IMPROVING BUSINESS DECISION MAKING:

VALUING THE HIDDEN COSTS OF PRODUCTION IN THE PALM OIL SECTOR

CITATION

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DISCLAIMER

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GLOSSARY

TERM	DEFINITION
Natural capital	The stock of renewable and nonrenewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people, both directly and indirectly (Natural Capital Coalition, 2016). Natural capital is frequently valued in terms of impacts on society, such as human health
Social capital	Social capital refers to the value inherent in relationships and networks amongst people and institutions that enables society to function more effectively. An example of an impact on social capital is land dispossession and associated land conflicts
Human capital	Human capital refers to people and their ability to be economically productive. Education, training and health care can help increase human capital. In this study, human capital impacts have a direct effect on the health and welfare of people working in the product's value chain, such as underpayment and occupational health & safety. Polluting air emissions, while valued by their impact on human health, are considered an impact on natural capital
Visible benefits	Economically visible positive flows/impacts such as employment wages
Visible costs	Economically visible negative flows/impacts such as carbon markets which put a monetary price on greenhouse gas (GHG) pollution
Hidden benefits	Economically invisible flows/impacts of agriculture and food system, both positive and negative, include those on water quality, air emissions, and food safety. Hidden costs and benefits are rarely captured by conventional economic analyses that usually value goods and services that have a market price (also referred to as positive externalities). Examples of hidden benefits include aesthetic appreciation of a managed agricultural landscape, leisure and recreation within such landscapes in the form of agro-tourism, or cultural identity arising from the cultivation of and consumption of local farming produce (TEEB, 2015)
Hidden costs	Economically invisible flows/impacts of agriculture and food system, both positive and negative, include those on water quality, air emissions, and food safety. These hidden costs and benefits are rarely captured by conventional economic analyses that usually value goods and services that have a market price (also referred to as negative externalities). Examples of hidden costs include health impacts arising from agro-chemicals and nutrient run-off from farmland affecting the quality of bathing water, which in turn impacts on the leisure and recreation opportunities (TEEB, 2015)
Environmental costs/benefits	Environmental costs/benefits is a term used for visible or hidden costs/benefits when referring to the effect they have on natural capital
Social costs/benefits	Social costs/benefits is a term used for visible or hidden costs/benefits when referring to the direct or indirect effect they have on society. This includes all direct and indirect effects of human and social capital impacts and most indirect effects of natural capital impacts
Externalities	An externality arises when the actions of one economic agent in society impose costs or benefits on other agent(s) in society, and these costs or benefits are not fully compensated for and thus do not factor into that agent's decision-making (TEEB, 2015). External costs and benefits are called respectively negative and positive externalities

Internalization of externalities	A range of drivers that can lead to privatization of the external cost to the creator e.g. carbon taxes leading to additional cost to companies releasing greenhouse gases (GHGs)
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (TEEB, 2015)
Ecosystem services	The direct and indirect contributions of ecosystems to human well-being: • 'Provisioning' ecosystem services - all nutritional, material and energetic outputs from living systems • 'Regulating and Maintenance' ecosystem services - all the ways in which living organisms can mediate or moderate the ambient environment that affects human performance • 'Cultural' ecosystem services - all the non-material, and normally non-consumptive, outputs of ecosystems that affect people's physical and mental states
Eco-agri-food systems complex	A collective term encompassing the vast and interacting complex of ecosystems, agricultural lands, pastures, fisheries, labour, infrastructure, technology, policies, culture, traditions, and institutions (including markets) that are variously involved in growing, processing, distributing and consuming food (TEEB, 2015)
Valuation, economic	The process of estimating a value for a particular good or service in a certain context (in monetary or non-monetary terms) (TEEB, 2015)
Natural/human/social capital accounting	A process of translating physical measures in terms of metric tons of air pollutants emitted, or cubic meters of water used, into a monetary figure expressing the damage caused to the environment and society. Also known as monetary valuation, or monetization
Human capital return on investment	The human capital return on investment (HCROI) measures the human capital benefits created (or human capital costs reduced) relative to the financial resources invested. It is defined as the difference between the financial investment of an intervention and the increase in human capital benefits (or reduction in human capital costs) caused by the intervention, divided by the financial investment of the intervention

SUMMARY FOR DECISION MAKERS

EXECUTIVE SUMMARY

This report demonstrates how natural and human capital accounting can be used to understand and reduce the environmental and human impact costs of palm oil production. It was commissioned by TEEB as part of a series of studies for its agriculture and food (TEEBAgriFood) project.

Palm oil is the world's most popular vegetable oil, widely used in the food, personal care, chemicals and energy sectors. Over 56 million tonnes of palm oil was consumed in 2013 and this is expected to double by 2050. Its popularity is due to palm oil's high productivity, low market price, and versatility compared to other vegetable oils. Two types of palm oil are produced – crude palm oil from the fruit of the plant and palm kernel oil from its seed – which are used differently. While palm oil is naturally very stable and suitable for cooking, palm kernel oil contains almost double the amount of saturated fats and lower levels of carotenoids which makes it useful for making soaps, cosmetics and detergents.

However, the rapid growth of palm oil production in some countries is having serious environmental and social impact costs due to carbon dioxide emissions and air pollution from using fire to clear rainforest and peatland for new plantations, water pollution and harm to health from applying fertilizers and pesticides to crops, methane released from palm oil mill effluent processing facilities, land property rights violations during land expansion and substandard wages and working conditions.

The root cause of these problems is that the agriculture sector is too often considered in isolation from the society that it feeds, and the environment that supports it. Instead, business and society need to shift their thinking towards a systems-based approach which recognizes the reality that agriculture, society and the environment are all connected. Natural and human capital accounting are used to reveal these mutual inter-dependencies. In so doing, it is possible to highlight outcomes that both improve human livelihoods and also reduce impacts and dependencies on ecosystems and biodiversity.

Natural capital refers to the resources and services provided by nature such as clean air and water, healthy soil and a stable climate. Human capital refers to people and their ability to be economically productive. Companies, including farmers, in the agricultural sector depend on natural and human capital to support their business activities, so that they can grow crops and raise livestock. However, natural and human capital are often undervalued in the market, leading to their unsustainable use and increasing degradation. Natural and human capital accounting can put a monetary value on these resources and services, as well as on the damage done to them, so that policymakers and businesses can integrate the "true" natural and human capital costs and benefits into decision making[1].

In this way, companies and investors can use natural and human capital accounting to better understand the risks they face as a result of environmental and social impact costs. These risks stem from stricter regulation driving higher compliance costs, changing consumer demand leading to a loss of

[1] In environmental economics and the Natural Capital Protocol (Natural Capital Coalition, 2016), valuation can extend beyond montization to include qualitative, quantitative, and monetary approaches, or a combination of these.

market share, and reputational damage reducing share prices. For example, public concern over deforestation could cause customers to switch to certified sustainable palm oil or palm oil-free products. Tougher regulation of burning to clear land for new plantations or requiring legal minimum wages could lead to large fines.

By incorporating natural and human capital accounting into their businesses, companies and investors can reduce these risks, as well as take advantage of opportunities from more sustainable products and production processes. Policymakers too can use natural and human capital accounting when designing regulations or economic instruments to stress test the effect of those on the environment and social well-being.

This research is organized in two parts. First, a materiality assessment quantifies and monetizes a selection of material natural capital impacts of palm oil across the 11 leading producer countries. This is followed by a case study that quantifies and monetizes natural capital impacts in more detail in Indonesia, the largest palm oil producer, and also quantifies and monetizes a selection of human capital impacts. A scenario analysis illustrates how natural and human capital accounting can be used in Indonesia to compare a selection of alternative techniques for growing palm oil which may lower impact costs.

The scope of the research is limited to palm oil production and its supply chain for inputs such as fertilizers and pesticides. This approach was chosen rather than a full value chain assessment because this is where most natural capital impact costs occur. It does not include downstream activities such as transportation, product manufacturing, consumption and end of use. For the same reason, the study also focuses on assessing the natural and human capital costs of palm oil production. The natural and human capital benefits of palm oil production do not fall within the scope of this study. TEEBAgriFood's universal Valuation Framework helps place this scope in context by illustrating a full value chain from production to disposal assessing the cost as well as the benefit side of the equation (TEEBAgriFood, 2016).

FIGURE 0.1: TEEBAGRIFOOD VALUATION FRAMEWORK

Value-Chain Stages / Visible and Invisible flows	Production (and associated waste)			Processing and Distribution (and associated waste)			Consumption (and associated waste)
	Landscape	Infrastructure and Manufacturing	Farm	Wholesale	Food and Beverage	Retail	Industry/Household/ Hospitality
Captured by System of National Accounts (SNA) (Profits, Wages, Taxes net of Subsidies, etc.)							
Provisioning (Materials, Energy, etc.)							
Regulation and maintenance (Soil, Water, Habitat for biodiversity, etc.)							
Cultural (Heritage, Recreation, etc.)							
Health (Nutrition, Diseases, Antibiotic resistance, etc.)							
Pollution (Nitrates, Pesticides, Heavy metals, etc.)							
Emissions (CO_2, CH_4, etc.)							
Social values (Food security, Gender equality, etc.)							
Risks and uncertainties (Resilience, Health, etc.)							

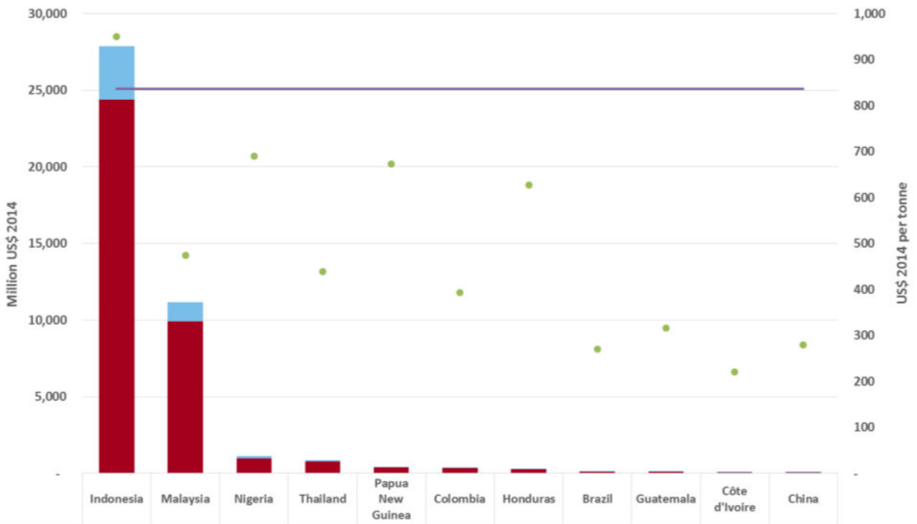
Countries included in the materiality assessment are Indonesia, Malaysia, Thailand, Nigeria, Colombia, Papua New Guinea, Guatemala, Honduras, Côte d'Ivoire, Brazil and China. The methodology followed by the research involves identifying the main natural capital impact costs of palm oil production and measuring them in physical terms such as tonnes of greenhouse gas (GHG) emissions. They are then converted into monetary values or natural capital costs. A similar strategy is applied for the measurement of the human capital costs in the case study.

MATERIALITY ASSESSMENT RESULTS

The results show that palm oil production in the 11 countries assessed has a natural capital cost of $43 billion per year compared to the commodity's annual value of $50bn. Of this cost, crude palm oil accounts for $37.5bn while palm kernel oil accounts for $5bn. Indonesia has by far the biggest share of the total natural capital cost at 66%, while Malaysia is second at 26%.

Overall, producing one tonne of crude palm oil (CPO) has a natural capital cost of $790 while one tonne of palm kernel oil costs $897 in 2013. If these costs were added to the weighted average market price of $837 per tonne of palm oil in 2013, the overall cost per tonne would almost double. The natural capital intensity of palm oil production varies widely between countries, which may have implications for siting palm oil operations or sourcing palm oil (see Figure 0.1).

FIGURE 0.2: TOTAL NATURAL CAPITAL COST AND INTENSITY



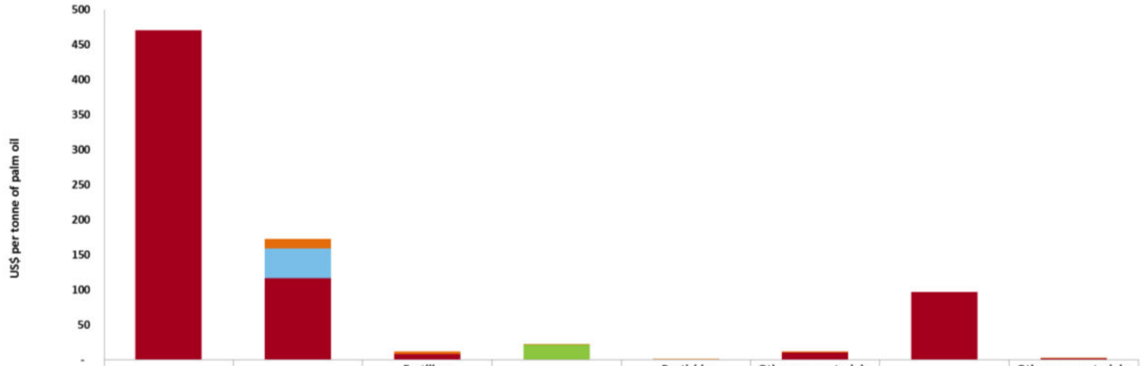
	Indonesia	Malaysia	Nigeria	Thailand	Papua New Guinea	Colombia	Honduras	Brazil	Guatemala	Côte d'Ivoire	China
Palm kernel oil	3,504	1,259	147	58	38	30	24	13	14	8	7
Palm oil	24,385	9,934	995	788	406	355	258	105	102	91	69
Average palm oil intensity (US$ per tonne)	950	475	691	439	674	394	628	270	316	221	280
Weighted average producer price (US$ per tonne palm oil)	837	837	837	837	837	837	837	837	837	837	837

The cost of Indonesia's palm oil industry is driven by the large size of its production and its high natural capital intensity. The total natural capital cost of palm oil production in Indonesia is almost $28bn while its natural capital intensity is $950 per tonne. Land-use change is the biggest single impact in Indonesia, mostly due to GHG emissions from peatland drainage and clearing rainforest.

Palm oil production in Malaysia has much lower natural capital intensity than Indonesia due to the lower cost of land conversion. Only 12% of Malaysia's plantations are planted on peatland and 30% on forested land.

Climate change due to GHG emissions from palm oil production, mostly as a result of land-use change, is responsible for 89% of the natural capital cost per tonne of palm oil. The use of fertilizers is responsible for 22% of the cost. Palm oil mill effluent contributes 12% of the cost, largely as a result of the climate change impacts of methane emissions. The impacts of pesticides contributes 3% of the cost per tonne. The upstream impacts from manufacturing fertilizers, pesticides and other raw material inputs are responsible for 3% of the cost (see Figure 0.2).

FIGURE 0.3: INTENSITY PER TONNE SPLIT BY PRACTICES AND IMPACT TYPE



	Land use change	Fertiliser application	Fertiliser manufacturing	Pesticide application	Pesticide manufacturing	Other raw materials, planting phase	Emissions from POME	Other raw materials, milling and refining
Health toxicity	-	14	4	1	1	2	-	0
Ecosystem toxicity - marine	-	0	0	0	0	0	-	0
Ecosystem toxicity - freshwater	-	43	0	0	0	0	-	0
Ecosystem toxicity - terrestrial	-	0	0	22	0	0	-	0
GHGs	470	116	8	-	1	10	97	2

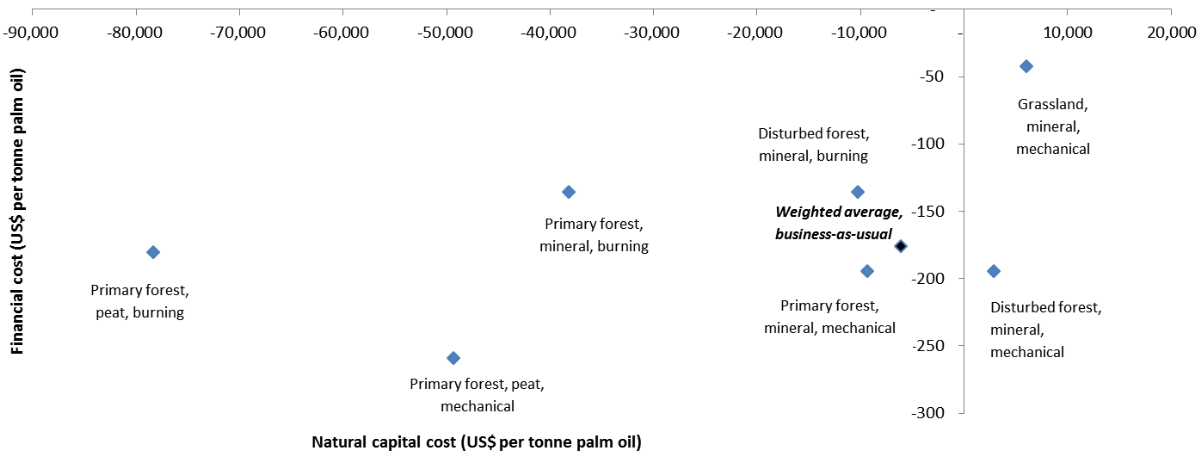
INDONESIAN CASE STUDY RESULTS

The case study on Indonesia shows how natural and human capital accounting can be used to assess alternative palm oil production practices that reduce the impact costs of the sector. These costs can be compared to the financial costs of the practices to inform decisions over which to implement. The case study illustrates this approach by focusing on three practices with the largest natural capital costs and two practices with substantial expected human capital costs: land selection and clearing, fertilizer application, and palm oil mill effluent remediation, as well as wages and occupational health and safety. The research does not attempt to assess an exhaustive range of practices, but to illustrate the usefulness of natural and human capital accounting as an assessment tool.

FIGURE 0.4: LIFE CYCLE STAGE AND PRACTICE SCOPE FOR THE INDONESIA CASE STUDY

The results show that converting primary forest on peat soil using burning techniques has highest natural capital cost due to GHG emissions and air pollution[2]. On average, burning a hectare of primary forest on peat soil releases 29 grams of pollutants to air; a hectare of primary forest on mineral soil releases 28 grams; and a hectare of disturbed forest on mineral soil releases 13 grams. At the other end of the spectrum of analyzed scenarios, converting grassland and already-disturbed forest using mechanical means yields a natural capital benefit as the palm oil plantation sequesters more carbon than the previous land use. The results also show that converting forest or peatland by burning appears less financially costly than mechanical means, but entails a higher natural capital cost (see Figure 0.3).

FIGURE 0.5: NATURAL AND FINANCIAL CAPITAL COSTS OF LAND CLEARING TECHNIQUES OVER LIFETIME OF PLANTATION



Over the lifetime of the plantation, using an optimized mix of organic fertilizer containing pruned palm oil fronds, empty fruit bunches (EFBs) and palm oil mill effluent (POME) combined with chemical fertilizers has the lowest natural capital cost at $1,640 per tonne palm oil, compared to $3,080 per tonne palm oil where chemical fertilizer use is not optimized. The optimization scenario also has the

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[2] Other ecosystem services rendered by natural ecosystems, and lost through land conversion, as well as other impacts of air pollution, are excluded from the scope of this study.

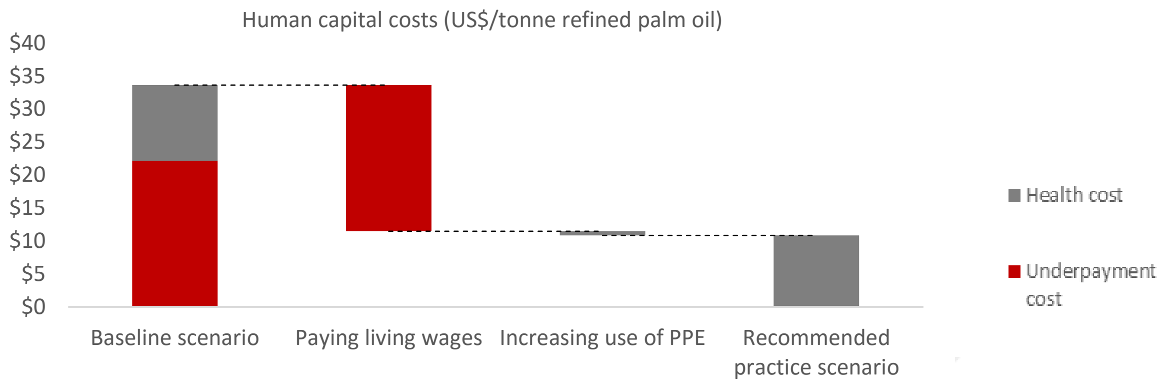
lowest financial cost due to the lower quantity of fertilizer.

Installing methane capture equipment on palm oil mill effluent (POME) treatment processes to generate energy is also identified as best practice to reduce natural capital costs. It also results in a 17% financial cost saving due to a hypothetical sale of carbon credits.

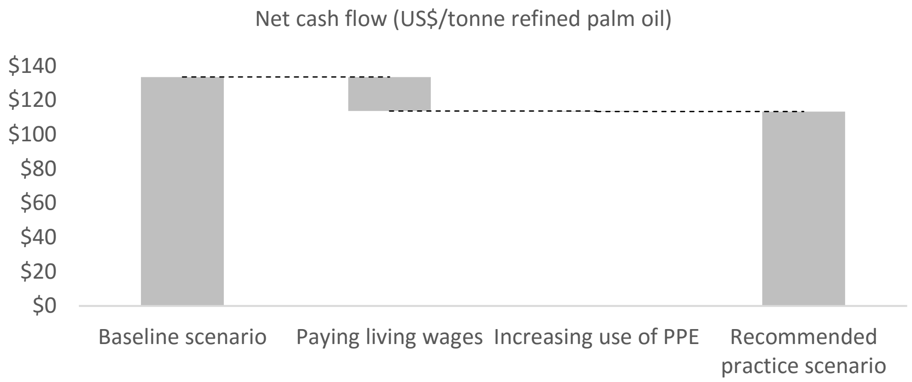
The results also show that underpayment and occupational health impacts have a total human capital cost of $592 per full-time employee, or $34 per tonne of palm oil and $53 per tonne of palm kernel oil. If plantation owners paid a living wage to casual workers, the human capital cost of underpayment would be reduced to zero, while plantations remain profitable with margins reducing from 28% to 24%. The human capital return on investment for this intervention is 11%, which means that the decrease in human capital costs is higher than the decrease in the net cash flow of the plantation.

Wearing personal protective equipment (PPE) reduces instances of pesticide poisoning, cutting the human capital cost of occupational health by 6%. The human capital return on investment for this intervention is 130%. As these results do not take into account positive effects of improved labor conditions on net cash flow or projected financial losses due to reputational and other risks, they should not be considered as a complete financial business case analysis for these interventions, but as a means to include human capital costs in business decision making.

FIGURE 0.6: DIRECT EFFECT OF INTERVENTIONS ON HUMAN CAPITAL COSTS AND NET CASH FLOW OF A PLANTATION[3]



[3] The change in net cash flow of a plantation represents the net financial investment needed to implement interventions. It not only includes increased labour costs (due to the payment of living wages) and purchasing costs of PPE, but also a change in interests paid on debts, taxes and depreciation.



This research makes a series of recommendations for business, financial institutions and policymakers, as well as identifying areas for further research.

RECOMMENDATIONS FOR BUSINESS

- Companies in the palm oil production sector should consider the use of natural and human capital accounting to assess the risks to their businesses posed by the environmental and social impacts of palm oil production. Factors such as tougher regulation and enforcement, changing consumer demand and reputational damage risk could force companies to pay the natural and human capital costs of palm oil production, threatening future revenues.
- Investors and banks are advised to assess their exposure to the natural and human capital costs of the palm oil sector in their equity portfolios and loan books. The internalization of natural and human capital costs could affect shareholder value and the ability of companies to repay loans. Investors and banks should engage with palm oil companies that have the highest natural and human capital costs to assess what they are doing to minimize the risks to their business.
- This research has demonstrated the applicability of natural and human capital accounting to decision making by revealing the hidden costs of production in the palm oil sector and shortlisting priority cost areas for businesses to focus on. For example, on the natural capital side it has identified the growing and milling practices having the highest impact: land use change and the associated carbon emissions contributing 89% to the cost of one tonne of palm oil; fertilizer application contributes 22% (with 67% from GHGs, 25% from toxic substances to freshwater environment, and 8% from toxic substances to human health) and the management of palm oil mill effluent emissions (POME) which is the third most costly practice in terms of environmental cost, contributing 12% of total costs, due to methane emissions contributing to climate change. On the social side it has found that on average underpayment of workers is a larger issue in the sector then occupational accidents, with human capital costs of the former being twice the size of the latter. The research showed that underpayment is predominantly an issue for casual workers and that the human capital cost of occupational accidents is mainly driven by fatal accidents and cases of acute pesticide poisoning.
- Furthermore, companies should consider implementing best practices for palm production to improve overall performance and reduce natural and human capital costs. Palm oil producers could use natural and human capital accounting to assess a range of alternative

practices to see which would have the greatest benefit for their operations.

- This research has also demonstrated the applicability of natural and human capital accounting to decision making by revealing the potential of an array of interventions to manage the above costs and their required investments. For example, analysis has revealed that using an optimized mix of organic fertilizer containing pruned palm oil fronds, empty fruit bunches and palm oil mill effluent combined with chemical fertilizers has the lowest natural capital cost and also the lowest financial cost due to the lower quantity of fertilizer needed. On the social side, it has revealed that if plantation owners paid a living wage to casual workers, the human capital cost of underpayment would be reduced to zero, while plantations remain profitable with margins reducing from 28% to 24%. Purchasing more personal protective equipment to reduce instances of pesticide poisoning was found to cause a large reduction in human capital costs compared to the required financial cost, translating in a human capital return on investment of 130%.

RECOMMENDATIONS FOR POLICY

- Policymakers should introduce measures to internalize the natural and human capital costs of palm oil production to create incentives for companies to improve performance. Such measures could take the form of environmental and social taxes, regulations, or voluntary agreements. Natural and human capital accounting could be used to devise these measures.
- Policymakers should bring together companies, investors, campaign groups, academics and consultancies to create a framework for natural and human capital valuation and integrated accounting. Such a framework is important to ensure consistent measurement of natural and human capital. The Natural Capital Coalition, which has created a Protocol and supporting sector guidance for natural capital accounting, provides an important model (Natural Capital Coalition, 2016).
- Further research should be conducted to:
    - Measure qualitatively and quantitatively the natural and human capital benefits of palm oil production
    - Measure qualitatively and quantitatively the positive and negative natural and human capital effects downstream from palm oil production should also be carried out
    - Measure the complete financial, natural and human capital costs and benefits of alternative production practices and other interventions. This should also consider how the investment costs of implementing these measures could be financed and shared along the supply chain
    - Monetize operational, marketing and product risks, as well as legal, regulatory, reputational and financial risks associated with natural and human capital costs.

READER'S GUIDE

1. The **Introduction** will first describe consumption and production trends, followed by an introduction of the TEEB eco-agri-food system framework. This is the major framework used in this study to assess all negative relations between palm oil production systems on one hand and the human (economic & social) system and ecosystems and biodiversity on the other hand

2. The **Scope and Methodology** highlights the overarching aims and objectives of this analysis, as well as the main activities included within the scope, followed by an introduction to the framework for assessment: the high-level approach used in this study to quantify and value the impacts and dependencies of palm oil production systems.

3. The **Materiality Assessment** section calculates the costs of palm oil and palm kernel oil production in the top eleven producing countries. The country with the highest total natural capital cost is identified, as well as practices that contribute the most to these costs. These form the basis for the subsequent section

4. The **Case Study** on Indonesia focuses on five practices and assesses the natural, human and financial cost implications of possible interventions. Practices include land conversion, fertilizer application, methane capture from palm oil effluent ponds, wages and occupational health and safety practices. Each section provides a description of the prevalent practice, possible interventions, a quantification and valuation of natural or human and financial implications, and an assessment of the main barriers and opportunities for change.

5. The **Recommendations** section concludes the report with recommendations for business, investors and policy makers and suggested future research.

TECHNICAL REPORT

INTRODUCTION

BACKGROUND, AIMS AND OBJECTIVES OF STUDY

The Economics of Ecosystems & Biodiversity (TEEB) is a global initiative focused on 'making nature's values visible'. Its principal objective is to mainstream the values of biodiversity and ecosystem services into decision-making at all levels (TEEB, 2015). The TEEB study on Agriculture and Food (TEEBAgriFood) aims at capturing the values of ecosystems and biodiversity across different agricultural systems where a variety of management practices are used. It takes into account the visible values of ecosystems and biodiversity as they are captured in the price tags of food, as well as the invisible costs and benefits of food systems, such as the provisioning of clean water and air (a positive value) and the polluting of water and air (a negative value).

At the heart of the study is the question: are we paying the correct price for our food? Answering this question involves capturing the complexity of food systems, looking at the positive and negative impacts, and analyzing the visible and invisible inter-relations with nature and society. Contrary to 'putting a price on nature', as some have confused with TEEB, the goal is to examine more closely the implicit values of the services that nature provides at zero or close to zero market cost.

As input for the TEEBAgriFood study, TEEB has commissioned a series of exploratory studies that attempt to populate the TEEBAgriFood framework: livestock (dairy, poultry and beef production); rice; palm oil; inland fisheries; agro-forestry; and maize (TEEB, 2015). This report studies palm oil production practices with a goal to improve business decision making with implications for all stages of the value chain. It does so by showcasing interactions between palm oil production and ecosystem services, and their value to society. Ultimately it demonstrates how natural[4] and human[5] capital accounting analysis can be used by businesses to underpin improved environmental and social sustainability in the sector.

Natural and social costs from economic production systems can only be assessed where data is available and of sufficient quality. In practice many times data quality is low or nonexistent. Owing to this limitation, this study should be understood as an example of how this type of analysis can be used.

Specific steps taken to achieve the study's aims include:

- A natural capital country level materiality assessment mapping the negative externalities of palm oil production systems and their supply chain,

[4] The stock of renewable and nonrenewable natural resources (e.g., plants, animals, air, water, soils, minerals) that combine to yield a flow of benefits to people, both directly and indirectly (Natural Capital Coalition, 2016). Natural capital is frequently valued in terms of impacts on society, such as human health

[5] Human capital refers to people and their ability to be economically productive. Education, training and health care can help increase human capital. The social costs in scope of this study – underpayment and occupational health – should as such be classified under human capital. Land dispossession – while not in scope – can be classified under social capital, as it has an effect on the relationships and networks amongst people and institutions that enables societies to function more effectively

- A case study on Indonesia[6] creating an industry aggregated natural and human[7] capital account, using secondary data on the current state of palm oil production
- Scenario analysis that assesses the natural, human and financial capital net present value (NPV) associated with possible interventions that can be undertaken to optimize palm oil production in Indonesia. This analysis follows a practice-based approach, which focuses on selected practices and choices that growers have to do at each stage of the palm oil production life cycle, and assesses alternatives from a natural, human and financial capital standpoint.

In this study two types of approaches are combined. A global assessment for the natural capital costs of palm oil production highlights the key natural capital aspects and geographical hotspots. A regional assessment then analyses specific kinds of palm oil practices in their geographical and socio-economic context. While the first approach allows a broad geographical coverage and identifies hotspots but also the costs of the sector worldwide, the latter enables the comparison of specific farming systems and the incorporation of region-specific nuances.

The primary audience of this study are agri-businesses and businesses buying palm oil from their suppliers. The secondary audience are other decision-makers such as investors and governments of palm oil producing and consuming countries that could benefit from using natural and human capital accounting techniques in the setting of investment appraisal techniques or regulatory frameworks to encourage corporate action.

THE PALM OIL SECTOR

With over 56 million tonnes consumed in 2013, palm oil is the world's most popular vegetable oil, followed by soybean, rapeseed and sunflower oil (Sime Darby, 2014). Palm oil consumption is expected to continue to grow as demand for vegetable oil is forecast to double over the next 40 years for use in food, cosmetics and biofuels (Fairhurst & McLaughlin, 2009). Consumption in Europe alone is up 365% since 2006. Indonesia and Malaysia are the largest producers, contributing 49% and 35% of total production respectively in 2013 (FaoStat, 2013).

The popularity of palm oil is mostly due to its relatively low market price and versatility compared to other vegetable oils (Sime Darby, 2014). On average, one hectare of oil palms will yield almost 4 metric tons of oil, which is almost 10 times the amount produced by a hectare of soy, and seven times the production of rapeseed. While accounting for 32% of total global production of oils and fats in 2012 (including animal sources), oil palms occupied only 5.5% of oilseed crop area (IFC & World Bank, 2011). At the same time, it is highly sought after in food production as one of the few naturally saturated vegetable oils, making it solid at room temperature and giving it a long shelf life (May-Tobin, et al., 2012).

Businesses involved in palm oil sector range from small producers to large vertically-integrated multinationals, as well as processors and manufacturers of finished products using palm oil (Forest

[6] In 2009, Indonesia was ranked by the World Bank as the third-largest greenhouse gas emitter globally due to high levels of deforestation and conversion of carbon-rich peatlands, most of which was undertaken to expand palm oil production

[7] The human capital account has a smaller scope than the natural capital account and was only calculated for the Indonesia case study analysis

Heroes, 2015). Supporting businesses include raw material suppliers, traders and transport companies. The palm oil production chain is complex and supplies several industries including food, personal care, chemicals and energy. In the context of production systems, a distinction is often made between holding types such as smallholders, state plantations and private plantations.

In Indonesia and Malaysia for example, smallholders (typically defined as holders with less than 50 ha) account for 35-45% of palm oil production while in Latin America and Africa, the majority of producers are smallholders (SPOTT, 2015). Smallholding systems are often characterized by lower level of inputs and lower yields. In a recent report the IFU investigated the acute challenges faced by smallholder farmers – those controlling 50 ha or less of cultivated land – as compared to their larger counterparts (IFC & World Bank, 2011b). Some the main differences are classified below.

TABLE 2.8: PALM OIL PRODUCTION BY GROWER TYPE (SUHARTO, 2009)

	SMALLHOLDERS	GOVERNMENT PLANTATIONS	PRIVATE PLANTATIONS
Areas (x1,000 ha)	2,903	697	3,497
%	41%	10%	49%
Yield (kg/ha)	2,523	4,165	3,846

- Independent smallholders are often less productive; studies have identified elements of inefficiency that include maintaining old oil palms too long, using smallholders' own (low-quality) seedlings, applying insufficient amounts of fertilizer, harvesting unripe fresh fruits bunches (FFBs), and not having strong data management systems
- Indonesia has seen particular challenges with smallholder land titling, as well as with troubling environmental practices such as burning for land clearing.
- Smallholder productivity is on average significantly lower than plantations. As Figure 30 depicts, in 2008 smallholders in Indonesia averaged a yield 34% lower than private plantations, and 39% below government plantation production (Suharto, 2009).

Palm oil production generates a range of positive economic, social and environmental benefits to different stakeholders. It constitutes a potential source of employment for local communities and revenue for smallholders. It has a number of advantages that make it one of the most potentially sustainable options for producing vegetable oil. When well-managed, plantations can also store carbon and contribute to climate regulation, as well as support a wide range of species and enhance biodiversity.

While the crop's positive economic, social and environmental impact is significant, the current situation is often suboptimal and resulting in widespread environmental and social damage. For example, the rapid growth in demand has driven investment in large parcels of land in equatorial regions across the globe where oil palms thrive. For the most part, the only undeveloped and cheap land in these regions is occupied by carbon-rich rainforests. Negative impacts from the deforestation of biodiverse and carbon-rich primary forests and peatlands include:

- Greenhouse gas (GHG) emissions: deforestation is the leading cause globally, accounting for roughly 15% of global totals, more than the operational impacts of agriculture, manufacturing, or transportation;
- Haze events from forest fires forming transboundary clouds of pollutants; and subsequent soil degradation and water pollution from the excessive application of chemical fertilizers and pesticides to maintain soil fertility post-fires;
- Substantial biodiversity loss; and
- Partial responsibility for social impacts on local communities, such as human rights abuses related to land acquisition and plantation development prior to deforestation.

FOREST FIRES IN INDOENSIA

Fires related to land clearing in Indonesia are a frequent occurrence. During June and July 2013, large fires caused smog, haze, and respiratory problems as far away as Malaysia and Singapore, creating an international health concern and serious liability issues for companies associated with the burning (Kapoor & Taylor, 2013). Another forest crisis occurred in February 2014, an unusual time of the year as the normal burning season is April to October (Alisjahbana, et al., 2014). Most recently in 2015, fires raged from April to November, with efforts to extinguish them hampered by seasonal dry conditions exacerbated by the El Nino effect. As climate change worsens, these events may become more frequent and severe.

According to analysis forest fires are caused by the ‘collective negligence’ of companies, smallholders and government, which isn’t investing sufficiently in preventative measures (Guardian, 2015). For example, in a 2015 World Resources Institute analysis in September 2015 37% of the fires in Sumatra occurred on pulpwood concessions, with a good proportion of the rest on or near land used by palm oil producers (WRI, 2015).

It is also increasingly recognized that palm oil practices bring with them an array of indirect natural and human capital costs, which are becoming ever more visible. For example, Indonesia government’s estimates suggest the financial damage from 2015’s fires could be as high as $47bn (almost the size of the commodity’s trading value worldwide) through disruptions to economic activities and events cancellations (Straits Times, 2015). The human cost involves an estimated half a million cases of respiratory tract infections and deaths since the start of 2015’s fires (Guardian, 2015b). A World Bank study on forest fires in 2014 in Riau province estimated that they caused $935m of losses relating to lost agricultural productivity and trade (World Bank, 2014).

Due to the importance of palm oil to the economies of major producing countries like Indonesia and Malaysia, the governments of these countries play a significant role in regulating and promoting sustainable development within the sector. A variety of other organizations supporting the interests of groups of stakeholders are also active in the sector, alongside certification standards, tools provided by non-governmental organizations, and initiatives put forward by businesses at different levels of the supply chain (IFC & World Bank, 2011).

PALM OIL PRODUCERS

The palm oil sector is characterized by a multitude of holding types and production practices exhibiting different structural profiles (such as area, levels of debt, size of the household, type of labor, quantity of inputs used), leading to differences in social, economic and environmental costs and benefits. For example, a distinction is often made between smallholders, state plantations and private plantations; with smallholding systems often characterized by lower level of inputs and lower yields. In addition, there may be differences between smallholders themselves in terms of holding sizes, structure, and strategy.

For example, recent research comparing and contrasting the typical practices associated with independent plots (not linked by contract to any company or mills) and plasma plots (acquired through development schemes and supported by a partner company in managing, financing and operating the farm) to oil palm estate companies and RSPO certified companies shows that practices, in terms of land use, nutrient management, pest management and other inputs use vary widely from one farm to another (Boer et al., 2012). Net margins also vary between $1,200 and $3,400 per ha per year.

In response to global environmental campaigns, the palm oil industry's largest growers like Wilmar International, Golden Agri-Resources, Cargill, Musim Mas have been engaging in policies against deforestation, destruction of carbon-rich peatlands, and abuse of human rights. For example, the Palm Oil Manifesto was supported by the largest five palm oil growers in the world aiming to enhance RSPO's work (HCSS, 2014). Sime Darby is a founding member of RSPO and is part of a group of organizations developing The Sustainable Palm Oil Manifesto (Sime Darby, 2013; 2013a). Wilmar worked with the Forest Trust and committed in 2013 to zero deforestation, no peatland development, no exploitation of people and local communities, no burning and no development on high conservation value areas. Wilmar also participates in a government-initiated smallholder schemes in Indonesia and Malaysia in which they help family-run plantations develop and lessen their environment impacts (Wilmar, 2013; Rhett, 2013). Other producers such as SIPEF, Golden Agri Resources, New Britain Palm Oil and Astra Agro Lestari have also put initiatives in place from development on degraded land to integrated pest-management practices (Sipef, Undated; Rhett, 2011; New Britain Palm Oil Limited, 2013; Astra Agro Lestari, Undated).

However effort is still ongoing. For example in 2015 a public campaign was launched by Forest Heroes against luxury hotel chain Mandarin Oriental owing to its links to palm oil company Astra Agro Lestari, which has been accused of deforestation (more than 14,000 hectares of deforestation between 2006 and 2014) and habitat destruction (27,000 ha of carbon-rich peat since 2009) (Forest Heroes, 2015).

The release of the Palm Oil Manifesto's draft HCS Science Study in October 2015 was also met with nearly universal criticism by stakeholders, they would lead to more conversion of forests and peatland for palm oil. For example, it is said that because the study does not take into account the High Carbon Approach, first developed in 2010 with broad support from business, NGOs and technical experts, a class of forests known as "young regenerating forest" protected under the HCS Approach, would be available for clearing under the threshold proposed by the SPOM study (Mongabay, 2015).

