Monitoring Natural Capital and Human Well-being in Madagascar

A National Demonstration of Indicators for Sustainable Development

Technical Report 2015

Compiled by:


Moore Center for Science and Oceans and Madagascar Country Program, Conservation International

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INTRODUCTION

Background

The ability to monitor and report on specific programs and policy activities is critical in order to track progress towards sustainable development and natural resource management. Conservation International (CI) has developed a monitoring framework – a set of national-level indicators or metrics and a “dashboard” for monitoring the status and trends in environmental and social change. For the first time, indicators have been developed that go beyond traditional measures such as protected area extent and deforestation to examine the role of natural capital in supporting Madagascar’s economy and people.

For CI, metrics are instrumental for identifying priorities, tracking progress towards our goals, and communicating the impact of our conservation efforts. Metrics give us the information needed to make smarter decisions to demonstrate CI’s and our partners’ contribution to building and supporting healthy, sustainable societies.

Information from CI’s metrics is used for several purposes:

- To understand the existing state of natural and social systems, and the context of countries and regions where CI works, to design appropriate strategies and investments;
- To identify the most important places to prioritize our conservation actions and maximize our success; and
- To monitor and report on the progress and impact of CI and partners’ actions and strategies.

Metrics gives us the information needed to make smarter decisions and to demonstrate our contribution to building and supporting healthy, sustainable societies. CI maintains that a healthy, sustainable society, which enhances social capital and equity and improves human well-being, requires the integrity, resilience and productivity of natural ecosystems and their biodiversity.

Context in Madagascar

One of the world’s largest islands, Madagascar harbors some of the world’s most rich and unique species and habitats due to its long geographic isolation from other continents. Madagascar’s natural capital, the stock of biodiversity and ecosystems that produce the flow of goods, services
and other benefits that support human well-being, are the natural assets upon which society depends for economic growth and prosperity.

To map out the pathway to sustainable development, a draft National Development Plan (PND) is under consideration by Madagascar’s government. The Department of Planning and Economics is leading the consultation process. The vision of the plan includes adding value and preserving Madagascar’s immense natural capital on the basis of strong and inclusive growth, in the service of equitable and sustainable development of all territories.

The ability to monitor and report on specific programs and policy activities is critical in order to track progress towards the PND’s strategic objectives. A Monitoring and Evaluation Framework for the PND has been drafted for this purpose. The proposed system will build from existing monitoring efforts in Madagascar, and will measure indicators related to governance, the economy, human well-being, and the environment.

Conservation International (CI), has been active in Madagascar for 24 years, has developed a monitoring framework, a set of national-level indicators, and a “dashboard” for monitoring the contribution of natural capital to human well-being. For the first time ever, indicators have been developed that go beyond traditional measures such as protected area extent and deforestation to examine the role of natural capital in supporting Madagascar’s economy and people. This presents a valuable opportunity to support the implementation of Madagascar’s PND, by providing additional indicators, methods and datasets.

Aim of the Case Study

The data and results shared in this report are outputs from a year-long case study of CI’s monitoring framework in Madagascar (Box 1. Case Study Approach). The case study involved collaboration and consultation between scientists and experts from Conservation International and partners from government, non-governmental organizations, research and academic institutions. In addition to informal meetings with key partners, a workshop of technical experts was convened from September 2-4th, 2014 in Antananarivo. The workshop brought together over 70 experts from government agencies, research partners, and members of civil society. A detailed workshop report is available from CI upon request.
Participants at the Madagascar Metrics Experts Workshop, September 2014

**Box 1. Case study approach used for national demonstration of CI framework in Madagascar**

- Refine and adapt monitoring framework for national context
- Compile and organize datasets from national and global sources
- Conduct analyses
- Engage technical experts to assist in validation of preliminary results
- Compile products
- Share and disseminate to key audiences
- Review and adapt

About this report

This report is intended to provide a comprehensive technical report on CI’s monitoring framework and indicators that might support Madagascar’s National Development Plan. Readers of this report will find detailed information on the definitions of specific indicators, step-by-step methods used to
calculate indicators, a summary of results from the case study, a review of limitations of our approach and guidance on replicating our approach in other places. Values for indicators, based upon the most recent data available to CI, have been calculated and validated by regional experts. Data sources and further literature and resources are also provided. A complementary high-level executive report, targeted at national government agencies, is also available in French and English upon request from CI.

MAPPING AND MONITORING NATURAL CAPITAL

Compiled by: Rachel Neugarten

Definition

Natural capital is defined as the stock of biodiversity and ecosystems that produce and maintain the flow of goods, services and other benefits that support human well-being. Natural capital provides a range of ecosystem services, which are the benefits people obtain from ecosystems (Figure 1). These include provisioning services such as food, fuel wood, and fresh water; regulating services such as protection from storms and flooding, and cultural services such as tourism, recreation, and spiritual values. For a complete summary of the ecosystem services provided by natural capital, see the Common International Classification of Ecosystem Services (Haines-Young and Potschin 2013, http://cices.eu/).
Figure 1. The links between natural capital, ecosystem services, and benefits to people. Natural capital, such as forests and rivers, provides flows of ecosystem services such as non-timber forest products, clean water, and nature tourism, which benefit people. Natural capital also supports production systems such as agriculture and fisheries, thereby supporting food security and economic productivity.

Examples of natural capital in Madagascar include forests that store carbon, reduce flooding, and provide habitat for globally significant biodiversity; mangroves and coral reefs that support fisheries and protect the coastline from storms; savannas that support cattle grazing; rivers that irrigate rice and other crops; and many other ecosystems that benefit the people and economy of the nation. Specific objectives, programs and indicators for sustainably regulating the use of natural resources and protecting natural capital are explicitly documented in Madagascar’s PND.
Indicators for mapping and monitoring natural capital

Monitoring the status and trends of a country's natural capital is important for measuring progress towards sustainable development goals. Historically, natural capital has been measured and monitored using indicators such as deforestation rates and the extent of protected areas. These indicators are important, but they do not provide information about the status of biodiversity and ecosystems that provide benefits to people and the economy. They also do not provide information about how effectively protected areas and other policies are being implemented. CI's monitoring framework goes beyond traditional environmental indicators and focuses on mapping and monitoring the status of essential natural capital.

**Essential natural capital is defined as natural capital that has irreplaceable biodiversity, a high level of human dependency, or supports important economic sectors.**

For example, a forested watershed that provides water for people in a drought-prone area is *essential natural capital for fresh water*. Globally significant biodiversity, such as threatened and endemic species, is *essential natural capital for biodiversity conservation*. A mangrove that protects people who are vulnerable to flooding due to climate change is *essential natural capital for climate adaptation*.

Natural capital provides numerous ecosystem services, but it is not possible to catalog them all. Therefore, CI focuses on several important types of natural capital. These include:

- **Biodiversity** (such as rare, threatened, or endangered species and ecosystems)
- Ecosystems that are essential for *fresh water services* (quantity, quality, or flow regulation),
- Ecosystems that are essential for *climate change mitigation* (carbon storage and avoided emissions from deforestation)
- Ecosystems that help people adapt to *climate change* (coastal protection, flood risk reduction, or other services), and
- Ecosystems that are essential for *food security* (wild sources of fish or non-timber forest products, or ecosystems that support agricultural production).

The total extent of essential natural capital (ENC) in a given geographic region is determined by measuring the spatial extent of biodiversity and ecosystems that represent key dimensions of
natural capital. This can be done using discrete biophysical characteristics, such as endemic species, carbon stocks, or watersheds. It also depends on links between biophysical characteristics and social and-political attributes, such as watersheds that are critical for water supply, or ecosystems that provide significant climate mitigation or adaptation benefits. Details on mapping and each of these types of natural capital are in the following sections.

CI's monitoring framework includes links between natural capital and *beneficiaries*.

**Beneficiaries are people or economic sectors that benefit from ecosystem services.**

Everyone in Madagascar benefits from natural capital, but some people and sectors are more dependent on natural capital than others. Identifying these *key beneficiaries* helps to prioritize and map the most essential natural capital. Key beneficiaries of ecosystem services in Madagascar identified by participants at the September 2014 experts’ workshop include:

- Population centers, such as cities
- People dependent on rice farming, fisheries, or forest products
- People along coastlines that are vulnerable to storm surge
- Agriculture sector – irrigated rice agriculture
- Energy sector – hydropower facilities
- Tourism sector – nature tourism

The metric used by Conservation International to measure natural capital is the **percentage of essential natural capital sustained through protection, effective management, or in an intact state.**

Essential natural capital can be considered “sustained” if it is:

- **Protected** – an area has formal protection status according to International Union for Conservation of Nature (IUCN) categories I-VI. In Madagascar, this refers to all protected areas managed by Madagascar National Parks (MNP) and new protected areas;
- **Intact** – an area and its features are in a relatively natural state, such as having natural vegetation cover;
- **Effectively managed** - how well a protected area is being managed, including the level of resources available and the capacity for enforcement.
The above three definitions of “sustained” are complementary, however, approaches to measuring each might vary depending on the context and the type of natural capital. For example, essential natural capital for biodiversity (such as biodiversity priority areas) might be contained within protected areas, but those areas may not be truly “sustained” if the biodiversity within them is threatened by overhunting or other pressures. Similarly, a watershed might have all of its original vegetation cover, but a dam downstream may prevent the flow of services to beneficiaries. Thus consideration of multiple dimensions of the “sustained” is required to understand the current and future state of natural capital.

Data on the spatial extent of protected areas is available in most places, e.g., from the World Database of Protected Areas (IUCN and UNEP-WCMC 2014, www.protectedplanet.net), therefore it is generally possible to measure the first dimension of “sustained” (essential natural capital that is protected) anywhere in the world. Data on areas with natural vegetation cover is available for many geographic areas, and it is available globally for a single ecosystem type (forests), thus it is also possible to measure the third dimension (essential natural capital that is intact) anywhere in the world that has forests. The second dimension, effective management, can only be measured for those areas that have data available, such as protected areas that have completed the Management Effectiveness Tracking Tool or the Marine Protected Areas scorecard (which iare available from all protected areas where CI works.)

The overall natural capital metric is composed of five sub-indicators:

- **Indicator 1**: Percentage of essential natural capital that has formal protection status
- **Indicator 2**: Deforestation rate within areas of essential natural capital
- **Indicator 3**: Deforestation rate within terrestrial protected areas (PAs)
- **Indicator 4**: Score of management effectiveness of protected areas
- **Indicator 5**: Score of Ocean Health Index

Mapping Essential Natural Capital

Measuring essential natural capital requires understanding and mapping the location and spatial extent (area) of essential biodiversity and ecosystems. In Madagascar, we undertook a set of steps, each of which required engagement with local experts and stakeholders (Figure 2).
First, we (1) identified important areas for biodiversity, which in Madagascar have already been identified (Key Biodiversity Areas.) Next, we set out to identify ecosystems that are essential for providing ecosystem services, which required (2) identifying the important beneficiaries (people, groups, or economic sectors) of those services, then (3) selecting the most essential ecosystem services (e.g. freshwater flows, carbon storage) to be included in the analysis. The next step was to (4) collect existing spatial data on biodiversity, ecosystems, ecosystem services, and beneficiaries, and to identify gaps in existing datasets.

Once the datasets were gathered, we worked with stakeholders to identify criteria or thresholds for defining “essential” natural capital (6). For example, there is a globally accepted threshold for biomass carbon in “natural” forests: 35 or more tons of aboveground biomass carbon per hectare. We explored these thresholds with stakeholders to identify essential natural capital for climate mitigation that was appropriate for the local context. Once definitions of essential natural capital were agreed upon, we conducted GIS analyses and modeling of key ecosystem services (6) in order to develop a series of maps of different types of essential natural capital (for biodiversity,
freshwater, climate mitigation, food security, etc.) More details on each of these analyses, including data sources and methods, are contained in the following sections.

We then worked with stakeholders to develop a definition of natural capital that is “sustained” (e.g. protected or with intact vegetation cover.) Next, we used the agreed-upon definition to calculate the percentage of each type of essential natural capital that is sustained. We also combined all the individual maps into a single map of total natural capital and calculated an overall indicator. Lastly, we held an experts workshop in Antananarivo (September 2-4th in Antananarivo) to review and refine the maps and indicators.

Methods and Results for Overall Essential Natural Capital

This section provides a summary of the methods used for mapping and calculating indicators related to essential natural capital. The most recent datasets available to CI at the time of the assessment (September 2014) were used for these analyses; most datasets were developed in the period from 2005-2013. Details on each of these analyses, including the data sources and methods used for defining and mapping essential natural capital for biodiversity, freshwater, climate mitigation, climate adaptation, and food security, can be found in the following sections.

**Natural Capital Indicator 1: Percentage of essential natural capital with formal protection status**

**Denominator:** total extent (hectares) of essential natural capital

**Numerator:** the extent of the above areas that are within protected areas

\[
\text{Proportion of essential natural capital (ENC) that is protected} = \frac{\text{Protected ENC}}{\text{Total ENC}}
\]

The total extent (hectares) of areas of essential natural capital in Madagascar was calculated by combining areas of essential natural capital for biodiversity (Key Biodiversity Areas) with areas essential for climate mitigation (ecosystems with high biomass carbon stock and ecosystems with high potential emissions from deforestation), fresh water (ecosystems that provide water quantity, quality, and flow regulation), food security (ecosystems that provide non-timber forest products
(NTFPs), freshwater fisheries, coastal fisheries, and rice irrigation), and climate adaptation (ecosystems that protect coastal populations from cyclone storm surge) (Figure 3).

These different areas were all combined in a single map of overall essential natural capital. This map was then overlaid with a map of protected areas in order to calculate the percentage of essential natural capital that is protected as of 2014 (Figure 3). "Protected areas" were defined as all the areas managed by Madagascar National Parks as well as all new protected areas.

![Image of maps showing essential natural capital and protected areas combined]

*Figure 3. Essential natural capital combined (left) overlaid with protected areas (right). NTFPs stands for non-timber forest products.*

In summary, much of Madagascar's essential natural capital is left unprotected, with only 18% falling within protected areas (PAs) overall (Figure 4). Essential natural capital for biodiversity is relatively better represented by the country's PA system, but still, only half (50%) of the area of Madagascar's Key Biodiversity Areas are protected. A little less than half (45%) of the mangroves and coral reefs protecting Madagascar's shorelines from storm surge, critical for climate adaptation,
are protected. The high carbon stock forests essential for mitigating global climate change are also less than half protected (42%). In terms of the essential natural capital for food (non-timber forest products, inland fisheries, and coastal fisheries), even less is protected, at 19%, 22%, and 36%, respectively. Only 11% of the essential natural capital for fresh water (ecosystems that supply the nation’s population centers, irrigation, and hydropower) is protected. Significant gains could be made by either expanding the existing formal protected area system, or implementing other forms of protection (such as locally managed marine areas, or LMMAs) to ensure that the country’s essential natural capital is preserved.

Figure 4. Percentage of each type of essential natural capital in protected areas as of 2014. Note that areas of essential natural capital overlap (see Figure 3), thus the percentage of all essential natural capital protected is not equal to the sum of all the other percentages.

Natural Capital Indicator 2: Deforestation rate within areas of essential natural capital
The map of essential natural capital was analyzed using the most recent national forest cover dataset available, which is from 2010 (ONE et al. 2013), updated with 2012 global forest cover data from the University of Maryland (Hansen et al. 2013) in order to calculate the deforestation rate within areas of essential natural capital from 2010-2012. Forest cover is defined as natural mature forest, generally over five meters in height and closed-canopy, meaning that tree crowns overlap when fully leafed-out. This analysis included only those areas of essential natural capital that were forested as of 2010 (for example, it is meaningless to calculate the percentage of coral reefs with intact forest cover). From 2010 to 2012, forest cover in areas with essential natural capital declined by 0.3% (Figure 5).
Figure 5. Essential natural capital, intact forest cover as of 2012, and deforestation 2010-2012.
In summary, Madagascar’s forests are rapidly being lost. Forests are essential for providing fresh water and non-timber forest products for Madagascar’s population, storing and sequestering carbon that mitigates global climate change, as well as providing critically essential habitat for Madagascar’s unique biodiversity. If the deforestation trend continues, many of the benefits that Madagascar’s essential natural capital provide to people will be lost.

**Natural Capital Indicator 3: Deforestation rate within terrestrial protected areas**

This indicator measures the overall (total) forest loss as a percent per year, for all protected areas, at a national scale. It addresses rates of forest loss and can reveal trends in deforestation rates across monitoring periods. It can also be disaggregated to measure the deforestation within individual protected areas. CI’s calculations use two datasets: one produced in-country for the 2010 baseline (ONE et al. 2013) and the other extracted from a global analysis with similar data inputs (Landsat images) and similar precision and accuracy (Hansen et al. 2013), which was used to calculate deforestation rates from 2010 - 2012. The deforestation rate for 2010 - 2012 within Madagascar’s protected areas was 0.19% per year (Figure 6, Table 1). This was slightly lower than the overall deforestation rate for the entire country during the same period (0.29% per year). No matching analysis was performed so we cannot through these results determine whether protected areas are having an impact on deforestation rates as other confounding factors such as distance to roads and populations, or elevation/slope many contribute to lower deforestation rates.

