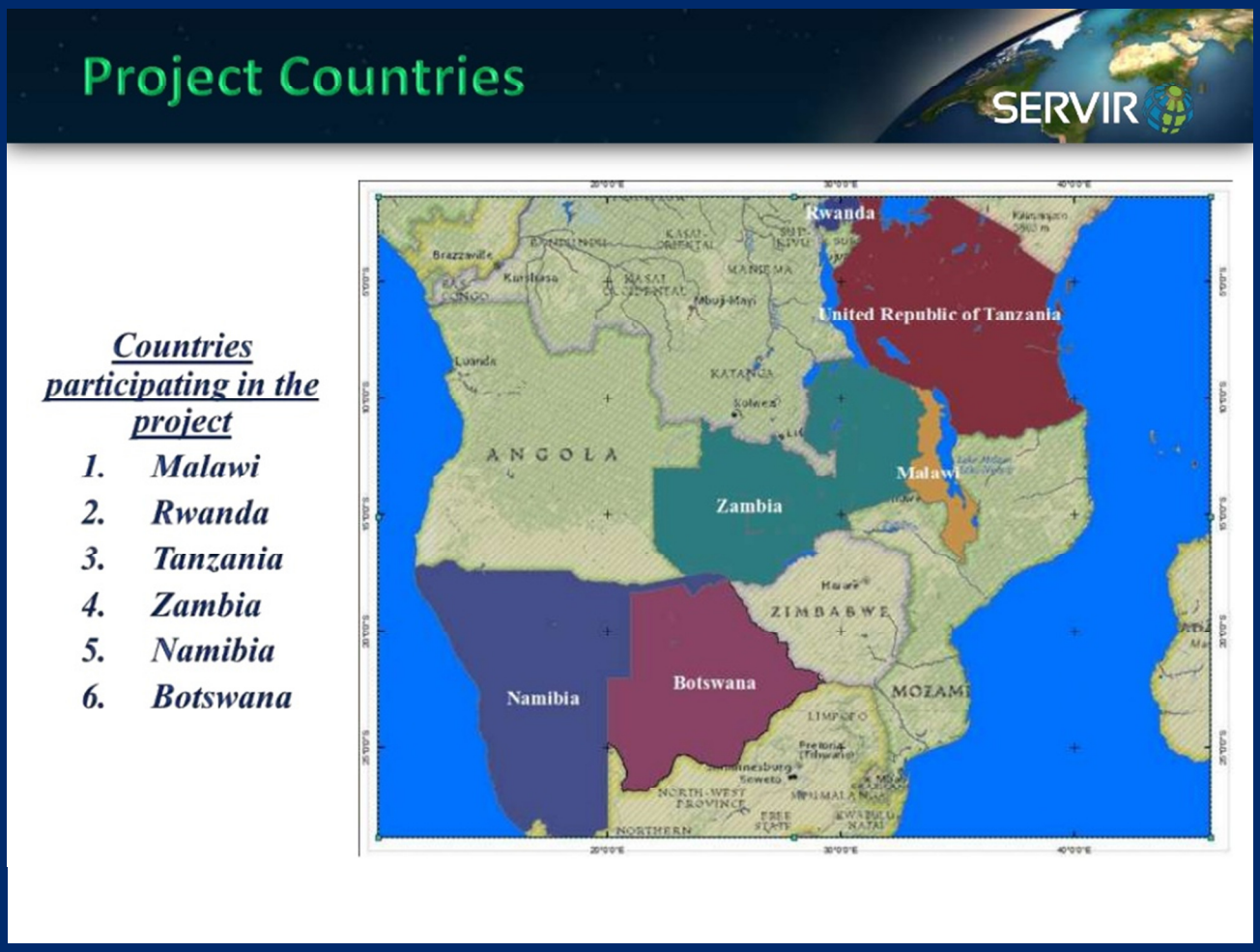
SERVIR PROGRAM DEMAND ACTIVITY

GHG CASE STUDY FINAL REPORT



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SERVIR PROGRAM DEMAND ACTIVITY

GHG CASE STUDY FINAL REPORT

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Editor's Note

SERVIR-Africa is a program within the Regional Centre for Mapping of Resources for Development (RCMRD). In some instances SERVIR-Africa is used. In some cases it makes more sense to refer the program, and in others the institution itself.

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The Demand team would like to acknowledge the Regional Center for Mapping and Resources for Development (RCMRD) who graciously worked with the case study team to answer questions and help the team better understand the project, the multiple stakeholders, and the interagency collaborations. Also, thanks to the RCMRD GHG Team for helping organize meetings and coordinate logistics with national GHG partners in Malawi, Namibia, and Rwanda, and for accompanying the case study team to provide helpful insights and knowledge on the ground in those countries. The Demand team would also like to acknowledge and thank the more than 30 interviewees who gave their time to share their work and experiences on the GHG project.

