FOUR AFRICAN CASE STUDIES EXPLORING HOW TO INCORPORATE BIODIVERSITY INTO LAND USE PLANNING USING SPATIAL PRIORITIZATION AND SCENARIO ANALYSIS

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AFRICA BIODIVERSITY COLLABORATIVE GROUP

COVER PHOTO: Western gorilla
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Africa Biodiversity Collaborative Group

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III. ACRONYMS

ABCG	Africa Biodiversity Collaborative Group
ACFAP	Agence Congolaise de la Faune et des Aires Protégées
AFD	Agence Française de Développement
AFR100	Africa Forest Landscape Restoration
AWF	Africa Wildlife Foundation
CAADP	Comprehensive Africa Agriculture Development Program
CACO-REDD+	Cadre de concertation des organisations de la société civile et des populations autochtones
CAP	Conservation Action Plan
CAZ	Corridor Ankeniheny-Zahamena
CI	Conservation International
CIB	Congolese Industrielle de Bois
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement (Agricultural Research Center for International Development)
CNIAF	Centre National d'Inventaire et d'Aménagement des Ressources Forestières et Fauniques
CN-REDD	REDD Coordination Unit
DRC	Democratic Republic of Congo
ERP	Emissions reduction program
ESRI	Environmental Systems Research Institute
EU	European Union
FAO	Food and Agriculture Organization
FCPF-ERPD	Forest Carbon Partnership Facility Emission Reduction Program Document
FSC	Forest Stewardship Council
GAEZ	Global agro-ecological zones
GDP	Gross domestic product
GIS	Geographic information system
IFL	Intact forest landscapes
IFO	Industrie Forestière de Ouesso
IUCN	International Union for Conservation of Nature
JGI	Jane Goodall Institute
LUM	Land Use Management
MAETGT	Ministry of Planning and Public Works
MEFDD	Ministry of Forests and Sustainable Development
MET	Ministry of Environment and Tourism
MODIS	Moderate resolution imaging spectroradiometer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Digital Vegetation Index
NGO	Non-governmental organization
NLUPC	National Land Use Planning Commission (Tanzania)
PA	Protected area
PBL	Problem based learning

PES	Payment for ecological services
RCP	Representative Concentration Pathways
PNAT	Plan national d'affectation des terres (National Plan of Land Allocation)
REDD+	Reduce emissions from deforestation and forest degradation
ROC	Republic of Congo
SAC	Schéma d'Aménagement Communal
SAGCOT	Southern Agricultural Growth Corridor of Tanzania
TANAPA	Tanzania National Parks Authority
tCO_2	Tonnes of carbon dioxide
TNC	The Nature Conservancy
TSH	Tanzanian Shillings
UNDP	United Nations Development Programme
UQ	University of Queensland
USD	U.S. Dollar
VCI	Vegetation Condition Index
VIIRS	Visible infrared imaging radiometer suite
WCS	Wildlife Conservation Society
WRI	World Resources Institute
WWF	World Wildlife Fund for Nature

IV. ACKNOWLEDGEMENTS

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1. INTRODUCTION

The Africa Biodiversity Collaborative Group (ABCG) overarching mission is to advance understanding of critical biodiversity conservation challenges and their solutions in sub-Saharan Africa. ABCG aspires to produce applicable conservation knowledge and put it into practice. ABCG is a voluntary coalition of seven US-based international conservation non-governmental organizations with extensive field programs in Africa: African Wildlife Foundation (AWF), Conservation International (CI), The Jane Goodall Institute (JGI), The Nature Conservancy (TNC), Wildlife Conservation Society (WCS), World Resources Institute (WRI) and World Wildlife Fund (WWF). In ABCG's current Phase II from 2015-2018, the mission is pursued within the context of five thematic foci critical to effective conservation efforts: 1) Land and Resource Tenure Rights; 2) Land use Management; 3) Managing Global Change Impacts; 4) Global Health Linkages to Conservation: Population Health and Environment; Water Sanitation and Hygiene; and; 5) Emerging Issues.

The main aim of the Land Use Management (LUM) task group is to develop methodological approaches for scenario analysis, and guidelines for its application in Africa. This is to help identify how to incorporate equitable and climate-smart alternatives into land use decisions for conservation. The aim of this document is to first introduce the broad approach that has been applied within the four case studies and review how this was applied in four countries: Republic of Congo, Democratic Republic of Congo, Tanzania, and Madagascar. Lessons learnt through this process are then summarized.

1.1 KEY CONCEPTS

What is land use? Land use reflects both: 1) the activities undertaken, and 2) the institutional arrangements put in place for a given area for the purposes of economic production, or the maintenance and restoration of environmental functions. This sometimes gets confused with land-cover (*Figure 1*). Land-cover is the biophysical cover on the surface of the earth, such as forests. Land use is related to land-cover in that often land uses such as agriculture can be reflected in the land-cover type. Land use is often a product of landscape pressures from people, such as, population growth, settlement and housing patterns, infrastructure, economic development, sectoral trends, infrastructure and conservation. It is also now also driven by climate change and this is only going to become an even bigger driver in the future.

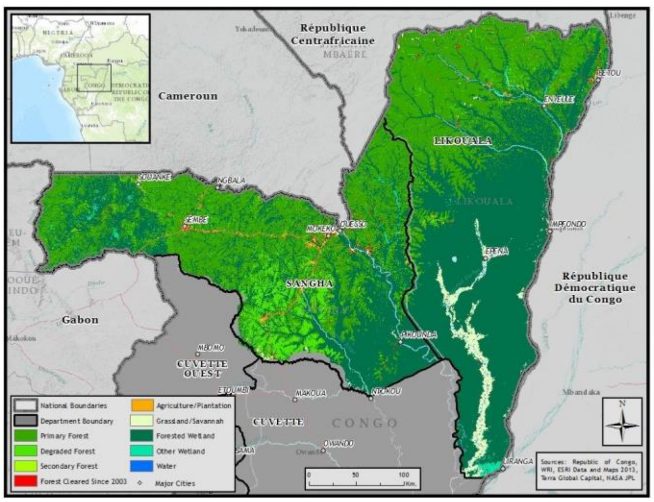
1.2 SCENARIO ANALYSIS AND PLANNING

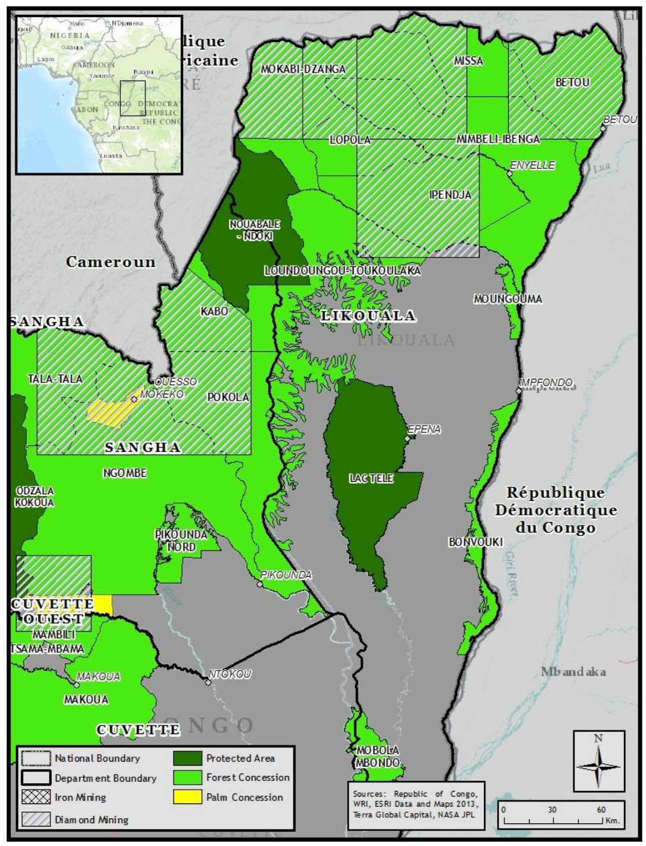
What is scenario analysis and planning? Scenarios are structured accounts of possible futures. They are often based on identifying landscape issues, and based on goals that want to be achieved, derived alternatives to the current situation to inform future plans. Scenarios typically describe futures that could be rather than futures that will be. In terms of land use planning, scenarios can be possible strategies that achieve objectives through tools like prioritization (discussed soon). Scenario analysis and planning focuses on developing alternative futures to identify favorable land uses by evaluating scenarios against landscape objectives.

Why develop scenarios? Scenarios can help:

- Identify spatial priorities for different land uses including conservation priorities;
- Recognize emerging issues;
- Reveal unforeseen risk (particularly for development); and
- Understand what drives undesirable change
- Provoke debate around trade-offs
- Expose future uncertainties
- Stretch imaginations and stimulate creative solutions
- Challenge assumptions and reveal contradictions

Figure 1 | Example of land cover (left) and land use (right) in northern Republic of Congo (FCPF ER-PD)





FCPF ER-PD[1]

[1] https://www.forestcarbonpartnership.org/sites/fcp/files/2014/June/Republic%20of%20Congo%20ER-PIN%2001%20June%202014.pdf

2. STEPS FOR PRIORITIZING LAND USE STRATEGIES AND DIFFERENT SCENARIOS OF LAND USE

For this project a number of broad steps and key activities for exploring potential land use strategies and scenarios in order to make land use recommendations on how to better incorporate biodiversity conservation into land use planning (*Table 1*) were taken. The following discusses this in more detail.

Table 1 | Steps for scenario planning used in the project. The role of stakeholders and experts is important to recognize and is included throughout the process.

Broad Steps	Key Activities	Role of Stakeholder & Experts
Context for identifying land use planning strategies for biodiversity conservation	Planning issues, drivers and actors of change	Provide input into identifying context
	Vision and planning goals	Help identify the vision and planning goals
	Landscape characterization, including trends in biodiversity and other landscape attributes	Provide data and input on any data and analysis
Identify, prioritize and assess different scenarios land use planning strategies	Identify potential land use planning strategies and their objectives for biodiversity conservation	Help identify implementable strategies and their objectives
	Prioritize application of land use planning strategies through scenario analysis	Help define parameters within scenarios of strategies to explore
	Assess land use planning strategies and scenarios with stakeholders and against landscape performance metrics	Provide review of analysis of land use planning strategies
Make recommendations for implementing land use planning strategies for biodiversity conservation	Summarize findings and make key recommendations	Provide feedback of finding and recommendations

2.1 STEP 1 – PLANNING ISSUES, DRIVERS AND ACTORS OF LAND USE CHANGE

This step aims to understand the drivers and actors causing land use change and implications for informing landscape goals, i.e., vision of the future. This sometimes also helps identify what business as usual looks like (i.e., a "current trends" scenario) as a baseline for the future more ideal scenarios. It can also be used to strategically target vulnerable areas for land use change as potential conservation areas. Assessment of trends and likely trajectories of key drivers of landscape change might include direct drivers (e.g., agricultural land use expansion and resource extraction); and indirect drivers (e.g., demographic change, and economic development). Some estimation of how these might affect key conservation values including land cover, at least qualitatively, is useful. If possible, the authors recommended developing a quantitative model of land use change. Multi-temporal analyses of historical or observed land use change can be valuable in generating maps of drivers (e.g., agricultural expansion), proximity measures (e.g., distance to roads, past deforestation), and means of incorporating future assumptions into prioritizations (e.g., what incentives or disincentives there are for land use change).

Box 1 I Drivers of land use change in Republic of Congo

Engagement with stakeholders in the Republic of Congo elucidated several major drivers of land-cover and biodiversity change, the most prevalent being forestry and species exploitation due to hunting. Logging in forestry concessions leads to reduced forest biomass, as well as potential reductions in food and habitat for conservation-dependent species such as chimpanzees that feed on the fruits of large trees favored for forestry. Hunting occurs across the landscape but preferentially towards certain species such as great apes and ungulates, and is more intense where humans have easier access to the forest. Other causes of change include alternative land uses such as mining, oil palm plantations and road development (*Figure 1*).

Box 2 I Visioning in Madagascar

"In 2030, the sustainable development of the two Regions depends on an economy that is based on the rationale use of resources, a healthy protected ecosystem, adequate infrastructure and a framework of conditions favorable for human wellbeing".

2.2 STEP 2 – VISION AND PLANNING GOALS IDENTIFIED

It can be useful to start the process with a visioning exercise to identify different stakeholder visions for the landscape and its land uses. For alternative visions, a "storyline" approach can be useful to characterize qualitatively different world-views. For example, one stakeholder group might be very interested in ensuring wilderness and maintenance of mega-fauna in the landscape, another more interested in poverty alleviation, another economic development, and so on. From here planning goals can be identified on what the outcome of planning should achieve, then it is easier to start delving deeper into what specific more quantitative objectives can be identified for land use strategies. Goals are very important to identify and typically drive land use planning.

2.3 STEP 3 – LANDSCAPE CHARACTERIZATION

The next step is to gather data to characterize the landscape in the context of current land use and other necessary data that will feed into the remaining steps.

Key datasets include the:

- Current land use system, including the protected area network. Also important, where possible, is understanding the future potential of new or existing land uses. This might include the suitability of the landscape for different crops or areas suitable for extraction of natural resources.
- Identification of key conservation values and their distributions. This might include:
    - Ecosystem distributions and if possible measurements of their condition (e.g., forest fragmentation). If there has been an assessment of threatened ecosystems this might be also useful.
    - Species of conservation concern include threatened species, charismatic, migratory, endemic, keystone. Most likely this will be point locality data, distribution maps, and sometimes important sites might have been identified (e.g., congregation sites). Some modeling or expert mapping might help aid in filling gaps where there are no data. It will also be useful to identify the responses of species to land use change and climate change.
    - Sites of importance for ecological (e.g., connectivity between populations) and evolutionary processes (e.g., ecological refugia).
    - Models of ecosystem services (can be current benefits to people, or potential benefits). It will be important to relate this to land use so the response of land use change can be estimated. For example, how do carbon values change when land use causes an area to go from primary forest to palm oil?
- Infrastructure, particularly roads (current distribution, plans) (*Figure 2*)
- Population data and town/village locations
- Land ownership
- Current management interventions (including incentives like REDD+)

Identify, prioritize and assess land use planning strategies

2.4 STEP 4 - POTENTIAL LAND USE PLANNING STRATEGIES AND THEIR OBJECTIVES

Developing land use planning scenarios is most useful when the specific management strategies and their objectives are used as a basis for the analysis. This step requires stakeholders to identify the potential land use strategies that can be used through the next steps of the planning process, and then identifying where these are going to be most useful. It can be helpful to have a scoping exercise to list all the potential land use strategies that might be considered and reduce this down through some evaluation of their benefits, feasibility and relevance. Strategies can be variable and include broad ones like creating national parks or even broader like 'conserve an area', to more specific ones like implementing set-asides within forestry management plans or changing the type of crop that is being grown. The more specific, the more useful. Objectives should ideally be quantitative, such as target based (e.g., X percent increase in protection for a threatened species), or ones that can be minimized or maximized (e.g., maximize coverage of ecosystem X within new protected areas). The focus of this project is on land use planning strategies that lead to improve biodiversity conservation outcomes.

Box 3 I Land use planning strategies identified for the Tanzania case study

From a workshop in Tanzania, 12 objectives were discussed for land use planning in the region. These were pared down through discussions of feasibility and likelihood to four planning objectives that involved either reducing conflict, improving land management practices or changing land use:

1) Improve management and survival of biodiversity in existing protected areas;
2) Increase economic yield of agriculture through innovations;
3) Minimize conflict between cropping and biodiversity; and
4) Minimize conflict between cropping and grazing land uses

Three future development scenarios have been developed. The first scenario is the "business as usual" scenario: the continuation of historic logging activity without assignation of set-asides for conservation of wildlife or carbon, leading to a steady depletion of forest biomass and a decline in animal abundance. The scenario assumes logging results in a depletion of forest biomass of 10 percent for each ecosystem type, with no forest set aside from logging. Species densities are re-calculated based on the observed relationship between forest biomass and species abundance for each ecosystem type.

The second scenario assumes the best 10 percent of each concession (as selected by the modelling approach) is placed in conservation (known as *serie de conservation*) and not subjected to logging, with continuation of logging outside of set-asides. The third scenario increases the portion of set aside (serie de conservation) to the top 20 percent of high carbon, high biodiversity areas.

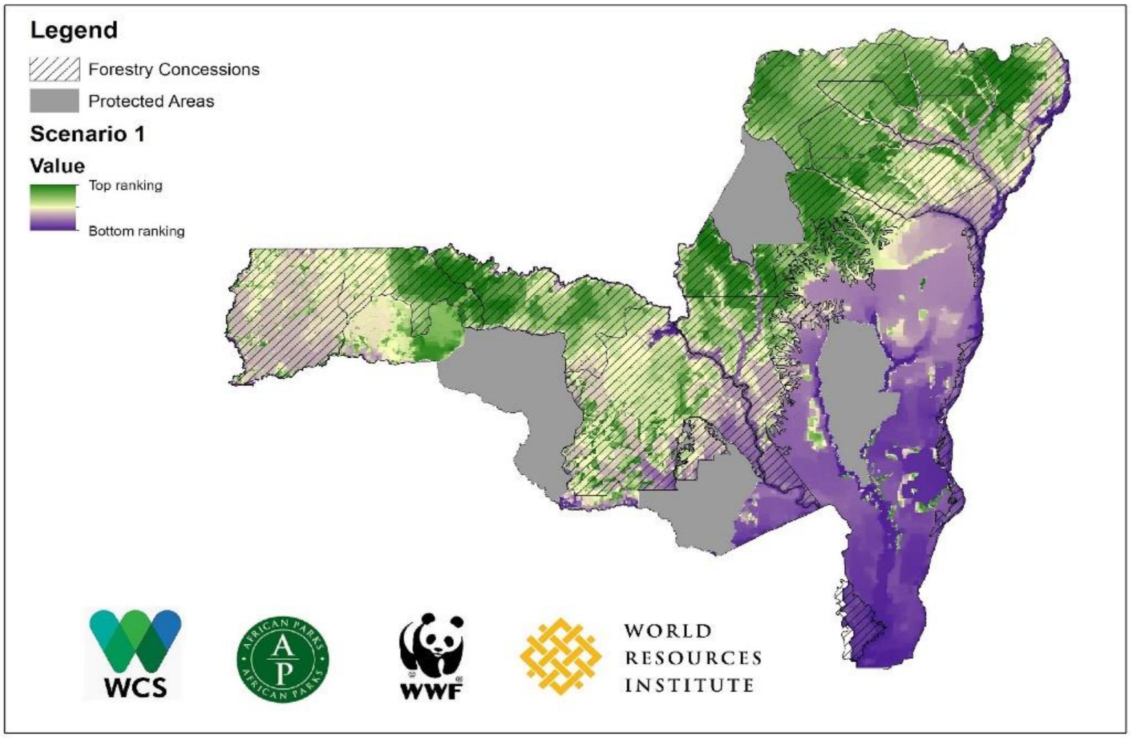
Species density models are used to show the beneficial effects of this optimistic future scenario on predicted animal populations. Further calculations could show the carbon sequestration benefits of such an approach.

2.5 STEP 5 – SPATIAL PRIORITIZATION AND SCENARIOS OF LAND USE STRATEGIES

There are various types of scenario analysis. For land use planning the most useful are ones prioritizing new land use strategies that achieve planning objectives. This is through the application of spatial prioritization analysis to find where potential new land use interventions might be most useful. Spatial prioritization analysis can help identify the best places to achieve one or more objectives. Prioritizations can focus on one land use (e.g., protected areas, agriculture) or multiple land uses simultaneously, and can optimize across multiple objectives and identify trade-offs where objectives cannot easily be met. Land use strategies include alternative forms of management within the same tenure systems, for example less intensive logging, set-asides within concessions, and alternative cropping systems.

Incorporating stakeholder input is important to develop scenarios that are feasible from a management perspective. Stakeholders (representative of the whole community) can help formulate scenarios during a scenarios workshop where the prioritization analyses can be presented and incorporated.
For biodiversity conservation, spatial prioritizations can be applied using conservation planning software to explore ideal plans for individual land uses (e.g., conservation, forestry) or more complex optimized landscapes designed to meet multiple and diverse objectives and land uses. Common software includes Marxan, Zonation, and C-Plan. Typically, they are target-based or use an objective function that identifies areas that best meet objectives while minimizing “costs”. Costs can be financial costs (e.g., costs of conservation actions, opportunity costs) or avoiding potential conflicts of others in the landscape where possible. Marxan with Zones allows multiple types of land uses to be optimized simultaneously. An example of a prioritization for new conservation areas for northern Republic of Congo is given in Figure 2.

Figure 2 | Prioritization of new sites for conservation using proximity to protected areas as a determining site selection criterion (Scenario 1). Green areas indicate those with the highest priority for conservation value.



Scenarios do not need to necessarily be completed based on prioritizations. Part of the scenario development process can include incorporating different futures using tools like GIS spatial analysis. An example of this was also in the northern Republic of Congo where different assumptions of forestry harvesting were included to explore how rates of harvesting might affect several species (*Box 4*).

Box 4 I Prioritization of conservation in northern Republic of Congo

Three future development scenarios have been developed for northern Republic of Congo. The first scenario is the "business as usual" scenario: the continuation of historic logging activity without assignation of set-asides for conservation of wildlife or carbon, leading to a steady depletion of forest biomass and a decline in animal abundance. The scenario assumes logging results in a depletion of forest biomass of 10 percent for each ecosystem type, with no forest set aside from logging. Species densities are re-calculated based on the observed relationship between forest biomass and species abundance for each ecosystem type. The second scenario assumes the best 10 percent of each concession (as selected by the modelling approach) is placed in conservation (known as serie de conservation) and not subjected to logging, with continuation of logging outside of set-asides. The third scenario increases the portion of set aside to the top 20 percent of high carbon, high biodiversity areas. The project used the species density models to show the beneficial effects of this optimistic future scenario on predicted animal populations. Further calculations could show the carbon sequestration benefits of such an approach.

2.6 STEP 6 – ASSESS SCENARIOS WITH LANDSCAPE PERFORMANCE METRICS

Once scenarios are developed based on the objectives, existing or new metrics can be used to evaluate scenario outcomes (i.e., landscape performance). Ideally metrics are linked to conservation objectives and targets. For example, one metric might measure the extent of change in a conservation feature's distribution compared to the target (e.g., aim to keep distribution losses below X percent). For each scenario the benefits and likely the trade-offs between conflicting objectives can be measured where useful. Scenario outcomes, including maps and associated landscape performance metrics, can be presented to stakeholders typically during a workshop. Preferable and plausible scenarios are chosen from the range of explored scenarios to develop final land use planning recommendations in the final steps.

Make recommendations for implementing land use planning strategies for biodiversity conservation

2.7 STEP 7 – SUMMARIZE FINDINGS

It is important that for any technical analysis that findings are summarized in a way that make it easier for decision-makers and stakeholders to understand and use these recommendations. This means summarizing the key findings around which land use strategies might be best where, what are the trade-offs, how are targets being met, etc.

2.8 STEP 8 – MAKE KEY RECOMMENDATIONS

Finally, even though the findings might be summarized in Step 7, the project recommend that a final set of key recommendations are made that can be presented quickly and easily to decision-makers and stakeholders. Doing this well can help ensure that all the technical work can easily be digested and be more likely to have impacts on the ground.

Figure 3 | The four case study areas of the project. They were northern Republic of Congo, eastern Democratic Republic of Congo, south-western Tanzania, and eastern Madagascar.

3. CASE STUDIES

Four case study countries were investigated in this project which has varying socio-ecological contexts around Africa. They included northern Republic of Congo, eastern Democratic Republic of Congo, south-western Tanzania, and eastern Madagascar (*Figure 3*). The following is a description of each of the four case study areas in the project and the summary of the process, methods and results of each case study using the framework and steps outline above.

