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Solidaridad

Spatial scenario modelling to support integrated landscape management in the Caribbean North Coast of Honduras

A case study on landscape strategies to achieve the Sustainable Development Goals

Background Report

20 November 2018

Spatial scenario modelling to support integrated landscape management in the Caribbean North Coast of Honduras

The Hague, 2018
PBL publication number: 2614

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Acknowledgements
PBL and EcoAgriculture greatly appreciate inputs to the framing and analysis of landscape processes and ambitions from the Solidaridad team in Honduras and from the participants in the May 2017 Landscape Leaders Workshop convened by Solidaridad in Tela, Honduras. We thank Flor Tejada of Solidaridad for her organization and translation skills during the field visits. Also many people generously provided knowledge and data for the modelling, including: SINIT, CREDIA, PROCORREDOR, FHIA, WWF, HonduCaribe, HonduPalma, FUNDEG, UNAH CURLA, Azunosa, Municipality of Tela, Omega Tours, the network of women cocoa and chocolate producers (REDMUCH), PROLANSATE, Jose Herrero and last but not least Sarahi Nunez Gomez (WUR) who guided us to many interesting documents, data sources and people.

Cover photo
J. Meijer (PBL), view over the Sula Valley.

PBL Netherlands Environmental Assessment Agency is the national institute for strategic policy analysis in the fields of the environment, nature and spatial planning. We contribute to improving the quality of political and administrative decision-making by conducting outlook studies, analyses and evaluations in which an integrated approach is considered paramount. Policy relevance is the prime concern in all of our studies. We conduct solicited and unsolicited research that is both independent and scientifically sound.

EcoAgriculture Partners is a non-profit organisation advancing the practice of integrated agricultural landscape management and the policies and tools to support it. By facilitating shared leadership and collaborative decision-making by all stakeholders in a landscape, EcoAgriculture Partners empowers agricultural communities to manage their lands to enhance livelihoods, conserve biodiversity and ecosystem services, and sustainably produce crops, livestock, fish and fibre. The organisation serves as the secretariat for the global partnership Landscapes for People, Food and Nature Initiative (LPFN).

Solidaridad is an international network with partners all over the world, that focused on producer support and sustainable supply chain and market development. We partner with those who want to make a difference by changing business practices from being a part of the problem to being a part of the solution. Markets have to work for the poor, and companies are the key change makers.

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Main findings

Modeling the impact of integrated landscape management on the SDGs

The Sustainable Development Goals (SDGs) provide a comprehensive framework for countries planning to achieve an integrated development vision for 2030. The interventions for realizing this vision will need to be planned and implemented at smaller scales where stakeholders can more clearly understand the impact of the specific actions. The landscape, a socio-ecological system which is organized around a distinct ecological, historical, economic and socio-cultural identity, is a manageable unit at which these goals can be integrated (Denier et al 2015).

Integrated Landscape Management (ILM) is a process by which managers and stakeholders can plan, implement and monitor actions to support the SDGs at a workable scale. ILM explicitly seeks to minimize tradeoffs between goals and maximize synergies between them. The ILM process can result in a plan for action that includes win-win interventions; opportunities for blended investments; an improved understanding among stakeholders of the conditions and dynamics in the landscape; and collaborative action to improve institutional and policy conditions (Scherr, Shames and Friedman 2013; Heiner et al 2017).

Goals and objectives of the project

PBL Netherlands Environmental Assessment Agency and EcoAgriculture Partners, with funding from the Netherlands Ministry of Foreign Affairs, are collaborating to develop and assess the use of spatially explicit modeling and scenario tools to help stakeholders in integrated landscape initiatives achieve multiple SDGs. This project seeks to understand the potential of scenario modelling to demonstrate the trade-offs, synergies, and spatial impacts of proposed interventions at the landscape scale, and to develop a tool and methodology that will strengthen the capacity of stakeholder groups for long-term collaborative planning and design. The project draws from three case studies, the North Coast of Honduras, the Atewa-Densu landscape in Ghana and the Kilombero Valley landscape in Tanzania.

Modelling of landscape scenarios can be a tool that helps stakeholders to articulate their ambitions for the landscape in more concrete terms, and make explicit their assumptions about how different sets of landscape actions—including policies, standards and investments--are expected to impact the landscape, expressed in SDGs and other indicators. This kind of model can also help landscape actors better understand how ongoing trends are shaping their landscape, socially, economically and ecologically.

The Caribbean North Coast of Honduras

The Caribbean North Coast of Honduras (Litoral Norte) encompasses a vast, vibrant landscape (22,000 km2)[1] that contributes to both the economy and environmental goals of the country in addition to supporting the livelihoods of 3.1 million inhabitants. A significant portion of the agro-industrial export commodities sold by Honduras in the international markets (bananas, pineapple, sugar cane, plantains, palm oil) is farmed and processed in the floodplains of the major rivers that flow into the Caribbean Sea of northern Honduras. 37% of land is in forest, with 11% of land in Protected Areas. Over 80% of the agricultural land is in mixed staple crop-livestock systems, mainly for domestic consumption. In Honduras, two dichotomous models of agriculture coexist, while in the northern zone (including the landscape of the this case study) the prevailing systems are intensive (banana, sugarcane, oil palm, pineapple, citrus), which are cultivated in valleys, using irrigation, a high level of external inputs, the productivity is growing and production is export oriented, in the interior of the country the model is extensive, dedicated to basic grains (corn, beans), cultivated in mountainous areas, without technology and external inputs and for national market.

In this landscape, the international NGO Solidaridad is supporting PASOS (Paisajes Sostenibles en Honduras or Sustainable Landscapes in Honduras), a multi-stakeholder landscape partnership to achieve sustainable agriculture, environmental and social goals

[1] This area represents almost half of the territory of the Netherlands, 20% of the territory of Honduras and the extent is similar to all of the country Belize, in Central America.

through integrated strategies. PASOS follows a previous 5-year sustainable supply chain program of Solidaridad with actors in the palm oil sector. The PASOS program involves a broader range of landscape stakeholders including not only palm oil, but also cocoa and ecotourism companies; indigenous peoples' and community-based organizations; farmer organizations and cooperatives; municipal governments; research institutes and universities; community water associations, and non-profits.

These stakeholders are motivated on building a shared vision to enhance opportunities and mitigate threats.

Threats include high rural poverty (67% rural poverty index and 56% extreme poverty) in all the country; high rural food insecurity (19% of under-five children malnourished); unbridled expansion of palm oil in fragile and unsuitable systems; threats to valued biodiversity from rapid habitat loss and fragmentation, sedimentation, and agrochemical pollution; increasing risk of landslides, hurricanes and flooding; and demand for clean water rapidly outstripping supply.

Opportunities include a high demand for sustainably produced palm oil, cocoa and other products; protect and preserve high remaining biodiversity and reasonably good conservation of many protected areas; support a growing ecotourism market; there is strong social organization in some sectors; some municipal governments are enthusiastic about sustainable development; there are many engaged scientists and academics; and a vibrant and diverse culture.

Landscape ambitions for the North Coast

To achieve inclusive green growth and meet the SDGs in this landscape, stakeholders from many sectors worked jointly in 2016-17 to define key landscape ambitions. They identified and characterized relevant technical, market and institutional interventions designed to meet several SDGs linked to management of the natural resource base, including 'Reduce Poverty', 'Zero Hunger', 'Clean Water and Sanitation', 'Climate Action', 'Life on Land' and 'Life below Water'. Interventions were designed to realize synergies among multiple ambitions and SDGs, reduce trade-offs, and to reflect a more integrated and collaborative spatial planning. Stakeholders also noted SDGs indicators on extreme poverty reduction, health, education, sustainable cities and communities, gender, energy and economic growth, but these issues were not explicitly incorporated into the North Coast Zone spatial scenario modelling.

The PASOS partners have defined nine landscape ambitions, which are being refined:

1) **Improved rural livelihoods** of the population, increasing and diversifying income and employment, raising rural wages and reducing rural poverty, through all the landscape management activities below, as well as investments in education, health, and gender equity. The stakeholders are exploring ways to use a 'landscape-friendly' label to attract and increase price received from buyers interested in sustainable sourcing.
2) **Improved food security for the rural population,** particularly through expanding and improving the productivity of mixed crop-livestock-forest mosaics to increase productivity, raise incomes, and mitigate environmental degradation, through technical assistance and improving infrastructure for local food storage and market access.
3) **Increased cocoa agroforestry land use, productivity and income,** by tripling (from a low base) the area under improved cocoa agroforestry systems, especially on degraded slopes, increasing cocoa productivity, intercropping staple foods, and generating income from timber, NTFPs and wood energy.
4) **Doubled production of sustainably produced palm oil**, to raise incomes and employment and mitigate environmental degradation, by increasing productivity on farms and processing, with 100% RSPO certification, meeting restrictions on high-risk sites. This includes the development of renewable energy based on biomass or biogas generated by oil palm.
5) **Clean and sufficient water for household, economic and environmental needs** by reducing sedimentation and agrochemical pollution, by strengthening municipal land use regulations on steep slopes, riparian and flood-prone areas; and improved municipal water governance and monitoring.
6) **Expanded 'green infrastructure'**, including forests, natural habitats (terrestrial and coastal) and biological corridors and networks (in addition to agroforestry and other of above), while increasing carbon sequestration and storage across the landscape.

7) **Resilience to flooding, climate change and extreme weather events**, through activities above and collaboratively developed municipal Resilience Plans. There is a national plan, but in the case of PASOS it only refers to the municipalities in the area of influence.
8) **Sustainable eco-tourism development** around terrestrial and coastal protected areas, linking to sustainable agriculture, wildlife resources and local culture, to increase income and employment.
9) **Strengthened land rights and territorial planning** as a foundation for long-term sustainable investment for socioeconomic development and healthy ecosystems.

Scenarios to 2030

The scenario development started with baseline conditions for the landscape around 2014-2017. Drawing from information provided by Solidaridad and interviews and workshops with the diverse stakeholders, three alternative scenarios were developed.

The first, a **Business as Usual Trend scenario** assumed a continuation of historical patterns 2000-2015 in population growth and land use changes, including expansion of oil palm, moderate conversion of protected areas to agricultural production, continued production in riparian areas and steep slopes, and slow conversion of annual food production to agroforestry and mixed crop-livestock systems.

The second, an **Accelerated Agricultural Export Growth scenario** builds on the Trend scenario, but assumes a much more rapid expansion of palm oil production and other mono-cultural crops, mainly for exporting. Population growth and urbanization will be slightly higher compared to the Trend due to in-migration of people attracted by the large scale agricultural growth. Much of the expansion of agricultural production will be in protected areas and riparian zones, also due to increasing competition for land used for food production.

The third scenario, an **ILM inspired scenario** reflects the landscape ambitions above: supporting diversification of incomes, investments in sustainable, higher-productivity oil palm, cocoa agroforestry systems, and mixed crop-livestock mosaics. There is much more attention to spatial regulations: strictly limiting intensive land use in riparian areas, flood-prone areas and on steep slopes and protected forests and bio-corridors. There is also more promotion of agroforestry systems in these sensitive areas.

Key elements of the modeling and scenario development

To capture the integrated socio-economic, cultural, biophysical and multi-level planning dynamics of diverse landscapes, a spatially explicit modelling framework was setup. This framework is tightly linked to the processes and activities that stakeholders are already working on collaboratively. The scenario building exercise was informed by input and feedback from local stakeholders through workshops, discussions and field visits, including a major stakeholder leaders' workshop in Tela, Honduras in May 2017. Visualizations were developed to facilitate stakeholder input.

The scenarios were analyzed by integrating results of several models: the CluMondo land use change model; the GLOBIO model that assess impacts on biodiversity from human pressures, and the MESH tool for mapping ecosystem service supply. Data for the models were drawn from numerous international, national and local sources, which had to be incorporated into a common geographic information system. The models set certain assumptions and rules for allocating different land uses (population and urbanization trends, land use suitability, et al), resulting in different land use patterns. The land use patterns and the consequential changes in ecosystem services were translated to indicators that describe impacts on the selected SDGs (food, water, climate and life on land). The model is spatially explicit, with a raster of 250 by 250 meter resolution. The ecosystem services analysis also uses and produces spatial outcomes to assess impacts.

The model does not reflect non-trend market signals or other sudden changes, nor links between agricultural, forestry, tourism and other activities to income or employment. Therefore the coverage of the socioeconomic features of the scenarios limited and the main focus is on spatial planning, also in relation to ecosystem services. The model's parameters are drawn from—and thus sensitive to--a mix of available data, expert judgement and stakeholder estimates of the impacts of different types of interventions on land use, resource management and productivity. Thus part of the value of the scenario development exercise was for stakeholders to come to agreement around the parameters to be used.

Process

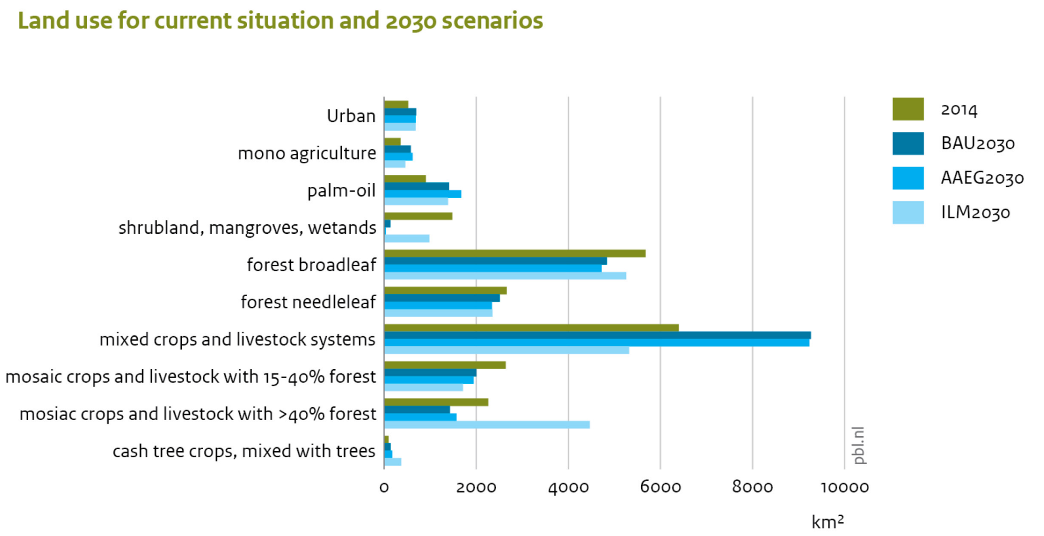
EcoAgriculture Partners had been working with Solidaridad in PASOS since 2016, and undertaken a landscape assessment that involved both data analysis and stakeholder consultations, and several staff trainings. After working closely with various stakeholder groups, Solidaridad convened the first multi-stakeholder event in May 2017. The landscape modelling project was timed to enable preliminary results to be presented. The scenario descriptions and data for the model were drawn from the landscape assessment, Solidaridad documents, and insights from interviews performed during a field visit carried out by PBL in March 2017, also to collect additional data. Participants provided rich feedback on the two initial draft scenarios. The model and scenario assumptions were revised substantially to reflect this input, as well as adding a third highly plausible scenario. Solidaridad, PBL and other colleagues provided additional feedback to refine this report.

Scenario results

The scenario analyses illustrates important differences between the Business as Usual, Accelerated Agricultural Export Growth and Integrated Landscape Management scenarios, in relation to land use change, progress towards landscape ambitions, and progress towards the SDGs. Results for each scenario assume full implementation and require adequate funding (public, private, civic); motivation of farmers, agribusiness, communities and municipal governments; and institutional capacities to implement strategies.

Land use changes

Figure 1



Source: PBL

The major differences between the three scenarios were (Figure 1):

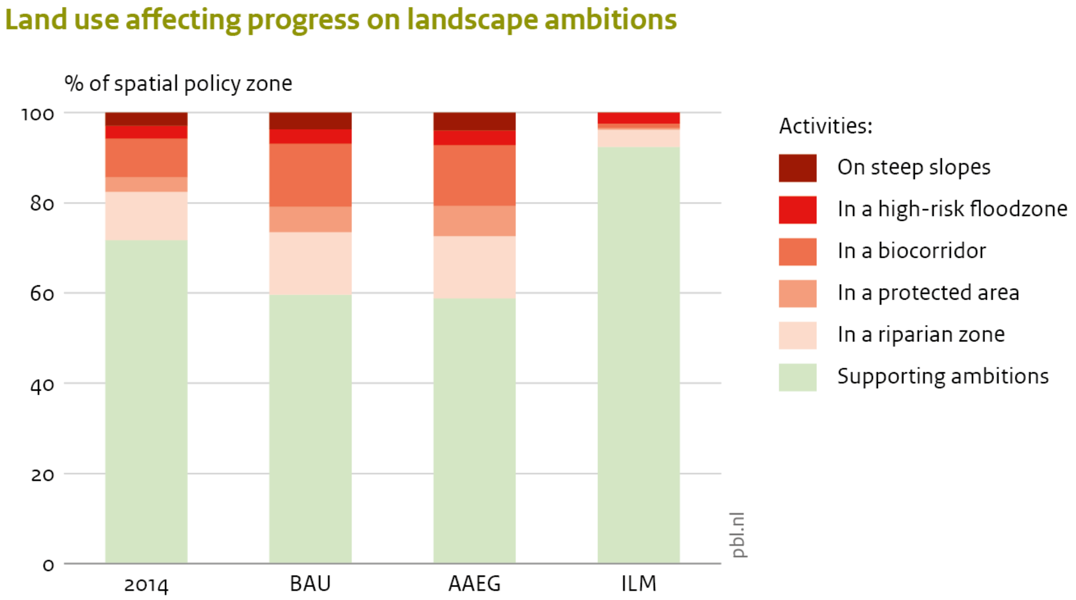
- Urban settlements expand around 30% under all scenarios, based on INE population projections;[2]
- Area wise technified monocrops are projected to expand more than 60% under BAU and AAEG scenarios; Under the ILM scenario this will be around half of this;
- Area under cocoa agroforestry nearly triples under ILM, but increases 45-80% under BAU and AAEG;

[2] This single trend deserves to be widely disseminated by the PASOS team among leaders of municipal governments, for its impact on territorial planning and on the demand for social infrastructure (drinking water, housing, urbanization, energy, etc.) Surely 30% growth is not figure in its growth projections or budgetary capacities.

- Area under oil palm expands about 50% in BAU and ILM, but over 80% in AAEG (without higher productivity)
- Shrublands, mangroves and wetlands nearly disappear under the BAU and AAEG scenarios, but are relatively stable in ILM;
- Traditional crop-livestock systems expand nearly 50% in BAU and AAEG scenarios, but in ILM traditional systems decline while area under mosaic crop-livestock-forest systems doubles

Progress towards landscape ambitions
Due to the focus of the spatial modelling combined with limited landscape level data availability for socioeconomic characteristics, the analyses does not provide quantitative projections on rural livelihoods, poverty reduction, household-level food or water security, ecotourism development or land rights. However the model outcomes illustrated some significant differences between the three scenarios for the identified ambitions, see also Figure 2 an overview of land use supporting and affecting progress towards the ambition.

Figure 2



Source: PBL

- ***Improved food security.*** Staple food production grows only 1.2%/year (far lower than population) in BAU and AAEG, and somewhat better, at 2%/year in ILM. In BAU and AAEG, only 1 and 2% of food is grown in areas complying with spatial policies and thereby support the landscape ambitions; in ILM the share is 38%.
- ***Expanded cocoa agroforestry area/production/income.*** Area nearly tripled in ILM (from a low base), as well as implied income increase from associated commercial products. Area grew, but by much less, in the BAU and AAEG scenarios.
- ***Doubled sustainably produced palm oil.*** Under the BAU scenario and especially the AAEG, palm oil plantations are projected to expand into natural areas and replace agroforestry, displacing shrubland and forest for reallocated food production and grazing. Under AAEG, palm oil production doubles mainly through area expansion. Under ILM, productivity growth of 33% over 15 years, increases production of palm oil 2.5 times, with much less land area and mostly in areas suitable for production and climate.
- ***Water use and quality.*** Due to population growth, urbanization and increasing agricultural activity, water use increases rapidly under BAU; the increase is significantly less in ILM and even declines in some watershed. Land use is sustainable in much more of the riparian areas and steep slopes in ILM than in BAU or AAEG.
- ***Resilience to flooding.*** Very little of the high-flood-risk land in the North Coast is under natural land cover, as its value for production is higher, and almost none by 2030 in BAU and AAEG. Around 300,000 hectares is under some urban and considerable intensive commercial monocultures and palm oil area, about the same in 2030 as currently, under

all scenarios. But there is more natural forest cover, agroforestry and crop-livestock-forest mosaic under ILM in 2030.

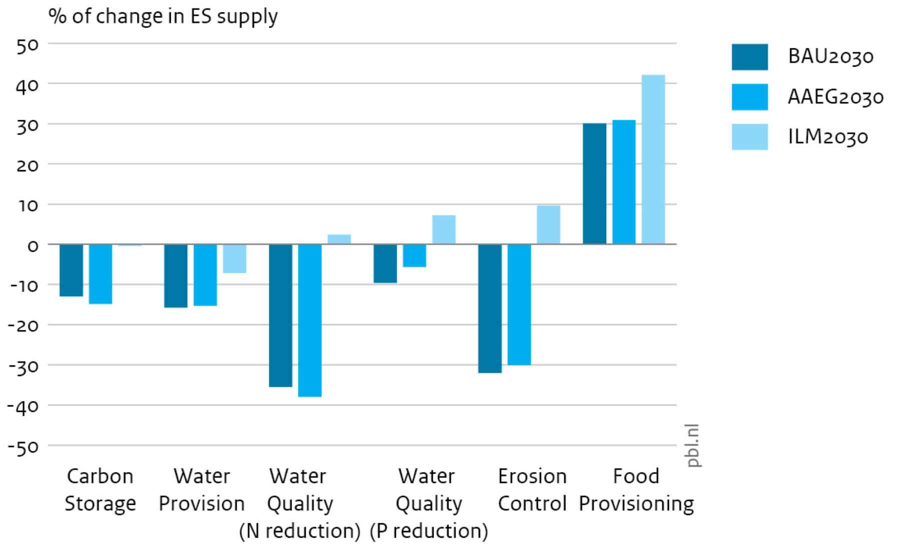
- ***'Green infrastructure'.*** Total forested areas in natural forests, mosaic crop-livestock-forest areas and agroforestry systems remains the same in ILM in 2030 as in the baseline, but in different configurations, while there is significant deforestation in BAU and even more so in AAEG (especially in natural forest). Terrestrial protected areas remain largely under natural land cover in ILM, but agricultural land uses increase in BAU and especially AAEG. In ILM, half of the bio-corridors are in natural land cover and most of the rest in compatible agroforestry systems and crop-forest mosaics, while there is more intensive commercial production and crop-livestock systems in BAU and AAEG. Mean species abundance declines in all scenarios by 2030, but significantly less so in ILM. Land use accounts for half of the pressure for biodiversity loss in ILM and more in BAU and AAEG; the other half is due to encroachment by hunting, fragmentation, infrastructure and climate change.
- ***Territorial planning.*** The ILM scenario is predicated on territorial planning, while there are limited land use restrictions in BAU and AAEG.

PASOS is sharing these main trends or scenarios widely with partners and stakeholders in public events (even with other actors who are not partners of PASOS) because the conclusions of the scenarios can help decision makers take actions, change plans of the private and municipal actors and boost investments towards situations closer to the landscape.

Changes in ecosystem services
By comparison (Figure 3), the ILM scenario potentially has better outcomes, with significant improvements in food provision while also significantly improving sustainable production and riparian protection, and RSPO certification.

Figure 3

Change in supply of ecosystem service compared to the current situation



Compared to the current situation, even with the proposed ambitious level of investment, the ILM scenario only slows the rate of degradation in some (mean species abundance), maintains them (nitrogen pollution in water, forest cover, protected areas, carbon storage), or improves them modestly (phosphorus pollution in water, bio-corridors. This illustrates the challenges the landscape is facing with respect to increasing population and human land use pressures impacting the environment.

Progress towards the Sustainable Development Goals
Looking at results from the SDG perspective complements the analysis.

