The Economics of Ecosystems and Biodiversity for Agriculture and Food (TEEBAgriFood)
Indonesia – *working paper*

Agroforestry Rapid Assessment

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Executive Summary

This rapid assessment suggests that cacao agroforestry production can be sustainably intensified, increasing yields significantly without expanding cultivated area, meanwhile providing social and environmental benefits. As such, it can play an important role as an efficient land use system that can contribute to both national and community development. cacao agroforestry coupled with strategies to capture value addition in farming communities can diversify incomes and protect vulnerable small farmers from price fluctuations. cacao agroforestry using good agricultural practices provides higher levels of ecosystem services (such as soil retention and carbon sequestration) than some other types of agriculture. Policies should target practices with fewest trade-offs between increased productivity and long run impacts, and spatial planning and regulation should be implemented to transition monoculture crops to agroforestry systems and promote agroforestry as a restoration land cover in degraded areas.

Objectives of the Policy Action

1. Increasing the yields of estate crops
2. Improve the productivity of small-holder farmers
3. Add value in the agricultural value chain
4. Promote sustainable agriculture to ensure long-run livelihoods and protect provision of environmental services, which tend not to be reflected in the price of agricultural commodities

Recommended Policies

Improve cacao **yields per hectare** by:

- Promoting and incentivizing proven intercrop agroforestry systems (e.g. coconut-cacao)
- Promoting and incentivizing replacement of old and unproductive plants and using best proven density of intercrop systems

Increase the provision of knowledge and training to small-holder farmers, with sustained extension service and monitoring following the successful models of the private sector, leading to the adoption of **Good Agricultural Practices** (GAP) including:

- Appropriate type and timing of fertilizers and pesticides
- Integrated pest management
- Efficient water management
- Preventing soil erosion and building soil organic matter and soil nutrients

Conduct spatial planning of agroforestry production of agroforestry production and optimize the allocation of agri-environment measures for cacao to provide evidence on the potential trade-offs between ecosystem services, biodiversity and productivity. This includes:

- Replacing existing cropland and degraded land instead of expanding into forested areas
- Discouraging farming in areas with potential risk to water quality and biodiversity
- Providing the economic case for the viability of very small cocoa farms (<1ha) through better use of labor (such as grafting), as well as sustainability certification; together, aim to achieve positive benefit-cost ratios when environmental impacts are internalized.

Add value by:

- Increasing cacao quality (fermentation or improved varieties)
- Supporting local processing
- Supporting traceability and certification schemes

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I. Introduction

Context for this report

1. Tropical commodities such as oil palm, coconut, rubber, and cacao are a core part of the Indonesian economy and development strategy, from small-scale farmers to large agribusinesses
2. Agricultural commodities globally and in Indonesia have been a driver of deforestation and associated greenhouse gas emissions, air pollution, erosion, water pollution, and loss of biodiversity
3. Indonesia has been losing yield, labour and land productivity. The cacao sector faces challenges in terms of production efficiency, quality, price fluctuations, lack of expertise, and access to capital
4. Because of rising demand and existing investments in the value chain, Indonesia wants to boost cacao yield, add value, increase incomes and increase exports, while improving sustainability
5. cacao agroforestry has a variety of strengths, weaknesses, opportunities, and threats compared to other agricultural commodities

For the reasons highlighted above, BAPPENAS should support reform of commodity production and in particular collect evidence to inform agroforestry policies. It is consistent with the objectives of the Government of Indonesia to create coherent, effective policies to increase the yields of estate crops, improve the productivity of small-holder farmers, add value in the agricultural value chain, and promote sustainable agriculture.

Indonesia is concerned about cacao production, which has been decreasing in recent years due to a variety of factors including aging plants, pests and disease, depleted soil, and farmers transitioning farms to produce other commodities. Studies suggest that most cacao farmers operate their farms relatively inefficiently and face challenges in terms of productivity, quality, and lack of expertise and financial capital. Furthermore, despite efforts to encourage reform, the cacao sector is currently ecologically unsustainable (FAO/INRA 2016). Three core challenges are:

1. chemical use for pest & disease management is largely excessive and unregulated with potential future impacts on agrobiodiversity and farmer health;
2. soil nutrient depletion due to poor land management practices and excessive dependence on synthetic fertilizers - leads to plot abandonment and forest clearing; and
3. cacao production continues to expand into natural forests, with implications for water systems, soil erosion, landslides, biodiversity, carbon etc.

This report summarizes a rapid assessment of cacao agroforestry, which, if supported by correct policies, may offer an opportunity to increase cacao yields significantly without expanding cultivated area, meanwhile providing social and environmental benefits. The research was focused on determining if and how cacao agroforestry can play a role as an efficient land use system that contributes to both national and community development. The report considers the entire value chain, i.e. not just on-farm yields and on-farm sustainability but also the potential to improve value-added and livelihood outcomes, and to reduce biodiversity impacts, across the value chain.

TEEBAgriFood

TEEB for Agriculture & Food (TEEBAgriFood), an initiative hosted by the United Nations Environment Programme (UNEP), provides a framework and technical assistance for evaluating all visible and invisible impacts of agriculture & food systems. The TEEBAgriFood Framework is a tool to evaluate or acquire scientific evidence to support policy making, such as BAPPENAS development plan for sustainable agricultural commodities. Indonesia has an opportunity to implement TEEBAgriFood, to promote biodiversity and sustainability in the agriculture and food sector through agro-ecological research and economic valuation.

II. Methods

This rapid assessment follows an internationally agreed methodological framework - the TEEBAgriFood Evaluation Framework - which provides a comprehensive and universal approach to capture all the positive and negative impacts and externalities across the entire agri-food value chain. The TEEB AgriFood Evaluation Framework therefore contributes to a new more holistic, multi-dimensional, systems-thinking paradigm. The analysis in the current project will provide an example for future evaluations to support food and agriculture policies in Indonesia.

Justification: measuring what matters in agriculture & food systems

Developing policies to create sustainable and equitable food systems requires understanding the vast and interrelated complex of ecosystems, agricultural lands, pastures, inland fisheries, labor, infrastructure, technology, policies, regulations, institutions (including those involved in making policies, framing regulations and providing markets), cultures and traditions that are involved in growing, processing, distributing and consuming food. Evaluating such complexity with (for example) a yardstick as narrow as "per-hectare productivity" of a single crop might appear naïve, and yet dominates the discourse on food systems. Per hectare productivity *remains important*, but it is not the sole metric we should rely on or try to maximize if we are interested in improving sustainable livelihoods.

Moving from per hectare productivity as a single metric to multiple metrics associated with eco-agri-food systems may appear challenging. It is. But equally it is *necessary.* Further, TEEBAgriFood has developed an Evaluation Framework that allows us to do just that, a Framework that the TEEB Office is applying in more than 15 countries to stimulate concrete policy uptake to improve livelihoods and biodiversity outcomes. This Evaluation Framework, which may use a combination of many methodological approaches to assessment, lies at the heart of TEEBAgriFood implementation.

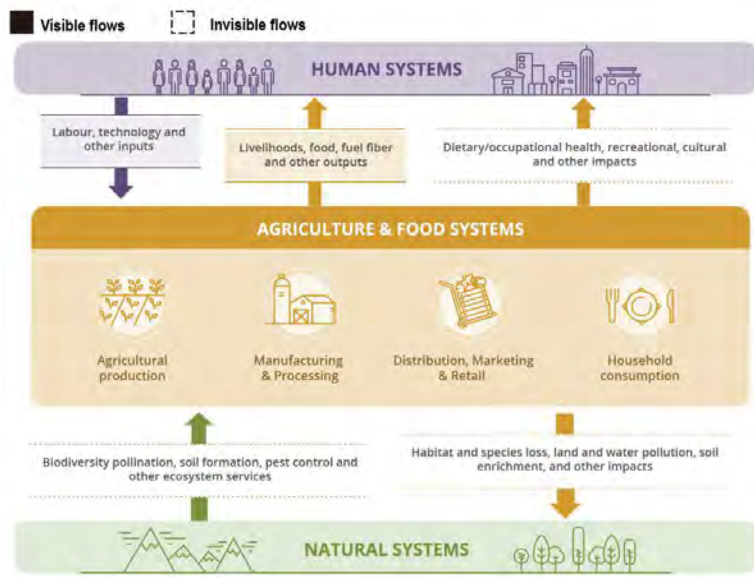


Figure 1: Diagram of visible and invisible inputs and outputs along the value chain of food systems (TEEB, 2018).

Combining multiple methods for gathering evidence

Implementing the TEEBAgriFood Framework and generating defensible, scientific evidence for the many visible and invisible impacts and dependencies of food systems requires combining many assessment methods and modelling tools.

This rapid assessment uses literature review, stakeholder consultation, spatial modelling of ecosystem services, and Life Cycle Assessment (LCA) to evaluate the impacts and dependencies in the cocoa value chain and arrive at the recommendations contained herein. The literature review focuses primarily on peer-reviewed scientific literature that evaluate agroforestry and cocoa value chains around the world. It also includes recommendations from Indonesian based cacao stakeholders.

Human benefits from natural ecosystem functions, called Ecosystem Services, are mapped by combining maps of land cover with information about the attributes of the land cover and use using modelling tools and geographic information systems (GIS). The spatial analysis (section IV) has been conducted by the World Conservation Monitoring Center (WCMC https://www.unep-wcmc.org/), using globally available biodiversity databases and modelled climatic suitability for cacao from the International Center for Tropical Agriculture (CIAT https://ciat.cgiar.org/). Ecosystem services modelers used WaterWorld and Co$ting Nature, web based model tools developed to facilitate spatial analysis of ecosystem services from relatively few data inputs (http://www.policysupport.org/home).

LCA is a “Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle”, as defined by ISO 14040/44:2006. These standards also have been adopted by Indonesian Standardization Body (BSN) in 2016 and 2017 respectively. Currently LCA have expanded into environmental LCA, social LCA and Life Cycle Costing (LCC). LCA consists of four iterative steps i.e. goal and scope definition, inventory analysis, impact assessment and interpretation. In addition to environmental impact assessment, social life cycle assessment (S-LCA) evaluates both potential and negative impacts of products toward social and sociological aspects along its life cycle. There are four main stakeholder groups in social LCA that can be considered, e.g. workers, users, local communities and small-scale entrepreneurs.

To promote sustainability, apart from the final products, stakeholders also play an important role in the life cycle of a product. The social aspects of a product life cycle may have a direct or indirect impact on the various stakeholder groups involved in the life cycle of a product. Consequently, this calls for social impact assessment in connection with certain stakeholder groups. One of the challenges is to make product social impacts visible and measurable throughout the value chain. The ultimate goal of social life cycle assessment (S-LCA) is to systematically identify the social conditions of a given product and promote improvement opportunities (Indrane, 2017).

Social topics for workers	Social topics for local communities
1.1 Health and safety 1.2 Remuneration 1.3 Child labour 1.4 Forced labour 1.5 Discrimination 1.6 Freedom of association and collective bargaining 1.7 Work-life balance	3.1 Health and safety 3.2 Access to tangible resources 3.3 Community engagement 3.4 Employment
Social topics for users	**Social topics for small-scale entrepreneurs**
2.1 Health 2.2 Product safety 2.3 Responsible communication 2.4 Privacy 2.5 Inclusiveness 2.6 Effectiveness and comfort	4.1 Meeting basic needs 4.2 Access to services and inputs 4.3 Women's empowerment 4.4 Child labour 4.5 Health and safety 4.6 Land rights 4.7 Fair trading relationships

Figure 2: Stakeholders and social topics in social LCA.

III. Literature Review

The TEEB office conducted a rigorous review of literature that suggests that cacao agroforestry production can be sustainably intensified in order to increase yields, providing local social and economic benefits while simultaneously protecting important ecosystem services and biodiversity. This review is organized according to the recommendations made above.

1) Improve cacao yields per hectare by promoting and incentivizing proven intercrop agroforestry systems, while encouraging farmers to replace/rejuvenate old and unproductive cacao plants;

Full-sun monocrop cacao cultivations have proven to increase short-term yields, making the approach attractive to small scale farmers to implement in hope of high cash-crop returns (Abou Rajab et al. 2016, Schneider et al. 2016). Most cacao plantations in Indonesia therefore are grown under full-sun or light shade conditions (ca 70% of plantations in Sulawesi), and there is an ongoing trend to remove shade trees. However, full-sun plantations require more inputs as physiological stress increases alongside the susceptibility of pests and diseases, which risks jeopardizing the future productive potential of the farmers' cacao stock (Clough et al. 2009). The intensification of cacao production systems though shade removal i.e. intensive mono-cropping full sun systems, therefore reduces the crop's ecological resilience just at a time when resilience is imperative due to increasing environmental changes and climate extremes (Schneider et al. 2016).

Crop intensification typically has negative consequences for associated biodiversity but **introducing shade trees** into cacao plantations has been proposed as a possible solution to the compound challenges of expanding sustainable cacao production, preventing deforestation, and securing against the boom and bust cycles that have plagued cacao cultivation during the past century (Ruf, 2011). Benefits range from higher long-term yields, biodiversity and ecosystem services conservation, climate change mitigation and improved farmer livelihoods (Schroth et al. 2015, Sonwa et al. 2018, Vaast and Somarriba, 2014).

Experts have recommended developing diverse and structurally complex canopy layers in agroforestry systems that combine native and exotic species in order to cultivate legumes for soil fertility enhancement and to provide increased climate change mitigation by introducing trees with high timber or carbon sequestration values (Abou Rajab et al. 2016, Mortimer et al. 2017, Vaast and Somarriba, 2014, Vandermeer, 2011). Diverse agroforestry systems also provide increased landscape connectivity and therefore allow for a higher level of biodiversity in both planted and natural areas, in comparison to conventional plantations (Beenhouwer et al. 2013). In addition to maintaining biological control through high levels of animal and plant diversity, including pest-feeding species, it has been suggested to introduce non-native tree species to act as natural barriers stopping pests and diseases from spreading from one cacao field to another (Vaast and Somarriba, 2014). Furthermore, studies have illustrated that agroforestry systems can improve nutrient cycling processes, accelerate decomposition, reduce the exposure to drought and physical stress, enhance soil productivity and minimize soil erosion which all help contribute to an increased productive lifetime of the cacao trees (Abou Rajab et al. 2016, Jose, 2009, Wartenberg et al. 2019).

Implementing shade trees into cacao plantations might produce lower annual yields per hectare but does ensure more stable yields and is therefore considered a more productive method in the long-term. In addition to environmental benefits, agroforestry systems can also offer socio-economic benefits through increased income security to farmers from intercropped species such as timber, fruit or other marketable goods. In this way, when illness strikes or when cacao prices drop, the intercropped species can provide additional income to the farmers through diversified revenues that are better shielded from fluctuating cacao prices (Abou et al. 2016, Vaast and Somarriba, 2014).

A recent study found that **shade trees** had a positive net effect on soil fertility, a negative effect on cacao tree growth, and lastly that the cacao yields were not significantly affected. The conclusion of the study was that including shade trees into cacao plantations is a viable approach to increasing sustainability measures, especially when shade trees are planted at low densities (Wartenberg et al. 2019). However, some species of shade trees compete with other crops for light, water and nutrients, creating trade-offs that are difficult to measure. Shade tree species that do not compete directly with cacao should therefore be selected, and for this, further agronomic research may be required. The most common intercropped shade trees in Sulawesi are gliricidia, rambutan, langsat, durian, jackfruit, jabon, guava, mango, petai, coconut and gmelina (ibid) intercrop tree species. Studies have revealed that one of the most successful types of **intercrop** is coconut-cacao, illustrating lower environmental impacts than in cacao monocultures and in cacao-rubber agroforestry systems in terms of global warming, acidification and eutrophication, as well as highest yields due to improved conditions for stimulated plant growth (Utomo et al. 2016). As such, coconut can help improve the efficiency of land use and sunlight and therefore maximize space with a lower impact than other comparable systems. Intercropping cacao with coconut could offer income diversification for small farmers, although research finds that the high cost of processing coconuts into copra result in small profit margins (Adam et al. 2017, Utomo et al. 2016).

Cacao plants are only productive for a maximum of 25 years. Between 1990 and 2000, a cacao planting boom took place in Indonesia, meaning that by 2015, many cacao trees began approaching the end of their productive life and productivity levels started to decline. Older cacao plants are also more susceptible to pests and diseases, and with the high price volatility of cacao, many farmers choose to convert their plantations into other commodities with higher income prospects (Nasution et al. 2019). In addition, many growers are older (38% over 50 years), revealing an apparent lack of interest in growing cacao, presumably linked to the high labor intensity of the crop, the fact that cacao typically is not the primary source of farmer income but is rather seen as a security crop, and the temptation of converting to other more lucrative and profitable crops such as coconut or palm oil (Daymond et al. 2017).

Experts recommend **rehabilitating** existing plantations rather than abandoning old plantations, as abandoned plots can lead to increased fire threats and expansion into natural forests causing further deforestation. Failure to sustain cacao production in current cultivation areas would presumably entail a shift to new areas such as West Sumatra and Papua which would involve accelerated deforestation (Clough et al. 2009). As pests and diseases represent major challenges to cacao production, experts frequently stress the importance of using superior genotypes with increased resistance levels, as they can help reduce the occurrence of pests and diseases and contribute to boosting cacao yields (Cilas et al. 2018, Vaast and Somarriba 2014).

Rejuvenating cacao plots through various grafting techniques has also been recommended, in order to increase the production of older cacao plants and ensure the genetics of seedlings. Grafting also allows the host tree to continue producing cacao beans during the time required for the graft to develop into a pod-producing branch (Moriarty et al. 2014). Grafting techniques are growing in popularity as replacing old, unproductive cacao plantations with resistant varieties is relatively expensive and requires both experience and knowledge. Decreasing yields and ecological instability from unshaded plantations are intensifying just as the next farmer generation begin taking over the cacao farms (Clough et al. 2009). Therefore, providing farmers with knowledge and training is fundamental to the sustainable future of the Indonesian cacao industry.

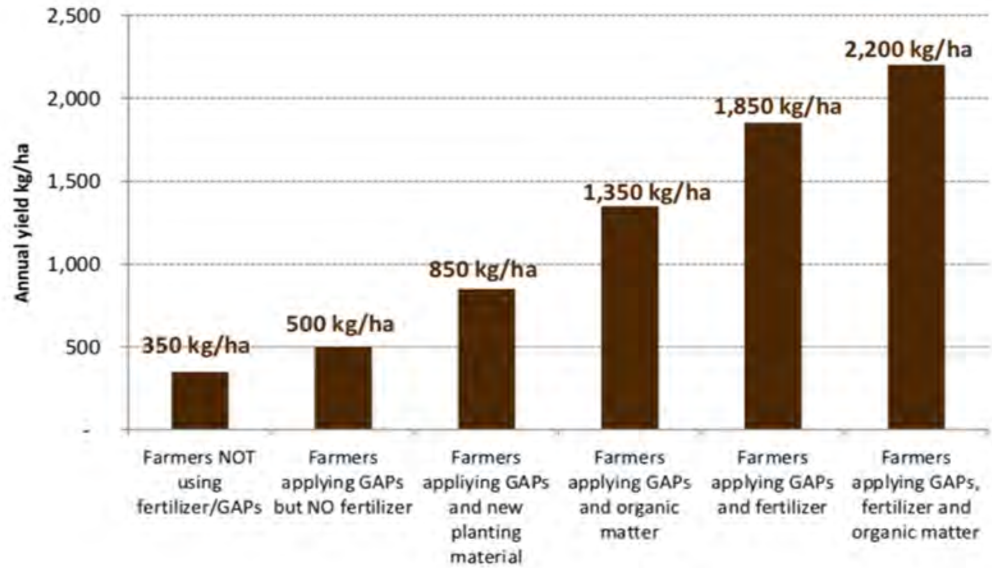
2) Increase the provision of knowledge and training to small-holder farmers, leading to the adoption of Good Agricultural Practices (GAPs):

Global cacao demand has been growing steadily during the past decades, particularly in emerging markets like Asia, and in response, the industry has been promoting the intensification of cacao cultivation to be able to meet demands (Blommer, 2011). The overarching dilemma in the cacao sector currently, therefore, is how to increase production in a sustainable way in order to meet a growing demand, without expanding the cacao cultivation area. A multitude of efforts from the Indonesian government, the private sector, NGOs, development organisations, researchers etc. have all through different initiatives aimed at increasing cacao yields while ensuring long-term sustainability and farmer income through improved farming practices. For instance, a tax on exporting unprocessed cacao beans was introduced in 2010 to incentivize the export of value-added processed cacao. A national program was recently launched to boost cacao bean production to 600 000 tons by 2024. However, there has been limited progress overall over the last decade in terms of farmers adopting recommended practices, suggesting that new interventions and technical innovations are needed to be able to intensify production in today's producing regions, interventions and innovations that are tailored towards small, family-managed cacao farms. It appears that relying on researchers' ideas of appropriate technologies alone is insufficient in terms of encouraging adaptation from farmers and that "bottom-up" interventions are needed (FAO/INRA 2016). Inappropriate intensification practices could result in an increased usage of more intense and less environmentally friendly inputs, and/or the replacement of cacao with other agricultural crops.

Accordingly, challenges have arisen in the Indonesian cacao sector due to a multitude of reasons, many of which seem to have occurred due to the nature of the sector being predominantly small scale with limited government involvement or formal education. Farmers take example of neighbouring farmer practices, which are not necessarily the recommended best practices (Clough et al. 2009). Studies have illustrated that there are large variations in yield per hectare and in bean quality between both farms and islands in Indonesia, and that the declines in quality are primarily related to inappropriate agricultural practices concerning shade and water management, use of pesticides and fertilizers, plant density and age, soil fertility, loss from animals and the occurrence of pests and diseases (e.g. cocoa stem borer and cocoa black pod disease). Chemical use for pest and disease management is to a large extent excessive and unregulated, and despite limited evidence of negative long-term impacts, it is likely that the excessive reliance on synthetic fertilizers has environmental and human health effects (FAO/INRA, 2016). Poor land management practices have led to consequences including soil nutrient depletion and the loss of organic matter from farms which in turn has led to plot abandonment and further forest clearing (Gockowski et al. 2013). Continued deforestation undeniably has implications for water systems, biodiversity conservation, soil erosion and carbon storage, as well as possible long-term impacts on societal wellbeing (FAO/INRA 2016).

For the cacao crop to remain competitive in comparison to other crops, therefore, it must be highly productive and provide sufficient income to farmers. Cacao can be profitable and of high quality under the right conditions and as such, farmers must be made aware of how to facilitate this through various management techniques. Hence, providing farmers with the **appropriate knowledge on good agricultural practices (GAPs)** is critical. Farmer field schools (FFS) and cacao development centres (CDCs) have been used by various bodies in Indonesia, as a group-based learning program merging concepts, methods and techniques from various constituencies to explain the reasons behind yield losses and help farmers learn about GAPs. GAPs can include management techniques on the dosage and timing of fertilizer and pesticide application, pruning practices, harvesting and sanitation methods, shade tree management and more. It has been estimated that when implementing GAPs by using appropriate types and amounts of fertilizers (organic and inorganic) and pesticides, compost, planting materials etc., yields could increase significantly (NewForesight, 2013). NewForesight Consultancy conducted a study in 2013 upon request from the Cacao Sustainability Partnership (CSP) to deliver a roadmap towards a future sustainable Indonesian cacao sector in 2020 (NewForesight, 2013). The roadmap was built around the 2020 Targets for the Indonesian cacao sector, as formulated by CSP members. They believed that the Indonesian cacao sector could become viable and profitable again if farmers doubled their productivity and improved the quality of their cacao in a sustainable way. They predicted that if farmers implemented GAPs, quality inputs and high-quality planting material, sustainable development could be achieved as well as an opportunity for farmers to make a competitive profit which in turn would attract the next generation of cacao farmers. These GAPs would cover the appropriate use of agro-inputs and planting materials, business and management skills, nursery management, pests and disease management, rehabilitation-, replantation- and grafting techniques, post-harvest product management and shade tree management.

Consequently, the main recommendations from their roadmap findings involved two interrelated components. The first, "Professional Farmer Package", involved increasing the appropriate use of higher quality agro-inputs and planting materials at scale, in combination with teaching farmers about



GAPs, financial management and farmer organization. The second component, "Enabling Environment", involved various modes of delivery and organization for the adoption of agro-inputs and knowledge, access to financial resources including various models for agri-finance and the roles of banks and value-chain partners, as well as the role of the government. According to the study, all farmers should implement basic GAPs as doing so could lead to significantly increased yields without colossal financial investments or environmental pressures (Figure 3 and Figure 4). In addition, training farmers in business management skills would enable them to understand the business case for productive cacao farms and act accordingly, which in turn, would reveal the potential investments needed to increase the efficiency and productivity of their cacao farms. The study argued that the average Indonesian farmer that refrains from implementing any kind of GAPs or inputs, tend to have very low yields (ca 350 kg/ha) and that trees become increasingly susceptible to pests and diseases, whereas if GAPs are implemented, including appropriate fertilizer use and improved cacao varieties, yields could potentially increase to as much as 2200 kg/ha, in areas with optimal growing conditions (NewForesight, 2013).

Figure 3: Estimated income of a 1 ha farm on an average year (no rehabilitation costs).
(NewForesight, 2013: 5).

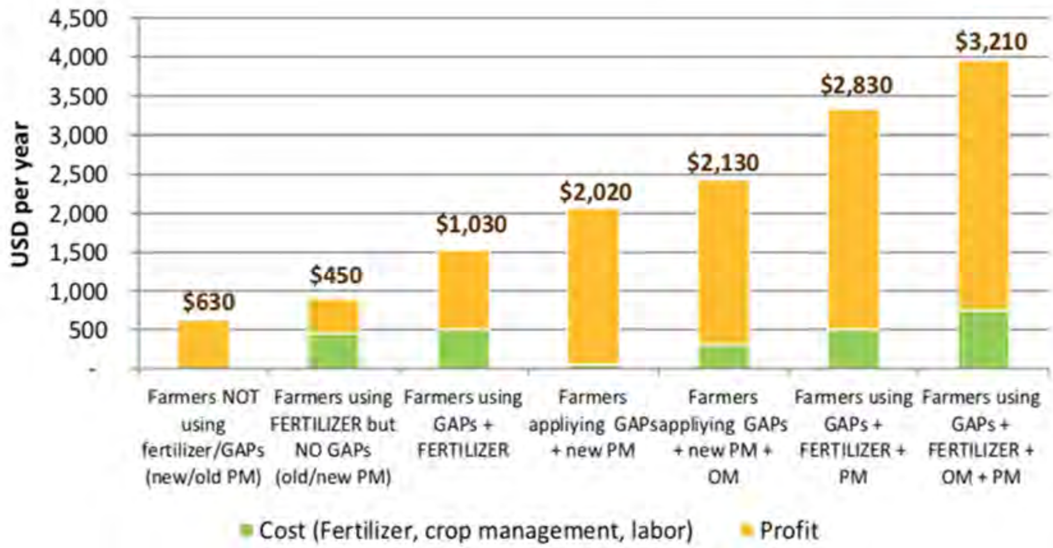


Figure 4: Projected yields according to inputs and management (NewForesight, 2013: 51).