3.1 REPUBLIC OF CONGO

3.1.1 Stakeholder and Expert Inputs

For this Republic of Congo (hereafter "Congo") case study, two workshops were used to get stakeholder and expert input into the project. In addition to the workshops described briefly below, there were numerous unilateral meetings with stakeholders and governments throughout the project.

The first workshop was organized in Brazzaville in June 2016. The aims of the workshop were to introduce the stakeholders to the project, identify the important planning issues, identify landscape objectives and collate data.

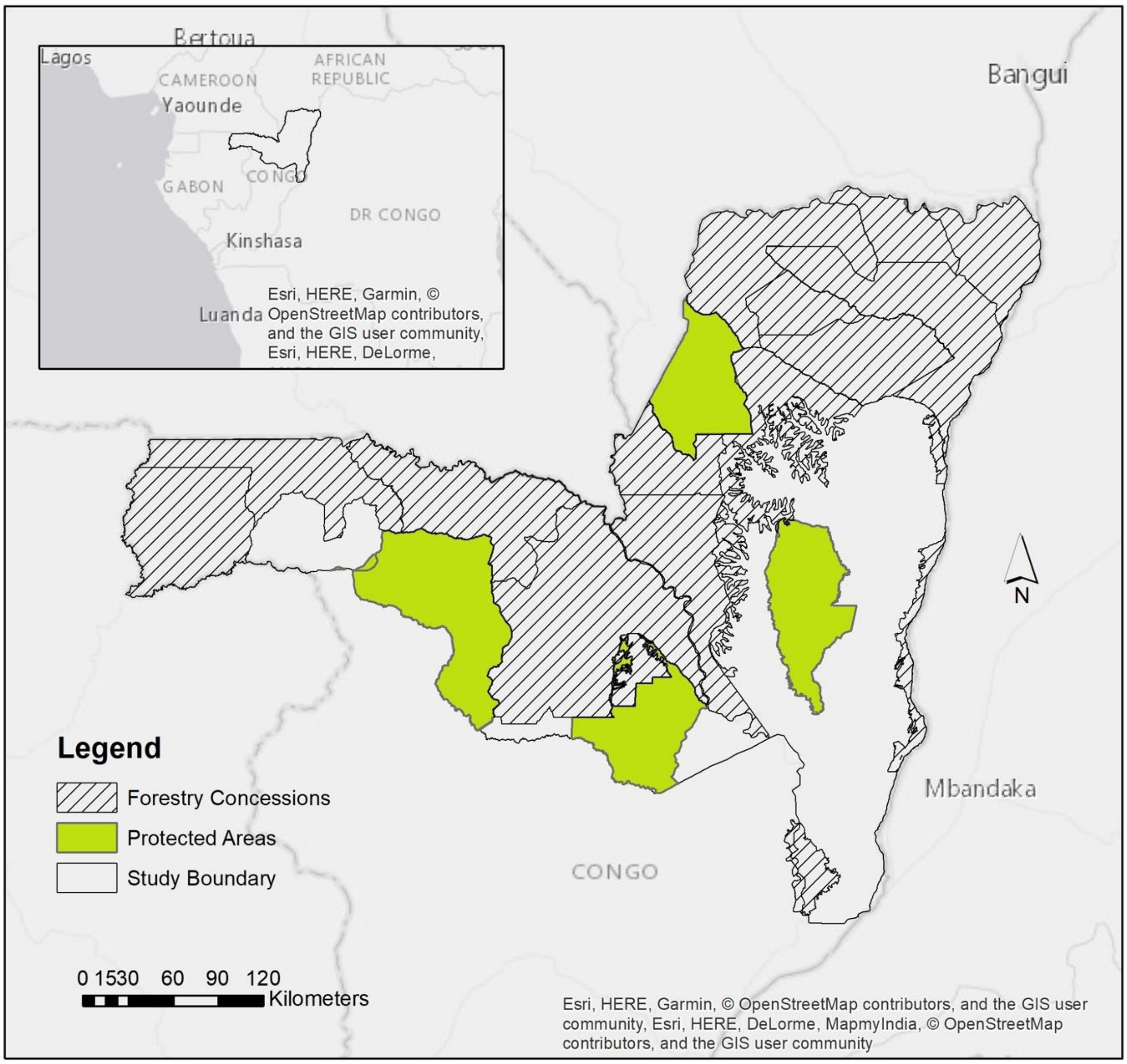
The second workshop was organised in Brazzaville on November 22-23, 2017 with a goal of presenting prioritization scenarios to key stakeholders in Congo, demonstrating the methodology and receiving feedback on some of the initial results. Meeting participants included representatives of the Ministry of Planning and Public Works (MAETGT), the Ministry of Forests and Sustainable Development (MEFDD) including departmental directors from Sangha and Likouala departments, the national REDD coordination unit CN-REDD, the National Parks Agency (ACFAP), and the forest management technical service (CNIAF), the Ministry of Environment and Tourism (MET), the World Bank, the EU, the AFD, the civil society platform CACO-REDD, WWF, the UNDP and the largest forest management company in the planning region, OLAM-CIB.

3.1.2 Context for Scenario Development

Planning Issues, Drivers and Actors of Change

The landscape of northern Congo is one of the more remote and inaccessible parts of central Africa, retaining a high percentage of primary forest cover, with a low human population density (*study area shown in Figure 4 below*). Nevertheless, almost all of the dry land (i.e., not seasonally inundated) forest is allocated under one or other form of commercial land use. The dominant land use by area is commercial timber harvesting, which takes place in large timber 'concessions' leased and managed by private companies. These timber concessions cover more than 80 percent of the total permanent forest area (a government land use classification for state owned forest land). Timber harvesting in these permits is 'selective' in that only a few tree species (of the several hundred that exist in the forest) are logged, leaving the majority of the forest structure unaffected. Estimates vary, but in general the level of biomass removed during selective logging in these forests is generally between 10 and 20 percent of the pre-logging total. However, to access the timber in the forest, the logging concession owners build elaborate networks of forest roads, opening up intact areas, creating forest edges and fragmenting habitats. These roads, if not swiftly de-commissioned after logging, can lead to further degradation of the forest structure and function. Logging is therefore the primary driver of forest quality change in the study area. Impacts of logging are modest on a per hectare scale, but the extent of logging operations across the landscape means these disturbances are occurring systematically and simultaneously across the landscape.

Figure 4 | The study region showing the protected areas and forestry concessions.



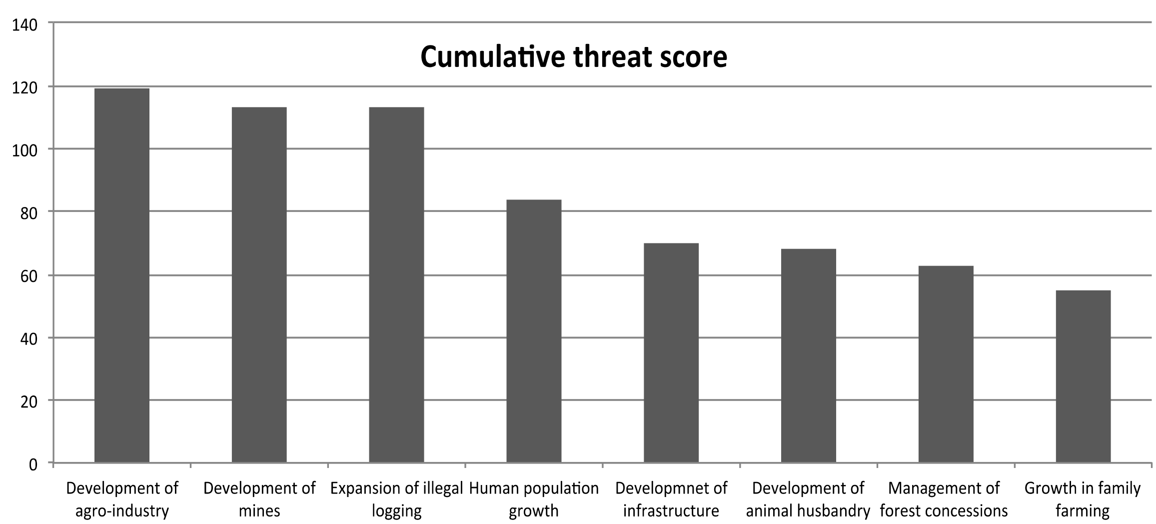
In addition to logging, four significant areas within the landscape, totaling around 100,000 hectares have been designated for the development of palm oil concessions. Of these, two are already undergoing forest clearance: Eco-oil near Ouesso in the centre of the landscape (expansion of an existing plantation), and Atama in the south of the landscape, near Makoua. Palm oil is a direct driver of forest loss (clearance of the forest is necessary for plantation establishment), but the substantial requirement for the personnel to operate these plantations is expected to draw in immigrant labor and contribute to additional forest clearance for subsistence agriculture. Most of this impact will be felt along existing public roads and around existing settlements.

The third significant driver of forest loss and degradation is human population expansion, and the need for agricultural land for shifting cultivation. While the population density of the region remains low by international standards (agriculture covers only one percent of the study area), commercial logging has turned villages of a few hundred people into towns of several thousand in the space of two decades. Ouesso, the region's main city carries a population of around 30,000, and population in the region is growing at an estimated 2.86 percent a year (FCPF ER-PD)[2]. Agriculture around these towns and villages remains basic: the cultivation of staple crops such as cassava and maize without the benefit of significant technical support, or access to improved seed or fertilizer. Rotational or shifting cultivation remains the main strategy to maintain yields. This is problematic as population density rises, and farmers are pushed further from the towns and villages in search of fertile ground.

Analysis of Conservation Challenges

Participants at the first workshop were asked to rank a list of conservation challenges according to those which are the most serious threat to biodiversity conservation in the planning region (*Figure 5*). Agro-industrial development, mining infrastructure, and illegal (unmanaged) logging were all cited as high threat, with human population growth as a secondary level concern.

Figure 5 | A ranking of threats to biodiversity within the study region by stakeholders.



[2] https://www.forestcarbonpartnership.org/sites/fcp/files/2014/June/Republic%20of%20Congo%20ER-PIN%2001%20June%202014.pdf

REDD+ and Low Carbon Development in the Region

Since the publication of the REDD-readiness Plan in 2012, Congo has established a draft national strategy to reduce emissions from deforestation and forest degradation. The National REDD Coordination (CN-REDD) at the Ministry of Forest Economy and Sustainable Development is currently moving into the implementation phase of REDD + which will be based on a series of jurisdictional 'Emission Reduction Programs' (ERPs). The first of these programs has been created in the northern part of the country, across the two departments of Sangha and Likouala.

To realize the effective implementation of REDD+ Congo is engaged in a process of land use planning, to produce a National Plan of Land Allocation (PNAT). The PNAT is seen as a critical enabling condition for REDD+. Therefore, coordination between these processes is critical and will result in considerable synergies.

Institutionally, the Ministere d'Amenageement du Territoire et des Grands Travaux (MATGT) has the strategic mandate for multi-sectoral planning and is envisioned as the overall coordinating agency for a roadmap process leading to the PNAT. The MAETGT and the National REDD+ Coordination Office (CN-REDD) will work together to ensure future land use is compatible with the country's Nationally Determined Contributions under the Paris Climate Agreement. This collaboration is beneficial because:

- It is consistent with Component 1 of Congo's draft National REDD+ strategy, which includes developing a national land use plan and strengthening the network of protected areas.
- New land use planning coordinating institutions could enhance links between planning and REDD+ agendas.
- Coordinated information systems could serve both land use planning as well as REDD+ planning and monitoring (e.g., carbon storage, safeguards).

The law number 43 (2014) on land use planning provides the framework for this coordination, and a national land use scenario (SNAT 2005) exists to guide decision making. However, at present, very few analytical datasets exist that can guide decisions on the balance of land uses for economic development and environmental sustainability. In particular, more information is necessary on:

- The distribution and abundance of biodiversity *outside* protected areas, for example in forest and mining concessions that are of high value for biodiversity.
- Areas important for the supply of ecosystem services such as carbon storage (REDD+), safeguarding of drinking water supplies, shore line protection (e.g., mangroves), and cultural ecosystem services (e.g., areas important for spiritual, religious, and aesthetic values).

Addressing this gap for the landscape of North Congo is one of the objectives of the ABCG. The result of these studies should contribute to guide land use planning within the Framework of the REDD+ strategy through the ERP Sangha-Likouala Program.

ABCG Input into the Jurisdictional REDD+ Program

The Sangha-Likouala Emissions Reduction Program is an important component of the REDD+ Initiative in Congo, and is designed to bring together and coordinate the various sources of funding available for sustainable development in Northern Congo[3]. A critical component of both jurisdictional and national REDD+ implementation is effective land use planning. Land use decisions in the target landscape should be guided primarily by their ability to reduce emissions, but they should also ensure biodiversity values are maintained. As such the north Congo landscape is an important test case for aligning land use planning, biodiversity conservation and REDD+.

The emissions reduction program (ERP) aims to reduce forest related emissions from the major land uses in the north of Congo. These include forestry, agriculture and mining. It is also supporting the creation of new protected areas and increasing the amount of protected forest within productive forest concessions, while supporting logging companies to reduce emissions from logging activities by improving the efficiency of timber extraction. The ABCG consortium is supporting the implementation of the ERP in northern Congo by identifying ways to increase the biodiversity conservation value of REDD+ actions. By providing technical data on the spatial distribution of biodiversity values, and how these overlap with carbon stocks, ABCG hopes to ensure that measures to reduce forest related emissions will also have the maximum possible benefit for biodiversity.

Vision and Planning Goals

The project in northern ROC covers two departments of Sangha and Likouala. The planning goals focused on:

- Sustainable forestry management that is economically viable;
- Appropriate siting of new industrial agriculture;
- Healthy populations of large mammals particularly apes and elephants; and
- Sustainable development for local people, particularly indigenous people. Respect for cultural values of the region.

Landscape characterization

Species

Wildlife surveys throughout Northern Congo have been carried out using a standardized methodology (used across the whole of central Africa) since 2002. The density of key species are used to assess the overall conservation status of landscapes: forest elephants *Loxodonta africana cyclotis*, two great ape species: western lowland gorilla *Gorilla gorilla gorilla* and central chimpanzee *Pan troglodytes troglodytes,* and various forest antelope species, which fall into three size categories (small, medium and large) and are mostly duikers in the genus *Cephalophus*, although other species are also included (two *Tragelaphus* species, the small *Philantomba monticola* and a wet forest specialist *Hyemoschus aquaticus).*

All ungulates are targeted by hunters throughout the region, and apes are taken opportunistically, although they are protected by law. The regionally standardized wildlife survey methodology uses the density of animal sign to estimate animal density. The sign used for elephant and ungulate density estimation is dung, and for great apes it is night nests.

[3] These include Readiness funds available through the Forest Carbon Partnership Facility, payments for performance from the World Bank Carbon Fund, and development funding available from the Forest Investment Program (PIF) and the Central African Forest Initiative (CAFI)

For this analysis, data from surveys that were carried out between 2006 and 2016 was used. Survey sites included four protected areas: the Odzala-Kokoua, Nouabale-Ndoki, and Ntoukou-Pikounda National Parks, and the Lac Tele Community Reserve. Other areas were the Djoua-Ikie interzone, the Messok Dja proposed protected area, four Congolese Industrielle de Bois (CIB) logging concessions, an Industrielle Forestiere de Ouesso (IFO) logging concession and a Rougier logging concession, and the vast swamp forests of the Likouala area in the northeast of Congo. In total, well over half of the total area of the planning region has been surveyed at least once within the last 10 years, using the regionally standardized methodology.

Figure 6 | Gorilla survey data 2006-2016 compiled across the planning region

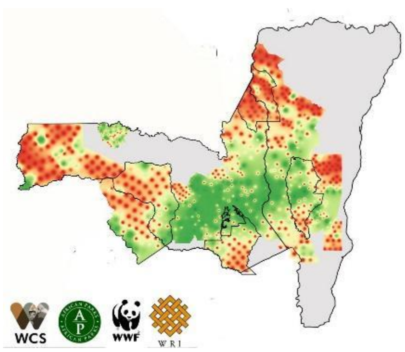


Figure 7 | Elephant survey data 2006-2016 compiled across the planning region

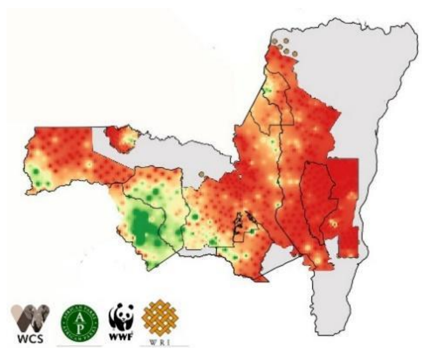


Figure 8 | Medium-sized duiker survey data 2006-2016 compiled across the planning region

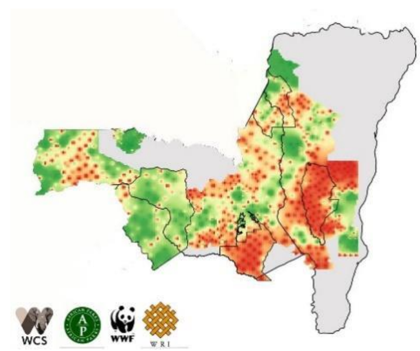


Table 2 | Survey strata and total survey effort for wildlife surveys in Northern Congo used in this analysis.

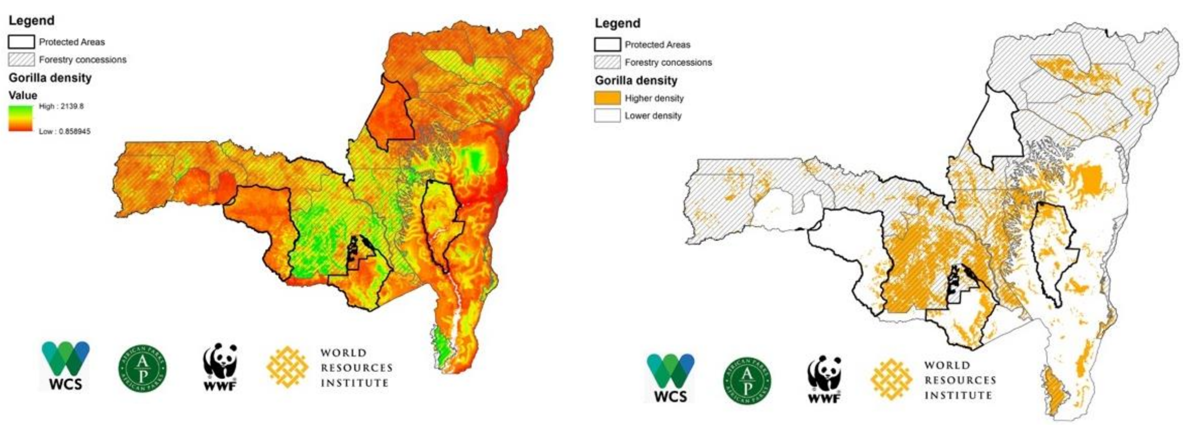
Site	Year Surveyed	Administrative Unit	Effort (km)[4]
Nouabale-Ndoki	2010	National Park	158
Ntokou-Pikounda	2014	National Park	70
Odzala-Kokoua	2012	National Park	415
Lac Tele	2010	Community Reserve	167
Kabo	2010	Logging concession	92
Pokola	2010	Logging concession	108
Loundougou-Toukoulaka	2010	Logging concession	120
Mokabi	2006	Logging concession	58
Ngombe	2014	Logging concession	683
Pikounda Nord	2014	Logging concession	18
Djoua-Ivindo	2016	Logging concession	297
Messok-Dja	2016	Logging concession	268
Bailly	2010	Swamp area	108
Batanga	2012	Swamp area	116
Impfondo	2008	Swamp area	88
Tanga	2008	Swamp area	306

[4] Individual transects vary in length between one to four km. The table shows the sum (total km.) of all transects surveyed in each stratum.

Survey data were used to create **species density models** (*Table 2 and Figures 6-8*). By quantifying the effect of different parameters (i.e., forest type, distance to roads, human population density, etc) on the observed density of different species, it is possible to use these parameters to model species density for the areas where no surveys have been undertaken. These models, like those used by Maisels, Strindberg *et al.* (2013)[5] and Strindberg, Maisels *et al.* 2018[6], have a high degree of accuracy when they are based on such a large database of actual survey data. Models also allow the exploration of future scenarios of conservation and development and what this might mean for the populations and distribution patterns of these species.

The model results show the predicted density of species (individuals per km^2 in the case of the great apes and elephants, and dung density in the case of ungulates) across the planning region (*Figures 6-8*). This allows the identification of areas *predicted* to have high species density even when these areas have not been surveyed (*Figures 9-12*). These predictive models are of immense significance for proactive planning.

Figure 9 | Model outputs for Gorilla density: (left) overall density across the landscape, and (right) highest density areas



[5] Maisels, F., Strindberg, S., Blake, S., *et al.*, 2013. Devastating decline of forest elephants in central Africa. *PLoS One* 8, e59469.

[6] Strindberg, S., Maisels, F., Williamson, E.A. *et. al.* 2018. Guns, germs and trees determine density and distribution of gorillas and chimpanzees in Western Equatorial Africa. *Science Advance*s In press.