PALM OIL STANDARDS AND GOVERNMENT INTERVENTIONS

The Roundtable on Sustainable Palm Oil (RSPO) was established in 2004 with the objective of promoting the growth and use of sustainable oil palm products through credible global standards and engagement of stakeholders. Voluntary at present, it has put in place several certification schemes to certify sustainable palm oil and is currently estimated that 18% of the world's palm oil is certified by the RSPO. Companies must meet a set of criteria in order to gain certification including commitment to transparency, compliance with applicable laws and regulations and use of appropriate best practices by growers and millers, among others (Savi, 2014; GreenPalm Sustainability, 2014).

RSPO's certification frameworks for growers and millers have been criticized for lack of legal force over its members whilst some growers have developed the principles and criteria further, through initiatives such as the Sustainable Palm Oil Manifesto. It was formed in 2014 by a number of key stakeholders in the industry who declared commitment to enhance the RSPO criteria with additional requirements to establish a traceable and transparent supply chain, accelerate the journey to no deforestation through the conservation of high-carbon stock forests, the protection of peat areas, and ensuring a positive social impact on people and communities (Rhett, 2014; Musim Mas, Undated).

Governments have also been stepping up their efforts. Both Indonesia and Malaysia have recently launched their own national sustainable palm oil standards, ISPO and MSPO respectively. The Indonesian Sustainable Palm Oil (ISPO) standard is a mandatory certification scheme that aims at certification of all Indonesian growers, including smallholders. The 2015-implemented third in the world Malaysian Sustainable Palm Oil (MSPO) is a voluntary certification standard, which has garnered strong support from both domestic palm oil industry players and exporters alike (Jakarta Post, 2015).

Indonesia's financial regulator announced in 2015 that it will introduce rules to restrict banks' lending to environmentally-damaging projects by 2018. The Financial Services Authority, is aiming to draft regulations by 2016 to target agriculture, energy, fishery and microfinance companies. While not specifically directed at the forest fires, it is expected that policing the environmental impact of projects and activities of companies that borrow funds from its banks will help Indonesia curb the burning that in 2015 covered an area four times the size of Bali Island. The eight largest Indonesian banks including PT Bank Central Asia and PT Bank Mandiri are also expected to work with the World Wildlife Fund in integrating sustainable financing criteria for the palm oil industry in a pilot project from January 2016 (Bloomberg Brief, 2015).

PALM OIL USERS

Traceability is one of the main issues facing users of palm oil. In response to global environmental campaigns, major brands like Unilever, Kellogg, Dunkin' Donuts, Mars, Hershey, and Johnson & Johnson have announced policies that commit them not to buy from companies engaged in deforestation, destruction of carbon-rich peatlands, or abuse of human rights.

For example, following a Greenpeace campaign against Nestlé on the significant natural capital costs of palm oil on deforestation, the company recognized that it needed to address the palm oil sourcing issue and turn the reputational risk into an opportunity (FT, 2012). It suspended sourcing from Sinar Mas, and the company held meetings with Greenpeace in which it provided details of its palm oil supply chain. With a focus on the longer term, Nestlé sought a credible external partner to certify the sustainability of its palm oil suppliers, choosing the Forest Trust to establish responsible sourcing guidelines, including legal compliance, respect of local and indigenous communities, respect of high conservation value areas, peatland and high-carbon stock forests protection, and compliance with RSPO Principles and Criteria (Nestle, 2012). Others such as Unilever pledged to source 100% of their oil from certified sources by 2015 and achieved their targets through the purchasing of Green Palm certifications, an offsetting scheme (GreenPalm Sustainability, Undated).

Nevertheless achievement is still in progress. In May 2015, the Rainforest Action Network published a survey of major companies using palm oil and their progress in sorting out their supply chains, listing a number of companies among the 'laggards': Kraft, Heinz (these two companies have now merged to form a single conglomerate), PepsiCo and Unilever (Rainforest Action Network, 2015). Unilever, for example was criticized for its reliance on GreenPalm certificates as a shortfall in its approach, as this offset model does not directly improve the practices of the companies from which it sources palm oil.

NON-GOVERNMENTAL ORGANISATIONS AND TOOLS

Many non-governmental organizations are active in the space and provide useful analysis and sustainable management tools. The World Resource Institute (WRI) developed a publicly-available Suitability Mapper tool that allows users to identify indicatively suitable sites in Indonesia for palm oil production based on a comprehensive set of criteria and aiming to help companies and governments implement better land use planning processes (World Resource Institute, 2013). WRI also provides a tool that enables users to assess forest cover change and risks related to sustainable palm oil production (World Resource Institute, 2013a). SPOTT (Sustainable Palm Oil Transparency Toolkit) is a tool developed by the London Zoological Society (ZSL) to assess oil palm growers on the information that they make publicly available about the sustainability of their operations (London Zoological Society, 2014).

INTRODUCING THE TEEB SCHEMATIC

TEEBAgriFood aims to assess the positive and negative socio-economic and environmental effects of agricultural production systems (TEEBAgriFood, 2016). Figure 1.1 summarizes the economic interdependencies between human (economic and social) systems, agriculture and food systems, and biodiversity and ecosystems. In doing so, it will address the economic invisibility of many of these links while exploring how biodiversity and key ecosystem services deliver benefits to the agriculture sector and also beyond, itself being a key contributor to human health, livelihoods and well-being.

The same schematic is adapted to assess palm oil production, illustrated in Figure 1.2. Palm oil production depends on inputs from other sectors such as fertilizers, fuel and machinery, as well as relying on support from services provided by ecosystems such as the nutrient cycle and water purification. Palm oil production has many benefits including providing employment and raising living standards, but also many social and environmental impacts such as health problems caused by pollution and land conversion.

These costs and benefits are not meant to be exhaustive. Key to the figure is that some of these costs and benefits are economically invisible **–** they are often not reflected in actual costs such as market prices**.** In section 2 (Scope and Methodology) it is explained how this schematic is used to assess the natural and human capital costs of palm oil production systems.

Not used in this assessment but equally important, TEEBAgriFood also offers an important resource in the face of its Valuation Framework, which enbles the user to hold to a common form of assessment all significant costs and benefits (whether they be economic, social or related to risks and uncertainty), each type of food system, production alternative, or consumer choice across the entire value chain. (TEEBAgriFood, 2016). The Valuation Framework is presented in Figure 1.3.

FIGURE 1.1: TEEBAGRIFOOD SCHEMATIC FOR ON-FARM PRODUCTION SHOWING THE COSTS AND BENEFITS OF THE ECO-AGRI-FOOD SYSTEM NEXUS

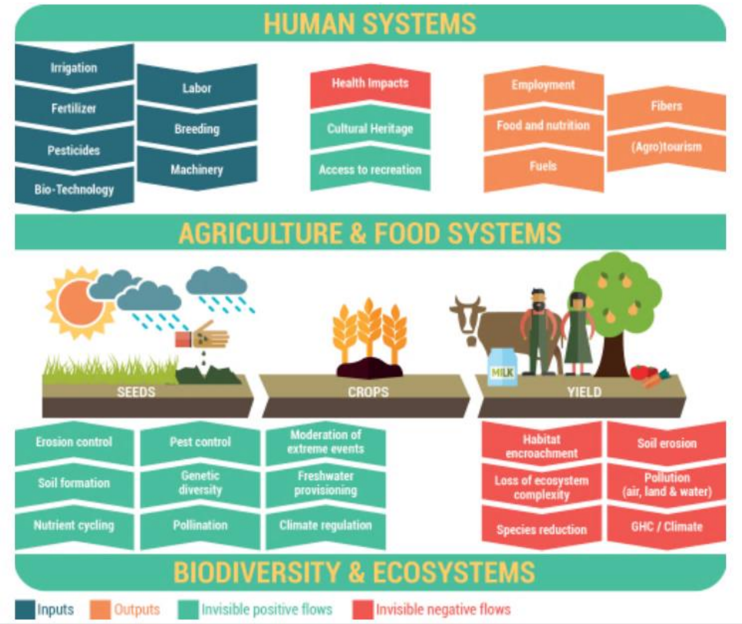
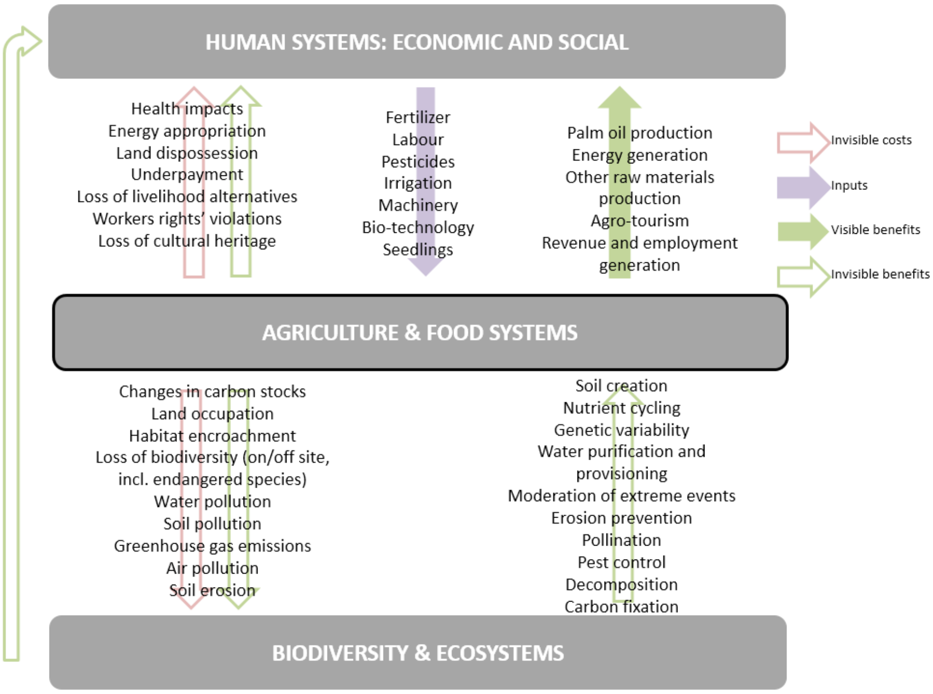


FIGURE 1.2: TEEBAGRIFOOD SCHEMATIC FOR ON-FARM PRODUCTION (ADAPTED FROM THE ECONOMICS OF ECOSYSTEMS & BIODIVERSITY, 2014)[8]



[8] This figure provides a non-exhaustive list of potential impacts and dependencies of palm oil production. This study focusses only on a subset of these. Detailed description of this study's scope is provided in Chapter 2

FIGURE 1.3: TEEBAGRIFOOD VALUATION FRAMEWORK

Value-Chain Stages / Visible and Invisible flows	Production (and associated waste)			Processing and Distribution (and associated waste)			Consumption (and associated waste)
	Landscape	Infrastructure and Manufacturing	Farm	Wholesale	Food and Beverage	Retail	Industry/Household/ Hospitality
Captured by System of National Accounts (SNA) (Profits, Wages, Taxes net of Subsidies, etc.)							
Provisioning (Materials, Energy, etc.)							
Regulation and maintenance (Soil, Water, Habitat for biodiversity, etc.)							
Cultural (Heritage, Recreation, etc.)							
Health (Nutrition, Diseases, Antibiotic resistance, etc.)							
Pollution (Nitrates, Pesticides, Heavy metals, etc.)							
Emissions (CO_2, CH_4, etc.)							
Social values (Food security, Gender equality, etc.)							
Risks and uncertainties (Resilience, Health, etc.)							

HUMAN SYSTEMS

Science and technology provide a number of inputs to agricultural and food systems. Some of these inputs have been developed and applied over many centuries (such as machinery) whereas others are more recent developments (chemical fertilizers). The cumulative effect of these inputs in recent decades has been the rapid expansion in food availability.

Labor is a factor of production but might also include more broadly human capital, when referring to people and their ability to be economically productive. An example of how human capital can increase is through the continuous growth of human knowledge on agro-ecological processes such as composting. But human capital can also be negatively affected, for example when workers' rights are being violated.

Costs and benefits to the human system can also affect social capital, which refers to the value inherent in relationships and networks amongst people and institutions that enables society to function more effectively. A social capital benefit can be an increased social cohesion in communities, a social capital cost can be land dispossession and associated land conflicts.

BIODIVERSITY & ECOSYSTEMS

Ecosystems and biodiversity, or natural capital, also provide inputs to agriculture and food systems. The agricultural sector is, and always has been, nested within ecosystems, where crop and livestock systems form the basis of an entire downstream economy. Oil palm cultivation depends on soil fertility, stable climate and precipitation levels. When natural ecosystems are cleared, the loss of services may affect an area larger than the cleared area. For example, primary forests and peatland contribute to water provisioning and regulation. According to the water footprint network, growing one tonne of oil palm fruit necessitates 1,057 cubic meters of rainwater (Mekonnen & Hoekstra, 2011). If local precipitation levels are affected, this water need will have to be met by irrigation, increasing the operating costs of the plantation and causing additional impacts on water sources.

Broader society also depends on the goods and services provided by the Earth's natural systems, directly through the provision of material and non-material goods to people, such as food, timber and medicines, and indirectly through the functioning of ecosystem processes. These includes the formation of soils and maintenance of soil fertility that sustains crop and livestock production which in-turn depends on the ecosystem process of the decomposition of, and nutrient cycling by soil micro-organisms.

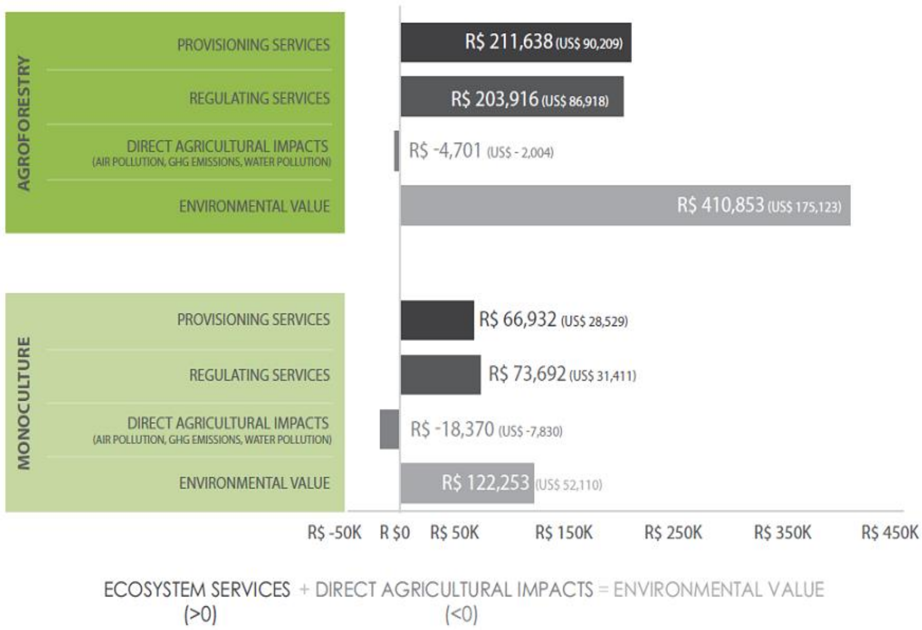
However, strong focus on productivity increases are shown to increasingly lead to perverse incentives promoting innovations that reduce the resilience of ecosystems and biodiversity (TEEB, 2015). The value of these services often remains invisible until it is no longer provided: an example is the need for agro-chemicals to substitute for natural forms of pest control, or provide a buffering service against storms normally rendered by mangroves.

AGRICULTURE & FOOD SYSTEMS

There are costs and benefits flowing from agriculture and food systems. Some of these are visible and generally marketed, such as food. In other cases there are benefits that are partially visible, or invisible. These might include aesthetic appreciation of a managed agricultural landscape, which can be seen through annual visits from tourism. There are also costs; some affect human welfare directly, such as health impacts arising from agro-chemicals or occupational accidents. Others affect humans indirectly, for instance nutrient run-off from farm land might affect the quality of bathing water, which in turn impacts on the leisure and recreation activities (TEEB, 2015). Indeed agriculture and seafood, sitting at the top of the sector's supply chain, are among the segments of business activity that pose the greatest threat to critical ecosystems through impacts such as soil erosion, air, land and water pollution, deforestation of habitats and species reduction (WWF, 2012).

The magnitude and even whether the practice leads to a cost or a benefit may also vary. For example, an analysis comparing palm oil monoculture and agroforestry in Brazil found that agroforestry generated three times as much ecosystem services than monoculture, all while having less negative environmental impacts (Figure 1.4) (TEEB for Business Brazil, 2014).

FIGURE 1.4: COMPARISON OF THE ENVIRONMENTAL VALUE OF PALM OIL MONOCULTURE, PALM OIL AGROFORESTRY OVER 25 YEARS



BUSINESS RELEVANCE

Businesses benefit from and impose a cost on natural and human capital through their use of inputs and production activities. These can represent real costs on society, either directly or indirectly, such as health costs due to air pollution or decreased recreational value due to land conversion. These costs can get internalized into companies' bottom lines through various internalization channels.

For example, agricultural commodities depend on soil fertility and the nutrient cycle. If this service is not provided by ecosystems any more, companies will either have to pay for a substitute (increased fertilizer application) or incur losses through decreased yield. Similarly, impacts on the health of workers may lead to increased costs for companies due to increased sick days or decreased efficiency. An increasing number of countries are also imposing GHG taxes or emission trading permits. While the price of these market instruments often does not reflect the full cost to society of emitting GHGs, they may be seen as a first step in the internalization of GHG costs.

This rate of internalization is growing at a faster pace than ever before, due to lower transaction costs[9], consumer demand for sustainable products and more effective regulation (de Groot Ruiz, et al., 2014). For example, the mining industry has increased spending on water by 250% from $3,4bn in 2009 to $12bn in 2013 and the average annual increase in minimum wages in China in 2011-2015 is 13% (de Groot Ruiz, et al., 2014). As a consequence, factors that previously were not priced, such as water or underpayment, are increasingly priced and impacting companies' bottom lines.

THE BENEFITS OF MONETIZATION

As the rate of internalization is increasing, natural and human capital costs are increasingly becoming profit drivers. However, conventional steps to measure and value economic performance such as Gross Domestic Product (GDP), investment performance, or traditional profit-and-loss statements and balance sheets do not reflect the full scale of environmental and social impacts caused by business. This leads to a lack of recognition of the true costs of business and suboptimal decision-making, as many decisions that involve environmental and social impacts today are based on heuristics and thus are prone to decision bias.

To bridge this gap and in order to understand the potential magnitude of risks to business profitability from the external cost of business activity, companies can monetize their natural and human capital costs. This translates physical measures in terms of metric tons of air pollutants emitted, or cubic meters of water used, into the dominant language of business and economics: a monetary value expressing the damage caused to environment and society. In other words it is a representation of the potential value that companies would have to internalize if they were to become accountable for their impacts.

This common monetary language is important as it allows business and decision makers in general to compare different types of impacts not normally comparable (such as across air pollutants) and weigh them off against other profit drivers. It also enables the identification of hotspots and facilitates comparison between companies. As an integration tool, it can be used to measure and report overall

[9] Transaction costs are the costs of providing for some good or service through the market rather than having it provided from within the firm. Examples are search and information costs, bargaining and decision costs, and policing and enforcement costs.

impacts and associated costs relevant for a range of stakeholders important to a business' value creation. Another advantage is that companies are in a better position to steer lobbying strategies for sustainable policies targeted at internalizing externalities.

USING MONETIZATION IN PRACTICE

Monetization of external cost is gaining ground through initiatives such as TEEB and the Natural Capital Coalition. Monetization is a layer on the TEEB framework that helps business understand the costs and benefits in monetary terms: valuation framework (i.e. what to value and why), valuation approach (i.e. how to structure and conduct valuation applications) and valuation methodologies (i.e. the actual valuation models and techniques used to derive economic value and other forms of value) are the cornerstones of economic valuation in general, as they will be for TEEBAgriFood (TEEB, 2015).

The approach to valuation will always be context-specific and will depend on the application being considered (TEEB, 2015). For example, recent applications of valuation have emerged in the context of policy, business and national accounting. The approach in each context and application will be different, but for the sake of completeness and comparability, it is important that the elements of value considered and evaluated in each approach are the same, defined and described in a consistent manner. Failing that, it would not be possible to draw policy or business conclusions from comparisons across different scenarios or strategies, as each evaluation would be using its own lexicon, making its own choices of what should be valued and why (TEEB, 2015).

A major collaboration within the private sector aiming to do just that is developed by the Natural Capital Coalition with support from the International Finance Corporation, the International Union for Conservation of Nature and The World Bank: the Natural Capital Protocol (Natural Capital Coalition, 2016). The objective has been to create a harmonized accounting framework, providing businesses with standardized tools and metrics to identify their impact and reliance on natural capital (Natural Capital Coalition, 2016).

Apart from the need for (globally) accepted standards, another challenge for monetization concerns the tension between the goal to quantify and the reality of qualitative observations (de Groot Ruiz, et al., 2014). Some parties suggest a possible lack of credibility to express social and environmental impacts in financial values. Others argue that some of the impacts with an ethical dimension – such as child labour or worker safety – cannot be given a monetary value (Accounting for Sustainability, 2012). Naturally, monetization should acknowledge possible limitations with respect to specific impacts and should not be treated as a one-off guidance for making decisions.

INTERNALISATION DRIVERS

A large proportion of natural and human capital costs are not yet fully internalized but companies may increasingly need to absorb these costs as regulatory, reputational and financing risk drivers become realized. The next section explores the relevance of these for the palm oil sector.

OPERATIONAL RISK DRIVERS

Operational risk materializes through increased operational costs to 'replace' services provided by the society and ecosystems which have disappeared. For example, planting on peat lands is a high cost and low yielding practice that will impact margins as soil erosion, water contamination and failure to maintain site fertility reduce future yields and returns (WWF, 2012b). Failure to maintain biodiversity will eliminate natural pest control animals and increase costs and pollution risks from use of pesticides, while the loss of natural habitat in and around plantations can lead to localized climate difference, in particular a drier microclimate, which further reduce palm oil yields.

On the other hand, it has been said that business benefits gained from practice optimization, such as the one delivered by RSPO certification (e.g. reduced social conflicts, operational improvements, reduced labor turnover, improved market access and access to capital) outweighs the incremental costs of implementation. In a study assessing the benefits of implementing RSPO principles and criteria on their plantations reported the key benefits in the realm of company operations one company stated that they have saved $250,000 annually across their estates due to reduced pesticide application, whilst another reported an annual savings of $73,859 in herbicide usage on a single estate (WWF, 2012c). A large producer also reported a 42% reduction in accident rates as a result of improved safety procedures and equipment. Several companies reported reductions in rates of worker turnover. Only one firm was able to quantify the change, reporting a 6% turnover reduction, a key benefit for a mid-sized estate operating in a remote, labor short region.

MARKETING AND REPUTATIONAL RISK DRIVERS

Market risks exist due to changing consumer preferences which can influence sales and market share presenting risks for laggards. These range from loss of market as demand for sustainable palm oil grows; fewer trading partners, reduced international opportunities.

Reputational risks as unsustainable practices can negatively impact a company's reputation and hence its market share. Downstream, consumer-facing companies using palm oil are also exposed to risk due to consumer or investors' concerns about impacts. For example, in 2010 Greenpeace criticized Sinar Mas, a major palm oil producer, for deforestation and peatland clearance in Indonesia, extending its criticism to the producer's clients and investors. The combined effect of this targeted campaign led to damage in reputation and loss of business for Sinar Mas, eventually reflecting its share price (Guardian, 2010). Greenpeace's social media campaign against Nestlé resulted in the company reversing its initial reaction was to force the video's withdrawal in favor of suspended contracts, and increased transparency.

More recently in 2015, luxury hotel chain Mandarin Oriental was targeted by Forest Heroes for having the same parent company as palm oil producer Astra Agro Lestari, resulting in a strong forest conservation and human rights policy and an immediate moratorium on forest clearance in the wake of the "She's Not a Fan" campaign (Innovation Forum, 2015). Reputational risk from association with companies acting illegally on palm oil has already also hit European banks and has the potential to affect companies that don't directly work in Indonesia (McKoy, 2014).

LEGAL AND REGULATORY RISK DRIVERS

Regulation and legal action can restrict access to resources, increase costs of access and influence expansion options. For example, in the palm oil sector compliance risks due to violation of existing regulations or increased stringency of regulation in future can lead to fines and/or suspension of plantation manager's/owner's concession, operating licenses or land lease. Companies that use palm oil are heavily reliant on a few political economies with rapidly evolving regulations, where any change in Indonesian political attitudes towards land allocation, climate change policy or trade tariffs could have a significant bearing on the production and trade of palm oil with implications for the whole supply chain.

Wilmar International, a company that is estimated to control 45% of all palm oil trade, reported that an Indonesian regulation passed in 2013, limiting ownership of land for new plantations, threatened its ability to meet its growth targets. In a landmark case, palm oil producer PT Kallista Alam was fined around $30 million by the Indonesian Ministry of Environment for illegally burning protected forest, the first major ruling of its kind. Attention on illegal trade in palm oil is also increasing, for example in relation to the theft of oil palm fruit bunches from plantations. Despite this, CDP's forests data from 2013 reveals that few companies (less than 15% of companies that responded to questions on palm oil), especially those further up the supply chain, recognize any material regulatory risk from palm oil to their business (McKoy, 2014).

FINANCING RISK DRIVERS

Investors are increasingly committed to using environmental data alongside other metrics to inform decision making and drive value. The main risk stemming from this trend for companies is related to increased financing costs and reduced financing options due to a lack of transparency and environmental metrics. For example, companies risk being cut off from bank financing if they fail to meet new voluntary bank guidelines on deforestation, such as the 'Soft Commodities Compact' adopted by 10 leading financial institutions, including Barclays, BNP Paribas and Santander (CDP, 2015). These guidelines require that clients whose operations include significant palm oil, timber, or soy production or processing, in areas of high tropical deforestation risk, must show these operations are consistent with zero net deforestation.

Transparency in the finance sector is becoming increasingly important. In its "Up in Smoke: Failures in Wilmar's promise to clean up the palm oil business" report following Indonesia's 2015 fire crisis, Friends of the Earth examines the role played by two palm oil companies, Bumitama Agri and Wilmar International, in creating conditions that allowed the fires to burn out of control across thousands of hectares of ecologically sensitive land in Central Kalimantan. Using satellite maps, field investigations, and financial markets research, the report also details failures in the implementation of Indonesia's national moratorium on peatland development, and argues that major U.S. and European investors are complicit in creating the conditions that led to the fires (FoE, 2015).

SCOPE AND METHODOLOGY

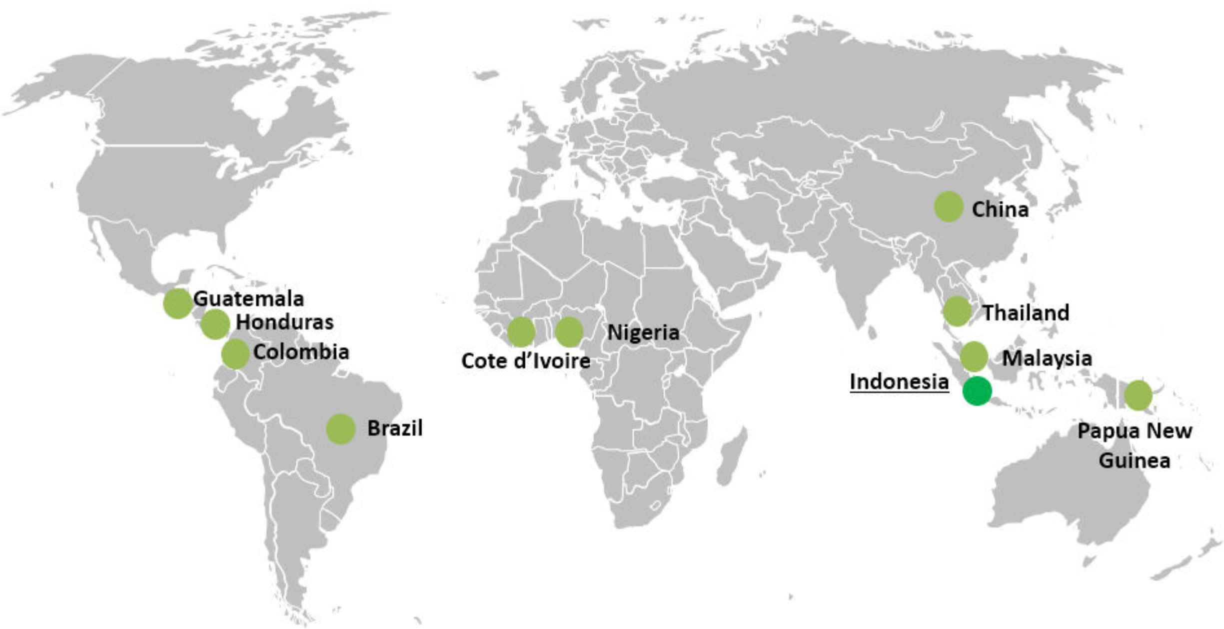
SCOPE

GEOGRAPHICAL SCOPE

The materiality assessment focuses on the natural capital costs of the top eleven palm oil and palm kernel oil producing countries, namely Indonesia, Malaysia, Thailand, Nigeria, Colombia, Papua New Guinea, Guatemala, Honduras, Cote d'Ivoire, Brazil and China. Together they account for 96% of total production, with Indonesia and Malaysia contributing 49% and 35% respectively. While it is recognized that costs may vary quite significantly from one location to another within a single country, the assessment was conducted at a national level.

The case study focuses on the natural and human capital costs of different practices and their possible optimizations in Indonesia.

FIGURE 2.1: GEOGRAPHICAL SCOPE



VALUE CHAIN SCOPE

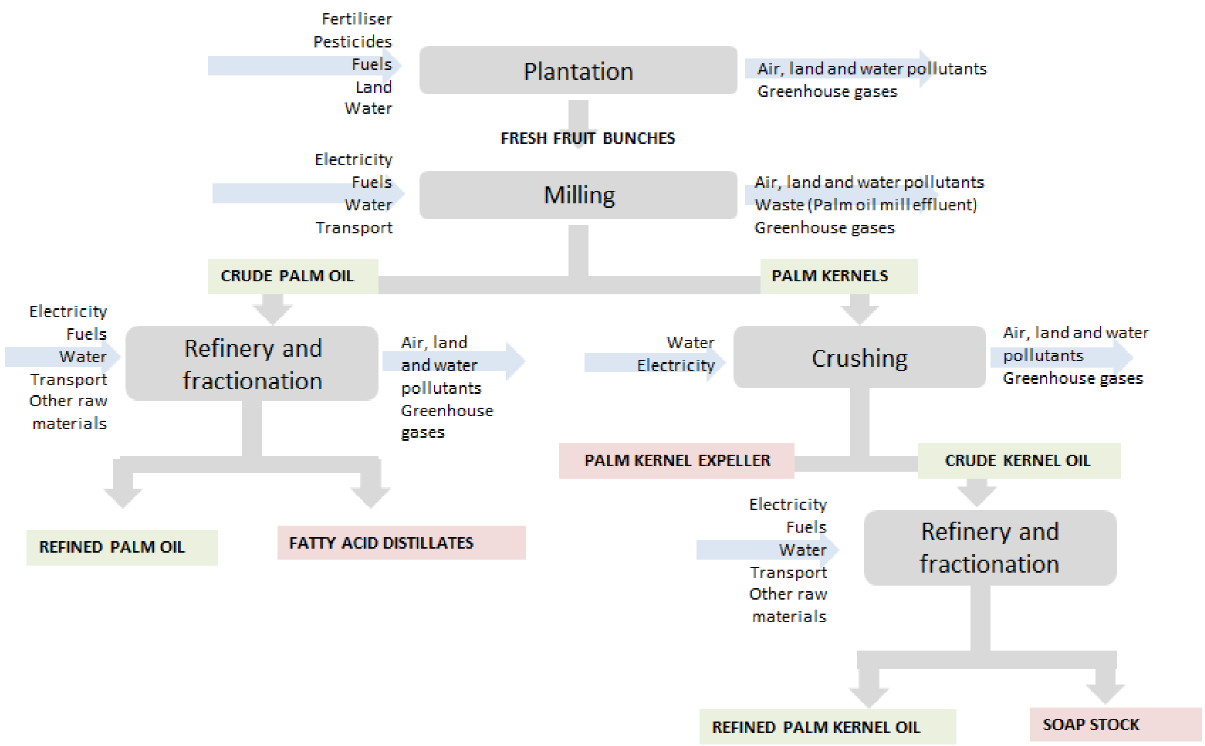
PALM OIL PRODUCTION PROCESS

Oil palm produces two distinct types of oils: crude palm oil from the mesocarp and crude palm kernel oil from the kernel (seed) of the fruit. Upon harvesting, oil palm fruits, which are produced in fresh fruit bunches (FFBs) are transported to a palm oil mill where the fruits are sterilized, stripped from the bunches and crushed to extract the crude palm oil (CPO). Oil palm fruits need to be processed within 24 hours to avoid denaturing; for this reason, mills are often small facilities which serve around 5,000 ha.

The seeds, or kernels, are crushed in order to produce palm kernel oil, and palm kernel meals as a by-product. However, due to the different composition of fatty acids between the two, they are used very differently. While palm oil has a balanced composition of both saturated and unsaturated fatty acids that is coupled with high vitamin E content, the oil is naturally very stable and suitable for cooking. Palm kernel oil is considered lower quality because it contains almost double the amount of saturated fats and lower levels of carotenoids than palm (fruit) oil thus distinctly promoting high cholesterol when eaten. It is therefore useful for making soaps, cosmetics and detergents (Palm Oil Health, 2015). The by-product is palm oil mill effluent, which can be treated and applied on fields as organic fertilizers. Palm oil is then refined into various palm oil products.

The materiality assessment studies the visible and invisible natural capital costs linked to the growing, milling and refining stages of palm oil production. It does not include the transportation, food processing and consumption stages. Palm oil and palm kernel oil were included within the scope of the analysis; other by-products such as fatty acid distillate or palm kernel expeller were excluded.

FIGURE 2.2: LIFE CYCLE STAGE AND PRACTICE SCOPE FOR THE MATERIALITY ANALYSIS



The Indonesia case study looks at the visible and invisible natural and human capital costs associated with five specific growing and milling practices.

FIGURE 2.3: LIFE CYCLE STAGE AND PRACTICE SCOPE FOR THE INDONESIA CASE STUDY

SCOPE OF NATURAL AND HUMAN CAPITAL COSTS

This study focuses on the significant but less studied visible and invisible costs associated with palm oil production. The scoping of costs to be included was conducted through a combination of consultation with TEEB and desk-based research. The review presented in table 2.1 looks at selected costs and is not intended to be exhaustive.

It is important to note that palm oil production also delivers a range of benefits, some of which are clearly visible such as employment, palm oil itself, as well as waste, which can sometimes be used as a source of energy in mills, or methane captured from palm oil mill effluent ponds. It also delivers less visible benefits such as ecosystem services including for example carbon sequestration.

For example, the industry employs an estimated six million people worldwide and generates up to 30 times more employment per hectare than other large scale farming operations due to low levels of mechanization. It has played a central role in generating export earnings and reducing poverty in producing countries. Smallholders, who control over 40% of Southeast Asia's cultivation, regularly report achieving more income from oil palm than alternative crops. Studies have indicated that every 1% increase in ha under cultivation contributes to a reduction of between 0.15 and 0.25 points of population living under poverty (IFC & World Bank, 2011). These benefits accrue to population above a certain threshold of skills and income, as oil palm cultivation requires significant investment and experience (Obidzinski, et al., 2012).

TABLE 2.1: SELECTED COSTS OF PALM OIL PRODUCTION

Cost	Description	Scope
Land dispossession and potential displacement of local communities	Land dispossession, and associated land conflicts, is described in many research papers as a major – perhaps the most important – social impact associated with palm oil expansion and production in Indonesia (Vermeulen & Goad, 2006; Obidzinski, et al., 2012). For example, in 2010 more than 630 land disputes took place in Indonesia between palm oil companies and local communities (Colchester, 2011). This issue is rooted in amongst others a lack of recognized customary rights and clarity over land tenure prior to plantation development, weak local governance, unfair and unclear agreements with local communities and the failure of companies to meet either contractual or perceived obligations (Obidzinski, et al., 2012; Marti, 2008; Rist et al., 2010). For Indonesia, most of the time, government agencies simply issue concession permits; they emphasize the need for prior community acceptance of plantation investment plans, but let the companies and communities negotiate the level and nature of compensation (Obidzinski, et al., 2012). The benefits companies claim plantation development has for local communities are often too high and companies tend to focus on village elite during negotiations causing problems of representation and elite capture (Obidzinski, et al., 2012).	Excluded
Underpayment and under earning	As noted earlier, palm oil has the potential to generate wealth and employment for local communities. However, palm oil has been linked to impoverishment of smallholder farmers (underearning) as well as workers (underpayment) as a result from debt, low wages, piece-rate labour via contractors and the avoidance of statutory employee benefits (Rist, et al., 2010; Marti 2008; Vermeulen & Goad, 2006; Navamukundan & Subramanian, 2003). Murray Li (2015) reports that payment of wages below the provincial minimum, a minimum wage insufficient for a decent standard of living and the prevalence of casual, subcontracted, temporary and part-time work are amongst the main points of concern. Many studies have noted that 2 ha of oil palm, the standard plot size allocated per household under most tied smallholder schemes in Indonesia, is not sufficient to sustain both farm and family (Murray Li, 2015). The U.S. Department of Labor reports that low labor costs in Southeast Asia are one of the reasons for the price of palm oil to remain competitive (Department of Labor, 2013).	Included in case study
Loss of livelihood alternatives	Oil cultivation displaces local cultivation practices, causing food insecurity, and also affecting social relations and land ownership (Obidzinski, et al., 2012).The expansion of plantations diminishes customary landholders' opportunities for independent farming, fishing, hunting and collection of forest products, which often is their way of life for generations (Manik, et al., 2013; Murray Li, 2015). As an example, Orth (2007) shows that oil palm development in Central Kalimantan has adversely affected the shifting cultivation practices of the local Dayak communities, causing food insecurity. However, the full livelihood impacts on rural communities involved in oil palm cultivation, particularly those on food security, health, social and cultural change, and the loss of environmental goods and services remain little understood (Rist, et al., 2010).	Excluded

Workers' rights violations	Palm oil production is linked to various breaches in workers' rights, including child & forced labor, freedom of association, social security, overtime, harassment discrimination, occupational health & safety. It is still often grown by means of child labor and forced labor in Indonesia and Malaysia (Department of Labor, 2013; Verité, 2012; Widiastuti, 2014). According to Widiastuti (2014) and Sawit Watch (2011), the palm oil sector in Indonesia is linked to widespread unacceptable or poor labor conditions, such as lack of employment contracts, overtime, discrimination, (sexual) harassment, forced and child labor, dangerous working conditions (including unprotected work with chemicals) and lack of the provision of basic services. The issues regarding working conditions and workers' rights are strongly correlated to situations where many of the jobs created in palm oil plantations and mills are for casual day laborers, which are particularly vulnerable to being paid in low wages, lacking of job security, without freedom to form unions, and with minimum legal protection (Manik, et al., 2013).	Occupational health & safety included in case study
Change in carbon stocks due to deforestation	Oil palm is a major contributor to deforestation and associated GHG and air pollutant emissions in most countries of production. Worldwide, destruction of tropical forests accounts for about 10% of annual climate change emissions. In Indonesia alone, where land use change and deforestation are the largest single contributors to GHG emissions, around 70% of oil palm plantations are on land that was previously forested (IFC & World Bank, 2011). GHGs are mainly emitted through the clearing of carbon-dense tropical forests and the burning of cleared biomass, the draining of peatlands, and the release of methane from effluent treatment ponds.	Included
Land conversion and loss of biodiversity, including endangered species	Due to the reduced structural complexity of plantations compared to forested ecosystems, oil palm plantations harbor significantly less biodiversity and do not provide the same level of environmental services, such as carbon storage, forest products (timber and non-timber) and soil benefits. When primary forests are cleared for such development, only about 15% of their animal species can survive in the resulting plantations (Fitzherbert, et al., 2008). In 2014, Savilaakso et al (2014) reviewed 9,143 articles and conducted a meta-analysis on 25 relevant and accessible articles, and found that only less than 40% of invertebrates and 20% of vertebrates was shared between oil palm cultivation and previous ecosystem. Considerable attention has been placed on endangered species, such as the Sumatran tiger, the Asian elephant, and the orangutan, which are particularly vulnerable to the clearing of forest areas, as the increased access leads to increased hunting, illegal logging, and opens areas to human settlement.	Excluded
Soil erosion	Soil erosion is a consequence of land clearing, when the soil is left uncovered. As highlighted by WWF (undated, based on Clay, 2004), erosion is accentuated by planting trees in rows up and down hillsides instead of cantors, by not properly siting or constructing infrastructure such as roads, and by establishing plantations and infrastructure on slopes of more than 15 degrees (Clay, 2004).	Included in case study
Air pollution from biomass burning (haze)	The burning of forests to clear land for plantations has also been a major source of haze in Southeast Asia, posing important and lasting health problems, as well as impacting the plantations themselves by reducing productivity of oil palm trees by hindering photosynthesis, reducing the activity of pollinating weevils, and affecting the health and vision of the plantation workers, thereby restricting their ability to harvest the fruit (WWF, 2008). The Association of Southeast Asian Nations (ASEAN) countries signed the ASEAN Agreement on Transboundary Haze Pollution in 2002 and have adopted a regional policy to implement zero burning. Yet, the practice continues mainly among smallholders and farmers who typically lack access to heavy machinery as an alternative (ASEAN, 2003) (Wicke, et al., 2011).	Included in case study

Eutrophication; air, land and water pollutants	Other impacts include indiscriminate use of fertilizers and insecticides by some producers, polluting surface and groundwater sources (WWF, 2008). The primary processing of palm oil in CPO mills presents a separate set of issues, the principal one being the potential for water pollution from the direct release of mill effluent, and the effects of this pollution on downstream biodiversity and people.	Included

This study does not only look at natural capital costs, but also aims to demonstrate how the measurement and valuation of human capital costs associated with certain practices can be used to underpin interventions that improve the social impact of palm oil cultivation.