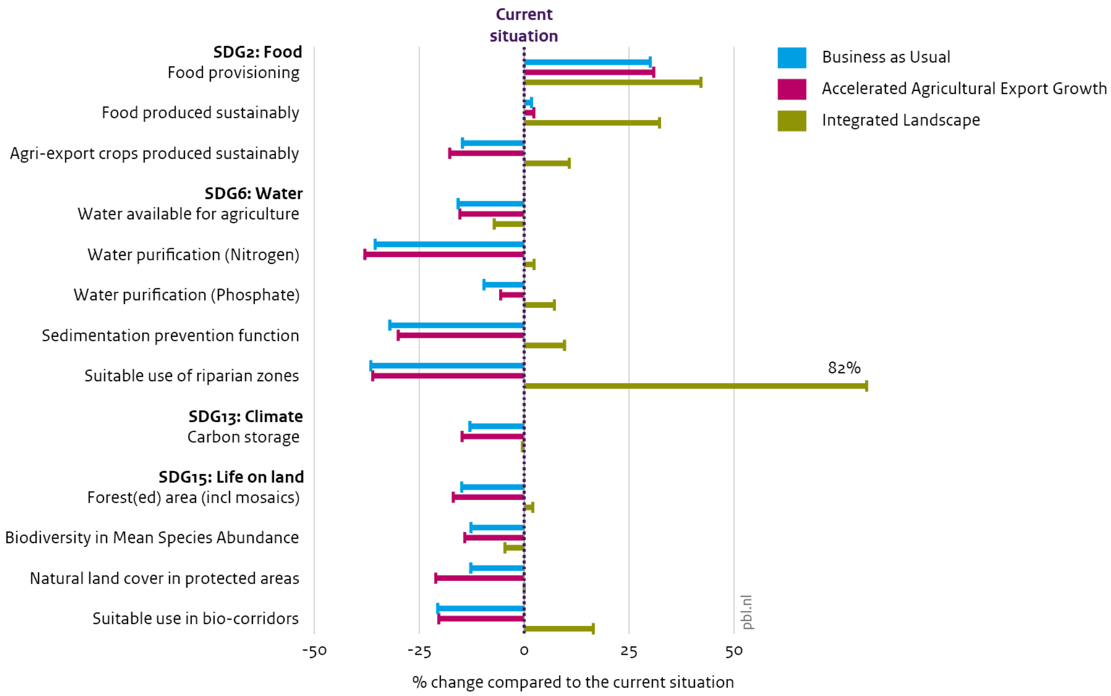
- ***SDG 2 (Zero Hunger***). The ILM scenario shows the greatest improvement in staple food provisioning and much higher improvement in sustainable agricultural land use in staple foods, because resources are invested in small crop-livestock-forest mosaics, and agroforestry. Sustainability of agri-export production is somewhat higher than the baseline, but sustainability is greatly reduced in BAU and AAEG.

- ***SDG 6 (Clean Water & Sanitation).*** While nitrogen and phosphorus levels in water worsen in BAU and AAEG by 2030, they remain stable (though not much improved) in ILM. There is a sharp contrast between the worsening of riparian area protection in BAU and AAEG, and a significantly improvement in ILM.
- ***SDG13 (Climate Action).*** In the ILM Scenario, carbon storage remains stable to 2030, while greenhouse gas emissions from land use deteriorate significantly in BAU and AAEG.
- ***SDG 14 (Life Below Water).*** Reduced sedimentation in the major rivers, reduced agrochemical pollution and effectively protected coastal/marine protected areas should have positive impacts on coastal and marine biodiversity.
- ***SDG 15 (Life on Land).*** Most indicators in the model for Life on Land show deterioration in BAU and AAEG scenarios. Under ILM, there are small or modest improvements in these indicators, but this is a concern, as the sustainable land management elements in the ILM model are quite ambitious.

Overall (Figure 4), the BAU and AAEG scenarios demonstrate significant improvement in food provisioning targets of the SDGs, but no progress on other aspects of sustainable production, and deterioration in environmental goals, especially around nitrogen pollution in water, riparian area protection and sedimentation.

Figure 4

Impact on selected SDGs under 2030 scenarios compared to the current situation



Potential areas for further elaboration of landscape ambitions and interventions in the modelling could be extreme poverty reduction, employment, rural-urban linkages, more explicit interventions around rural wages, nutrition support for vulnerable groups, and direct social support and social insurance.

Value of spatial scenario development for landscape platform

For Solidaridad and local stakeholders in the North Coast landscape, the model-based spatial scenario development helped to clarify stakeholder ambitions, drivers of change and baseline conditions, options for action and investment priorities. Early versions of the model found that the initial ILM intervention set did not significantly advance towards the SDGs for food security, coastal biodiversity, or flood protection, which prompted refinements in the proposed interventions to achieve higher projected SDG performance.

The modeling also demonstrated the scale of action required to meet the SDGs. These insights motivated interest in a more ambitious and coordinated landscape investment portfolio, and became part of the 'pitch' by PASOS to prospective public, private and civic investments.

By highlighting the potential interactions among different interventions, the scenario modeling deepened stakeholder understanding of, and interest in, exploring cross-sector synergies and trade-offs. This 'mental model' of the landscape, informed actions by Solidaridad and PASOS stakeholders. For Solidaridad and collaborators, the most valuable insights were the potential for synergy between palm companies and researchers and marine biologists to protect the reef together.

1 Introduction

1.1 Modelling landscape interventions to assess progress towards the SDG

Background and objectives of the study

The Sustainable Development Goals (SDGs) provide a comprehensive framework for action. Integrated Landscape Management (ILM) offers a promising means of implementing the Sustainable Development Goals (SDGs) to meet the full range of Goals by minimizing tradeoffs and maximizing synergies between them. The anticipated improved outcomes may result from improved understanding among stakeholders of the ongoing socioeconomic and ecological processes in the landscape; from facilitated negotiations among stakeholders to design more win-win interventions and opportunities for blended investments; opportunities to address farm, forest or business problems through solutions at a landscape scale; and/or collaborative action to improve institutional and policy conditions (Denier et al 2015; Scherr, Shames and Friedman 2013; Heiner et al 2017).

PBL and EcoAgriculture Partners, with support from the Netherlands Ministry of Foreign Affairs, are collaborating to assess the potential use of spatially explicit modelling and scenario tools to help inform stakeholders in large landscape initiatives about the results of land-use management to achieve multiple SDGs. By identifying options for action and potential investment priorities in relation to the SDGs, the project aims to develop a clearer understanding of the trade-offs, synergies, and spatial impacts of proposed interventions at the landscape scale, and strengthen capacity of stakeholder groups for long-term collaborative planning and design.

In 2017, PBL and EcoAgriculture collaborated with the Solidaridad-PASOS project to model how ILM could contribute to the SDGs in the Northern Coastal Zone of Honduras, where Solidaridad-PASOS is supporting a large landscape partnership. To capture the integrated socio-economic, cultural, biophysical and multi-level planning dynamics of a diverse landscape, PBL and EcoAgriculture piloted a spatially explicit modelling framework, with input and feedback from local stakeholders through workshops designed to define anticipated scenarios. They identified and characterized the spatial dimensions of relevant technical, market and institutional interventions anticipated to realize greater progress towards achieving the selected SDGs (e.g. food, health, water, climate and biodiversity) simultaneously by 2030. The main field consultations were in March 2017, and at the North Coast Landscape Leadership Workshop held in Tela, May 22-26.

The Scenario Modeling was undertaken with two sets of users in mind. The first was the stakeholders in the North Coast Landscape of Honduras who are actively collaborating in a new platform to transform their landscape in more sustainable directions. Participatory scenario development was designed to deepen shared stakeholder understanding of the landscape, and motivate sharper analysis of options and impacts.

The second audience was policymakers seeking to advance sustainable development and spatial planning. This report aims to provide them insights on useful approaches, tools and methods for integrated landscape-scale modelling that is multi-stakeholder, multi-sector and spatially-explicit.

The authors fully recognize the limitations of models. They are meant to illustrate broad changes and highlight potential interactions and implications of different avenues of action. Models provide a simplified view of reality, but can help make explicit the trends over time, distinguish what variables have the largest effects, and identify gaps in policy and action. Our model focuses on areas where close linkages between ecosystem services from natural resources in the landscape are expect to impact achievement of the SDGs.

1.2 Organization of the Report

Section 2 of the report briefly introduces the North Coast landscape and the work of PASOS. Section 3 describes the participatory methods and modelling tools used for the scenario development. Section 4 describes the current state of sustainable development in the landscape and stakeholder ambitions for the future. Section 5 describes the scenarios used in the study and Section 6 presents the results of the scenario analysis. Section 7 concludes the report and reflects on how the study has been used by the North Coast stakeholders and how the methodology could be further improved.

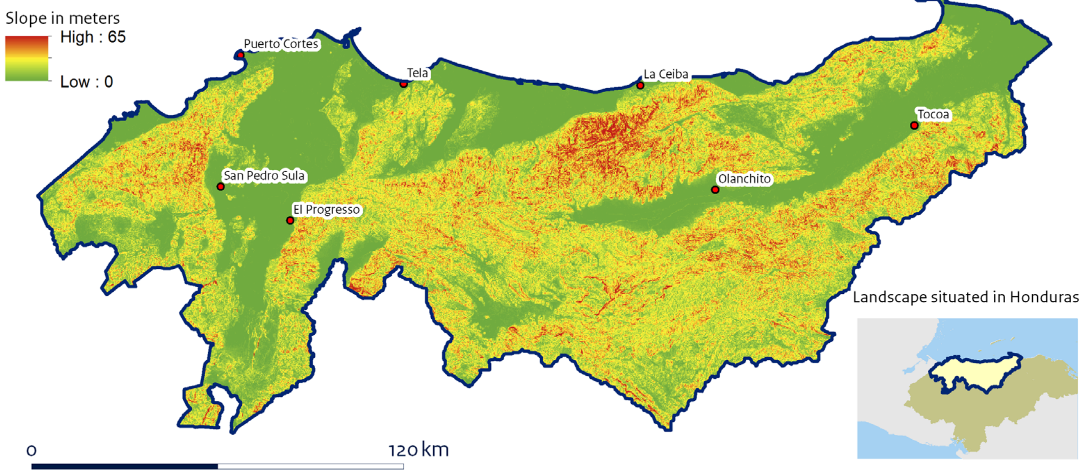
2 The landscape and the PASOS initiative

2.1 The landscape

The Caribbean North Coast of Honduras (Litoral Norte) encompasses a vast, vibrant landscape that contributes to both the economy and conservation goals of the country and supports the livelihoods of millions of inhabitants. An important share of the agro-industrial export commodities sold by Honduras in the international markets is farmed and processed in the floodplains of the major rivers that flow into the Caribbean Sea of northern Honduras, including the floodplains carved by the Ulua, Chamalecon, Lean, Cuero and Aguan rivers.

Figure 2.1

The Litoral Norte landscape

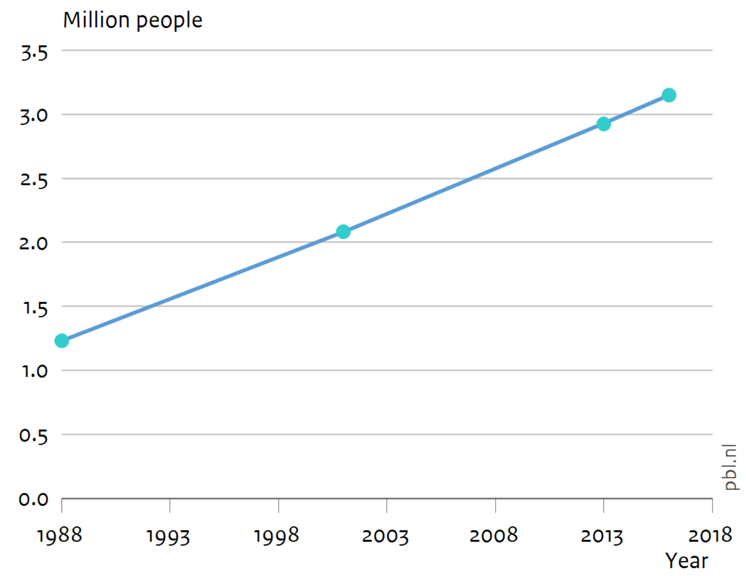


Source: PBL

The total population of the landscape is around 3.1 million, of which 72% is urban and 28% is rural, in 48 municipalities. Important ethnic groups include the Miskito, the Garifuna, Lenca, Pech and Maya-Chorti. The population growth rate over the past years has been 3.4% per year (see Figure 2.2). The total numbers mask a high level of emigration to the cities of the region from its poorer mountainous regions.

Figure 2.2

Population development in the landscape



Source: INE, 2017

The total area of the landscape is about 22,000 km2. Much of the land is still in forest cover. Some 24% of the landscape is classified as forest outside protected area and 12% has been designated as forest protected area. The coastal areas has areas of shrubland, wetlands and mangrove forest (in total 6%), and there are several coastal and marine protected areas. Urban settlements account for slight more than 2% of the land.

The dominant land use --50% of total area-- is under mixed crop-livestock systems that are important for incomes and food security. Of this area, about 57% has relatively low tree cover, while 43% is in crop-livestock-forest mosaics. High-value commercial cultivation of tree crops like oil palm, cocoa, coffee and oranges covers about 4% of the area. Much of the cocoa and coffee are in agroforestry systems. Annual mono-culture crops, mainly bananas, pineapples and sugar cane cover 2% of the total area (See Figure 2.3).

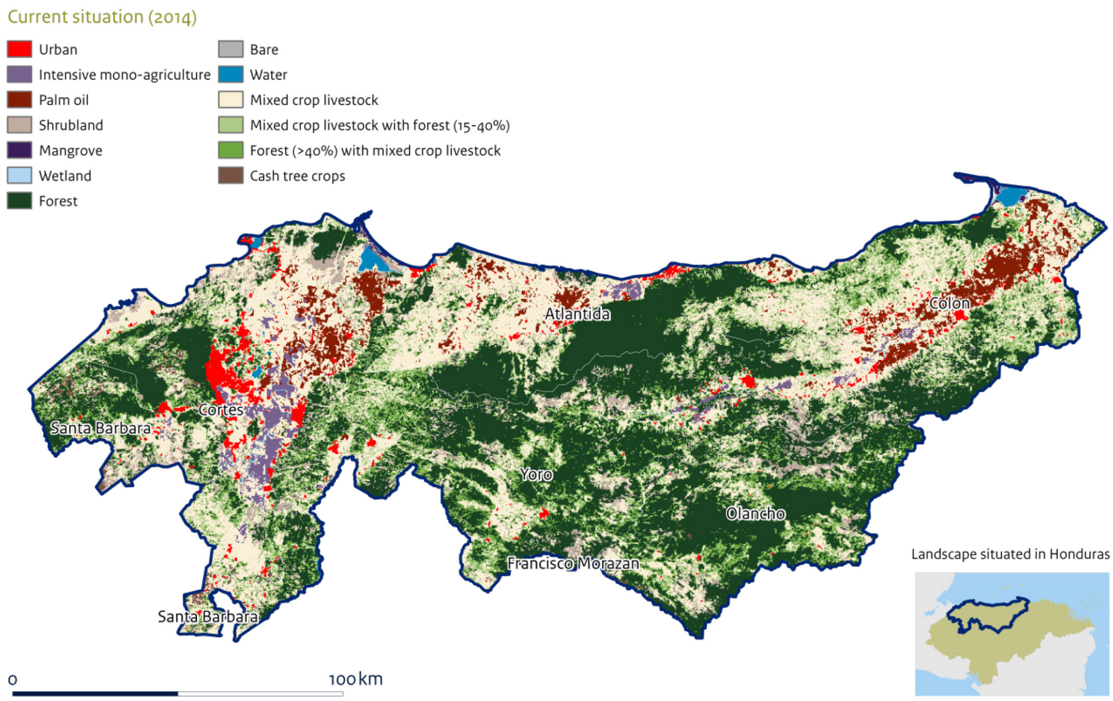
The landscape encompasses three major watersheds with contrasting land use.

The ***Valle de Sula*** (which includes the cities of San Pedro Sula, Puerto Cortes and Choloma) encompasses a series of natural ecosystems, including mixed tropical deciduous forest and seasonal and permanent wetlands, lagoons and mangrove forest. Many high conservation value ecosystems on the coastline lie within Jeanette Kawas and Punto Izopo National Parks. Agricultural land use includes palm oil (which has experienced high recent growth), cattle pastures, sugar cane, king grass, plantains, and bananas. Other industries that contribute to the local economy include clothing manufacturers, tourism enterprises, retail enterprises in urban centers, and a commercial port neighboring the city of Puerto Cortes.

The ***Lean and Cuero River flood and coastal plains*** (including the municipalities of La Ceiba, Esparta, Masica, Jutiapa), contain natural ecosystems such as wet tropical forests and mangroves. The Nombre de Dios mountain range sits parallel to the Caribbean coast and contains various microclimates. There are a number of protected areas, including Cuero y Salado wildlife refuge, Pico Bonito National Park, and Texiguat wildlife refuge. In this region, oil palm is cultivated in the coastal plains. Other agricultural production includes oranges, cocoa, pineapple, and low density cattle. The city of La Ceiba is a large urban centre and among the five most populated cities in the country, though it is currently struggling to create employment and business opportunities. The tourism industry is quite active in this region.

The ***Valle de Aguan*** (including the munipalities of Sonaguera, Saba, Tocoa, Santa Rosa de Aguan, Bonito Oriental), contains land with fertile alluvial soils and mountains to the east, with important forest fragments still intact (although poorly protected). As in the Valle de Sula, oil palm production is expanding into higher-fertility areas previously cultivated banana, plantain, and staple crops. The region has a history of social conflict over land ownership. In the 1990s, a new law that allowed cooperatives to sell communal lands previously allocated to them during the agrarian reform of the 1970s and 1980s triggered a series of land purchases by big palm oil companies that were contested by younger cooperative members. The resulting conflict between members of campesino movements and security forces cause violent clashes that took the lives of an estimated 200 people. The central government has since repurchased the land and transferred them to newly formed cooperatives, now producing oil palm.

Figure 2.3



Source: PBL

Many biodiversity-rich ecosystems that provide a host of services are located in the Caribbean coast of Honduras. An important proportion of the mountains and hills in this area are still covered by tropical humid forests, while mangrove and coastal lagoon ecosystems can be found in and near the shore line. However, land use change, slash and burn agriculture and deforestation continue to threaten these ecosystems, endangering the wellbeing of the rural, resource-poor population that depends on this environment and the health of the marine ecosystems that are affected by the pressures inflicted upstream (Bosques del Mundo, 2016).

With 55% of the landscape under cultivation by agro industrial actors and impoverished rural populations that are vulnerable to the effects of climate change and associated threats to food security, agriculture is both a central challenge and a key opportunity to more sustainable resource management. Expansion of agricultural activities is happening in areas where the forest is more easily accessible. Balancing biodiversity conservation, agricultural production, tourism development and livelihood enhancement requires an integrated approach to development in the Litoral Norte (Bosques del Mundo, 2015 and 2016; Castro-Tanzi and Gross, 2016; Honduras government, 2010; Sanders et al., 2011, Sanders et al., 2013).

The urban economy is mostly centered around agro processing, commerce and trade. The Sula Valley provides 60% of Honduran cloth manufacturing. Mining is growing—900 new mining concessions were granted in the last two years across the whole country (Registry of the Ministry of Environment of Honduras).

2.2 The Sustainable Landscapes initiative in Honduras

Solidaridad Network has been working in Honduras since 2011, principally supporting Roundtable on Sustainable Palm Oil (RSPO) certification and other efforts toward sustainable palm oil, including supporting the establishment of the Honduran PASH (sustainable palm oil) consortium. In 2016, with funding from the Government of the Netherlands, Solidaridad began implementing the project "Paisajes Sostenibles en Honduras" (Sustainable Landscapes in Honduras) or PASOS project in the northern coastal zone of Honduras. In addition to building upon the partnership work already done with the palm oil sector through PASH, the new project is using an "integrated landscape management approach" to include a broader array of stakeholders who share and use the landscapes to address pressing environmental and governance issues through multi-stakeholder dialogue, planning and action, which exceed the scale of individual plantations and/or value chains (document of the PASOS Honduras program approved by the Ministry of Cooperation of the Netherlands).

Key stakeholders already involved include private cocoa, palm oil and ecotourism companies; indigenous peoples' and community-based organizations; farmer organizations and cooperatives; municipal governments; research institutes and universities; community water associations, and non-profits, including wildlife reserves. The Ministries of Agriculture and Environment are supportive of the project. After a series of bilateral consultations between Solidaridad and different stakeholder groups and a public launch of the project in September 2016, a Landscape Leadership Workshop was convened for joint training, dialogue and collaborative planning, in May 2017. Working groups were formed to advance planning for a multi-stakeholder landscape platform, the diversification of cocoa, the mountain-to-the-sea integrated planning, ecotourism development and sustainable palm oil.

3 Modelling and participatory scenarios

A key element in this project was to combine and try out a set of suitable tools to capture local and spatially explicit landscape characteristics and use these to compare several plausible future scenarios that were developed in a participatory way, based on information and discussions with the stakeholders involved the PASOS initiative.

The research was setup in 4 phases: (1) gather and share landscape information and required datasets to support building the modelling framework and create a 2030 trend scenario; (2) organize a landscape stakeholder workshop to present the first outcomes and collectively design alternative scenarios and identify integrated landscape interventions with stakeholders; (3) produce preliminary results of the scenario analysis and report on the impacts of these interventions for feedback; (4) generate feedback on the outcomes from landscape stakeholders for revision and final reporting of the results.

This section describes the role of the stakeholders and the key elements of the modelling exercise: the modelling framework concept, landscape delineation, models used, data sources and land systems classification.

3.1 Role of stakeholders in scenario development

The landscape assessment report (Castro-Tanzi and Gross, 2016) that included an overview of the stakeholders and the developments in the last decade formed the starting point of this project. Two visits to the landscape were part of the case study, both organized and facilitated by Solidaridad-PASOS. The first (March 2017) was used to familiarize the PBL team with the landscape, collect existing landscape analyses and data, consult separately with various stakeholders to understand and articulate their landscape ambitions for the future and already identify a number of potential interventions that stakeholders suggest in order to achieve their ambitions. Based on this information a draft Trend scenario was developed and applied to the modelling framework to produce some first outcomes.

During the second visit (May 2017), the team joined a Landscape Leadership Workshop for 30 PASOS landscape stakeholders. Following the workshop sessions with stakeholders about current state, trends, and priorities for interventions in the landscape, the team presented the draft Trend scenario analyses for group discussion and recommendations for refining input datasets, model assumptions and the scenario storyline. Based on the feedback, the team modellers enriched the model, presented some first results at the workshop and solicited further inputs from the stakeholder group to refine scenario storylines and interventions, with a focus to identify those actions that are more likely to support the selected SDGs.

Following the workshop, the team modellers updated various model assumptions and interventions and settings for the scenarios. Based on feedback from the PASOS team and landscape stakeholders, the report is being revised.

3.2 Landscape delineation

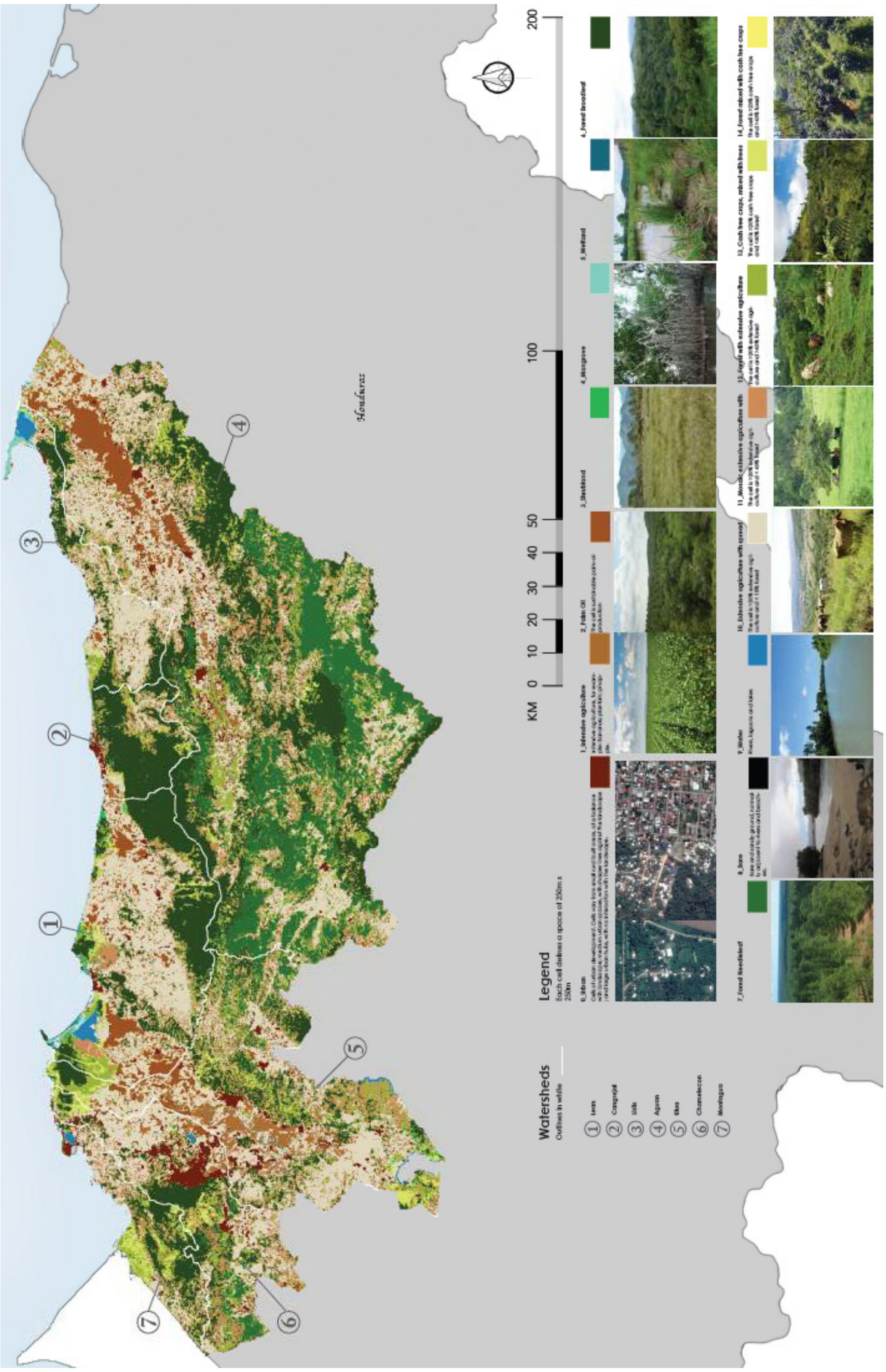
Preliminary boundaries for the North Zone Landscape of Honduras were developed based on coarse watershed maps and information provided by Solidaridad. They were refined with watershed data from HydroSheds database (Lehner et al, 2013). The landscape boundary (see Figure 3.1) intersects with (parts of) the departments of Atlantida, Cortes, Yoro, Colon, Olancho and Santa Barbara. By focusing on watersheds the analysis emphasizes the “from the mountain to the sea” idea that connects many stakeholders in the landscape and also the core role of water, either too little, too much or too dirty. The focus on watersheds did provide a challenge for finding suitable census and socioeconomic data. Where available we used municipality data that fitted the landscape area and otherwise department level data was interpreted. There are no regional/local Water authorities or basin boards, though there are local water user groups in some municipalities.