ABBREVIATIONS

DAI	Development Alternatives Inc.
EPA	Environmental Protection Agency
ESA	Eastern and Southern Africa
ETM	Enhanced Thematic Mapper
FAO	Food and Agricultural Organization of the United Nations
GHG	Green House Gas
GIS	Geographical Information System
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use and Land Cover
LULCC	Land Use and Land Cover Change
NASA	National Aeronautics and Space Administration
RCMRD	Regional Centre for Mapping of Resources for Development
TM	Thematic Mapper
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
USGS	United States Geological Surveys

EXECUTIVE SUMMARY

The SERVIR Program Demand Activity – also referred to as the "SERVIR Demand Activity" or simply "SERVIR Demand" – was launched in July 2012 as a task order separate from the overall SERVIR Program managed by the NASA Coordination Office (CO) in Huntsville, Alabama. NASA's efforts have primarily focused on working with SERVIR hubs to develop and provide access to geospatial decision-support tools and information services – the "supply" of SERVIR program offerings. The key objective of the SERVIR Demand Activity is to help the SERVIR Program strengthen the capacity of SERVIR users to utilize the geospatial tools and decision-support applications created by the Program. In other words, the Demand Activity is focused on cultivating the demand for and increasing the uptake of user-friendly climate change decision support tools and applications supported by SERVIR, while building capacity of stakeholders to incorporate such data into development decision-making.

For the SERVIR Demand Activity, a critical first step in strengthening demand is to take stock of the suite of tools, products and services developed through the SERVIR Program and ensure it is well documented. The following report on the Greenhouse Gas Inventory (GHG) Land Use and Land Cover (LULC) Project was prepared in order to provide an in-depth case study of one of SERVIR-Africa's flagship projects. The SERVIR-Africa hub in Nairobi, hosted by the Regional Center for Mapping of Resources for Development (RCMRD), is responsible for producing national Landsat-derived LULC maps for two to three different time frames under the GHG project. At this stage, the GHG project is focused on six Eastern and Southern African countries. In addition to producing the LULC maps, RCMRD supported efforts in the six countries to build the capacity at the national level to produce similar maps in 2014.

The original intention of the case study was to identify the known users, elucidate additional potential users, and ultimately, generate opportunities for growth and expand the landscape of users for the information produced by the GHG Project. During the Demand team's fieldwork however, it became apparent that RCMRD was not intended to play a direct role in how or when information from this project was disseminated to users within the national-level governments of the partner countries. Furthermore, since the GHG Project is not expected to conclude until December 2013 or later, no data in its final form had been released to national-level users at the time this report was generated. That said, RCMRD's approach to producing the LULC maps included initial user engagement activities. This report identifies potential users based on these initial interaction as well as recommendations for increasing demand within the scope of RCMRD's role in this project.

The timing and specific mandate of RCMRD under the GHG Project altered the original direction of the country visits from documentation of what data had been received, disseminated, and utilized, to what might be done in the future to increase demand. The Demand team looks forward to taking these recommendations forward with RCMRD to enhance and strengthen the approach to data dissemination and the structure of the end of project wrap-up workshops scheduled to take place in each country in early 2014. These recommendations are detailed in the Finding and Recommendations Section.

In addition, an important indirect result of the Demand-led field research and in-country interview process was improved outreach and awareness-raising for the GHG LULC activities led by RCMRD among local scientists and organizations. More specifically, the in-country field teams (which included an RCMRD

scientist as well as Demand team staff) obtained suggestions on product format and dissemination processes to increase uptake and improve usability. While not a direct part of the Demand Activity mandate, these visits were also used to better understand how to build sustainable capacity at the national level for LULC mapping.

Based upon the information collected during the Demand team's field research, there is considerable interest from the ministries participating in the project in the LULC maps and other ancillary products produced by RCMRD. Unfortunately, most of the organizations visited had a limited, if any, effective knowledge of what the deliverables (including the associated LULC products) would be and the timing or process of dissemination. However, once they were informed of the primary LULC products that will be developed, the national-level GHG teams expressed interest in their potential use within various ministries for planning and change analysis. Typically maps of this type can be used at both national and local administrative levels for applications such as forestry, agriculture, transportation, mining and economic development among others.

While only three countries were visited, an obvious but critical observation is that conditions varied widely from country to country as well as internally from organization to organization within a country. The noted differences included internet speed, hardware, software, governmental organization and mandates relative to future LULC mapping, competing data sets, staffing and budgets. These differences require individualized approaches in data dissemination and future support in capacity building on a country-by -country basis.

As mentioned previously the original purpose of the report and the in-country interview process undertaken by the Demand Activity was to facilitate exchange and learning to illuminate when, why, and how SERVIR program tools and services influence decision-making processes. While it was not possible to identify stakeholders who were using data in their decision-making processes at this time, key potential users are identified in this report. The study did serve to build awareness among of the relevant stakeholders about the SERVIR-Africa's flagship project, and plans are underway to increase the effectiveness and reach of the end-of-project national workshops, which will increase demand among the relevant ministries in each country. In addition, what resulted was a better understanding of the initiatives and partnerships that SERVIR-Africa is undertaking with the GHG project. Finally, one of the key takeaways and unexpected outcomes was that this process served to encourage or facilitate data sharing among partners on the GHG project. In fact, more open dialog and continuous partner and user engagement may serve to encourage data sharing practice in this type of collaboration.