The scope of this assessment is more limited and only includes two negative human capital costs associated to the production of palm oil FFB (Fresh Fruit Bunches). The selection of these two costs was based on a qualitative materiality assessment of all human and social capital costs (based on a literature research), data availability assessment and RSPO expert review[10] were conducted. The criteria for the selection were:

- Relevance of social or human capital cost during the establishment and cultivation phase of palm oil in Indonesia;
- Availability of footprint data (KPI's)

The qualitative materiality analysis showed that the most relevant negative human capital costs linked to oil palm plantations in Indonesia are: land dispossession, loss of livelihood alternatives (which can be linked to land dispossession), underpayment of workers and workers' rights issues, such as child labor, gender discrimination and health loss due to occupational incidents (see Table 2.1 for context). Following a data gap analysis, underpayment and health loss due to occupational incidents were selected and subsequently measured and monetized. The practices relating to these impacts are payment of wages and occupational health & safety policies and practices (OHS).

[10] Julia Majail, smallholder program manager and social impact expert at RSPO was interviewed

TABLE 2.2: SIMPLIFIED NON-EXHAUSTIVE SCHEME FOR SELECTION OF NEGATIVE HUMAN AND SOCIAL CAPITAL COSTS (DARK GREY: HIGH, GREY: MEDIUM, LIGHT GREY: LOW, GREEN: IN SCOPE)

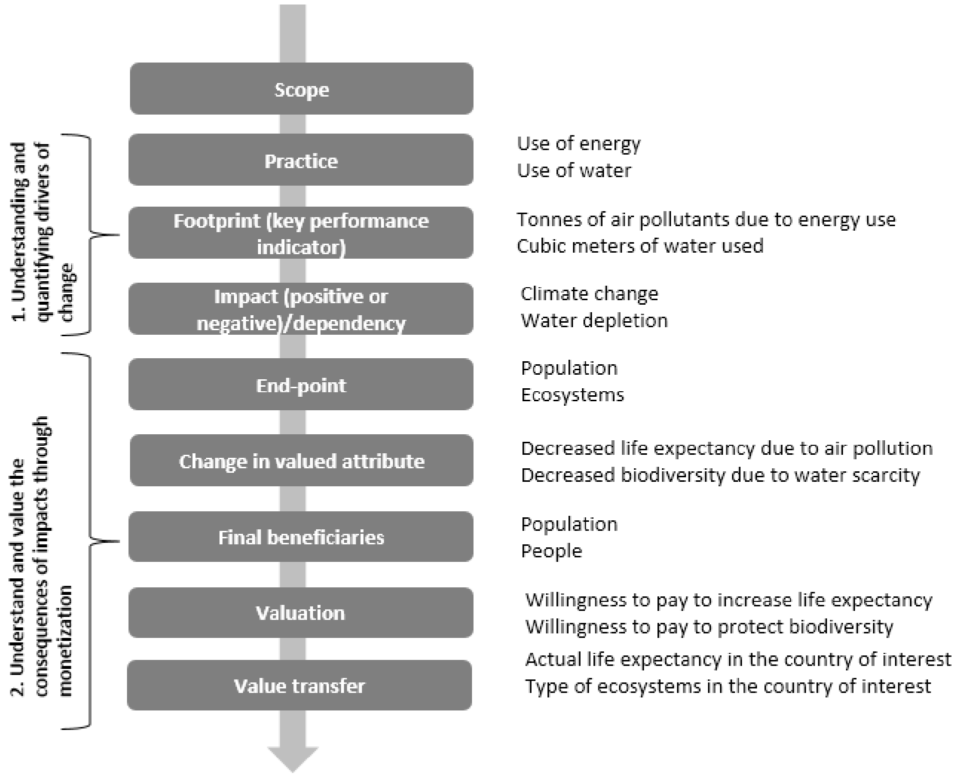
Impact	Materiality (estimate)	Data availability	In scope
Land dispossession			
Health loss (occupational)			
Underpayment			
Lack of social security			
Child labor			
Discrimination			
Forced labor			
Lack of freedom of association			
Harassment			
Health loss (local communities)			
Loss of livelihood alternatives			

One material impact out of scope is land dispossession, which is poorly documented in a quantitative way. This is not surprising, given the nature of this issue. However, it does mean that due to the limited scope of this part of the analysis and its goal – exploring the value of social and/or human capital valuation in decision making, rather than providing a complete estimation of human and social capital costs – land dispossession was not further investigated.

OVERVIEW OF METHODOLOGY SPECIFIC TO STUDY

The framework for assessment used in this study comprises distinct analysis stages: understanding and quantifying the drivers of change, understanding the consequences of the impacts and valuing these impacts. It makes use of existing literature to showcase the natural and human capital impacts of specific practices and how this leads to a change in the condition of specific societal groups: local communities, employees, businesses and the wider society. Figure 2.4 illustrates the framework and the next sections detail each step.

FIGURE 2.4: OVERALL METHODOLOGY (ADAPTED FROM KEELER, ET AL., 2012)



UNDERSTAND AND QUANTIFY DRIVERS OF CHANGE

The analysis combines the use of secondary global life-cycle assessment studies and the application of country-specific valuation coefficients, where data availability and quality is sufficient. The first step is to understand the drivers of change by devising appropriate key performance indicators (KPIs) that measure the relationship between palm oil systems, human systems, and ecosystems and biodiversity. For example, decisions around irrigation practices can lead to water depletion or replenishment, a negative or positive impact, measured by the amount of water used (KPI). Similarly, energy use in manufacturing processes could lead to climate change or acidification, through the emission of GHGs and other pollutants, measured in tonnes.

Several techniques exist to quantify KPIs and related impacts. These can include primary and secondary data collection. In this study secondary data collection is used from life cycle analysis studies, academic research, expert interviews and input-output modeling, due to data availability and granularity. The Agri-footprint database released in June 2014 was used to model the average impacts of refined palm and palm kernel oil (Agri-Footprint, 2014). The choice of methodology is mainly driven by the aim of the study and data availability.

Detailed methodology on the quantification of KPIs and data sources for both the materiality analysis and the Indonesia case study are available in Appendix 2.

UNDERSTAND & VALUE THE CONSEQUENCES OF IMPACTS

The second step is to understand the consequence of the impact to a specific end-point. An end point is the primary receptor of this impact–society, the environment, or the business itself. Each impact can have several end-points. For example, water depletion (negative impact) can affect society (end point 1) through lack of drinking water and decreased food supply, and the environment (end point 2) through decreased water availability to sustain fauna and flora. It can also affect the business itself (end point 3) through increased water scarcity in a specific location.

Impacts are quantified in biophysical terms. Examples of metrics, or 'valued attributes', are changes in life expectancy or changes in species richness due to the emission of pollutants. Biophysical models are used to estimate these metrics, based on a thorough literature review, and adapted to reflect local conditions. For example, the extent to which water pollution impacts society through decreased life expectancy depends on local social and environmental factors such as access to drinking water and pollutant dispersion based on hydrological patterns.

The choice of the valued attribute is informed by both the scope and requirements of the study and as importantly by how it feeds in step 3. One limitation of some valuation frameworks is that biophysical (step 2) and economic modelling (step 3) are conducted in isolation, leading to a discrepancy in metrics. For example, water quality metrics are often not well connected with what the society values - recreational tourists do not value the concentration of phosphorus or other water pollutants, but rather water clarity (Keeler, et al., 2012).

The last step consists of converting the biophysical metrics into monetary terms that reflect the costs and benefits to specific beneficiaries of the change in valued attribute using a valuation coefficient. The output of this step is a valued impact that reflects cost or benefit of specific practices and associated use of inputs and emissions on human health and ecosystems. In this sense, the valuations reflect the damage on different endpoints: the damage to ecosystems and/or the damage to human health.

NATURAL CAPITAL VALUATION

Several techniques exist to assign a value to a change in valued attribute and calculate the costs and benefits in monetary terms of a specific action. Techniques span from observing behavior on already-existing alternative markets as a proxy, for example how much is spent on aquatic recreational activities, or creating artificial markets by asking population their willingness-to-pay for the existence of wildlife habitat.

A global approach has been used for the valuation exercise. This approach consists of creating a global valuation function that can be applied to specific locations. Benefit transfer, or value transfer, is an underlying principle of this approach. According to Brander (2013), 'value transfer is the procedure of estimating the value of an ecosystem service of current policy interest (at a "policy site") by assigning an existing valuation estimate for a similar ecosystem elsewhere (at a "study site")'. Value transfer techniques were applied to create country-specific valuations. Similarly to the quantification phase, the valuation of direct natural capital impacts was as country specific as possible, and the valuation of the supply chain was based on global average factors. An estimate on the range of uncertainty associated with its valuations by varying some of the key variables over which there is control is provided in Appendix.

Natural capital costs cover five categories:

- GHG emissions
- Air pollutants
- Water consumption
- Water pollutants (from fertilizer application)
- Soil pollutants (from pesticide application)

Downstream impacts from the farm gate to the end consumer are not included in the scope of the analysis. A differentiation between farming systems has not been included in the global approach and has been captured as part of the analysis in the case study.

Table 2.3 outlines the scope of the valuation for each monetized cost associated with palm oil production included in the analysis.

TABLE 2.3 NATURAL CAPITAL COSTS OVERVIEW

NATURAL CAPITAL COSTS	SCOPE OF THE VALUATION
GHGs (from energy and non-energy sources)	Multitude of impacts, including but not limited to, changes in net agricultural productivity, human health and property damages from increased flood risk. The GHGs considered in this analysis include carbon dioxide, methane and nitrous oxide. The Social Cost of Carbon, in 2015 USD, used in this study is $128 per tonne CO_2 (USIAWG, 2013)[11].
Air Pollutants	The impacts of air pollutants on human health are captured in this valuation. This includes impacts from the emission of SOx, NOx, PM10, VOCs and Ammonia from sources such as fuel use, fertilizer application, and pesticide application.
Water pollutants (from fertilizer application)	Eutrophication impacts on ecosystems and human health, associated with algal blooms and drinking water quality. This valuation includes the impacts from the emission of nitrogen, nitrates, phosphates and phosphorus.
Soil pollutants (from pesticides application)	Soil pollutants have toxic impacts on human health and ecosystems. This valuation includes the impacts of over 60 pollutants, including pesticides such as atrazine, herbicides such as Diuron and fungicides such as Folpet.
Water consumption	Water consumption valuation includes the impacts on human health and ecosystems. The unit of measurement for human health impacts is disability adjusted life years (DALYs) and affected Net Primary Productivity (NPP) in the case of ecosystem damage.

Additional methodological details on natural capital valuation are available in Appendix 1. The actual natural capital valuation coefficients are presented in the Materiality Analysis.

HUMAN CAPITAL VALUATION

The methodological developments for the valuation of human capital costs are in general less mature then for natural capital costs. However, the final beneficiaries of human capital costs (i.e. people) are similar to most natural capital costs, as are many of the valuation techniques. For example, the human capital cost of occupational accidents can be valued by the change in DALY's (Disability Adjusted Life Years) – a metric developed by the WHO – where a DALY has a certain value. This valuation coefficient is the same as that used to determine the natural capital costs of air pollution, which also looks at the change in DALY of people due to air pollutants.

Many other human capital costs can be valued with similar techniques based on human health and welfare approaches.

[11] A social cost represents the cost to society as a whole resulting from an action, in this instance, the emission of carbon. According to USIAWG (2013), "the Social Cost of Carbon is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year".

Many human capital costs, such as child labor, overtime and discrimination, can and are being valued today and open source protocols and standards on human and social capital impacts are being developed by amongst others the World Business Council of Sustainable Development and True Price.

Similarly to the quantification phase, the valuation of human capital impacts for the case study was as country specific as possible. An estimate on the range of uncertainty associated with its valuations by varying some of the key variables over which there is control is provided in figure 4.15.

Human capital costs in this study cover two categories:

- Underpayment
- Occupational health

Downstream supply chain impacts, from the farm gate to the end consumer, are not included in the scope of the analysis. The valuation of human capital costs in the case study focuses on large private palm oil estates[12], and not on smallholders.

Table 2.4 outlines the scope of the valuation for each cost associated with palm oil production included in the analysis (monetized only, through the use of valuations).

TABLE 2.4 HUMAN CAPITAL COSTS OVERVIEW

HUMAN CAPITAL COST	SCOPE OF THE VALUATION
Underpayment	This valuation includes the impact of underpayment on human well-being. Underpayment prevents workers to provide an adequate standard of living for themselves and their families.
Occupational health	This valuation includes the impacts on human health from occupational incidents. The unit of measurement for human health impacts is disability adjusted life years (DALYs).

Table 2.5 shows the human capital valuation coefficients for each human capital impact covered in the Indonesian case study analysis. The valuation of underpayment is somewhat different in the sense that the change in valued attribute – underpayment – is not directly measurable, but depends on the country-specific living wage. The amount of underpayment (US$) is the difference between the total (financial and in-kind) wage and the living wage. This living wage is based on country specific characteristics, such as the rural household size, components of the food basket and income taxes (see Appendix 1 for more details on the living wage calculation). As a valuation coefficient, 1 US$/US$ underpayment was selected in this study. This is a conservative valuation coefficient, as it does not account for opportunity costs.

[12] Private estate palm plantations account for 54.35% of the CPO production in Indonesia (Indonesia Ministry of Agriculture, 2014)

TABLE 2.5: HUMAN CAPITAL VALUATION COEFFICIENTS FOR THE INDONESIA CASE STUDY ANALYSIS (IN 2015 US$ PER UNIT)

Underpayment (US$/US$ underpayment)	Occupational health (US$/incident)			
	Light incidents	Heavy incidents	Fatal incidents	Acute Pesticide Poisoning (APP) incidents
1	3	866	1,159,469	2,157

For the human capital valuation methodologies, a more detailed description can be found in Appendix 1.

LIMITATIONS

NATURAL CAPITAL VALUATION

The materiality assessment relies on national output data from which natural capital impacts are derived at a country level. Calculating all impacts from a regional perspective covering all producer countries worldwide would not be feasible from a resources and timing perspective. In addition, the global approach does not attempt to capture intra-national differences in impacts, or differences between specific technologies and farming practices. These results are therefore strengthened by the regional analysis in the case study.

General limitations regarding the natural capital valuations used in the global approach are described below in Table 2.6. Those limitations are related to aspects such as the aggregation of data, the exclusions of specific costs, or the use of value transfer techniques. Specific limitations for the different valuation methodologies, such as water consumption and eutrophication, appear in Appendix.

TABLE 2.6: SUMMARY OF LIMITATIONS FOR THE VALUATIONS APPLIED IN THE GLOBAL APPROACH

LIMITATION	EXPLANATION
Aggregation of data	In some cases, components of valuations which represent impacts on different receptors, such as human populations, are aggregated and use different valuation techniques. The individual components of valuations may or may not be directly comparable, but the methodology applied is consistent across the different impact categories and to each unique receptor.
Exclusions	Some natural capital costs have been excluded on the basis of materiality or data availability. Please see the relevant methodology sections in Trucost (2015) for further information. In addition, benefits are covered only briefly and mainly assessed qualitatively.
Static	Valuations are adjusted using inflation rates applied at a specific point in time.
Value transfer	Value transfer was used to assess the impacts on ecosystems and human health. Value transfer techniques inherently imply a degree of uncertainty when compared to primary valuation techniques (Brander, 2013).

One key consideration here is that the monetization of external impact is inherently human-centric, with the values reflecting the impact of the environmental change on the wellbeing of the individual, society or business. This is so even in a context where the end-point is the environment. For example, the costs and benefits of a change in biodiversity are valued based on the services that biodiversity provides to society. This is consistent with the approach taken in the international Millennium Ecosystem Assessment, which focuses on contributions of ecosystems to human well-being while at the same time recognizing that potential for non-anthropocentric sources of value.

HUMAN CAPITAL VALUATION

It is important to note that there are limitations to the results of the human capital valuation. An overview of key limitations regarding the human capital valuation in the case study is provided below in Table 2.7:

TABLE 2.7: OVERVIEW OF KEY LIMITATIONS FOR THE HUMAN CAPITAL VALUATIONS

LIMITATION	EXPLANATION
Data quality	Averages were used to represent the data. However, there often was a high variability across sources and regions for key indicators (i.e. wages, accident rates, labor intensity). When data for private estate plantations in Indonesia were not available, data from comparable regions or farm types were used for some of the H&S parameters. For example, data on the use of personal protective equipment was partially based on data from palm oil plantations in Thailand and from smallholder plantations in Indonesia. Global data on pesticide poisoning rates were used as recent data on Indonesian palm oil plantations are not available. Some data sources are possibly prone to bias. For example, average light, heavy and fatal accident rates were mainly based on plantation specific sustainability and audit reports, which can result in an underestimation of accident rates as plantations with better labor conditions are more likely to have sustainability reports or certification programs.
Scope of human capital costs	Many human capital costs have been excluded on the basis scope, materiality or data availability. In addition, benefits are mainly assessed qualitatively.
Scope of supply chain	The scope for the human capital valuation was limited to private estate plantations, established on mineral soil grasslands via mechanical clearing. Furthermore, only the establishment and cultivation phases were in scope.
Static	Valuations are adjusted using inflation rates applied at a specific point in time.
Assumptions	Many specific assumptions were made throughout the analysis. For example, it was assumed that commodity prices in traditional markets in urban areas of palm-oil producing provinces are the same as those in rural areas.

Other specific limitations of the human capital valuation are described in Results.

FINANCIAL CAPITAL

Despite every care being taken to ensure the triangulation and reliability of financial analysis presented alongside each practice in the Indonesia case study, the assessment has some limitations that must be acknowledged and improved upon in future analyses. The principal limitation of the analysis is that it relies on secondary rather than primary data and as such some uncertainty and context, as well as time lag are inevitably introduced.

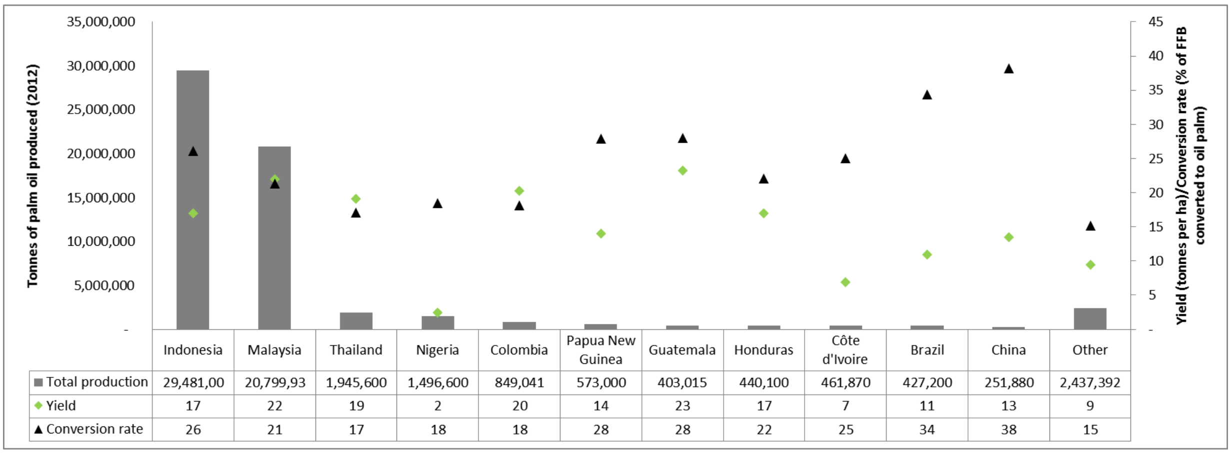
In addition, it is important to acknowledge the notable lack of producer specificity when addressing the costs incurred above. For example, Fairhurst & McLaughlin (2009) note in their analysis a wide variability in the cost of inputs, particularly fertilizers, the largest plantation variable cost, due to differences in procurement strategy. Some estates had long-term fixed price contracts for fertilizers, whilst others purchased according to need. This variation is related to the nature and purchasing strength of the different players that classify the Indonesian palm oil industry.

MATERIALITY ANALYSIS

NATURAL CAPITAL QUANTIFICATION

Fully mature oil palms produce 18 to 30 metric tonnes of fresh fruit bunches (FFB) per hectare. Palm oil extraction rate from FFBs varies around 20%, while for palm kernel oil it is much lower at around 4%. Figure 3.1 displays total per country combined palm oil and palm kernel oil production in 2013, as well as the average yield (tonnes FFB per hectare) and combined conversion rate (palm oil and palm kernel oil production as a percentage of fresh fruit bunch (FFB) production).

FIGURE 3.1: PALM OIL PRODUCTION, YIELD AND CONVERSION RATE (ADAPTED FROM FAOSTAT, 2013)



In 2011, yields ranged from 2 tonnes of FFB/ha in Nigeria to 22 tonnes in Malaysia. Conversion rates from FFB to palm oil range from 18% in Nigeria & Colombia to 38% in China; conversion rates from FFB to palm kernel oil range from 1% in Thailand to 9% in Brazil. Though no correlation is found between yields and conversion rates, these variables are essential in understanding the variability of impacts across selected countries.

Table 3.1 summarizes the key inputs to the analysis. A detailed list of outputs and a detailed methodology of calculation methods is available in Appendix 1.

TABLE 3.1: KEY INPUTS

	YIELD (T FFB PER HA)	CONVERSION RATE FROM FFB TO PALM OIL (2011)	CONVERSION RATE FROM FFB TO PALM KERNEL OIL (2011)	% OF PEAT SOIL	% OF FOREST	% OF GRASSLAND	% OF PERMANENT CROP	KG OF N PER HA PER YEAR	KG OF P205 PER HA PER YEAR	KG OF GLYSOPHATE PER HA, Global Average	KG OTHER PESTICIDES (Other) PER HA, Global Average
Indonesia	17	22	2	30%	81%	6%	0%	89	23	2.6	0.3
Malaysia	22	20	2	12%	30%	0%	25%	86	41	2.6	0.3
Thailand	19	15	1	<1%	74%	0%	1%	72	35	2.6	0.3
Nigeria	2	12	6	<1%	17%	6%	0%	65*	24*	2.6	0.3

Colombia	20	17	2	1%	0%	0%	8%	100	30	2.6	0.3
Papua New Guinea	14	28	2	13%	52%	0%	12%	120	24*	2.6	0.3
Guatemala	21	20	6	<1%	59%	31%	0%	80	40	2.6	0.3
Honduras	17	20	2	3%	72%	0%	1%	120	40	2.6	0.3
Cote d'Ivoire	6	23	2	<1%	0%	0%	13%	65*	24*	2.6	0.3
Brazil	12	21	9	<1%	0%	0%	11%	83	28	2.6	0.3
China	13	34	4	<1%	0%	0%	0%	146	42	2.6	0.3

*Based on global estimates

Peat soil conversion is most important in Indonesia (30%), Papua New Guinea (13%), Malaysia (12%), Honduras (3%) and Colombia (1%). Less than 1% of plantations are established on peatland in other selected countries. In addition, 81% of plantations are established on forest in Indonesia, followed by 74% in Thailand, 72% in Honduras, 59% in Guatemala, 30% in Malaysia and 17% in Nigeria.

One of the main challenges in quantifying the type of land converted for oil palm plantations is the lack of official land type classification and data at a global level (Gingold, et al., 2012). For example, figures may be overestimated due to the Direct Land Use Change Assessment Tool methodology, which does not make the difference between different types of perennial crops (Blonk Consultants, 2014). A study published in 2013 found that between 1990 and 2010, prior land use of all new plantation established in the three main oil palm regions of Indonesia, was 34% agro-forest and plantation, 19% disturbed upland forest and 20% upland shrub and grassland (Gunarso, et al., Undated). However, this data source was used to maintain consistency in measurement across countries.

Quantity of fertilizer applied per hectare is the highest in China, 146 kg of nitrogen and 42 kg of phosphorus per hectare. It is noticeable that this does not translate into higher yields. Global averages were used for Nigeria, and Colombia, Papua New Guinea, Guatemala, Honduras, and Cote d'Ivoire for lack of national estimates. Finally, quantity is pesticides is held constant and based on Indonesia estimates.

Table 3.2 displays key outputs calculated as part of the materiality analysis. A detailed list of outputs and a detailed methodology of calculation methods is available in Appendix 2.

TABLE 3.2: KEY CALCULATED OUTPUTS

	THAILAND	CHINA	INDONESIA	MALAYSIA	NIGERIA	COLOMBIA	PAPUA NEW GUINEA	CÔTE D'IVOIRE	HONDURAS	BRAZIL	GUATEMALA
PER TONNE OF PALM OIL											
Air pollutants (ammonia and nitrous oxide) (kg)	4.8	4.4	4.5	3.8	4.9	6.7	4.4	2.8	6.3	5.2	5.3
GHGs (Nitrous oxide) (kg)	2.3	2.1	3.6	2.3	3.6	3.1	2.7	1.9	3.1	2.8	2.4
Nitrate to water (kg)	83	114	77	59	148	143	103	76	146	132	104

Phosphate to water (kg)	<1	<1	<1	<1	1	1	<1	<1	<1	1	1
Heavy metals to land (mg)	14,183	11,500	7,832	11,099	17,201	14,793	8,018	8,818	16,921	13,692	16,264
Pesticides to land (kg)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon emissions from land transformation (kg)	17	31	5,835	1,914	4,445	105	1,950	63	1,474	108	555
Methane to air from POME (kg)	49	22	34	37	64	43	27	33	37	36	38
PER TONNE OF PALM KERNEL OIL											
Air pollutants (ammonia and nitrous oxide) (kg)	8.1	5.4	5.9	5.3	1.3	8.3	8.5	3.8	9.2	1.8	2.6
GHGs (Nitrous oxide) (kg)	4.0	2.7	4.7	3.2	1.0	3.8	5.2	2.5	4.5	0.9	1.2
Nitrate to water (kg)	140	142	102	82	40	177	197	103	214	45	51
Phosphate to water (kg)	1	<1	<1	<1	<1	1	1	<1	1	<1	<1
Heavy metals to land (mg)	23,981	14,373	10,321	15,341	4,613	18,366	15,377	11,894	24,719	4,645	7,985
Pesticides to land (kg)	0.5	0.2	0.3	0.3	0.1	0.4	0.4	0.3	0.4	0.1	0.1
Carbon emissions from land transformation (kg)	29	39	7,689	2,646	1,192	131	3,739	85	2,153	37	272
Methane to air from POME (kg)	7	3	5	6	9	6	4	5	6	5	6

Carbon emissions from land transformation are highest in Indonesia, Nigeria, Malaysia, Papua New Guinea, and Honduras. In these countries, a significant proportion of plantations are established on peat soils, leading to methane emissions from drainage. In addition, a larger than average proportion of plantations are established on previously forested land, hence contributing to a larger change in carbon stocks, both above-ground and soil carbon. However, land use is not always the only explanatory variable. For example, Nigeria has the second highest carbon emissions from land transformation per tonne of refined oil, after Indonesia, because of lower yields and conversion rates.

Resource use and associated emissions, measured by relevant key performance indicators such as tonnes of air pollutants or pollutants to water, are the result of a combination of three main factors:

- Yield (tonnes of FFB per ha) and conversion rate (tonnes of FFB per tonne of finished product) is a key explanatory factor when comparing a tonne of refined oil and kernel oil in different countries. A large proportion of resource use and emissions are attributable to the growing stage; hence, the more efficient the planting and refining system, the less resources used and the less associated emissions.

- The quantity and type of inputs also explain part of the differences between countries, for example the quantity of fertilizer applied per ha; and the type of land and soil on which the plantation was established.

- The quantity of fertilizer applied explains another part of the trend. A similar trend can be observed for the emissions of nitrous oxide during fertilizer application. In addition, soil type can have an impact on emissions due to fertilizer application. For example, while the yield and conversion rate of Indonesia is within the average, 30% of oil palms are planted on peat soils, thus leading to higher nitrous oxide emissions from fertilizer application.

NATURAL CAPITAL VALUATION

Table 3.3 displays the average cost per output by country. Appendix 1 provides the detail the specific methodological steps undertaken to calculate these coefficients, as well as a detailed list of limitations.

TABLE 3.3: VALUATION COEFFICIENTS

	Thailand	China	Indonesia	Malaysia	Nigeria	Colombia	Papua New Guinea	Côte d'Ivoire	Honduras	Brazil	Guatemala	Average
Greenhouse gases (t)	126	126	126	126	126	126	126	126	126	126	126	126
Heavy metals to land - Health (kg)	51.38	181.03	0.17	445.72	2.76	0.22	82.57	0.97	47.18	159.69	138.20	100.90
Heavy metals to land - Terrestrial ecosystems (kg)	12.96	3.76	13.79	12.98	3.64	4.20	22.67	15.49	6.26	4.16	6.04	9.63
Heavy metals to land - Freshwater ecosystems (kg)	0.33	0.35	0.35	0.33	3.38	0.32	0.05	3.38	4.20	0.32	4.06	1.55
Heavy metals to land - Marine ecosystems (kg)	0.87	0.43	0.94	0.88	5.38	0.29	2.71	0.95	2.49	0.29	2.39	1.60
Pesticides to land - Health (kg)	1.41	4.90	0.00	12.24	0.08	0.01	0.61	0.00	0.72	3.90	2.07	2.36
Pesticides to land - Terrestrial ecosystems (kg)	109.45	30.18	109.45	109.45	18.93	63.09	158.78	0.02	68.84	63.09	68.84	72.74
Pesticides to land - Freshwater ecosystems (kg)	0.21	0.21	0.21	0.21	0.11	0.25	0.18	1.82	0.37	0.25	0.37	0.38
Pesticides to land - Marine ecosystems (kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eutrophication - Health (kg N)	0.13	0.06	0.02	0.00	0.09	0.00	0.02	0.00	0.02	0.00	0.01	0.13
Eutrophication - Water treatment (kg N)	0.61	0.78	0.51	0.74	0.60	1.04	0.63	0.70	0.80	1.18	0.80	0.76
Eutrophication - Freshwater ecosystems (kg N)	7.21	3.30	0.89	1.16	2.24	2.67	9.11	1.78	5.16	2.06	1.86	3.40
Eutrophication - Health (kg P)	0.94	0.44	0.15	0.02	0.68	0.04	0.16	0.03	0.18	0.02	0.08	0.94
Eutrophication - Water treatment (kg P)	4.46	5.67	3.75	5.37	4.40	7.59	4.57	5.10	5.80	8.57	5.80	4.46
Eutrophication - Freshwater ecosystems (kg P)	52.52	24.05	6.47	8.45	16.35	19.42	66.34	12.97	37.61	14.98	13.53	52.52

The cost per tonne of GHGs is held constant, at $126 per tonne, as impacts are global regardless of where it is emitted, due to dispersion patterns. The coefficient is based on estimates from the US EPA (United States Environmental Protection Agency, 2013).

The cost and variation of heavy metals emitted to land is mainly driven by health impacts. Explanatory variables are embedded within the model used to calculate health impacts, and include population density, typical diet and access to safe drinking water (Lijzen & Rikken, 2004).

Finally, terrestrial ecosystem damage and costs are the main explanatory variable in overall pesticide cost. Part of it is due to the dispersion model built in EUSES-LCA (Lijzen & Rikken, 2004) which calculates the proportion of species lost due to the application of a given pesticide on agricultural land. In addition, the value of species lost is linked to the average species density, the type of ecosystem and average ecosystem service value in a given location. The cost of biodiversity lost is highest in Papua New Guinea, Thailand, Indonesia and Malaysia, and lowest in China. The average value of one meter square is lower in Eastern Asia (\$0.12 per m^2 in 2007) and highest in Melanesia (\$0.62 per m^2).

The main drivers explaining variation in eutrophication costs are:

- Average perimeter of freshwater bodies, and average volume of water in freshwater bodies
- Percentage of population with access to safe drinking water, 3) population density around freshwater bodies and 4) average distance to freshwater on land. The average volume of freshwater has an impact on the dispersion of eutriphying substances, leading to variations in concentration for a given quantity of substances emitted, and thus variations in health, treatment, and freshwater ecosystems impacts and costs. The average distance to freshwater is used for estimating how much of the emissions to land will end up in a freshwater ecosystem.

Eutrophication has the highest health cost in Thailand, followed by Nigeria and China. Nigeria has the largest population density living close to freshwater in the sample, combined with a lower proportion of population with access to safe drinking water. However, in northern Africa there is a greater distance to freshwater and so, on average, less of the nutrients end up being leached into freshwater which drives down the cost below Thailand.

The highest overall cost of eutrophication is in Papua New Guinea, followed by Thailand and Honduras. This can be explained by the relatively low average volume of freshwater bodies in these countries compared to the sample average, impacting the rate of dilution. On the other hand, eutrophication has the lowest cost in Indonesia and Malaysia, mainly driven by the large average volume of freshwater bodies, leading to higher dilution and lower concentration of nitrates and phosphates in water.

DEEP-DIVE INTO HEALTH AND ECOSYSTEM IMPACTS OF PESTICIDE APPLICATION

Table 3.4 provides data relating to the change in the quality of human health and ecosystems (the valued attribute), the intermediary step between the calculation of key performance indicators and monetary valuation for the health and ecosystems toxicity effects of pesticides. The quantity of pesticides applied to soil per hectare on average, the related health effects expressed in disability adjusted life year (or DALYs) and the related terrestrial toxicity effects are expressed in potentially disappeared fraction of species (PDFs). Additional methodological detail is available in Appendix 2.

TABLE 3.4: DISABILITY ADJUSTED LIFE YEAR AND POTENTIALLY DISAPPEARED FRACTION OF SPECIES PER TONNE OF PALM OIL PRODUCED (WEIGHTED AVERAGE OF TOP 11 PRODUCING COUNTRIES)

	Result
Kg of pesticides applied per tonne of palm oil (weighted average)	0.21
Disability adjusted life years (weighted average)	3.67E-05
Potentially disappeared fraction of species (weighted average)	2.78E-06

DEEP-DIVE INTO HEALTH AND ECOSYSTEM IMPACTS OF HEAVY METALS

As previously outlined, the valuation coefficient for health toxicity from heavy metals emitted to land is mainly driven by health impacts. Table 3.5 explains tis by displaying the varying disability-adjusted life years lost due to the emission of 1 kg of each substance to land. Additional methodological detail is available in Appendix 1.

TABLE 3.5: DALYS PER KG OF HEAVY METAL EMITTED TO LAND, COLOUR CODED IN ORDER OF SIGNIFICANCE

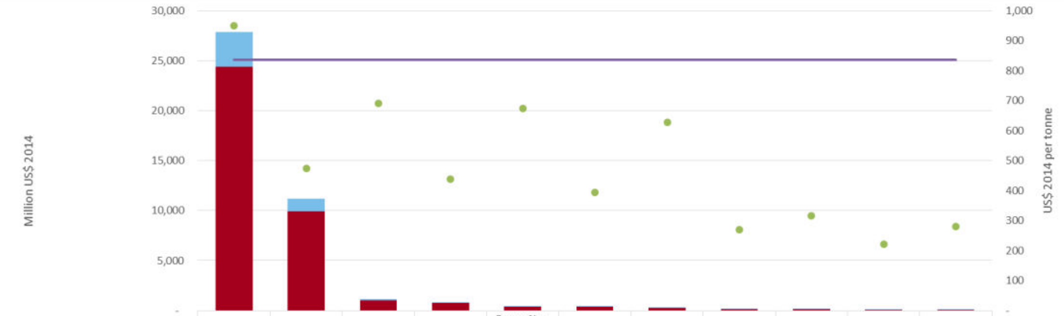
	Thailand	China	Indonesia	Malaysia	Nigeria	Colombia	Papua New Guinea	Côte d'Ivoire	Honduras	Brazil	Guatemala
Arsenic	4.00E-01	4.00E-01	4.00E-01	4.00E-01	2.20E-01	2.50E-01	1.98E-01	2.20E-01	2.27E-01	2.50E-01	2.27E-01
Cadmium	1.92E-01	1.92E-01	1.92E-01	1.92E-01	5.56E-02	4.43E-02	1.63E-02	5.56E-02	2.12E-01	4.43E-02	2.12E-01
Chromium	4.07E-05	4.07E-05	4.07E-05	4.07E-05	1.08E-05	1.09E-05	5.63E-06	1.08E-05	1.14E-05	1.09E-05	1.14E-05
Cobalt	1.32E-15	1.32E-15	1.32E-15	1.32E-15	5.37E-16	1.76E-16	1.09E-16	5.37E-16	2.55E-16	1.76E-16	2.55E-16
Copper	3.43E-05	3.43E-05	3.43E-05	3.43E-05	1.29E-05	1.43E-05	9.27E-06	1.29E-05	1.99E-05	1.43E-05	1.99E-05
Mercury	1.35E+00	1.35E+00	1.35E+00	1.35E+00	2.37E-01	4.78E-01	2.46E-01	2.37E-01	2.28E-01	4.78E-01	2.28E-01
Nickel	1.85E-04	1.85E-04	1.85E-04	1.85E-04	1.02E-04	1.15E-04	9.13E-05	1.02E-04	1.08E-04	1.15E-04	1.08E-04
Lead	5.04E-02	5.04E-02	5.04E-02	5.04E-02	9.54E-03	1.60E-02	4.32E-03	9.54E-03	1.10E-02	1.60E-02	1.10E-02
Selenium	9.52E-01	9.52E-01	9.52E-01	9.52E-01	5.72E-01	7.43E-01	4.73E-01	5.72E-01	6.34E-01	7.43E-01	6.34E-01
Zink	2.13E-03	2.13E-03	2.13E-03	2.13E-03	6.67E-04	8.83E-04	4.77E-04	6.67E-04	8.55E-04	8.83E-04	8.55E-04
Weighted average	6.76E-03	6.85E-03	6.88E-03	6.76E-03	2.45E-03	2.71E-03	1.43E-03	2.45E-03	5.47E-03	2.73E-03	5.47E-03

NATURAL CAPITAL COST PER PRACTICE AND COST TYPE

In total, palm oil production in the top ten countries generates a cost of $43bn per year, with Indonesia and Malaysia contributing 66% and 26% respectively. Palm oil production has a total cost of $37.5bn and palm kernel oil $5bn. On average, producing one tonne of palm oil and palm kernel oil has an environmental cost of $790 and $897 respectively. Producing one tonne of palm kernel oil has a higher intensity, or cost per tonne, than palm oil, as more fresh fruit bunches (FFB) are needed for the same quantity of end product.

Figure 3.2 displays the natural capital cost of producing palm oil and palm kernel oil in the eleven countries selected, as well as the average intensity of environmental cost per tonne palm oil plotted against weighted average producer price per tonne palm oil.

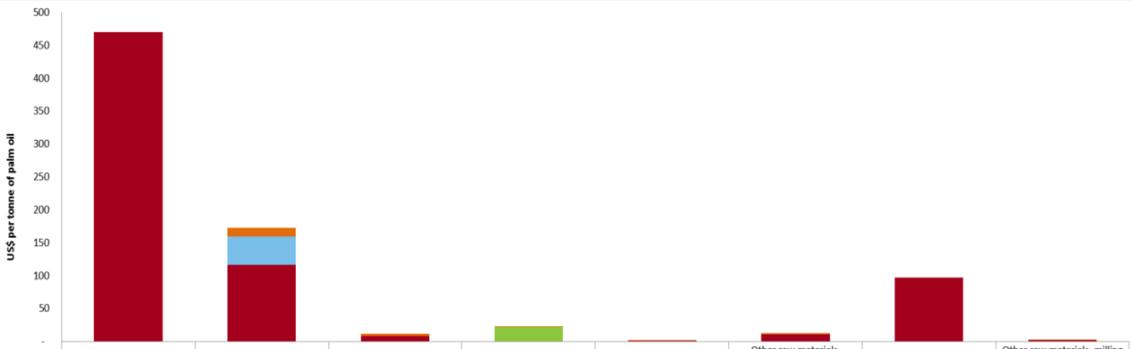
FIGURE 3.2: TOTAL NATURAL CAPITAL COST AND INTENSITY



	Indonesia	Malaysia	Nigeria	Thailand	Papua New Guinea	Colombia	Honduras	Brazil	Guatemala	Côte d'Ivoire	China
Palm kernel oil	3,504	1,259	147	57.63	38	30	24	13	14	8	7
Palm oil	24,385	9,934	995	788.09	406	355	258	105	102	91	69
Average palm oil intensity (US$ per tonne)	950	475	691	439	674	394	628	270	316	221	280
Weighted average producer price (US$ per tonne palm oil)	837	837	837	837	837	837	837	837	837	837	837

Figure 3.3 displays the natural capital cost of producing one tonne of palm oil, weighted by production across countries, and split by activities and impact type.

