Testing approaches to define High Conservation Value thresholds in Gabon

ABCG B.2 HCV forest assessment

Final report (Sept 2011-March 2015)

Africa Biodiversity Collaborative Group

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Contents

Contents 4
Executive summary 6
Introduction 8
1.1 Project aim 8
2. The themes addressed under the project 9
3. Critical areas for great apes and forest elephants 10
3.1 Data collation and analyses 10
3.1.1 Distribution and abundance modelling for great apes and elephants 10
3.1.2 Setting priorities and thresholds 10
3.2 Results 11
3.2.1 Species distributions and population blocks 11
3.2.2 "Conservation cost" layers 13
3.2.3 Setting conservation priority zones 15
4. National endemic plant distributions 20
4.1.1 Pre-project data limitations 20
4.1.2 Improvements in the mapping of endemic plants: areas of endemism 20
5. National forest classification maps 23
6. Prioritising river basins by aquatic diversity 25
6.1 Sampling methods 25
6.2 Initial results 25
6.3 Recommendations and perspectives 27
7. Landscape scale case study: Grande Mayumba 28
7.1 Objectives 28
7.2 Methods and tools 29
7.2.1 Analytical approach to identify conservation zones 29
7.2.2 Ecosystem classification of the Mayombe area 31
7.2.3 Slope and erosion risk 38
7.2.4 Aquatic diversity and catchment protection 39
7.2.5 Local community basic needs and cultural values 40
7.2.6 Economic value 41
7.3 Spatial prioritization 41
7.4 Conclusions from the landscape trial 45

8. Overall conclusions 47
8.1 Summary of the work 47
8.2 The limitations of the voluntary approach 48
8.3 New data and modelling approaches offering new insights 48
8.4 Conservation targets 48
8.5 Next steps 49
8.6 The link to governmental land use planning 49
8.7 Caveats 50
8.8 Conclusions 50
ANNEX 1 51

Executive summary

The High Conservation Value (HCV) concept aims to provide a framework for identifying conservation values in the landscape, so that they are managed in a way that ensures their continued persistence. The approach emerged from forest certification (under the Forest Stewardship Council) and is used by the forestry and agriculture sectors as part of voluntary certification schemes that are intended to ensure that products are sourced from responsibility managed concessions.

The HCV process demands that national and regional conservation priorities are taken into account in planning and management. However, in the absence of clear, high-level objectives, this has typically been a bottom-up process, where companies have used their own data to identify conservation values and define management actions to sustain those values.

If HCV is to be an effective framework for biodiversity conservation, the values identified and managed for through voluntary schemes like HCV should complement conservation efforts at other scales and work towards achievement of local, regional, national, and international conservation objectives. Management of HCVs at the concession level should be consistent, and contribute to the achievement of higher level objectives.

The application of the HCV framework can be particularly challenging in countries whose ecosystems are largely intact but where data is poor, such as Gabon in central Africa. In contrast to many of its neighbours, Gabon's forested landscapes are largely intact, and thus critically important for the continued survival of endemic and endangered species. Application of the HCV approach based on common targets and thresholds can increase the cohesion and coherence of the process.

This project was conceived to trial methods and provide guidance to improve decision making about the definition and management of HCV areas in Gabon. During the course of this project, we compiled and improved national biodiversity data sets for Gabon, and demonstrated the application of various analytical approaches for the identification of HCV types 1 to 4 based on clearly articulated objectives.

We highlight some of the key contributions below:

1. **Large mammals**. We used recently published models on great ape and elephant density and distribution for the region and the Zonation decision support tool to identify priority areas that achieve defined population targets for each species, while minimising inclusion of areas with high socio-economic value.
2. **Zones of plant endemism**. Predicted distribution models were generated for 193 of Gabon's 650 known endemic plant species. A preliminary assessment of distribution of these endemic species identified distinct phyto-geographic regions at the national scale using hierarchical cluster analysis. These regions can be used to inform national and regional conservation efforts to ensure representation of plant endemism. Both the models for the distribution of individual species and the phyto-geographic regions identified represent works in progress that will continue to be updated in future projects that build on this work.
3. **Forest ecosystem types**. At the national and local scale, plant assemblage data collected as a requirement for forestry company management plans, was analysed to identify forest types based on species' abundances. The identification of major forest types at both the national

and local level is essential to ensuring that the diversity of forest types are represented by regional and national conservation efforts.

4. **Prioritising freshwater catchments on fish diversity**. A national data set on spatial distribution of fish species was compiled, to support a preliminary assessment of the catchments based on biodiversity indices.

We also present an approach for the integration of national and local level biodiversity data in a spatial planning exercise at the level of an individual concession. The Marxan spatial planning software was used to combine spatial information on the distribution of different conservation features with information on the cost of managing individual parts of the landscape for conservation, to produce land use configurations that achieve conservation objectives while minimizing costs. The process provides a transparent framework through which stakeholders can articulate individual objectives for the region, and visualise the consequences of those decisions on the areas selected for conservation priorities. To inform HCV delineation at the concession level, the national scale information was combined with locally collected information on distribution of plant and animal species, values on community forest use (HCV 5 and 6), and erosion vulnerability (HCV 4), and revised maps for the distribution of other threatened species in the region.

The land use scenario maps presented as part of this report, provide examples of 'optimum' configuration of conservation set aside areas, for a given set of conservation priorities. While the best available information was utilized to identify these land-use alternatives, the areas identified are highly dependent on the objectives for which the areas are to be identified. The approach can be used to ensure the representation of different HCVs in strict conservation areas and minimize the cost of achieving those objectives. We have included a preliminary assessment of relative economic costs of achieving these objectives as an example for how costs can be included in the analysis to explicitly assess trade-offs between conservation and extractive use. The implications of adopting national conservation targets for HCV species are discussed for both timber harvesting and agro-industrial development.

We also identify knowledge gaps and outline priority data needs. These needs are identified to compliment the data collected as part of the this project, and would significantly improve the identification and management of HCV areas in Gabon. The methodologies developed and applied in this report are broadly applicable in other countries, and many of the data sets, for instance the elephant and ape models extend the respective range of each species in central African countries. We suggest that objective and data-driven frameworks such as the one we detail here are a useful foundation for national standard setting processes currently underway in both forest and palm oil sectors.

Introduction

1.1 Project aim

The concept of a High Conversation Value (HCV) forest emerged over 15 years ago within forestry management and has been used as a tool for individual land owners/concessionaires to identify and protect attributes of outstanding conservation value. The delineation of HCV areas gained momentum within the industry and nineteen countries have produced guidance documents on the process for identifying HCV areas. This has typically been a bottom-up process, where companies have used their own data to define conservation priorities in the absence of agreed national conservation priorities or planning frameworks. The HCV framework is now expanding beyond the forestry sector and into agricultural and plantation sectors (e.g. RSPO) as operators attempt to demonstrate good environmental practice and show that their activities are not impacting areas deemed important for biodiversity conservation. The HCV concept is simple and straightforward; identify important values in the landscape and continue to manage those areas to ensure persistence of those values. The HCV framework can be applied at a variety of scales, including national, regional and at an individual plantation concession. In practice, HCV areas have been primarily delineated based solely on local conservation values, without consideration for how these values contribute to higher level (national, regional) conservation objectives. While national parks and protected areas are generally considered to be the cornerstone of conservation efforts, the HCV framework provides a useful framework for incorporating the contribution of conservation management from working landscapes into broader conservation efforts.

In order for HCV to be an effective framework for biodiversity conservation, the HCV concept needs to incorporate national priorities and account for emergent properties (e.g. connectivity) that cannot be assessed based solely on local values. HCV areas must compliment conservation efforts at other scales (e.g. national, regional, local), and the areas identified and values managed for at the concession level must collectively achieve the conservation objectives defined at those scales. National and regional level analysis that identify areas important for maintaining values that operate at levels larger than the individual concession scale are critical. Ensuring that the HCV framework considers values like connectivity, requires this information *before* land is allocated for forest conversion. The identification of these HCV areas should be based on the conservation objectives of Gabon and not generic criteria. Data sets available at the national scale provide an objective and transparent platform for priority setting and defining HCV criteria, and then mapping HCVs at the national scale.

WCS, MBG, WWF and CI are keen to ensure that future industrial developments take into consideration areas of important biodiversity. For instance, plantation developments should be orientated to degraded lands and areas that are of low priority for biodiversity, both at the national and concession level scale. The HCV criteria provide a useful framework for organizing and managing priority conservation areas in working landscapes, but it is first necessary to develop reliable, consistent and transparent methods for the delineation of HCV areas. For HCV to be effective, the role that HCV areas will play in regional, national, and international conservation efforts need to be defined and agreed at the national level to ensure that HCV areas compliment other conservation efforts. For each HCV criteria, it is necessary for stakeholders to agree on *when* a given conservation feature will be considered an HCV. The development of a shared vision and common set of objectives for biodiversity conservation is necessary to ensure that HCV areas identified at the concession level, contribute to achievement of national conservation objectives.

This report contains a number of maps that show a set of areas identified as 'conservation priorities' based on basic biological concepts and given thresholds. The intention in publishing these maps is to help stakeholders visualise the spatial consequences of adopting a particular threshold or limit. It is not the goal of this project to propose the 'right' threshold for each parameter, but to show how quantitative and objective based approaches can be used in a transparent process to identify conservation priority.

The project focused on production of national data sets in four thematic areas, shown in the table below, to complement the work already underway by the government of Gabon. This report also identifies a number of gaps in the existing knowledge base and provides recommendations for furthering priority setting at the national scale.

2. The themes addressed under the project

The goal of this project was to explore approaches for identifying HCV areas through the setting of objective targets for inclusion of biodiversity values in those areas, and to facilitate land-use planning so it takes into account areas of high conservation value. The HCV attributes considered for this project are the biodiversity and ecosystem service components (HCVs 1-4) where a reasonable amount of spatially explicit data now exists, and those that can be mapped at large scales. We would have liked to include a number of additional features, but we did not have sufficient information to do so. An additional aim was to facilitate decision making on land use at the district, provincial or landscape scale. Decisions about HCVs 5 & 6, which concern local peoples cultural and forest use values were included in the landscape scale analysis (see below). The available community data that we used was not, however, collected for the purposes of a HCV assessment and therefore its use here should be treated as a demonstration only for the mapping. Compiling such data is an essential component of land use decisions within an individual concession, where one would also assess sustainability and potential for viable alternatives.

Theme	Objective	Organisation
1.	Modelling of populations of great apes and elephants to: • Provide the information base necessary for identifying priority areas (size, intactness, population viability etc • Coarse scale maps of priority areas), that take into account the human footprint	WCS & MBG (chapter 3)
2.	• Modeling distribution of endemic plant species in Gabon • Identification of distinct areas and hotspots of endemism	WCS & MBG (chapter 4)
3.	Development of methods for the identification of forest types and land units, to facilitate the planning process	WCS (chapter 5)
4.	Using a biotic index of fresh water systems to identify important river catchments	WWF (chapter 6)

In addition to the mapping of these features at a national scale we have completed a case study example, using national scale priority maps in a conservation planning exercise designed to identify conservation priorities at the landscape scale (chapter 7). This 'landscape case study' has enabled us to explore the utility of national scale priority maps, complementing this with locally acquired data and identified HCVs and develop techniques for integrating such data into planning decisions in a real world scenario.

3. *Critical areas for great apes and forest elephants*

3.1 Data collation and analyses

3.1.1 Distribution and abundance modelling for great apes and elephants

The modelling and mapping of forest elephant (*Loxodonta africana cyclotis*), central chimpanzee (*Pan troglodytes troglodytes*) and western lowland gorilla (*Gorilla gorilla gorilla*) populations at the regional level was recently completed by WCS and partners (Maisels *et al*. 2013[1], IUCN 2014[2]). Individual models were developed to estimate the distribution and abundance across central Africa for each sub-species. The models were based on field data collected by an extensive network of partners and from a number of national parks and park peripheral areas over the course of ten years, using standard data collection techniques, as well as environmental and social variables that can be used to predict the distributions. The model outputs for apes have recently been used to redefine the priority areas for ape conservation across all of central Africa (IUCN 2014).

The outputs from the modelling exercise are spatially explicit predictions of the density of each species at 5 km^2 resolution for elephants and a 1km2 resolution for chimpanzee and gorilla across the region. The data can be used to set explicit targets for the conservation of individual populations of each species and to quantify the contribution of areas to achievement of those targets. However, the decision about when a concentration becomes nationally significant requires the definition of a threshold value.

3.1.2 Setting priorities and thresholds

This part of the project used the model data to consider different ways to visualise the results and promote discussion about appropriate conservation targets by stakeholders and decision makers in the region. Conservation objectives and values are subjective by definition, and many methods have been proposed to identify and delineate areas of greater conservation value. Some approaches, such as the methodologies for selection of Key Biodiversity Areas (IUCN) suggest applying thresholds to select areas with a large proportion of the national population of the species. For example, Endemic

[1] Maisels, Fiona, Samantha Strindberg, Stephen Blake, George Wittemyer, John Hart, Elizabeth A. Williamson, Rostand Aba'a, et al. "Devastating Decline of Forest Elephants in Central Africa." Edited by Sergios-Orestis Kolokotronis. *PLoS ONE* 8, no. 3 (March 4, 2013): e59469. doi:10.1371/journal.pone.0059469.

[2] IUCN. "Plan d'action régional pour la conservation des gorilles de plaine de l'Ouest et des chimpanzés d'Afrique centrale 2015–2025." Gland, Suisse: Groupe de spécialistes des primates de la CSE/UICN, 2014.

[2] IUCN. "Plan d'action régional pour la conservation des gorilles de plaine de l'Ouest et des chimpanzés d'Afrique centrale 2015–2025." Gland, Suisse: Groupe de spécialistes des primates de la CSE/UICN, 2014.

Bird Areas are selected on the basis that they contain a threshold of 5% of the global population of the species.

The drawback of such approaches is that there is no clearly defined objective that will be achieved if all areas that contain >5% of species distribution are conserved. The aggregate protection afforded the species may be highly variable and is entirely dependent on the spatial distribution of the species in the landscape. Rather than focus on defining a specific thresholds above which the population of a species was deemed to be important, we focused on achieving overall objectives for the individual species considered in the analysis. For example, rather than saying that areas that contain >5% of the distribution of the species are important, we define an overall target for species conservation (ex. 70% of the total population) and define all areas as important if they efficiently contribute to achieving that target.

To guide the selection of areas where conservation of forest habitat will be the most appropriate land-use, we generated a human influence layer, or 'cost of conservation layer'. This layer allowed us to effectively identify areas that are more suitable for conservation should be avoided when identifying conservation zones, because of increased pressure from the human activities.

Population block maps were produced separately for elephants and apes, based on known barriers to movement by these species groups. Population blocks were primarily defined based on boundaries posed by large rivers and major areas of human habitation and development which represent bio-geographic divisions between populations. These divisions are largely speculative, and should themselves be subject of more detailed discussion. For the purposes of prioritisation and our analyses, each block represents a distinct conservation feature, within which a specified populations would need to be maintained in order to ensure persistence of the species within the block. The purpose of defining population blocks was to ensure that each species was conserved across its full range.

To identify areas that were important to contribute to the targets we defined, we used two spatial planning software packages (Zonation and Marxan). These select the best ('least cost') areas that efficiently achieved the targets we considered (ex. 70%) within in each population block. Separate analyses were conducted for apes and forest elephants.

3.2 Results

3.2.1 Species distributions and population blocks

Elephant density is very heterogeneous (Figure 1 left) across Gabon; distance to human habitation and forest management are important factors in determining density. Following discussion of the results of the elephant population analysis carried out in year 1, a number of different techniques were tested for the identification of priority zones. Figure 1 right shows the predicted elephant population in each of 15 'population blocks' as a proportion of the global population of forest elephants. The map clearly shows the importance of Gabon in supporting forest elephant populations around the world (it supports ~50% of the total population), and the relative distribution of elephants in the population blocks in Gabon.