Accordingly, by informing farmers, they can gain skills to make informed decisions, solve problems and develop future business plans, to be able to develop sustainable agricultural practices while generating larger incomes (NewForesight, 2013, Moriarty et al. 2014). Effective and impactful schemes are needed not only to improve farming and land use planning and practices through GAPs, but also to provide farmers with information on natural resource management, biodiversity conservation, and to encourage safer working conditions and improved storage, handling and disposal of agrochemicals. Studies have also suggested that sustainable cacao development should be closely linked to community development programs, as enhancing the capabilities of farmer communities can help farmers collectively carry out actions to add value and improve marketing processes etc. with increased long-term resilience and performance (Nugraha et al. 2019). It is thus important to include farmers in the decision-making process so that their local knowledge as well as their aspirations and goals can be taken into consideration in the management and planning of the system (Anglaaere et al. 2011).

In summary, studies such as the above-mentioned report conducted by NewForesight, and other sustainability initiatives developed by different stakeholders (e.g. SwissContact's training guidelines in their Sustainable cocoa Production Program), could function as a set of comprehensive guidelines to train farmers in GAPs, boost financial returns and sustainably intensify cacao production.

3) Analyzing the economic viability of very small cacao farms

An important consideration for agroforestry policies is the profitability of very small farms. In contrast to other tropical commodities such as rubber and palm oil that are cultivated by large plantations, the majority of cacao production occurs on small-holder farms. In 2016, 97% of cacao production in Indonesia occurred on smallholder plantations (Nasution et al. 2019). Indonesia cacao farms in particular are relatively small, the average size of an Indonesian cacao farm 0.7 hectares is less than half the size of African cacao farms (Daymond et al. 2017). Facing perennial global competition and limited market power, commodity producers depend upon economies of scale to survive amidst small profit margins and price fluctuations. In short, it is challenging to make very small commodity farms economically viable. *The benefits of agroforestry are not short-run profit maximization, but rather* *income security and food security, sustaining long-run production by reducing soil depletion, minimizing input costs, and decreasing pesticide, fungicide, and fertilizer pollution*. Less-input intensive agroforestry systems are a *land sharing* strategy rather than a *land sparing* activity, and as such may be better suited to larger farms and/or as a corridor land use between or around protected forest.

A recent study by Nasution et al. (2019) found that in North Sumatra many small cacao farms in recent years have transitioned to growing palm oil because net farm incomes are higher. However, because cacao farming is labor intensive but not input intensive, the study found that the revenue to cost ratio is higher for cacao farming. This means that farmers with limited land and financial resources, despite these limitations, could still increase incomes in cacao farming through better use of labor through activities such as grafting (Nasution et al. 2019). Small cacao farms may also be well suited for sustainability certification, which has shown positive benefit-cost ratios when environmental impacts are internalized (van Beukering, Kuik, and van Drunen, 2014). The value added from certification is multiplied in the processing and manufacturing components of the value chain, adding further incentive to invest in those downstream activities.

IV. Spatial Assessment

1) Conduct spatial planning of agroforestry production to maximize benefits

There are many important spatial dimensions to cacao farming, including the total land area used, the size of cacao farms, where cultivation is currently occuring, where cacao production has expanded or contracted in recent years, and where cultivation could and should or should not occur in the future. These spatial dimensions, and more importantly the impact of these dimensions upon communities, households, and their environment should be considered in the development of agroforestry policies. The multiple spatial dimensions of food production are often neglected in favor of simpler measures of yield per hectare. TEEBAgriFood has argued that yield per hectare is not the best measure by which to evaluate a farming sector (TEEB, 2018). Instead, multiple diverse measures of the wellbeing of farmers and wellbeing of farming communities should be evaluated simultaneously.

For example, a TEEBAgriFood study of agroforestry systems in Africa highlighted the food security benefits of agroforestry systems in contrast to intensive, “high tech” production systems (Namirembe et al. 2015). At first glance one can see that the high-tech systems produced more cacao per hectare, but this does not mean high tech farmers are better off than agroforestry farmers. The sum of many food products produced by agroforestry systems was much higher than the value of cacao output from high tech systems (Figure 5) when subtracting the high input costs of the intensive systems (Figure 6). High tech and full sun systems often require external inputs that are too costly for the predominantly smallholder farmers producing cacao.

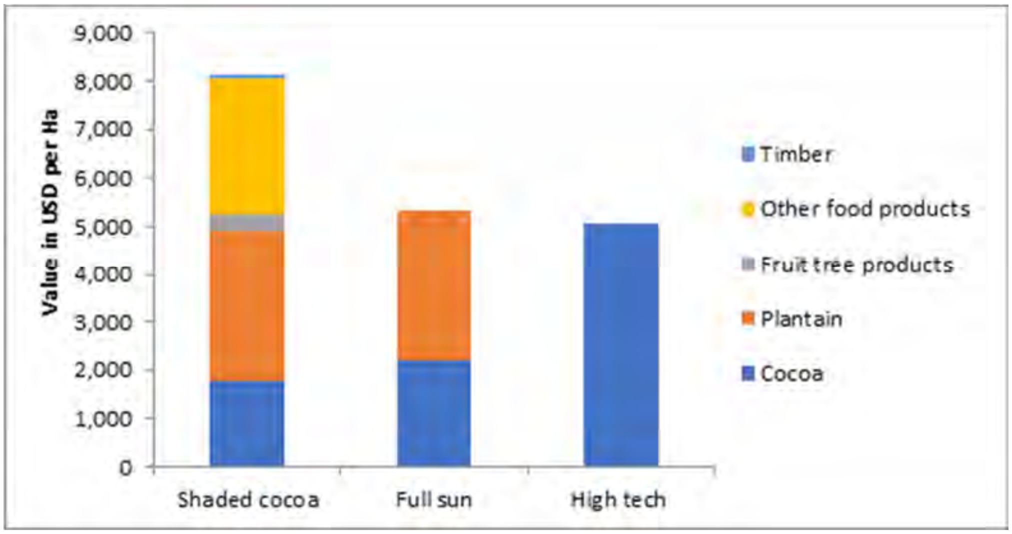


Figure 5: A comparison of the agricultural and food outputs among the three cacao production systems in Ghana (Namirembe et al. 2015).

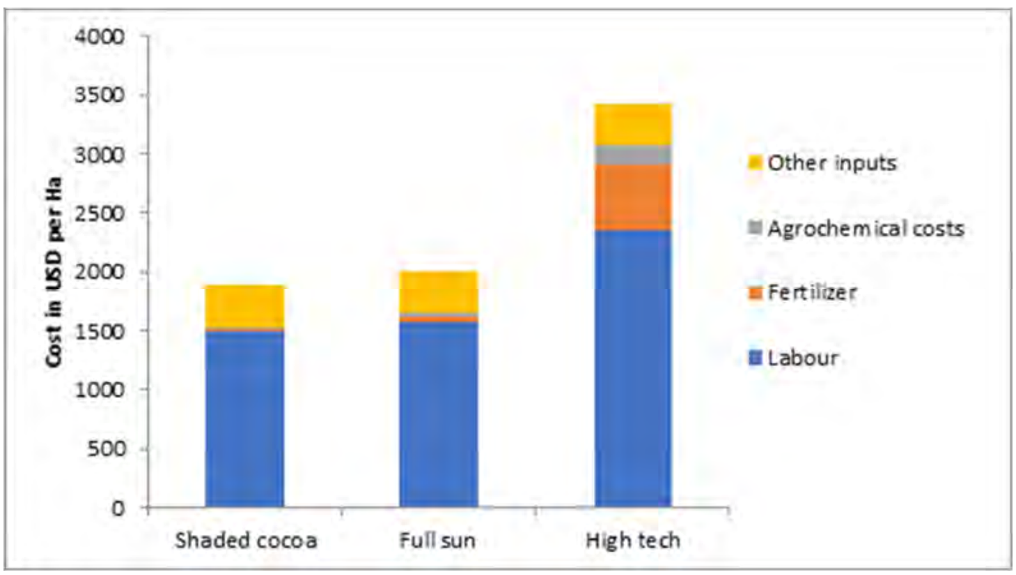


Figure 6: A comparison of input costs in the cacao production by cacao system (Namirembe et al. 2015).

There are also a variety of non-market ecosystem goods and services that can be produced by agricultural ecosystems ("agro-ecosystems"), including carbon sequestration, water regulation, biodiversity habitat, erosion control, and soil nutrient cycling. These goods and services offer tangible benefits to cacao farming communities and to the country of Indonesia. For example, soil fertility, achieved through decomposition of organic matter in an agroforestry system, can boost cacao yields providing direct benefits to farmers (Barrios et al. 2012). Agroforestry systems can also capture and store carbon dioxide from the atmosphere, helping Indonesia contribute to climate regulation globally. Although this may not have a local benefit to farmers, it is a measurable benefit of agroforestry systems that should be valued by policy makers. The value of these non-market goods and services should be recognized in addition to the profitability of the agro-ecosystem. It should be noted that there are trade-offs between yield, climate change mitigation and other services, but at the farm level these trade-offs can be optimised at intermediate levels of shade cover (Blaser et al. 2018).

The total value of ecosystem services may be irrelevant – policy makers need to know how impacts vary between potential scenarios, such as agroforestry compared to monoculture cacao, or monoculture cacao compared to monoculture palm or rubber. In other words, ecosystem services need to be measured relative to a counterfactual scenario. The single most important factor influencing the value of ecosystem services throughout the value chain of commodity production is the location where production occurs and what land cover it is displacing (van Beukering, Kuik, and van Drunen, 2014).

To measure these services researchers must model landscapes and compare scenarios of land cover and land use practices. The World Conservation Monitoring Centre, in collaboration with the International Center for Tropical Agriculture (CIAT), have made a preliminary assessment of ecosystem services in Indonesia with a focus on potential cacao growing regions now and under a changing climate.

Climate change is likely to strongly reduce the cocoa production potential in the main cocoa growing area of Indonesia, Sulawesi (Bunn et al. 2017). This means that cocoa farmers may expand into new areas that will remain suitable for cocoa, such as forested area on Sulawesi and elsewhere. If Indonesia aims to maintain the total area currently under cultivation then geographical diversification may be necessary. Assuming that, without any restrictions, most cocoa expansion takes place into (secondary) forest areas, we explored where such areas may be available currently and under a future climate. Alternatively, geographical diversification of cacao production could be planned for and incentivised in other areas, such as currently degraded areas or other plantation crops where this conversion might offer greater ecosystem services benefits than converting forests. This should be accompanied by support and incentives to farmers to improve productivity (Figure 7).

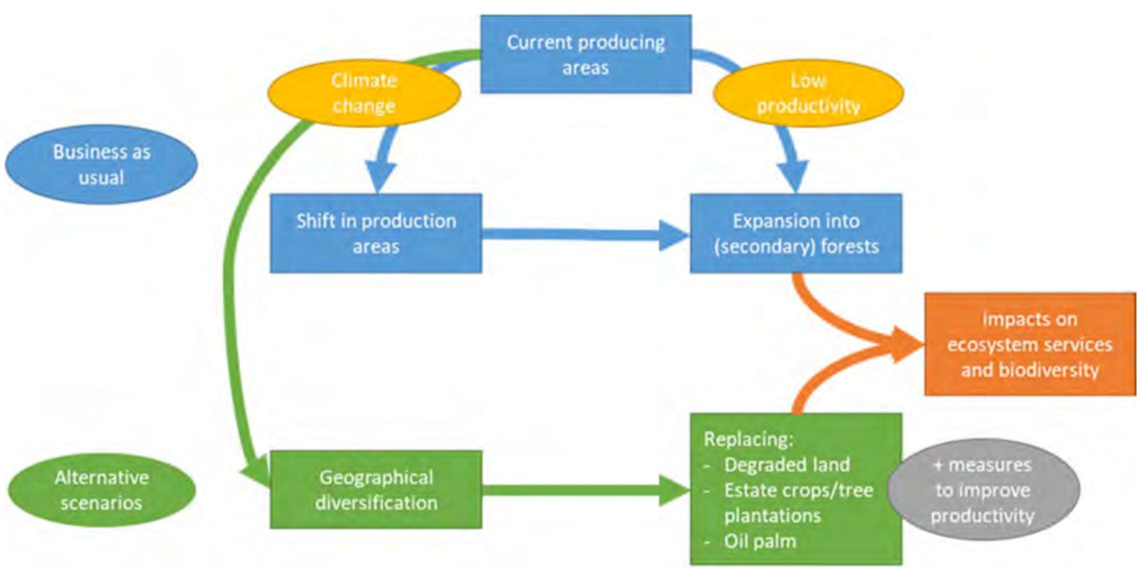


Figure 7: Business as usual and alternative scenarios overview for this study. Low productivity leads to expansion into forests locally, whilst climate change may lead to shifts between regions. This can happen either in (secondary) forests (business as usual scenario) or as a replacement of other land uses (alternative scenarios).

Because maps of agroforestry cocoa land cover have not been produced for all of Indonesia, we analyse the ecosystem services of agroforestry in general. More detailed land cover data is required to compare differences between estate crops grown in agroforestry systems, but this rapid assessment highlights areas where cacao expansion could offer the greatest benefits and where it poses the greatest threat to ecosystem services.

2) Spatial context for cacao in Indonesia

2.1. Land cover and climatic suitability for cacao maps for Indonesia

The land cover map for Indonesia (Figure 8) was created using data from Indonesia's Ministry of Environment and Forestry for the year 2017, obtained from Global Forest Watch (GFW, 2017). Spatial data on agroforestry or cacao specifically was not available within the land cover dataset. Data on forest management, which includes agroforestry and plantation crops is however in preparation through the Naturemap project (Lesiv et al. in prep.) and will become available in the near future.

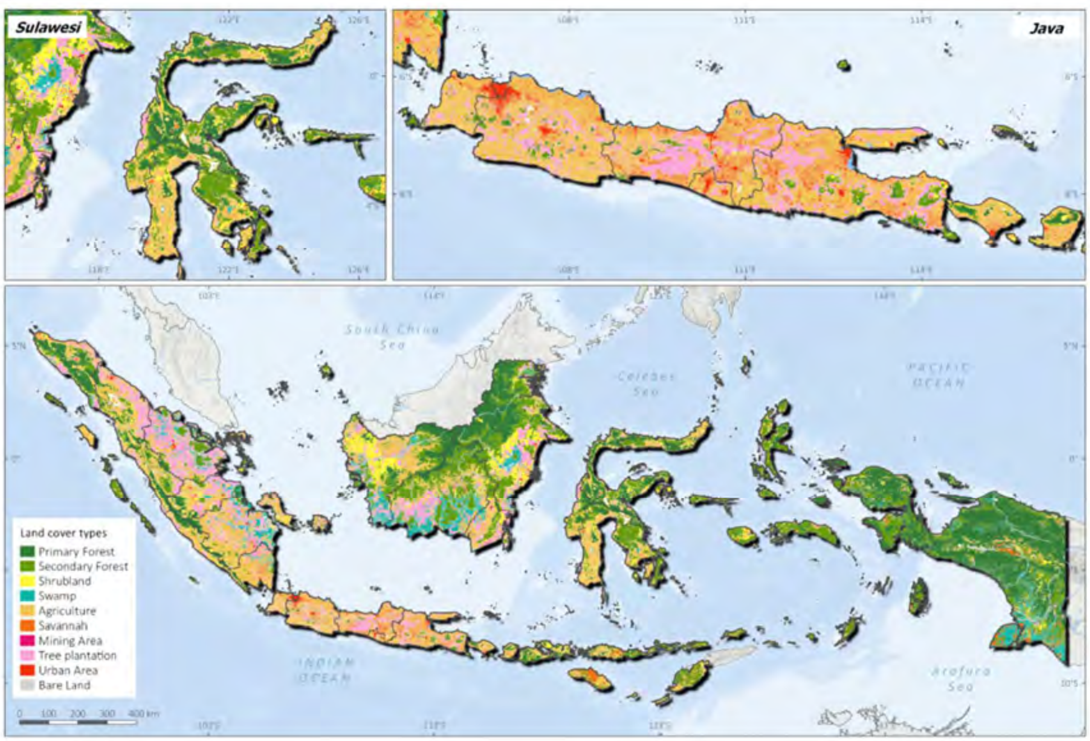


Figure 8: Land cover map of Indonesia (data source: Ministry of Environment & Forestry, 2017 obtained from GFW (2017).

Cacao is currently grown mostly in Sulawesi, though there is a large production area in Sumatra as well (Table 1).

Table 1: Cacao area and production in Indonesia. Total area of cacao in Indonesia is estimated at almost 17,000 km2 (source: Machmud 2014).

Province	Production (tons)	Area (km2)

Sulawesi	523,356	9,939.8
Sumatra	146,946	4,137.1
Maluku & Papua	39,583	119.0
Java	39,133	945.3
Nusa Tanggara & Bali	17,468	784.2
Kalimantan	11,053	367.9

The map in Figure 9 shows the distribution of climate zones that are characteristic of areas where cacao is currently grown in Indonesia (purple colour) and climate zones that are considered potentially suitable for cacao in terms of climate (orange colour, based on data from Bunn et al. (2017). These latter areas are often lowland areas, where temperatures are higher than in areas where currently most cacao is grown.

Most of Sumatra, Papua and Sulawesi are likely to be suitable for cacao production under current climatic conditions. Kalimantan and Java were found to be partially suitable.

Figure 9: Current distribution of cacao climate zones in Indonesia (adapted from data by Bunn et al. 2017).

The map in Figure 10 shows the modelled distribution of climate zones for cacao in Indonesia in 2050 (RCP 6.0 scenario, Masui et al. 2011), based on data from Bunn et al. (2017). The model used a combination of 19 GCMs, using downscaled scenario data from WorldClim (Hijmans et al. 2005). This map shows a change in the characteristics of the cacao climate zones. Precipitation under this scenario is projected to increase with around 10 mm/yr. Mean annual temperature is projected to increase by 1.1 deg C. The current cacao climates (purple colour) almost disappears, and the climate areas available for cacao will be mainly those that were classified as "potential" under current climatic conditions (see Figure 9). On Sulawesi (and also Sumatra), there seems to be a large loss of suitable areas (white areas). The impact of temperatures on cacao are not straightforward and there is still some uncertainty in the models. However, the results show that it is important to consider the potential impacts of future climate change when devising policy on the development of cacao production in Indonesia. Different coping strategies might include transformation out of cacao, adaptation or expansion into newly suitable areas. These strategies will have different impacts on the environment, the ecosystem services it provides and farmer livelihoods.

For example, we found that areas that are potentially suitable for cacao in 2050 on Sumatra are currently oil palm. In light of the findings by Nasution et al. (2019) that, although palm farms earn greater net revenue, the revenue to cost ratio is higher for cacao farming than for oil palm, especially for small farms, this poses the question: would it be sensible to seek to promote cacao agroforestry in areas that are now (smallholder) oil palm? This would depend on a careful consideration of the gains and losses in terms of ecosystem services, livelihoods, resilience to further climate change etc.

Figure 10: 2050s distribution of climate zones for cacao in Indonesia in the RCP 6.0 scenario. Modal classification across 19 GCMs. Climatic areas where most cacao is currently grown (purple) almost disappear, but potential cacao climates expand.

2.2. Spatial planning: mapping biodiversity, carbon stocks and sequestration, erosion risk and water quality

Biodiversity

The maps below show two spatially explicit measures of biodiversity: a biodiversity significance index, based on rarity-weighted richness and a biodiversity intactness index. The maps allow the identification of important biodiversity areas which may be at risk of being converted to cacao plantations, given that they are located in climatically suitable areas and are not currently protected. They are mapped for the country as a whole (Appendix 4.1 map 1 and map 2) as well as only for natural habitat areas in areas currently suitable, in terms of climate, for cacao (Figures 11 and 12).

The biodiversity significance index is a weighted (by endemism-so smaller range species get higher weight) index based on refining species ranges from IUCN red list data (mammals, amphibians, birds) (IUCN, 2017) using species specific habitat preferences, land cover data from the ESA Climate Change Initiative (ESA CCI, 2017) and land cover elevation data from GMTED2010 (Danielson and Gesh, 2011). Significance is based on refining by all landcover types, as opposed to Hill et al. (2019), which focuses on forest classes and forest dependent species.

We calculated biodiversity significance scores within climatically suitable areas for cacao in each scenario, with results grouped by island. Average (mean) values are shown as an indication of the risk of converting a given Km^2 area, as well as total significance to show overall risk if all areas are converted.

The approach assumes any land use change has the potential to negatively impact species. In reality, impacts would vary depending on whether the conversion is to full-sun cacao or shade-grown cacao (agroforestry). The biodiversity intactness index addresses this.

The underlying data is based on refining each species' global range using ESA CCI land cover. To account for possible discrepancies between global and national land cover data, we compared these results to those from a significance dataset based on raw IUCN ranges (i.e., not been refined by suitable land cover or elevation). Biodiversity scores show nearly identical patterns overall, apart from discrepancies in the degraded land use and monocrop replacement scenarios. This agreement suggests results are relatively robust to the choice of land cover and driven heavily by high scoring areas from hotspots of endemism.

The Biodiversity Intactness Index is based on modelled estimates of impacts to biodiversity intactness (change in the community composition of native species from a pristine baseline) caused by land use conversion. Biodiversity intactness is likely to correlate strongly with ecosystem structure and functioning. Dramatic impacts to biodiversity intactness are therefore likely to impact upon ecosystem service provision as well as ecosystem resilience. Biodiversity data was extracted from the PREDICTS database (https://data.nhm.ac.uk/) and subset to the biomes present in Indonesia. The dataset contains information on over eleven thousand sites and comprises data on approximately fifteen thousand taxa including vertebrates, invertebrates, plants and fungi.

Each sampling site recorded within the PREDICTS database includes a description of the site's land use and use intensity recorded by the data provider at the time of the survey. To produce maps of biodiversity intactness within Indonesia, the LU/UI categories in the database were matched to the categories present in the MOEF maps (Figure 8). As the MOEF maps document broad agricultural categories which do not match well with biodiversity impacts, it was necessary to augment the MOEF maps with knowledge of the distribution of specific crops, such as oil palm and rice, taken from the NatureMap project (Lesiv et al. in prep.). The final land use categories used within the models were: Primary forest, Secondary forest (lightly or non-utilised), Secondary forest (highly utilised), Plantation forest, Cropland, Grassland, Cocoa Cacao (all production methods), Cacao (monoculture), Cacaoocoa (agroforest), Rice paddy, and Oil palm plantation.

To examine the impacts of cocoa cacao production, it was assumed that current-day (baseline) cacao production within Indonesia comprises a range of production methods from high-intensity monoculture to low intensity agroforestry. Scenarios were then produced to explore how both the area selected for development, as well as the production method (monoculture or agroforestry), impact upon biodiversity.

Protected area boundaries originate from the World Database of Protected Areas (UNEP-WCMC and IUCN, 2019).

Natural habitat areas are the result of a reclassification of the Ministry of Environment and Forestry map (2017) into natural vegetation classes and artificial classes (urban areas, crops, etc.) present in climatically suitable areas for cacao (both current and potential) in present time. Protected areas are overlaid on the top, allowing to visualize which areas may be more at risk of land use conversion (Figures 11 and 12).

Indonesia is characterised by biodiversity hotspots with extremely high species richness and endemism (significance) values (Appendix 4.1 map 1); however, biodiversity is being significantly degraded by land conversion and degradation with an average loss of local biodiversity intactness of 14.45% across Indonesia. Regional differences are evident. Java shows widespread loss of biodiversity intactness throughout the island, whereas Sumatra and Kalimantan are more diverse; regions of concentrated oil palm plantations in the centre of the islands (not shown on maps) display the lowest values of intactness recorded, whereas northern regions are largely intact. There are areas of high species richness and biodiversity intactness in suitable natural areas for cocoa that are not protected (e.g. in Sulawesi, the Banda Arc, and Papua) (Figures 11 and 12). This means that they may be at risk of conversion from cocoa expansion if these areas are not protected

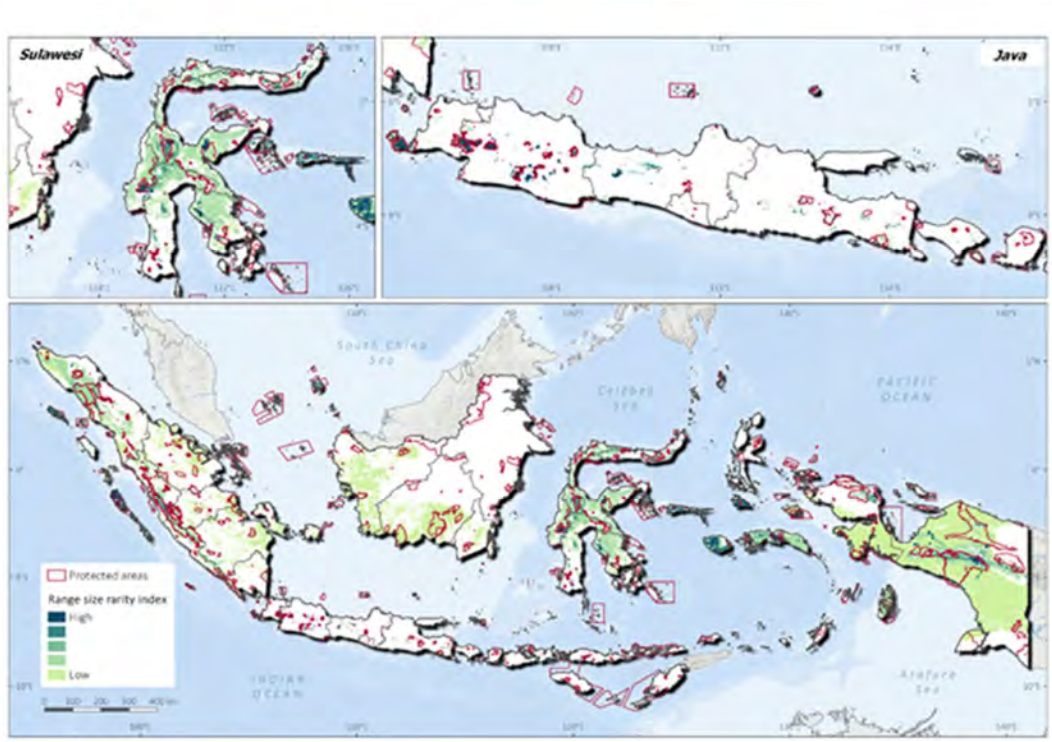


Figure 11: Rarity-weighted richness index for biodiversity in natural habitats in currently climatically suitable areas for cacao production.