FIGURE 3.3: INTENSITY PER TONNE SPLIT BY PRACTICES AND IMPACT TYPE



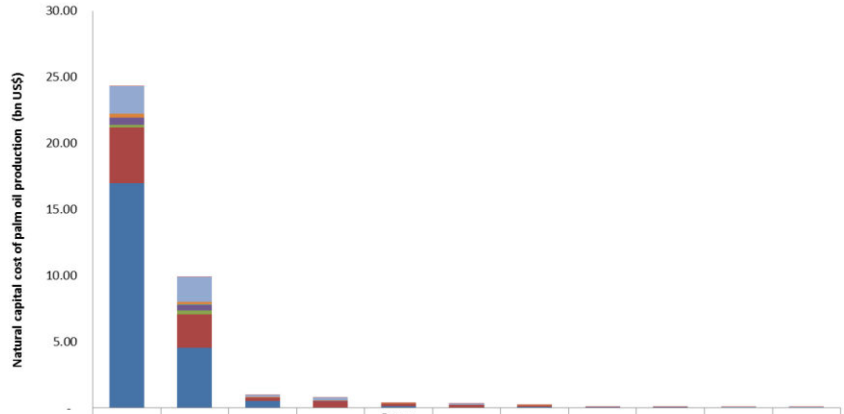
	Land use change	Fertiliser application	Fertiliser manufacturing	Pesticide application	Pesticide manufacturing	Other raw materials, planting phase	Emissions from POME	Other raw materials, milling and refining
Health toxicity	-	14	4	1	1	2	-	0
Ecosystem toxicity - marine	-	0	0	0	0	0	-	0
Ecosystem toxicity - freshwater	-	43	0	0	0	0	-	0
Ecosystem toxicity - terrestrial	-	0	0	22	0	0	-	0
GHGs	470	116	8	-	1	10	97	2

Land use change and the associated carbon emissions and their impact on climate change contribute 89% to the cost of one tonne of palm oil. Fertilizer application contributes 22%, with 67% from GHGs, 25% from toxic substances to freshwater environment, and 8% from toxic substances to human health. Palm oil mill effluent emissions (POME) is the third most costly practice in terms of environmental cost, contributing 12% of total costs, due to methane emissions causing climate change. Pesticide application contributes 3%, mostly due to damage caused to terrestrial ecosystems. Finally, upstream impacts from fertilizer, pesticide and other raw material inputs manufacturing contribute another 3%.

NATURAL CAPITAL COST OF PALM OIL PRODUCTION PER COUNTRY

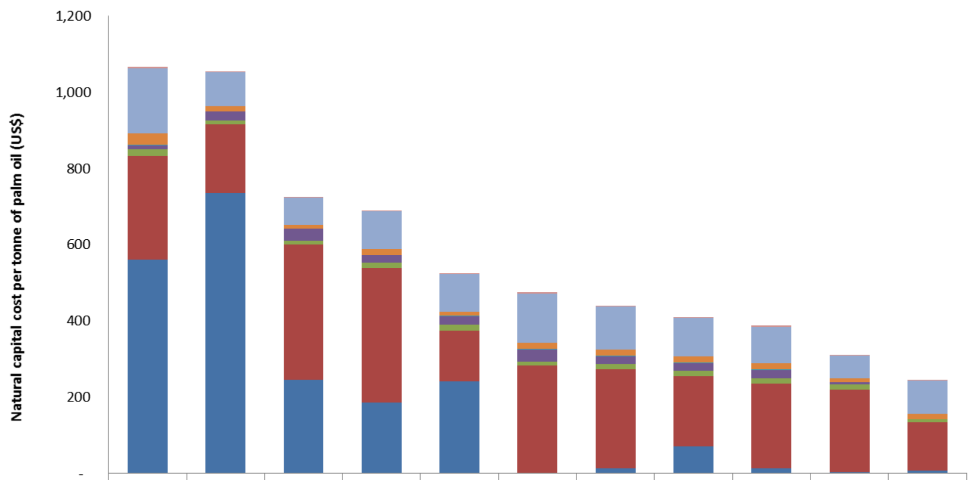
The country-specific environmental costs associated with one tonne of palm oil and palm kernel oil production are related to the quantification variables discussed before (yield and extraction rates, quantity and quality of resource use and associated emissions), as well as the monetary value per quantity of emissions, which is dependent on local environmental and socio-economic conditions.

FIGURE 3.4: NATURAL CAPITAL COST OF PALM OIL PRODUCTION PER COUNTRY AND PRACTICE



	Indonesia	Malaysia	Nigeria	Thailand	Papua New Guinea	Colombia	Honduras	Brazil	Guatemala	Côte d'Ivoire	China
Other raw materials, milling and refining	0.06	0.05	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissions from POME	2.08	1.87	0.16	0.21	0.04	0.09	0.04	0.03	0.02	0.03	0.01
Other raw materials, planting phase	0.29	0.19	0.03	0.03	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Pesticide manufacturing	0.02	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pesticide application	0.54	0.42	0.01	0.05	0.02	0.02	0.01	0.01	0.00	0.00	0.00
Fertiliser manufacturing	0.21	0.28	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00
Fertiliser application	4.19	2.52	0.25	0.46	0.20	0.21	0.13	0.06	0.05	0.05	0.05
Land use change	16.98	4.56	0.52	0.00	0.14	0.01	0.07	0.00	0.02	0.00	0.00

FIGURE 3.5: AVERAGE NATURAL CAPITAL COST OF PRACTICES PER COUNTRY FOR ONE TONNE OF PALM OIL



	Nigeria	Indonesia	Papua New Guinea	Honduras	Malaysia	Thailand	Colombia	Guatemala	Brazil	China	Côte d'Ivoire
Other raw materials, milling and refining	4	3	2	2	3	3	3	3	2	2	2
Emissions from POME	170	90	71	99	99	129	113	100	95	58	87
Other raw materials, planting phase	30	13	10	15	10	16	16	17	17	10	13
Pesticide manufacturing	2	1	1	1	2	1	1	1	2	1	1
Pesticide application	9	24	31	19	22	31	20	20	22	6	0
Fertiliser manufacturing	18	9	9	14	15	11	13	13	14	13	7
Fertiliser application	273	181	355	353	133	281	261	186	222	215	126
Land use change	560	735	246	186	241	2	13	70	14	4	8

INDONESIA

Indonesia contributes most of the total cost of palm oil production among the 11 countries analyzed ($24.5 bn). This is driven both by its higher production quantity, and intensity (or cost per tonne). Land use change is the practice that contributes the most to total cost, mostly due to the high greenhouse gas emissions from peatland drainage, as Indonesia has a higher proportion than other countries of oil palm planted on peat soils (30%). The second reason is the change in carbon stock due to land conversion. 81% of plantations are established on forests, with a carbon stock of 195 tonnes of carbon per ha, one of the highest in the sample of countries analyzed.

A higher quantity of N fertilizer compared to the world average is also applied per ha per year (89 kg of N compared to 65 kg) and a similar quantity of P (24 versus 23 kg per ha per year). This results in higher quantities of pollutants released to air, in particular nitrous oxide from fertilizer application on peat soils, nitrates, and other air, land and water pollutants.

Yet, human health and freshwater ecosystems are less affected in Indonesia than in other countries; the natural capital cost of toxic pollutants is lower per tonne of substance, in particular nitrates and phosphates, due to higher average volume of freshwater leading to lower concentration of pollutants.

MALAYSIA

Malaysia is the second largest contributor to total natural capital cost of palm oil production. Yet, palm oil production is significantly less costly per tonne of oil than Indonesia. The cost of land conversion is lower than average and Indonesia's – 12% of plantations are established on peat soil and 30% on forested land.

The cost of fertilizer application is lower than average, mostly driven by a lower cost per tonne of pollutant, in particular nitrate to water. The lower cost per quantity of nitrate leaching to water can be explained by lower health and freshwater toxicity costs, due to higher volume of freshwater and higher dilution.

NIGERIA

Nigeria is the third contributor to total palm oil production cost. Producing palm oil in Nigeria has the highest cost per tonne, primarily due to lower productivity: both in terms of yield per ha and conversion rate. Health toxicity of fertilizer application, in particular of nitrate emissions to water, is one of the most material impacts. This result is driven by the relative unavailability of water, as 48% of the population does not have access to drinking water in this country.

COTE D'IVOIRE

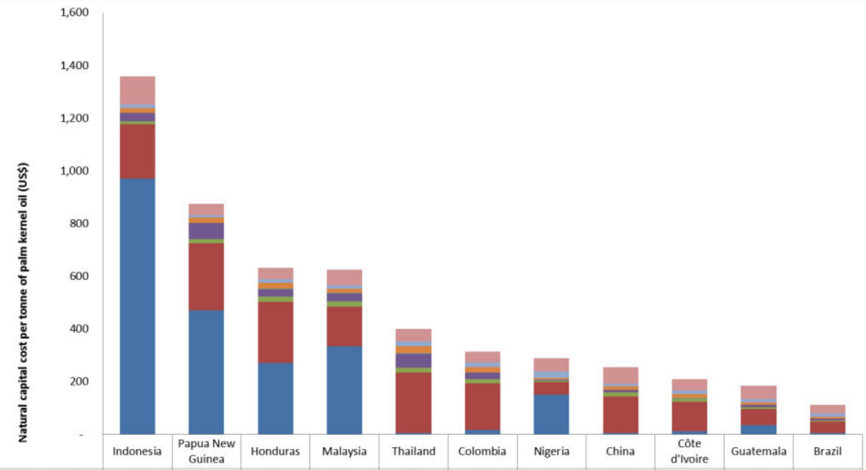
Cote d'Ivoire has the lowest cost per tonne, even if its yield is the second lowest of the peer group. One explanation is the lower natural and social capital costs from fertilizer application. The cost per kg of nitrate emitted to water is lower in Cote d'Ivoire, due to the larger average size of its water bodies, leading to higher dispersion of nitrate emissions and lower concentration overall, combined with lower population density and population with no access to safe drinking water compared to other countries in the peer group.

Cote d'Ivoire also has lower cost than average per tonne due to land use change and pesticide application. In Nigeria, a small proportion of pristine ecosystems with high-carbon stock are converted to palm oil. Most new plantations (24%) are established on land already used as arable and crop land, leading to a positive change in carbon stocks. In addition, less than 1% of plantations are established on peatland, leading to lower than average peat soil emissions due to drainage. The application of pesticides also lead to a lower than average cost, due to the lower proportion of species lost and lower value of ecosystems on average.

NATURAL CAPITAL COST OF PALM KERNEL OIL PRODUCTION PER COUNTRY

The natural capital cost of producing one tonne of palm kernel oil is driven by the same variables as described previously in this section. On top of the quantity of inputs and associated outputs, as well as average natural capital cost per unit of output, yield and conversion rates play an important explanatory role in the overall results. Producing one tonne of palm kernel oil in Indonesia yields the highest natural and social capital cost intensity, as displayed on Figure 3.6.

FIGURE 3.6: AVERAGE COST OF PRACTICES PER COUNTRY FOR ONE TONNE OF PALM KERNEL OIL



	Indonesia	Papua New Guinea	Honduras	Malaysia	Thailand	Colombia	Nigeria	China	Côte d'Ivoire	Guatemala	Brazil
Other raw materials, milling and refining	107	41	43	59	48	41	49	64	42	49	31
Emissions from POME	13.2	10.4	14.6	14.6	19.0	16.7	25.0	8.6	12.8	14.8	14.0
Other raw materials, planting phase	16.6	19.0	21.8	14.1	27.4	20.5	8.0	13.0	17.6	8.2	5.6
Pesticide manufacturing	1.2	1.6	1.7	2.4	2.3	1.5	0.6	1.4	1.3	0.7	0.7
Pesticide application	31.1	60.4	28.2	31.0	52.3	24.9	2.4	7.8	0.6	9.8	7.4
Fertiliser manufacturing	11.9	17.2	20.7	20.3	18.0	15.7	4.7	16.7	10.1	6.5	4.8
Fertiliser application	207	252	230	150	230	176	48	138	113	61	43
Land use change	969	471	271	333	4	16	150	5	11	34	5

The next section provides a case study on Indonesia, the country that contributes the most to natural capital cost of palm oil production. It examines the growing and milling practices identified in this section as having the highest impact in light of possible interventions: land use change and the associated carbon emissions contributing 89% to the cost of one tonne of palm oil; fertilizer application contributes 22% (with 67% from greenhouse gases, 25% from toxic substances to freshwater environment, and 8% from toxic substances to human health) and the management of palm oil mill effluent emissions (POME) which is the third most costly practice in terms of environmental cost, contributing 12% of total costs, due to methane emissions contributing to climate change.

INDONESIA CASE STUDY

Palm oil production in Indonesia was identified in the materiality analysis as the highest contributor to the total sector impact, at $25 bn. This is due to the large proportion of palm oil produced in Indonesia, as well as the high intensity per tonne of palm oil produced, at over $1,000 per tonne of finished product.

Land use change, fertilizer application, and management of palm oil mill effluents (POME) ponds were identified as the most significant practices in terms of natural capital cost. In addition, wages, as well as occupational health and safety practices were analyzed. This section focuses on these five practices. In particular, this section:

- Provides a description of the current issue and prevalent practices, as well as possible interventions to alleviate the impact,
- Compares the natural/human capital cost of each intervention with the business-as-usual baseline,
- Discusses the financial implications of changing practices for the business,
- Provides an overview of the other barriers to overcome in order to make the more sustainable practice business-as-usual.

This section is not intended to provide a definite answer on how different production practices compare, but rather at showing how this type of framework can be used to evaluate possible interventions. The scope of this analysis is limited to specific resource use and emissions, and key performance indicators, and does not take into account all material positive and negative costs and benefits, due to data and time constraints.

LAND CONVERSION

PREVALENT PRACTICE AND ISSUE

The rapid growth in demand for palm oil has led to an expansion in the amount of land used to produce it. As oil palm usually grows under humid tropical climate, much of this expansion has historically come about at the expense of carbon-rich tropical forests and underlying peatlands, with consequences for the communities and species that rely on them, as well as the planet’s climate. Fire-clearing practices constitute an additional compounding factor in terms of social and natural capital impact.

In Indonesia, around 70% (4.2 million ha) of oil palm are planted on land that was previously part of the Forest Estate (IFC & World Bank, 2011). Forest destruction accounts for approximately 34% of worldwide GHG emissions related to land use, land use change and forestry; and 94% of the country’s total GHG emissions, making it the third largest emitter after the United States and China (Fairhurst & McLaughlin, 2009). The clearing of primary forests also has a significant impact on biodiversity, as only about 15% of animal species can survive in plantations (May-Tobin, et al., 2012). In addition, tropical forests provide goods and services which are partially or totally lost when replaced by oil palm plantations. These include but are not limited to water and forest products provisioning, nutrient cycling and tourism services.

PRIMARY AND SECONDARY FORESTS

Around half of the world's tropical forests, after experiencing disturbance from selective logging or other activities, naturally regenerate and can be classified as secondary or regenerating forests (International Tropical Timber Organisation (ITTO, 2002) . Within about 80 years, secondary forests can approach similar levels of stored carbon as primary forests (Page, et al., 2002). Voluntary organizations such as the RSPO currently restrict the clearing of primary forests for palm oil, but still allow oil palm's expansion into secondary forests.

Another challenge is related to the establishment of plantations on carbon-rich peatlands. Peatlands build up slowly over extended periods of time when leaves and woody materials do not fully decompose under the waterlogged conditions, and store as much as 18 to 28 times carbon than trees in the overlaying forest (Page, et al., 2011a). Peatlands also play a vital role in water regulation. Peat soil absorbs rainwater and slowly releases it during drier periods, providing both flood prevention and freshwater for the local community.

Fire-clearing practices have been a major source of air pollution, or haze in Southeast Asia, posing lasting health problems, reducing productivity of oil palm trees by hindering photosynthesis, reducing the activity of pollinating weevils, and affecting the health and vision of the plantation workers, thereby restricting their ability to harvest the fruit (WWF, 2008). The Association of Southeast Asian Nations (ASEAN) countries signed the ASEAN Agreement on Transboundary Haze Pollution in 2002 and have adopted a regional policy to implement zero burning. Yet, fire-clearing continues, mainly among smallholders and farmers who typically lack access to heavy machinery (ASEAN, 2003). An overview of fire clearing practices in Indonesia is provided in the introductory section.

POSSIBLE INTERVENTION

From a land use perspective, production can be increased through means of yield intensification and area expansion, under certain conditions (such as optimized chemical inputs), and assuming optimized milling efficiency further downstream has already been achieved. Closing the gap between potential and current yields (yield intensification), and establishing plantations on adequate land from an environmental, social and financial perspective can improve the sustainability of oil palm production (area expansion). In addition, avoiding the use of fire for land clearing maintains existing soil fertility and soil structure, ensures nutrient recycling through decomposed materials, and prevents surface/soil erosion.

CRITERIA TO IDENTIFY SUITABLE LAND FOR EXPANSION

Three broad land classifications are discussed in the literature in order to determine the most suitable land for the establishment of new oil palm plantations. These are based on conservation value, carbon stocks and levels of degradation.

HIGH CONVERSATION VALUE LAND

Land with high conservation value (HCV) can be classified in six categories depending on the biological, ecological, social or cultural services rendered at the national, regional and global level. The categories span from land with high concentration of biological diversity including endemic species, and rare, threatened or endangered species (HCV1), to land with global or national cultural, archaeological or historical significance, and/or of critical cultural, ecological, economic or religious/sacred importance for traditional cultures of local communities or indigenous peoples (HCV6) (HCV Resource Network, 2005-2015).

HIGH-CARBON STOCK LAND

According to the RSPO (2014), there is no standard definition for "high-carbon stocks" area, or methodology to identify them. A study conducted by Golden Agri Resources in collaboration with the Forest Trust and Greenpeace suggests that any land with carbon stocks higher than 35 tonnes of carbon per ha can be classified as high-carbon stocks. High-carbon stocks area may not necessarily be high conservation value areas and vice versa (Suksuwan, 2014).

DEGRADED LAND

Finally, the concept of degraded land has been put forward to identify areas suitable for oil palm expansion. Many definitions exist and the term is used in multiple contexts, creating further confusion (Gingold, et al., 2012). The World Resources Institute suggests a set of eight considerations to identify such areas: 1) carbon and biodiversity, 2) soil and water protection, 3) crop productivity, 4) financial viability, 5) zoning, 6) rights, 7) land use, and 8) local interests. This approach may be seen as a bridge between the high-carbon stock and high-conversation value land approaches and has been gaining momentum in recent years (Gingold, et al., 2012).

NATURAL CAPITAL QUANTIFICATION

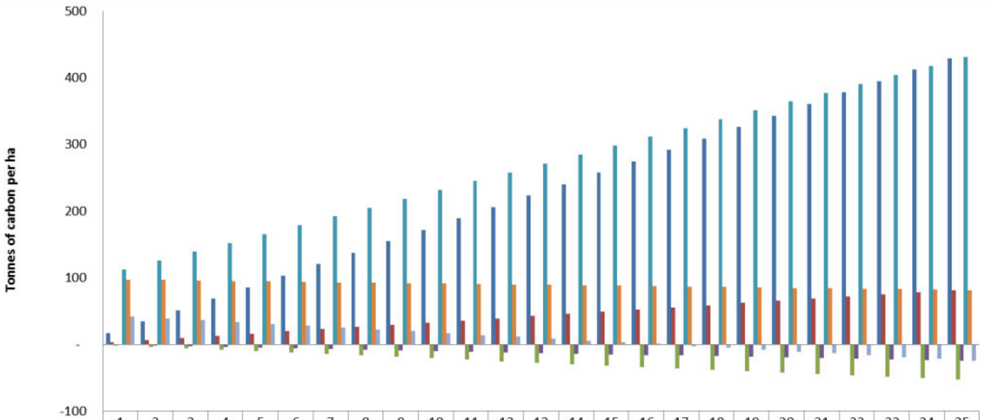
Seven land conversion scenarios were evaluated, drawing from three types of land use (primary and disturbed forest, and grassland), two soil types (peat and mineral), and two methods of land clearing (mechanical and through fire) (Table 4.1). These scenarios do not relate directly with the different land classification discussed above for lack of adequate data but can form the basis of further analysis and provide a useful roadmap for improvement.

TABLE 4.1: LAND CONVERSION SCENARIOS

1	Primary forest	Peat soil	Mechanical clearing
2	Primary forest	Mineral soil	Mechanical clearing
3	Grassland	Mineral soil	Mechanical clearing
4	Disturbed forest	Mineral soil	Mechanical clearing
5	Primary forest	Peat soil	Use of fire
6	Primary forest	Mineral soil	Use of fire
7	Disturbed forest	Mineral soil	Use of fire

This analysis only takes into account changes in carbon stocks and health impacts of air pollution due to land conversion practices. Other ecosystem services rendered by natural ecosystems, and lost through land conversion, as well as other impacts of air pollution, have been excluded from the scope of this study. Figure 4.1 displays the cumulative carbon emission per hectare for each clearing practice and type of land converted.

FIGURE 4.1 CUMULATIVE CARBON EMISSION PER HA PER CLEARING PRACTICE AND TYPE OF LAND CONVERTED



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Decomposition Primary forest on peat soil	17	34	51	69	86	103	120	137	154	172	189	206	223	240	257	275	292	309	326	343	360	378	395	412	429
Decomposition Primary forest on mineral soil	3	7	10	13	16	20	23	26	29	33	36	39	42	46	49	52	55	59	62	65	69	72	75	78	82
Decomposition Grassland on mineral soil	-2	-4	-6	-8	-11	-13	-15	-17	-19	-21	-23	-25	-27	-29	-32	-34	-36	-38	-40	-42	-44	-46	-48	-50	-53
Decomposition Disturbed forest on mineral soil	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25
Burning Primary forest on peat soil	112	126	139	152	165	179	192	205	218	232	245	258	271	285	298	311	324	338	351	364	377	391	404	417	431
Burning Primary forest on mineral soil	97	96	96	95	94	94	93	92	92	91	91	90	89	89	88	87	87	86	85	85	84	84	83	82	82
Burning Disturbed forest on mineral soil	42	39	36	33	31	28	25	22	20	17	14	11	8	6	3	0	-3	-5	-8	-11	-14	-16	-19	-22	-25

RESULTS OVERVIEW

Over 25 years, converting primary forest on peat soil emits the most carbon per ha, or 429 per ha. When burnt, an additional 2 tonnes is emitted due to peat soil burning. Converting primary forest on mineral soil leads to overall emissions of 82 tonnes per ha.

The most positive outcome is when disturbed forest and grassland are mechanically converted on mineral soil. This leads to a positive change in carbon stocks indicating that oil palm plantation sequesters more carbon than the net loss due to land use change. This is however highly contingent on assumptions made around carbon stocks of different ecosystems, especially in the case of degraded forest where, as seen in Section 2 the exact definition is not clear.

Table 4.2 displays the quantity of air pollutant released per type of ecosystem being cleared using fire.

TABLE 4.2 QUANTITY OF AIR POLLUTANT RELEASED DUE TO THE BURNING OF BIOMASS AND PEATSOILS

	PRIMARY FOREST ON PEAT SOIL	PRIMARY FOREST ON MINERAL SOIL	DISTURBED FOREST ON MINERAL SOIL
Carbon Monoxide (CO)	18.66	18.15	8.26
Acetylene (C2H2)	0.09	0.09	0.04
Ethylene (C2H4)	0.21	0.21	0.09
Propylene (C3H6)	0.13	0.12	0.06
Isoprene (C5H8)	0.03	0.03	0.01
Benzene (C6H6)	0.08	0.08	0.03
Toluene (C6H5CH3)	0.05	0.05	0.02
Methanol (CH3OH)	0.49	0.47	0.22

Phenol (C6H5OH)	0.10	0.09	0.04
Formaldehyde (HCHO)	0.34	0.34	0.15
Glycol aldehyde (C2H4O2)	0.56	0.55	0.25
Acetaldehyde (CH3CHO)	0.31	0.30	0.14
Acetone (C3H6O)	0.13	0.12	0.06
3-Pentanone (C5H10O)	0.01	0.01	0.00
Furan (C4H4O)	0.08	0.08	0.04
Acetol (C3H6O2)	0.23	0.22	0.10
Acetonitrile (CH3CN)	0.09	0.08	0.04
Formic Acid (HCOOH)	0.16	0.15	0.07
Acetic Acid (CH3COOH)	0.62	0.60	0.27
Hydrogen Cyanide (HCN)	0.10	0.08	0.04
Ammonia (NH3)	0.31	0.26	0.12
Nitrogen Oxides (NOx as NO)	0.50	0.50	0.23
PM2.5	1.78	1.78	0.81
PM10	3.61	3.61	1.64

RESULTS OVERVIEW

On average, burning a hectare of primary forest on peat soil releases 29 grams of pollutants to air; a hectare of primary forest on mineral soil releases 28 grams; and a hectare of disturbed forest on mineral soil releases 13 grams. Carbon monoxide contributes approximately 65% of this figure, followed by PM10 (13%) and PM 2.5 (6%).

NATURAL CAPITAL VALUATION

As with the Materiality Analysis, a carbon dioxide cost of $126 per tonne was used. Indonesia-specific valuation coefficients were also derived to calculate the social capital cost of air pollution due to haze. Coefficients were derived for toluene, methanol, phenol, acetaldehyde, acetonitrile, ammonia, nitrogen oxides, and particulate matter due to data availability. Table 4.3 displays the coefficients used in this study.

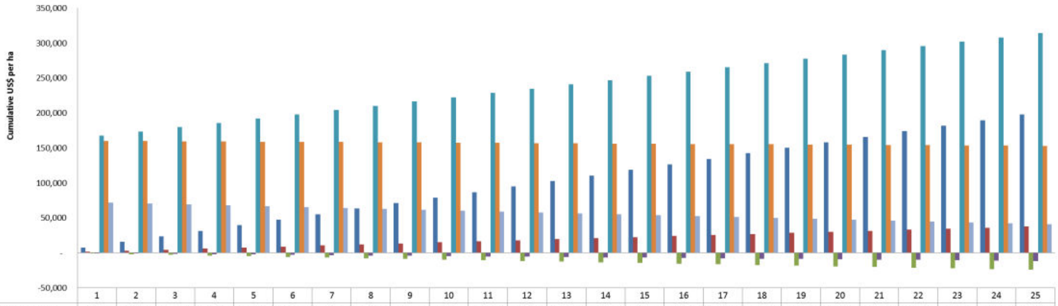
TABLE 4.3 NATURAL CAPITAL COST OF AIR POLLUTANTS EMITTING THROUGH BIOMASS BURNING

EMISSION	US$ PER KG	US$ PER HA OF PRIMARY FOREST ON PEAT SOIL BURNT	US$ PER HA OF PRIMARY FOREST ON MINERAL SOIL BURNT	US$ PER HA OF DEGRADED FOREST ON MINERAL SOIL BURNT
Toluene (C6H5CH3)	<1	<1	<1	<1
Methanol (CH3OH)	<1	31	30	14
Phenol (C6H5OH)	1	119	109	49
Acetaldehyde (CH3CHO)	<1	108	105	48
Acetonitrile (CH3CN)	<1	1	1	1
Ammonia (NH3)	3	1,009	851	387
Nitrogen Oxides (NOx as NO)	2	1,140	1,134	516

Particulate Matter (PM 10)	10	37,540	37,541	17,084
Particulate Matter (PM 2.5)	43	76,054	76,054	34,611

Figure 4.2 displays the cumulative natural capital cost of each land conversion scenario.

FIGURE 4.2 CUMULATIVE SOCIAL AND NATURAL CAPITAL COST PER HA



	1	2	3	4	5	6	7	8	9	10	11	12	13
Decomposition Primary forest on peat soil	7,914	15,829	23,743	31,658	39,572	47,486	55,401	63,315	71,229	79,144	87,058	94,973	102,887
Decomposition Primary forest on mineral soil	1,505	3,010	4,516	6,021	7,526	9,031	10,536	12,042	13,547	15,052	16,557	18,062	19,568
Decomposition Grassland on mineral soil	-968	-1,937	-2,905	-3,874	-4,842	-5,811	-6,779	-7,747	-8,716	-9,684	-10,653	-11,621	-12,589
Decomposition Disturbed forest on mineral soil	-457	-914	-1,371	-1,827	-2,284	-2,741	-3,198	-3,655	-4,112	-4,568	-5,025	-5,482	-5,939
Primary forest on peat soil	167,545	173,659	179,773	185,887	192,002	198,116	204,230	210,344	216,458	222,572	228,686	234,800	240,914
Primary forest on mineral soil	160,294	159,999	159,704	159,409	159,114	158,819	158,524	158,229	157,933	157,638	157,343	157,048	156,753
Disturbed forest on mineral soil	71,806	70,530	69,254	67,978	66,702	65,426	64,149	62,873	61,597	60,321	59,045	57,769	56,492

	14	15	16	17	18	19	20	21	22	23	24	25
Decomposition Primary forest on peat soil	110,801	118,716	126,630	134,545	142,459	150,373	158,288	166,202	174,116	182,031	189,945	197,860
Decomposition Primary forest on mineral soil	21,073	22,578	24,083	25,588	27,094	28,599	30,104	31,609	33,114	34,620	36,125	37,630
Decomposition Grassland on mineral soil	-13,558	-14,526	-15,495	-16,463	-17,432	-18,400	-19,368	-20,337	-21,305	-22,274	-23,242	-24,211
Decomposition Disturbed forest on mineral soil	-6,396	-6,853	-7,310	-7,766	-8,223	-8,680	-9,137	-9,594	-10,051	-10,508	-10,964	-11,421
Primary forest on peat soil	247,028	253,142	259,256	265,370	271,484	277,598	283,712	289,826	295,940	302,054	308,168	314,282
Primary forest on mineral soil	156,458	156,163	155,867	155,572	155,277	154,982	154,687	154,392	154,097	153,801	153,506	153,211
Disturbed forest on mineral soil	55,216	53,940	52,664	51,388	50,112	48,835	47,559	46,283	45,007	43,731	42,455	41,178

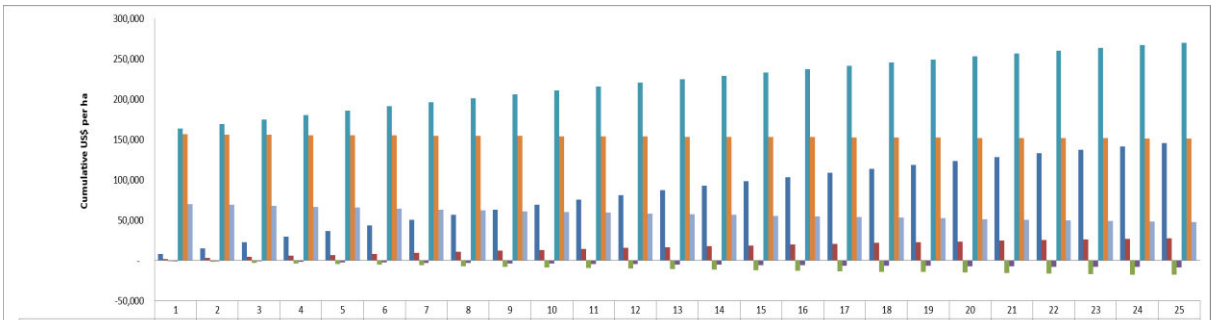
RESULTS OVERVIEW

Converting primary forest on peat soil using burning techniques has the highest cumulated natural capital cost over the 25 year plantation lifecycle, at $314,280 per hectare. Applying a flat palm oil yield rate of 4.01 tonnes palm oil/ha (FaoStat, 2013), this is equivalent to $78,350 per tonne palm oil (or $3,130 per year). 37% of this is related to health costs from the emission of air pollutants, or haze. Converting primary forest on peat soil using mechanical clearing yields the second highest cumulated natural and social capital cost, or $197,850 per ha ($49,320 per tonne palm oil), followed by burning primary forest on mineral soil ($153,200 per ha, or $38,190 per tonne palm oil, where 75% of the impact is from haze).

When disturbed forest on mineral soil is being burned, the health costs related to haze offset the benefit of carbon sequestration ($53,000 vs $11,000 per ha, or $13,200 vs $2,700 per tonne palm oil). Finally, converting grassland and disturbed forest through mechanical clearing yields a benefit related to changes in carbon stocks, at $24,210 and $11,420 respectively. In per tonne of palm oil terms, this is equivalent to $6,030 and $2,850 respectively).

The results were recalculated using a social discount rate of 2.5% to take into account the timescale of emissions over 25 years. The order of preference between scenarios does not change. The total discounted natural capital cost per ha of converting primary forest on peat soil using burning techniques is $270,000 per ha; of converting primary forest on peat soil using mechanical clearing techniques $146,000; converting primary forest on mineral soil using burning techniques $151,000; converting disturbed forest on mineral soil using burning techniques $48,000; and converting primary forest on mineral soil using mechanical clearing $28,000. Converting grassland and disturbed forest on mineral soil using mechanical clearing techniques yields a net benefit of $18,000 and $9,000 per ha respectively.

FIGURE 4.3 CUMULATIVE NATURAL CAPITAL COST PER HA (DISCOUNTED AT 2.5%)



	1	2	3	4	5	6	7	8	9	10	11	12
Primary forest on peat soil	7,721	15,254	22,604	29,774	36,769	43,593	50,252	56,747	63,085	69,267	75,299	81,184
Primary forest on mineral soil	1,468	2,901	4,299	5,663	6,993	8,291	9,557	10,793	11,998	13,174	14,321	15,440
Grassland on mineral soil	-945	-1,867	-2,766	-3,643	-4,499	-5,334	-6,149	-6,944	-7,719	-8,476	-9,214	-9,934
Disturbed forest on mineral soil	-446	-881	-1,305	-1,719	-2,122	-2,516	-2,901	-3,276	-3,641	-3,998	-4,347	-4,686
Primary forest on peat soil	163,459	169,278	174,956	180,495	185,899	191,171	196,314	201,332	206,228	211,004	215,664	220,210
Primary forest on mineral soil	156,385	156,104	155,830	155,563	155,302	155,047	154,799	154,557	154,320	154,090	153,865	153,645
Disturbed forest on mineral soil	70,055	68,840	67,655	66,499	65,371	64,271	63,197	62,150	61,128	60,131	59,158	58,209

	13	14	15	16	17	18	19	20	21	22	23	24	25
Primary forest on peat soil	86,925	92,526	97,991	103,322	108,524	113,598	118,549	123,379	128,091	132,688	137,173	141,549	145,818
Primary forest on mineral soil	16,532	17,597	18,636	19,650	20,640	21,605	22,546	23,465	24,361	25,235	26,088	26,921	27,732
Grassland on mineral soil	-10,636	-11,322	-11,990	-12,643	-13,279	-13,900	-14,506	-15,097	-15,673	-16,236	-16,785	-17,320	-17,843
Disturbed forest on mineral soil	-5,018	-5,341	-5,656	-5,964	-6,264	-6,557	-6,843	-7,122	-7,394	-7,659	-7,918	-8,171	-8,417
Primary forest on peat soil	224,646	228,973	233,194	237,313	241,331	245,251	249,076	252,807	256,447	259,998	263,463	266,844	270,141
Primary forest on mineral soil	153,431	153,222	153,019	152,820	152,626	152,437	152,252	152,072	151,896	151,725	151,557	151,394	151,235
Disturbed forest on mineral soil	57,284	56,381	55,499	54,640	53,801	52,983	52,185	51,406	50,646	49,905	49,181	48,476	47,788

Other ecosystem services rendered by natural ecosystems, and lost through land conversion, as well as other impacts of air pollution, are excluded from the scope of this study, but estimates of other potential natural capital costs associated with land conversion are reviewed next.

LAND CONVERSION, PRIMARY TROPICAL FOREST

Primary tropical forests have been shown to provide many ecosystem services. Academics in the US and the Netherlands have calculated the total economic value of Leuser National Park in Sumatra, Indonesia – one of the two remaining habitats for Sumatran orangutans – which is under threat of deforestation for the cultivation of palm oil and rubber. Table 4.4 displays the results of this analysis.

TABLE4.4: COMPARISON OF THE ECOSYSTEM SERVICES PROVIDED BY LEUSER NATIONAL PARK IF CONSERVED AND DEFORESTED FOR CULTIVATION (BASED ON VAN BEUKERING, ET AL., 2003)

	CONSERVATION ($ VALUE PER HA PER YEAR)	DEFORESTATION FOR CULTIVATION ($ VALUE PER HA PER YEAR)
Water supply	32	9
Fisheries	9	7
Flood and drought prevention	21	16
Agriculture	22	33
Hydropower	12	3
Tourism	11	2
Biodiversity	7	1
Carbon sequestration	3	1
Fire prevention	10	0
Non-timber forest products	1	3
Timber	0	16
Total	**128**	**91**

They calculated the value of the forest to local community members, the local government, the logging and plantation industry, the national government, and the international community over a 30-year period if it were protected, and the value if it were destroyed for logging and subsequent cultivation. The main contributors in the conservation and selective use scenarios are water supply, flood prevention, tourism and agriculture. Timber revenues play an important role in the deforestation scenario. Compared to deforestation, conservation of the Leuser Ecosystem benefits all categories of stakeholders, except for the logging and plantation industry.

LAND CONVERSION, TROPICAL PEAT SWAMP FORESTS

In addition to carbon storage, peatland renders a variety of services to society, including direct provisioning services. A study from Wetland International found the value of products provided by peat forests for local population in Central Kalimantan to be $950 per ha per year, with fish contributing 70%, construction and fire wood 23% and other products 7$ (Silvius, 2009) .

USE OF FIRE

A study by the Institute of Southeast Asian Studies has evaluated the total cost of the 1997 fires when an average of 5 million ha burned in Sumatra and Kalimantan, including 20% of forest, 50% of agricultural land, and 30% of non-forest vegetation and grassland, at $4.47 bn. Economic estimates of fire has a cost on health, tourism, timber losses, agriculture losses, forest and biodiversity, carbon releases and fire-fighting expenses were assessed for Singapore, Malaysia and Indonesia. Table 4.5 displays the results.

TABLE 4.5: ECONOMIC COSTS OF THE 1997 FIRES IN INDONESIA (GLOVER & JESSUP, 1999)

	LOSS TO INDONESIA (US$ MILLION)	LOSS TO OTHER COUNTRIES (US$ MILLION)	TOTAL (US$ MILLION)	PERCENTAGE
FIRE-RELATED DAMAGES				
Timber	494	0	494	11%
Agriculture	470	0	470	10%
Direct forest benefits	705	0	705	16%
Indirect forest benefits	1,077	0	1,077	24%
Biodiversity	30	0	30	<1%
Fire-fighting costs	12	13	25	<1%
Carbon release	0	272	272	6%
HAZE-RELATED DAMAGES				
Short-term health	924	17	941	21%
Tourism	70	186	256	6%
Others	18	181	199	4%
Total	3800	670	4,470	100%

FINANCIAL CONSIDERATIONS

In order to assess the economic viability of possible interventions, the financial cost of each scenario was calculated (Table 4.6). Methodology and key assumptions are discussed in Appendix 2.

TABLE 4.6 FINANCIAL COSTS OF LAND CONVERSION (FAIRHURST & MCLAUGHLIN, 2009)

ESTABLISHMENT OF PLANTATION - YEAR 0 (2014 US$)	

CLEARING METHOD	LAND	LAND CLEARING ($/HA)
Mechanical	Grassland on mineral soil	170
Burning	Primary forest on mineral soil	543
Burning	Disturbed forest on mineral soil	543
Burning	Primary forest on peat soil	723
Mechanical	Primary forest on mineral soil	781
Mechanical	Disturbed forest on mineral soil	781
Mechanical	Primary forest on peat soil	1,039

Land clearing on peat soil involves the highest financial cost regardless of the clearing method. Plantation managers are typically locked into costly repeated drainage cycles when establishing plantation on peat soils, as the level of drained peat soils drops down to the level of water (May-Tobin & Goodman, 2014). Yields from oil palm planted on deep peat are also generally very poor and management is difficult due to the requirements for water management and plant nutrition (zinc and copper deficiencies).

When clearing primary or disturbed forest on mineral soil, clearing by fire appears to be less costly than clearing by mechanical means. This holds in the short run, due to the avoided labour and machinery costs during the clearing process, applicability to all types of terrain, destruction of pests and diseases, suppression of the growth of bushy weeds and quick release of nutrients.

However, analysis has shown than the long-term financial costs outweighs the short term benefits from fire-clearing, due to reduced soil fertility and increased erosion. Analysis by WWF and IUCN (2002) shows that in the long-term, the value of nutrient loss in land clearing with fire use was more than RM 2,000 per ha, mostly due to the cost of intensive fertilisation program required to compensate the loss of nutrient through burning.

