BIODIVERSITY RESTORATION PRIORITY ASSESSMENT TOOL

A CONTRIBUTION FOR BIODIVERSITY OFFSETS IMPLEMENTATION IN MOZAMBIQUE

Final Report

By The Wildlife Conservation Society & BIOFUND

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Cover photo: a degraded area in Pomene National Reserve, Inhambane Province, Mozambique. © Naseeba Sidat, WCS-Mozambique

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Glossary and abbreviations

Abbreviation or term	Definition
AOI	Area of Interest
BIOFUND	Foundation for Biodiversity Conservation - *Fundação para Conservação da Biodiversidade*
FNDS	National Fund for Sustainable Development – *Fundo Nacional de Desenvolvimento Sustentável*
IUCN	International Union for Conservation of Nature
KBA	Key Biodiversity Area
PDUT	Land Use District Plan – *Plano Distrital de Uso da Terra*
ROAM	Restoration Opportunities Assessment Methodology
WCS	The Wildlife Conservation Society

1. Introduction

1.1 Aim of this report

As part of the Biodiversity Offset Program carried out by the Government of Mozambique, in partnership with the Wildlife Conservation Society (WCS) and the Foundation for the Conservation of Biodiversity – BIOFUND – a new regulation was developed for the implementation of Biodiversity Offsets[1], as required in Decree 54/2015 of 31 December on the Environmental Impact Assessment regulation (see explanatory video here). It involves the development of a series of tools and technical guidelines for the application of the regulation.

The development of tools that can be used by developers to plan their projects in advance is essential. One such tool is an ecosystem map that can be used by proponents to determine whether their project will impact the biodiversity considered most important. Complementary it would allow the developers and the environmental authorities to find areas of equivalent biodiversity that can be improved as part of the offset. Such a tool has been developed through a WCS-led project and is currently under improvement.

Once it is necessary to determine the type of biodiversity that needs to be offset, it is necessary to identify potential sites for restoration where offsetting can be implemented. This list of sites would be particularly useful for developers and the envrionmental authorities for the early planning of the biodiversity offsets according to the country's requirements. This would imply identifying strategic areas that maximize the potential benefit of enhancement/restoration activities for targeted biodiversity, which would include understanding the current degradation of ecosystems, and identifying strategic areas for restoration. While final site choice will always require field verification, GIS based assessments can provide useful first-pass filters to identify potential target areas.

There have been previous attempts to identify ecosystem restoration priorities in Mozambique using the IUCN ROAM, that is the Restoration Opportunities Assessment Methodology approach (MICAIA et al., 2018; MITADER, 2018). While this approach compiled an impressive array of social and environmental data to assess restoration priorities, it was primarily focused on functional ecosystem restoration, for example to reduce riverbank erosion or increasing connectivity between forest patches. Such objectives are not directly applicable to restoration for biodiversity offsets, which should be related with a specific biodiversity enhancement. As such, there is a clear need for an updated assessment of restoration priorities in Mozambique, with a focus on identifying potential offset receiving sites.

The ROAM tool supports the identification and mapping of potential restoration areas, at different scales depending on the available information. Field validation studies can then be targeted to these areas to determine which are most suitable for restoration of a particular type of biodiversity. This includes the application of metrics for determining the ecological condition of the ecosystems that occur at those sites, so that biodiversity loss and gain can be calculated.

The approach proposed in this report will complement existing ROAM assessments and use similar analytical techniques, but will be focused on identifying restoration areas to achieve the objectives of Mozambique's biodiversity offset legislation. It is important to note that the following data and

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[1] Instrument under development by the National Directorate of Environment (DINAB) in collaboration with WCS and BIOFUND – the Foundation for Conservation of Biodiversity.

methods described in this document are able to be revised based on feedback or provision of alternate datasets, and can thus be targeted for improvement. This approach focuses on identifying priority areas for ecosystem restoration, which is here used to refer to any kind of ecosystem improvement activity, regardless of whether the ecosystem being restored has been completely removed, or it is only somewhat degraded. No distinction is made here between restoration of degraded parts of a still existing ecosystem and restoration that aims to re-establish ecosystems in places where they have been totally lost.

1.2 Overview of approach

The overall objectives of biodiversity offsets in Mozambique are to maximise biodiversity (within and outside Protected Areas - PAs, and then protect the latter) as well as the ecosystem services gains, while minimising overall risk of failure when implementing the concept. Many of the indicators used in previous ROAM assessments are not related to these objectives, and thus they should not be used to inform the location of restoration activities under the biodiversity offsets legislation in Mozambique. Instead, we here use a set of simple indicators with direct links to restoration for biodiversity offsets, and we clearly justify the reason for inclusion of each indicator.

The approach outlined here is designed to be flexible and work for use at multiple scales, dependent on the specific needs of each application. For example, it can be used to identify broad restoration priorities at the provincial or national level but can also be used to identify priority areas within a Protected Area, KBA, or specific ecosystem of interest. So long as the general steps and logic outlined below are followed, and indicator choice for each step is well justified, the scale of analysis and exact datasets used can vary. Ideally, analyses performed at a small-scale will incorporate high resolution data that are not available at larger scales. Here an example is presented using global/national scale datasets that can be used as a standard if better data is not available.

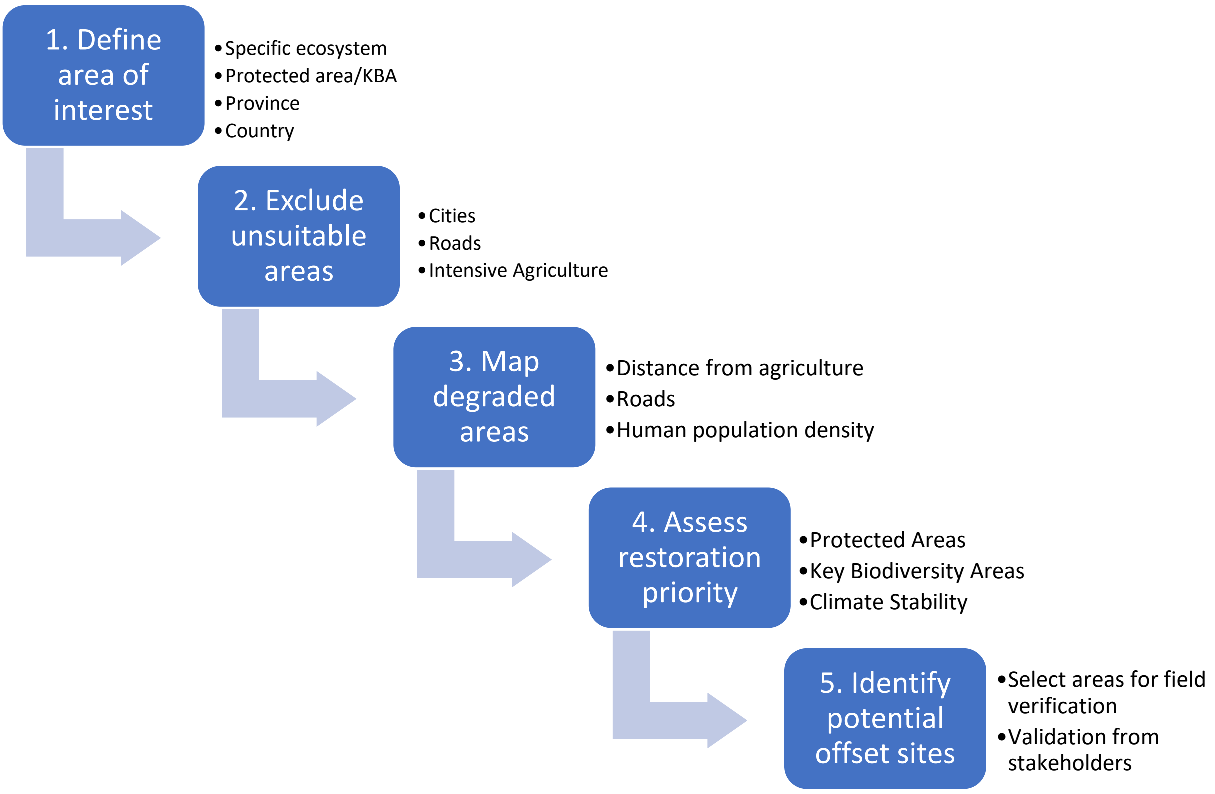

Figure 1. Approach for identifying potential restoration sites by implementing biodiversity offsets.

