Peatland management scenarios

Four peatland management scenarios in Central Kalimantan were chosen: a business as usual (BAU) scenario, a BAU and palm oil expansion (BAU + Palm) scenario, a green economy (GE) scenario, and a Jelutung scenario. The **BAU scenario** assumes the continuation of historical and present trends of peatland management, which includes land use changes, policies, and interventions currently implemented and enforced. The **BAU + Palm scenario** represents a likely future scenario of the rapid conversion of fallow lands into palm oil. It follows the assumptions of the BAU scenario with the additional assumption of gradually converting all fallow lands into palm oil starting from 2015 until the end of the study period in 2030. Under the **GE scenario**, the implementation of several management and conservation efforts are assumed, including the implementation of government regulation No. 71/2014 on the Protection and Management of Peatland Ecosystems; rehabilitating and rewetting the peatlands in order to keep the water table depth (WTD) below the peatland surface less than 20 cm; halting the conversion of peatlands; and gradually rewetting fallow lands and converting them to secondary peatland forests over the years. Other green economy transitions included are the implementation of sustainable agriculture, vessel removal, fish conservation, waste reuse, and energy and solar efficiency. The scenario assumes the implementation of Government Regulation 71/2014 from 2015 onward and the other policy changes from 2020 onward. Finally, the **Jelutung scenario** models the outcome of a policy that converts all palm oil plantations to Jelutung forest or agroforestry systems in order to provide an extreme case of using paludiculture to rehabilitate degraded peatlands from 2015 onward. The scenario further assumes the same policy changes as the GE scenario.

2.4 KT-GEM key equations for peatland analysis

To assess the impact of paludiculture development and other policies in a green economy scenario, the study looked at various indicators in the KT-GEM peatland module, namely total peatland emissions, subsidence and flooding impacts, and costs and profits, in order to calculate impacts on natural capital change, Green GDP and GDP of the Poor. The implications of the different policy scenarios were analyzed for the period 2015–2030.

2.4.1 Total peatland emissions

Total peatland emissions were obtained by summing up the total biological emissions and emissions from fire. To estimate the biological emissions, a biological emission factor on different land types in Central Kalimantan was estimated. Land use and land use change in the KT-GEM Peatland Module was adapted from the classification of peatlands from Krisnawati et al. [25] and categorized into four land uses on peat: agricultural peatland, secondary peatland forest, production forest on peatland, and fallow peatland. The emission factor on the four different land uses was calculated by adapting the linear regression equations from Husnain et al. [23] and Hooijer et al. [22] and the water table depths for the land uses in each scenario came from data obtained from several publications [16, 21, 23].

Fire emissions were calculated based on the amount of burnt areas, which were estimated by calculating fire hotspots. Because of the significant influence of the El Niño Southern Oscillation (ENSO) on fire activity in Indonesia [41], the KT-GEM integrated an ENSO indicator, namely Nino3.4 Sea Surface Temperature (SST) Index to forecast fire hotspots.[3] Historical dry season data from the Nino3.4 SST Index from 2000 to 2014 and MODIS-derived hotspot data from 1998 to 2006 from Reynolds et al. [38] were used for the assessment. Data from the Nino3.4 Index was extrapolated to create a trend in the relationship between SST and hotspots until 2030. The historical and extrapolated data were then used to predict the amount of hotspots per dry season in Central Kalimantan by measuring the relationship between Nino3.4 index data and fire hotspots using an exponential regression analysis as can be seen in **Figure 2**.

The exponential regression model was then adapted to each management scenario and set into formulas to forecast the amount of hotspots in each scenario.[4] The formula developed by Tansey et al. [50], in their study in Central Kalimantan, was then used to calculate the total burnt area:

$$\text{Burnt area (hectare)} = 2925 \times \text{Hotspots} \times 155.49.$$

Finally, to calculate fire emissions, the KT-GEM Peatland Module adapted a method used by the Indonesia National Forest Reference Emissions Level or FREL [6]:

$$L_{fire} = A \times MB \times CF \times G_{ef}$$

where **A** denotes the extent of burnt area (in hectares), **CF** is the combustion factor with a default factor that equals to 1.0, and **MB** denotes the mass of fuel

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[3] A hotspot is a fire pixel in a satellite imagery that indicates fire in an area. Yet it does not specify the number, size or intensity of fires and burned areas. See further [40].