<table>
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<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside PAs</td>
<td>0.30%</td>
<td>0.20%</td>
<td>0.19%</td>
<td>0.31%</td>
</tr>
<tr>
<td>All Madagascar</td>
<td>0.48%</td>
<td>0.37%</td>
<td>0.29%</td>
<td>0.40%</td>
</tr>
</tbody>
</table>

Annual deforestation rates within protected areas between 2005 and 2010 (0.19%) were lower compared to the previous time period, 2000-2005. Despite optimistic results, the most recent data on forest change (2010-2012) suggests that the deforestation rate trend may not be consistent across all land-use designations. The deforestation rate within protected areas between 2010 and 2012 was 0.19%, which is about the same as it was in the previous time period, 2005 to 2010. However, the overall deforestation rate has gone down across all three time periods, indicating that
while the overall trend of deforestation is decreasing, protected areas by themselves were not effective in reducing deforestation in the period from 2010-2012.

Figure 6. Annual deforestation rate within terrestrial protected areas from 2005-2010 (left) and from 2010-2012 (right).

This analysis shows that even within protected areas, forests are being lost. This indicates that simply designating an area protected is not enough. These areas must have sufficient resources - including funding and human capacity – to ensure that the essential natural capital they contain is effectively protected. A new dataset on forest cover and deforestation up to 2013 will be available from the Wildlife Conservation Society (WCS), but was not available at the time of this report.
Natural Capital Indicator 4: Scores of management effectiveness of protected areas

This indicator assesses how well a protected area is being managed – i.e. how well an area is protecting biodiversity and ecosystems, and achieving the site’s management goals and objectives. To compile and assess management effectiveness, a qualitative scorecard is used: the Management Effectiveness Tracking Tool (METT) in terrestrial ecosystems, and the related World Bank Marine Protected Area (MPA) scorecard in marine ecosystems. The scorecards are applicable for IUCN PA categories I-VI.

The scorecards are completed by site managers and local experts and are therefore subjective; however they can provide very useful information about the level of management effectiveness (such as the existence of a management plan, the availability of funding, the capacity of staff, and the level of enforcement of the protected area rules). The scorecard is intended to be updated at least every two years to monitor change over time.

In Madagascar, METT or MPA scorecard scores were available for only three protected areas where CI is engaged: the Ankeniheny-Zahamena Corridor (CAZ), the Ambodivahibe Marine Reserve, and the Ambositra-Vondrozo Forest Corridor Natural Resource Reserve (COFAV). Management effectiveness scores at these protected areas improved by 6% or 7% between 2013 and 2014 (Table 2).

Table 2. Management Effectiveness Tracking Tool (METT) results for three protected areas in Madagascar.

<table>
<thead>
<tr>
<th>Protected Area</th>
<th>Score 2013 Ratio (percent)</th>
<th>Score 2014 Ratio (percent)</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankeniheny-Zahamena Corridor (CAZ)</td>
<td>50/88 (57%)</td>
<td>59/94 (63%)</td>
<td>+6%</td>
</tr>
<tr>
<td>Ambodivahibe Marine Reserve</td>
<td>65/101 (64%)</td>
<td>97/139 (70%)</td>
<td>+6%</td>
</tr>
<tr>
<td>Ambositra-Vondrozo Forest Corridor Natural Resource Reserve (COFAV)</td>
<td>50/90 (56%)</td>
<td>58/92 (63%)</td>
<td>+7%</td>
</tr>
</tbody>
</table>

As CI currently only has access to two years of data on protected area management effectiveness, information on long-term changes or improvements in management effectiveness are not yet available, but CI plans to update with additional assessments in the future. Data on management effectiveness for the rest of Madagascar’s protected areas would ideally be collected and included in future analyses.
Natural Capital Indicator 5: Ocean Health Index Score

The Ocean Health Index (OHI) provides a single aggregated score that reflects the health and sustainability of a country’s ocean resources. OHI scores are available for every country from 2012, 2013, and 2014.

The overall OHI score is made up of 10 “goals” such as Food Provision, Carbon Storage, Coastal Protection, Clean Waters, Biodiversity, and others. Each goal is made up of one or more “components” (e.g. the “Biodiversity” goal is further divided into “Species” and “Habitats” components). We selected a set of goals and components related to biodiversity and ecosystem services, because they are most relevant for assessing natural capital (Table 3). In 2014, scores for the selected components ranged from 40 (for Coastal Protection) to 82 (for Biodiversity – Habitats).

Table 3. Ocean Health Index Scores for Madagascar (Ocean Health Index 2013)

<table>
<thead>
<tr>
<th>Goal - component</th>
<th>Scores out of 100 (% change from previous year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2012</td>
</tr>
<tr>
<td>Overall OHI score</td>
<td>59</td>
</tr>
<tr>
<td>Food Provision - Wild Caught Fisheries</td>
<td>53</td>
</tr>
<tr>
<td>Carbon Storage</td>
<td>65</td>
</tr>
<tr>
<td>Coastal Protection</td>
<td>40</td>
</tr>
<tr>
<td>Clean Waters</td>
<td>73</td>
</tr>
<tr>
<td>Biodiversity - Overall</td>
<td>81</td>
</tr>
<tr>
<td>Biodiversity - Species</td>
<td>79</td>
</tr>
<tr>
<td>Biodiversity - Habitats</td>
<td>83</td>
</tr>
</tbody>
</table>

Overall, Madagascar’s oceans are relatively healthy, but extremely threatened. The overall OHI score declined slightly from 2012 to 2013, then improved slightly in 2014, but most of the component scores related to natural capital have shown little or no improvement. Marine biodiversity and habitats are all doing relatively well (receiving scores of 78 or higher out of 100). The carbon stored in Madagascar’s coastal ecosystems is still relatively intact, and the country’s coastal waters are still relatively clean (scores of 64 or higher). Much of Madagascar’s coastline is unprotected, however (with a score of only 40) and the state of the nation’s fisheries is not very good (53) indicating that there is a real need for greater efforts to protect and sustainably manage Madagascar’s marine resources. Madagascar’s global rank (182 out of 236 countries) also indicates there is room for improvement.
Assumptions & Limitations

The maps of essential natural capital were created using existing datasets. Thus, they have a number of limitations. Primary data on the ecosystem services are limited. Some information is available about forest systems, but there is limited information about other ecosystem types. Thus the maps were created using a number of assumptions related to the use of natural resources by people. For example, it was assumed that people in close proximity to natural ecosystems are more likely to benefit from fish and non-timber forest products produced by those ecosystems, and people who are more food-insecure are assumed to be even more likely to benefit (see section on Natural Capital for Food Security, below). Also, the results are based on spatial modeling and analyses and have not been validated using field measurements. With additional time and resources, these assumptions and results should be tested on the ground.

Due to lack of data, our analysis does not include all ecosystem services, such as the supporting services (soil and nutrient cycling), nature-based recreation and ecotourism, or important cultural and spiritual values of ecosystems. In some cases, data about these services is available at a site or local-scale, but was not available for all of Madagascar.

We defined overall “essential natural capital” as the total extent of essential natural capital for biodiversity, climate mitigation, food security, and fresh water. Our analysis relied on simply combining all the individual layers into a single layer. Arguably, this is appropriate as any area that is defined as “essential” for a single ecosystem service should also be treated as “essential” in the final layer. Other methods can be applied, such as assigning higher levels of importance to those areas that are essential for multiple ecosystem services (e.g. carbon stock AND freshwater) and lower levels of importance to areas essential for only a single ecosystem service. However, this approach is also problematic as it treats areas that are essential for multiple services as more essential than areas essential for a single service. Therefore we used the simpler method.

The final map of essential natural capital is influenced by the individual component layers used to create it, and the assumptions, limitations, and thresholds used to define each of those component layers (see other sections for more details on each component layer.)
Our definition of “sustained” (e.g. protected, effectively managed, and/or containing intact forest) is somewhat limited. Arguably, an area needs to have all three components to be truly sustained. With currently available data, it is possible to estimate areas that are protected and have intact forest (see above) but there is currently insufficient data on management effectiveness of most sites.

We defined essential natural capital “protected” as that which falls within protected areas; however it is clear from subsequent indicators (e.g. deforestation within protected areas) that natural capital is not necessarily protected simply by having some form of protected designation.

Our definition of “intact” relies on data available for only a single ecosystem type (forests) and therefore does not include important information on the status of other important ecosystems (e.g. freshwater and coastal ecosystems.)

For a more detailed description on limitations of the Ocean Health Index, please see Halpern et al., 2015.

Replication of Analyses

It is possible to replicate these analyses over time for Madagascar, as well as in other countries. Updated data on protected areas boundaries and forest cover change is relatively low-cost and could easily be accessed using global datasets (e.g. the World Database of Protected Areas, the Hansen et al. 2013 deforestation dataset), or using national datasets as they come available (e.g. data on new or expanded protected areas).

This would require some basic expertise in geographic information systems (GIS) software in order to calculate the total extent of essential natural capital, as well as the extent of natural capital that is protected. Interpretation of the Hansen forest change dataset also requires raster analysis, in order to download the data and process it to identify forested and deforested areas. Processing time for this dataset depends on the size of the country, with small countries requiring only a few hours and large countries (such as China) requiring a day or more to process. With this relevant expertise, annual updates could be done in as little as 2-3 days per country.

Updating the underlying maps of essential natural capital requires a more significant additional investment of time and resources, which is appropriate if there is an opportunity to do so, such as a new planning cycle, or as new data becomes available. We estimate replicating this analysis would require weeks or months of time and greater expertise in GIS, raster analysis, and ecosystem
service modeling. Therefore we recommend doing this less frequently, such as every 5 or 10 years, as appropriate.

Additional, complementary information such as changes in non-forest habitat types, species status (such as the Red List Index), biomass carbon stocks, water pollution levels, or other indicators can be included as appropriate.

Similarly, updated Ocean Health Index (OHI) scores should be available annually. The Management Effectiveness Tracking Tool (METT) will be updated by CI for a limited number of protected areas every 2 years.

In summary, the “denominator” (the extent of essential natural capital) will likely only be updated every 5-10 years or as new data becomes available, while the “numerator” (the sub-set of that essential natural capital that is protected, intact, or has improved management) could be updated on an annual or biannual basis.

Many of the analyses could be replicated in other countries; indeed, all the analyses have already been conducted by CI in Cambodia. The specific set of ecosystem services (or types of essential natural capital) that are most important in each country should be selected in consultation with local experts and stakeholders, but some types of essential natural capital (e.g. biodiversity, ecosystems essential for freshwater, and climate mitigation) are likely to be consistent across all countries. Some datasets are available globally (e.g. protected areas, forest cover and change, forest biomass carbon stock, human population density, mangrove and coral reef habitats, and others) while other datasets (e.g. non-forest vegetation types, poverty and food insecurity, locations of important fisheries and freshwater demand) are not available globally and therefore must be collected for each country at the national level.

References


MAPPING AND MONITORING ESSENTIAL NATURAL CAPITAL FOR BIODIVERSITY

Compiled by: Trond Larsen

**Biodiversity Natural Capital Indicator:** Percentage of areas of essential natural capital for biodiversity that have been sustained through protection, improved management, or as intact habitat.

**Definition**

Areas of essential natural capital for biodiversity include habitats harboring threatened and protected species, threatened and unique/rare ecosystems, exceptionally high species richness, endemic and restricted-range species, migratory and congregatory species, including spawning grounds, and areas where key evolutionary and ecological processes occur.

**Biodiversity**—the variability among species, ecosystems, and ecological processes—is fundamental to the planet’s health and humanity’s survival. It is the essential base of natural capital which supports Healthy Sustainable Societies.

**Methods**

We first assessed existing sources of data for biodiversity priority areas in Madagascar. In 2014, a comprehensive update of key biodiversity areas (KBAs) was published (Critical Ecosystem Partnership Fund 2014), which also includes other areas identified as biodiversity priorities (Important Bird Areas (IBAs), Alliance for Zero Extinction (AZE) sites, Important Plant Areas (IPAs), and Ramsar wetlands. This updated analysis increased Madagascar’s number of KBAs from 118 in 2006 to 212 in 2014. We then assessed, through analysis of criteria used to develop each priority-setting exercise and through stakeholder engagement, whether these existing priorities were adequate and appropriate for representing biodiversity priorities in Madagascar, or whether additional species-level analysis would be needed. Existing priorities were deemed relatively thorough and appropriate (e.g., the approaches considered many of the criteria for important biodiversity described in our definition above). Considering also the broad scope of the KBA analysis, which assessed plants, birds, mammals, reptiles and amphibians, fish, molluscs, echinoderms, cnidarians, and select arthropod taxa, as well as marine, terrestrial and freshwater
ecosystems, we felt confident that we could use the 2014 KBA map layer to represent essential natural capital for biodiversity.

To calculate the amount of essential natural capital for biodiversity effectively sustained, we used four approaches, three of which use the same Key Biodiversity Areas layer described above. First, we calculated the percentage of important biodiversity areas that are covered with intact forest using the most recent data available, from 2010 and 2012 (ONE et al. 2013 and Hansen et al., 2013). Since KBAs include marine areas for which forest cover is not relevant, we focused on the change in important biodiversity areas within intact forest from 2010 to 2012. Second, we calculated the percentage of important biodiversity areas encompassed by protected areas. Third, recognizing that management effectiveness of protected areas has a large impact on the conservation of biodiversity (e.g., regulation of illegal hunting, fishing, logging), we used Management Effectiveness Tracking Tool scorecards (METT) which had been calculated for three protected areas to modify the percent of biodiversity sustained within this subset of protected areas:

Fourth, we used Ocean Health Index (OHI) scores to indicate the effectiveness of marine conservation strategies for biodiversity. OHI scores for biodiversity are available for 2012, 2013 and 2014, and reflect the health of species and habitats.

**Results and Implications**

10.73 million ha were identified as important biodiversity areas (KBAs) in Madagascar. Of these areas:

1. 50% is sustained within protected areas
2. Without excluding marine KBAs, 45.8% of the total area encompassed by KBAs had intact forest cover in 2010 and 45.6% had intact forest cover in 2012 (Figure 7). As a result, 0.2% of important biodiversity areas experienced forest loss from 2010 to 2012
3. Using the METT management effectiveness modifier for 2013, 57% of important biodiversity areas within Ankeniheny-Zahamena Corridor (CAZ) is effectively sustained; 64% within Ambodivahibe Marine Reserve is sustained; and 56% within Ambositra-
Vondrozo Forest Corridor Natural Resource Reserve (COFAV) is sustained. Management effectiveness improved by 6-7% in 2014 (Table 2).

4. **OHI** biodiversity scores were 81, 80 and 80 (out of 100) for 2012, 2013 and 2014 respectively, and are also broken down by species and habitats (Table 3, above). 46% of important areas for biodiversity sustained within intact forest is a relatively low number globally, and implies that Madagascar’s terrestrial biodiversity is especially imperiled. However, OHI scores for marine biodiversity are relatively high compared to many tropical countries, and are much higher than OHI scores for other aspects of ocean health in Madagascar, indicating that marine biodiversity remains relatively intact. The metrics approach used here can provide a common international framework for long-term monitoring of biodiversity, guiding future actions. Our biodiversity results can also provide data to support the Convention on Biological Diversity (CBD) and Aichi targets, National Biodiversity Strategies and Action Plan (NBSAP), and Sustainable Development Goals (SDGs).

![Maps of Madagascar showing where Key Biodiversity Areas (KBAs) overlap with existing protected areas (left) and where KBAs are covered with intact forest in 2012 (right).](image)

**Figure 7.** Maps of Madagascar showing where Key Biodiversity Areas (KBAs) overlap with existing protected areas (left) and where KBAs are covered with intact forest in 2012 (right).
Assumptions and Limitations

- While marine KBAs have been defined in Madagascar, broadening the scope of marine taxa included in the KBA analysis would improve marine biodiversity priorities.

- Measurements of biodiversity sustained within intact forest do not consider natural non-forest ecosystems, such as grasslands and wetlands, although these systems can be difficult to distinguish from human-modified ecosystems in Madagascar, where anthropogenic influences have transformed landscapes at a large scale and over a long period of time. It is difficult to know what the reference or benchmark condition is for Madagascar.

- According to feedback from experts at the 2014 workshop, some spatial and taxonomic bias remains in the available data. More research at accessible or research-friendly field sites has created spatial bias, while a stronger focus on terrestrial vertebrates (especially lemurs and birds) has led to taxonomic bias.

- Not all biodiversity within protected areas or intact forest can be considered effectively sustained, especially due to (often illegal) hunting, fishing, mining and logging, as well as other land-uses. These can be difficult to measure, although METT scorecards may provide one way to gauge management effectiveness. However, scorecards are not available for much of the country and as they are currently written, do not assess abundance or condition of biodiversity features. Ideally, management scorecards could be designed in such a way that the condition of essential areas for biodiversity within the protected area can be tracked over time. IUCN Red List Assessments, when repeated, can also provide important information to track trends over time through the calculation of a Red List Index.

