Towards a Living Landscape: using modelling and scenarios in the Atewa-Densu landscape in Ghana

A case study on landscape strategies to achieve Sustainable Development Goals

Background Report

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Towards a Living Landscape: using scenarios and modelling in the Atewa-Densu landscape in Ghana

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Cover photo
A Rocha Ghana. In March 2018 residents on the fringe communities of the Atewa Forest Reserve commenced a multi-day walk from Kibi to Accra (95km) to protest the government's decision to mine bauxite in the Atewa Forest Reserve in the Eastern Region.

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).

A Rocha Ghana (ARG) is a non-governmental, non-profit environmental organization with a Christian background. The name A Rocha means 'The Rock' in Portuguese. The A Rocha family currently has branches in 21 countries in 5 continents around the world and is coordinated by a central unit, A Rocha international (ARI). With four project offices spread across the Southern and Northern parts of Ghana, A Rocha Ghana has emerged as a committed environmental NGO with a wide variety of projects. These include providing practical conservation interventions aimed at contributing to the sustainable management of important ecological habitats, and initiating programs aimed at facilitating certain communities' ability to adapt to current trends in climate change and other environmental threats.

IUCN NL is the Dutch national committee of the International Union for Conservation of Nature, the world's largest and most diverse environmental network. Within the international IUCN umbrella organization, IUCN NL works with NGOs, companies, governments and scientists to strengthen human wellbeing through worldwide nature conservation. IUCN NL's activities focus on four themes: nature conservation; climate, water & food; environmental justice and green economy. IUCN currently has 37 Netherlands-based member organizations.

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MAIN FINDINGS

Achieving the Sustainable Development Goals at the landscape level

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.

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.

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 tools and scenarios to help stakeholders in integrated landscape initiatives exploring strategies that could potentially achieve progress on multiple SDGs. The project seeks to understand the potential of spatial modelling to capture the trade-offs, synergies, and spatial impacts of proposed interventions at the landscape scale, and to support the capacity of stakeholder groups for long-term collaborative planning and design. The project will draw from three case studies, the Northern Coastal zone of Honduras, the Atewa-Densu landscape in Ghana, and the Kilombero Valley landscape in Tanzania.

The Atewa-Densu Landscape, Ghana

The landscape is characterized by the Atewa Range, about 90km north of the capital of Ghana, Accra. The range, as defined by the TEEB report (IUCN NL et al, 2016), consists consist of a protected forest reserve and a surrounding buffer zone and includes closed and open canopy upland evergreen forest, grasslands and herbaceous areas, cocoa and other crop plantations, small scale (often illegal[1]) gold mining and some built up areas. The forest within the range functions as the source of three important rivers, the Densu, Birim and Ayensu. It supports several communities who live on the forest fringes, and is home to a large diversity of plants and animals. The protected Atewa Forest Reserve is recognized as a Global Significant Biodiversity Area and hotspot. The Atewa Forest Reserve is one of only two reserves with upland evergreen forest in Ghana.

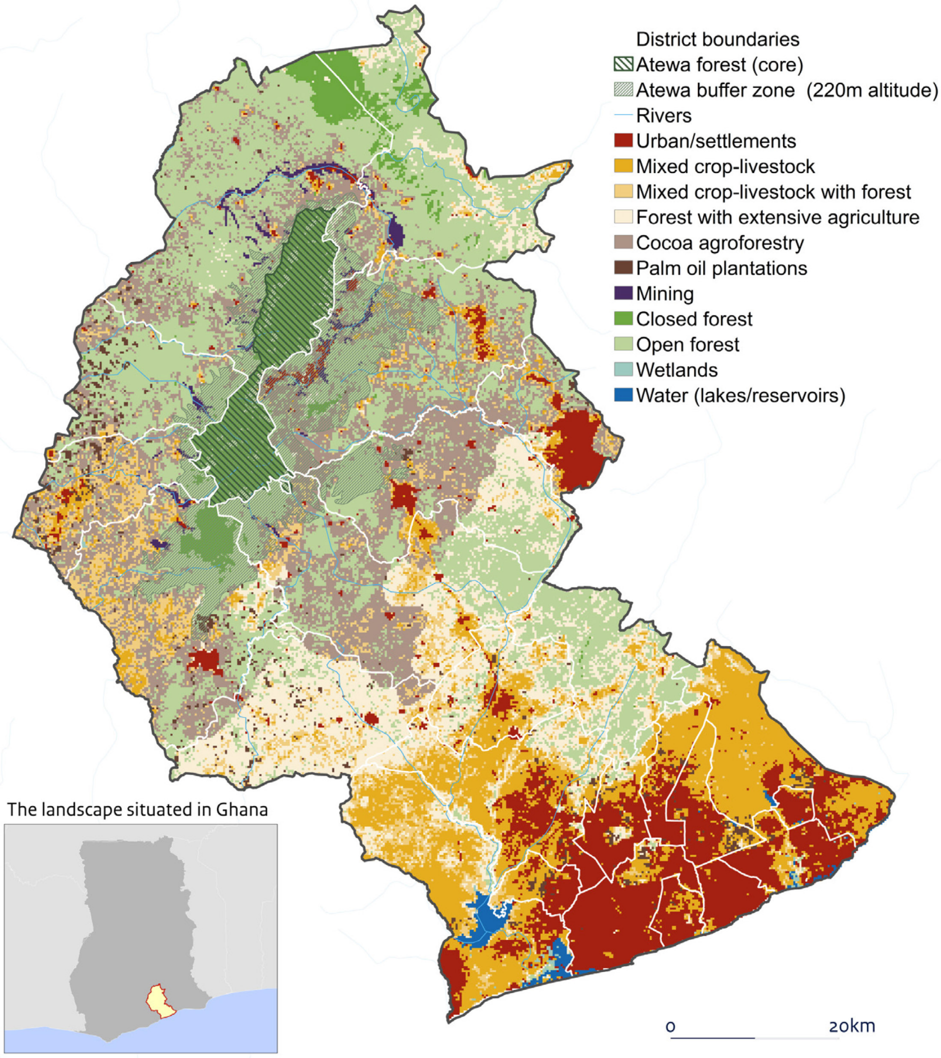
The boundaries of the Atewa-Densu landscape, for the purposes of this project, include the disctricts that cover the Atewa Range, the Densu Basin and the area of the greater Accra Metropolitan Area that is supplied with water by the Densu Basin (Figure 1). The Densu basin, the most densely populated and most important river system for Accra, feeds the Weija water reservoir which is used for irrigation and is also one of the two main sources of

[1] Following the widespread devastation of water resources and forest reserves as a result of the activities of illegal mining, the Lands and Natural Resources Ministry, in January 2017 (when the Akufo-Addo government took office) placed a ban on all forms of small scale mining for a period of six months, which has been extend in October 2017 and again in January 2018. According to the Minister of Lands and Natural Resources the ban will be active until targets, agreed on with the sector, have been met.

potable water for the Accra Metropolitan area. The Densu Delta is part of a Ramsar site, an internationally recognized and protected wetland area. The landscape covers about 6,000 km2 and is home to about 6 million people. It covers 26 districts and/or municipalities: 12 in the Eastern region and 12 in the Greater Accra region.[2]

Figure 1

Landsystems in the Atewa-Densu landscape, 2015



Source: PBL

Landscape ambitions in the Atewa-Densu landscape

Stakeholders articulated six major ambitions for their landscape. These ambitions are:

- Improve food security and livelihoods
- Conservation of the forest ecosystem and protect biodiversity
- Sustainable management of water resources and supply
- Sustainable cocoa and palm oil production
- Develop a tourism industry centered on the Atewa forest
- Partnership development and landscape planning

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[2] The boundaries of the landscape are broader than the area analysed in the TEEB report, which focused mainly on the Atewa range.

These ambitions were generated through a review of landscape-scale multi-stakeholder work conducted by A Rocha, particularly in the TEEB report (IUCN NL et al, 2016), preparatory field interviews, and discussions during the organized landscape planning and stakeholder workshop. These ambitions also align with national development plans including the Medium Term National Development Policy Framework; the Ghana Shared Growth and Development Agenda II (GSGDA II) and the forthcoming 40-year long-term national development plan by the National Development Planning Commission.

Scenarios to 2030

Building on the scenarios from the TEEB report (IUCN NL et al, 2016), this study compares the results of scenarios reflecting a 'Business-as-Usual' approach with a large scale mining oriented 'Taking All Resources' scenario and a 'Living Landscape' scenario inspired by strategies of integrated landscape management.

A Business as Usual (BAU) scenario

Based on information from the TEEB report and additional literature, government plans, historical and current data, a benchmark scenario for the year 2030 has been created. This so-called Business as Usual (BAU) scenario assumes that current pressures in the landscape will persist and the current policy framework will continue.
The core assumptions of the BAU by 2030 are:

- Population increases by 3 million people (GSS, WRC) with consequential expansion of urban areas.
- Agricultural food production expansion follows trend in population change with a 45% increase. The focus is on expansion of current low productive mixed crop livestock systems at the expense of natural land cover. No dietary changes are assumed.
- Cocoa and palm oil follow ambitions are taken from national plans (MOFA and COCOBOD). The productivity follows historical production trends and future demands will be met by expanding the area under cultivation
- Small scale mining will follow TEEB projections with small increases in Atewa Forest Reserve and buffer zone.
- No new land regulation or spatial planning policies introduced or implemented.

A Taking All Resources (TAR) scenario

The 'Taking All of the Resources' (TAR) scenario was created as a 'worst case' for resource extraction within the landscape trends towards 2030. It includes many of the assumptions as the Business as Usual scenario, with the primary difference being a much stronger increase in mining (for either gold and bauxite).
In this scenario, 50% the forest in the Atewa forest reserve and 49% of the forest in the buffer zone will be cleared as a consequence of increased mining and demand for wood. The remaining closed forest will be degraded and would become open forest.

A Living Landscape scenario

The Living Landscape scenario has been designed with the aim to meet the landscape stakeholders' landscape ambitions for sustainable development, including synergies between economic and agricultural growth, environmental protection and local livelihoods.
The scenario assumes the following specific landscape interventions to achieve inclusive green growth:

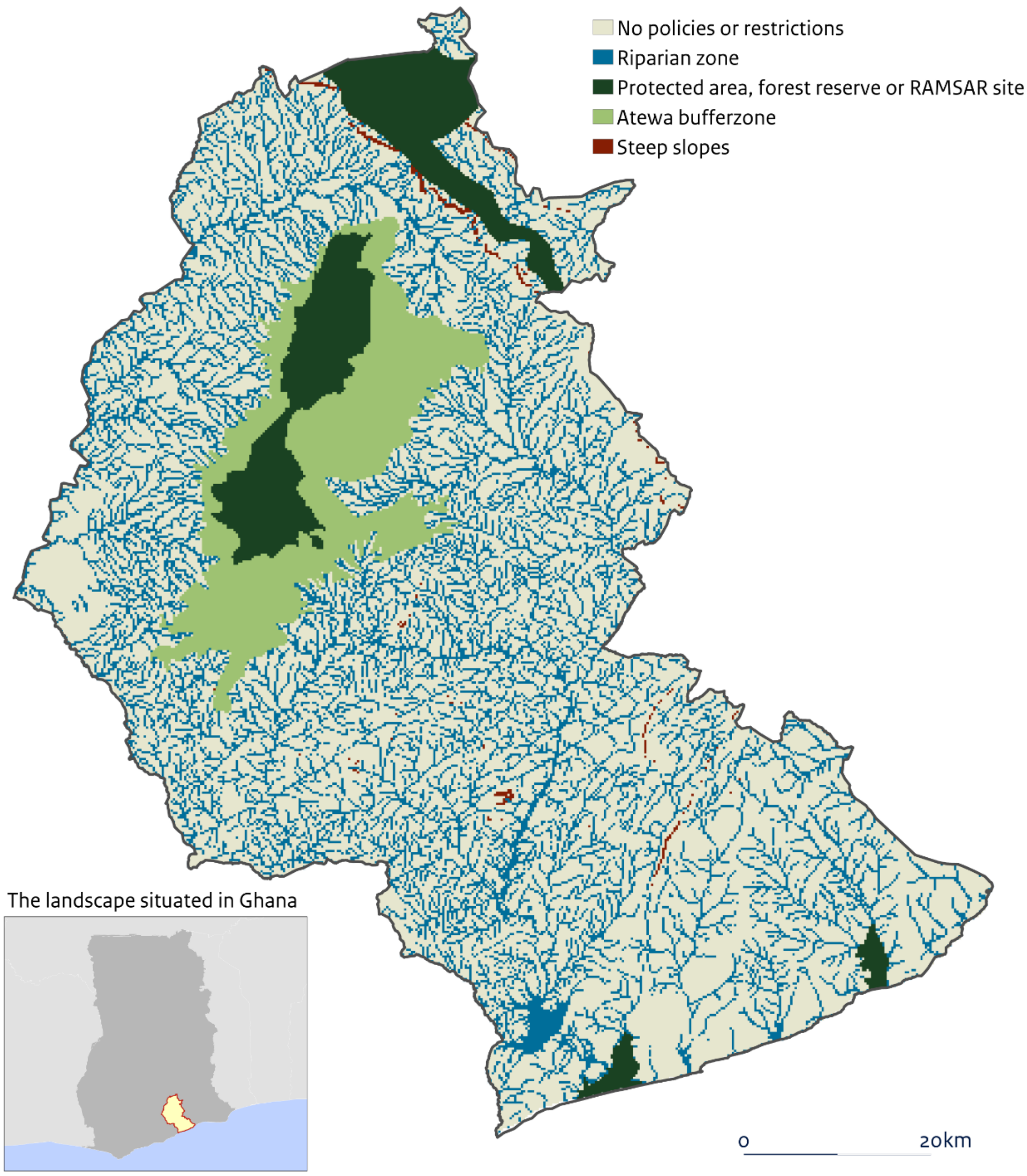
- More attention to land use regulation policies to promote synergies in social and economic development and minimize environmental risks
- Increasing productivity and environmental performance of existing cocoa and palm oil plantations, apply certification (RSPO) standards and limit expansion of new plantations in the trade-off areas
- Respect riparian zones, reforest them with a mixture of trees/agroforestry, also in regions that are prone to flooding

- Conserve upland forests for sustainable water provisioning and climate regulation; respect slopes and maintain or reforest them with mixture of trees/agroforestry, also to prevent soil erosion
- Maintain protected areas (core and buffer) to safeguard global biodiversity and potential biological corridors, also in line with contours of tourism development.

Key elements of the spatial modeling
In order 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 that can guide, promote or restrict certain activities or land uses under specific scenarios.

Figure 2

Spatial policies and zones in the landscape



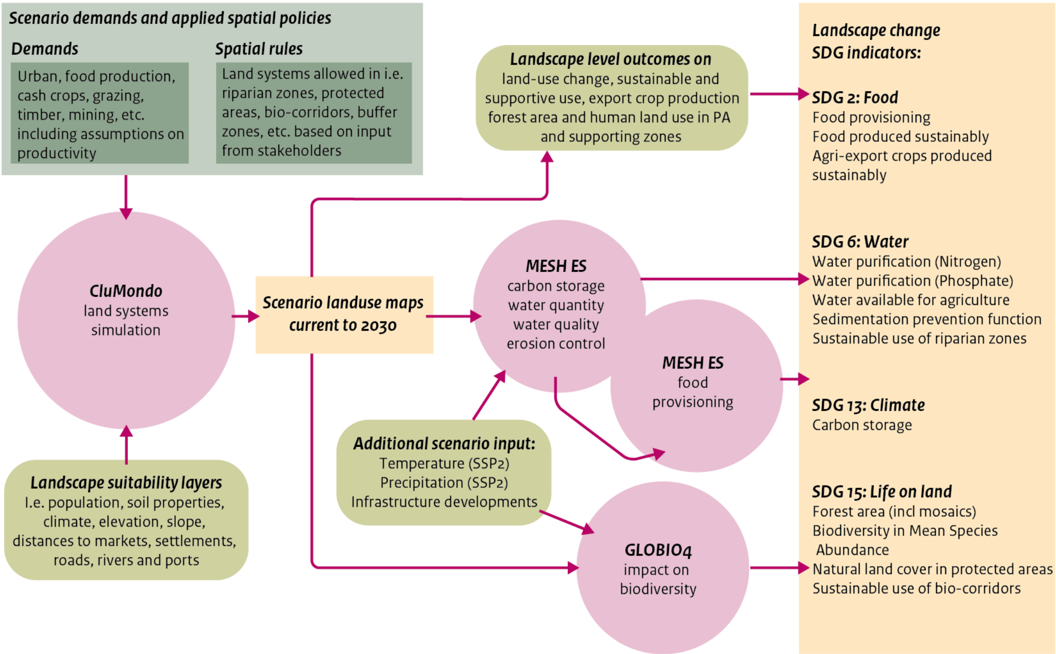
Source: PBL

With the intention to assess various tools, the core modelling tools selected for this project are the CluMondo landsystems simulation model (for analyzing land use change in response to market demand and policy/program interventions, the GLOBIO model that assesses impacts on biodiversity from human-induced pressures and the MESH tool that maps (changes in) ecosystem services to impacts on human well-being.

Figure 3 shows how these tools are connected and how the information flows from input data and assumptions to output indicators. The tools are all open source and freely available.

Figure 3

Overview of the models used and the flow of information



Source: PBL

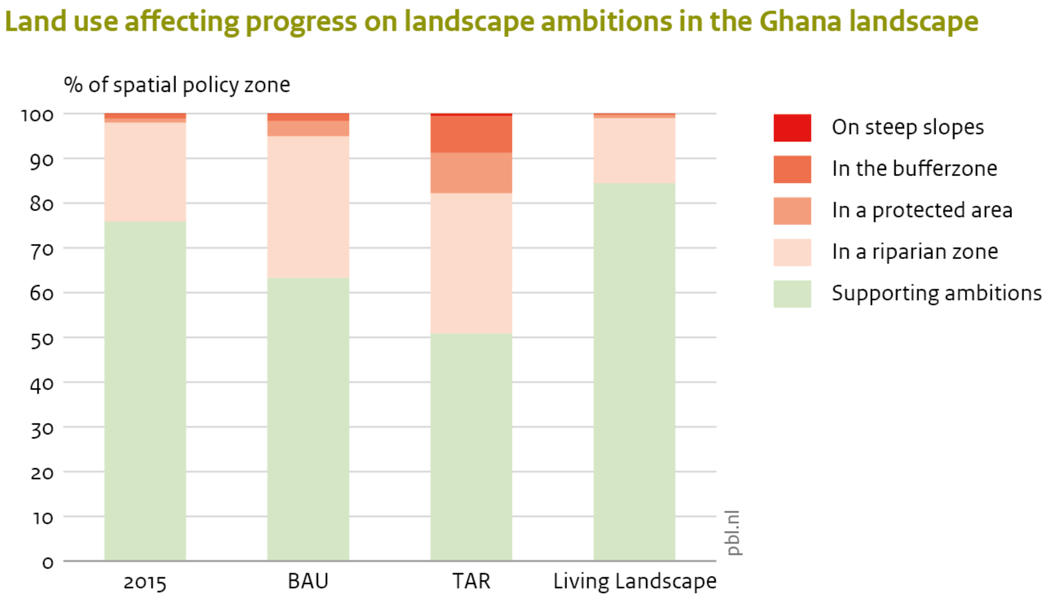
Source: PBL

Main outcomes

The following two figures aim to summarize the scenario outcomes and to visualize the trade-offs occurring within and between the different scenarios that were explored. First focus will be on the changes in the supply of the ecosystem services that were included in the analysis.

The synergy that can be derived from Figures 4 and 5 is that by aiming for strategies and actions that organize the various activities and regulate access to resources in the landscape according to the Living Landscape scenario, the supply of most ecosystem services is higher than under the Business as Usual and Taking all Resources scenarios. In order to produce sufficient food and create a sustainable livelihood for the current and an additional projected 2.5 million people, the improvement of water quality and the protection of soils and forest are essential to maintain the green infrastructure on which the sustainable future is the Atewa-Densu landscape needs to be build. This includes protecting the Atewa forest reserve and restoring the supporting buffer zone, both important elements of the Living Landscape scenario.