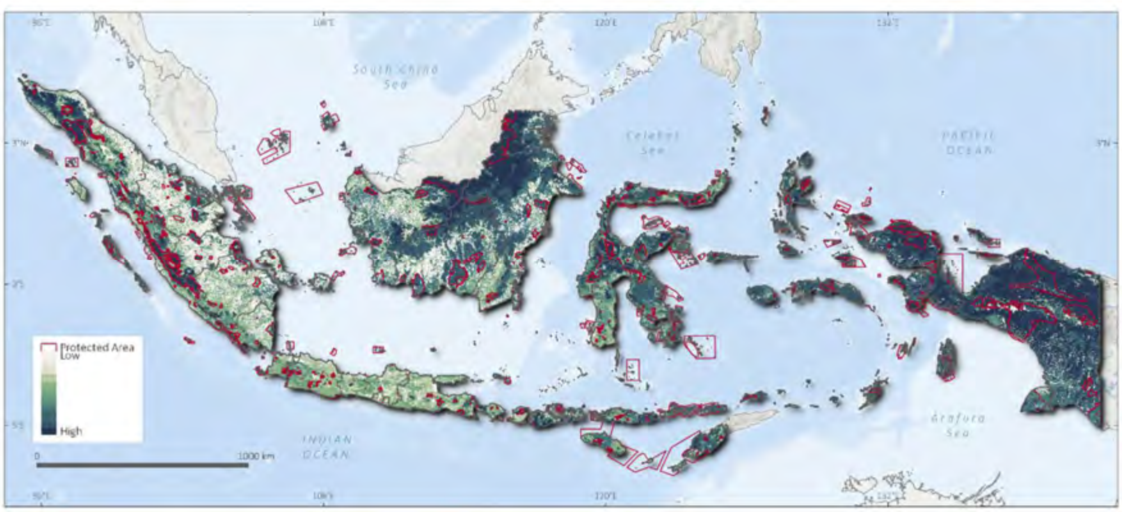


Figure 12: Biodiversity intactness map for Indonesia. Darker greens indicate areas of relatively high intactness, whereas lighter greens indicate degraded areas where the makeup of species communities has been highly altered.

Ecosystem services by land cover and use type

We used the WaterWorld and Co$tingNature web-based ecosystem services modelling tools to assess the impacts of scenarios on changes in water quality, soil erosion, carbon stock and carbon fluxes. The WaterWorld V3 model (Mulligan, 2013) was used to model water quality and soil erosion while the Co$tingNature model (Mulligan, 2015) was used for assessment of changes in carbon stock and fluxes. Both models use fractional land cover data of tree, herb and bare covers to represent land cover and use based on Copernicus 2015 data (Buchhorn et al., 2020). To represent scenario conditions for sustainable cocoa production, tree cover was assumed to be a minimum of 40%.

Water quality is a metric of potential water pollution defined as the Human Footprint on water quality index. This is an index of potential pollution taking into account point (e.g. mines) and diffuse (e.g. agriculture) sources of pollution in combination with a fully distributed hydrological model using downstream routing along a hydrological network derived from the Hydrosheds (Lehner et al, 2007) digital elevation model.

Soil erosion is modelled in WaterWorld using an erosion equation according to Thornes (1990) that takes into account soil erodability, water runoff, slope and vegetation cover. Pixel based soil erosion change was calculated in mm/year and aggregated to tonnes/ha per year for sub basins based on Hydrobasins level 07 data (Linke et al., 2019).

Carbon stock includes total above and below ground stocks and were modelled with the Co$tingNature ecosystem services model based on various carbon data sets (e.g. Saatchi et al., 2011, Ruesch and Gibbs, 2004, Scharlemann et al., 2009, Baccini et al., 2012). Changes in carbon scale with changes in aboveground vegetation cover. Carbon sequestration is based on mean dry matter productivity for 2013-2018 from PROBA-V data (Mulligan, 2019).

The land cover classes for primary forest, secondary forest, plantation and cropland from the Ministry of Environment and Forestry (2017) (Figure 8) were aggregated using the same grouping as described on the GFW website:

- Primary Forest: Primary dry land forest, primary mangrove forest, primary swamp forest
- Secondary Forest: Secondary dryland forest, secondary mangrove forest, secondary swamp forest
- Plantation Forest: Plantation forest
- Cropland: Estate crop plantation, dryland agriculture, shrub-mixed dryland farm, rice field

The aggregated classes were then overlaid on the baseline ecosystem service maps (Appendix 4.2) modelled with Co$tingNature (Mulligan et al. 2010) and WaterWorld (Mulligan, 2013) and mean values for each were calculated. Figure 13 shows the mean ecosystem service delivery for each land use type. To assess the differences of ecosystem service production in different land use types spatially, the modelled ecosystem services were masked using the extent of each land cover type: primary forest, secondary forest, plantation forest and cropland (Appendix 4.2).

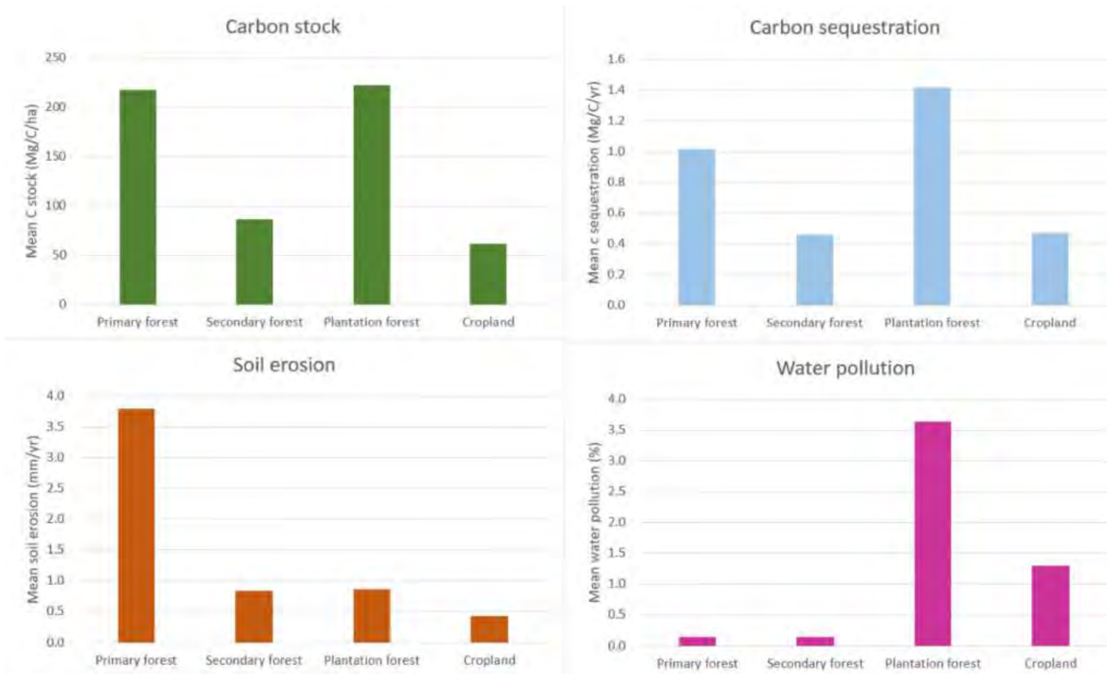


Figure 13: Mean ecosystem service delivery by land use type for four ecosystem services.

3) Scenarios for cacao expansion under current and future climate conditions

We considered different scenarios for potential cacao expansion (see also Figure 7):

- A "business as usual" type scenario where cacao would expand into secondary forests. We considered the current climate (as a baseline scenario) and the projected climate in 2050
- Three "policy on" scenarios, 1) where cacao expansion is incentivised into currently climatically suitable degraded land (and therefore also supports a land restoration strategy), 2) where cacao replaces climatically suitable areas of estate crops and plantation forests (non-oil palm), 3) where cocoa is promoted to replace oil palm in smallholder systems (in this case assumed to be oil palm outside of known established large scale oil palm plantations – recognising data limitations).

An initial exploration of the expansion of cacao agroforestry into other cropland revealed little effect at the scale of analysis used here. Areas were very small as we did not consider replacing rice (we did not think this plausible). Therefore, we did not pursue this scenario.

Within the time and data limitations of this rapid assessment we could not explore all possible options (e.g. under climate change and for different types of cocoa systems) for each scenario, but selected those that we could readily carry-out and that illustrate the need to consider different options when thinking about the future spatial planning of cocoa production in Indonesia, their potential costs and benefits for biodiversity and ecosystem services.

3.1. Cocoa expansion into secondary forests

Cacao is typically grown in forested areas, often in a system of gradual thinning and replacement of the original forest, often in secondary forest areas. We therefore assume that in the absence of drivers other than those encouraging increased production or geographical diversification farmers would in first instance expand into secondary forests. The only other driver considered in this scenario is climate change. Because most cacao is currently grown in Sulawesi and any near future expansion is likely to take place in this region, the first scenario analysis focused on Sulawesi (scenario 1). We considered expansion under current climate and future (2050) climate conditions (scenario 2). For both scenarios, expansion was constrained by cacao suitability (Bunn et al. 2017).

Research by Bunn et al. 2017 has found that climatic suitability for cacao is projected to drastically reduce in Sulawesi by 2050. We therefore also consider which other areas throughout the country have the greatest expansion potential under climate change defined here as cacao suitability under climate change overlap with secondary forest, and the costs of such a "regional diversification" in terms of biodiversity and climate change impacts (scenario 3).

<u>Scenario 1: convert secondary forest to cacao in Sulawesi and other regions under current climatic conditions</u>

Modelling results are shown in Figure 12. Water quality decreases under this scenario with a mean increase of 0.21%, although some areas see an increase in potential pollution of 33%. Water quality reduces mainly in the areas converted but do have downstream impacts, e.g. areas around the city of Kendari are not projected to be converted but river water in the Sungai Konaweha all the way to the outflow in the sea (some 100km away from the converted areas) is projected to increase in pollution by a few percent. In West and South Sulawesi this affects several rivers, e.g. the Sadang river, the Mamasa river, the Sungai Karana and a few smaller ones.

Total aboveground carbon for Sulawesi under this scenario reduces with a total of 32,129,200 tonnes. The largest changes are found in West and South East Sulawesi. Soil carbon is projected to reduce with a total of 20,781,500 tonnes for the whole of Sulawesi but mostly affecting West Sulawesi. Overall, the mean total carbon stock change is -0.26 tonnes/C/ha. Mean carbon sequestration is projected to reduce by -0.2 tonnes/C/ha/yr under this scenario.

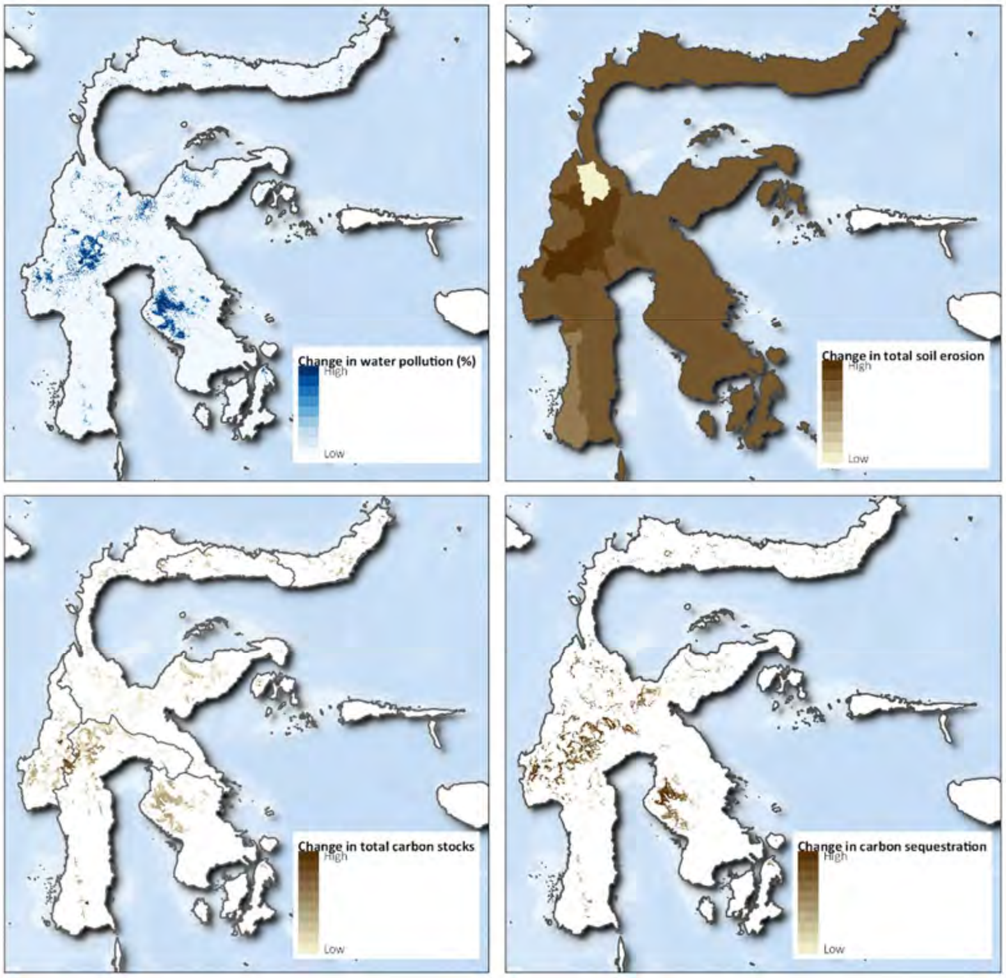


Figure 14: Changes in ecosystem services modelled for the scenario converting secondary forest to cacao on Sulawesi (change in water pollution (% contamination), change in soil erosion in mm/year total carbon stocks is in tonnes C/km2, C sequestration Dg/ha/day,).

A key thing to note in this analysis is that we have modelled changes/losses compared to retaining secondary forest. We would *expect* a reduction in ecosystem service provisioning, water quality etc. The key question is this: If cacao production is to expand, where is it best to target that expansion? (see alternative scenarios 4,5 and 6.). We always need to be aware of and model *the switch*, i.e. the marginal change.

We also considered expansion into secondary forest under the current climate for the whole country. Results can be found in Appendix x.

<u>Scenario 2: Convert secondary forest to cacao in Sulawesi and other regions in areas suitable under climate change (2050)</u>

This scenario combines a conversion and climate change scenario for areas of secondary forest that overlap with areas potentially suitable for cacao under a climate change scenario (RCP6.0) in Sulawesi. The combination of rainfall and temperature changes with changes in tree cover as a result of the conversion of secondary forest to cacao leads to a mean increase in evapo-transpiration (water loss to the atmosphere) of 8.5 mm for the whole of Sulawesi. However, in areas converted to cacao there is generally a decrease, leading to some areas experiencing less water in rivers, e.g. the Sungai Konaweha near Kendari and other areas experiencing significant increases in water, e.g. Sungai Karana in West Sulawesi.

Since the potential for cacao under climate change on Sulawesi is very small (~ 5600 km2), relatively little secondary forest gets converted and impacts on water quality and soil erosion are small. Water pollution in this scenario is projected to increase on average by 0.07%, although some areas see increases of water pollution of up to 90% while some areas see decreases in pollution, due to more water availability overall and thus pollution dilution. Soil erosion overall increases by around 0.02 mm/yr for the whole of Sulawesi but in converted areas, these increases can be as high as 54 mm/yr.

This scenario shows that 1) Sulawesi is currently important for cacao production but according to the models, there is hardly any suitability in the future. 2) The model only looks at monthly means and thus does not incorporate (projected) increase in frequency of extreme (rainfall) events that will exacerbate soil erosion and flush through additional pollutants used in cacao plantations. 3) Assessment of areas for expansion of cacao should take into account the climatic suitability under a variety of climate scenarios as well as looking at differences in impacts on ecosystem services by modelling the combined scenario of land use and climate changes as shown here.

Since the potential for cacao under climate change on Sulawesi is so small (~ 5600 km2, so about half of the current estimated area), national cocoa production objectives may have to be met from other regions that remain or become suitable for cocoa under climate change. Without any other incentives than increased demand, we assume farmers (in other regions) will expand into secondary forests (assuming also that most primary forests are protected or otherwise inaccessible). We therefore consider which areas have the greatest expansion potential under climate change (in Indonesia), defined as cocoa suitability under climate change overlap with secondary forest.

Areas of cocoa suitability under future climate change conditions were overlaid and clipped by areas of secondary forest (MOEF, 2017). As this is an unsustainable expansion scenario, suitable areas which overlapped with protected areas and peatlands were not excluded from the analysis (Figure 15).

Figure 15: 2050s distribution of climate zones for cacao within secondary forests in Indonesia in the RCP 6.0 scenario.

Climatic areas characteristic of current cocoa growing areas in Indonesia are greatly reduced under the climate change scenario, whilst climatic areas with potential for cocoa growing increase in 2050 (see also Figure 10). Kalimantan has the greatest potential area for expansion into secondary forests under the climate change scenario, ~52,700 km2.

Though we did not model the impacts on ecosystem services for this scenario, the implications are expected to be similar to those for Sulawesi. However, in 2050 the area of secondary forest in suitable cocoa areas is much higher outside Sulawesi, so, depending on the area of expansion, absolute effects can be much larger. In addition, biodiversity intactness is likely to correlate strongly with ecosystem structure and functioning and cacao agroforestry hosts less biodiversity than forests (Figure 17).

Biodiversity Impacts

In this expansion scenario, the highest average scores for biodiversity significance are present in Sumatra, Maluku and Papua and Sulawesi (Figure 16, details in Appendix 4, 4.5). This is largely due to the presence of smaller islands in these provinces, which contain species with a higher degree of endemism. Similarly, if all secondary forest areas are converted the greatest risks would be to species in Maluku and Papua, followed by Sumatra with total significance scores nearly double that of Kalimantan (the next highest), despite the larger area available for conversion.

Figure 16: Biodiversity significance values within secondary forest expansion scenario, under future climate change conditions (RCP 6.0 scenario). Data has been log transformed for visualisation, symbology stretch based on unsustainable secondary forest scenarios to best demonstrate variability within the data.

Biodiversity intactness decreases in areas where secondary forest is converted to cacao regardless of how the cacao is produced (Figure 17). Cacao agroforestry hosts less biodiversity than forests, in particular fewer forest specialist species, but it is more similar to secondary forests than to monoculture cropland in terms of species composition (UNEP-WCMC, unpublished data). However, expansion of full sun monoculture production over agroforest production had notable effects on biodiversity intactness with lower projected intactness values for all regions in Indonesia (Table 4). Sumatra, Kalimantan, Maluku and Papua experienced the greatest declines in biodiversity in this scenario (Figure 17; Table 4)

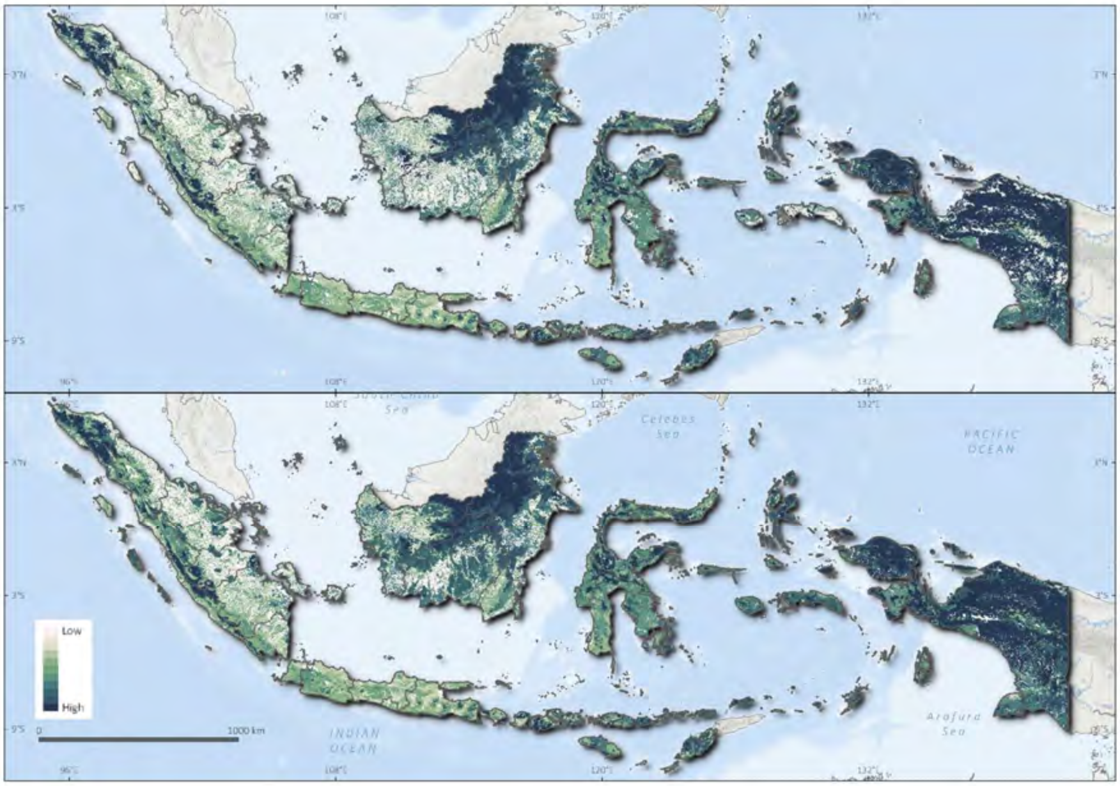


Figure 17: Biodiversity Intactness Index values within Indonesia following expansion of cocoa into climatically suitable areas of secondary forest under climate change (RCP 6.0). Top: replacement of secondary forests with full-sun cocoa, bottom: replacement of secondary forests with cocoa agroforestry.

3.2. Cocoa expansion into degraded lands

Scenario 3: cocoa expansion is promoted in degraded lands

Figure 18: Distribution of cocoa expansion into degraded lands under current climatic conditions.

Land classes for expansion to degraded land were described as barren land, brush, swamp and swamp brush in Koh and Ghazoul (2010). Initially, degraded land areas were identified using the Ministry of Environment and Forestry (2017) land cover dataset. Swamp classes were not included in the scenario, as draining of swamps for agriculture was not deemed to be sustainable. Additionally, areas classed as savannah are also included in the scenario to increase the potential for expansion. When comparing this layer to fractional tree cover (Copernicus, 2015) values were high, despite the land being degraded. Therefore, the global land cover dataset from Copernicus (2015) was used to determine areas classed as degraded. Classes were chosen to best fit with the Koh and Ghazoul (2010) description of degraded lands. These were bare or sparse vegetation, herbaceous vegetation and shrub.

Areas of current climate cocoa suitability was overlaid and clipped by the degraded lands layer. As this is a scenario for sustainable expansion, areas overlapping with peatlands (WRI) and protected areas (UNEP-WCMC and IUCN, 2019) are removed (Figure 18).

Promoting cocoa expansion into degraded lands could contribute to national forest restoration objectives, such as through Indonesia's REDD+ strategy as a potential restoration activity and means to increase carbon stocks in the country.

Ecosystem services changes (Figure 26)

The potential for cocoa conversion into degraded lands is greatest for Kalimantan with nearly 5,000 km2 available. Converting this land to sustainable cocoa would results in a mean decrease of water pollution of -0.42 % but up to -13% in some areas. Changes are mainly around the city of Banjarmasin but benefits of decreased water pollution are found much farther upstream in places where even only small areas are converted to sustainable cocoa.

Similarly, some of the greatest reductions in soil erosion are found on Kalimantan with some basins nearly seeing 8.3 mm/year less. Also, Sumatra and Papua see relatively large reductions in soil erosion under this scenario.

Total carbon stock changes are as high as 409 tonnes/ha with a mean change of 97 tonnes/ha in Kalimantan. Mean carbon sequestration changes in Kalimantan are 0.3 Mg/C/ha/yr but can be as high as 1.3 Mg/C/ha/yr.

Biodiversity risks and impacts

Highest average scores for biodiversity significance in this scenario are present in Sulawesi, followed by similarly high scores for Java, Maluku and Papua and Nusa Tengarra and Bali (Figure 19, details in Appendix 4, 4.5). However, if all degraded areas are converted the greatest risks would be to species in Maluku and Papua with total significance scores of nearly double that of Sulawesi (the next highest).

Figure 19: Biodiversity significance in areas of degraded land replacement by cocoa under current climate suitability. Data log transformed for visualisation, symbology stretch based on values from “policy-on” scenarios to increase visibility of variation within these scenarios.

As the area of degraded lands is negligible compared to the area of land available in other scenarios, the overall impact to biodiversity intactness of conversion of degraded lands to cocoa is minimal (results not shown). The maximum impacts were observed in Sulawesi where the potential for land restoration is greatest.