- We used a binary area-based approach based on a select set of existing definitions of biodiversity priority areas – meaning an area was either considered “essential” or “not essential”. In reality, there is a continuous distribution of relative importance which depends on multiple criteria (e.g., more weight can be assigned to critically endangered species when compared to less endangered species, more weight can be assigned to more threatened ecosystems when compared to less threatened ecosystems, etc.). The thresholds and criteria used to define cut-offs for these boundaries will differ depending on priorities and objectives of any given mapping or monitoring exercise, and this would alter the results.

Replication of analyses

Steps for replication of our methods include:

1. Biodiversity scoping, review, data collection
2. Identify existing biodiversity datasets
   - Tier 0 - Utilize existing maps of spatially explicit priority areas for biodiversity (for appropriate criteria to define these areas in the first place, see definition at the start of the document) [Note: Tier 0 does not imply less detailed data are used, only that existing analyses suffice]
   - Tier 1 – Utilize existing but disaggregated species-level or ecosystem-level data to create a new map defining essential biodiversity areas for critical natural capital
   - Tier 2 – Generate new primary data to be used for defining essential biodiversity areas (e.g., expert workshops, field assessments)

3. Create maps defining areas of critical natural capital for biodiversity
   - Tier 0. Combine existing biodiversity priority layers into a single layer
   - Tier 1. Adapt data as needed, e.g., convert point localities into species range maps; overlay range maps of species fitting criteria defined above; use prioritization tools to incorporate habitat representation; delineate overall essential biodiversity areas
   - Tier 2. Supplement Tiers 0 and 1 approaches with new data generation
   - Add new data layers consisting of range maps, ecosystem types, protected areas, etc., to define final map of critical natural capital for biodiversity

4. Calculate % of essential biodiversity areas sustained within protected areas and intact forest, accounting where possible for management effectiveness as well as disturbances that are expected to disrupt biodiversity within these areas

References and Data Sources

Landcover:

Key Biodiversity Areas:

Important Bird Areas:

Alliance for Zero Extinction Sites:

Important Plant Areas:

Ocean Health Index
• http://www.oceanhealthindex.org/
MAPPING AND MONITORING NATURAL CAPITAL FOR CLIMATE MITIGATION

Compiled by: Andres Cano, Timothy Max Wright, Marc Steininger, and Karyn Tabor

Definition

As an input to CI’s essential natural capital metrics, the intended goals of this indicator for climate-change mitigation are two-fold: 1) to enable CI to quantitatively consider climate-change mitigation in its process of prioritizing where and how to conduct conservation actions; and 2) to enable CI to quantitatively consider climate-change mitigation in its assessment of the impacts of these actions.

Climate mitigation involves actions taken to limit the magnitude and/or rate of long-term anthropogenic climate change. As inputs to CI’s essential natural capital metrics, indicators for climate-change mitigation measure two trends:

- Long-term maintenance of biotic carbon stock in natural and managed areas
- Reduction of potential greenhouse gas emissions from anthropogenic activities in landscapes / seascapes, including land-use change

Each measurement is represented by a 30m continuous surface across the entire country. The first is long-term maintenance of carbon stock, defined as the amount of carbon that is present within forests. It is measured using existing global maps of biomass carbon stock and global or national maps of forest cover. The second measure is the reduction of potential emissions from deforestation, which is represented by calculating a baseline emission scenario based on biomass and observed trends of deforestation. It is calculated using the best available (global or national) historic deforestation maps.

This baseline forms part of the identification of essential natural capital for climate mitigation. It is intended for use with information on the location and effectiveness of conservation efforts (such as protected areas) to assess the proportion of natural capital essential for climate mitigation that is “sustained” through conservation efforts (protection, restoration, or improved management).
Climate Mitigation Indicator 1: Percentage of protected areas with intact forest cover

Proportion of intact forest cover remaining in protected areas =
\[
\frac{\text{Amount of intact forest within PAs at time 1}}{\text{Amount of intact forest within PAs at time 0}}
\]

The habitat indicator shows the change in the percentage of intact forest in protected areas between 2010 and 2012. For the analysis of Madagascar, we used 2010 as a baseline year because we wish to build on past forest cover assessments, which have already been completed for the country through 2010 (e.g. ONE et al. 2013). Monitoring changes in this indicator is performed by tracking changes in forest cover (e.g. deforestation) within protected areas over time. This indicator is important because intact forest cover can be monitored on up to an annual basis, pending timely re-analyses of the availability of updated global datasets. It also can serve as a useful indicator of overall intact habitat.

| Percentage of protected areas with intact forest cover in 2010 (baseline) | 100% |
| Percentage of protected areas with intact forest cover in 2012 | 99.6% |

Climate Mitigation Indicator 2: Long-term carbon storage: carbon stock

2.1 Proportion of high carbon areas in protected areas =
\[
\frac{\text{High carbon stock areas in PAs}}{\text{Total high carbon stock areas in the country}}
\]

2.2 Proportion of high carbon areas intact =
\[
\frac{\text{Total high carbon stock areas in the country at time 1}}{\text{Total high carbon stock areas in the country at time 0}}
\]

Denominator 2: total extent (hectares) of areas of high carbon stock in 2010 (baseline), above a certain threshold (e.g. an internationally recognized threshold of 42 tons of carbon per hectare (tC/ha).

Numerator 2.1: the extent of the above areas that are within protected areas
**Numerator 2.2:** the extent of the above areas that have intact forest cover (in the first reporting period, 2012, this indicator will be close to 100%, because both the denominator and the numerator are defined based on intact forest, but over time we expect the numerator to decline as forest is lost).

**Climate Mitigation Indicator 2: Methods**

Based on a global 1-km spatial resolution total biomass dataset (Saatchi et al. 2011) and a 2012 forest cover dataset for Madagascar (a combination of the CI Madagascar forest cover map 90-00-05-10 (ONE et al. 2013), and forest loss data from Hansen et al., 2013) an estimation of the average carbon stock on mature forest only, measured in tC/ha, was calculated for the country and within protected areas (CI Madagascar) at a 30m resolution. The 1-km biomass cells containing over 90% of forest cover were identified, and then biomass values from the cell’s centroid were spatially interpolated using the Inverse Distance Weighting (IDW) interpolation to create a 30m biomass product. This layer was clipped to forest cover to obtain a final forest carbon (C) stock map.

Essential areas for high C stocks were identified using a threshold of total carbon greater than 42 t C per hectare. This value was calculated using Cairns, et al (1997) equation and an above-ground biomass threshold of 35 t C per hectare (equivalent to 42 tC/ha total (above and below-ground) biomass carbon). This threshold has been used and documented by international organizations to distinguish forest from degraded lands in certification of sustainable palm oil (Poynton, 2014). The proportion of such areas in 2010 that are located with protected areas was calculated. The indicator was updated in 2012; however, since there was no change in the PA extent, the number remained the same across both time periods.

**Climate Mitigation Indicator 2: Results & implications**

In 2010, 43% of high carbon areas (defined as areas with c stock >42 tC/ha) are located within protected areas. In addition, 530 km² of high carbon areas were lost between 2010 and 2012 in the country (Figure 8).

Results for Indicator 3 are:

<table>
<thead>
<tr>
<th>3.1 Percentage of high carbon areas under protection in 2010</th>
<th>42.6%</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Percentage of high carbon areas under protection in 2012</td>
<td>42.6%</td>
</tr>
<tr>
<td>3.2 Percentage of high carbon areas intact in 2010 (baseline)</td>
<td>100%</td>
</tr>
<tr>
<td>3.2 Percentage of high carbon areas intact in 2012</td>
<td>99.3%</td>
</tr>
</tbody>
</table>
Climate Mitigation Indicator 2: Assumptions & limitations

1. This analysis assumes that 2010 is the baseline year, and 2010-2012 the first monitoring period. 2010 was chosen as the baseline year to align with many national products that have decadal landcover maps. The monitoring period was until 2012 because at the time of this analysis, the most recent global forest cover and loss dataset (Hansen et al. 2013) was available up to the year 2012.

2. Calculations of carbon storage are based on a global dataset. Ideally, these data would be validated using ground-based sampling of biomass carbon stock.

3. Carbon stock is biotic carbon in above- and below-ground vegetation, but not soil carbon.

4. A global biomass dataset (Saatchi et al. 2011) was used. Other biomass data available are from Baccini, et al. (2012) at 500 m. However; the Baccini data set does not extend over the southernmost portion of Madagascar.

5. Forest cover is defined as natural mature forest, generally over 5m in height and closed-canopy, meaning that tree crowns overlap when fully leafed-out.
6. Mature forest, Tapia forest (a native tree that is used in plantations) and mangrove were used to define forest extent.

7. Some areas were covered in clouds in 2010 and therefore forest cover could not be determined. These areas were considered to be forested, based on the global Hansen et al. 2013 dataset, only if the national forest cover dataset (ONE et al. 2013) observed forest in 2005 or 2000, and there was not observed deforestation between 2005-2010 or 2000-2010, respectively.

8. Forest cover change between 2010 and 2012 was defined as observed loss (based on the Hansen et al. 2013 dataset), superimposed on the forest, mangrove, and Tapia forest class from the national forest cover dataset (ONE et al. 2013).

9. Essential areas for high carbon stocks were identified using a threshold of 42 tC/ha; however, different thresholds such as carbon stocks above the national mean or ± 1 standard deviation from the mean would result in different areas identified as “essential.”

10. The global biomass carbon data, which has a resolution of one square kilometer, was converted to 30m to match the forest cover resolution. The 1km biomass data are estimates for the entire grid cell, not just the forested part, and thus represent the average biomass of forest and non-forest cover within that cell. Thus, the biomass data are under-estimates if interpreted as values for forest only. This is a limitation of global datasets but only becomes a significant concern at the site level in fragmented-forest landscapes. To overcome this, a 30 m biomass layer was created by identifying cells with area greater than 90% of forest cover to ensure the entire 1km pixel was forest and the biomass was not representative a combination of forest, non-forest vegetation or bare ground.

11. The boundaries of protected areas were used when calculating the "percent sustained" - these areas are assumed to be effectively protected/managed, but it is known that not all protected areas are effectively conserved (as demonstrated by ongoing deforestation within some protected areas).

**Climate Mitigation Indicator 3: Reduction of potential greenhouse gas emissions from deforestation**

3.1 Proportion of areas with high potential emissions in protected areas

\[
\frac{\text{Areas with high potential emissions in protected areas at time 1}}{\text{Total area of high potential emissions in the country at time 0}}
\]
3.2 Proportion of areas with high potential emissions intact

\[
\frac{\text{Total areas with high potential emissions at time 1}}{\text{Total area of high potential emissions in the country at time 0}}
\]

**Denominator 3:** total extent (hectares) of areas that are both vulnerable to deforestation and have high biomass carbon stock in 2010, and therefore have high potential avoided emissions (measured in tons of CO\(_2\) equivalents), above a certain threshold (e.g. national mean value, +/- 1std deviation)

**Numerator 3.1:** the extent of the above areas that are within protected areas

**Numerator 3.2:** the extent of the above areas that have intact forest cover (in the first reporting period (2012) this will be close to 100%, but we expect it will decline over time)

**Climate Mitigation Indicator 3: Methods**

Two datasets are needed: a 30 meter resolution vulnerability map (*Figure 9*) and a 30 meter resolution biomass map (*Figure 9*). To create the vulnerability map, the deforestation rate within each 30m grid cell was assigned. The deforestation rate per 30cm cell was calculated by summing the observed deforestation from 2005 to 2010 within a 20 kilometer radius around that cell, then dividing the observed deforestation by the 2005 forest area within the same 20 km radius. The output is a 30m resolution map that shows the expected deforestation rate within a given 30m forest cell, based on the historical rate from 2005 to 2010. This baseline deforestation was divided by the number of years in the observation period, which provided the baseline deforestation per year. The baseline deforestation per year (vulnerability map) was multiplied by the average forest carbon stock (measured in tons of carbon) within the 30m cell to calculate the CO\(_2\) emissions equivalent (CO\(_2\)e). Then it was multiplied by \(\frac{44}{12}\) (CO\(_2\) conversion factor). The output layer will express the projected emission as tCO\(_2\)e per hectare per year (*Figure 10*). Essential areas for high potential avoided emission were identified using an arbitrary threshold (the national mean value) (*Figure 10*).

The CO\(_2\) emissions equivalent provides an indication of the potential CO\(_2\) emission if deforestation was to continue. Areas essential for avoided emissions were identified using an arbitrary threshold (mean) of 0.77 tCO\(_2\)e.

**Climate Mitigation Indicator 3: Results & implications**
In 2010, protected areas in Madagascar encompassed 42% of the total high carbon stock areas and almost 35% of the high potential emissions areas for the country. Between 2010 and 2012, the forest cover in high potential emissions areas decreased by 1.12%.

Results for **Indicator 4** are:

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Description</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Percentage of areas with high potential emissions under protection in 2010</td>
<td>34.6%</td>
</tr>
<tr>
<td>4.2</td>
<td>Percentage of areas with high emissions potential intact in 2010</td>
<td>100%</td>
</tr>
<tr>
<td>4.2</td>
<td>Percentage of areas with high emissions potential intact in 2012</td>
<td>98.9%</td>
</tr>
</tbody>
</table>

*Figure 9. Vulnerability to deforestation map (left) and carbon C stock (right)*
Climate Mitigation Indicator 3: Assumptions & limitations

1. The historic deforestation rate (a percentage based on area deforested) within a 20 km radius of each grid cell is being used as a proxy for potential future deforestation. However, this assumes that future deforestation will be at exactly the same rate as historic deforestation, which may or may not be true.

2. The 20km radius is based on the literature and expert opinion, as it approximates a realistic distance that people would be willing to travel from roads and infrastructure. It is assumed that areas within 20km of a given site will have similar land-use pressures to the site (managed unit or raster-analysis cell) in question. This analysis is based on a global biomass carbon layer; ideally, this data would be validated with ground-based sampling of forest biomass carbon. A national data set of forest biomass carbon was not available.

3. These indicators should not be interpreted as an estimate of a Reduced Emissions from Deforestation and Degradation (REDD+) reference level or of emissions reductions; those
would require more complex and rigorous methodologies (e.g. Voluntary Carbon Standards) to enter the carbon market. In contrast, these analyses are adequate for use in ranking the appropriateness of sites for potential future REDD+ feasibility studies and activities.

**Climate Mitigation Indicator 4: Total Amount of C stock stored in forest (tC)**

*Starting forest carbon stock = Total Amount of C stock stored in forest in 2010*

*Change in forest carbon stock = Amount of C stock stored in forest in 2010 minus deforestation 2010-2012*

This indicator provides information on the country's total carbon stock in tons based on forest cover. It monitors the change of the amount of total tons of carbon in forest during the monitoring period.

These are the results for Madagascar:

<table>
<thead>
<tr>
<th>Amount of C stock in forest 2010 (tC)</th>
<th>858,104,433</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of C stock in forest 2012 (tC)</td>
<td>852,745,140</td>
</tr>
<tr>
<td>Change in C stock in forest 2010-2012 (tC)</td>
<td>53,59,293</td>
</tr>
</tbody>
</table>

**Climate Mitigation Indicator 4: Assumptions & limitations**

This indicator is based on global datasets and therefore should be considered only a rough estimate of forest carbon stock; it is likely that in the future better national-level carbon inventories will be developed.

**Climate Mitigation Indicators: Updating and Replication**

Climate mitigation indicators can be updated by tracking changes in the numerator (e.g. due to protected area expansion or degazettement, or changes in the intact forest carbon stock due to forest loss). Necessary data layers (assuming reference period 2005-2010, 2010 baseline, and 2012 monitoring period) to create the 30m biomass density map are: forest cover maps for 2005, 2010, and 2012 and biomass data.
While the specific source of data is not proscribed here, some recommendations are provided below:

Remote sensing-derived land-cover dataset and biomass information. Land cover data will be of comparable spectral and spatial resolution so that it can be used for multi-temporal analysis (10-100m resolution). It must have at a minimum forest/non-forest classes, although additional classes (such as different forest types) can be beneficial. If generation of a new Land Use Cover Change (LUCC) map is required, Conservation International (CI) has developed a simple and fast methodology for classification (e.g. Harper et al. 2008) of forest cover and change (deforestation) that can be applied to forest monitoring efforts throughout the world. Researchers from CI, universities, and research institutions have and continue to produce national and global maps that may be appropriate for direct use, or for combining with existing data for an updated analysis. If so, data should first be evaluated for their appropriateness and accuracy in the particular region of interest. In cases where forest cover maps are outdated and there are limited resources to produce a national forest cover update, annual forest loss data from the global forest cover and change dataset (Hansen et. al 2013) can be used to update the map.

Conclusion for all Climate Mitigation Indicators

The overall status of forest in Madagascar seems consistent with what has been historically observed. Of the area most important for carbon storage, only 42% is captured within protected areas. When vulnerability to deforestation is included in the analysis, only about 35% of areas important for reducing potential emission are captured within the existing PA network. This means that there is an opportunity to expand the PA network or implement other conservation measures to incorporate both high carbon stock forests and areas that are currently vulnerable to deforestation.