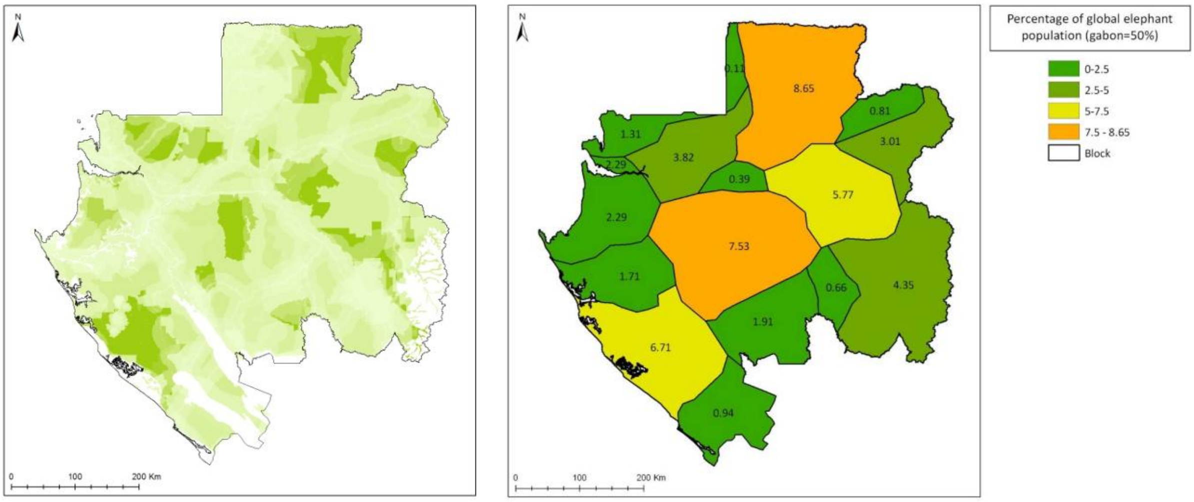


Figure 1. Density distribution map of forest elephants at 5km resolution in Gabon where dark green represent higher densities (l). Overall importance of elephant blocks expressed as percentage of the global population of forest elephants (r).

The density distribution data for the two ape species combined (gorillas and chimpanzees), and for each species separately are presented in Figure 2. For this analysis, we combined major rivers and major roads (including those with high levels of continuous human presence) to divide the country into 19 blocks. Combing the map of population units and the predicted density surface, shows the expected number of great apes within each unit (Figure 2). This is already informative, at it shows the blocks that are likely to be able to sustain viable populations over the long term.

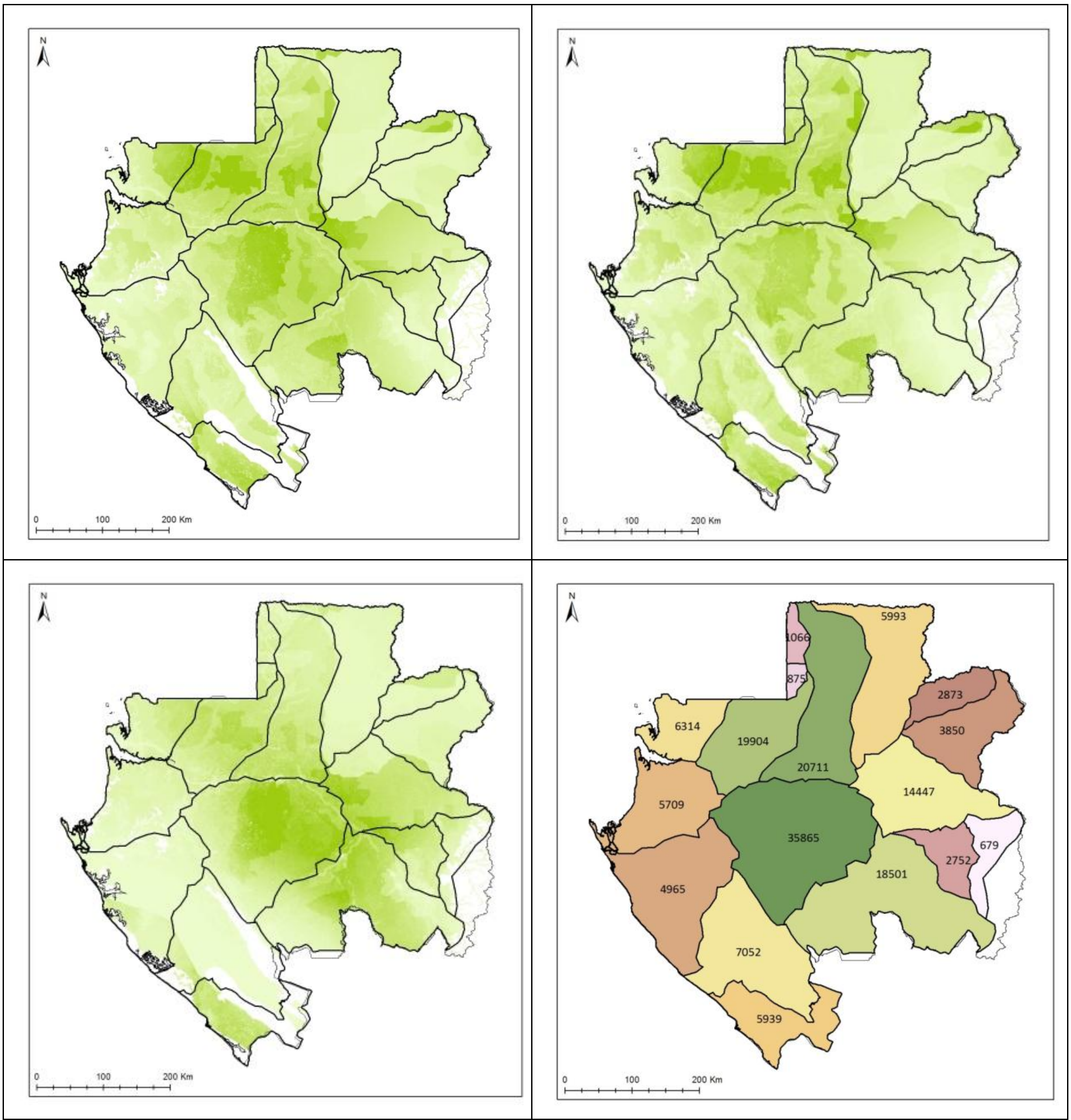


Figure 2. Basic density surface from the modelling of great ape densities, with densities shown as individuals per square kilometre. Great apes combined (top left), Gorillas (top right) and chimpanzees (bottom left). The lower than expected density predictions for apes in north east of Gabon are the result of previous ebola outbreaks. Data from IUCN 2014[3]. The total population estimate of both gorillas and chimpanzees in each block (bottom right).

3.2.2 "Conservation cost" layers

An accessibility layer was created by combining human population density and ease of access, using roads, navigable rivers and topography to measure the 'ease of travel' to any given point (Figure 3).

[3] IUCN. "Plan d'action régional pour la conservation des gorilles de plaine de l'Ouest et des chimpanzés d'Afrique centrale 2015–2025." Gland, Suisse: Groupe de spécialistes des primates de la CSE/UICN, 2014.

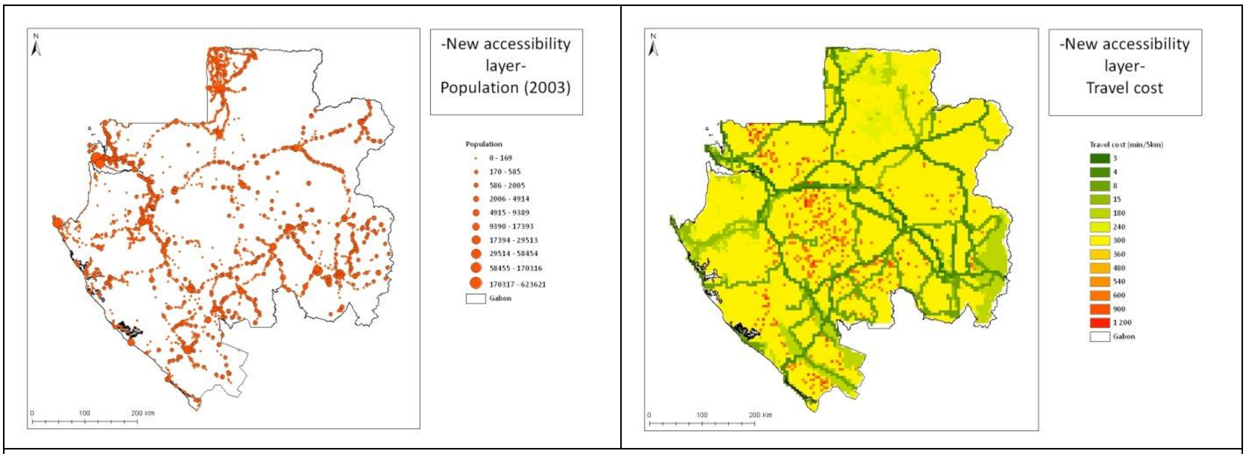


Figure 3. Human population density (l) and accessibility (r)

In addition to the accessibility layer, we considered existing land use and tenure categories, such as forestry concessions and their management status, and potential suitability for agricultural crops (notably palm oil and rubber). The combination of these layers produced a relative measure of the ‘cost’ of setting aside the area for a conservation related land use, where in addition each cost parameter can be assigned different weightings of importance (Figure 4). In this context, 'cost' is not necessarily the 'cost' in monetary terms, but an approximation of the relative difficulty in attempting to set aside an area for conservation based on existing and potential future use of the area. The systematic approach we used to identify areas of higher conservation value preferentially selects areas of lower 'cost' and higher value for species conservation.

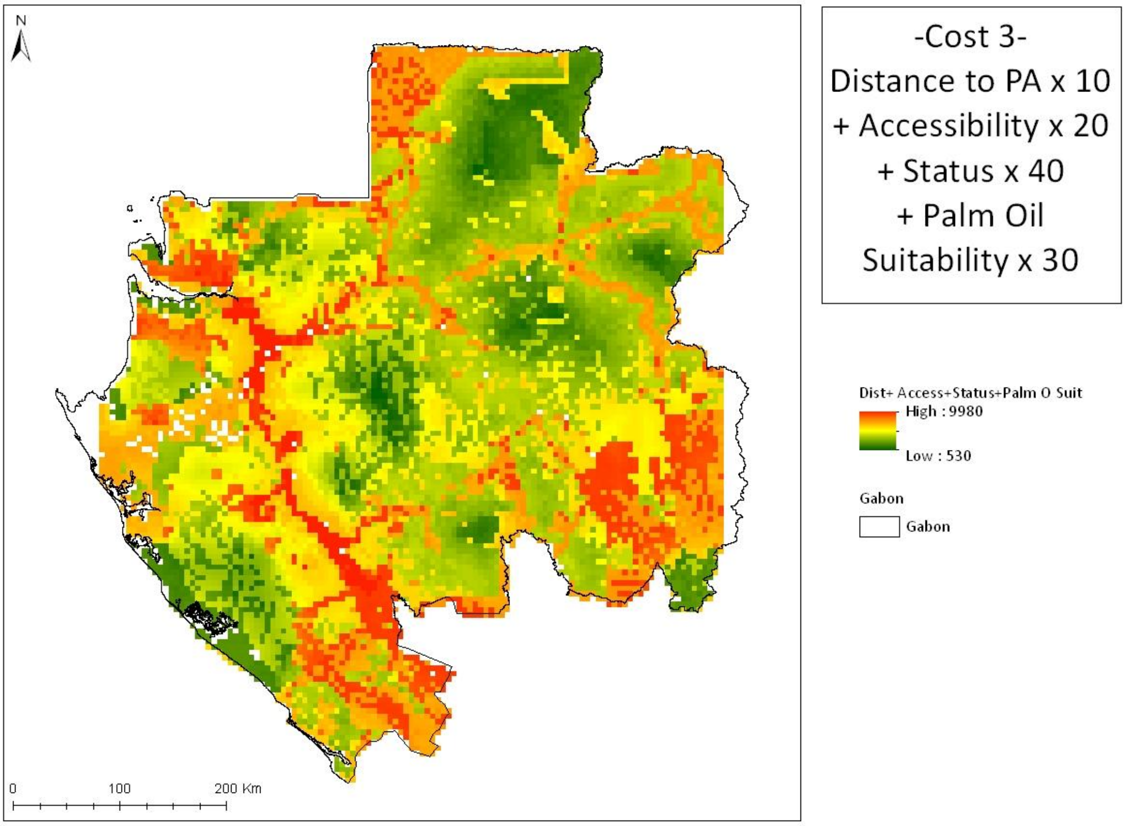


Figure 4. An example map of the 'cost' of conserving wildlife in a given area. Red areas have the highest cost, as they are already settled and or have high suitability for other land uses. Green areas have lower cost, due to low levels of human pressure and lower suitability for crops. Four cost parameters are combined: distance to protected areas (PA), accessibility (public roads, rails etc), management status (PA, certified forestry, CFAD etc), environmental suitability for oil palm, with the weight of each parameter in the cost layer as a percentage.

3.2.3 Setting conservation priority zones

The simplest prioritisation approach would be to prioritise population blocks based on the percentage of the national (or global) population of they contain (see Figure 1, Figure 2). However this approach does not take account of the different land uses, or the feasibility of conservation action within each block. This approach would also treat the elephants and apes in individual populations as fungible, essentially ignoring that the blocks are distinction units.

To improve on this, the examples below show how we used a *population target* for each block to define a 'significant concentration' of elephant or apes at the national scale. The Zonation software package was used to combine the population density data, with the cost layer to select the best areas for elephant conservation. In the model, pixels are selected by conservation priority (i.e. high population density and low cost) until a given population target figure has been satisfied for each block.

In the first analysis on the elephant model, we tested the spatial prioritization process by defining targets per population block based on their overall importance; defining higher conservation targets for blocks with higher populations (Figure 5).

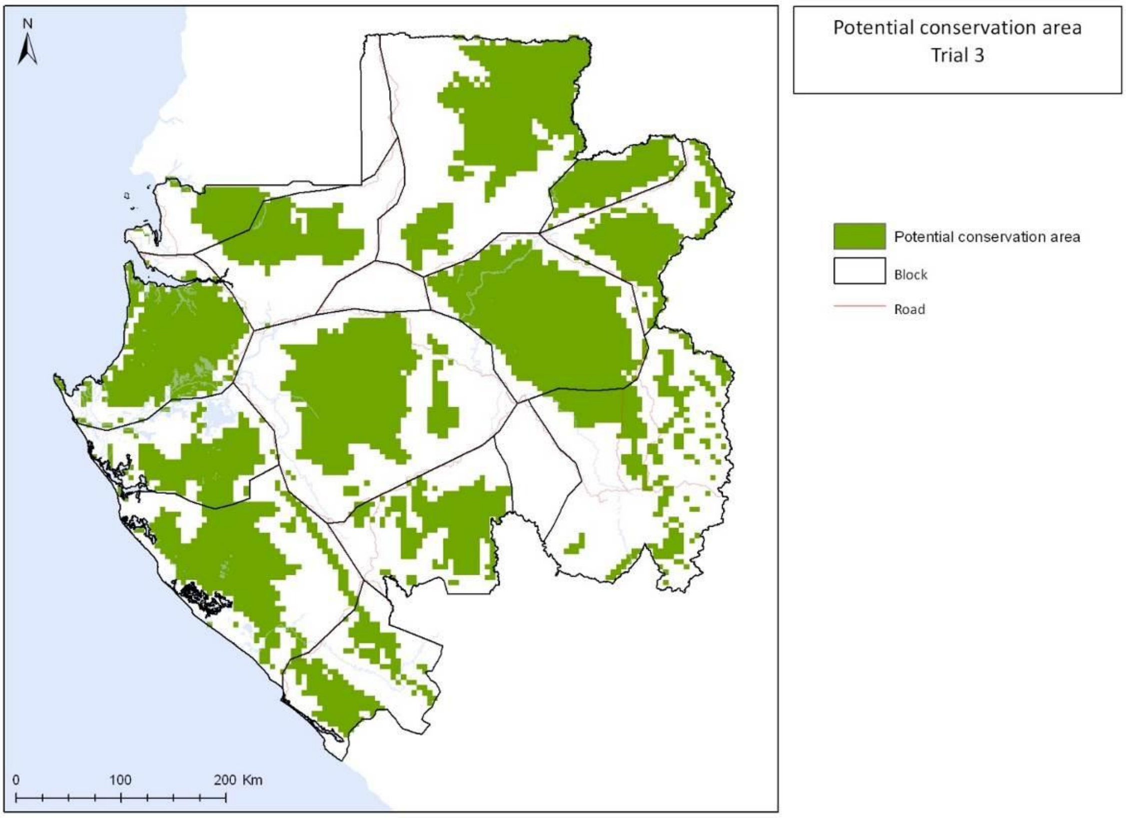


Figure 5 Results from a modelling exercise in yr 1. Variable targets were set for each population block and Zonation was asked to find the optimal area to achieve the given population target in each block.