[4] The study by Thoha et al. (2014) found that 63 percent of all hotspots in Central Kalimantan occur on peatlands and total hotspots calculated were therefore multiplied by 0.63 to adjust the results.
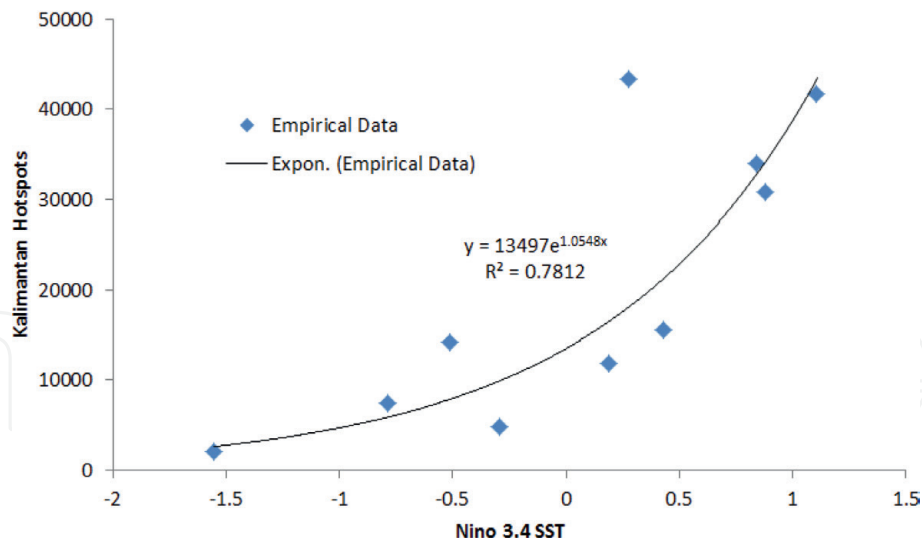
Figure 2.
Central Kalimantan hotspots and Nino3.4 SST correlation (for the period July–August–September–October) [57].

available for combustion. The latter is estimated for the BAU scenario by multiplying the mean depth of burned peat with the bulk density (BD) as assumed in the studies by Mulyani et al. [32] and Ballhorn et al. [2]. From here, the average depth of burned peat in other scenarios was calculated by building a linear relationship between the assumed water table depth (WTD) and the burned depth. Furthermore, G^{ef} denotes the CO_2 emission factor calculated by multiplying the organic carbon content (Corg, % of weight) of 0.4986 [32] with the conversion factor from tC to tCO_2e which is 3.67. This conversion factor was derived through dividing the atomic weight of carbon dioxide (i.e., 44) by the atomic weight of carbon (i.e., 12).

2.4.2 Land subsidence and flooding

Land subsidence was estimated to forecast the amount of flooded agricultural land to be subtracted from agricultural land, production, and profits in the Green GDP calculations. The KT-GEM Peatland Module calculates the subsidence rate using the equation from Hooijer et al. [21] which measured a relationship between water table depth and subsidence level, as follows:

$$Subsidence\ rate\ (cm\ per\ year) = 0.69 - 5.98 \times WTD$$

This formula was simulated for each land use category in all selected peatland management scenarios and adjusted the WTD accordingly. Based on the subsidence rate, the module then measured the risk of flooding in agricultural peatlands with an equation from that demonstrates the relationship between the accumulated agricultural subsidence and the proportion of flooded agricultural peatlands. The result was then multiplied with the existing agricultural land (in hectare) and the inverted Nino3.4 SST Index (where wet years are positive instead of the other way around) in order to obtain the extent of flooded agricultural land.