Figure 1 displays the overall steps in this approach. The rationale for each step in the approach is outlined in the detailed sections below, but a general overview is provided here. The first step in this approach consist to define an area of interest (AOI), to which all further analysis is constrained. Next, it is important to exclude areas likely to be severely degraded or converted to intense anthropogenic land uses (e.g. urban areas, roads, intensive agriculture), as these are unlikely to be feasible as restoration sites. Next, indicators of ecosystem degradation are used to assess the current state of land within the AOI and identify converted/degraded areas where restoration could improve ecosystem state (**NB** – this step *does not* assess the priority of restoring one area over another, but simply aims to map all degraded areas in the AOI). Following this, indicators reflecting restoration priority are compiled and assessed for the AOI, to identify high-priority areas for biodiversity enhancement. Finally, the above degradation and restoration priority maps are combined to identify potential restoration sites, the suitability of which must then be verified through more detailed assessments of restoration feasibility, including field validation.

2. Step 1 - Define Area of Interest

In order to map potential ecosystem restoration sites, a key first step consist to identify the area of interest (AOI) in which to search. Focusing on a specific region of interest, rather than conducting analysis at a broader scale, helps streamline further analysis and allows for the best available datasets to be used in subsequent steps. An AOI can effectively be any defined geographical area for which offset priorities need to be identified, but there are a few datasets which will likely be primarily used for AOI definition.

Because offsets in Mozambique will ordinarily be like-for-like, meaning that restoration occurs in the same type of ecosystem that was impacted by a development[2], AOI will likely be defined as the boundary of a certain ecosystem type. This allows restoration priority assessments to occur across the entire historical range of an impacted ecosystem, and to identify potentially suitable suites for restoration offsets to deliver like-for-like compensation. In other cases, AOI's might be defined as the boundaries of protected areas or Key Biodiversity Areas, both of which are priority areas for restoration in Mozambique. Restoration priorities could also be identified for an entire district or a province, using the respective boundaries of the government unit to define the AOI.

In the following sections, we demonstrate the use of this approach to identify restoration priorities for specific regions of interest. We use the Sussungenda disctrict as a first example, and then later test the approach for Forest Ecosystems in Matutuine district.

[2] Note that for offsets related to species, this approach could be slightly different as a species can occur in several ecosystems; in those cases, the offset receiving area can include different ecosystem types or can even be designated in a different ecosystem from the one impacted if the feasibility of the offset is more likely.

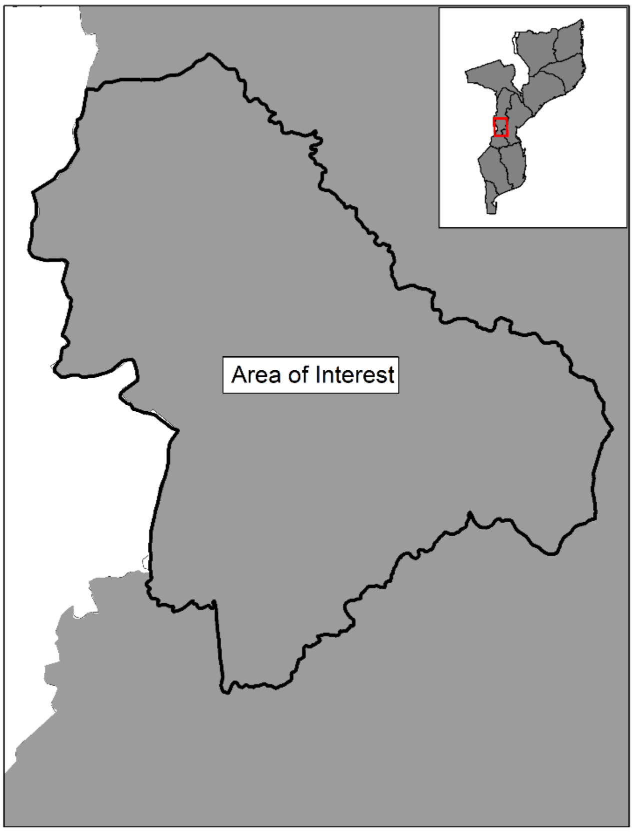

Figure 2. Sussundenga district, used as an AOI for demonstration of methodology in this document.

3. Step 2 - Exclude unsuitable areas

After defining an AOI, a key next step consists to identify areas that are unsuitable for offset activities (e.g. cities, roads, intensive agriculture). This can help focus the analysis to areas that may potentially receive offsets and avoid wasting time and effort assessing the restoration potential of unsuitable areas. There are numerous datasets that could be used to map areas that are unsuitable for offsets, and the exact data used will depend on the AOI being assessed. However, some common ways to identify unsuitable areas are:

1) Map areas of intense human activity (e.g. cities, commercial agriculture) where restoration is inappropriate or likely to be infeasible due to high financial costs and social impacts of potential resettlement, removing buildings, infrastructure etc.
2) Identify places where bio-physical constraints make restoration infeasible or very costly, such as areas that are very hard to access (e.g. steep slopes), or areas that are earmarked for future development.

In our example assessment, we used two simple layers to exclude unsuitable areas: Roads, and human population density. Roads are generally unsuitable for restoration, because these are necessary infrastructure and its removal may have socio-economic impacts on local people, and because the cost and effort required to remove road infrastructure is prohibitive. Areas of high human population density are also unsuitable for restoration, for similar reasons and because population is likely to expand within these areas. Other datasets which would be useful could include data on commercial agriculture, forest plantations, or active mining concessions[3].

To map roads in Mozambique we obtained data from Administração Nacional de Estradas (Figure 3.2). To define areas of high human population density, data on 2020 human population density was obtained from the Worldpop project (https://www.worldpop.org/). We excluded areas with population density > 243/km^2, which corresponds to the top two quintiles of population density for Mozambique (Figure 3). These datasets were combined to generate an overall offset suitability mask, which is used later to exclude unsuitable areas from the analysis (Figure 3.3).

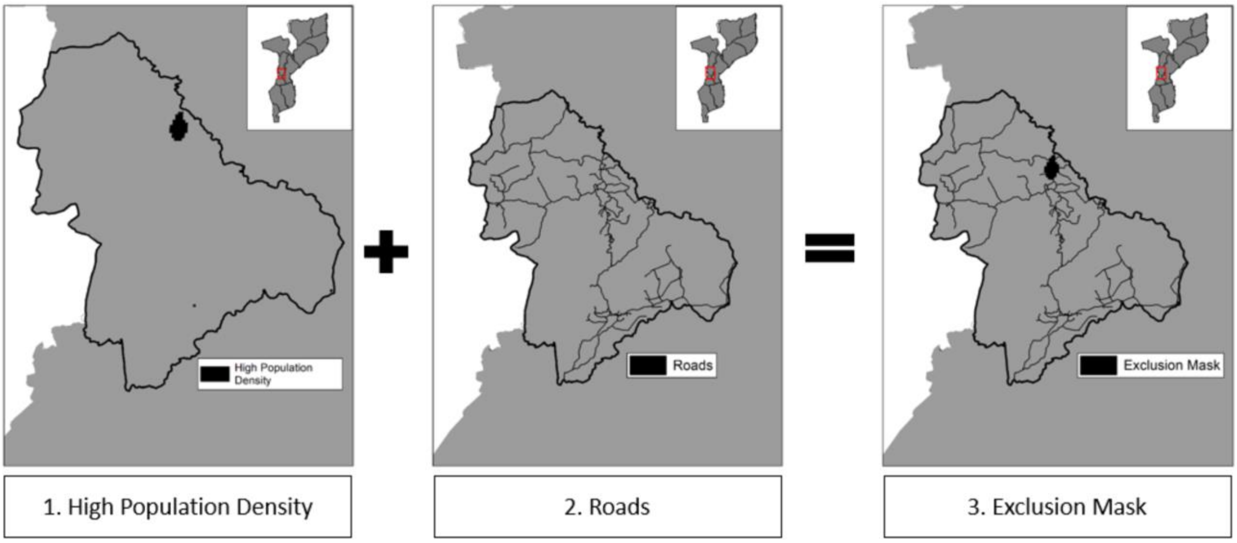

Figure 3. Exclusion map, used to remove unsuitable areas from further analysis.