However, this is only one potential approach to defining important concentrations, and conservationists and decision makers can always argue over which blocks are the most important or what the precise target population should be for each block.

An alternative approach to the targets presented above is to maintain a set percentage of the elephant population in *each* block. In the example below (Figure 6) we show the minimal land area required to represent 70% of the current elephant population in each block.

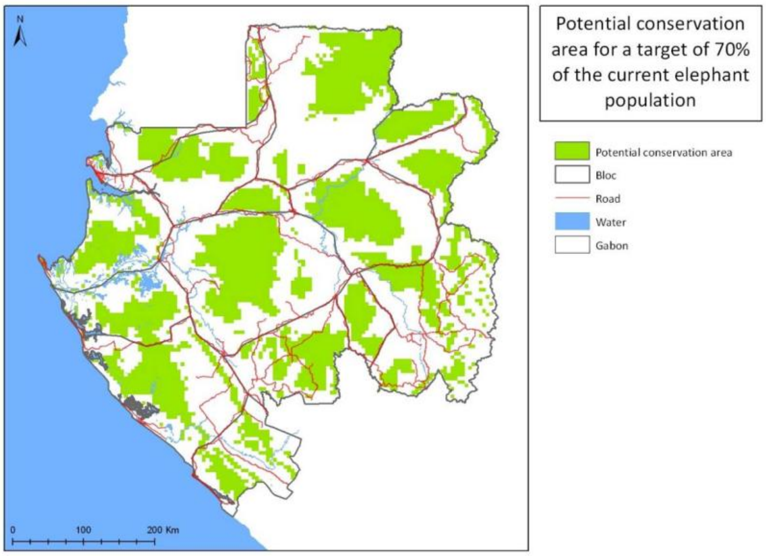


Figure 6 Area of land required to conserve 70% of the elephant population in each block

Repeating this analysis at different percentage target is informative, as it shows how much more land would be required to be managed for conservation if the target percentage is increased. The example below shows the results of a Zonation prioritization exercise to represent 70, 80 and 90% of the total population of elephants in each block (Figure 7).

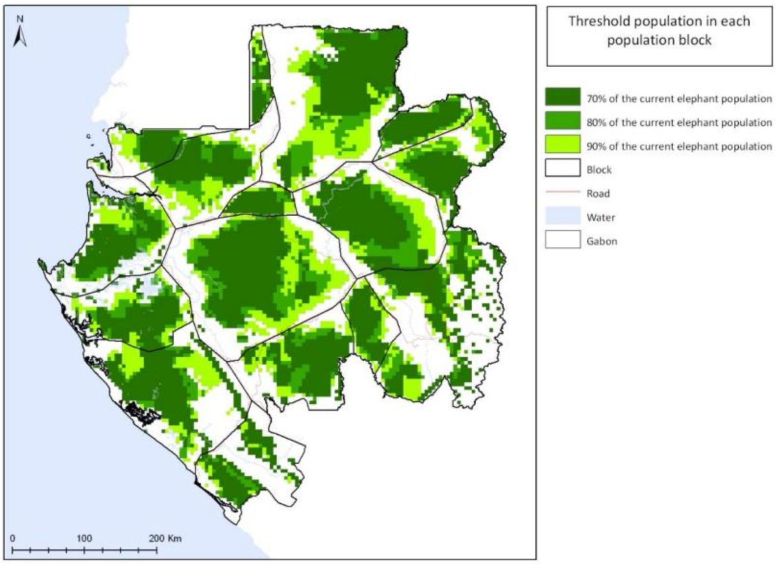
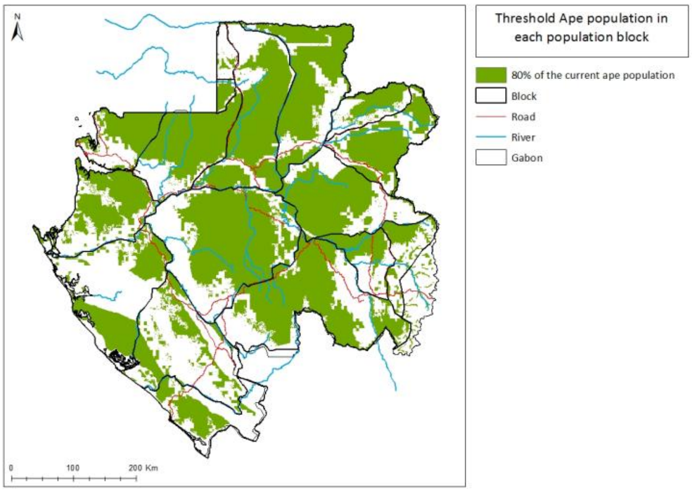


Figure 7 Overlay of different percentage thresholds: the area required to conserve 70, 80, and 90% of the elephant population in each block.

For apes, similar discussion can be held on setting targets, fixed targets for each population block, or variable targets per block depending on other factors. Here we present two Zonation analysis outputs. The first achieves an 80% population target in each block. The second superimposes outputs from three separate analyses with population targets of 70, 80 and 90%, to illustrate the addition forest area required to achieve increasingly high targets (Figure 8).



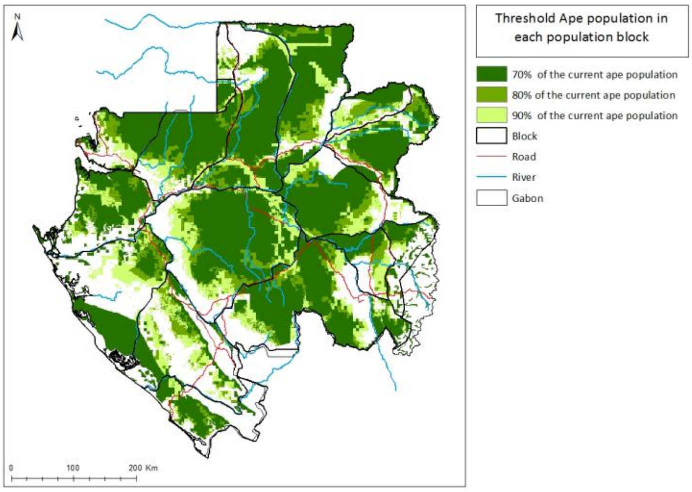


Figure 8 (top) Map showing Zonation results at a target population threshold of 80% for each block. These are the areas that the model suggests should be maintained under forest cover if 80% of Gabon's great apes are to be conserved in each population block. In this example the 'cost' layer used in the analysis included oil palm suitability as a factor to avoid when selecting conservation areas. (bottom) Map showing an overlay of Zonation results at a target population of 70, 80, 90% of the total great ape population.

Note on publication of results

Please note that these results are preliminary in nature, and are primarily presented to demonstrate the application of an analytical method. Thus the maps presented here are intended to provide an example for how detailed datasets and spatial prioritization tools can be used to inform decision making and should be considered prescriptive in nature. It is intended that these results be discussed with a wider stakeholder group and the prioritization approach revised and improved based on input from interested parties. The maps presented in this report are shown as example outputs and do not represent the definitive view of WCS, WWF and CI on conservation priority areas in Gabon.

4. National endemic plant distributions

4.1.1 Pre-project data limitations

650 plant species are endemic or sub-endemic to Gabon. Efforts to develop national maps of endemic plants from which priority areas could be identified, are confronted with the problem that botanical sampling is heavily biased towards accessible areas, and areas zones of high endemism are found across Gabon (Figure 9). Funds from the USAID cooperative agreement have enabled the MBG team to expand their botanical collections into some of the less sampled area, in the coastal region of Gabon, and to ground truth historical records for plants thought to be endemic to the coastal forest eco-region. The botanical analysis has improved our understanding of the diversity of forest ecosystem types in the region, and has enabled the development of a map of endemic areas for the coastal region of Gabon.

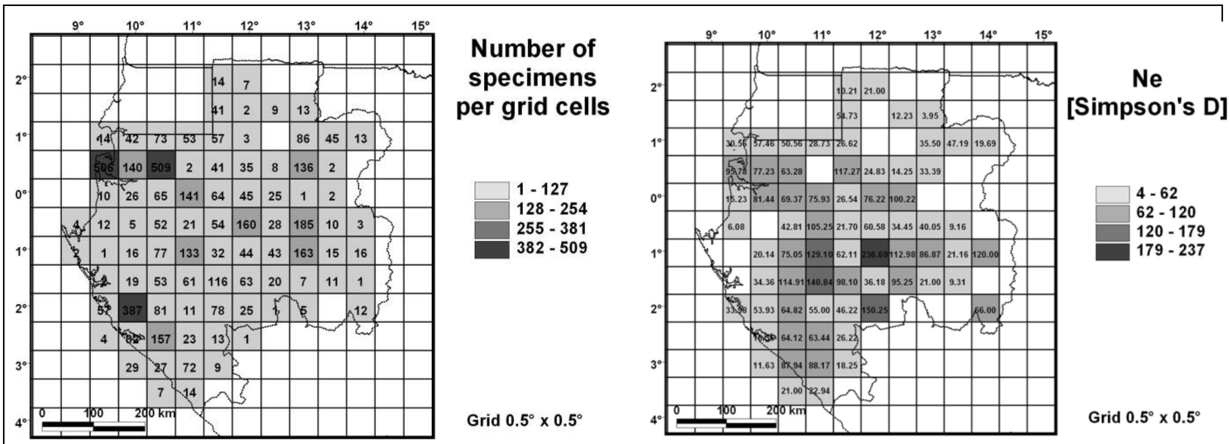


Figure 9. Endemism centers of Gabon; endemic species richness per 0.5 degree grid cell (l), and Simpsons D diversity index using re-sampling methods per 0.5 degree grid cell (r).

4.1.2 Improvements in the mapping of endemic plants: areas of endemism

Of the 322 species inventoried, 88 were endemic or sub-endemic to Gabon (Figure 9). When the distribution of individual species is mapped, floristic groups emerge at the national scale, such that it becomes possible to identify three different zones of endemism in the coastal part of Gabon (Figure 10). Endemic species data confirmed that the western part of the area supports species found in a narrow coastal band now referred to as the Mayombe-Loango zone of endemism (dark blue zone in Figure 10). The inland part of the Mayombe massif has vegetation consistent with the southern coastal zone (sky blue in Figure 10) which is more widespread. This information is useful in spatial planning to ensure representative samples of each forest type are included in conservation areas.

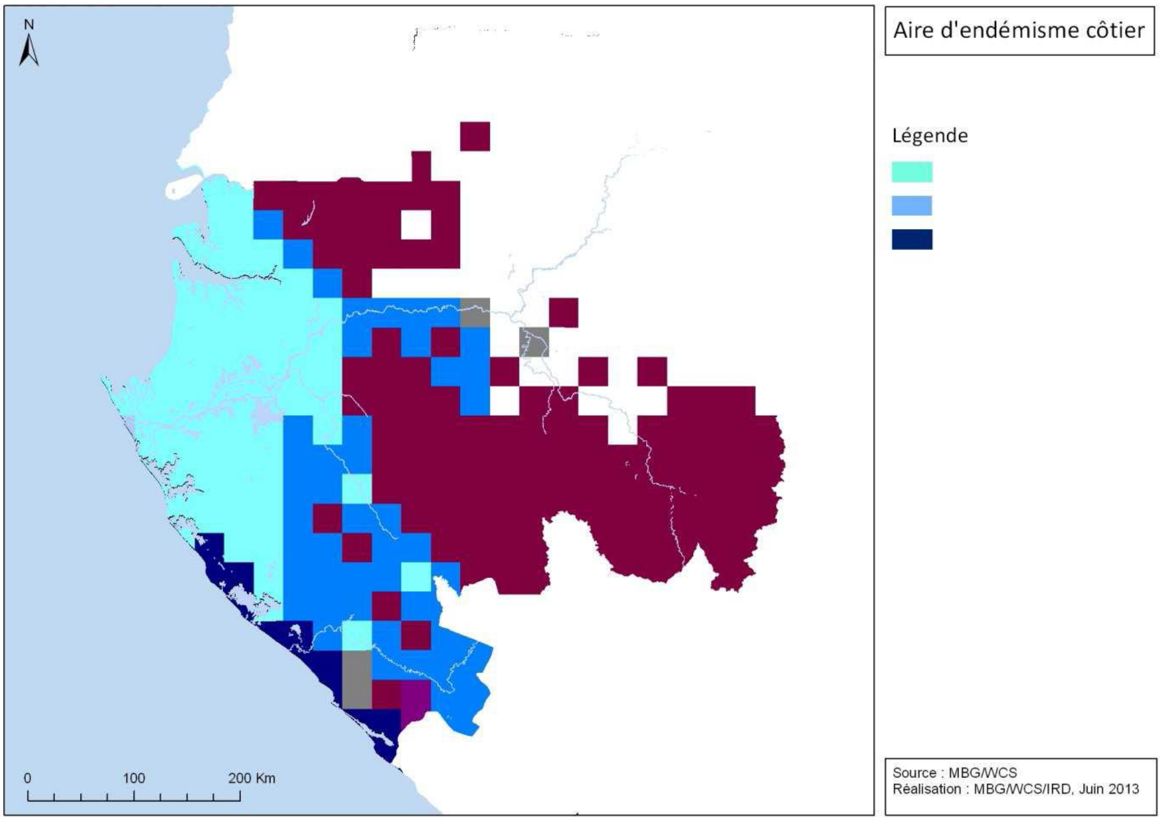


Figure 10. Areas of endemism in the coastal part of Gabon. The north coastal zone (turquoise) the south coastal zone (sky blue) and the Mayombe-Loango zone (dark blue) can be distinguished from statistical analysis of endemic species ranges.

A second analysis was conducted using the predicted distribution for more species endemic or sub-endemic to Gabon, 193 in total, and cluster analysis to define the major compositional groups. The following endemism area map of Gabon was produced (Figure 11). This map provides a better spatial coverage to the first analysis that used just 88 species, and clearly shows the main phyto-geographical trends for Gabon. It is, however, far from the 650 endemic and sub-endemic species to Gabon, and therefore being a final map. In addition the data used remain to be fully verified by taxonomists. Additional work would add endemic species, including information from future collection in the remaining sampling gaps, particularly in the north-east for Gabon, and to improve the resolution in the distribution of zones of endemism.

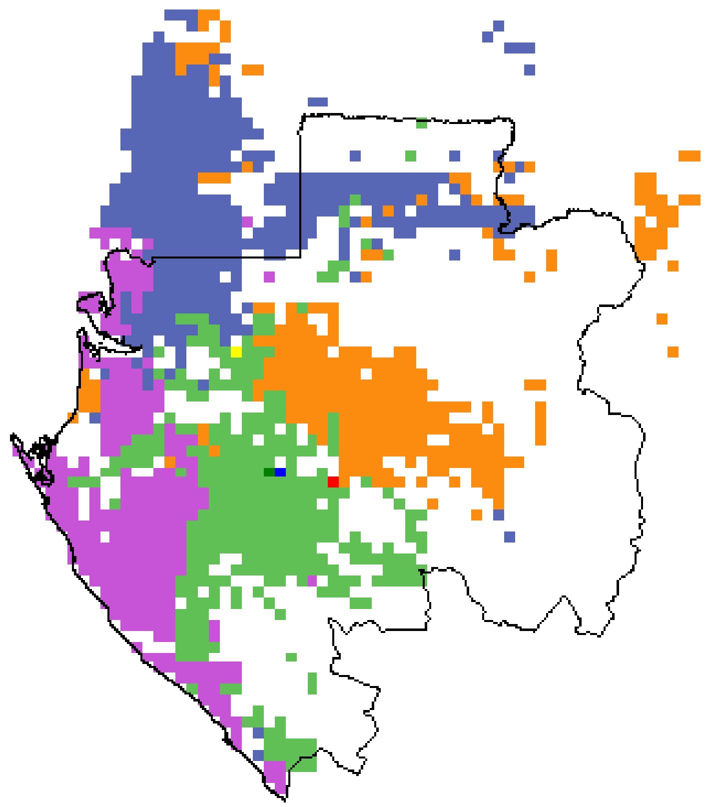


Figure 11 Areas of plant endemism in the coastal and central regions of Gabon. The different zones were identified through statistical analysis of range of endemic species.