RESULTS OVERVIEW

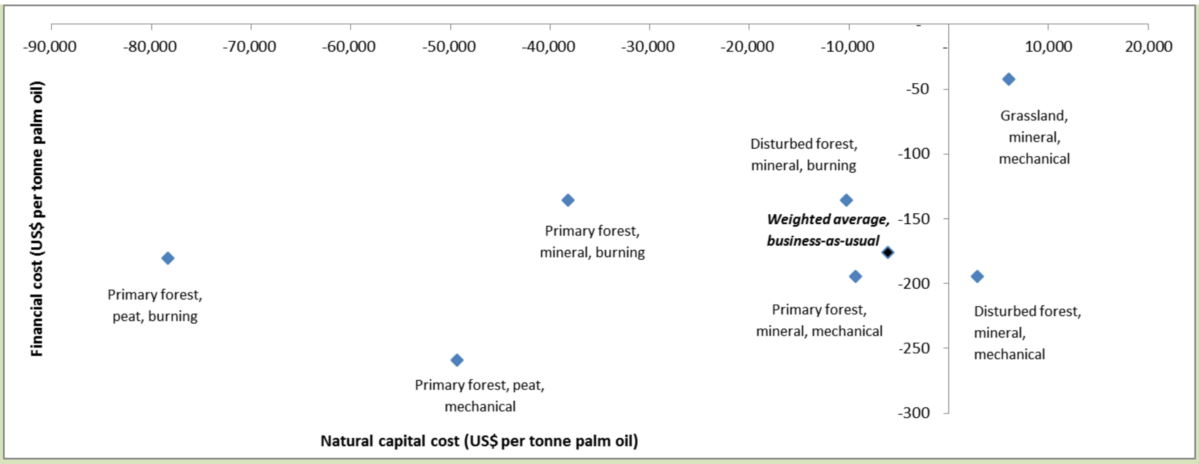
Overall, land clearing through mechanical means is the preferred option. Its main advantages include maintenance of soil fertility, maintenance of soil structure, nutrient recycling through decomposed materials and reduction in the long-term use of fertilizers, and prevention of surface/soil erosion. The use of zero burning method also results in higher fruit brunch yields in the first year (WWF & IUCN, 2002). The financial analysis also indicates that mechanical clearing of grassland is by far the cheapest option from an economic standpoint, at just $170/ha.

LONG TERM INTEGRATED SUSTAINABILITY

RESULTS OVERVIEW

Figure 4.4 illustrates the overall natural capital costs and financial costs of land clearing for each scenario. The black dot represents the business-as-usual scenario, derived from the materiality analysis. The results of this analysis are highly contingent on assumptions, but they also strive to provide an illustrative framework for businesses to integrate natural and social capital alongside financial considerations.

FIGURE 4.4: NATURAL AND FINANCIAL CAPITAL OF LAND CLEARING TECHNIQUES OVER LIFETIME OF PLANTATION



Burning primary forest on peat soil has the highest cumulated natural capital cost, due to the climate change impact of carbon and methane emissions, and health costs of air pollutants emitted through the burning of biomass. Growers also incur the largest financial cost when clearing forest on peat soils. Yet in the short run, clearing by fire appears to be less financially costly than clearing by mechanical means. This is an example of a trade-off situation, where natural capital and financial costs and benefits are not aligned between the private costs of growers and social costs to society. The intervention of other stakeholders, such as the state or the international community, may be required to regulate, finance or implement training programs to shift and realign incentive structures.

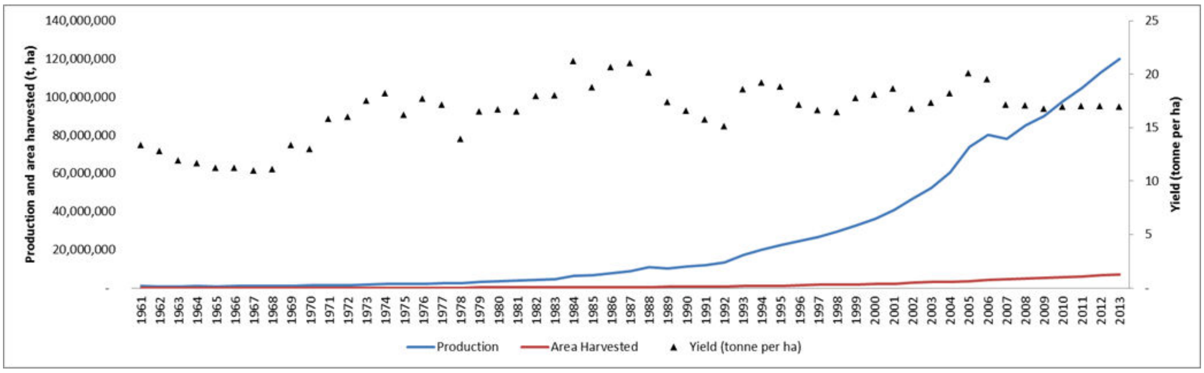
At the other end of the spectrum, converting grassland and disturbed forest using mechanical clearing yields a net benefit, as the newly established plantation sequesters more carbon than the previous ecosystem. This illustrates a win-win situation, where interests of growers and society are aligned. Yet, other barriers may exist to encourage a shift in practice. The next section explores some of the barriers related to land availability, knowledge and international financing.

BARRIERS AND OPPORTUNITIES

LAND AVAILABILITY

Historically, growth has been delivered through area expansion rather than yield intensification (illustrated in figure 4.5). Over the past forty years, the area of oil palm planted and in production in Indonesia has expanded almost exponentially from about 80,000 ha in 1965 to 7 million ha in 2013, whilst yields have stagnated at about 17 tonnes of fresh fruit bunches per ha (Fairhurst & McLaughlin, 2009) (FaoStat, 2013). In 2013, the maximum observed quantity of oil that can be extracted from fresh fruit bunches (extraction rates) is around 24%.

FIGURE 4.5: HISTORIC TRENDS IN PRODUCTION, AREA HARVESTED AND YIELD (BASED ON FAOSTAT, 2013)



The demand for vegetable oil is expected to double to around 240 million tonnes per year in 2050 globally (Fairhurst & McLaughlin, 2009). If the proportion of palm oil compared to other type of oils remains constant, this represents a doubling in production. Assuming that this takes place in Indonesia, holding yield and extraction rate constant, this represents an increase of 7 million ha of land planted.

The Government of Indonesia announced a production goal of 40 million tonnes of palm oil by 2020. At current yield and oil extraction rates, it means that the area harvested must be increased to around 10 million of ha planted, or 3 million ha more than in 2013. In May 2010, Indonesia's President announced a policy to develop plantations on degraded land. As discussed in Section 7.1.2, there is a broad consensus that further planting on peatland and forested land should be avoided and that future expansion should be directed towards the large amount of degraded forestland and grassland that can be converted into productive oil palm plantations. In addition, the social, natural and financial capital analysis has shown that it is the least costly option across the three dimensions.

According to a compilation of estimates by the World Resources Institute, there are around 14 million ha of degraded land in the Province of Kalimantan potentially suitable for development. This is potentially enough to support expected expansion by 2020 and 2050 but should be heavily caveated. In practice, land cover datasets may not be 100% accurate and land use often changes rapidly. Much of the land shown to be potentially suitable on the map is already developed as oil palm, timber, rubber or some other form of agriculture (calculated based on World Resources Institute, 2013).

The tool thus provides only indicative figures, which can be used as a useful first screen to help narrow down key areas for further investigation in the field. It was designed to help companies and governments implement better land use planning processes rather than quantifying the total amount of suitable degraded land available for palm oil expansion in Indonesia. Additional legal, economic and social criteria are not captured in the map but should still be considered when determining the suitability of land for development.

TABLE 4.7 POTENTIAL AND SUITABLE LAND AREA

REGION	TOTAL AREA (HA)	POTENTIAL (HA)	NOT SUITABLE (HA)
West Kalimantan	14,731,575	5,145,650	9,585,925
South Kalimantan	3,735,900	1,746,025	1,989,875

Central Kalimantan	15,445,825	3,211,000	12,234,825
East Kalimantan	19,663,275	4,170,600	15,492,675
Total (excluding Sumatra)	53,576,575	14,273,275	39,303,300

A key challenge is that no single definition of “degraded land” exists and no corresponding definition in Indonesian law or policy, creating confusion and debate as to which forests can be developed (Gingold, et al., 2012). The term has been used in different contexts to describe land with a wide variety of characteristics. Suitability criteria taken into account by the World Resources Institute include comprehensive indicators including conservation area buffer, elevation, land cover, peat depth, rainfall, soil acidity, soil depth, soil drain, soil type, and slope and water resource buffers (WRI, 2012). Even so, degraded land varies substantially from site to site and any shortlisted locations require field assessments to confirm or reject the potential suitability of a site, including alternative uses of land that may be more beneficial to local people (e.g. forest based livelihoods and NTFPs).

Another barrier is the often weak regulatory framework in place. Legislation exists in various countries banning the development of plantations in rainforests, such as the moratorium in Indonesia. Yet, there are flaws in the ban, leading institution such as the World Resources Institute to conclude that it will not affect Indonesia’s GHG emissions due to the “questionable status of secondary forests, exemption of existing concessions, and the limited enforcement of the moratorium boundaries” (Kemen, et al., 2012). In addition many bans and initiatives that would require plantations to be developed away from peat soils and forests are not going to be enforced for several more years, further slowing the whole process down.

Ultimately, the prevention of deforestation requires international cooperation. REDD+, for example, has potential to contribute to the protection of forest assets by providing financial incentives to avoid forest conversion. This can steer palm oil expansion to degraded/converted lands. The Indonesian government has announced that the development of oil palm on degraded land will be part of the national REDD+ strategy to be developed under a $1 bn partnership with Norway (IFC & World Bank, 2011).

FERTILIZER USE

PREVALENT PRACTICE AND ISSUE

Oil palm is unrivalled in its ability to convert solar energy into dry matter and vegetable oil, but this process requires a large amount of nutrients which must be supplied by soil or fertilizers. Mineral fertilizers are usually necessary to achieve and sustain good palm nutritional status and large yields (Tarmazi & Mohd Tayeb, Undated). The nutrient demand for oil palms can be met by inputs of biomass residuals (pruned fronds, EFB and POME) and decomposition from the atmosphere, but most frequently it is met by artificial fertilizers.

Fertilizers represent the biggest palm oil plantation variable cost and rising fertilizer costs is one of the most significant external economic challenges faced the palm oil industry today (Joshua, 2012). The indiscriminate use of chemical fertilizers and insecticides by some producers is responsible for the emission of significant quantities of GHGs and the pollution of surface and groundwater sources (WWF, 2008). This suggests an immediate need to optimize the use of mineral fertilizer but also crop residues in order to minimize costs and maximize yields. This is particularly important given that proper agronomic management has been shown to be the most important determinant to yield, more so than previous land use.

A study conducted by WWF (Fairhurst & McLaughlin, 2009) found that yields on soil with suitable clay structure were low in certain sites, due to poor management and application of fertilizers. On the other hand, yields on well managed sites were significantly higher for a range of soil structures. On very coarse soil, a steady application of soil residues is needed to rehabilitate soils for new planting. The same study found that sampled degraded land was deficient in phosphorus, potassium and magnesium, thus requiring larger quantity of fertilizer.

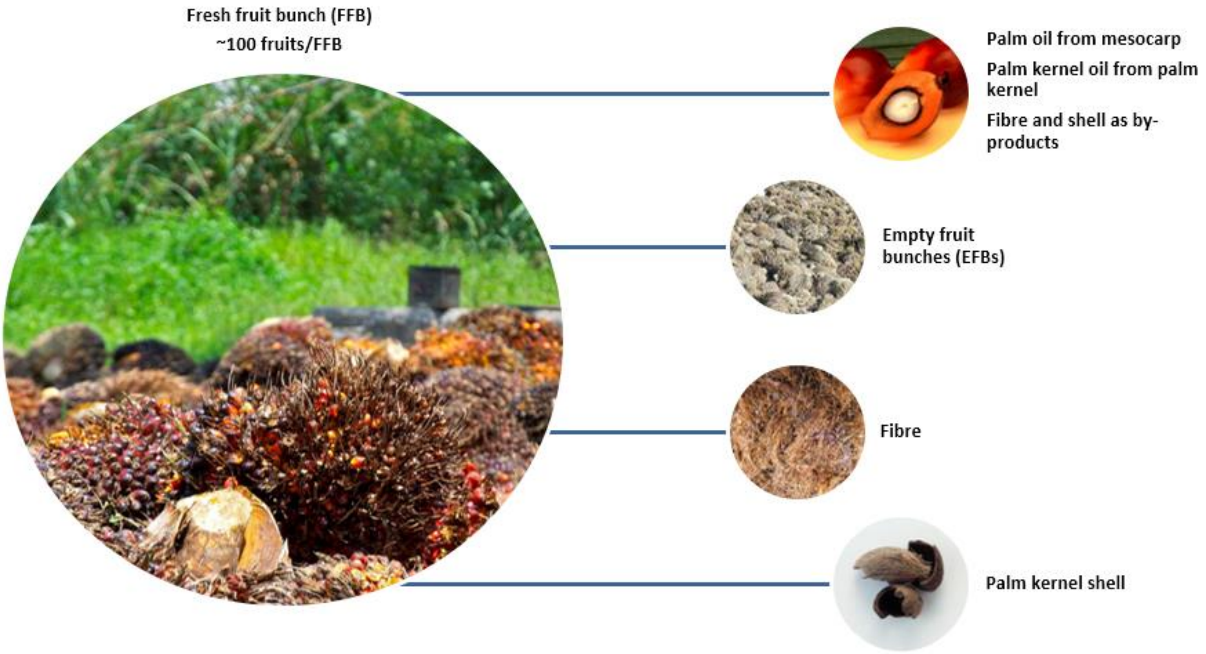
POSSIBLE INTERVENTION

According to Goh et al (1999), the main objectives of a fertilizer management system are:

- To supply each palm with adequate nutrients in balanced proportion to ensure healthy vegetative growth and optimum economic FFB yields;
- To apply fertilizers in the prescribed manner over the areas of the estate that are likely to result in the most efficient nutrient uptake;
- To integrate the use of mineral fertilizers and palm residues;
- To minimize negative environmental impacts related to over-fertilization, land degradation, and pollution from heavy metals such as cobalt and eutrophication by phosphorus application

Best practice systems maintain soil fertility at, or where possible improve soil fertility to, a level that ensures optimal and sustained yield. This is achieved through the recycling of organic materials and considered use of chemical fertilizers. Organic fertilizer is preferred to mineral fertilizer and this can, ideally be produced from the plantations waste products, POME, EFB, and pruned fronds.

FIGURE 4.6: ORGANIC MATERIALS AT OIL PALM PLANTATIONS



Biomass like pruned fronds, empty fruit bunches (EFB) and old palm stems are an excellent source of fertilizer, high in potassium, nitrate, magnesium, phosphate and other soil nutrients. Water used in processing palm fruits - palm oil mill effluent (POME) can be biologically treated and returned to the land for its fertilizer and moisture benefits. The soil filters the organic matter and nutrients, returning clean water to the ground. POME, combined with EFB, produces compost. Used in sufficient amounts, it replaces 66% of chemical fertilizers otherwise required (Big Lands Brazil, n.d.).

In addition, establishing legume crop cover is an important tool to restore and build fertility in degraded soils, as it fixes a large quantity of nitrogen and phosphorus and keeps the soil cool and moist, thus favoring biological activity, organic matter build up and moisture retention (Fairhurst & McLaughlin, 2009).

NATURAL CAPITAL QUANTIFICATION

Tackling the issue of excessive fertilizer application necessitates an understanding of the nutrient cycling process to avoid unnecessary nutrient application and the optimization of the split between chemical and organic fertilizers. When faced with a decision to increase fertilizer application to improve yields, growers must choose between supplementing the difference with chemical fertilizers, or a mix of chemical and organic fertilizers.

The analysis thus focuses on three main scenarios – the baseline scenario models a situation where a mixture of organic and chemical fertilizers are applied in excess on the field; scenario 1 where the exact need of the plant is met to maintain yields at current levels by a mixture of chemical and organic fertilizers; and scenario 2 where the exact need of the plant is meet by chemical fertilizer only. Table 4.8 details each scenario. The plantation is assumed to be established on mineral soil.

TABLE 4.8: FERTILIZER SCENARIOS

	INPUTS	OPTIMISATION
Baseline	EFB, POME, crop cover, use of pruned fronds, chemical fertilizers	No - Surplus of nutrients
1	EFB, POME, crop cover, use of pruned fronds, chemical fertilizers	Yes - Quantity of each input adjusted to provide the adequate quantity of nutrients
2	Chemical fertilizer only	Yes - Quantity adjusted to provide adequate quantity of nutrient

In the baseline scenario, 2,618 kg of N and 764 kg of P is applied over the 25 years, leading to an N-balance and P-balance of 1,887 kg of N and 545 kg of P respectively. Inputs of chemical fertilizer could thus be decreased without impacting overall yields.

In scenario 1, the use of chemical fertilizer is optimized alongside organic inputs such as FFB, POME and felled fronds. In this scenario, the N and P balance is decreased to 447 and 0 kg of N and P respectively. Related emissions of nitrates, ammonia, nitrogen oxide, nitrous oxide and phosphorus are thus lower in this scenario.

In scenario 2, only chemical fertilizers are used, but the quantity of chemical fertilizer applied is optimized to reduce residual emissions. The total quantity of fertilizer applied is 5,201 kg of N per ha and 619 kg of P per ha. Yet, the N and P balance, as well as associated emissions, are lower than the baseline scenario. The N and P balance is also lower than scenario 1.

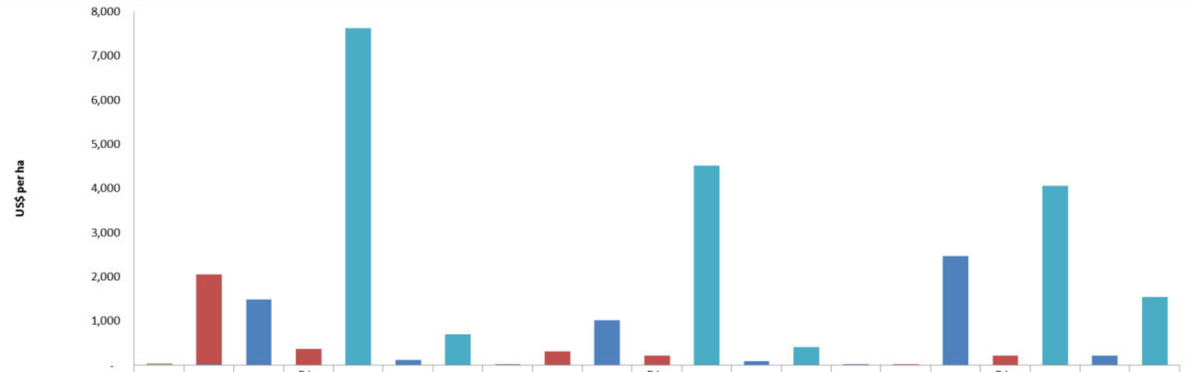
The distribution of emissions varies between scenario 1 and 2. Scenario 1 leads to higher emissions of nitrates to water, especially in the first years when the release of nitrogen by the legume cover is higher than the requirements of the plantation. Scenario 2 leads to higher emissions of ammonia, nitrogen oxide and nitrous oxide to air due to the application of chemical fertilizer.

In addition, the baseline scenario and scenario 2 yield higher emissions of heavy metals to land, due to the higher application of chemical fertilizer. 1.18 kg of heavy metals is emitted in scenario 1; 0.39 kg in scenario 2 and 0.47 kg in scenario 3. Finally, manufacturing the quantity of fertilizer applied in the baseline scenario emits 6 tonnes of greenhouse gases, compared to 3 tonnes in scenario 1 and 12 tonnes in scenario 2.

NATURAL CAPITAL VALUATION

The same coefficients as displayed in Section 3 are applied. Figure 4.6 displays the result for each scenario, broken down by output and type of impact.

FIGURE 4.7: NATURAL CAPITAL COST PER HA OF EACH SCENARIO OVER LIFETIME OF PLANTATION



	Heavy metals S1	Nitrate to water S1	Ammonia to air S1	P to water (rest in soil) S1	N20 to air S1	N0 to air S1	Fertilizer manufacturing S1
Other (GHGs)		-	-	-	7,618	-	694
Marine toxicity	1	-	-	-	-	-	-
Terrestrial toxicity	16	-	-	-	-	-	-
Freshwater toxicity	0	2,027	-	368	-	-	
Health toxicity	0	29	1,491	5	-	121	-

	Heavy metals S2	Nitrate to water S2	Ammonia to air S2	P to water (rest in soil) S2	N20 to air S2	N0 to air S2	Fertilizer manufacturing S2
Other (GHGs)	-	-	-	-	4,520	-	408
Marine toxicity	0	-	-	-	-	-	-
Terrestrial toxicity	6	-	-	-	-	-	-
Freshwater toxicity	0	304	-	216	-	-	-
Health toxicity	0	4	1,022	3	-	93	-

	Heavy metals S3	Nitrate to water S3	Ammonia to air S3	P to water (rest in soil) S3	N20 to air S3	N0 to air S3	Fertilizer manufacturing S3
Other (GHGs)	-	-	-	-	4,063	-	1,536
Marine toxicity	1	-	-	-	-	-	-
Terrestrial toxicity	10	-	-	-	-	-	-
Freshwater toxicity	0	24	-	216	-	-	-
Health toxicity	0	0	2,472	3	-	221	-

RESULTS OVERVIEW

The baseline scenario has the highest natural capital cost per ha over the lifecycle of the plantation, at $12,370 per ha. Applying a flat palm oil yield rate of 4.01 tonnes palm oil/ha (FaoStat, 2013), this is equivalent to $3,080 per tonne palm oil (or $123 per year)

- Nitrous oxide emissions yield the highest cost, 62% of the total, followed by freshwater and health toxicity costs of nitrates to water (19%).
- Supply chain costs of fertilizer manufacturing only contributes 6% of the total.
- 13% of costs are related to health toxicity, 19% to freshwater toxicity, and 67% to climate change.

The optimized scenario 1, where a mixture of organic and chemical fertilizers is applied, has the lowest natural capital cost, or $6,580 per ha. Applying a flat palm oil yield rate of 4.01 tonnes palm oil/ha (FaoStat, 2013), this is equivalent to $1,640per tonne palm oil (or $66 per year):

- Nitrous oxide contributes 69% of these costs, followed by ammonia (16%) and nitrates (5%).
- Supply chain costs of fertilizer manufacturing only contributes 6% of the total.
- 75% of total costs are related to climate change impacts, 17% to health toxicity and 8% to freshwater toxicity.

Finally, the optimized scenario 2, where only chemical fertilizers are applied, has a natural capital cost of $8,550 per ha. Applying a flat palm oil yield rate of 4.01 tonnes palm oil/ha (FaoStat, 2013), this is equivalent to $2,130 per tonne palm oil (or $85 per year):

- Nitrous oxide emissions contribute 48% of this figure, followed by ammonia to air (29%).

    - Supply chain costs of fertilizer manufacturing contribute a significantly higher proportion to total cost, or 18%.

- Climate change costs explain 66% of the total cost, human health toxicity 32% and freshwater toxicity only 3%.

When applying a social discount rate of 2.5%, total discounted cost per ha is:

- $9,300 for the baseline scenario;
- $4,800 for scenario 1 and
- $5,000 for scenario 2.

Scenario 1 and 2 have a similar natural capital cost when using discounting due to the time repartition of emissions. Higher nitrate emissions occur at the beginning of the lifecycle of the plantation in scenario 1, due to N emissions from the legume cover crop.

SOIL EROSION

Other factors influence the use of fertilizer and its associated costs, illustrated in this section by a short case study on soil erosion. Depending on the ability of farmers to replace nutrients lost through soil erosion, soil erosion may lead to a decrease in yield or increase in the financial cost of fertilizers, coupled to an increase in eutrophication impacts through the leaching of nitrates and phosphates. Increased sediments in freshwater may also have an impact on the financial cost of treating the water by wastewater treatment facilities. This demonstrates the need to apply holistic thinking to these issues.

The quantity of soil eroded per ha was calculated for different scenarios based on the Universal Soil Loss Equation. The rainfall erosivity index is the measure of the erosion force of rainfall and is calculated based on average precipitation in Indonesia (Cooper, 2011) (Trading Economics, 2011). The soil erodibility index measures the susceptibility of soil to erosion and the rate of runoff, and is based on the average soil type in Indonesia (FAO, Undated) (Harmonized World Soil Database, 2012). Both of these indexes are held constant in each scenario.

Depending on where the plantation is established, the length-slope index may vary, depending on the gradient and length of the slope. The World Resources Institute identifies any land with a slope lower than 8% as highly susceptible when rainfall is between 1,750 and 6,000 mm per year (Gingold, et al., 2012). A decree of the Minister of Forestry and Plantations Number 376/Kpts-II/1998 about Criteria of Provision of Forest Areas for oil palm plantations states that land with slopes between 0 and 25% is suitable (Darussamin, Undated).

The cover-management factor reflects the effect of cropping and management practices on erosion rates, while the practice factor reflects the impact of support practices. Depending on the size of the root and crown cover, as well as the presence of legume cover, the cover-management factor can range anywhere from 0.1 to 1, most likely between 0.1 and 0.3 (Kuok, et al., 2013). The practice factor ranges from 1 (no conservation practices) to 0.15 when terracing is used. The practice factor is 0.6 when contouring is used and 0.350 when contour strip-cropping is used. Table 4.11 displays each scenario and associated quantity of soil eroded per ha.

TABLE 4.9 QUANTITY OF SOIL ERODED

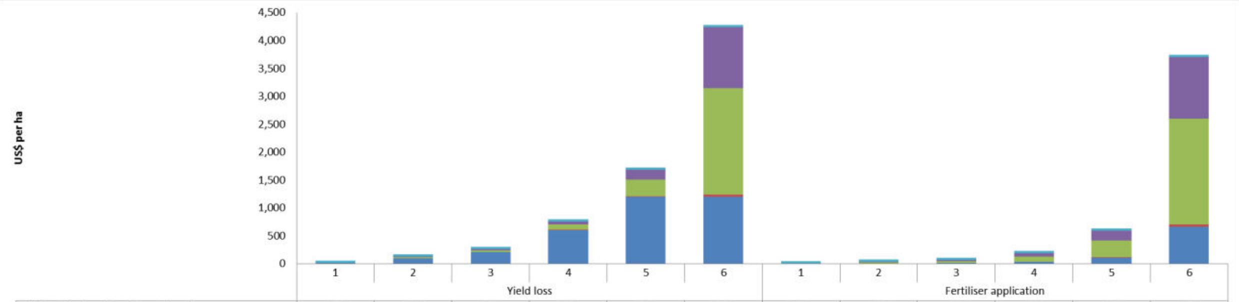
SCENARIO	1	2	3	4	5	6
Rainfall erosivity index	922	922	922	922	922	922
Soil erodibility factor	0.4	0.4	0.4	0.4	0.4	0.4
Slope (20m)	0.5%	8%	0.5%	25%	8%	25%
Length-slope factor	0.1	0.8	0.1	5	0.8	5
Cover management factor	0.1	0.1	0.3	0.1	0.3	0.3
Practice factor	0.15	0.15	1	0.15	1	1
Tonnes of soil eroded per ha	1	12	26	76	243	1,515

When the use of chemical and organic inputs is optimized, 239 kg N is applied to the field during an average year, through a combination of chemical and organic inputs. A reduction in 1 kg of N leads to a reduction in yield of 0.04 tons per ha. Based on the average concentration of N in topsoil, 1 tonne of erosion amounts to a loss of 1.5 kg of N.

In the case where farmers cannot compensate for the loss of fertilizer with additional inputs, using an average price of $133 per tonne of FFB in Indonesia (FAO, 2012), 1 tonne of soil eroded thus leads to a net loss of $8 per ha. If additional chemical fertilizer is applied, using an average price of $0.29 per kg for nitrogenous fertilizers (United Nations, 2013), farmers have to incur an additional $0.4 per ha for each tonne of soil eroded.

The increased quantity of nitrogen leached to water also has a marginal cost to society, measured by valuation coefficients. 1.5 kg of N leaching to water has a health impact of $0.03, a water treatment cost of $0.73 and a freshwater ecosystem cost of $1.27. In addition, wastewater treatment facilities may incur an additional water treatment cost due to turbidity, estimated at $5 if all the sediments eventually make their way to freshwater bodies.

FIGURE 4.8: COST OF SOIL EROSION PER HA PER YEAR



	Yield loss 1	Yield loss 2	Yield loss 3	Yield loss 4	Yield loss 5	Yield loss 6	Fertiliser application 1	Fertiliser application 2	Fertiliser application 3	Fertiliser application 4	Fertiliser application 5	Fertiliser application 6
Water treatment costs - sediment	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9	42.9
Water treatment cost - N	0.9	8.8	18.7	55.0	176.0	1,099.3	0.9	8.8	18.7	55.0	176.0	1,099.3
Freshwater toxicity cost	1.6	15.2	32.2	94.9	304.0	1,898.4	1.6	15.2	32.2	94.9	304.0	1,898.4
Health toxicity cost	0.0	0.3	0.7	2.2	6.9	43.0	0.0	0.3	0.7	2.2	6.9	43.0
Financial cost of Yield lost/ additional fertiliser applied	10.3	96.8	205.2	604.6	1,197.0	1,197.0	0.6	5.3	11.2	33.0	105.5	659.2

RESULTS OVERVIEW

As this additional piece of analysis demonstrates, it is not only necessary to optimize the use of chemical and organic fertilizers, but also to minimize soil erosion through crop management and conservation practices in order to reduce the natural capital cost of fertilizer application.

FINANCIAL CONSIDERATIONS

In order to assess the economic viability of possible interventions, the financial cost of each scenario was calculated (Table 4.12). Methodology and key assumptions are discussed in Appendix 2.

TABLE 4.9: FINANCIAL COST OF FERTILIZER APPLICATION

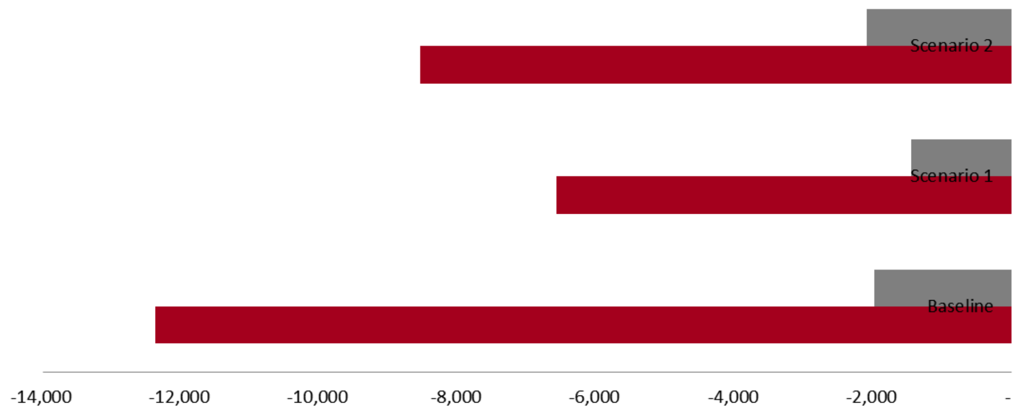
TOTAL (OVER 25 YEARS OF OPERATION)	BUSINESS AS USUAL (2014 US$/HA) – Baseline	OPTIMISATION PRACTICE 1 (2014 US$/HA) – S1	OPTIMISATION PRACTICE 2 (2014 US$/HA) – S2
Fertilizer type: Ammonium sulphate	698	305	1,160
Fertilizer type: Urea	119	52	199
Fertilizer type: Phosphate rock	106	29	59
Fertilizer type: Ammonium phosphate	7	2	4
Fertilizer type: KCl	648	648	648
Fertilizer type: K2S04	37	37	37
Legume cover plants	380	380	0
Total fertilizer costs	**1,995**	**1,453**	**2,107**

The financial cost of each scenario was calculated based on a literature review (Fairhurst & McLaughlin, 2009; FaoStat, 2013; United Nations, 2013). The analysis shows that growers also have a financial interest in understanding the exact nutritional needs of their plantation, and applying the exact nutrients needed using a combination of organic and chemical fertilizers (scenario 1). Indeed, costs are likely to be the lowest in this case, due to the lower quantity of fertilizer bought. Scenario 2 has the highest cost, due to the higher quantity of chemical fertilizers applied.

LONG TERM INTEGRATED SUSTAINABILITY

Figure 4.7 combines the natural and financial capital costs of fertilizer application for each scenario. Scenario 1, where the system is optimized using a mixture of chemical and organic fertilizer, has the lowest financial cost and the lowest social and natural capital cost. The results of this analysis are highly contingent on assumptions but they provide a useful framework for businesses to integrate natural and social capital alongside financial considerations.

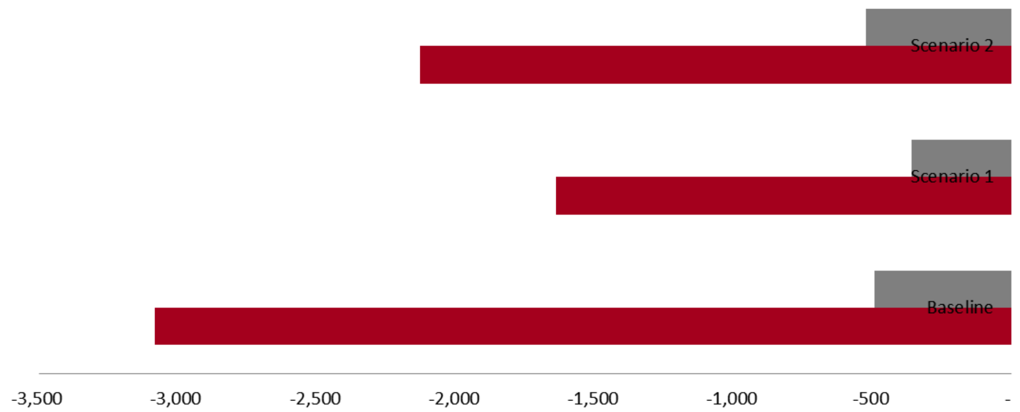
FIGURE 4.10: NATURAL AND FINANCIAL COSTS PER HA OVER LIFETIME OF PLANTATION



	Baseline	Scenario 1	Scenario 2
Financial capital costs	-1,995	-1,453	-2,107
Natural capital costs	-12,371	-6,577	-8,547

US$ per ha

FIGURE 4.11: NATURAL AND FINANCIAL COSTS PER TONNE PALM OIL OVER LIFETIME OF PLANTATION



	Baseline	Scenario 1	Scenario 2
Financial capital costs	-497	-362	-525
Natural capital costs	-3,084	-1,640	-2,131

US$ per tonne palm oil

BARRIERS AND OPPORTUNITIES

Organic fertilizers are easily available and a cheap source of nutrients in a context of increasing chemical fertilizer prices. Yet, problems may arise when not appropriately used, such as ground and surface water contamination, introduction of pathogens and odour problems (Embrandiri, et al., 2012). Therefore, appropriate training is necessary in order to ensure that sustainable fertilizer application practices are implemented adequately.

One of the best approaches is the use of fertigation when administering fertilizer, which uses a drip irrigation system so all the fertilizer reaches the plants (and thus less is used). According to one case study there are substantial economic benefits from installing such a system however it still requires a reasonably large initial investment, particularly in areas without the benefit of government subsidies (Surendra & Govindasamy, Undated). For smallholdings, in particular, this frequently represents a prohibitive cost in the absence of support from larger palm oil production companies or NGOs such as the RSPO.

Palm oil waste can and has been used for other purposes, such as energy generation in the milling stage. The shell and fibber alone can meet the mill's energy requirements (Abdullah & Sulaiman, 2013). A question of ownership thus arises when the growing and milling operations are not vertically integrated. Waste can also be used in other industries, such as to produce pulp and paper industry (Singh, et al., 2012). A holistic analysis is needed to determine what use of waste is associated with the highest human and natural capital benefit.

WAGES AND OCCUPATIONAL HEALTH & SAFETY

PREVALENT PRACTICE AND ISSUE

Despite the rapid development of the oil palm plantation sector in Indonesia, the conditions of workers in the sector remain challenging due to substandard wages, leniency in work conditions and labor rights, and inefficient occupational health and safety implementation (Pye and Bhattacharya, 2013; Sinaga, 2013). According to the Indonesian Ministry of Agriculture (2014), palm plantation area is estimated to grow 11.51% a year, which will likely result in increasing amounts of workers and communities being exposed to the social impacts of palm oil production.

Underpayment on palm oil plantations in Indonesia is an issue for casual workers, known as BHL (*Buruh Harian Lepas*), which constitute the majority (71.4%) of the workforce. These casual workers suffer from uncertain employment and receive a much lower financial wage and less in-kind benefits. For example they only benefit from work transport and child schooling, while permanent or SKU workers (*Syarat Kerja Umum*) receive work transport, child schooling, housing (including electricity), water and rice (Sinaga, 2013; Sawit Watch, 2014; Pardamean, 2008). Casual workers often must bring members of their families, including their children, to assist them in fulfilling their targets (Potter, 2015).

TABLE 4.10 TOTAL AVERAGE YEARLY WAGE OF CASUAL AND PERMANENT PALM OIL PLANTATION WORKERS

	Casual workers (BHL) US$/FTE	**Permanent workers (SKU)** US$/FTE
Financial wage	907	1,603
Transport	323	323
Education	173	173
Rice	-	329
Housing	-	186
Electricity	-	67
Water	-	17
In-kind wage	496	1,095
Total average yearly wage	**1,403**	**2,698**

Only casual workers are being underpaid, with a total average yearly wage of 1,403 US$ per full-time employee (FTE), which is 547 US$ below the calculated living wage of 1,950 US$ per year. A breakdown of the living wage is provided in table 4.11.

TABLE 4.11: LIVING WAGE BREAKDOWN[13]

	US$/YEAR
Food	1,253
Housing	682
Clothing	161
Health & hygiene	106
Healthcare & social security	18
Transport & communication	609
Education	106
Basic living income/household	**2,935**
Insurance	174
Pension contribution	790
Net living income/household	**3,899**
Taxes	0
Gross living income/household	**3,899**
Gross living wage/FTE	**1,950**

Apart from the underpayment of casual workers, an important issue affecting workers of palm oil plantations are dangerous working conditions, caused by inefficient health & safety implementation. The most common accidents on palm oil plantations are caused by fallen fruits (fresh fruit bunches weigh between 10 and 20 kg), pesticide exposure, thorn pricks and cuts (harvesters), tool use, road accidents, snake and insect bites and spine pain of harvesters (Levin, et al., 2014; Guereña & Zepeda, 2013; Wakker, 2005; Sinaga, 2013). The average fatal incident rate of plantation workers is 0.013%. This rate is comparable to the average fatal incident rate in agriculture in Malaysia, the other major palm oil producing country, which is estimated at 0.031% (Abas et al, 2013).

While recent data on rates of acute pesticide poisoning (APP) on Indonesian palm oil plantations are unavailable, global studies suggest the frequency of APP for pesticide sprayers to be 7% (Matthews, 2008), which is confirmed by other more regional studies in Asian countries (Zhang, et al., 2011). One cause for this issue is the application of hazardous pesticides. WHO class I pesticides, like Paraquat, are still applied on palm plantations in Indonesia (IPEN, 2011). Apart from that, only 1.7% of the pesticide sprayers are equipped with all five pieces of PPE (protective clothing, boots, a mask, gloves and a cap) and 8.7% of the workers are not using any protection at all during pesticide spraying (Thongrak, et al., 2011; Brandi, et al., 2013).

POSSIBLE INTERVENTION

A possible intervention for decreasing underpayment is to provide all workers with at least a living wage. This intervention refers specifically to casual workers, as they are the ones being underpaid. Plantations can fill the underpayment gap of these workers by increasing their financial wage or their in-kind benefits.

Occupational accidents can be reduced by installing adequate occupational health & safety systems and training plantation managers and workers in safe working practices, as well as providing sufficient PPE

[13] More information on the living wage methodology can be found in Appendix 1

to workers. Another possible way to reduce occupational accidents is by reducing or avoiding the application of WHO class I pesticides.

For this study, two interventions were selected, leading to one optimization scenario:

- Paying casual workers a living wage
- Increasing the use of PPE for all workers active in pesticide spraying

HUMAN CAPITAL QUANTIFICATION

In the optimization scenario a living wage is paid to casual workers, which reduces the average underpayment gap to zero. Apart from that, 5 pieces of PPE are provided to all pesticide sprayers that work with 2 or less PPE in the baseline scenario. This intervention is based on a decrease in APP of 44.3% for pesticide sprayers when more than 2 pieces of PPE are used (Dasgupta, et al. 2007). As the APP frequency for the baseline plantation is 7.0%, it decreases to 5.3% for the optimization practice plantation, proportionate to the amount of workers engaged in pesticide spraying. While it is highly plausible that light, heavy and fatal accidents will reduce as well when more PPE is used, only the effect on APP has been accounted for in this analysis. The key characteristics of the baseline and optimization scenario plantation are provided in Table 4.12.