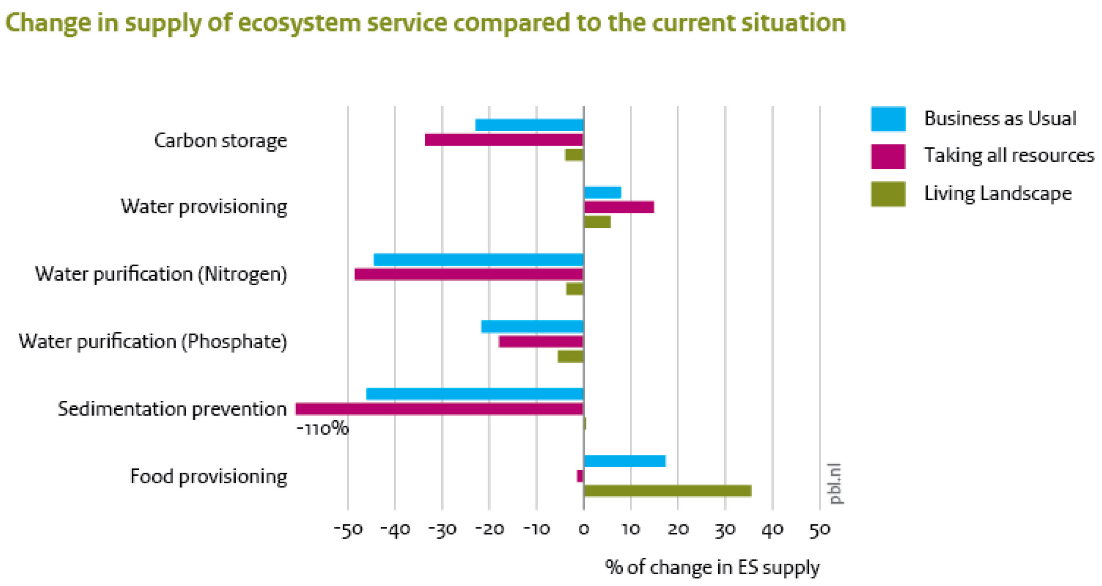
Figure 4



Source: PBL

The only exception from Figure 5 is water provisioning for agriculture, which describes the trade-off in the landscape, as reflected in the modelling tools, of having more trees (that consume and hold on to water) and therefore, under similar climatic circumstances, leave less water available for agricultural production. Unfortunately, due to increasing erosion, pollution and sediment flow, the increasing water provisioning under the BAU and TAR scenarios is more likely to cause trade-offs (increased runoff, uncontrolled timing of available water flow, risk of flooding) than synergies.

Figure 5



Source PBL

As stated in Section 3.1, from the perspective of Accra citizens, the availability of water for drinking is currently not seen as much of an issue, but rather the quality and the cost of treating it for consumption are becoming more problematic. Famers in the Densu basin area however, are facing unfavourable periods of drought recently, with the Densu river even falling dry at certain times.

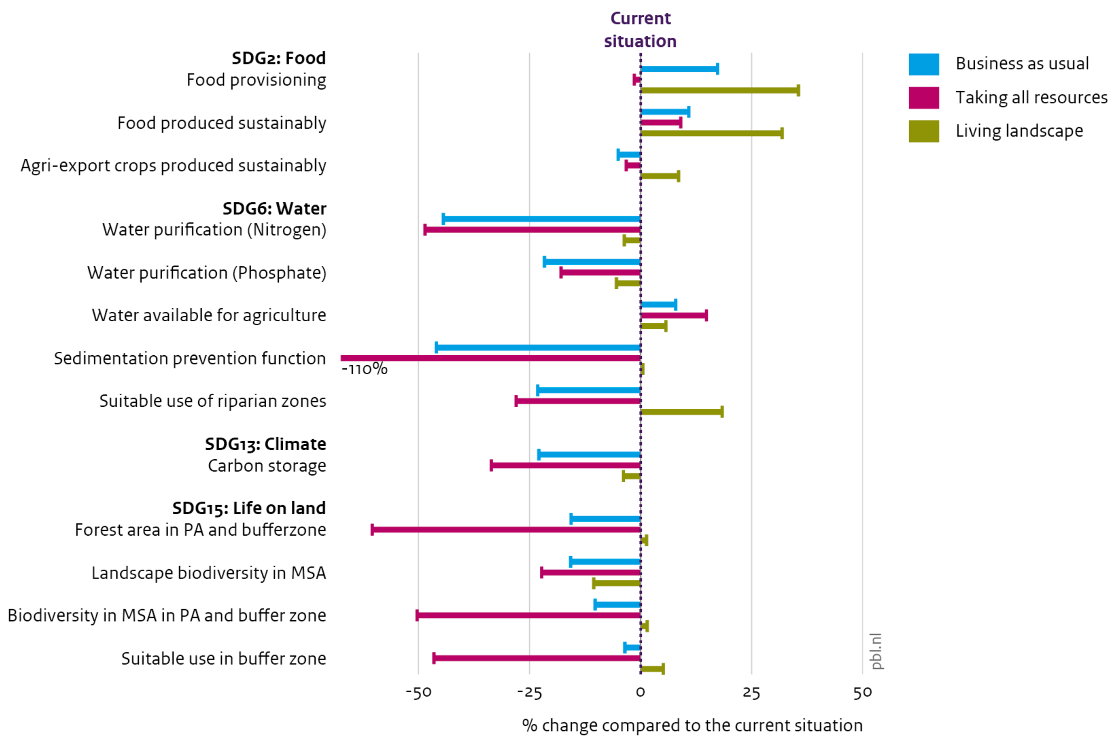
With respect to the selected SDGs, Figure 6 provides an overview of the scenario outcomes on the indicators presented in Figure 3.

For **SDG2** only the Living Landscape scenario is showing a positive change on all indicators, compared to the current situation. With the increasing area in use for food production, even under the BAU and TAR scenarios an increase of food being produced sustainably can be achieved, but the 32% increase projected under the Living Landscape scenario illustrates the other two scenarios are performing far below the landscape's potential. If food provisioning is translated to per capita change (see Figure 5.11), it is clear the growing population is putting a large demand on the landscape, also given its relatively small area (6,000 km2) that limits the space available for options in combination with the identified spatial policy zones. To cope with this challenge and secure SDG2, it might be that the required agricultural productivity increases need to be even higher than those used under the Living Landscape scenario (see Table 4.2), which would require larger investments.

For **SDG6** the implementation of the riparian zone policy, protection of Atewa forest and the restoration of the buffer zone clearly have a positive outcome the water quality and sedimentation prevention function, that controls soil erosion, for the Living Landscape scenario. The BAU and TAR scenarios are not showing any improvement and will not support the landscape in achieving this SDG. Due to increasing agricultural production the nitrogen load is increasing and affecting water quality under all scenarios, to varying degrees though.

Figure 6

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



Source: PBL

For **SDG13** only carbon storage was included. Due to the overall loss of trees in the whole landscape under all scenarios (see Figure 5.8) this indicator slightly decreases. The Living

Landscape scenario shows the best results, by limiting the loss to just 4%, mainly because of the conversion of open forest to mixed agricultural systems and agroforestry in the zone between Atewa and Accra (see Table 4.1).

For **SDG15** the results for the Living Landscape scenario are obviously the most optimistic. Given the magnitude of the pressures affecting biodiversity in the landscape it is very promising that the Living Landscape scenario is able to reduce the loss in MSA occurring under the BAU scenario by a 33%. The other indicators illustrate that under the Living Landscape scenario specific focus is on protecting forest in Atewa and the role of the buffer zone, also in relation to supporting indicators under SDG2, 6 and 13 as was also shown in section 5.2. This a potential synergy that is clearly turning into a trade-off under the BAU and TAR scenarios.

Value of scenario modeling for ongoing landscape initiatives

Spatial modelling tools can help to increase awareness among stakeholders about the order of magnitude of drivers of landscape change, like a growing population and increasing urbanization, the (unbridled) expansion of agricultural production and the development of infrastructure and mining, and how these are affecting natural resources in a landscape.

Spatial modelling of potential alternative future scenarios can be a catalyst for building landscape partnerships. The focus of the modelling tools was on facilitating stakeholder discussions, and not so much on being the most advanced and complex model in covering every detailed element of i.e. biodiversity or hydrology. By delineating the landscape on district boundaries and covering the whole area from the Atewa Range in the north to the capital of Accra in the south, our results and the discussions could also be useful for the land use planning process, even though district level stakeholders from the southern part of the landscape were not participating in the workshop. In this planning process the National Development Planning Commission (NDPC), supported by UNDP, is promoting the integrating of the SDGs into the district level development plans.

The Sustainable Development Goals, considered as an integrated and inseparable framework for sustainable development, provide a useful framework for focusing discussions on shared ambitions and benefits, and can, in combination with spatial scenario analyses, be used in action planning of integrated landscape initiatives. In our modelling we focused on SDGs that could be more directly related to spatial planning and land use change modelling: food, water, climate and life on land.

Overall, based on the outcomes, we would conclude that a scenario that uses an integrated approach like the Living Landscape scenario, that involves multiple sectors, is organized in (effective) multi-stakeholder platforms, has a larger potential in achieving progress on multiple SDGs simultaneously in this landscape, provided that it is also combined with substantial increases in productivity of current agricultural activities, increased capacity and enforcement of local and landscape level land use planning and (continued) effective management of protected areas and nature reserves. Given the limited SDG coverage in our modelling is it obvious that in order to achieve sustainable development in the landscape also progress on other SDGs like health, education and gender needs to be achieved.

1 Introduction

1.1 Study goal and objectives

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 trade-offs 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

In 2017, PBL and EcoAgriculture collaborated with IUCN-NL and A Rocha Ghana on a project to explore various landscape scenarios and assess their potential contribution to selected SDGs in the Atewa-Densu landscape of Ghana. A Rocha is working here to protect the Atewa forest along with the associated Densu river basin and develop sustainable livelihood strategies for the landscape. 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 a workshop designed to define anticipated scenarios. These efforts 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 a field visit in June 2017 by PBL and in a workshop held in Koforidua, November 1st, 2017.

This Report was prepared with two audiences in mind. The first is to inform and stimulate the stakeholders of the Atewa-Densu landscape who are actively collaborating to transform their landscape in more sustainable directions. The second is policymakers on sustainable development and spatial planning, including within the Ghanaian government (at the district and national levels). The 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.

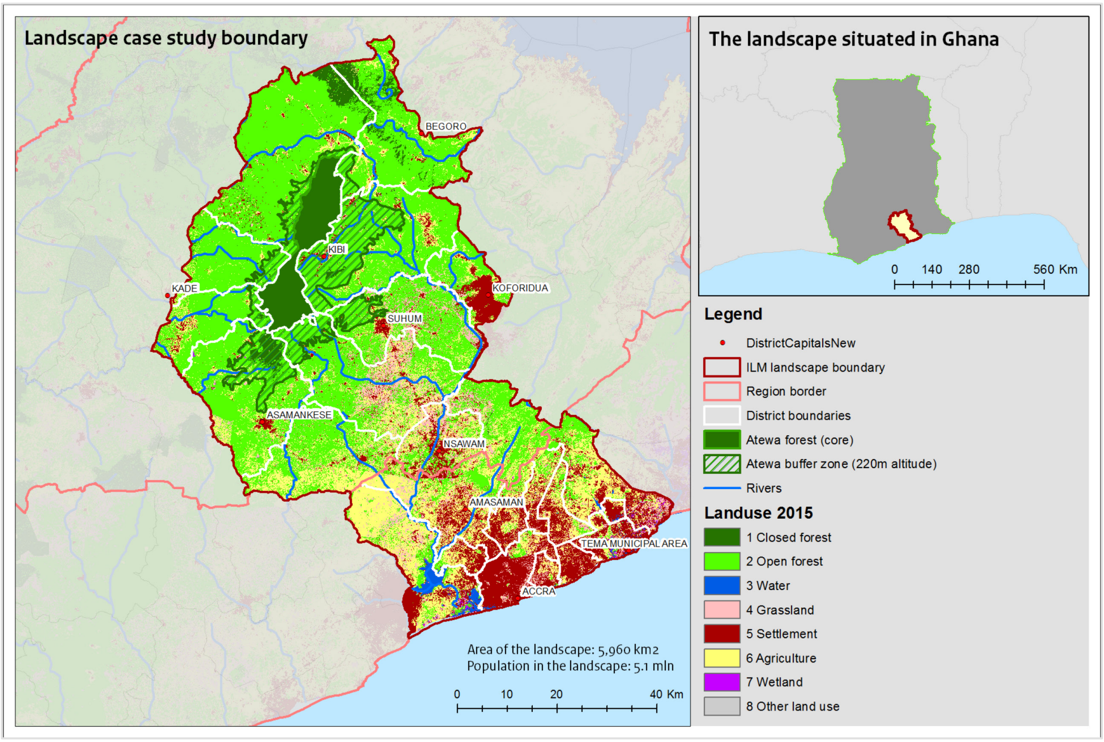
Section 1 of the report briefly introduces the Atewa landscape, the work of A Rocha and related landscape initiatives. Section 2 describes the participatory methods and modelling tools used for the scenario development. Section 3 describes the current state of sustainable development in the landscape and stakeholder ambitions for the future. Section 4 describes the scenarios used in the study and Section 5 presents the results of the scenario analysis. Section 6 concludes the report.

1.2 The Atewa-Densu landscape

The Landscape

The landscape is characterized by the Atewa Range, about 90km north of the capital of Ghana, Accra. The range, as defined by the TEEB report (IUCN NL et al, 2016), consists consist of a protected forest reserve and a surrounding buffer zone and includes closed and open canopy upland evergreen forest, grasslands and herbaceous areas, cocoa and other crop plantations, small scale (often illegal[3]) gold mining and some built up areas. The forest within the range functions as the source of three important rivers, the Densu, Birim and Ayensu. It supports several communities who live on the forest fringes, and is home to a large diversity of plants and animals. The protected Atewa Forest Reserve is recognized as a Global Significant Biodiversity Area and hotspot. The Atewa Forest Reserve is one of only two reserves with upland evergreen forest in Ghana.

Figure 1.1
Overview of the extent of the Atewa-Densu landscape



Source: PBL and Ghana Forestry Commission

[3] Following the widespread devastation of water resources and forest reserves as a result of the activities of illegal mining, the Lands and Natural Resources Ministry, in January 2017 (when the Akufo-Addo government took office) placed a ban on all forms of small scale mining for a period of six months, which has been extend in October 2017 and again in January 2018. According to the Minister of Lands and Natural Resources the ban will be active until targets, agreed on with the sector, have been met.

The boundaries of the Atewa-Densu landscape, for the purposes of this project, include the disctricts that cover the Atewa Range, the Densu Basin and the area of the greater Accra Metropolitan Area that is supplied with water by the Densu Basin (Figure 1.1). The Densu basin, the most densely populated and most important river system for Accra, feeds the Weija water reservoir which is used for irrigation and is also one of the two main sources of potable water for the Accra Metropolitan area. The Densu Delta is part of a Ramsar site, an internationally recognized and protected wetland area. The landscape covers about 6,000 km2 and is home to about 6 million people. It covers 26 districts and/or municipalities: 12 in the Eastern region and 12 in the Greater Accra region.[4]

The boundaries were set in this way for a variety of reasons. First, these boundaries include not only the forest resources, but the areas impacted hydrologically and economically by the health of the forest. By considering this area's identity as a watershed the relevant stakeholders can more easily recognize their common concerns. Also, by including districts and municipalities, this exercise can link well with the Ghanaian government's existing spatial planning process. This system mandates that the Municipal and District Assemblies (MMDAs) prepare their annual plans and program of activities to fit into the national development framework prepared by the National Development Planning Commission (NDPC).

Threats to the landscape

Despite Atewa's protected status, the forest both inside and outside the Forest Reserve is steadily degrading for a variety of reasons, including:

- Population growth and urban expansion: Annual population in the last decade was 2.5%, (based on a 2015 report of the Water Resource Commission);
- Expanding agricultural area for food and commodity production: growing population drives the expansion of agricultural food production. Meanwhile, the area under oil palm is expanding and cocoa plantations are aging. Recent data shows that the closed canopy forest has decreased by around 10% in the Forest Reserve and by at least 35% in the buffer zone around the reserve in the last twenty years (CERSGIS info for 1990, 2000, 2010 in the TEEB report);
- Illegal activities for timber and non-timber harvesting;
- Due to erosion and sedimentation, seasonal droughts and floods have increased and water quality has deteriorated, since chemical pollution is on the rise: the Densu is a highly exploited river that is marked by pollution, flooding as well as occasional water shortages. As a result of upstream soil erosion the Weija reservoir is silting up at around 2% per year. Affected stakeholders include local communities and farmers that live close to the Forest Reserve, over 5 million people in the Accra metropolitan area that depend on the water sourced from Atewa Range as well as a variety of businesses in the landscape;
- Small scale gold mining, illegal and regulated, encroach the Atewa Range and cause water pollution, deforestation and biodiversity loss. Gold mining around the reserve took off in 2009 and now occupies around 2.8% of the buffer zone (RMSC, 2016). Currently, since January 2017, a ban on all forms of small scale gold mining is active, which has put a (temporary?) hold on these activities.
- Potential large scale bauxite exploration and mining activities in the Forest Reserve.

1.3 Atewa landscape initiatives

A Rocha Ghana has been working with landscape stakeholders over the past five years to protect the Atewa forest, to halt illegal logging and gold mining and prevent bauxite mining,

[4] The boundaries of the landscape are broader than the area analysed in the TEEB report, which focused mainly on the Atewa range.

and to promote and support sustainable livelihood options for the local population. This has come in a variety of forms. In 2012, a three-year programme – **Atewa Critical Conservation Action Programme (ACCAP)** Phase I, funded by the A.G. Leventis Foundation, was initiated to carry out awareness-raising and advocacy activities which resulted in greater international and local visibility of the threats to Atewa. The AACP enabled the development of a long-term action plan for the protection of Atewa Forest and its watershed catchments. A Rocha is now building on this work in partnership with IUCN Netherlands in an advocacy focused effort entitled **Living Waters from the Mountain: protecting Atewa Water Resources**. An offshoot of this work is the **Campaign to Save the Atewa Forest Now!**, an advocacy partnership under the Green Livelihoods Alliance, including A Rocha Ghana, IUCN NL, Tropenbos International and Ghana, Friends of the Earth Ghana and Vereniging Milieudefensie.

A Rocha Ghana has also led the development of the **Atewa Living Landscape Vision** which was endorsed by an NGO coalition including Tropenbos Ghana, Friends of the Earth Ghana, Okyeman Environment Foundation, The Development Institute, Save the Frogs and Herp Ghana. Proposals in this vision are for an 'integrated landscape that respects the region's history, its environment and its people, and one that bring development to the region in a sustainable way.' The vision is centered on the development of a national park with an associated tourism industry. The area around the National Park would form an enterprise zone where sustainable land use practices including natural forest restoration, agro-forestry and commercial reforestation would be encouraged (following also Jezeer et al., 2017). The coalition has requested that the government work in partnership with key stakeholders to develop a landscape master plan, including a protected area management plan and buffer zone plan which takes into account hydrological considerations. It calls for the establishment of sustainable financing plan to encourage investment in ecotourism, sustainable forestry, certified cocoa and carbon credits.

Another relevant multi-stakeholder process within the landscape is the **Integrated Water Resources Management Plan for the Densu Basin**. Substantial effort was devoted to creating an appropriate basin-based management structure. Established in 2004, it centered on the WRC Densu Basin Secretariat, the Densu Basin Board (which administratively is established as a WRC sub-committee) and the strengthening of linkages with the Local Government Assemblies. Quarterly Board meetings are held for these entities to strategize and institute interventions to ensure the sustainability and development of the Basin.

2 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.

2.1 Role of stakeholders in scenario development

The TEEB report on the Atewa Forest range (IUCN NL et al, 2016), including 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 A Rocha Ghana. The first visit (June 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 the storylines of 3 scenarios from the TEEB report were expanded and applied to the modelling framework to produce some first outcomes.

During the second visit (November 2017) a Landscape Leader Workshop for 30 landscape stakeholders was organized and additional organizations (UNDP, NDPC) were visited. Following the workshop sessions with stakeholders on current state, the 3 scenarios, and priorities for interventions in the landscape, the team presented the draft scenario analyses for group discussion and recommendations for refining input datasets, model assumptions and the scenario storylines. Based on the feedback, the team modellers enriched the model and refined 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 IUCN NL/A Rocha Ghana team and landscape stakeholders, the report was revised.