The amount of carbon that is stored in the forest of Madagascar estimated in Indicator 4 only provides a rough estimate, and therefore should not be used to represent the precise gross carbon storage. Nevertheless it should be noted that the annual deforestation rate from 2010-2012 is 0.3% per year, which is almost identical to the 0.62% decrease in carbon storage experienced over the same two year time period. This would indicate that deforestation is not targeting high- or low-carbon biomass forests, and does deviate from what would be randomly expected. This could potentially highlight an opportunity to divert deforestation from high carbon areas to already-degraded or low-carbon areas.
References and Data Sources


MAPPING AND MONITORING ESSENTIAL NATURAL CAPITAL FOR FRESHWATER

Compiled by: Leonardo Saenz and Natalia Acero

Summary

This summary aims to outline the implementation of a conceptual framework to determine essential natural capital for fresh water. The framework uses the ecosystems approach in order to map essential natural capital for freshwater, in hillslope and river streams, their services and benefits. Results from the framework are combined in a Freshwater Natural Capital Index, which is used to derive the percentage of natural capital sustained through protection, restoration, or improved management.

Definition

The index is defined as the fraction of combined realized freshwater services (quality, quantity and regulation), per unit of area, supplied by freshwater habitats on hillslopes and in river channels. Realized services are calculated for a discrete number of service benefits. Service benefits are the benefits people reap from ecosystem services and functions, such as water for hydropower, domestic use, industrial use, and irrigation, among others.

According to the index, freshwater habitats are defined as those that play a role in the pattern and distribution of services and can be found on hillslopes (i.e. forests that enable regulation and water quality maintenance), flood plains, river channels and lakes (and their associated sub-basins). Service benefits included in this framework were hydropower dams, agriculture, population centers and inland fisheries systems.

Freshwater Natural Capital Indicator: Percentage of essential freshwater natural capital that is sustained through protection, improved management, or as intact habitat.

Essential natural capital (ENC) that is “sustained” was defined in two ways:

a. By protected areas: the extent of essential natural capital for freshwater that is in protected areas;
b. By intact forest cover: the extent of essential natural capital for freshwater that has intact forest cover.

Formula 1 shows the rationale for calculating the indicator for each of the categories.

**Formula 1. Rationale for calculating the percentage of essential freshwater natural capital (ENC) that is sustained.**

\[
\frac{\text{Proportion of ENC for freshwater sustained}}{\text{Freshwater ENC sustained}} = \frac{\text{Total ENC for freshwater}}{\text{Total ENC for freshwater}}
\]

The numerator in the formula is the extent of freshwater essential natural capital sustained (either within protected areas or with intact forest) and the denominator is the extent of total essential natural capital for freshwater across the country.

**Methods**

To develop the indicator the following steps were carried out (Figure 11)

- We summarized the main lessons learned from the literature on freshwater issues in Madagascar.
- We collected data from secondary sources to implement an eco-hydrological assessment of service supply areas.
- We identified and validated the ecosystem service users, and their location, such as dams, rice production, urban water use and inland fisheries, with local stakeholders in an experts’ workshop.
- We developed an explicit definition of ecosystem service functions related to the provision of water quantity and quality.
- We implemented function service quantification analysis for water quantity and quality using eco-hydrological modeling.
- We mapped ecosystems of high potential service supply by using eco-hydrological functions.
• We mapped ecosystems supplying services realized by service users such as dams, rice production, urban areas and inland fisheries, weighting potential services by the amount of service assumed to be demanded by selected service users.

• Finally we created a combined map of ecosystems supplying realizable services for this discrete number of beneficiaries, which became our final map of total essential freshwater natural capital for Madagascar.
Figure 11. Conceptual framework of series of steps implemented to identify, model, map and monitor essential freshwater natural capital
Results and implications

**Combined Freshwater Natural Capital Index**

Our combined freshwater natural capital index, including four service benefits and two ecosystem services (water quantity and quality) is illustrated in Figure 12. The four service benefits assessed were existing hydropower dams, urban areas, rice production and inland fisheries. We combined a water flow transport index in order to illustrate key river channels important to sustain the flow of services in quantity and quality. Figure 12 includes improvements in the determination of critical river channels, and associated sub-basins, for the transport of water across the river systems.

![Combined essential freshwater natural capital index](image)

*Figure 12. Combined essential freshwater natural capital index*

**Combined Freshwater Natural Capital Index**

Finally we combined the Freshwater Natural Capital Index with a map of natural ecosystems in order to produce a consolidated index of freshwater natural capital (Figure 13) that encompasses the role of habitats on hillslopes and priority river channels, lakes or wetlands in the supply of
freshwater services to people (according to the set of service benefits selected). Natural systems included natural habitats on hillslopes, including different types of natural forests and natural savanna vegetation, according to the most recent landcover dataset available (Kew Royal Botanic Gardens 2007, updated with ONE et al. 2013 and Hansen et al. 2013). Natural ecosystems also included water bodies such as river channels, lakes and wetlands which are important either for the flow and/or realization of freshwater services in quantity and quality.

Next, we assigned arbitrary thresholds to determine areas with relatively higher Freshwater Index values: areas above the national mean in terms of their Freshwater Index value, and areas above the national mean plus one standard deviation. Figure 14 shows the important areas for fresh water based on these two different thresholds. We recommend using the percentile above the mean value.
of the essential freshwater natural capital index as it shows a better spatial distribution of the freshwater ecosystem services in the country.

**Freshwater Indicator: Essential Freshwater Natural Capital Sustained within Protected areas**

Using the above definition of “sustained” (within a protected area or with intact forest cover), we calculated the percentage of freshwater essential natural capital sustained. As shown in Figure 15, left, 11.4% of essential natural capital for fresh water falls within protected areas as of 2014, using a threshold of the national mean value of the Freshwater Natural Capital Index. Only 1% of essential natural capital for freshwater is protected when the mean plus one standard deviation is used as the threshold (Figure 15, right).
We calculated the percentage of freshwater essential natural capital “sustained” through intact forests. The intact forest cover is based on the Kew Royal Botanical Garden Land Cover map 2007, updated with a 2010 national forest cover map (ONE et al 2013).

This assessment indicates, as shown in Figure 16, left, that 14.4% of freshwater essential natural capital is found in areas that were classified as intact forest in the year 2010. This value is obtained when the national mean value of the Freshwater Natural Capital Index is used as the threshold. If we use a threshold of the national mean plus one standard deviation, we get a similar figure (11.7%). This similarity indicates that our essential freshwater natural capital on hillslopes has an important correlation with the presence of intact forest.

Figure 15. Essential natural capital for fresh water sustained within protected areas. Freshwater Index values above the mean (left), values above the mean + one standard deviation (right).

Freshwater Indicator: Essential Natural Capital Sustained as Intact Forest
In order to monitor the change due to deforestation in Madagascar, we calculate the fresh water essential natural capital sustained through intact forests as of 2012, taking into account forest loss according to Hansen et al. (2013) for the period of time 2010 – 2012. We found that that only 13.3% of freshwater essential natural capital is found in the areas that were classified as intact forest for the year 2012 using the mean value as threshold and only 5.5% is sustained, if we use a threshold of the mean plus one standard deviation. Thus between 1.1% and 6.2% of essential natural capital for fresh water was lost due to deforestation in the period 2010-2012.

Assumptions and limitations of this analysis

- We assumed that well-maintained natural habitats upstream help to maintain normal supply of freshwater services – maintaining the status quo. Degradation of habitats is assumed to affect natural regimes causing them to deviate from the norm.

*Figure 16. Essential natural capital for fresh water sustained within intact forest. Freshwater Index values above the mean (left), values above the mean + one standard deviation (right).*
• We used a combination of local and globally-available data for model implementation for priority setting and policy support purposes. Locally relevant data for benefits were updated, but local data from water resources management are needed for accurate validation and valuation exercises beyond this application (i.e. groundwater). These data are not currently available for Madagascar.

• No analysis of flow regulation services are tackled here, but is the focus of future work. No detailed assessment of seasonality, sediment transportation, flood indexes or nutrient recycling processes was added due to time and data limitations.

References and Data Sources


Open Development Cambodia. Protected Areas. http://www.opendevelopmentcambodia.net/

Mapping and Monitoring Essential Natural Capital for Food Security

Compiled by: Curan Bonham, Zo Ratakobe, Kellee Koenig, and Rachel Neugarten

Definition

Ecosystems that provide essential wild sources of food (fisheries and non-timber forest products) to vulnerable populations dependent upon them

-and-

Ecosystems that provide essential services to agriculture systems that produce crops and livestock for consumption (e.g. freshwater, soil fertility, pest and disease control, climate regulation, and/or pollination.)

In Madagascar, examples of essential natural capital for food security include:

- Forests or other natural habitats that provide non-timber forest products, habitat for hunted species, and natural pollination and pest and disease controls for agriculture production
- Freshwater ecosystems providing fish and other food sources, and water for irrigated agriculture
- Coastal ecosystems providing fish and other food sources

Core to any analysis of natural capital contribution to food security is an understanding of the way human populations utilize the products originating from areas of natural capital. Although all natural capital has value for maintaining food security, certain areas of natural capital are more important in terms of provision of some economically important benefits. These benefits were distilled into a value, determined by analyzing four types of data:

- levels of food insecurity
- proximity of people to areas of natural capital
- dependence of people on areas of natural capital
- importance of areas of natural capital based on the value or importance of the non-timber forest products provided by certain types of ecosystems
In order to track change in the extent of essential natural capital for food security, it is necessary to first measure the extent of natural ecosystems that provide food security benefits. Next it is necessary to measure the extent of those ecosystems that are “sustained.” A definition of term “sustained” is required. An overlay of protected areas boundaries alone is not sufficient to capture the concept of “sustained” in regards to food security, as in many cases protected areas can exclude human use. However, it should be mentioned that some protected areas do allow certain levels of human use (Dudley, 2008). For example, IUCN protected areas category VI includes “areas that conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.”

Protected areas can also serve as important reservoirs which support sustainable flows of non-timber forest products, fisheries, or agricultural production in adjacent areas through seed dispersal, pollination, fresh water, nurseries, or other indirect ecological processes. For example, seeds and pollinators from a strictly protected area may replenish degraded forests near the protected area, which are used by local people for fuelwood collection, livestock grazing, collection of edible and medicinal plants, or other non-timber forest products. In order to provide a simple measure of “sustained” we propose the indicator to be expressed as the percentage of essential natural capital for food security that has intact vegetation cover, using a baseline defined by the below mapping methodology.

**Food Security Natural Capital Indicator**: Percentage of essential natural capital for food security sustained through protection, improved management, or as intact habitat

**Denominator**: total extent (hectares) of natural capital identified as essential for food security, above a certain threshold (e.g. upper 10% of values, or one standard deviation above the national mean)

**Numerator**: the extent of the above areas that have intact forest cover
Methods

Essential natural capital for non-timber forest products and wild food

We completed a weighted multi-criteria evaluation (MCE) for key habitats which impact food insecurity in Madagascar. Using the Kew Royal Botanic Garden Landcover dataset (2007) forest cover classification, updated with 2010 forest extent (ONE et al. 2013) we extracted different forest types and habitats based on existing knowledge on their importance for non-timber forest products (NTFPs).

We assigned weights to the extracted habitat types (Table 4) based on a series of expert meetings held in September of 2014. Experts included 15 national and international experts (in the fields of marine fisheries, flora, fauna, and agriculture) from the Ministry of Agriculture, the University of Antananarivo, the conservation NGOs such as Missouri Botanical Garden and Royal Botanical garden, the national offices and associations for environment such as ONE (Office National pour l’Environnement), SAGE (Service d’Appui a la Gestion de l’Environnement) ARSIE (Association du Reseau des Systemes d’Information Environnementale) and ANAE (Association Nationale d’Actions Environnementales).

The weighting system included a list of more than 40 species of known economic importance, however it is recognized that there are many thousands more species of local value when all medicinal plants are taken into account. These weights were based on the product (multiplication) of the average importance value of each NTFP as evaluated according to eight socio-economic criteria (Appendix 1) –and- the evaluation of the frequency and abundance of each NTFP in each habitat type (Appendix 2). These weights were then normalized (using maximum-minimum). The map in the upper left corner of Figure 17 shows a spatial representation of the results of this prioritization.

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Raw Score</th>
<th>Normalized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humid forest</td>
<td>4.430121</td>
<td>100</td>
</tr>
<tr>
<td>Degraded humid forest</td>
<td>4.426301</td>
<td>99.8092</td>
</tr>
<tr>
<td>Littoral forest</td>
<td>3.929217</td>
<td>74.9822</td>
</tr>
<tr>
<td>Degraded Western dry forest</td>
<td>3.895881</td>
<td>73.3173</td>
</tr>
</tbody>
</table>
Using the 2011 Landscan data (which provides population density at one square kilometer resolution), we calculated and weighted distances between people (at least 3 people per square km) and proximity to natural habitats. Estimates of average foraging distances were used to calibrate the weighting system (Neumann and Hirsch, 2000). The weights were used to rank the importance of ecosystems in terms of proximity to people (Table 5).

Table 5. Distances between people and natural habitats, based on identified foraging distances

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>100</td>
</tr>
<tr>
<td>5-10</td>
<td>80</td>
</tr>
<tr>
<td>10-15</td>
<td>60</td>
</tr>
<tr>
<td>15-20</td>
<td>40</td>
</tr>
</tbody>
</table>

In order to identify the areas of natural capital that were most likely to be more frequently used, we focused on areas above a minimum threshold of human population per square kilometer. We included in our analysis all Landscan grid cells with population over 3 (cutting off lowest 25% of pixels). The resultant area of analysis is represented in the map in the lower left corner of Figure 17.
In the future an analysis may be explored which weights pixels according to population density. This will allow us to account for areas that are more likely to be important for a larger population for forest product collection.

Commune-level food insecurity and forest product dependency was measured by the percentage of households experiencing food insecurity during part or all of the year (Figure 17 lower right corner), and percentage of households living on income from forest products (Figure 17 upper right corner), from the 2007 commune database (Moser et al. 2008). Rather than set a threshold or reclassify the data, both values were used to generate raster datasets at the same spatial resolution as the population buffers, using the percentages as the cell value. This dataset, although comprehensive, has some issues with data quality as well as missing or incomplete data for some communes; for this reason we have explored the use of additional more coarse, but possibly more reliable, district-level data to corroborate our evidence (WFP, 2011).

By normalizing (max-min), weighting them equally from 0-100, and combining (additively) these raster datasets, we identified habitats that are likely important for non-timber forest products. Different weightings were used to detect changes in areas of importance (sensitivity analysis). For the purposes of this report we present the simplest weightings system, by equally weighting the four components (commune-level food insecurity, dependence on NTFPs, distance from habitat to population of at least 3 people, and importance of habitat type for NTFPs).

This multi-criteria analysis resulted in a spatial data layer that showed relative importance of natural ecosystems for NTFPs, from low to high (Figure 18). In order to define discrete areas of “essential natural capital for non-timber forest products”, we then applied an arbitrary threshold, including all values one standard deviation above the mean (Figure 18). All areas above this threshold were defined as essential natural capital for NTFPs. The resulting maps are presented below.
Figure 17. Visualization of input data sets comprising the analysis of natural capital for non-timber forest products: vegetation types weighted by importance for NTFPs (top left), percentage of households dependent upon forest products (top right), distance from population (bottom left), and percentage of food insecure households (bottom right).
Figure 18. Complete results of multi-criteria analysis of natural capital for non-timber forest products (left), and the same results, with an arbitrary threshold (values above the mean plus one standard deviation) used to distinguish "essential" natural capital for NTFPs.

**Essential natural capital supporting agricultural production and fisheries**

Two key commodities for ensuring food security in Madagascar at a national level are rice and fish. 75% of Madagascar population is employed in the agricultural sector, with rice (nationally) and cassava (regionally) being two of the most important staples (Instat, 2010). Being an island nation, a major source of protein intake is derived from fish, of which the majority (70%) is provided by small-scale artisanal fisheries (LeManch et. al, 2012). Due to the importance of rice and fish to Madagascar’s national food security, the ecosystem services which underpin production of these two commodities were selected for analysis.

In order to assess ecosystem services important for fish production, freshwater and coastal ecosystems of known importance for fisheries (based on commune-level data of dependence on fisheries, expert knowledge, and the extent of coral reefs, mangroves, and inland water bodies) were identified.
Coastal fisheries

Global datasets on coral reefs (Burke et al. 2011) and mangroves (Giri et al. 2011) were used to identify these habitats located along the coast of Madagascar. According to FAO (2007), fishermen travel different distances into the ocean along the eastern and western coasts of the country (due to variable distances from the shore to the continental shelf). Therefore different distances from the coast were used: mangroves and coral reefs falling within a 30-km zone in the Mozambique Channel off the west coast of Madagascar, and a five-km zone of the Indian Ocean off the east coast were included. Next, these areas were further refined by identifying coral reefs and mangroves that were offshore of communes with high fisheries dependence, based on the 2007 commune census dataset (Moser et al. 2008). “High fisheries dependence” was defined as those communes in which fishing as a source of income was defined as highly important (Figure 19) (Moser et al. 2008). The result of this overlay is presented in Figure 20.