3.3 Land systems classification

Land systems represent typical combinations of land cover, livestock, and land-use intensity that describe human-environment interactions. Based on the characteristics of the landscape (area, land cover, land use) and available datasets we decided to create a land systems map at a 250x250 meter resolution. The land system map contains 15 classes and is shown in figure 3.1. Besides several discrete land systems (e.g. urban, mono agriculture, palm oil plantations, water) we tried to describe several mosaic classes for combinations of mixed crop/livestock systems with varying forest cover and for combinations of commercial tree crop classes, like cocoa, also with varying degrees of forest cover. The land system classification procedure is further illustrated in Annex 9.2.

These land systems are associated with different social and economic conditions of the people living and working there. Additional socioeconomic analysis would permit extending the Scenarios to reflect implications for income, wealth and social equality.

Figure 3.1
The land systems distinguished in the landscape.



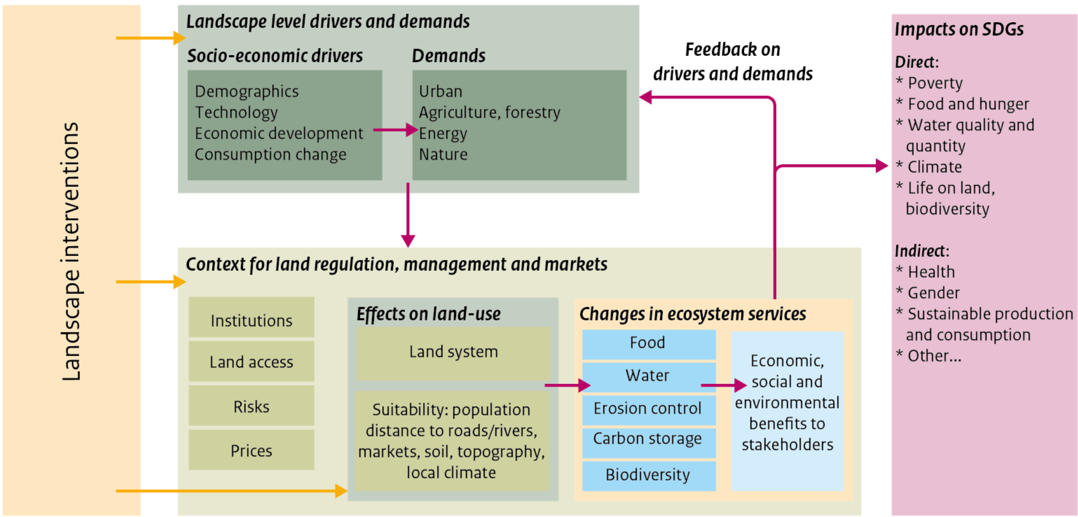
Source: PBL

3.4 Overview of the modeling framework

The ambition of the modelling is to connect the different spatial scales (global, national, landscape, local) and the sectors and stakeholders that are affecting spatial developments in the landscape. The conceptual framework covering this is shown in Figure 3.2. ILM inspired interventions are expected to influence regional and landscape level socio-economic drivers, enabling conditions at the landscape level and land use practices at the very local level.

Figure 3.2

Conceptual modelling framework for the scenario analysis



Source: PBL

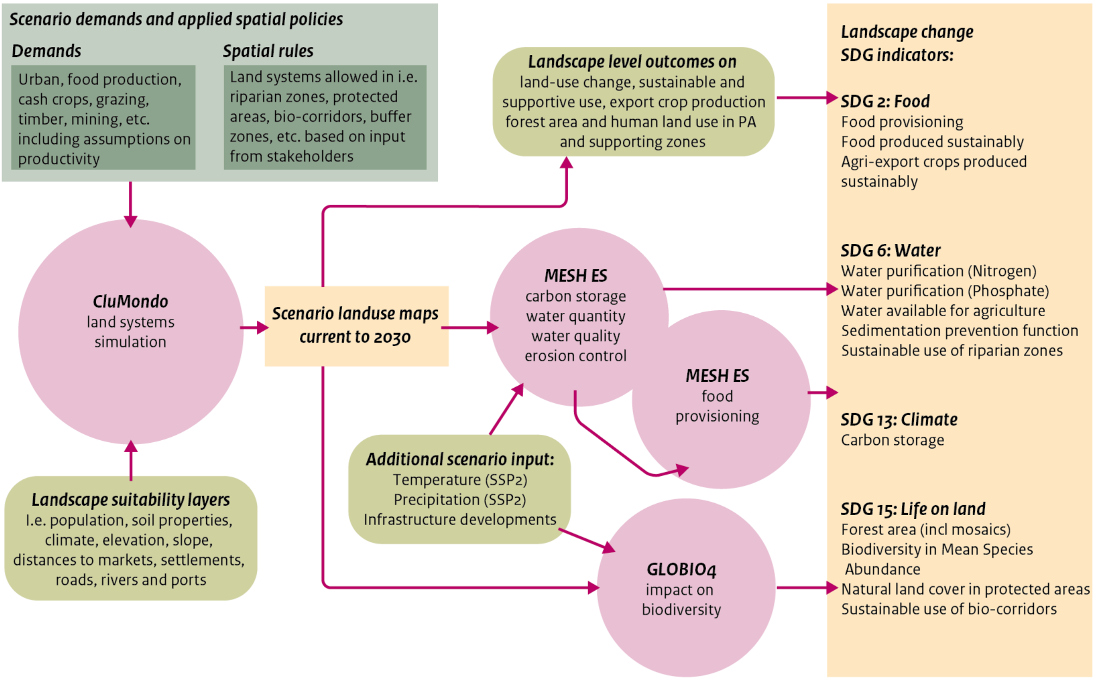
The modelling framework in this project centers around spatial planning, configuration of activities in the landscape and impacts on natural resources. The model does not (presently) include an economic or employment sub-model, but defines economic drivers of change at the landscape level. The indirect impacts are assumed to be reflected in the parameters used. It is assumed that no significant changes in the price trends for inputs and commodities will occur during the 2017-2030 period, that would modify incentives for investment or changing practices/utilization beyond the storylines of the scenarios analyzed.

The model emphasizes impacts on the landscape ambitions and selected SDGs resulting from changes in land cover/use, agricultural production and ecosystem services resulting from natural resources in the landscape. We realize that beyond these elements there are also other important factors that affect the achievement of the ambitions and SDGs, such as institutional services and effectiveness, and complementary investments in built infrastructure. Therefore the project focuses more on comparing outcomes between various scenarios and the change from the current situation and to a lesser extent on the actual achievement of official SDG targets, since for many of these the current score and the distance from the target is unknown, uncertain or the required data is not available at the moment.

3.5 Models used in the analysis

With the intention to assess various tools, the core modelling tools selected for this project are the CluMondo land systems simulation model (for analyzing land use change in response to market demand and policy/program interventions, Van Asselen and Verburg, 2013), the GLOBIO model that assesses impacts on biodiversity from human-induced pressures (Schipper et al, 2016), the MESH tool that maps (changes in) ecosystem services to impacts on human well-being (Johnson et al, in prep) and the related MESH-SDG application that relates ecosystems changes to Sustainable Development Goals (based on Wood et al, 2018).

Figure 3.3
Overview of the models used and the flow of information



Source: PBL

Figure 3.3 shows how these tools are connected and how the information represented in the conceptual model in Figure 3.2 flows from input data and assumptions to output indicators. The tools are all open source and freely available. They are explained in short below.

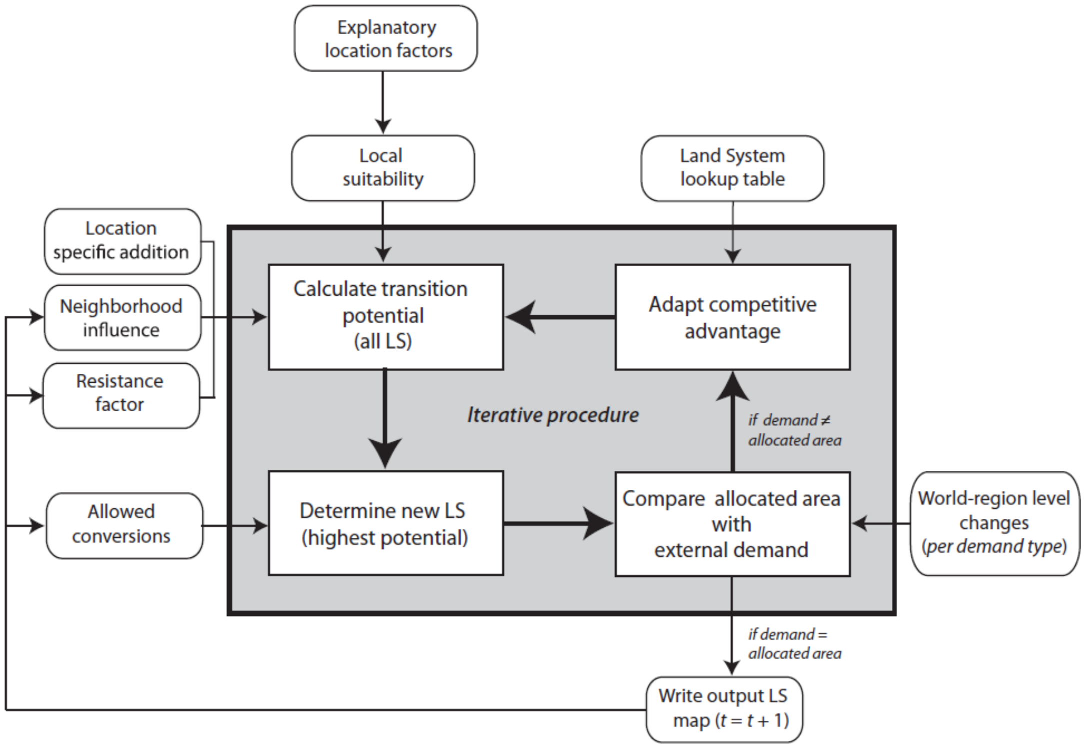
CluMondo

The CLUMondo model is the most recent version from the CLUE model family that has been used in many local, national and continental level land use change studies (Van Asselen and Verburg, 2013). CluMondo provides a flexible and innovative approach for land-use change modeling to support integrated assessments. Demands for goods and services are, in the model, supplied by a variety of land systems that are characterized by the land cover mosaic, the agricultural management intensity, and livestock production systems. Together these are called land systems. Changes in land systems are simulated by the model and driven by regional market demand for goods and influenced by local factors that either constrain or promote land system conversion.

Figure 3.4 provides an overview of the model. The model allocates at every time step (t) for each grid cell the land system (LS) with the highest transition potential. The transition potential is the sum of the local suitability, the conversion resistance and the competitive advantage of a land system. The local suitability of a land system is determined based on an econometric model that is parameterized by logistic regression. In the model a set of biophysical and socioeconomic explanatory variables is used to predict the probability of occurrence of each land system in each pixel.

The CluMondo model can be influenced by promoting or even enforcing interventions, as defined by stakeholders, that only allow, restrict or stimulate certain land use and land cover types that contribute to positive effects on the various landscape ambitions. For example in riparian zones land clearing for palm oil plantation development, as part of RSPO measures, can be restricted, existing forests can be conserved and/or development of agroforestry activities can be promoted. If combined with investments leading to increased productivity of existing palm oil production systems synergies between income and food production, erosion control, flood prevention, water quality, carbon storage, biodiversity and even tourism can be achieved.

Figure 3.4
Overview of the CluMondo land systems (LS) modelling structure



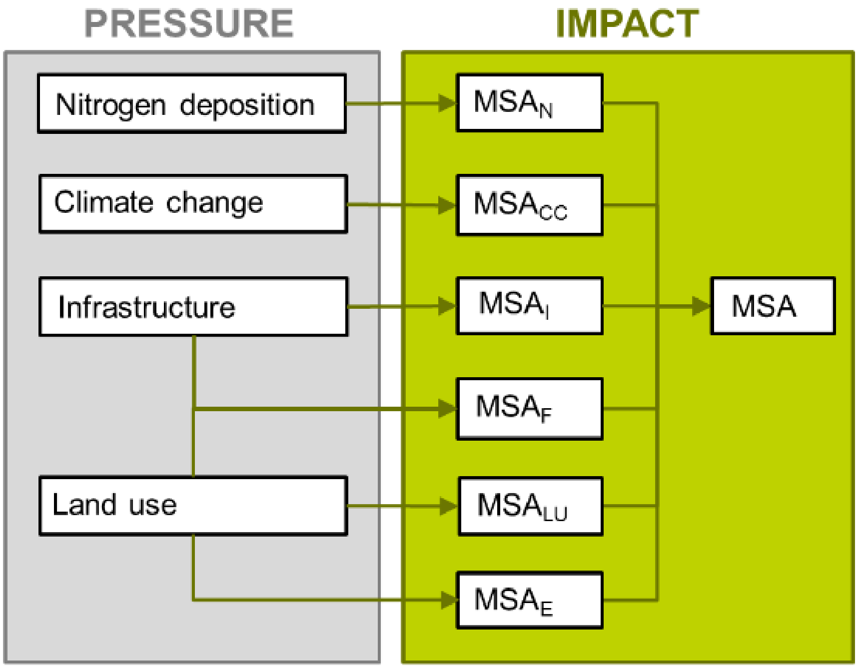
Source: Van Asselen and Verburg, 2013.

For each scenario time step (16 years) the CluMondo model produces a new land systems map that for this project has a 250x250 meter resolution. A number of indicators related to the selected SDGs are directly derived from the CluMondo outputs. More info on CluMondo can be found on https://www.environmentalgeography.nl/site/data-models/models/clumondo-model/.

GLOBIO

GLOBIO is a modelling framework to calculate the impact of environmental drivers on biodiversity. GLOBIO is based on cause-effect relationships, derived from the literature and the model uses spatial information on environmental drivers as input. The GLOBIO model quantifies biodiversity as the mean species abundance (MSA), which is calculated by dividing the abundance (density, numbers or coverage) of each species in disturbed conditions by its abundance in an undisturbed reference situation (Alkemade et al., 2009). Pressures included in the GLOBIO model are climate change, atmospheric nitrogen deposition, human land use, infrastructure and human encroachment by hunting.

Figure 3.5
Schematic representation of the cause-effect relationships included in the GLOBIO model

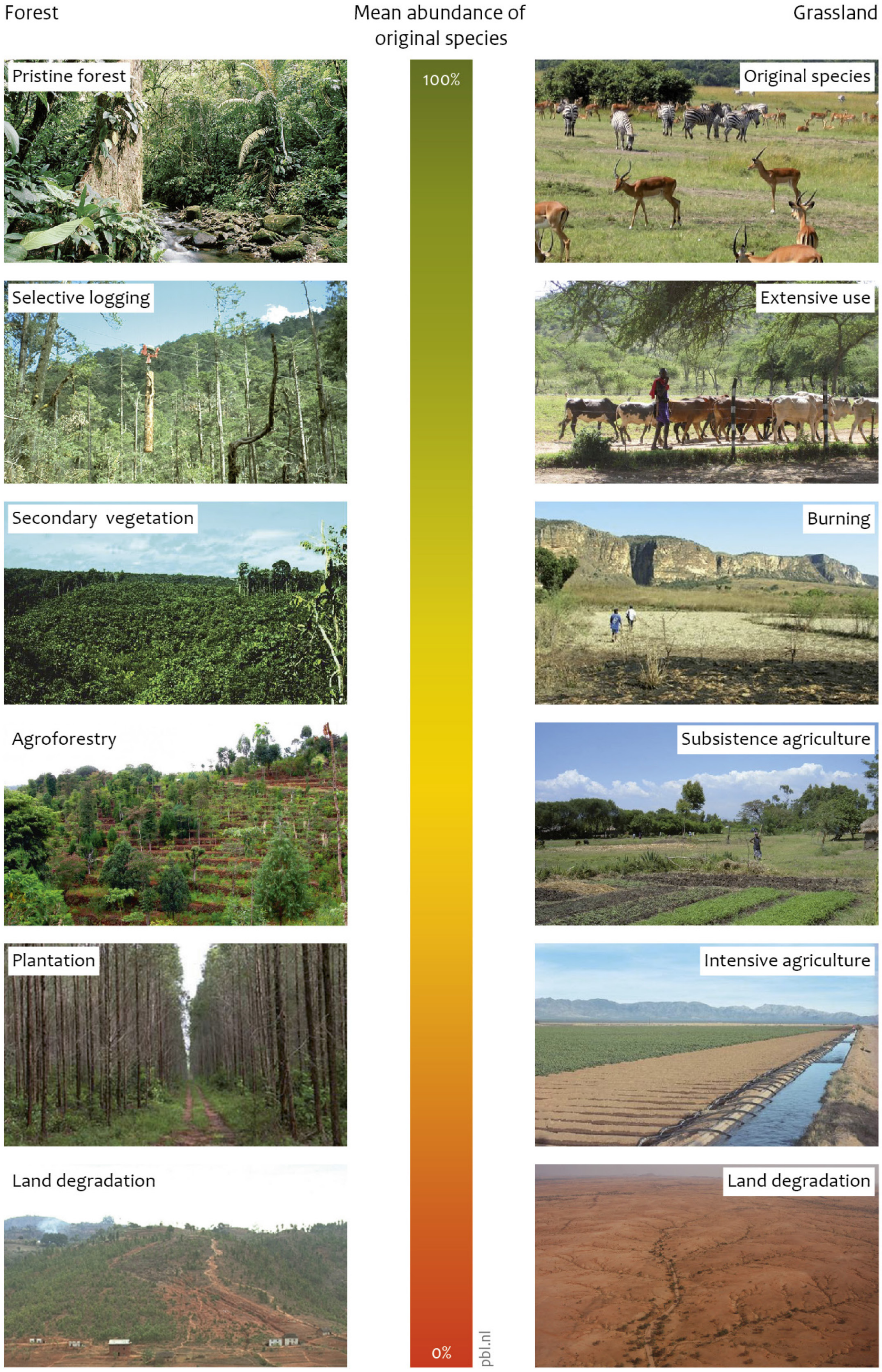


Source: PBL

Figure 3.5 shows the key pressures included in the GLOBIO model. These are the effects from human land use (MSA_{LU}, incl urban settlements, cropland, pastures, mining, plantations of oil palms and forestry), direct disturbance from infrastructure (MSA_I, roads and railroads), fragmentation of natural areas by roads and intensive agriculture (MSA_F), disturbing encroachment effects from hunting activities on the abundance of birds and mammals (MSA_E), effects from nitrogen deposition (MSA_N) and the effects from climate change on ecosystems (MSA_{CC}) (Schipper et al, 2016; Benítez-López et al, 2017). For this case study nitrogen deposition data was unavailable, so this pressure was not included in the analysis. The individual pressures are combined in an overall MSA value. For each scenario the GLOBIO model produces a spatially explicit map of the MSA values and landscape level aggregates with MSA impacts per pressure. In general GLOBIO model and MSA indicator do not cover all aspects of biodiversity, but provide an idea of the naturalness of the landscape, see Figure 3.6 for a photographic impression of various levels of MSA. More info on GLOBIO can be found on http://www.globio.info.

Figure 3.6

Photographic impression of mean species abundance indicator at landscape level



Source: PBL

MESH

The Mapping Ecosystem Services to Human well-being (MESH) tool is an integrative modelling platform that calculates and maps ecosystem service supply under different landscape management scenarios. MESH runs on a backbone of InVEST toolkit models (Sharp et al, 2018), that can be tuned to local situations. For the this landscape the following ecosystem services models were included:

- watershed water provisioning, representing water available for agriculture;

- erosion control by avoided sedimentation;
- nutrient exports (nitrogen and phosphate) as an indication of water purification;
- carbon storage;
- food provisioning.

As shown in Figure 3.3, per scenario the models take the specific land systems outcomes map and produce spatial and landscape level outputs on the same resolution of the supply of the selected ecosystem services. These outcomes are used to calculate the relative change in supply between the current situation and the future scenarios and between the scenarios. More info on MESH can be found on https://www.naturalcapitalproject.org/mesh/.

As indicated with the arrow in Figure 3.3, the food provisioning outcomes are adjusted for changes in scenario explicit assumptions on productivity in agricultural production and the relative changes in supply of the water related ecosystems services (provisioning and water purification) are used to derive a tentative indication of crop failure impacting agricultural production in riparian zones. This indication is still very much under development and mainly based on some literature covering the landscape and local expert judgement. The availability of monitoring time series data on both crop harvests and water quality indicators could also improve this.

3.6 Coverage of Sustainable Development Goals

The original design of the project assumed that it would be too difficult to model more than four of the SDGs in the scenarios.

Table 3.1
Selected SDGs and used model outcome indicators

SDG	Related target	Theme	Model outcome indicators
2	2.1-2.3	Food provisioning	Change in food provisioning function (%)
2	2.4	Land used sustainably	Change in share of food production complying to spatial polices on sustainable land use (%)
2	2.4	Land used sustainably	Change in share of agro-export production complying to spatial polices on sustainable land use (%)
6	6.3	Water quality	Change in water purification function (Nitrogen) (%)
6	6.3	Water quality	Change in water purification function (Phosphate) (%)
6	6.3	Water quantity	Change in water availability for agriculture (%)
6	6.6	Water quality/soil conservation	Change in sedimentation prevention function (%)
6	6.6	Ecosystems	Change in suitable use of riparian zones (%)
13	13.2	Climate	Change in carbon storage (%)
15	15.1	Land system	Change in forest(ed) area (%)
15	15.5	Biodiversity	Change in Mean Species Abundance in the landscape (%)
15	15.2	Supporting bio-corridors	Change in suitable use in bio-corridors (%)

In practice, the scenarios identified for the North Coast of Honduras included elements of seven of the 17 SDGs: Zero hunger (2), Clean water and sanitation (6), Responsible production/consumption (12), Climate action (13), Life below water (14), Life on land (15) and Partnership in the Goals (17). Table 3.1 notes the specific SDG Targets or indicators that were included in the models.

These reflect the focus on land and natural resources, and the relatively limited socioeconomic data incorporated into the models. Still, the interconnectedness of the SDGs and the multi-faceted impacts of interventions are notable. And the study demonstrated the feasibility of expanding such scenario modelling further with the availability of spatially explicit datasets.