Figure 10 | Model outputs for Chimpanzee density: (left) overall density across the landscape, and (right) highest density areas

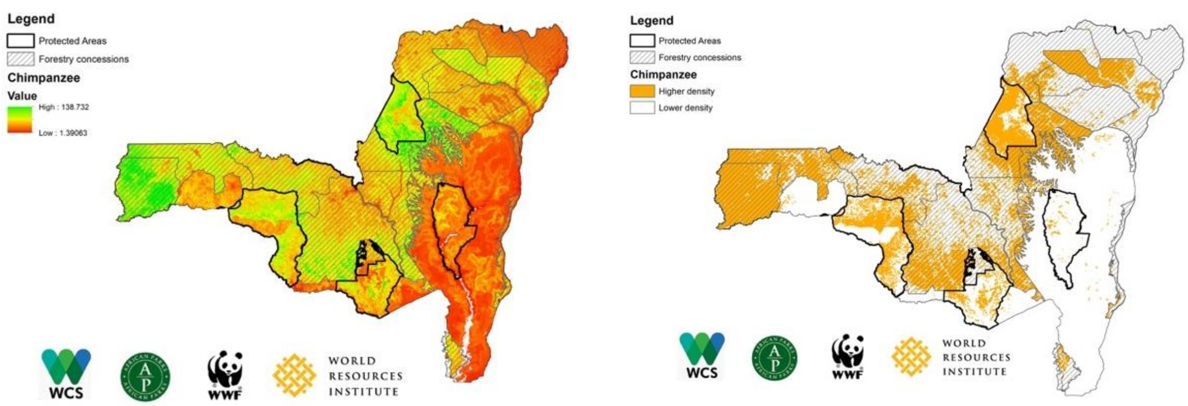


Figure 11 | Model outputs for Elephant density: (left) overall density across the landscape, and (right) highest density areas

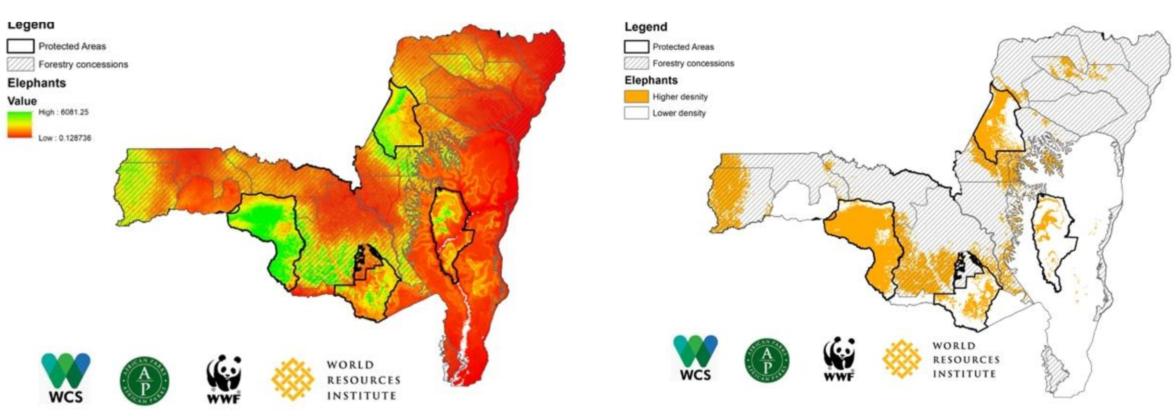
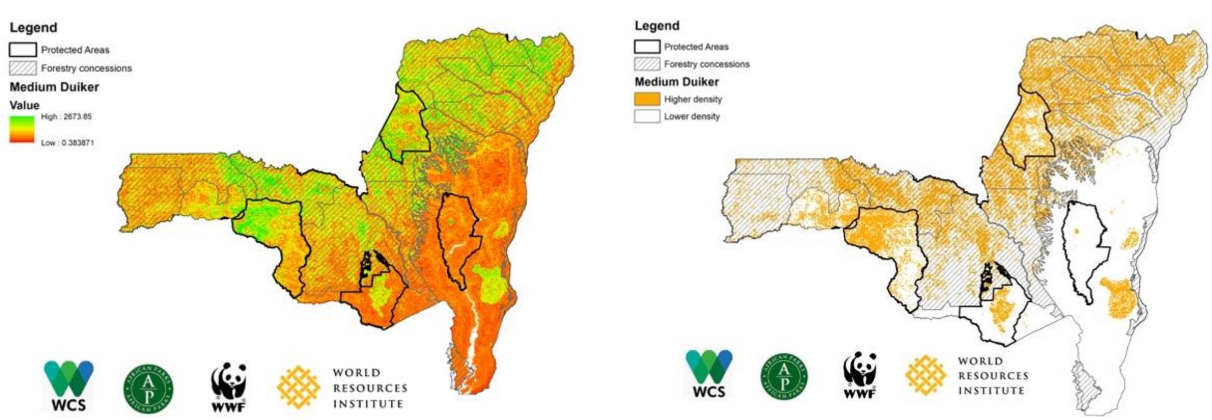


Figure 12 | Model outputs for medium bodied ungulate density: (left) overall density across the landscape, and (right) highest density areas

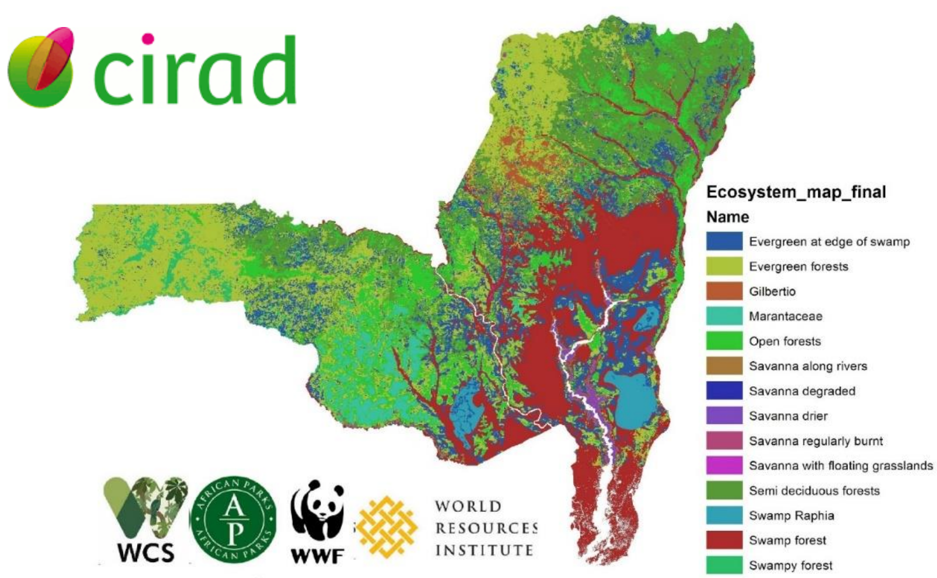


Ecosystems

A new ecosystem type map was developed for this project (*Figure 13*), based on the refinement of an existing map (Gond *et al*. 2013[7]), which used a remote sensing methodology (canopy reflectance). Expert input based on local field knowledge of a suite of sites within the area of interest to combine some categories and refine others was used.

The analysis of Gond *et al.* (2013) identifies 23 classes of forest, but found some of these did not correlate well to known ecological characteristics, and some were successional stages of each other. To improve this, new classes for Marantaceae forest were added using expert input and old aerial photo-based habitat maps[8] and Raphia swamps (from field data combined with image interpretation). Some classes (e.g., open forests, semi deciduous, evergreen, swamps) were merged to create a simpler map that is more informative for existing management practices. The Gond *et al*. data does not cover the entire planning region: an area in the south of Sangha Likouala is excluded. To fill this gap, the predictive map from Dargie et al (2017[9]) was used, which is based on correlating plot samples in peat areas with satellite images. The adapted Gond map with the swamp areas as defined by Dargie was combined to get a map of ecosystems for the whole planning region. Some open forest areas close to human settlements and infrastructure (especially roads and towns) were reclassed as human-modified ecosystems based on image interpretation and Google Earth.

Figure 13 | The final map of forest ecosystems based on a combination of data sources including work by CIRAD (Gond et al 2013) and Leeds University (Dargie et al 2017) together with expert input.



[7] Gond V, Fayolle A, Pennec A, Cornu G, Mayaux P, Camberlin P, Doumenge C, Fauvet N, Gourlet-Fleury S. 2013 Vegetation structure and greenness in Central Africa from Modis multi-temporal data. Phil Trans R Soc B 368: 20120309.

[8] FAO, 1975. Inventaire forestier Nord-Congo Formations vegetales. FAO. (Maps drawn using the 1960s aerial images as the basis for vegetation classification)

[9] Dargie, G., Lewis, S., Lawson, I., Mitchard, E., Page, S,. Bocko Y,. & Ifo, S. (2017) Age, extent and carbon storage of the central Congo Basin peatland complex. doi:10.1038/nature21048

To ensure multiple objectives, including carbon sequestration were considered in scenario analyses (i.e., to attempt to combine biodiversity conservation, climate mitigation and carbon sequestration), the map of carbon stocks developed by the CN REDD, NASA and TGC for the ERP (*Figure 14*) was used. To ensure adequate assessment of the quality of the forest and its associated animal species (i.e., apes, ungulates, elephants) a map of human access for hunting and logging activities was developed in collaboration with CIRAD, FSC, WRI, and WWF (called the Human Pressure Index) (*Figure 15*). This was then used to produce a map of ecosystem habitat quality, developed by combining the ecosystem map, the biomass layer and the human access layer.
Some forest areas (including most National Parks) are actively patrolled to reduce illegal hunting. To consider the level of protection from illegal hunting that is afforded to different forest areas, mapping of eco-guard presence and approximate numbers throughout the entire area of interest, including the logging concessions, the protected areas, and the areas without any form of protection was performed (*Figure 16*).

Figure 14 | Map of biomass stocks (source data: NASA/TGC)

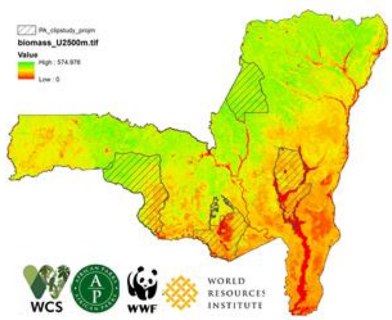


Figure 15 | The Human Pressure Index (Source data: WRI)

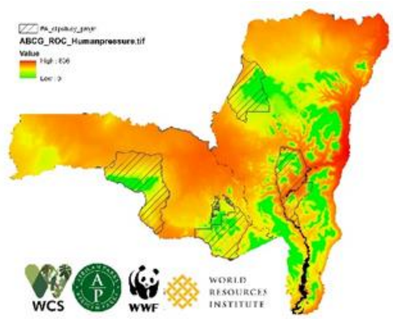
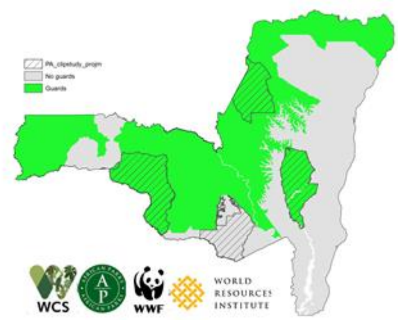


Figure 16 | Current presence of ecoguards (Source data: WCS)



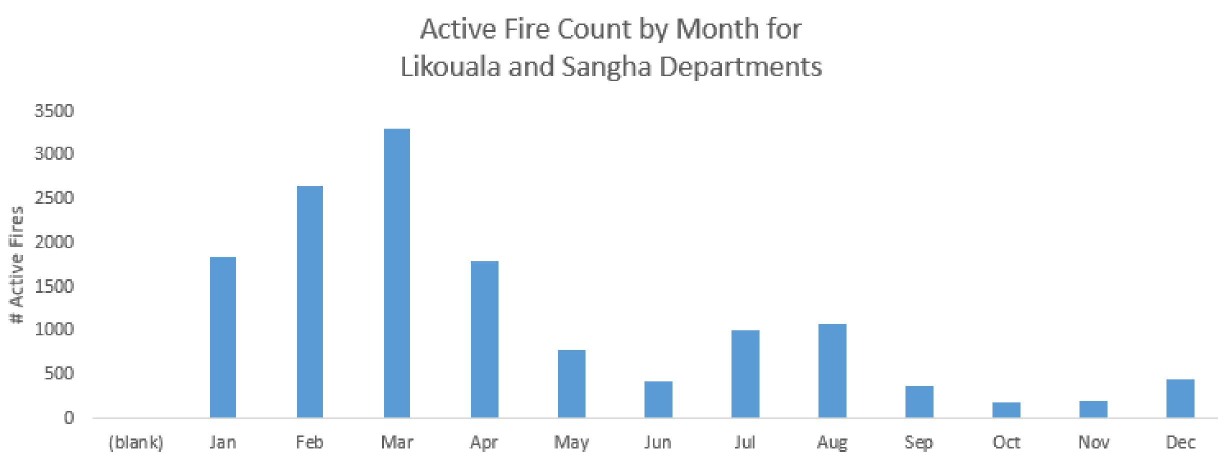
Fires in Northern Congo were analysed for their statistical significance using the ESRI Emerging Hot Spot Tool. A hot spot is an area that exhibits statistically significant clustering in the spatial pattern of fire occurrence. Hot spots are locations where observed patterns are not likely the result of random processes or subjective cartographic design decisions; they represent places where there are underlying spatial processes at work (Ord and Getis 1995). Emerging Hot Spot Analysis extends this definition to incorporate information about the temporal dimension of the data. This tool allows for relatively quick identification of spatiotemporal trends in fire data and provides insight about potential trajectories and locations of future fires.

Two sources of satellite-derived active fire data were available from NASA for this analysis: MODIS and VIIRS. While the VIIRS sensor provides an improved ability to detect night-time fires and relatively small fires, at the time of this study VIIRS data was only available for 2016. The temporal aspect of this analysis benefits from the longer archive of data provided by the MODIS product (2001 to present), thus standard science quality MODIS Collection 6 data from January 2001-April 2016 was used for this study. The Emerging Hot Spot Analysis tool evaluates spatiotemporal patterns in MODIS active fires in the Northern Congo using a combination of two statistical measures: 1) the Getis-Ord Gi* statistic (Ord and

Getis 1995) to identify the location and degree of spatial clustering of forest loss; and 2) the Mann-Kendall trend test (Mann 1945; Kendall and Gibbons 1990) to evaluate temporal trends across the time series. Data is aggregated into bins, which represent the sum of fires that occur within the bin's area and specified length of time. Bins are then arranged into a cube structure with space on the X and Y axis, and time on the Z axis. A one kilometer and one month bin size was chosen for this study, and a five kilometer neighborhood distance was used, representing the average radius of fire corridors in the two departments.

Seasonality of fires was also considered, as fires are typically more intense during certain months of the year. Fires in Likouala and Sangha are more frequent in the months of January through April (*Figure 17*).

Figure 17 | MODIS Active Fire occurrence by month in Likouala and Sangha Departments.

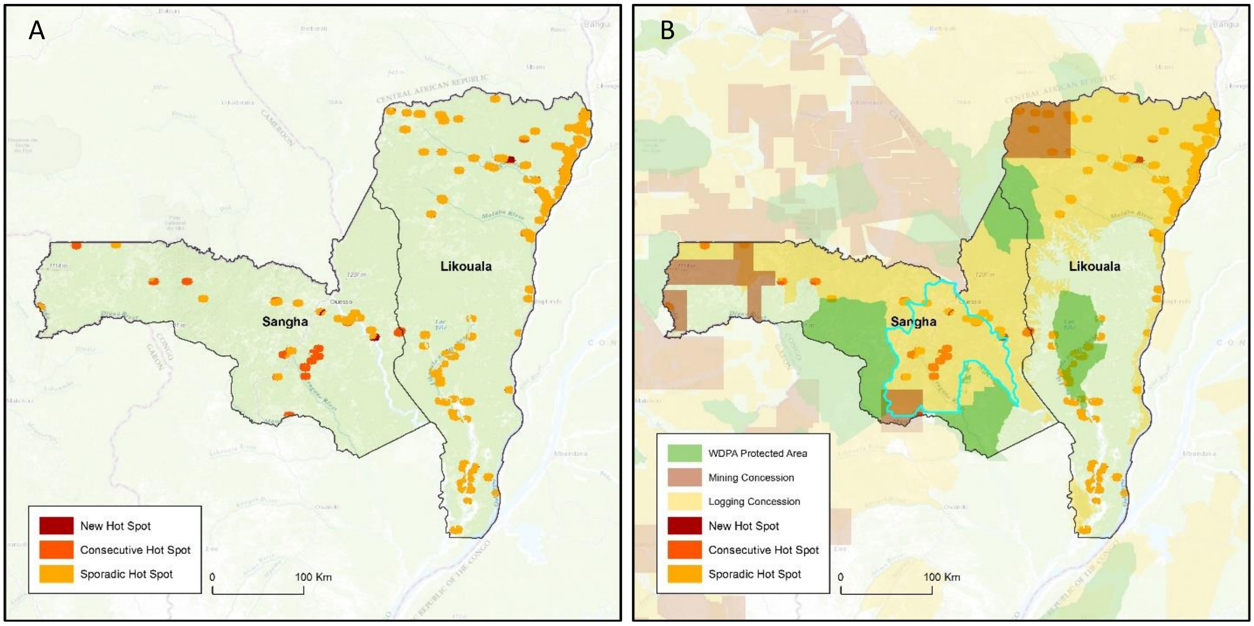


To test the effect of seasonality in the time series trend analysis, a second version of the analysis with only fire occurrences from January to April was run for the sixteen years of data.

Results from the Emerging Hot Spot tool indicate that there are hot spot clusters of active fires during the 2001-2016 time period in both departments. A New Hot Spot represents a location that is new for the last time-step interval (April 2016), but has never been a hot spot before. A Consecutive Hot Spot represents a single, uninterrupted run of significant hot spots in the final time-step intervals, including the last time-step (for example, Jan-April 2016). And finally, a Sporadic Hot Spot is an on-again, off-again hot spot area without a discernible pattern through time. Any area in the departments not identified as a hot spot does not have a statistically significant amount or concentration of fire occurrences through time.

The analysis results reveal linear Sporadic Hot Spots located along the Likouala Aux Herbes River and the Motaba River in Likouala. Emerging Hot Spots overlap with logging concessions in both departments and the large Ngombe fire from early 2016 is identified as a Consecutive Hot Spot. Protected areas are relatively free of hot spots; however, some sporadic hot spots are identified along the Likouala Aux Herbes River in Lac Télé protected area

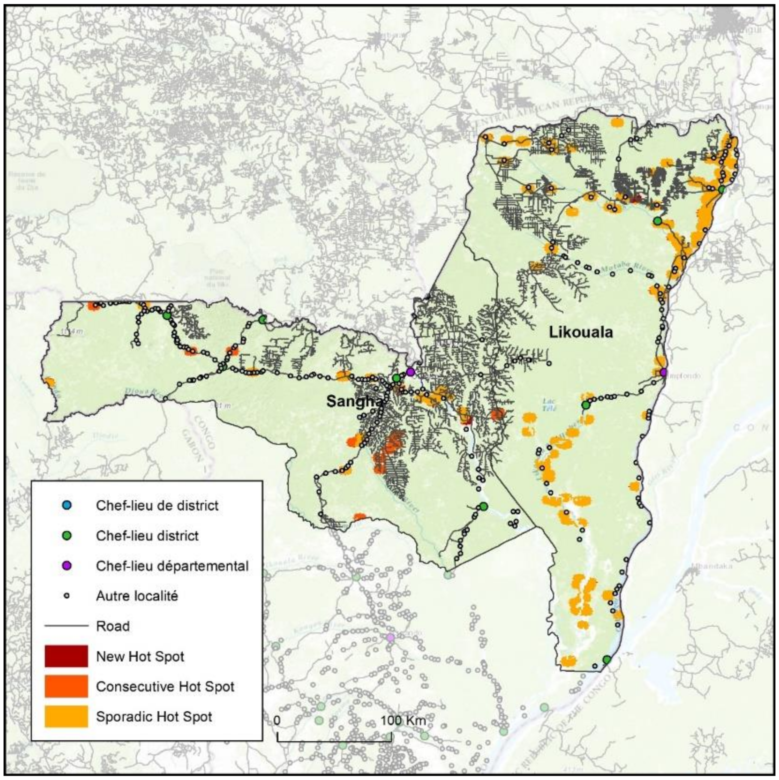
Figure 18 | (A) Emerging Hot Spots for all weeks during 2000-2016 in Sangha and Likouala and (B) Emerging Hot Spots with protected areas, logging concessions, and mining concessions, with Ngombe Concession highlighted.



A number of cities and settlements overlap with Emerging Hot Spot results. In Northern Likouala, many settlements are completely surrounded by Sporadic Hot Spots. Fires in the savannahs of Congo and Gabon are part of the traditional land management by rural communities. Fires are deliberately started, sometimes more than once a year, by the people living in the villages in the Bateke Plateau and the Cuvette area further south, and within the Likouala area in our study area. The purpose of the fires are to facilitate access on foot across the savannahs by removing the long grass, and to encourage young grass growth which attracts wildlife that can then be hunted. In the early 1900s, fire management was more coordinated by local traditional leaders, but this has become a less organised activity in later years (Walters 2015)[10]. These include the county seats of Betou and Enyelle, among others. Emerging Hot Spots appear less associated with settlements in Sangha, although some groupings of cities are surrounded by Sporadic and Consecutive Hot Spots in the western part of the department. Finally, hot spots appear to be more closely associated with settlements and rivers than with roads. A notable exception is in Northern Likouala, where Sporadic Hot Spots follow the road southeast of Enyelle.

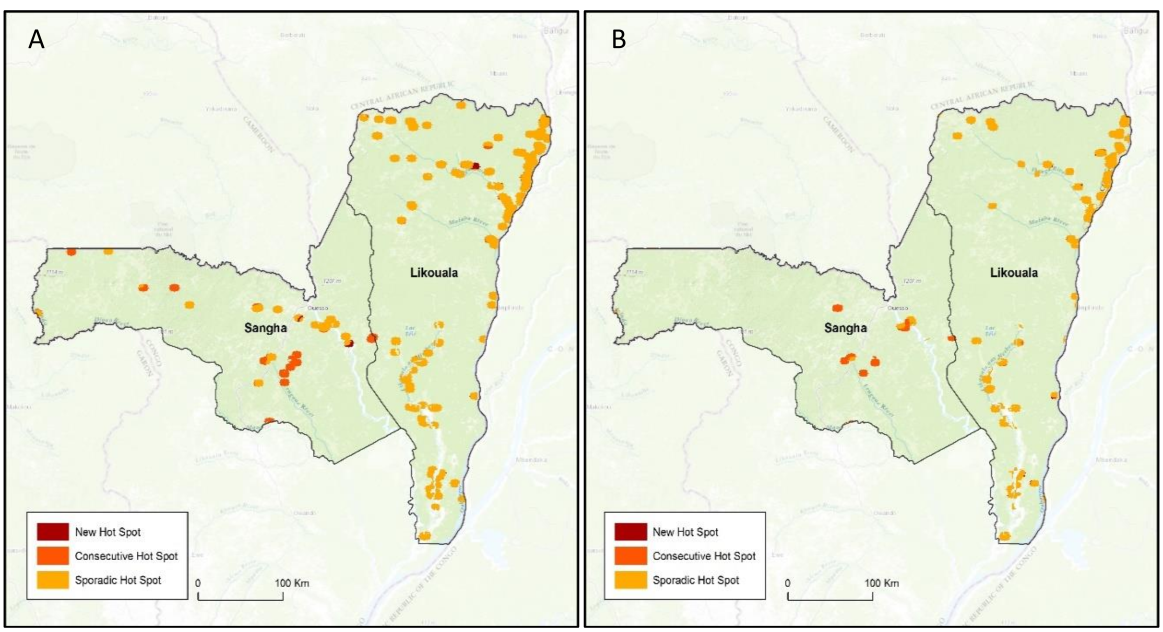
[10] Walters, G., 2015. Changing Fire Governance in Gabon's Plateaux Bateke Savanna Landscape. Conservation and Society 13, 275-286.

Figure 20 | Emerging Hot Spots with settlements and roads.



Overlaying all MODIS fire hot spot points reveal that approximately 3,800 fire occurrences, or half of all points, fall outside the hot spot areas. In this way, hot spots can help prioritize fire prevention efforts by focusing just on fires within hot spots or just areas considered a hot spot. Hot spots account for approximately seven percent of the total area in the two departments.

Figure 19 | (A) Emerging Hot Spots for all months, (B) Emerging Hot Spots for fire season months only (January-April) in Sangha and Likouala Departments.

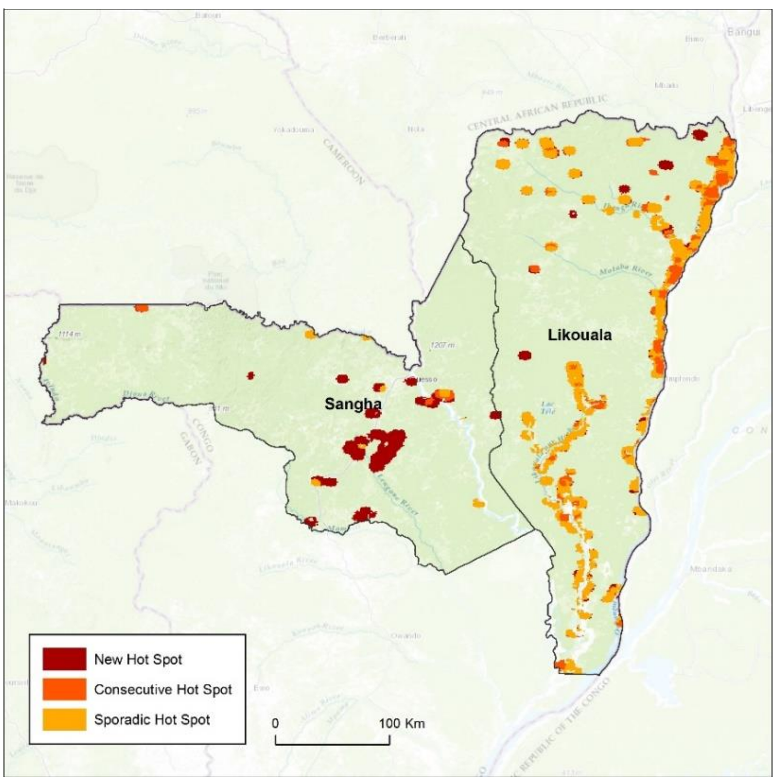


Results from the Emerging Hot Spot tool using the fire season version (January-April) of the data show that a number of areas that were hot spots for the entire dataset do not register as hot spots when just examining the fire season months. Many hot spots associated with settlements disappeared when analyzing only fire season months and therefore are not likely to contribute a significant amount of fires from January to April. Sporadic Hot Spots remained consistent along the Likouala Aux Herbes River and Motaba River.