2.2 Landscape delineation

In Ghana, land use planning is locally organized at the district level. To connect to these local planning processes and to potentially involve and inform district level assemblies, the district level is considered the main entry point for this case study, which is a slight change and expansion compared to the TEEB study research area.
To clearly define the boundary of the landscape research area, the following procedure was applied:

- Select the districts (from the CERSGIS 2015 district map, containing 216 districts in total) that:
  - Contain part of the Atewa range (=Atewa Forest Range and/or the Atewa buffer zone (area above 220m elevation version), as defined in the TEEB study).
  - Cover the Densu river basin, limited to those that are (mainly) within the Eastern and Greater Accra administrative regions
  - Cover the Greater Accra Metropolitan Area. (Based on https://en.wikipedia.org/wiki/Greater_Accra_Region and Adank et al 2011)
- Due to its large area and natural divide the Eastern region Fanteakwa district (also bordering Lake Volta) was cut off at the natural watershed boundary that intersects the district from the northwest to the southeast.

In broad terms this area is similar to the upstream, midstream and downstream Densu water basin areas defined in the TEEB study, but now corresponds directly with administrative district boundaries that link more closely to the land use planning process. It is assumed that policies and spatial regulations of relevant stakeholders in the landscape (e.g. the Forestry Commission, the Water Resources Commission, the Ghana Water Company) that focus on specific areas (e.g. forests, watersheds and rivers/water) within the landscape can be integrated in the research since the actual modelling will be grid cell based (e.g. on a 240x240meter resolution).

2.3 Land systems classification

Land systems represent typical combinations of land cover, land use (e.g. livestock, agriculture) 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 240x240 meter resolution.

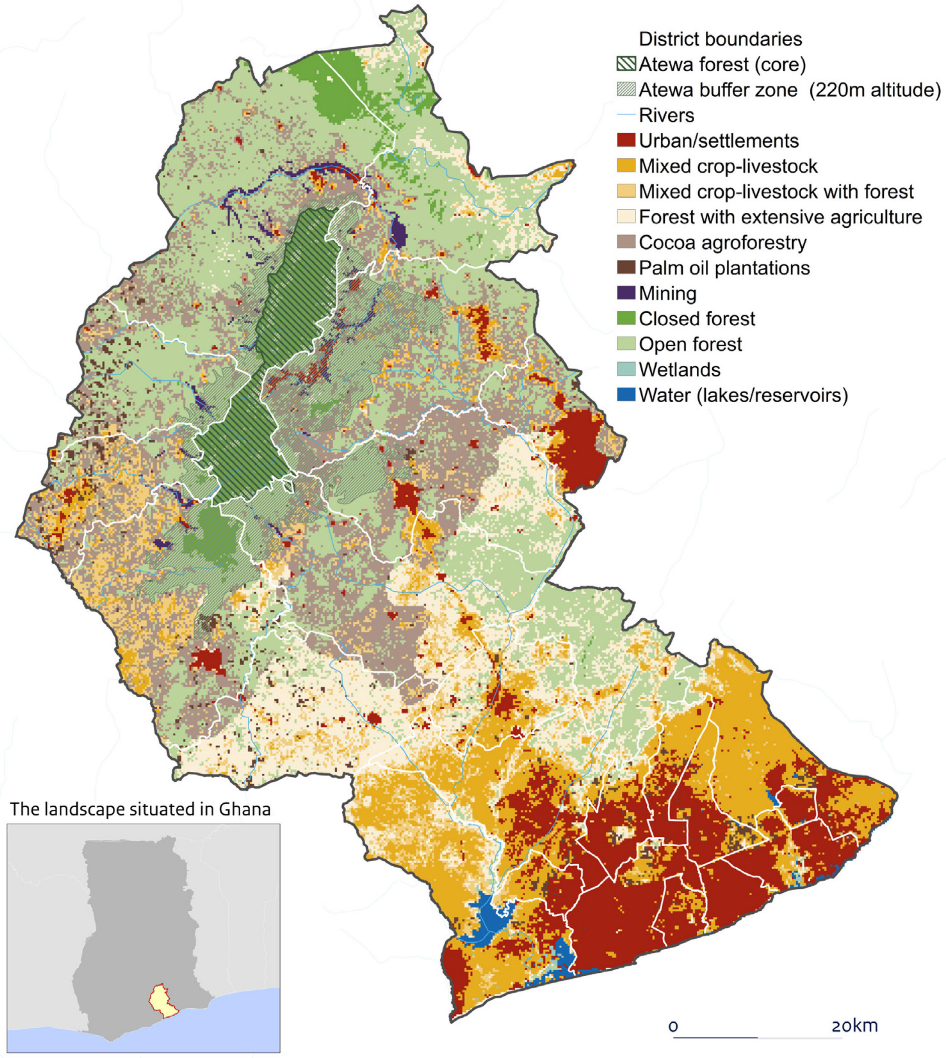
The following steps and input datasets were used:

- Forestry Commission 2010, 2013, 2015 data: concensus dataset on 30m:
  - Closed forest, Open forest, Water, Grassland, Settlement, Agriculture, Wetland, Other land
  - Added oil palm plantations (PBL outsourcing to create this map by Satelligence based on remote sensing data)
  - Added mining areas, based on TEEB report data (IUCN NL et al, 2016)
- 30m to 240m aggregation to generate:
  - Mixed crop-livestock mosaic
  - Mixed crop-livestock with forest (15-40%) mosaic
  - Forest (>40%) with mixed crop-livestock mosaic
- Cocoa areas: reclassification of "Forest with crop-livestock" cells within land use 2000 cocoa areas, verified with district level statistics where possible.

The land system map contains 11 classes and is shown in figure 2.1. Besides several discrete land systems (e.g. urban, mining, closed canopy forest, palm oil plantations, water) we 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 agroforestry. The land system classification procedure is further described in Annex 8.2.

Figure 2.1

Landsystems in the Atewa-Densu landscape, 2015



Source: PBL

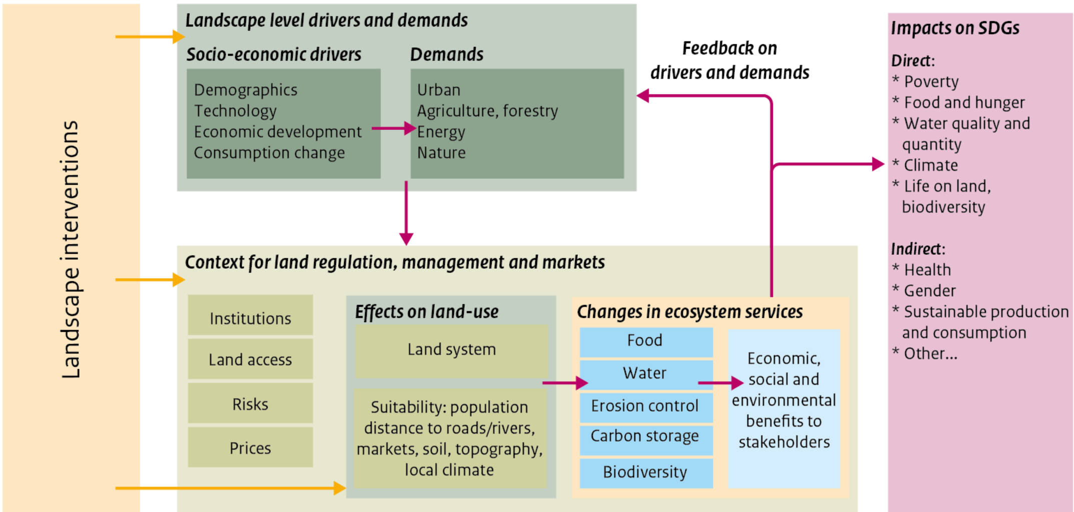
2.4 Overview of the modeling framework

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 2.2. 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.

The modelling framework in this project centres around spatial planning, configuration of activities in the landscape and impacts on natural resources. The model does not (presently) include an economic 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 analysed.

Figure 2.2

Conceptual modelling framework for the scenario analysis



Source: PBL

2.5 Models used in the analysis

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

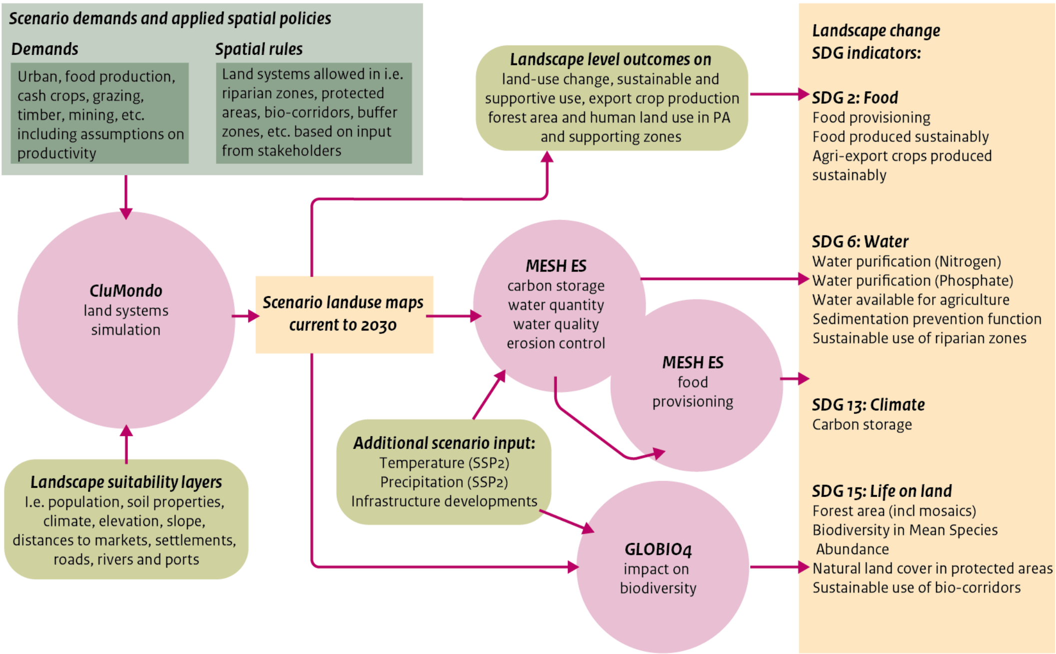
Figure 2.3 shows how these tools are connected and how the information represented in the conceptual model in Figure 2.2 flows from input data and assumptions to output indicators. The tools are all open source and freely available. They are explained in short below.

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 2.3

Overview of the models used and the flow of information

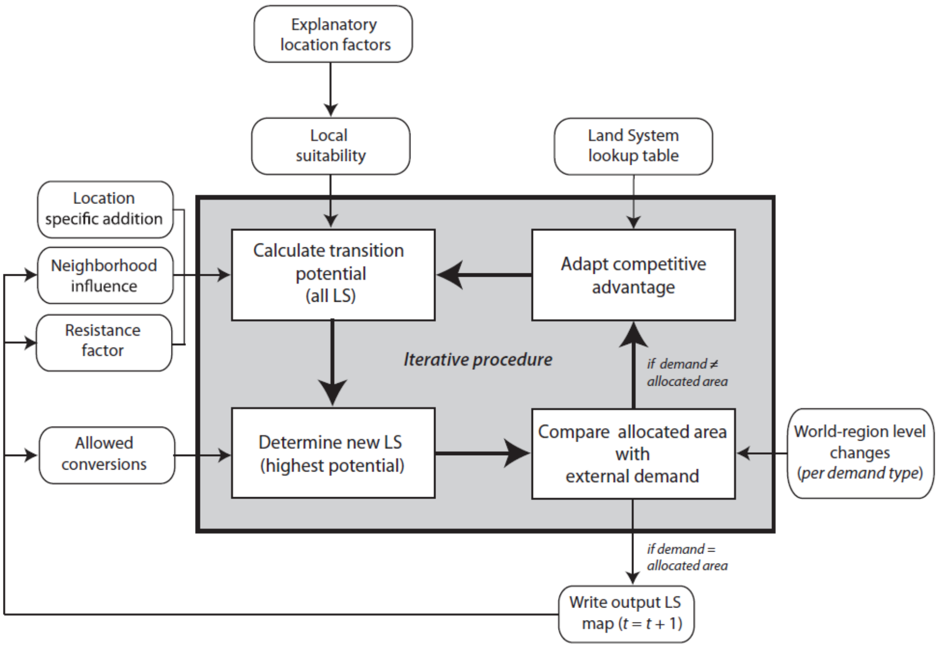


Source: PBL

Source: PBL

Figure 2.4 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.

Figure 2.4



Source: Van Asselen and Verburg, 2013

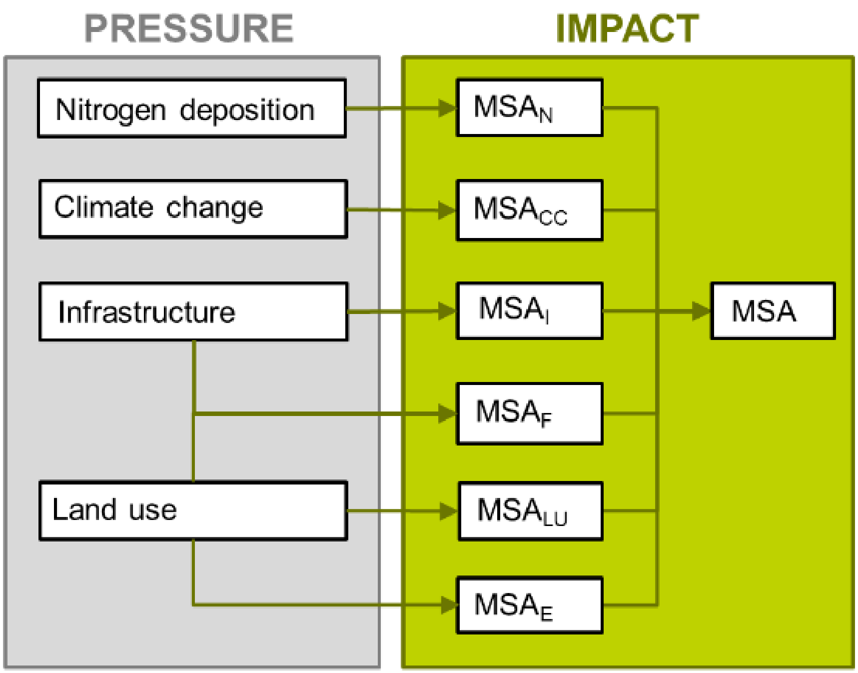
The CluMondo model can be influenced by promoting or even enforcing interventions, as defined by stakeholders, that only allow, restrict or stimulate certain land use and land cover types that contribute to positive effects on the various landscape ambitions. For example in riparian zones land clearing 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.

For each scenario time step (15 years) the CluMondo model produces a new land systems map that for this project has a 240x240 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 2.5
Schematic representation of the cause-effect relationships in the GLOBIO model

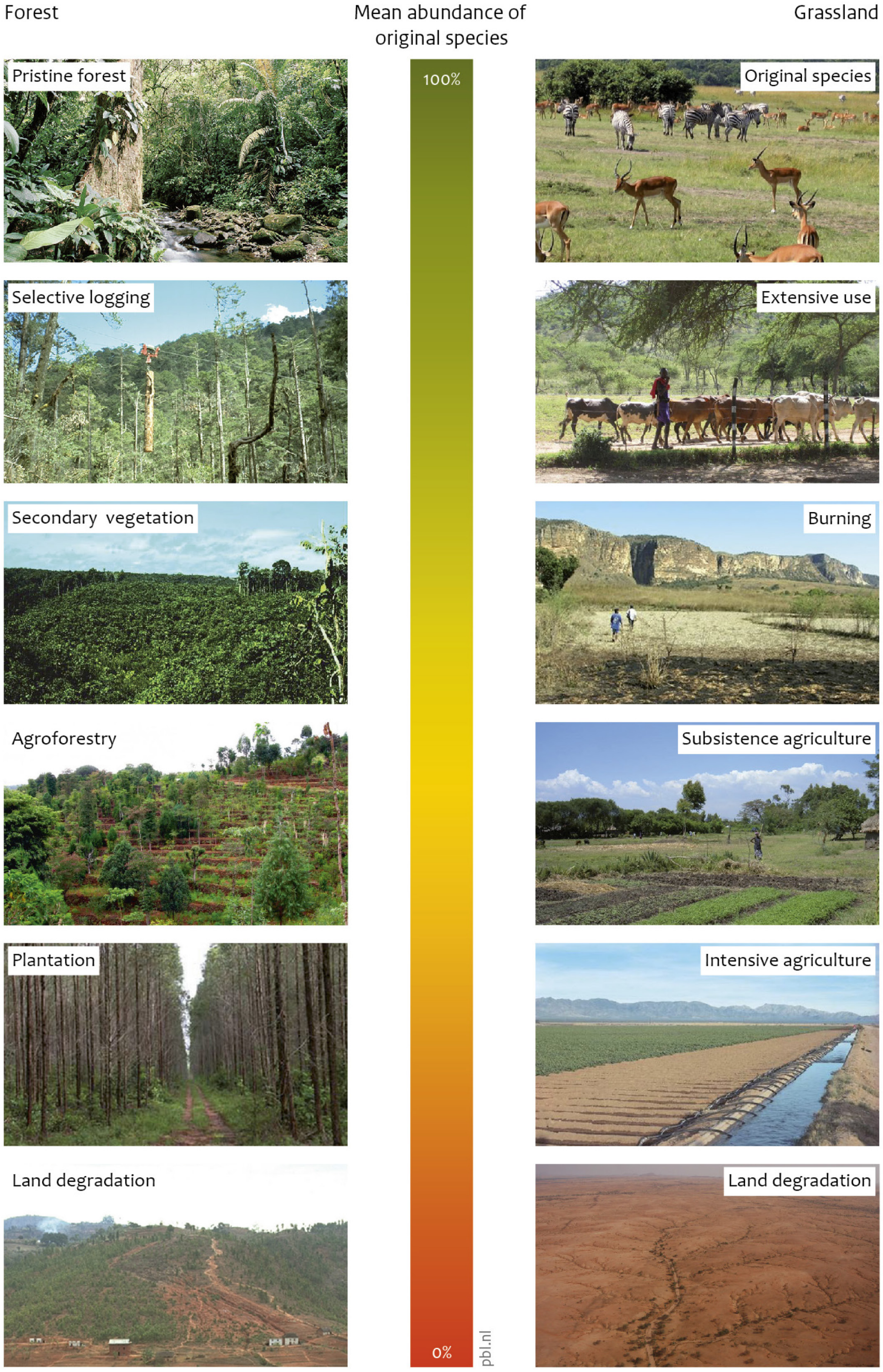


Source: PBL

Figure 2.5 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.

Figure 2.6

Photographic impression of mean species abundance indicator at landscape level



Source: PBL

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 2.6 for a photographic impression of various levels of MSA. More info on GLOBIO can be found on http://www.globio.info.

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 2.3, 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 2.3, 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.

2.6 Coverage of Sustainable Development Goals

The models emphasize impacts on the landscape ambitions and selected SDGs (focusing on SDG 2, 6, 13 and 15, see Table 2.1) resulting from changes in land cover/use, agricultural production and impacts on ecosystem services depending on the natural resources in the landscape.

We realize that there are also more factors that may 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 definition and/or score and therefore distance to the target is unknown, uncertain or the required data is not available at the moment. Whenever additional model outcomes and SDG indicators were considered relevant by the stakeholders (i.e. gender, education, health) and these had a spatial impact in the landscape, they were explored and analysed depending the availability of suitable input datasets.

Table 2.1
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 and 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 (%) in protected area and Atewa buffer zone
15	15.5	Biodiversity	Change in Mean Species Abundance in the landscape overall and Atewa range specifically (%)
15	15.2	Supporting buffer zone	Change in suitable use in Atewa buffer zone (%)

2.7 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 IUCN-NL and A Rocha Ghana and local organizations and partners to improve. During Phase 1 of this project many relevant documents and statistical and spatial datasets were gathered and many datasets gathered for the TEEB report were shared. 30 meter resolution land use/cover maps for the years 2010, 2013 and 2015 were retrieved from the website of the Forestry Commission and used to create a 2015 consensus land systems map at a 240x240 meter resolution. Cocoa production areas were identified with help from CERSGIS data and indications from literature and COCOBOD documents. With some additional PBL funding a coarse indicative map of palm oil plantations within 1000x1000m blocks was created by Satelligence based on Sentinel remote sensing data. Various statistics were collected from the websites of the Ghana Statistics Service, the National Development Planning Commission (NDPC) and the Ministry of Finance. For a complete overview of data sources used see Annex 8.1.