TABLE 4.12: KEY PLANTATION CHARACTERISTICS FOR BASELINE AND OPTIMIZATION SCENARIO

PARAMETER	VALUE – BASELINE	VALUE - OPTIMIZATION SCENARIO	UNIT
Labour intensity	0.28	0.28	FTE/ha/year
% harvesters % pesticide sprayers	70.3 29.7	70.3 29.7	%
% permanent workers (SKU) % casual workers (BHL)	28.6 71.4	28.6 71.4	%
Average wage of worker (SKU) Average wage of worker (BHL)	2,698 1,403	2,698 1,950 (gross living wage)	US$/FTE/year
Light incident rate	0.0538	0.0538	/FTE/year
Heavy incident rate	0.0014	0.0014	/FTE/year
Fatal incident rate	0.0001	0.0001	/FTE/year
APP frequency	0.0700	0.0527	/FTE/year
Workers using personal protective equipment (PPE)	0 PPE: 8.7 1 PPE: 10.96 2 PPE: 36.24 3 PPE: 19.89 4 PPE: 22.52	0 PPE: 0 1 PPE: 0 2 PPE: 0 3 PPE: 19.89 4 PPE: 22.52	%

	5 PPE: 1.70	5 PPE: 57.59	

HUMAN CAPITAL VALUATION

The human capital cost of underpayment of hired workers equals $390 per average FTE or $22 per tonne of refined palm oil and $35 per tonne of refined kernel oil.

The human capital cost of health, caused by occupational incidents, is valued at $202 per average FTE or $11 per tonne of refined palm oil and $18 per tonne of refined kernel oil. Fatal incidents are the largest contributor to this human capital cost ($153 per FTE), followed by cases of APP ($45 per FTE).

In the optimization scenario, the human capital cost of underpayment is reduced to $0 and the human capital cost of health to $190 per FTE or $11 per tonne of refined palm oil and $17 per tonne of refined kernel oil.

FIGURE 4.12: HUMAN CAPITAL COSTS OF HEALTH AND UNDERPAYMENT FOR THE BASELINE PLANTATION

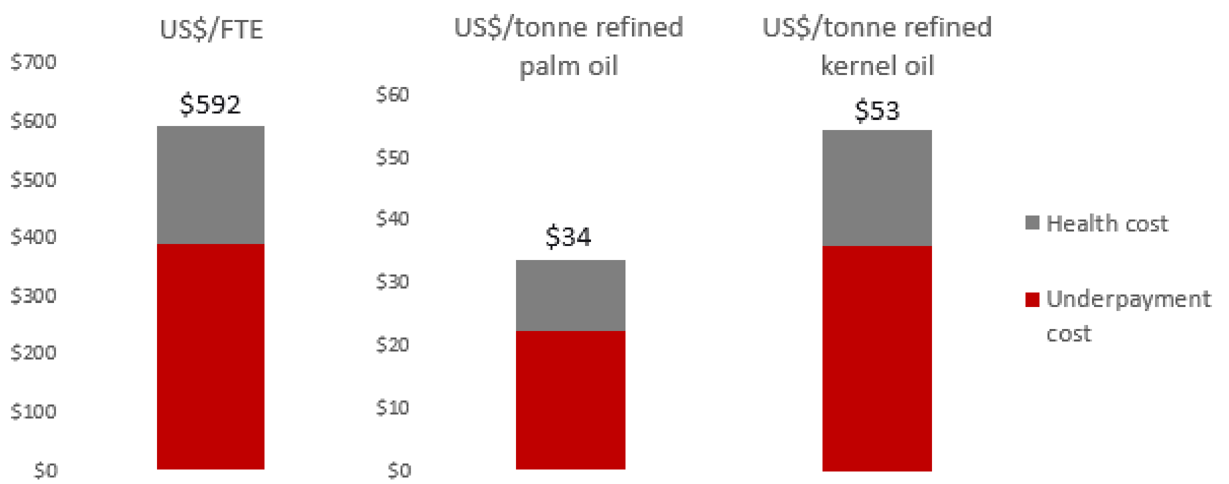
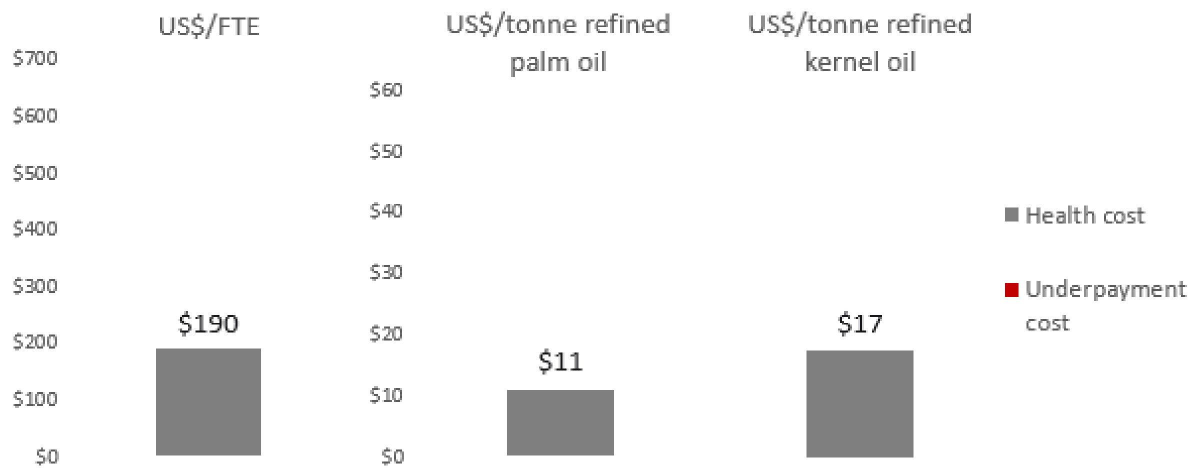


FIGURE 4.13: HUMAN CAPITAL COSTS OF HEALTH AND UNDERPAYMENT FOR THE OPTIMIZATION SCENARIO PLANTATION



FINANCIAL CONSIDERATIONS

In order to weigh the human capital cost reductions of the optimization scenario against the investments that need to be made by the plantation, a cash flow analysis of an average plantation was constructed. Table 4.13 represents the financial model of a baseline and optimization scenario plantation, averaged out over one year[14]. The interventions in the optimization scenario have an effect on labor costs – the payment of a living wage to all casual workers – and purchasing costs of extra PPE. They also significantly influence investments – as labor and PPE costs made during the establishment phase of the plantation are considered to be investments – as well as interests paid on debts, taxes and depreciation.

TABLE 4.13: CASH FLOW ANALYSIS OF BASELINE AND OPTIMIZATION SCENARIO PALM PLANTATION

	BASELINE PLANTATION (US$/HA/YEAR)	OPTIMIZATION SCENARIO PLANTATION (US$/HA/YEAR)
Total revenue	**2,304**	**2,304**
Non-labour costs[15]	327	327
Extra PPE costs	0	1
Total labour costs	252	332
Wages	218	295
In-kind (rice & education)	25	25
Social security contribution	9	13
Total costs	**579**	**660**
EBITDA	**1,725**	**1,644**
Depreciation	224	260
EBIT	**1,501**	**1,384**
Interests	467	471
Taxes	378	356
Net earnings	**657**	**557**
Depreciation (+)	224	260
Gross cash flow	881	817
Investments	224	260
Net cash flow	**657**	**557**

[14] The financial model is calculated for all production per ha, including side products.
[15] Non-labour costs include the provision of worker's compounds (incl. electricity, water) and work transport, which are counted as in-kind benefits in the wages calculation

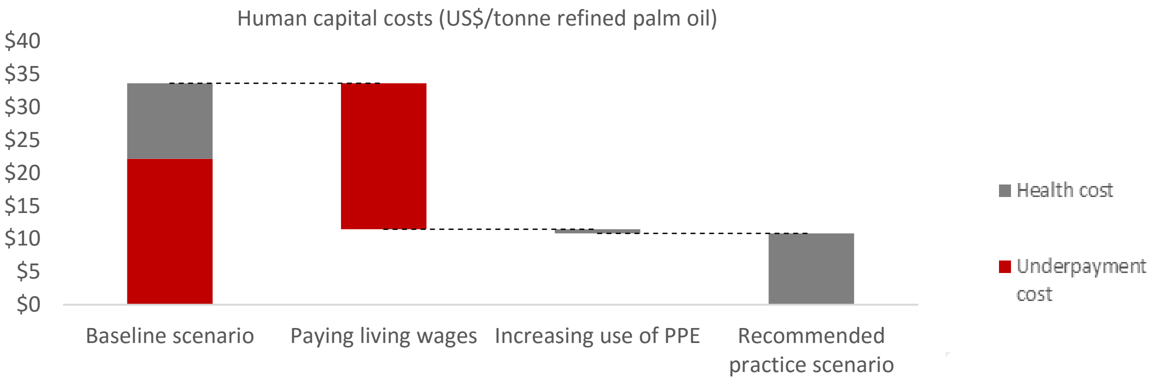
Profit margin[16]	28.5%	24.2%

LONG TERM INTEGRATED SUSTAINABILITY

Figure 4.14 and Table 4.14 show that plantations can reduce the human capital cost of underpayment to zero by paying living wages to casual workers. This intervention has a positive human capital return on investment (HCROI)[17] of 11%. This means that the reduction in human capital cost is higher in absolute terms than the financial investment needed by the plantation to implement the intervention. Plantations remain profitable, with a yearly profit margin reduction from 28% to 24%.

The human capital cost of health can be reduced by 6% by increasing the use of PPE, which in turn reduces APP frequencies. The HCROI of this intervention is 130% and the profit margin of plantations remains at 28%.

FIGURE 4.14: EFFECTS OF INTERVENTIONS ON HUMAN CAPITAL COSTS AND NET CASH FLOW



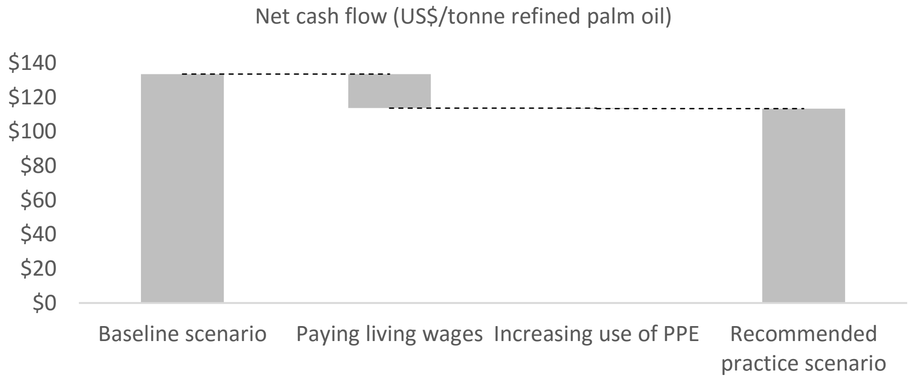


TABLE 4.14: EFFECTS OF INTERVENTIONS ON HUMAN CAPITAL COSTS AND NET CASH FLOW

[16] Profit margin represents the net cash flow available to equity investors divided by total revenue
[17] The human capital return on investment is defined as the difference between the financial investment of an intervention and the reduction in human capital costs caused by the intervention, divided by the financial investment of the intervention

US$/TONNE REFINED PALM OIL	**BASELINE**	**PAYING LIVING WAGES**		**INCREASING USE OF PPE**		**OPTIMIZATION SCENARIO**[18]	
	VALUE	VALUE	CHANGE IN VALUE	VALUE	CHANGE IN VALUE	VALUE	CHANGE IN VALUE
Human capital costs							
Underpayment	22.2	0	-22.2	22.2	0	0	-22.2
Health	11.5	11.5	0	10.8	-0.7	10.8	-0.7
Internal benefits							
Net cash flow	133.6	113.7	-19.9	133.3	-0.3	113.4	-20.2
Human capital return on investment		**11.4%**		**130.4%**		**13.1%**	

It is found that both paying living wages to casual workers and increasing the use of PPE for pesticide sprayers reduce human capital costs to a greater extent than they require financial investments by the plantation. In other words, these interventions have a positive HCROI. In absolute terms, more impact can be achieved by paying living wages.

Neither the effect of increased PPE use on light, heavy or fatal incidents, nor the effect of better health and safety conditions and lower incident rates on productivity, labor turnover rates and absenteeism, was taken into account. These effects are expected to strengthen the business relevance for increased PPE use by increasing the net cash flow of the optimization scenario plantation. Similarly, effects on productivity and labor turnover caused by increased wages were not taken into account but are also expected to strengthen the business relevance for decent wages.

UNCERTAINTY ON HUMAN CAPITAL COSTS

While the human capital cost of underpayment is expected to be quite robust, the human capital cost of health (and the associated intervention) is expected to have a higher uncertainty. In order to measure this uncertainty and evaluate which conclusions are robust, an uncertainty analysis was performed on the health cost.

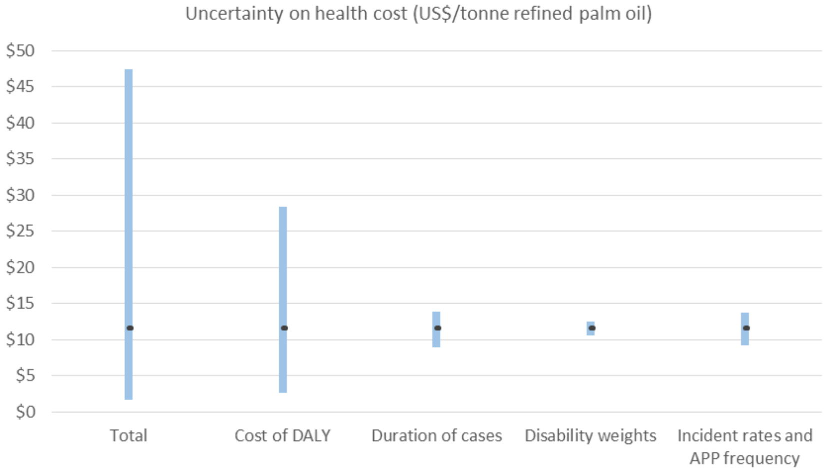
Table 4.15 shows the range for the human valuation coefficients, based on documented uncertainties on disability weights, duration of incident cases and the cost of a DALY (see Appendix 1 for more information on the valuation methodology). Taking into account these valuation coefficient ranges, as well as an estimated uncertainty of 20% on researched incident rates and APP frequencies, the uncertainty range on the total human capital cost of occupational health was calculated (figure 4.15).

TABLE 4.15: RANGE FOR THE MONETARY VALUATION COEFFICIENTS FOR HUMAN CAPITAL IMPACTS MONETIZED IN THE INDONESIA CASE STUDY ANALYSIS (IN US$ 2015 PER UNIT)

Occupational health (US$/incident)			
Light incidents	Heavy incidents	Fatal incidents	Acute Pesticide Poisoning (APP) incidents
0.7 – 7	194 – 2,150	259,811 – 2,877,946	488 – 5,354

[18] The optimization scenario combines higher wages with increased use of PPE

FIGURE 4.15 RANGE ON THE HUMAN CAPITAL COST OF HEALTH



The cost of a DALY was found to cause the highest uncertainty on the health cost. Investing in extra PPE as an intervention was found to have a negative HCROI when (i) a minimal duration of the cases (incidents) was accounted for all incidents on the plantation, and (ii) when the cost of one DALY was represented by its minimum value, i.e. three times the GDP per capita in Indonesia. The uncertainties on the incidents' disability weights, incident rates and APP frequency do not influence the conclusions of this part of the study.

The cost of a DALY clearly has a large impact on the human capital cost of health. Country-specific values of a DALY are usually based on a multiple of the GDP per capita (World Health Organization, 2010b), which makes the monetary value of a human life dependent on a country's national budget or willingness-to-pay. Drake (2014) argues that a global minimum value for DALY is justified on similar grounds to the Millennium Development Goals or the absolute poverty threshold. In expectation of further research, the cost of one DALY in this study was based on a European estimate published by the NEEDS project (Desaigues, et al., 2006, 2011) and subsequently adjusted for income to derive a global average, resulting in a value of $49,506. An alternative approach to determine the cost of a DALY is to multiply the world average GDP per capita by three. This would result in a cost of $39,300/DALY, which would bring back the HCROI of increased use of PPE from 130% to 83%. To determine the uncertainty range on the human capital cost caused by the cost of a DALY, a minimum value of $11,093/DALY and a maximum value of $122,880/DALY were used. The former represents the GDP per capita of Indonesia multiplied by three, while the latter is a value derived from an advisory report by the Dutch Council for Health and Society (RVS, formerly RVZ) to the Dutch Ministry of Health, Welfare and Sport (Raad voor de Volksgezondheid en Zorg, 2006).

BARRIERS AND OPPORTUNITIES

This analysis has found that both paying living wages to casual workers and increasing the use of PPE for pesticide sprayers reduce human capital costs significantly, and to a greater extent than they require financial investments by the plantation. The next question is whether these interventions are attractive to businesses. Reducing the human capital costs of health is an opportunity to create value for society that does not come at the expense of the business. To justify the living wage increase, either a business must care about it intrinsically or it must see a longer term business case. An intrinsic business motivation would be the case if a business considers paying a decent wage as its responsibility or if a business considers it as a goal to maximize its value for society. A business could identify a longer term business case for paying the living wage if it considers underpayment as a reputational and internalization risk, paying a living wage as a reputational opportunity or if it can share the costs of the increased wage with other actors in the value chain. The reasoning behind this shared investment is that all supply chain actors (buyers, retailer, and even consumers and governments) share a mutual responsibility for the external costs occurring in the value chain. Another way to overcome this implementation barrier is to work with intervention packages, where relatively costly interventions, such as living wage payments, are compensated by the simultaneous implementation of more profitable – often environmental – interventions, such as energy savings.

The inclusion of reputational risks and benefits, as well as financing, legal, operational and marketing risks in future analysis – not only for growers but for all supply chain actors – and exploring solutions to overcome possible implementation barriers, such as investment sharing between stakeholders, have the potential to not only increase HCROI's but also create a financial business case for all stakeholders and as such improve the attractiveness of social interventions.

A more practical implementation barrier for wearing more PPE, is the fact that certain protective gear is uncomfortable to wear in hot climates (Matthews, 2008; World Rainforest Movement, 2007). This intervention should, as such, be combined with health & safety trainings to inform workers about proper use of PPE and the importance of wearing PPE. Aside from stimulating PPE use by workers, capacity building is expected to further reduce incidents by increasing health & safety awareness and promoting good and safe agricultural practices, not only for pesticide sprayers but for all workers. As the quantitative effect of capacity building on incident rates in comparable situations has not yet been investigated, it was excluded from the scenario.

METHANE CAPTURE FROM PALM OIL MILL EFFLUENT (POME)

PREVALENT PRACTICE AND ISSUE

The primary processing of palm oil in crude palm oil (CPO) mills generates important quantities of wastes whose disposal poses a range of challenges. In a typical plantation, almost 70% of fresh fruit bunches (FFBs) are turned into wastes in the form of empty fruit bunches, fibers and shells, and the most environmentally damaging by-product of the milling process, Palm Oil Mill Effluent (POME). In a conventional palm oil mill, 600-700 kg of POME is generated for every tonne of processed FFB, or around 2.3 m^3 POME/tonne CPO (London Zoological Society, Undated) .

POME is a concentrated hot, acidic effluent that contains oil, plant debris, and nutrients. It is often discarded in open-air treatment ponds, and its handling and disposal has large environmental consequences, such as greenhouse gas emissions, odor, and water and land contamination (including seepage, runoff, and over application). For example, the open ponds are a major source of methane, which is significantly more potent than carbon in terms of climate change effect. Its large oxygen depleting capability in aquatic systems can also cause natural capital impacts (Zafar, 2014). Untreated, or raw, palm oil mill effluent (POME) is 100 times more polluting than domestic sewage. In a single year, the entire Indonesian palm oil industry produced POME equivalent to the domestic sewage of 20 million people, or one-tenth of the country's total population in 1999.

Currently, in most countries, there are regulations in place that require the treatment of palm oil mill effluents before they are discharged into waterways. The most widely used system is the anaerobic digestion of the effluent through a series of ponds. However, at present, most of the open pond treatment systems do not capture the methane released (IFC & World Bank, 2011). The underutilization of productive by-products in the palm oil value chain presents an important cost-cutting and revenue-generating opportunity to produce large amounts of electricity for captive consumption as well as for export of surplus power to the public grid.

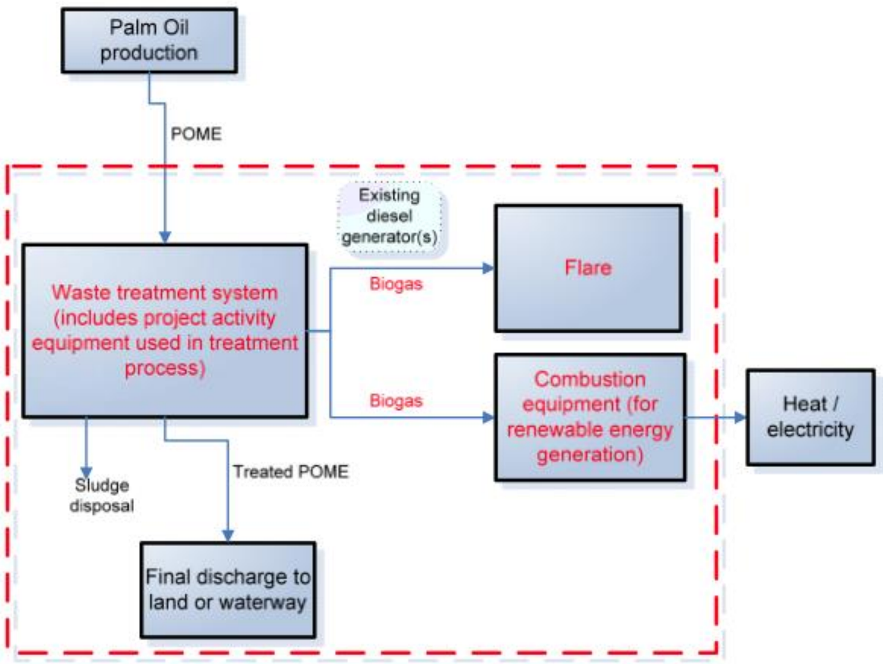
POSSIBLE INTERVENTION

Many new technologies are being developed to generate energy from POME and reduce associated greenhouse gas emissions and other pollution. These include biological sequencing batch reactors, biofiltration systems, high aeration rate systems, and decanters, activated sludge plants with aerobic reactors, bioflow polishing plants, and membrane bioreactors (London Zoological Society, Undated).

An established approach is to process POME through an anaerobic generator, capturing the methane from the waste organic matter to run a gas engine and generate electricity. An alternative option is to burn the biogas in a boiler to generate steam and hot water. The energy produced through the biogas plant can then either be used for the mill's own production and staff quarters, or sold to the electricity grid for additional revenue. At the same time, processed POME anaerobic sludge can also be added to enrich compost thus potentially lowering the cost associated with fertilizer inputs as seen in Section 7.2.

Projects realized under the Kyoto Protocol's Clean Development Mechanism (CDM) provide a suitable blueprint for best practice. For example, between 2006 and 2012 several projects were financed under the CDM with the purpose of "recovering methane caused by the decay of biogenic matter in the effluent stream of an existing palm oil processing mill by introducing methane recovery and combustion to the existing anaerobic effluent treatment system (lagoons)" (UNFCCC, 2015). The methane gas is subsequently used as an alternative fuel to diesel, generating electricity for the mills and estates.

FIGURE 4.16: EXAMPLE PROJECT BOUNDARY – CDM METHANE RECOVERY IN WASTEWATER TREATMENT



NATURAL CAPITAL QUANTIFICATION

Two scenarios were evaluated, ponds with and without methane capture. On average, 0.7 m^3 of POME is generated per tonne of FFB, or 19.6 m^3 of biogas with a methane content of 65%, a density of 0.7 kg per m^3 and a global warming potential of 21 (Brinkmann Consultancy, 2009). As a result, the quantity of carbon dioxide generated is 3.2 tonnes per ha per year, or 82 tonnes per ha over 25 years taking into account yearly yield.

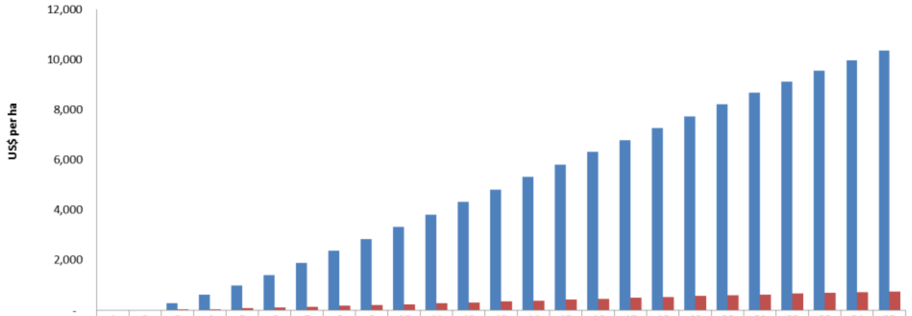
Impacts associated with methane capture systems relate to the use of energy, treatment of the remaining wastewater, fugitive emissions and flaring. An average of eight monitoring reports of methane capture projects financed under CDM schemes were used. In this scenario, greenhouse gas emissions amount to 0.23 tonnes per ha per year, or 6 tonnes per ha over 25 years.

NATURAL CAPITAL VALUATION

Using a social cost of carbon of $125 per tonne, the cost of POME with and without methane capture is $30 and $410 per ha per year respectively. Applying a flat palm oil yield rate of 4.01 tonnes palm oil/ha (FaoStat, 2013), this is equivalent to $7 per tonne palm oil or $102 per year respectively. Over the full lifecycle of the plantation, the cost is $745 and $10,360 per ha respectively, adjusting for yearly yield.

Implementing a methane capture system thus leads to a cost saving of $380 per ha per year, or $9,620 over 25 years. The discounted cost of POME with and without methane capture is $531 and $7,377 per ha. Figure 4.17 presents the cumulative, undiscounted cost of POME with and without methane capture.

FIGURE 4.17: CUMULATIVE NATURAL CAPITAL COST OF POME WITH AND WITHOUT METHANE CAPTURE



	1	2	3	4	5	6	7	8	9	10	11	12	13
Ponds - no methane capture (US) - cumulative	-	-	282	607	976	1,409	1,886	2,363	2,840	3,317	3,816	4,314	4,813
Anaerobic digester system (gas to electricity) - impacts (US) - cumulative	-	-	20	44	70	101	136	170	204	239	275	310	346

	14	15	16	17	18	19	20	21	22	23	24	25
Ponds - no methane capture (US) - cumulative	5,311	5,810	6,309	6,786	7,263	7,739	8,216	8,672	9,127	9,560	9,972	10,363
Anaerobic digester system (gas to electricity) - impacts (US) - cumulative	382	418	454	488	523	557	591	624	657	688	718	746

FINANCIAL CONSIDERATIONS

The economic viability of Palm Oil Mill Effluent (POME) remediation is assessed through marginal capital and operating expenditure costs derived from eight UNFCCC Clean Development Mechanism project design documents (UNFCCC, 2015). These documents are all dated from 2009-2012, and relate to Methane Recovery in Wastewater Treatment in Indonesia. Three scenarios are compared against each other:

- No POME capture
- POME is captured and destroyed through flaring, without generating any cost savings or additional revenues.
- POME is captured and generated electricity displaces the use of diesel generators at the mill and also generates CER credit revenues for every tonne of GHG mitigated.

The overarching findings are that 17% of total (CAPEX & OPEX) cost of $0.54 per tonne of FFB processed can be recovered through the average cost saving from displaced electricity and revenue from the sale of Certified Emissions Reduction allowances. The main purpose of constructing methane recovery plants is to mitigate the emission of potent GHGs such as methane; as such CER credits are expected to form significant proportion of the project revenue. However, the weak recent performance of the CER spot price on the carbon markets, reaching half a dollar from over $20 in 2008, has been reflected in the analysis of projected revenues.

TABLE 4.18: FINANCIAL COSTS (UNFCCC, 2015)

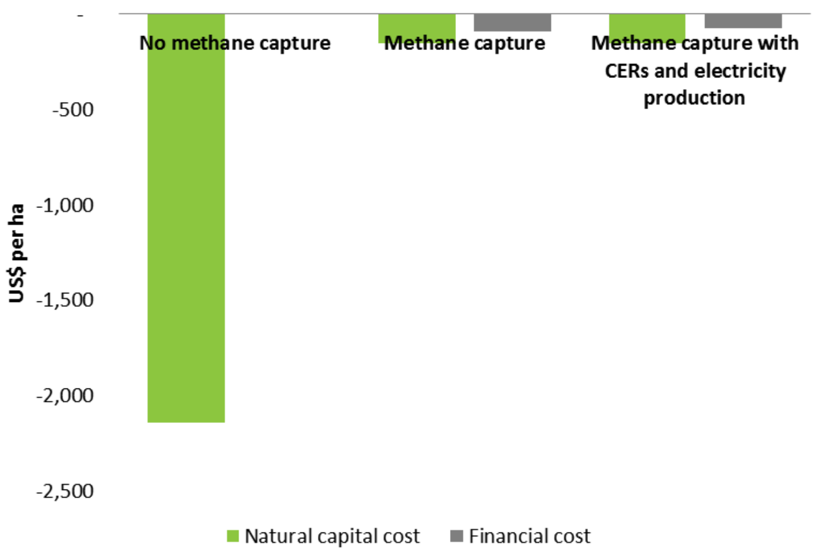
SCENARIO	ANNUAL CAPEX/ TONNE FFB (2014 $)	ANNUAL OPEX/ TONNE FFB (2014 $)	TOTAL COST/ TONNE FFB (2014 $) (discounted)	COST SAVING FROM DIESEL DISPLACEMENT 2014 S/TONNE FFB	REVENUE FROM SALE OF CER (2013 $)	COST SAVING & REVENUE GENERATED AS % OF TOTAL COST (discounted)
POME remediation & Flaring	0.14	0.41	0.26	NA	NA	NA
POME remediation & Electricity from diesel cost savings + Revenue from CER	0.14	0.41	0.26	0.10	0.05	17%

LONG TERM INTEGRATED SUSTAINABILITY

The natural capital cost of POME with and without methane capture is $29 and $409 per ha per year respectively. The average net present financial cost of methane capture is $0.26 per year per tonne of FFB, or $91 per ha over the full lifetime of the project (21 years on average). With electricity generation and CER sales, the net present financial cost is $75 per ha over 21 years.

Based on these figures, each dollar invested in the capital and variable costs of the methane capture project without electricity sales or CERs generates $86 per ha per year, and $203 per ha per year with electricity generation and CERs.

FIGURE 4.19: NATURAL CAPITAL BENEFIT VERSUS FINANCIAL COSTS



BARRIERS AND OPPORTUNITIES

Several larger firms have implemented methane capture technology but this is often financially out of the reach of smaller operators. For example, Musim Mas, which has about 100,000 ha of planted area and eight palm oil mills, has fitted one of its mills in Riau Province with a methane capture facility for electricity generation since 2010 (London Zoological Society, Undated). Motivated by reducing GHG emissions from operations by providing a sustainable, cheaper and more reliable electricity supply to their premises, they self-funded the majority of the installation, with a small contribution from the Danish Ministry of Climate and Energy covering the development of the Project Design Document, registration with UNFCCC and verification of emission reductions for CER credits. Even so, internal analysis demonstrated significantly long payback time (Sustainable Palm Oil Platform, 2014).

CDM projects also frequently report that investment barriers are the most relevant when it comes to implementing without the assistance of CDM for waste treatment systems. The Indonesian palm oil industry views the installation of waste treatment technology as a means to satisfy statutory discharge requirements rather than a revenue source. The existing lagoon-based waste treatment systems adhere to Indonesian government requirements and are significantly lower in capital and operating costs than anaerobic digestion technology. Though costs vary according to required lagoon size and other factors, initial costs to install an anaerobic digester system (excluding the cost of lagoon construction) can run in the hundreds of thousands of US dollars.

One way to render such investments financially viable is for mills to generate additional revenue from verified GHG reductions via the Kyoto Protocol‘s Clean Development Mechanism (CDM) or other environmental financial mechanisms. Obtaining such financing is conditional on challenges such as regulatory uncertainty and low prices for credits for carbon emission reductions, which typically inhibit the suppression of methane emissions through the UN mechanisms of Kyoto (IFC & World Bank, 2011). Registering such projects is also reportedly complicated, lengthy and expensive. Overall, carbon revenues have been significantly lower than projected in 2004 and often were obtained several years after the start of commercial operation (Siteur, 2012).

These challenges are characteristic of the broader market developments over the last five years. The World Bank Group reports in a comprehensive assessment that since the second half of 2012 there has been a growing feeling in the CDM market that demand is saturated, little prospect of a significant recovery with the biggest players leaving the market. The level of activity in CDM projects on the ground mirrors the market downturn; with a CER price that averaged €0.37 ($US0.51) in 2013 and no price recovery foreseen in the near future, the whole CDM pipeline, from start of validation to issuance, has seen a considerable decrease in 2013 (World Bank, 2014). Nevertheless, at COP 19, the negotiations on CDM reform were encouraging given current market circumstances and prospects. The areas for reform currently being considered are the historical ones, namely governance, streamlining of procedures and environmental integrity. Revision of the CDM modalities and procedures was postponed, with a recommendation on this expected at COP 20 (UNFCCC, 2013).

Other purely technical details related to the viability of this activity depend on the mill’s characteristics, in particular:

- The mill’s electricity versus thermal energy needs,
- Capacity of existing boiler,
- Distance and access to the grid, one of the principal revenue streams from such investments alongside carbon credits. Distance to the electricity grid from Indonesia palm oil mills varies with some mills located more than 20km from the grid. In order to get connected with electricity grid the mills have to share the infrastructure cost or contracting the connection with higher price. Hence, palm oil mills are usually generating their own electricity either utilizing biomass waste and/or using diesel generators.

Other barriers include:

- Incomplete legal and regulatory frameworks. Without legislation plantations do not necessarily see the point in remediation particularly if not financially attractive enough,
- Limited models of successful biogas projects and successful projects to prove concept,
- Project developers and financial institutions lack understanding of each other’s requirements and constraints,

- Dilution of facility resources and many plantation owners will be unaware of the benefits,
- Bad experience, particularly with covered lagoons and failure of some CDM projects. There are also limited models of successful biogas projects to prove the concept.

RECOMMENDATIONS FOR BUSINESS

MEASURE, MANAGE AND MINIMISE INTERNALISATION RISK

Businesses can act to improve the sustainability of palm oil production through implementing more sustainable production practices such as increasing yield and conversion rates and optimizing the quantity and quality of inputs used, and by holistically relocating to areas less vulnerable to social and environmental impacts.

These elements should be considered together to identify trade-offs and ensure that the overall natural and human capital impact of the system is minimized. For example, an increase in the quantity of chemical fertilizer applied (depending on background local conditions) may lead to both an increase in yield but also costs from fertilizer application. The net change in natural capital cost may be positive or negative. In summary:

- Companies in the palm oil production sector should consider the use of natural and human capital accounting to assess the risks to their businesses posed by the environmental and social impacts of palm oil production. Factors such as tougher regulation and enforcement, changing consumer demand and reputational damage risk could force companies to pay the natural and human capital costs of palm oil production, threatening future revenues.
- Investors and banks are advised to assess their exposure to the natural and human capital costs of the palm oil sector in their equity portfolios and loan books. The internalization of natural and human capital costs could affect shareholder value and the ability of companies to repay loans. Investors and banks should therefore engage with palm oil companies that have the highest natural and human capital costs to assess what they are doing to minimize the risks to their business.
- This research has demonstrated the applicability of natural and human capital accounting to decision making by revealing the hidden costs of production in the palm oil sector and shortlisting priority cost areas for businesses to focus on. For example, on the natural capital side it has identified the growing and milling practices having the highest impact: land use change and the associated carbon emissions contributing 89% to the cost of one tonne of palm oil; fertilizer application contributes 22% (with 67% from greenhouse gases, 25% from toxic substances to freshwater environment, and 8% from toxic substances to human health) and the management of palm oil mill effluent emissions (POME) which is the third most costly practice in terms of environmental cost, contributing 12% of total costs, due to methane emissions contributing to climate change. On the human capital side it has found that on average underpayment of workers is a larger issue in the sector then occupational accidents, with human capital costs of the former being twice the size of the latter. The research showed that underpayment is predominantly an issue for casual workers and that the human capital cost of occupational accidents is mainly driven by fatal accidents and cases of acute pesticide poisoning.
- Furthermore, companies should consider implementing best practices for palm production to improve environmental and social performance and reduce natural and human capital costs. Palm oil producers could use natural and human capital accounting to assess a range of alternative practices to see which would have the greatest benefit for their operations.

- This research has also demonstrated the applicability of natural and human capital accounting to decision making by revealing the potential of an array of interventions to manage the above costs and their required investments. For example, analysis has revealed that using an optimized mix of organic fertilizer containing pruned palm oil fronds, empty fruit bunches and palm oil mill effluent combined with chemical fertilizers has the lowest natural capital cost and also the lowest financial cost due to the lower quantity of fertilizer needed. On the social side, it has revealed that if plantation owners paid a living wage to casual workers, the human capital cost of underpayment would be reduced to zero, while plantations remain profitable with margins reducing from 28% to 24%. Purchasing more personal protective equipment to reduce instances of pesticide poisoning was found to cause a large reduction in human capital costs compared to the required financial cost, translating in a human capital return on investment of 130%.

RECOMMENDATIONS FOR POLICY

PAY THE FULL PRICE

- Negative externalities should be internalized in the price of palm oil products, but food security should not be affected. This can be done for example via voluntary commitments, environmental or social taxation or environmental and social regulation. These measures should however not increase food prices for vulnerable shares of the population. Internalization of negative externalities will help to steer the palm oil production sector towards a trajectory that minimizes losses of natural and human capital.

STREAMLINE VALUATION OF NATURAL AND HUMAN CAPITAL

- The Natural Capital Coalition, a global multi-stakeholder collaboration that brings together leading global initiatives and organizations to harmonize approaches to natural capital, is made up of organizations from research, science, academia, business, advisory, membership, accountancy, reporting, standard setting, finance, investment, policy, government, conservation and civil society. Its recent Natural Capital Protocol offers a standardized framework to identify, measure, and value impacts and dependencies on natural capital, while the accompanying food and beverage sector guide develops the business case for natural capital assessments and uses practical examples to demonstrate sector-specific business applications of the Protocol. It is expected that owing to such frameworks, the hidden costs (and benefits) of palm oil production could increasingly be captured together with visible costs and benefits. This would allow informed decision making to move towards sustainable production practices.

IMPROVE PALM OIL PRODUCTION SYSTEMS

- A limited selection of scenario studies show that increased palm oil production is possible without increasing the natural capital costs. Governments should focus environmental programs and reduction initiatives on natural capital impacts identified as key contributors to natural capital costs. In this sense, developing and promoting good agricultural practice can be strongly beneficial to reduce the impacts of palm oil production. For example, improving land use change practices or palm oil mill effluent management. On the other hand, avoiding the excessive fertilization of oil palms would decrease nutrient run off and thus pollution of water bodies associated with palm oil production.

- Given that on a purely financial basis many interventions are not yet profitable for a producer acting on their own, governments should investigate certain mechanisms and taxation structures that can direct investment towards interventions with the highest return on natural and human capital cost reductions.
- Policy makers should promote knowledge sharing platforms amongst countries, as technology and farming practices that already exist in developed countries could be applied to decrease natural and human capital impacts in developing countries. In any case, special attention should be given to the adaptability of those techniques to local conditions. Governments can also issue studies for research in key areas that can explore the effects of more interventions and strengthen the business case for natural and human capital optimization.

FURTHER RESEARCH

Palm oil production systems are key components of agro-ecosystems and under specific management practices they can also enhance the provision of beneficial ecosystem services. One of the limitations of the study is its sole focus on the environmental cost of palm oil, which is only one side of the coin.

Palm oil plantations have significant social and natural components that were not explored in this study. Palm oil landscapes provide a number of important ecosystem services such as soil erosion control, biodiversity, water regulation, other agricultural production that support subsistence livelihood. Moreover, it covered only the production side of palm oil and did not account for any costs or positive benefits associated in distribution and consumption side of the equation, as well as food security aspects, access, distribution, markets, agribusiness, supply chain, waste reduction which are all important parts of food systems. These are important areas for future research.

Further development of the methodologies used in this report should also consider further populating the unifying TEEBAgriFood Valuation framework that includes all relevant positive and negative externalities and approaches for their valuation at different scales, and with different levels of data availability and data integrity (TEEBAgriFood, 2016). Such an assessment in palm oil should explicitly reveal economic value at production, distribution and consumption stages of the value chain.