CASE STUDY REPORT

INTRODUCTION

The SERVIR Program Demand Activity – also referred to as the "SERVIR Demand Activity" or simply "SERVIR Demand" – was launched in July 2012 as a task order separate from the overall SERVIR Program managed by the NASA Coordination Office (CO) in Huntsville, Alabama. NASA's efforts have primarily focused on working with SERVIR hubs to develop and provide access to geospatial decision-support tools and information services – the "supply" of SERVIR program offerings. The key objective of the Demand Activity is to help the SERVIR Program strengthen the capacity of users to utilize the geospatial tools and decision-support applications created by the SERVIR program. In other words, the Demand Activity is focused on cultivating the demand for and increasing the uptake of user-friendly climate change decision support tools and applications supported by SERVIR, while building capacity of stakeholders to incorporate such data into development decision-making.

For the SERVIR Demand Activity, a critical first step in building demand is to take stock of the suite of tools and services currently offered by the SERVIR Program and ensure it is well documented. The following report on the Greenhouse Gas Inventory (GHG) Land Use and Land Cover (LULC) Project was prepared in order to provide an in-depth "case study" of one of the flagship projects of SERVIR-Africa, identify the known users, elucidate additional potential users, and ultimately, generate opportunities for growth and expand the landscape of users for SERVIR-Africa.

The SERVIR-Africa hub in Nairobi, hosted by RCMRD, is responsible for producing national Landsat-derived LULC maps for 2000 and 2010 for six countries under the GHG project. For three countries, 1990 maps were also created. The GHG project in its entirety covers eight Eastern and Southern African countries, of which RCMRD is providing technical support in LULC mapping to six of them, including Tanzania, Malawi, Rwanda, Zambia, Botswana and Namibia. The LULC mapping activity is part of a larger partnership project, called the Capacity Building for National Greenhouse Gas (GHG) Inventory Systems in Developing Countries, between the US Environmental Protection Agency (USEPA), US Agency for International Development (USAID) and the United Nations Framework Convention on Climate Change (UNFCCC). The objective of this broader project is to support capacity building efforts in developing countries to estimate and track GHG emissions.

OBJECTIVE OF THE CASE STUDY

The Demand Activity undertook research and in-country interviews to facilitate exchange and learning in order to illuminate when, why, and how SERVIR program tools and services had influenced decision-making processes. During this process, it became evident that the data had not yet been released to national level-users within the partner countries. As a result the focus shifted from documenting what data had been received, disseminated and utilized, to what might be done in the future to enhance the use of GHG Project data.

However, due to the timing of the research (no data had yet been released to national-level users) and the nature of RCMRD's involvement in the user engagement process, this report is focused on what might be done in the future to increase utilization and grow the user base for GHG Project data within RCMRD's

current mandate. In addition, the objective of this study is also to provide a more thorough understanding of the LULC mapping process, SERVIR-Africa's contribution to the broader GHG Project, and stakeholder engagement in the product development process to date. While there currently are no users of these maps and data, the case study still remains a critical first step in documenting the known audiences and potential users for a flagship SERVIR-Africa project, and provides recommendations on how to leverage upcoming meetings to best increase demand for these products. Finally, this initial information gathering is necessary for the Demand team as we work with SERVIR-Africa over the coming months to identify new opportunities and potential for expanding and leveraging the investments made under their GHG project.

METHODOLOGY

To establish an initial "baseline" of information, the Demand Activity team conducted an initial desk review of documents provided by NASA and RCMRD. Further information was obtained in two site visits. The first, which was conducted over two weeks in late June and early July 2013 in Nairobi, focused on gathering background information through document collection and interviews at RCMRD and participation in an ongoing LULC workshop hosted by UNEP. During this initial visit, the Demand team conducted interviews with members of the GHG team to gain insight into the history of the project, the mapping methods employed, the potential user groups, and collect documentation on the project. Prior to that visit a conceptual framework had been drafted to guide the case study, and those questions were used in discussion with SERVIR-Africa staff (see Appendix 1).

The second field visit was conducted in August 2013. The team traveled to three countries where ongoing LULC mapping was underway to better understand the user perspectives. Those countries were Malawi, Namibia and Rwanda. These countries were selected because they were at different stages in the mapping process, had varied climatic and LULC characteristics and had different internal spatial capacities. Each visit was approximately one week in duration and the Demand team representative was accompanied by a staff scientist from RCMRD (more details are contained in Appendix 2).

The field visits to Malawi, Namibia, and Rwanda included meetings primarily with governmental organizations as well as a few academic and other organizations such as the United Nations Development Programme (UNDP). The organizations and individuals engaged during these Demand team country visits were generally selected from those that had prior involvement with the project either in the initial 2011 Mauritius workshop, the national classification and ancillary data workshops, or the RCMRD provided LULC mapping capacity building.[1] A semi-structured interview protocol was created and is included in Appendix 5. The protocol and questions asked changed depending upon the organization visited. A list or these organizations as compiled by the Demand team is contained in Appendix 3. The actual organizations visited during these case study national visits are found in Appendix 4.