5. National forest classification maps

Missouri Botanic Gardens (MBG) has developed and tested an approach to identify distinct forest vegetation types that uses plant assemblage data collected by forestry companies for their forest inventories (legally required for the completion of a forest management plan). The multi-step analytical approach uses statistical ordination and clustering analyses to identify the vegetation types, based on the relative abundances of common tree species.

In this study, we used forest inventory data collected by the company Sylvafrica from 20 forestry concessions across Gabon, which covers at least 15% of Gabon's land area (see **Error! Reference source not found.**). Ordination and clustering analyses applied on this data set, has been tested by MBG to produce a preliminary national classification of forest ecosystem types for Gabon.

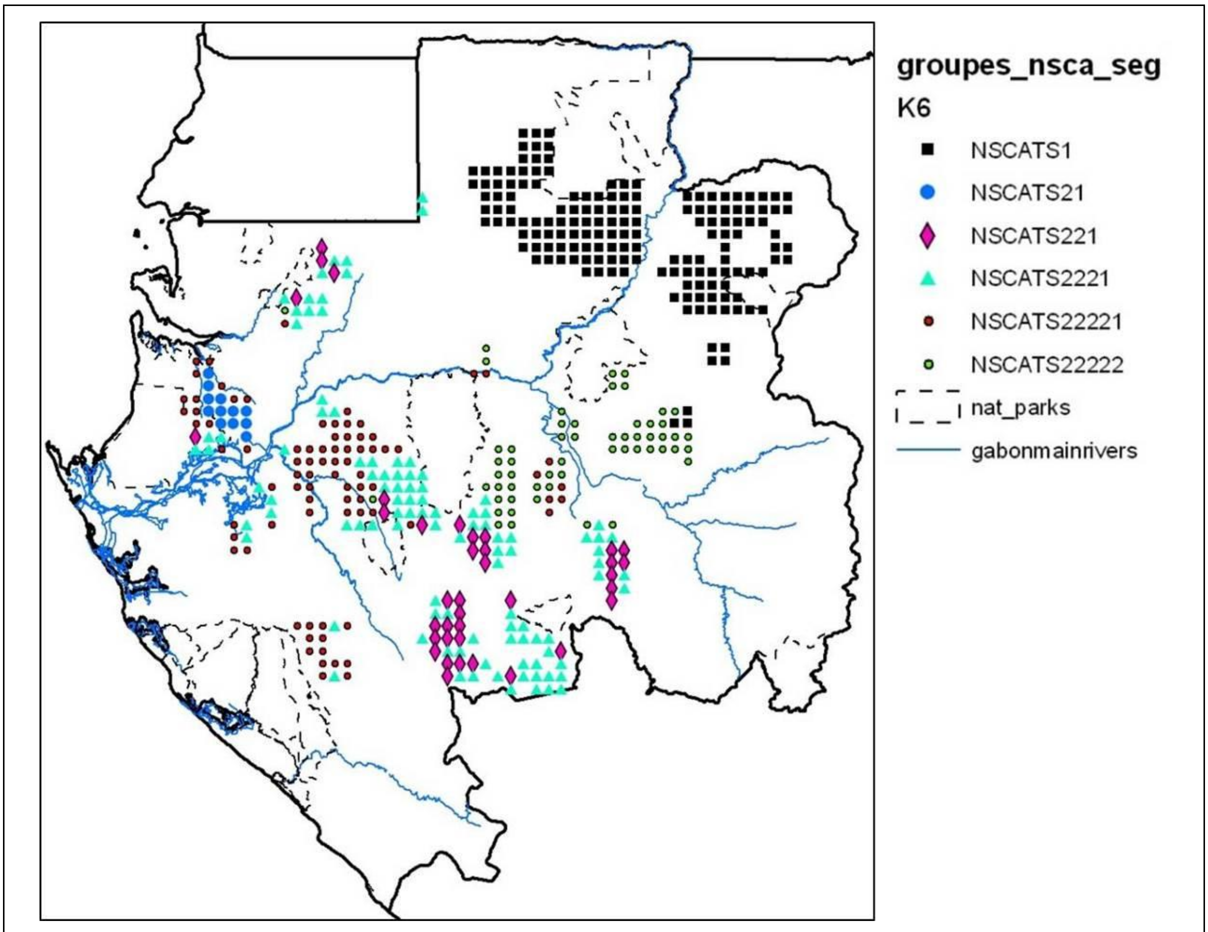


Figure 12. Preliminary results of the statistical analysis of forest inventory data from 14 companies provided by Sylvafrica to classify forest types based on vegetation diversity. The different forest types shown in the legend are defined by species associations. If this analysis was completed across the entire country the results could be considered in conservation planning work to ensure the representative coverage of conservation areas. However, acquiring and processing the necessary data poses a number of challenges.

The categories of forest type that have been defined based on this sample are shown in the table below:

No	Designation	Description
1	NSCATS1	Continental forest without Okoumé
2	NSCATS21	Estuarine forest
3	NSCATS221	Mature central forest rich in Okoumé
4	NSCATS2221	Mature central forest
5	NSCATS22221	Costal forest
6	NSCATS22222	Ivindo forest

While the map does not cover the whole of the country, it is believed to have reasonably good representation of most forest types since concessions in all broad phyto-geographical delimitations (see Figure 11) were included in the analysis. These preliminary results, which are shortly to be published by MBG, show that the approach has major implications for conservation planning (assuring representativity) and for the identification of spatially restricted or rare habitat types, consistent with HCV 2 and HCV 3.

To complete a national forest type classification requires additional data from certain locations, notably the south west and the north east of Gabon, and also from non-forest vegetation types. The other vegetation types have thus far not been included in this large scale analysis.

This work package has not yet been fully completed since additional forest inventory data, although available from other sites (see landscape study below), was not fully compatible with the methods used by Sylvafrica. For example, Sylvafrica data are collected by the same field team, meaning that it is relatively unbiased comparing to data collected by different companies employing various field team and methods. This risks introducing bias that, although not surmountable, must be controlled for and represents a future challenge. Moreover, an analysis of the data at the national scale will also be hampered by technical problems due to the huge quantity of the data that represent forest inventories.

The approach used at the national scale are applicable to identifying forest ecosystem types at finer scales, as we demonstrate in the landscape study in chapter 7. This provided the basis for applying a prioritization approach to identify HCV 2 (rare forest types) that took into account national rarity.

6. *Prioritising river basins by aquatic diversity*

The objective of this module of the project was twofold. Firstly to investigate how aquatic (fish species) diversity varies between Gabon's river basins, and secondly to evaluate the feasibility of classifying and prioritising river basins based on their species richness and endemism. Based on the data collected and analysed on aquatic biodiversity in Gabon's river systems that was completed in Yr II, it was possible to assign river catchments to different priority levels for conservation planning based on their uniqueness.

6.1 Sampling methods

A review was undertaken of all aquatic biodiversity sampling in Gabon since 1859, including collections made by Paul du Chaillu in 1862. To complete and update the state of knowledge from historical studies, some additional sampling missions were undertaken by Yves Fermon and a team from Institute de Recherche Agronomique et Forestiere (IRAF) with funds from this project.

The final database on aquatic diversity comes from samples taken at 991 'stations' in Gabon, from a total of 1644 sampling visits since 1859. 88.3% of these stations were sampled only once or twice. The greatest density of sampling was carried out in the Ogooué and Ivindo River basins. Fifteen basins, only accounting for 0.01 % of the territory, were never sampled.

Data analysis: grouping basins by diversity/endemism

To synthesize all the information collected, a hierarchical classification was conducted taking into account the weighted total species richness and endemism per basin/watershed.

6.2 Initial results

Overall diversity of fish fauna

There are 407 described species in Gabon of which 31 are endemic and five were introduced. They are divided into 26 orders, 74 families and 181 genera.

Classification of river basins into zones

From a detailed study of topographic maps and historical classifications, 73 river basins draining into the Atlantic Ocean or the Gulf of Guinea are identified. We adopted Paugy *et al*. (Faunafri[4]) combination of these 73 basins into 33 'zones' (Figure 13), where the Ogooué River accounts for the most number of zones and therefore .

A hierarchical classification of these 33 zones, based on known and expected species richness and endemic species richness, resulted in the identification of five categories (including a category 0 for basins where no data was available).

The Ogooué which includes several important sub-basins as the Ivindo and the Ngounié all appear extremely important for overall diversity and endemism (Figure 14).

[4] Paugy, D., Zaiss, R. & Troubat, J.J. (eds), 2008. "Faunafri". http://www.ird.fr/poissons-afrique/faunafri/

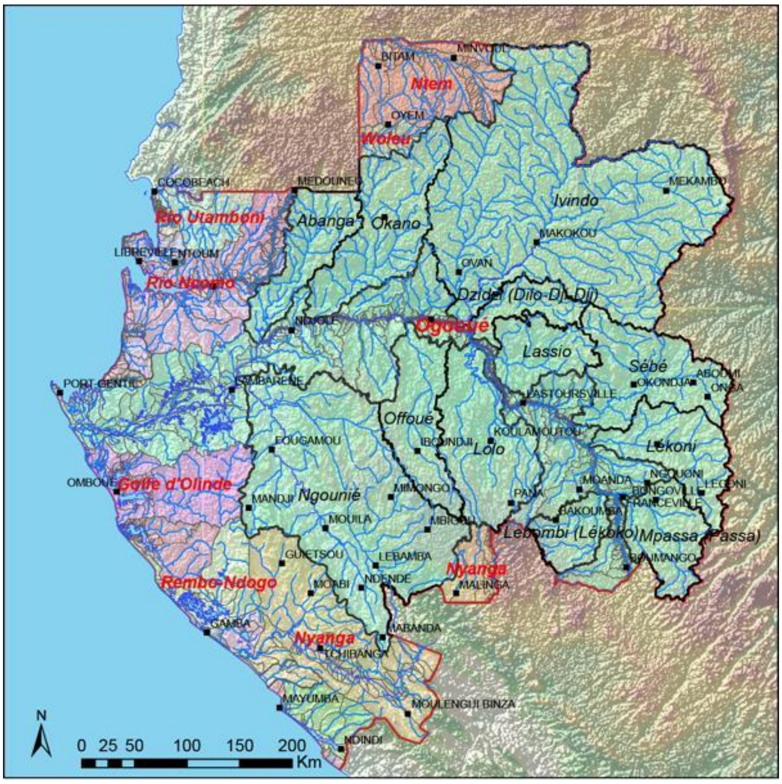


Figure 13 The regrouping of river basins into 33 zones following the classification of Faunafri

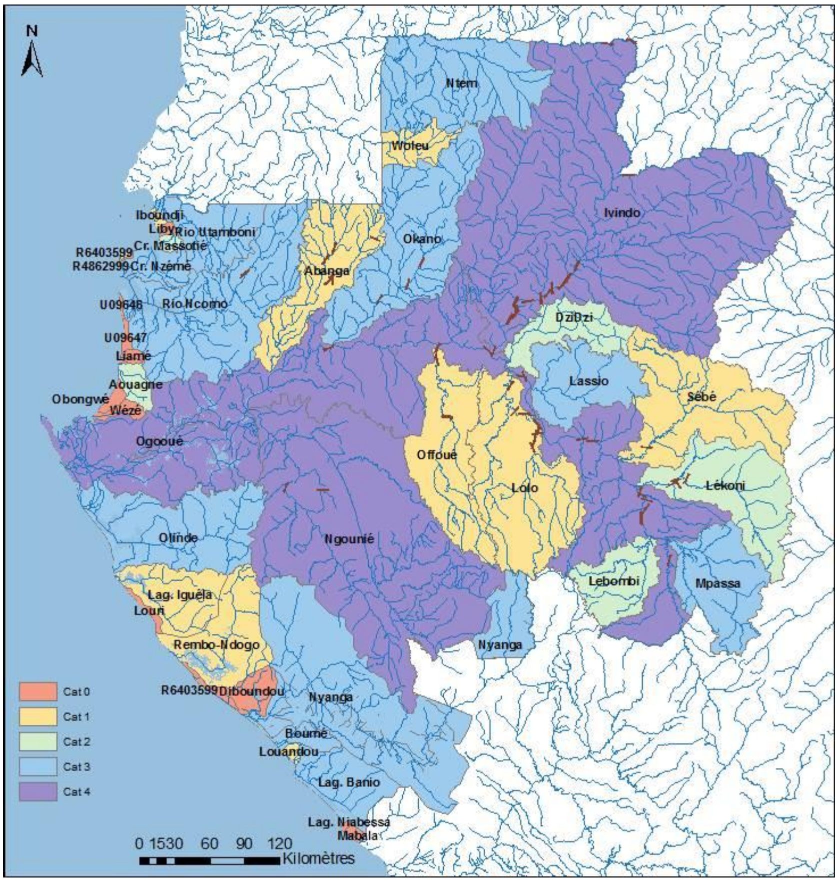


Figure 14 Hierarchical classification of river basins by aquatic diversity. Category 4 has the highest richness and endemism. Basins in Category 0 have not yet been sampled.

Data collection issues

After compilation of data collected during sampling surveys, we had a database containing 9122 survey events. Only 6401 of these (70%) were retained due to poor data quality. There has been an undeniable loss of information that is related to:

(i) specimens poorly determined of the museum collections;

(i) partial information on the collection of specimens;

(iii) information from articles and grey literature were unusable because of their weakness and incomplete or inaccurate data (poorly defined species, not well defined data collection points...)

Due to these un controllable factors (and resulting loss of information), and the patchy spatial coverage of sampling effort, the findings we present on fish diversity and distribution in Gabon remains incomplete, and a work in progress.

6.3 Recommendations and perspectives

Given the potentially rapid expansion of oil, gas and mining infrastructure in Gabon, and the likely impacts of this on water quality and river basin integrity, this data provides valuable base-line data for many of Gabon's river basins, where impacts of industrial development and pollution is still considered negligible. However, the majority of river basins were sampled only once, and some small river basins have not yet been sampled at all. Species diversity data plotted against the number of samples per basin shows that the full diversity Gabon's rivers has not been determined. Further sampling, notably of the small coastal basins, tributaries and the upper reaches of the Ogooué is therefore likely to yield important revisions to the diversity hierarchy map.

This historical study shows us that there are a number of issues to improve upon in terms of institutional capacity, training, and data management in Gabon, to ensure the on-going quality of data and accessibility. This is typical for much of the sciences. This study has identified gaps in sampling effort that are being addressed. Further analytical work is currently being conducted by The Nature Conservancy (TNC), who will shortly publish a national aquatic ecosystem atlas of Gabon based on biological and geo-physical properties, where this fish species data-base forms an essential data layer.

7. Landscape scale case study: Grande Mayumba

7.1 Objectives

The objective of the landscape case study was to combine national scale data and local scale data in a conservation planning exercise at the level of a land management unit or concession. It was intended as a test case for HCV mapping at an operational (land management) scale. The concession chosen for this exercise was the concession awarded to the Greater Mayumba Development Company (GMDC) to develop integrated land-use management based on forestry, agribusiness and agriculture, infrastructure development, agroforestry conservation and ecotourism. The full concession area is also known collectively as Grande Mayumba.

The outputs from priority setting exercises at the national level are often too coarse-scale to inform decision making within an individual management unit. For example, the mapping of endemic species distributions in the coastal forest zone, completed by MBG in year II of the project, was based on 25km^2 grid cells. The resolution of this analysis, which was limited by the available data, is such that one cell may cover an entire forest concession. In order to use this data to inform decisions at the scale of a management unit, (i.e. where to build a logging road) it is necessary to refine the predicted distribution using finer resolution information (e.g. topography and forest type data) to produce a finer resolution map of where the species is most likely to occur.

The conservation planning exercise assigned each portion of the concession area to mutually exclusive zone based on types of conservation management:

1. Conservation areas where no extractive activities are permitted
2. HCV zones where specific management activities are applied to ensure the values are maintained, but where timber extraction is possible under certain conditions
3. Areas where use is not restricted by additional regulations

Zones were determined by combining all the available spatial data and selecting the most efficient configuration of uses according to the relative contribution of each portion of the landscape to biologic and socioeconomic objectives of the analysis. The selection of a set of aside areas was designed to maximise the representation of national scale priority areas in conservation areas. The exercise used the Marxan software package to integrate the individual data layers and produce alternative land use configurations within the concession that reflected the conservation ambition and spatial management requirements. Marxan provides a systematic and transparent approach to the identification of HCV areas that integrate national scale priorities into management decisions at the scale of the management unit.