Future research requirements for social practices considered in this report can be subdivided into three categories that represent their underlying goals:

- Increase knowledge on the size of total human and social capital costs related to palm oil production
    - Perform quantitative research to improve the robustness of the human capital cost of occupational health. This includes research on incident frequencies (per type of incident) on plantations and incident durations, but also – more general – on disability weights of incidents and the appropriate value of a DALY. The latter has shown to be a key driver of uncertainty on the human capital cost of occupational health;
    - Perform quantitative research on other human capital costs, such as child labor, lack of social security and gender discrimination;

- Perform quantitative research on land dispossession. Examples of useful quantitative data points are rates of land dispossession (area and people affected), types of agreements between communities and companies and the (intrinsic) value of land in palm oil expansion regions.

- Increase and strengthen insight in the social as well as financial business case of interventions
  - Perform research on the quantitative relation between better working conditions (increase in wages, decrease in incident rates etc.) and productivity, labor turnover rate and other possibly hidden financial gains;
  - Perform research on the quantitative relation between increased use of PPE and (various types of) capacity building on the one hand and light, heavy and fatal incident rates on the other hand;
- Asses viability of various intervention strategies to improve human capital costs
  - Perform research on human capital costs associated with the entire supply chain (not only growers);
  - Monetize reputational risks and benefits, as well as financing, legal, operational and marketing risks for various supply chain actors;
  - Perform value chain analysis and explorative research on investment cost sharing of interventions between supply chain actors and other stakeholders, by investigating absorption capacities of all stakeholders as well as possible mechanisms, such as shared stakeholder funds, taxation mechanisms and consumer premiums.

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Appendices

APPENDIX 1: VALUATION METHODOLOGIES

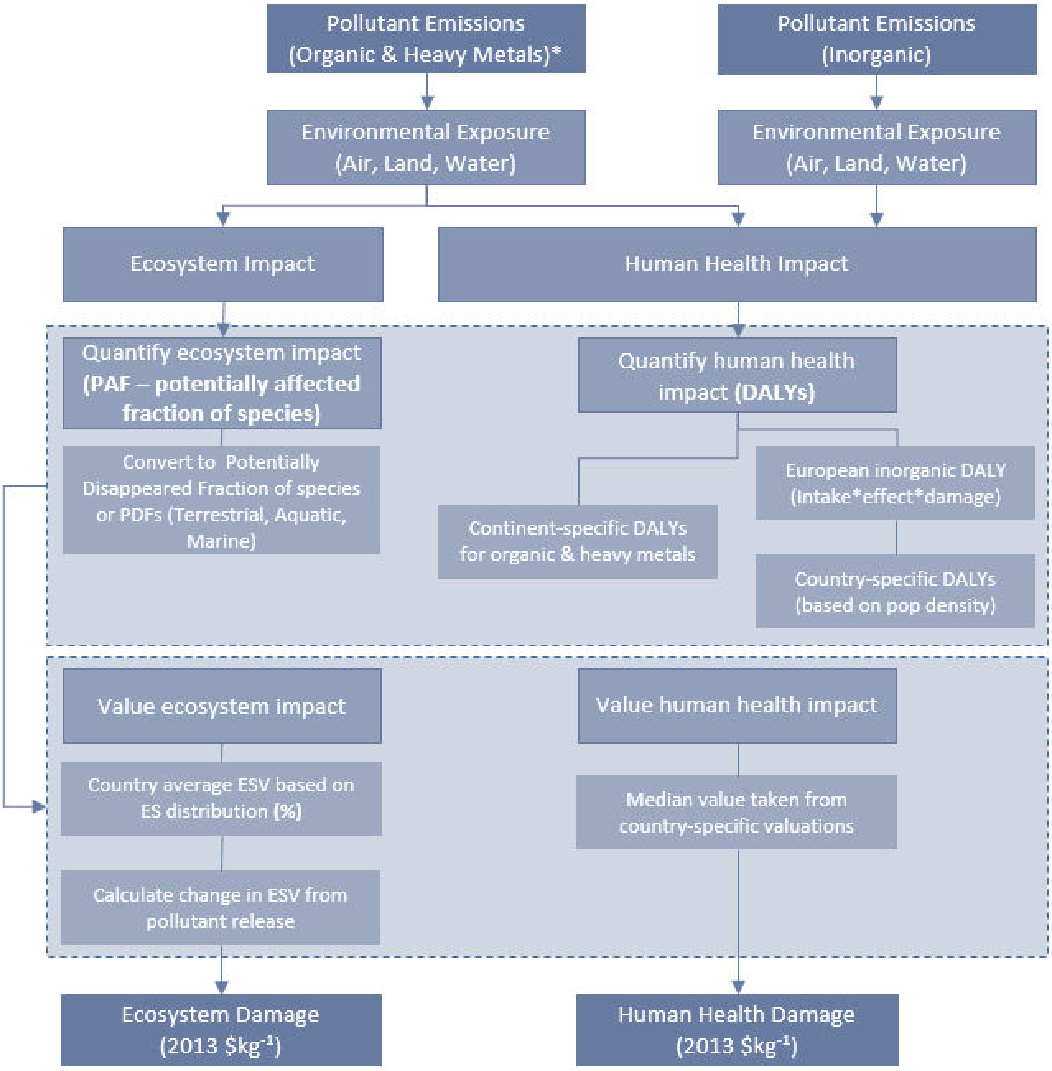
NATURAL CAPITAL VALUATION: AIR, LAND AND WATER POLLUTANTS

OVERVIEW

GENERAL PROCESS

Figure A1.1 summarises the overall approach used to value the emission of air, land, and water pollutants. The first shaded box indicates the steps taken to quantify the environmental impacts of these pollutants, while the second indicates the steps taken to value these impacts.

Figure A1.1: General overview of Trucost valuation process for Air, Land and Water Pollutants



- **ESV**: Ecosystem Services Value
- **DALY**: Disability Adjusted Life Years
- **ES**: Ecosystem Services
- Inorganic pollutants include carbon monoxide (CO), sulphur dioxide (SO2), nitrous oxides (NOx), ammonia (NH3), particulate matter (PM), and volatile organic compounds (VOCs)
- *Organic pollutants and heavy metals are grouped together due to the similarity in methodology, not chemical properties.

VALUATION METHODOLOGY SUMMARY

IMPACT ON HUMAN HEALTH

Biophysical Modelling

ORGANIC SUBSTANCES AND HEAVY METALS

Trucost uses disability adjusted life years (DALYs) as a measure of the impact on human health from environmental impacts. In order to calculate the quantity of DALYs lost due to the emission of pollutants to air, land and water, Trucost used USES-LCA2.0 (EC, 2004; National Institute of Public Health and the Environment, 2004). This model, originally developed in the context of life cycle assessment (LCA) studies, calculates the quantity of DALYs lost due to emission of over 3,300 chemicals to: freshwater and seawater; natural, agricultural and industrial soil; and rural, urban and natural air. USES-LCA2.0 takes into account the impact of cancer and non-cancer diseases caused by the ingestion of food and water, and the inhalation of chemicals.

The output of this analysis step is the number of DALYs lost due to the emission of each pollutant, to a specific media, at the continental level.

Note that organic substances and heavy metals are grouped together due to the similarity in methodology, not their chemical properties.

SULPHUR DIOXIDE, NITROGEN OXIDE, AND PARTICULATE MATTER (PM10)

USES-LCA2.0 does not estimate DALY impacts for common inorganic air pollutants such as sulphur dioxide, nitrogen oxide and PM10. Adaptation of USES-LCA2.0 to model these substances would result in higher than acceptable uncertainty due to the different characteristics of organic and inorganic substances. Trucost conducted a literature review to find an alternative method to quantify the DALY impact of emission of these pollutants.

Economic Modelling

Once the quantity of DALYs lost is calculated, several valuation methods can be used to put a monetary value on a DALY, such as the cost of illness, the value of a statistical life (VSL), and the value of a statistical life year (VOLY).

Trucost decided to use the WTP technique utilized in the VOLY method to value DALYs, as it encompasses most aspects relating to illness and expresses the value of a year of life to the wider population. To value DALYs, Trucost used the results of a stated preference study conducted for the

New Energy Externalities Development for Sustainability (NEEDS) project (Desaigues et al., 2006; 2011). This is a proactive cost estimate, which takes into account the perceived effects of morbidity. The value of a life year used in this methodology is just in excess of $49,500 in 2014.

IMPACT ON ECOSYSTEMS

Biophysical Modelling

ORGANIC SUBSTANCES AND HEAVY METALS

USES-LCA2.0 models the impact of polluting substances emitted to air, land and water, on terrestrial, freshwater and marine ecosystems. This model was adopted by Trucost for assessing the ecosystem damage caused by organic substances and heavy metals. It follows the same modelling steps as for human toxicity, namely exposure assessment, effect assessment, and risk characterization. USES-LCA2.0 has also been adapted to generate results at a continental level.

USES-LCA2.0 estimates the potentially affected fraction of species (PAF) due to the emission of pollutants to air, land and water. It is important to note that affected species need not disappear. Trucost adjusted the PAF results to reflect the proportion of species disappeared (PDF) using assumptions from the Eco-Indicator 99 model (Goedkoop & Spriensma, 2000). This was done to match the valuation methodology, which uses PDF (and not PAF) as an input due to data availability.

OZONE, SULPHUR DIOXIDE, NITROGEN OXIDE, AND PARTICULATE MATTER (PM10)

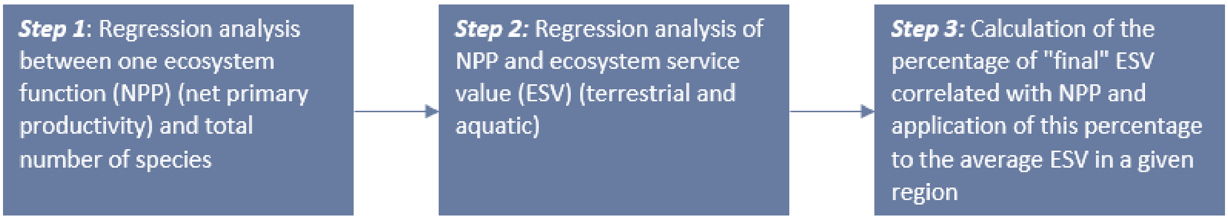
Impact on ecosystems has not been included for ozone, sulphur dioxide, nitrogen oxides and PM10.

Economic Modelling

VALUING THE IMPACT ON ECOSYSTEMS IN THIS STUDY

Trucost's approach to valuing a change in the PDF of species follows a three-step process, as shown in Figure 2.

Figure 2: STEPS FOR CALCULATING THE VALUE OF ECOSYSTEM SERVICES LINKED DIRECTLY TO BIODIVERSITY



In this methodology, Trucost decided to assess the link between biodiversity, measured species richness (IUCN, 2015), net primary productivity (NPP) (Costanza et al., 2007), and ecosystem service value (ESV). NPP was chosen over other ecosystem processes, such as nutrient cycling, due to data availability and its direct link with key ecosystem services. A monetary value for the provisioning, regulating and cultural services by terrestrial ecosystem type was first calculated based on the analysis of De Groot et al. (2012) using the specific ecosystem split per country (Olson et al., 2004). De Groot et al. calculate the minimum, maximum, median, average and standard deviation for each service provided by key terrestrial and aquatic ecosystems. Finally, Trucost calculated the percentage difference pre- and post-change of ESV at a country and substance level, and applied this percentage to the average value of one square meter of natural ecosystem in a given region. This aligns with the results of USES-LCA2.0, which calculates change of species richness, or PDF, at a continental level.

For more information on the above, as well as sensitivity analysis for selected parameters, please refer to the full Trucost valuation methodology at Trucost (2015)

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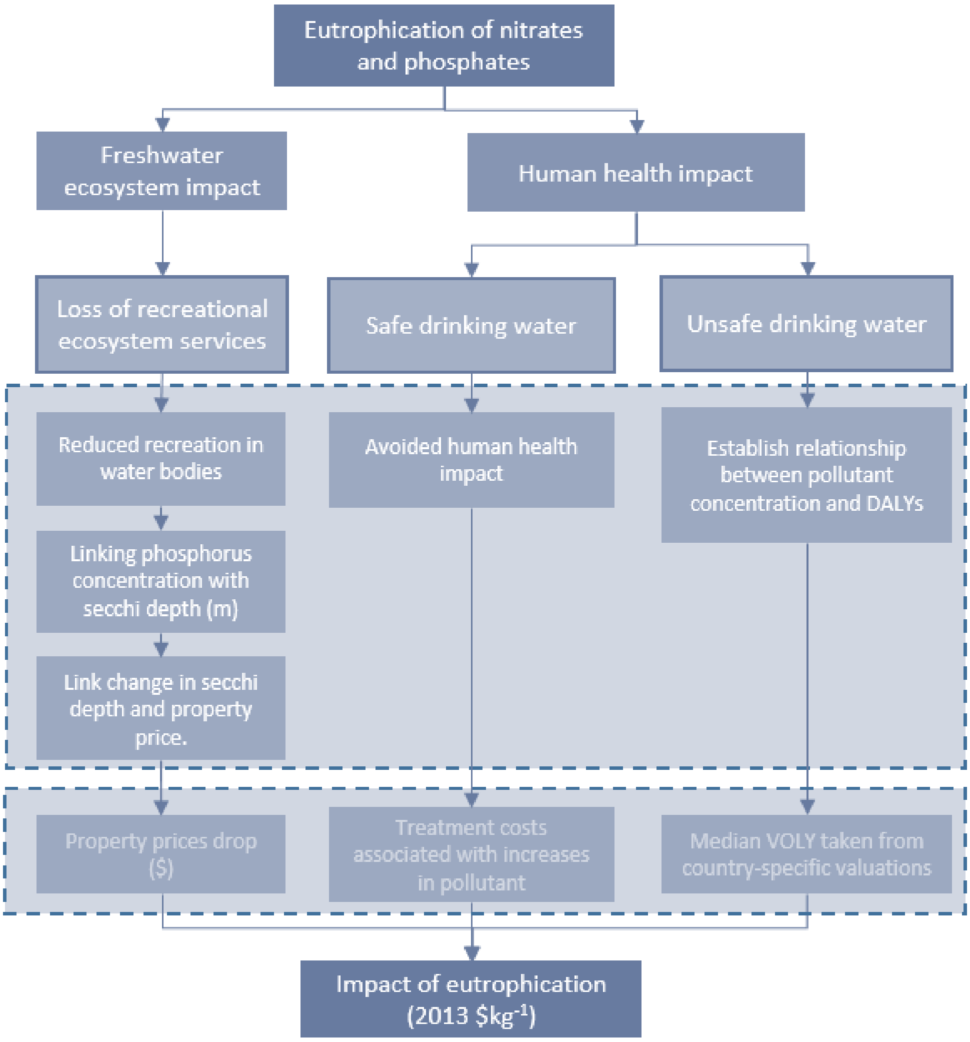
NATURAL CAPITAL VALUATION: EUTROPHICATION

OVERVIEW

GENERAL PROCESS

Figure A1.2 summarizes the high-level steps taken to value the impacts of eutrophication. Not all of the possible impacts have been included in the current methodology, such as the loss of fish yields in freshwater and marine ecosystems, and the loss of recreational services in marine ecosystems.

Figure A1.2: General overview of Trucost valuation process


Eutrophication of nitrates and phosphates
Freshwater ecosystem impact
Human health impact
Loss of recreational ecosystem services
Safe drinking water
Unsafe drinking water
Reduced recreation in water bodies
Avoided human health impact
Establish relationship between pollutant concentration and DALYs
Linking phosphorus concentration with secchi depth (m)
Link change in secchi depth and property price.
Property prices drop ($)
Treatment costs associated with increases in pollutant
Median VOLY taken from country-specific valuations
Impact of eutrophication (2013 $kg-1)

VALUATION METHODOLOGY SUMMARY

IMPACT ON HUMAN HEALTH

Biophysical Modelling

Water pollution can directly impact human health when unsafe drinking water is consumed. However, water is also treated to prevent the negative impacts of polluted water consumption and this comes with an economic cost. Therefore, to account for the true impact on human health, it is necessary to look at the economic costs of both safe and unsafe drinking water.

UNSAFE DRINKING WATER

Trucost used the data from the EXIOPOL study to calculate the median years of life lost (YLL) per 100,000 males and females within a country due to the consumption of unsafe drinking water. Population data obtained from the World Bank allowed YLL to be made country-specific via adjustments for the demographic breakdown of each nation by gender. The biophysical indicator used for determining YLL was the concentration of nitrates in drinking water.

To calculate the percentage of the national population exposed to unsafe drinking water, Trucost assumed that water was taken directly from freshwater lakes. Due to the ongoing complexities involved in estimating the quantity and quality of global groundwater it is currently out of scope, though a possible addition to future versions of this methodology.

For this approach, it was necessary to estimate the catchment area from average-sized lakes within each country to determine the proportion of the national population that were most likely to be affected by drinking unsafe water caused by eutrophication. Trucost assumed a three kilometer catchment area for each national average-sized lake. This was selected from a study that found that the majority of the world’s population live within three kilometers of a freshwater source (Kummu et al., 2011). The population density of each country was applied to calculate how many people live in the catchment area.

Finally, the percentage of the population with access to safe drinking water (World Bank Group, 2015) was removed from the calculation so that the valuation was only applied to those who were expected to be reliant on the consumption of unsafe drinking water.

Trucost used YLL as a proxy for DALYs as no information on the years of healthy life lost due to disability (YLD) from consuming eutrophic drinking water could be sourced.

SAFE DRINKING WATER

For the proportion of water that is safe to drink, there is an economic cost associated with cleaning the water to a high enough quality. The model used in this approach requires an input of phosphorus yield in a watershed in order to calculate the cost of treating eutrophic water. Information reported by the Nature Conservancy (McDonald & Shemie, 2014) was used to determine the incremental change in phosphorus from an initial sediment yield, which could be used to calculate the biophysical metric.

Economic Modelling

UNSAFE DRINKING WATER

Once the total YLL (hence DALYs) lost is calculated, several valuation methods can be used to put a monetary value on a DALY, such as the cost of illness, the value of a statistical life (VSL), and the value of a statistical life year (VOLY).

Trucost decided to use the WTP technique utilized in the VOLY method to value DALYs, as it encompasses most aspects relating to illness and expresses the value of a year of life to the wider population. To value DALYs, Trucost used the results of a stated preference study conducted in the context of the New Energy Externalities Development for Sustainability (NEEDS) project (Desaigues et al., 2006; 2011). This is a proactive cost estimate, which takes into account the perceived effects of morbidity. The value of a life year used in this methodology is just in excess of $46,500.

SAFE DRINKING WATER

With increasing sedimentation and nutrient load, the cost of removing sediments increases. A reduction in sedimentation from nutrient pollution by an average of 10% reduces treatment costs by 1.9% (McDonald & Shemie, 2014). This paper presents the relationship between phosphorus yield (tonnes of phosphorus per square kilometer of watershed) and treatment cost. The method was applied to calculate the total cost of water treatment after the unit mass of phosphorus has been applied in the watershed.

IMPACT ON ECOSYSTEMS

Biophysical Modelling

Trucost used the hedonic pricing approach in this methodology to quantify the impact on ecosystems, which estimates the effect of eutrophication on waterfront property prices, as these are significantly affected by water clarity (Gibbs et al., 2002). Secchi depth is the most widely used measure of water clarity, and a link between secchi depth and phosphorus level has been used to quantify the biophysical effect of eutrophication (Downing et al., 2010). This relationship has been investigated as early as the 1970s (see Canfield & Bachman, 1980).

Trucost calculated the increase in phosphorus equivalent concentration, in a national average-sized lake, associated with the use of one kilogram of nitrogen or phosphorus. Trucost calculated the marginal cost of an increase in eutrophication due to excess nutrient loading, changing the state of a lake from oligotrophic to eutrophic. The phosphorus concentration increase was calculated for an average-sized freshwater lake in a country. Using GIS data and the Global Lakes and Wetlands Database (Lehner & Döll, 2004), the median area of a lake, and the average perimeter of a median lake, was calculated for each country.

Trucost then converted the change in excess nutrient concentration into the change in secchi depth, and used the percentage change in secchi depth as the metric for valuation.

Economic Modelling

Trucost used data from three studies (Krysel et al., 2003; Gibbs et al, 2002; Michael et al., 1996) in the US, comprising a total of 44 estimates of water frontage price decreases (per foot) due to a one meter reduction in secchi depth, and calculated the median value.

Trucost adjusted the value for each country and calculated the price per waterfront meter. Finally, the value per waterfront meter for each country was applied to the perimeter of the average-sized national lake to establish the hedonic cost of eutrophication at a country-level.

For more information on the above, as well as sensitivity analysis for selected parameters, please refer to the full Trucost valuation methodology at Trucost (2015)

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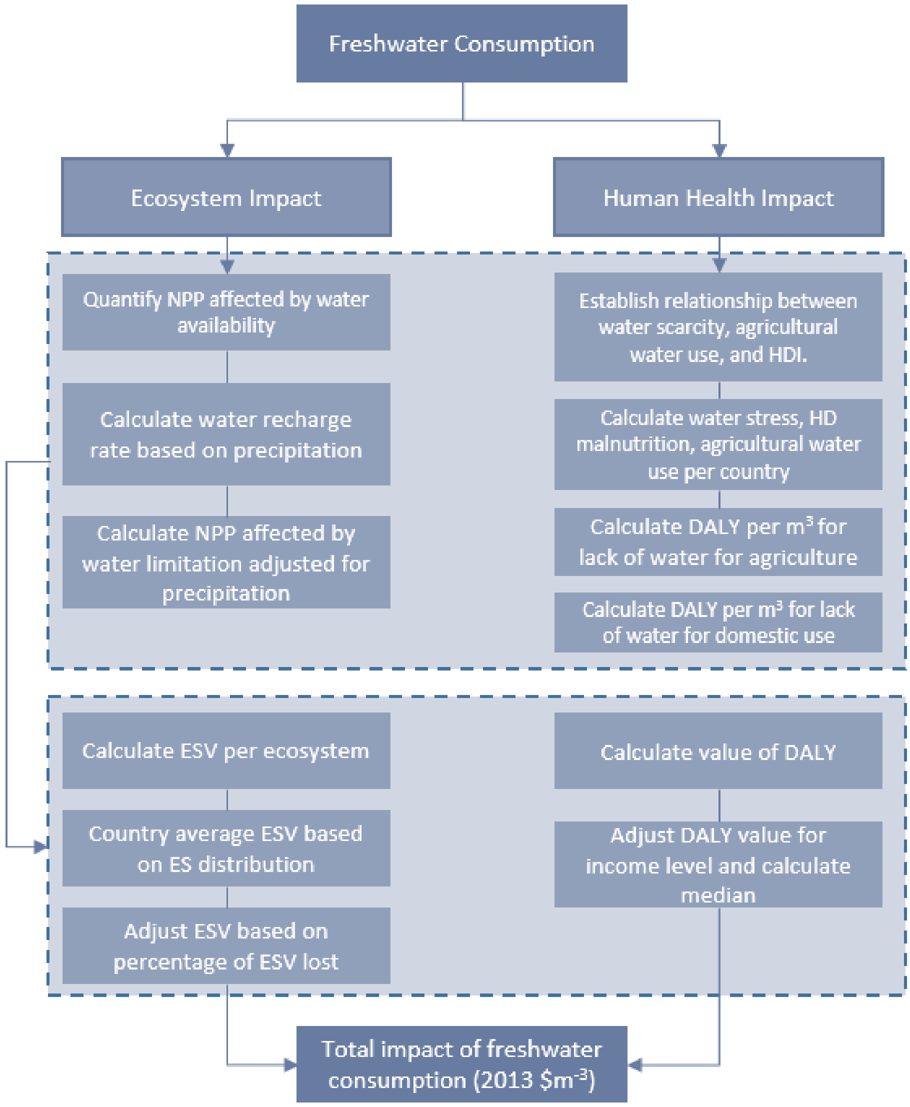
NATURAL CAPITAL VALUATION: WATER CONSUMPTION

OVERVIEW

GENERAL PROCESS

Figure A1.3 summarises the overall approach used to value water consumption. The first shaded box indicates the steps taken to quantify the environmental impact of water consumption, while the second indicates the steps taken to value these impacts.

Figure A1.3: General overview of Trucost valuation process for water consumption



LEGEND

- NPP: Net Primary Productivity
- ESV: Ecosystem Services Value
- HDI: Human Development Index
- DALY: Disability Adjusted Life Years

VALUATION METHODOLOGY SUMMARY

IMPACT ON HUMAN HEALTH

Biophysical Modelling

The quantification methodology for human health impacts due to water consumption was developed using an estimate of the disability adjusted life years (DALY) lost per unit of water consumed as reported in Eco-indicator 99 (Goedkoop & Spriensma, 2000). The impacts due to lack of water for irrigation and lack of domestic water are both quantified in 'DALYs per cubic meter' of water abstracted.

LACK OF WATER FOR IRRIGATION

In order to quantify human health impacts associated with malnutrition as a result of lack of water for irrigation, Trucost uses the methodology developed by Pfister (2011). This parameter is country-specific and depends on several variables such as water stress, share of total water withdrawals used for agricultural purposes, human development, and per-capita water requirement to prevent malnutrition.

LACK OF DOMESTIC WATER

For the quantification of human health impacts due to the spread of diseases, country-specific factors were sourced from Motoshita et al. (2010). This model is based on a multiple regression analysis and covers health impacts related to the incidence of diarrhea and three intestinal nematode infections: ascariasis, trichuriasis, and hookworm disease.

Economic Modelling

Once the quantity of DALYs lost is calculated, several valuation methods can be used to put a monetary value on a DALY, such as the cost of illness, the value of a statistical life (VSL), and the value of a statistical life year (VOLY).

Trucost decided to use the WTP technique utilized in the VOLY method to value DALYs, as it encompasses most aspects relating to illness and expresses the value of a year of life to the wider population. To value DALYs, Trucost used the results of a stated preference study conducted in the context of the New Energy Externalities Development for Sustainability (NEEDS) project (Desaigues et al., 2006; 2011). This is a proactive cost estimate, which takes into account the perceived effects of morbidity. The value of a life year used in this methodology is just in excess of $46,500.

IMPACT ON ECOSYSTEMS

Biophysical Modelling

Impacts of water consumption on ecosystems were measured based on net primary productivity (NPP). NPP, which is the rate of new biomass production (by plants) that is available for consumption, is used by Trucost as a measure of how well an ecosystem is functioning. NPP was considered here as a proxy to measure impacts on ecosystems, as it is closely related to the vulnerability of vascular plant species (Pfister, 2011). Furthermore, vascular plants are primary products in the food chain and are therefore essential for the healthy functioning of an ecosystem (*Ibid*). In addition, it is assumed that damage to vascular plants is representative of damage to all fauna and flora species in an ecosystem (Delft, 2010).

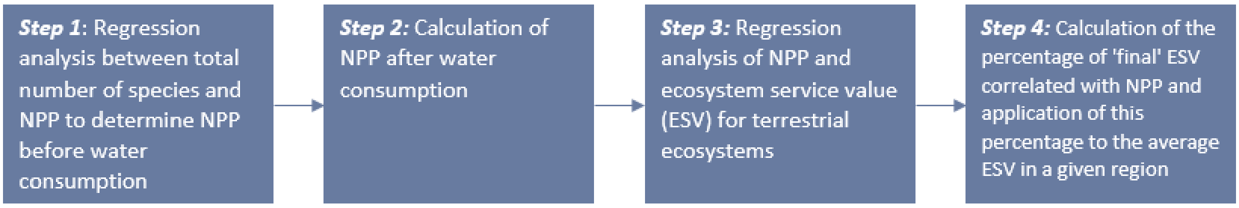
The objective of biophysical modelling is to determine the fraction of NPP which is limited only by water availability, and thus captures the vulnerability of an ecosystem to water deficiencies. However, as the effects of water consumption on ecosystems depend on local water availability, NPP is adjusted to take into account the prevailing water scarcity. Thus, the metric is expressed as the percentage of one square meter that will be affected by the consumption of one cubic meter of water in a year.

Economic Modelling

VALUING THE IMPACT ON ECOSYSTEMS IN THIS STUDY

Trucost's approach to valuing a change in NPP due to water abstraction follows a four-step process, as displayed in FIGURE below. The underlying approach calculates NPP before and after water consumption, and links those to the ecosystem service value (ESV) before and after water consumption. This allowed for quantifying the loss of ESV due to water abstraction.

FIGURE A1.4: STEPS FOR CALCULATING THE VALUE OF ECOSYSTEM SERVICES LINKED DIRECTLY TO BIODIVERSITY



Trucost first calculated the average NPP for each country in its database, based on the average NPP per ecosystem type (Costanza et al., 2007) and the ecosystem split per country (Olson et al., 2004). Species richness is based on the International Union for Conservation of Nature (IUCN) Red List, which provides at a country-level, the number of fauna and flora species, as well as their conservation status (IUCN, 2015).

Trucost then tested the strength of the relationship between NPP and species richness to assess whether a significant correlation exists. Trucost used this relationship to calculate the pre- and post-change in average NPP for each country in its dataset based on species richness

In order to calculate the post-change NPP, Trucost used the NPP limited by water availability to estimate the change in NPP that is attributable to water consumption. By using the percentage of NPP affected by water availability, the NPP remaining after water consumption was determined.

A monetary value for the provisioning, regulating and cultural services by terrestrial ecosystem type was first calculated based on the analysis of De Groot et al. (2012). De Groot et al calculate the minimum, maximum, median, average and standard deviation for each service provided by key terrestrial ecosystems.

Finally, Trucost calculated the percentage difference between pre- and post-water consumption ESV at a country level. Trucost applied this percentage to the average value of one square meter of natural ecosystem in a given region to align with the results of the biophysical modelling.

For more information on the above, as well as sensitivity analysis for selected parameters, please refer to the full Trucost valuation methodology at Trucost (2015)

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HUMAN CAPITAL VALUATION: UNDERPAYMENT

Underpayment occurs when hired workers do not receive enough financial and in-kind wages to provide for themselves and their families the standard of living as defined in the Universal Declaration of Human Rights.

> The Universal Declaration of Human Rights Article 25.1
>
> "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services, and the right to security in the event of unemployment, sickness, disability, widowhood, old age or other lack of livelihood in circumstances beyond his control"

In this study, the human capital cost of underpayment is represented by the living wage gap, i.e. the difference between the living wage and the average wage[19]. Following the methodological structure in Figure 2.4, the average wages are the footprint and the living wage gap is the change in valued attribute. As the living wage gap is already expressed in terms of income, no further transformation in monetary terms needs to be applied. True Price decided to use a valuation coefficient of 1$/$ underpayment for this study. This means that the living wage gap per worker equals the human capital cost of underpayment per worker. This is a conservative valuation coefficient as it does not take into account compensation or opportunity costs.

The living wage gap is only calculated for the proportion of workers that is underpaid, i.e. that have wages below the living wage. This is important, as in some cases the average wage of all workers is above the living wage, but a subgroup of workers might be severely underpaid. In these events, calculating an average living wage gap would give the false impression that there is no underpayment.

The average wage of a worker is calculated by summing up the financial wage with the financial value of in-kind benefits received, such as transport, schooling, rice and housing.

The calculation of the living wage is based on the costs for workers in palm oil producing areas of Indonesia to provide for their families the standard of living as defined in Universal Declaration of

[19] Note that underpayment is not considered necessarily as an external cost under all definitions. In particular if one considers labor as a marketable good only, a wage is in itself only a price on the labor market. Nonetheless, it can be considered a human capital cost as it is a broadly shared norm that wages should allow workers to cover their essential costs and from an economic perspective human capital depreciates if people cannot cover their essential costs.

Human Rights (UN General Assembly, 1948). A basic living income is constructed for an average household, which in this study consists of 3.9 members (Statistics Indonesia, 2013). Subsequently, insurance costs, pension contributions and income taxes are added to obtain the gross living income per household and gross living wage per FTE, assuming two earnings providers per household. Table A1.1 shows the breakdown of the living wage calculation.

TABLE A1.1: EXAMPLE LIVING WAGE BREAKDOWN FOR A PALM OIL PLANTATION WORKER IN INDONESIA

	US$/YEAR
Food	1,253
Housing	682
Clothing	161
Health & hygiene	106
Healthcare & social security	18
Transport & communication	609
Education	106
Basic living income/household	**2,935**
Insurance	174
Pension contribution	790
Net living income/household	**3,899**
Taxes	0
Gross living income/household	**3,899**
Gross living wage/FTE	**1,950**

True Price's methodological construction of the living wage is comparable to living wage calculations of amongst others Anker, Asian Floor Wage and Social Accountability International (Anker, 2011; Asian Floor Wage, 2009). These methods differ in the inclusion or exclusion of certain components (e.g. taxes and savings) or the way certain costs are calculated (e.g. clothing costs as a percentage of food costs). True Price calculates all components of the living wage in a granular and bottom-up way. For example, a family clothing basket is constructed and subsequently each piece of clothing is costed based on local market prices or surveys.

More information on the methodological foundations for impact measurement and valuations can be found in True Price (2016).

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HUMAN CAPITAL VALUATION: OCCUPATIONAL HEALTH

In this study, the human capital cost of health is calculated using the Disability Adjusted Life Years (DALY) approach. Following the methodological structure in Figure 2.4, incident rates are the footprint and the loss of DALY, caused by these incidents, is the change in valued attribute.

The total loss of DALY as a result of occupational incidents is calculated by summing up Years of Life Lost (YLL), caused by fatal incidents, with Years Lost due to Disability (YLD), caused by non-fatal incidents.

$DALY = YLL + YLD$
$YLL = N \times L$
$YLD = I \times DW \times L$

where:

- N = number of deaths
- L = standard life expectancy at age of death (years)
- I = number of incident cases
- DW = disability weight of average incident
- L = average duration of the case until remission or death (years)

This simplified calculation is based on the method described in the Global Burden of Disease (GBD) Study 2010 by the Institute for Health Metrics and Evaluation, which builds on earlier GBD studies commissioned by the World Bank and the World Health Organization (Murray, et al. 2010).

True Price based disability weights for light and heavy incidents as well as for cases of APP on the database of the Institute for Health Metrics and Evaluation (2012). To determine average durations of cases (incidents), True Price used Reed Group's MDGuidelines (Reed Group, 2015).

The cost of one loss of DALY in this study is estimated at $49,506 in 2014. This value was based on a European estimate published by the NEEDS project (Desaigues, et al., 2006, 2011) and subsequently adjusted for income to derive a global average. An alternative approach to determine the cost of one DALY can be to multiply the world average GDP per capita by three (World Health Organization, 2015). This would result in a cost of $39,300 /DALY. One important thing to note is that the DALY measure only takes into account compensation costs and no other costs, such as lost work days. This may result in an underestimated human capital cost of health.

The sensitivity of the result to the costing of a DALY, as well as to the estimated disability weights and durations of cases is shown in figure 4.15.

More information on the methodological foundations for impact measurement and valuations can be found in True Price (2016).

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APPENDIX 2: ADDITIONAL METHODOLOGICAL DETAIL AND DATA SOURCES

MATERIALITY ANALYSIS

Secondary life cycle analysis methods were used instead of primary data collection and input-output modelling to conduct the materiality assessment, due to data availability and granularity. The modeling of the growing phase includes the application of fertilizer and pesticide, the use of energy and water, and land conversion. Modeling of the milling phase includes the use of electricity, manufactured raw materials and water, and palm oil mill effluent management. Modeling of the refinery phase includes the use of electricity, energy, manufactured raw materials such as chemicals and water. The analysis combines the use of secondary global life-cycle assessment studies and the application of country-specific valuation coefficients, where data availability and quality is sufficient. The Agri-footprint database released in June 2014 was used to model the average impacts of refined palm and palm kernel oil (Agri-Footprint, 2014).

The methodology and assumptions are publicly available and the database accessible through the software Simapro 8. Agri-footprint was externally reviewed by the Centre for Design and Society, RMIT University, Melbourne, Australia. External reviewers checked the consistency and transparency of the methodology applied and completeness and transparency of data documentation.

The data corresponds to a typical farm and milling operation in Indonesia and Malaysia. Certain key data points were regionalized to be country-specific, where available and significant. These include yield, quantity of fertilizer used, quantity of water used, and type of land converted. All other data points were held constant across countries.

Table A2.1 describes the scope of the key performance indicators (KPIs) taken into account in this analysis for each practice selected.

TABLE A2.1: PRACTICES AND KPIS

INPUT: PRACTICE	MEASUREMENT: KPIs	DATA SOURCE
Land use change	Loss in carbon stored (above-ground and soil)	Direct Land Use Change Assessment Tool (Blonk Consultants, 2014)
Fertilizer application	Air, land and water pollution from application Indirect impacts of manufacture	Fertistat data on total quantity of nitrogen (N) and phosphate (P) chemical fertilizer used in a country per crop (Heffer, 2013) brought back to a quantity per ha using production and yield data of FAOStat (FaoStat, 2011)
Pesticide application	Land pollution from application Indirect impacts of manufacture	The quantity and type of pesticide applied was held constant and is based on AgriFootprint (2014)
Water use	Water depletion	Water Footprint Network (Mekonnen & Hoekstra, 2011) data on quantity of water per tonnes of fresh fruit bunch (FFB) at a country and province level.

Use of other inputs: energy, raw materials and transportation	Air, land and water pollution from use Indirect impacts of manufacture	FaoStat data on yields and conversion factors per ha (FaoStat, 2011)
POME management	Methane (greenhouse gas) emissions	

LAND USE CHANGE

The Direct Land Use Change Assessment Tool (Blonk Consultants, 2014) was used to estimate the type and extent of ecosystems converted into oil palm plantations at a country level. This tool is consistent with the PAS 2050-1 Protocol, which describes how to derive the attribution of land transformation to a given crop/country combination. The estimate is based on a number of reference scenarios for previous land use, combined with data from relative crop land expansions based on FAOStat. The percentage of peat soil is provided by Wetland International (Joosten, 2010).

FERTILIZER USE

Fertistat data was used on the total quantity of nitrogen (N) and phosphate (P) chemical fertilizer used in a country per crop (Heffer, 2013), brought back to a quantity per ha using production and yield data of FAOStat (FaoStat, 2011). Quantities of the different types of chemical fertilizer products applied in the field were calculated based on the N and P content of fertilizers and the relative split of fertilizer products as provided by Schmidt (2007) for Indonesia. Thus, the quantity rather than the type of fertilizer is country-specific in this materiality assessment.

The impact of fertilizer includes both the upstream impacts of manufacturing and the direct impacts of field application. Ecoinvent v3 was used (Swiss Center for Life Cycle Inventories, 2014) to calculate the upstream impacts of ammonium sulphate, urea, phosphate rock, potassium chloride and potassium sulphate production. Included were GHG emissions, eutrophication, and other toxic land and water pollutants, as well as water use.

Emissions related to the field application of fertilizer are calculated from mass balances on nitrogen (N) and phosphorus (P) during the oil palms lifecycle. The first step consists in quantifying all known inputs and outputs of N and P. Inputs and outputs vary from year to year. In the materiality assessment, a straight average over the 25 lifetime year of the plantation is used. In the Indonesia case study, results are presented per year.

TABLE A2.2: N AND P INPUTS USED IN THE MATERIALITY ANALYSIS

CATEGORY	ADJUSTEMENTS	SOURCE	INCLUDED IN:
INPUT – NET INPUTS			
Fertilizer (chemical)	Country-specific	Heffer, 2013	N and P balance
N-decomposition from the atmosphere	Fixed	Schmidt, 2007	N balance
N-Fixation by legumes	Fixed	Schmidt, 2007	
Planted palm seedlings	Fixed	Schmidt, 2007	N and P balance
Empty fruit bunches	Adjusted for yield	Schmidt, 2007; FaoStat, 2011	
Palm oil mills effluent	Adjusted for yield and extraction rate	Schmidt, 2007; FaoStat,2011	
INPUT - RELEASED FROM DECOMPOSITION OF BIOMASS			
Pruned fronds, present generation	Adjusted for yield	Schmidt, 2007; FaoStat,2011	N and P balance
Pruned fronds, previous generation	Adjusted for yield	Schmidt, 2007; FaoStat,2011	

Felled biomass, from replanting	Adjusted for yield	Schmidt, 2007; FaoStat,2011	
Dying back of legume cover crop	Fixed	Schmidt, 2007	N balance
OUTPUT – INCREASE IN STANDING BIOMASS			
Uptake in oil palms	Adjusted for yield	Schmidt, 2007; FaoStat,2011	N and P balance
Uptake in cover crop	Fixed	Schmidt, 2007	N balance
Pruned fronds	Adjusted for yield	Schmidt, 2007; FaoStat,2011	N and P balance
OUTPUT – HARVESTED FRESH FRUIT BUNCHES			
Harvested FFB	Adjusted for yield	Schmidt, 2007; FaoStat,2011	N and P balance

The residuals are then calculated and distributed on various emissions based on different models. The N surplus is distributed on emissions of ammonia, nitrous oxide, and nitrogen oxides to air; nitrate emissions to water; and indirect nitrogen oxide emissions to air from ammonia and nitrate. Phosphorus residual is all emitted to water. Table 2.10 describes the methodology for each emission. The N and P balance data used in the case study is available in Appendix.