3.3. Cocoa expansion into current estate crop areas/oil palm

<u>Scenario 4: cocoa expansion is promoted as an alternative to other perennial crops</u>

In this scenario cocoa agroforestry is promoted to replace certain plantations and monocrops, in this case areas identified as plantation forest and estate croplands using the Ministry of Environment and Forestry land cover dataset (MOEF, 2017). Areas of cocoa suitability within existing monocrop plantations were identified and peatlands and protected areas were removed. Furthermore, areas overlapping with oil palm plantations (source: NatureMap, Lesiv et al. in prep.) were removed, as oil palm conversion is being treated as a separate scenario (Figure 20).

Figure 20: Distribution of cocoa expansion into estate crops and plantation forests under current climatic conditions.

This scenario provides large expansion opportunities in West and Central Indonesia, primarily in Sumatra, Kalimantan and Java. Most of these potential expansion areas are also under potential cocoa climates, with few opportunities in current cocoa climate zones.

Ecosystem services changes (Figure 27)

Under this scenario, some of the greatest changes are projected for Sumatra and Java with 31,422 km2 and 11,564 km2 of potential land for cacao respectively. Water pollution decreases for both these regions with a maximum decrease of 13.2% for Java and a maximum decrease of nearly 99% on Sumatra although mean values are much lower with -0.001 and -0.04% for Java and Sumatra respectively.

Soil erosion changes are greatest on Sumatra and Kalimantan under this scenario. Mean soil erosion changes on average with -1.2 mm/year for Sumatra and -5.1 mm/year for Kalimantan while maximum reduction of soil erosion can be as high as 290mm/year on Kalimantan and 114 mm/year on Sumatra.

Total carbon stock for Sumatra increases on average by 95 tonnes/ha, 44 tonnes/ha for Java and 98 tonnes/ha on Kalimantan. Maximum increase is also highest on Kalimantan with 436 tonnes/ha although Sumatra and Java also see increases of up to 378 and 257 tonnes/ha respectively. Carbon sequestration changes are also greatest on Kalimantan with a mean of 0.19 Mg/C/ha/yr but with maximum sequestration rate increases of 1.3 Mg/C/ha/yr.

Biodiversity risk and Impacts

Biodiversity significance values in areas of potential conversion under this scenario are on average highest in Maluku and Papua, primarily due to small hotspots of significance in Maluku. Sulawesi has the next highest average score (Figure 21). When looking at total scores however, the highest risk of converting all monocrop areas is in Java by far, due to consistently high values over large areas (see Figure 21). The next highest total score is in Sumatra, with a larger extent of monocrop but more variable pattern of significance with hotspots mainly in the north (Sumatera Utara) and scattered along the west coast.

Figure 21: Biodiversity significance in areas of plantation forests replacement by cocoa under current climate suitability. Data log transformed for visualisation, symbology stretch based on values from "policy-on" scenarios to increase visibility of variation within these scenarios.

The biodiversity intactness of plantation forests are mixed and highly dependent upon both crop and production regime. On average, cacao agroforests contain higher levels of biodiversity than plantation forests (WCMC unpublished data), but biodiversity intactness is reduced when plantation forests are converted to full-sun cacao farms. Plantation forest conversion scenarios showed that biodiversity within Sumatra would be particularly impacted, with greatest degradation of intactness if full-sun farming was adopted but greatest gains in intactness if agroforestry practices were applied (Figure 22, Table 4).

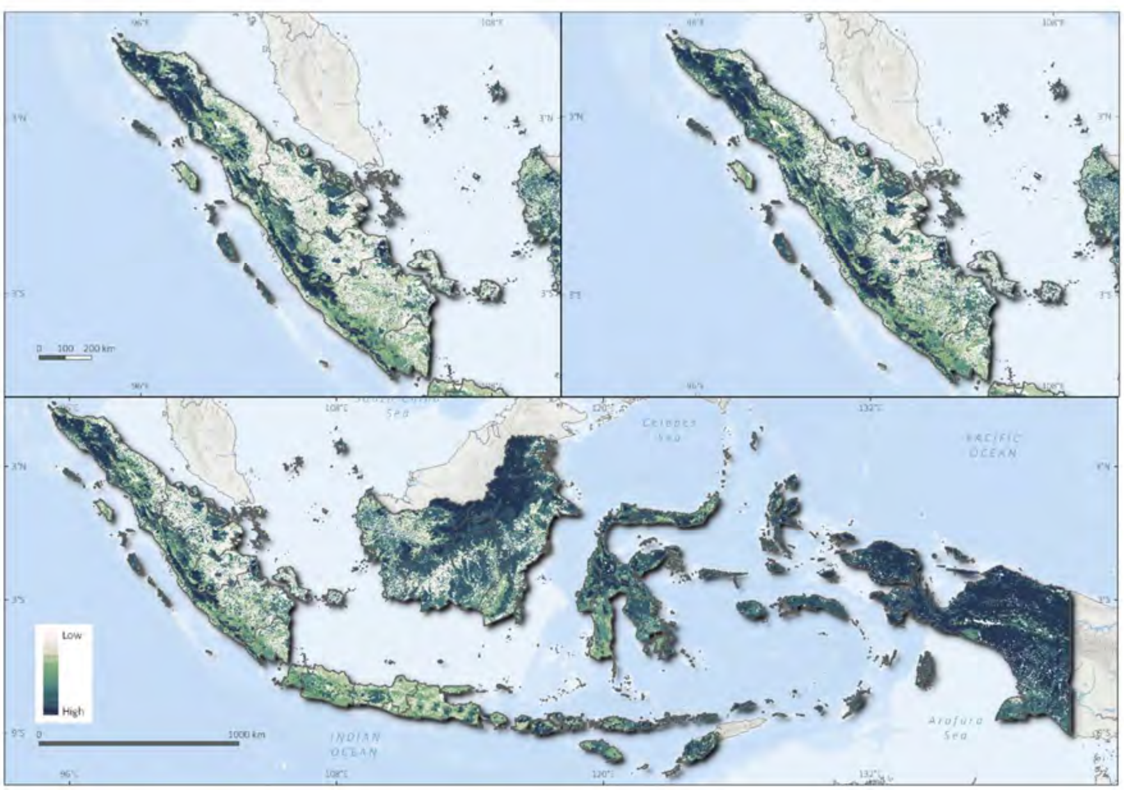


Figure 22 Biodiversity intactness assuming a scenario where areas of plantation are converted to cocoa agroforest. Top left: plantations are replaced by full-sun cocoa in Sumatra, top right: plantations are replaced by agroforestry cocoa in Sumatra, bottom: plantations are replaced by cocoa agroforestry in Indonesia)

Scenario 5: cocoa expansion is promoted as an alternative to oil palm.

In the face of falling returns from cocoa due to aging cacao trees, disease, but also declining cocoa prices and increasing input prices price drops, cocoa farmers in Indonesia have been increasingly converting from cacao to oil palm (Ruf and Yoddag 2014). Conversely, section III showed that cocoa productivity could be improved in many ways to become an economically viable alternative. Here we seek to explore the potential ecosystem services implications of converting oil palm areas outside of large industrial concessions to cocoa agroforestry systems.

Areas for oil palm are identified using the forest management layer from NatureMap (Lesiv et al. in prep.), large oil palm concessions (source: GFW) are removed as cocoa agroforestry is best suited to small holders. Areas overlapping with peat and protected areas are also removed from this scenario to promote sustainable expansion (Figure 23).

Figure 23: Distribution of cocoa expansion into oil palm plantations (excluding concessions) under current climatic conditions.

Ecosystem services changes (Figure 28)

Under this scenario, the greatest changes are projected for Sumatra and Kalimantan. Water pollution decreases on average with 0.07% for Sumatra and 0.02% for Kalimantan but reductions can be as high as 99% in some areas in Sumatra.

Soil erosion reduced on average with 1.2mm/yr on Sumatra with a maximum reduction of 114 mm/year while on Kalimantan the average reduction is 5mm/year with a maximum reduction of 290mm/year.

Carbon stock increases on average with 101 tonnes/ha and 114 tonnes/ha for Kalimantan and Sumatra respectively although maximum potential changes are higher on Kalimantan with 410 tonnes/ha versus 380 tonnes/ha on Sumatra. Carbon sequestration increases by 0.17 and 0.16 Mg/C/ha/yr for Sumatra and Kalimantan respectively with maximum values similar for both areas around 1.4 Mg/C/ha/yr.

Biodiversity risks and impacts

Scores for average biodiversity significance are highest for Sulawesi, Java and Nusa Tengarra and Bali; all notably higher than the rest of the islands albeit concentrated in smaller areas. Despite having the second lowest average significance score, the scores for total biodiversity significance in oil palm areas were highest in Sumatra.

Figure 24: Biodiversity significance in areas of oil palm replacement by cocoa under current climate suitability. Data log transformed for visualisation, symbology stretch based on values from "policy-on" scenarios to increase visibility of variation within these scenarios.

Intensive oil palm plantations are estimated to have the greatest detrimental impact on biodiversity intactness of all plantation crops grown in tropical areas (WCMC unpublished data) therefore the opportunity to restore biodiversity in this scenario is high. Biodiversity in Sumatra is considerably improved within the agroforestry scenario due to the current dependence of this region on oil palm production (Figure 25 Table 4). Conversely regions such as Java, Nusa, Tengarra and Bali see negligible differences.

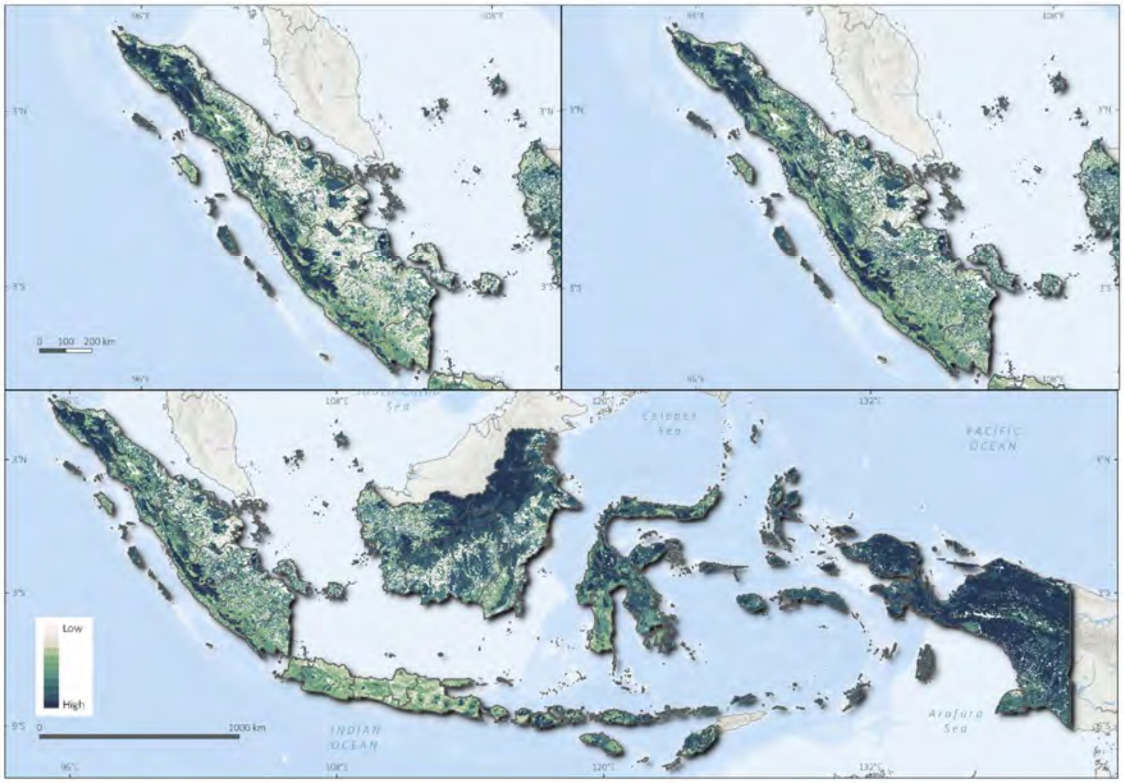


Figure 25 Biodiversity intactness assuming a scenario where areas of oil palm are converted to cocoa agroforest. Top left: oil palm is replaced by full-sun cocoa in Sumatra, top right: oil palm is replaced by agroforestry cocoa in Sumatra, bottom: oil palm is replaced by cocoa agroforestry in Indonesia)

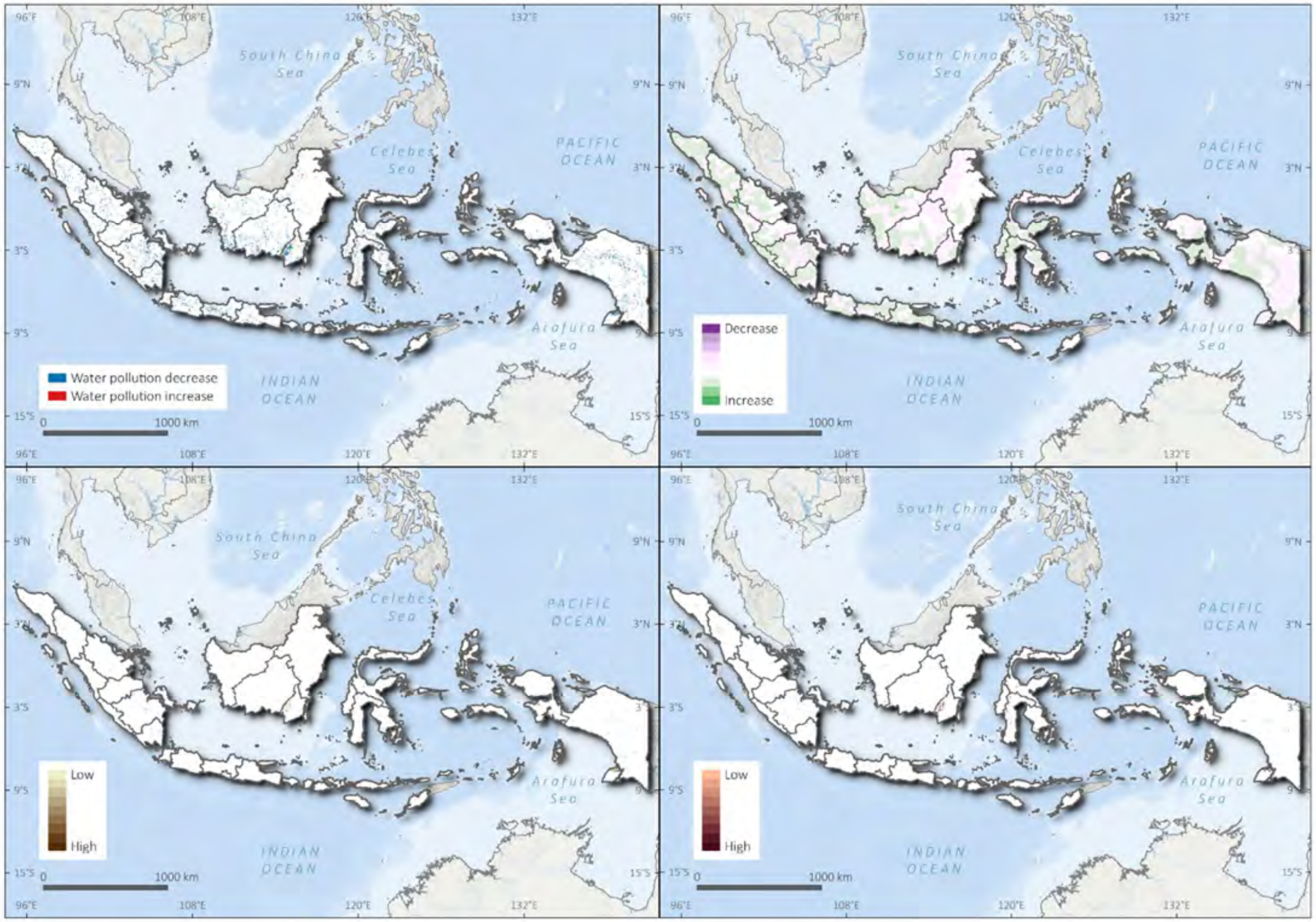


Figure 26: Changes in ecosystem services modelled for converting degraded land to cacao in Indonesia. Highest impacts are on Kalimantan (see detailed map in Annexe 4, 4.4).

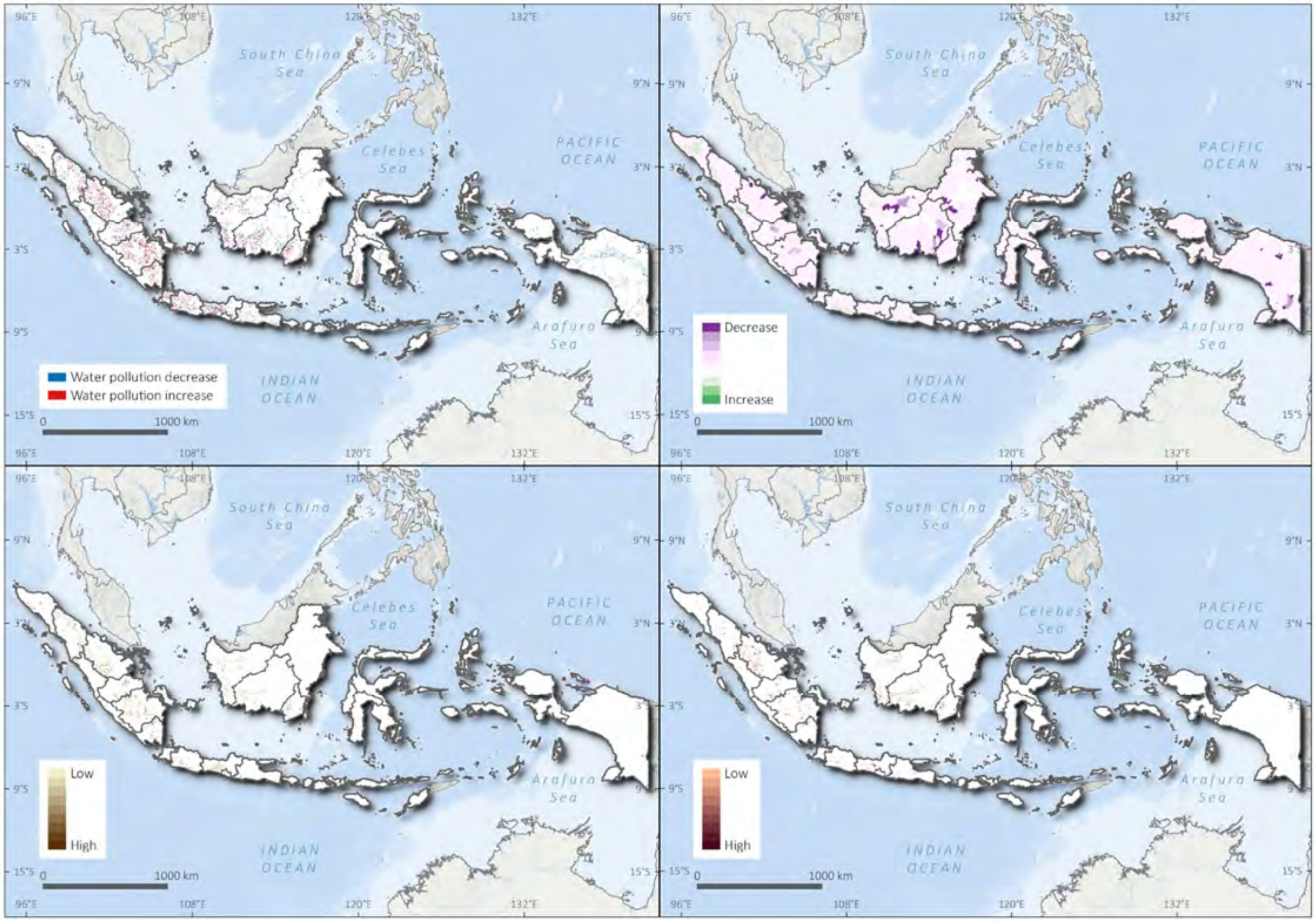


Figure 27: Changes in ecosystem services modelled for converting plantations to cacao in Indonesia Highest impacts are on Sumatra (see detailed map in Annexe 4, 4.4)

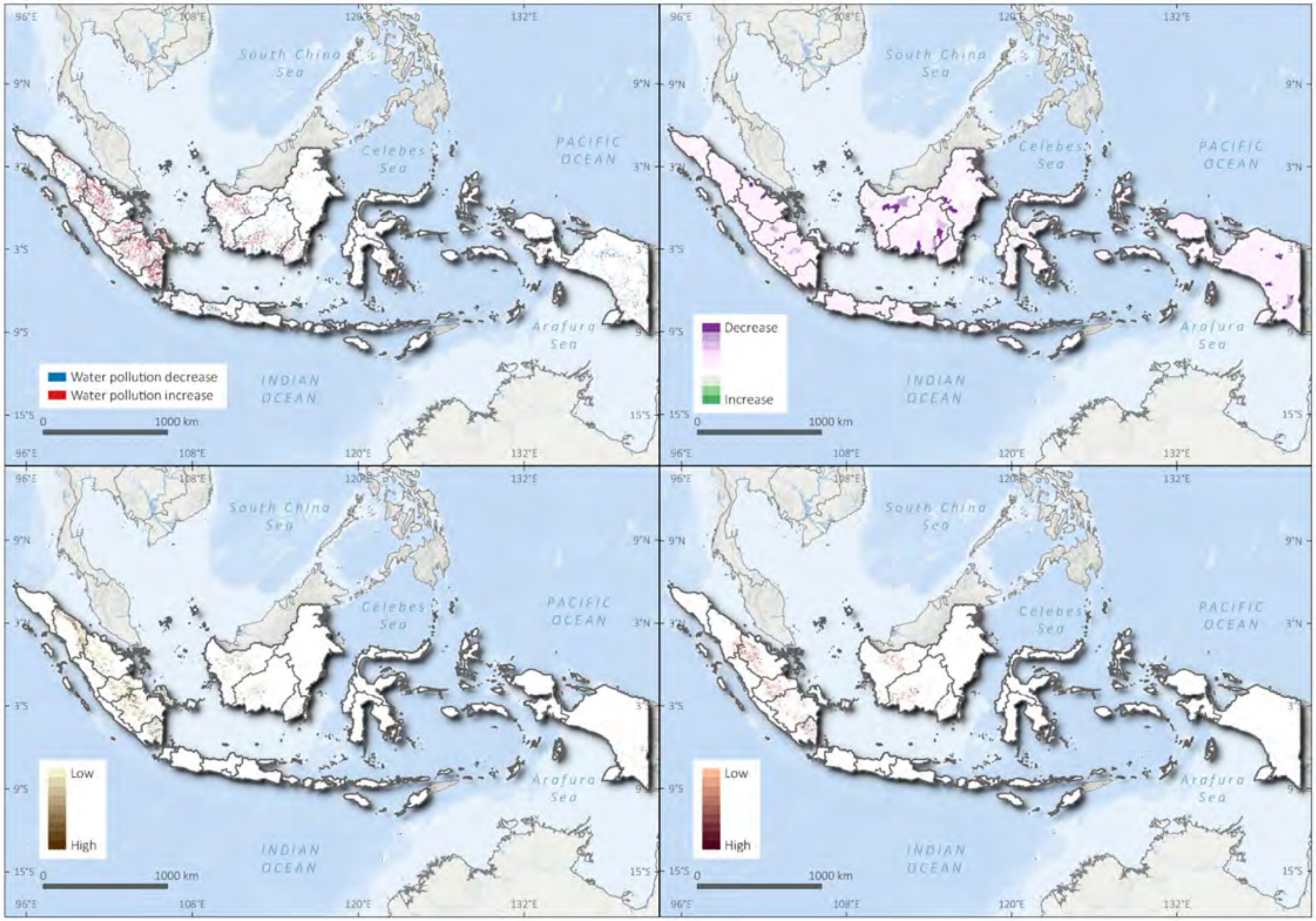

South China Sea
Celebes Sea
PACIFIC OCEAN
Arafura Sea
INDIAN OCEAN
Water pollution decrease
Water pollution increase
Decrease
Increase
Low
High
Low
High
0
1000 km
96°E
108°E
120°E
132°E
9°N
3°N
3°S
9°S
15°S

Figure 28: Changes in ecosystem services modelled for converting oil palm plantations to cacao in Indonesia Highest impacts are on Sumatra (see detailed map in Annexe 4, 4.4)

4) Comparing scenarios

4.1 Expansion potential

Currently there is almost 10.000km2 of cocoa in Sulawesi (Machmud, 2014). For geographical diversification under the current climate, degraded lands in current cocoa climates are available mainly in areas now under plantations (trees or oil palm). Degraded lands are mostly available in potential cocoa climates (Table 2).

If most of this area becomes unsuitable for cocoa production under climate change and a sustainable option for geographical diversification is aimed for, then the future suitability of areas that may be replaced with cocoa need to be assessed. This will include climatic suitability and other criteria. Of course climate smart agricultural practices (e.g. irrigation, shading, new varieties etc.) may help expand the climatic range for cacao production in Indonesia.

Table 2: Areas potentially suitable for cocoa under each scenario (km2).

Province	Secondary forest (current climate)		Secondary forest (future climate)		Degraded lands		Plantations		Oil Palm	
	Current	Potential	Current	Potential	Current	Potential	Current	Potential	Current	Potential
Sulawesi	3,328	14,260	151	4,636	1,785	520	2,373	70	2,037	111
Sumatra	2516	47,085	716	35,445	210	3,748	1105	30,317	2,633	64,384
Maluku and Papua	1,560	77,470	-	39,479	736	2,965	147	1,030	131	3,919
Java	220	3,326	-	1,600	148	330	1,801	9,763	56	131
Nusa Tenggara and Bali	13	102	-	15	3.4	20.1	0.03	0.2	1.3	2.2
Kalimantan	1,351	36,110	-	52,726	1049	3,993	1,584	9,861	1,344	15,817

4.2. Ecosystem services implications

Converting secondary forests to cacao agroforestry leads to an increase in water pollution and a decrease in carbon stocks. Impacts on ecosystem services of the three “policy-on” scenarios vary. Overall, water pollution reduces more where cocoa replaces degraded lands than where it replaces plantations or oil palm. Soil erosion improves where cocoa agroforestry replaces plantations or oil palm. For carbon stocks the differences between provinces are higher than between scenarios, reflecting the variance in tree cover among provinces, though for most provinces, converting degraded lands leads to higher gains in carbon stock and sequestration than converting plantations or oil palm.