4. Step 3 - Degradation Assessment

The third step in identifying restoration priorities is to assess the current state of the environment within the AOI, in order to identify converted or degraded areas where restoration may be beneficial (in healthy, good condition areas there is no need for restoration). Importantly, this step does not involve deciding on restoration priorities or ranking areas based on restoration importance or environmental value. Instead, this step simply produces an assessment of the state of the environment within the AOI, by using indicators of human pressure to map ecological degradation across the AOI. After this degradation assessment is complete, then potential restoration priorities can be identified (this process is explained in the next section of the report).

There are a multitude of indicators that can be used to measure human impact on the environment and identify degraded areas. The most appropriate indicators for use will depend on the AOI being assessed, and the types of ecosystems occurring in that AOI. For example, a map of slash & burn agriculture may be a useful indicator of degradation for forest or woodland ecosystems but is unlikely to be useful for a marshland AOI. Conversely, erosion or water pollution may be a good

[3] As soon is available for consultation

indicator of degradation for a wetland, but is unlikely to be useful for a savannah ecosystem. As such, it is crucial that indicator choice is clearly justified based on the specific AOI being assessed, and that evidence showing a direct link between the indicator and environmental degradation is provided.

Here, we present an example degradation assessment for the Sussundenga district. For this example, we use global/national scale datasets which will be available for anywhere in Mozambique. Better datasets, and data showing different kinds of human impacts will likely be available for many regions. We deliberately use a small number of indicators, so that if a particularly degrading activity is detected, then this area receives a high degradation score. When large numbers of indicators are combined, then a particular area must score highly in all indicators to receive a high degradation score, something that could negatively influence the assessment. Table 1 compares the indicators used in the previous ROAM assessment, and the indicators used in the approach presented here.

Table 1. Indicators used in previous ROAM assessment (1.1) and indicators used in example assessment of new methodology (1.2)

1. ROAM Assessment criteria	
Biophysical indicators	**Socio-Economic indicators**
Low tree cover	Land tenure insecurity
Forest loss	Food insecurity
Bare soil	High women proportion
Infrastructure Development	Low institutional capacity
Increased settlement	Population pressure
Fires	**Food insecurity indicators**
Low soil carbon	Climate Change vulnerability
Aridity	Reliance on rain fed agriculture
Steep slopes	Low income/poverty
Floods	Lack of agricultural resources
Soil Erodibility	Poor market accessibility

2. Restoration priority assessment criteria	
Degradation indicators	**Restoration priority indicators**
Agriculture	Protected Areas & KBAs
Roads	Climate Stability
Population Density	Recent Deforestation

4.1 Indicator 1 – Proximity to agriculture

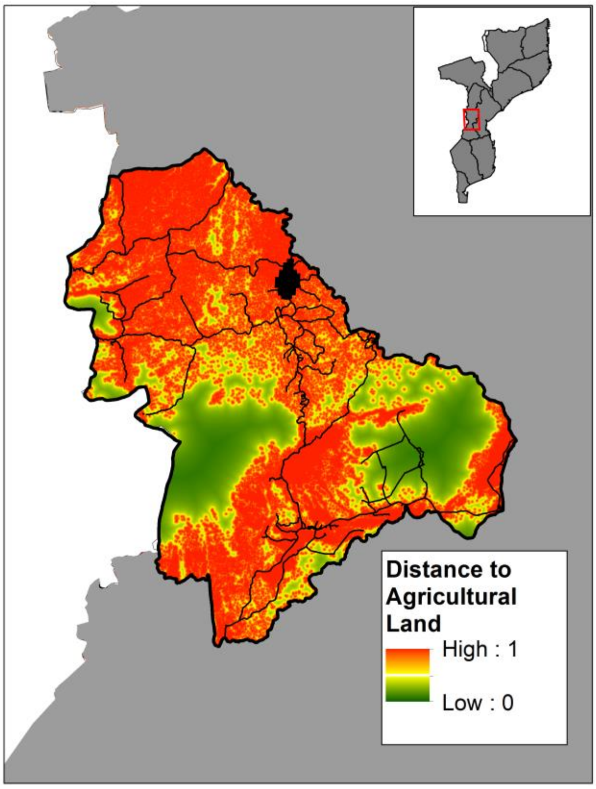

Figure 4. Distance to agricultural land, rescaled between 0 and 1. Roads and areas of high population density are masked from the assessment, as described in step 2.

4.1.1 Rationale

Small-scale agricultural land is converted to human uses, and thus a suitable restoration site in some cases. Areas nearby agricultural land are likely to be degraded, as agriculture indicates human presence, and thus a variety of related anthropogenic pressures such as selective logging, fuelwood collection, hunting; spread of fires and invasive species, pollution, and livestock grazing (Grantham et al., 2020). While in many cases agricultural land will not be a suitable restoration site, especially if converted a long time ago and/or used for commercial agriculture, we were unable to source country-wide land cover data that provides information on land conversion date, or data to separate different categories of agriculture.

4.1.2 Description

Data showing location of agricultural land for 2016 was obtained from FNDS. For areas that are not agriculture, we used the Euclidean Distance tool in ArcMap to calculate the distance to the nearest agricultural land pixel. This data was transformed in values between 0 and 1 using fuzzy logic membership in ArcMap, such that agricultural fields received a score of one, and areas far from agriculture received a score of zero. This data does not allow for delineation of subsistence and commercial agriculture, so all areas are treated the same. If available for the country or for a specific region, data that distinguishes these types of agriculture can be used to replace this layer.

4.2 Indicator 2 - Roads

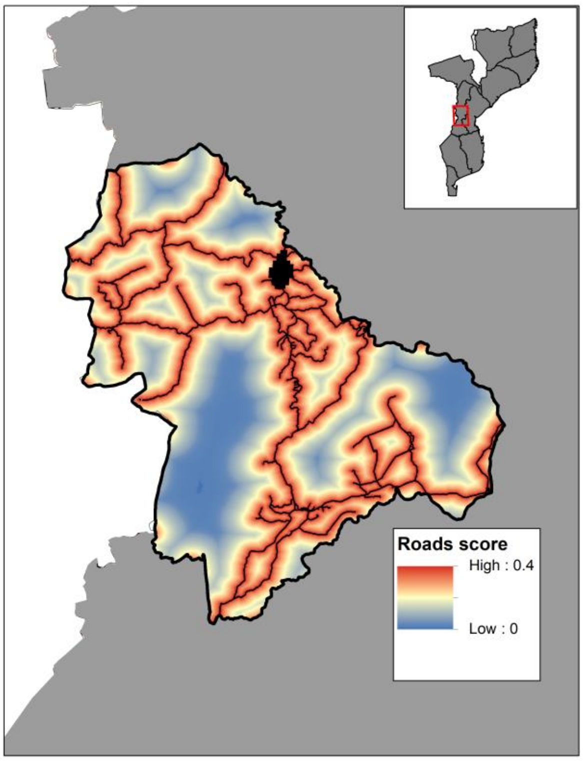

Figure 5. Scores for the road component that were used in the degradation assessment, ranging from 0.4 near roads to zero when located within 15km from a road. Roads and areas of high population density are masked from the assessment, as described in step 2.