2.4.3 Calculating costs and profits

In estimating the total costs and profits, the KT-GEM included costs of rewetting and reforestation, costs from fires, and profits from palm oil plantations and jelutung.

Rewetting and reforestation costs in the green economy and jelutung scenarios applied mainly to production forests, secondary forests, and fallow lands and were gradually implemented between 2015 and 2025, after which only small rewetting costs for maintenance were calculated. In order to estimate rewetting and reforestation costs, data on peat forests rehabilitation costs by were used. The cost of fire damage was calculated by multiplying the extent of burnt areas with fire damage cost per unit, which were estimated at 172 USD per hectare of burned area by Tacconi [51].

Palm oil is the main crop on agricultural land, especially in the BAU + Palm scenario, and the profits of palm oil plantations were estimated based on calculations in the study by Suharno et al. [46]. This number was multiplied by the agricultural peatland (Ha) to obtain the total profits from oil palm production (IDR/Year). Jelutung profitability was calculated based on a cultivation period of 30 years [52] and the value reported in the ICRAF report, which was multiplied with the total area of jelutung (ha). The value used is the net profit per hectare per year, which contains all the annual costs. Hence, the capital (CAPEX) and operational (OPEX) costs associated with intervention are lumped together to minimize the complexity of the model.

2.4.4 Calculating natural capital change and Green GDP

The estimation of Green GDP was performed by adding the change in natural capital to real GDP. Real GDP of Central Kalimantan is calculated by adding the production value from several sectors, namely agriculture, fisheries, forestry, industry, services, labor, mining, and tourism [43, 44]. Natural capital change is calculated by adding the carbon loss value and the value of emissions and fires in peatlands. To do so, the study uses a fixed-rate carbon price (i.e., 5 USD per tCO_2) through the entire study period and assumes a functioning carbon credit markets in order to incorporate the benefits from GHG emissions reduction.

3. Results and discussion

1. Policy interventions in the GE and Jelutung scenarios lead to lower cumulative peatland emissions

Figure 3 shows the total cumulative peatland emissions in the four selected peatland management scenarios. Up to 2015, the year in which the interventions are expected to begin, total peatland emissions are the same in all the scenarios considered. The GE and Jelutung scenarios result in significantly lower cumulative peatland emissions in Central Kalimantan compared to the BAU and BAU + Palm scenarios in the simulation up to 2045, with the scenario BAU + Palm having the highest level of cumulative emissions. Given the large contribution of peat-related emissions in Central Kalimantan to Indonesia's total GHG emissions, the adoption of policies aimed at reducing peatland emissions will significantly help the country achieve its climate change mitigation goals [31].