Using a one-month time step for fire season data provides a useful comparison to the monthly results of the entire dataset and an appropriate temporal scale to understand shorter trends in active fire occurrences. However, a one-year time step allows annual trends to be examined and can be especially useful for planning annual fire prevention efforts. New and Consecutive Hot Spots are especially useful for planning purposes. A New Hot Spot represents could indicate change or otherwise abnormal activity. A Consecutive Hot Spot repeatedly shows up as a hot spot and could do so again in the future. The New Hot Spot for the Ngombe Concession fire is especially prominent in the one-year time step results.

Until the year 2015, the number of fires detected inside Ngombe forest concession oscillated between 20 and 50 fires per year. In 2016 there were 384 fires, of which 231 were associated with the late January fire. This sharp increase in fires is responsible for the large New Hot Spot in the one-year time step analysis results.

Figure 21 | Emerging Hot Spots for fire season years in Sangha and Likouala Departments.



3.1.3 Identify, Prioritize and Assess Land Use Planning Strategies

Identify potential land use planning strategies and their objectives for biodiversity conservation

Within the second stakeholder workshop, the potential mechanisms for the implementation of conservation measures that could be applied within the region was discussed. The discussion included consideration of both regulatory measures and incentives, such as of REDD+ payments and other potential sources of compensation that could be employed to incentivize conservation measures. A summary of the results is presented in Table 3.

Table 3 | Summary of key land use planning strategies for northern Republic of Congo.

Regulatory Options	Opportunities	Constraints
Creation of new protected areas	Increase PA coverage in the zone to the international guideline of 17%	Compensation may be required for land users whose concessions are de-gazetted for the creation of a protected area.
Compensation fund created from levies on major infrastructure or mining projects	Compensation funds are operational in some sectors, notably mining.	Complex to create, and to ensure effective transfer of funds between different sectors.
Incentive measures		
REDD+ payments for performance	Mechanism already forming	Prices based on tonnes of carbon likely to be insufficient to offset opportunity cost of conserving forest.
Tax relief for areas that are conserved (for example, non-payment of area tax on set asides)	Viable incentive mechanism	Government may require compensation for lost tax revenue.
PES (e.g., for water provision services)	Large theoretical potential, especially when downstream urban populations are considered.	No existing mechanisms, and large uncertainties over calculation methods.
Logging concession set-asides	Some forest concessions are certified by Forest Stewardship Council (FSC) that already have set-asides incorporated into management planning. Carbon payments might form part of the incentive for set-asides.	This would mostly be voluntary and can result in large opportunity costs to companies.

Illustration of developmental scenarios

- During the workshop, the idea of scenario building was illustrated for the case of palm oil development in Congo. For illustrative purposes, an analysis of suitable soils for palm oil was used as an example (CIRAD 2015). The analysis shows that large areas of the northern Congo planning region are moderately suitable for palm oil development, and could be brought into production.

- However, scenarios can be envisaged where government regulations are enacted to impose constraints on the area that can actually be developed for palm oil. An example of such a constraint is to forbid deforestation of currently forested land. The analysis of Feintrenie *et al* (2014) shows that even under such a restrictive scenario, there remains more than one million hectares of suitable land available for palm oil development: enough, were it all to be developed, to make Congo the second largest producer of palm oil in Africa without the need for any associated deforestation.

In the end, some of the issues around palm oil were too hard to explore within this project, rather the focus turned to forestry management. The final set of land use planning strategies and scenarios to be explored within this project were:

- Rank areas that maximize the benefits of conservation management across the region for potential new protected areas;
- Identify priority set-aside areas within each concession that maximize conservation objectives but are planned in a coordinated manner; and
- Compare alternative levels of harvesting reduction across forestry concessions.

Prioritize Application of Land Use Planning Strategies through Scenario Analysis

Spatial prioritization is the process of identifying the areas likely to have the highest combined value for achieving one or more objectives, so that conservation actions can be targeted to these areas. This project has generated prioritization analyses by applying an analysis tool called ZONATION. The selection of priority sites was based on maximizing high species densities, high biomass (and thus high potential for carbon storage) and the best possible representation of the different forest ecosystems. Another criterion was to ensure connectivity between highly ranked areas and with existing protected areas where possible. The results of the prioritization identify areas that are the richest in terms of forest carbon *and* forest biodiversity, while ensuring that all species and ecosystem types are represented in the priority conservation areas.

The selection of priority sites can be weighted using other criteria, such as the feasibility that a site could be effectively protected, or the type of management unit in which a site is located. Several iterations of the prioritization maps were made, adjusting the weighting accorded to different selection criteria that were linked to alternative land use strategies. For example, Figure 22 shows a prioritization of the richest areas using a strategy of selecting the best sites based on *proximity to protected areas* in addition to biodiversity and carbon values. In this way a data point is more likely to be selected by ZONATION if it is near an existing national park.

These results emphasize the importance of sites near existing protected areas, in effect reducing the priority of sites in other parts of the landscape. The top-ranked sites (the best 25 percent for biodiversity and carbon by area) are shown in Figure 23 below.

Figure 22 | Prioritization of sites for conservation using proximity to protected areas as a determining site selection criterion.

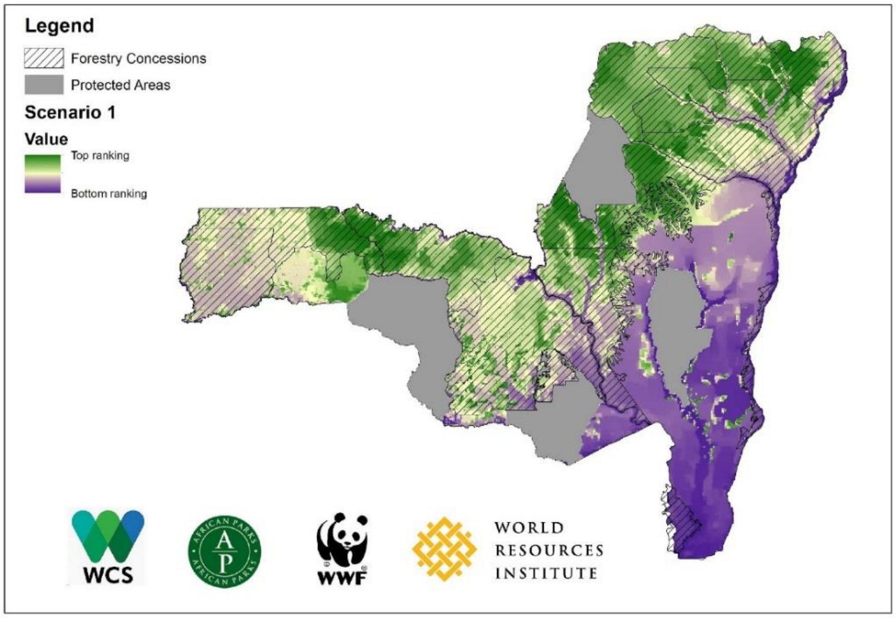
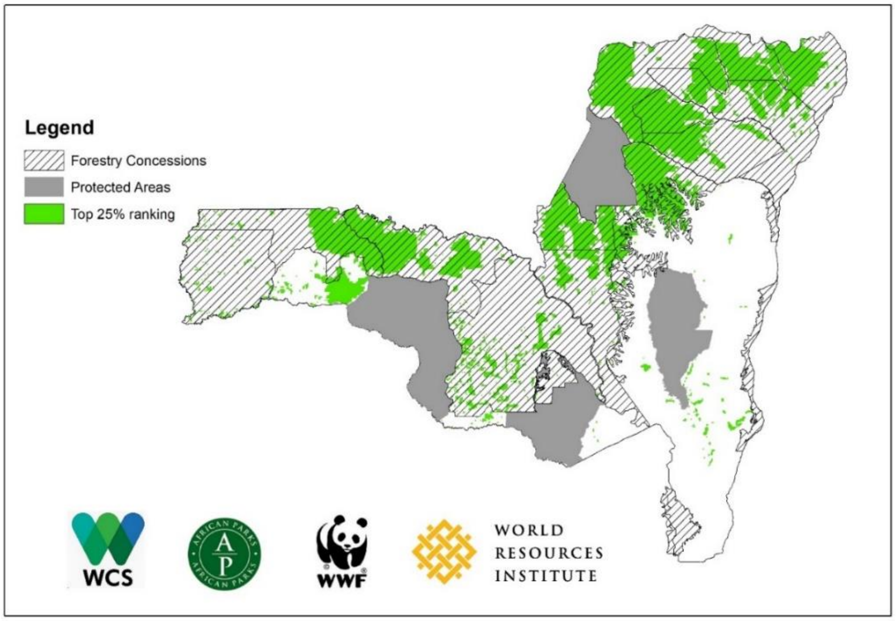


Figure 23 | Top 25 percent ranked areas for conservation using proximity to protected areas as a determining site selection criterion (Scenario 1). Green areas indicate those with the highest priority for conservation value.



While valuing connectedness to existing large protected areas may make good sense from an ecological point of view, it raises concerns of equity between land users. This is because if Figure 23 was to be used for the selection of new conservation areas, the burden of conservation would fall on a few management units unless those concessions were able to be purchased.

The land use strategy in Figure 24 below includes an 'equity function' where the best sites are selected within each management unit, but regardless of their proximity to protected areas. The final selection of priority sites is more equitably distributed though the landscape, and, as such, it ensures that each management unit plays a more equal role in conserving some of the priority biodiversity sites.

Both of these approaches to priority setting have value, and both should be considered as potential options. The feasibility of implementation of conservation measures in the prioritized sites is a necessary consideration for the way in which these results should be used.

Figure 25 | Prioritization of sites for conservation using equity between management units as a selection criterion (Scenario 2). The best sites within each management unit are selected.

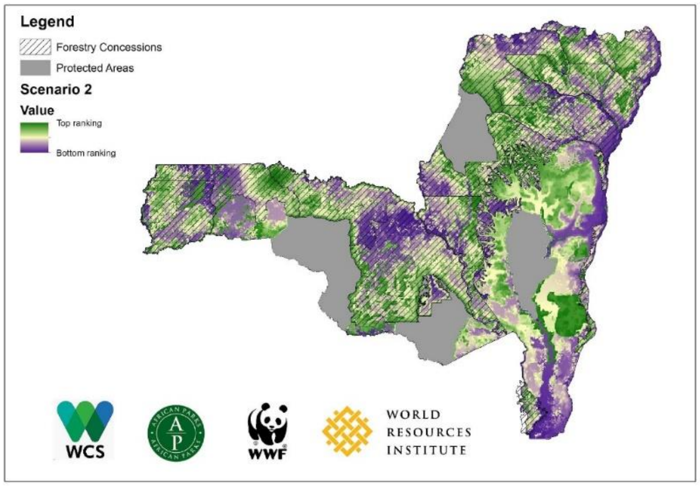
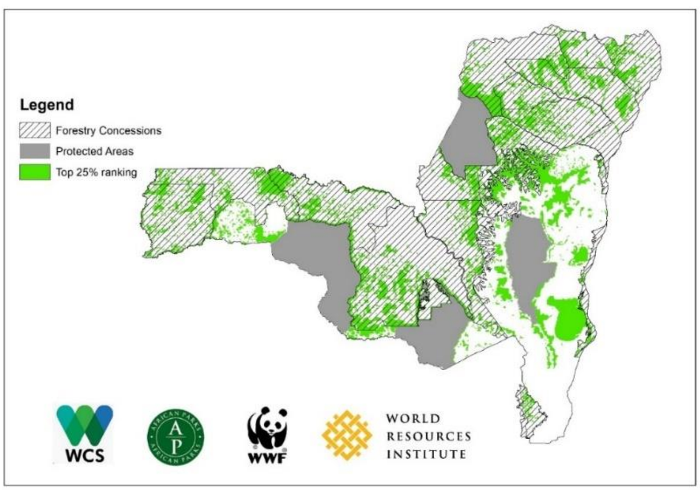


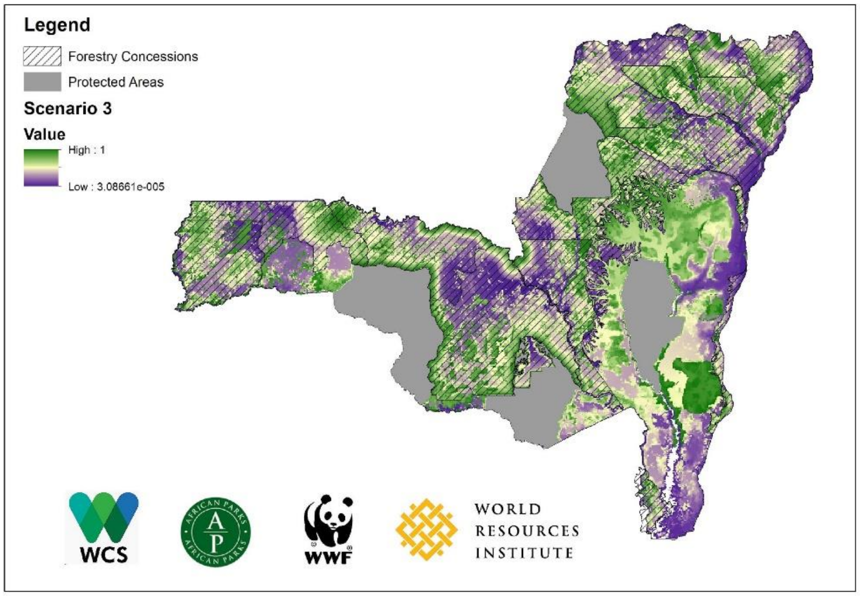
Figure 24 | Top 25 percent ranked areas for conservation using equity between management units as a selection criterion (Scenario 2). The best sites within each management unit are selected.



Prioritizing within Intact Forest Landscapes

In a further iteration of the priority setting process, a specific investigation looking for priority sites within the remaining portions of Intact Forest Landscapes (IFL) in the Sangha Likoula planning region was conducted. Figure 26 shows the results of the priority setting analysis where Intactness is used as a weighting factor for the selection of the priority sites (here, proximity to protected areas and equity were also prioritized).

Figure 26 | Prioritization of sites for conservation using Intact Forest Landscapes as a selection criterion. This analysis emphasizes the importance of IFLs to conservation across the landscape



The results of prioritization example three show that the prioritization process is effective at capturing the parts of IFL with the highest biodiversity and carbon value. The results from example two and three are not significantly different. The other parameters in the analysis appear to ensure intact or less disturbed areas are already selected as a matter of course. The prioritization process with ZONATION appears to be an effective way to select the highest priority areas within IFLs.

Assess land use planning strategies and scenarios with stakeholders and against landscape performance metrics

To add another dimension to the prioritization process, this work also examined the impact of future developments on biodiversity and other values (e.g., carbon). At this stage considerations have only been made to the expansion of logging activity across the region, and changes to the practice of forest management in the future development scenarios, due to a lack of data on other likely changes to the landscape. However, it is also possible to use these data and the modelling approach to estimate other impacts, for example of industrial agriculture developments on biodiversity and carbon, if future concession boundaries were available.

Three future development scenarios were explored. The first scenario is the “business as usual” scenario: the continuation of historic logging activity without the creation of set-asides for conservation of wildlife or carbon, leading to a steady depletion of forest biomass and a resulting decline in animal abundance. The scenario assumes logging results in a depletion of forest biomass of 10 percent[11] for

[11] See: Pearson et al (2014) *Carbon emissions from tropical forest degradation caused by logging*. Environ. Res. Lett 9 034017

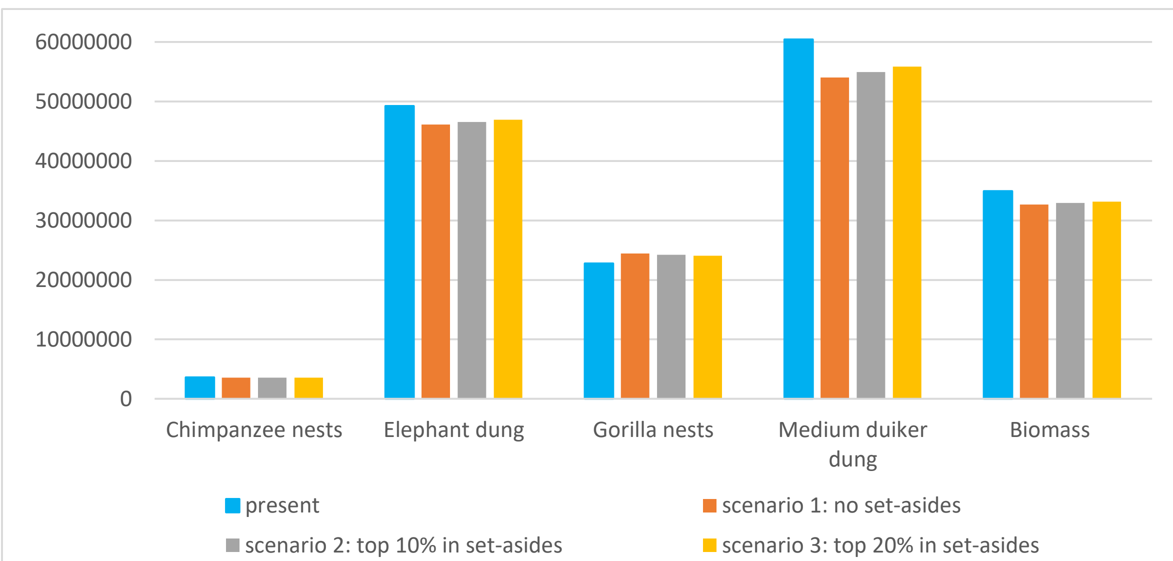
each ecosystem type, with no forest set aside from logging. Species densities are re-calculated based on the observed relationship between forest biomass and species abundance for each ecosystem type.

As selected by the prioritization approach above, the second scenario assumes the best 10 percent of each concession is placed in conservation areas or set-asides (known as *series de conservation*) and not subjected to logging, with continuation of logging outside of set-asides. The third scenario increases the portion of set-asides (*series de conservation*) to the top 20 percent of high carbon, high biodiversity areas.

The project used the species density models to show the beneficial effects of this optimistic future scenario on predicted animal populations. Further calculations could show the carbon sequestration benefits of such an approach.

The scenarios show that future land use management decisions that deliberately seek to conserve high biodiversity and high carbon forests by implementing set-asides in forestry concessions could retain more of the current biodiversity and forest carbon stocks (*Figure 27*). Under the business as usual scenario that allows logging across the entire landscape without set asides, elephant densities fall by 6.3 percent, ungulate densities by 10.6 percent and forest biomass by 6.5 percent. When the best areas for carbon and biodiversity are set aside from logging, losses across the landscape are reduced to 4.6 percent, 7.6 percent and 5.0 percent.

Figure 27 | Results of alternative logging scenarios where no set asides are implemented (red) versus 10 percent or 20 percent of high priority sites protected from logging (green and purple). Numbers are total values of dung or nests under each scenario.



3.1.4 Land Findings and Recommendations

There are five main results areas:

1. Key datasets that were derived for this project have individual merit, as well as being key for spatial prioritization analysis.
    a. The modelling of the distribution and density of certain species of conservation importance across the landscape, based on the extrapolation of field survey data.
    b. The creation of an updated map of forest habitats for planning purposes at the jurisdictional scale
2. Key results from the spatial prioritization analysis were
    a. The identification of the areas that are high in forest carbon and rich in high conservation value species (prioritization) that might be further explored as new protected areas.
    b. The consideration of implementation options to enhance the protection of forest carbon and biodiversity within forest concessions, possibly through the implementation of the ERPD
3. The modelling of the impacts of different future scenarios were able to be achieved by combining this with models of species abundance across the landscape. This was through management interventions part of these species density models.

The findings show that:

1. Despite the remoteness of the area, detailed planning of land use on the basis of forest habitat type, forest biomass and animal species density is now possible. The data on species and forest habitats forms a useful complement to those data already brought together for the ERP, and should now be included in the planning and execution of emissions reduction activities in the departments of Sangha and Likouala.
2. The results of the modelling can be used to identify the highest priority areas for forest carbon and biodiversity. These maps should guide the implementation of certain actions under the ERP, notably the selection of additional set aside areas in forest concessions and the creation of new protected areas.
3. The results of future scenario monitoring present a convenient baseline from which to judge the future success of measures planned under the ERP for the conservation of forest and biodiversity.
4. A range of incentives, including but not limited to direct payments for emissions reductions, are possible to promote the protection of additional forest lands. These options include tax reductions on land users and compensation payments levied from major infrastructure development projects and agro-industry.

Potential Next Steps for Project

The products from these different analyses are intended to inform choices about future developments within the North Congo landscape under the ER Program. These results show the areas that represent the best possible options to maximize biodiversity conservation and the safeguarding of carbon stocks. The examination of future development scenarios shows the ways in which land management decisions can influence this potential, and provides a series of quantitative benchmarks by which to judge the positive and negative impacts of these choices.

The project recommends that these spatial planning processes, and the indicative results presented here, could be used to identify additional conservation areas in the North Congo ERP Landscape. The priority sites indicated in the results should be considered as priorities for set aside from commercial activities. Carbon payments, and other incentives could be targeted to these areas to support their long-term protection.

This analysis could be expanded to national scale, to facilitate the full development of the PNAT in a way that adequately considers carbon stocks and biodiversity value.

3.2 DEMOCRATIC REPUBLIC OF CONGO

3.2.1 Stakeholder and Expert Inputs

There have been two workshops within the project. The first one in July 2016 started with a visioning exercise to identify different stakeholders visions for the landscape and its land uses. From the workshop delved deeper into what specific more specific strategies and conservation objectives can be identified for different land uses. It also reviewed data availability.

The second workshop in August 2017 focused on reviewing the draft results of different scenarios of prioritizations and received valuable input on reviewing the analysis. It also provided training for participants to help them understand the technical tools and how to use them. This included hands-on exercises running different scenarios of prioritization analyses.

3.2.2 Context for Scenario Development

Planning issues and drivers and actors of change

JGI and its partners have initiated a project to promote spatial planning concepts and processes with government and community institutions in eastern Democratic Republic of Congo (*Figure 28*). This case study aims to help to preserve functional ecosystems to maintain biodiversity and services in Eastern DRC while accounting for key threats to species and ecosystems. The case study seeks to support the land use planning in DRC through providing tools and analyses of priorities across landscapes subject to multiple processes of change (e.g., hunting, deforestation, human warfare, and mining).

Spatial ***prioritizations*** that show the most important areas to conserve that support key ecosystem processes and functions given current knowledge of threats across the landscape (forest degradation, human hunting pressure and conflict) were developed. These prioritizations build on existing momentum from a recent coordinated conservation action plan (CAP) for great apes in Eastern Democratic Republic of Congo (DRC), and can inform choices on, for example, the locations of investment in enforcement activities to protect key species responsible for ecosystem functioning from illegal clearing and poaching, or locations to encourage investment in improving agricultural returns or market access. Prioritizations will also be informed by ***future scenarios*** that attempt to quantify the potential impacts of human development activities detrimental on the environment, in particular artisanal mining. By quantifying the consequences of development activities, human development goals can be reshaped to accommodate and protect biodiversity conservation priorities and carbon benefits.

Figure 28 | Study region within the Democratic Republic of Congo.