4.2.1 Rationale

Roads are directly linked to declines in biodiversity, as they result in direct conversion of natural areas, fragment landscapes, and facilitate human access leading to a multitude of environmental impacts (Trombulak and Frissell, 2000).

4.2.2 Description

Road data for Mozambique was obtained through Administração Nacional de Estradas (ANE). Because roads in some areas of Sussundenga have been intensively mapped, while in others they have not, we filtered the roads dataset to exclude intensively mapped roads. A visual examination of these roads shows that most are small footpaths and tracks. We only included roads in the following categories: Primary, Secondary, Tertiary, Residential, Service, Trunk & Unclassified.

Because roads themselves are unlikely to be suitable for restoration, we assigned road pixels a restoration priority score of zero. However, because roads often lead to nearby ecosystem degradation, we assigned pixels adjacent to roads a score of 0.4, which decayed exponentially to zero at 15km either side of the road. The road dataset used here can also be used to distinguish roads into different categories (e.g. highway, residential), such that larger, more regularly used roads can be assigned higher scores. In the future, an attempt will be made to obtain a reliable classification of road types so that this kind of analysis can be done.

4.3 Indicator 3 - Human population density

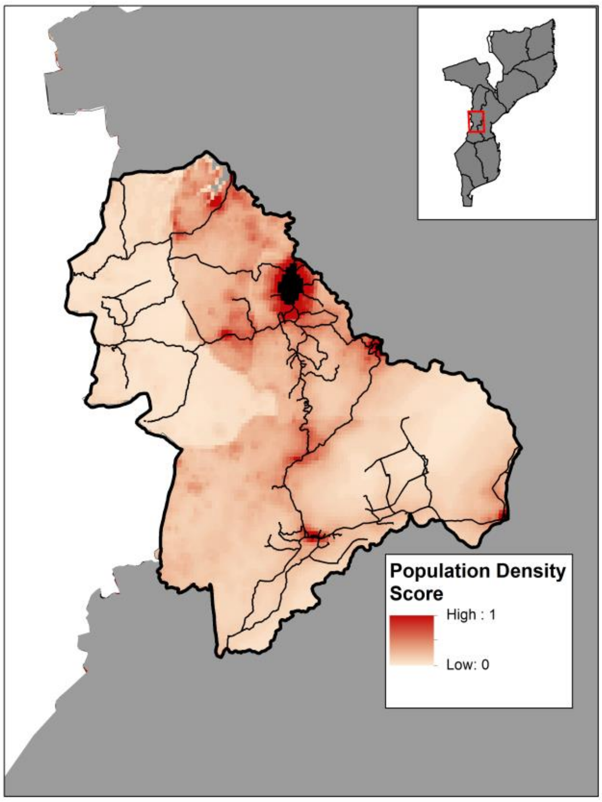

Figure 6. Human population density scores used in degradation assessment. Roads and areas of high population density are masked from the assessment, as described in step 2.

4.3.1 Rationale

Many of the pressures humans impose on the environment are proximate to their location, such as habitat conversion, hunting and the persecution of non-desired species (Venter et al., 2016). Moreover, even low-density human populations with limited technology and infrastructure developments can have significant impacts on biodiversity, as evidenced by the widespread loss of various taxa, particularly mega fauna, following human colonization of previously unpopulated areas (Brashares et al., 2001; Burney and Flannery, 2005).

4.3.2 Description

Data on 2020 human population density was obtained from the Worldpop project (https://www.worldpop.org/). As with the roads indicator, areas of very high human population density are likely to be unsuitable for restoration (e.g. cities, towns), so we excluded areas with population density > 243/km^2 (described in step 2 above). For all other areas, data was transformed between 0 and 1 using fuzzy logic membership in ArcMap, such that the most populous areas received a score of one, and the least populous a score of zero.

5. Overall Degradation Assessment

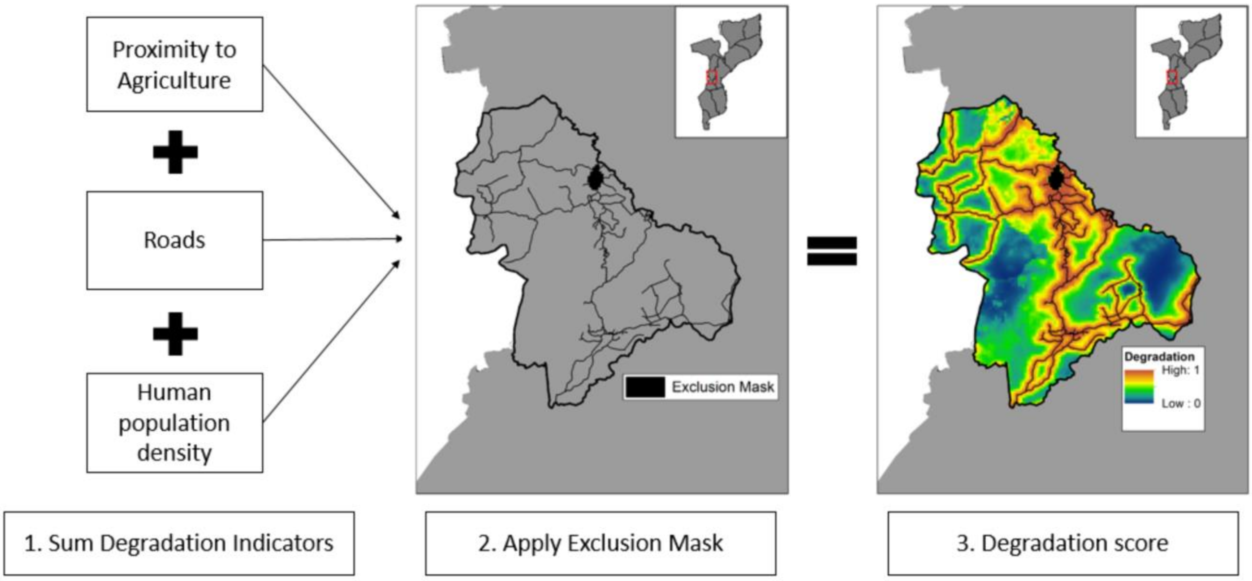

Figure 7. Combining degradation indicators to generate an overall degradation score Sussundenga district. Black areas in the AOI are likely unsuitable for restoration offsets, and were removed using the exclusion mask described in step 2.

To develop an overall degradation map, degradation indicators were rescaled between 0 and 1 and then summed. Indicators must be placed on the same scale, as the raw data for each indicator will use different units, and we want to avoid one indicator dominating the final degradation map. In our example assessment, we rescaled all indicators between 0 and 1 using fuzzy logic in Arcmap, and then used the raster calculator tool to sum the indicators. We then used the exclusion mask (Figure 7) to remove areas that are likely to be unsuitable for restoration. The final map (Figure 10) displays overall likelihood of degradation within the AOI. While the degradation score map shows linear features with the appearances of roads, we excluded any pixel ($250m^2$) with a road running through it. The linear, road-like appearance of the degradation map is due to areas adjacent to roads being highlighted as likely to be degraded.