2.8 Stakeholders consulted

During the exploratory visit by PBL in June 2017, A Rocha Ghana enabled connecting to many stakeholders in the landscape. This provided access to more locally relevant datasets from for instance the Ghana Water Company Ltd and paper maps from the Minerals Commission. Also visits to the facilities of the Forestry Commission, Ghana Water Company

Weija office and CERSGIS in Accra, the Water Resource Commission and the Environmental Protection Agency in Koforidua and the East Akim District Assembly and A Rocha office in Kyebi 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. We also visited the UNDP and NDPC offices in Accra for information and feedback on our activities. These agencies are heavily committed to integrating the SDGs into the national and district planning activities.

3 Landscape ambitions for the future

An important condition for any successful theory of change and the implementation of an integrated landscape management plan is the shared agreement on the various ambitions that are pursued by the stakeholders in a landscape. This section first provides an overview of the landscape ambitions expressed by the stakeholders included in the Atewa-Densu landscape and how these relate to the SDG goals and targets that are considered in the spatial modelling framework. Following this, a number of potential interactions between the identified ambitions and related SDGs, that are considered important for realising synergies and preventing trade-offs in the next 15 years, are highlighted.

3.1 Stakeholder ambitions in the landscape

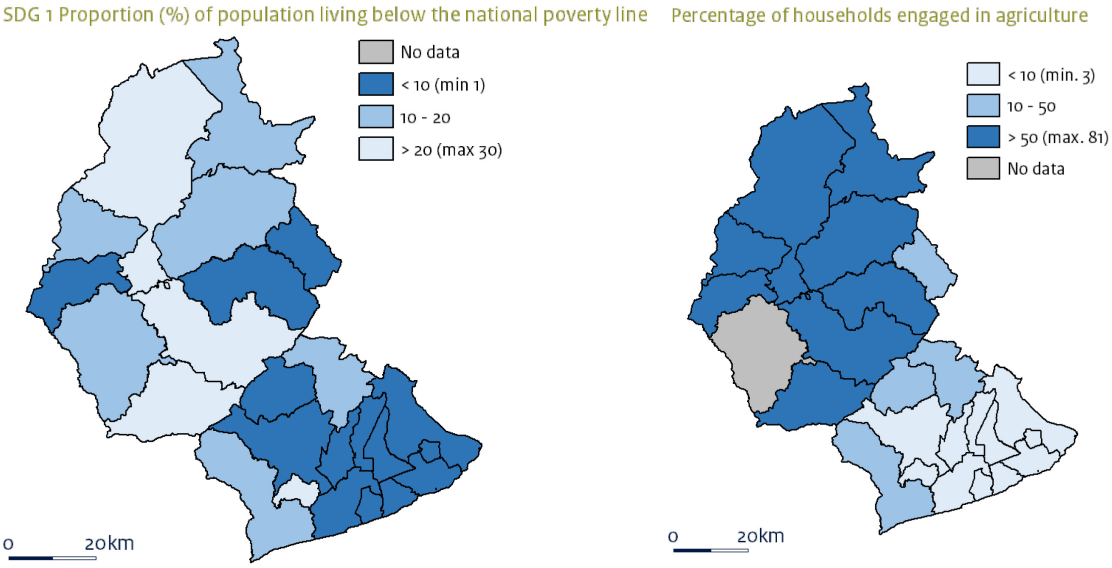
Stakeholders articulated six major ambitions for their landscape. These ambitions are described below and were generated through a review of landscape-scale multi-stakeholder work conducted by A Rocha, particularly in the TEEB report, preparatory field interviews, and discussions during the workshop. These ambitions also align with national development plans including the Medium Term National Development Policy Framework; the Ghana Shared Growth and Development Agenda II (GSGDA II) and the forthcoming 40-year long-term national development plan by the National Development Planning Commission. This section provides an overview of the current status of the landscape with respect to each ambition, noting links with the SDGs.

Ambition 1: Improve food security and livelihoods

A fundamental goal for the landscape is to improve the food security and overall socioeconomic condition of the population. Based on the last census data (2010) around 8% of the total population in the landscape is still considered to live below the national poverty line. However, when focusing on districts around Atewa this value increases up to 20-30%. For many households in the landscape, especially around Atewa and downstream the Densu river towards Accra, agriculture is the primary economic activity. This means many policies oriented to improving their livelihood will focus on improving agricultural productivity and diversification of the production to become more resilient as well as the strengthening of market linkage. A Rocha is also promoting alternative livelihoods in agriculture or tourism for people involved in small scale gold-mining activities within the Atewa Range. Even though the current ban is putting small scale mining activities temporarily on hold in Ghana, still many people derive an income from this. Making these practices more sustainable, including effective restoration after mining has finished, will be a major challenge.

The landscape will need to increase food production to be on track to achieve achieving SDG 2 (zero hunger). Underpinning rural livelihoods will require universal public services and infrastructure for health and education, SDGs 3 and 4.

Figure 3.1



Source: PBL

Ambition 2: Conservation of the forest ecosystem and protect biodiversity

The Atewa Forest, a critical ecosystem and Globally Significant Biodiversity Area, is degrading, and the pace of the degradation has accelerated over the past few decades. This is due to a number of pressures including an expansion of farming (including illegal encroachment), illegal logging, unregulated artisanal and small-scale gold mining (galamsey), hunting for bushmeat, and over-exploitation of certain non-timber forest products. Another serious threat to the Atewa and Densu ecosystems is the potential for large-scale bauxite mining and quarrying within the boundaries of the Forest Reserve.

The closed canopy forest cover in the Atewa Range decreased from almost 88% (668 km2) of the total range area in 1990 to less than 60% (452 km2) in 2010. The protected status of the Forest Reserve area has clearly succeeded to some extent as the rate of deforestation has been lower than in the Range as a whole. In 1990, the closed- canopy forest formed about 91% (212 km2) of the total reserve area; whereas in 2010, it decreased to around 81% (190 km2). Most of the decrease in closed-canopy forest in the Forest Reserve occurred after 2000 and was accompanied by an increase in open-canopy forest. This might be explained by new pressures leading to the degradation of forest (from closed- to open-canopy). In the buffer zone, the decrease in closed-canopy forest cover dropped from about 85% in 1990 to nearly 50% in 2010.

Based on this pattern of degradation, A Rocha and its allies are advocating for the government of Ghana to declare Atewa Range Forest Reserve as a national park. The Forest Reserve status has been successful relative to Atewa forest as whole, but it has not been able to stop the deforestation entirely. The designation of a national park would strengthen legal protection to restore the forest ecosystem and limit mining. It would also help to enable the development of an eco-tourism industry.

The Forestry Commission, which manages the Forest Reserve, is supportive to update the status of the reserve to a National Park. An upgrade to National Park would imply a higher priority to conservation of the forest, an increase in conservation efforts and a shift of management from the Forestry Services Division to the Wildlife Division. However, a national park alone would not necessarily lead to improved management within the surrounding area of the reserve, where unsustainable agriculture is being practiced and gold mining activities

have been taking place. The current ban on galamsey has temporarily put the (illegal) mining activities on hold. The Minerals Commission, which is part of the Ministry of Land and Natural Resources, is in charge of issuing concessions to eligible mining companies, also controlled and approved by the EPA. Therefore, the management of the biggest threat to the watersheds of the Atewa Range outside the Forest Reserve (gold mining) lies within their jurisdiction.
Strategies to ensure the effectiveness of this process should consider awareness raising campaigns, training and capacity building for patrolling, increased presence on the ground, improved enforcement logistics alongside creating alternative livelihoods.

In order to meet this ambition and SDG 15 (life on land), institutional arrangements need to be improved, strengthened and empowered, political decision making should allocate adequate resources (both in terms of funding and technical capacity) toward national and decentralized agencies responsible for spatial planning and enforcing environmental regulations, including the local district authorities. Additionally, stakeholders will increase education about environmental issues among youth and within universities, to instill values of good environmental stewardship among the population (SDG 4).

Ambition 3: Sustainable management of water resources and supply

The Water Resources Commission (WRC) is responsible for regulating and managing Ghanaian watersheds, including the river basins originating from the Atewa Range: the Ayensu (1,238 km2), Birim (3,922 km2) and the Densu (1,873 km2). Of the three river basins that the Atewa Forest feeds, the Densu River Basin is the most densely populated one. This basin also has the highest dependency on, and share of, extracted water resources (WRC, 2015). Consequently, the value of the ecosystem services provided by the Atewa Forest to the Densu watershed has been assumed to be the most significant (IUCN-TEEB, 2016). Some of the causes that threaten the ecological integrity of the Densu River basin are: indiscriminate harvesting of wood from the micro-catchments of the river, agricultural activities on the banks of the river, the use of agrochemicals in farming and harmful chemicals in fishing and mining and quarrying in and around the basin.

The Weija dam blocks the Densu river, and has the main function to safeguard water supply to the city of Accra, though it was originally commissioned to also provide water for irrigation. Considering the size of the reservoir and the non-use of the portion that was once envisaged for irrigation, the amount of fresh water is not likely to be a limiting factor in the near future. The infrastructure related to cleaning water and getting it into the homes may be more limiting. Water quality issues are related to eutrophication and sedimentation. Eutrophication is related to the surrounding residential developments, and as such not so much influenced by the Atewa region. Sedimentation in the reservoir is difficult to address as there are no objective data on it. In the TEEB report it is mentioned that “anecdotal evidence suggests that the reservoir is silting up (a couple of meters by now, since its construction in 1978), which is closely linked to upstream land use” (IUCN-TEEB, 2016; WRC, 2015).

The construction of the Weija Dam has led to the drying up of the Sakumo Lagoon below the dam as water flow into the lagoon is regulated. The reduction of fresh water flow into the lagoon has promoted salt mining in the Densu Delta, an internationally recognized RAMSAR area.

From the TEEB report we learned that the Weija Reservoir has a maximum storage capacity of 133 million m3 (WRC, 2007). Upstream land clearance and the subsequent increased erosion rates can lead to problems with sediment accumulation downstream. The sediments that enter the Weija Reservoir accumulate in the lake and behind the dam walls and decreases storage capacity. Akuffo (2003) stated that the reservoir is silting up at a rate of 2% per year. GWCL estimated that the average depth of the reservoir has been reduced to 3 m, instead of 5 m when the reservoir was constructed (GWCL, 2015). If the high sediment influx continues, the decrease in storage capacity might lead to water supply problems in Accra (directly from IUCN NL et al, 2016). As a result of the these pressures, water is increasingly overflowing the Weija reservoir which spills it's excess water into the delta. This process creates further flooding of coastal neighborhoods in Accra with polluted water.

Figure 3.2
Weija reservoir excess water being spilled into Accra suburbs and the Densu Delta

Source: PBL/J. Meijer

This current land use is affecting the quality and extent of water ecosystems which constitute an important element of SDG 6 on clean water and sanitation and also relates to SDGs 9 and 11 that aim to create, maintain or restore (green/blue) infrastructures supporting cities and human settlements to become inclusive, safe, resilient and sustainable.

In order to achieve progress on those two SDGs, the Densu River Basin is a classic case of an area in need of a basin-wide planning approach involving stakeholder participation, awareness raising, public meetings, capacity building and training, and environmental engineering. It is believed that this approach could lead to the sustainable implementation of effective measures to improve land use and watershed management, protection of riparian buffer zones along the river banks as well as improved management of liquid and solid wastes from the towns and communities within the basin.

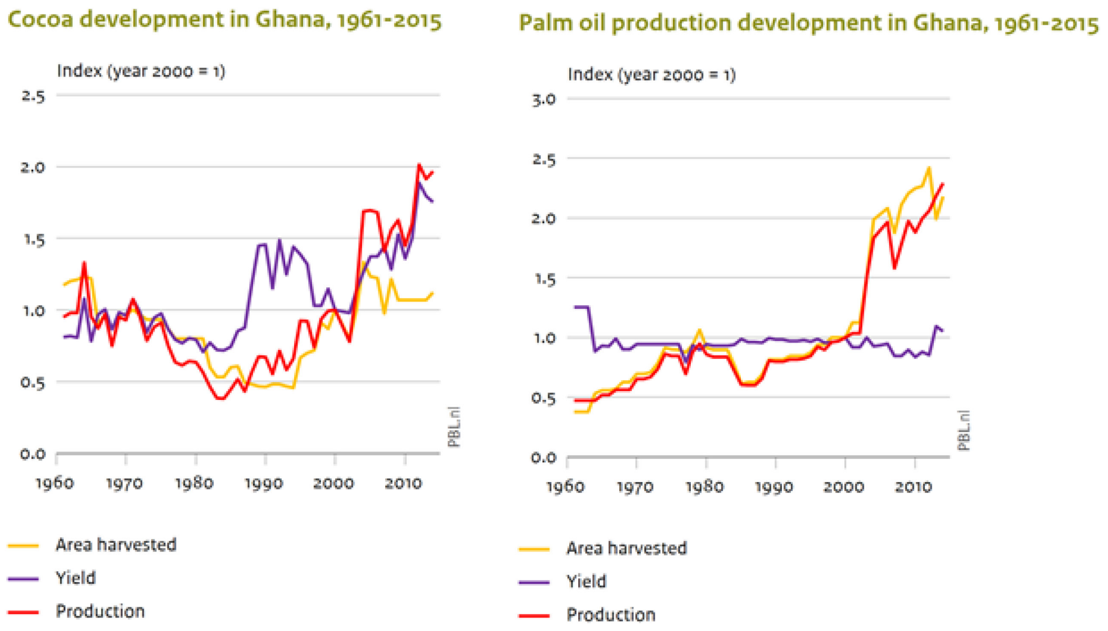
Although under-funded and in need of political empowerment, the WRC is undertaking various activities aimed at preventing further degradation of the basin and to restore the ecological integrity of the basin. These include creating awareness about the challenges, expanding education and collaborating with key stakeholder institutions such as the Environmental Protection Agency, the local Government Assemblies, Fisheries Commission, Forestry Commission, Minerals Commission the Ghana Water Company Limited and the Community Water and Sanitation Agency among others, and performing ecological and water quality monitoring. Water quality within the basin is improving partly due to improving sanitation and changing attitudes. However, much more work need to be done.

A plan to setup a basin-based Integrated Water Resource Management (IWRM) structure for the Densu river basin was created. The decentralized IWRM governance structure, which has evolved through a targeted participatory and consultative process, combines the following partners: a broadly anchored stakeholder-oriented coordinating body, i.e. the Densu Basin Board, respective planning officers of the District Assemblies and WRC's Densu Basin office in Koforidua (WRC, 2015). This multi-stakeholder platform seems to have many similar objectives and involves many of the same stakeholders that A Rocha is working with in its initiatives, hence this potentially seems a very strategic partnership.

Ambition 4: Sustainable cocoa and palm oil production

Ghana is a major global player in cocoa production and is increasingly expanding its oil palm industry. They are both important sectors for the country's overall economic development. See Figure 3.2. Ghana would like to maintain its role as a global player, while ensuring that production and expansion occur in ways that are as sustainable as possible. In the Atewa landscape, this means that they are as sensitive as possible to the ecological needs of the Atewa forest and the hydrology of the Densu Basin.

Figure 3.3



Source: PBL

Currently cocoa production is around 400 kg per hectare often depending on the type of plantation ownership and the length of the rainy seasons. In the past plantations have suffered from the swollen-shoot virus killing many trees, since 2010 the Cocoa Research Institute of Ghana (CRIG) has created a special research program to find solutions to this problem. According to the national ambitions of the COCOBOD the productivity per hectare could even be doubled.

Also regarding oil palm plantations, a major policy goal of the Government of Ghana has been to raise productivity, as stated by a 2011 oil palm masterplan study of the Ministry of Food and Agriculture. Productivity in the oil palm sector has been very low. The world average production of fresh oil palm fruit bunches is 18 MT/ha, 3.6 MT of palm oil and 0.8 MT/ha for palm kernel. However, plantations in in Ghana on average only yield 15 MT/ha of fruit bunches. The potential to increase productivity in Ghana is therefore possible. Unsatisfactory palm nutrition, moisture conservation, planting material, fragmented nature of the industry and agro-management practices are the factors contributing to these sub-optimal yields.

Besides cocoa and palm oil the landscape has a large potential for fruit production. BlueSkies, an 18-year-old agribusiness company located between Nsawam and Accra, is a private sector success story in Ghana and was represented at the stakeholder workshop. The company sends about 20 tons of fresh fruit and juices to European supermarkets every year, accounting for nearly 1 percent of Ghana's exports. The majority of the company's 3,000 workers are under 30 years old, and are residents of the surrounding area. BlueSkies' philosophy values employing people in production rather than using machines.

Figure 3.4
Factory workers producing fresh fruit drinks at BlueSkies, in Nsawam district

Source: World Bank Photo Collection on Flickr, 2015

Progress toward achieving this landscape 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).

Ambition 5: Develop a tourism industry centered on the Atewa forest

Many in the Atewa region are interested in developing the tourism industry. A relatively short distance to Accra and a well-developed road network create the enabling conditions for potential success. The focus of these ideas has been on a combination of ecotourism and coastal cultural tourism. The primary characteristics of this vision are a flagship national park, with a thriving tourism industry that supports the operation of the National Park and brings much needed income to the surrounding communities. Tourism development could contribute to SDG 8 (decent work and economic growth) and 15 (life on land), but this will require great effort to halt deforestation and encroachment of mining and agriculture into protected areas. This will be necessary in order to preserve the wildlife that attracts visitors, and to manage agricultural systems so that they support biodiversity.

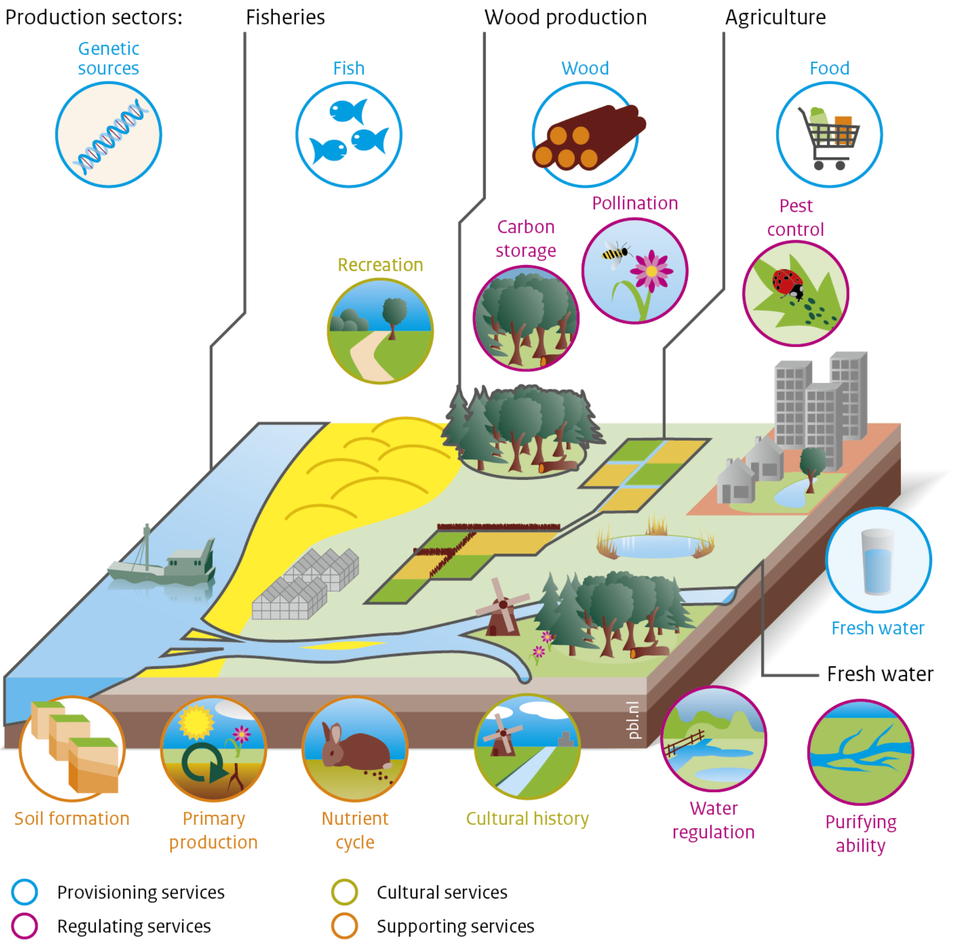
Ambition 6: Partnership development and landscape planning
The successful achievement of the identified ambitions and to protect the values of the Atewa Range will only be possible with the collaboration between diverse actors, which will include conservation organizations such as A Rocha, agribusinesses and mining companies operating near the forest, downstream farmers and industries along with government entities including the Environmental Protection Agency, the Forestry Commission, FORIG, the Ministry of Local Government and Rural Development, the Ministry of Lands and Natural Resources, the Minerals Commission, the Ministry of Food and Agriculture, the District Assemblies, and Traditional Authorities. In particular Atewa-Densu landscape planning should be linked with the integrated planning processes at the district level. The establishment of an Atewa-Densu landscape platform is itself a contribution to both SDG16 (peaceful and inclusive societies and institutions) and SDG17 (partnerships for the Goals).