Inland fisheries

Inland water bodies including lakes, streams and other freshwater habitats such as wetlands were identified based on a national land cover dataset (Kew Royal Botanic Gardens 2007). Those freshwater habitats occupying or adjacent to communes of high fisheries dependence (defined in the same way as in the above analysis) (Moser et al. 2008) were identified in Figure 20.
Figure 19. Percentage of people working in fishing per commune (Moser et al. 2008)
Figure 20. Communes with a high level of dependency on fishing (in yellow), important coastal fisheries (mangroves and coral reefs, left) and important inland fisheries (inland water bodies, right).

**Essential natural capital for freshwater for rice production**

Areas providing the greatest freshwater flows to important areas of rice production were also identified based on modelling efforts (see section on Freshwater Essential Natural Capital). Quantity or volume of freshwater is an important constraint to sustained rice production in Madagascar and the ecosystem service which is most directly linked to food security vis-à-vis paddy rice production. Areas of natural capital identified through this analysis were located in naturally vegetated upland watersheds of the central highlands that were hydrologically connected to important areas of rice cultivation, as identified from national landcover data (Kew Royal Botanic Gardens 2007) (Figure 21). More detailed methods on this analysis can be found in the section on Freshwater Essential Natural Capital.
Results & implications

Figure 22 shows the combined area of essential natural capital for food security in Madagascar. Through this analysis over 12 million hectares of natural capital in Madagascar have been identified as essential for the provisioning of NTFPs, 18% of which is currently protected. 10.4 million people (nearly half the country’s population) reside within 5km of these essential areas of natural capital. These populations are potentially among the most food insecure and dependent upon natural capital for livelihoods, subsistence agriculture, and wild food sources. However this is likely a conservative estimate because it is estimated that 75% of the total population of Madagascar relies on forest products, particularly in the form of charcoal for cooking and heating, and 75% of the country are rural farmers. While only a fraction of the total value of natural capital essential for NTFP production is encompassed by this area, it corresponds to regions of the country that are
highly food insecure and more likely dependent upon NTFPs, making these areas priority for both conservation and development.

Figure 22. Areas of essential natural capital for non-timber forest products, coastal and inland fisheries, and freshwater for rice production.

Essential natural capital for food security that is sustained

Once the extent of essential natural capital for food security was mapped and measured, it was possible to calculate the area that is sustained, as intact forest or within protected areas (Table 6). These overall indicators can be dis-aggregated by the type of essential natural capital.

Table 6. Essential natural capital for food security that is “sustained” in protected areas or has intact forest cover

<table>
<thead>
<tr>
<th>Type of Natural Capital</th>
<th>Total area (ha)</th>
<th>Area protected (ha)</th>
<th>Area protected (%)</th>
<th>Area with forest cover 2010 (ha)</th>
<th>Area with forest cover 2012 (ha)</th>
<th>% intact in 2012 (2010 is baseline)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-timber forest products</td>
<td>12,893,100</td>
<td>2,386,941</td>
<td>19%</td>
<td>4,277,189</td>
<td>4,275,271</td>
<td>99.96%</td>
</tr>
<tr>
<td></td>
<td>Value 1</td>
<td>Value 2</td>
<td>Percentage</td>
<td>Value 3</td>
<td>Value 4</td>
<td>Percentage</td>
</tr>
<tr>
<td>----------------</td>
<td>---------</td>
<td>---------</td>
<td>------------</td>
<td>---------</td>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>Freshwater</td>
<td>18,047,700</td>
<td>2,051,070</td>
<td>11%</td>
<td>2,610,676</td>
<td>2,597,839</td>
<td>99.51%</td>
</tr>
<tr>
<td>Coastal Fisheries</td>
<td>586,859</td>
<td>265,586</td>
<td>45%</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Inland Fisheries</td>
<td>368,393</td>
<td>145,644</td>
<td>40%</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

**Assumptions & limitations**

For these analyses, natural capital is assumed to be especially important for:

- Food insecure populations (Neumann and Hirsch, 2000),
- Populations living in close proximity to natural ecosystems (Pearce and Pearce, 2001),
- Populations that derive their livelihoods from collection and utilization of forest products or fisheries

The limitations associated with these assumptions include:

1) Local experts pointed out that populations dependent on natural capital for food security may not actually be food insecure due to the value that is currently being generated through harvesting practices. However, it is also recognized that in Madagascar, the poorest people tend to live near forests because they do not have the means to own more desirable agricultural land; while the farmers who are relatively better off own crop land near towns.

2) Field-sampled data on the dynamics of areas of natural capital essential for non-timber forest products that are currently used by people is limited to selected sites within Madagascar, therefore it was not sufficient for this national-level analysis. Collecting additional field data from representative sites around the country would complement and help to verify the outcomes of this analysis.

3) Certain habitats provide more value in terms of non-timber forest products than others; however it is difficult to acquire comprehensive data on this or to estimate these values without field level data or a body of literature which can be used to project shadow prices. Thus for this analysis, we relied on expert opinion to estimate the importance of different habitat types.

4) Due to lack of previous empirical research on total economic value of natural habitats in Madagascar, this analysis relied on a panel of experts to systematically evaluate the importance of
different habitat types for NTFPs. This was a qualitative, subjective assessment. Once developed, those values were applied consistently across the country due to lack of data about variation at the site level.

5) This analysis doesn’t consider the “level of sustainability” of the current management of the wild food sources (fisheries or non-timber forest products) or agricultural production practices. A next step in the refinement of these indicators would be to address that key issue.

In order to address the limitations identified through the validation process, in future iterations several additional analyses could be added:

- Regional review of literature (published and grey) of current NTFP harvesting and utilization trends, including the contribution of bush meat to local food security
- Market and household surveys of the value of NTFPs at national and local scale
- Field sampling to validate mapping results, for example, household surveys or site visits to locations flagged as “essential natural capital” in the mapping analyses

Updating and replication of analyses

Updates to this metric will require the acquisition of more current data sets as they become available. It is expected that levels of food security, population, and forest cover will change over time and will need to be incorporated on a periodic basis. A review of this baseline using newly acquired data will be useful, but should not replace the current analysis unless fundamental changes are made to the framework.

Annual collection of data on changes in protected area boundaries and forest cover change data will be required in order to calculate the proposed indicator of percent sustained, and should require a relatively low level of effort (i.e. one day of spatial analysis). This data is expected to be made available on annual basis through the World Database on Protected Areas (protectedplanet.net) and the global forest cover product created by Hansen et. al., 2013.

References


Guidance on Recognising Protected Areas and Assigning Management Categories and Governance Types, Best Practice Protected Area Guidelines Series No. 21, Gland, Switzerland: IUCN.

FAO (Joël Nageon de Lestang). 2007. ‘Study on Safety at Sea for Small-scale Fisheries: Southwest Indian Ocean.’


MAPPING AND MONITORING ESSENTIAL NATURAL CAPITAL FOR CLIMATE ADAPTATION

Compiled by: David Hole, Rachel Neugarten and Kellee Koenig

Definition

As input to CI’s overall ‘essential natural capital’ metric, this indicator is intended: 1) to enable users to identify and quantify the spatial extent of ecosystems providing climate adaptation services, and thereby inform priority-setting of conservation actions and investments; and 2) to enable users to quantify the contribution of conservation efforts in sustaining adaptation services provided by these ecosystems.

**Climate Adaptation Natural Capital Indicator:** the percentage of essential natural capital for climate that has been sustained through protection, improved management, or as intact habitat.

This indicator assesses and tracks changes in the spatial extent of ecosystems providing climate change adaptation services that are important to one or more identified groups of beneficiaries. These services could include protection from climate-driven extreme events such as coastal storm surge or flooding; buffering the impacts of chronic, long-term shifts in temperature or precipitation; or supporting alternative livelihoods thereby increasing adaptive capacity. Important ecosystems for providing adaptation services are identified based on three key criteria: 1) Who is vulnerable and to what aspect of projected climate change; 2) The extent to which an ecosystem(s) can significantly reduce that vulnerability through the sustainable provision of one or more ecosystem services (i.e. *adaptation services*); and 3) The location of the ecosystems providing the adaptation service(s) within the geography of interest.

The denominator of the indicator is calculated as the total extent (in hectares) of essential natural capital (ENC) providing a *threshold level* (that will vary depending on the purpose or audience) of
adaptation services within the geography of interest; the numerator is calculated as the portion of the total (in ha) that is being sustained by existing conservation efforts.

\[
\text{Proportion of ENC for climate adaptation sustained} = \frac{\text{ENC for adaptation sustained}}{\text{Total ENC for adaptation}}
\]

The numerator can be updated annually, as new data on the extent of protected areas becomes available. The denominator should be updated when a new or updated national level vulnerability assessment becomes available, or when major new climate data and/or climate impact information becomes available (e.g. IPCC reports every 6-7 years).

Methods

To calculate this indicator, key steps involve identifying (quantitatively where feasible, otherwise qualitatively): 1) the key climate-related threats (exposure) people face within a given geography; 2) where (spatially) people are most sensitive to those threats (sensitivity); 3) the resources those people have to ameliorate those threats (adaptive capacity); and 4) the role that ecosystems can play in reducing the identified vulnerability(ies) (the composite of exposure, sensitivity and adaptive capacity).

Given limited time and resources, we applied a simple but transparent approach to identify key vulnerabilities in Madagascar based on a three step process: 1) review pre-existing internal and external assessments of vulnerability and key adaptation needs (e.g. National Adaptation Plans of Actions (NAPAs) and regional assessments [CI, 2008]); 2) utilize expert judgment to define a set of priority adaptation needs that are likely to be relevant for an ecosystems approach to adaptation; 3) based on information from (1) and (2) select the top three identified vulnerabilities for further analysis. For Madagascar these were: i) the direct and indirect impacts of climate change on terrestrial and freshwater wild food sources (e.g. lemurs, turtles); ii) the direct and indirect impacts of climate change on coastal and marine fisheries, primarily as a result of negative impacts on coral reefs; iii) an increased threat of storm surge and coastal erosion due to sea-level rise and an increase in the power and/or frequency of tropical cyclones.
Given limited time and resources, we were able to investigate only one of these vulnerabilities – namely an increased threat of storm surge and coastal erosion. The ecosystem services model ‘InVEST’ (Sharp et al, 2014) was used to approximate vulnerability based on a range of biophysical and socio-economic characteristics (e.g. geomorphology, wave exposure, sea level rise, coastal population density). The model produces a qualitative estimate of *relative* vulnerability, ranging from low to high, which includes the potential role of natural habitats in reducing that vulnerability. For Madagascar, sufficiently robust, spatially explicit datasets were available for mangroves (Giri et al, 2011 – global mangrove distributions at 30m resolution for the year 2000) and coral reefs (Burke et al, 2011 – global distribution of shallow coral-reef ecosystems at 30m resolution centered on the year 2000), natural habitats that are among the most effective in providing coastal protection (Spalding et al, 14). Datasets used for the analysis are summarized in Table 7.

*Table 7. Datasets used to run the InVEST coastal vulnerability model*

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathymetry</td>
<td>Global elevation projected to UTM Zone 38S</td>
<td>2-Minute Gridded Global Relief Data <em>(ETOPO2v2)</em>, June 2006 (<a href="http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html">http://www.ngdc.noaa.gov/mgg/fliers/01mgg04.html</a>)</td>
</tr>
<tr>
<td>Population</td>
<td>Landscan data clipped to Madagascar and projected to UTM Zone 38s</td>
<td>Oak Ridge National Laboratory, Landscan (<a href="http://web.ornl.gov/sci/landscan/landscan_data_avail.shtml">http://web.ornl.gov/sci/landscan/landscan_data_avail.shtml</a>)</td>
</tr>
<tr>
<td>Elevation</td>
<td>Global elevation at 30m resolution. Projected to UTM Zone 38s</td>
<td>USGS, Global 30 Arc-second Elevation <em>(GTOPO30)</em> (<a href="https://lta.cr.usgs.gov/GTOPO30">https://lta.cr.usgs.gov/GTOPO30</a>)</td>
</tr>
<tr>
<td>Geomorphology</td>
<td>Coastline geomorphology, digitized and Ranked to InVEST standards. Used GoogleEarth imagery to identify geomorphology of coastline</td>
<td>Google Earth (<a href="https://www.google.com/earth/">https://www.google.com/earth/</a>)</td>
</tr>
<tr>
<td>Land mass</td>
<td>Outline of Madagascar projected to UTM</td>
<td>NOAA, Global Self-consistent, Hierarchical, High-resolution Geography Database(GSHHG)</td>
</tr>
</tbody>
</table>
Wave exposure data from InVEST default data, projected into UTM Zone 38s

NOAA, Wave Watch III

Values classified from low to high (ranked 1-5)

National dataset provided by CI Madagascar

Global datasets for coral reefs (Reefs at Risk, Burke et al., 2011), and mangroves (Giri et al., 2011)

See relevant citations below

‘Adaptive capacity’ in this instance was not incorporated into the analysis since we lacked data at a sufficiently fine resolution to distinguish heterogeneity in the adaptive capacity of different socio-economic or cultural groups within coastal communities in Madagascar. Hence, ‘beneficiaries’ were defined simply as coastal populations that would be likely to experience a substantial increase in relative vulnerability to storm surge and coastal erosion if neighboring mangroves or coral reefs were degraded or lost completely.

Results and Implications

Figure 23 indicates where the loss or degradation of mangroves or coral reefs would likely result in greater exposure to coastal erosion and storm surge, both in the present and in the future as climate change proceeds, increasing the risks to people’s lives and livelihoods in those areas. We use a scale bounded by 0 and 1 to indicate the relative importance of natural capital for reducing coastal vulnerability and a threshold of 0.5 in order to define “essential natural capital” – i.e. areas with a value > 0.5 represent areas of mangroves and coral reefs that are relatively more important for providing that function. The threshold is subjective and is used here simply as a demonstration. To be of utility for prioritizing any form of actions at the local or national scale, relevant stakeholders should identify a suitable threshold in a participatory and equitable process.

The total extent of essential natural capital for coastal protection under climate change in Madagascar is 151,000 ha of coral reefs and 86,000 ha of mangroves, of which 56,000 ha and 25,000 ha respectively are classified for this exercise as “sustained” (i.e. included in Madagascar’s national protected area system as defined for 2014). Hence, 37% and 29% (respectively) of
essential natural capital for climate adaptation in terrestrial, freshwater or marine ecosystems of Madagascar, has been sustained. These figures represent 23% and 9% respectively of the total areas of these ecosystems in Madagascar (i.e. the extent of essential natural capital falling in a protected area as a proportion of the total extent of each ecosystem within Madagascar). Note that the data is not available to calculate any recent change in these figures (mangrove deforestation data is unavailable, likewise any indicator related to coral reef health over time).

In total, around 500,000 people living on the coast of Madagascar are expected to benefit from the coastal protection service provided by these ecosystems now, with that service increasing in value and importance in the future under climate change (derived from LandScan population values summed across all points above our threshold value of 0.5 – see middle panel of Figure 23).

Figure 23. Essential natural capital for enhancing coastal protection under climate change in Madagascar. Relative importance of natural capital (mangroves and coral reefs) for reducing the vulnerability of coastal human communities (each point represents the centroid of a 1km² analysis cell) (left); All points (red dots) above a threshold value of 0.5 indicating locations where natural capital is “essential” for contributing to a reduction in human vulnerability, in relation to the existing protected area network (black polygons) (middle); Magnified inset indicating the use of a 2km buffer around all points above the 0.5 threshold used to calculate the extent of essential natural capital for climate adaptation (the denominator of the overall indicator) (right).
Assumptions and Limitations

Key assumptions and limitations inherent to this analysis include:

- Our results assume that the relative distribution of coastal populations remains the same into the future.

- The number of people benefitting from the coastal protection service provided by essential natural capital is an estimate for the present, and is therefore likely a conservative estimate for the medium-term future, given population increase and likely ongoing settlement of the coastal zone.

- The InVEST model is able to include the potential increase in vulnerability of coastal populations due to sea-level rise, but does not explicitly capture any projected changes in tropical cyclones. Hence, our results assume simply that climate change will not alter the spatial pattern or relative strength and frequency of existing and historical cyclones, but will instead be additive (i.e. those areas getting hit hardest and most often in the future will be the same areas getting hit hardest and most often in the present).

- InVEST is an indicator-based model and so doesn’t include the complex processes, dynamics, and interactions between the physical, ecological and social components of the system. For example, the effectiveness of a mangrove forest or coral reef in reducing vulnerability will vary significantly, depending on the interplay between a large number of variables, including mangrove species, reef depth, width of the mangrove or coral reef, etc.

- InVEST is ‘blind’ to the precise locality of human communities in any given analysis cell, relative to the spatial location of mangroves in that cell. Hence, there will be occurrences where a community is, in reality, on the seaward side of the mangrove and so fails to benefit from the coastal protection service provided by the mangrove.