6. Step 4 - Restoration Priority Assessment

After identifying degraded areas, the next step is to use data on restoration priorities to help choose potential restoration areas. Restoration priority indicators will be used to develop a restoration priority index, which can be combined with the degradation index developed in step 3 to generate a map of potential restoration areas. These restoration priority indicators have a large influence on the final map of potential restoration sites, so it is important that they are carefully selected and the reason for inclusion is well justified. For example, if restoration is occurring as a biodiversity offset, then an indicator prioritising restoration towards protected areas could be justified using Mozambique's biodiversity offset legislation, which states that restoration offsets should be preferentially located in underfunded protected areas and in key biodiversity areas (KBAs). Alternatively, if restoration is occurring as part of an initiative to improve water quality, then an indicator prioritising restoration in degraded riverbanks would be well justified.

There are a multitude of datasets and methods that could be used to generate restoration priority indicators, and the most appropriate indicators may depend on many factors, including:

- The kinds of ecosystems within the AOI being assessed (e.g. prioritise forest ecosystems)
- The overall objectives of restoration (e.g. improve forest condition vs prevent erosion vs increase connectivity)
- Relevant jurisdictional/governmental priorities
- The socio-economic situation of the AOI
- Feasibility/cost of restoration across the AOI (e.g. avoid steep slopes)

Here, we combined a small number of restoration priority indicators for Sussundenga district as an example, and used these to generate an overall map of restoration priority. Importantly, this map alone cannot be used to identify potential restoration sites, as it does not incorporate information on ecosystem degradation. In order to identify potential restoration sites, the restoration assessment and degradation assessment must be combined, as demonstrated in step 5.

6.1 Indicator 4. Protected Areas & Key Biodiversity Areas

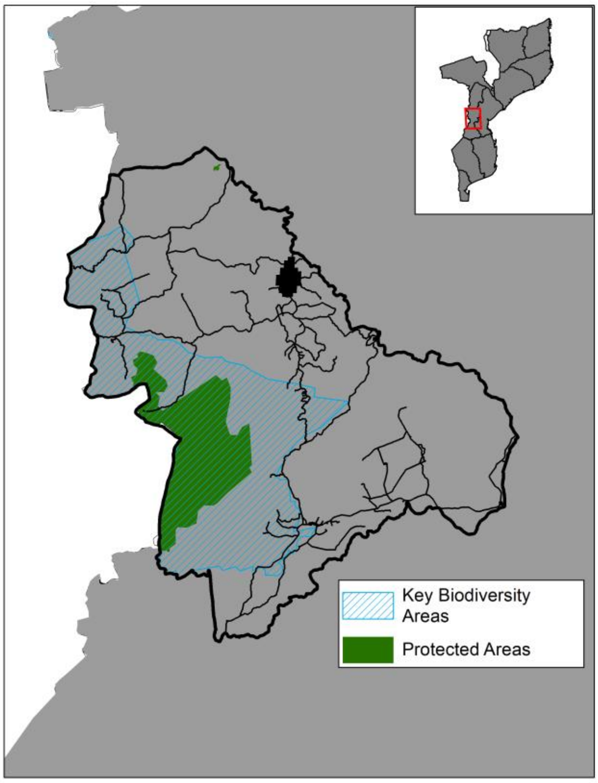

Figure 8. Protected areas (Chimanimani National Park) and Key Biodiversity Areas in Sussundenga district.

6.1.1 Rationale

In Mozambique's biodiversity offset legislation, offsets should primarily be targeted towards underfunded protected areas and KBAs, if the relevant biodiversity features occur in these areas. This is because, in many cases, protected areas lack sufficient resources to protect and restore degraded biodiversity and some of them face impacts resulting from population expansion that interfere with the conservation objectives for which they were designated.

6.1.2 Description

Data on Mozambique's protected areas was obtained from the Mozambican government, and data on KBAs was obtained from the ongoing KBA identification process led by National Directorate for Environment and by WCS. Because protected areas are, in principle, the highest priority for offsets, we assigned these areas a score of 1, and assigned forest reserves & KBAs a score of 0.8.

6.2 Indicator 5. Climate Stability

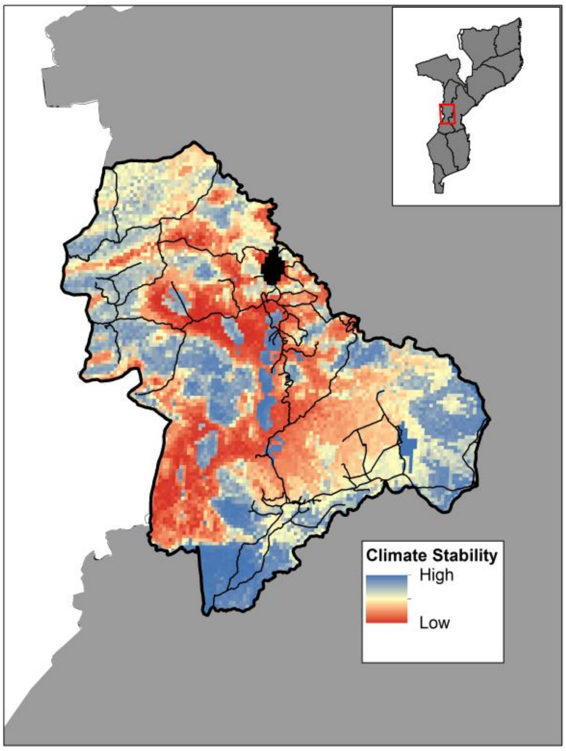

Figure 9. Climate Stability scores used in restoration priority assessment.

6.2.1 Rationale

Climate stability is a measure of how similar current and future climates are projected to be. Offsets may be more likely to fail in areas of low climate stability, both because the ecological conditions of a site may change (making it unsuitable for the restored ecosystem), or because climatic changes may affect ecosystem conditions and people's livelihoods, increasing their reliance on natural ecosystems (e.g. for charcoal or bushmeat). In contrast, areas of high climate stability are likely to be change less into the future, increasing the likelihood that offsets will succeed in the long-term. There are many other climatic datasets that could be included instead of/along with this dataset, based on what climatic variables or indicators are considered most relevant to determine offset priority.

6.2.2 Description

Climate model data for the present day and 2080-2100 was obtained from CHELSA and represents the ensemble output of multiple climate models under the rcp 8.5 scenario (Karger et al. 2017). For each of the 14 climatic variables modelled by CHELSA, we compared current and future values, with larger differences = less climatic stability. We then took the average percentage change across all variables to develop an overall climate stability map for Mozambique. This data was transformed between 0 and 1 using fuzzy logic membership in ArcMap, such that the most stable area received a score of one, and the least stable area received a score of zero.

7. Overall Restoration Priority Assessment

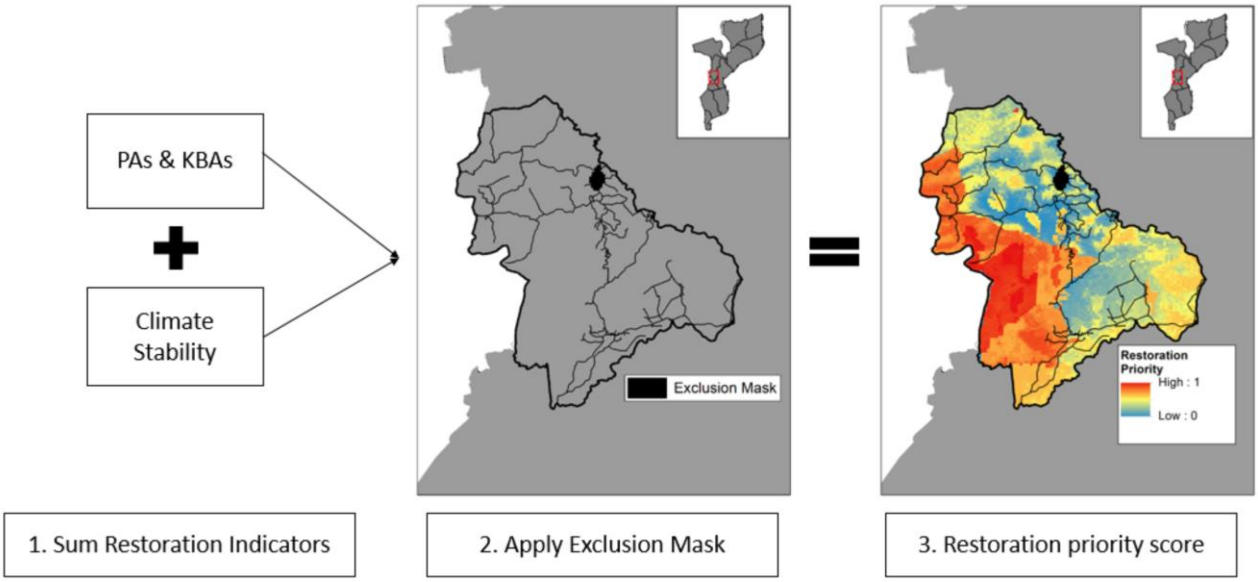

Figure 10. Combining indicators to generate an overall restoration priority score for Mozambique.