7.2 Methods and tools

7.2.1 Analytical approach to identify conservation zones

Technicians from WCS, WWF MBG and SFM Africa met together in Libreville in June 2014 to pool data and resources and to develop the prioritization methodology. The agreed upon approach involved combining national scale priority data with local scale data in a Marxan analysis, as shown in Figure 15 below. Below is an outline of the general processing steps used to identify HCV areas in the landscape:

- Produce a land cover map based on remotely sensed imagery and forest ecosystem types identified through statistical analysis of the forest inventory data, with extrapolated forest habitats to the landscape scale based on geographical features
- Compile local scale data from wildlife surveys and maps of expected distributions for species listed as NT, VU, EN and CR. Refine maps based on species specific habitat requirements.
- Compile distribution maps for endemic plant species expected to be present in the landscape
- Produce an erosion risk map for the landscape using an analysis of topographical data
- Compile data from participatory mapping of village use areas from previous survey work undertaken in the landscape
- Set numeric targets for representation of all conservation features in set asides and HCV areas.
- Compile a conservation cost-layer on relative value of each portion of the concession for forestry exploitation, representing areas to be avoided for conservation set-aside.

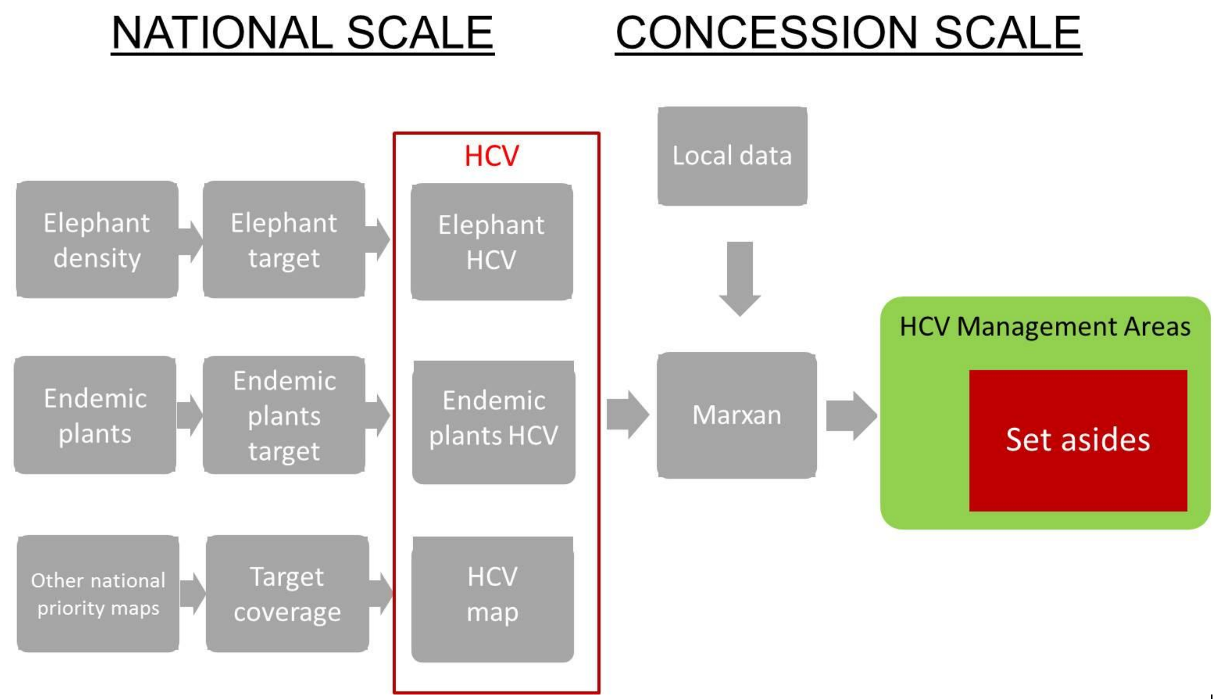


Figure 15 Illustration of the general process of integrating national HCV areas and local data to define HCV management areas and complete protection zones. The process diagram is meant to be illustrative of the overall process, and not an exhaustive list of the datasets included in the assessment.

Spatial explicit data layers were developed for each of conservation features identified above (elephants, great apes, forest habitat types, etc.). Within Marxan, threshold values (targets) were set for the inclusion of each conservation feature (e.g. 20% of the predicted distribution of red-capped mangabey) inside HCV areas and conservation set asides. Targets were selected for each conservation feature, to indicate how much of the conservation feature, as a percentage, should be included in the areas identified as 'conservation set asides'. The target values selected for each conservation feature, in three sets of analyses, are shown in Annex 1.

If an area was determined to be of High Conservation Value *a priori* (i.e. resulting from a national scale prioritisation), the extent of the areas within the concession was treated as an HCV area. The identification of an area as HCV does not preclude all activities in the area. Selective logging with appropriate management controls can be compatible with the maintenance of certain HCVs (elephants, gorillas, endemic plant hotspots) if management practices are implemented that are specifically designed to maintain these values. Therefore it is necessary to distinguish between two distinct recommendations for area management in the planning process. The first is areas that are appropriate for conservation set asides, and the second is HCV areas which allows extractive activity, subject to controls that maintain the HCV values of the area.

The flow-chart below (Figure 16) shows the analytic process used to support the HCV delineation process. Where the maintenance of a given HCV is compatible with some low impact extractive industries, the HCV area does not have to be assigned to complete protection zone. Instead part of the area (determined by a target value e.g. 30%) can be assigned to protection, and low impact activities can be permitted in the remaining area.

Where even selective logging is likely to damage the value in question, the area associated with this value must be assigned to complete protection (i.e. a target of 100% of the area to be classed as set aside).

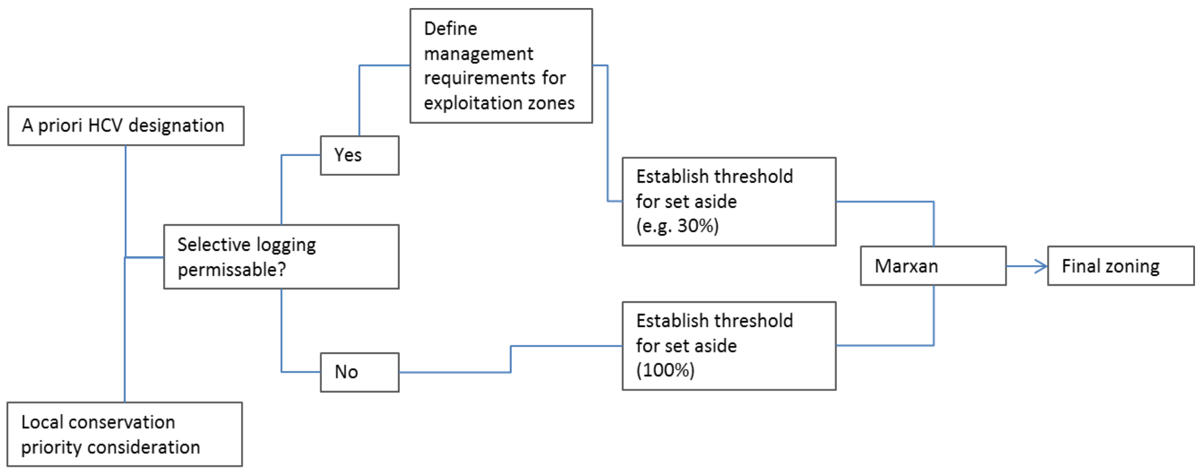


Figure 16 Flow chart indicating the decision making process for establishing threshold values for the amount of each area to be protected in the final zoning.

7.2.2 *Ecosystem classification of the Mayombe area*

A team of MBG botanists carried out two data collection missions in the Mayombe in 2011-2. Groups of plots were established at two sites, one on the eastern and one on the western side of the Mayombe range of hills. In each of the two sites, four plots of 0.1 ha were positioned to take account of the local physiographical variation of the terrain. All plants with a DBH greater than 5cm were identified.

Results of the sampling were analyzed through multi-dimensional scaling using the PRIMER software, to identify vegetation types based on floristic composition. This enabled the team to identify three different forest types in the area surveyed, and to distinguish a broader distinction between the dominant tree vegetation of the Mayombe and that of the Evaro area.

Ordination and clustering analyses were conducted using R software using forest inventory data that covered a large part of the concession (see example outputs in Figure 17), mirroring the analytical technique used at the national scale on other inventory data. This allowed us to define the main forest types of the area. The forest ecosystem type map produced from the cluster analysis of the inventory data was extrapolated to the entire planning zone by looking for correlations between the clusters and factors known to influence species composition within the region, including geology, land-form and altitude.

The observed altitudinal gradient was possibly due to rainfall gradients from west to east, proceeding up the Mayombe mountain range. Altitudinal classes were defined and adjusted based on expert opinion to account for the variation between the transitions in community composition identified through the cluster analysis, and information by individual samples of species with known habitat preferences collected by MBG botanists. Delineation of the sub-montane forest type and the dry forest on the eastern slopes were especially dependent on presence of individual species that are characteristic of these cover types.

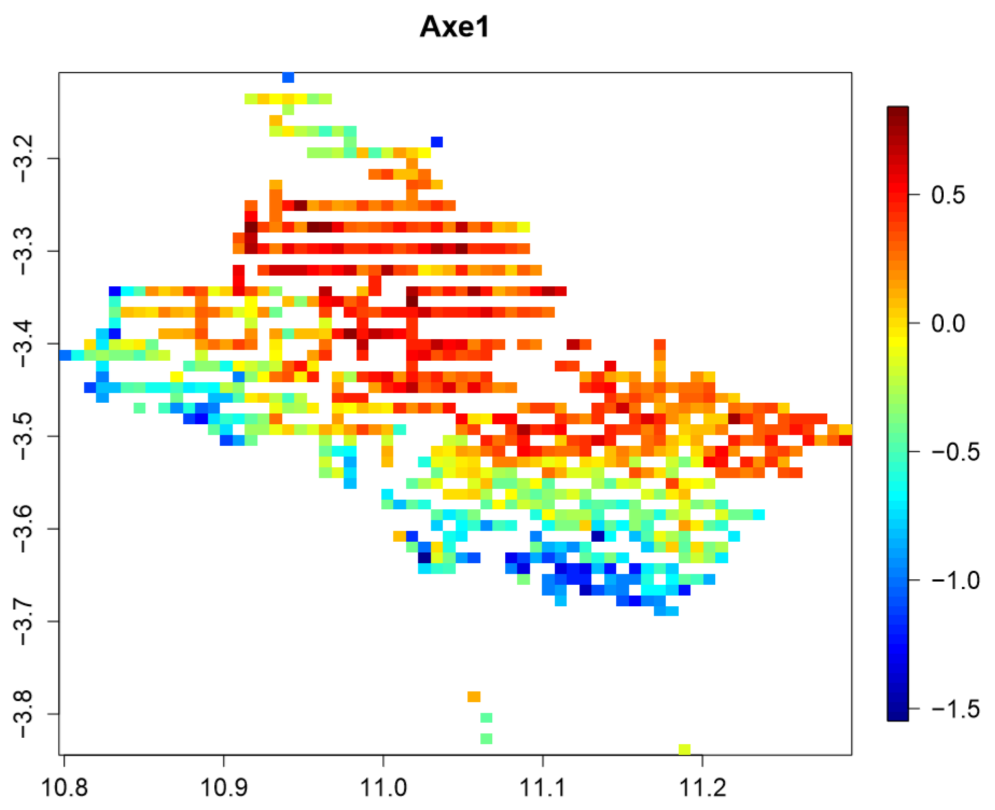


Figure 17 Spatial heterogeneity in the botanical community composition of the Mayumba region. The primary axes of the of the NASCA analysis of the forest inventory data is plotted with x and y axis representing variation in latitude and longitude.. The association between species composition, altitude and distance from the coast can be seen in the colour changes, with coastal forest types (south west) differing from montane forest types (north east).

Based on this review, a draft forest ecosystem type classification was produced, and confirmed in discussion with MBG botanical experts and based on field data collected in the Mayombe. The habitat type map presents 13 habitat types (Figure 18), with the analyses conducted by MBG distinguishing two additional forest types based on species composition, to those identified by GMDC using remote sensing analysis of satellite imagery and an intensive fly-over survey (Figure 19).

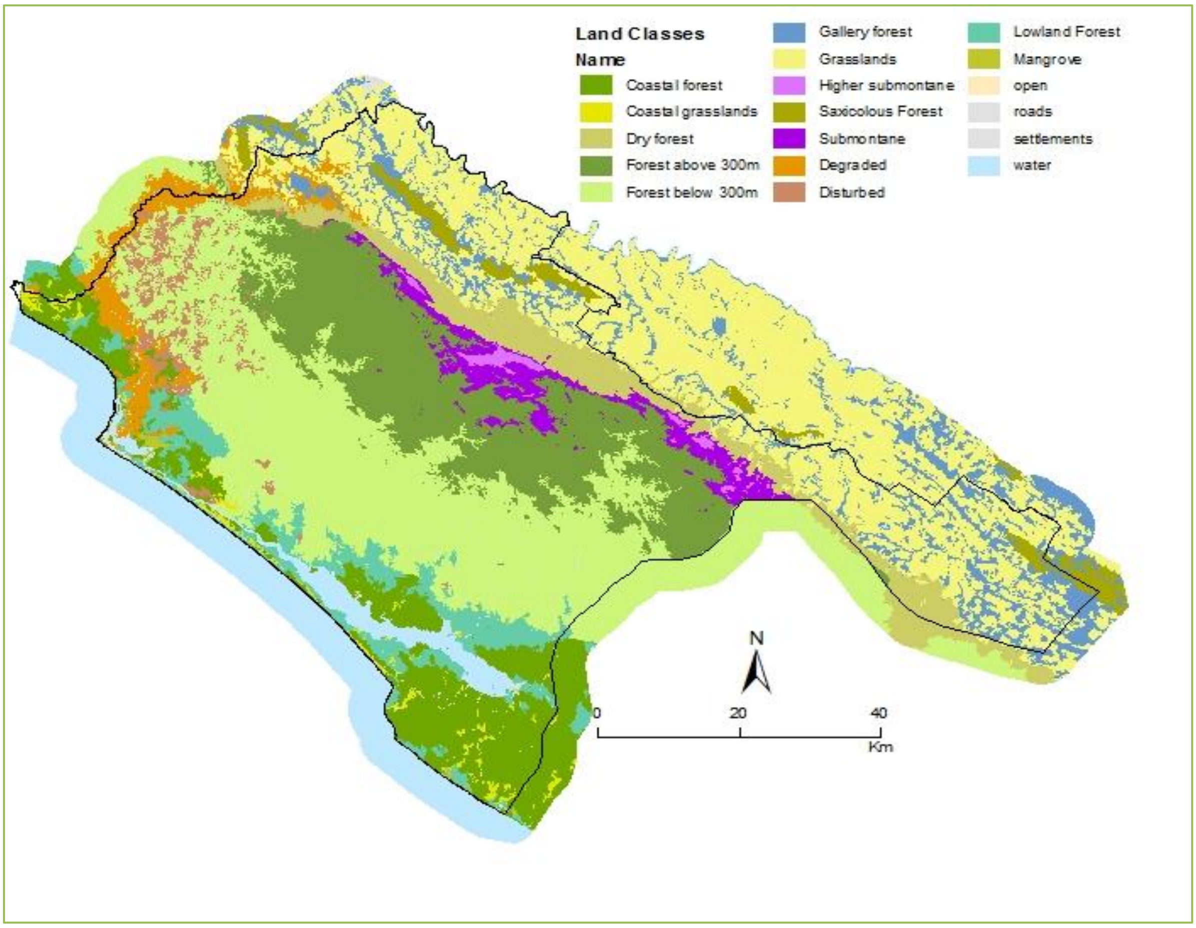
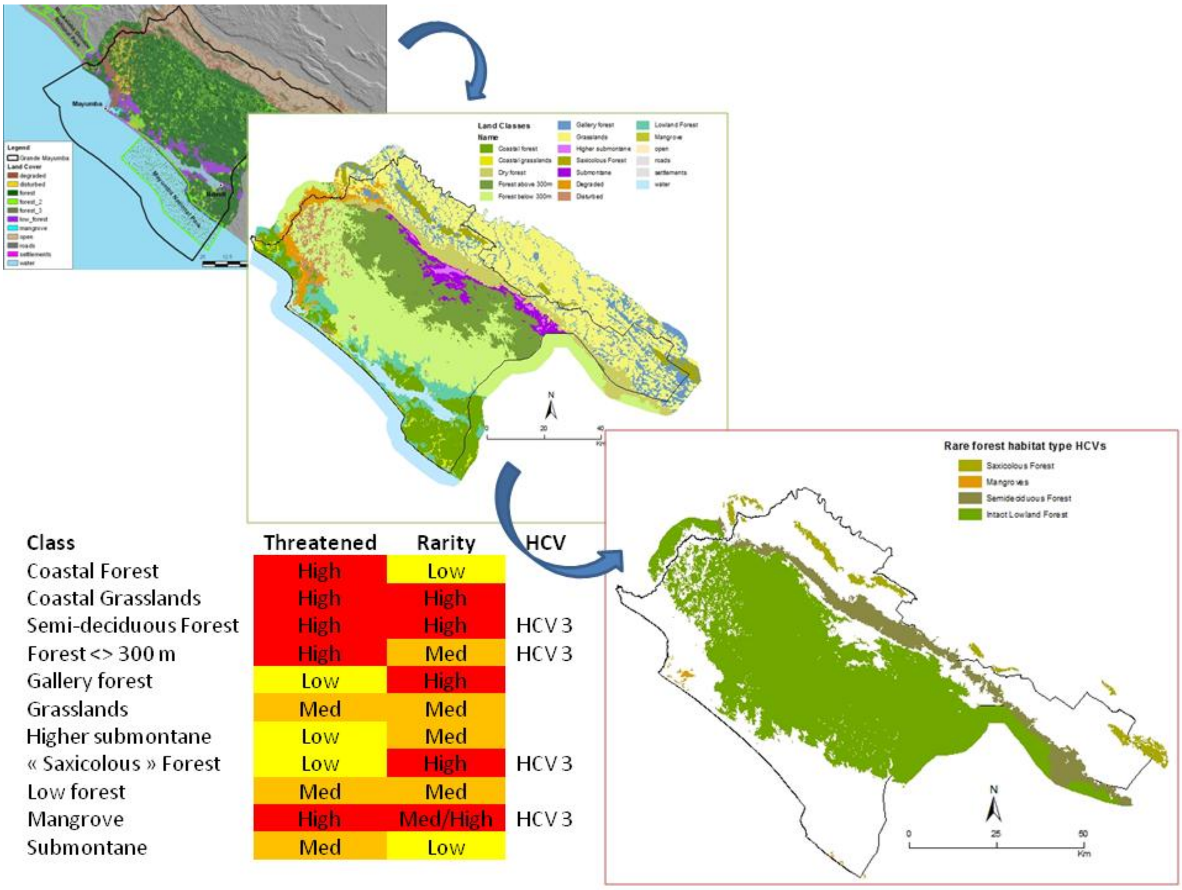