3.7 Data sources

With the tools and models determined and the landscape boundary for this study defined, the list of data requirements was created. PBL provided a list of potential sources, with the challenge for Solidaridad and local organizations and partners to improve. During Phase 1 of this project many relevant documents and statistical and spatial datasets were gathered. Specifically a 5 meter resolution land use/cover map for the year 2014 was retrieved from the National Map Collection created by the governmental Instituto de Conservacion Forestal (ICF). Many other important spatial datasets were retrieved from the official Sistema Nacional de Información Territorial (SINIT, www.sinit.hn). The National Statistical Agency (INE) proved to be an important source for departmental and municipal level statistics on population and households. For a complete overview of data sources used see Annex 9.1.

During the exploratory visit by PBL in March 2017 Solidaridad enabled connecting to many stakeholders in the landscape. This provided access to more locally relevant datasets from for instance WWF (RSPO reports), FHIA (crop suitability characteristics) and the Puerto Cortes and Tela municipalities. Also visits to the facilities of HonduCaribe, HonduPalma, FUNDEG, CREDIA, UNAH CURLA, Azunosa, Omega Tours and the farm of Mr. Fausto Martinez. Also meeting with Jose Herrero and also the network of women that produce cocoa and chocolate (REDMUCH) gave many insights into the current landscape challenges and also sketched the ambitions the stakeholders have for a more sustainable and inclusive future of the region.

4 Landscape ambitions for the future

An important condition for the implementation of an integrated landscape management plan is a shared agreement on the various ambitions to be pursued by the stakeholders in a landscape. This section first provides an overview of the 10 landscape ambitions expressed by the stakeholders included in the PASOS initiative and how these relate to the SDG goals and targets. Then the importance of ecosystem services in a sustainable landscape, and their impacts on both the landscape ambitions and the SDGs is discussed, highlighting their role in generating synergies and preventing trade-offs in the next 15 years.

4.1 Landscape stakeholder ambitions and links to the SDGs

Poverty and environmental degradation are perceived by landscape stakeholders to be the major challenges for development in the North Coast. Through the multi-stakeholder assessment and planning process, they articulated nine major ambitions for their landscape over the next 15-20 years. This section provides an overview of the current status of the landscape with respect to each ambition, noting links with the SDGs.

1) Improve rural livelihoods

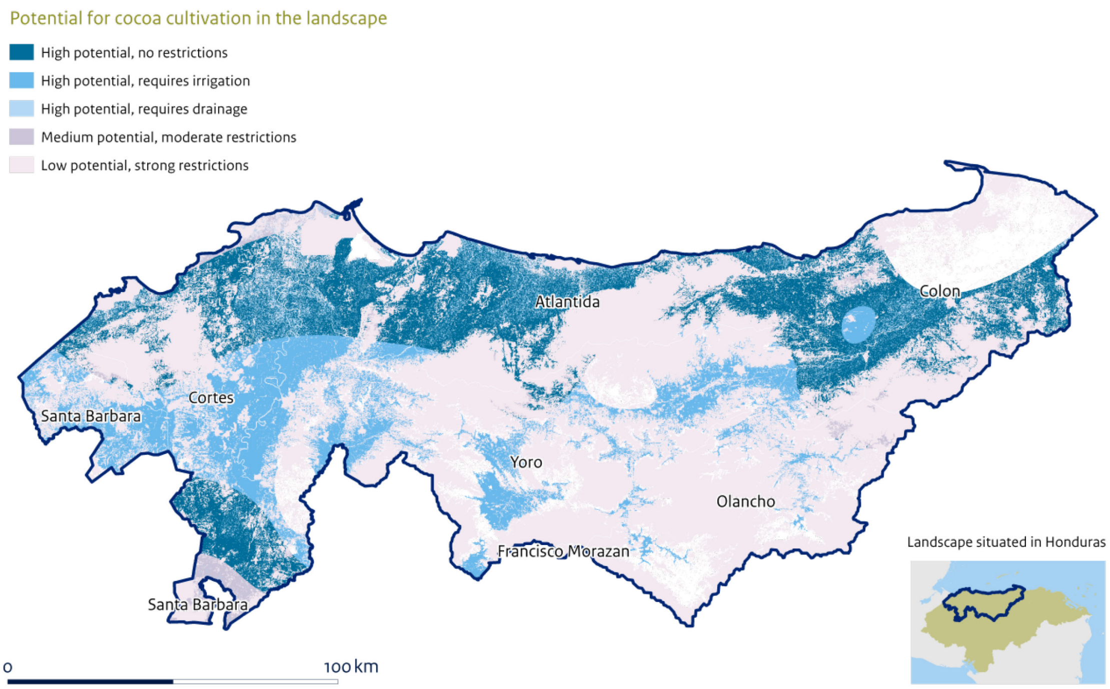
In 2016, the rural poverty index was 67%, with 56% in extreme poverty and 31% living on less than $1/day. While the urban poverty index was nearly the same --66%, fewer (though still 32%) lived in extreme poverty and only 9% were living on under $1/day. The region is not on track to achieving SDG 1 (no poverty), or 8 (decent work and economic growth). The major strategies identified to improve rural livelihoods are through diversifying income sources and employment growth from investments in sustainable expansion of oil palm, cocoa agroforestry, and ecotourism; and conservation of terrestrial and marine biodiversity as 'green infrastructure' for development, and the associated demand for local goods, processing and services from the increased income generated. Investment is needed to promote value-added for agricultural, livestock and fish products, and establish alternative economic activities that do not require use of land, such as apiculture. For landless workers, they will develop opportunities to provide services to the value chains. Underpinning rural livelihoods will require universal public services and infrastructure for health and education [SDGs 3 and 4]. It is critical to invest in new forms of sustainable energy generation, such as hydro, solar, and biogas, and to recycle waste products (e.g., plastic bottles) to turn into building materials for homes. Stakeholders will promote corporate responsibility for economic, social and environmental sustainability.

2) Improve food security of the rural population

Currently, 19% of the population under 5 years old is malnourished. Much of the rural population depends on agriculture for their livelihoods, with their income vulnerable to market price fluctuations, pests and diseases, and abnormal weather conditions due to climate change. Average yields of maize, the most important food crop, are only 1.6 tons per hectare. Monoculture systems (including oil palm and sugar cane) and lack of local production of staple crops make families vulnerable to food insecurity and malnutrition if food prices fluctuate (Castro-Tanzi and Gross, 2016). Thus, the region is not on track to achieving the hunger and food security targets of SDG 2 (zero hunger). The priority strategy identified by local stakeholders for addressing these challenges is to promote mixed crop-livestock systems in mosaics with forest cover, improving the productivity, sustainability and market stability and access for staple foods, and food security, water security and resilience. Efforts are needed to stabilize basic grain prices to incentivize production, and also to diversify production to include higher-value crop and tree species for the market. Food storage facilities need to be built within the producing zones, so producers don't need to sell immediately. Transport infrastructure needs to be improved, through local roads and canals. Efforts are needed to promote native foods of the communities, as well as for processing and artisanry of native products, and educate the population about the use and cooking of local foods. Expanded technical and financial support for agro ecological and more sustainable practices are needed.

3) Increased cocoa agroforestry land use, productivity and incomes
Stakeholders identified increased production of cocoa within diversified farming systems as a potential strategy to mitigate some of these risks for rural farmers while also conserving or improving biodiversity (following Jezeer et al., 2017). Figure 4.1 shows the potential for cocoa production in the landscape based on climate and soil properties. Cocoa is profitable and Honduras is competitive in the global market. Currently average cocoa yields in Honduras are 500 kg/ha, but have the potential to reach 1000-1200 kg/ha. Increased extension services and technical support to farmers is needed to close this yield gap. Additionally, cocoa is suitable for agroforestry systems and can be grown alongside bananas, avocados, and other fruits, providing both additional nutrients for familial consumption and additional income if these products are sold. Agroforestry systems mitigate risks associated with pests, diseases, and weather fluctuations, as they promote improved ecosystem services that can maintain crop health and a create a more diverse source of income that decreases vulnerabilities to losses associated with one crop. Cocoa agroforestry systems are an attractive alternative land use on steep slopes and near waterways, relative to oil palm. Thus an ambition in the landscape is to triple or quadruple the area of diversified cocoa systems, while increasing yields of cocoa, with food crops intercropped, and timber and non-timber products from tree intercrops.

Figure 4.1



Source: FHIA

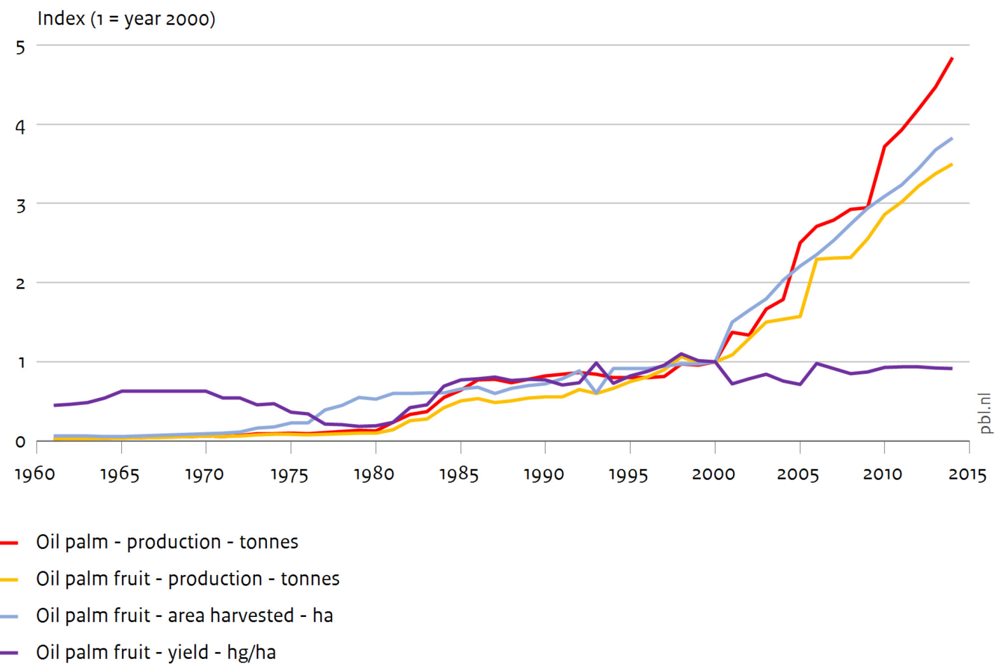
4) Doubled production of sustainably grown palm oil
Since 2000, oil palm production in Honduras has more than tripled, as has the area under cultivation (see figure 4.2); currently, Honduras is the largest palm oil producer in Central America and a player in the global market. Because palm oil production is an important source of economic development and income generation, many stakeholders in the landscape would like to see production increase sustainably. Major players in the industry are in various phases of RSPO (Roundtable for Sustainable Palm Oil) certification and seek to increase production in the region while maintaining compliance with the requirements, and have even discussed pursuing jurisdictional certification. Progress toward achieving this

ambition would indicate progress in achieving SDG 1 (no poverty), 2 (zero hunger), 6 (clean water and sanitation), 8 (decent work and economic growth), 12 (responsible consumption and production), 13 (climate action), and 15 (life on land).

However, rapid expansion of the crop has led to encroachment onto critical habitats and protected areas, as well as unsuitable terrain, such as steep slopes. This has led to soil degradation, deforestation, decrease in water quality and quantity, degradation of fragile ecosystems, and threats to biodiversity. Many independent and smallholder producers are not involved in RSPO certification efforts, are not trained in sustainable practices, and do not have access to extension services. Meanwhile, yield remains low; the current average yield is 18 MT/ha of oil palm fruit, whereas the potential is 24 MT/ha or even higher. Current extraction facilities are only operating at a portion of their capacity, creating a high demand for fruit and encouraging further expansion onto unsuitable areas (Castro-Tanzi and Gross, 2016). To achieve this ambition will require a combination of increased productivity, increased adoption of sustainable agricultural practices and supporting finance, substitution of oil palm for more suitable crops such as cocoa on steep slopes, and improved land use planning and natural resource management.

Figure 4.2

Palm oil development in Honduras, 1961 - 2014



Source: FAO

5) Clean and sufficient water for household, economic and environmental needs

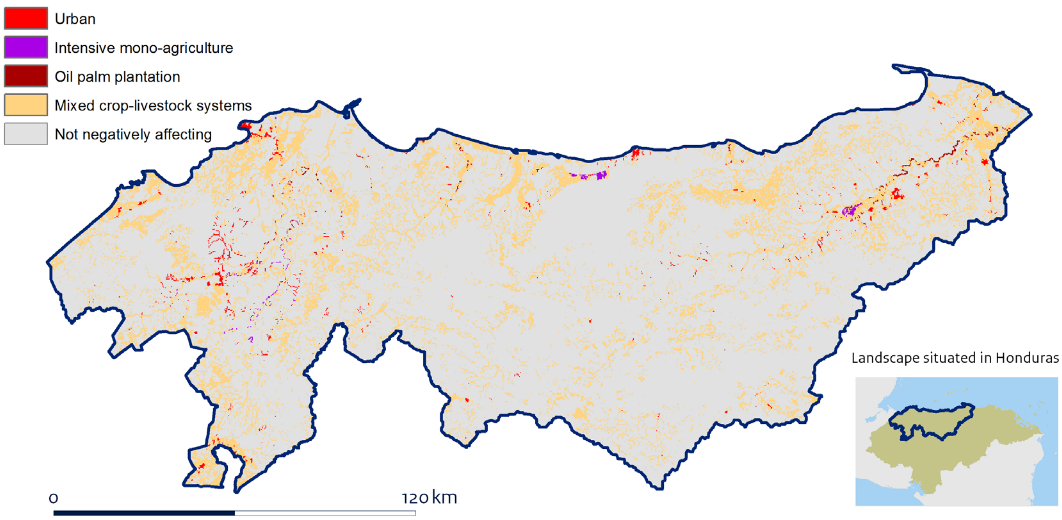
A major ambition is to have sustainable management of watersheds to provide clean and sufficient water for household, economic and environmental needs, prevent erosion and pollution, and support irrigation. Expansion of oil palm onto slopes has degraded hydrologically sensitive recharge sites and watersheds and caused erosion and runoff into streams and rivers. Likewise, deforestation caused by over extraction of timber and agricultural expansion affects water quality and availability downstream. Water scarcity has been an issue that has affected the availability of water for irrigation and for the population in the Valle de Sula, particularly during drought conditions and dry months (Castro-Tanzi and Gross, 2016). An analysis of the current settlements and agricultural areas shows that 21% of the area is being used unsustainable. This means the current land use is affecting the quality and extent of water ecosystems like wetlands, mangroves, rivers and due to its location in or nearby riparian zones, which constitute an important element of SDG6 (Figure 4.3).

Currently, most of the population has access to safe and affordable drinking water, but deteriorating water supplies, pollution and fast-growing population threaten to reduce water security. National numbers are 91% access, from UNDP Honduras report. INE data at municipality even higher[3].

Legislation already exists to regulate the management of natural resources, such as preserving vegetative cover on riverbanks, reducing point and non-point source pollution, but government institutions lack the human and financial resources to effectively implement them. The PASOS stakeholders will strengthen municipal capacities to enforce these rules, and ensure that land use on steep slopes over 20 degrees is restricted to agroforestry or forestry. Water Juntas will become more proactive with the producers, strengthening their capacities for action and for water analysis; providing access to laboratories (currently only bacterial, not chemical analyses), and addressing the problem of transporting water samples to labs. They will establish a program of community water monitoring, saving more expensive analyses for most critical water sources. Agro- and industrial-processing facilities need to be equipped with facilities to ensure pollutants do not enter water sources. Well-managed micro-watersheds can serve as bio-corridors.

Figure 4.3

Current land use affecting agricultural productivity, watersheds and biodiversity.



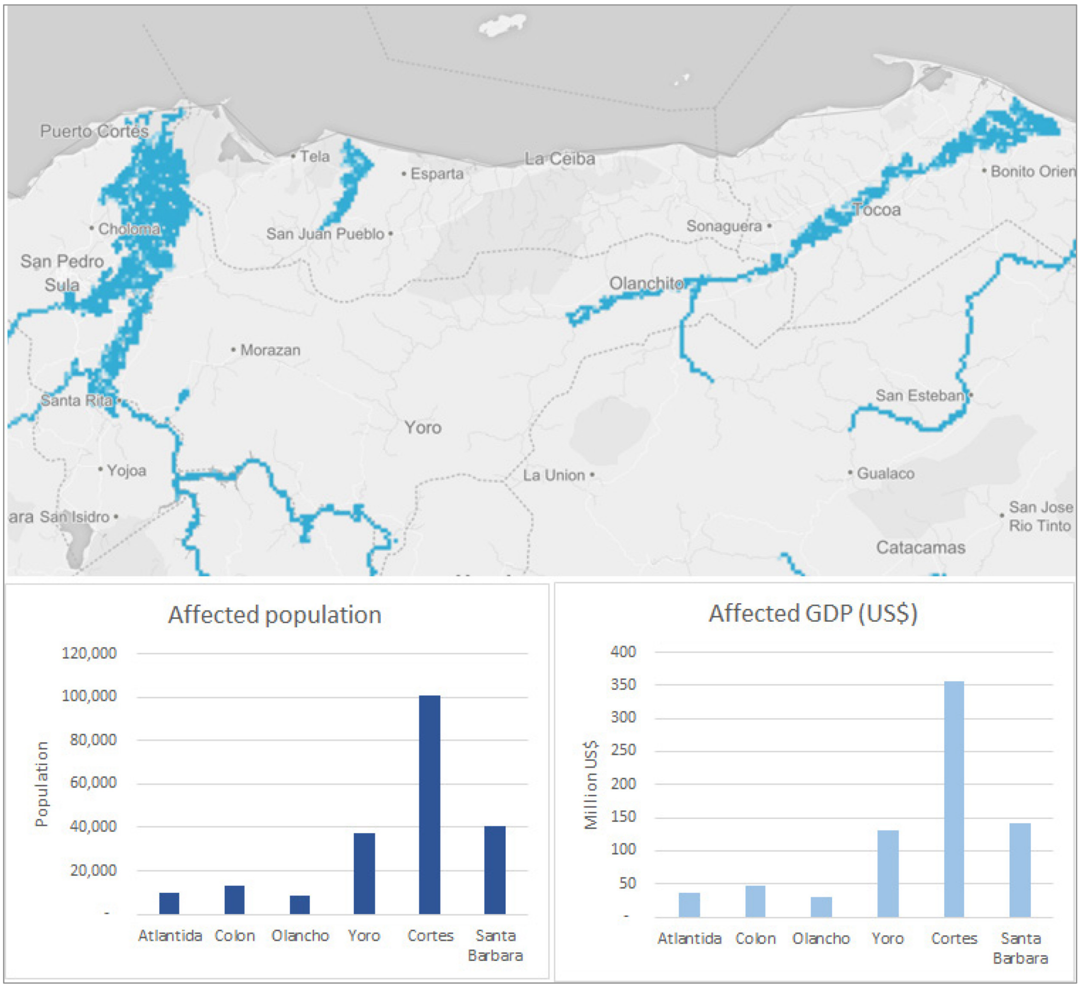
Source: PBL

6) Build resilience to flooding, climate change and extreme weather events

As a coastal region, the landscape is vulnerable to hurricanes, flooding and drought. In recent years, the landscape has experienced lower rainfall levels and an extended dry season. The Valle de Sula and Valle de Aguan are also prone to seasonal flooding, including large areas in use for palm oil production, as can also be seen in Figure 4.4[4]. These vulnerabilities particularly affect the agriculture sector, and farmers who rely primarily on agriculture for their livelihood: lower rainfall causes a strain on valuable water resources, whereas flooding can damage crops. Likewise, extreme weather events, such as hurricanes, are a threat. In 1998, hurricane Mitch caused widespread flooding and landslides, damaging crops, infrastructure, and houses, and causing thousands of deaths. Better management of natural resources, particularly water and vegetation cover, can help mitigate these risks. In addition to improving watershed management (above), landscape actors will promote development of community, municipal and landscape resilience plans, advancing SDG 13 (adaptation to climate change).

[3] Info from INE website (accessed at 2018-09-11) at http://170.238.108.227/binhnd/RpWebEngine.exe/Portal?BASE=CPVHND2013NAC&lang=ESP
[4] Note that oil palm can tolerate short period of flooding relatively well, but is vulnerable to longer periods of submersion (Hardanto et al, 2017).

Figure 4.4
Current flood Risk in North Coast, Honduras, based on Aqueduct Flood Analyser



Source: WRI Aqueduct (http://floods.wri.org)

7) Expand sustainable eco-tourism development

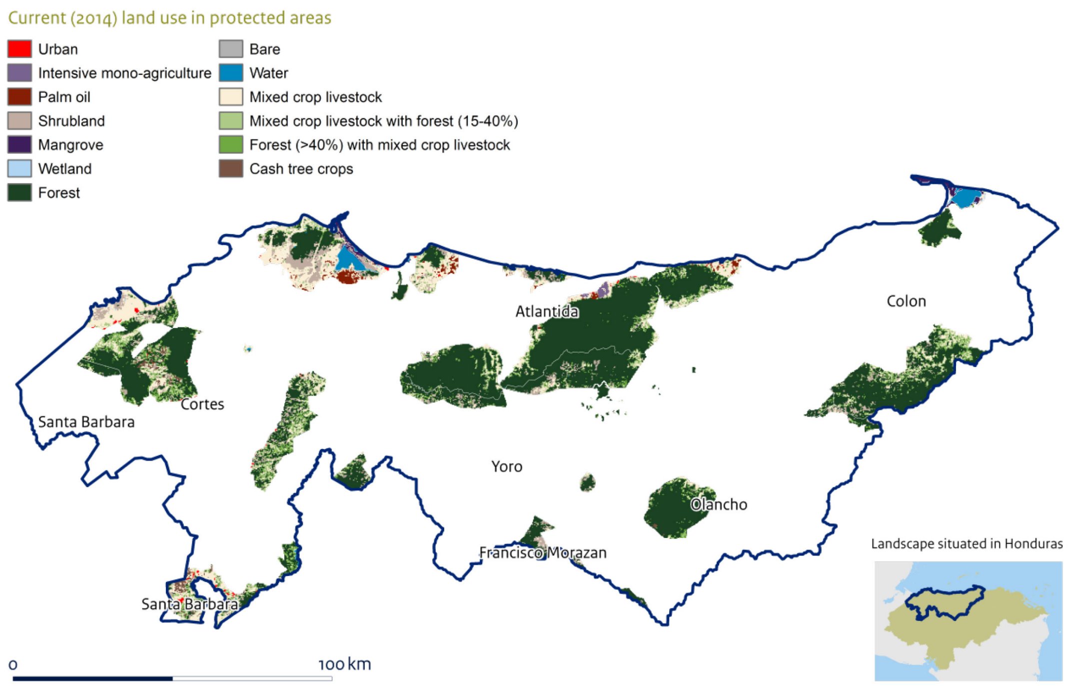
Tourism is growing in the Northern Coast of Honduras. The Mesoamerican Barrier Reef—the second largest in the world—is a valuable draw. Beach resorts and hotels exist on the coastline between Tela and La Ceiba, and La Ceiba is a launching point to visit the Caribbean Bay Islands off the coast, including Roatan, a popular site for scuba divers. Eco-tourism is growing around Pico Bonito National Park and the Cangrejal River, and outfitters offer rafting, hiking, and horseback riding excursions. Stakeholders in the landscape would like to see eco-friendly and sustainable tourism grow, as it offers great potential to provide additional jobs and stimulate economic growth while also providing an incentive to protect the region's beautiful natural resources and wildlife. Stakeholders have also expressed interest in exploring agro-ecotourism, potentially offering hikes and tours of sustainable oil palm or cocoa agroforestry farms in the region. Tourism development could contribute to SDG 8 (decent work and economic growth), 14 (life below water), and 15 (life on land), but this will require great effort to halt deforestation and encroachment of oil palm and other forms of agriculture into protected areas in order to preserve the wildlife that attracts visitors, and to manage agricultural systems so that they support biodiversity. They noted the need to prepare communities to participate effectively in eco-tourism (such as developing a community diploma in ecotourism), and see opportunities to integrate tourism in the landscape with national tourist routes and will produce documentaries for internal and external audiences.

8) *Conserve and expand 'green infrastructure', including forests, terrestrial and coastal/marine habitat, and biological corridors*

The North Coast landscape has a number of protected areas (see figure 4.5) that boast a variety of ecosystems and abundant wildlife. Approximately 11% of the land area is protected, and 36% is covered by forests. Many agricultural areas under agroforestry and mixed crop-livestock-forest mosaics, also sustain biodiversity and watershed quality. Areas of agricultural soils with high organic matter, tree crops and perennial grasses and natural vegetation are important stores of terrestrial carbon that mitigate climate change (SDG13). However, these areas continue to be threatened by agricultural expansion, such as oil palm, as well as over-extraction of timber in some areas. Legislation that protects these areas is not adequately enforced. Stakeholders have expressed a desire to see an increase in terrestrial protected areas to 14-17% (particularly nearby agricultural production zones in the Sula Valley and the coastal region between Tela and La Ceiba), as well as better connectivity between areas already protected by maintaining and improving bio-corridors incorporating well-managed micro-watersheds, agroforestry systems and habitat networks in and around production agriculture. To meet this ambition and SDG 15 (life on land), adequate resources (both in terms of funding and technical capacity) will need to be allocated toward agencies responsible for enforcing environmental regulations. Additionally, stakeholders will increase education about environmental issues (particularly among youth), to instill values of good environmental stewardship among the population (SDG 4).