To develop an overall restoration priority map, restoration indicators are rescaled between 0 and 1 and then summed. Indicators must be placed on the same scale, as the raw data for each indicator will be using different units, and we want to avoid one indicator dominating the final map. In our example assessment, we rescaled all indicators between 0 and 1 using fuzzy logic in Arcmap, and then used the raster calculator tool to sum the indicators. We then used the exclusion mask (Figure 10) to remove areas that are likely to be unsuitable for restoration offsets. The final map (Figure 11) displays overall restoration priorities for our AOI, based on the simple indicators used in this example. This map clearly reflects the high priority given to restoration within PAs and KBAs (Figure 8), with Chimanimani National Park and the respective KBA given the highest priority in the AOI. Outside PAs and KBAs, areas of high climate stability are assigned higher priority than areas of low stability.

8. Step 5 – Identify potential restoration sites

To identify potential restoration sites across the AOI, the final step is to combine the degradation assessment (step 3) and restoration priority assessment (step 4) described above, to generate a final restoration suitability map (Figure 11). This generates an overall index of restoration suitability which can be used to identify potential sites for more detailed assessment and fieldwork.

In the case of Sussundenga district, areas of high restoration priority (dark green) are found to the south-west of the map, inside Chimanimani National Park and its buffer zone. Other potential areas are found along roads or on the outskirts of populated areas that were excluded due to high population density.

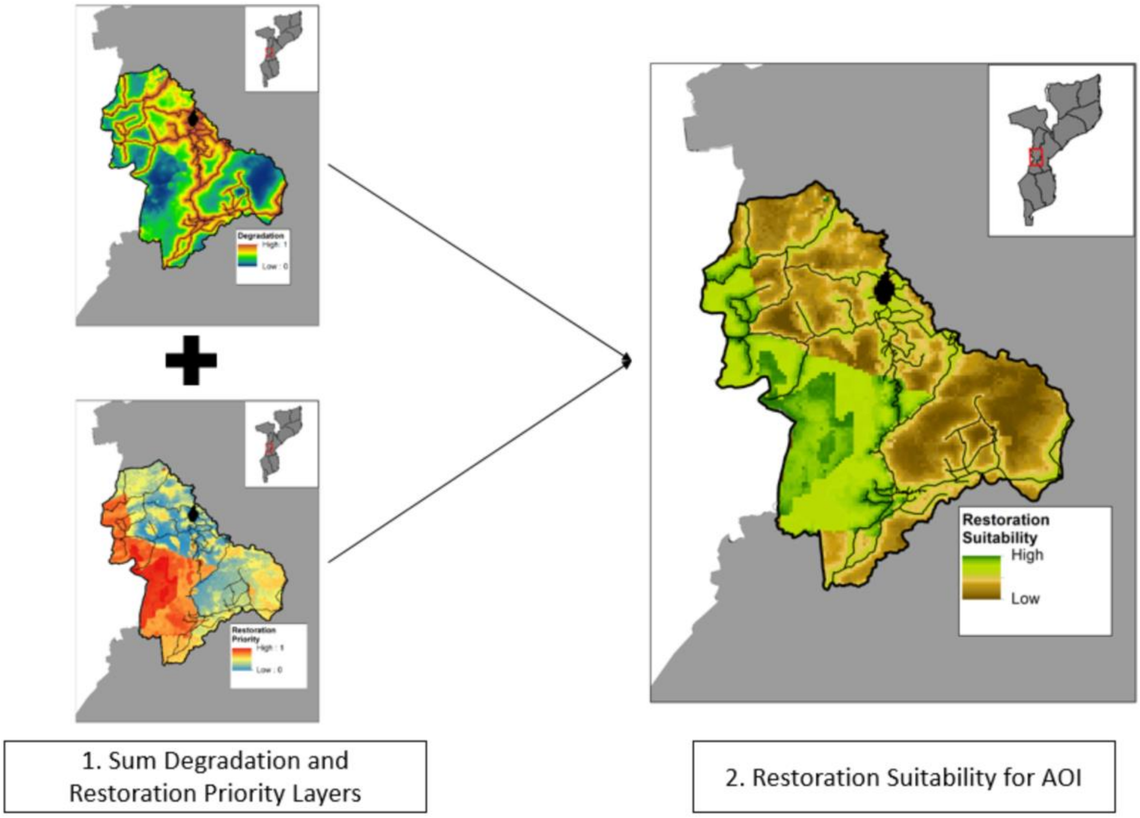

Figure 11. Generating an overall restoration suitability map using degradation and restoration priority maps.

9. Validation workshop

A workshop was held in February 2021, through a webinar, to discuss the development ofan updated assessment of restoration priorities in Mozambique, with a focus on identifying potential recipient areas for biodiversity offsets. The webinar was attended by 35 participants from 15 institutions representing the Government, NGOs, Academia, Research Institutes, Multilateral agencies and Conservation Areas.

The main conclusions of the webinar were:

- It is important to contact the consultants who are developing the District Land Use Plan ("Plano Distrital de Uso de Terra – PDUT") of Sussundega and LAUREL Project which is about to start the second phase and will include Chimanimani landscape, to obtain recent data and information from the Chimanimani that can be very useful for the development of the ROAM tool;

- Other indictors for restoration priority could include topographical datsets such as elevation or slope, as both influence the suitability of sites for restoration. For example, in Chimanimani National Park, data on slope could be used to remove very steep areas that are not suitable for restoration actions, if data exist and if they are up to date;
- It was suggested to take into consideration not only roads that are part of the network of the National Road Administration (ANE) but also roads opened by the population that are probably not in the ANE database. If these data are not available, they can be included manually woth a Google Earth check. However, it is only possible to do this for areas at a local scale as it would require a great effort to map these additional roads manually at a larger scale;
- In terms of the population density indicator, this is a very dynamic variable, so this must be taken into account when implementing the ROAM tool as it may imply changing the locations previously indicated as priorities;
- It is important to consider invasive species that are greatly affecting the Park and would be good to include in the tool's indicators. However, this is dependent on appropriate data being available;
- The tool has great potential to identify and map potential areas for restoration. An advantage includes that the application of the methodology and the respective analyses, can be performed in any GIS software. Also, it can be applied at various levels, i.e. from the national to the local level. However, it all depends on the type of information available. If we have specific information for a district, we can go to a more detailed level.

<u>As next steps, it was agreed to:</u>

- Present the ROAM tool to decision makers in order to show the usefulness of making the data available to various stakeholders and the general public;
- Share the ROAM review report with stakeholders who did not have access to previous information;
- Hold a meeting with other stakeholders who could not participate in the webinar, but from whom it is important to get input on the revision of the ROAM tool, such as FNDS, IIAM, etc.