3.2 Changes in ecosystem services

Achieving the ambitions formulated by the stakeholders in the Atewa-Densu 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.

Figure 3.3

Examples of ecosystem services for production sectors



Source: PBL

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 3.5

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 3.2 illustrates how the landscape ambitions map onto achievement of the SDGs.

Table 3.2
SDGs addressed through the Atewa-Densu 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
Improve food security and livelihoods	■	■	■	■	■	■		■	■								
Conservation of the forest ecosystem and protect biodiversity		■		■		■							■		■		
Sustainable management of water resources and supply						■			■		■						
Sustainable cocoa and palm oil production	■	■				■		■					■		■		
Develop a tourism industry centered on the Atewa forest	■							■							■		
Partnership development and landscape planning																■	■

The SDG framework is seen as an integrated and inseparable framework for sustainable development. For example, there are powerful interactions between **agriculture, food security, water, terrestrial biodiversity and human settlements (SDGs 2, 6, 15, and 11)**. 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 result 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 and on water quality and quantity in urban areas.

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. Limiting impacts from more climate smart agricultural and land use practices play an important role in climate adaptation and mitigation.

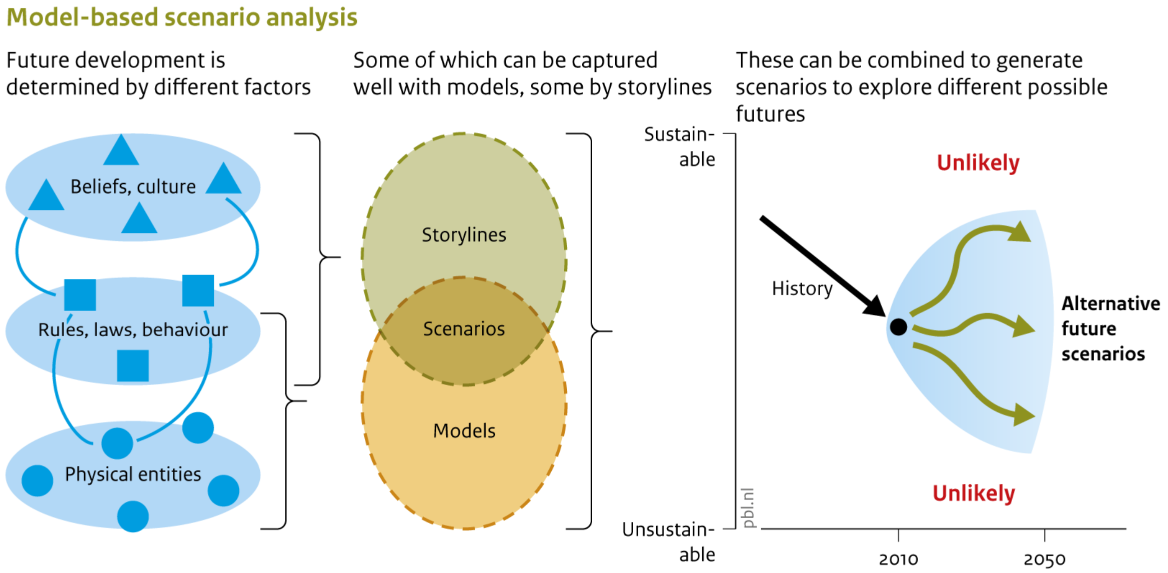
These interactions are a strong rationale for integrated landscape planning, action and monitoring. Reflecting these relationships is a key feature of the scenario modelling approach, by showing how interventions in one part of the landscape will impact ecosystem services, and how those changes in turn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

4 Exploring scenarios to 2030

This project explored different plausible futures for the Atewa-Densu landscape by combining stakeholder storylines with models to generate 'scenarios' (Figure 4.1). 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.

Building on the scenarios from the TEEB (IUCN, 2016) report, this study compares the results of scenarios reflecting a 'Business-as-Usual' approach with a large scale mining oriented 'Taking All Resources' scenario and a 'Living Landscape' scenario inspired by strategies of integrated landscape management.

Figure 4.1



Bron: PBL

4.1 A Business as Usual (BAU) scenario

Based on information from the TEEB report and additional literature, government plans, historical and current data, a benchmark scenario for the year 2030 has been created. This so-called Business as Usual (BAU) scenario assumes that current pressures in the landscape will persist and the current policy framework will continue.
The core assumptions of the BAU by 2030, which builds on TEEB scenario 1 are:

- Population increases by 3 million people (GSS, WRC) with consequential expansion of urban areas.

- Agricultural food production expansion follows trend in population change with a 45% increase. The focus is on expansion of current low productive mixed crop livestock systems at the expense of natural landcover. No dietary changes are assumed.

- Cocoa and palm oil follow ambitions are taken from national plans (MOFA and COCOBOD). The productivity follows historical production trends and future demands will be met by expanding the area under cultivation

- Small scale mining will follow TEEB projections with small increases in Atewa Forest Reserve and buffer zone.

- No new land regulation or spatial planning policies introduced or implemented.

4.2 A Taking All Resources (TAR) scenario

The 'Taking All of the Resources' (TAR) scenario builds on TEEB scenario 4 and was created as a 'worst case' for resource extraction within the landscape trends towards 2030. It includes many of the assumptions as the Business as Usual scenario, with the primary difference being a much stronger increase in mining (for either gold and bauxite).

In this scenario, 50% the forest in the Atewa forest reserve and 49% of the forest in the buffer zone will be cleared as a consequence of increased mining and demand for wood. The remaining closed forest will be degraded and would become open forest.

4.3 A Living Landscape scenario

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, et al 2013)

1) Shared or agreed management objectives that encompass multiple benefits (the full range of goods and services needed) from the landscape
2) Field, farm and forest practices are designed to contribute to multiple objectives, including human well-being, food and fiber production, climate change mitigation, and conservation of biodiversity and ecosystem services
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 for dialogue, planning, negotiating and monitoring
decisions are in place
5) Markets and public policies are shaped to achieve the diverse set of landscape objectives.

The Living Landscape scenario, building on the TEEB scenario 3, has been designed with the aim to meet the Atewa landscape stakeholders' landscape ambitions for sustainable development, including synergies between economic and agricultural growth, environmental protection and local livelihoods.
The ILM scenario assumes the following specific landscape interventions to achieve inclusive green growth:

- More attention to land use regulation policies to promote synergies in social and economic development and minimize environmental risks

- Increasing productivity and environmental performance of existing cocoa and palm oil plantations, apply certification (RSPO) standards and limit expansion of new plantations in the trade-off areas
- Respect riparian zones, reforest them with a mixture of trees/agroforestry, also in regions that are prone to flooding
- Conserve upland forests for sustainable water provisioning and climate regulation; respect slopes and maintain or reforest them with mixture of trees/agroforestry, also to prevent soil erosion
- Maintain protected areas (core and buffer) to safeguard global biodiversity and potential biological corridors, also in line with contours of tourism development.

4.4 Overview of assumptions

Tables 4.1 and 4.2 summarize the assumptions made in the 3 scenarios, based on information from the TEEB report, various policy documents, literature and reflections of the stakeholder during the workshop. 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 3 (related to suitability, distance to markets, etc.) and interactions among variables.

Table 4.1
Scenario assumptions for different areas in the Atewa-Densu landscape

	Business as usual	Taking all resources	Living landscape
Landscape zone			
Atewa Range	Forest reserve status remains, but encroachment by illegal logging and hunting	50% of the forest cleared for large scale mining, remaining forest degraded	Status upgraded to national park, effective management protects the park from illegal activities. Tourism is developed
Atewa buffer	Further expansion of settlements, agriculture and mining weaken the function of the bufferzone	Open for gold and bauxite mining (49% of area used and cleared of vegetation)	All mining activities are abandoned and the areas are restored, sustainable agroforestry increases and tourism is developed.
Around Atewa and Mid-stream Densu basin	Increase in mixed crop-livestock systems, in line with population growth. Focus on expansion of area under cultivation and no increase in productivity compared to current levels.	as BAU	Increasing agricultural production, but with implementation of IWRM and riperian zone policies, focus on on mixed systems like agroforestry and timber. Taking future suitability for cocoa and palm oil areas into account
Down-stream and Accra	Urban expansion in Densu Delta, remaining wetlands under pressure	as BAU	Ambition to protect and restore Densu Delta RAMSAR area and the border of Weija reservoir

Each of these interventions was translated in the landscape model into specific, spatially-explicit activities, rules and conditions, in a trajectory over time between 2015 and 2030. The model enabled assessment of the outcomes that include the interaction effects among land and resource users and uses. By building the BAU, TAR and Living Landscape scenarios, it was possible to compare results from both to the goals laid out in the SDGs. The results are summarized in section 5.

Table 4.2
Scenario assumptions for different sectors and population

	Business as usual	Taking all resources	Living landscape
Assumptions			
Population	45% growth in 2030 compared to 2015, based on Eastern and GA region 2010-2016 GhanaStats data. Equal to 2.5% annual growth. This drives urban expansion	Same as BAU	Same as BAU, but ambition to convert urban cells in less suitable areas (in PA, riperian zones, Densu Delta)
Food production	45% growth of area used for foodproduction, following population and household increase. Priority for more crop-livestock production systems, with only sparse tree coverage. Due to pollution of sediments a 75% cropfailure applied in riparian zones in the landscape	Same as BAU, due to extreme pollution of sediments a 100% cropfailure is applied in riparian zones in the whole landscape	45% growth of production, but priority for multi-functional mosaic crop-livestock production systems with >15% and >40% treecover. Improved practices and investments improve productivitiy of crop production by 2% annually.
Cocoa	Annual increase of 2.5% of production. Productivity growth based on historical FAO Ghana national timeseries of 14% in 2015-2030 period	Production in Atewa Range lost, rest landscape same as BAU	Annual increase of 2.5% of production. Productivity increase based on literature and COCOBOD statistics for the eastern region: potential is 3 times the increase of the Trend productivity in 2030 (43%)
Palm oil	53% growth of production from 2015-2030 period based on MASDAR projections up to 2025. Current productivity based on statistics and literature (15MT/ha). Increase of productivity based on literature, other production areas and technical experts: 20MT/ha.	Production in Atewa Range lost, rest landscape same as BAU	Similar 53% increase of production. Productivity increase of 30% compared to Trend productivity in 2030: 26MT/ha, based on field experiences in other production areas (i.e. Honduras). Also complying to RSPO guidelines on slopes and riparian zones
Mining	Small increase of mining (2%) in the forest reserve and larger increase of mining in the buffer zone (12%)	Open for gold and bauxite mining (50% of both the forest reserve and the bufferzone are cleared of forest)	No mining activities within national park and forest reserve, outside mining still exists, but practices improve and restoration enforced.

For the all scenarios the polluting impacts of mining and the consequences of deforestation on sedimentation are affecting water quality and quantity and erosion control. The changes in these indicators are used to create tentative crop failure indications that affect productivity of agricultural production on the floodplains. The crop failure indications from the TEEB report were used as a simple validation for this method (IUCN NL et al, 2016)

4.5 Spatial operationalization of the interventions

In order 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 that can guide, promote or restrict certain activities or land uses under specific scenarios. These are the following:

- A spatial layer containing the riparian zones, defined by the WRC riparian zone policy report, based on river network data from CERSGIS.
- A spatial layer containing the core zones of the latest version of the protected areas in the landscape, derived from the TEEB report, Forestry Commission and RAMSAR website
- A spatial layer containing the buffer zone around the Atewa forest reserve, derived from the TEEB report and defined as the area at or above 220m in altitude.
- As spatial layer containing the areas with more than 20 degrees slope, as derived from the global SRTM digital elevation model (see Annex 8.2)

Figure 4.2
Workshop participants discussing the landscape ambitions and scenarios

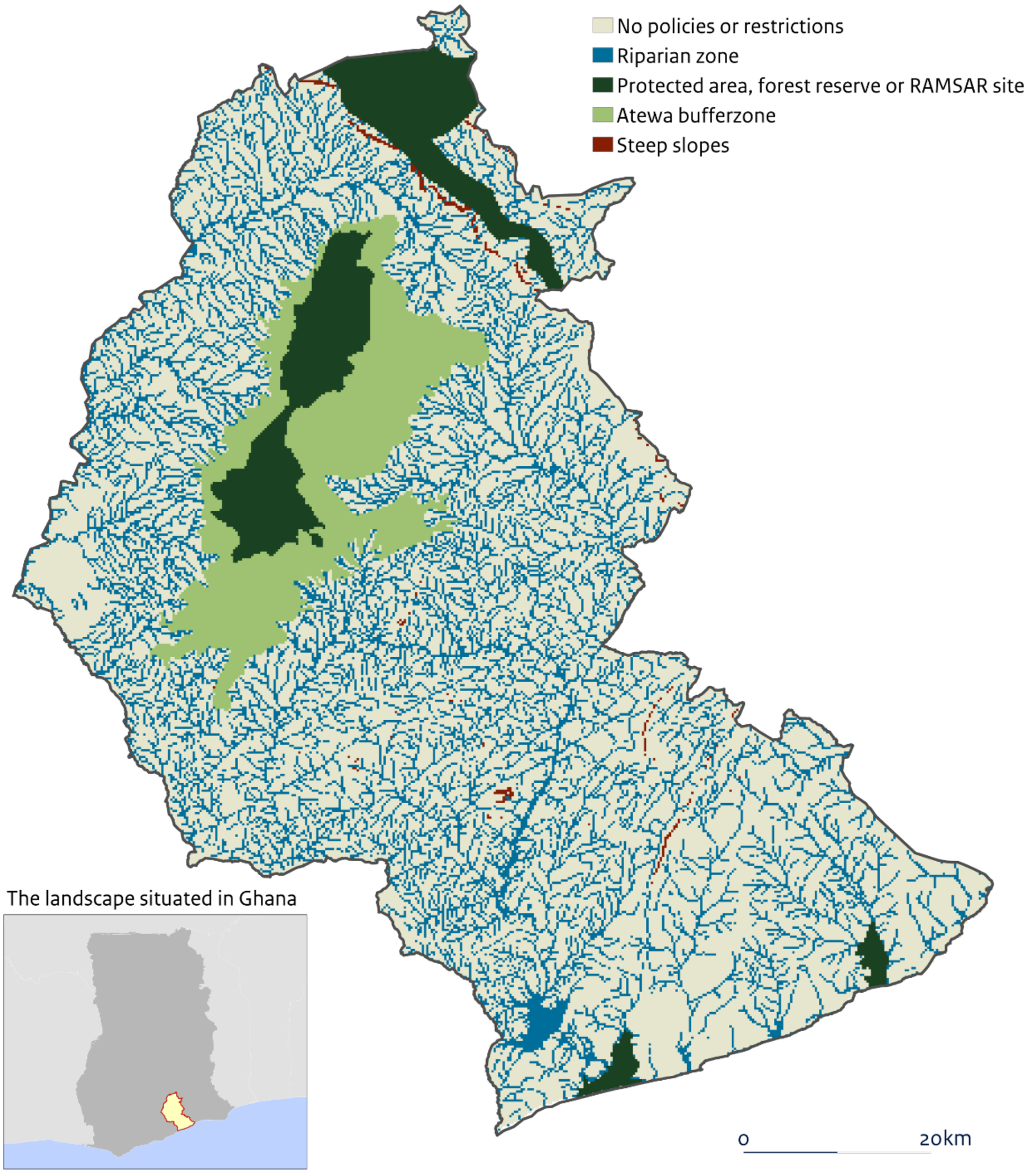
Source: A Rocha Ghana

Figure 4.3 displays an overlay of the spatial policies and the respective zone layers. In total 2,300 km2 is covered by the these policy layers, similar to 38% of the landscape area.

The spatial policies and restrictions were specifically used in the CluMondo landsystems simulation which is described in Chapter 2. For the BAU and TAR scenarios no policies or restrictions were applied to simulate a low level of effectiveness on preventing conversion of natural areas. This means the 2030 land allocation for those scenarios is based on the land use suitability regression models developed by CluMondo. For the Living Landscape 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 4.2 information is provided on how the different land systems and the policies and restrictions were combined under the Living landscape scenario.

Figure 4.3

Spatial policies and zones in the landscape



Source: PBL

These policies and restrictions have also helped to assess the current activities in these areas. Under the Living Landscape 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.

Table 4.2
Policies applied on land system change under the Living Landscape scenario

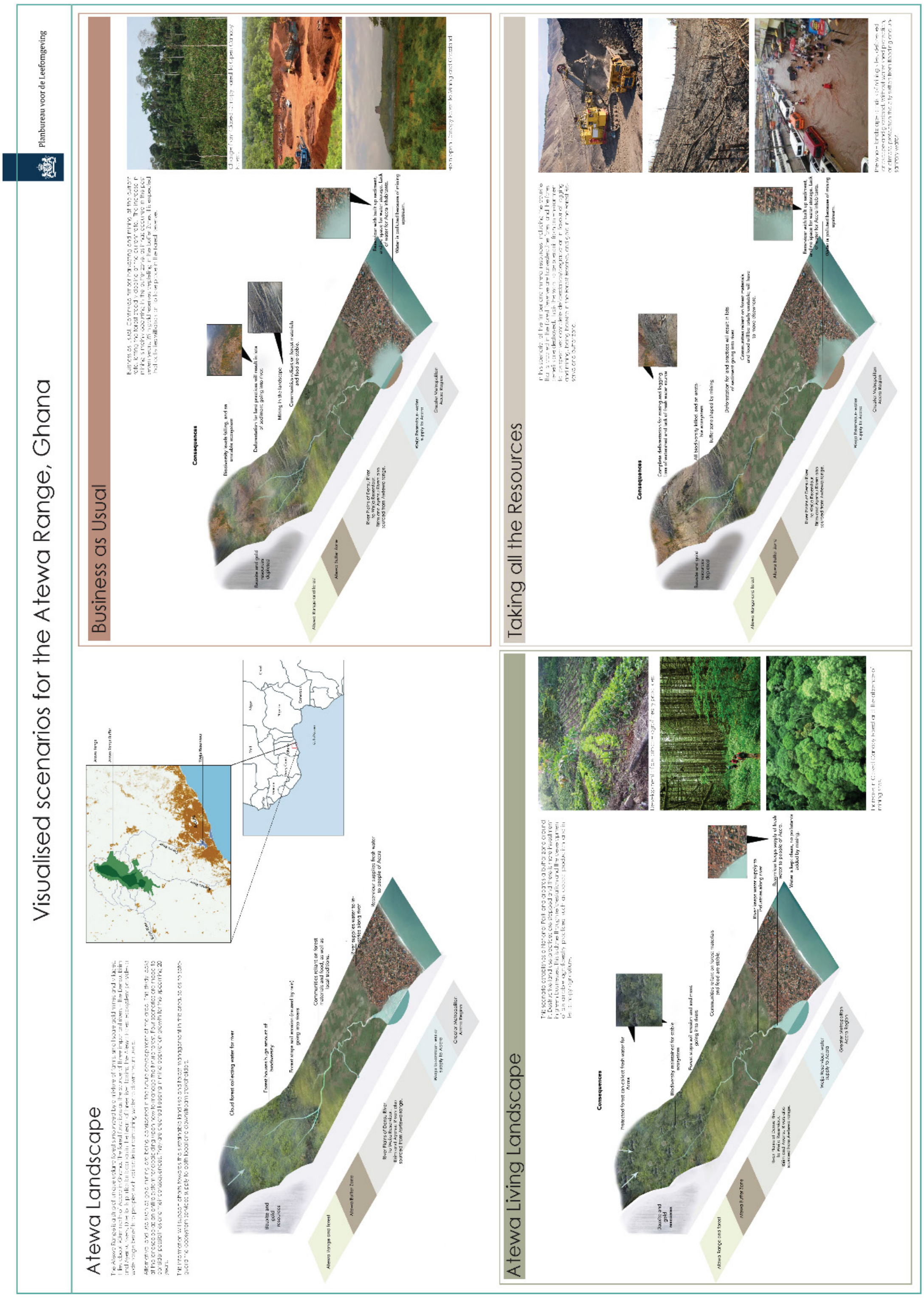
Land system	Riparian zone	Protected area	Bufferzone	Steep slopes
Urban/settlements	0	0	0	0
Mixed crop-livestock	0	0	0	0
Mixed crop-livestock with < 15% forest	0	0	0	0
Mixed agroforestry	1	0	1	1
Cocoa agroforestry	1	0	1	1
Palm oil plantations	0	0	2	0
Mining	0	0	0	0

Info: value 0 means the land system is allowed to exist (depending on the current situation), but 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.