The Northern Coast landscape is also home to valuable coastal and marine ecosystems such as coral reefs, mangroves, lagoon, that are important for ecosystem stability, fisher incomes and subsistence, and for ecotourism. However, agricultural pollution, and climate change threaten the health of these ecosystems, and the landscape is not on track to meet SDG 14 (life below water). To address this challenge, landscape stakeholders propose to expand marine protected areas and promote more sustainable land management practices to decrease the sediment flow from rivers that impact coastal marine life and establish fishing/no-fishing zones and restore corals through natural and accelerated recuperation.

Figure 4.5



Source: ICF and PBL

9) *Strengthen land rights and territorial planning*

A foundation to achieve the objectives above will be a robust system of land rights and rules. There are still opportunities to identify areas that are not being used and distribute them to landless campesinos and also professionals. Lands that have been confiscated by the state from criminals, etc., can be reassigned to the landless, and organized into micro-businesses by the current workers. Coastal indigenous peoples' resource rights will be protected. Juridical security for property that has already been given ownership and indigenous rights should be assured. A complete cadastral study of land, its current use, soil characteristics and potentials/intervention will be implemented as a foundation for ILM. Producers need access to soil studies. It is recommended to devise a territorial plan that will incorporate key features of the landscape ambitions.

The stakeholders also are establishing a dialogue platform, and hope that all communities will be part of that. They noted the importance of strengthening the judicial system and application of existing law, and strengthening capacities for associations and governance. The establishment of the North Coast landscape stakeholder platform is itself a contribution to both SDG16 (peaceful and inclusive societies and institutions) and SDG17 (partnerships for the Goals), as is the strengthening of farmer and community organizations, and private sector organizational commitments to sustainability.

4.2 Changes in ecosystem services

Achieving the ambitions formulated by the stakeholders in the landscape relies on many factors, but in this case study we focus on the role of spatial planning by doing the right thing in the right place and how this can support, conserve or restore various ecosystem services that are generated by land, vegetation and water resources.

There are four categories of ecosystem services:

- provisioning services (e.g. food production)
- regulating services (e.g., carbon storage)
- cultural services (e.g., biodiversity values in local culture)
- supporting services (e.g., nutrient cycling)

How these services can be identified in a landscape is illustrated in Figure 4.6

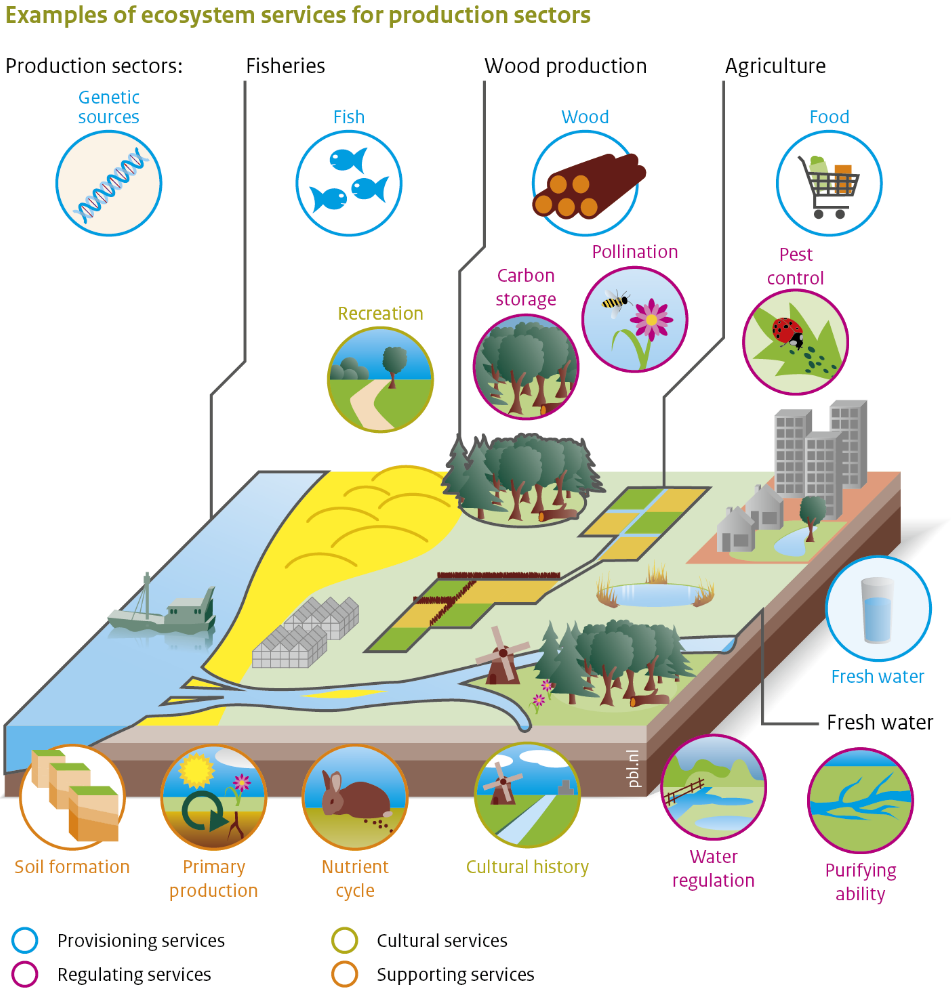
In our analysis we are using the changes in the supply of ecosystem services to analyse the potential synergies or trade-offs occurring under the developed scenarios and to identify strategies to contribute to achieving progress on the selected SDGs simultaneously.

Table 4.1 illustrates how the landscape ambitions map onto achievement of the SDGs.

For example, there are powerful interactions between **agriculture, food security, water and terrestrial biodiversity (SDGs 2, 6 and 15)**. Farming is strongly dependent on and affects the quality and availability of water, because boosting agricultural production can increase water withdrawals and worsen land and water degradation. Achieving nutrition targets requires access to clean water and sanitation, and in many places, to wild plants and animals for micronutrients or supplemental food and livestock feed. Sustainable agricultural systems and practices contribute to ecosystem health, while unsustainable systems may resulting in deforestation and land and water degradation, jeopardizing long-term food security. Water and watershed management have important impacts on habitat conditions for native biodiversity.

There are also important interactions and interdependencies between **agriculture, food security and climate (SDGs 2 and 13).** Agriculture is an important source of greenhouse gas emissions, through soil disturbance, land clearing, fossil fuel use for agricultural machinery and irrigation,and use of nitrogen fertilizers. Conversely, climate change has wide-ranging impacts on agriculture and food security through extreme weather events as well as long-term changes in temperature and precipitation. Sustainable agricultural and land use practices play an important role in climate adaptation and mitigation.

Figure 4.6



Source: PBL

Source: PBL

There are similar synergies and tradeoffs between **coastal area sustainability and human settlements (SDGs 14 and 11)**. Coasts are attractive for urban development, due to opportunities for economic activities and the availability of natural resources. But coastal settlements are a major factor increasing environmental pressures along the coast-sea interface. Conflicts may occur where ocean and coastal conservation limit options for housing, infrastructure or transport.

These interactions are a strong rationale for integrated landscape planning, action and monitoring. Reflecting these relationships is a key feature of the scenario modelling approach, by showing how interventions in one part of the landscape will impact ecosystem services, and how changes in turn affect outcomes in other sectors.

Table 4.1
SDGs addressed through the North Coast landscape ambitions. Top row highlighted SDGs (2, 6, 13, 15) are covered in the spatial scenario analysis. (More info on the SDGs can be found at https://sustainabledevelopment.un.org/sdgs)

	Sustainable Development Goals																
Ambitions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Improved land-based livelihoods	■	■						■	■								
Food security through sustainable production	■	■			■	■				■			■		■		
Strong cocoa agroforestry	■	■			■	■	■			■			■		■		
Doubled sustainable palm oil production	■				■	■						■			■		
Sustainable watersheds providing water for all	■	■	■			■								■	■		
Green infrastructure for ecosystems & biodiversity		■				■							■	■	■		
Resilience to disasters, climate change, flooding		■				■							■		■		
Sustainable ecotourism industry	■							■	■			■					
Strong territorial planning and secure land rights for smallholders											■					■	■

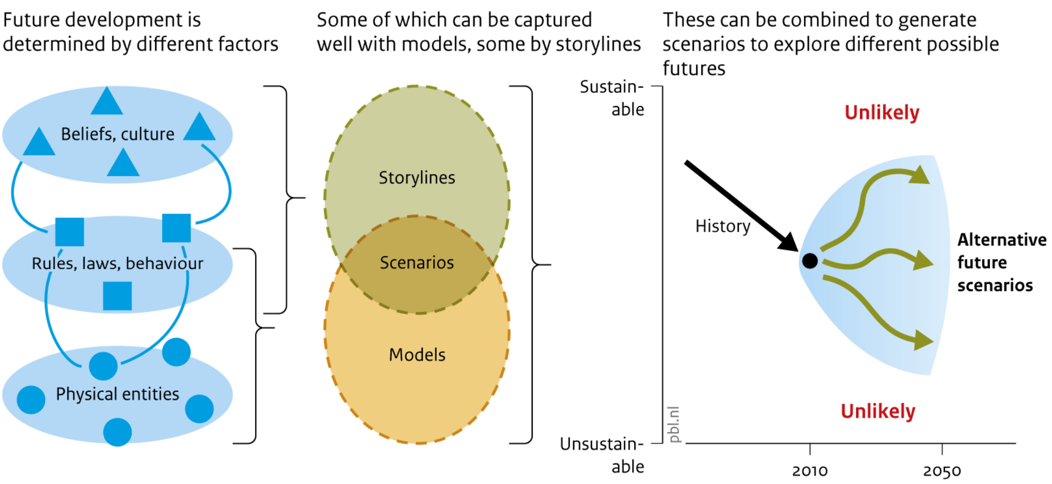
5 Exploring scenarios to 2030

The ambitions of the North Coast landscape initiative stakeholders are highly aligned with the Sustainable Development Goals. But will the intervention strategies they are planning actually achieve the desired impacts by 2030? Do interventions in different sectors and sub-sectors conflict with one another? In order to refine these action strategies, they need to be made more concrete and spatially specific. The strategy can be improved if constraints and limitations are identified early on. The aim of this study was to provide insights into potential strategies whose synergies enable simultaneous progress on multiple Sustainable Development Goals.

The project explored different plausible futures by combining stakeholder storylines with models to generate 'scenarios' (Figure 5.1). The process builds on the classic 'driver-pressure-state-impact-response' (DPSIR) approach to change. That is, certain external factors provide pressures on the current state of the landscape which produces an impact (changing state), which in turn provokes a response from the resource or from human actors.

Figure 5.1

Model-based scenario analysis



Bron: PBL

Each of these elements was defined for the North Zone landscape of Honduras. The study compared the results of scenarios reflecting 'business-as-usual', i.e., a continuation of current trends in the landscape, with scenarios inspired by strategies of integrated landscape management reflected in the Landscape Ambitions (section 3). Given the focus on achieving the SDGs, the time frame for the analysis was to 2030.

Sub-sections 5.1, 5.2 and 5.3 describe, respectively, the Business as Usual Trend, Accelerated Agricultural Export Growth and ILM scenarios, and also the visualizations developed to assist in scenario development. Sub-sections 5.4 and 5.5 summarize the main scenario assumptions that generate the outcome maps. Sub-section 5.6 describes the visualizations that were developed to help stakeholders envision how the landscape would look and behave under different scenario

5.1 A Business as Usual Trend scenario to 2030

Based on literature, government plans, historical and current data a benchmark scenario for the year 2030 was created. This Business as Usual 'Trend' scenario assumes that current pressures in the landscape will persist and no new or extra policy responses will be implemented.

The core features of the Business as Usual Trend scenario are:

- The population in the landscape will increase from 3.1 to 4.2 million people;
- The production of palm oil will follow the recent trend and increase by 50% but due to aging trees and no active investments the productivity per hectare slightly declines compared to current levels. There are no effective limits on spatial expansion;
- Area used for food production will increase, following population growth;
- Marginally suitable lands will continue to be used for agricultural production;
- Degradation of riparian zones, over-extraction of water for irrigation, and water pollution in general will continue;
- Buffer zones of protected areas and other zones of high remaining biodiversity will be encroached, as well as core zones of protected areas in areas where conversion has already begun; more remote core protected areas are effectively protected;
- Low productivity and sustainability will continue for most agricultural commodities;
- Community organization will continue to be weak
- Risks from climate change will increase for water, agricultural productivity and natural disasters.

5.2 An Accelerated Agricultural Export Growth scenario to 2030

A second scenario was inspired by stakeholders and various government documents focusing on achieving national ambitions on economic growth by developing This scenario builds on the business as usual Trend scenario but aims at achieving high rates of growth in the production agricultural export commodities, especially palm oil, pineapples, bananas but also sugar cane.

This scenario has the ambition to:

- Double palm oil production. Similar to the business as usual Trend scenario the focus on achieving this is by expansion of the area under cultivation, but in this scenario also small investments in intensification and slow rate of replacing old oil palms with new higher yielding variety oil palm trees, results in 10% increase of productivity per hectare compared the current levels.
- Expand the production of intensive mono-cultural export crops like pineapples, bananas and the cultivation of sugar cane by 80%, following earlier scenarios developed by the PROCORREDOR project.
- Production of cash tree crops for export (like cocoa, citrus, rambuttan) is set to double as well.
- The above activities are assumed to attract slightly more people compared to the Business as Usual Trend scenario, so urban settlement development is also slight higher. In relation to the additional population, the area need for food production will also be higher compared to the Trend scenario. Focus here is remains in mixed crop-livestock systems with only sparse tree cover.

The agricultural activities will continue to produce on steep slopes, in riparian zones and areas of high risk to flooding. In this scenario weak and non-effective protection of protected areas is assumed and the promotion of mixed crop-livestock under agroforestry practices is minimal.

5.3 An ILM-inspired scenario to 2030

Integrated Landscape Management (ILM), regardless of the 'entry point' for action in a particular landscape or the community of practice, has five key features (Scherr, Shames and Friedman 2013):

1) Shared or agreed management objectives that encompass the economic, social and environmental outputs and outcomes desired from the landscape (commonly human well-being, poverty reduction, economic development, food and fiber production, climate change mitigation, and conservation of biodiversity and ecosystem services)
2) Field, farm and forest practices are designed to contribute to those multiple objectives
3) Ecological, social, and economic interactions among different parts of the landscape are managed to realize positive synergies among interests and actors or to mitigate negative trade-offs
4) Collaborative, community-engaged processes are in place for dialogue, planning, negotiating and monitoring decisions
5) Markets and public policies are shaped to achieve the diverse set of landscape objectives.

The North Coast stakeholders' landscape ambitions for inclusive green growth reflect an ILM strategy, explicitly aiming for synergies and reducing trade-offs between economic and agricultural growth, environmental protection and local livelihoods.

The ILM scenario used in this modelling study is inspired by those landscape ambitions. Specific landscape interventions were defined that could be incorporated into a land use-driven scenario model to achieve inclusive green growth. During the workshop there was particular attention to identify interventions that would meet multiple ambitions and SDGs.

The scenario interventions exercise was particularly useful for stakeholder discussions, as it required clarifying interventions, including the scale of action and explicit spatial focus.

Key interventions incorporated in the ILM inspired scenario model were:

1) **Improve livelihoods** of the population
   a. Impacts of agricultural interventions (area expansion, productivity growth, sustainability, new products and product markets) are assumed to improve livelihoods based on vision of the stakeholders, but are not explicitly modelled.
   b. *Not included in the model: proposed market innovations; expanded education, health, sustainable urban developments, expand sustainable energy*
2) **Increase local sustainable production of staple foods** by shifting from annual crop to mixed crop-livestock-agroforestry-forest systems, to improve rural food security, and mitigate environmental degradation:
   a. Promote a shift of food production systems from annual crop-livestock systems to crop-livestock-agroforestry-forest systems
   b. Increased productivity in mixed crop-livestock systems in mosaics by
   c. Increase use of soil conservation practices in cropping systems (modelled by switching to more mixed systems)
   d. Improve infrastructure for local food storage and market access (not included in the modelling)
3) **Expand cocoa agroforestry systems** and increase productivity to raise incomes and employment:
   a. Expand area of cocoa agroforestry systems by 300%
   b. Expand area of staple food intercrops in cocoa
   c. Increase productivity of staple foods in cocoa agroforestry systems
   d. Increase income generation from timber and NTFPs
4) **Double production of sustainable palm oil**, with 100% RSPO certification, to raise incomes and mitigate environmental degradation
   a. Increase productivity existing palm oil plantations by 30%, by replacing older trees with higher producing and resilient species
   b. Reduce most palm oil production on slopes
   c. Limit expansion of new plantation, especially on forested or unsuitable land and in protected areas

    d. Investment in palm oil processing plants (not included in the modelling)
5) **Promote sustainable watershed management** to meet household, economic and environmental water needs, and minimize environmental risks for flooding, sedimentation and agrochemical pollution.
    a. Strengthen and enforce municipal regulations requiring year-round natural vegetative cover or agroforestry systems in riparian zones—reflected in assumptions on effective enforcement
    b. Strengthen and enforce municipal regulations requiring year-round natural vegetative cover or agroforestry systems on slopes greater than 20 degrees
    c. Increase soil conservation and erosion control in agricultural production (modelled by switching to mixed classes and reforestation)
    d. Improved water governance and monitoring to ensure adequate flow of water for household, economic and environmental needs (not explicitly included in the modelling)
6) **Expand 'green infrastructure'**, including forests, protected areas, and biological corridors/habitat networks [coordinated with agroforestry and other above]
    a. Strengthen protection of core parts of terrestrial and coastal protected areas.
    b. Promote only sustainable land uses in the buffer zones of protected areas.
    c. Expand protected areas
    d. Increase terrestrial carbon sequestration and storage across the landscape.
7) **Build resilience** to flooding, climate change and extreme weather events
    a. Promote only sustainable land uses in the high flood risk zones
    b. *Social/institutional innovations not included in the model.*
8) **Promote sustainable eco-tourism development** around terrestrial and coastal protected areas, and link to sustainable agriculture and local culture, to increase income and employment
    a. *Ecotourism innovations, infrastructure, training, marketing not explicitly in the model*
9) **Expand coastal protected areas and improve fisheries** management to protect coastal and marine biodiversity and ecotourism opportunities
    a. *Coastal protected area expansion or coastal wetlands/mangroves protection not included in the model]*
10) **Strengthen land rights and territorial planning.**
    a. Territorial planning is embedded in the assumptions above.
    b. *Land rights not included in the model.*

Each of these interventions was translated in the landscape model into specific, spatially-explicit activities, rules and conditions, in a trajectory over time between 2014 (year of the land use map) and 2030. The model enabled assessment of the outcomes that include the interaction effects among land and resource users and uses.

The modelling did not take into account the costs or gross income changes or multiplier effects from the various interventions. The business models currently being generated by the PASOS stakeholders for major landscape interventions, will provide more rigorous estimates of economic costs and benefits that could be used in subsequent studies.

Table 5.1 summarizes the assumptions made in the model about interventions. The model takes these assumptions, and then shows the resulting land use and ecosystem impacts, given the basic rules of land system allocation described in section 4 (related to suitability, distance to markets, etc.) and interactions among variables. Note that these are not 'outcome' variables; for example, the model does not 'conclude' that 300,000 hectares of cocoa agroforestry will be planted (i.e.. there are no price-response or market sub-models), but assumes that investments will be mobilized to plant the additional area.

By building the BAU, AAEG and ILM scenarios, it was possible to compare results from both to the goals laid out in the SDGs. The results are summarized in section 6.

5.4 Overview of the main scenario assumptions

Table 5.1 provides the main assumptions related to agricultural production area and productivity that were used in the spatial modelling exercise to characterize each scenario. These reflect estimates from data and stakeholder definition of landscape ambitions.

The costs associated with achieving changes in area and productivity are not included in the model, however examining these assumptions helped stakeholders to consider what kinds of interventions would be required to make them happen. The model did not include different use levels for agrochemical fertilizers and pesticides or the nitrogen and phosphorus levels associated with the different land use systems.

Table 5.1
Scenario assumptions for key variables under Trend, AAEG and ILM scenarios

Variable in model	Metric in model	Current	Trend scenario	AAEG scenario	ILM scenario
Food crop production productivity (i.e. maize and beans)	Average tons/ha (% change)	1.6 t/ha (=maize)	0%	0%	+40%
Increase of crop-livestock production	Hectares under crop-livestock	639,900	+33%	+39%	+33%
Cocoa productivity	Avg kg/ha (% change)	500	0%	0%	0%
Expansion of cocoa agroforestry systems	Hectares under AF systems	5,000	+50%	+100%	+300%
Palm oil productivity	Metric tons per hectare	18.0	15.3 (-15%)	19.8 (+10%)	24 (+33%)
Area under oil palm production	Hectares	96,600	+60%	+90%	+60%

5.5 Spatial operationalization of the interventions

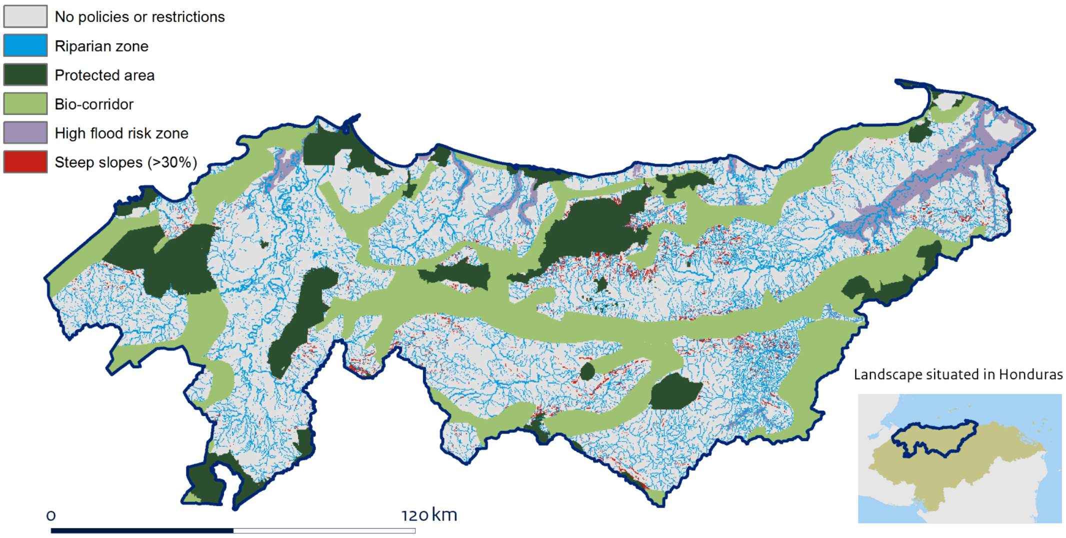
To operationalize the interventions suggested by the stakeholders and to assess the scenario outcomes on progress towards the landscape ambitions, a number of spatial policies and restriction layers have been created an guide, promote or restrict certain activities or land uses under the specific scenarios. These are the following:

- A spatial layer containing the riparian zones, defined as the area covered by a 100 meter buffer of rivers, which were derived from the SINIT data portal (www.sinit.hn)
- A spatial layer containing the core zones of the latest version of the protected areas in the landscape, derived from the ICF Geoportal (http://geoportal.icf.gob.hn/geoportal)
- A spatial layer containing the bio-corridors for the landscape, as derived from the SINIT portal
- A spatial layer containing the high risk flood zones in the landscape, as derived from the SINIT portal
- As spatial layer containing the areas with more than 30 degrees slope, as derived from the global SRTM digital elevation model (see Annex 10)

Figure 5.2 displays an overlay of the spatial policies and restrictions layer. In total 12,185 km2 is covered by these policy layers, similar to 53% of the landscape area.

Figure 5.2

Spatial policy zones applied to the landscape



Source: PBL

The spatial policies specifically used in the CluMondo land systems simulation which is described in Chapter 3 and Annex 9. For the BAU scenario only the protected areas restriction zone was used, to apply a low level of effectiveness on preventing conversion of natural areas as described in the scenario assumptions above. For the AAEG scenario no policies or restrictions were applied, so the 2030 land allocation for that scenario is based on the land use suitability regression models developed by CluMondo. For the ILM inspired scenario however all the identified spatial policies and restrictions were applied in order to support as many of the landscape ambitions as possible. In Table 5.2 information is provided on how the different land systems and the policies and restrictions were combined under the ILM inspired scenario.