TABLE A2.3: METHODOLOGY USED TO CALCULATE EMISSIONS BASED ON THE P AND N BALANCE

OUTPUT	ASSUMPTIONS	SOURCE
Ammonia to air from crops	5 kg NH3-N/ha	Schmidt, 2007
Ammonia from chemical fertilizer application	9.6% of applied N fertilizer	
Direct nitrous oxide from denitrification to air	Based on the quantity of chemical and organic fertilizer, presence of the legume cover, type of soil (peat or mineral)	
Direct nitrogen oxide to air	Based on the fertilizer quantity and type, type of soil (peat or mineral), and soil drainage	
Nitrate to water	Residual emissions from the N balance which was not distributed across other emissions	
Indirect nitrous oxide to air from ammonia and nitrate	0.025 kg per kg ammonia; 0.01 kg per kg nitrate/N	
Phosphorus emissions to water	Residual emissions from the P balance, 2.9% is emitted to water	
Phosphorus emissions to water, from erosion	0.9 kg P/ha	

The quantity of heavy metals to land is also determined based on the metal content of fertilizers and the quantity applied. It includes arsenic, cadmium, chromium, cobalt, copper, mercury, nickel, lead, selenium and zinc.

WATER USE

Water use data was sourced from the Water Footprint Network (Mekonnen & Hoekstra, 2011), which calculates quantity of water per tonnes of fresh fruit bunch (FFB) at a country and province level. No irrigation water is used at the growing stage for all countries under consideration here. The quantity and type of pesticide applied was held constant and is based on AgriFootprint (2014). Finally, FaoStat data was used on yields and conversion factors per ha (FaoStat, 2011). 2011 was used as the year of analysis for the yield and fertilizer data to be aligned.

PESTICIDE APPLICATION

The impact of pesticides includes both the upstream impacts of manufacturing and the direct impacts of field application. Ecoinvent v3 was used (Swiss Center for Life Cycle Inventories, 2014) to calculate the upstream impacts of glyphosate and chlorothalonil. No factors were found for cypermethrin and warfarin. Chlorothalonil was used as a proxy for these two substances. Upstream impacts include the GHG emissions, eutrophication, and other toxic land and water pollutants, as well as water use. Finally, to estimate the direct impacts of field application, all emissions were allocated to land.

OTHER INPUT USE

Other inputs include energy inputs (diesel, steam, electricity), and chemicals used in the milling and refinery stages (bleaching earth, phosphoric acid, nitrogen). Upstream impacts were calculated based on Ecoinvent V3 (Swiss Center for Life Cycle Inventories, 2014). They include the emission of greenhouse gas, eutrophying, and other land and water toxic land and water pollutants, as well as water use.

ALLOCATION

Economic allocation was used to allocate emissions throughout the palm oil supply chain to different by-products. Table 2.11 and 2.12 display the

factors used, based on Agrifootprint (2014) and FaoStat (2011).

TABLE A2.4: ALLOCATION FACTORS FOR 1 TONNE OF REFINED PALM OIL

COUNTRY	LIFECYCLE STAGE	PRODUCT/BY-PRODUCT	MASS (TONNES)	PERCENTAGE OF ECONOMIC VALUE
All	Refinery	Refined palm oil	1	95%
All	Refinery	Fatty acid distillates	0.07	5%
All	Milling	Crude oil	1	86%
Thailand	Growing	Fresh Fruit Bunches	6.53	NA
China	Growing		2.95	NA
Indonesia	Growing		4.55	NA
Malaysia	Growing		5	NA
Nigeria	Growing		8.60	NA
Colombia	Growing		5.73	NA
Papua New Guinea	Growing		3.57	NA
Cote d'Ivoire	Growing		4.41	NA
Honduras	Growing		5.01	NA
Brazil	Growing		4.82	NA
Guatemala	Growing		5.08	NA

TABLE A2.5: ALLOCATION FACTORS FOR 1 TONNE OF REFINED KERNEL OIL

COUNTRY	LIFECYCLE STAGE	PRODUCT/BY-PRODUCT	MASS (TONNES)	PERCENTAGE OF ECONOMIC VALUE
All	Refinery	Refined kernel oil	1	98%

All	Refinery	Tonnes of soap stock	0.6	2%
All	Crushing	Crude kernel oil	1.06	90%
All	Crushing	Expeller	1.2	10%
All	Milling	Kernels	2.27	14%
Thailand	Growing	Fresh Fruit Bunches	75	NA
China	Growing		25.08	NA
Indonesia	Growing		40.68	NA
Malaysia	Growing		46.93	NA
Nigeria	Growing		15.67	NA
Colombia	Growing		48.33	NA
Papua New Guinea	Growing		46.51	NA
Cote d'Ivoire	Growing		40.40	NA
Honduras	Growing		49.65	NA
Brazil	Growing		11.10	NA
Guatemala	Growing		16.94	NA

A detailed breakdown of inputs and outputs at each life cycle stage is available next.

A2.6: DETAILED INPUTS AND OUTPUTS FOR THE PRODUCTION OF ONE TONNE OF PALM OIL

	THAILAND	**CHINA**	**INDONESIA**	**MALAYSIA**	**NIGERIA**	**COLOMBIA**	**PAPUA NEW GUINEA**	**CÔTE D'IVOIRE**	**HONDURAS**	**BRAZIL**	**GUATEMALA**	**UNIT**
GROWING												
INPUTS												
Energy	1,350	852	1,043	893	2,304	1,536	957	1,181	1,341	1,578	1,361	mj
Ammonium sulphate	70	90	67	56	108	111	83	56	116	94	78	kg
Urea	12	15	11	10	19	19	14	10	20	16	13	kg
Phosphate rock	28	21	14	22	33	28	14	17	32	26	33	kg
Ammonium phosphate	2	1	1	1	2	2	1	1	2	2	2	kg
KCl	37	30	44	68	90	60	37	46	52	58	53	kg
K2S04	2	2	3	4	5	3	2	3	3	3	3	kg
Glysophate	1	0	1	0	1	1	1	1	1	1	1	kg
Cypermethrin	0	0	0	0	0	0	0	0	0	0	0	kg
Chlorothalonil	0	0	0	0	0	0	0	0	0	0	0	kg

Warfarin	0	0	0	0	0	0	0	0	0	0	0	kg
OUTPUTS												
Ammonia to air – fertilizers	2	3	2	2	4	4	3	2	4	3	3	kg
Ammonia to air – crops	2	1	1	1	0	2	1	1	2	1	2	kg
N20 to air – direct	2	1	3	2	2	2	2	1	2	1	1	kg
N20 to air - indirect	1	1	1	1	1	1	1	1	1	1	1	kg
NO to air	1	0	1	0	1	1	1	0	1	1	1	kg
Nitrate to water	83	114	77	59	148	143	103	76	146	132	104	kg
phosphorus to water	0	0	0	0	1	1	0	0	1	1	1	kg
Arsenic	11	11	8	9	15	14	9	8	15	12	13	mg
Cadmium	264	200	134	207	311	260	131	159	301	244	304	mg
Chromium	6,239	4,771	3,199	4,875	7,360	6,177	3,149	3,773	7,159	5,793	7,170	mg
Cobalt	17	22	16	14	27	27	20	14	29	23	20	mg
Copper	1,493	1,307	907	1,171	1,880	1,668	971	964	1,877	1,519	1,707	mg
Mercury	1	1	1	1	2	2	1	1	2	1	1	mg
Nickel	464	378	258	363	564	487	265	289	556	450	532	mg
Lead	158	139	96	124	199	177	103	102	199	161	181	mg
Selenium	20	18	12	16	25	23	13	13	25	21	23	mg
Zink	5,514	4,652	3,200	4,320	6,818	5,959	3,355	3,495	6,758	5,468	6,314	mg
Glyphosate to soil	0	0	0	0	0	0	0	0	0	0	0	kg
Cypermethrin to soil	0	0	0	0	0	0	0	0	0	0	0	kg
Chlorothalonil to soil	0	0	0	0	0	0	0	0	0	0	0	kg
Warfarin to soil	0	0	0	0	0	0	0	0	0	0	0	kg
C02 from drainage of peat soil	17	31	3,359	1,150	173	105	1,386	63	316	108	18	kg
C02 - carbon stock changes	-	-	2	1	4	-	1	-	1	-	1	tonnes
MILLING												
INPUTS												

Energy	160	72	112	123	211	141	88	108	123	118	124	MJ
Water	4	2	3	3	5	3	2	3	3	3	3	tonnes
Electricity	4	2	3	3	6	4	2	3	3	3	3	MJ
OUTPUTS												
Methane to air	49	22	34	37	64	43	27	33	37	36	38	kg
REFINERY												
INPUTS												
Water	123	123	123	123	123	123	123	123	123	123	123	kg
Bleaching earth	11	11	11	11	11	11	11	11	11	11	11	kg
Phosphoric Acid	1	1	1	1	1	1	1	1	1	1	1	kg
Nitrogen	1	1	1	1	1	1	1	1	1	1	1	kg
Steam	300	300	300	300	300	300	300	300	300	300	300	kg
Electricity	27	27	27	27	27	27	27	27	27	27	27	kwh

TABLE A2.7: DETAILED INPUTS AND OUTPUTS FOR THE PRODUCTION OF ONE TONNE OF KERNEL PALM OIL

	THAILAND	**CHINA**	**INDONESIA**	**MALAYSIA**	**NIGERIA**	**COLOMBIA**	**PAPUA NEW GUINEA**	**CÔTE D'IVOIRE**	**HONDURAS**	**BRAZIL**	**GUATEMALA**	**UNIT**
GROWING												
INPUTS												
Energy	2,283	1,065	1,375	1,235	618	1,907	1,835	1,593	1,959	535	668	mj
Ammonium sulphate	118	112	88	77	29	137	159	75	169	32	39	kg
Urea	20	19	15	13	5	24	27	13	29	5	7	kg
Phosphate rock	48	27	19	31	9	34	26	23	47	9	16	kg
Ammonium phosphate	3	2	1	2	1	2	2	1	3	1	1	kg
KCl	63	37	58	94	24	75	72	62	77	20	26	kg
K2S04	4	2	3	5	1	4	4	4	4	1	2	kg
Glysophate	1	1	1	1	0	1	1	1	1	0	0	kg

Cypermethrin	0	0	0	0	0	0	0	0	0	0	0	kg
Chlorothalonil	0	0	0	0	0	0	0	0	0	0	0	kg
Warfarin	0	0	0	0	0	0	0	0	0	0	0	kg
OUTPUTS												
Ammonia to air - fertilizers	4	4	3	3	1	5	5	3	6	1	1	kg
Ammonia to air - crops	3	1	2	2	0	3	2	1	2	0	1	kg
N20 to air - direct	3	1	4	2	1	2	3	2	3	1	1	kg
N20 to air - indirect	1	1	1	1	0	2	2	1	2	0	0	kg
NO to air	1	1	1	1	0	1	1	1	1	0	0	kg
Nitrate to water	140	142	102	82	40	177	197	103	214	45	51	kg
Phosphorus to water	1	0	0	0	0	1	1	0	1	0	0	kg
Arsenic	19	14	10	12	4	17	17	10	22	4	6	mg
Cadmium	447	250	176	285	83	322	251	215	440	83	149	mg
Chromium	10,550	5,963	4,215	6,738	1,974	7,669	6,038	5,089	10,458	1,965	3,520	mg
Cobalt	30	27	21	19	7	34	38	19	42	8	10	mg
Copper	2,525	1,634	1,196	1,619	504	2,071	1,862	1,300	2,742	515	838	mg
Mercury	2	2	1	1	0	2	2	1	3	0	1	mg
Nickel	784	473	340	502	151	604	509	390	812	153	261	mg
Lead	267	173	127	171	53	220	198	138	291	55	89	mg
Selenium	34	22	16	22	7	28	26	18	37	7	11	mg
Zink	9,323	5,814	4,217	5,971	1,829	7,399	6,435	4,714	9,872	1,855	3,100	mg
Glyphosate to soil	0	0	0	0	0	0	0	0	0	0	0	kg
Cypermethrin to soil	0	0	0	0	0	0	0	0	0	0	0	kg
Chlorothalonil to soil	0	0	0	0	0	0	0	0	0	0	0	kg
Warfarin to soil	0	0	0	0	0	0	0	0	0	0	0	kg
C02 from drainage of peat soil	29	39	4,426	1,590	46	131	2,658	85	461	37	9	kg
C02 - carbon stock changes	-	-	3	1	1	-	1	-	2	-	0	tonnes
MILLING												

INPUTS												
Energy	24	11	16	18	31	21	13	16	18	17	18	MJ
Water	1	0	0	0	1	0	0	0	0	0	0	tonnes
Electricity	1	0	0	0	1	1	0	0	0	0	0	MJ
OUTPUTS												
Methane to air	7	3	5	6	9	6	4	5	6	5	5	kg
CRUSHING												
INPUTS												
Water	-	-	-	-	-	-	-	-	-	-	0	kg
Electricity	838	838	838	838	838	838	838	838	838	838	837	MJ
REFINERY												
INPUTS												
Water	-	-	-	-	-	-	-	-	-	-	0	kg
Bleaching earth	4	4	4	4	4	4	4	4	4	4	4	kg
Phosphoric Acid	-	-	-	-	-	-	-	-	-	-	0	kg
Sulfuric acid	-	-	-	-	-	-	-	-	-	-	0	kg
Activated carbon	-	-	-	-	-	-	-	-	-	-	0	kg
Sodium hydroxide	-	-	-	-	-	-	-	-	-	-	0	kg
Energy	356	356	356	356	356	356	356	356	356	356	356	MJ
Process steam	577	577	577	577	577	577	577	577	577	577	577	MJ
Electricity	47	47	47	47	47	47	47	47	47	47	47	kwh

INDONESIA CASE STUDY

LAND USE CHANGE

The same methodology and sources were used to calculate the change in carbon stock as in the Materiality Assessment. Impacts considered within the scope include change in aboveground and soil carbon stock for the mechanical clearing scenarios, as well as air pollutants from biomass and peat soil burning for the scenarios with fire clearing. The difference between baseline and oil palm plantations carbon stocks represent a net loss to the environment:

- Forests in Indonesia are assumed to hold 195 tonnes of carbon per hectare, including 141 from above-ground biomass;
- Grasslands 61 tonnes, including 7.6 from above-ground biomass;
- Disturbed forests 89 tonnes; and oil palm plantations 113 tonnes, including 60 from above-ground biomass (FAO, 2014; (European Commission, 2010; IPCC Task Force on National Greenhouse Gas Inventories, 2003 in Blonk Consultants, 2014).

These estimates fall between the ranges provided in the literature. For example, based on an extensive literature review, Germer and Sauerborn calculated the total and below ground carbon stocks of tropical lowland forest to be 171 +/- 89 tonnes of carbon per ha. Similarly, estimates of oil palm plantations' carbon uptake range from 50 tonnes per ha to over 100 tonnes per ha (Brinkmann Consultancy, 2009).

When cleared mechanically, carbon is released as biomass decomposes while carbon is sequestered by growing oil palms. Decay and uptake are faster over the first few years and then slows down (Germer & Sauerborn, 2008). A linear decay and linear uptake over 25 years was assumed to calculate net emissions per year over the plantation lifetime. There are many uncertainties around exact timelines and percentages decomposition of biomass (Weijie, et al., 2013). This assumption may underestimate the net present cost of land clearing when discounting is applied.

Peatland drainage emissions are estimated to be 14t per ha per year (Agus, et al., 2011). This average figure may vary depending on drainage depth (Page, et al., 2011). Conversion of peatland to oil palm plantations requires drainage of 60 to 80 cm below soil surface, causing carbon losses through peat oxidation and increased fire risk. It should be noted that the mapping of peat depth, carbon storage capacity, and the resulting extent of the oxidation process is not well understood and as such constitutes a major area of uncertainty (Lucey, et al., 2014).

When using fire as a land clearing technique, a large quantity of carbon is released. It was assumed that 50% of tropical forest biomass is combusted, leaving the rest to decompose with a linear decay over 25 years (Brinkmann Consultancy, 2009). For fire on peat soil, it is estimated that 7% of the 33 t of peat per ha burn (calculated based on Agus, et al., 2011; Murdiyarso, et al., Undated; Page, Undated). Fire propagation outside of the area burnt on purpose is not taken into account; figures provided in this study are thus conservative.

Air pollutant emission from burnt biomass, or haze, is also calculated (Christian, et al., 2003) (Akagi, et al., 2011), and based on Indonesia-specific emission factors per kg of tropical forest and peatland biomass. 24 air pollutants are taken into account, including but not limited to ammonia, nitrogen oxides and particulate matter.

The impact of land use change is calculated based on the difference in carbon stock between the original ecosystem and palm oil plantations. This relates to the carbon sequestration service of these systems and does not include other provisioning, regulating and cultural services. For this reason, the impact of land use change is probably underestimated.

The carbon stock calculations are based on IPCC rules. The basic approach is to first calculate the carbon stocks in the soil and vegetation of the original ecosystem and then subtract these from those of the plantation, to arrive at the net carbon stock change. Above-ground and soil carbon quantities are based on IPCC default values (2006), the Global Forest Resources Assessment (2010) and the European Commission (2010) used in (Blonk Consultants, 2014). Table A2.8 provides the detailed breakdown of carbon stocks for each ecosystem and country included in the analysis.

TABLE A2.8: TONNES OF CO_2 (SOIL AND ABOVE GROUND) PER HA

	FOREST	GRASSLAND	PERMANENT CROP	ARABLE	PALM OIL
Thailand	366	212	249	89	404
China	298	173	320	130	382
Indonesia	714	224	312	94	416
Malaysia	805	245	339	107	437
Nigeria	645	191	208	87	388
Colombia	646	221	310	93	413
Papua New Guinea	544	223	308	102	415
Cote d'Ivoire	864	206	232	86	398
Honduras	576	235	283	100	427
Brazil	680	222	276	93	414
Guatemala	645	257	316	110	449

An amortization period of 20 years is used, consistent with the recommendations of PAS-1 2050 and IPCC guidance for GHG inventories (Blonk Consultants, 2014).

GHGs emissions from peat soils drainage were also included, using a factor of 14 tonnes of carbon per ha (Brinkmann Consultancy, 2009).

FERTILIZER USE

The nitrogen (N) and phosphorus (P) balance is calculated on a yearly basis over the full lifecycle of the plantation based on inputs such as chemical fertilizers, N-fixation by legumes, EFB, POME, and pruned fronds, and outputs such as uptake in oil palms, legume cover, pruned fronds and harvested FFB. Yearly residuals are then calculated and allocated to emissions to air, land and water using formulas developed by FAO and IPCC (IPCC, 2000; (FAO & IFA, 2001 in Schmidt, 2007).

The model developed by Schmidt (2007) was adapted to calculate the residuals and corresponding emissions for each scenario. In scenario 2 and 3, the chemical fertilizer input was adjusted in order to minimize residual emissions. Yields are held constant as the primary focus of this analysis is to calculate the benefit of fertilizer optimization for a given quantity of FFB. Tables 4.9 and 4.10 display the N and P balance for each scenario.

In the baseline scenario, 2,618 kg of N and 764 kg of P is applied over the 25 years, leading to an N-balance and P-balance of 1,887 kg of N and 545 kg of P respectively. Inputs of chemical fertilizer could thus be decreased without impacting overall yields.

In scenario 1, the use of chemical fertilizer is optimized alongside organic inputs such as FFB, POME and felled fronds. In this scenario, the N and P balance is decreased to 447 and 0 kg of N and P respectively. Related emissions of nitrates, ammonia, nitrogen oxide, nitrous oxide and phosphorus are thus lower in this scenario.

In scenario 2, only chemical fertilizers are used, but the quantity of chemical fertilizer applied is optimized to reduce residual emissions. The total quantity of fertilizer applied is 5,201 kg of N per ha and 619 kg of P per ha. Yet, the N and P balance, as well as associated emissions, are lower than the baseline scenario. The N and P balance is also lower than scenario 1.

The distribution of emissions varies between scenario 1 and 2. Scenario 1 leads to higher emissions of nitrates to water, especially in the first years when the release of nitrogen by the legume cover is higher than the requirements of the plantation. Scenario 2 leads to higher emissions of ammonia, nitrogen oxide and nitrous oxide to air due to the application of chemical fertilizer.

In addition, the baseline scenario and scenario 2 yield higher emissions of heavy metals to land, due to the higher application of chemical fertilizer. 1.18 kg of heavy metals is emitted in scenario 1; 0.39 kg in scenario 2 and 0.47 kg in scenario 3. Finally, manufacturing the quantity of fertilizer applied in the baseline scenario emits 6 tonnes of greenhouse gases, compared to 3 tonnes in scenario 1 and 12 tonnes in scenario 2.

The appendix provides a detailed breakdown of the data used to compute the N and P balance.

TABLE A2.9: N BALANCE DATA USED IN THE INDONESIA CASE STUDY

N BALANCE	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
INPUTS - NET INPUTS													
N-Fertilizer – Baseline	90	90	106	106	106	106	106	106	106	106	106	106	106
N-Fertilizer - Scenario 1	98	-	-	-	-	60	66	66	66	66	68	68	68
N-Fertilizer - Scenario 2	11	22	205	209	215	223	228	228	228	228	231	231	231
N-decomposition from the atmosphere	18	18	18	18	18	18	18	18	18	18	18	18	18
N-Fixation by legumes	200	160	120	80	40	-	-	-	-	-	-	-	-
Planted palm seedlings	9	-	-	-	-	-	-	-	-	-	-	-	-
EFB	12	12	12	12	12	12	12	12	12	12	12	12	12
POME	3	3	3	3	3	3	3	3	3	3	3	3	3
INPUTS - RELEASE FROM DECOMPOSITION OF BIOMASS													
Pruned fronds, present generation	-	-	33	98	131	131	131	131	131	131	131	131	131
Dying back of legume cover crop	-	72	72	72	72	-	-	-	-	-	-	-	-
OUTPUT: INCREASE IN STANDING BIOMASS													
Uptake in oil palms	36	36	36	36	36	36	36	36	36	36	36	36	36
Uptake in cover crop	289	-	-	-	-	-	-	-	-	-	-	-	-
Pruned fronds	-	-	131	131	131	131	131	131	131	131	131	131	131

OUTPUT: HAVESTED FFB													
Harvested FFB	-	-	31	36	40	47	52	52	52	52	55	55	55
N balance – Baseline	**7**	**319**	**166**	**186**	**174**	**55**	**50**	**50**	**50**	**50**	**48**	**48**	**48**
Nitrates to water (kg)	0	1,351	666	755	703	182	161	161	161	161	150	150	150
Ammonia to air (kg)	16	16	18	18	18	18	18	18	18	18	18	18	18
N20 to air (kg)	6	19	13	14	13	7	6	6	6	6	6	6	6
N0 to air (kg)	2	2	2	2	2	2	2	2	2	2	2	2	2
N balance - Scenario 1	**15**	**214**	**12**	**3**	**4**	**9**	**10**	**10**	**10**	**10**	**10**	**10**	**10**
Nitrates to water (kg)	2	932	40	2	3	1	3	3	3	3	1	1	1
Ammonia to air (kg)	17	6	6	6	6	13	14	14	14	14	14	14	14
N20 to air (kg)	6	13	4	4	4	4	4	4	4	4	4	4	4
N0 to air (kg)	2	1	1	1	1	2	2	2	2	2	2	2	2
N balance - Scenario 2	**2**	**4**	**25**	**24**	**26**	**26**	**27**	**27**	**27**	**27**	**27**	**27**	**27**
Nitrates to water (kg)	0	4	6	1	3	3	2	2	2	2	3	3	3
Ammonia to air (kg)	7	9	30	30	31	32	32	32	32	32	33	33	33
N20 to air (kg)	0	1	4	4	4	4	5	5	5	5	5	5	5
N0 to air (kg)	1	1	4	4	4	4	4	4	4	4	4	4	4

	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Total**
INPUTS - NET INPUTS													
N-Fertilizer - Baseline	106	106	106	106	106	106	106	106	106	106	106	106	-
N-Fertilizer - scenario 1	68	68	68	66	66	66	63	63	60	58	55	55	-
N-Fertilizer - scenario 2	231	231	231	229	229	229	226	226	223	220	218	218	-
N-decomposition from the atmosphere	18	18	18	18	18	18	18	18	18	18	18	18	-
N-Fixation by legumes	-	-	-	-	-	-	-	-	-	-	-	-	-
Planted palm seedlings	-	-	-	-	-	-	-	-	-	-	-	-	-
EFB	12	12	12	12	12	12	12	12	12	12	12	12	-
POME	3	3	3	3	3	3	3	3	3	3	3	3	-
INPUTS - RELEASE FROM DECOMPOSITION OF BIOMASS													
Pruned fronds, present generation	131	131	131	131	131	131	131	131	131	131	131	131	-
Dying back of legume cover crop	-	-	-	-	-	-	-	-	-	-	-	-	-
OUTPUT: INCREASE IN STANDING BIOMASS													
Uptake in oil palms	36	36	36	36	36	36	36	36	36	36	36	36	-
Uptake in cover crop	-	-	-	-	-	-	-	-	-	-	-	-	-
Pruned fronds	131	131	131	131	131	131	131	131	131	131	131	131	-
OUTPUT: HAVESTED FFB													
Harvested FFB	55	55	55	52	52	52	50	50	47	45	43	43	-
N balance - Baseline	**48**	**48**	**48**	**50**	**50**	**50**	**53**	**53**	**55**	**58**	**60**	**60**	**1,887**
Nitrates to water (kg)	150	150	150	161	161	161	171	171	182	192	203	203	6,806
Ammonia to air (kg)	18	18	18	18	18	18	18	18	18	18	18	18	455
N20 to air (kg)	6	6	6	6	6	6	7	7	7	7	7	7	195
N0 to air (kg)	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**53**

N balance - Scenario 1	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**9**	**10**	**9**	**9**	**447**
Nitrates to water (kg)	1	1	1	3	3	3	2	2	1	3	2	2	1,021
Ammonia to air (kg)	14	14	14	14	14	14	13	13	13	13	12	12	312
N20 to air (kg)	4	4	4	4	4	4	4	4	4	4	4	4	116
N0 to air (kg)	2	2	2	2	2	2	2	2	2	2	2	2	41
N balance - Scenario 2	**27**	**27**	**27**	**28**	**28**	**28**	**27**	**27**	**26**	**26**	**26**	**26**	**619**
Nitrates to water (kg)	3	3	3	5	5	5	4	4	3	2	4	4	79
Ammonia to air (kg)	33	33	33	33	33	33	32	32	32	31	31	31	754
N20 to air (kg)	5	5	5	5	5	5	5	5	4	4	4	4	104
N0 to air (kg)	4	4	4	4	4	4	4	4	4	4	4	4	97

TABLE A2.10: P BALANCE DATA USED IN THE INDONESIA CASE STUDY

NET INPUTS													
P- Fertilizer - Baseline	15	15	32	32	32	32	32	32	32	32	32	32	32
P- Fertilizer - scenario 1	1	2	13	9	8	9	9	9	9	9	10	10	10
P- Fertilizer - scenario 2	3	4	17	18	19	20	20	20	20	20	21	21	21
Planted palm seedlings	1	-	-	-	-	-	-	-	-	-	-	-	-
EFB	1	1	1	1	1	1	1	1	1	1	1	1	1
POME	0	0	0	0	0	0	0	0	0	0	0	0	0
INPUTS - RELEASE FROM DECOMPOSITION OF BIOMASS													
Pruned fronds, present generation	-	-	2	7	9	9	9	9	9	9	9	9	9
OUTPUT: INCREASE IN STANDING BIOMASS													
Uptake in oil palms	4	4	4	4	4	4	4	4	4	4	4	4	4
Pruned fronds	-	-	9	9	9	9	9	9	9	9	9	9	9
OUTPUT: HAVESTED FFB													
Harvested FFB	-	-	4	5	6	7	8	8	8	8	8	8	8
	0	0	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1
	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1	1	1	1	1
	0	0	0	0	0	0	0	0	0	0	0	0	0
	1	1	1	1	1	1	1	1	1	1	1	1	1

	14	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**Total**
NET INPUTS													
P-Fertilizer – Baseline	32	32	32	32	32	32	32	32	32	32	32	32	-

P- Fertilizer - scenario 1	10	10	10	9	9	9	9	9	9	8	8	8	-
P- Fertilizer - scenario 2	21	21	21	20	20	20	20	20	20	19	19	19	-
Planted palm seedlings	-	-	-	-	-	-	-	-	-	-	-	-	-
EFB	1	1	1	1	1	1	1	1	1	1	1	1	-
POME	0	0	0	0	0	0	0	0	0	0	0	0	-
INPUTS - RELEASE FROM DECOMPOSITION OF BIOMASS													
Pruned fronds, present generation	9	9	9	9	9	9	9	9	9	9	9	9	-
OUTPUT: INCREASE IN STANDING BIOMASS													
Uptake in oil palms	4	4	4	4	4	4	4	4	4	4	4	4	-
Pruned fronds	9	9	9	9	9	9	9	9	9	9	9	9	-
OUTPUT: HAVESTED FFB													
Harvested FFB	8	8	8	8	8	8	7	7	7	7	6	6	-
P balance – Baseline	**22**	**22**	**22**	**22**	**22**	**22**	**23**	**23**	**23**	**23**	**24**	**24**	**545**
P to water (kg)	1	1	1	1	1	1	1	1	1	1	1	1	16
P to water -erosion (kg)	1	1	1	1	1	1	1	1	1	1	1	1	22
P balance - Scenario 1	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
P to water (kg)	0	0	0	0	0	0	0	0	0	0	0	0	0
P to water -erosion (kg)	1	1	1	1	1	1	1	1	1	1	1	1	22
P balance - Scenario 2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
P to water (kg)	0	0	0	0	0	0	0	0	0	0	0	0	0
P to water -erosion (kg)	1	1	1	1	1	1	1	1	1	1	1	1	22

WAGES AND OCCUPATIONAL HEALTH AND SAFETY

For both human capital practices, a bottom-up approach was used to calculate the footprints and changes in value attributes.

For human capital valuations, a key driver of results is the labor intensity or labor index, which can be expressed in full-time employee (FTE) per ha or FTE per tonne of output product. For example, if an average worker is underpaid by $100/year, than a high labour intensity will drive up the human capital cost per tonne of output product. Naturally, yield is also a key driver of human capital cost per tonne of output product.

Table A2.11 summarizes the key data sources used to determine the foot printing data of the baseline plantation and other characteristics used for the intervention scenario. Input data for the calculation of human capital costs was derived mainly from the top CPO (crude palm oil) producing provinces (Indonesia Ministry of Agriculture, 2014): Riau (26% of total Indonesian CPO production), North Sumatra (16%) and Central Kalimantan (10%).

TABLE A2.11: KEY DATA SOURCES USED TO DETERMINE THE CHARACTERISTICS OF THE BASELINE PLANTATION

DATA POINT	KEY DATA SOURCES
Labour Index	Ginoga et al. 2002, Mutu certification 2011, World Agroforestry Centre 2012, Bakrie Global 2011
% harvesters and pesticide sprayers	Lentera Rakyat 2014
% casual workers (SKU) and permanent workers (BHL)	Marti 2008, Sajogyo Institute 2014
Average wage casual worker (SKU) and permanent worker (SKU)	Sawit Watch 2014, Sajogyo Institute 2014, Sinaga 2013, Marti 2008, Sawit Watch 2011, Oxfam 2013, ILRF & Sawit Watch 2013, Larasati & Howell 2014
Light accident rate	Kulim (Malaysia) Berhad 2013, Situmorang 2010, Bakri Sumatera Plantations 2013, PT Astra Agro Lestari Tbk 2012, Mutu Certification (2009, 2013a, 2013b, 2013c, 2013d), Matthews 2008
Heavy accident rate	
Fatal accident rate	
Acute pesticide poisoning (APP) rate	
Amount of workers using personal protective equipment (PPE)	Thongrak et al. 2011, Brandi et al. 2013

To calculate changes in value attribute for the occupation health cost, disability weights and durations of accidents had to be determined (more information on the methodology is provided in Appendix 1). The former were based on data from the Institute for Health Metrics and Evaluation (2012) and the latter on Reed Group's MDGuidelines (Reed Group, 2015).

To calculate changes in value attribute for the underpayment cost, i.e. the amount of underpayment, an Indonesian living wage had to be determined. A basic living income was constructed for an average household of 3.9 members (Statistics Indonesia, 2013). The input data for this living wage were mainly based on national and regional household expenditure surveys and local market price research. A gross living wage of $1,950 was obtained, which falls between the living wages calculated by the Indonesian government for the top palm oil producing provinces, varying between $1,209 and $2,144 per FTE (Wahyuni, 2014). A breakdown of the living wage is provided in the main body and more information on the methodology can be found in Appendix 1.

The intervention affecting the occupational health cost is based on a decrease in acute pesticide poisoning (APP) of 44.3% for pesticide sprayers when more than 2 pieces of PPE are used, as found by Dasgupta et al. (2007).

FINANCIAL ANALYSIS

The principal objective of the financial quantification is to align the natural and human capital optimization scenarios assessed with the associated required capital and operating expenditure.

A thorough literature review revealed the analysis conducted by Fairhurst and McLaughin (2009) as the most appropriate basis for calculation due to the granularity of reported primary financial costs data (Fairhurst & McLaughlin, 2009). They develop plantation lifetime cash flow models for four different planting scenarios after interviews and reviews with financial and management staff in seven estates visited in Kalimantan, Indonesia. The establishment and operating cash flow components were analyzed and adapted to match the assumptions in this study's analysis as follows.

PRACTICE 1: LAND SELECTION AND CLEARING METHODS

Land selection and clearing is assumed to take place in year 0 and to encompass the following costs:

- Mechanical clearing calculated based clearing costs on mineral soil and weed control (incl. labour and inputs)
- Fire-clearing costs on mineral soil calculated based on slash, cut, slice and burn costs
- Peat soil costs inflated from mineral soil costs by 33% in line with Budidarsono et al., 2012.

PRACTICE 2: FERTILIZER APPLICATION

Fertilizer application scenarios are assessed in the context of the lifetime operation of the plantation. Three practices, business-as-usual and two optimization scenarios are assessed for their financial viability alongside the natural capital implications. Operational costs encompass:

- Fertilizer application: throughout lifetime of plantation: In line with broader literature, Fairhurst and McLaughin (2009) report in their study that fertilizers represent the largest plantation variable cost due to differences in procurement strategy (Fairhurst & McLaughlin, 2009). For example, some estates have long-term fixed price contracts whilst others purchase according to needs. In this assessment, an average fertilizer cost per type of fertilizer (nitrogenous, phosphatic and potassic) is derived from the UN Comtrade database Indonesia-specific 2013 import quantity and import value (United Nations, 2013).
- Legume cover plants: allocated to year 1 only when appropriate

PRACTICES 3 AND 4: WAGES AND OCCUPATIONAL HEALTH & SAFETY

The intervention to reduce the underpayment cost consists of paying casual workers a living wage. The financial viability of this intervention is assessed by increasing the labor costs of the plantation. On the one hand wage costs are increased by adding the accumulated living wage gap of all casual workers (full time equivalents). On the other hand, the social security contribution that the plantation has to pay increases, as this is dependent on wage levels. Labor costs that occur during the establishment phase are classified as investment costs.

The intervention to reduce the occupational health cost is based on a scenario where all workers exposed to toxic chemicals are equipped with at least 3 pieces of PPE (such as protective clothing, boots, mask, gloves and a cap). Based on research from the German Development Institute and GIZ Thailand, it was calculated that only 1.7% of pesticide sprayers wears all 5 pieces of PPE (see above), while 22.5% wears 4 PPE, 19.9% wears 3 PPE, 36.2% wears 2 PPE, 11.0% wears 1 PPE and 8.7% does not wear any PPE (Brandi, et al., 2013; Thongrak, et al., 2011). The intervention is realized by providing 5 PPE to all workers exposed to toxic chemicals wearing only 2 PPE or lower, which requires an investment of $19.5 per average exposed worker (FTE) or $5.8 per average worker (FTE). The price per average PPE is $10.0 and was determined via a price analysis from ILRF 2013 and local manufacturer's websites (Krisbow, 2015; Indonetwork, 2015).

PRACTICE 5: POME REMEDIATION

Palm Oil Mill Effluent (POME) remediation is assessed through average capital and operating expenditure costs documented in eight UNFCCC Clean Development Mechanism project design documents. These documents are all dated between 2009 and 2012, and relate to Methane Recovery in Wastewater Treatment in Indonesia.

TABLE A2.12: UNFCCC CDM PROJECT DOCUMENTS RAW DATA (UNFCCC, 2015)

PROJECT DOCUMENT	YEAR	CAPEX (2014 US$)	OPEX 2014 US$ (PA)	CAPACITY (PA) - TONNES FFB	ANNUAL OPEX/ TONNE FFB (2014 $)	ANNUAL CAPEX/ TONNE FFB (2014 $)	TOTAL COST/ TONNE FFB (PA, 2014 $)
PROJECT AIN08-W-03	2009	396,118	66,059	466,336	0.14	0.04	0.18
PROJECT AIN07-W-05	2009	446,829	69,608	202,941	0.34	0.10	0.45
PROJECT ID08-WWP-10	2012	652,983	81,514	195,688	0.42	0.16	0.58
PROJECT AIN08-W-07	2009	610,583	81,071	162,981	0.50	0.18	0.68
PROJECT AIN08-W-06	2009	322,626	60,915	332,947	0.18	0.05	0.23
PROJECT ID08-WWP-09	2009	569,232	79,688	170,398	0.47	0.16	0.63
PROJECT ID08-WWP-14	2009	1,183,318	169,502	237,475	0.71	0.24	0.95
PROJECT ID08-WWP-11	2009	530,536	76,979	160,037	0.48	0.16	0.64

DATA TRIANGULATION

Throughout the financial analysis multiple sources have been compiled together to derive comprehensive and reliable financial analysis of the different practices in the study. For example, the calculation of land clearing methods by mechanical and fire means is the product of four different sources: Suyanto et al., 2004, WWF & IUCN, 2002, Fairhurst & McLaughlin, 2009 and Budidarsono et al., 2012. The same approach applies for the financials from fertilizer application. For POME remediation, the costs have been compiled from a set of eight recent Indonesia specific CDM documentations. As such, every care has been taken to triangulate the sources and ensure their reliability within the context of available literature.

TABLE A2.13: MAIN DATA SOURCES USED IN THE FINANCIAL ANALYSIS

DATA POINT	SOURCE
COST COMPARISON OF LAND CLEARING TECHNIQUES [ON MINERAL SOIL] FOR OIL PALM PLANTATIONS IN RIAU PROVINCE, INDONESIA MECHANICAL CLEARING COST/HA FIRE-CLEARING COST/HA	Suyanto, et al., 2004

COST COMPARISON OF LAND CLEARING [ON PEAT SOIL] FOR OIL PALM PLANTATION IN LAVANG, NEAR BINTULU, SARAWAK, MALAYSIA MECHANICAL CLEARING COST/HA FIRE-CLEARING COST/HA	WWF & IUCN, 2002
COST COMPARISON OF PALM OIL CULTIVATION ON PEAT AND MINERAL SOILS, INDONESIA COST COMPARISON, % TERMS	Budidarsono, et al., 2012
KEY COSTS IN THE FINANCIAL ANALYSIS OF OIL PALM ESTABLISHMENT ON FOUR LAND TYPES IN KALIMANTAN, INDONESIA ALANG-ALANG [GRASSLAND], ESTABLISHMENT & OPERATING BREAKDOWN COSTS/HA SECONDARY FOREST ON FLATLAND, ESTABLISHMENT & OPERATING BREAKDOWN COSTS/HA	Fairhurst & McLaughlin, 2009
FERTILIZER COSTS/KG MINERAL OR CHEMICAL FERTILIZERS, NITROGENOUS MINERAL OR CHEMICAL FERTILIZERS, PHOSPHATIC MINERAL OR CHEMICAL FERTILIZERS, POTASSIC	United Nations, 2013
INFLATION RATES, CONSUMER PRICES (ANNUAL %), 2009-2013 INDONESIA UNITED STATES	World Bank, 2014
FRESH FRUIT BUNCHES (FFB), REAL PRICE, IDR/KG	Masliani, et al., 2014
DIESEL, US$/LITRE AVERAGE, THAILAND, NOV-FEB 2015	Global Petrol Prices, 2015
CER, AVERAGE PRICE OF SECONDARY CERS IN 2013	World Bank, 2014
SOCIAL SECURITY CONTRIBUTION (HEALTH INSURANCE PREMIUM)	Clearstate, 2015
PERSONAL PROTECTIVE EQUIPMENT COSTS	ILRF & Sawit Watch, 2013; Krisbow, 2015; Indonetwork, 2015
RICE AND EDUCATION COSTS (IN-KIND BENEFITS FOR WORKERS)	Sawit Watch, 2011; Sawit Watch, 2014; GoRiau, 2014)
CORPORATE TAX RATE	KPMG, 2014
INTEREST ON DEBT	World Bank, 2014; Wall Street Journal, 2014