High peatland emissions are correlated with higher costs associated with fires on peatlands, as reflected in **Figure 4**. Results of the BAU and BAU + Palm coincide and are highly fluctuating over time, signifying that there is a high variability in the probability that peat fires will take place on any given year. Ultimately, this trend illustrates that both the BAU and the BAU + Palm scenarios generate the highest costs related to annual fire damage as compared to the other two scenarios. The model forecasts that future fire damage costs in the BAU and the BAU + Palm scenarios could reach up to 700 billion IDR; whereas, in the GE and Jelutung scenarios,
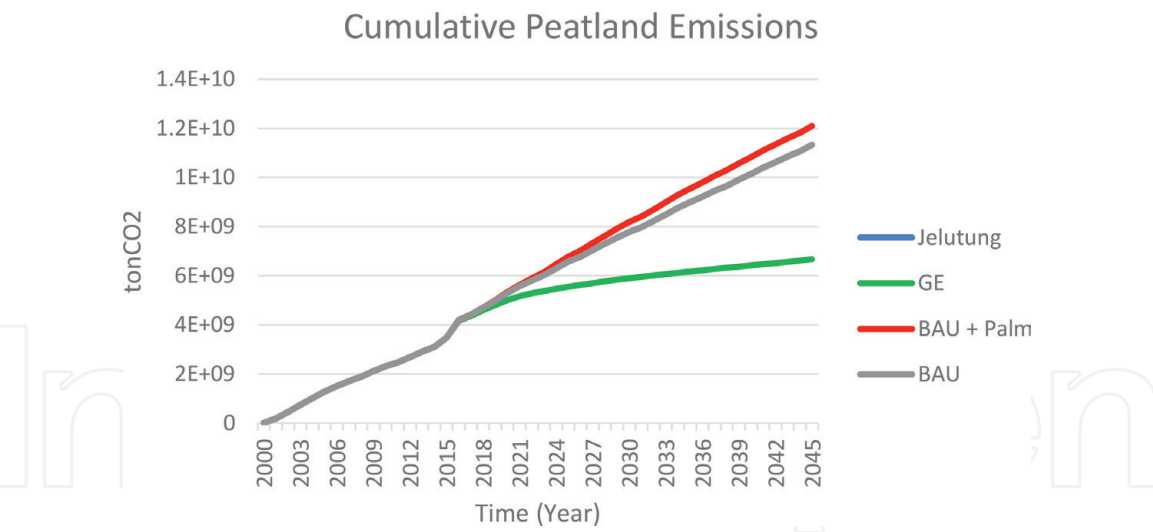
Figure 3.
Cumulative peatland emissions of different policy scenarios in Central Kalimantan.
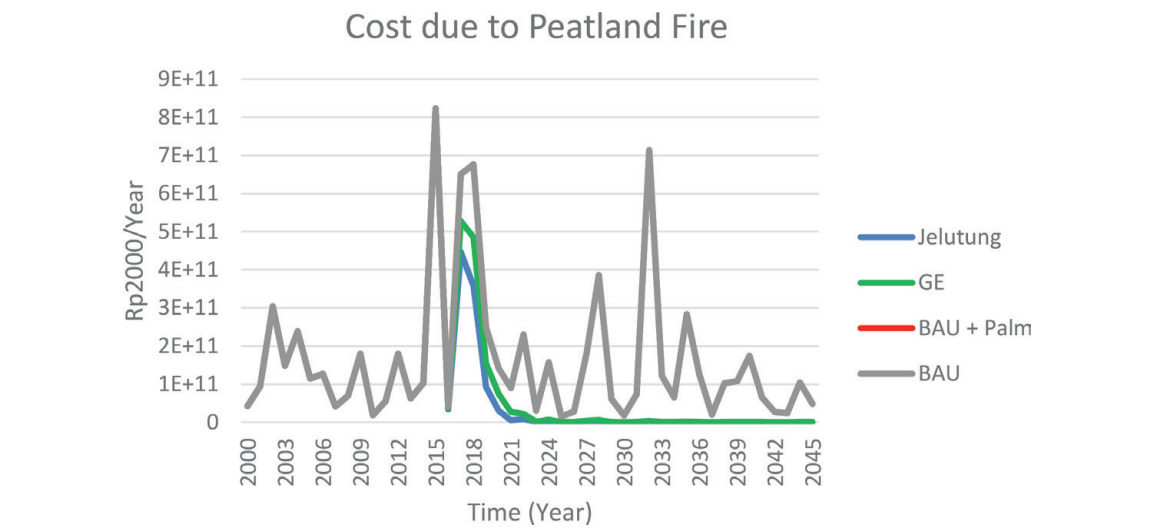

Figure 4.
Cost due to peatland fire in Central Kalimantan.

these costs would be equal to zero after the initial years of intervention. In the KT-GEM peatland module, these results are further integrated in the calculation of Green GDP as part of natural capital losses and the BAU and BAU + Palm scenarios are therefore significantly contributing to lower Green GDP than the other two scenarios.

The 2015 fires, which were caused by El Niño, are proof that historical data alone are inadequate to be used as a benchmark for forecast the actual costs of fire damage. In addition to the direct impacts and costs of fire and haze, studies indicate long-term negative health impacts from endured exposure to haze, including a significant increase in mortality [26]. The World Bank [53] calculated that post-fire and haze rehabilitation costs of 2015 amount to USD 16.1 billion, more than double the costs of the Aceh-Nias tsunami in 2004.