4.6 Visualizing landscape scenarios

To support the understanding of the scenario storylines by the stakeholders and the potential effects of the various scenarios in the landscape, PBL organized an internship with the TU Delft University in the Netherlands. The goal was to create visualizations that would make stakeholders aware of the consequences of their choices, show different solutions for the landscape, and help to integrate the agendas of the different stakeholders.
Figure 4.4 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 and to check the accuracy of protected area boundaries, and where additional protected areas are needed.

Figure 4.4
Visualised landscape scenarios used at the stakeholder workshop



Source: PBL

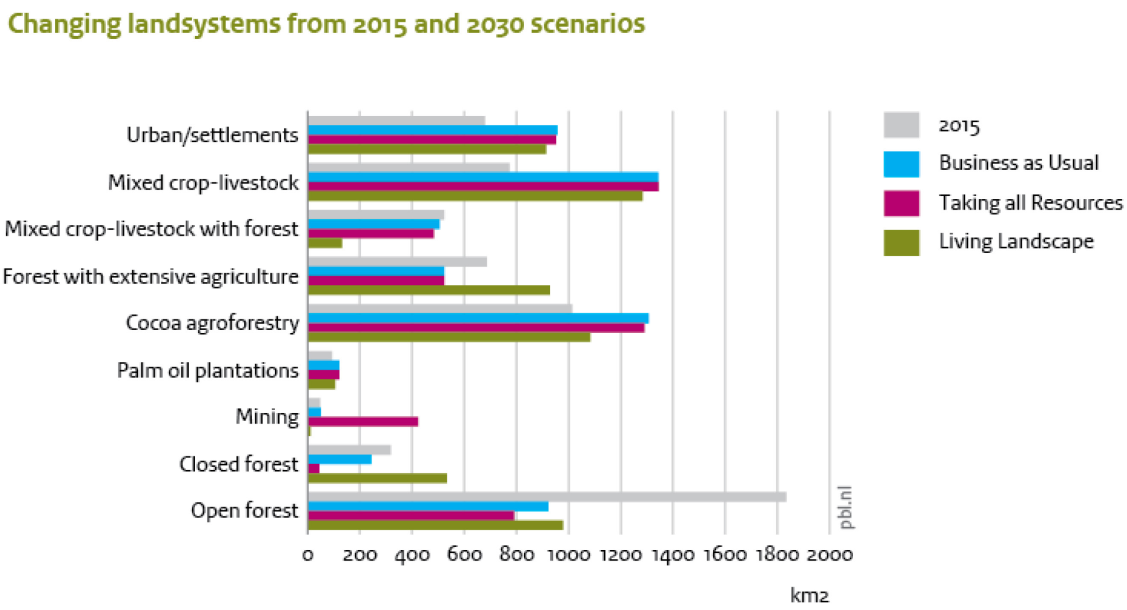
5 Results from the scenario analysis

This section presents the results of the spatial scenario modelling exercise. The outcomes of the Business as Usual Trend (BAU), Taking All Resources (TAR) and Living Landscape scenarios to 2030 are compared with to the current situation and also with each other. First a number of key projected changes in the landscape are presented, followed by an assessment of the impacts on the identified landscape ambitions and related SDGs, and an overall comparison of scenario outcomes.

5.1 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.

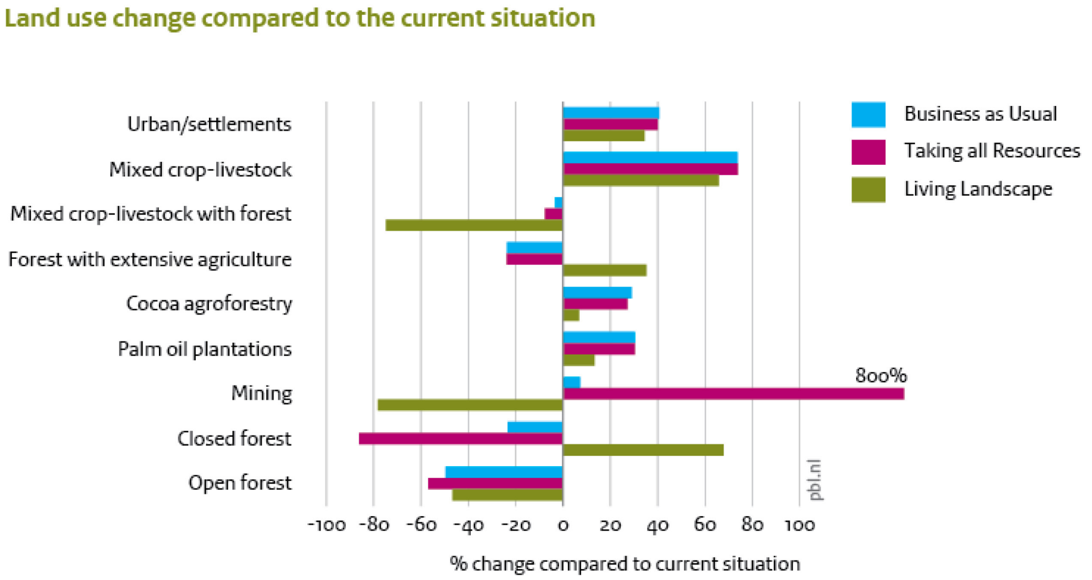
Figure 5.1



Source: PBL

Compared to the current situation the scenarios all show considerable changes (Figure 5.1 and 5.2) at the landscape level. The maps in Figure 5.4 show the scenario outcomes for land use spatially, on which also many other results are based. Each element is described below.

Figure 5.2

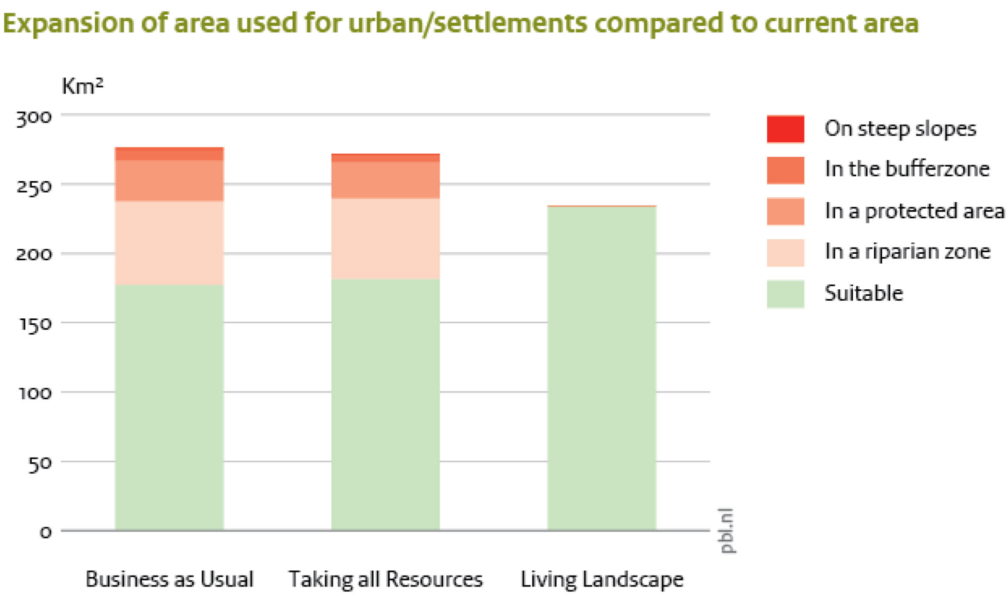


Source: PBL

Urban settlements

Currently 67% of the population is living in urban settlements, as defined by combining the land use maps from the Forestry Commission with population statistics from the WRC. This areas is covering 680 km2 (WRC, 2015; FC, 2015). By the year 2030 there will be an additional 3 million people (a 2.5% annual growth rate) living in the landscape. According to WRC projections up to the year 2020 70% of this growth will be in urban areas.

Figure 5.3



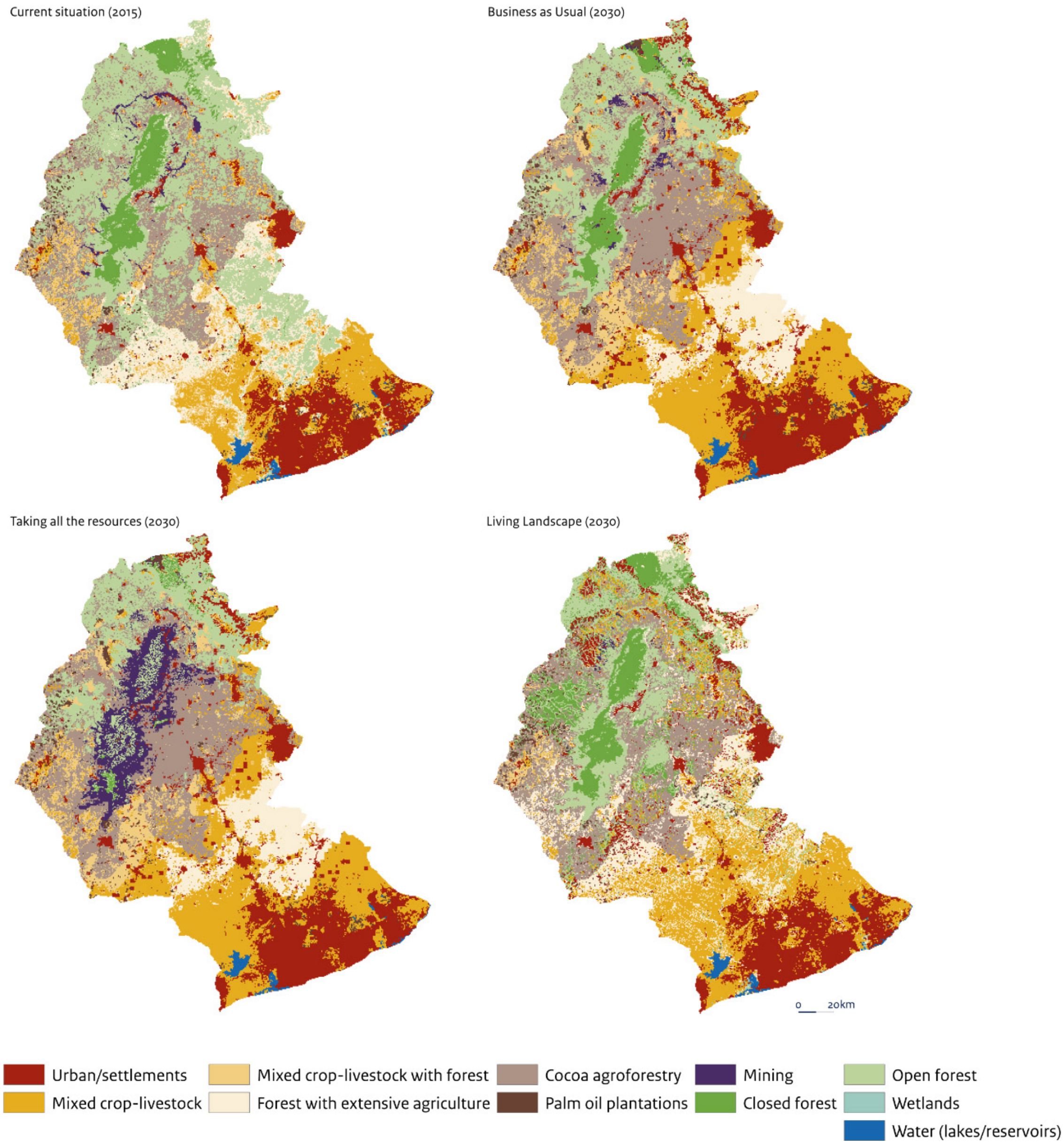
Source: PBL

Following the scenario outcomes this will result in an 41% increase in urban settlement area under BAU scenario. Under the TAR and Living Landscape scenarios this growth is just slightly lower with 40% and 37% respectively, due to higher competition for suitable land

and with more people living in and attracted by agricultural production areas. Also, under the Living Landscape scenario strict spatial expansion policies are applied for urban expansion, making it more challenging to fulfil this demand. Figure 5.3 shows that, in contrary to the Living Landscape scenario, under the BAU and TAR scenarios a large part of expansion is projected to take place in restricted zones, thereby not contributing to the ambitions of the landscape and could cause trade-offs to for instance water quality and biodiversity.

Figure 5.4

Land use: current situation and scenario outcomes



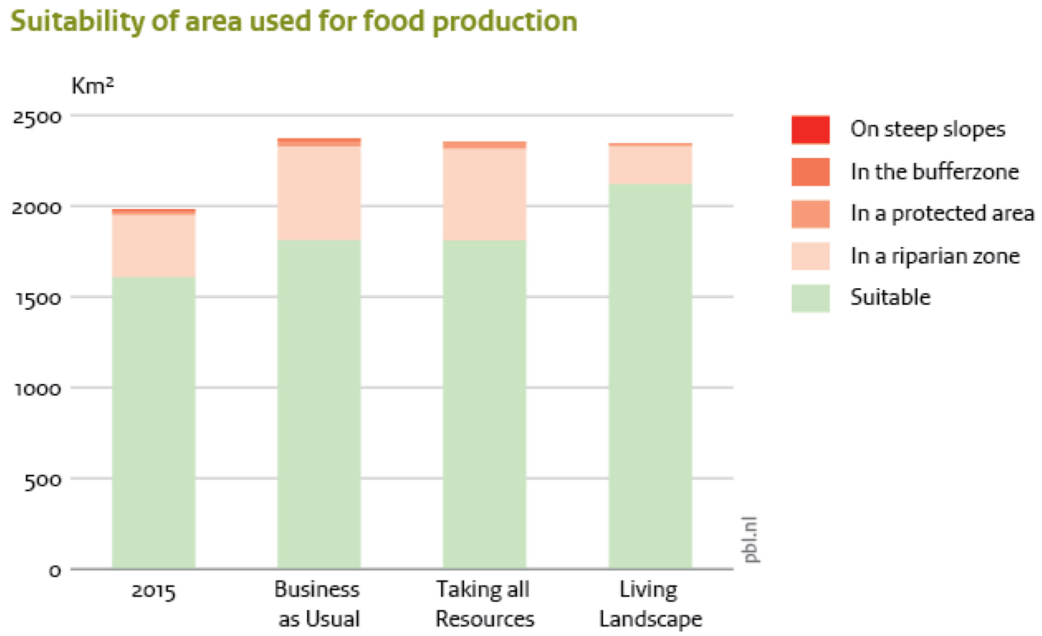
Source: PBL

Food crop area

As can be derived from Figures 5.1 and 5.2, in the period 2015-2030 the total area used for food production is expected to increase from 1,980 km2 to around 2,350 km2 under all scenarios, in response to increased demand from a growing population. However, under the BAU scenario and the TAR scenario, this happens mainly by converting forest areas to mixed crop and livestock systems, where none or only sparse tree coverage (15%) remains. Under

the Living Landscape scenario productivity of existing mixed crop and livestock practices is increased (2% annually), thereby producing more on the same amount of land. The slightly contradictory decrease of mixed crop-livestock with forest (15%) under the Living Landscape scenario, actually signals the trend that in many of the crop livestock areas that still had about 15% tree cover left, reforestation takes place, causing these areas to shift to the agroforestry mosaic class with over 40% tree cover. This specifically occurs in many of the specified policy zones, like the Atewa forest reserve and buffer zone, riparian flood plains, steeper slopes. This has to potential to create both socioeconomic (increased and diversified agriculture income) and environmental benefits (improved carbon storage, water quality and soil protection).
As shown in Figure 5.5 about 18% of the area currently used for more intensive food production (with absent or low tree coverage) is in riparian zones near rivers, in protected areas, in the buffer zone, and on slopes. Under the BAU and TAR scenarios this percentage increases up to 23%. Under the Living Landscape scenario this decreases to just 9% by applying various spatial policies, reforestation and combined with a higher productivity in existing agricultural lands. Therefore expansion takes place on more suitable areas and current unsuitable production practices are preferably changed (i.e. by reforestation) to more supporting and suitable areas and land systems.

Figure 5.5



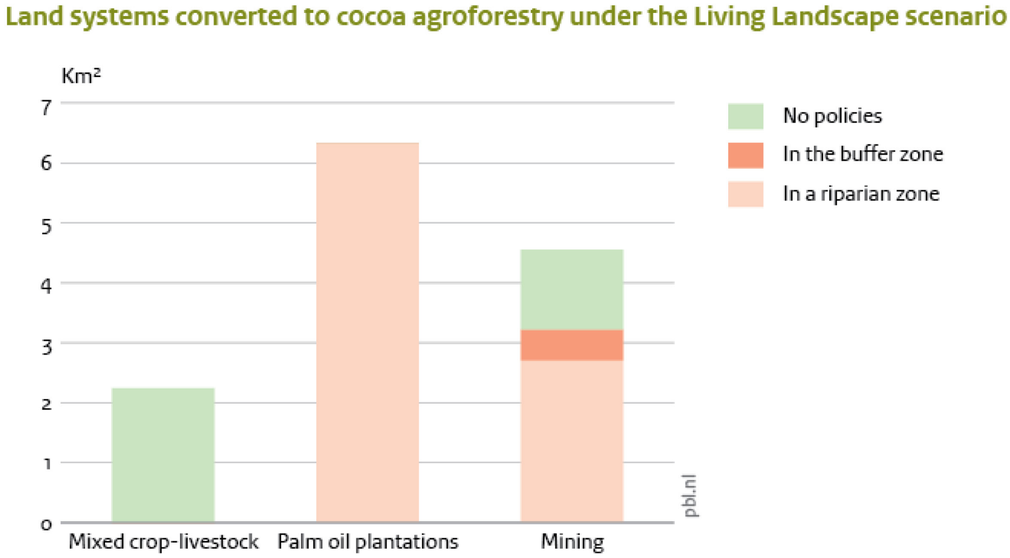
Source: PBL

Cocoa agroforestry

ased on our land systems map the area used for non-shaded cocoa agroforestry is estimated at just over 1,000 km2 for the current situation. We have used this area in our scenarios, but due to the spatial inaccuracy and outdated coverage (year 2000) of the cocoa extent dataset used in the land systems classification, it could be that also parts of the land system "Forest with extensive crop-livestock" contain also some cocoa plantations mixed with trees for timber and shading and crop-livestock activities.

Under the BAU and TAR scenarios the area under cultivation is projected to expand by 29 and 27% respectively. Under the Living Landscape scenario, cacao agroforestry is an important element in making the landscape more sustainable and resilient, both in environmental as economic terms. Therefore cacao agroforestry systems are promoted but the main focus is on improving quality and productivity per hectare (see Table 4.2). This means that with the same ambition to increase production of cocoa by 45%, the area under cultivation only needs to expand by 6%, especially by introducing shaded cocoa plantations and by replacing other activities in areas were these are causing trade-offs to the soils, water and biodiversity. This conversion is also seen in Figure 5.6, were oil palm plantations, mixed crop-livestock systems and mining in restricted zones are converted to shaded tree crops agroforestry systems including cocoa.