[1] RCMRD and national GHG coordinators took responsibility for scheduling meetings for this case study. Organizations were chosen that had some prior involvement with the RCMRD project, or based on simply availability. The concept of National GHG teams is vague, one of the problems in this effort.

LIMITATIONS OF THE STUDY

There are several important caveats that must be considered when reading this report. First, the RCMRD mapping activity is ongoing with a current anticipated closure date of 31 December 2013. This report is based on conditions as they existed on 1 September 2013 and not after project completion. During the collection of information for this report, no final data had yet been delivered to any of the six countries. It was discovered by the field team that USEPA—and not RCMRD—drives the decision of when to release data and in what format. There are many datasets near final completion; however it must be kept in mind that RCMRD does not have direct influence on when (and how) they are released to national governments.

Furthermore, because RCMRD plays only a limited role in the broader GHG Project, when discussing successes (i.e. dissemination to users or uptake by decision-makers) attribution becomes a complex issue. While RCMRD does play a significant part in the delivery and dissemination of the data and maps to national governments, they are not solely responsible for the release. In fact, USEPA has decided on a more cautious approach for the data delivery. USEPA intend to release these datasets, likely through RCMRD, in the next calendar year on a rolling schedule starting with Rwanda, Malawi, Zambia, and Namibia. In some countries, draft products had been provided for review (Rwanda), which will be discussed in the Findings and Recommendations section below.

Finally, mapping had been nearly completed for four countries and was ongoing or being initiated in Botswana and Tanzania at the time the field visits were conducted. The following section, as others in this case study report, was extracted from RCMRD reports and provides a summary on the origins of the RCMRD GHG LULC activity.

BACKGROUND ON THE LULC PROJECT

While many countries had made progress in preparing GHG inventories consistent with the requirements of the Intergovernmental Panel on Climate Change (IPCC), significant gaps in institutional capacity were preventing certain countries from completing the requirements. In response, the UNFCCC Secretariat and other partners launched the Capacity Building Project for Sustainable National GHG Inventory Management Systems in participating countries within ESA. During a scoping meeting for the project in 2010, it was determined that the project would provide support in the form of training and capacity building to relevant stakeholders in Botswana, Malawi, Mauritius, Namibia, Rwanda, South Africa, Tanzania and Zambia.

A follow up workshop, called the Regional Workshop for the Capacity Building Project for Sustainable National Greenhouse Gas Inventory Management Systems in Eastern and Southern Africa, was organized in Mauritius in March of 2011 to identify specific areas of support needed to build a sustainable GHG inventory management system in the eight countries. In addition to representatives of seven of the eight focus countries, attending organizations included the UNFCCC secretariat, Colorado State University, USEPA, ICF International, Food and Agriculture Organization of the United Nations (FAO), United National Environment Programme (UNEP), IPCC and RCMRD (more details on the participants are contained in Appendix 3).

The overall conclusion from the workshop assessment process was that the eight countries did not have sustainable GHG inventory management systems. Previous GHG inventories had in most cases been produced on a short-term ad-hoc project basis with the goal of fulfilling reporting obligations to the

UNFCCC, namely submission of the National Communications. Other gaps and constraints identified in the workshop included:

- Inadequate institutional arrangements and the need to institutionalize the inventory in the government;
- Lack of awareness on the importance of GHG inventories within the development agenda;
- Limited application of good practices as recommended by the IPCC;
- Insufficient active data collection;
- Need to develop an archiving system for better storage of inventory data;
- Poor documentation of methods and tools;
- Unsustainable development of resources;
- Need to develop more accurate emission factors instead of using default emission factors for country-specific activities, particularly for key sources; and
- Insufficient capacity and research for developing country emission factors.