The BAU and BAU + Palm Oil scenarios are so-called high risk, high reward scenarios with short-term economic benefits. Keeping in mind Indonesia's sustainability and economic ambitions, the more effective scenarios (Jelutung and GE)—as illustrated on the graphs—should be prioritized; as they signify the lower levels of deviation from predicted future emission levels, and this "predictability" is a stable environment for government officials to formulate policies as well as for other key stakeholders that have initiatives in this area.

Implicitly, the lower cost due to reduced peatland fires will inherently improve results of Green GDP.

2. Jelutung and GE scenarios are less profitable than palm oil development, but the latter is unsustainable

The GE and Jelutung scenarios are less profitable than palm oil development when relying on traditional GDP indicators, as is made apparent in **Figure 5**. The calculation of the natural capital component in the Green GDP valuation is dependent on both the release of emissions, as well as on the revenues from agricultural activities. As a result, the direct income derived from palm oil production increases short-term profitability, but the negative impacts of depleting natural resources and generating more emissions are not captured by traditional GDP.

At the end of the study period, the GDP of BAU + Palm Oil scenario would reach more than 100 trillion IDR, while the real GDP in the other three scenarios approximates IDR 75 trillion. The major increase in GDP for the BAU + Palm Oil scenario is due to the high profits obtained from palm oil plantations. This remains as one of the direct challenges faced by key stakeholders that want to shift practices to more sustainable alternatives.

However, the conventional GDP indicator has many shortcomings, which makes it unreliable as a measure of social welfare. The GDP indicator ignores the future consequences of current consumption [5] and is criticized for not internalizing environmental externalities and natural resources depletion (e.g., [4]). Consequently, the value of nature is often underestimated in policy making since its contribution is deemed low, and this leads to struggling efforts in conserving nature. In Indonesia, conventional GDP only captures a small portion of nature's contribution to the economy, estimated around 21% of the total GDP. Yet, Indonesia has approximately 99 million poor inhabitants who depend on ecosystem services, and their dependence on nature is not considered in the conventional GDP indicator.

The KT-GEM clearly points out these shortcomings, and estimates an alternative indicator: Green GDP. This indicator shows that the GE and Jelutung scenarios would reduce economic volatility and the vulnerability to external shocks as well as to climate change (and peat fires). Furthermore, the economic performance now differs only slightly across all the scenarios, indicating that the value of nature is relevant and should be explicitly considered. Overall, the GE scenario achieves the best performance with regard to the Green GDP indicator, as its value is higher than BAU
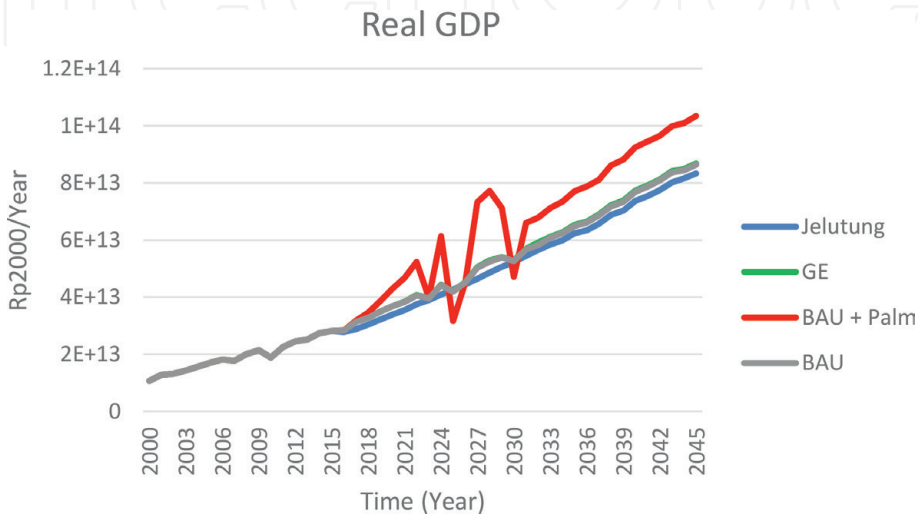