Figure 5.6



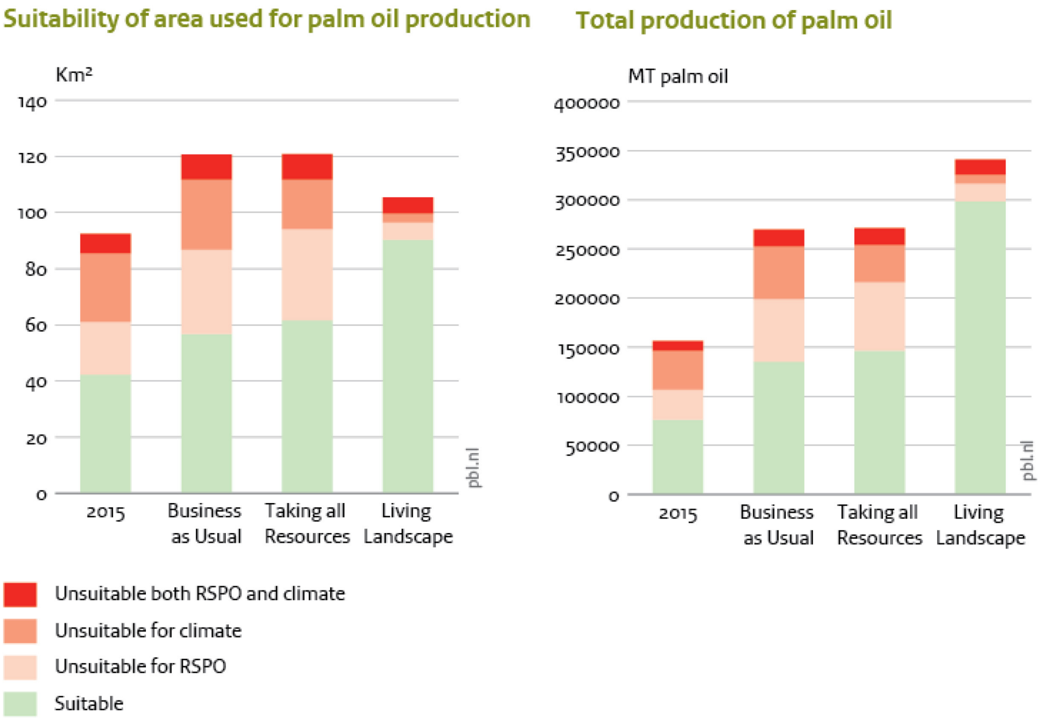
Source: PBL

Oil palm plantations

Currently the area used for palm oil cultivation in the landscape is relatively small (less than 2%), but the production of palm oil is potentially an important driver of change in the landscape, both in terms of land use and cover as well as for economic development. Based on ambitions of the Ministry of Food and Agriculture the production is assumed to increase by 50% which is applied to all scenarios. Driven by varying levels of investments in increasing productivity of palm oil produced per hectare (see Table 4.2) the spatial outcomes in terms of area under cultivation differs considerable among the scenarios.

Under the BAU scenario and TAR scenario, palm oil plantations are projected to expand mainly into natural areas and are either conflicting with RSPO guidelines (i.e. in protected areas, riparian zones or on steep slopes) or into areas that are becoming less or even unsuitable due to the effects of climate change (as shown in Figure 5.7).
Under the Living Landscape scenario more investments in productivity will lead to an increase of production of 30% per hectare, which is gradually applied over the next 15 years, also simulating the proactive replacement of currently ageing and traditional low productive trees by new higher yielding tree varieties that start producing within 18 months. Taking into account basic assumptions on productivity loss due to climate change and sub-optimal production locations (Oettli et al, 2018; Russel et al, 2017; Woittiez et al, 2017; Zainal et al, 2012) this will result in a 118% increase of the production of palm oil under the Living Landscape scenario, by more intensification on current plantation areas and less expansion in unsuitable areas, as indicated by the spatial policies. Also current plantations in unsuitable areas, mainly according to RSPO guidelines, are gradually abandoned and converted to another, more favourable, land system for that location (Figure 5.7).

Figure 5.7



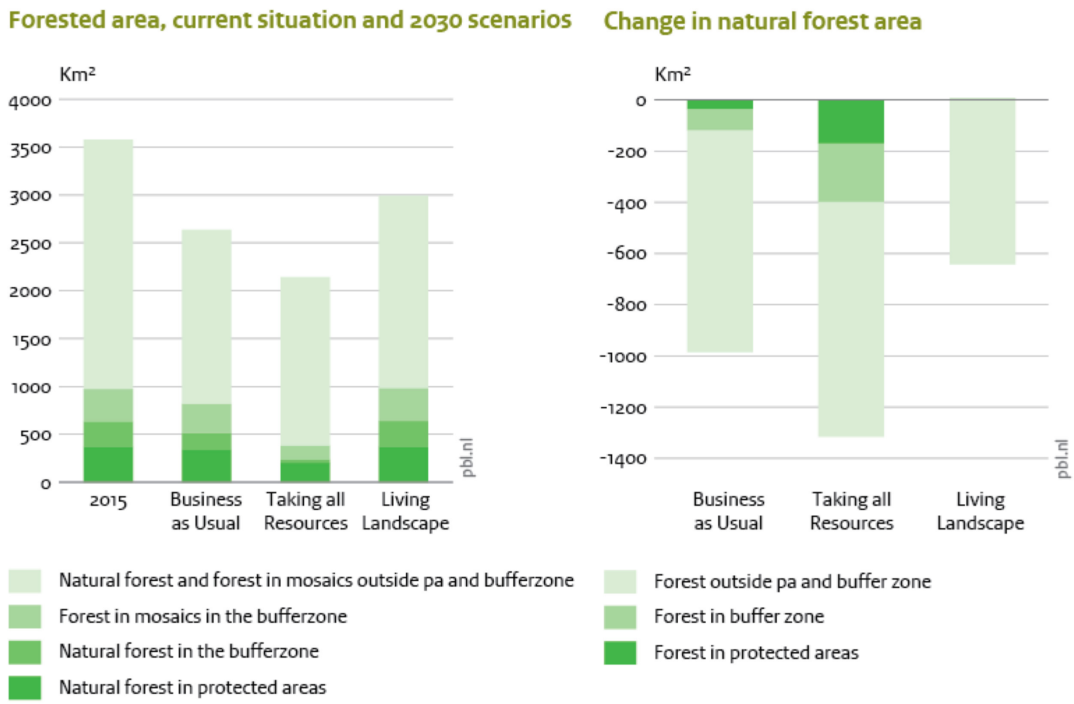
Source: PBL

Area under forest cover

The forested area in the landscape is defined as the area covered by natural forest (undisturbed closed and open forest) plus the tree cover contained in the mosaic land system classes with mixed crop-livestock and tree cash crop agroforestry systems, like cocoa. In the analysis we distinguished between forest in protected areas, the buffer zone and forest outside these areas.

Most deforestation, especially concerning natural and pristine undisturbed forest in the Atewa protected reserve and the buffer zone, is expected to take place under the TAR scenario (Figure 5.8), mainly due to large expansion of mining and the lack of efficient protection of protected areas. Under the Living Landscape scenario protected areas are assumed to be effectively managed. The loss of natural forest under this scenario is mainly caused by the expansion of agroforestry activities into open forest areas in the Densu basin between the Atewa Range and the northern outskirts of Accra. Reforestation, for instance in the form of mixed cacao or citrus or trees for timber, also takes place under the Living Landscape scenario hence just the relatively smaller decrease of the total forested area.

Figure 5.8

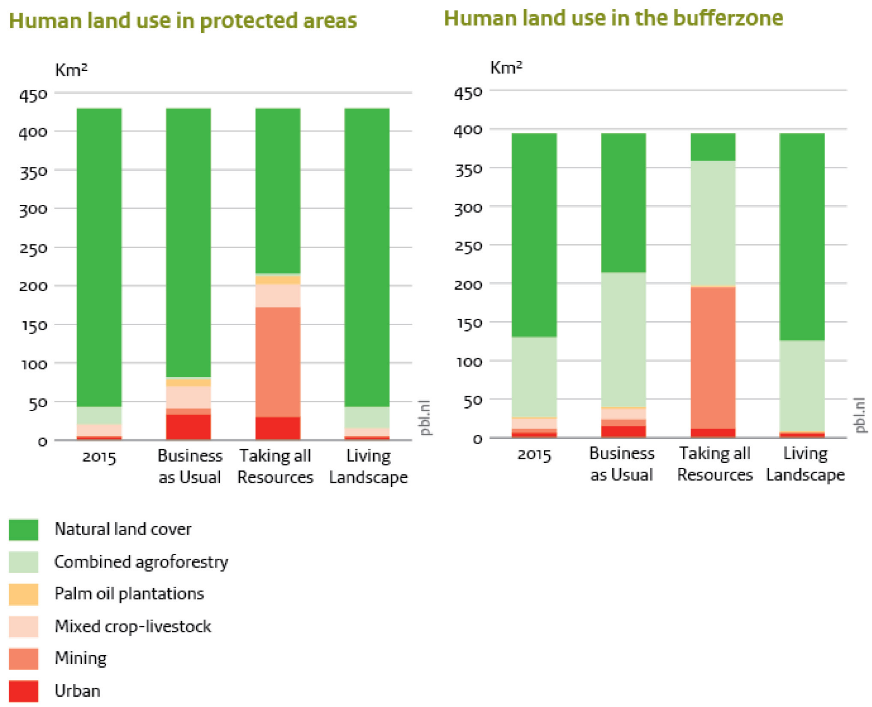


Source: PBL

Protected Areas and the buffer zone

For the scenario analysis there were no additional areas added to the most recent delineated protected areas dataset. From the stakeholder workshop there were mainly suggestions on conserving and improving the supporting role of the Atewa reserve by upgrading its status to a national park.

Figure 5.9



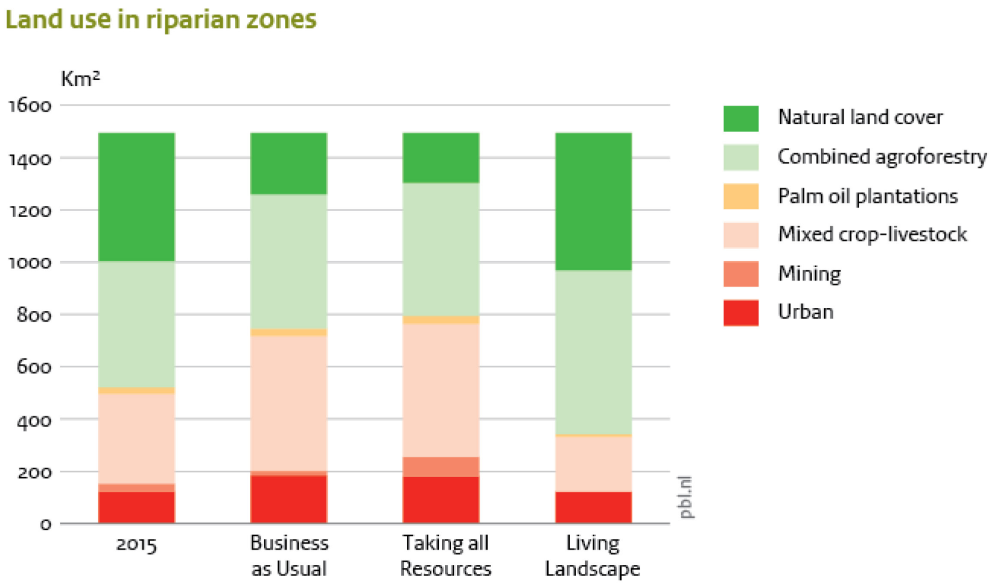
Source: PBL

As shown in Figure 5.9, the applied spatial policies under the Living Landscape scenario are clearly able to limit the expansion of more intensive human land use activities and promote the income generating agroforestry activities with a high level of tree cover that support the function of the buffer zone. This prevents further degradation and encroachment of the protected areas, as compared to more intensive agricultural and mining activities, like projected to take place under the BAU and, even more, the TAR scenario. Also, as was shown in Figure 5.1, the remaining natural land cover varies over the scenarios, with a much higher share of closed forest under the Living Landscape scenario.

Land use in riparian zones

In 2015, more than 37% of the area classified as riparian zones was used for more intensive human land use activities that are assumed to have a negative effect on water quality and soil protection. Without any spatial policies or restrictions this is expected to increase under both the BAU and TAR scenarios to 50 and even 53% respectively, mainly due to the expansion of urban areas, mixed crop-livestock agriculture and mining activities. The Living Landscape scenario is challenged to change as many of these practices as possible and promote the large scale shift towards agroforestry practices in this zone, potentially requiring investments in various types of commercially interesting and ecologically sound tree crops.

Figure 5.10



Source: PBL

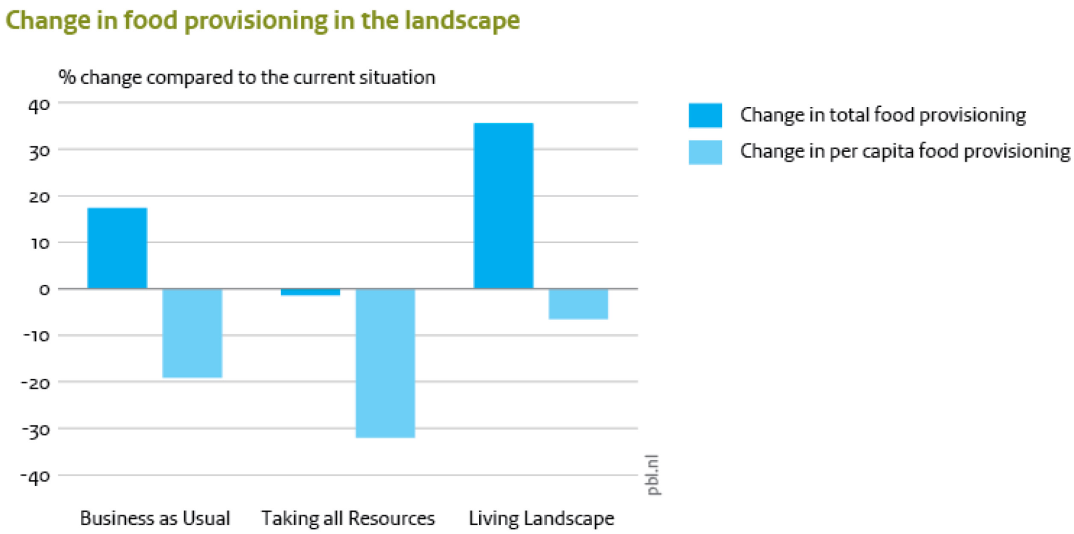
5.2 Impacts on landscape ambitions

The model projects that the land use changes described have significant socioeconomic and ecological impacts by 2030, with significant differences between the BAU, TAR and Living Landscape scenarios in achieving the landscape ambitions of the Atewa-Densu landscape. Each is summarized in turn below, also recapturing some of the outcomes described in section 5.1.

Ambition 1: Improve food security and livelihoods

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 all scenarios, with the Living Landscape scenario being able to absorb most of the population increase. Assuming that, also nowadays, a certain share of the food consumed in the landscape is imported (from other regions in Ghana or from abroad) and considering the difference between for instance Accra residents and rural households around Atewa 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. Based on results reported in section 5.1 on increased production of cocoa and palm oil and also the potential value of protecting the Atewa forest for developing tourism, it appears the Living Landscape scenario provides the most potential in actually achieving this. According to the TEEB report the benefits from the large scale mining, as explored under the TAR scenario in this report, are highly unlikely to contribute to the welfare of the local communities.

Figure 5.11



Source: PBL

Ambition 2: Conservation of the forest ecosystem and protect biodiversity

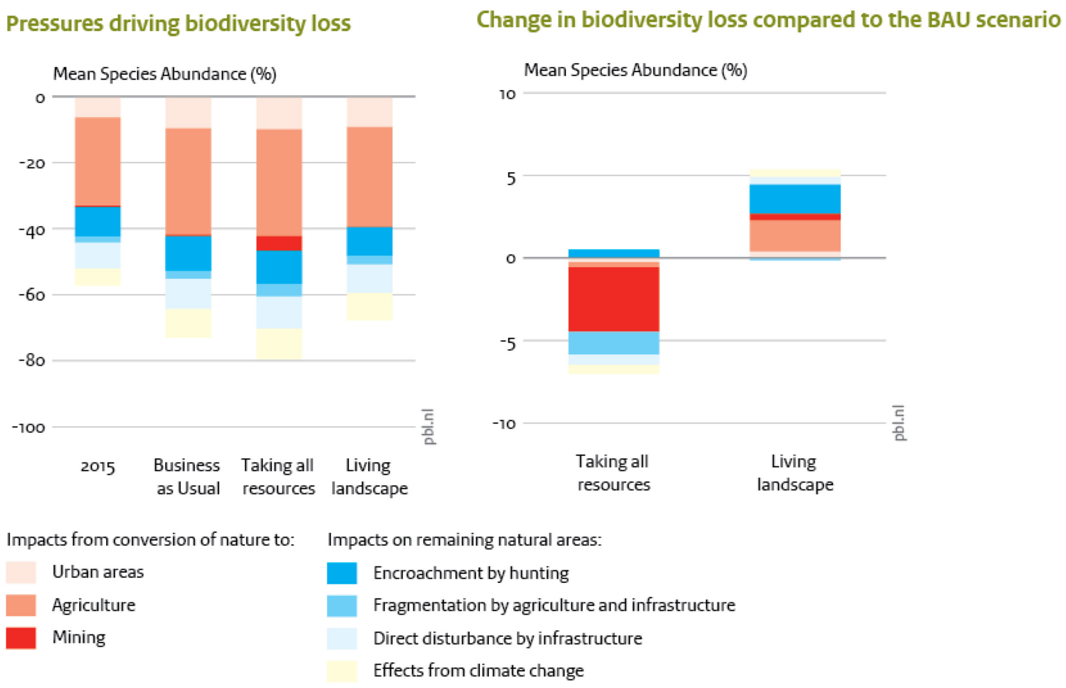
As shown in section 5.1 the scenarios have different outcomes with respect to changes in natural forest, forested areas in mosaics and the encroachment of human activities in protected areas and the buffer zone. Figure 5.12 shows the resulting impacts on biodiversity, expressed as the loss in mean species abundance.

When looking at the whole landscape, none of the scenarios is able to completely halt the loss of biodiversity by 2030, which is given the challenges of increasing population and agricultural land use a serious challenge. Most biodiversity loss is caused by the conversion of natural areas now used for agricultural production and encroachment by hunting. Nevertheless, the Living Landscape scenario is able decrease the rate of loss and even able to prevent a third of the loss in biodiversity when compared to the BAU scenario. To illustrate the order of magnitude of change, a 1% loss of MSA for the whole landscape, would be equal to converting a 60 km2 pristine and undisturbed closed forest to an urban settlement.

The apparent prevented loss on encroachment by hunting under the TAR scenario, when compared to the BAU scenario, is rather a sign that there is even less nature left where hunting could actually take place.

Figure 5.12 covers the loss of biodiversity in the whole Atewa-Densu landscape, including the capital of Accra. To analyse how the scenarios perform in the rich biodiversity area of the Atewa Range we have performed an additional analysis. These results are shown in Figure 5.13.

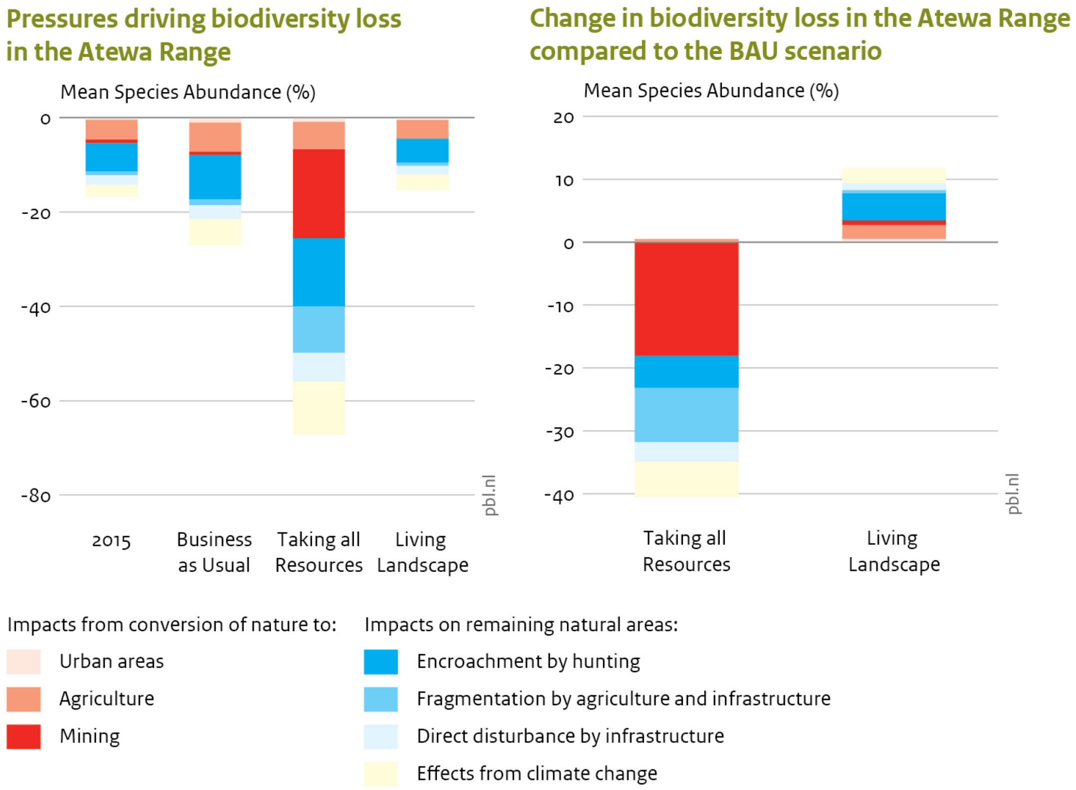
Figure 5.12



Source: PBL

When zooming in on the Atewa Range, Figure 5.13 shows that only the Living Landscape scenario is able to protect and even slightly restore the high level of biodiversity that characterizes this global significant biodiversity area. Under the BAU scenario conversion and disturbance of natural areas continues and under the TAR scenario an additional 50% of MSA is lost, compared to the current situation.