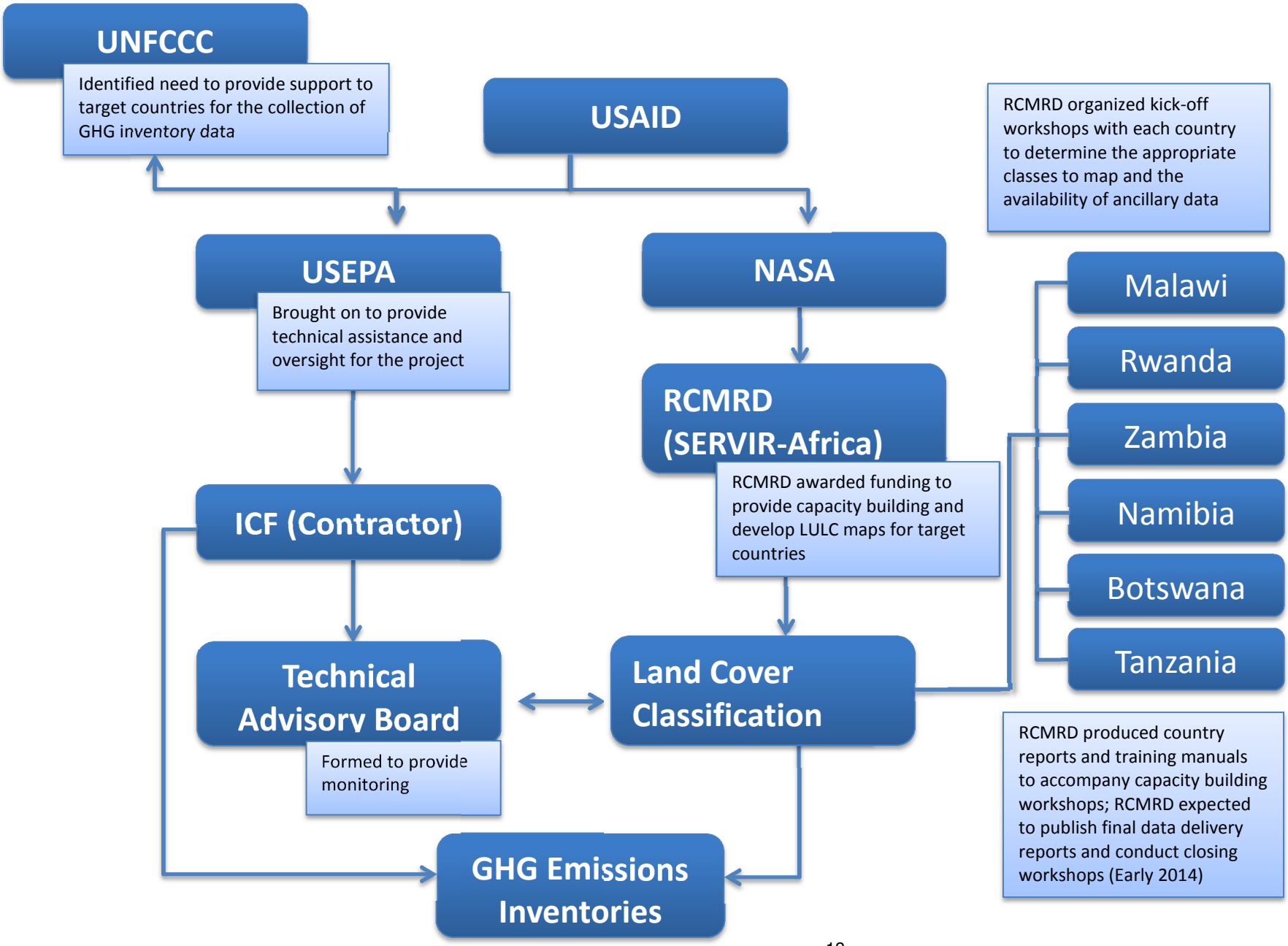
It was determined that a Capacity Building Project would address these gaps and constraints through training sessions with emphasis on LULC mapping, which is a significant contributing component in national GHG balances. In addition, the project would produce well-documented, good quality LULC maps for the eight focus countries during the first phase of the project (from 2011 – 2013).

RCMRD INVOLVEMENT

The overarching GHG emissions inventory effort is complex and non-linear. The ESA GHG emissions inventory effort was a joint USEPA and UNFCCC effort, partially funded by USAID. USAID/Washington staff connected the SERVIR program to the USEPA group, who were planning to develop rudimentary land use land cover (LULC) maps for the countries they were engaged in. Given RCMRD's strong LULC mapping capability and past experience, USEPA was happy to hand over the land cover mapping work, as long as the effort was well coordinated. Working in close collaboration with USEPA, RCMRD developed a proposal to the SERVIR Coordination office (NASA), which was accepted and funded using USAID monies. The project is ongoing, and a joint technical advisory board closely monitors the progress. However, USEPA did not have a direct collaboration with RCMRD, nor did USEPAs funding and collaboration with UNFCCC factor directly into RCMRDs effort. The RCMRD LULC mapping effort is considered a joint "sister project" to ensure the needs of USEPA are met (see Figure 1).

Based upon their regional mandate, their role as a SERVIR hub, and existing capacities, RCMRD was selected to develop a framework for each of the target countries to support LULC mapping according to IPCC methodologies. Furthermore, this effort was already well underway by RCMRD before the Mauritius meeting. The goal of RCMRD was to produce an approach to LULC mapping that could be shared and vetted with representatives from each of the target countries. Once the approach was developed, RCMRD planned to obtain required input from the country's representatives by April 2011. Adjustments would then be made to the draft plan based on feedback from sectoral experts within each country, and then the process would be implemented. Developing the maps was an essential, but potentially long-term effort that needed to be initiated in the very early stages of the GHG Inventory project to be completed in a time frame that met the project objectives.