Figure 5.
The projection of GDP of the simulated policy scenarios in the Central Kalimantan.
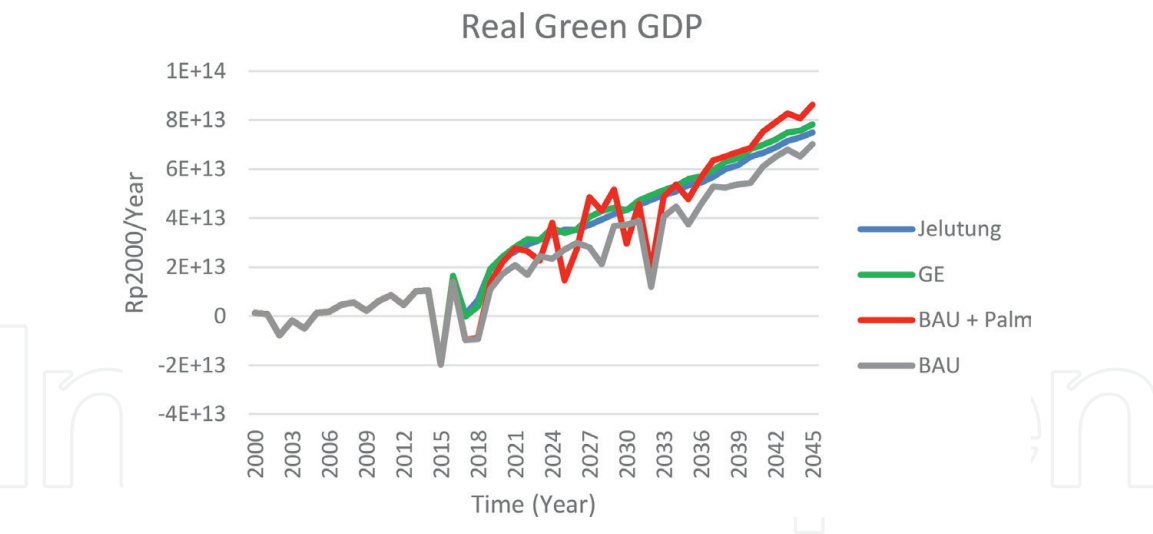
Figure 6.
The projection of green GDP of the simulated policy scenarios in Central Kalimantan.

and Jelutung annually and cumulatively, and it is also highly competitive with the BAU + Palm oil scenario. Most importantly, the growth of the GE scenario is more consistent and resilient than what is observed for the other scenarios (**Figure 6**).

3. The Jelutung and GE scenarios result in lower total natural capital change costs

The analysis shows that both the BAU and the BAU + Palm Oil scenario result in heavily fluctuating costs due to peat fires and natural capital depletion, a sign that palm oil and continued deforestation continue to undermine the value of natural capital throughout the study period (**Figure 7**). This is also one of the strong inputs that explain the reduced fluctuation of Green GDP, in which a smaller number of peat fires is forecasted. The years 2018 and 2032, in particular, show high losses of natural capital due to forest fires, but only in the BAU and BAU + Palm Oil scenarios.