- We identify essential natural capital for adaptation in terms of a single adaptation service (i.e. the increased need for coastal protection for human populations under climate change). Hence, we identify only a fraction of the natural capital in Madagascar that may support a reduction (or at least a reduced increase) in the vulnerability of people to climate change.

- Areas defined as “sustained” in this exercise are, in some cases, likely to be undergoing continued exploitation (e.g. so-called ‘paper parks’) despite their legal protected status.
Replication of analyses

Identifying essential natural capital for adaptation in other geographies will be challenging – principally because of the sheer scope of potential climate change impacts across all sectors of society and the economy, meaning only some fraction of relevant natural capital will be identified. As added to this is the high degree of technical capacity required to model the provision of multiple ecosystem services under climate change (e.g. proficiency in one or multiple modeling platforms such as InVEST, WaterWorld or ARIES). Simpler methods do exist, involving the use of existing, often regional or global level analyses (“Tier 0”) or simplifying assumptions regarding the spatial provision of services to beneficiaries. However, for coastal protection-related climate-driven vulnerabilities the model used here (InVEST) could equally be applied in any geography of interest, assuming the relevant technical capacity and input datasets are available.

This specific analysis should be updated on a semi-regular basis, either as datasets iteratively improve (e.g. more accurate population data; greater breakdown of demographic indicators, ecosystem service models are updated (e.g. to include coastal dynamics)) and/or in line with the IPCC reporting cycle (i.e. every 6-7 years) when future climate projections are updated.

Key References and Data Sources


LandScan (2011) High Resolution global Population Data Set.


MONITORING NATIONAL GOVERNANCE FOR ENVIRONMENTAL SUSTAINABILITY

**Governance Indicator:** Status and trends in national policy effectiveness

**Compiled by:** Madeleine McKinnon, Ando Rambelson

Definition

This indicator is intended to measure effectiveness of the cross-sectoral and transnational policies necessary to enable conservation of essential natural capital, and to ensure environmental sustainability is central to a country’s development agenda.

It assesses and tracks changes in the effectiveness of a country’s national and subnational policies created to govern and regulate natural capital and production systems, and ensure that there is equitable access to, and sharing of, nature’s benefits. Policy effectiveness is defined by two criteria: 1) the level of policy soundness, and 2) the extent of policy adoption, implementation, enforcement and evaluation.

A highly sound policy is defined as having clear, realistic and measurable objectives and offers well-designed solutions to a problem based upon widely-accepted scientific evidence and/or best practice. It sufficiently incorporates relevant, widely-recognized social safeguards (such as a Rights-Based Approach; Free, Prior and Informed Consent; Access and Benefit-Sharing; Climate, or Community and Biodiversity Alliance (CCBA) Standards). It sufficiently incorporates relevant environmental safeguards in accordance with international standards (e.g., CCBA). It was designed with sufficient participation of stakeholders affected by the issue, and those responsible for its implementation. It aligns with relevant global conventions or agreements supported by Conservation International (such as the UN Convention on Biological Diversity, the UN Convention on Human Rights, the UN Watercourses Convention, the Ramsar Convention on Wetlands, the UN Framework Convention on Climate Change, or others).
Methods

The effectiveness of policies is assessed using a scoring questionnaire, or “scorecard” which is designed to be completed by CI program staff with input from representatives from government and partner NGOs (see Appendix 3). This scorecard was developed by CI in 2013 and has been applied by CI programs to assess governance in 26 countries. In 2014, CI-Madagascar completed a preliminary scorecard for Madagascar.

The process involved a qualitative assessment of 34 relevant national policies. Each policy is assessed against two criteria: level of soundness and extent of implementation, and scored between 0 (e.g., policy is not sound and/or policy is early planning phases) and 10 (e.g., policy is highly sound and actively implemented and monitored with long-term financing secured).

Table 8. Scoring criteria for assessing the level of soundness (top) and level of implementation (bottom) of a national policy.

<table>
<thead>
<tr>
<th>Scoring Criteria: Level of soundness</th>
<th>Criteria</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not applicable</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Information not available</td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>A highly sound policy/course of action has clear, realistic and measurable objectives and offers well-designed solutions to the problem based upon widely-accepted scientific evidence and/or best practice. It sufficiently incorporates relevant, widely-recognized social safeguards (e.g., RBA, FPIC, ABS, CCBA). It sufficiently incorporates relevant environmental safeguards in accordance with international standards (e.g., CCBA). It was designed with sufficient participation of stakeholders affected by the issue and those responsible for its implementation. It aligns with relevant global conventions/agreements supported by CI (UNCBD, UN Convention on Human Rights, UN Watercourses Convention, Ramsar, UNFCCC, etc.).</td>
<td>Not sound</td>
<td>1</td>
</tr>
<tr>
<td>Limited sound</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Somewhat sound</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>
| Moderately sound                     |          | 4     | Policies that are relevant, but no information is available to make assessment.
| Policies that are not relevant to the country or region | | Policies that is poorly written with no clear objectives and proposed policy activities are not well-supported or possibly refuted by best practice. Implementation of policy has the potential risks or potentially adverse environmental, social or economic impacts. | Policies objectives may be missing or lacking and rationale for policy activities is unclear. Policy might have good components but have with significant areas for improvement. Risk of negative social or environmental impacts from policy. | Policy has stated objectives and activities are documented, but perhaps insufficient. Objectives and/or activities might be ambitious or difficult to measure. | Policy has measurable objectives and clear set of policy activities. Full set of safeguards and measures may not be yet be present. Stakeholders have been consulted, but perhaps not all groups. |
### Scoring Criteria: Level of implementation

<table>
<thead>
<tr>
<th>Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information not available</td>
<td>0</td>
</tr>
<tr>
<td>&quot;Agenda setting &quot;+&quot;Policy formulation&quot;: Decision makers are beginning to acknowledge and define the problem requiring better governance. Or, a policy/course of action, which follows Strategic Social-Environmental Assessments best practices, is being developed to address the problem.</td>
<td>1</td>
</tr>
<tr>
<td>&quot;Policy legitimation&quot;: A policy/course of action has been adopted or ratified, giving it legal force.</td>
<td>2</td>
</tr>
<tr>
<td>&quot;Policy implementation-Low&quot;: Implementation is extremely limited (e.g., due to very low funding or capacity).</td>
<td>3</td>
</tr>
<tr>
<td>&quot;Policy implementation-Medium&quot;: Implementation somewhat limited (e.g. funding/capacity for 2 years only).</td>
<td>4</td>
</tr>
<tr>
<td>&quot;Policy implementation-High &quot;+&quot;Evaluation&quot;: Policy/action undergoing full implementation, enforcement and evaluation.</td>
<td>5</td>
</tr>
</tbody>
</table>

In Madagascar, CI staff with oversight by Vice President Leon Rajaobelina completed an initial assessment of the relevant national policies. Mr. Rajaobelina was formally Finance Minister for the national government of Madagascar and Madagascar Ambassador to the United States. He currently serves as a Special Advisor to the President of the Republic of Madagascar. Staff held meetings with representatives from several relevant NGO partners and government departments to fill in scorecards or score specific policies.

Where possible, scores were validated using existing sources of evidence such as policy reports, survey data, and other indices. Additionally, experts at the September 2014 validation workshop were asked to identify and prioritize the five most important current policies for Madagascar.

### Results and implications

In Madagascar, 34 policies were identified as relevant for assessment by the team. With a total possible score of 340, an overall score of 224 was calculated in 2014 for Madagascar. Results by specific policy themes are listed in Table 9 below. Madagascar has ratified many major international...
and regional environmental conventions, yet effective implementation has been limited by financial resources.

The existing governance system lacks adequate multi-sectoral policies that integrate natural capital into regulation of other sectors or promote equitable rights and resource access. Policies to foster capacity and training in sustainable development and natural resource management are still in early stages of development in the national policy agenda.

The governance scorecard is useful beyond monitoring, as it can be used to understand the broader policy landscape, and can be applied at the national, subnational, or municipal scales. Alternative scorecards can be developed and adapted for intergovernmental, private sector and regional-level policies.
Table 9. Summary of 2014 national policy scorecard assessment in Madagascar. Appendix 3 includes the full completed scorecard. The maximum combined score for each policy is 10. A score of 8 or higher indicates that a policy is sound though implementation might still be constrained by available funding.

<table>
<thead>
<tr>
<th>Category</th>
<th>Soundness</th>
<th>Implementation</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2014 OVERALL SCORE</strong></td>
<td>118/170</td>
<td>106/170</td>
<td>224/340</td>
<td>66%</td>
</tr>
<tr>
<td>International conventions</td>
<td>32</td>
<td>28</td>
<td>60/90</td>
<td>67</td>
</tr>
<tr>
<td>4 of 10 relevant policies with score greater than 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policies for national engagement in Convention for Biological Diversity; CITES; UNFCCC and UNESCO World Heritage Convention</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservation of natural capital</td>
<td>38</td>
<td>36</td>
<td>74/110</td>
<td>67</td>
</tr>
<tr>
<td>4 of 11 relevant policies with score greater than 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policies for protecting marine zones; government protected areas; private protected areas and IUCN categories for protected area network</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainable production systems</td>
<td>27</td>
<td>24</td>
<td>51/70</td>
<td>73</td>
</tr>
<tr>
<td>3 of 7 relevant policies with score greater than 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policies for extractives, infrastructure and fisheries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investment &amp; fiscal policies</td>
<td>4</td>
<td>5</td>
<td>9/10</td>
<td>90</td>
</tr>
<tr>
<td>Only 1 of 7 policies with data available</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy for publicly accessible national budget with score of 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy integration &amp; safeguards</td>
<td>7</td>
<td>6</td>
<td>13/20</td>
<td>65</td>
</tr>
<tr>
<td>1 of 2 relevant policies scoring greater than 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy integrating biodiversity and ecosystem services into national accounting system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>10</td>
<td>7</td>
<td>17/40</td>
<td>43</td>
</tr>
<tr>
<td>No policy with score greater than 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assumptions and Limitations

- Only relevant policies, those currently applicable to the country’s political context, are included in country scorecard
- Policies are not currently weighted – i.e. all policies are given equal importance
- Exercise caution in comparing scores between countries as scorecard is intended to track progress within a country year to year. Scores also vary between countries due to contextual differences.
- Assessment is subjective and will vary depending on the knowledge and capacity of assessors. Areas of uncertainty should be documented and validated, where possible.
• Scorecard does not currently capture existing policies that might be detrimental to environmental or social outcomes, such as incentives which result in habitat conversion or unsustainable extraction of resources

Updating and Replication of Analyses

Policy change often occurs over lengthy time horizons and therefore significant changes in policy conditions might not be observed on an annual basis. We recommend therefore updating these results through review and re-assessment of policies on a biannual basis.

Future assessments would benefit from collection of data on the level of certainty of each assessor and validation of scoring (through review of policy documents, data from surveys and synthesis of multiple experts’ opinions), in particular for those policies identified as most important for the national context.

The methods have been designed to be flexible for different countries. The scorecard has currently been applied to all CI countries. Refinement of policy types, possible reduction in the number of policies, and wording of criteria would need to be revised for application at subnational scales.

References and Data Sources

https://sites.google.com/a/conservation.org/metrics/measure-effective-governance/policy-effectiveness
MONITORING SUSTAINABLE PRODUCTION

Compiled by: Kellee Koenig, Bambi Semroc, and Zo Rakotobe

Sustainable Production Indicator: Status and trends in output of key production sectors & impact of key production sectors on natural capital

Definition

Sustainable production is defined as the volume or quantity of commodities produced that can be sustained over time while supporting economic development for society and ensuring the long-term persistence of natural capital to meet the needs of future generations. The target sectors for Madagascar were agriculture, fishing, mining, and oil and gas (hereafter referred to as “energy”).

Methods

Sustainable production metrics must therefore enable us to monitor the amount of a commodity produced while also tracking impacts on natural capital over time. We followed a five-step process to complete the analyses.

1. Define objectives for the analysis, identify key research questions and indicators based on consultations with the project team.
2. Identify key sectors and agricultural commodities to include in the analysis through consultation with CI-Madagascar staff and analysis of change in percentage of area under production from 2005–2010.
3. Collect and organize national and subnational data sources on production, land under production (including concessions) and changes based on available tabular and spatial data for the country.
5. Conduct GIS analysis of mining sector in relation to important areas for natural capital to determine and quantify the potential threat posed by the sector to natural capital based on degree of overlap with key biodiversity areas and protected areas.
The objectives for the analysis were to: identify key economic sectors having the greatest impact on natural capital in Madagascar; understand the level of production from these sectors, and; identify potential sustainability issues associated with these sectors. We prioritized the agriculture and mining sectors for this analysis as these sectors have the largest current impacts on natural capital in Madagascar compared to fisheries and energy production. For each sector, we identified a small number of indicators to monitor changes in production in relation to natural capital over time. While coastal fisheries were also identified as having large impact on natural capital, we were not able to analyze the sustainability of this sector due to a lack of data. The energy sector was identified for potential future impact on natural capital, and the impact is presented as a map below. Due to the limited availability of data on the sustainability of target sectors (agriculture, energy, mining, and fisheries) we focused the indicators on understanding and monitoring the status of current production levels, and where possible, linking these trends to priority areas for conservation.

For the agriculture sector our production metrics monitor the area of a region cultivating a key crop, and the change in percentage of a region cultivating that crop over time, to understand whether increased production is due to intensification or expansion of agricultural systems. These analyses also enable us to identify regions where a given crop is more significant in terms of area, to identify places where conservation or sustainable agricultural practices could be concentrated. For the energy and mining sector, we look at the overlap of current concessions with protected areas and key biodiversity areas (KBAs), to represent the extent of potential impacts the sector could have on natural capital. The final set of indicators and their definitions are included in Table 10.

Table 10. Priority sectors and associated indicators

<table>
<thead>
<tr>
<th>Sector</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agriculture</strong></td>
<td>Area of a region (<em>faritra</em>) under cultivation, 2010*</td>
</tr>
<tr>
<td></td>
<td>Change in percentage of region under a given crop’s cultivation 2005–2010</td>
</tr>
<tr>
<td><strong>Mining</strong></td>
<td>Percentage of KBA area overlapping with titled mining concessions</td>
</tr>
<tr>
<td></td>
<td>Area of mining concessions falling within a KBA</td>
</tr>
</tbody>
</table>

*note: 2010 is the most recent year for which data is available

Results & Implications

**Agriculture:** We focused our analysis on cassava, clove, coffee, maize, rice, and sugar (Table 11). This selection reflects a combination of importance to local diets, commercial value, and CI global
priorities. Bananas and cattle were identified as important, but were omitted due to lack of data. Vanilla was excluded because of its small footprint and restricted distribution nationally.

Table 11. Crop production in 2010 by percent of region and total area under production

<table>
<thead>
<tr>
<th>Crop</th>
<th>% of Regions</th>
<th>Total Area, 2010 (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cassava</td>
<td>100</td>
<td>405,816</td>
</tr>
<tr>
<td>Clove</td>
<td>28</td>
<td>117,950</td>
</tr>
<tr>
<td>Coffee</td>
<td>72</td>
<td>36,890</td>
</tr>
<tr>
<td>Maize</td>
<td>100</td>
<td>264,979</td>
</tr>
<tr>
<td>Rice</td>
<td>100</td>
<td>1,307,043</td>
</tr>
<tr>
<td>Sugar</td>
<td>100</td>
<td>23,540</td>
</tr>
</tbody>
</table>

_Cassava_

Cassava is produced in all regions, with the largest area under production in Atsimo Andrefana in the southwest (Figure 24). The percent under cultivation has a greater relative increase in the eastern coastal regions.
While clove production only existed in five regions as of 2010 with a relatively small area under production, the production of this crop is rapidly increasing in Madagascar (Figure 25). It has historically been a component of Malagasy cuisine and medicine, with some produced for export, but the low price meant the area under production was minimal. The recent increase in price for export has led to an increase in production, with the potential to surpass vanilla in its economic impact. Analanjirofo is currently the region with the largest area under clove production, and also the only region that saw a decline in area under production during 2005–2010. The price of cash crops (e.g. coffee, vanilla, cloves) is volatile, and this fluctuation is reflected in the change in area under production.

Figure 24. Cassava production throughout Madagascar, by area per region under cultivation in 2010 and the change in percent of a region under cultivation from 2005–2010. On the left, darker colors indicate the regions with greater areas growing this crop. On the right, darker colors mean a greater increase from 2005 to 2010 in the percentage of that region growing this crop.

Clove

While clove production only existed in five regions as of 2010 with a relatively small area under production, the production of this crop is rapidly increasing in Madagascar (Figure 25). It has historically been a component of Malagasy cuisine and medicine, with some produced for export, but the low price meant the area under production was minimal. The recent increase in price for export has led to an increase in production, with the potential to surpass vanilla in its economic impact. Analanjirofo is currently the region with the largest area under clove production, and also the only region that saw a decline in area under production during 2005–2010. The price of cash crops (e.g. coffee, vanilla, cloves) is volatile, and this fluctuation is reflected in the change in area under production.
Figure 25. Clove production throughout Madagascar, by area per region under cultivation in 2010 and the change in percent of a region under cultivation from 2005–2010. On the left, darker colors indicate the regions with greater areas growing this crop. On the right, green indicates an increase from 2005 to 2010 in the percentage of that region growing this crop; tan indicates a decrease in the percentage of a region growing that crop.
Coffee

Coffee is produced in most of the regions, with the exception of the west coast where it is too dry (Figure 26). The production is increasing most rapidly along the eastern coast, where the climate is most favorable for coffee production, and is decreasing in Ihorombe. The decrease is due to lack of rainfall, and a maize plantation project in Ihorombe may also account for switching farmland away from coffee production. The larger increase along the eastern coast may be explained by an increase in the price of coffee. The price of cash crops (e.g. coffee, vanilla, cloves) is volatile, and this fluctuation results in the change in area under production.