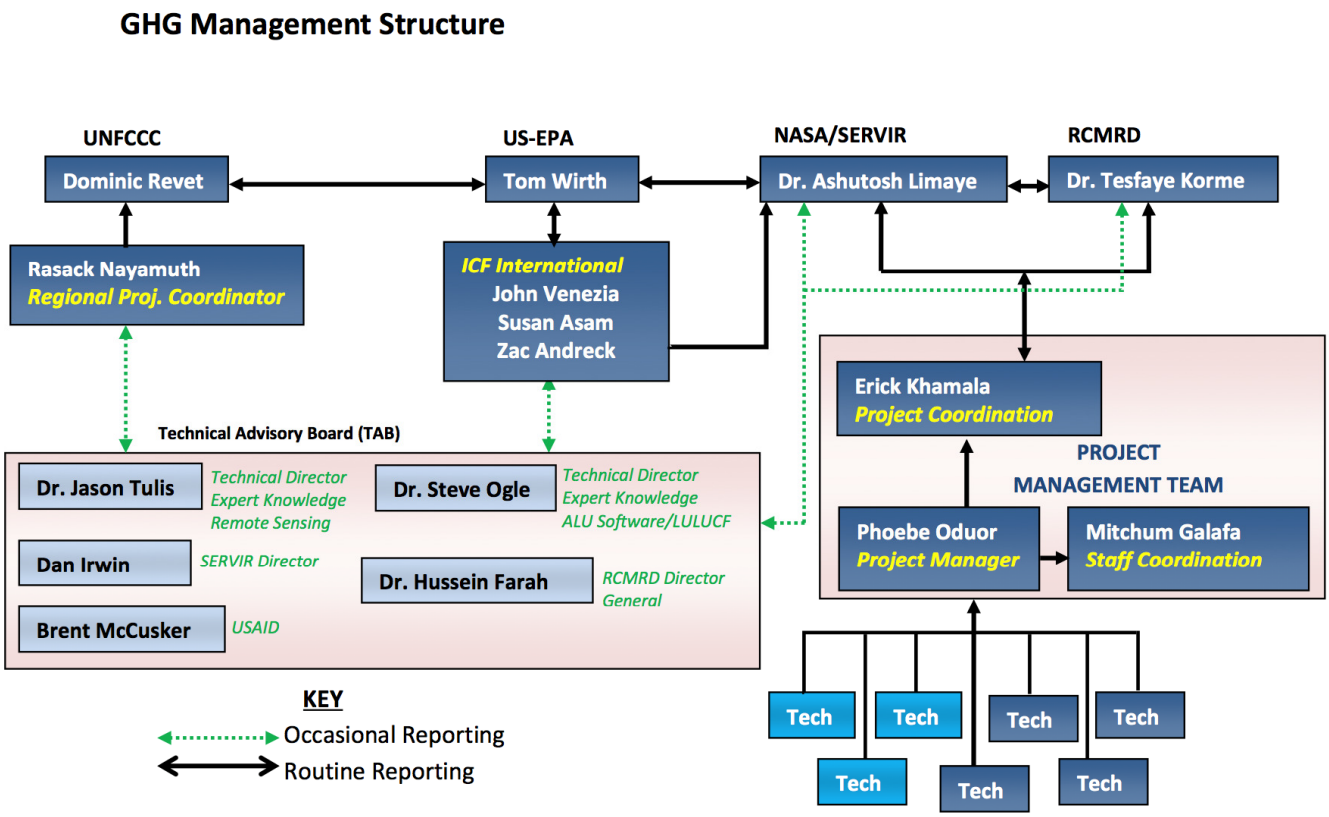
Figure 1: RCMRD Involvement in GHG Emissions Inventory Effort



Based upon the endorsement of the Mauritius meeting participants, and after submission of a proposal to SERVIR-NASA in May 2012, RCMRD was awarded funding to provide capacity building and development the LULC maps for this ESA project. While the RCMRD mapping work was under the auspices of the UNFCCC's GHG Inventory, in reality they worked mostly with the USEPA, who played the role of technical intermediary and middleman. The UNFCCC is interested in the inventory numbers being reported out from each country. The means to do this was left to the USEPA, which has technical experience in this area. They worked closely with RCMRD while the LULC maps were being developed and were able to ensure technical integrity.

Figure 2 contains the organizational structure for the LULC mapping component. The activities were focused on six ESA countries only as shown in Figure 2, since Mauritius and South Africa opted to complete their own maps. RCMRD would map all six countries for 2000 and 2010. RCMRD also mapped Rwanda and Malawi for 1990 and Zambia scientists internally mapped their country for 1990. The following section summarizes the mapping procedures by RCMRD.

Figure 2: RCMRD GHG LULC project management structure



Source: Technical Proposal, Land Cover Mapping Component of the Capacity Building Project for Sustainable Greenhouse Gas Management Systems in East and Southern Africa, (ESA) Region, RCMRD, 2012. Updated November 2013.

Figure 3: The six participating countries in the RCMRD GHG LULC mapping activity

Source: U.S. EPA African Activities Supporting National GHG Inventory Mapping in Six ESA Countries, P.Odure RCMRD scientist, Presentation, International Symposium on Land Cover Mapping for the African Continent, Nairobi, 2013.

RCMRD LULC MAPPING PROCEDURES

One of the most significant observations from the Demand-led field research was that RCMRD followed textbook scientific procedures to generate excellent maps. In addition, the field team noted that the framework RCMRD employed to define, gather, and include ancillary datasets proved highly successful. The resulting overall LULC map accuracies, generally in excess of 80 percent, which exceeds normally accepted industry standards[2], document the quality of the maps. The effort is particularly impressive given the amount of data processed and the number of maps and reports produced in a very limited time frame.