The total Natural Capital Net Change becomes a key piece of information when development practitioners attempt to negotiate with private sector institutions that a win-win solution can be obtained by adopting GE or Jelutung policy scenarios and moving away from traditional BAU practices and palm oil development. Many initiatives—most famously, efforts by Pavan Sukhdev and the TEEB initiative—have attempted to formulate tools and processes to give ecosystem services a numerical
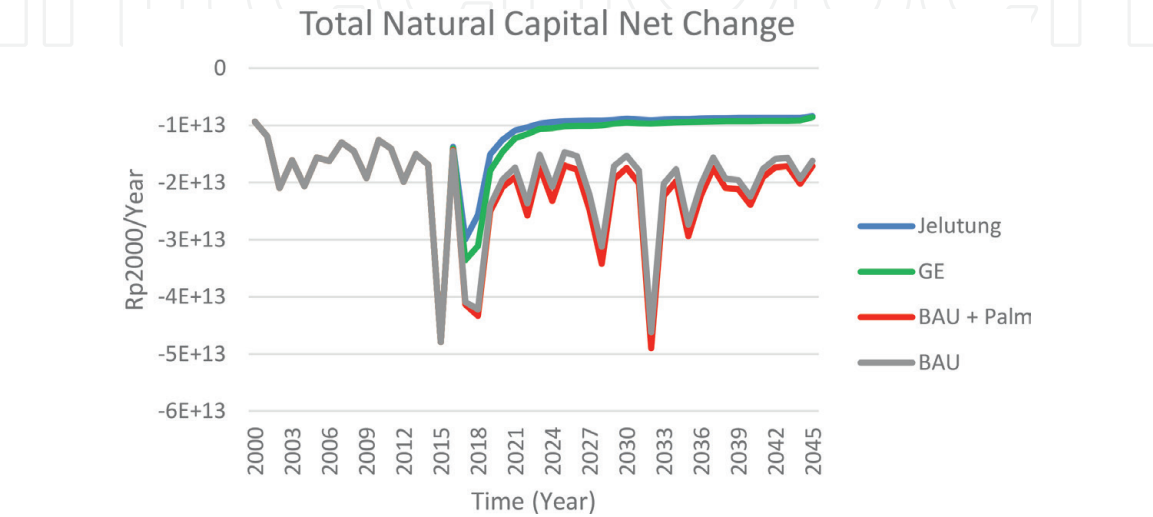

Figure 7.
Total Natural Capital Net Change.

value; intended to drive new conservative business practices that go along with the assumed primary interest of businesses—maximizing profit. This can be looked at as a marketing attempt to increase the tangibility of ecosystem services. By giving natural resources and ecosystem services a numerical value, private sector institutions—especially those in industries that are highly dependent on these shared assets—become inclined to input these numbers onto their financial scorecards and balance sheets.

Doing so could lead to a more sustainable business environment, with a long-term accumulation of profit for businesses at a consistent rate. The question and challenge is whether businesses, government officials, and other key stakeholders are able to envision this outcome and make the trade-off between BAU/BAU + Palm oil and GE/Jelutung scenario, which leads to short-term profit loss, but sustainable long-term business activity—inherently meaning, increased accumulative profit. In fact, the GE scenario has the highest cumulative Green GDP, and that even though BAU + Palm oil is a little more profitable than Jelutung, the Jelutung scenario is just as competitive considering it possesses far more intangible benefits (e.g., in the provision of ecosystem services and resilience) for policy makers, businesses, and communities. On the other hand, being intangible and not being accrued by any specific economic actors, these benefits are difficult to quantify and can hardly influence decision making.