Table 5.2
Policies and restrictions on land system change under the ILM scenario

Land system	Riparian zones	Protected areas	Bio-corridor	High flood risk	Slopes
Urban	0	0	0	0	0
intensive agriculture	0	0	0	0	0
palm-oil	0	0	2	2	0
Mixed crop-livestock	0	0	0	0	0
Mixed crop-livestock with forest	0	0	2	2	0
Forest with extensive agriculture	1	0	1	1	1
cash tree crops, mixed with trees	1	0	1	1	1
forest mixed with cash tree crops	1	0	1	1	1

Info: value 0 means the land system is not allowed to expand in this zone, value 1 means the land system is allowed to expand in this zone, value 2 means the land system is allowed to expand in this zone, but cannot replace existing natural land systems like forests or wetlands.

These policies and restrictions have also helped to assess the current activities in these areas. Under the ILM scenario the ambition was to convert existing restricted and undesired land systems to supporting land systems allowed in the respective zones. Both the current situation and the scenario outcomes are assessed on their support to the landscape ambitions based on the settings from this table, i.e. urban or palm oil plantations in a protected area or riparian zone are considered undesired and therefore not supporting progress towards achieving the ambitions.

5.6 Visualizing landscape scenarios

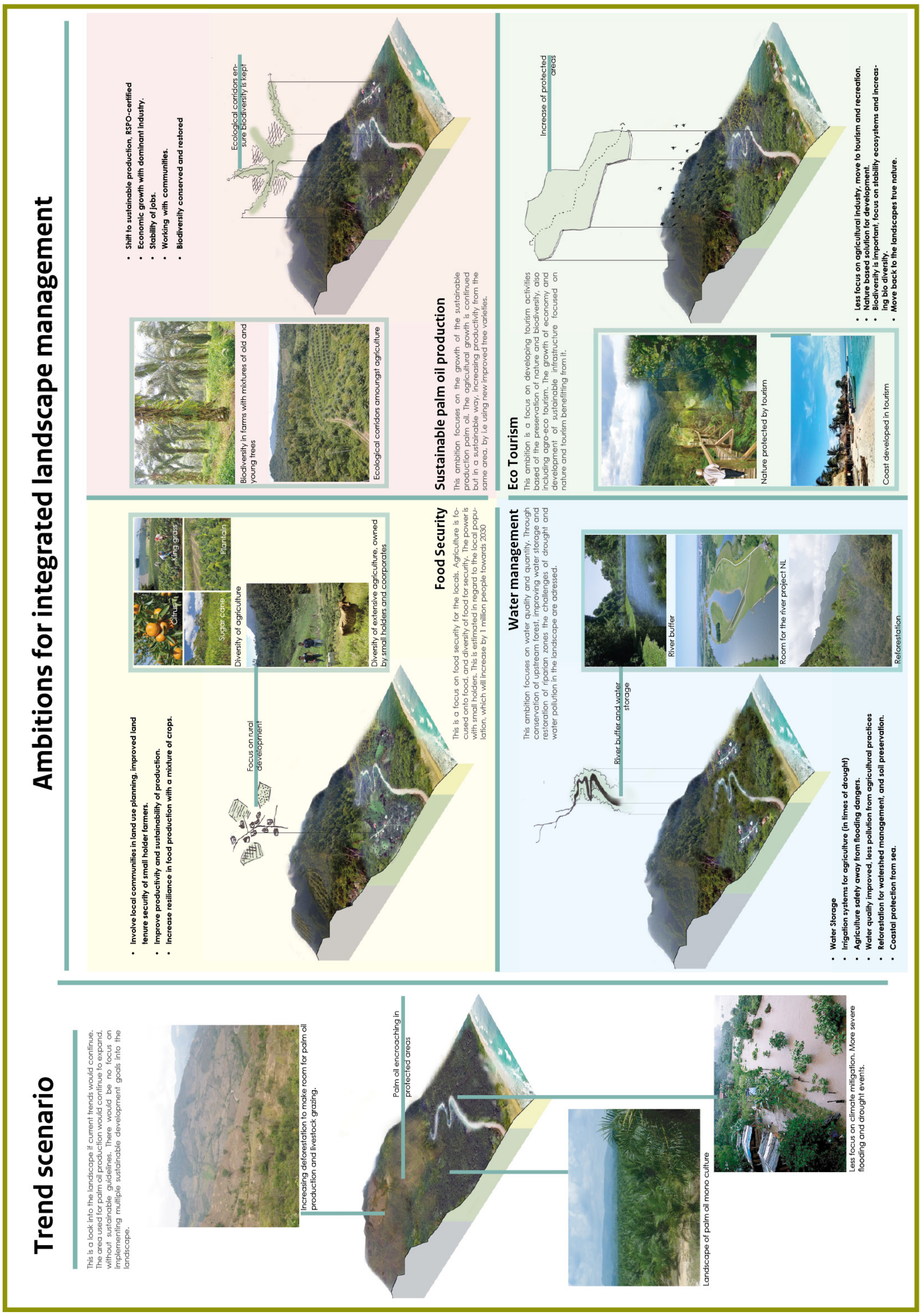
To support the development of the scenario storylines by the stakeholders and their understanding of the various scenarios in the landscape, PBL created visualizations. These helped stakeholders be aware of the consequences of their choices, showed different solutions for the landscape, and helped to integrate the agendas of the different stakeholders. These visualizations were developed through a PBL internship with the TU Delft University in the Netherlands, and are described in a report describing the historical and cultural context of Honduras in general and the PASOS landscape in specific (Appleton, 2017).

Figure 5.4 illustrates the key themes of the visualizations. The visualizations were posted on the walls of the workshop meeting room for easy discussion and direct marking by the participants. They were particularly valuable in enabling stakeholders to understand and compare the ambitions and impacts of the various scenarios, to discuss to potential effects, to check the accuracy of protected area boundaries, and to mark where additional protected areas are needed.

Figure 5.3
Photo of workshop participants discussing the scenario interventions

Source: PBL

Figure 5.4
Scenarios and themes of the landscape design analysis focusing on the idea of connecting the "mountains to the sea", used in the scenario workshop.



Source: PBL

6 Results from the scenario analysis

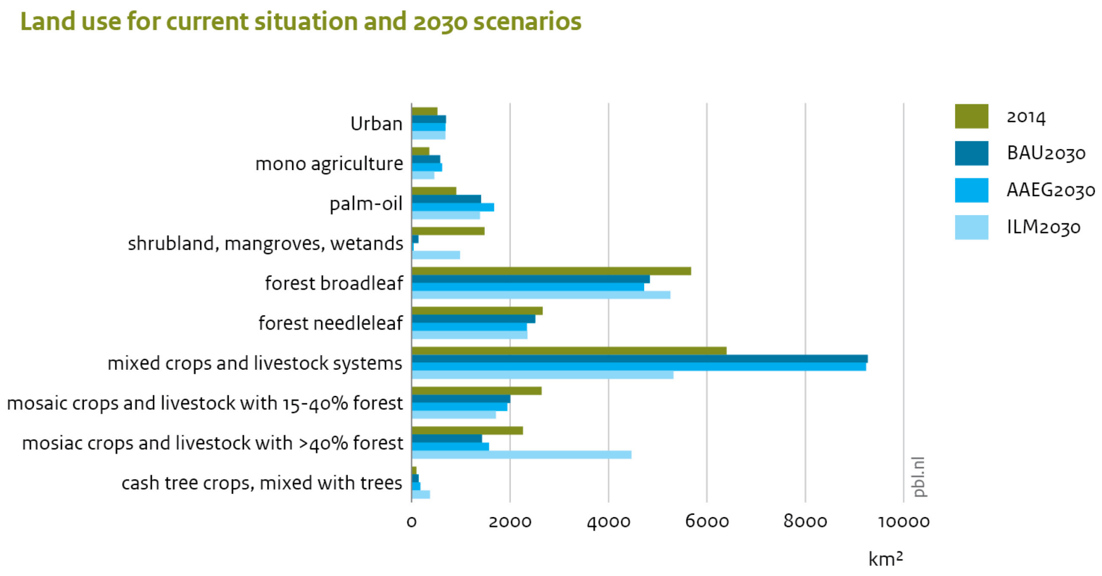
This section presents the results of the spatial scenario modelling exercise. The outcomes of the Business as Usual Trend (BAU), Accelerated Agricultural Export Growth (AAEG) and Integrated Landscape (ILM) scenarios to 2030 are compared with to the current situation and also. First a number of key projected changes in land use are presented, followed by an assessment of the impacts on the identified landscape ambitions and related SDGs, and an overall comparison of scenario outcomes.

The North Coast landscape ambitions informing the ILM scenario assume that the landscape interventions described in section 4 are successfully implemented.

6.1 Changes in the landscape

Changes in land use and cover are the most prominent outcome of change in the landscape and provide a first insight into how the scenario storylines and assumptions are translated into spatially explicit outcomes for the year 2030. Figure 6.1 shows total area, based on data summarized in table 6.1.

Figure 6.1



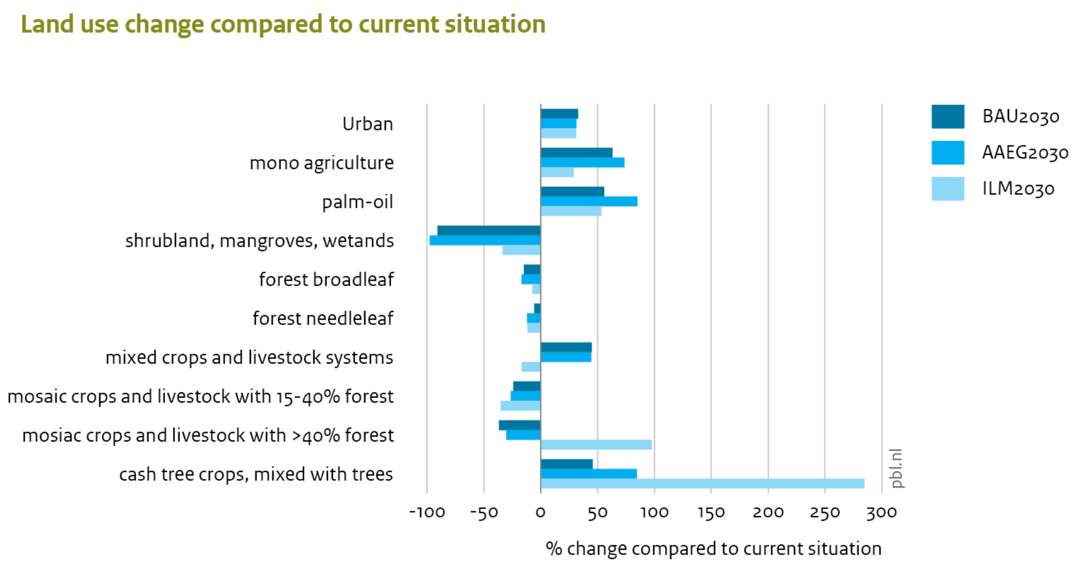
Source: PBL

Figure 6.2 illustrates the proportional change relative to the current situation. The maps in Figure 6.3 show the scenario outcomes for land use spatially, on which also many other results are based. Each element is described below.

Table 6.1
Landscape level land use for current situation and 2030 scenarios

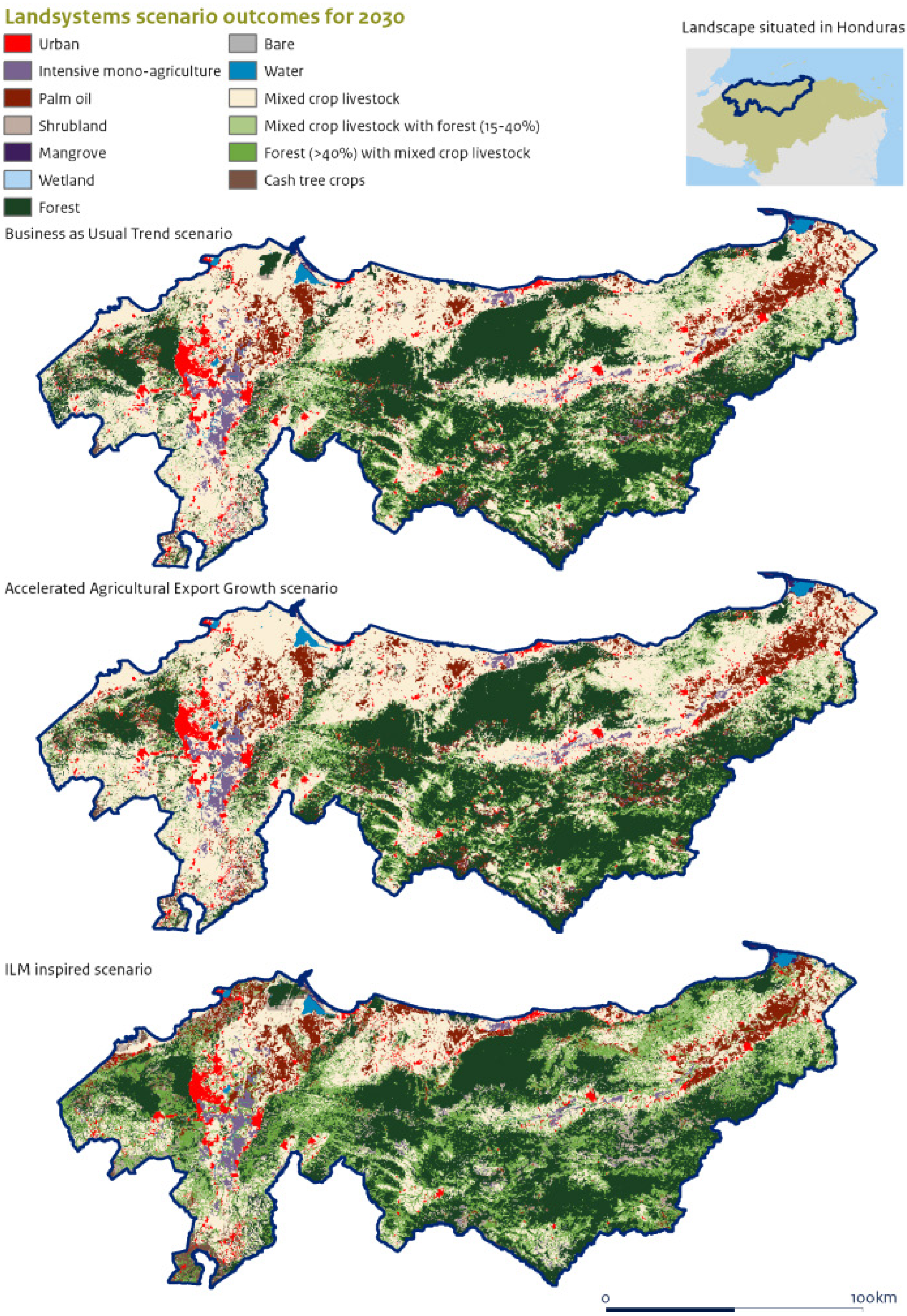
Land use for current, BAU, AAEG and ILM scenarios				
		2030		
Km2	**2014**	**BAU**	**AAEG**	**ILM**
Urban	523	695	687	686
Intensive mono agriculture	356	580	618	459
Oil palm plantation	906	1,412	1,676	1,389
Shrubland	1,430	89	2	931
Mangrove	47	46	34	47
Wetland	5	-	-	5
Forest broadleaf	5,676	4,837	4,725	5,260
Forest needleleaf	2,663	2,514	2,342	2,352
Bare	23	16	14	23
Water	136	136	136	136
Mixed crop-livestock systems (with < 15% forest)	6,399	9,266	9,232	5,320
Mixed crop-livestock with 15-40% forest	2,641	2,003	1,944	1,714
Forest (>40%) with crop-livestock (agroforestry)	2,260	1,428	1,574	4,468
Cash tree crops, mixed with trees	81	126	165	352
Forest mixed with cash tree crops	16	16	15	21

Figure 6.2



Source: PBL

Figure 6.3

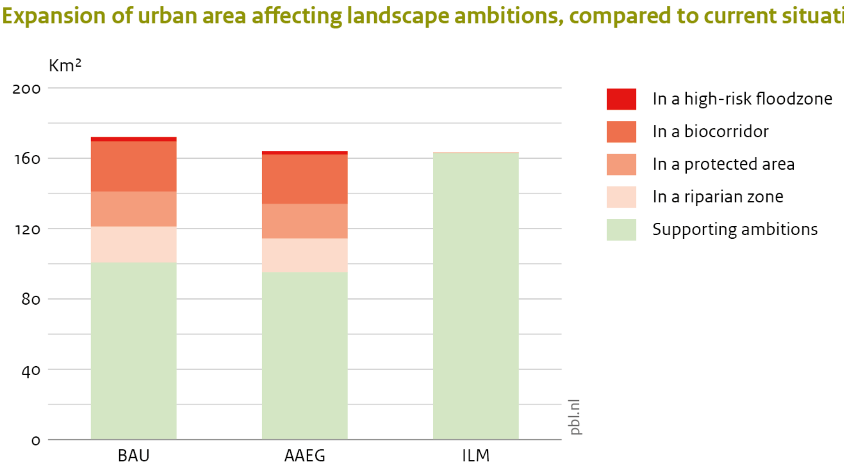


Source: PBL

Currently 72% of the population is living in **urban settlements** covering 523 km2 (INE, 2017; ICF, 2014). By the year 2030 there will be an additional 1 million people (a 25% increase) living in the landscape. According to INE projections 63% of this growth will be in urban areas. Under the BAU scenario, this will result in a 33% increase in urban settlement area. Under the AAEG and ILM scenario this growth is just slightly lower with 31% due to higher competition for suitable land and with more people living in and attracted by agricultural production areas.

Figure 6.4 shows that, contrary to the ILM scenario, under the BAU and AAEG scenarios a large part of expansion is projected to take place in restricted zones, negatively affecting water quality and biodiversity.

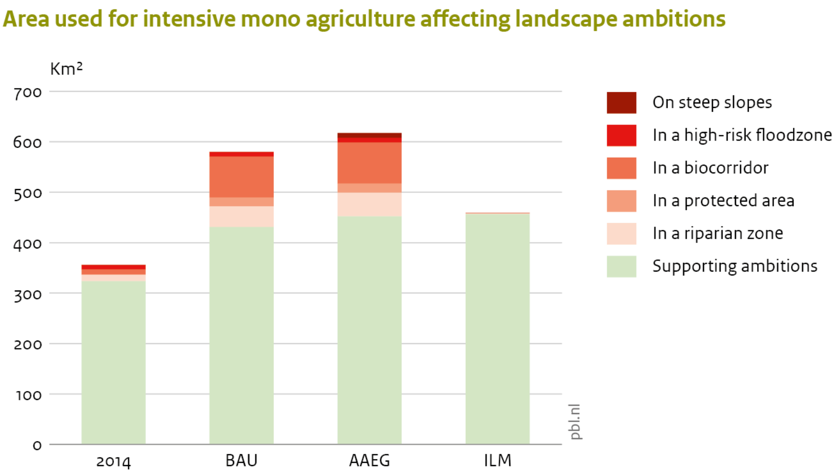
Figure 6.4



Source: PBL

The area used for highly **technified monoculture agriculture** (e.g. pineapples, sugarcane, bananas) also increases in all scenarios compared to the current situation. Growth is highest in the export production oriented AAEG scenario (+74%) followed by BAU (+63%) and ILM (+29%). In both the BAU and AAEG scenarios most expansion is projected to take place in restricted areas, with bio-corridors and riparian zones being the most affected under these scenarios. Under the ILM scenario the area used for this type of agricultural activity still expands, but focus is more on making it more integrated in the landscape and in line with the applied policies and restrictions. Therefore most expansion is assumed to take place in suitable areas and the existing activities that are causing negative trade-off area are converted to more suitable practices.

Figure 6.5



Source: PBL

The **land area under grazing** was determined within the model, rather than defined as an intervention. In all scenarios the area for the 3 mixed crop-livestock systems is increasing and there are no specific interventions identified to address this.

6.2 Progress towards the PASOS landscape ambitions

The three scenarios of 'Business as Usual' (continuing 2000-2017 trends), 'Accelerating Agricultural Export Growth' (without associated food crops or natural resource management), and 'Integrated Landscape Management' have significantly different impacts on the Landscape Ambitions as defined by the PASOS stakeholders.

Improved rural livelihoods

Given the limited availability of detailed socio-economic data for households, the model was not able to differentiate quantitatively the difference between the scenarios in terms of rural livelihoods, also it did not include datasets on employment or income, by social group.

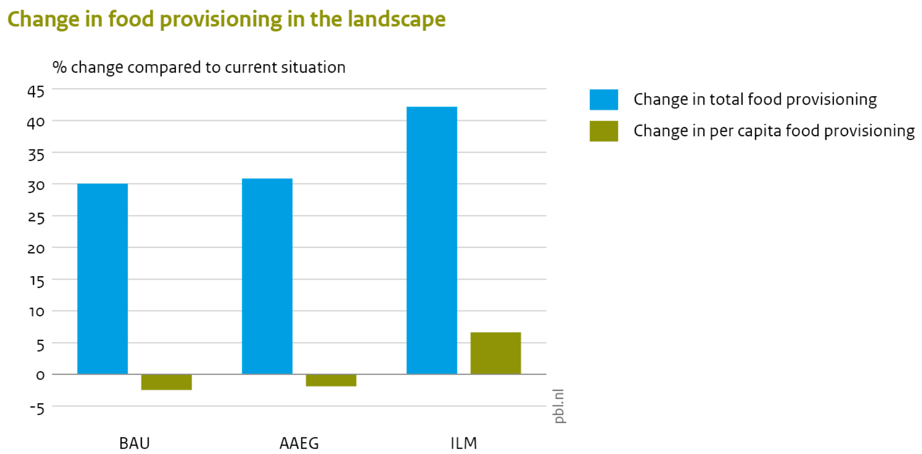
Evidence below on growth of food production, oil palm, cocoa agroforestry systems, resilience, and ecotourism development are all associated with improved rural livelihoods, if designed for benefits to flow to the rural poor.

Improved food security of the rural poor

Compared to the current situation more food is expected to be produced in the landscape by 2030. Depending on the scenario this will either be achieved by expanding the area under cultivation, often at the expense of natural areas, or by increasing productivity of the current production areas. However, when taking into account the growing population, per capita availability of locally produced food appears to be decreasing under the BAU and AAEG scenarios, with the Integrated Landscape scenario being the only one able to improve the food provisioning per capita (Figure 6.6). Assuming that, also nowadays, a certain share of the food consumed in the landscape is imported (from other regions in Honduras or from abroad) and considering the difference between for instance San Pedro Sula residents and rural households in the share of locally produced foods in their total food consumption, it seems clear additional income is needed to maintain or improve food security of the population.

Production of staple foods is significantly higher in the ILM scenario, due to improved yields from technical assistance. The additional staple food/feed production that is or could potentially be consumed within the landscape. With population growth so high, there should be local markets that can be tapped by rural producers, rather than having all foods imported. There may be better resilience on food crop losses from drought, disaster, flooding, climate changes.

Figure 6.6



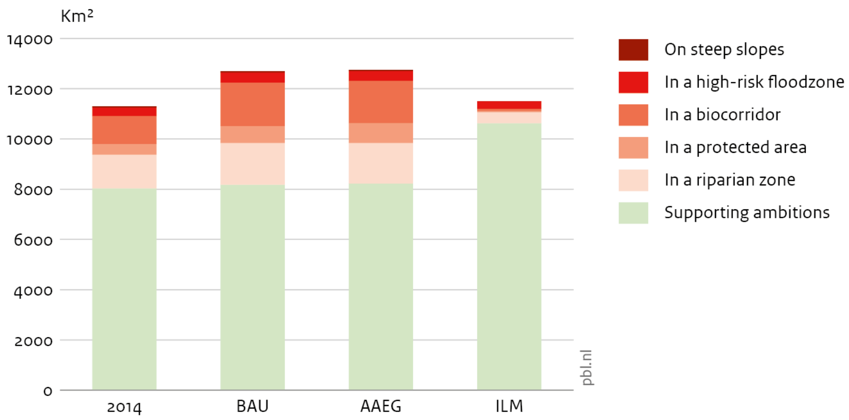
Source: PBL

The total amount of and the area used for food production increases in response to increased demand from a growing population. However, in the BAU scenario and even to a greater extent in the AAEG scenario, this happens mainly by converting shrubland and accessible forest areas to higher intensity mixed crop and livestock systems. Intensification of food production is much more prominent under the ILM scenario, with investments promoting to produce more from the same area.