The methodology for accuracy assessment was also seen as a success by the Demand team. To achieve 80% accuracy, RCMRD is now using a combination of collected *in situ* data for field validation in

[2] The accuracy of LULC maps are determined by designing and implementing an accuracy assessment, often comparing classified satellite date with field data collected on the ground.

addition to independent point interpretation of the Landsat images,[3] which allows them to have good coverage for the entirety of each country. Using a dot matrix also corrects temporal issues between the time in which the classification references and the time data is collected in the field. This has been completed for Namibia, Botswana, and Tanzania and the RCMRD team plans to follow the same approach to complete the accuracy assessment for the other GHG countries.

To launch the mapping process, RCMRD science staff had a series of interactions with the individual country scientists to identify an approach that considered each country's specific requirements for developing the LULC map. This included different procedures in each of the six countries as a function of varied climates, cultural features, landforms and availability of existing data to support the mapping activities. For each country there was an initial workshop to determine the appropriate classes to map, typically 12 to 15, and the availability of ancillary data that might be employed in the mapping. Those initial workshops resulted in very detailed, professional and informative reports. RCMRD produced, with national counterpart input, a lengthy second report for each county (typically about 80 pages) fully describing the process for mapping.[4] RCMRD also developed training manuals to accompany these initial capacity building workshops. Finally, they will also publish end-of-project data delivery reports and conduct closing workshops, most likely to be held in the beginning of 2014.

All mapping was based upon Landsat Thematic Mapper (TM) or Enhanced Thematic Mapper (ETM) imagery which is free and can be downloaded from the US Geological Survey website. These are seven band images at 30 m spatial resolution. The basic procedure was data acquisition and preprocessing, spectral signature extraction for the classes of interest, signature evaluation using separability measures, application of a maximum likelihood decision rule, visual editing for quality control and assurance, accuracy assessment primary using field verification and final compilation and reporting. As stated, the procedures and the resulting accuracies were excellent.

One particularly effective practice noted by the Demand team was that RCMRD organized national workshops to both establish country specific classification systems for the LULC maps but also to identify and collect ancillary data to assist in the classification of the satellite imagery. The type of ancillary data varied from country to country and some examples included existing LULC maps, annual agricultural census, periodic land use surveys, existing forest maps, relevant reports and publications, ground reference locations, high spatial resolution imagery and any other remote sensing data. The availability of these data was a critical initiative for establishing a baseline for GHG inventories.

More importantly for the Demand team purposes was the fact that these initial, country-specific ancillary data collection workshops served as a platform for involvement of key national stakeholders (see Appendix 3). These meetings also form the core potential user base for these LULC products down the road. RCMRD also promoted openness in data collection, processing, application, sharing and archiving as discussed and agreed upon in the workshop. During these sessions, the national GHG inventory development team provided information on the availability of the required data and identified key national stakeholders who would be interested in utilizing the products from the LULC mapping.

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[3] Based on methodology from Stehman, S.V., 2001, Statistical rigour and practical utility in thematic map accuracy. Photogrammetric Engineering and Remote Sensing, 67, pp. 727–734.

[4] The reports describing the mapping process for each country are detailed and extensive and are a helpful resource, which can be obtained from RCMRD.

In addition, an assessment of the capacities of the national institutions involved in LULC mapping was ascertained and in consultation with the country teams, a preferred classification scheme was determined. The LULC classes considered in this effort included 12-15 country-defined categories, including variations of forest types, grassland types, cropland types, wetlands and other lands whose sub-categories were informed by the national policies and mapping goals, definitions, and descriptions. As a result, the classification for each country mapped by RCMRD was more detailed and specific than the two classes required by the IPCC.[5] A more detailed summary of the RCMRD mapping process was extracted from a review of those reports and is found in Appendix 2.

The Demand team received positive feedback from the USEPA officials and consultants involved in this project and they affirmed the excellent work done by RCMRD on the mapping effort. The USEPA officials cited the complexity of the task and acknowledge that the effort required a high level of coordination across many disparate countries. USEPA mentioned that RCMRD's network in the region has also been a critical factor in their ability to develop these maps – an undertaking seldom tried at this scale and rarely successful on any scale. RCMRD started with little knowledge of the IPCC requirements for this type of analysis, but according to the feedback the Demand team received from USEPA, they learned quickly to produce successful results. Overall, the USEPA considers this project a success and are pleased with all aspects of RCMRD's technical work.

[5] The IPCC only requires two classes for global consistency, defined as Scheme 1 and 2 (which includes these 12-15 classes used by RCMRD).