Detailed results tables with mean, minimum and maximum change values are in Appendix 4, 4.5.

4.3. Biodiversity implications

When comparing significance scores in potential conversion areas for each scenario clear patterns emerge: average scores (i.e., by area) and total scores (if all areas are converted) are highest in the secondary forest scenario with current climate, followed by future climate (see Table 3). These scores are much higher than in the other three scenarios. Plantation and degraded lands scenarios have roughly similar average significance scores, and oil palm the lowest, whereas when considering total scores, the degraded lands scenario has notably lower scores than all the rest (primarily due to having much smaller areas of potential conversion in total).

The biodiversity intactness values under each scenario illustrate that converting secondary forests to cacao leads to a reduction in biodiversity intactness. This is more pronounced if cacao is grown in a full sun monoculture system. Cacao agroforestry can improve biodiversity intactness values where it replaces plantation and oil palm areas (Table 4).

Table 3 Showing mean and total biodiversity significance scores within cacao replacement areas in each scenario. Details per province are in Annexe x

Scenario	Mean	Total
Oil palm	0.00006969522	7.36685495835
Plantations	0.00013900449	9.44243571743
Degraded lands	0.00014322906	2.55162573312
Secondary forests (future climate)	0.00019284466	31.23080687960
Secondary forests (current climate)	0.00023954276	58.60102096520

Table 4: Mean Biodiversity Intactness Index (BII) values under each expansion scenario for each province, as well as the current day baseline BII.

Province	**Current day baseline**	**Secondary forest (current climate)**		**Secondary forest (future climate)**		**Degraded lands**		**Plantations**		**Oil Palm**	
		Full Sun	Agroforestry	Full Sun	Agroforestry	Full Sun	Agroforestry	Full Sun	Agroforestry	Full Sun	Agroforestry
Sulawesi	-10.61	-16.64	-11.23	-12.45	-11.68	-10.84	-10.49	-10.84	-10.46	-10.73	-10.4
Sumatra	-20.39	-23.86	-20.67	-23.11	-20.76	-20.51	-20.27	-21.32	-19.36	-20.66	-16.5
Java	-18.17	-19.11	-18.22	-18.68	-18.28	-18.25	-18.13	-20.07	-17.29	-18.2	-18.15

Maluku and Papua	-4.993	-10.13	-5.397	-8.043	-5.665	-5.122	-4.903	-5.034	-4.964	-5.162	-4.934
Nusa Tangarra and Bali	-10.98	-11.04	-10.99	-11	-10.99	-10.99	-10.98	-10.98	-10.98	-10.98	-10.98
Kalimantan	-13.42	-15.86	-13.76	-16.61	-13.69	-13.57	-13.29	-13.73	-13.1	-13.56	-12.62

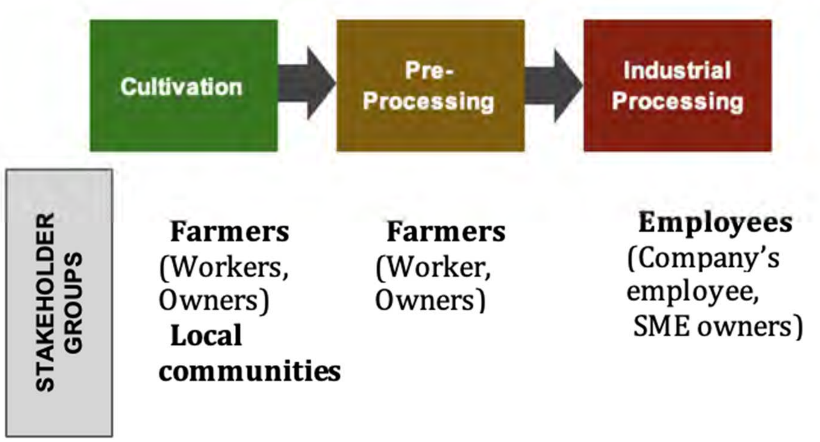
4) Uncertainty

All spatial and modelled data used in this study is subject to uncertainty (see methods as well for assumptions). It is meant for and has been tested at the scales used in this analysis and should not be considered representative at local site scales. Other methods and models exist for more local scales. For suitability: there is uncertainty inherent to the future climate projections, though Bunn et al. (2017) considered 19 global climate model projections and integrated the modelling uncertainty into their suitability classification. Also, suitability is not only defined by climate, but also by soil characteristics. These are, however, often dependent on local conditions and management, which could not be included in analysis at this scale. Local soil characteristics and health should be considered when considering cocoa expansion on the ground.

V. Life Cycle Assessment

In this section, we aim to understand the current impact of the cocoa value chain to the social and environment within the cradle-to-gate system boundary. We conduct a life cycle assessment across three different value chains; Cultivation, Pre-Processing, and Industrial Processing, within a certain timeframe.

For the social LCA, we identify the stakeholders for each value chain component (Figure 14). S-LCA was performed for each value chain from cacao production in Indonesia based on data collected from the stakeholders. The S-LCA was conducted using methodology and measurements adopted from Product Social Impact Assessment (Goedkoop



et al. 2018). The output of this assessment provides an in-depth overview of the social conditions of each value chain within a certain timeframe, which will be beneficial to identify further improvements that need to be completed.

Figure 14: Stakeholder groups across the value chain.

Every stakeholder has specific topics and priorities. These topics are based on an analysis of the interaction between companies and society:

1. They are dependent on the way society functions (social dependencies)
2. They affect the way society functions (social impacts)

The impacts and dependencies that companies have on stakeholders influences human well-being.

The Area of Protection (AoP) for the stakeholders, or endpoint in ISO 14044 terminology, is defined as 'human wellbeing'. The concept of human wellbeing for each of the stakeholders can be defined as follows:

- Workers: job satisfaction and engagement
- Local communities: healthy communities
- Users: wellbeing
- Small-scale entrepreneurs: livelihood.

Based on the Focus Group Discussion and literature review, we have selected 4 stakeholders along the value chain that is relevant to cacao sector, namely farmers, small medium enterprises (SME), employees, and local communities. The farmers from cultivation and pre-processing processes as well as small medium enterprises in the industrial processing were classified as stakeholders from small-scale entrepreneurs. Each of the stakeholders were asked relevant questions derived from the key social topics in the Product Social Impact Assessment report. Overall, there are seven social topics for farmers in cultivation and pre-processing, six social topics for SMEs in industrial processing, four social topics for employees in industrial processing, and three social topics for local communities in cultivation and industrial processing. Appendix 5 shows details of social topics related to stakeholders in each process. There are 7 topics that are being measured across stakeholders with different indicators to be measured as shown in Table 1.

Table 1: Social topics analysed for Cacao Stakeholders.

No.	Topics	Cultivation - Farmer	Pre-Processing - Farmeri	Processing - SME	Processing - Worker
		Mark	Mark	Mark	Mark
1	Meeting Basic Needs	V	V	V	
2	Access to services and inputs	V	V	V	
3	women's empowerment	V	V	V	
4	Health and safety	V	V	V	V
5	Child labour	V	V	V	
6	Fair trading relationship	V	V	V	
7	Land rights	V			

A scoring-based approach is applied to each of the topics to measure the social condition quantitatively. Ranging from (-2) to (+2), each score represents certain social conditions that correspond to the topic assessed. Negative scores depict a condition that is non-compliant with local laws and international standards, zero score depicts a condition where the local laws and international standards are met, and positive scores depicts a condition that is beyond-compliance with local laws and international standards. These measurements also refer to Product Social Impact Assessment (PSIA) report. The key components of social assessment methodology according to PSIA is shown in Figure 17.

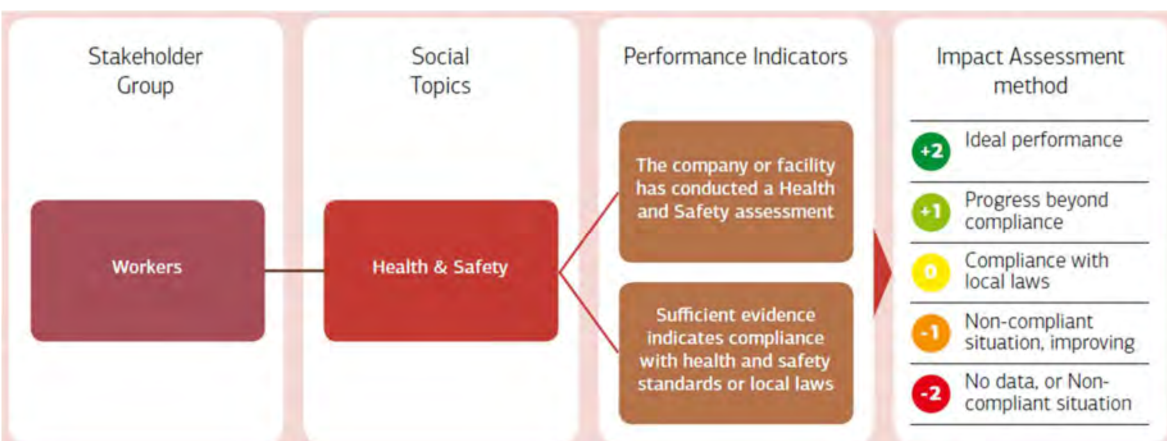


Figure 15: Example of Key Components of PSIA Methodology (Goedkoop et al. 2018).

The scale-based approach for social assessment allows both negative and positive performance within the production process. It helps to identify potential hotspots for each stakeholder. In this study, the result of social assessment will be illustrated by a spider chart with the scale-axis ranging from -2 to +2 to represent the performance of each social topics.

SOCIAL LCA DATA COLLECTION AND ASSESSMENT

The inventory data used to obtain social LCA (S-LCA) was gathered through surveys, focus group discussions (FGD), and literature review. The survey was performed by distributing questionnaires and interviews to farmers, owners of SME or industry, research organizations, extension services, and other relevant stakeholders. Three FGDs were attended, one in Solok and two in Jakarta. While surveys and FGDs were conducted to obtain primary data for S-LCA, the availability of the primary data is very minimum. Therefore, an assessment of the existing studies on cacao were performed to complement the social analysis and assessment.

A total of ten studies and articles were collected, all of which focus on the cacao cultivation process in different time periods (2010-2018). The references used for the assessment are based on the cacao projects occurred from 2010 to current. Unfortunately, no literature regarding the social aspect of pre-processing and industrial processing in Indonesia was found. The references analysed in this project are considered to demonstrate the best practices sustainable cacao development programme(s). These practices cannot represent the whole picture of cacao cultivation in Indonesia.

A total of two survey forms regarding the cultivation process, three survey forms regarding industrial processing, and ten reviewed literatures/articles regarding the cultivation process were obtained and used as the input for S-LCA.

1. Survey

One method in social inventory data collection is performing surveys to the targeted stakeholders. A questionnaire (Appendix 2) that correlates with the topics for each of the stakeholders was developed and sent to 11 leading cacao associations and organizations in Indonesia, representing the stakeholders. Nonetheless, only three respondents filled out the questionnaires (<30% of the total respondents). This lack of response could depend on the respondents' data confidentiality considerations, as well as on the bureaucracy in requiring each respondent's Board of Directors approval.

Within these three respondents, a respondent filled the survey forms for all the three stakeholders in the industrial processing section (SME Owner, Worker, and local community). Overall, two survey forms from cultivation process and three survey forms from industrial processing were collected. The data quality of the five survey forms were then measured and shown in Table 2. Based on the Table, it can be concluded that most of the survey only provides qualitative data to answer the social topics. Some of them provide some quantitative data but not a sufficient amount needed for the quantitative assessment.

Table 2: Quality Data of Survey.

No	Respondent	Location	Process	Basic Needs	Access to Services & Inputs	Women Empowerment	Health and Safety	Child Labour	Fair Trading	Land Rights
1	ICCRI	Oveall Indonesia	Cultivation	n/a	*	*	*	*	*	*
2	Farmer	Kotamobagu, North Sulawesi	Cultivation	**	**	*	**	**	**	**

No	Respondent	Location	Process	Basic Needs	Access to Services & Inputs	Women Empowerment	Health and Safety	Child Labour	Fair Trading
3	SME	Ngampilan, Jogjakarta	Industrial Processing_SME	**	n/a	**	**	**	**

No	Respondent	Location	Process	Health & Safety	Remuneration	Freedom of Association	Work Life Balance
4	SME	Ngampilan, Jogjakarta	Industrial Processing_Worker	**	**	*	*

No	Respondent	Location	Process	Access to Tangible Resources	Community Engagement	Employement and Skill Development
5	SME	Ngampilan, Jogjakarta	Industrial Processing_ Local Community	n/a	*	**

Legend

n/a	no information
*	qualitative (a glimpse of program)
**	qualitative & a bit quantitative
***	complete

Based on the collected survey forms, the result of S-LCA in cultivation process from the two respondents are shown in Figure 16. The center of the heptagon indicates the lowest score (-2), the smallest heptagon represents the second lowest score (-1), and the largest heptagon represents the highest score (+2).

Figures 16a and 16b: S-LCA Results in Cultivation Process.

The data gathered from Indonesia Coffee and cacao Research Institute (ICCRI) respondent (Figure 16a) described the overall condition of cacao farmers in Indonesia in the cultivation area. The result shows that social issues on women's empowerment is the only topic that received a score of (-1), a topic linked to women's role in the household and the work environment is recognised and has equal rights and opportunities. Meanwhile, no information was given regarding the fulfillment of basic needs. The result for the remaining aspects shows that no actions (screening, evaluation, monitoring) have been taken to assess the conditions and evaluate improvement opportunities.

On the other hand, data from the respondent from Kotamobagu, North Sulawesi, shows different results. Based on Figure 16b, it can be seen that most of the basic needs required are already met. The respondent described that around 90% of people in the area already have access to clean water and around 50% of people already have access to proper sanitation, despite around 40% of people still suffering from the lack of food availability throughout the year. However, the interventions focused on improving water management, sanitation, hygiene and diverse diets are undertaken and continuously monitored to improve the current situation. In terms of social welfare, the average monthly income of a farmer in the area is around 1.5 million Rupiah. A good fair trading relationship of farmers in Kotamobagu is also depicted, proven with the ability of farmers to obtain price premium and also facilitated in joining cooperatives and farmer associations or groups. While around 40% of farmers are still lacking in understanding the standard quality, price structures, and premium requirements, there are opportunities for improvement in this aspect. Women's role is also recognised in Kotamobagu. Compared to ICCRI results, empowerment programmes or other interventions that focused solely on women are already promoted and carried out in Kotamobagu.

In terms of access to services and inputs, training and support (financial, fertilizer, seeds, etc.) are not given consistently and intensively. Around 20% of farmers are satisfied with the services and inputs offered. However, room for improvements have been identified and evaluated. In Kotamobagu, child labour issues have also been detected. However, no incidents regarding child labour have been reported. Furthermore, the actions to raise awareness of the issue, mitigate the risk of child labour, and support children's school education are already taken. In terms of land rights issue, only 40 % of farmers have already documented their land legally. No special attention is also given in health and safety aspects, proven with only around 10% of farmers have access to adequate PPE. Subsequently, the risks and opportunities for improving working conditions/occupational safety and farmers health are also unidentified.

In the industrial processing section, the results of S-LCA from a respondent representing SME are shown in Figure 17.

Figure 17: S-LCA Results in Industrial Processing.

The survey result shows that industrial processing (represented by an SME) has given special attention to health and safety as well as the remuneration of the workers. The company complies with health and safety standards or local laws and provides the workers with OHS training and PPE. The occupational health and safety of workers is monitored and the company has recognised the importance of the subject. In terms of remuneration, the wages of workers have met at least legal or industry minimum standards, specifically around 1.5 to 4 million Rupiah. In order to encourage healthy work-life balance, the industry enacts normal working hours in a week, not including overtime, that complies with the law or national standards. There is also a policy on flexible working arrangements/working hours/parental leave for the workers. In addition, to support the fundamental human rights of the workers, the company has a policy that allows freedom of association and collective bargaining but does not however have a system in place to enforce the policy.

The health and safety topic is also the highest score from the SME perspective. It is in line with the worker's social assessment results where the working conditions, practices and progress are regularly monitored. SME also has access to safe water sources, proper sanitation and has a sufficient food supply throughout the year. In the industry, there is around 73% female workers that shows women's role is recognised and have equal rights and opportunities. No child labour is also detected. Regarding access to services and inputs, no information is given from the respondent.

In terms of employment and skill development of local community, the company has committed to grow local employment or at least keep a stable workforce. The company also contributes to skill development in connection to the future need of staffing. Fair working conditions, fair salaries, non-discrimination for workers and grievance mechanism to handle complaints are the focus and commitment of the company. For community engagement, the company has a system or mechanism in place to enforce the policy to address the local community's queries and grievances. The company is also engaging in a dialogue with the community representatives and incorporates their views into management decisions. Meanwhile, no information was given regarding the access to tangible resources.

Nonetheless, the actual social conditions of cacao production in Indonesia cannot be fully depicted from these results due to the lack of primary data collected. However, these results provide partial view that indicate current social conditions in certain areas. women's empowerment, meeting the basic needs, and fair trading relationships are the social topics that have positive performance in cacao cultivation processes, meaning that the minimum standards conditions for those aspects are already met. Meanwhile, no actions (screening, evaluation, monitoring) have been taken to assess the conditions and evaluate improvement opportunities for the rest of the aspects. In industrial processing, health and safety of the workers is the social aspect with the highest performance where the company is committed to protect the workers from hazards and maintain safe working conditions. In addition, good engagement is already built between the company and the local community.

2. Assessment based on Literature Survey

Table 3 shows the summary of quality data from each literature. Out of all the seven social topics, most of the literature has no information regarding land rights, child labour, and health and safety. Meanwhile, for basic needs, access to services and inputs, women's empowerment, and fair trading, several literatures have quantitative data to support the social topics.

Table 3: Quality Data of Literature Review.

No	Literature	Year of Literature	Location	Process	Basic Needs	Access to Services & Inputs	Women Empowerment	Health & Safety	Child Labour	Fair Trading	Land Rights
1	Research by BAPPEDA & ICCRI	2010	District Pidie Jaya, Aceh	Cultivation	**	*	*	n/a	n/a	*	n/a
2	MARS	2011	South Sulawesi	Cultivation	n/a	*	n/a	* (only safety)	*	* (farmer knowledge)	n/a
3	Research by USYD	2012	Polewali Mandar West Sulawesi	Cultivation	**	**	**	**	n/a	**	**
4	Research by NREL	2014	West Sulawesi, South Sulawesi, South East Sulawesi	Cultivation	*	**	**	n/a	n/a	*	**
5	Mondelez	2015	South Sulawesi & Lampung	Cultivation	* (only for nutrition/ foods)	***	**	* (only health)	**	**	n/a
6	Cargill	2016/2017	Indonesia, Pantai Gading, Ghana, Cameroon	Cultivation	*	**	*	* (only health)	*	**	n/a
7	UTZ Evaluation in Indonesia Cocoa Sector	2016	Aceh, South East Sulawesi	Cultivation	n/a	**	*	**	n/a	**	n/a
8	SCPP	2016	Aceh, North Sumatera, West Sumatera, Lampung, Bali, NTB, South Sulawesi, West	Cultivation	*	***	***	* (only health)	*	***	**
9	SCPP	2017	Sulawesi, South-East Sulawesi, Central Sulawesi, Gorontalo	Cultivation	* (only for nutrition/ foods)	***	***	n/a	*	***	n/a
10	READSI	2018	Central Sulawesi	Cultivation	***	***	***	n/a	n/a	n/a	*

Legend

n/a	no information
*	qualitative (a glimpse of program)
**	qualitative & a bit quantitative
***	complete (but not seperated by location)

To capture the trend of the social conditions in cacao cultivation over time in Indonesia, the articles and literatures were reviewed chronologically. The results of S-LCA from the ten articles presented in the periodical order are shown in Figure 20.

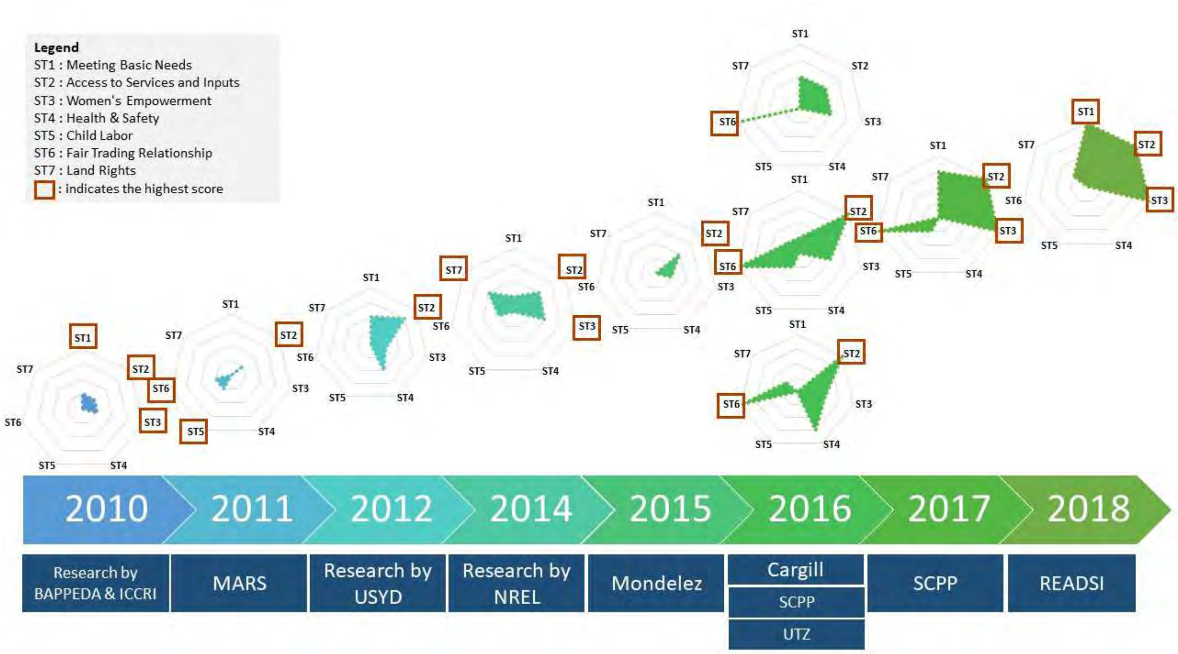


Figure 20: S-LCA Based on Literature Review.

From all of the gathered articles, the earliest study on social condition of cacao cultivation process was conducted by BAPPEDA and ICCRI in Pidie Jaya, Aceh (2010). The study presented mostly qualitative data with some quantitative data on how farmers can access the basic needs. Meanwhile, no data was found on health and safety, child labour, fair trading relationship and land rights issues, which resulted in a (-2) score in the S-LCA for each of the aspects. The aspects of meeting the basic needs, women's empowerment, and access to service and inputs score the highest with a value of only (-1). This concludes that in 2010, 59.61% of household including farmers are still classified as poor where the opportunities for improvement for access to basic needs (water, sanitation, food) have been identified, but no action has been taken. Moreover, no services and inputs were undertaken, and activities tailored specifically for women were not identified.

In 2011, Mars reported its Mars Cocoa Sustainability Initiative (MCSI) (World Agroforestry, 2012) project, a development program for cacao production (mainly in cacao cultivation) focused in South Sulawesi. Overall, the report only presented qualitative data with no information on farmers conditions in meeting the basic needs, women's empowerment, health issues, and land rights, resulting in an S-LCA with (-2) scores in those aspects. Meanwhile, the other three aspects gained a score of only (-1). This also depicts the farmers conditions in South Sulawesi in 2011 had identified access to services and inputs as well as the risk of child labor with no action undertaken, and only few farmers had knowledge on quality standards, price structure, and premium requirements.

Starting from 2012, studies are seen to give significant data especially on the farmers access to services and inputs, which translates that reports on the certification scheme and many cacao production sustainability development programmes are also started to be published. In 2012, researchers from the University of Sydney (Neilson, 2013) reported their pilot survey results that took place in Polewali Mandar, West Sulawesi. The report shows good qualitative data with some quantitative data provided for almost every social aspects assessed, except that no data was available on child labor topic. The S-LCA result shows that the farmers in the area had already good access to basic needs (food, water, and sanitation) as well as personal protective equipment (PPE), with lack of knowledge on premium cacao within the farmers and no land rights were legally documented. Meanwhile, researchers from the National Renewable Energy Laboratory (Moriarty, 2014) conducted a feasibility study of cacao production development project in targeted areas of West Sulawesi, South Sulawesi, and South East Sulawesi in 2014. Overall, the study presents qualitative information on five social topics, leaving health and safety and child labor issues with no data provided. The result of the S-LCA shows that farmers in the area have already been introduced to interventions to access to services and inputs, the role of female workers are evaluated, and most farmers (around 60%) have legally documented their own land.

Simultaneously, Mondelez group had been aiding the cacao farmers in Soppong, South Sulawesi and Lampung, Sumatra. The program, called Cacao Life, was started in 2013 and in 2017 they released their assessment of the project up to 2015 (Jones, 2017). Overall, Cacao Life did not disclose a lot of the actual data. The assessment shows that a lot of of service were given to the farmers, and some implementation of women's rights were in place, and child labour monitoring system was in place for 17 communities as a pilot project.

As seen in Figure 20, three studies that were published in 2016 (Swisscontact, 2017) show that fair trading relationship within farmers has the highest score (+2), which can be translated as the farmers in the study had thoroughly understand about premiums as well as gaining benefits from the scheme. Moreover, the farmers under study had also gained benefits from the services and inputs provided by cacao sustainable development programme(s), and activities focused on developing the productivity of female workers had been established. Looking solely on the report from SCPP (Swisscontact, 2018), it can be seen that an additional score was gained in terms of women's empowerment in the 2017 report. This means that the role of female within the scope of the study area was highly emphasized and support that correlates with this topic was already being monitored. Nonetheless, information and data on child labor and land rights issue still need to be clearly exposed. In 2018, reports from READ project (IFAD, 2019) presents that most farmers in Central Sulawesi had already gained significant benefits from the continuously monitored activities that deal with meeting the basic needs, access to services and inputs (trainings etc.), and women's empowerment. Meanwhile, no information was given in terms of health and safety, child labor, and fair trading relationship issue.