Figure 18 Vegetation and cover type map of the Mayombe area (13 cover types recognized based on the existing data on species composition and current land cover at each location.

The final land cover map was then used for two purposes:

- Mapping the spatial distribution of rare and threatened habitat types (equivalent to HCV 3) were selected from these habitat types based on national rarity and level of threat (see Figure 19). National rarity and threat were assessed using expert judgement.
- Refining maps for the predicted distribution of endemic and sub-endemic plant species and red-listed animal species within the landscape based on their known habitat preferences.



Class	Threatened	Rarity	HCV
Coastal Forest	High	Low	
Coastal Grasslands	High	High	
Semi-deciduous Forest	High	High	HCV 3
Forest <> 300 m	High	Med	HCV 3
Gallery forest	Low	High	
Grasslands	Med	Med	
Higher submontane	Low	Med	
« Saxicolous » Forest	Low	High	HCV 3
Low forest	Med	Med	
Mangrove	High	Med/High	HCV 3
Submontane	Med	Low	

Figure 19 Land cover map development & HCV 3s (rare habitats) in GMDP. Top; original habitat map, middle; additional forest types were identified through additional expert opinion and analysis, bottom; example conservation prioritisation table of habitat types to identify candidate HCV-3s.

Great ape and elephant priority zones

The recent regional density distribution models were used to map chimpanzee, gorilla and forest elephant density distributions within Grande Mayumba, and calculate their likely abundance. These were found to corresponded closely with density data available from the transect study conducted in the Mayombe area of GMDP in 2011. We used these maps to estimate that the Grande Mayumba landscape supports ~600 forest elephants (1,4% of total population in Gabon), ~2700 gorillas (2.6% of total population in Gabon) and ~1400 chimpanzees (2.6% of total population in Gabon). Priority areas for each species were identified using Marxan and population unit targets (see 3.1.2) (70%, 80% and 90% of the population within the management unit). In addition to the population level target for each species, additional spatial criteria were utilized to ensure connectivity with existing protected areas. A minimum width of 5km was also used to minimize edge effects within the priority block. To ensure a contiguous area within the block was selected for each species, and smooth variation in the individual Marxan solutions that results from the stochastic search function, HCV areas were defined using the selection frequency from 100 Marxan runs using the same population target. The HCV area for each species was defined as all planning units with a selection frequency above the selection frequency at which the sum of all selected planning units meet the target for that run. Iterative search was used to identify the selection frequency at which the target for the species would be met. The search began by summing the population of the species in all planning units selected 100% of the time. If this total population of the species in planning units with a selection frequency of the given value was less than the target for the species, then the selection frequency criteria was reduced in increments of 1 (e.g. to 99%, then to 98%)and the species total was recalculated until the species target was satisfied. There are two critical features of this process with respect to the national priority areas defined in earlier parts of this project for great apes and elephants. The first is that the planning software is instructed to return to the underlying population model and to find a configuration to reach the same target (e.g. enough suitable habitat to support 80% of all elephants within that population block) but to do so while considering finer scale features at the landscape scale.

This means that:

- The final configuration of the elephant HCV area at the landscape scale may differ from the polygon identified at the national scale, but the same elephant conservation objective is achieved, and
- The result is more likely to be appropriate to the local context (Figure 20)

The second is that this area, which we consider to be one form of 'national HCV designation', is input into the analysis, but not *automatically* assigned to a land use of 'complete protection'. Instead, Marxan seeks to assign as much of this 'HCV management area' as possible to complete protection, while permitting compatible extractive use (e.g. selective logging) in the parts of the block that are least important. In attempting to include 'national HCV zones' inside the set aside for the concession we attempt to minimize the overall management costs of the concession operator to maintain the HCV values.

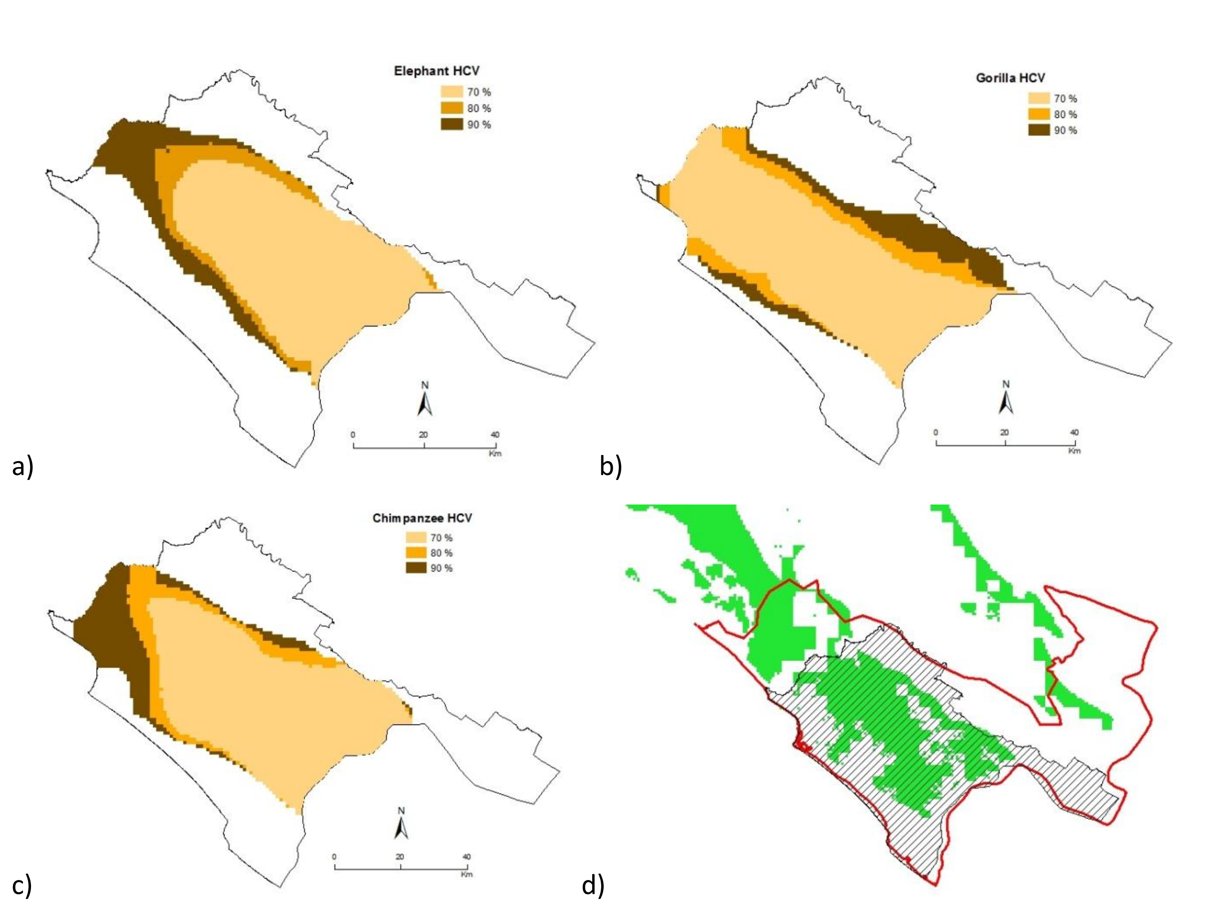


Figure 20 Marxan output maps for the area within the Grande Mayombe planning zone that retained to assure the maintenance of 70, 80 and 90% of elephants, chimpanzees and gorillas. Map (d) shows the original outputs from the national scale Zonation model for great apes that was completed in Yr II of the project. The GMDC zone (shaded) and the great apes population block (red line) are indicated.

Other rare and endangered animals

Distribution maps for terrestrial amphibians, birds, mammals and reptiles where sourced from the ICUN Redlist and Birdlife International. Because these maps generally represent species extent of occurrence rather than their area of occupancy, range maps were refined for all species listed by IUCN Red list as Near Threatened and above. Refined predicted distribution maps were made using known habitat preferences and the vegetation types generated by MBG (Figure 21). Vegetation types that did not represent suitable for the species were excluded. Although these species distributions would not be considered HCVs in themselves as none of the species were above the red list level of Vulnerable, they were included in the Marxan analysis for the production of the land use plan.

For this analysis we asked Marxan to include a certain percentage of each species range in conservation set asides. This way, the final configuration of set aside area ensures that part of each of these species' ranges is completed protected.

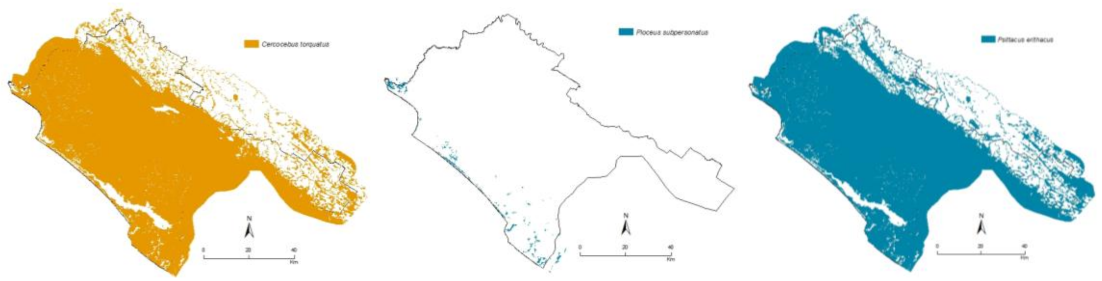


Figure 21 Example habitat maps for three species listed as Vulnerable on the IUCN Redlist (left to right) Red capped managebey, Loango weaver, and African grey parrot.

Endemic plant species

Information on endemic plant species was acquired from recent surveys conducted in discrete botanical plots within concession, and from a comprehensive data base of Gabon's plants[5], that lists all species known in Gabon, and associated information from when they have been recorded. From the database, 88 endemic species have been recorded in the area, while during the surveys, a new species to science was recorded, and another species was identified that was previously known from only one other locality in Gabon[6].

Because time and budget constraints precluded the development of detailed distribution maps for all floral species in the region, we conducted an initial screening to focus effort on species of greatest conservation concern. This approach is adheres to the performance standards of the International Finance Cooperation (IFC) used for mining projects to define critical habitats. We started with the endemic species recorded within GMDP from recent and historical surveys which were all selected for inclusion in the assessment (n=25). An additional 24 endemic species were predicted to occur within the concession, but were not yet confirmed to exist in the concession due to the limited survey effort to date. These species were also included in the assessment, bringing the total selected for additional assessment to 49. Since the evaluation of plants in Gabon on the IUCN Redlist is considered to be particularly poor (less than 3% are assessed and many assessments are out-dated or incorrect), a preliminary threat status assessment was conducted for each of 49 species by MBG. This assessment placed each species into a preliminary IUCN Redlist status group based on the available information for the species. The assessment identified two species that are likely to be Critically Endangered and seven additional species that are likely to be Endangered. The species identified as Critically Endangered, Endangered or Vulnerable (hereafter referred to collectively as 'threatened'). As with the endangered animals, critical habitat maps were produced where there was sufficient ecological knowledge to link the plant's habitat preferences with habitat types found in the concession. Where this was not possible, the point locality data was used (Figure 22).

It should be noted that mapping decisions about HCV areas for these range-restricted threatened species, is different when predicted habitat maps are produced, rather than relying on collection point data. One approach prioritises the predicted presence of the species, while the other

[5] http://herbaria.plants.ox.ac.uk/bol/Gabon/Home/Index

[6] Boupoya, Archange, Tariq Stévart, and Gilles Dauby. *Évaluation de La Diversité Végétale et Floristique de La Région Du Mayombe, Province de La Nyanga, Gabon.* Libreville, Gabon: MBG, IRET and WCS, 2013.

prioritises the single point where the species is known to occur. Prioritizing protection around known points of occurrence may be appropriate for sessile species that are thought to be highly range restricted and are only know from a few locations. For such species it is critical that we ensure protection species it is critical that we ensure protection of known occurrences. This indicates the need to collect more information on habitat preference for these little known endemics. For many species however, especially in areas that have had limited survey effort, focusing only known locations is likely to underestimate the true area of occurrence and bias protection towards areas of greater survey effort. Species distribution modelling can be used to fill the gaps between known portions of a species range and areas that the species is likely to inhabit, but where presence has not yet been confirmed. Within systematic conservation planning exercises both forms of information are often utilized, known locations to ensure the species is included conservation areas, and predicted (or likely) range to ensure a more accurate representation of the full distribution is targeted for protection.

We follow this conservative treatment of including both sources of information. Where a habitat preference map was available, we used a target threshold of the percentage of this area to be retained in conservation set asides. For the threatened CR and EN endemic plants, this was 20 or 30% of the total predicted range, depending on the species habitat sensitivity. Where a habitat map was not available due to insufficient ecological information, the point locations were retained in set aside areas.

Figure 22 Endemic plant distributions (left) Known occurrence points for all endemic species temporarily classified as Least Concern and above, and predicted habitat maps for *Mischogyne elliotianum* classed as Critically Endangered, and *Agelaea gabonensis* as Endangered.

7.2.3 Slope and erosion risk

WCS has developed a method for mapping areas at high risk of soil erosion when the forest is disturbed. The method uses a measure of slope steepness, and measure of the area of an individual catchment covered by steep slopes. Threshold values for both parameters can be calibrated based on experience, to set tailor the model to the environmental risks of a particular site.

This method enables the identification of areas that may be particularly prone to erosion and thus should likely be excluded from logging activity. The technique can be applied across a wide variety of landscapes, including in national park buffer zones to identify individual catchments where forestry activity should be restricted, to minimise negative impacts on the park.

We used a Digital Elevation Model (DEM)[7] to map steepness across the catchments. By setting a series of thresholds, we identified areas which are particularly steep and undulating, both at the watershed and 1 km^2 grid cell scale across concession. We considered slopes of >16 deg (30%) to be steep, and calculated the proportional coverage of steep areas within each watershed and each km^2 grid cell. They were then classified into groups by the portion of the surface that exceeds the steepness threshold (e.g. >30%, >35% or >40% of their area classified as steep), which can be considered a progression from lower to higher erosion risk for each catchment or each km grid cell (Figure 23*)*.