Threats

In the first stakeholder workshop JGI had experts list factors most likely to degrade the value of a planning unit for supporting biodiversity, carbon, and associated ecosystem function. These were: a) forest degradation and fragmentation (reduces biodiversity condition, e.g., through edge effects); b) human access along infrastructure routes (places closer to roads are more degraded due to access by humans for agriculture, logging and hunting, up to a threshold of ~20 km); c) mining; and d) conflict due to human warfare. Both mining and conflict degrade ecosystems but more importantly impact certain animal species, such as great apes, negatively due to hunting associated with mining camps. With this information, available maps of ecosystem condition related to forest degradation (determined from fragmentation analysis using the methods of Shapiro and colleagues 2016[12]) were collated, the relative forest condition is calculated as a proportion of maximum potential biomass for that forest type; (*Figure*

[12] Shapiro, A.C., Aguilar-Amuchastegui, N., Hostert, P. and Bastin, J.F. (2016) Using fragmentation to assess degradation of forest edges in Democratic Republic of Congo. *Carbon balance and management*, **11**: 11.

29), human access for resource extraction (WRI FSC Human Pressure Index), warfare conflicts[13] (*Figure 30*), and mining[14]. Each ecosystem function surrogate could be impacted by either an independent threat (e.g., just forest fragmentation impacts sunbirds) or combined threats (e.g., conflict, mining, human access for hunting and forest degradation all impact great apes; Figure 31).

Figure 29 | Condition of biodiversity related to forest fragmentation and degradation.

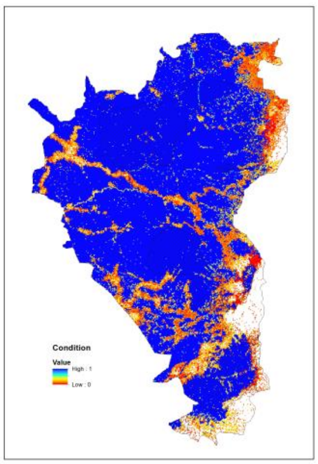


Figure 30 | I Condition of biodiversity related to conflict and human warfare.

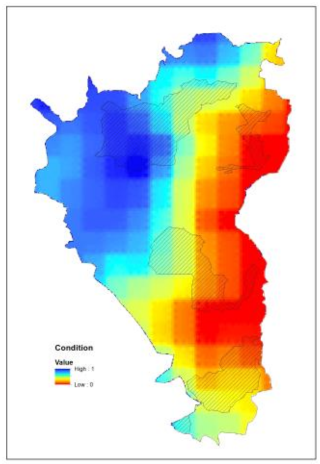
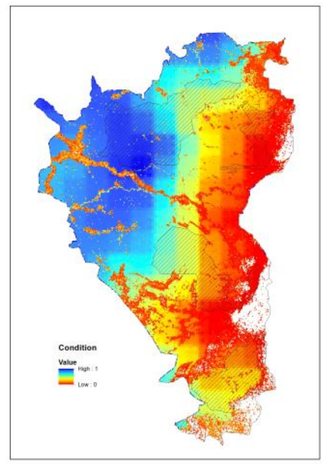


Figure 31 | Condition of biodiversity related to cumulative impacts of forest degradation and human warfare conflict.



Vision and Planning Goals

There were several alternative visions discussed at the first workshop. Most of these discussed the importance of community-based approaches to conservation and development essential for improving the situation in the region. The landscape goals focused on:

1. Improving the populations of megafauna species, particularly the great Apes within the region;
2. Maintaining ecological function of intact ecosystems;
3. Improving livelihoods and ensuring sustainable development; and
4. Sustainable industry, particularly around forestry and mining.

[13] Hammill, E., Tulloch, A.I.T., Possingham, H.P., Strange, N. & Wilson, K.A. (2016) Factoring attitudes towards armed conflict risk into selection of protected areas for conservation. *Nature communications*, **7:** 11042.
[14] International peace information service (IPIS). (2018) DRC mining site data. URL:http://geo.ipisresearch.be/geoserver/web/wicket/bookmarkable/org.geoserver.web.demo.MapPreviewPage?1 (accessed 8.10.18).

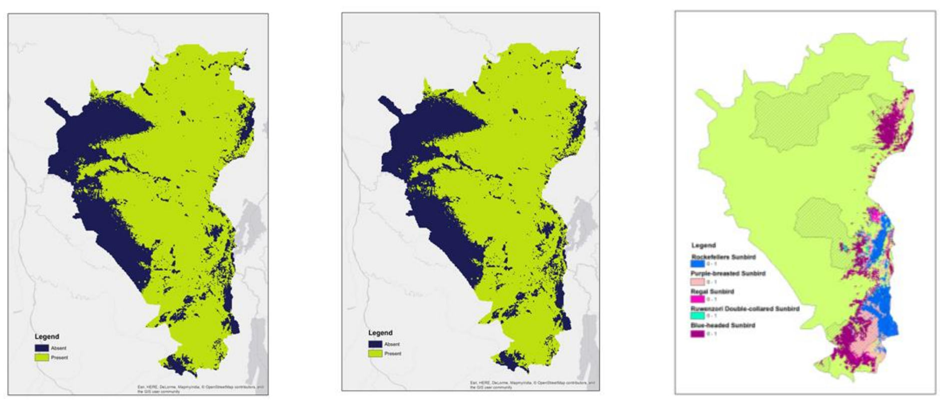
Landscape Characterization

Species

This case study compiled all available distributional maps for species that exist in the landscape, including models of distributions from a previous prioritization process (CAP for Great Apes). The study went through an assessment process to assign each species to one of 11 established ecosystem functions (Table 4) including pollination and seed dispersal (*Figure 32*), climate, energy and nutrient regulation, and biological control. While the preservation of ecosystem function is important, the study acknowledge that ecosystem function does not always directly equate to diversity[15].Therefore, the study ensured that multiple species were assigned to each established function, and that iconic species with an IUCN threat status above “Near Threatened” that are of high importance for conservation were included. This included a Chimpanzee (*Pan troglodytes troglodytes)* model developed by the JGI (unpublished) representing the probability of occupancy, Grauers gorilla (*Gorilla beringei graueri*), Forest elephant (*Loxodonta africana cyclotis*), Hippo (*Hippopotamus amphibius*), Lion (*Panthera leo*) and the Spotted Hyena (*Crocuta crocuta*). By using species that represent ecological function and are of high importance for conservation the aim was to prioritize areas that had value towards both of these objectives simultaneously.

Figure 32 | Maps of ecosystem pollination and dispersal surrogates compiled across planning region for: a) Chimpanzee; b) Gorilla; and c) five species of Sunbirds.

a) b) c)



[15] Schwartz, M.W., Brigham, C.A., Hoeksema, J.D., Lyons, K.G., Mills, M.H., Van Mantgem, P.J., 2000. Linking biodiversity to ecosystem function: implications for conservation ecology. *Oecologia,* **122**:297–305.

Table 4 | Ecosystem Functions.

Function	Description	Example of surrogate
Climate regulation	Influence of ecosystems on climate	Aboveground biomass (carbon sequestration)
Disturbance regulation	Influence of ecosystem attributes on environmental disturbances	Intact high-condition ecosystems
Water regulation	Role of ecosystems in regulating runoff and river discharge	Intact high-condition ecosystems
Energy/Nutrient regulation	Role of ecosystems in the transport, storage and recycling of nutrients and energy	Intact high-condition ecosystems, Okapi, Hippopotamus
Pollination/Dispersal	Role of biota in movement of floral gametes, seeds or spores, eggs and larvae	Sunbirds, Elephant, Chimpanzee, Squirrels
Biological control	The interactions within biotic communities that act as restraining forces to control population of potential pests and disease vectors	Lion, Congo Bay Owl, Spotted Hyena, Okapi
Barrier effect of vegetation	Vegetation/structures impedes the movement of airborne and waterborne substances such as particulate matter, dust and aerosols, enhances air mixing and mitigates noise	Intact high-condition ecosystems
Supporting habitats	Preservation of natural and semi natural ecosystems as suitable living space for wild biotic communities and individual species. This function also includes the provision of suitable breeding, reproduction, nursery, refugia and corridors (connectivity)	Ecosystem types
Food	Biomass that sustains living organisms. Material that can be converted to provide energy and nutrition.	Aboveground biomass,
Raw materials	Biomass used by organisms for any purpose other than food	Aboveground biomass
Provision of shade and shelter	Relates to vegetation/structures that ameliorates extremes in weather and climate at a local landscape/seascape scale	Aboveground biomass, high-condition ecosystems

3.2.3 Identify, Prioritize and Assess Land-use Planning Strategies

Land Use Planning Strategies and Their Objectives

Land use planning in this region of eastern DRC is complicated by conflict, land use rights and a lack of governance. For this project, focus was on identifying strategic areas for broad conservation actions such as where NGOs can focus their efforts for the biggest likely benefits through participatory land use planning with communities, or through advising government on management of existing protected areas. This was quite different to the ROC case study which focused on much more specific land use strategies.

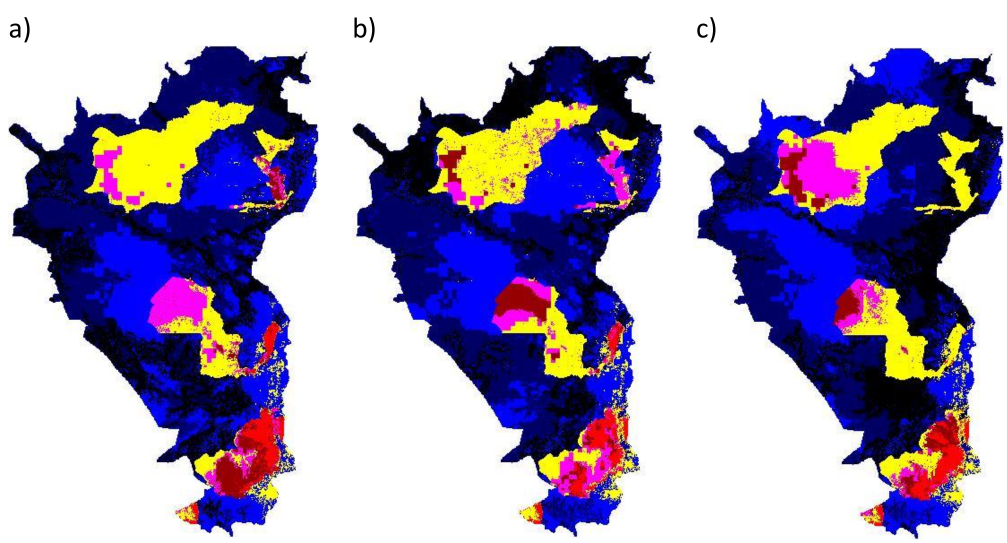
Spatial prioritization scenarios of land use and management

Prioritization Based on Protection of Ecosystem Functions

Spatial prioritization is the process of identifying the areas likely to have the highest biodiversity value, so that conservation actions can be targeted to these areas. Examples include selecting candidate areas for new national parks, or allocating enforcement patrols to sections of protected area estate with high conservation value and low risk of conflict.

This project has generated priority zoning for conservation by accounting for individual species distributions, ecosystems and carbon storage, and their degradation due to deforestation, hunting and conflict to identify broad priority areas for further assessment of the specific management actions needed (*Figure 33*).

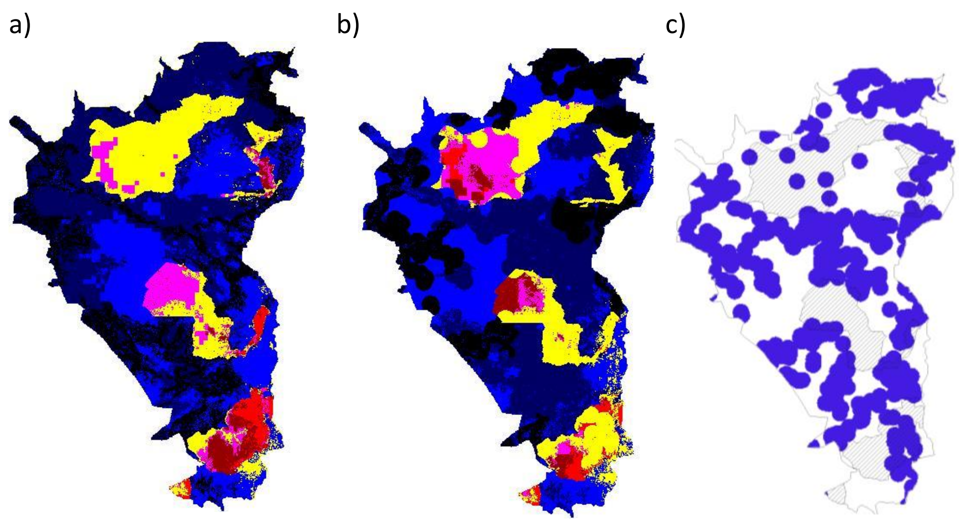
Figure 33 | Conservation priorities under: a) baseline scenario where only deforestation and road access reduce condition; b) areas with chimpanzees have higher priority than others; and c) conflict-prone areas are avoided for conservation (pink/red areas = high conservation priority, blue/black = low conservation priority). Protected area estate is ranked higher than unprotected sites.



To add another dimension to the prioritization process, the project examined the impact of future developments or conservation actions on biodiversity and other values (e.g., carbon). Four future scenarios were developed through consultation with landscape planning and conservation experts at the first and second stakeholder workshops: a) local-scale mine degradation of only vegetation around existing mines; b) broad-scale mine-associated hunting of certain species (e.g., apes) up to 20 km from the mine; c) local- and broad-scale species and vegetation impacts of existing mines and associated hunting; and d) ecosystem degradation in all current mining concessions including those without current mines.

The first scenario degrades condition of ecosystems and carbon at distances up to one kilometer from the mine, and results in lower conservation priorities in these areas (*Figure 34b*). The second scenario degrades condition of habitat for species at distances up to 20 kilometers from the mine, and results in lower conservation priorities in these areas. The third scenario combines the impacts of Scenarios 1 and 2. The forth scenario reduces the condition of all mining concessions by 50 percent, and moves priorities away from some areas at risk of heavily degradation.

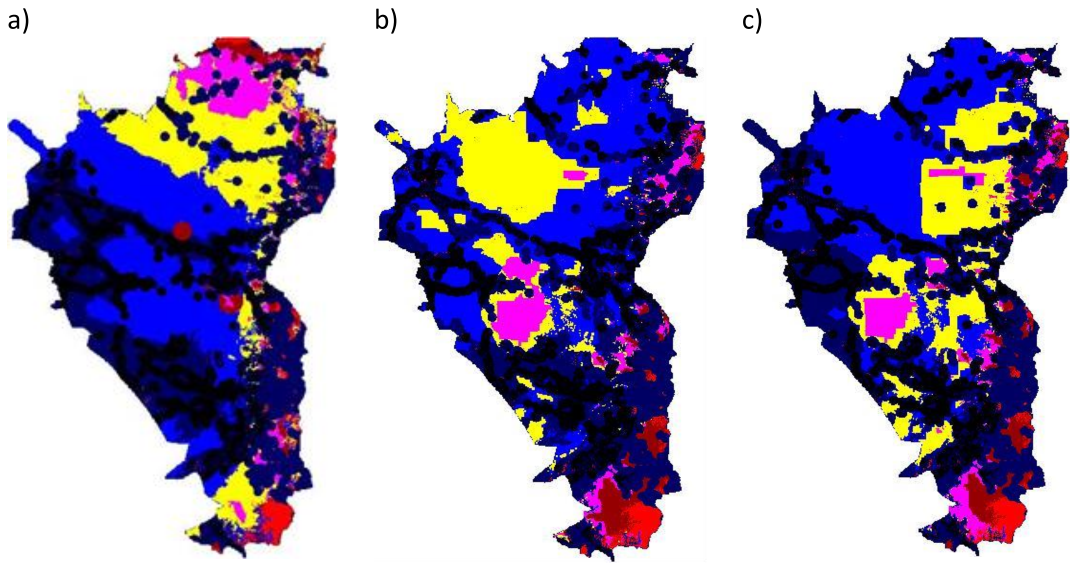
Figure 34 | Conservation priorities under: a) baseline scenario; b) mine-associated hunting scenario (pink/red areas = high conservation priority, blue/black = low conservation priority). Protected area estate is ranked higher than unprotected sites; and c) locations of all artisanal mining sites open between 2009 and 2016.



Prioritization Based On Protection of Species at Risk from Hunting

Additionally, the project explored the different ways in which conservation priorities might change when threats to biodiversity that exist within the landscape are viewed differently. Focus was put on the additional hunting pressure that exists from mining and conflict within the region. The project found priority areas for conservation based on the distribution of species that are likely to be hunted, that is, species within the classes Carnivora, Cetartiodactyla, and Primate. Compared to a baseline (*Figure 35a*), priorities for conservation change when you avoid areas that are at risk of hunting (*Figure 35b*), or when you accept that although the risk is present, there is still conservation value present within an area (*Figure 35c*). By providing stakeholders with a variety of outputs from scenarios that explore questions asked in different ways, initiatives or actions based on their own informed conservation goals and values may be implemented.

Figure 35 | Conservation priorities under a (a) baseline scenario where only deforestation and road access reduce condition (b) areas at risk from hunting from artisanal mining and areas of conflict are avoided (c) this risk is accepted and acknowledged that there may still be conservation value within areas that have this additional hunting pressure (pink/red areas = high conservation priority, blue/black = low conservation priority). Urban areas are avoided, and protected area estate is not considered here.

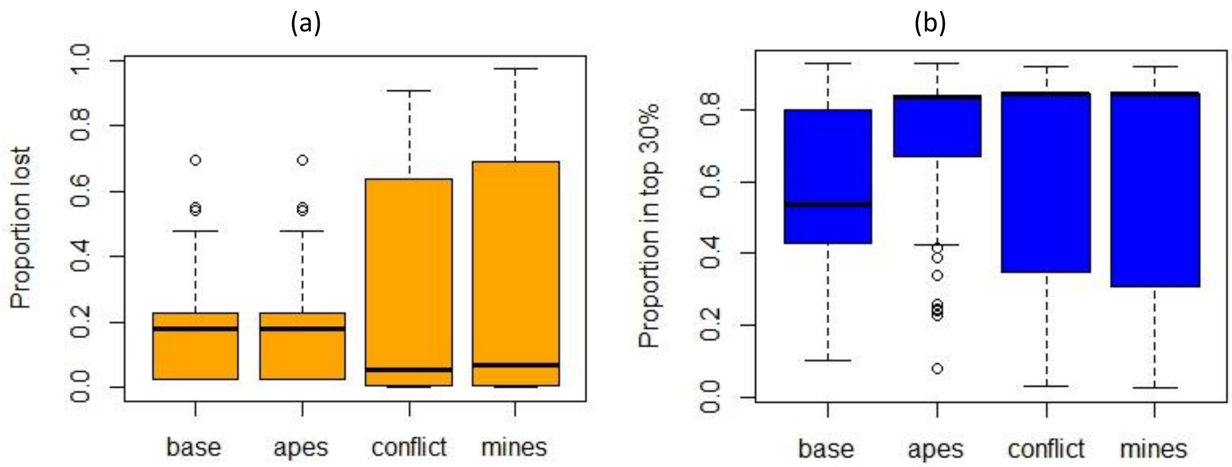


Assessment of Scenarios with Landscape Performance Metrics

The project used the outputs from spatial prioritizations to show the beneficial or negative effects of alternative scenarios on predicted biodiversity distributions, associated ecosystem function and total carbon sequestration, across the region. The scenarios show that on average, up to 70 percent of the distributions of remaining species and ecosystems are impacted by the combined impacts of hunting and forest degradation (Figure 36a, base scenario), but strategic enforcement efforts in the top 30 percent of priority areas could protect on average 57 percent of all distributions (Figure 36b, base scenario).

Scenario analyses also show that accounting for conflict or mine-associated deforestation and hunting impacts on biodiversity and carbon leads to higher loss of species and ecosystem distributions (*Figure 36a*) and lower representation of features in the top priority areas (*Figure 36b*) than in the current baseline prioritization.

Figure 36 |Impacts of alternative conservation planning scenarios on the proportion of features: a) lost entirely under different combinations of threatening processes; and b) represented in the top 30 percent of priority areas



3.2.4 Land Use Recommendations

Summarize Findings and Make Recommendations

The products from these different analyses are intended to inform choices about future allocation of conservation efforts and possible opportunities for ecotourism development within the eastern DRC region, and to provide a framework for future land use planning in other high-risk regions. The results of the first prioritizations show the areas that represent the best possible options to maximize biodiversity conservation and the safeguarding of carbon stocks, and the places with the lowest risk of activities likely to degrade biodiversity (the mining scenario), or risk human lives (the conflict scenario). The final prioritizations highlight how the formulation of conservation problems in slightly different ways yield very different solutions. The examination of alternative scenarios provides a series of quantitative benchmarks by which to judge the positive and negative impacts of different resource allocation choices.

3.3 TANZANIA

3.3.1 Stakeholder and Expert Inputs

There were two main workshops for the project.

Workshop 1

In April 2017, 22 workshop participants representing four ABCG member organizations, four government ministries, and three organizations specializing in agriculture, forestry, water resources convened for the first stakeholder workshop in Mbeya, Tanzania. It was hosted by AWF and WCS. The complete Mbeya workshop report, *ABCG Tanzania Land Use Planning Workshop Report* is available on the ABCG website.

Stakeholders presented work by various organizations in the region emphasizing biodiversity, water services, agricultural land, SAGCOT, pilot planning exercises, and an analysis of drivers of land use change. Collectively these presentations provided a situational analysis of the region followed by an open forum to discuss and prioritize key land use planning issues. A key finding was that much of the land outside protected areas is managed by villages, but only 13 percent of Tanzania's villages had undergone a process overseen by the Tanzania National Land Use Planning Commission (NLUPC) to create village land use plans.

To guide development of scenarios of future change to incorporate into land use planning breakout groups formulated a set of 16 potential objectives spanning the following six themes: 1) Livelihoods/economic development; 2) biodiversity; 3) water; 4) governance; 5) capacity; and 6) scale of planning. Guided by a set of questions, stakeholders then tried to match objectives with data sets or potential source contacts/organizations.

Based on the objectives, the team formulated nine rough planning focal areas representing stakeholder goals for further exploration in term of feasibility considering data requirements and assimilation into prioritization analysis. Of these they felt four could be immediately addressed considering available data:

1. Protected area effectiveness: Reduced effectiveness in some/all protected areas due to increased human population pressure and unsustainable hunting
2. Change in technology: Irrigated versus rainfed agriculture. Would that increase productivity?
3. New crop type (not currently targeted for investment)
4. Climate change (e.g., rainfall change or drought) affecting crop yields + ecosystem persistence (or climate change effect on water availability)

Workshop 2

Recognizing the critical planning role of the Tanzania National Land use Planning Commission (NLUPC), the second Tanzania case study workshop was co-hosted by NLUPC, AWF, and WCS. Participants gathered in Morogoro representing government ministries (e.g., TANAPA), conservation organizations (e.g., Southern Tanzania Elephant Program, TNC), NGOs (e.g., Sokoine University, Tanzania Water

Resources Integration Development Initiative), and private sector interests (e.g., Iringa Farmers Development Organization). The workshop convened 27 participants from government and development and conservation NGOs representing 23 organizations.

As all but a few attendees had not participated in the Mbeya workshop, this workshop invested a significant amount of time reviewing the following components:

- Planning framework goals and process;
- Workshop 1 from situational analysis through to questions/objectives stakeholders agreed on in to guide scenario model construction;
- Key datasets compiled to create the scenario models; and
- Key concepts and principles of systematic conservation planning using Marxan.

The project presented findings from another stakeholder driven, scenario modeling approach led by PBL Netherlands Environmental Assessment Agency and EcoAgriculture Partners targeting the Kilombero area, a landscape within the broader ABCG Tanzania case study area. Their process aimed to help stakeholders achieve multiple Sustainable Development Goals (SDGs) through integrated landscape initiatives; AWF played the role of landscape facilitator. A 'green growth' or integrated landscape scenario outperformed a business as usual scenario in offering more agricultural productivity, cleaner and more abundant water resources, more robust wildlife/biodiversity and far greater prospects for a sustainable future to 2030 and beyond. A multi-stakeholder platform emerged from the process to work towards landscape ambitions informed by the integrated landscape scenario.