Based on the contributions from the partipants and complementary comments received from FNDS in a meeting held after the workshop, it was proposed that this methodology should be tested in two of the landscapes where the BIOFUND and WCS/COMBO Project are implementing pilot projects for biodiversity offsets: i) Matutuíne district and ii) Sussundenga district.

10. Testing of the proposed approach in Matutuíne District

As recommended at the validation workshop, to further test the methodology presented above for Sussundenga, we conducted an assessment in another region of the country, in this case in the Matutuíne district, where the project team is implementing a pilot study. Focusing on a specific region of interest, rather than conducting analysis at a broader scale, helps streamline further analysis and allows for the best available datasets to be used in subsequent steps. For this example, we defined the AOI as forest ecosystems within the Matutuíne district. We used the recent Mozambique's updated historical ecosystem map (Lotter et al. 2021) to include only Forest Ecosystems. This contrasts with the Sussundenga example, which is focused on the entire district. The approach presented here is flexible and designed so it can be applied for a range of different AOIs depending on the specific restoration priorities that need to be identified.

The specific datasets and methods used to apply our approach in Matutuine district are outlined in (Sidat et al., 2021), but they follow the approach outlined for Sussundenga in this document. The final output is an overall index of restoration suitability which can be used to identify potential sites for more detailed assessment and fieldwork (Figure 12).

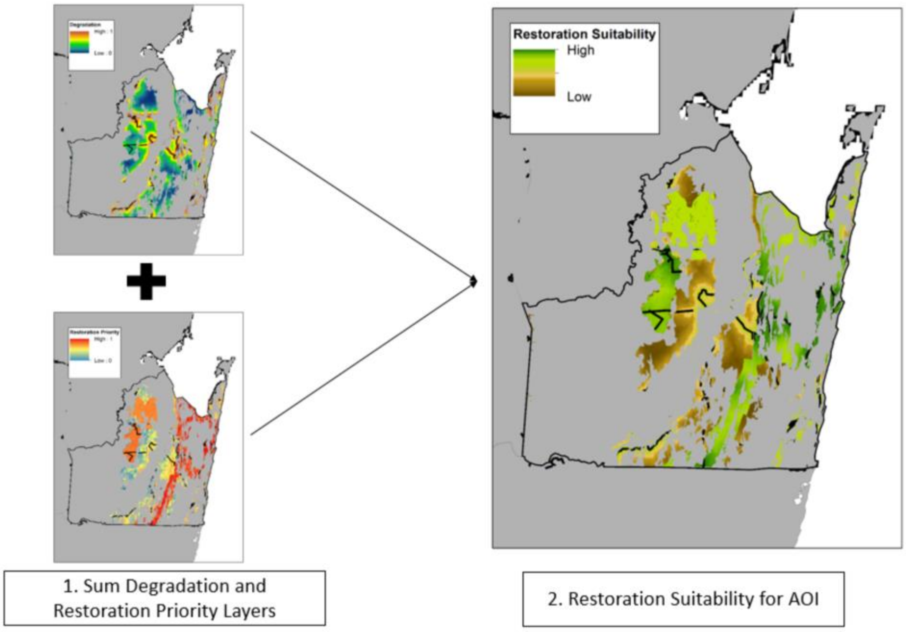

Figure 12. Generating overall restoration suitability map using degradation and restoration priority maps and including only forest ecosystems.

Importantly, this approach is useful for identifying restoration sites at a macro-level and should be used cautiously at site specific levels. For example, in the Matutuíne region we can see broad priority areas (dark green) (Figure 12). However, field work will always be required to assess site feasibility, social context, and ecosystem equivalence, among any other relevant factors to consider. Therefore, we conducted a rapid field assessment between 1 and 6 March 2021 to validate the maps obtained with the proposed methodology.

Figure 13 shows the location of sites visited in the Licuáti Forest Reserve (LFR) to verify offset suitability.

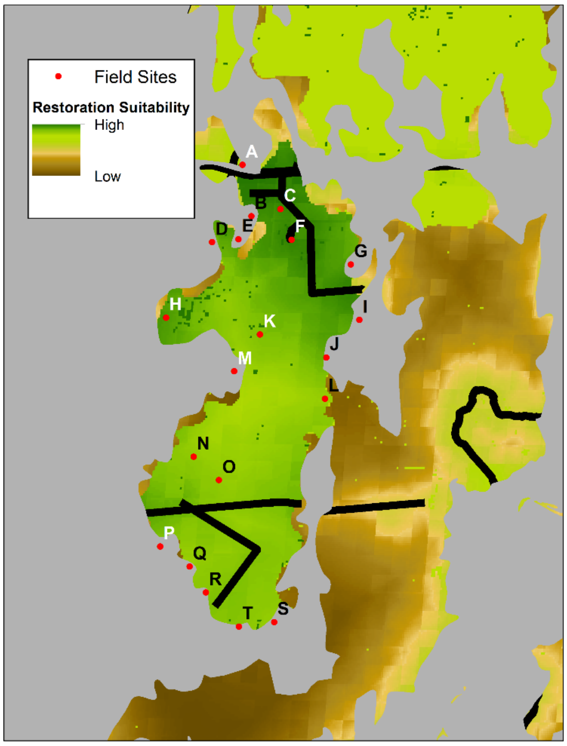

Figure 13. Twenty (20) sites marked for field verification, from which only 7 sites (white colour letters) were visited during the field visit conducted in March 2021.

While our restoration priority assessment exercise does show LFR to be a priority for restoration offsets at a macro-scale, field visits showed that some of the identified areas are unsuitable offset sites for a variety of reasons.

Based on the information obtained so far, it was concluded that the ROAM tool has potential to identify potential restoration sites in LFR. Although all the seven sites checked in the field were not free of risk factors, at leats three sites showed high potential for restoration due to signs of regeneration and low to medium degree of modification. One site presented high degree of modification, but it was determined that it has medium potential for restoration. Two sites seemed to have low potential for successful restoration actions, mainly due to the vulnerability of the area to human activities. These results showed that remote sensing combined with field verification is crucial for site validation and there is a need to assess several other sites that were not possible to visit during the field work carried out in March. Therefore, a more detailed groundtruthing exercise to validate the ROAM outputs will be carried out in Matutuíne.

11. Recommendations & Next Steps

Our approach is designed to assist with identification of potential restoration sites for biodiversity offsetting purposes. Here we applied the approach in a specific area of interest, in this case simulating a situation that would occur within the boundaries of an ecosystem impacted by a development project.

By assessing levels of degradation and restoration priority for an ecosystem, the achieved results can help inform the location of detailed field-based studies to assess site feasibility, social context, ecosystem equivalence, among any other relevant factors to consider for the application of future conservation projects, particularly biodiversity offsets or other type of conservation measures. The suitability of these sites should be first cross-checked or verified before any field work is planned, for example through expert opinion and/or visual inspection of high-resolution satellite imagery (e.g. Google Earth). After this, field visits to determine local suitability will be required (Figure 14).

1) Desktop site suitability analysis

- Identify an Area of Interest (AOI)
- Use satellite imagery and expert opinion to verify:
  - Degradation levels
  - Location of unsuitable areas (towns, roads, development projects, etc.)
  - Likely ecosystem type
- Assess land availability (e.g. ownership, existing mining concessions, etc.)
- Consult relevant stakeholders

2) Plan field visits to AOI

- Map potential restoration parcels that could be assessed
- Design field surveys & social surveys
- Contact local stakeholders

3) Conduct field visits to AOI

- Field visits to ground truth:
  - Ecosystem type
  - Degradation level
- Socio-economic surveys to assess:
  - Local livelihoods
  - Risk factors (e.g. charcoal collection, hunting)
- Validate local context with local stakeholders

4) Define the suitability of the restoration sites

- Analyse data collected through the field visits
- Assess the suitability of each potential restoration site considering factors such as:
  - Technical feasibility
  - Economic feasibility
  - Social support
  - Legal feasbility
- Select restoration sites
- Complete baselines
- Use the information to develop the full Biodiversity offset Management Plan in coordination with local stakeholders

Figure 14. Steps to assess suitability of potential restoration sites following the restoration priority assessment described here.