As shown in Figure 6.7 about 29% of the area currently used for food production is in marginal and less suitable areas near rivers, in protected areas, in bio-corridors, and on slopes and therefore affecting the landscape ambitions. Under the BAU and AAEG scenarios this percentage increases to 36% mainly affecting bio-corridors and protected areas. Under the ILM scenario, area under food production decreases to 8%, but productivity is assumed to be higher (Figure 6.5) and by applying various spatial policies expansion is projected to take place on more suitable areas and current unsuitable production is almost completely relocated or changed (i.e. by reforestation) to more supporting and suitable areas.

Figure 6.7

Area used for food production affecting landscape ambitions



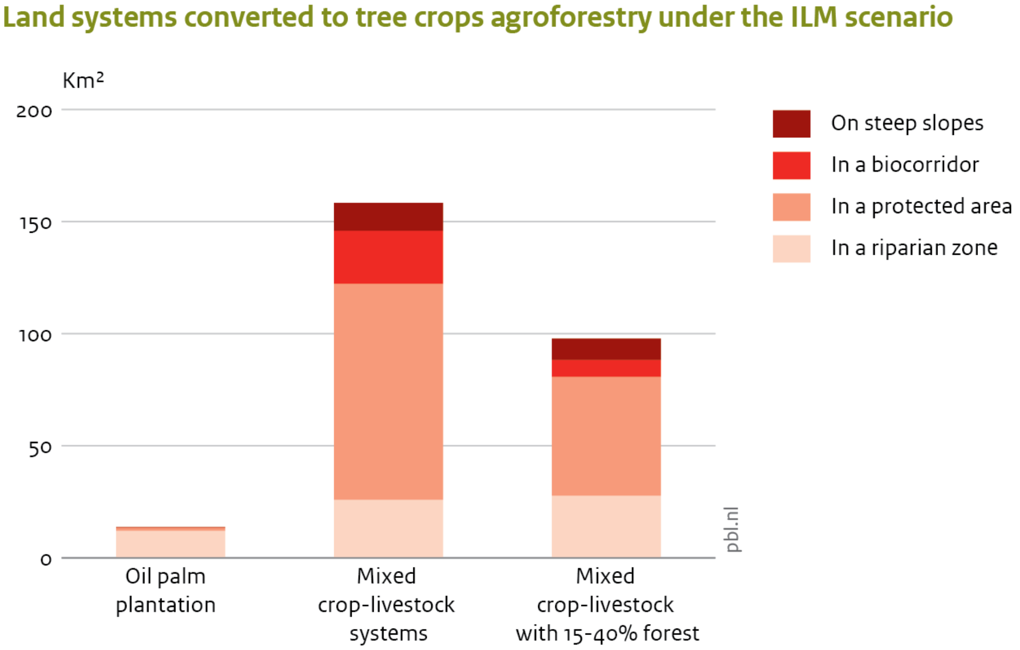
Source: PBL

Increased cocoa agroforestry land use, production and income

According to information from FHIA the area covered by cocoa agroforestry systems was roughly 50 km2 in 2016, with the largest shares in the departments of Cortes and Atlantida producing in total about 1,500 metric tonnes of cocoa. On average this means productivity is around 300 kg/ha, but not all plantations are producing yet. In the mid-90s production of cocoa was much larger (4,700 metric tons per year), but after Hurricane Mitch and the effects from Moniliophthora roreri, a basidiomycete fungus that causes frosty pod rot disease, the production was drastically reduced (FHIA, 2016).

Based on our land systems map the area used for cocoa agroforestry is estimated at almost 100 km2 for the current situation. We use this area in our scenarios, but it could be that parts of the land system "Forest with extensive crop-livestock" also contain some cocoa plantations mixed with trees for timber and shading and crop-livestock activities.

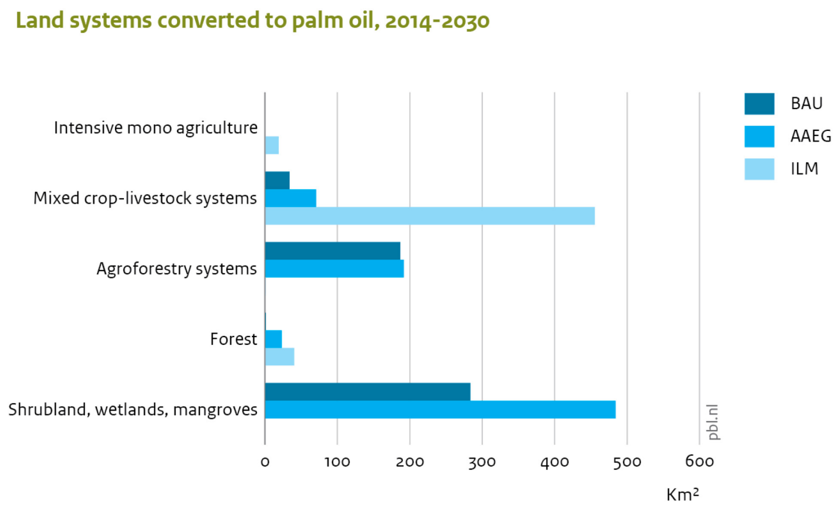
Figure 6.8



Source: PBL

Under the BAU scenario the area under cultivation is projected to expand by 50% and under the AAEG scenario, with its focus on producing large scale agricultural products for exporting, the area is projected to double. Under the ILM scenario, cocoa agroforestry is seen an important element in making the landscape more sustainable and resilient, both in environmental as economic terms. Therefore cocoa agroforestry systems are promoted and the area is projected to expand by 300%, especially in replacing other activities in areas were these are causing trade-offs to the soils, water and biodiversity. This conversion is also seen in Figure 6.10, where oil palm plantations and mixed crop-livestock systems in restricted zones are converted to tree crops agroforestry systems like for instance cocoa.

Figure 6.9



Source: PBL

Doubled production of sustainably produced palm oil

The production of palm oil is an important driver of change in the landscape, both in terms of land use and cover as well as for economic development. In the BAU scenario the production is assumed to increase by 50% and in both the AAEG and the ILM scenarios the amount of palm oil produced is projected to double. Driven by varying levels of investments in increasing productivity of palm oil produced per hectare the spatial outcomes in terms of area under cultivation differs considerable among the scenarios.

Box 6.2 Exploring the FHIA cocoa business model under the BAU, AAEG and ILM scenarios

To explore the landscape level financial effects derived from the cultivation of cocoa plantations we applied the FHIA cocoa business investment model to the BAU, AAEG and ILM scenario outcomes.

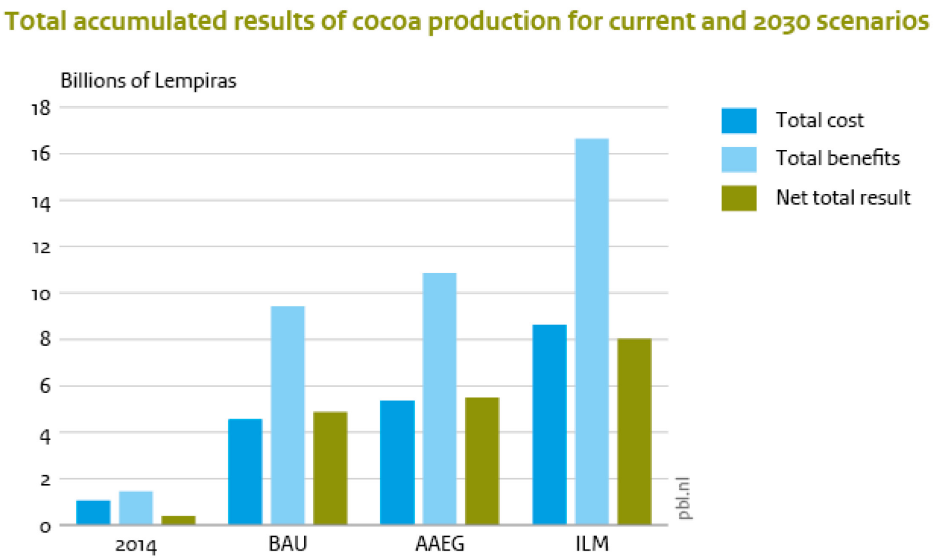
FHIA is the Honduras National Agricultural Research station. Their cocoa business model assumes a 20 year lifetime of a cocoa plantation and includes the derived annual income from cocoa and bananas (used for shading) and the potential timber harvest of shade trees in year 20. It also provides the annual cost of production over the 20 year period.

The model was applied to a 16 year time series of CluMondo land use data. The CluMondo model monitors the number of years a certain land system has been in use by that system, in this case cocoa tree crops. The FHIA cocoa model assumes a cocoa system with plantain as shade crop in the first years, the costs and benefits in these systems are accounted for in this model, income from timber harvest from shade trees (after 20 years) is not included, due to the limited length of the scenario period. Also the FHIA model does not take any environmental benefits of cocoa tree crop systems into account (i.e soil protection on slopes) or potential cost (pollution) when not implemented in a sustainable way.

The total area under cocoa cultivation in 2030 is 142 km2 under the BAU scenario, 179 km2 under the AAEG scenario and 373 km2 under the ILM scenario, all increasing compared to 97 km2 currently. This results in the largest net accumulated result in 2030 for the ILM scenario (Figure 1) of just over 8 billion Lempiras (~332 million US$).

In all scenarios the increase is applied in a linear way towards 2030. Meaning the majority of the plantations under the ILM scenario (a 300% increase) are still relatively young, compared to the smaller increases under BAU and AAEG. So, according to the FHIA model, after 2030 the annual cost will further decrease and benefits will increase, compared to BAU and AAEG.

Figure Textbox 1



FHIA promotes cocoa as a sustainable agro-forestry crop. It is seen as an alternative to palm-oil in areas not suitable for palm-oil due to the proximity of water bodies, situation on steep slopes and/or area's with a high risk of flooding.

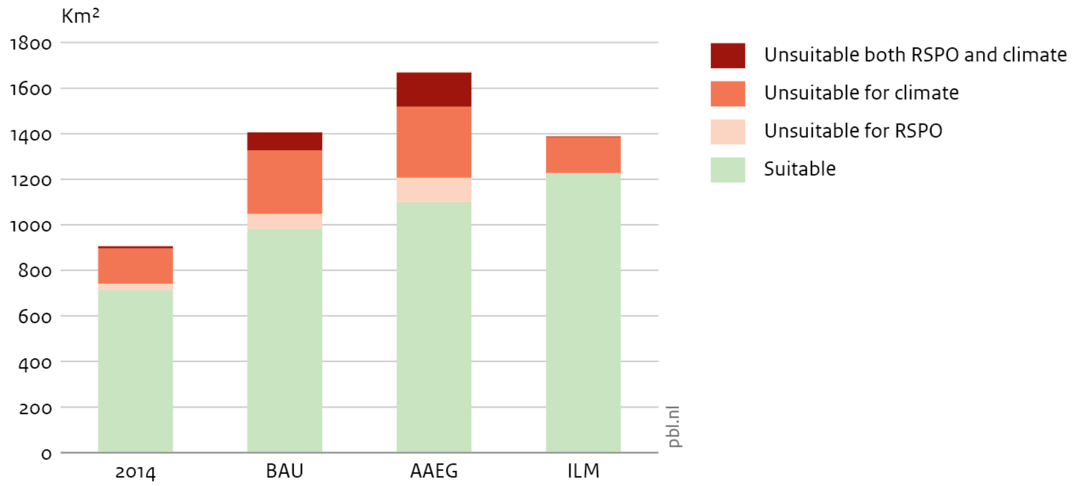
Sources: FHIA and PBL

Under the BAU scenario and to even a larger extent the AAEG scenario, palm oil plantations are projected to expand into natural areas and replace agroforestry areas with a considerable tree coverage that are used for food production (as shown in figure 6.7) and are either conflicting with RSPO guidelines or into areas that are becoming less or even unsuitable due to the effects of climate change (as shown in figure 6.8). As a consequence of this effect more shrubland (relatively suitable) and forest is being cleared for reallocated food production and livestock grazing.

Under the ILM scenario investments in productivity will lead to an increase of production of 33% per hectare, which is gradually applied over the next 15 years, simulating the proactive replacement of ageing and traditional low productive trees by new higher yielding tree varieties that start producing within 18 months. This, like the AAEG scenario, will also result in a doubling of the production of palm oil and in more intensification on current plantation areas and less expansion in unsuitable areas, as indicated by the spatial policies and restrictions. Also current plantations in unsuitable areas, mainly according to RSPO guidelines, are gradually abandoned and converted to another, more favorable, land system for that location.

Figure 6.10

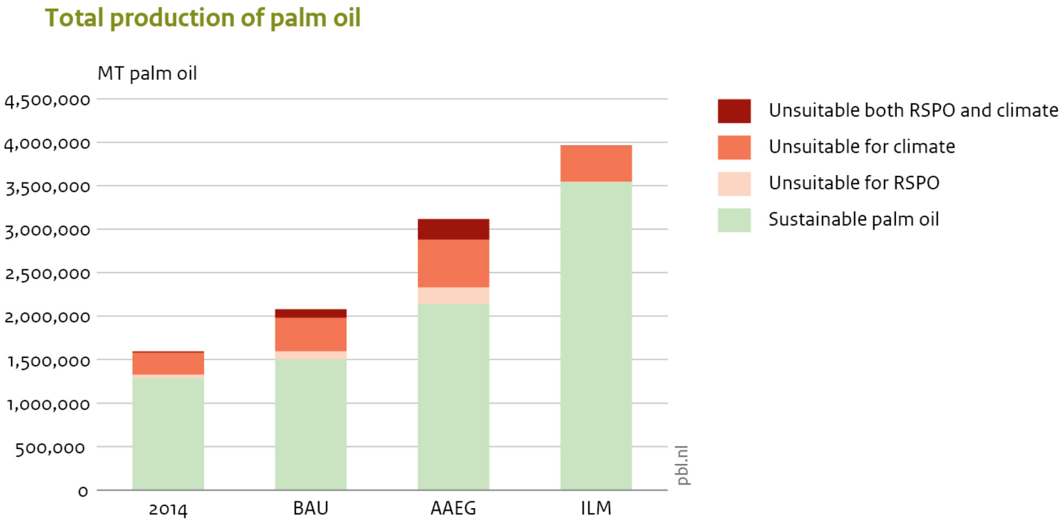
Suitability of area used for palm oil production



Source: PBL

Due to investments in improving productivity of oil palm plantations, i.e. by proactively introducing higher and earlier yielding tree varieties the total amount of palm oil being produced in a sustainable way is projected to be highest under the ILM scenario. Impacts for producing in unsuitable locations (slopes, riparian zones) and the effect of climate change are accounted for and clearly have their impact on the projected production under the AAEG scenario.

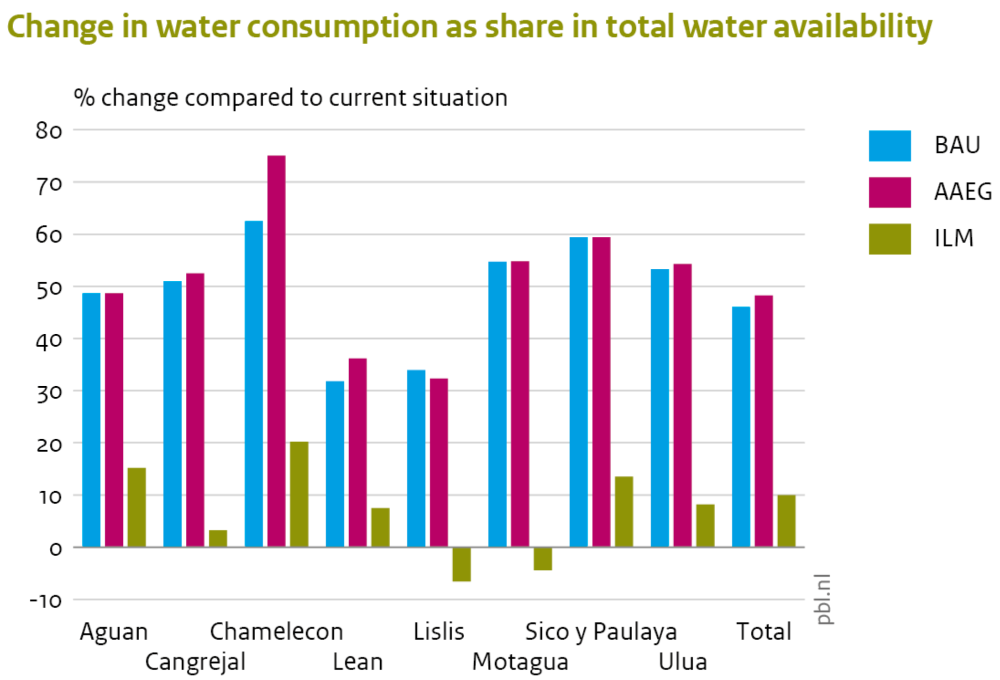
Figure 6.11



Source: PBL

Clean and sufficient water for households, economy and environment
Due to one million additional people, 33% increase in urban area and increasing agricultural activities the amount of water used per watershed in rapidly increasing under the BAU and AAEG scenarios (figure 6.12).

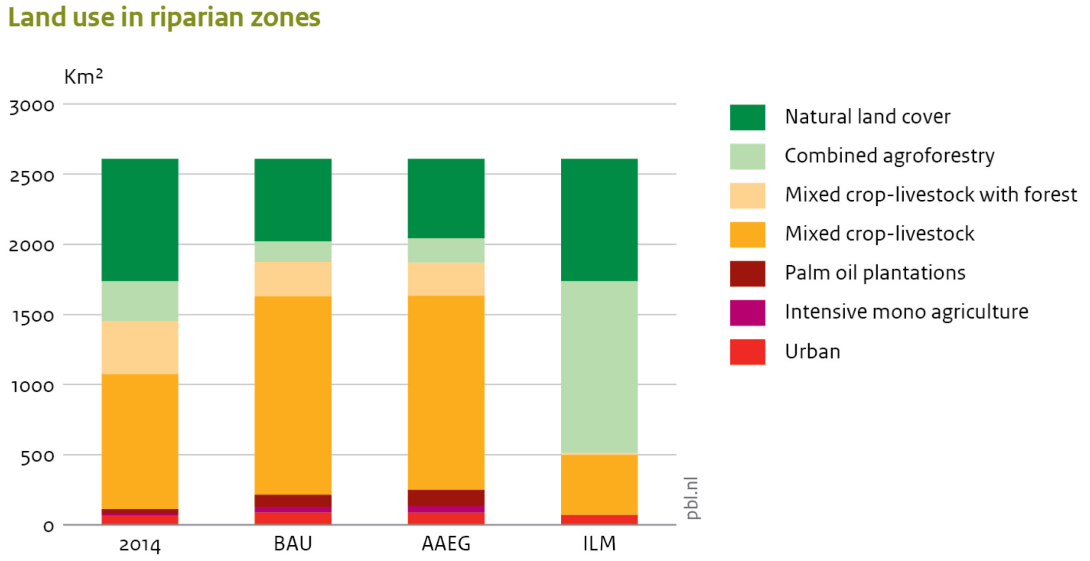
Figure 6.12



Source: PBL

The ILM scenario shows a more moderate increase in some and even a decline in some other watersheds. This relates to the spatial restrictions that were set on activities that could be developed nearby rivers (preferably agroforestry), on slopes and the prevention of deforestation and restriction on conversion of natural vegetation in high flood risk zones. Due to lack of data on monitoring, the potential increase in water use for irrigation, due to decreasing precipitation in some drier zones of the Sula Valley, has not been taken into account here.

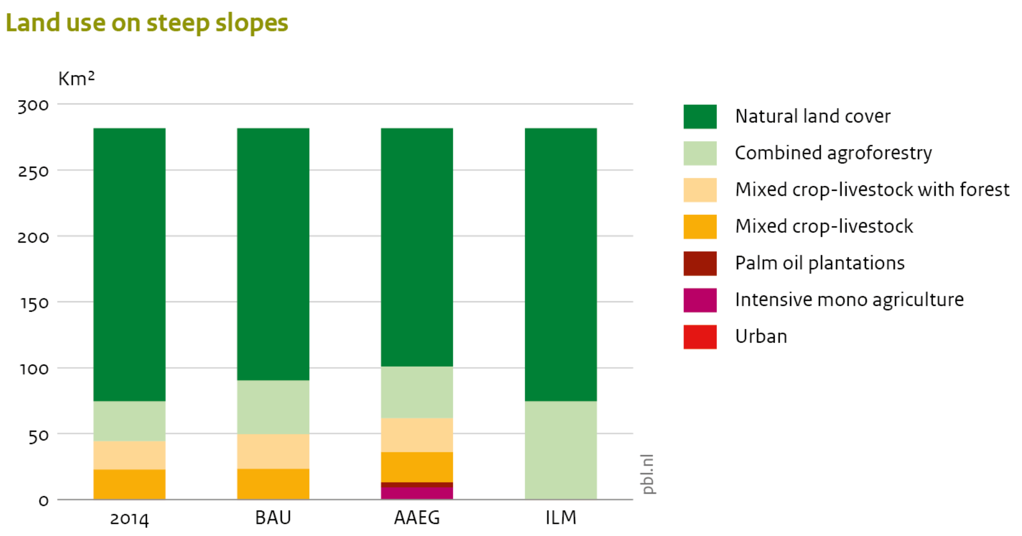
Figure 6.13



Source: PBL

In 2014, more than 55% of the area classified as **riparian zones** were used for more intensive human land use activities that are assumed to have an negative effect on water quality and soil protection. Without any spatial policies or restrictions this is expected to increase under both the BAU and AAEG scenarios to 72% mainly due to the expansion of mixed crop-livestock activities and intensive mono agricultural activities. The ILM scenario is challenged to change as many of these practices as possible and promote the large scale shift towards agroforestry practices in this zone, requiring investments in various types of tree crops.

Figure 6.14



Source: PBL

Legally in Honduras, restrictions on agricultural land use are imposed for slopes above 30%, which was used as a spatial policy in the modelling and scenarios. In 2014 more than 16% of the area with **steep slopes** is used for production, especially for intensive mixed crop-livestock land systems.

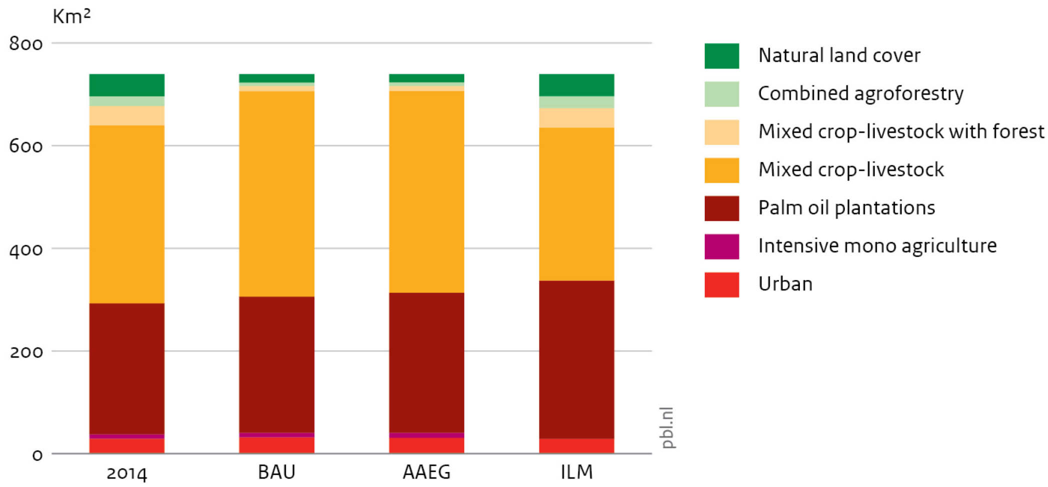
Under the BAU and AAEG scenarios the share increases to 18% and 22% respectively, caused by large and unrestricted expansion of oil palm plantations. The ILM scenario is using spatial policies and restrictions to convert these practices to land systems, like high tree cover agroforestry systems, that are more suitable and protect slopes from being eroded. This helps decreasing sedimentation flows in rivers that could be beneficiary to valuable and fragile coastal and marine ecosystems. The modelling did not explicitly look at community or municipal resilience planning beyond more sustainable land use changes.

Resilience to flooding, climate change and extreme weather events

The areas in the landscape that face a high risk of flooding are characterized by large oil palm plantations, such as in the Aguan Valley, which are not easily converted or relocated. Also, various local experts stated that oil palms can survive prolonged periods of flooding (2-3 months) and in that sense provide some form of protection against exposed soils being washed away. Hence the ambition of the ILM scenario was to maintain at least existing natural land cover and to promote agroforestry systems instead of intensive (high value) mono agricultural systems and to restrict the further development of urban settlements in these zones.