The project presented the ABCG scenario outputs constructed to address and interpreted the results. Participants posed many questions about the results and implications. Much discussion of next steps tilted towards SAGCOT and the NLUPC as key stakeholders. Potential collaborations emerged from the discussions as the workshop closed.

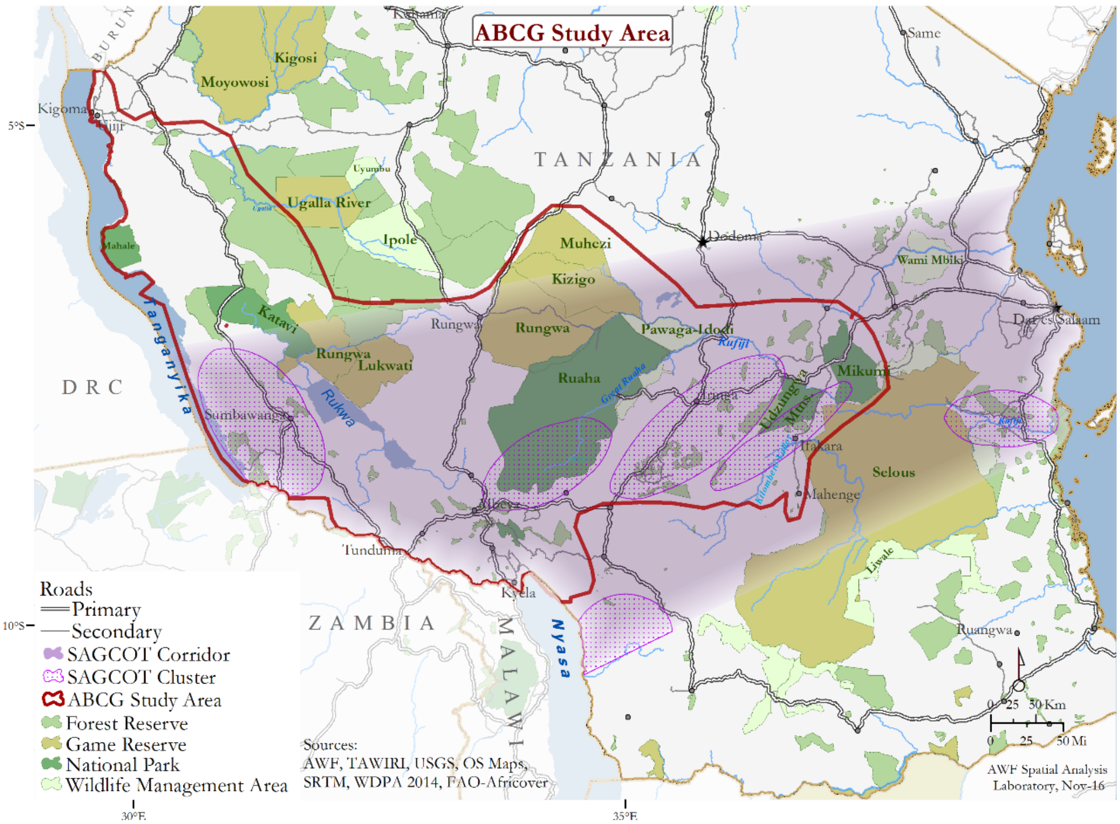
3.3.2 Context for identifying land use planning strategies for biodiversity conservation

Planning Issues, Drivers and Actors of Change

The southern portion of Tanzania is particularly rich with resources and great potential for both agriculture and biodiversity conservation (*area shown in Figure 37*). It contains some of the country's most fertile lands, extensive forests and wildlife, and access to water. Permanent cropping, predominantly maize and rice paddy, is carried out by both commercial and smallholder farms. The current reserve network protects approximately 129,912 km^2 of the study area (30 percent), including national parks that are allocated to the strictest protection category that excludes hunting and grazing (IUCN Category I to IV) and Game Controlled Areas and Game Reserves that allow hunting and sometime grazing.

In southern Tanzania, agriculture is the main source of livelihood for the >80 percent of the population living in rural areas, contributing 95 percent of Tanzania's food supply, 25 percent of GDP and 30 percent of foreign exchange earnings. Agriculture, therefore, holds a unique position with respect to the socioeconomic wellbeing of Tanzania. Within Tanzania, opportunities for agricultural development include 44 million hectares of arable land, of which only 24 percent is being utilized due to Tanzania's agriculture being dominated by smallholders characterized by very low productivity and limited use of modern technology and techniques for production.

Figure 37 | Study region which focused on the SAGCOT agricultural development area.



Southern Agriculture Growth Corridor of Tanzania (SAGCOT)

Since 2009, the government of Tanzania has put in place policy initiatives to transform the agricultural sector through crop intensification and diversification, including the Kilimo Kwanza ('Agriculture First'), the SAGCOT, the Agricultural Sector Development Programme I and II, the Comprehensive Africa Agriculture Development Program (CAADP), the New Alliance for Food Security and Nutrition, and the Big Results Now (BRN) initiative. All these initiatives aim to increase private acquisition of farmland, facilitate large agribusiness investment in agriculture, and improve engagement of Tanzania's small-scale farmers in commercial agriculture.

Agriculture also contributes to species declines and extinctions through land conversion and associated activities such as infrastructure development and hunting by farmers. The challenge is to maximize the potential for agricultural development while also maximizing the potential for biodiversity to persist in human-modified landscapes. Addressing agricultural transformation challenges therefore requires a multi-objective approach that targets the needs of biodiversity as well as the needs of humans.

Legal and illegal hunting is also a driver of wildlife declines in Tanzania. The main ongoing management action aimed at controlling illegal hunting to protect wildlife in Tanzania is law enforcement carried out by Tanzania National Parks (TANAPA) rangers and personnel of Game Reserves. The intensity and spatial spread of this action varies temporally and spatially due to the large areas required for management and known variability in hunting pressure (some places, particularly national park boundaries close to human settlements, experience more illegal hunting than other more remote locations). Most areas are under-resourced, so prioritizing the location and intensity of management effort within protected areas is important to ensure limited conservation resources are spent wisely.

Outside of protected areas, there are locations where biodiversity and humans come into conflict due to wildlife impacting crops (particularly elephants) or livestock (mostly carnivores such as lions). This human-wildlife conflict is not easily resolved, as it usually means either forcing humans or wildlife off preferred resource locations. Some solutions include habitat manipulation (e.g., wildlife corridors or buffer zones) to discourage use of agricultural land, compensation payments to those affected by crop or stock depredation. Participatory planning of interventions to mitigate human-wildlife conflicts and systematic landscape planning to ensure new agricultural investments are targeted away from high-risk locations. Agricultural conflicts also occur directly between humans in Tanzania, such as when large-scale commercial enterprises enter landscapes traditionally managed as smallholder farms causing competition in a limited market or when two types of agriculture (e.g., cropping and grazing) compete for the same land. As for human-wildlife conflict, spatial land use planning ensuring that alternative agricultural uses target land that maximizes economic potential while minimizing conflict is essential to avoid inefficient use of resources.

Vision and Planning Goals

The SAGCOT initiative was launched in 2010 to rapidly develop the region's agricultural potential. The SAGCOT Corridor covers approximately one-third of mainland Tanzania, and its vision is to attain 350,000 hectares of profitable agricultural production by 2030 through $3.5 billion in public and private investments, with the ultimate objective of lifting two million people out of poverty through new employment opportunities and new farms, achieving $1.2 billion in annual value of farming revenues.

The planning goals include to protect biodiversity values while achieving agricultural development in Tanzania. ABCG LUM working group held a workshop in Tanzania during which 12 objectives were discussed for land use planning in the region. These were pared down through discussions of feasibility and likelihood to four planning objectives that involved either reducing conflict, improving land management practices or changing land use:

1) Improve management and survival of biodiversity in existing protected areas;
2) Increase economic yield of agriculture through innovations;
3) Minimize conflict between cropping and biodiversity; and
4) Minimize conflict between cropping and grazing land uses.

Landscape Characterization

Species

The project chose a set of 13 species that are likely to come into conflict with objectives of increasing agricultural land uses in the region, either due to being threatened by clearing for agriculture (five primate species), or being threatened by hunting due to resource conflict associated with cropping and grazing occurring in places preferred by native species (four mammalian predators and the elephant), or threatened by both hunting and clearing for agriculture (two small ungulate species and the giant pangolin that are declining due to hunting plus loss of habitat from clearing for agriculture). Species range maps were downloaded from the IUCN (for predators) or from other published sources, and the distribution of each species was allocated to each planning unit.

Ecosystems

Data on the identity and distribution of ecosystems across the study area were downloaded from the "Potential natural vegetation of east Africa" dataset.[16] This resulted in 22 ecosystems ranging from freshwater swamps to rainforest. These were overlaid with data on the quality of natural vegetation in Tanzania (high, medium or low), and all low-quality vegetation areas were removed, resulting in a final list of 41 ecosystem features classified as either high or low quality.

Other Conservation Data

Because bird distribution maps or models were not available for the study area, the study used a map of the 22 Important Bird Areas (IBAs) identified by BirdLife International as having very high value for the conservation of birds in Tanzania and globally. These IBAs are chosen for a number of reasons such as having very high population abundances and/or richness of rare or endemic species, being important breeding or feeding grounds for migratory species.

To represent water availability across the study region a map of water budget derived from the Tanzania Waterworld dataset was created. This map shows the local water balance (mm./yr.; rainfall + fog + snowmelt minus evapotranspiration).

The study obtained a map representing cumulative long-term drought conditions across the landscape, by compiling information from all years between 1990 and 2016 on the Vegetation Condition Index (VCI), a remotely-sensed NDVI product.

Agriculture

Information on cultivation land use was downloaded from the FAO Global Agro-ecological Zones[17] Data Portal version 3.0 (hereafter GAEZ v3). Maps of crop suitability were created for seven crops (i.e., maize, soybean, wetland rice, dryland rice, sugarcane, Irish potato and citrus) under high input level rainfed conditions most likely to be replicated by commercial agriculture. These maps indicate the agro-climatically attainable yield for low, medium or high input level rain-fed crops for a baseline period 1961-1990. Consideration was made to only medium and high input rain-fed crops, with high input cropping analogous to commercial farming and medium input cropping more representative of intensive smallholder farming.

For each crop map, the GAEZ crop suitability index (baseline period 1961-1990) was converted from a categorical value between 0 (not suitable) and >85 percent (very high suitability) to a binary "suitable" or not by classifying any planning units with suitability >55 percent ("good suitability") to one and all

[16] http://vegetationmap4africa.org/

[17] FAO/IIASA, 2011-2012. Global Agro-ecological Zones (GAEZ v3.0). FAO Rome, Italy and IIASA, Laxenburg, Austria

others to zero. For each crop, the potential economic yield within each planning unit was calculated by multiplying GAEZ-estimated total production capacity (tonnes/hectare) under high input level rainfed conditions with the average market value of each crop.[18] All costs were adjusted for inflation from the time of cost data collection at average inflation rates of 2.7 percent per year.

3.3.3 Identify, Prioritize and Assess Land-use Planning Strategies

Identify Potential Land Use Planning Strategies and Their Objectives for Biodiversity Conservation

During the first workshop, several strategies were developed to address the overall planning goals. These were:

Goal 1: Improve management and survival of biodiversity in existing protected areas.
Strategy: Increase investment in ecoguards in existing protected areas to prevent or reduce illegal hunting.

Goal 2: Increase economic yield of agriculture through innovations.
Strategy: In existing agricultural areas, land management is improved by prioritizing crop choice, targeting commercial rainfed crops with the highest potential yield that avoid the need for supplemental irrigation due to acidic soils and unreliable water flows which can degrade water quality and quantity downstream (SNAPP unpublished).

Goal 3: Minimize conflict between cropping and biodiversity.
Strategy: Prioritize crop placement. In areas with agricultural potential, as well as biodiversity values, agricultural land use is prioritized towards high productivity areas that coincide with the lowest biodiversity values, and away from areas with high biodiversity values (e.g., wildlife corridors).

Goal 4: Minimize conflict between cropping and grazing land uses.
Strategy: In locations with high value for more than one crop, agricultural land use is prioritized towards areas with the lowest lost opportunity from other crops, ensuring that high value locations for crops are not allocated to crops with lower economic returns.

Summarized as:

1) Improve management and survival of biodiversity in existing protected areas;
2) Increase economic yield of agriculture through innovations;
3) Minimize conflict between cropping and biodiversity; and
4) Minimize conflict between cropping and grazing land uses.

Prioritize Application of Land-use Planning Strategies through Scenario Analysis

[18] http://nbs.go.tz/nbstz/index.php/english/statistics-by-subject/agriculture-statistics/1023-2016-17-annual-agriculture-sample-survey-crop-and-livestock

The planning goal was to meet a set of conservation and economic targets, while minimizing the opportunity cost of allocating land to particular uses. The project used Marxan with Zones conservation planning software, which uses simulated annealing as the optimization algorithm to find multiple, near-optimal solutions for this multiple land use planning problem. This algorithm also accounts for the impact of undesirable combinations of adjacent land uses (e.g., avoids placing cropping adjacent to protected areas, where possible).

The application of Marxan with Zones to land use planning in southern Tanzania required information on land use and conservation strategies and the cost of implementing these strategies, the distribution of biodiversity, conservation targets, and the contribution of each land use to achieving these targets.

This study evaluated 11 land uses: 1) formally protected areas with highest enforcement (two guards per 50 km^2 + surveillance aircraft); 2) formally protected areas with recommended[19] enforcement (one guard per 50 km^2); 3) formally protected areas with low enforcement (one guard per 150 km^2); 4) formally protected areas allowing sustainable use where hunting is allowed but controlled (e.g., Game Controlled Areas) with very low enforcement (one guard per 1,000 km^2); 5) grazing; 6-8) commercial cropping of maize, rice or sugarcane (the three targeted crops for SAGCOT private investment); 9) small holder cultivation using a multi-cropping system (the three target crops, plus potatoes, citrus and soybean); 10) agricultural exclusion areas that contribute to wildlife movement but are not formally protected (e.g., corridors); and 11) other land uses not incorporated in the above. This 'other' category represents the land remaining for other development (e.g., urban, mining or other agriculture) after achieving the policy targets.

Information on management effort in protected areas was derived from the literature and discussion with experts at the workshop. The recommended number of ecoguards per km^2 in Ruaha National Park, the largest NP in the region, is one ecoguard per 50 km^2 ($3,191/10 km^2), and this was taken to be the adequate level of enforcement across all protected areas (although it should be noted that this does not deter all illegal hunting), with two additional zones at lower enforcement levels to replicate existing efforts. Additional higher investment zone to account for the fact that the current effectiveness of anti-poaching patrols is anywhere from 0 to 95 percent was created, so the highest PA investment zone included a manned anti-poaching surveillance aircraft and twice the number of recommended guards.

The project estimated the benefits of applying the zones based on the distributions of species and ecosystems that could be protected from being lost or biodiversity features, and on the potential economic income ($/ha) that could be gained for agricultural features.

The study followed four scenarios:

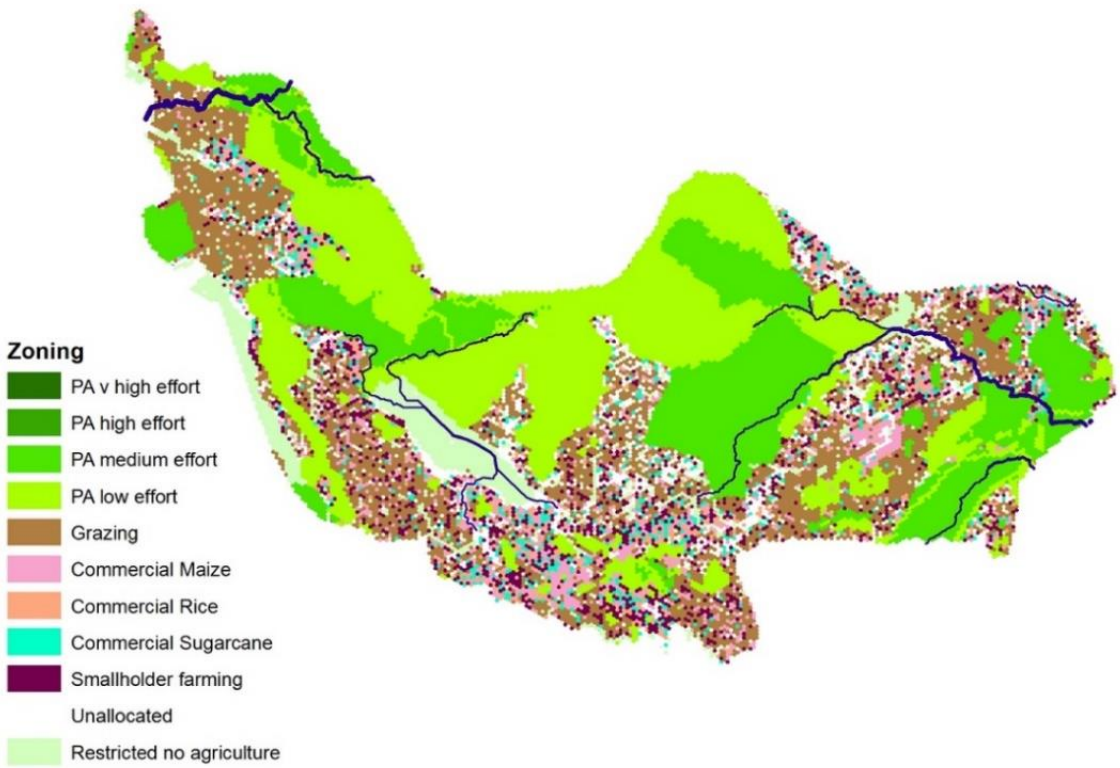
1) *Baseline development plan for sustainable agriculture development*: Meeting SAGCOT targets for agricultural expansion and avoiding resource or conservation conflict through strategic placement of agriculture land uses such that: a) cropped LUs avoid pastureland; and b) cropped LUs avoid being placed close to protected areas (where species are highly likely to roam outside of boundaries from time to time). PAs locked into current conservation categories I-IV with adequate anti-poaching patrols of one per 50 km^2 and low hunting, and sustainable use categories >IV allowing high hunting.

[19] Nahonyo (2005) ASSESSMENT OF ANTI-POACHING EFFORT IN RUAHA NATIONAL PARK, TANZANIA http://gridarendal-website.s3.amazonaws.com/production/documents/:s_document/331/original/Tanzania_draft2.pdf?1491561606

2) *Increased investment in ecoguards in protected areas to protect species from illegal hunting*: Agricultural targets and conflict avoidance the same as Scenario 1. Protected area options were either:
   a) Current fixed: No increase in investment (one ranger per 150 km^2 in IUCN I-IV), one ranger per 1,000 km^2 in IUCN >IV, no anti-patrol investment outside parks), resulting in low to average levels of hunting occurring within park boundaries;
   b) Perceived adequate fixed: Increase in investment to "adequate" levels in strict protected areas (one ranger per 50 km^2 in IUCN I-IV), one ranger per 1,000 km^2 in IUCN >IV, no anti-patrol investment outside parks), resulting in low levels of hunting occurring within park boundaries;
   c) Optimistic adequate fixed: Increase in investment to "adequate" levels in strict protected areas (one ranger per 50 km^2 in IUCN cat I-IV), increase investment in IUCN >IV to one ranger per 150 km^2 to reduce illegal poaching in IUCN V and VI, no anti-patrol investment outside parks), resulting in very low levels of hunting occurring within park boundaries;
   d) Optimistic equal effort fixed: Increase in investment to "adequate" levels in strict protected areas (one ranger per 50 km^2 in IUCN I-IV), increase investment in IUCN >IV to one ranger per 50 km^2 to reduce illegal poaching in IUCN V and VI, no anti-patrol investment outside parks), resulting in very low levels of hunting occurring within park boundaries;
   e) Optimistic variable effort focusing on buffers: Fix investment as "adequate" levels in all buffers (50 km from any unit with at least five people per km^2, i.e., a household) within strict protected areas (one ranger per 50 km^2 in IUCN I-IV), allow investment in remaining IUCN I-IV and V-VI to be one per 150 km^2 + include spotter aircraft across all PAs; and
   f) Optimistic unequal effort: Increase in investment to optimal levels in strict protected areas, can vary according to biodiversity needs and (one ranger per 50 km^2 in IUCN I-IV, one ranger per 1,000 km^2 in IUCN >IV, anti-poaching aircraft in all IUCN I-IV, anti-patrol investment increased near parks close to human settlements), resulting in minimum levels of hunting occurring within park boundaries
3) *Increased investment in agriculture*: Future change in agricultural investment that triples the target area cropped for major investment crops and smallholder crops. All conservation targets and conflict avoidance identical to Scenario 1, but targets for agriculture tripled.
4) *Future climate change:* Possible impacts of future drought on conservation and agricultural interests if it is: a) not considered when setting priorities for agriculture and conservation management, versus; and b) included in prioritization by avoiding places with a history of >50 percent chance of having extreme droughts (VCI<35 percent). All conservation and agriculture targets and conflict avoidance identical to Scenario 1.

Box 5 l Spatial results from Tanzania

Given the number of scenarios from the Tanzania case study for prioritization, all the results are not shown here. But below is an example showing the output for the first baseline scenario.



Costs of Each Conservation Strategy

The project determined the cost of each conservation strategy from the perspective of a conservation agency. The project assumed there to be no cost to stay in the current land use. However, there is a cost to change a planning unit from production to protected status, or to improve the management of production or protected land. Table 5 below outlines the types of cost (operating, management and opportunity costs) that apply to each conservation strategy, which are applied across the study region.

Table 5 | Land use management strategies allocated to different zones and costs per planning unit.

Values	Description	Annual Units	Conversion Rate	Value per km^2
Pasture	Price of cattle: mature male cattle grade two 800,000TSH mature female cattle grade two 700,000TSH	US$ per 3 ha	Convert by 1 animal per 3 ha (0.03 km) to animals per km	11,250
PA enforcement	Anti-poaching patrol investment - 1/3 recommended (1 ranger = 143 km^2)	US$ per km per year (2000)	Adjusted for inflation (average rate 2.7% per year	106.35
	Anti-poaching patrol-recommended levels (1 ranger per 50 km^2)	US$ per km/per year (2000)	Adjusted for inflation (average rate 2.7% per year)	319.06
	Anti-poaching patrol-buffer levels within park (2 ranger per 50 km^2)	US$ per km per year (2000)	Adjusted for inflation (average inflation rate 2.7% per year)	638.13
	Anti-poaching patrol-pessimistic levels outside PAs (1 ranger per 1,000 km^2)	US$ per km per year (2000)	Adjusted for inflation (av inflation rate 2.7% per year)	15.19
	Additional investment in anti-poaching aircraft to fly over 50,000 km^2 in Selous NP	US$ per aircraft per year	Adjusted for deflation and area surveyed	42.94
	Operations costs (Recurrent management costs include operations (e.g., staff salaries and training, fuel, maintenance, community engagement, and monitoring and evaluation) + 1 ranger per 50 km^2	US$ per km^2/per year (2000)	Adjusted for inflation (average inflation rate 2.7% per year)	820.77
No agriculture	BASE: Operations costs (including rangers) - Operations costs (not including anti-poaching patrol)	US$ per km^2/per year (2000)	Adjusted for inflation (average inflation rate 2.7% per year)	589.25

Cropping	Maize	US$ per tonne (2000)	Adjusted for inflation (average inflation rate 2.7% per year)	236.50
	Soybean	US$ per tonne (2000)	Adjusted for inflation (average inflation rate 2.7% per year)	624.83
	Rice (dryland and wetland)	US$ per tonne (2000)	Adjusted for inflation (average inflation rate 2.7% per year)	340.28
	Citrus	US$ per tonne (2000)	Adjusted for inflation (average inflation rate 2.7%)	293.40
	Potato	US$ per tonne (2000)	Adjusted for inflation (average inflation rate 2.7% per year)	345.80
	Sugarcane	US$ per tonne (2000)	Adjusted for inflation (average inflation rate 2.7% per year)	401.36

Assess land use planning strategies and scenarios with stakeholders and against landscape performance metrics

Land management scenario outputs were evaluated using the following metrics:

1) Protected Area Strategies: total cost of management relative to species' ranges protected;
2) Agricultural Area Strategies: total production yield ($) for each crop, change in water balance within the greater Ruaha; and
3) Water balance

Scenarios of Increasing Investment in Protected Area Patrol Efforts

In protected areas, the total cost of management varied depending on the anti-poaching patrol effort (Table 1). Scenarios of increasing investment within National Parks using different allocations of fixed versus variable patrol effort showed high returns for all biodiversity features; this relationship is not linear, rather, benefits diminish with increasing investment according to power-law (*Figure 38*). Increasing PA investment also reduced the shortfall in biodiversity distributions saved (*Figure 39*). However, increasing investment does not result in uniformly increasing management effectiveness; a threshold was found in the average effectiveness of management, with investments >$100 million not associated with increased management effectiveness or improvement in feature representation (*Figure 39*).