Figure 26. Coffee production throughout Madagascar, by area per region under cultivation in 2010 and the change in percent of a region under cultivation from 2005–2010. On the left, darker colors indicate the regions with greater areas growing this crop. On the right, darker green indicates a greater increase from 2005 to 2010 in the percentage of that region growing this crop; tan indicates a decrease in the percentage of a region growing that crop.
Maize

Maize production is spread throughout the country, and is increasing the most in Itasy and Vakinakaratra (Figure 27). The significant increase in Vakinakaratra may be explained by an increase in rainfall, according to the FAO (2013).

Figure 27. Maize production throughout Madagascar, by area per region under cultivation in 2010 and the change in percent of a region under cultivation from 2005–2010. On the left, darker colors indicate the regions with greater areas growing this crop. On the right, darker colors indicate a greater increase from 2005 to 2010 in the percentage of that region growing this crop.
Rice

Rice is the dominant crop in Madagascar, in terms of area cultivated (Figure 28). All regions experienced an increase in land area producing rice for the period 2005–2010, with the greatest increases occurring along the eastern coast and in the central plateau. In the central plateau, farmers have adopted appropriate techniques to improve rice production such as SRA (Système de riziculture améliorée)/SRI (Système de riziculture intensive) and irrigation systems for rice cultivation on slopes.

Figure 28. Rice production throughout Madagascar, by area per region under cultivation in 2010 and the change in percent of a region under cultivation from 2005–2010. On the left, darker colors indicate the regions with greater areas growing this crop. On the right, darker colors indicate a greater increase from 2005 to 2010 in the percentage of that region growing this crop.
**Sugar**

Sugar cultivation is concentrated along the eastern coast, but is grown in all regions (Figure 29). There are major sugar production companies based in Ambilobe, Namakia, Morondava, and Brickaville. During the political crisis, funding and management difficulties led to a decrease in production. The areas growing sugar have largely decreased from 2005 to 2010, with the exception of Alaotra Mangoro, Analanjirofo, Atsinanana. The completion of a production complex in Namakia in 2010 is expected to change the area under production in that region.

![Sugar production map](image)

*Figure 29. Sugar production throughout Madagascar, by area per region under cultivation in 2010 and the change in percent of a region under cultivation from 2005–2010. On the left, darker colors indicate the regions with greater areas growing this crop. On the right, green indicates an increase from 2005 to 2010 in the percentage of that region growing this crop; darker browns indicate a greater decrease in the percentage of a region growing that crop.*

**Mining**

It is illegal for a mining concession to overlap a protected area, but not all KBAs are formally protected. Of all the KBAs in Madagascar, 45% have a titled mining concession overlapping their boundaries (Figure 30). These permits were issued prior to the government’s commitment to tripling the protected areas, and before the KBAs were identified and updated, and should be
revisited. The area of this overlap, as a percent of all KBA area, is shown in Table 12. Total area for each designation of granted mining concession, and its area of overlap with all KBAs, is presented in
Table 13. This could pose a threat to these priority areas for conservation, depending on the footprint and impacts of the concession. This trend will be important to monitor as interest in mineral exploration increases across the country.

Figure 30. Granted mining concessions in Madagascar. On the left, all granted mining concessions are shown with current protected area and KBA boundaries. On the right, mining concessions are symbolized by type.

Table 12. Percent of all KBA area overlapping with a titled mining concession.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of KBA area* covered by a titled mining concession</td>
<td>9</td>
</tr>
</tbody>
</table>

*includes offshore and marine KBA area
Table 13. Area of titled mining concession by designation, and the total area of its overlap with all KBAs.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Total Area (ha)</th>
<th>Area of overlap with KBAs (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AERP</td>
<td>625.54</td>
<td>0.00</td>
</tr>
<tr>
<td>E * Permis d'Exploitation (full production mine)</td>
<td>535,496.39</td>
<td>45,000.09</td>
</tr>
<tr>
<td>PRE * Permis Réservés aux Petits Exploitants (small/artisanal mine)</td>
<td>2,370,304.59</td>
<td>69,981.12</td>
</tr>
<tr>
<td>R * Permis de Recherche (exploration only)</td>
<td>20,585,643.47</td>
<td>800,592.12</td>
</tr>
</tbody>
</table>

Energy

The oil and gas sector is expected to grow in Madagascar, and most of the coastal concessions overlap mangrove habitat (Figure 31). This could pose a threat to this habitat, depending on the footprint within the blocks. This trend will be important to monitor, particularly along the northwest coast, as this sector develops.

Figure 31. Petroleum blocks and their intersection with mangrove extent in Madagascar. Most coastal blocks have mangroves within their extent.
Assumptions and limitations

**Agriculture:** This analysis assumes that the current yield is sustainable and optimal, and does not account for factors aside from land area that may present barriers to achieving improved yields. We do not examine the impact of crop expansion or reduction on natural capital, and do not know if reduction in area growing a particular crop resulted from switching crops or abandoning degraded land. We were not able to evaluate other types of impacts of agriculture on natural capital (e.g., sedimentation or pollution of water bodies, soil erosion or soil quality degradation, or other impacts.) No data is available to indicate where within each region each crop is produced. We limited the analysis to six crops, but other crops might be more important in certain regions. We did not look at suitability for these crops as a potential for expansion or intensification.

**Mining:** The analysis assumes that the entire area allocated to the concession will be impacted, and thus likely overestimates the impact of mining concessions (in terms of area converted) on KBAs. We were not able to evaluate other types of impacts, such as pollution or greenhouse gas emissions. Data is not available on the degree of impact within the concessions, or whether the concession is in active operation.

**Energy:** The analysis assumes that the entire area allocated to the concession will be impacted, and thus likely overestimates the impact of the sector (in terms of area converted) on mangroves.

**Fisheries:** Data is not available on productivity of fisheries, nor changes in fisheries management policy. We were unable to evaluate the sustainability or impacts of Madagascar’s fisheries sector.

Replication and Updating of Analyses

This analysis should be updated regularly, depending on resources available. Every 2-5 years may be realistic for updated data to be available. This process requires statistical and GIS expertise to run the data analysis and mapping. Findings should be validated with stakeholders from each of the priority sectors. As the methodologies required to replicate and update this analysis have been defined through this activity, we estimate one week of staff time with GIS and statistical expertise to repeat this analysis.
The analysis in Madagascar should be easily replicable in other countries. National-level data can help identify the priority sectors and commodities for analysis. In the case of Madagascar, regional-level data provided deeper and richer insights into specific geographies where a crop's production was significant. However, this data did not enable us to understand the actual footprint of each commodity. If a country does not have its agriculture, mining, or fisheries information freely available, additional time and effort will be required to track down datasets from multiple sources.

Data Sources

**Agriculture table.** StatAgri, Service statistique in the Ministry of Agriculture.

**Key Biodiversity Areas.** Conservation International-Madagascar; Biotope.

**Mining Concession.** BD500, Foiben-Taosarinitanin’i Madagasikara.


**Protected Areas.** Ministere de l'Environnement, de l'Ecologie, de la Mer et des Forets (MEEMF).
MONITORING HUMAN WELL-BEING

Compiled by: Wu Yang and Madeleine McKinnon

Human Well-Being Indicator: Status of human well-being at the commune and district levels

Definition

Human well-being (HWB) is defined as the physical and mental satisfaction of human needs to be healthy, happy, and prosperous (Yang et al. 2013). Accordingly, high levels of poverty is defined as a low status of human well-being.

Human Well-being Indicators

*Status of human well-being at the commune level (2007)*: a composite index and five sub-indices composed to characterize basic materials for good life, security, health, good social relations, and freedom of choice and action.

*Status of human well-being at the district level (2008, 2013)*: overall living conditions and nine other indicators of specific components of HWB.

For Madagascar, due to data constraints, we focused on objective measures of HWB (or physical satisfaction) at the commune level in 2007, and the subjective HWB (or mental satisfaction) at the district level from 2008 to 2013.

Methods

Selection and description of data

We considered several data sets for constructing HWB indices for Madagascar. The USAID Demographic and Health Surveys (DHS) ([http://www.dhsprogram.com/](http://www.dhsprogram.com/)) contain some indicators on population, health (primarily diseases such as HIV and malaria), and nutrition status. These could have been candidate indicators for the health dimension of HWB, but represent neither a
comprehensive coverage of health, nor do they represent all components of HWB. The primary reason that we did not use the DHS data for this study is that the data sets are representative nationally but not at a subnational level (e.g., commune or district levels). Therefore the DHS data cannot be used to determine variation within the country, or to detect spatial patterns within the country. Similarly, the Institute Pasteur in Madagascar (http://www.pasteur.mg/) also collects data on health and family planning. But their health measures mostly focus on common diseases and fertility and thus do not satisfy our scope of a comprehensive index system for HWB. There are also many other national-level well-being indicators available, such as the Human Development Index (HDI) and the Life Satisfaction Index (LSI). National-level indicators are useful for global analyses but again do not reflect details at subnational level. Thus, ultimately we decided to use the Commune Database in Madagascar (Moser et al. 2008) and the Afrobarometer Survey Data (http://www.afrobarometer.org/).

The Commune Database is a census product that aims to provide information for monitoring of service delivery, government, and local institutional accountability in Madagascar. The first census of communes was implemented in 2001, with collaboration among FOFIFA, INSTAT, and Cornell University. The second census was conducted in 2007 by the World Bank, the Government of Madagascar, and Fonds d’Intervention pour le Développement (FID). While the 2007 survey was intended to maintain much of the methods from 2001, many new questions related to infrastructure, media, tourism, mining, FID projects, and constraints to business activities were added. There were 106 indicators in 2001 and 1,159 indicators in 2007 for a total of 1,549 communes, representing nearly 100% of the communes in the country. The datasets are geographically coded so that they can be linked with a spatial commune shapefile in Geographic Information System (GIS). But due to administrative adjustments, there were many changes in commune boundaries between 2001 and 2007 data sets. Since there were very few shared indicators of HWB between the two time periods, and the 2001 data set was not spatially compatible with the 2007 data set, we ultimately decided to work only with the 2007 data set. Since there are major data constraints (e.g., 75% of indicators had over 15% of the values missing or had zero values), for this study we selected 28 indicators (Appendix 4. Table S1) which had relatively good data quality and were directly related to HWB.

The Afrobarometer Survey is a long-term collaborative project among the Institute for Democracy in South Africa (IDASA), the Ghana Centre for Democratic Development (CDD-Ghana), and Michigan State University. The surveys are implemented repeatedly in 35 African countries on a regular cycle
(the time interval varies, from three years to longer). The surveys ask for self-reported attitude toward the social, political, and economic atmosphere in each country. So far, there have been three rounds of surveys (2005, 2008, and 2013) in Madagascar. Approximately 1200 individuals were randomly sampled with a clustered, stratified, multi-stage, area probability sample designed to be nationally representative of population size and age structure. We identified 10 directly relevant indicators of HWB (Appendix 4. Table S2) in 2008 and 2013 as complementary information for the 2007 commune database, and to provide more up-to-date information about the status of HWB in Madagascar.

**Construction of HWB indices**

At the commune level, only 28 indicators were available with relatively good data quality (Appendix 4. Table S1) in 2007. We used the widely accepted Millennium Ecosystem Assessment framework (2005) and classified the HWB index system into five dimensions (basic materials for good life, security, health, good social relations, and freedom of choice and action). Thus, our HWB indices include five sub-indices and an overall composite index.

We constructed the HWB indices based on equal weighting aggregation. First, all 28 indicators were transformed into the same range of 0 to 1 via minimum-maximum normalization. Indicators with negative values were also transformed into positive values. Such normalization allows us to aggregate all indicators, even those with different raw units and ranges. We aggregated all indicators in each sub-index using the mean value, and then aggregated all sub-indices into the overall composite index using the mean value.

At the district level, there were 10 indicators (Appendix 4. Table S2) directly related to HWB and were surveyed both in 2008 and 2013. One indicator represents the overall living conditions and the other nine indicators measure specific disaggregated components of HWB. We therefore also mapped these individual indicators to show the more recent status of HWB, especially changes from 2008 to 2013, which captures a period of political crisis in Madagascar.

**Results & Implications**

At the commune level, our derived HWB indices show that the overall HWB status was relatively better in northeastern and eastern Madagascar in 2007, especially around the capital city of Antananarivo (*Figure 32*). This overall spatial pattern was primarily driven by the sub-index of basic material for good life, as there was no obvious spatial pattern for the other four sub-indices. If
we look into the individual indicators constructing the basic material sub-index, it appears that the spatial pattern was driven by the literacy indicator related to remoteness (i.e., distance to major cities). Literacy rate tends to be lower in the west and higher in the east of Madagascar.
Figure 32. Maps depicting spatial distribution of HWB indices of Madagascar in 2007 at the commune level.
Figure 32 (continued). Maps depicting spatial distribution of HWB indices of Madagascar in 2007 at the commune level.
At the district level, despite many data gaps, our results show that overall, there was a deteriorating trend in HWB status (Figure 33). Only 15% of the districts reported an improvement in overall living conditions from 2008 to 2013; thus 85% of districts reported either a decline or no change in overall living conditions. The primary reason for the overall low and declining HWB in the country is widely recognized to be the political crisis which began in 2009.

Figure 33. Spatial distribution of overall living conditions of Madagascar in 2008 (left) and 2013 (right) at the district level.

At the district level, if we look into the individual indicators of specific HWB components, the temporal patterns were generally consistent with the overall HWB status but the magnitude of changes varies from one component to another (Appendix 6). Specifically, from 2008 to 2013, the percentages of districts with reported improvements for different HWB components were 24% for food security, 15% for clean water access, 34% for health treatment, 22% for energy security, 15% for income security, 15% for psychological security, 3% for property security, 2% for physical security, and 24% for freedom, respectively (see Appendix 4, Table S2 for detailed description of indicators).
Additional Tables in Appendix 4:
Table S1. Conceptual framework of the index system of human well-being (HWB) at commune level.
Table S2. List of individual indicators of HWB at district level.

Assumptions & Limitations
The biggest limitation for this analysis is the lack of available, up-to-date, reliable data to construct HWB indices. There were limited indicators available to measure different dimensions of HWB. Many indicators (e.g., access to safe drinking water, mental health, social trust, and social cohesion) were not available at a subnational level, and therefore variation in HWB within the country was not possible to measure. Data quality is another big challenge. Available indicators were mostly binary or categorical with limited variability, and there was a high frequency of missing values, which prevented us from conducting detailed quantitative analyses.

Due to the data limitations, we used relatively simple methods to present the HWB status at a subnational level in Madagascar. Unlike in the metrics demonstration in Cambodia, where it was possible to construct HWB composite indices with weightings estimated based on data variation, in Madagascar the weightings were assumed to be equal and thus the mean values were used during the aggregation process.

Replication of Analyses
Given the methods used here are relatively simple, if similar data on HWB related indicators are available, this approach can be easily applied in other places by following the procedures described above.