Figure 6.15

Land use in high risk flood zones



Source: PBL

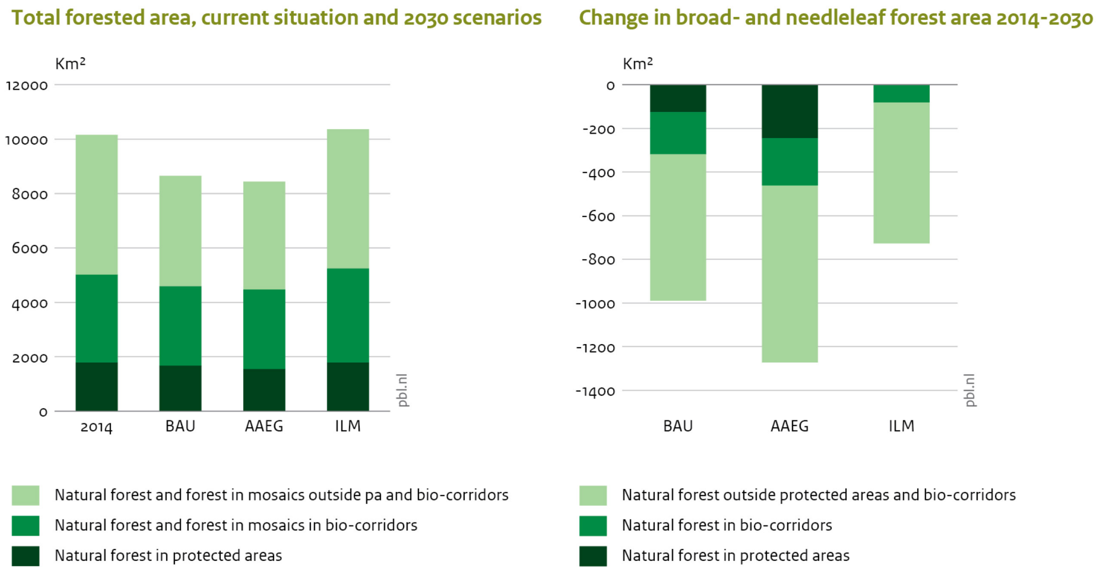
Expanded, sustainable eco-tourism development

The landscape scenarios did not provide any quantitative indicators showing the achievement of sustainable eco-tourism. It is possible that the improved protection of Protected Areas and other habitat improvements would attract more tourists, but there is no information on accompanying infrastructure, training, etc.

Expanded 'green infrastructure', including forests, terrestrial and coastal/marine protected areas and biological corridors

The **forested area** in the landscape is defined as the area covered by natural forest (undisturbed broadleaf and needle leaf forest) plus the tree cover contained in the mosaic land system classes with mixed crop-livestock and tree cash crop agroforestry systems. In the analysis we distinguished between forested area in protected areas, bio-corridors and forest outside these areas. The worrying signals expressed by various stakeholders on the deforestation in the eastern Moskitia region due to expansion of livestock grazing is not covered due to the extent of the landscape.

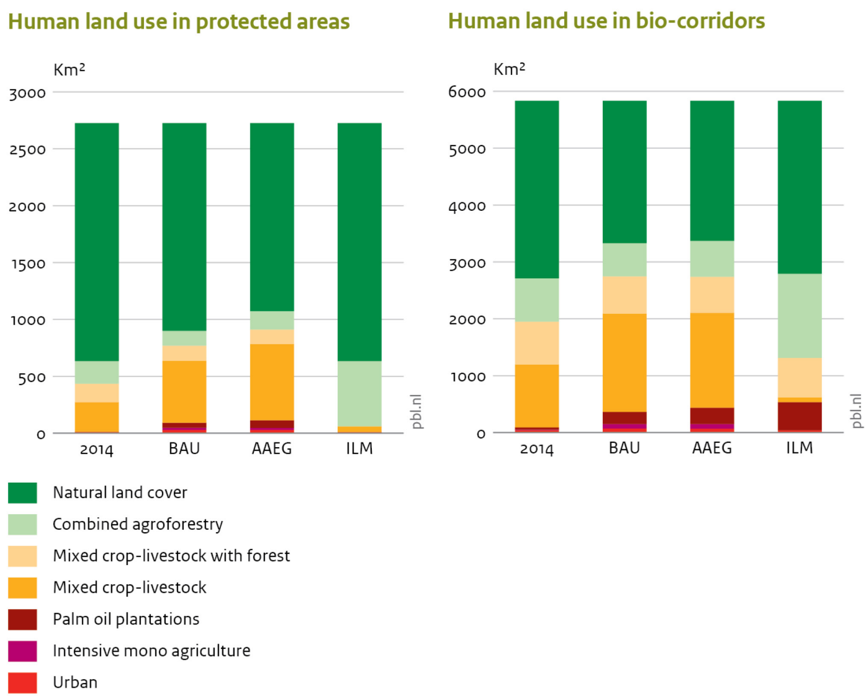
Figure 6.16



Source: PBL

Most deforestation is expected to take place under the AAEG scenario (Figure 6.16, -17%), mainly due to large expansion of agricultural activities and the lack of efficient protection of protected areas. Under the ILM scenario protected areas are effectively managed and the loss of natural forest is mainly caused by the expansion of agroforestry activities. Reforestation, for instance in the form of mixed cocoa or citrus or trees for timber, also takes place under the ILM scenario hence the slight increase of the total forested area (+2%)

Figure 6.17

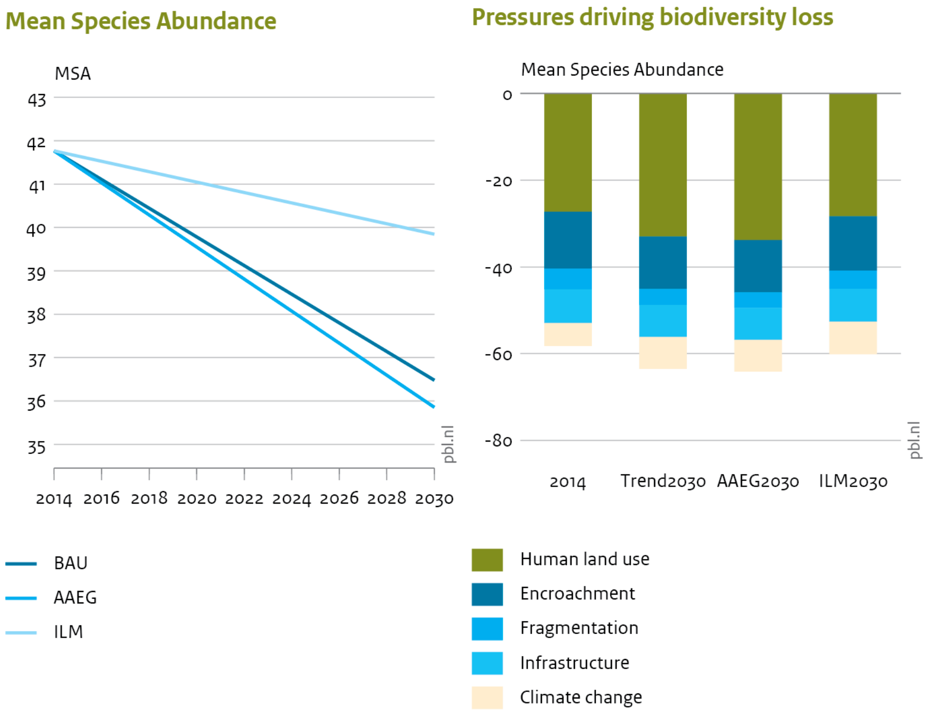


Source: PBL

For the scenario analysis the Mico Quemado reserve was considered as a protected area, all areas were taken from the most recent delineated **terrestrial protected areas** dataset (ICF, 2017). From the stakeholder workshop there were many suggestions on conserving and improving the supporting role of bio-corridors in connecting currently protected areas. Ones that were specifically mentioned were the corridors between Lago Yojoa and Nombre de Dios and between Jeanette Kawas National Park and Punto Izopo.

As shown in Figure 6.17, the applied spatial policies and restrictions under the ILM scenario are able to limit the expansion of more intensive human land use activities and promote the agroforestry activities with a high level of tree cover that support the function **of bio-corridors** and cause less degradation of protected areas compared to more intensive mono agricultural and livestock activities, like projected to take place under the BAU and, even more, the AAEG scenario.

Figure 6.18



Source: PBL

Driven by the agricultural character and history of the landscape the current remaining **Mean Species Abundance** (MSA) is at almost 42%. See explanation of this metric in section 5. Urban expansion and the continuing conversion of natural areas to more intensively used agricultural land are the main elements of the human land use pressure contributing to further loss of MSA under the Trend scenario, followed by encroachment and climate change. Under the ILM scenario the focus on agroforestry mosaics with a high level of forest cover, allowing for a slightly lower impacts on biodiversity, stabilizes the loss of MSA (see Figure 6.18). Climate change, due to temperature increase, similarly affects the MSA under the ILM scenario.

Strengthened land rights and territorial planning

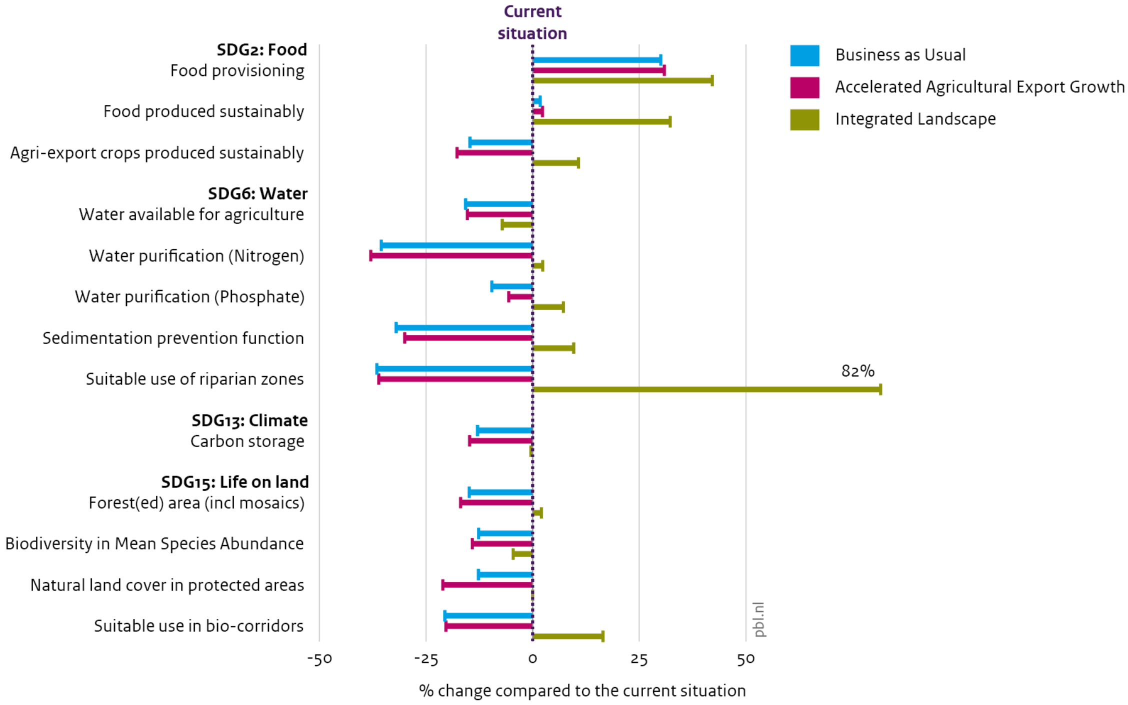
The scenario models did not include data or projections on land rights. Only the ILM scenario reflected strong territorial planning.

6.3 Progress towards the SDGs

The model also enables a direct comparison of scenarios for delivering selected indicators for the Sustainable Development Goals, as shown in Figure 6.19

Figure 6.19

Impact on selected SDGs under 2030 scenarios compared to the current situation



Source: PBL

SDG 2 (Zero Hunger). The ILM scenario shows the greatest improvement in staple food provisioning and much higher improvement in sustainable agricultural land use in staple foods. Sustainability of agri-export production is somewhat higher than the baseline, but this compares well with the reduced sustainability in BAU and AAEG.

SDG 6 (Clean Water & Sanitation). While nitrogen and phosphorus levels in water worsen in BAU and AAEG by 2030, they remain stable (though not much improved) in ILM. There is a sharp contrast between the worsening of riparian area protection in BAU and AAEG, and a significantly improvement in ILM.

SDG13 (Climate Action). In the ILM Scenario, carbon storage remains stable to 2030, while greenhouse gas emissions from land use deteriorate significantly in BAU and AAEG.

SDG 14 (Life Below Water). Although marine areas were not included in the modelling, reduced sedimentation in the major rivers and effectively protected coastal protected areas could have positive impacts on coastal and marine biodiversity.

SDG 15 (Life on Land). Most indicators in the model for Life on Land show deterioration in BAU and AAEG. Under ILM, there are small or modest improvements in these indicators, but this is a concern, as the sustainable land management elements in the model are quite ambitious.

7 Conclusions

The experience of the North Coast Landscape scenario modelling study was highly satisfactory for all of the partners, even as many lessons were learned to refine and improve the process for application in other landscapes.

7.1 Value of scenario modeling for strategic planning in the North Coast

The modelled findings in section 6 helped North Coast stakeholders identify the elements of their ILM strategy that are on track to meet their ambitions, and the related SDGs and others whether they are not.

The scenario modelling also suggests that integrated analysis and strategic planning across sectors has real benefits. Some of the key insights that would not have been fully recognized in conventional sector-specific planning include:

- Planning for oil palm that takes into account environmental goals in water, biodiversity and food security shows the importance of limiting area expansion to only around 100%, well below some proposed sub-sectoral plans.
- Urban planning is far more central to medium-term rural livelihoods and well-being than is generally recognized.
- The benefits for biodiversity and green infrastructure, as well as water quality and supply, of promoting biodiversity-compatible agroforestry and mixed crop-livestock-forest mosaics are considerable.

7.2 Value of scenario analysis for landscape stakeholder dialogue

The scenario analysis presented and discussed with the landscape stakeholders during the Landscape Leadership Workshop in May 2017 was valuable in providing a framework for stakeholders to discuss the current status of the landscape in relation to achieving their ambitions for sustainable development, in several respects. The models were a useful tool for communication across sectors and they provided a basis for negotiating priorities between stakeholders from different sectors. Additionally, they were useful in identifying data gaps. They stimulated discussion of how to define the landscape geographically. For example, many stakeholders felt La Mosquitia should be included as well. Finally, they facilitated visualization of the outcomes of interventions and helped stakeholders identify where further action may be needed for them to achieve their ambitions and further advance the SDGs.

PASOS leadership has already begun to share scenarios with municipal mayors, palm oil companies and others to raise awareness about the implications of current trends and needs for action on landscape sustainability. The scenarios have also been used to assess the design of investment portfolios being developed. The exercise helped identify gaps in plan, particularly around rural poverty alleviation, and sustainable urban development, which PASOS is beginning now to consider.

The modelling did not include many aspects on the landscape ambitions around rural poverty, employment. This also related to the limited data availability on the topics.

7.3 Next steps in refining landscape scenario modeling methodology

The methodology developed her for landscape scenario modelling made significant advances in awareness of changes and pressures in the landscape. Further improvements in the modelling methods will be developed and tested in two other landscapes, in Ghana and Tanzania, and a final synthesis paper on lessons learned will be produced.

The modelling would benefit from strong socioeconomic sub-models. The business models being generated by the PASOS stakeholders now for major landscape interventions will provide more rigorous estimates of economic costs and benefits that could be used in subsequent studies. With additional data on average per hectare revenues and labour use from different land use systems, the model results on land use and productivity could be used to roughly compare the impacts of different scenarios on income and employment. Adding data on spatial patterns of poverty and malnutrition could help to illuminate the impacts of investment in different parts of the landscape and different activities on social well-being.

8 References

Appleton, J. (2017) Research into the potentials of Integrated Landscape Management: a study into Honduras, PBL-TU Delft internship report, available at https://repository.tudelft.nl/islandora/object/uuid%3Ac3f5b9c0-e8c7-462c-9df2-0a067953c167

Asselen, S. and Verburg, P. H. (2013), Land cover change or land-use intensification: simulating land system change with a global-scale land change model. Glob Change Biol, 19: 3648-3667. doi:10.1111/gcb.12331

Benítez-López, A., Alkemade, R., Schipper, A. M., Ingram, D. J., Verweij, P. A., Eikelboom, J. A. J., Huijbregts, M. A. J. (2017), The impact of hunting on tropical mammal and bird populations, Science, Vol. 356, Issue 6334, pp. 180-183, DOI: 10.1126/science.aaj1891

Bosques del Mundo (2015) Memoria del proceso de creacion del observatorio de turismo sostenible y cambio climatico de Honduras (OTSCC), UNAH-CURLA: https://curla.unah.edu.hn/observatorios/outscc/

Bosques del Mundo (2016) 15 anos conservando el bosque tropical: sistematizacion de la colaboracion de bosques del mundo y el mix de socios de Honduras, https://makingcitieswork.files.wordpress.com/2016/04/sistematizacion-honduras-mix-y-bdm-04-2016.pdf

Castro-Tanzi, S. and L. Gross (2016) Supporting Sustainable Landscapes in Northern Honduras Landscape assessment (scoping) for the northern zone of Honduras: Recommendations for program design and implementation. EcoAgriculture Partners: Washington, D.C..

CIES (2014) Situación Actual y Perspectivas del Sub Sector de Palma Aceitera, Centro de Investigaciones Económicas y Sociales.

Denier, L., Scherr, S.J., Shames, S., Chatterton, P., Hovani, L. and Stam, N. (2015) Little Sustainable Landscapes Book. Global Canopy Programme: Oxford.

FHIA - Fundacion Hondurena de Investigacion Agricola (2016) Manual de produccion de cocoa, segunda edicion, La Lima, Cortes, Honduras

Government Honduras (2010) Visión de País y Plan de Nación para Honduras 2010-2038.

Gross, L., Castro-Tanzi, S. and Scherr, S. (2016) Connecting farm to landscape for Biodiversity conservation, The CAMBio project in Central America, EcoAgriculture Discussion paper 15. EcoAgriculture Partners: Washington, D.C.

Hardanto A, Röll A, Niu F, Meijide A, Hendrayanto, & Hölscher D (2017) Oil Palm and Rubber Tree Water Use Patterns: Effects of Topography and Flooding. Frontiers in Plant Science 8(452).

Heiner, K., Buck, L., Gross, L., Hart, A., Stam. N. (2017) Public-private-civic partnerships for sustainable landscapes: A convener’s guide. EcoAgriculture Partners and IDH-The Sustainable Trade Initiative: Washington, D.C.

ICF - Instituto de Conservacion Forestal (2014) Sistema de Clasificación del Mapa Forestal y Cobertura de la Tierra de Honduras, Nota Tecnica 6, Programa Regional REDD/CCAD-GIZ, El Salvador.

INE - Instituto National Estadistica (2018), online access via http://www.ine.gob.hn/

Jezeer, R, Verweij P, SantosMaria J, Boot R. (2017) Shaded coffee and cocoa – double dividend for biodiversity and small-scale farmers, Ecological Economics 140 (2017) 136–145, http://dx.doi.org/10.1016/j.ecolecon.2017.04.019

Lehner, B., Grill G. (2013): Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes, 27(15): 2171–2186. Data is available at www.hydrosheds.org

Sanders, A., Manueles, A. and McLean, D. (2011) Proyecto de Gestión Sostenible de los Recursos Naturales y Cuencas del Corredor Biológico Mesoamericano en el Atlántico Hondureño, PROCORREDOR project.

Sanders, A., McLean, D., Manueles, A. (2013) Assessment of Land Use Effect on Climate Change Sensitivity on the Northern Coastal Zone of Honduras, Lincoln Institute of Land Policy Working Paper WP13AS1.

Sapon and Artero, (2013) Escenario de expansión del cultivo de palma africana en el norte de Honduras, Zamorano University thesis.

Scherr, S. J., Shames, S., & Friedman, R. (2012). From Climate-Smart Agriculture to Climate-Smart Landscapes. Agriculture & Food Security, 1, 12.

Schipper, A., Bakkenes, M., Meijer, J., Alkemade, R., Huijbregts, M. (2016) The GLOBIO model. A technical description of version 3.5., PBL Netherlands Environmental Assessment Agency, The Hague, PBL publication number: 2369

Sharp, R., Tallis, H.T., Ricketts, T., Guerry, A.D., Wood, S.A., Chaplin-Kramer, R., Nelson, E., Ennaanay, D., Wolny, S., Olwero, N., Vigerstol, K., Pennington, D., Mendoza, G., Aukema, J., Foster, J., Forrest, J., Cameron, D., Arkema, K., Lonsdorf, E., Kennedy, C., Verutes, G., Kim, C.K., Guannel, G., Papenfus, M., Toft, J., Marsik, M., Bernhardt, J., Griffin, R., Glowinski, K., Chaumont, N., Perelman, A., Lacayo, M. Mandle, L., Hamel, P., Vogl, A.L., Rogers, L., Bierbower, W., Denu, D., and Douglass, J. (2018). InVEST +VERSION+ User's Guide. The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund.

UNDP – Honduras (2016), Marco de asistencia de las naciones unidas para el desarrollo Honduras 2017-2021. Tegucigalpa, Honduras.

Wood, S., Jones, S.K., Johnson, J.A., Brauman, K.A., Chaplin-Kramer, R., Fremier, A., Girvetz, E., Gordon, L.J., Kappel, C.V., Mandle, L., Mulligan, M., O'Farrell, P., Smith, W.K., Willemen, L., Zhang, W., DeClerck, F.A. (2018) Distilling the role of ecosystem services in the Sustainable Development Goals, Ecosystem Services 29 (2018) 70–82.

WWF (2001) Quarrels in a Crowded Reserve: The Río Plátano Biosphere Reserve project in Honduras. Living Documents.

9 ANNEX

9.1 Data sources used in modelling

Data source	Description of usage
Instituto Nacional de Estadística Honduras (INE), 2017, http://www.ine.gob.hn/	Population data, current and 2030 projections at municipality level
Fundación Hondureña de Investigación Agrícola (FHIA), 2017, http://fhia.org.hn/	Cocoa cost-benefit model and map of cocoa potential in Honduras
Sistema Nacional de Información Territorial de Honduras (SINIT), 2017, http://www.sinit.hn/	Administrative boundaries, roads, rivers, watersheds, bio-corridors, land cover/use, flood risk zones and HDI
Instituto de Conservación Forestal (ICF), 2017, http://icf.gob.hn/	Protected areas 2017 and land use 2014
FAO, Harmonized World Soil Database, Fischer, G., F. Nachtergaele, S. Prieler, H.T. van Velthuizen, L. Verelst, D. Wiberg, 2008. Global Agro-ecological Zones Assessment for Agriculture (GAEZ 2008). IIASA, Laxenburg, Austria and FAO, Rome, Italy. http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/	Soil characteristics used for suitability layers for CluMondo
Lehner, B., Grill G. (2013): Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. Hydrological Processes, 27(15): 2171–2186. Data is available at www.hydrosheds.org	Watersheds, also used in landscape boundary delineation
Oak Ridge National Laboratory, LandScan	Population counts and density per 30 arcsecond (~1x1km) raster used in CluMondo suitability layers
WorldClim, Robert J. Hijmans, Susan Cameron, and Juan Parra, at the Museum of Vertebrate Zoology, University of California, Berkeley, in collaboration with Peter Jones and Andrew Jarvis (CIAT), and with Karen Richardson (Rainforest CRC): http://www.worldclim.org/	Global mean annual temperature and precipitation rasters at 30 arcsecond resolution, used in CluMondo suitability layers
World Database on Protected Areas (WDPA), 2017, UN Environment and the International Union for Conservation of Nature (IUCN): http://www.protectedplanet.net	Protected areas (not used in final model runs) for comparison.
Global forest watch,Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." Science 342 (15 November): 850–53. http://www.globalforestwatch.org	Global treecover timeseries data (2000-2014) on a 30m resolution. Used for deforestation estimation and analysis on estimating the age of oil palm plantations

NASA, JPL, SRTM, Farr, T. G., et al. (2007), The Shuttle Radar Topography Mission, Rev. Geophys., 45, RG2004: https://lta.cr.usgs.gov/SRTM1Arc	Global relief data at 90m resolution, used for elevation and slope suitability layers in CluMondo
GRIP Global roads: Meijer, J.R., Huijbegts, M.A.J., Schotten, C.G.J. and Schipper, A.M. (2018): Global patterns of current and future road infrastructure. Environmental Research Letters, 13-064006. Data is available at www.globio.info	Global database of road infrastructure. Data used in CluMondo and GLOBIO models.

9.2 Landscape land systems classification procedure