Figure 38 | Relationship between investment in PA management and benefits for 74 biodiversity features

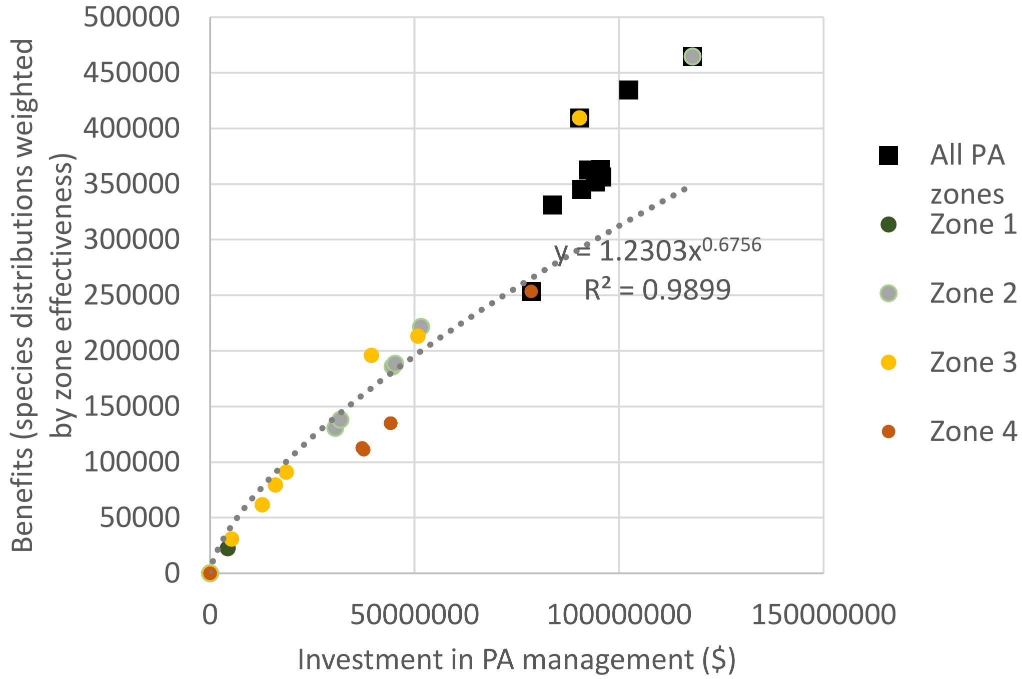
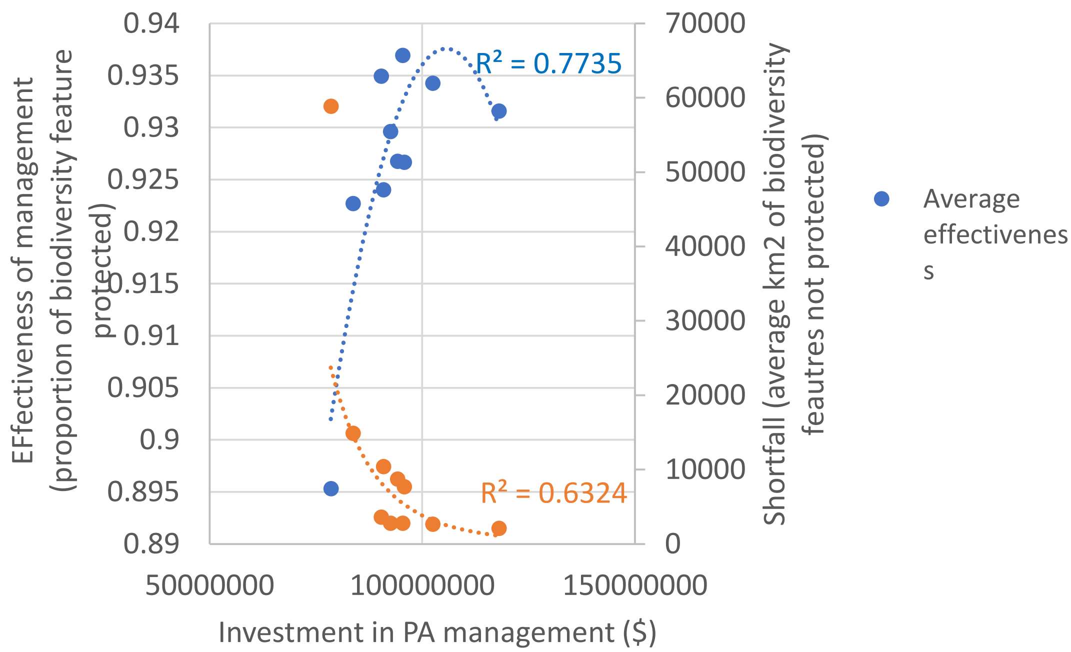


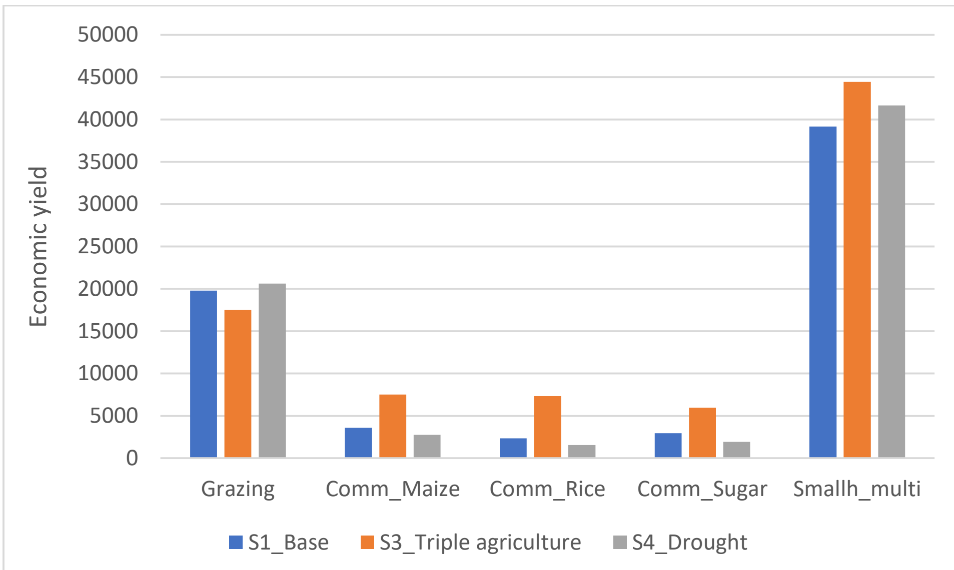
Figure 39 | Relationship between investment in PA management and average effectiveness of management for 74 biodiversity features.



Scenarios of Increasing Agricultural Production

Tripling agricultural production by tripling the area of land under cultivation by target crops while avoiding key biodiversity areas (e.g., corridors, intact high-quality ecosystems) would increase economic yields (*Figure 40*). Accounting for future drought conditions by avoiding areas likely to experience extreme drought resulted in economic yields similar to the baseline scenario for all commercial crops. However, smallholder cropping yields still increased under the drought scenario, indicating potentially higher value of investing in smallholder cropping under future uncertainty in environmental conditions.

Figure 40 | Effects of alternative scenarios of "business as usual" (not increasing current agricultural production rates; S1_Base), tripling agricultural production (S3_Triple agriculture) or tripling agricultural production while avoiding locations likely to experience drought (S4_Drought), on economic yield of target crops.



Hydrology and Water Balance

To test the impact of land use management on water balance, the results of scenario 1 (the baseline scenario) were used as a potential land use "plan" and linked to the hydrological model for Southern Tanzania. Land uses were reclassified to allocate crop factor coefficients (i.e., coefficients used for estimating evapotranspiration in a hydrological model). Land uses 5-9 were allocated to coefficients for cultivated land, while classes 1-4, and 10-11 were set to background land use (i.e., native vegetation and future land use).

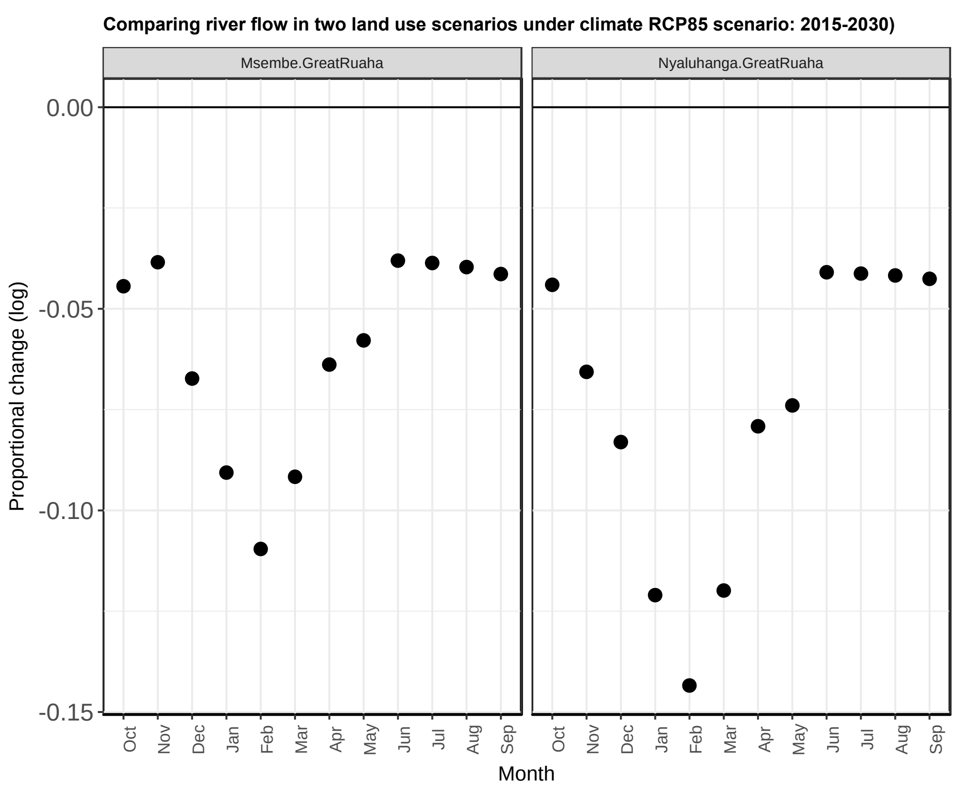
The spatial extent of the SAGCOT Marxan scenario differed from that of the hydrological model, with a large part of the outside the study extent of the hydrological model. Notably, Marxan land use extent transverses three basins in Southern Tanzania. The Marxan scenario map was reclassified and mosaicked with the projected land use, such that for overlapping areas Marxan scenario was applied in the model, and future land use applied where the extents did not overlap. Therefore, subsequent modelling adopted the study extent of the hydrological model with Marxan scenario applied for only the areas where there was overlap with the hydrological model extent.

Two runs configured at daily time step for 2015-2030 using RCP 8.5 climate scenario were initiated. In the first run, projected land use was applied, and in the second the integrated Marxan/projected land use was applied. Outputs from the runs were 11,686 maps of simulated daily river flow from January 2015 to December 2030.

To analyze for the differences between the runs, time series data for two stations along the main river in Rufiji basin (i.e., Great Ruaha) were extracted and aggregated for each month. These were then plotted as hydrographs to illustrate differences at a monthly level between the two simulations and the relative impacts of the two land use maps on river flow. Differences between current water balance and future water balance under climate change were calculated as proportional change (ratio of Marxan scenario to Projected LU scenario).

Results suggest a difference of up to ~15 percent during the wet season and five percent during the dry season with Marxan land use generating less run off/river flow than the projected land use. However, these results are based on only two stations along the main river that drains one of the basins included in the Marxan study extent (Marxan extent transverses three basins). To fully evaluate the impact of Marxan scenario in specific River basins in Southern Tanzania, the study extents of the model and Marxan output would need to be aligned, such that complete basin wide impacts could be evaluated.

Figure 41 | Proportional change of average river flow for each month obtained as a ratio of simulations based on Marxan land use scenarios to projected land use for: a) a baseline scenario of SAGCOT investment in alternative crops (Scenario 3); b) a future scenario of tripling investment in cropping (Scenario 4); and c) a scenario of SAGCOT investment in alternative crops that avoid drought-prone areas (Scenario 5). The Y axis is the logarithm of the ratio of Marxan land management to projected land use. Therefore, it could be interpreted as percent change by multiplying change values by 10. The figure suggests up to 15 percent difference during wet season, with Marxan resulting in lower flow than projected land use.



3.3.4 Land Use Recommendations

Summarize Findings and Make Recommendations

Some of the important findings of this study were:

- Protected area investment in patrol efforts can be done in a way that maximizes coverage of the distributions of vulnerable species while targeting key at-risk areas;
- Increased agricultural investment can be done in a way that reduces conflict with biodiversity while ensuring increased economic yields; and
- Future risk of drought could erase these yields if investment is only focused on commercial crops (e.g., maize, rice). Diversifying investment to focus on smallholders is important to ensure yields under possible future drought conditions.

Potential Next Steps for Project

Overall recommendations that emerged from the workshop included the following:

a. Use the scenario outputs here were produced at a scale that will be especially useful to address cross-sectoral priorities and shared resources in zonal/regional level planning.
b. Establish a land use data management system to house the input data and scenario model outputs presented at the workshop. This would enable NLUPC and other planning agencies to apply their findings more effectively at various scales.
c. Enhancement of land use planning systems at the regional and district levels. This would involve bolstering capacity in GIS and land use planning at the NLUPC and district levels.
d. Evaluate the impact of future climate change to regional water balance/resources in scenario modelling. This would be a step towards 'Climate Smart' landscape development and was identified as an objective in Workshop 1, but there were no resources to explore it.
e. Community involvement in land use planning is essential to promote a more open and transparent process. The multi-stakeholder platform that emerged from the Kilombero planning process offers a good example of this.

More specifically, the NLUPC invited AWF to work with them to incorporate recommendations from the scenario analyses to guide land use planning in the region. The collaboration could involve:

- AWF technical support to help NLUPC streamline uptake of case study findings at district to village scales;
- Effort to address NLUPC technical capacity constraints in plan development and implementation.

Given AWF's experience, presence, and ongoing programs, the Kilombero region would be a likely place to pilot collaboration. That collaboration could also benefit from the PBL/EcoAgricultural process findings and related multi-stakeholder platform.

By streamlining uptake of the case study recommendations and bolstering NLUPC technical capacity, the collaboration could improve NLUPC land use planning and implementation with other stakeholders in the region (e.g., Southern Tanzania Elephant Program and JGI) making those collaborations more impactful and sustainable.

3.4 MADAGASCAR

3.4.1 Stakeholder and Expert Inputs

This case study had numerous and extensive stakeholder and expert engagement throughout.

Developing a Common Vision and Objectives for the CAZ Landscape – August 2016

Stakeholders of the CAZ were convened for the first time and developed a common vision and objectives to ensure a sustainable development for the CAZ landscape. Data needs were discussed along with the institutions that hold them. Activities for the next steps were identified.

Data Collection Workshops – July 2017

CI team went to Toamasina and Ambatondrazaka to deliver a refreshing presentation of the ABCG project to the stakeholders in the Regions of Alaotra Mangoro and Atsinanana. This allowed the participants to deepen their knowledge about the project and its needs, specifically in terms of data. Data collection plans were established so that stakeholders from each Region could start to look for data from their respective Department and also find out the procedure to be followed for CI team to get the data. These workshops started the project data collection process that continued all over the course of the project.

Weighting of Data – August 2017

Available data to this date were presented to stakeholders. While there were still urged to speed up the process to make further data available for the project, each was separately asked to rank each parameter according to their perceived importance. The ranking results were there summed up for each parameter to serve as weight of the data that were used later in Zonation.

Scenario Development Training – August 2017

Once again, stakeholders met to discuss about possible land use alternatives including the baseline and future land use alternatives for which participants were asked to project into the future and guess the most probable pathways and alternatives. The main ideas were noted to be considered in further analysis. The Zonation software was also first introduced to the stakeholders who learnt about its capabilities and its use for land use planning.

Building Stakeholders' Capacity in Land Use Planning – May 2018

When several data were available, the project began the stakeholders capacity building process on the use of the Zonation software. Additionally, there was also a long refresh of GIS concepts and the use of GIS software. This was the first time participants translated scenario into maps and assessed the impacts of each scenario on biodiversity and ecosystem services. This practical side of the training made it very interesting for the participants. Interestingly, participants discovered the possible use of Zonation for designing and/or solving spatial issues in other sectors. This also triggered the sharing of additional data, namely for the mining sector. Participants requested that follow-up trainings should be conducted afterwards.

Presentation of Land Use Scenario – July 2018

More data were received from stakeholders and, as a result, further scenarios were developed, and others were refined. This new set of scenarios were then discussed with the stakeholders to account for their opinion. It is worth noticing that they also proposed other probable scenarios. This was a sort of local/regional validation of what had be done so far - including the methodology from data selection to scenario development - before their presentation to higher level stakeholders. It was also an opportunity to answer questions and solve problems encountered by stakeholders while using Zonation.

Presentation the Project Contribution – Aug 2018

Decision makers at the national level were convened at the final national workshop to get acquainted with the works that had been done by the ABCG project. CI staff presented the project history and methodology while Directors of the Rural Development from the Regions of Alaotra-Mangoro and Atsinanana presented the final scenario that were agreed upon by the participants in all the workshops. The Department in charge of the land use planning took note of the methodology and promised to provide the necessary support when translating this into the development of the “Schéma d’Aménagement Communal” (Municipal Land use Plan) at the commune level, or ideally one big schema for the entire CAZ landscape.

3.4.2 Context for Identifying Land Use Planning Strategies for Biodiversity Conservation

Planning Issues, Drivers and Actors of Change

Case Study Boundary

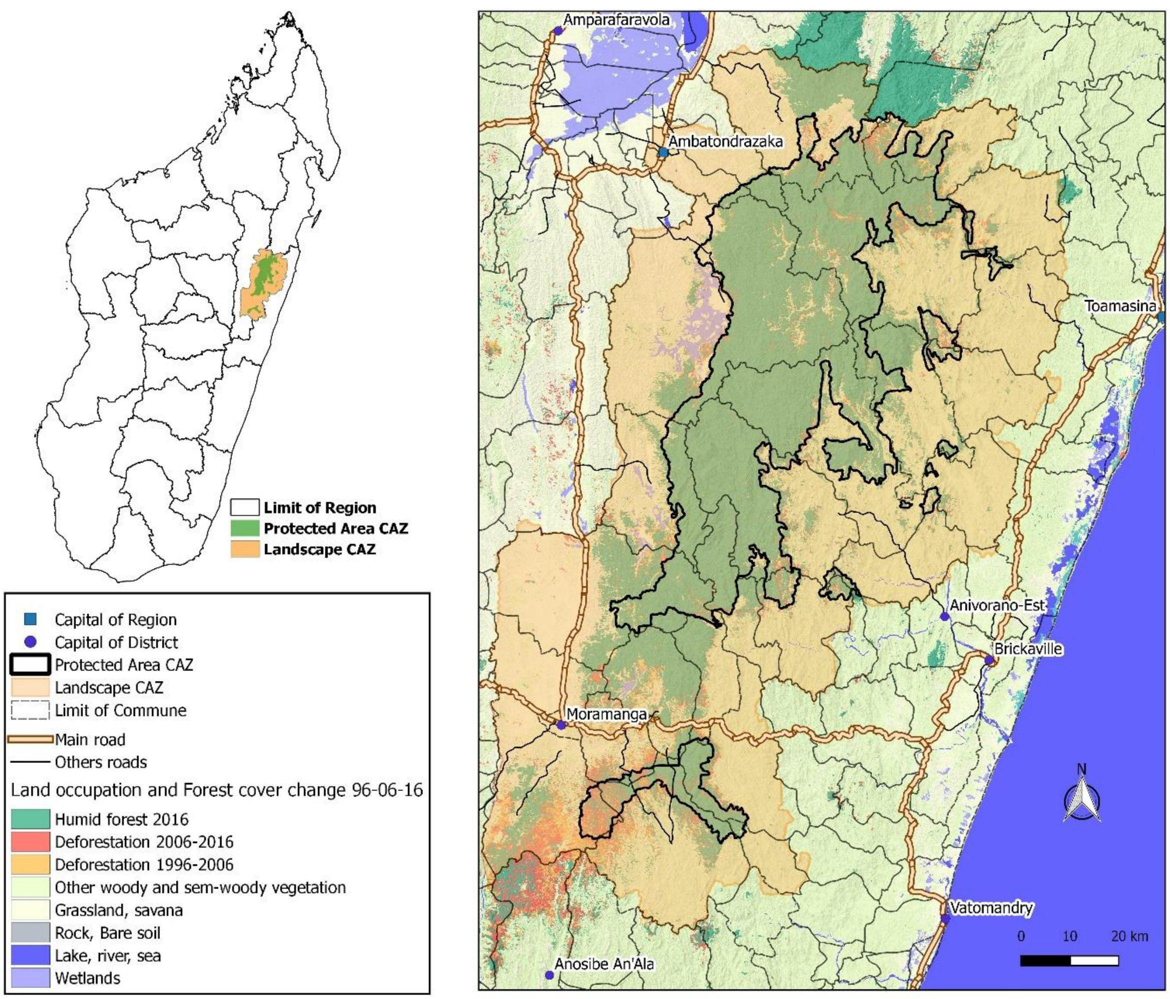
The team encountered some problems that hindered the progress of the project activities. One of the first issues the team came across was the delineation of the landscape for the geographical analysis. After analyzing the pros and cons of different possibilities, they opted for the inclusion of Communes that surrounded the Corridor Ankeniheny-Zahamena (CAZ) Protected Area as most decisions are made based on this administrative division, while the team also considered other critical criteria for each watershed (*Figure 42*).

Drivers and Actors of Change

Small-scale household farming is the most important cause of deforestation in Madagascar. It consists in converting forest into cropland by burning for subsistence crops, mainly rice which is sometimes associated with corn, beans or cassava. When taken together, they cause such an important loss to the country’s remaining natural forests. Some of the fires for slash and burn agriculture could go out of control and spread to nearby forest, which may easily catch them during the now more frequent extended dry season where the thick litter and carbon rich underneath soil constitute a perfect combustible. The rich topsoil is progressively ripped off and lowland rice fields are silted. As a result, agricultural productivity drastically decreased. This led farmers to look for new forest to clear, which in turn resulted in water being polluted and subsequent health problems.

Both legal and illegal mining leads to substantial deforestation with the legal ones bound to restore the area after the mining operations. The rush to find precious stones (sapphires), or gold has left a vast, degraded landscape with little or no opportunities for restoration. Additionally, mining creates negative impacts on the agricultural production, health and economies of downstream communities and aquatic ecosystems.