In comparison with the data collected from the survey, the results provided from recently published studies (2016 - 2018) are relevant to the survey data that depicts the condition of the cacao farmers in North Sulawesi, where high positive performances are seen in meeting the basic needs and fair trading relationships aspects. Within the reviewed studies, a high score in access to services and inputs aspect is also indicated as a result of the well-established sustainable cacao development programmes, in which only cover certain areas in Indonesia.

Thus, it could be safe to conclude that the recent studies can be used as indicators, however, cannot provide the full picture of actual social conditions in cacao cultivation process in Indonesia. These reports present the areas that has received interventions. However, for other areas that have not received any interventions, the conditions might be different.

Environmental LCA

To assess the environmental impact of the cacao production we use the EcoInvent database for cacao bean production in Indonesia. A calculation was performed using SimaPro LCA Software. Only 1 impact category is used for this calculation, which is the Global Warming Potential, calculated in kg CO2-eq. Table 4 shows additional data for each literature contained data of production, farmers, income of the farmers, selling price of cacao bean, and environment assessment based on the Global Warming Potential (GWP). The symbol (*) indicates that emission data use Ecoinvent database for 1 kg cacao bean production in Indonesia as general measurement.

The GWP is presented in a functional unit of 1 hectare of land to provide a comparative perspective of per hectare productivity. The results show that only SCPP program calculated the GWP and shared the results in the report. Since others did not provide such information, the calculation is made using the data from the database and calculated based on the production yield per hectare. Further research or primary data collection is required to know the actual value of global warming potential and other impact categories.

Table 4: Additional Data of Literature Review.

No	Literature	Year of Literature	Location	Production (kg/ha)	Farmers (house-hold)	Income (million rupiah/ month)	Selling Price (Rp/kg)	Global Warming Potential	
								(kg CO2 eq/kg)	(kg CO2 eq/ha)
1	Research by BAPPEDA & ICCRI	2010	District Pidie Jaya, Aceh	622	14,602	>4	20,000	41.19*	25,617.28*
2	MARS	2011	South Sulawesi	400	743	>6	n/a	41.19*	16,474.13*
3	Research by USYD	2012	Polewali Mandar West Sulawesi	407	158 people	0.6	18,000	41.19*	16,762.43*
4	Research by NREL	2014	West Sulawesi, South Sulawesi, South East Sulawesi	562	60,000 (target)	1.5-4	18,000	41.19*	23,146.16*
5	Mondelez	2015	South Sulawesi & Lampung	n/a	499	1	n/a	n/a	n/a
6	Cargill	2016/ 2017	Indonesia, Pantai Gading, Ghana, Cameroon	n/a	n/a	n/a	n/a	n/a	n/a
7	UTZ Evaluation in Indonesia cacao Sector	2016	Aceh, South East Sulawesi	675	n/a	<1.5	25,000	41.19*	27,800.10*
8	SCPP	2016	Aceh, North Sumatera, West Sumatera, Lampung, Bali, NTB, South Sulawesi, West Sulawesi, South-East Sulawesi, Central Sulawesi, Gorontalo	729	130,000	n/a	n/a	0.77	561.33
9	SCPP	2017		685	165,000	n/a	n/a	0.77**	527.45
10	READSI	2018	Central Sulawesi	630	45,000	1.5-4	27,500	41.19*	25,946.76*

**) assumes to be same as previous year

VI. Conclusions and Recommendations

Productivity for cocoa is currently below potential in Indonesia. This can lead to farmers expanding into forests in search of fertile soils. In addition, due to climate change, Sulawesi will potentially loose much climatic suitability (Bunn et al. 2014). This means that cacao farmers may expand into remaining suitable forest areas. The highest risk of this occurring is on Sulawesi where most cocoa is currently produced. This will lead to a decrease in carbon stocks, increased water pollution and loss of biodiversity.

Indonesia reportedly aims to increase yields of cocoa and geographically diversify production without expanding the current total cocoa area (Machmud 2014). Without any incentives to encourage otherwise, this may happen in forest areas with negative impacts on biodiversity and important ecosystem services. Alternatively, cacao expansion in other provinces could be incentivised as a replacement to non-forested land covers. We found that:

- Replacing secondary forest with cacao in suitable areas leads to loss of biodiversity (though this loss is less in agroforestry compared to full sun cacao systems) and other ecosystem services.
- Replacing degraded lands with cacao in suitable areas (most potential in Kalimantan 5000km2), leads to a decrease in pollution and soil erosion and an increase in carbon stocks, especially in some particularly degraded areas. These areas in Kalimantan also show less risk in terms of biodiversity significance loss compared to other suitable areas (e.g. Papua and Maluku) and an improvement in biodiversity intactness due to the conversion, if to cacao agroforestry, not a full sun system.
- Replacing plantations (most potential in Sumatra and Java), yields gains mainly in decreased soil erosion and increased carbon stocks and sequestration. Risks to biodiversity depend on the size of the areas converted, for example on Java there are few areas of high biodiversity significance which would mean a large loss if converted, whilst on Sumatra, values are lower but potential area of conversion is larger.
- Replacing oil palm with cacao agroforestry in suitable areas outside of large industrial concessions (Kalimantan, Sumatra), leads to a decrease in water pollution and an increase in carbon sequestration. Biodiversity in Sumatra is considerably improved due to the current dependence of this region on oil palm production.

We considered the potential for expansion into climatically suitable (in 2050) only for secondary forest areas. For the "policy on" scenarios, we only considered areas currently climatically suitable for cacao. This allowed us to explore differences between the scenarios in terms of ecosystem services implications, though ideally we would also consider future climatic suitability as well. This would help compare options even better. Our results do show the potential losses and gains in ecosystem services between these land uses and cacao (agroforestry).

To fully assess costs and benefits among these scenarios, other values than the ones considered here will need to be taken into account. Including costs of conversion, impacts on livelihoods etc.

This research revealed that numerous policies should be implemented in order to transition monoculture crops to agroforestry systems and to promote agroforestry as a restoration land cover in degraded areas. These policy recommendations primarily aim to achieve the following goals; 1) increase the yields of estate crops, 2) improve the productivity of small-holder farmers, 3) add value in the agricultural value chain, 4) promote sustainable agriculture to ensure long-run livelihoods and protect provision of environmental services under a changing climate.

The TEEBAgriFood Framework outlines a comprehensive method of evaluation of food systems, including analysis of four capitals - produced capital, natural capital, human capital, and social capital - and all the associated positive and negative impacts that arise when changes are made to these capitals. The recommendation of this

report is that policies consider the full range of possible impacts from a policy scenario. There are many dimensions to cacao agroforestry that are not explored in this report, such as socio-economic dynamics and farm-level implementation. However, some conclusions can be drawn and recommendations made.
Data and models are available that can help plan the development of cacao production to avoid expansion in areas with potential risk to important ecosystem services such as biodiversity, carbon sequestration and water quality.

Results from the spatially explicit scenario analyses illustrate that there may be (spatial) trade-offs and synergies among different ecosystem services between scenarios and between regions of Indonesia. It is important to consider that outcomes on the ground may depend on the type of land cover or land use that cacao is replacing. For example whether cacao is replacing smallholder oil palm in mixed landscapes or large-scale oil palm plantations. The examples presented here show the potential for such analyses.

It is important to consider the potential impacts of future climate change on future cacao production in Indonesia. Different coping strategies in different regions might include transformation out of cacao, fast or incremental adaptation (for example by increasing shading) or expansion into newly suitable areas. Different cocoa growing systems can also be considered, for example full sun or shaded agroforestry systems. These strategies will have different impacts on the environment, the ecosystem services it provides and farmer livelihoods. It is also important to consider the size of the farms that would be targeted by agroforestry policies and how the policies would impact the livelihoods of these farms.

The social condition within the cacao production value chain in Indonesia is evaluated using S-LCA method, with an adoption in methodology and measurements from Product Social Impact Assessment report (Goedkoop et.al, 2018). The results of the S-LCA show that within the cultivation process, cacao farmers have periodical improvements in terms of access to basic needs (water, sanitation, food), good knowledge of premiums cacao, and environment where female workers are recognized and gender equality is encouraged. Information from the best practices in various cacao sustainable development programmes, based on the reviewed articles, show that access to inputs and services (trainings, financial aids, etc.) have also been well-established on areas covered with the programmes. However, critical issues such as child labor and land rights are still rarely evaluated or exposed. In the industrial processing, health and safety topic is seen to have special attention where both workers and SME already had high awareness of safety and hygiene at work especially for the food industry. Moreover, health and safety standards for industrial processing seems to have more attention from Indonesian government and also international company for exporting cacao products rather than in cultivation processing. Nonetheless, the actual social conditions of cacao production in Indonesia cannot be fully depicted from these results due to the lack of primary data collected. However, these results may provide partial view that indicate current social conditions in certain areas.

RECOMMENDATIONS

This report is to feed into a wider (three-year, fully funded) TEEBAgriFood report and implementation of change on-the-ground in Indonesia and as such the project itself will take forward some of the recommendations set out below, particularly on gathering and ground-truthing information. But it is useful to document these recommendations at this stage:

1. On S-LCA: further evaluation and assessment of the actual conditions for all the social topics is recommended to identify improvement opportunities especially critical issues related to child labour, health and safety of the farmers, and land rights.

2. On the current findings of the S-LCA: An intensive program to improve access to services and inputs for farmers only applied on certain areas, and there is an argument that this should be applied evenly in more areas.

3. More primary data is needed to gain comprehensive results that can depict the actual conditions of the stakeholders in the value chain of cacao production especially in pre-processing and industrial processing where no literature was found to describe the social condition in these processes.

4. More detailed classification of spatial imagery that specifically identifies agroforestry and cacao would facilitate spatial modelling of water quality, carbon storage, and biodiversity habitat. These results could in turn permit valuation, specifically, the potential cost or benefit from predicted changes in land cover.

VII. Appendices

Appendix 1: Material Topics to BAPPENAS vs Issue Identified by Cacao Stakeholders

A materiality identification was held within the relevant internal stakeholders of Directorate Food and Agriculture of Ministry of National Development Planning (BAPPENAS). The materiality shows that the main topics to be prioritised will be seven i.e. natural capital, produced capital, human capital, social capital, agricultural and food outputs, purchased inputs, and ecosystem services. The table below summarises by classifying the topics into the important topics for BAPPENAS and issues identified by Cacao stakeholders. The issues identified were captured from direct interviews.

Topic material to Bappenas	Issues Identified by Cacao Sector Stakeholders
Spatial planning for natural capital, i.e. land suitability, land use change	•Land suitability •Land use change and land occupation •Agroforestry - Diversification with forest trees (pine, teak, Albizia Chinensis)
Seed Quality	•Lack of availability of local seeds •Anticipate Vascular Streak Dieback (VSD) (virus) •Anticipate Black Pod (phytophthora fungus) •Anticipate climate change (drought) •Seed productivity •Research and database of seed types vs. taste
Research and Development to improve agriculture production system (for produced capital)	•Application of technology in GAP •Research and database of seed types vs. taste •Waste management and utilisation
Education/Skills for human capital	•Knowledge of Good Agricultural Practice (GAP) •Implementation of GAP •Farmers' assistance/extension (Penyuluh) •Knowledge for Farmers •Aging trees •Pruning •Sanitation (Fungicide Application) •Fertilizer application •Fermentation techniques - increased risk of failure with inappropriate fermentation techniques) •Knowledge for Farmers
Local Spatial Planning for social capital (e.g. availability and distribution of local expertise)	•Aging farmers •Declining number of farmers •Farmers' assistance/extension (Penyuluh)
Soil Quality	•High soil acidity
Infrastructure development	•On-farm post-harvesting facility •Access to tangible resources for farmers (electricity, clean water,

	etc)
Health	•Potential health impact to human (farmers) due to fungicide/chemicals/fertilizer application
	•Health benefit of consumption of cacao - cacao culture
Food Security (Access/Distribution)	•Low income for farmers leads farmers to switch to other crops •Price indifference for fermented cacao on farmer level (no fair trade) •Farmers' assistance/extension (Penyuluh) - low income for extension-
Labour inputs (incl. skills)	•Aging farmers •Declining number of farmers •Knowledge of Good Agricultural Practice (GAP) and application of technology •Implementation of GAP •Farmers' assistance/extension (Penyuluh)
Water Quantity & Quality	•Agroforestry - Diversification with forest trees (pine, teak, Albizia Chinensis)
	•Knowledge of Good Agricultural Practice (GAP) and application of technology
	•Implementation of GAP

Appendix 2: Consultation results

Topic material to Bappenas	**Issues Identified by Cacao Sector Stakeholders**	**Policy Recommendation**
Spatial planning for natural capital, i.e. land suitability, land use change	- Land suitability - Land use change and land occupation - Agroforestry - Diversification with forest trees (pine, teak, Albizia chinensis)	- Spatial planning for cacao cultivation development or expansion - Agroforestry
Seed Quality	- Lack of availability of local seeds - Anticipate Vascular Streak Dieback (VSD) (virus) - Anticipate Black Pod (phytophthora fungus) - Anticipate climate change (drought) - Seed productivity - Research and database of seed types vs. taste	- Seed distribution/logistics - Development of local seeds and evaluation of its environmental impact throughout its life cycle
Research and Development to improve agriculture production system (for produced capital)	- Application of technology in GAP - Research and database of seed types vs. taste - Waste management and utilisation	- Collaboration with academics and research institution - Financial assistance to promote R&D - Best practice from private sectors
Education/Skills for human capital	- Knowledge of Good Agricultural Practice (GAP) - Implementation of GAP - Farmers' assistance/extension programme (Penyuluh) - Knowledge for Farmers - Aging trees - Pruning - Sanitation (Fungicide Application) - Fertilizer application - Fermentation techniques - increased risk of failure with inappropriate fermentation techniques) - Knowledge for Farmers	- Benchmarking with best practise on cacao assistance/extension program - Provide knowledge management tool (digitisation) for smallholder farmers

Local Spatial Planning for social capital (e.g. availability and distribution of local expertise)	- Aging farmers - Declining number of farmers - Farmers' assistance/extension (Penyuluh)	- Price policy for improving farmers livelihood - Development of local education or vocational studies - Proper Remuneration for farmers' extension/ assistance
Soil Quality	- High soil acidity	- Agronomy research
Infrastructure development	- On-farm post-harvesting facility - Access to tangible resources for farmers (electricity, clean water, etc)	- Facility location allocation - Acceleration of Rural Development
Health	- Potential health impact to human (farmers) due to fungicide/chemicals/fertilizer application	- Capacity building and knowledge management to farmers and workers – Farmers certification - Development of Occupational health and safety standards for farmers and workers
	- Health benefit of consumption of cacao - cacao culture	- Establish cacao culture consumption
Food Security (Access/Distribution)	- Low income for farmers leads farmers to switch to other crops - Price indifference for fermented cacao on farmer level (no fair trade) - Farmers' assistance/extension (Penyuluh) - low income for extension-	- Cooperative for farmers to improve the livelihood, knowledge sharing, and bargaining power (BUMDES) - Development of regulation on fair trade - Implementation of fair trading - Pricing policy for premium market
Labour inputs (incl. skills)	- Aging farmers - Declining number of farmers - Knowledge of Good Agricultural Practice (GAP) and application of technology - Implementation of GAP - Farmers' assistance/extension (Penyuluh)	- Cooperative for farmers to improve the livelihood, knowledge sharing, and bargaining power (BUMDES) - Development of local education or vocational studies - Proper Remuneration for farmers' extension/ assistance

Water Quantity & Quality	- Agroforestry - Diversification with forest trees (pine, teak, Albizia chinensis)	- Agroforestry
	- Knowledge of Good Agricultural Practice (GAP) and application of technology	- Life Cycle Assessment
	- Implementation of GAP	- Monitoring
Integration along the value chain	- Unsynchronized information between upstream and downstream (supply and demand) - Data discrepancies and reliability	- Development of mutual business partnership between farmers and private players (such as input suppliers and chocolate manufacturers) - Data tracking and integration

Appendix 3: TEEBAgriFood Evaluation and Implementation Roadmap

1. **Capacity development for implementing TEEBAgriFood**
    - Led by the UNEP TEEB office (Geneva)
    - To develop skills for evidence-based policy generation in agriculture and environment sectors
    - *August 2019 – December 2020*

2. **Rapid assessment policy brief**
    - Led by **Jacob Salcone** and **Jessica Hanafi**
    - Literature review and stakeholder consultation
    - Complete by *November 2019*

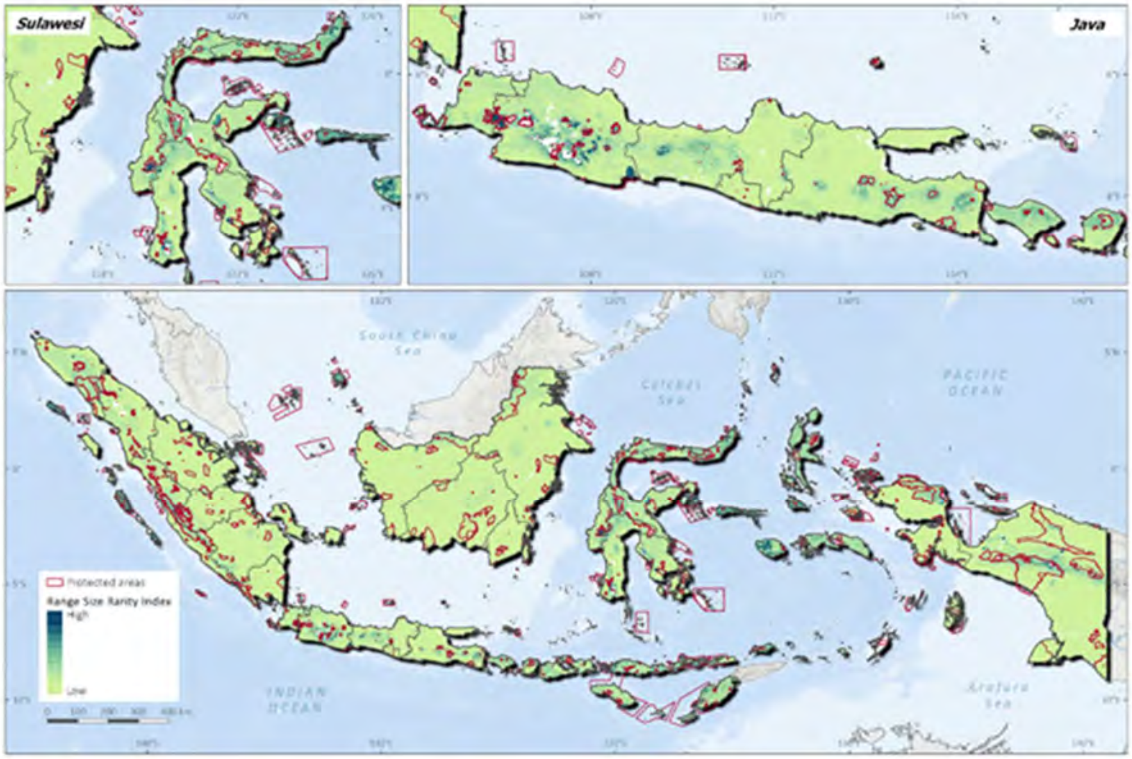
3. **Life-cycle assessment scoping**
    - Led by **Jessica Hanafi**
    - General results by *December 2019*

4. **Landscape level assessment of land use and land cover scenarios**
    - Led by **Jacob Salcone with support from BAPPENAS and WCMC**
    - Modelling and mapping of ecosystem services, focus on transition from monoculture in lowland areas suitable for cacao
    - Complete by *December 2020*

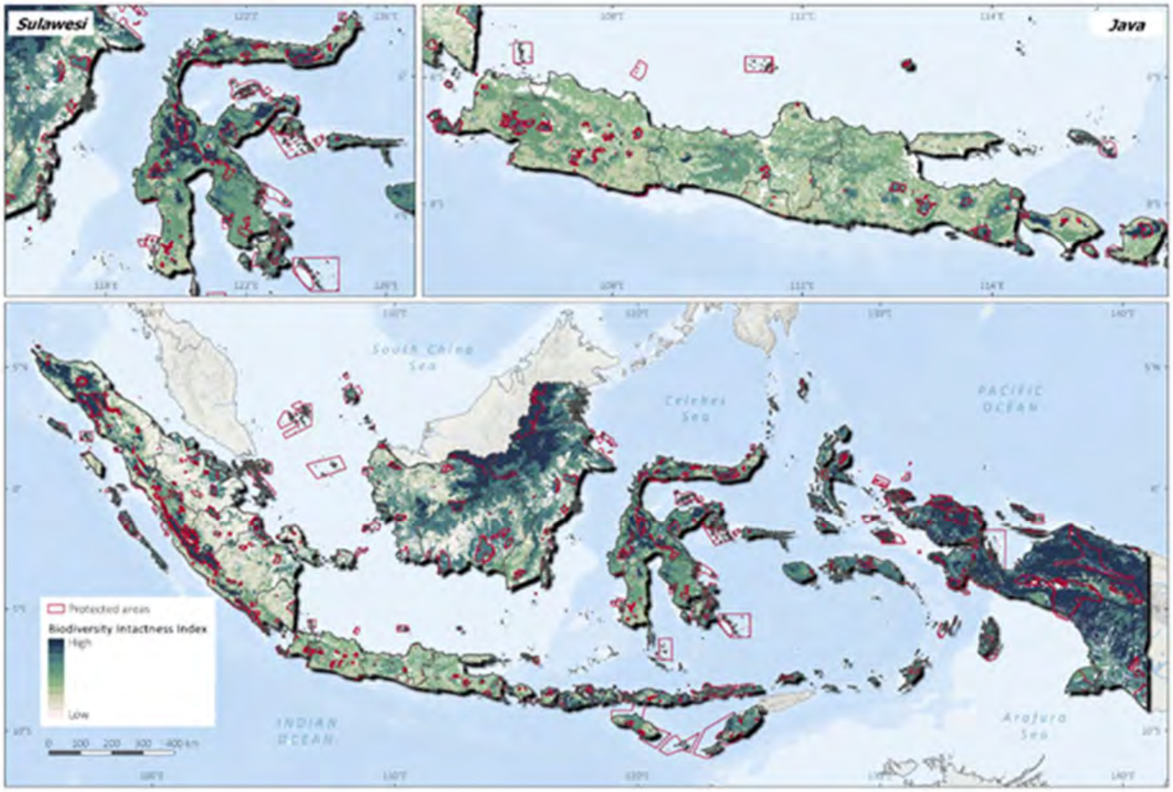
5. **Full TEEBAgriFood farm management practice comparison**
    - Led by **TBD**
    - Results to inform policies for input supports or extension services
    - Complete by *December 2020*

Appendix 4: Additional maps for section IV Spatial Assessment

4.1 Biodiversity in Indonesia



Map 1: Range rarity index for biodiversity for all Indonesia.



Map 2: Biodiversity intactness map (relative to a pristine state) for Indonesia, overlaid with protected areas.

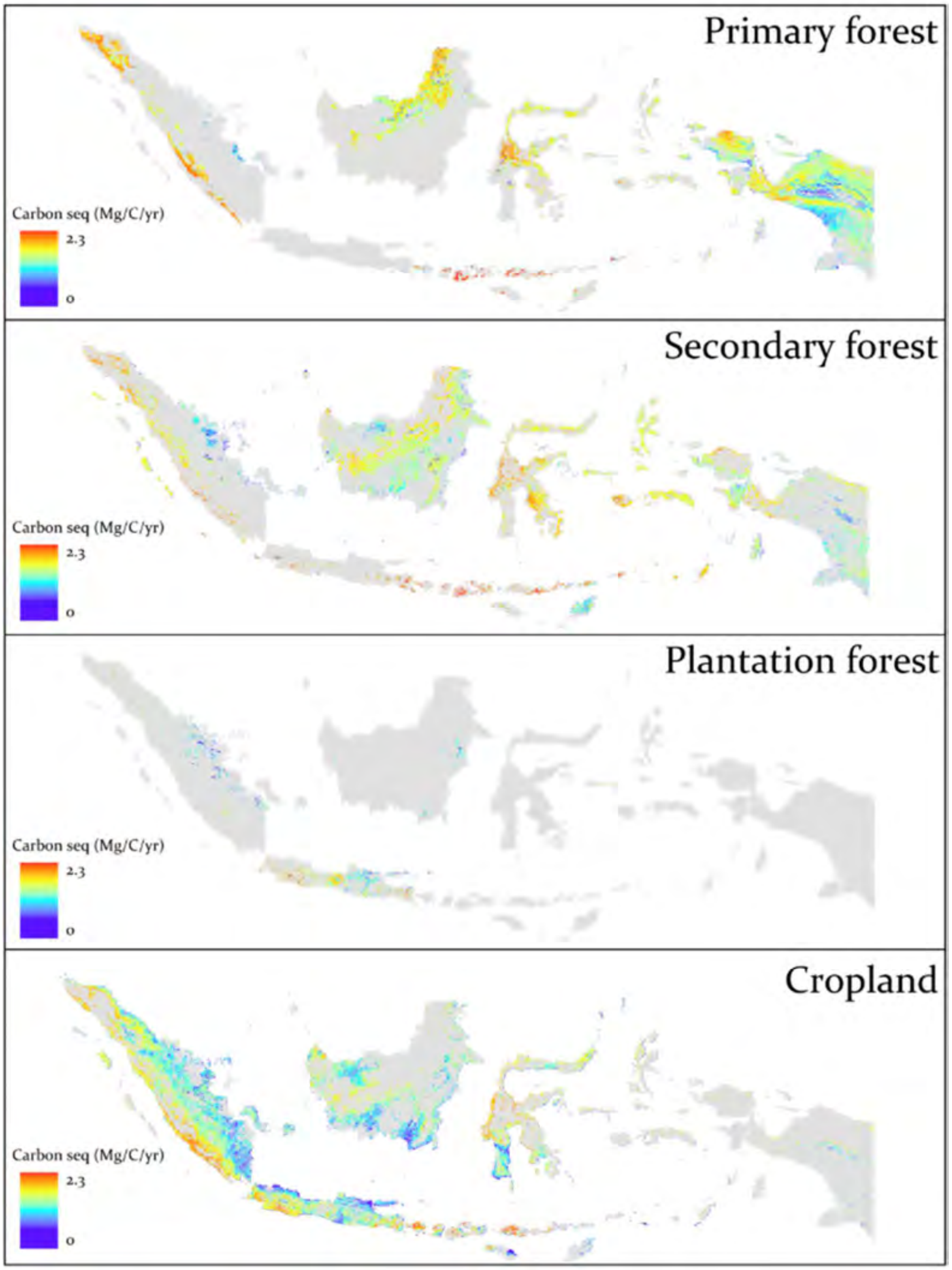
4.2 Maps of ecosystem services by land cover type in Indonesia

1. **Carbon stock**

Carbon stock includes total above and below ground stocks which were modelled with the Co$tingNature ecosystem services model (www.policysupport.org/costingnature) based on data from Saatchi et al. 2011, Ruesch and Gibbs, 2008, Scharlemann et al. 2009, Baccini et al. 2012. The highest mean values of carbon stock are found in primary forest and plantation forests. However, primary forest encompasses a much larger area (460,000 km2 vs 46,000 km2 for plantation forest). The high values in primary forest are mainly found in West Papua and West Sumatra. Plantation forest has some high carbon stock values in West Sumatra as well. These are mainly the result of high soil carbon.