Figure 5.13

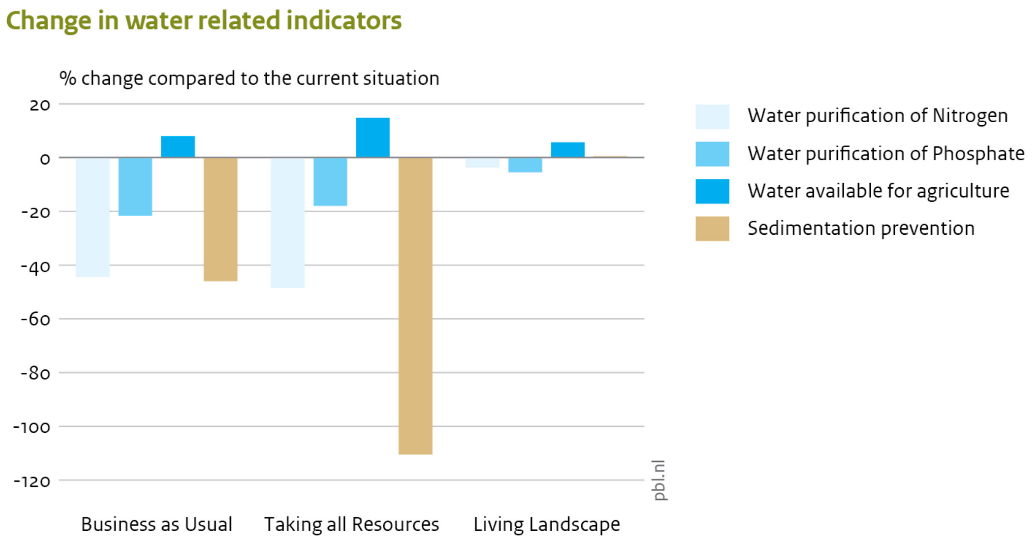


Source: PBL

Ambition 3: Sustainable management of water resources and supply

Doing the right thing in the right place is especially important when trying to prevent deterioration of water quality. By improving land use in riparian zones, limiting expansion of agriculture on steep slopes and halting further deforestation in upstream areas of the Densu catchment the Living Landscape scenario is the only pathway that is able to prevent large negative changes in water quality, which seriously affect food production in the floodplains under the BAU and TAR scenarios.

Figure 5.14



Source: PBL

Increasing deforestation under the BAU and TAR scenarios clearly result in potentially more water being available for agriculture, as less trees are around to capture and maintain their share of the precipitation. However, taking the decreased water quality and high levels of sedimentation under these 2 scenarios into account, the projected increase in water flow is threatening agricultural production in floodplains and also adds to the risk of flooding and the potential cost of maintaining the quality of drinking water supplies. Under the Living Landscape scenario even a small improvement in the prevention of sedimentation is achieved, thereby also contributing to preventing increased spillage of untreated excess water into the Densu Delta and the suburbs of Accra.

Ambition 4: Sustainable cocoa and palm oil production

The area under cultivation for cocoa and palm oil is increasing under all scenarios. By investing in improved tree varieties and management practices higher productivity can be achieved. By combining this with effective spatial planning and for instance indications of RSPO guidelines, premium price incentives could be received. The results from this are best reflected by the Living Landscape scenario by achieving the production growth ambition by producing more on less land in more suitable locations.

Ambition 5: Develop a tourism industry centered on the Atewa forest

Proposed investments for expanding sustainable ecotourism were not explicitly included in the model. However, the foundation of protected forests and remaining biodiversity as essential elements for successful ecotourism are best promoted under Living Landscape scenario, in comparison to the BAU and TAR scenarios.

Ambition 6: Partnership development and landscape planning

The Living Landscape scenario assumes strong territorial planning and collaboration between various organizations (government, NGOs and private sector) in order to successfully implement the various spatial policies. The costs and organization to do so are not explicitly included in the model. This is also so for details on land access and ownership. The National Development Planning Commission (NDPC) is coordinating the district level land use planning process. With support from the United Nations Development Program (UNDP), they are now promoting that districts integrate the SDGs into their spatial planning process to improve the integrated multi sectoral coverage of these plans. During the workshop various district planning officers were present and specifically asked for local support from the national agencies attending, like WRC, EPA and FC, to realize this. We think the policies underlying the Living Landscape scenario and its outcomes could potentially be helpful for this process.

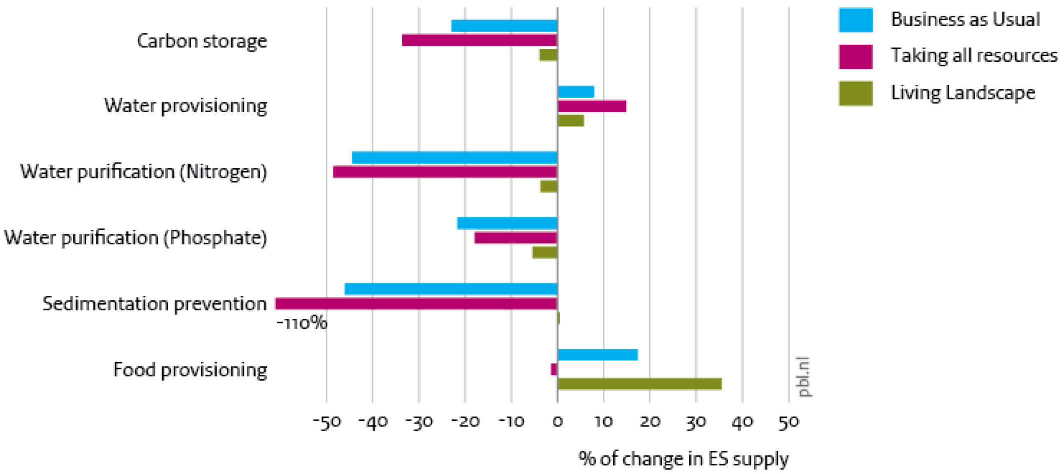
5.3 Summary of synergies and trade offs

The following two figures aim to summarize the scenario outcomes and to visualize the trade-offs occurring within and between the different scenarios that were explored. First focus will be on the changes in the supply of the ecosystem services that were included in the analysis.

The synergy that can be derived from Figure 5.15 is that by aiming for strategies and actions that organize the various activities and regulate access to resources in the landscape according to the Living Landscape scenario, the supply of most ecosystem services is higher than under the Business as Usual and Taking all Resources scenarios. In order to produce sufficient food and create a sustainable livelihood for the current and an additional projected 2.5 million people, the improvement of water quality and the protection of soils and forest are essential to maintain the green infrastructure on which the sustainable future is the Atewa-Densu landscape needs to be build. This includes protecting the Atewa forest reserve and restoring the supporting buffer zone, both important elements of the Living Landscape scenario.

Figure 5.15

Change in supply of ecosystem service compared to the current situation



Source: PBL

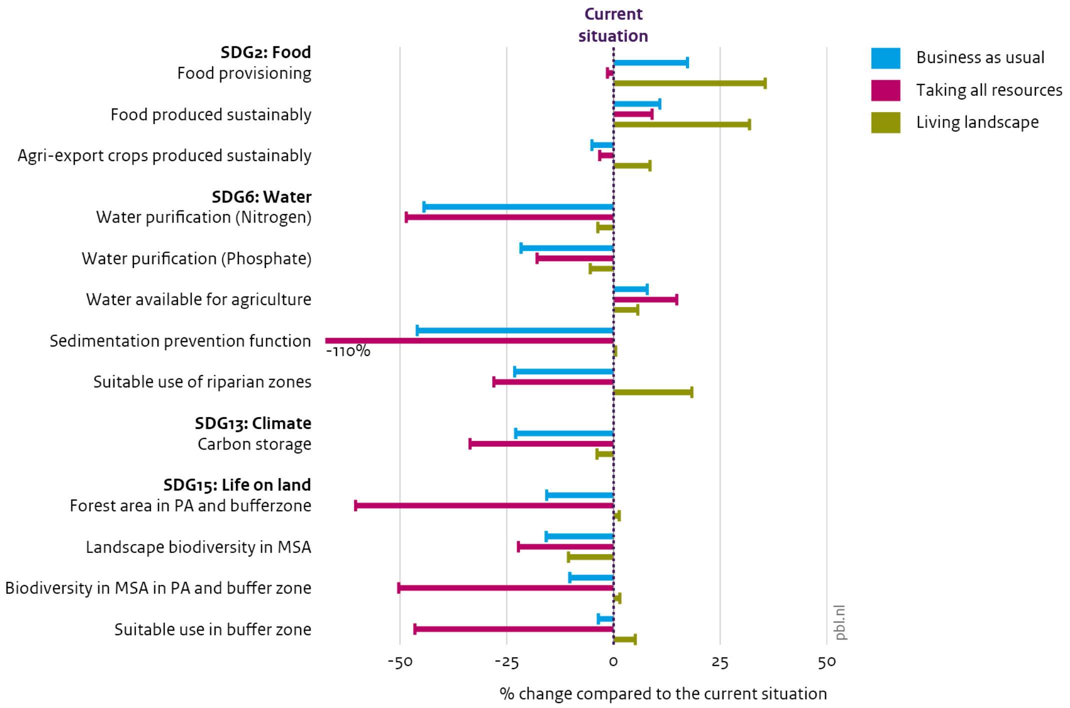
The only exception from Figure 5.15 is water provisioning for agriculture, which describes the trade-off in the landscape, as reflected in the modelling tools, of having more trees (that consume and hold on to water) and therefore, under similar climatic circumstances, leave relatively less water available for agricultural production. Unfortunately, due to increasing erosion, pollution and sediment flow, the increasing water provisioning under the BAU and TAR scenarios is more likely to cause trade-offs (increased runoff, uncontrolled timing of available water flow, risk of flooding) than synergies. As stated in Section 3.1, from the perspective of Accra citizens, the availability of water for drinking is currently not seen as much of an issue, but rather the quality and the cost of treating it for consumption are becoming more problematic. Famers in the Densu basin area however, are facing unfavourable periods of drought recently, with the Densu river even falling dry at certain times.

With respect to the selected SDGs, Figure 5.16 provides an overview of the scenario outcomes on the indicators presented in Table 2.1.

For **SDG2** only the Living Landscape scenario is showing a positive change on all indicators, compared to the current situation. With the increasing area in use for food production, even under the BAU and TAR scenarios an increase of food being produced sustainably can be achieved, but the 32% increase projected under the Living Landscape scenario illustrates the other two scenarios are performing far below the landscape's potential. If food provisioning is translated to per capita change (see Figure 5.11), it is clear the growing population is putting a large demand on the landscape, also given its relatively small area (6,000 km2) that limits the space available for options in combination with the identified spatial policy zones. To cope with this challenge and secure SDG2, it might be that the required agricultural productivity increases need to be even higher than those used under the Living Landscape scenario (see Table 4.2), which would require larger investments.

Figure 5.16

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



Source: PBL

For **SDG6** the implementation of the riparian zone policy, protection of Atewa forest and the restoration of the buffer zone clearly have a positive outcome the water quality and sedimentation prevention function, that controls soil erosion, for the Living Landscape scenario. The BAU and TAR scenarios are not showing any improvement and will not support the landscape in achieving this SDG. Due to increasing agricultural production the nitrogen load is increasing and affecting water quality under all scenarios, to varying degrees though.

For **SDG13** only carbon storage was included. Due to the overall loss of trees in the whole landscape under all scenarios (see Figure 5.8) this indicator slightly decreases. The Living Landscape scenario shows the best results, by limiting the loss to just 4%, mainly because of the conversion of open forest to mixed agricultural systems and agroforestry in the zone between Atewa and Accra (see Table 4.1).

For **SDG15** the results for the Living Landscape scenario are obviously the most optimistic. Given the magnitude of the pressures affecting biodiversity in the landscape it is very promising that the Living Landscape scenario is able to reduce the loss in MSA occurring under the BAU scenario by a 33%. The other indicators illustrate that under the Living Landscape scenario specific focus is on protecting forest in Atewa and the role of the buffer zone, also in relation to supporting indicators under SDG2, 6 and 13 as was also shown in section 5.2. This a potential synergy that is clearly turning into a trade-off under the BAU and TAR scenarios.

6 Conclusions

The goal and ambition of the project and this case study was to assess how spatial modelling tools and scenarios can be used in an ongoing landscape initiative and support the involved stakeholders in exploring and discussing strategies that could potentially achieve progress on multiple Sustainable Development Goals simultaneously. Given the relatively short lead time of the project, it was not the goal to build the most complex and complete model from scratch, but to explore, combine and built on various existing and proven tools that were sufficiently flexible to be adapted to the landscape characteristics and cover the main drivers of change. For the analysis we derived a selected set of indicators that could be related to the selected SDGs on food, water, climate and life on land. Even though the modelling framework roughly describes the complex and dynamic natural and socio-economic processes that take place in landscapes, they are able to capture the main drivers of change for a comparative scenario analysis to support strategic landscape planning discussions. This could only be successful if sufficiently accurate and recent landscape data is available and can be used in the models. Therefore the case study partners IUCN NL and A Rocha Ghana had a crucial role to provide landscape level information and to organize and identify participants for the landscape planning workshop. In the next sections some conclusions and lessons from this case study are described.

6.1 Value of scenario modeling for strategic planning in the landscape

- Spatial modelling tools can help to increase awareness among stakeholders about the order of magnitude of drivers of landscape change, like a growing population and increasing urbanization, the (unbridled) expansion of agricultural production and the development of infrastructure and mining, and how these are affecting natural resources in a landscape.
- Spatial modelling of potential alternative future scenarios can be a catalyst for building landscape partnerships. The focus of the modelling tools was on facilitating stakeholder discussions, and not so much on being the most advanced and complex model in covering every detailed element of i.e. biodiversity or hydrology. By delineating the landscape on district boundaries and covering the whole area from the Atewa Range in the north to the capital of Accra in the south, our results and the discussions could also be useful for the land use planning process, even though district level stakeholders from the southern part of the landscape were not participating in the workshop. In this planning process the National Development Planning Commission (NDPC), supported by UNDP, is promoting the integrating of the SDGs into the district level development plans.
- The Sustainable Development Goals, considered as an integrated and inseparable framework for sustainable development, provide a useful framework for focusing discussions on shared ambitions and benefits, and can, in combination with spatial scenario analyses, be used in action planning of integrated landscape initiatives. In our modelling we focused on SDGs that could be more directly related to spatial planning and land use change modelling: food, water, climate and life on land.

6.2 Value of scenario analysis for landscape stakeholder dialogue

- Overall based on these outcomes we would conclude that a scenario that uses an integrated approach like the Living Landscape scenario, that involves multiple sectors, is organized in (effective) multi-stakeholder platforms, has a larger potential in achieving progress on multiple SDGs simultaneously in this landscape, provided that it is also combined with substantial increases in productivity of current agricultural activities, increased capacity and enforcement of local and landscape level land use planning and (continued) effective management of protected areas and nature reserves. Given the limited SDG coverage in our modelling is it obvious that in order to achieve sustainable development in the landscape also progress on other SDGs like health, education and gender needs to be achieved.

- The outcomes of scenario analyses should always be interpreted with caution. They are meant to facilitate stakeholder discussions and to explore planning strategies. To prevent misunderstanding, stakeholders should understand the assumptions and the effort required to implement a scenario, with respect to requirements for governance, technological development, awareness and financial investments.

6.3 Next steps in refining landscape scenario modeling methodology

- Based on the current experiences, there is a need to improve the coverage of other SDGs, various types of ecosystem service modelling and more dynamic coupling of feedbacks in the used tools.

- In order to improve facilitation and understanding of scenarios and their outcomes within stakeholder groups and to support next steps in strategic landscape planning it would be useful to extend the economic impacts of the outcomes and to combine identified scenario outcome actions into landscape governance and investment financing tools.

7 References

Adank, M., Darteh, B., Moriarty, P., Osei Tutu, H., Assan, D., Rooijen, D. van (2011) Towards integrated urban water management in the Greater Accra Metropolitan Area, Current status and strategic directions for the future, SWITCH/RCN Ghana, Accra, Ghana

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., R. Alkemade, A. M. Schipper, D. J. Ingram, P. A. Verweij, J. A. J. Eikelboom, M. A. J. Huijbregts, (2017), The impact of hunting on tropical mammal and bird populations, Science 14 Apr 2017: Vol. 356, Issue 6334, pp. 180-183, DOI: 10.1126/science.aaj1891

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

FC – Forestry Commission (2015) land use/cover maps accessed via http://fcghana.org/nrs/index.php/reports-documents/category/4-spatial-data

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

IUCN-NL, A Rocha Ghana and IVM Institute for Environmental Studies (2016) The economics of the Atewa forest range; Living water from the mountain Protecting Atewa water resources, IUCN-NL, Amsterdam.

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

Oettli, P., Behera, S. and Yamagata, T. (2018) Climate based predictability of oil palm tree yield in Malaysia, Nature Scientific Reports 8:2271, DOI:10.1038/s41598-018-20298-0

RMSC (2016). Inventory and mapping of planned an on-going activities in Atewa Forest and its immediate environment. Resources Management Support Centre, Forestry Commission, Kumasi. Info taken from IUCN-NL et al 2016.

Russell, R. Paterson, M., Lima, N. (2017) Climate change affecting oil palm agronomy, and oil palm cultivation increasing climate change, require amelioration, Ecology and Evolution, Volume 8, issue 1, pages 452-461.

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.

Woittiez, L., van Wijk, M., Slingerland, M., van Noordwijk, M. and Giller, K. (2017) Yield gaps in oil palm: A quantitative review of contributing factors, European Journal of Agronomy, Volume 83, pages 57-77

Wood, Sylvia, Sarah K. Jones, Justin A. Johnson, Kate A. Brauman, Rebecca Chaplin-Kramer, Alexander Fremier, Evan Girvetz, Line J. Gordon, Carrie V. Kappel, Lisa Mandle, Mark Mulligan, Patrick O'Farrell, William K. Smith, Louise Willemen, Wei Zhang, Fabrice A. DeClerck, (2018) Distilling the role of ecosystem services in the Sustainable Development Goals, Ecosystem Services 29 (2018) 70–82.

WRC – Water Resource Commission (2015), Densu river basin, Integrated Water Management Plan, Koforidua

Zainal, Z., Shamsudin, M., Mohamed, Z. and Adam, S. (2012) Economic Impact of Climate Change on the Malaysian Palm Oil Production. Trends in Applied Sciences Research, 7: 872-880. DOI: 10.3923/tasr.2012.872.880

8 Annexes

8.1 ANNEX: Data sources used in modelling

Data source	Description of usage
District level data and projections: Ghana Statistical Service (http://www.statsghana.gov.gh/) and WRC 2015 report on the Densu Basin	Population data, current and 2030 projections at district level
Data used by the TEEB report on Atewa (IUCN-NL et al 2016), mainly originating from CERSGIS (http://www.cersgis.org) and Water Resource Commission Most recent district map via http://197.255.124.67/maps/103	Administrative boundaries, rivers, watersheds, Atewa core and bufferz zone, land cover/use, mining areas
Forestry Commission Ghana: http://fcghana.org/nrs/index.php/reports-documents/category/4-spatial-data	Land use/cover 2000-2015
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, check for comparison with other data.
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 used for forest reserves and RAMSAR sites
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

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.
Satelligence interpretation of Sentinel remote sensing data, 2015-2016	Palm oil plantations
Selected areas from the 2000 land use map, retrieved via CERSGIS	Cocoa plantations
CIAT: P. Läderach & A. Martinez-Valle & G. Schroth & N. Castro (2013) Predicting the future climatic suitability for cocoa farming of the world's leading producer countries, Ghana and Côte d'Ivoire, Climatic Change DOI 10.1007/s10584-013-0774-8	Cocoa climate suitability
Minerals Commission, digitized paper maps by PBL and checks in Google Earth.	Mining areas and concessions
National Development Planning Commission – District progress reports, retrieved from http://ndpc-cms.herokuapp.com/downloads/34/	SDG and other district level statistics.

8.2 ANNEX: Landscape land systems classification procedure