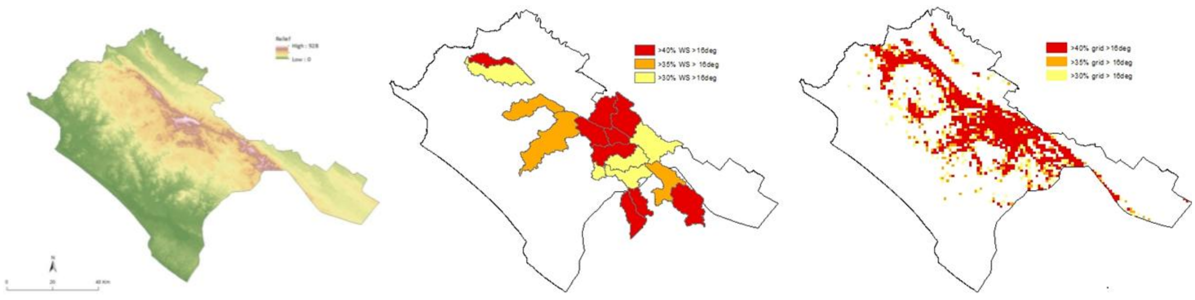


Figure 23 Watersheds or 1km grids that have steep slopes (defined as >16 deg) that cover >30% (yellow), >35% (orange) and >40% (red) of their area

The red areas in the Figure 23 maps are the steepest, and therefore the most vulnerable to soil erosion in the event the forest and top-soil is disturbed, including through road and bridge construction. Very steep areas are typically avoided for timber extraction due to the difficulty of access and are therefore generally less likely to be distributed. Thus the areas where disturbance is most likely to impair water quality through increased sedimentation are the moderately steep areas that are more accessible for exploitation.

7.2.4 Aquatic diversity and catchment protection

The map of aquatic diversity presented in Figure 14 shows that the river basins of the Mayombe area were not considered to have particularly elevated aquatic diversity in the national context (though it should be noted that the catchment in the extreme south of the planning area has never been sampled). It was not therefore possible to include aquatic diversity as a parameter in the landscape scale conservation planning approach at this time steep slopes prone to erosion risk were selected for protection. This was considered sufficient to ensure the conservation of the Mayombe's aquatic diversity. Fishing on the Banio lagoon is the principle source of protein and income for the local communities, and therefore maintaining water quality and integrity of this resource is essential for local livelihoods.

[7] DEM data and maps are freely available on the internet e.g. http://www.mapmart.com/Products/Digital-Elevation-Models/DEM/Digital-Elevation-Model-Gabon.htm

7.2.5 Local community basic needs and cultural values

Although the mapping of community use and cultural values was not the primary focus of this project, the available information on community use was incorporated where possible. Data from local participatory mapping exercises was available from two different sources, to identify how and where the forest is exploited by local communities. The surveys used[8] differed in their approach as well as in the villages surveyed. Thus we caution that the information extracted for mapping community use values is likely to be incomplete (see Figure 24).

The WCS 2012 study along the Tchibanga access road, surveyed a comprehensive range of community forest-use, including non-timber forest products (NTFP), fishing points, and other activities. The focus of the survey was on documenting the different types of use, rather than the spatial location of those activities. While data was collected on hunting locations, the hunting area was not clearly defined, representing a weakness in mapping community use of the forest. It was not possible to map areas of hunting use on the basis of this survey data, and detailed participatory mapping of use areas around these villages will be necessary in further iterations of this planning approach. In the ASF 2011 study along the Banio lagoon, hunting areas were mapped and was described as a seasonal supplement to fishing, which is the major source of protein, and for subsistence, and therefore these zones could reasonably qualify as HCV 5. While some other forest uses were recorded, such as NTFPs, their location was not geo-referenced.

Thus, where land use zones have been mapped and were available for integration in the analysis we have included this data in the zoning exercise. It will nevertheless be necessary to refine this analysis in light of new participatory mapping data for the villages along the Tchibanga-Mayumba road.

[8] Loundou, Paul, Malcolm Starkey, Wilfrid Mbombe Tsongue, and Prisca Roseline Mapangou. *Projet d'Appui Au Renforcement Des Capacités de Gestion Des Parcs Nationaux et de La Biodiversité (PARC): Evaluation Socioéconomique Du Massif Du Mayombe*. Libreville, Gabon: WCS Gabon, 2013. Sounguet, Guy-Philippe, Andréa Minkwe, Carmen Oliwina Kouerey, and Marie Céline Garnier. *Diagnostic Des Dynamiques Socioéconomiques Des Village Périphériques Au Parc National de Mayumba*. Libreville, Gabon: ASF, 2011.

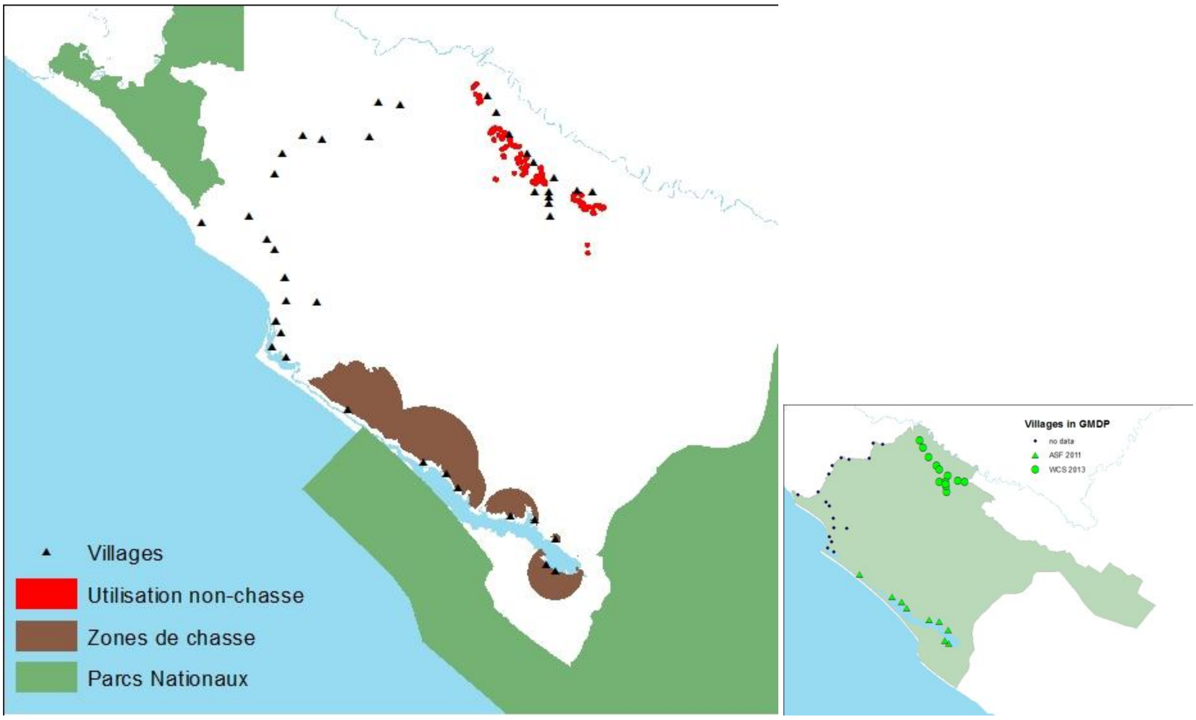


Figure 24 Community Basic needs and cultural values: villages along the Tchibanga access road in the north of the GMDC concession surveyed by WCS in 2012, show the location of community forest use including cultural values (fishing, agriculture, NTFPs, community forestry, sacred sites and ancient villages), but not the hunting zones as this was not effectively surveyed, while in the ASF 2011 survey of villages in the south along Banio lagoon described hunting zones.

7.2.6 Economic value

For the purpose of the analysis, a map of detailing the relative economic value was prepared by SFM Africa. The map was based on the expected timber yields across the concession minus the predicted cost of timber harvesting (which is largely a function of distance from the sawmill and topography). This economic layer was used as a cost factor in the analysis. This cost layer was utilized to minimise the overlap between conservation set-asides and areas of high economic value. This means that for two areas of forest of equivalent importance for conservation, the area of lower potential economic value was selected for set aside. For reasons of confidentiality, the economic value map layer is not presented in this public summary report.

7.3 Spatial prioritization

Identification of conservation Set-aside areas

After the spatial extent of all conservation features was mapped, targets were established for each feature to specify the extent of that feature that should be included in the conservation set aside.

The initial targets for inclusion in conservation set asides for each feature reflected the rarity of the feature, inclusion of the feature in other protected areas in Gabon, and the extent to which activities proposed in the landscape are likely to impact the feature. For some rare features that were considered vulnerable to any extractive use (e.g. nationally rare habitat types), the best approach to maintain them is to avoid any disturbance or exploitation, and they were therefore assigned a threshold value of 100%. In practice at threshold of 100% means that the entire distribution of the feature is included in set-aside areas.

Other features that can be maintained as long as the appropriate forestry best practices are applied, a lower target was set for complete protection. Baseline targets for inclusion in set asides typically ranged between 10% 30% of the distribution, but were varied depending on the regional and local threat level. Annexe 1 has the target values for each data layer under three analyses conducted in Marxan (see best solution set-aside results in Figure 25).

Marxan is a spatially explicit optimization tool, that was designed to account for the heterogeneous cost of conservation action within the landscape, and identify areas where conservation objectives can be achieved most efficiently. Marxan uses simulated annealing to identify multiple good options that solve the "minimum set" problem; the identification of a set of areas that achieve a set of defined objectives while minimizing the overall cost of achieving those objectives. For example, protect 25% of each forest type in the minimum possible area, or protect 25% for each forest type at a minimum cost to forestry operations. Both are examples of the type of minimum set problems that Marxan solves. In each Marxan solution, the targets for each conservation feature (species or habitat polygon) for conservation set-asides were achieved at the levels specified in the Annex 1. The cost which Marxan attempts to minimize can be any number (or a combination) of individual values so long as those values can be mapped spatially. Cost in a Marxan analysis does not have to be represented in strictly economic terms, it can also be the total area or a measure of landscape utility for other uses. Examples of potential 'costs' include economic value, total boundary length of selected areas, and distance to roads or settlements. The cost layer included in our analyses was the forestry cost layer described above. We applied different weights of importance of the cost layer in the various analyses (see Table below). The greater the weight of forestry cost layer relative to other "costs" used in the analysis (e.g. area, distance to roads, population density), the less areas indicated to be of high timber value would be selected as conservation set-aside. Or the greater the emphasis on avoiding high value timber areas when indentifying conservation set-asides.

Three scenarios are presented, each with a different approach to setting the targets and using cost data (see Table below, and Annex 1), with the resulting "best solution" set-aside outputs shown in Figure 25.

Scenario	Summary of targets for conservation features Description	Weight of forestry cost layer
Scenario 1	Species distribution thresholds 30%, and greater for very range restricted species	1
Scenario 2	Species distribution thresholds between 10-30 % depending on IUCN and local threat levels	1
Scenario 3	Species distribution thresholds between 10-30 % depending on IUCN and local threat levels	0.3

The set-aside areas selected in all three scenarios generally correspond with the distribution of conservation features for which a threshold of 100% was established (e.g. very steep slopes). The areas that are selected for set-asides which differ between the scenarios were highly influenced by the choice of cost layer (e.g. the features to avoid in identifying the set aside). Where greater emphasis was placed on avoiding opportunity costs to forestry (i.e. areas of high timber value) these were generally not selected for set asides in Scenario 1 & 2. Because the targets used for the individual conservation features were generally modest (10-30% of the distribution in region) there was significant flexibility in where set-asides could be placed to achieve those targets.

Figure 25 The 'best' solution for conservation set-asides (green areas) as identified by marxan based on targets set for conservation attributes, with scenario 1, 2 and 3 explained in the text, and target thresholds listed in Annexe 1. Scenario 1 has generally higher threshold levels for species distributions, and Scenario 3 has a reduced forestry cost influence.

Conservation management zones

Determining the HCV status of the Marxan map outputs:

In the final analysis there are three categories of land management zone (Figure 26 below).

1. Areas with lower conservation priority, where a greater variety of uses could be permitted (white)
2. Areas of HCV status where selective logging and community use can be permitted but restrictions apply on hunting and forest conversion = HCV management areas (green)

3. High priority areas which are placed in 'strict protection' = conservation set-aside (red)

The HCV management areas include a combination of several different conservation features, which can be presented separately to guide the implementation of appropriate management activities.

This third category, shown in red in Figure 26 below, we could refer to as set aside. The areas selected for this category (equivalent to those shown in the three scenarios in Figure 25) are the areas where several conservation priorities overlap. The set aside of these areas ensures the most sensitive areas are protected, and ensures that *a proportion* of all the HCV attributes are included in strict protection zones while optimising all other parameters.

The areas identified as higher conservation priority are likely candidates for inclusion in conservation set-asides were highly dependent on the conservation features (e.g. species and ecosystems) used in the analysis and the specific threshold values set for each. Both the decision to include or exclude individual features and the target for inclusion in conservation set asides are subjective decisions which can of course be varied and debated. Here we do not suggest that the target values we have adopted are necessarily the best result. They are presented to highlight the results of the process, and to promote stakeholder dialogue. One party (or stakeholder) may feel that the full range of an individual species should be included inside set-aside areas, while another stakeholder might suggest that the same species should not be considered at all. It was not our intention to adjudicate these value judgements. Our focus was on developing a process that could be used to capture value based differences (like the ones outlined above) and objectively translate them into spatially explicit land-use proposals for further evaluation. The process provides transparency into the value laden decisions made by the stakeholder, and provides a framework for comparing the conservation benefits, and socio-economic costs of individual proposals.

Attribute

Combined HCV management area
- 70% Elephants, Gorillas, Chimps
- CR & EN endemic plants distributions (9 species)
- Threatened habitat type
- Steep Erosion vulnerability
- Community fishing, hunting

Scenario 2 conservation set-aside:
- spp. targets based on IUCN & concession-level threats
- Restricted range rare habitat types
- V steep erosion vulnerability
- Community agriculure, NTFP & cultural values

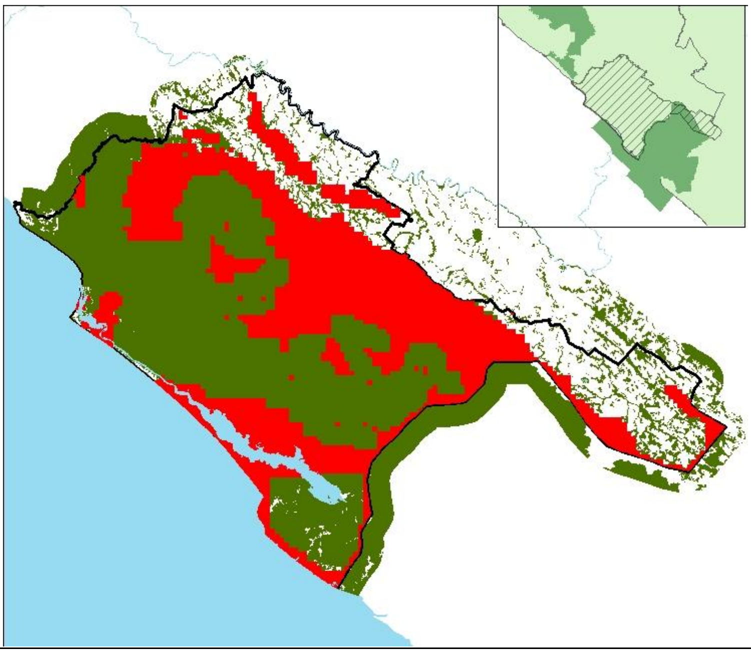


Figure 26 Map of HCV areas and 'HCV+' areas (Marxan outputs from Scenario 2). Areas possessing one or more conservation priority attributes classified by management approach, where some extractive use can been permitted in green areas, and red areas are placed under 'strict

conservation'. Map insert shows position of concession in relation to nearby Protected Areas.

7.4 Conclusions from the landscape trial

The objective of the landscape case study was to test the integration of national conservation priority designations into management decisions at the scale of a land management unit. There were two major concerns:

- What are the implications of using national scale priorities (e.g. areas required to meet a national target for elephant conservation) in planning decisions at the management unit scale?
- Is there a consistent and transparent way to arrive at the appropriate land management decisions in areas considered to be of High Conservation Value at this scale?