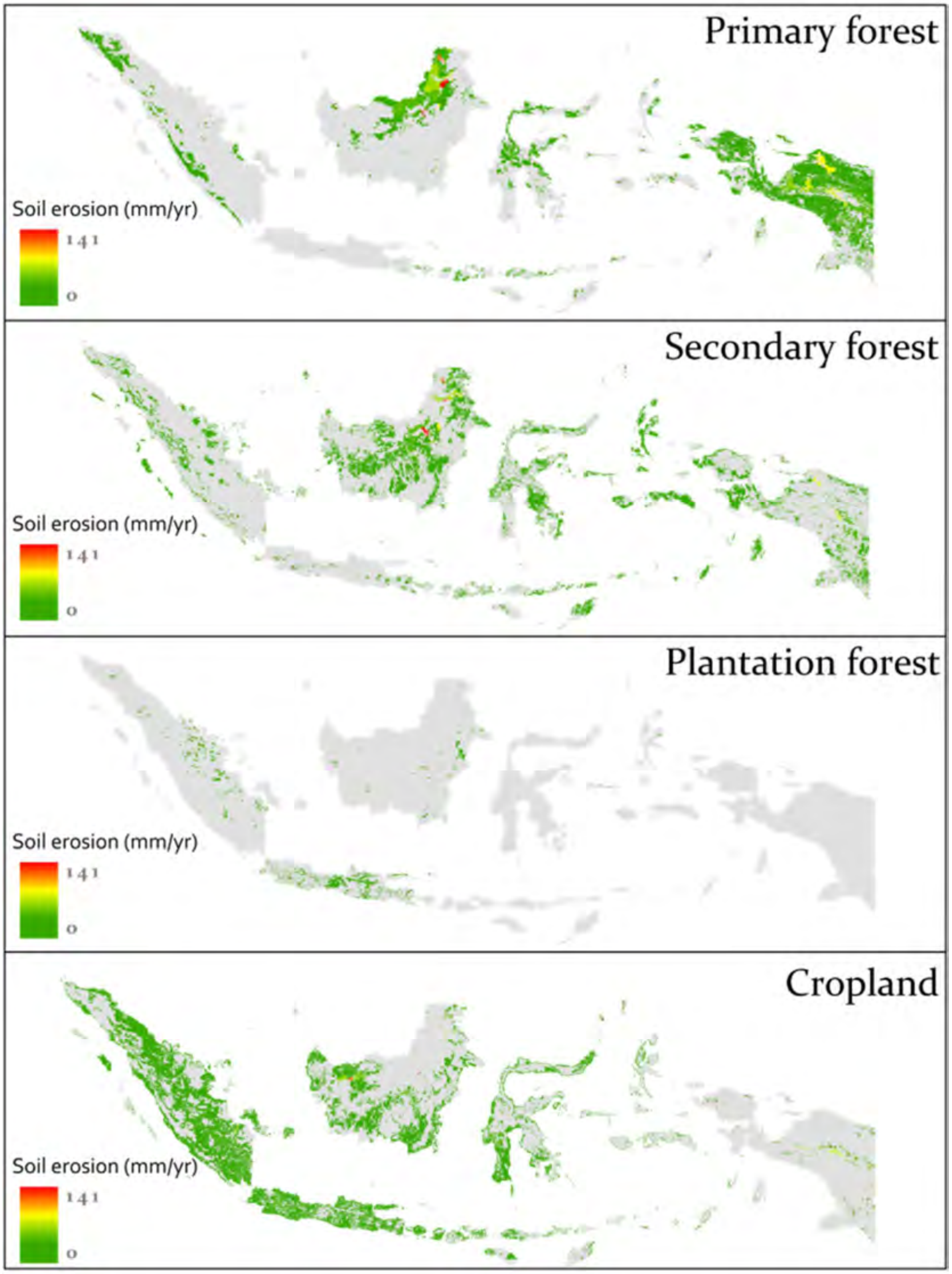
2. Carbon sequestration

Carbon sequestration modelled using Co$tingNature ecosystem services model based on mean dry matter productivity for 2013-2018 from PROBA-V data. Highest mean values for carbon sequestration are also found in primary forest and plantation forest, the latter being more productive but again for much smaller total area than primary forest.



3. Soil erosion

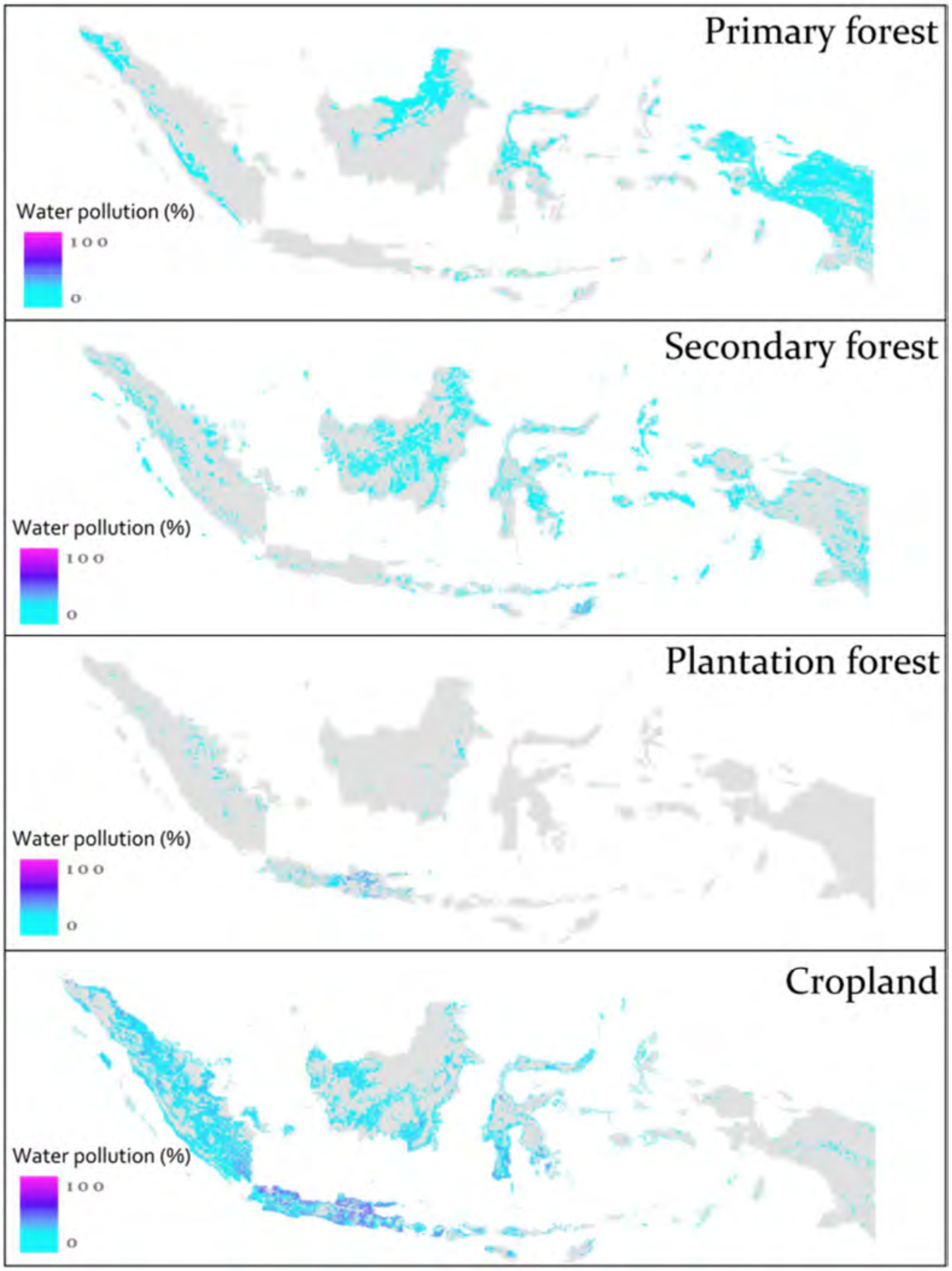
Gross annual soil erosion, modelled using WaterWorld V3 ecosystem services model in mm/yr. Highest soil erosion is found in primary forest, mainly in North Kalimantan and are the result of steep topography.



4. Water quality

Water quality is a metric of potential water pollution defined as the Human Footprint on water quality index, modelled using WaterWorld V3 ecosystem services model (www.policysupport.org/waterworld). This is an index of potential pollution taking into account point (e.g. mines) and diffuse (e.g. agriculture) sources of pollution in combination with a fully distributed hydrological model using downstream routing along a hydrological network derived from the Hydrosheds (Lehner et al. 2008) digital elevation model.

Mean potential water pollution is highest for plantation forest and croplands particularly in South Sumatra and Central Java.



4.2 Country wide analysis for scenario 1

<u>Scenario 1: displacement of cocoa production in secondary forests under current climatic conditions</u>

The previous scenario was also repeated for cocoa suitability under current climatic conditions, to demonstrate where cocoa expansion may occur in the near future without planning for more sustainable options, and the effects this would have on biodiversity.

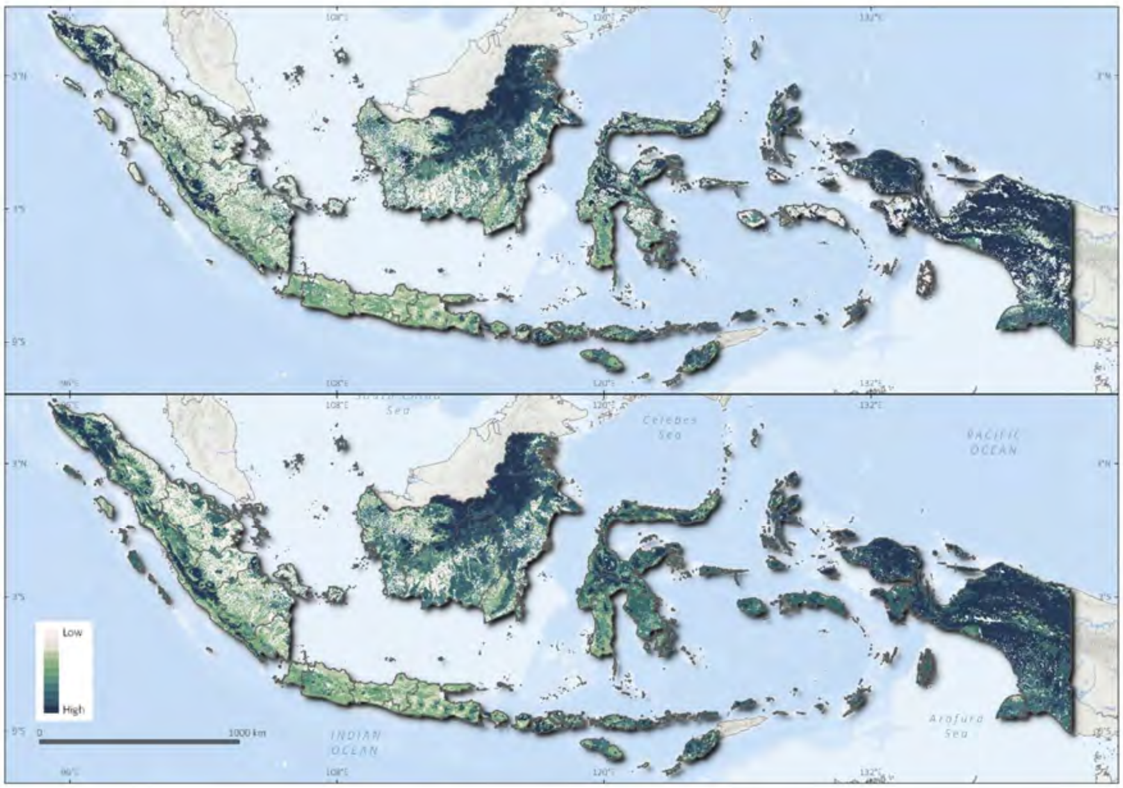
Map 3: Current distribution of climate zones for cacao within secondary forests in Indonesia.

Under current climatic conditions, the greatest areas for expansion into secondary forests are currently in eastern Indonesia, with ~ 79,000km2 for potential expansion in the Maluku and Papua province. Followed by Sumatra and Kalimantan. Compared to future climate change, Sulawesi currently has larger areas suitable for cocoa growing , ~17,600km2, a lot of which might be under cocoa already (even though it is classified as secondary forests) versus ~4,700km2 under future climate change conditions (Table X).

Biodiversity risk and Impacts

Map 4: Biodiversity significance within secondary forest expansion scenario, areas suitable for cocoa under current climatic conditions. Data is log transformed for visualisation, symbology stretch based on unsustainable secondary forest scenarios to best demonstrate variability within the data.

Similarly to the secondary forest expansion under future climate change scenario, the highest areas of biodiversity significance are seen in the smaller islands of the Sumatra and Maluku and Papua provinces (map4). However, due to the larger areas of expansion in Sulawesi, high biodiversity significance values are also seen here. Under current climatic conditions, Maluku and Papua would also have the highest total significance scores should all areas be converted to cocoa. This is followed by Sulawesi and Sumatra.



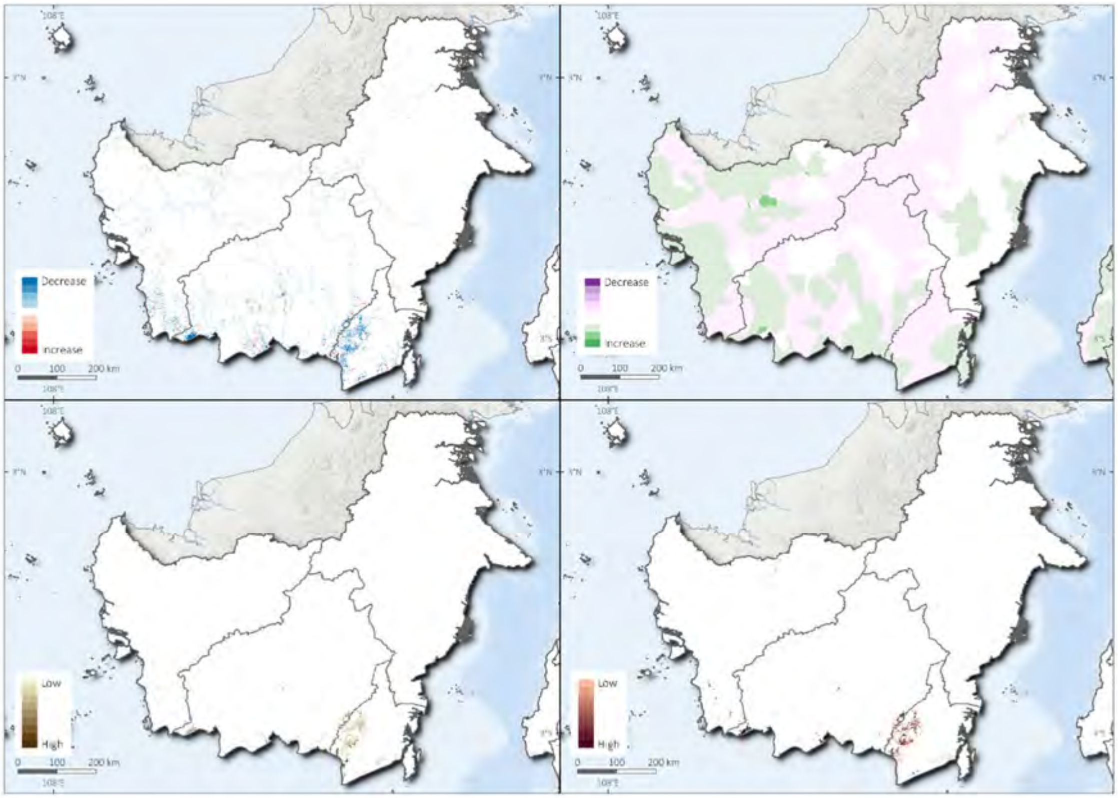
Map 5: Biodiversity Intactness Index values within Indonesia following expansion of cocoa into currently climatically suitable areas of secondary forest. Top: replacement of secondary forests with full-sun cocoa, bottom: replacement of secondary forests with cocoa agroforestry

As previously, impacts of secondary forest conversion were strongly dependent upon cocoa production method. Of all scenarios investigated, the greatest average loss in biodiversity intactness was observed when secondary forests deemed suitable for cacao production under current climatic conditions were converted to cocoa monoculture plantations, especially in areas of Sulawesi and Maluku and Papua (map5).

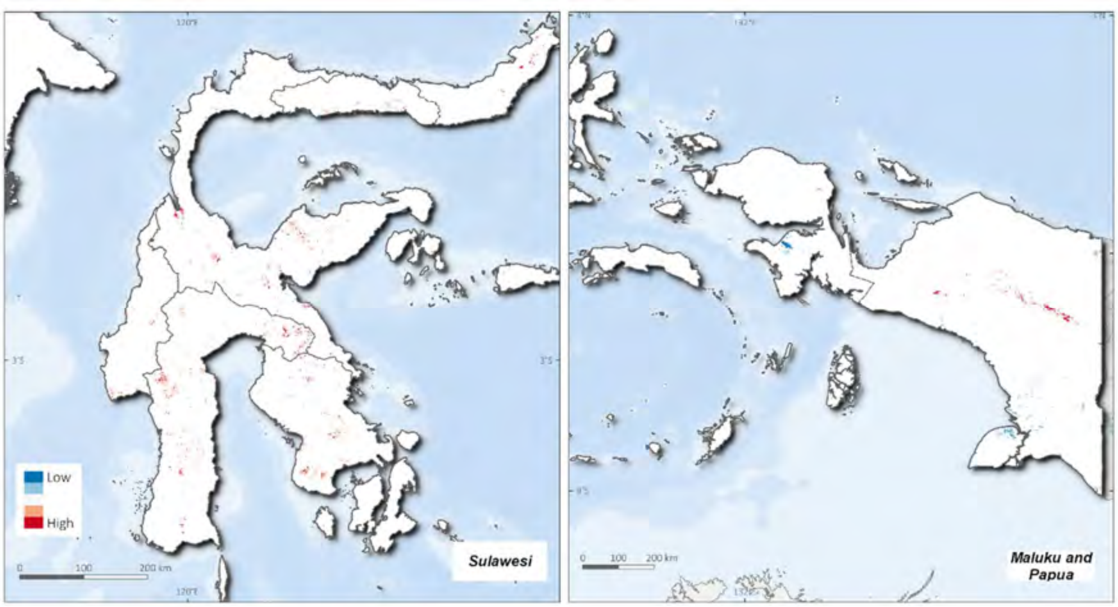
4.4. Province insets per scenario

Insets focussing on provinces with largest change per scenario. Water pollution change is shown with stretched symbology here to demonstrate where the effects decrease downstream.

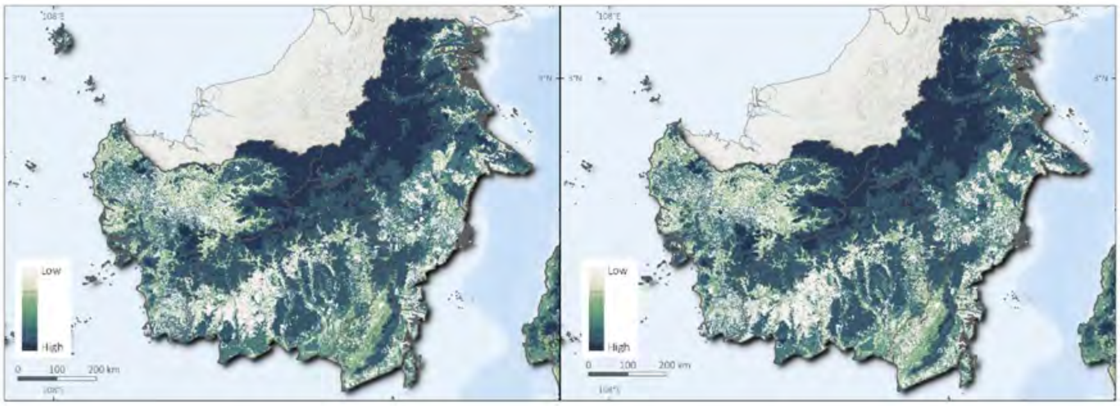
Scenario 5: cocoa expansion is promoted in degraded lands



Map 5: Changes in ecosystem services modelled for converting degraded land to cacao in Kalimantan, Indonesia (change in water pollution (% contamination), soil erosion in tonnes/ha, Total Carbon is in tonnes C/ha, Carbon sequestration is in Mg/C/ha/yr).

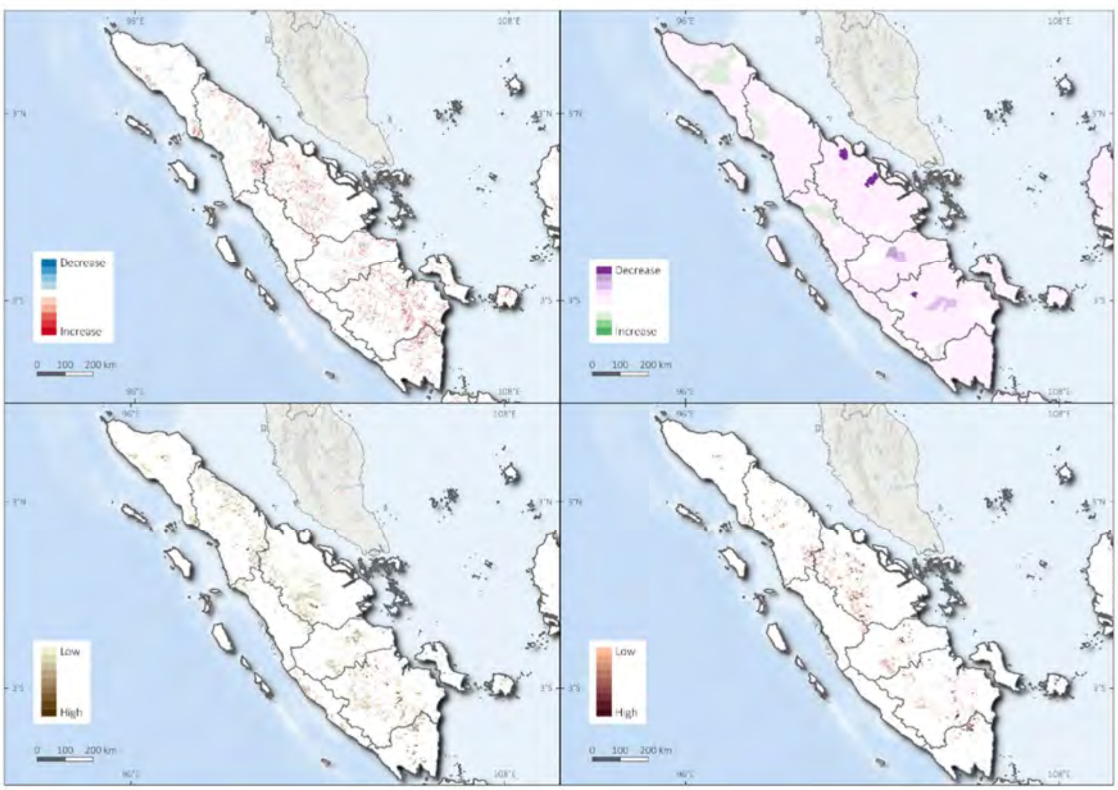


Map 6: Biodiversity significance in areas of degraded land replacement by cocoa under current climate suitability were highest in Sulawesi and Maluku and Papua. Data log transformed for visualisation, symbology stretch based on values from "policy-on" scenarios to increase visibility of variation within these scenarios.

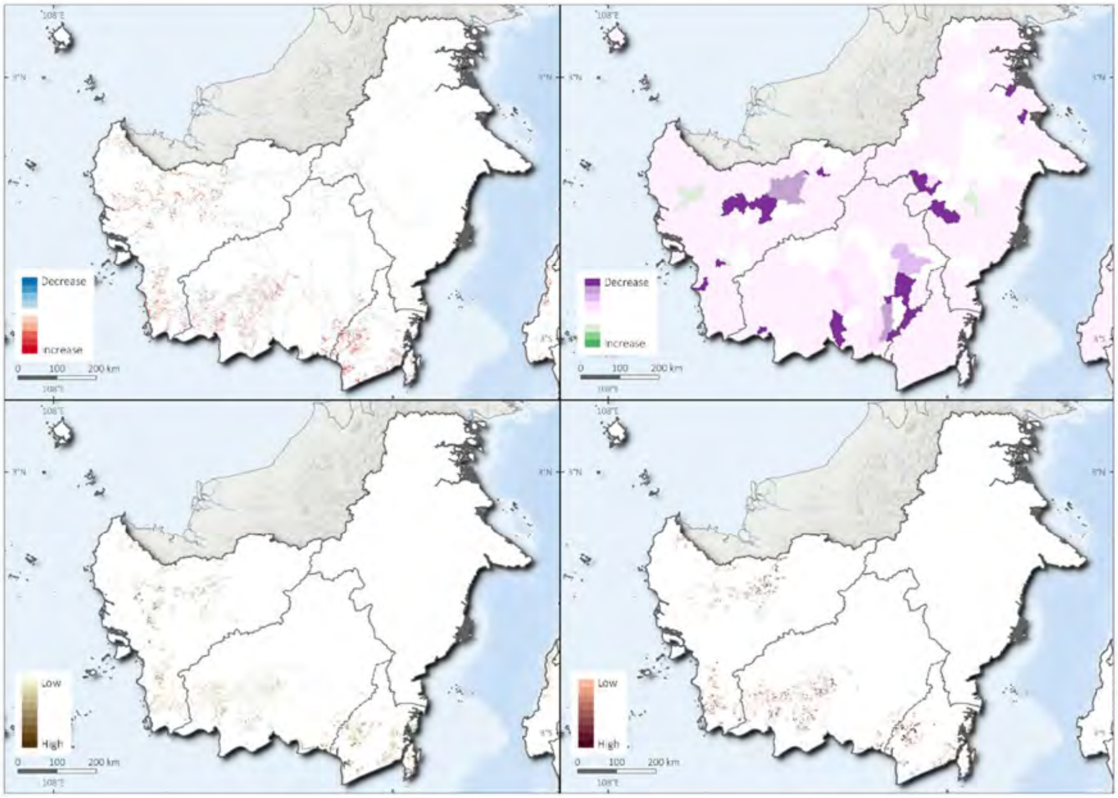


Map 7: Biodiversity Intactness Index values within Kalimantan following expansion of cocoa into currently climatically suitable areas of degraded land. Left: replacement of secondary forests with full-sun cocoa, right: replacement of secondary forests with cocoa agroforestry.