Because our approach is general framework that can be applied to any AOI, the exact data available for each assessment will vary. It is necessary to highlight the importance of having detailed and up to date data, and the ROAM tool shows the how crucial is making the data available to the various stakeholders and the general public.

Here we discuss some general data availability concerns that may apply in many cases. For example, our approach could be improved if it is possible to obtain data which can distinguish between different agricultural land uses. Areas of shifting agriculture or small-scale farming will be much more feasible to restore compared to areas of industrial agriculture or forest plantations, especially if they have been converted recently. For smaller AOIs, it may be feasible to use high-resolution imagery to map smallholder agriculture and assist with choosing between potential restoration sites. Similarly, data which can determine how recently land was converted to agriculture (e.g. deforestation maps) could be used to inform restoration priority, as recently converted areas may be less impacted and more feasible to restore. If these areas are overlapped with those of shifting agriculture or small-scale farming, then they will be very informative. When considering roads in the degradation assessment map, data which can distinguish between different road categories (especially paved and unpaved) would be useful. Paved roads have a substantially higher impact than unpaved roads, and this could be incorporated by giving paved roads a higher impact score than unpaved.

It is also important to note that the example assessment undertaken here does not attempt to rank areas based on their conservation status or their value for ecosystem service provisioning. This was a deliberate decision, as Mozambique's biodiversity offset legislation generally requires like-for-like offsets, and thus there is no need to prioritise between ecosystems. Because ecosystem enhancement will likely correspond to a substantial portion of future offset projects in Mozambique, we here demonstrated how our approach could be used to identify like-for-like restoration areas. However, in cases where like-for-like is not a requirement, or where restoration activities are not offset related, there are multiple datasets that could be used to help set restoration priorities. For example, the results of an IUCN Red List of Ecosystems assessment could be used to prioritise the most threatened ecosystem types.

Mozambique's National Strategy and Action Plan for the Conservatin of Biological Diversity (NBSAP 2015-2035) also includes national scale restoration priorities which could inform the location of offsets, such as critical ecosystems or those that provide essential goods and services. Finally, restoration priorities may also be set based on ecological connectivity, where offsets can be targeted to link separated areas of great importance and improve connectivity. When incorporating such datasets, it is crucial that they are used only in **Step 4 – Restoration Priority Assessment**. When indicators of degradation and restoration priority are mixed in the same analytical step, the results often become muddled and difficult to interpret clearly.

Considering that BIOFUND and WCS/COMBO Project are developing biodiversity offsets pilot projects in the Sussundenga and Matututíne landscapes, we recommend that more detailed fieldwork is carried out to test the accuracy of this method to select potential restoration sites through offset projects, considering different scales: landscape vs local levels. Using the work developed so far, it will be possible to carry out field work for groundtruth tha areas pre-selected by the proposed approach. That will provide information on the accuracy of the method to be used at different scales.

It will be especially useful to compare the results in the present study with other maps of restoration priorities identified for our regions in analysis. For example, the PDUT process in Sussundenga has identified a number of restoration priorities in the north of the district (Figure 15). Reforestation in the Sussundenga PDUT is focused on the use of native species for **i)** reducing environmental vulnerability by stimulating the replanting of native trees in places that have suffered deforestation, thus minimizing the effects of floods and cyclones; and **ii)** areas of conservation and community interest, where reforestation aims to ensure the recovery of native vegetation and safeguard the biological diversity of the region. In contrast, our restoration priorities are driven primarily by the location of degraded land, with a high priority given to existing protected areas and KBAs, because these are priority areas for restoration under Mozambican biodiversity offset legislation. As such, it is therefore likely that different types of restoration efforts will have different priority areas, especially if some focus on benefits to communities and others focus on offsets for the impacts of development. Regardless of the approach used to identify restoration priorities, it is key that the indicators used to decide on priorities are directly related to the objectives of the restoration activitiy being undertaken (see **Step 4** secton above).

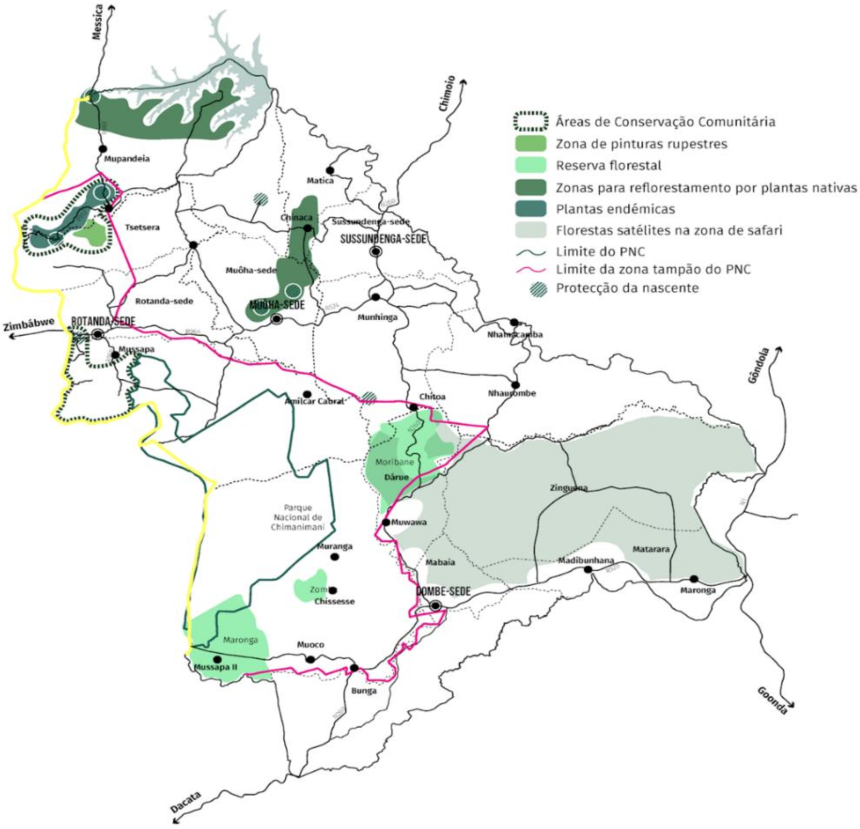

Figure 15. Restoration priorities identified under the PDUT for Sussundenga district, Manica province (Source: Governo do Distrito de Sussundenga, 2021)

12. Conclusion

Here we present an initial attempt to develop a system for scoping potential restoration sites across the country, at least at a macro-scale. The exact datasets used in this methodology are flexible, as is the way indicators are processed (e.g. the scores they are given), as long as the broad steps outlined here are followed and indicator choice is well justified. It is also important that ecosystem degradation assessments (step 3) and restoration priority assessments (step 4) are conducted separately, to avoid mixing of indicators – as this can muddle final results and make them difficult to interpret. Finally, it is important to note that this methodology cannot replace more detailed desktop and field-based verification of potential restoration sites, but it can help to focus such verification on areas that are likely to be suitable, therefore improving the efficiency of the process (e.g. time spent and costs), contributing to better planning. This tool is particularly important for i) national authorities who would like to earmark potential offset receiving areas at the national, provincial or landscape levels; ii) for developers who are potentially required to develop biodiversity offsets, and are interested in screening such potential sites. To continue exploring the value of this tool to select potential restoration sites through biodiversity offsetting, as a next step, groundtruthing should be conducted in the Sussundenga and Matutuíne Districts.

A special coordination effort should be done in Sussundenga district to ensure intercation between the biodiversity offset pilot project team and PDUT team to promote experience exchange opportunities regarding restoration practices between involved parties.

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