Figure 42 | A map of the case study area, the Corridor Ankeniheny Zahamena (CAZ) in the eastern rainforest of Madagascar.



Illegal logging, charcoal making, and poaching are often the precursors of deforestation. After a series of quiet illegal timber harvests, these people establish themselves permanently and begin slash and burn cultivation. In addition to this, the forests near the road infrastructure tends to disappear, undermining the traditional belief that the Eastern forest would be never be exhausted.

Vision and Planning Objectives

Representatives of different technical sectors, regional decision-makers (chief of regions and their respective staff, chiefs of districts, mayors, communities) were gathered to debate on the landscape objectives. That allowed stakeholders to share information to constitute the database for future scenarios on development and on conservation. A common vision for the whole landscape including the two regions was then developed. Working groups from the different technical services per region were created and organized to deal with data in landscape characterization. From three tentative visions, the final one was formulated as follows: "In 2030, the sustainable development of the two Regions depends on an economy that is based on the rationale use of resources, a healthy protected ecosystem, adequate infrastructure and a framework of conditions favorable human wellbeing". At the beginning, it was hard to find a consensus because most of individual ministerial objectives are mutually exclusive in terms of land use. However, each sector representative made concession in order to meet the sustainability criteria for landscape without which the whole regional economy would not stand in the long run.

Landscape Characterization

Species

Survey data from field biodiversity surveys were compiled by CI for six target species: Akoholahiala (Crested Ibis) *Lophotibis cristata*, Taitso (Coua) *Coua gigas,* Babakoto (Indri) *Indri indri,* Godroka (Bamboo lemur) *Prolemur simus,* Simpona (Sifaka) *Propithecus candidus*, and Varikandana (Variegated lemur). These latter four are critically endangered (CR) lemur. These occurrence data were converted to Extent of Occurrence maps using minimum convex polygon methods prescribed by the IUCN Red List for Threatened Species. EOO was then clipped to remnant vegetation using information from Landsat forest cover change satellite imagery from 1996-2006-2016 (*Figure 42*).

Figure 45 | Indri Indri species model (blue = higher values, yellow = lowest value).

Figure 44 | Crested Ibis model (blue = higher value, yellow = lowest value).

Figure 43 | Variegated lemur (blue = higher value yellow = lowest value).

Carbon

A map of carbon stock has been established by surveying 66 forest sample plots (*Figure 46*). Parameters surveyed were: 1) tree height; 2) tree diameter at breast height; and 3) soil. An allometric equation was applied to the dendrometric parameters of the forest to obtain a value of carbon per hectare at each plot location. This information coupled with satellite images was used to create a seamless continuous carbon stock map to represent carbon sequestration services for the entire region. Ex-ante emissions reductions are currently estimated to be one million tCO_2 per year but evolution of carbon stock and emissions from deforestation will be monitored over the years. The latest estimates of carbon stocks are about 46 $MtCO_2$ for the CAZ Protected Area and 87 $MtCO_2$ for the whole landscape.

Hydrology

A map of Water balance ($_1$) data has been produced (*Figure 47*). It represents the combination of precipitation fallen and evapotranspiration evaluated in laboratory. The values then represent the sum of the combination of mean precipitation and evapotranspiration. A second map derived from a hydrology layer for the region was used to represent existing water bodies (e.g., lakes) and major permanent river courses in need of protection (e.g., from soil degradation and silting of water due to unsustainable agricultural practices).

Agriculture

Three maps were created to represent various facets of agricultural land use and importance for agricultural development. A map of agricultural suitability was derived from a global map produced by (Florian et al, 2014) and downscaled to fit the area of interest (*Figure 48*). In this analysis, only rice, corn and cassava have been taken in account as those are the most dominant crop in CAZ. Other maps representing agriculture were: 1) current land under agriculture (non-forest uses); 2) derived from a global forest change database; and 3) distance to villages (representing access to markets).

During a stakeholder workshop CI had experts list factors most likely to degrade the value of a planning unit for biodiversity, carbon, water or agriculture. These were: 1) deforestation (reduces biodiversity condition, e.g., through edge effects; Figure 49); 2) distance to roads (places closer to roads are more degraded due to access by humans for agriculture and hunting, up to a threshold of ~20 km; Figure 50): 3) mining (reduces condition of biodiversity, water and carbon assets); and 4) drought and inappropriate water usage (reduces condition of biodiversity, water, carbon and agriculture). With this information, the project created alternative condition maps representing the quality of the landscape for alternative features of interest, i.e., biodiversity (*Figure 51*), water, carbon and agriculture (as features impacted in different ways by these degrading processes). These rules will be applied throughout the analysis.

Figure 46 | Carbon stock data compiled across planning region (blue = higher carbon values, yellow = lowest value).

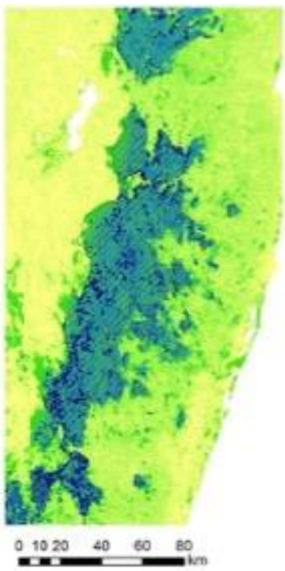


Figure 47 | *Water balance data compiled across planning region (blue = higher value for water provisioning services, yellow = lowest value).*

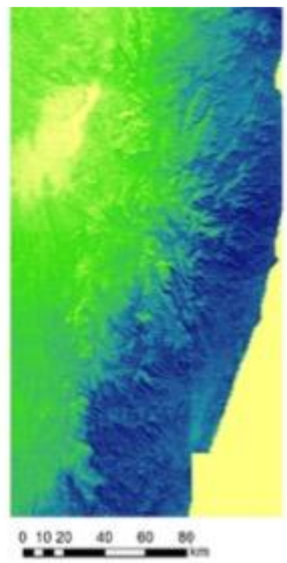


Figure 48 | Agricultural suitability data compiled across planning region (blue = higher suitability for agriculture, yellow = lowest value).

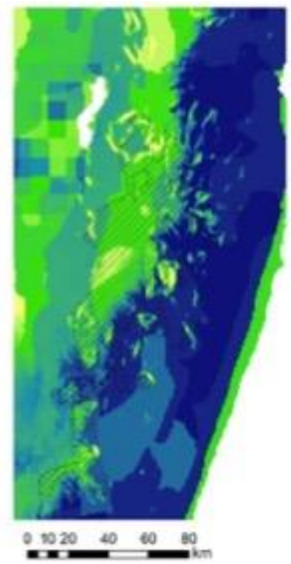


Figure 49 | Deforestation data compiled across planning region (red = deforested in last 10 years, blue = National Park).

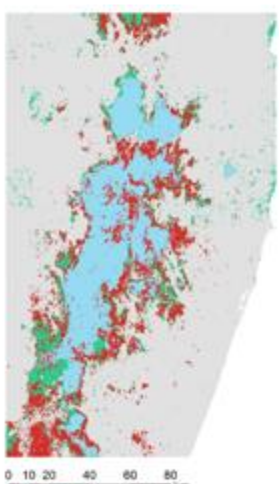


Figure 50 | Map of distance to roads across region (blue = further from roads and no impact on biodiversity, red = closer to roads and higher impacts on biodiversity).

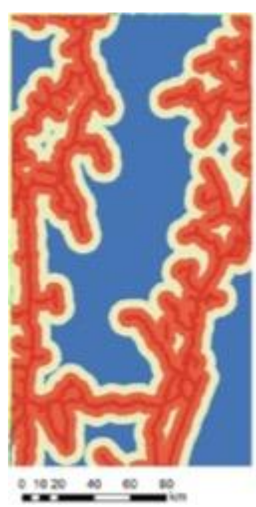
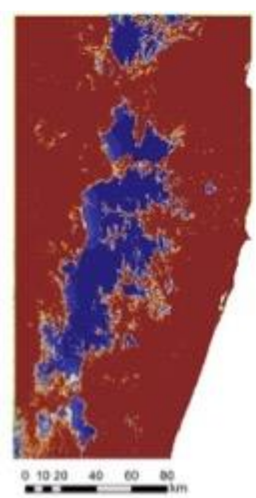


Figure 51 | Final condition layer representing impacts on biodiversity of roads and deforestation (red = very poor condition, near 0; blue = very high condition, near 100%).



3.4.3 Identify, Prioritize and Assess Land Use Planning Strategies

Identify Potential Land Use Planning Strategies and Their Objectives for Biodiversity Conservation

The objective was to highlight the different factors of change and thus come up with land use strategy scenarios that maximizes both biodiversity and livelihood benefits. This led to a consensus map for each scenario.

Some strategies/activities proposed by stakeholders include:

- Improved protected area management;
- Agricultural development;
- Infrastructure development;
- Restoration or Reforestation of degraded areas (or deforestation);
- Reforestation of bare areas;
- Reforestation for wood products (construction or firewood) and Energy (Coal) need;
- Hydro-agricultural development (irrigated perimeter or watershed; road);
- The implementation of Agroforestry systems combining cultivation and reforestation;
- Testing the few smart agriculture climate pilot sites: combining soil defense and restoration and adaptation to climate change;
- Developing Cash crops, mainly coffee and cloves; and
- Reservation of Pasture Zones.

Prioritize Application of Land Use Planning Strategies through Scenario Analysis

Selection of stakeholders posed some challenges, largely due to budget constraints while working to be as efficient as possible. The project also opted for Maxent and Marxan software before switching to Zonation which proved to be more user friendly and that can process several sets of data. While stakeholders agreed to freely provide data depending on their respective department, getting these data required a lot of communication and procedurally heavy. Data about the future highway was unavailable as the Ministry in charge of the "Travaux Publics" was never sure about which choice to make among the highway options some donors promised to push. Another issue was the availability of the stakeholders in the same period. Lastly, the plague that was occurring around October 2017 slowed down project activities.

The project developed prioritizations that identified where the most important areas were to conserve based on overall biodiversity, water and carbon values, as well as those places that were most important for agricultural development (primarily for the three dominant crops, rice, corn and cassava). These prioritizations can inform choices on, for example, the locations of investment in enforcement activities to protect key species and their habitats from illegal clearing and poaching (e.g., *Varecia variegata*, *Indri indri*, *Coua sp*.), or locations to encourage investment in improving agricultural returns or market access.

Prioritizations were also informed by future development scenarios that attempt to quantify the potential impacts of human development activities detrimental on the environment such as planned infrastructure routes, or with positive impacts (e.g., forest restoration). These scenarios help to quantify the consequences of future forest changes, such that development goals can be reshaped to accommodate and protect biodiversity conservation priorities, water provisioning services and carbon benefits.

Figure 55 | Conservation priorities under a (a) baseline scenario, (b) hypothetical autoroute scenario, (c) mining scenario where mines degrade entire communes by 50% (insets = condition for biodiversity), where carbon, water and species distributions are prioritized for conservation (pink/red areas), and high-value agricultural areas are prioritized for development (black/blue areas), and (d) water shortages scenario.

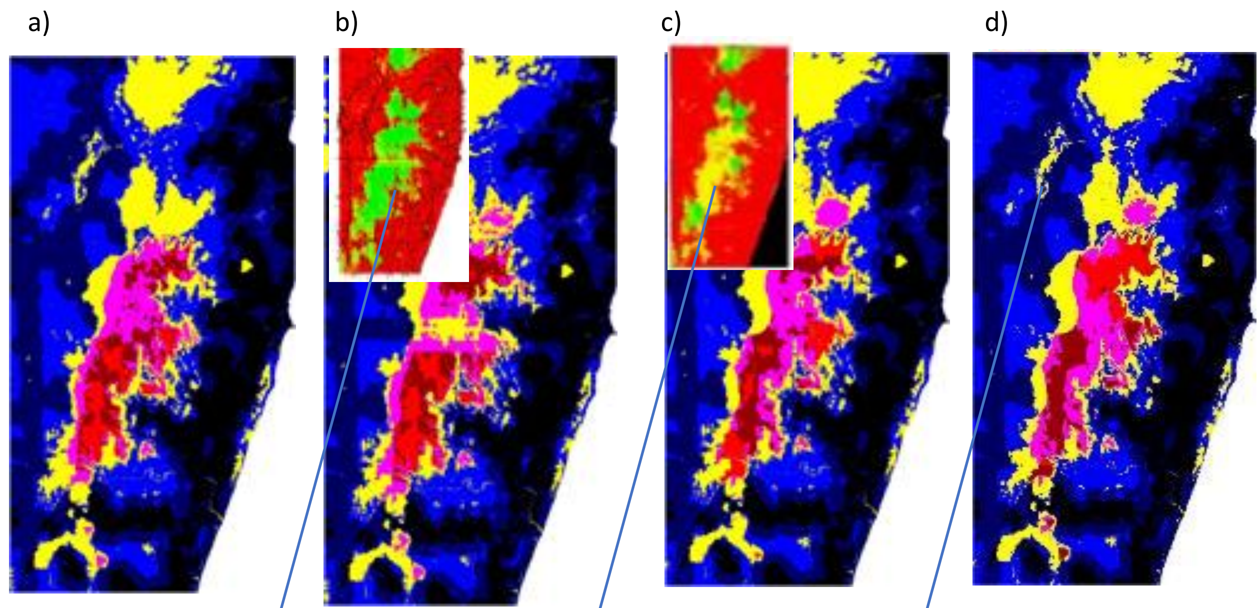
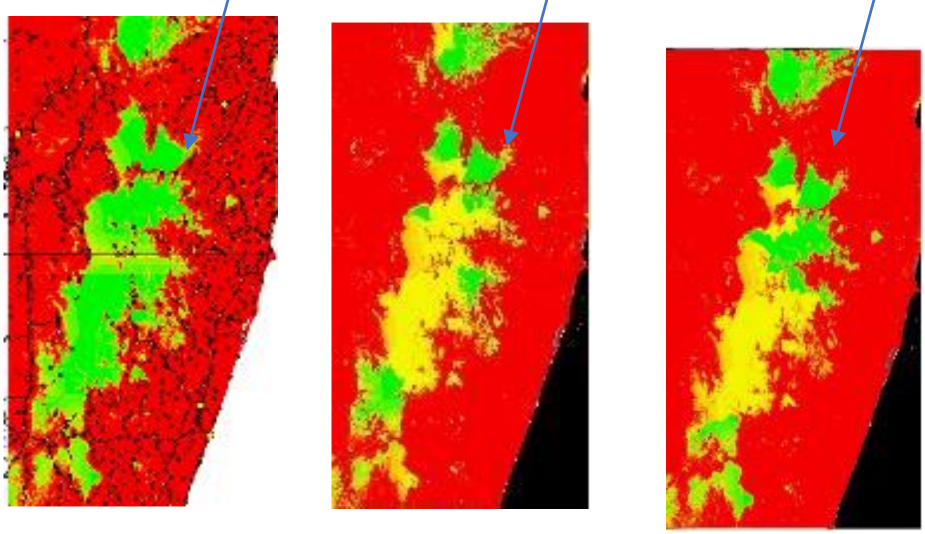


Figure 54 | Condition of units that have lost forest cover since 2000.

Figure 54 | Condition of all communes affected by mining.

Figure 54 | Condition of all communes affected by possible water shortages.



This project generated priorities for conservation by accounting for individual species distributions, carbon storage and water services, and their degradation due to deforestation and road impacts (*Figure 52a, pink/red areas*). The project also used agricultural suitability and production values to identify areas that have the highest value for agricultural development (*Figure 52a, black/blue areas*).

Future Scenarios

In order to add another dimension to the prioritization process, the project examined the impact of future developments or conservation actions on biodiversity and other values (e.g., carbon). Five future scenarios through consultation with landscape planning and conservation experts at the first and second stakeholder workshops were developed: 1) infrastructure improvement through development of an autoroute; 2) restoration of recently cleared areas; 3) forest degradation due to mining; 4) forest degradation due to water shortages: and 5) degradation due to mining and water shortages.

The first scenario degrades condition of forest, species distributions and carbon at distances up to 20 kilometers from the planned route, and results in lower conservation priorities (*Figure 52b*). The second scenario improves condition of units that have lost forest cover since 2000 (*Figure 53*) by 50 percent, simulating possible replanting activities and halting of further illegal forest extractive activities. The third scenario reduces the condition of all communes affected by mining (*Figure 54*) by 50 percent and moves priorities away from some heavily degraded areas (*Figure 52c*). The fourth scenario assumes the condition of all communes affected by possible water shortages (*Figure 55*) is reduced by 50 percent.

An example of change in condition of region for biodiversity when mine impacts are added to existing impacts of deforestation and roads and further degrade landscape by 50 percent:

Figure 56 | Data provided by experts on commune-level mining impacts (orange) or water shortages (hashed).

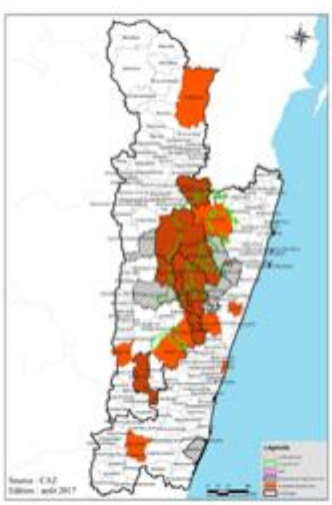
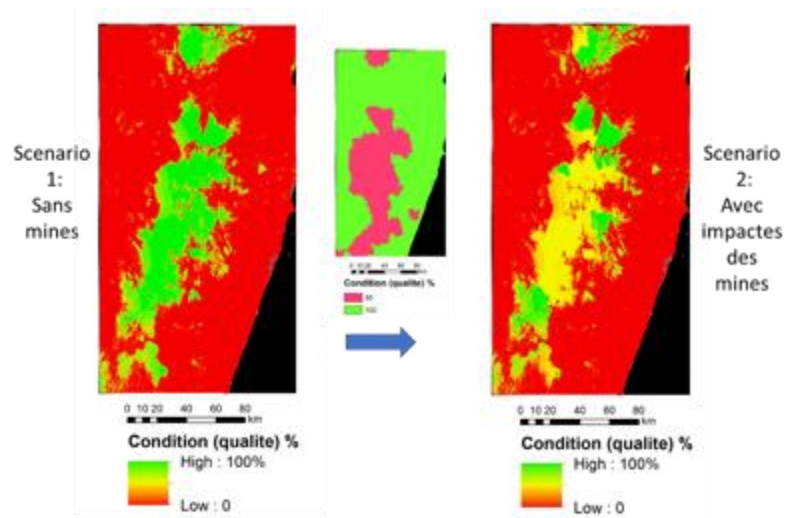


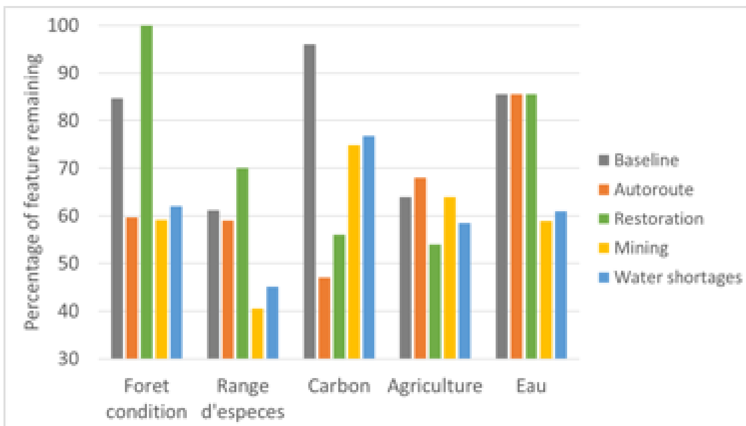
Figure 57 | Scenario that impacted quality of biodiversity within the communes.



Assess Land Use Planning Strategies and Scenarios with Stakeholders and Against Landscape Performance Metrics

The project used the outputs from spatial prioritizations to show the beneficial or negative effects of alternative scenarios on predicted biodiversity distributions, total carbon sequestration, across the region. Further calculations could show the carbon sequestration benefits of such an approach (*Figure 58*). The scenarios show that future land use management decisions that deliberately seek to restore high biodiversity and high carbon forest areas could yield 12 percent more habitat for species and 10 percent more forest carbon stocks than the baseline scenario but reduces available land for agriculture by 11 percent. A hypothetical autoroute results in negative outcomes for biodiversity (up to 25 percent loss of forest condition and >40 percent loss of carbon stocks, and only slightly improved agricultural value (four percent).

Figure 58 | Impacts of alternative scenarios of development (e.g., autoroute, mining), conservation activities (restoration of recently cleared land) and environmental change (water shortages) on the percentage of features remaining in the study region (forest, species distributions, carbon stocks, agricultural value, and water balance).



3.4.4 Land Use Recommendations

Summarize Findings and Make Recommendations

The Ownership from Government Technical Agencies and Regional Authorities Facilitates Information Collection

The strength of this project lies in the level of ownership and interest of the stakeholders, especially in the technical services of the government, regional authorities ("Préfet de Region", "Chef de Region", Head of District) and NGOs. Indeed, these different stakeholders from different sectors were engaged from the beginning of the project in a participatory process. They altogether defined the common vision of sustainable development for the two "Régions" based on the protection of natural capital which would endlessly deliver ecosystem services to the population of these "Régions". As a result, representatives of the Technical Services willingly shared their data to conduct the modelling and they actively participated in the scenario development and analysis exercises.

The "Zonation" Tool Fits Well with the Government Land Use Planning Process Need

The Government of Madagascar is currently in the process of developing its decentralized referential for land use planning (such as municipality development plans, regional development plans, etc.), and the launch of this project and the tool utilized is very well welcomed. With its multisectoral perspective, the "zonation" tool brought around a table a platform of discussions to deal with different issues related to land use. The stakeholders showed active participation in debates and developing suggestions for developing scenarios of land use planning.

The maps developed during the project also allowed the identification of potential restoration sites. Indeed, Madagascar is striving to locate the most appropriate areas to conduct the country's pledged four million hectares of restoration for the African Forest Landscape Restoration Initiative (AFR 100). Not only had the project identified the related sites within the CAZ landscape, but also showed the very geographical locations where the restoration activity would deliver the maximum impacts for the surrounding communities and even further downstream.

The project triggered a key approach to land use planning process. In the past, very few sectors (two or three at most) often dealt with common problem. Over the course of the project implementation, a total of 11 ministerial sectors, often conflicting in terms of objectives, were called to sit together around the same table to define a common vision for the whole landscape. Each sector's representative then went through a learning process of the other's objectives and plans. Thus, arriving to a shared vision was facilitated and greatly contributed to the ownership of the project mentioned above.

Apart from the original use of the Zonation for conservation, participants realized that Zonation could also be used to solve planning issue in a specific sector. The representative of the Ministry in charge of the Land use mentioned that the project gave him an idea of how to identify not only the area to be impacted by a proposed road construction, but also that it helps to assess how much compensation the Government had to spend for each possible route.

Potential Next Steps for Project

The products from these different analyses are intended to inform choices about future developments within the Corridor Ankeniheny-Zahamena protected area (CAZ) region, and to provide a framework for future land use planning in other regions of Madagascar. The results of prioritizations show the areas that represent the best possible options to maximize biodiversity conservation and the safeguarding of carbon stocks, and the places with the highest value for sustainable agricultural development that reduce conflicts with biodiversity values. The examination of future development scenarios shows the ways in which land management decisions can influence this potential and provide a series of quantitative benchmarks by which to judge the positive and negative impacts of these choices.

The next step, beyond the project period, is then to use the methodology and possibly the scenarios to develop the "Schéma d'Aménagement Communal" (Municipal Land use Plan) mostly known as SAC for a one commune or "Schéma d'Aménagement Inter-Communal" for two or more commune which is a binding document describing activities that all local stakeholders mutually agreed to undertake in the future.