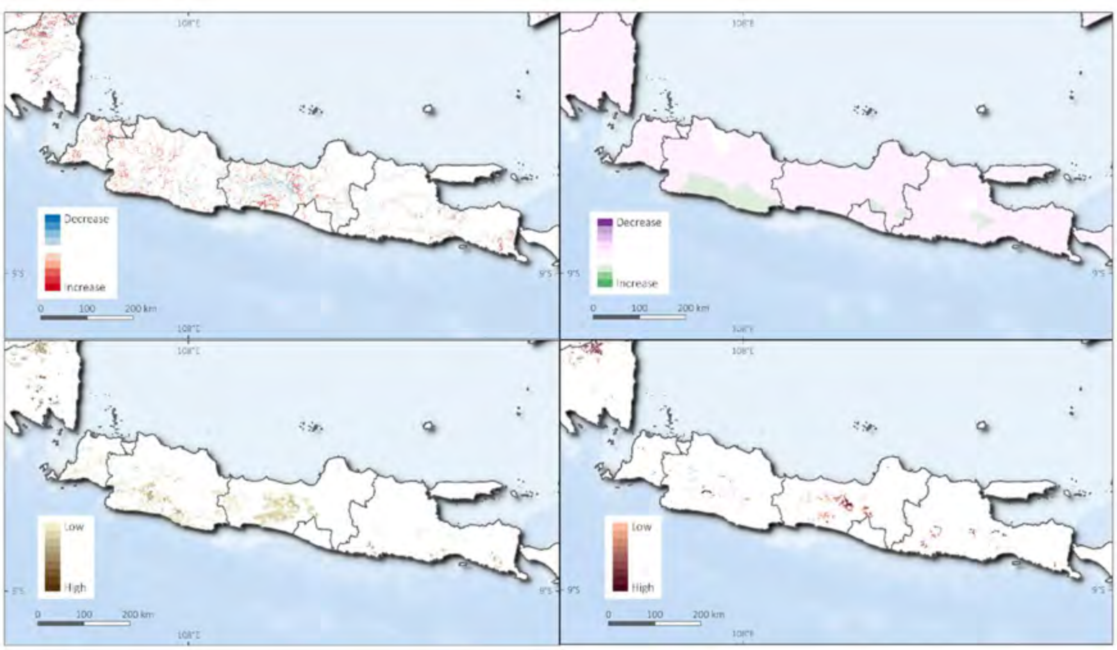
<u>Scenario 6: cocoa expansion is promoted as an alternative to other perennial crops</u>



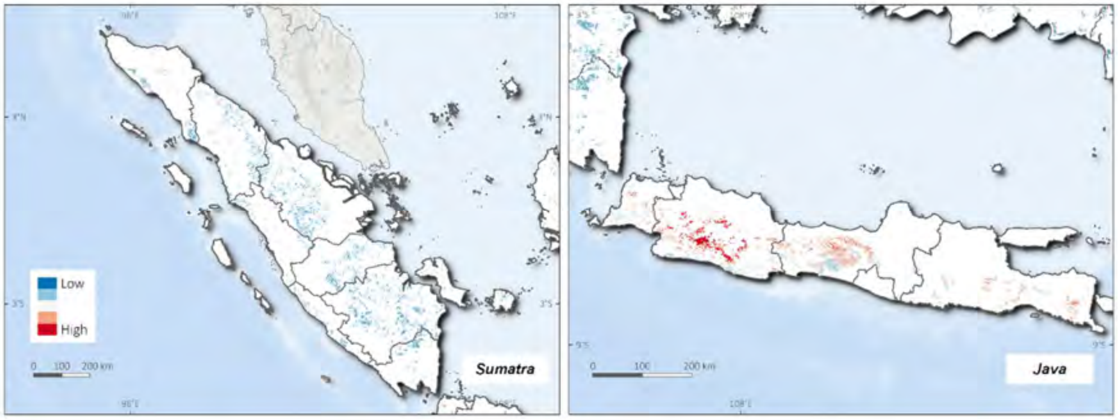
Map 8: Changes in ecosystem services modelled for converting other perennial plantations to cacao in Sumatra, Indonesia (change in water pollution (% contamination), soil erosion in tonnes/ha, Total Carbon is in tonnes C/ha, Carbon sequestration is in Mg/C/ha/yr).



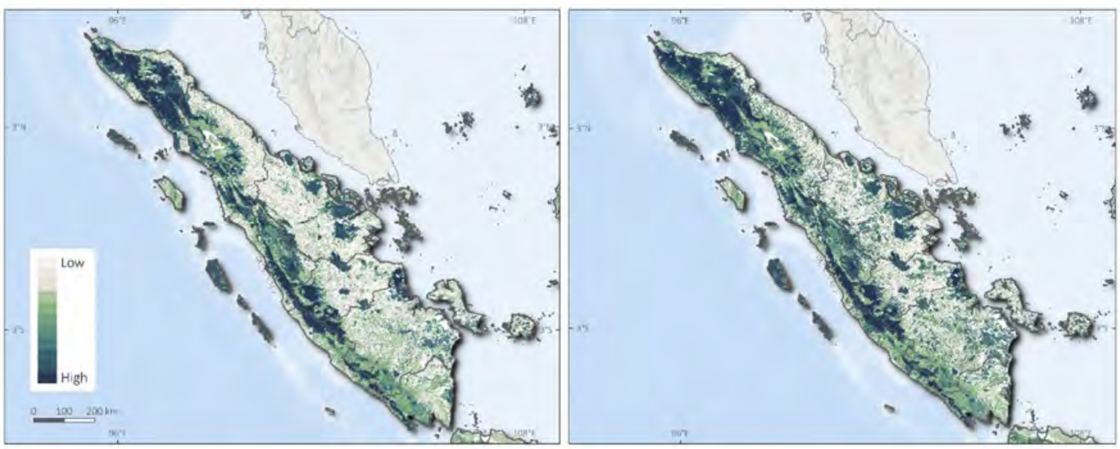
Map 9: Changes in ecosystem services modelled for converting other perennial plantations to cacao in Kalimantan, Indonesia (change in water pollution (% contamination), soil erosion in tonnes/ha, Total Carbon is in tonnes C/ha, Carbon sequestration is in Mg/C/ha/yr).



Map 10: Changes in ecosystem services modelled for converting other perennial plantations to cacao in Java, Indonesia (change in water pollution (% contamination), soil erosion in tonnes/ha, Total Carbon is in tonnes C/ha, Carbon sequestration is in Mg/C/ha/yr).

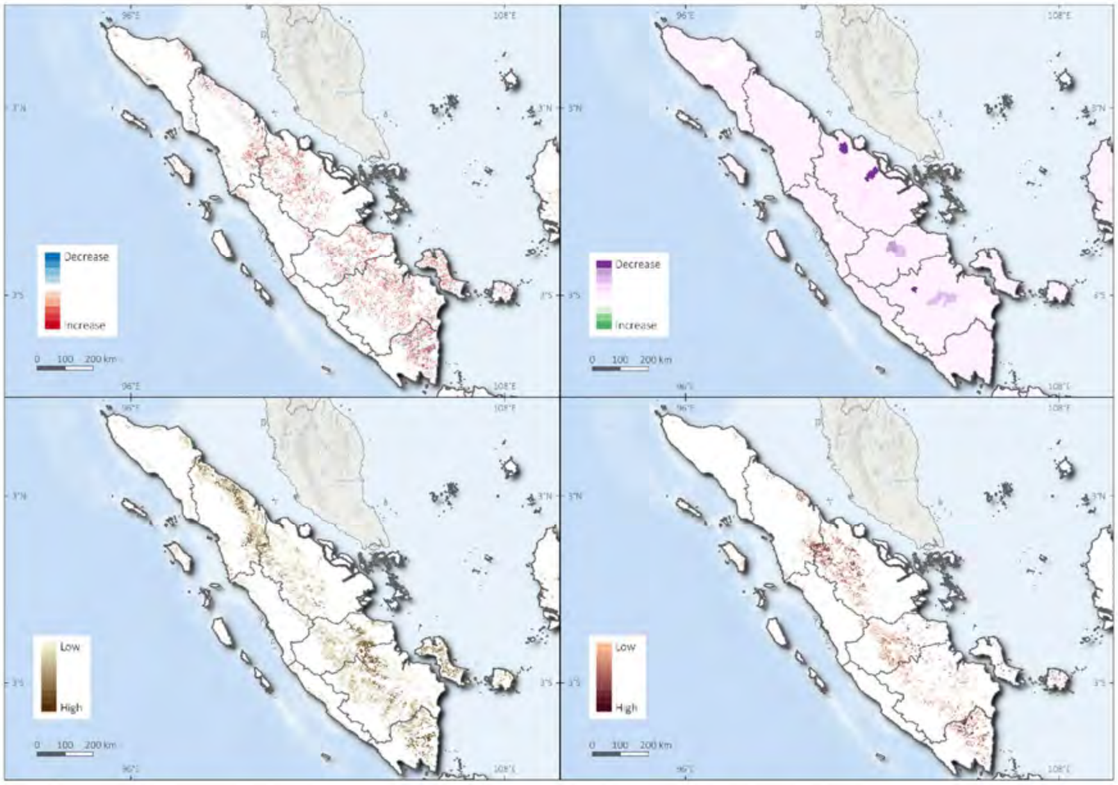


Map11: Biodiversity significance in areas of plantation replacement by cocoa under current climate suitability in Sumatra and Java. Data log transformed for visualisation, symbology stretch based on values from "policy-on" scenarios to increase visibility of variation within these scenarios.

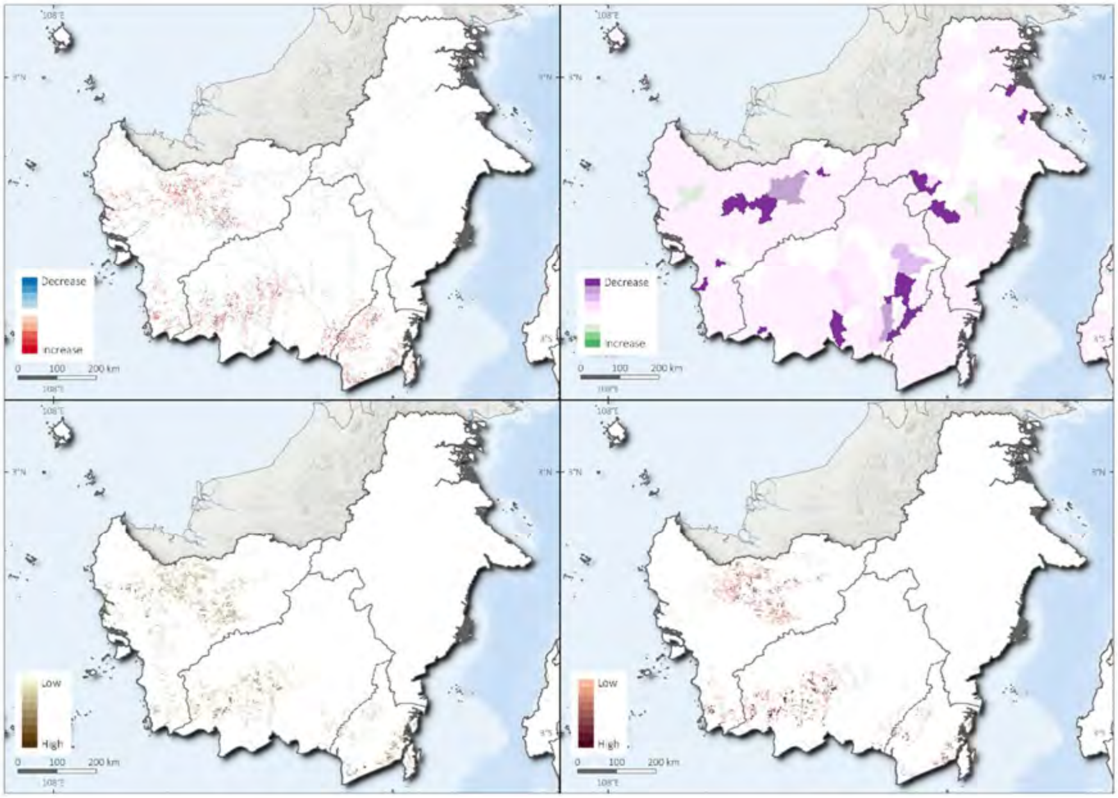


Map 12: Biodiversity Intactness Index values within Sumatra following expansion of cocoa into currently climatically suitable areas currently used as plantations. Top: replacement of secondary forests with full-sun cocoa, bottom: replacement of secondary forests with cocoa agroforestry.

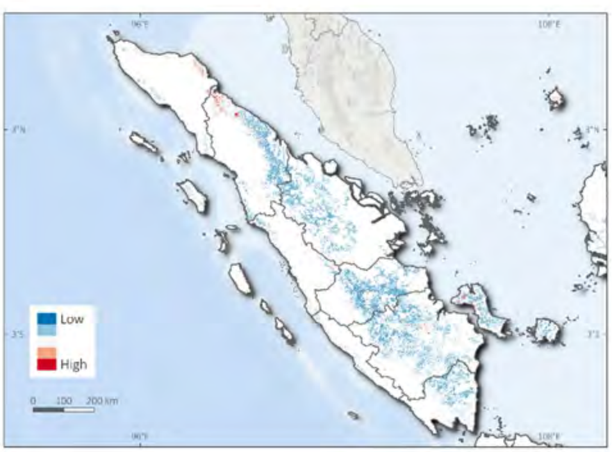
<u>Scenario 7: cocoa expansion is promoted as an alternative to oil palm.</u>



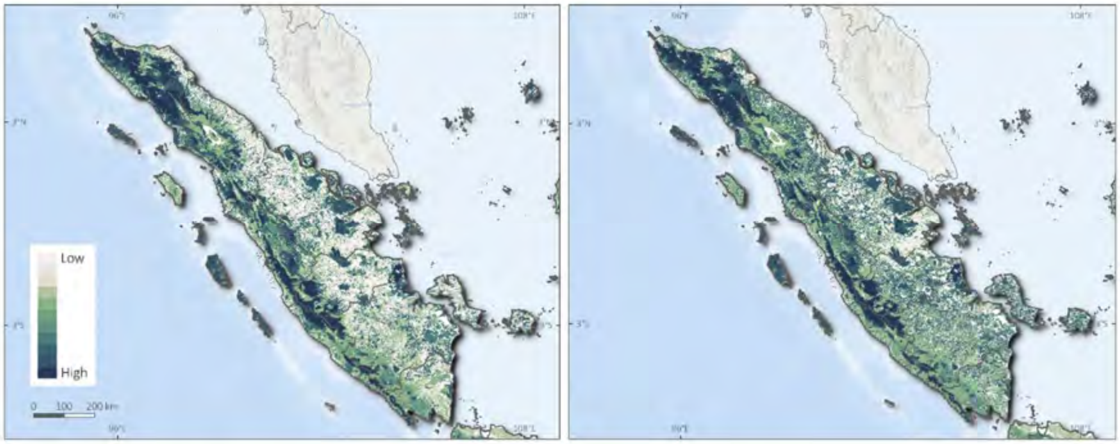
Map 13: Changes in ecosystem services modelled for converting oil palm to cacao in Sumatra, Indonesia (change in water pollution (% contamination), soil erosion in tonnes/ha, Total Carbon is in tonnes C/ha, Carbon sequestration is in Mg/C/ha/yr).



Map 14: Changes in ecosystem services modelled for converting oil palm to cacao in Kalimantan, Indonesia (change in water pollution (% contamination), soil erosion in tonnes/ha, Total Carbon is in tonnes C/ha, Carbon sequestration is in Mg/C/ha/yr).



Map 15: Biodiversity significance in areas of oil palm replacement by cocoa under current climate suitability in Sumatra. Data log transformed for visualisation, symbology stretch based on values from "policy-on" scenarios to increase visibility of variation within these scenarios.



Map 16: Biodiversity Intactness Index values within Sumatra following expansion of cocoa into currently climatically suitable areas currently used for Oil Palm cultivation. Left: replacement of secondary forests with full-sun cocoa, right: replacement of secondary forests with cocoa agroforestry.

4.5. Ecosystem services changes under three "policy-on" scenarios

Table 1: Mean, min and max water pollution change (%) in each province under each cocoa expansion scenario.

Province	Degraded Lands			Plantations			Oil Palm		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Sulawesi	-0.42	-99.99	33.57	0.02	-14.49	89.67	-0.005	-7.46	4.04
Sumatra	-0.26	-27.81	70.01	-0.04	-99.99	64.63	-0.07	-99.99	83.75
Java	-0.16	-99.99	6.38	0.001	-13.27	43.29	0.01	-4.81	7.25
Maluku and Papua	-0.24	-18.90	95.39	-0.0005	-5.61	16.74	-0.001	-5.61	16.74
Nusa Tenggara and Bali	-0.02	-4.09	0.67	-0.00004	-0.02	0.001	-0.00004	-0.02	0.001
Kalimantan	-0.42	-13.28	10.96	-0.01	-10.08	8.20	-0.02	-13.19	10.54

It is important to consider that the absolute changes shown depend on the baseline values in the tables below.

Table 2: Mean, min and max soil erosion change for sub-basins (mm/year) in each province under each cocoa expansion scenario.

Province	Degraded Lands			Plantations			Oil Palm		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Sulawesi	-0.001	-0.03	0.01	-0.32	-4.86	0.000004	-0.33	-4.86	0.000002
Sumatra	-0.03	-1.79	0.24	-1.23	-114.23	0.0006	-1.22	-114.23	0.002
Java	-0.004	-0.06	0.001	-0.25	-2.78	0.0001	-0.25	-2.78	1E-12
Maluku and Papua	-0.04	-1.12	0.02	-2.58	-120.58	0.0002	-2.56	-120.58	0.0001
Nusa Tenggara and Bali	-0.01	-0.05	0.00001	-0.19	-0.71	2E-7	-0.19	-0.71	2E-7
Kalimantan	-0.05	-8.27	0.05	-5.10	-290.01	0.00003	-5.07	-290.01	0.00002

Table 3: Mean, min and max soil erosion change for sub-basins (tonnes/ha/year) in each province under each cocoa expansion scenario.

Province	Degraded Lands			Plantations			Oil Palm		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Sulawesi	-7.3E-07	-3.8E-05	2.44E-05	-0.00036	-0.008	1.3E-08	-0.00036	-0.008	3.27E-09
Sumatra	-5.7E-05	-0.01855	0.028952	-0.00946	-59.37	2.09E-06	-0.00936	-59.4	0.0002
Java	-5.9E-06	-8.3E-05	4.14E-06	-0.00053	-0.02	6.23E-07	-0.00053	-0.02	3.93E-13
Maluku and Papua	-5.3E-05	-0.00317	3.25E-05	-0.01428	-22.5	0.000121	-0.01418	-22.5	9.59E-05
Nusa Tenggara and Bali	-9E-06	-0.00011	1.9E-08	-0.0002	-0.0009	1.6E-08	-0.0002	-0.0009	1.6E-08
Kalimantan	-0.00035	-0.07336	0.001	-0.04	-41.9	4.11E-06	-0.04029	-41.9	2.15E-06

Table 4: Mean, min and max total carbon stock change (tonnes/ha) in each province under each cocoa expansion scenario.

Province	Degraded Lands			Plantations			Oil Palm		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Sulawesi	82.22	0.12	222.71	43.95	0.15	204.00	43.04	0.20	205.00
Sumatra	111.39	0.09	372.00	95.31	0.08	378.03	114.02	0.14	379.53
Java	48.99	0.01	158.07	43.68	0.07	257.80	29.22	3.57	147.46
Maluku and Papua	140.99	0.05	417.53	89.38	0.01	385.53	97.31	0.01	425.75
Nusa Tenggara and Bali	58.26	3.38	153.61	11.57	11.57	11.57	12.90	12.90	12.90
Kalimantan	97.38	0.27	409.90	98.51	0.08	436.68	100.93	0.08	410.80

Table 5: Mean, min and max carbon sequestration change (Mg/C/ha/yr) in each province under each cocoa expansion scenario.

Province	Degraded Lands			Plantations			Oil Palm		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Sulawesi	0.26	0.0001	1.45	0.21	0.001	1.43	0.19	0.001	1.43
Sumatra	0.24	0.0002	1.28	0.19	-0.09	1.50	0.17	-0.09	1.40
Java	0.18	0.0001	1.23	0.19	0.0001	1.45	0.10	0.0004	0.57
Maluku and Papua	0.36	0.001	1.35	0.18	0.00003	1.29	0.11	0.0001	1.39
Nusa Tenggara and Bali	0.30	0.02	0.54	0.00	0.00	0.00	0.00	0.00	0.00
Kalimantan	0.30	0.00002	1.32	0.19	-0.20	1.32	0.16	0.00	1.44

4.6. Biodiversity significance within areas of potential conversion in all scenarios per province

Table 6: Mean and sum biodiversity significance within areas of potential conversion for each expansion scenario. Biodiversity significance in each scenario. Mean scores are shown as an indication of the potential risk of converting *a given area*, and total (sum) scores to show overall risk if *all areas* are converted for that scenario (e.g. where all oil palm is converted to cocoa in the oil palm scenario).

Province	Secondary forest (current climate)		Secondary forest (future climate)		Degraded lands		Plantations		Oil Palm	
	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total
Sulawesi	0.0004	17.98	0.0004	2.51	0.0002	0.64	0.0003	0.8	0.0005	1.12
Sumatra	0.0002	13.26	0.0002	10.55	0.00007	0.3	0.00008	2.77	0.00006	4.62
Java	0.0008	3.57	0.001	2.17	0.0003	0.14	0.0004	4.95	0.0004	0.08
Maluku and Papua	0.0002	20.74	0.0002	11.5	0.0003	1.18	0.0002	0.31	0.0001	0.61
Nusa Tangarra and Bali	0.0005	0.07	0.0003	0.005	0.0003	0.008	0.0005	0.0005	0.0004	0.002
Kalimantan	0.00007	2.98	0.00007	4.49	0.00005	0.28	0.00005	0.6	0.00005	0.93

Appendix 5

Table 5.1: Social Topics in Each Process.

No	Social topics	Types of capital	Assets & capabilities
Farmers in Cultivation and Pre-Processing			
1	Meeting basic needs	Human capital	Physical health, ability to work
		Natural capital	Access to water
		Physical capital	Sanitation, water supply system
2	Access to inputs and services	Physical capital	Inputs such as equipment, tools, seeds, information and communication technologies, roads
		Financial capital	Income, credit, trade
3	women's empowerment	Human capital	Skills, knowledge, health
		Social capital	Relationship of trust
4	Child labour	Human capital	Health of children, safety, education
		Physical capital	Schools
5	Health & Safety	Human capital	Physical health, ability to work, knowledge of safety procedures
		Physical capital	Personal protection equipment, quality of machinery or chemicals used
6	Land rights	Natural capital	Land
		Social capital	Relationship of trust
7	Fair trading relationship	Social capital	Relationship of trust to facilitate collaboration, membership of formalised groups, informal networks
		Human capital	Knowledge, education, skills
SME in Industrial Processing			

1	Meeting basic needs	Human capital	Physical health, ability to work
		Natural capital	Access to water
		Physical capital	Sanitation, water supply system
2	Access to inputs and services	Physical capital	Inputs such as equipment, tools, seeds, information and communication technologies, roads
		Financial capital	Income, credit, trade
3	women's empowerment	Human capital	Skills, knowledge, health
		Social capital	Relationship of trust
4	Child labour	Human capital	Health of children, safety, education
		Physical capital	Schools
5	Health & Safety	Human capital	Physical health, ability to work, knowledge of safety procedures
		Physical capital	Personal protection equipment, quality of machinery or chemicals used
6	Fair trading relationship	Social capital	Relationship of trust to facilitate collaboration, membership of formalised groups, informal networks
		Human capital	Knowledge, education, skills
Employee in Industrial Processing			
1	Health & safety	Human capital	Overall health of workers, number of injuries, knowledge of safety procedures, etc.
		Physical capital	Personal protection equipment, quality of machinery, ergonomic furniture
		Social capital	Interactions, office culture, company policies
2	Remuneration	Financial capital	Wages, benefits
3	Freedom of association &	Social capital	Interactions between

	collective bargaining		management & workers, office culture, Relationship of trust
4	Work-life balance	Human capital	Health and ability to work (i.e. no burnouts)
Local Communities in Cultivation and Processing Industry			
1	Access to tangible resources	Physical capital	Basic infrastructure: roads, water supply system, schools
		Natural capital	Land, water, forest, relevant non-renewable resources, ore, oil, gems
		Human capital	Knowledge
		Social capital	Relationship of trust that facilitates cooperation
		Financial capital	Access to financing, taxes from the company or facility that contribute to local economic development, financial infrastructure
2	Community engagement	Social capital	Interactions, relationship of trust that facilitates cooperation
3	Employment & skill development	Human capital	Skills and knowledge

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