4. Under a higher carbon price the Jelutung scenario outperforms the BAU + Palm Oil scenario

The valuation of natural capital in the Green Economy Model is dependent on the carbon price that is used, which in this case is the baseline carbon price that is set in the Letter of Intent between Indonesia and Norway. However, carbon prices may fluctuate leading to different impacts on Green GDP depending on land use management scenarios. As the effect of the Jelutung scenario on Green GDP is highly dependent on carbon price and profitability of Jelutung, a sensitivity analysis of the carbon price on the cumulative Green GDP was carried out. Results demonstrate that under a higher carbon price, the Jelutung scenario generates a higher cumulative Green GDP than the BAU and the BAU + Palm Oil scenarios (see **Figure 8**). This is caused by the gain in revenues from the decrease in peatland emissions
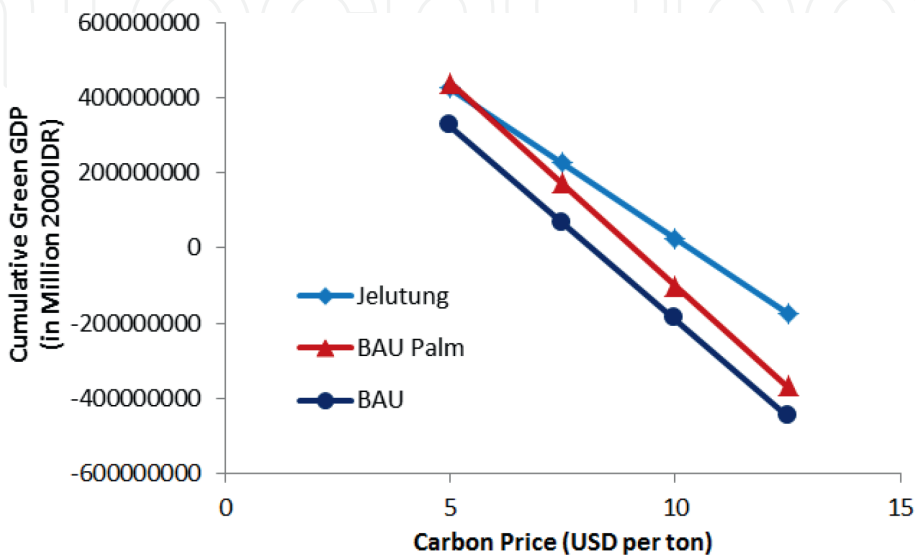
Figure 8.
The effect of the carbon price on the cumulative Green GDP in Central Kalimantan.

under the Jelutung scenario as compared to the high peatland emissions under BAU and BAU + Palm Oil scenarios.

For policy makers, this means that an increase in carbon prices will result in more favorable conditions—higher profit—for GE/Jelutung scenarios and an increase in the costs of BAU/BAU and oil Palm ones. As carbon prices increase, these results become more distinct and would encourage a change in policies. Yet, if national policy makers remain reluctant in adopting sustainable policy options with carbon pricing incentives, local government, the private sector, and local communities will not be incentivized to transition to the GE and/or the Jelutung scenario, because the profit margins remain low.

4. Conclusions

The assessment carried out with KT-GEM has pointed out that the BAU scenario and the continuation of palm oil expansion are not only best performers concerning economic profitability, but also lead to the highest variability in revenues, leading unsustainable social as well as environmental outcomes. When these outcomes are valued economically, taking a societal perspective, the BAU, and oil palm expansion are not economically viable. In fact, with increased emissions, fire and land subsidence, the BAU, and palm oil expansion scenarios will continue to cause significant economic damage to the communities of Central Kalimantan and beyond, negatively affecting the health of both Indonesian population as well as those in adjacent countries. Further, when taking land subsidence into account, expanding plantations across the peatlands is unlikely to be feasible beyond 50 years, which calls for a different approach to the utilization of the degraded peatlands.

The Jelutung and GE scenarios are less profitable than palm oil development when relying on traditional economic indicators, such as GDP. On the other hand, if the transformation of current practices into paludiculture development on peatland are coupled with strengthening market access for these products, and if the lower profitability of jelutung cultivation—and many other paludiculture species—compared to palm oil could be improved by implementing investments in jelutung across the value chain, the efficiency and profitability of jelutung production is expected to improve and it may be turned into a more viable alternative than palm oil production.

The KT-GEM Peatland model has shown that sustainable peatland management as included under the GE and Jelutung scenarios have a positive impact on Green GDP in Central Kalimantan and will be essential for achieving sustainable economic growth. Further, since the sustainable management of peatland also reduces fire risks and emissions, this scenario would contribute to the ambitions of a haze-free ASEAN by 2020 and Indonesia's emission reduction target. Indonesia has a lot to gain from restoration with paludiculture species in relation to reduced fires, health impacts, emissions, and potential for other forms of community-based development.

Despite its limitations, the KT-GEM Peatland Module and Green GDP calculations provide interesting insights for policy makers, especially in finding solutions to the fire problem and exploring policy options for peatland rehabilitation. It further demonstrates the impact of natural capital change on economic growth and supports a better understanding among policy makers that current GDP calculations are not adequate. It shows that building environmental resilience can not only maintain natural resource assets, but also lead to lower social and environmental costs.

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