The GMDC management unit in the Mayombe area of south west Gabon provided an excellent opportunity to examine these questions. The concession operator for the area has developed a land use plan that includes a wide range of different activities, including timber extraction and tourism development. The production of this data-base and the process outlined in this report may be of use for revision of the existing plan, making improvements to the forest management plan, or for other planning efforts in the region, such as for the enlargement of Mayumba national park.

The main conclusions from the exercise can be summarised as follows:

Defining HCV areas and conservation set asides:

If we adopt the proposed approaches for setting national HCV thresholds for large mammals and plants, large areas of the GMDC are likely to be considered HCV under one of the six types of HCV. It is important to note that management recommendations will not be uniform across areas identified as HCV. Some HCV types may require that no disturbance of an area, while other HCV categories, especially those related to community use, may need to allow continued human access and use to maintain the value for which it was identified. The area is important for maintaining a broad suite of biodiversity values, including forest elephants, gorillas, chimpanzees and plant species endemic to the coastal forest ecoregion of Gabon.

Maintaining the HCV status does not necessarily rule out extractive use. Timber extraction may be permitted in some areas, following specific management practices to protect the features that make it HCV. However, it *does* rule out conversion to plantations in these areas. This would not be compatible with maintaining the value for which the landscape was identified as HCV. The national importance of Gabon's savannas remains to be unanimously decided, and this would appear to be an important point of stakeholder discussion in refining the HCV areas for the Grande Mayombe.

The areas identified as HCV and potential conservation set-asides in this assessment are a direct reflection of conservation features included, the choice of threshold for each (e.g. the area occupied by 70% of the forest elephant population), and the features ('costs') we sought to avoid (e.g. higher value forestry areas). The results of the analysis clearly demonstrate that altering any one of these will result in a different set of areas being identified. The critical dependence of the results of the analysis on the stated objectives should come as no surprise, but highlight the importance of these objectives. The objectives should be carefully considered and thoroughly debated with different stakeholders. In order to set appropriate conservation objectives for the area, careful consideration must be given to answer questions like, "What is our ideal vision for what the area will look like in 20 years?" and "How will the areas conserved in the GMDC landscape contribute to the larger conservation objectives in Gabon?" Part of the purpose of the exercise was to try to provide a framework through which the answers to these questions could be evaluated. Rather than considering the conservation values of GMDC in isolation, we sought to place them in the wider context of regional and national conservation values. Within this context, the decision to set-aside or manage for the maintenance of a value has critical implications for management elsewhere. Species or ecosystems that are conserved to a greater extent in the region are less likely to require as much management elsewhere. While species or ecosystems that occur, but are not managed for are likely to require additional protection or management effort elsewhere.

The question of thresholds for complete protection is particularly pertinent for attributes such as rare endemic plants, where maps are based on predicted range for the species. For species occurring in widespread forest types, the protection of the entire forest type is likely an unrealistic outcome. However, attaching a lower threshold risks the accusation of an inconsistent approach. In this case, a more promising approach seems to be to focus on only those endemic plants that are listed as CR or EN by IUCN, and to make an effort to characterise their habitat requirements in more detail. More detailed maps of the distribution of the features might allow for refining and potentially downsizing the areas that require complete protection. The approach developed in this project can be applied elsewhere in Gabon. However, it requires doing a rapid red-listing of selected species known to or predicted to occur in the study area. The rapid red-listing process conducted by MBG to support this process, should be treated as preliminary in nature. The rapid assessment required only about 15 minutes per species, while full a full evaluation of a species conservation status can take up to 10 hours per species, and therefore requires greater time and financial investment than was available for this project.

Despite its cost, updating the threat classification for plants, and more accurate maps of their ranges would be beneficial, and would certainly aid in the more accurate delineation of HCV areas identified for these attributes. Further work to refine this is recommended.

Technical requirements of the process

Much of the data analysis and mapping demands a high level of technical skill with GIS and conservation planning software. Similarly, IUCN assessments needs a high degree of experience and training. The analysis and interpretation of forest inventory data is a good example, and sufficient time and effort should be allocated in order to assure high quality results.

The quality of data collection is critical. In this example, the Saxicolous forest in the Mayombe mountains has been identified from photographs, but should be confirmed by field visits, and the presence of endemic plant species in the predicted areas could benefit from being confirmed in the field. The absence of reliable participatory mapping data across the planning region means that the areas suggested as likely to contain HCVs 5 and 6 are preliminary in nature and are unlikely to represent a comprehensive list of community uses.

8. *Overall conclusions*

8.1 Summary of the work

This project was established to test methods that could improve decision making about the definition and management of HCV areas in Gabon. The concept of High Conservation Value emerged from voluntary forest management certification schemes, and is guided by generic international criteria, which lack specific performance thresholds or clearly defined objectives through which the HCV areas can be identified

Under this project we have compiled some useful data building blocks, and developed replicable methods for defining HCV areas in a more objective and transparent way. We have developed and tested various approaches for setting thresholds for when an area should be considered High Conservation Value. Some of these methods appear to be promising. Others still need more thought and development.

We have focused on conservation attributes (such as wide ranging mammals, endemic plants, catchment protection and the prevention of erosion risk) that can be mapped at large scales. While this effort does include some preliminary identification of HCV based on criteria concerning local people's use of land, a full assessment of HCV values based on local use of the land was beyond the scope of the project. Assessment of HCV criteria 4, 5 & 6 requires extensive efforts to collect information at the community level, and is heavily dependent on detailed local consultation.

During this project we pooled data from different sources, and, in the case of plants and aquatic biodiversity, conducted additional data collection activities where this had the potential to contribute new knowledge for spatial planning.

WCS have used the recently published population models for elephants and great apes (Maisels et al 2013 etc) and suggested a way that these population models can be used in conservation planning. MBG have also produced predictive species presence maps for a number of rare and endemic plants, and shown the strengths and weaknesses of using these maps in the context of HCV assessments.

MBG have also developed a technique to analyse botanical forest inventory data to characterise the major forest types in a given area. This approach can be used to identify rare forest habitats and ensure that these are protected from clearance.

Parallel work by WWF has provided some pointers to a method for the prioritisation of catchment areas as a function of their aquatic diversity. This data, combined with a thresholds approach for slope limits and erosion risk (derived from readily available digital elevation data) can be directly incorporated into conservation planning to identify areas likely to be of high conservation value for watershed protection.

The data generated in these exercises was brought to bear on a test case at the scale of a landscape. In the Landscape case study, we examined ways to combine the different data sources to produce a land use map for a forestry concession. This exercise used Marxan software to integrate the data layers to prioritize areas for protection that achieved the specified targets for each conservation feature.

8.2 The limitations of the voluntary approach

HCV assessments are required by voluntary certification standards, and are completed by private sector operators on a case by case basis. These depend heavily on data collected locally, and can vary considerably in their results. Consideration of local conservation values, without a structured framework for taking into account the wider context or regional and national conservation objectives is likely to lead to sub-optimal conservation outcomes.

Within the conservation community, there has always been scepticism that a case by case HCV approach could ensure adequate conservation of threatened species and habitats. Various attempts have been made to structure the process, by setting guidelines and national interpretations for the use of the HCV framework in different national contexts. It has, however, proved difficult to establish universal criteria for when an area is considered HCV i.e. significant for conservation at the national, regional or global level.

8.3 New data and modelling approaches offering new insights

New data and modelling approaches recently developed in the sub-region provide promising solutions to this challenge, by providing data at the national scale. Models that predict the value of an area for a given environmental attribute can be used even when actual data from that area is lacking. This enables the values of such areas to be considered in its national context, and facilitates decision making at the appropriate scale.

This project has presented examples of this for large mammals, forest ecosystems, endemic plants, aquatic biodiversity and high erosion risk areas. Some of these models are more promising than others. The accuracy of elephant and great ape population modelling has been improved during the life of this project. Much discussion during a workshop in March 2015, that presented each of the major chapter in this report, was focused on the national ape and elephant maps and approaches to identifying priority areas. This demonstrates the need for broad stakeholder engagement at an early stage, to avoid confusion and to ensure final decisions are based on consensus (a full summary of the workshop is provided in a separate report). The project has also shown how data on endemic plants can be used to identify HCV areas at the national scale. It has proved difficult to produce the national forest ecosystem classification map that was hoped for. The data needed to complete this task at the national scale are not yet easily accessible. The habitat mapping technique has nevertheless proved extremely useful at the landscape scale.

8.4 Conservation targets

A data driven approach based on high level conservation objectives requires stakeholders to take difficult decisions about targets. Spatial prioritization and decision support tools such as Marxan enable the consequences of these decisions to be visualised and allow the evaluation of alternative sets of objectives. Such approaches enable informed decisions to be made about which areas should be higher conservation priorities and for which features they should be managed. This process can be used to guide the setting of criteria and indicators, in such a way that they contain *verifiable limits*. It can also ensure that the chosen limits are appropriate to the national scale and the national socio-economic context. This helps to move the process of HCV assessment (and indeed natural resource management certification schemes such as FSC and RSPO) away from ad-hoc and case by case decision making, even in cases where field data is limiting. The framework we have utilized is also easily updated as refined information on the distribution of any species or feature becomes available. We have presented an example for how national scale conservation targets (e.g. 70% of elephant habitat conserved) can be utilized in a landscape scale assessment. The case study (in the Mayombe landscape of SW Gabon) involved a scenario where the land use plan for the concession responded to the need to conserve 70% of the elephants *present in the landscape*. By meeting this threshold at the landscape scale, the operator can ensure that he/she is acting in accordance with a national conservation plan or vision to conserve 70% of elephants in each population block.

8.5 Next steps

The work presented here is preliminary in nature and should be viewed as the starting point rather than the end point of the HCV identification process. Through the course of the project we have identified a number of areas in which the analysis itself could be improved and we hope that future work on identifying HCVs in Gabon address these issues. A list of potential next steps or improvements to existing datasets is provided below.

- Review and improve the accuracy of national scale elephant and ape maps by examining finer scale features at the landscape that are critical to the conservation of species. IN the case of elephants, priority should be placed on the identification of features such as bais or specific assemblages of fruiting trees that attract large number of a local population during certain seasons.
- Delineate core ranges of chimpanzee populations in the region.
- Include a broader suite of species in the assessment. A number of taxa (including reptiles and amphibians) are unrepresented in the current analysis because the available spatial data was too coarse to support concession level management decisions.
- Develop national scale maps for forest ecosystem types
- Extensive community consultation process to inform identification of areas that provide services to local communities and appropriate management actions to maintain those values.

If addressed, the information gaps and needs outlined above would contribute to better natural resource management in Gabon more broadly, not just to better delineation of HCV areas.

8.6 The link to governmental land use planning

At the same time, the expansion of commodity crops through the sub-region shows that large scale land conversion is becoming a reality in central Africa.

This project, was designed to provide methodological approaches that could be used to reinforce the credibility of natural resource management certification. However, the outputs could be equally important in informing the national land use planning process in Gabon. We suggest that an objective-based approach could provide a solution to the problem of identifying priority areas at the national scale and is essential for ensuring that the identified land-use plans provide the benefits intended for people and biodiversity.

8.7 Caveats

The outputs from an objective based process, such as the one presented here, will only be as good as the data that is used to inform the analysis. The available data tends to bias the analysis of priorities. This report presents only a sub-set of the current work underway in Gabon to identify and protect important conservation priorities, and it should not be taken in isolation. Furthermore, efforts are still needed to ensure accurate and up to date information is available for more red-listed species. It is a common misconception that decision support tools and reliance on data-driven approaches to decision making preclude the input of experts. This is unfortunate because in many data limited environments the best information available resides in the minds of a few knowledgeable individuals. In order to use such information in an objective decision process, that information must be first be captured and documented like any other input dataset. We would strongly encourage that further planning efforts in the region seek out additional experts on the flora and fauna of region, and work with them to develop maps of their understanding of distribution of species and processes that shape the region.

8.8 Conclusions

Data and modelling techniques are now becoming available that can provide a quantitative basis for value-based judgements such as 'an important concentration' of threatened species. Of the techniques presented in this report, the mapping of rare endemic plant species is singled out as particularly promising for use in HCV assessment. The distribution and abundance models for great apes and elephants should help to stimulate debate on the preservation of large blocks of forest capable of supporting viable populations of these wide-ranging animals.

Delineation of HCV areas and conservation set asides through ad-hoc processes at the concession scale are unlikely to deliver the benefits that are intended. The methodologies used as part of this process leverage the available data and establish clear objectives to inform identification of conservation areas. The process provides a transparent framework through which stakeholders can articulate individual objectives for the region and visualise the consequences of those decisions on conservation priorities in the area. It also provides a framework for participatory planning and setting objectives for the future of the region. We have also attempted to integrate conservation values at different scales to ensure complimentarity with better local, regional, national and international conservation efforts. HCV areas within an individual concession must not be conservation islands. If properly designed they will contribute to larger conservation objectives of the country or region.

This type of approach can provide the basis for ensuring HCV areas are adequately identified and managed under voluntary certification standards for commodities such as timber and palm oil.

ANNEX 1

Representation targets for each conservation feature, used in the Marxan analysis to identify optimal conservation areas. Representation targets are expressed as a proportion of the total amount of the feature in the landscape. For example, target of 0.1 indicates that 10% of the feature should be included in conservation areas. Scenario 1 & 2 Forestry cost = 1, Scenario 3 Forestry cost = 0.3

Data layer	Scenario 1	Scenario 2	Scenario 3
GorillaDensity_CR	0.3	0.2	0.2
Chimpanzee_EN	0.3	0.3	0.3
Elephant_VU	0.3	0.3	0.3
Caracal_aurata_Mamm_NT	0.3	0.1	0.1
Cercocebus_torquatus_Mamm_VU	0.5	0.2	0.2
Eidolon_helvum_Mamm_NT	0.3	0.1	0.1
Mandrillus_sphinx_mamm_VU	0.3	0.2	0.2
Panthera_pardus_mamm_NT	0.3	0.1	0.1
Phataginus_tricuspis_NT	0.3	0.1	0.1
Smutsia_gigantea_Mamma_NT	0.3	0.1	0.1
Bubo_shelleyi_bird_NT	0.3	0.1	0.1
Coracias_garrulus_bird_NT	0.5	0.1	0.1
Gallinago_media_bird_NT	0.5	0.1	0.1
Numenius_arquata_bird_NT	0.5	0.1	0.1
Ploceus_subpersonatus_bird_VU	0.8	0.3	0.3
Psittacus_erithacus_VU	0.3	0.2	0.2
Scotonycteris_ophiodon_bird_NT	0.5	0.1	0.1
Stephanoaetus_coronatus_bird_NT	0.3	0.1	0.1
Terathopius_ecaudatus_bird_NT	0.5	0.1	0.1
Adhatoda_le-testui_plant_EN	0.3	0.3	0.3
Agelaea_gabonensis_Plant_EN	0.3	0.2	0.2
Allophylus_hallaei_Plant_VU	0.3	0.1	0.1
Costus_gabonensis_Plant_EN	0.3	0.2	0.2
Costus_maboumiensis_Plant_EN	0.3	0.2	0.2
Dactyladenia_floretii_Plant_VU	0.3	0.1	0.1
Erlangea_plumosa_Plant_VU	0.3	0.1	0.1
Guibourtia_arnoldiana_Plants_VU	0.3	0.1	0.1
Mischogyne_elliotianum_Plant_CR	0.3	0.3	0.3
Synsepalum_congolense_Plant_EN	0.3	0.2	0.2
Tapura_carinata_Plant_EN	0.3	0.2	0.2
Trichoscypha_imbricata_Plant_VU	0.3	0.1	0.1
Begonia_ferramica_EN_POINT DATA	1	1	1
Afrothismia_Engl_Schltr_Sp_nov_CR_POINT DATA	1	1	1
hcv3_Forest greater_300m	0.2	0.2	0.2
hcv3_Forest less_300m	0.2	0.2	0.2
hcv3_Mangroves	1	1	1

hcv3_nselbergs	1	1	1
hcv3_SemideciduousForest	1	1	1
Hcv4_steepSlopes>40percent	1	1	1
HCV5_Community_NTFP	1	1	1
HCV5_Community agriculture	1	1	1
HCV6_Community sacred sites	1	1	1
HCV6_Community_ancient villages	1	1	1