Data Sources
Afrobarometer Survey Data (http://www.afrobarometer.org/).
# APPENDICES

## Appendix 1. NTFP Importance Value Ranking Matrix for Madagascar

Score on a scale of importance (1-3)
1 is least important, 2 is moderately important, 3 is most important (see "Criteria" tab for specific criteria)

<table>
<thead>
<tr>
<th>Non-timber forest products</th>
<th>Criteria</th>
<th>market value</th>
<th>consumer demand</th>
<th>contribution to household income</th>
<th>seasonal / temporary importance / importance as a safety net</th>
<th>importance for women, children, or other vulnerable groups</th>
<th>geographic extent of use</th>
<th>frequency of use</th>
<th>multiple uses of the same species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal products</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birds</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mammals (Furs, wild boar ...)</td>
<td></td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
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<tr>
<td>Amphibians</td>
<td></td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
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<tr>
<td>Reptiles (serpent, tortoises,...)</td>
<td></td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
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<tr>
<td>Insects (Honey, silkworms,</td>
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<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2</td>
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<td>Lemurs+</td>
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<td>3</td>
<td>3</td>
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<tr>
<td>Carnivores (Hemicentetes semispinosus, Tenrec eucaudatus)</td>
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<td>2</td>
<td>2</td>
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<tr>
<td>Fish</td>
<td></td>
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<td>Crayfish, crab</td>
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<td>3</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Edible plants/ edible plants/spices</td>
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<tr>
<td>Bananas (wild &amp; cultivated)</td>
<td></td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Coconut palms</td>
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<td>Tapia</td>
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<td>Lamonty</td>
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<tr>
<td>Baobab</td>
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<tr>
<td>Goyave</td>
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<td>Tamarind</td>
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<tr>
<td>Noix de cajou</td>
<td></td>
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<td>1</td>
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<td>3</td>
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<tr>
<td>Wild Oranges/ citrus</td>
<td></td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>1</td>
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<td>Cactus</td>
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<tr>
<td>Category</td>
<td>Afromomum</td>
<td>Mushrooms</td>
<td>Yams (Dioscorea sp)</td>
<td>Tacca pinnatifida (Tavolo)</td>
<td>Palms (stem, beverage)</td>
<td>Via (Typhonodorum Lyndleynum)</td>
<td>Ravinala</td>
<td>Peppers</td>
<td>Cinnamosma spp.</td>
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</tbody>
</table>
### Appendix 2. Habitat Importance Value Ranking Matrix for Madagascar

<table>
<thead>
<tr>
<th>NTFP Category</th>
<th>Animal products</th>
<th>Edible Plants/fruits/spices</th>
<th>Fiber</th>
<th>Medicinal plants</th>
<th>Resins/Oils/Waxes</th>
<th>Fuel</th>
<th>Construction Materials and other raw materials</th>
<th>Mean Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degraded Western dry forest</td>
<td>5.21</td>
<td>2.62</td>
<td>4.75</td>
<td>2.94</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>4.16</td>
</tr>
<tr>
<td>Western dry forest</td>
<td>5.43</td>
<td>2.45</td>
<td>4.75</td>
<td>2.55</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>4.12</td>
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<tr>
<td>Degraded humid forest</td>
<td>4.3</td>
<td>2.94</td>
<td>5.94</td>
<td>3.53</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>4.33</td>
</tr>
<tr>
<td>Humid forest</td>
<td>4.53</td>
<td>2.94</td>
<td>5.94</td>
<td>3.33</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>4.34</td>
</tr>
<tr>
<td>Western humid forest</td>
<td>4.3</td>
<td>2.62</td>
<td>4.75</td>
<td>2.55</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>3.98</td>
</tr>
<tr>
<td>Western sub-humid forest</td>
<td>4.53</td>
<td>2.62</td>
<td>4.75</td>
<td>2.55</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>4.01</td>
</tr>
<tr>
<td>Degraded south western dry spiny forest</td>
<td>4.53</td>
<td>2.78</td>
<td>3.56</td>
<td>2.94</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>3.92</td>
</tr>
<tr>
<td>South western dry spiny forest-thicket</td>
<td>4.53</td>
<td>2.62</td>
<td>3.56</td>
<td>2.55</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>3.84</td>
</tr>
<tr>
<td>Woodyed grassland</td>
<td>2.94</td>
<td>1.8</td>
<td>3.56</td>
<td>2.55</td>
<td>4.88</td>
<td>7.5</td>
<td>4.5</td>
<td>3.96</td>
</tr>
<tr>
<td>grassland</td>
<td>2.72</td>
<td>1.8</td>
<td>3.56</td>
<td>2.55</td>
<td>4.88</td>
<td>2.5</td>
<td>2.25</td>
<td>2.89</td>
</tr>
<tr>
<td>Tapia forest</td>
<td>3.17</td>
<td>1.96</td>
<td>4.75</td>
<td>2.55</td>
<td>1.63</td>
<td>7.5</td>
<td>3.38</td>
<td>3.56</td>
</tr>
<tr>
<td>Mangroves</td>
<td>2.94</td>
<td>1.64</td>
<td>3.56</td>
<td>2.55</td>
<td>1.63</td>
<td>7.5</td>
<td>4.5</td>
<td>3.47</td>
</tr>
<tr>
<td>Littoral forest</td>
<td>3.17</td>
<td>2.45</td>
<td>4.75</td>
<td>2.55</td>
<td>1.63</td>
<td>7.5</td>
<td>6.75</td>
<td>4.11</td>
</tr>
<tr>
<td>Wetlands</td>
<td>4.08</td>
<td>1.96</td>
<td>7.13</td>
<td>3.92</td>
<td>1.63</td>
<td>2.5</td>
<td>4.5</td>
<td>3.67</td>
</tr>
<tr>
<td>Water</td>
<td>3.17</td>
<td>1.8</td>
<td>3.56</td>
<td>2.55</td>
<td>1.63</td>
<td>2.5</td>
<td>2.25</td>
<td>2.49</td>
</tr>
<tr>
<td>Bare Soil/Rock</td>
<td>2.49</td>
<td>1.64</td>
<td>3.56</td>
<td>3.33</td>
<td>1.63</td>
<td>2.5</td>
<td>2.25</td>
<td>2.48</td>
</tr>
</tbody>
</table>
## Appendix 3. Full governance scorecard for Madagascar

<table>
<thead>
<tr>
<th>Score/Total Possible Score:</th>
<th>224</th>
<th>340</th>
<th>66%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DASHBOARD</strong></td>
<td>A. Level of Soundness</td>
<td>B. Level of Implementation</td>
<td>MED/HIGH CI Engagement</td>
</tr>
<tr>
<td><strong>QUESTIONS</strong></td>
<td>A. Level of Soundness</td>
<td>B. Level of Implementation</td>
<td>C. Level of CI Engagement</td>
</tr>
</tbody>
</table>

### Scoring Criteria is available below starting in row 62.

<table>
<thead>
<tr>
<th>Question</th>
<th>International Convention</th>
<th>Score FY14</th>
<th>Total Possible Score</th>
<th>Level of CI Engagement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Convention on Biological Diversity (CBD)</td>
<td>4</td>
<td>4</td>
<td>High</td>
</tr>
<tr>
<td>2</td>
<td>Convention on the Conservation of Migratory Species of Wild Animals (CMS)</td>
<td>3</td>
<td>2</td>
<td>Medium</td>
</tr>
<tr>
<td>3</td>
<td>Convention on the International Trade in Endangered Species of Wild Flora and Fauna, (CITES)</td>
<td>4</td>
<td>4</td>
<td>High</td>
</tr>
<tr>
<td>4</td>
<td>Framework Convention on Climate Change (UNFCCC)</td>
<td>4</td>
<td>4</td>
<td>Medium</td>
</tr>
<tr>
<td>5</td>
<td>Ramsar Convention on Wetlands of International Importance</td>
<td>4</td>
<td>2</td>
<td>Medium</td>
</tr>
<tr>
<td>6</td>
<td>UN Convention on the Law of the Non-navigational Uses of International Watercourses</td>
<td>3</td>
<td>3</td>
<td>Low</td>
</tr>
<tr>
<td>8</td>
<td>The United Nations Declaration on the Rights of Indigenous Peoples</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>9</td>
<td>World Heritage Convention Concerning the Protection of the World Cultural and Natural Heritage</td>
<td>4</td>
<td>4</td>
<td>Medium</td>
</tr>
<tr>
<td>10</td>
<td>International Labour Organisation Convention No. 169 (1987)</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>11</td>
<td>UN Convention on Sustainable Development Millennium Development Goals (or post-2015 development goals)</td>
<td>3</td>
<td>2</td>
<td>High</td>
</tr>
</tbody>
</table>

<p>| Total Score FY14 | 32 | 28 |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>considers the use of coastal and marine zones?</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>enables watershed management?</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>considers the conservation, use and management of wild species?</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>considers the identification of priority areas, the use, and the management of threatened species and their habitats?</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>enables the control of invasive species?</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>17</td>
<td>considers the creation, implementation, and use of government protected areas?</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>18</td>
<td>considers the creation, implementation, and use of community-based protected areas?</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>19</td>
<td>considers the creation, implementation, and use of private protected areas?</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>20</td>
<td>considers the demarcation and environmental management of indigenous lands?</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>21</td>
<td>allows for creation of all IUCN categories of protected areas?</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>22</td>
<td>considers payment for ecosystem services schemes?</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>23</td>
<td>considers or enables biodiversity offsets?</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>24</td>
<td>considers land-use based carbon emissions?</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>considers agriculture activities (to conserve water/biodiversity/other ecosystem services, minimize air/solid/water pollution, require SEIA, and define compensation/penalties)?</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>26</td>
<td>considers extractives activities (to conserve water/biodiversity/other ecosystem services, minimize air/solid/water pollution, require SEIA, and define compensation/penalties)?</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>27</td>
<td>considers infrastructure development (to conserve water/biodiversity/other ecosystem services, minimize air/solid/water pollution, require SEIA, and define compensation/penalties)?</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>28</td>
<td>considers fisheries and aquaculture (to conserve water/biodiversity/other ecosystem services, minimize air/solid/water pollution, require SEIA, and define compensation/penalties)?</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>29</td>
<td>considers timber/logging activities (to conserve water/biodiversity/other ecosystem services, minimize air/solid/water pollution, require SEIA, and define compensation/penalties)?</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>30</td>
<td>considers ALL or other specific key sectors that significantly impact natural capital (e.g., tourism) (to conserve water/biodiversity/other ecosystem services, minimize air/solid/water pollution, require SEIA, and define compensation/penalties)?</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>INVESTMENT &amp; FISCAL POLICIES - Does the country have a policy or set of policies that:</td>
<td>31 requires that national budget is publicly available?</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>32 reduces the subsidies for economic activities that have negative impact on natural capital?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>33 increases the public investments in the conservation and sustainable use of natural capital?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>34 provides fiscal incentives (i.e. tax breaks) for private investment in projects that promote the conservation and sustainable use of natural capital?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>35 enables government green procurement?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>36 increases public investments through overseas development aid for sustainable development in other countries?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>37 defines social-environmental standards for private foreign direct investment in other countries?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>POLICY INTEGRATION + SAFEGUARDS - Does the country have a policy or set of policies that:</td>
<td>38 establishes an integrated conservation and development plan that aligns individual policies (e.g., land use, agriculture, fiscal, climate policy, human rights, etc.)?</td>
<td>N/A</td>
<td>0</td>
</tr>
<tr>
<td>39 enables the incorporation of the values of the biodiversity and ecosystem services into the national accounts?</td>
<td>4</td>
<td>5</td>
<td>High</td>
</tr>
<tr>
<td>40 considers Land Rights and Access? (use Millennium Challenge Corp [IFAD/IFC] indicator)</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>41 considers the creation of public-private partnership for the management of natural resources?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>42 recognizes that healthy environment is a basic right of citizens and an obligation of the state?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>43 requires application of FPIC principles for any economic/development project or program that has social-environmental impacts?</td>
<td>3</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>44 requires the incorporation of gender equality in decisions on natural resource management?</td>
<td>N/A</td>
<td>0</td>
<td>Medium</td>
</tr>
<tr>
<td>45 recognizes and values the role of traditional knowledge on the management of natural resources?</td>
<td>N/A</td>
<td>0</td>
<td>N/A</td>
</tr>
<tr>
<td>CAPACITY - Does the country have a policy, set of policies or programs that:</td>
<td>46 Do adequate policies/programs exist to provide professional training and university-level education for natural resource management?</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>47 Do adequate policies/programs/networks exist to support research and development on natural resource management?</td>
<td>3</td>
<td>1</td>
<td>Low</td>
</tr>
<tr>
<td>48 Is there any policy or set of policies that requires mainstreaming environmental education in the formal educational system?</td>
<td>3</td>
<td>2</td>
<td>Low</td>
</tr>
<tr>
<td>49 Is there a policy or set of policies that enables the development of civil society organizations focused on socio-environmental issues and allows them to operate?</td>
<td>3</td>
<td>2</td>
<td>Low</td>
</tr>
</tbody>
</table>
Appendix 4. Conceptual framework of the index system of human well-being (HWB) at the commune level.

<table>
<thead>
<tr>
<th>Category layer</th>
<th>Indicator code</th>
<th>Indicator description</th>
<th>Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic material for good life</td>
<td>V11</td>
<td>Percent population literate in 2007</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>V23</td>
<td>Number of kilometers repaired unpaved roads</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>V33</td>
<td>Average income of the inhabitants of the Commune as reported by the neighboring Commune</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>V48</td>
<td>Percentage of school-age children who attend school</td>
<td>+</td>
</tr>
<tr>
<td>Security</td>
<td>V7</td>
<td>Security conditions and risk of theft of property</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>V15</td>
<td>Occurrence of fair and honest trial</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>V16</td>
<td>Occurrence of fair and honest local authorities</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>V17</td>
<td>Occurrence of affordable local authorities</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>V18</td>
<td>Occurrence of fair and honest traditional authorities</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>V36</td>
<td>Lean period, in months</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>V37</td>
<td>Percentage of people who do not have enough to eat during the lean period</td>
<td>-</td>
</tr>
<tr>
<td>Health</td>
<td>V34</td>
<td>Health status of the inhabitants of the Commune as reported by neighboring Commune</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>V35</td>
<td>New born mortality rate of the Commune as reported by neighboring Commune</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Description</td>
<td>Sign</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>-------------------------------------------------------------------------------------------------------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>V49</td>
<td>Total number of hospital beds in both public and private sectors (including the CSB1, CSB2, CHD1, CHD2, CHU, private clinics)</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V45</td>
<td>Number of children &lt;1 year who died in 2006 in the commune</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Good social relations</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V25</td>
<td>Participation rate of the population in rural organizations</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V26</td>
<td>Participation rate of the population in groups of fishermen</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V27</td>
<td>Participation rate of the population in artisan groups</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V28</td>
<td>Participation rate of the population in groups of traders</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V29</td>
<td>Participation rate of the population in organizations of water users</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V31</td>
<td>Participation rate of the population in youth organizations</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V32</td>
<td>Participation rate of the population in sports associations</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><strong>Freedom of choices and actions</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V9</td>
<td>Percent of the population who listened to the radio in 2007</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V10</td>
<td>Percent of the population who watched TV in 2007</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V12</td>
<td>Percent of the population who used mobile phones in 2007</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V19</td>
<td>Number of truck owners</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V20</td>
<td>Number of van owners</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>V30</td>
<td>Participation rate of the population in women's groups</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:** For the "Sign" column, a positive sign means that the higher value of the indicator represents a better well-being status; conversely, a negative sign means that a higher value represents worse well-being status. For indicators with positive and negative signs, they were normalized using the Min-Max normalization method based on equations “var = (var-min(var))/(max(var)-min(var))” and “var = - (var-max(var))/(max(var)-min(var))”, respectively. In doing so, indicators with negative signs were transformed into positive signs for easy interpretation.
### Appendix 5. List of individual indicators of Human Well-Being at the district level.

<table>
<thead>
<tr>
<th>Category layer</th>
<th>Indicator code</th>
<th>Indicator description</th>
<th>Sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall well-being</td>
<td>Q3B</td>
<td>In general, how would you describe: Your own present living conditions?</td>
<td>+</td>
</tr>
<tr>
<td>Food security</td>
<td>Q8A</td>
<td>Over the past year, how often, if ever, have you or anyone in your family gone without: Enough food to eat?</td>
<td>-</td>
</tr>
<tr>
<td>Clean water access</td>
<td>Q8B</td>
<td>Over the past year, how often, if ever, have you or anyone in your family gone without: Enough clean water for home use?</td>
<td>-</td>
</tr>
<tr>
<td>Health</td>
<td>Q8C</td>
<td>Over the past year, how often, if ever, have you or anyone in your family gone without: Medicines or medical treatment?</td>
<td>-</td>
</tr>
<tr>
<td>Energy security</td>
<td>Q8D</td>
<td>Over the past year, how often, if ever, have you or anyone in your family gone without: Enough fuel to cook your food?</td>
<td>-</td>
</tr>
<tr>
<td>Income security</td>
<td>Q8E</td>
<td>Over the past year, how often, if ever, have you or anyone in your family gone without: A cash income?</td>
<td>-</td>
</tr>
<tr>
<td>Psychological security</td>
<td>Q9B</td>
<td>Over the past year, how often, if ever, have you or anyone in your family: Feared crime in your own home?</td>
<td>-</td>
</tr>
<tr>
<td>Property security</td>
<td>Q10A</td>
<td>Over the past year, how often, if ever, have you or anyone in your family: Had something stolen from your house?</td>
<td>-</td>
</tr>
<tr>
<td>Physical security</td>
<td>Q10B</td>
<td>Over the past year, how often, if ever, have you or anyone in your family: Been physically attacked?</td>
<td>-</td>
</tr>
<tr>
<td>Freedom</td>
<td>Q17A</td>
<td>In this country, how free are you: To say what you think?</td>
<td>+</td>
</tr>
</tbody>
</table>

Notes: For the “Sign” column, a positive sign means that the higher value of the indicator represents a better well-being status; conversely, a negative sign means that a higher value represents worse well-being status.
Appendix 6. Spatial distribution of nine individual (disaggregated) HWB indicators of Madagascar in 2008 and 2013 at district level.

List of Figures
Frequency of Any Family Member Been Stolen in 2008

Frequency of Any Family Member Been Stolen in 2013

Legend
Index value
- Null
- Never
- Once or twice
- Several times
- Many times
- Always

Legend
Index value
- Null
- Never
- Once or twice
- Several times
- Many times
- Always

0 50 100 200 km

0 50 100 200 km