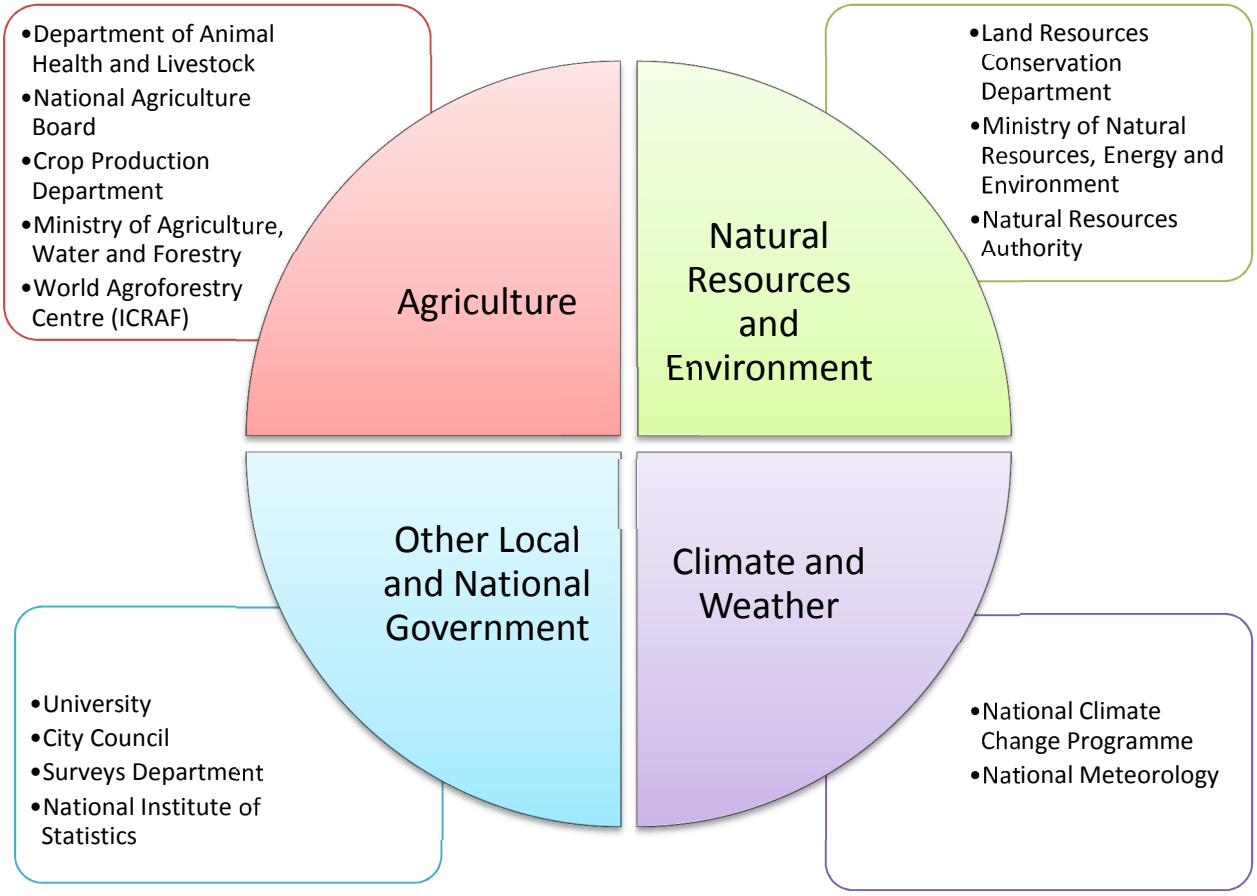
FINDINGS AND RECOMMENDATIONS

The following section describes the key observations and recommendations in three areas: 1) Potential users and user groups; 2) data dissemination to increase demand; and 3) building capacity at the national level for LULC mapping.

POTENTIAL USERS AND USER GROUPS

As of the preparation of this report, none of the RCMRD final LULC products has been delivered to the national level governments in the target countries. That effort is currently planned to take place during the end-of-project workshops in each country. That said, RCMRD did conduct some initial user engagement activities through the kickoff workshops in each country. From these initial national-level meetings, a picture of the landscape of potential users emerges.

Figure 4: Potential user categories based on participation in the LULC mapping meetings



Source: RCMRD stakeholder participant lists from Rwanda, Malawi, and Namibia.

Different government ministries and departments such as forestry, agriculture, environment, surveys and mapping, land use and planning, water, natural resources, and wildlife have all been active in the GHG LULC process and will benefit from the final results. Other groups such as international organizations, NGOs, universities, and research institutions are also likely potential users. Based upon the country visits, there will be considerable interest in the RCMRD products and particularly the LULC maps.

Unfortunately, most of the organizations visited had a limited, if any, effective knowledge of what the deliverable products would be and the timing or process of dissemination. However, when informed of the primary LULC products there was expressed interest in their potential use within various ministries for planning and change analysis. Typically maps of this type can be used at both national and local administrative levels for applications such as forestry, agriculture, transportation, mining and economic development among others. Some illustrative applications based on these categories of users are listed in Table 1 below.

Table 1: Illustrative applications for LULC products by potential user category

User Category	Illustrative Application
Agriculture	Crop maps and food security planning
	Hydrological mapping
	Forest inventory maps and forest management
Natural Resources and Environment	Protected areas management
	Corridor and biodiversity planning
	Extractive industries management
	Rangeland Management
Climate and Weather	Adaptation planning
	Flood/water management
	Disaster risk reduction planning
Local and National Government	Adaptation planning on local and city level
	Urban planning
	Infectious disease research and planning
	Waste water systems
	Education and research

A simple word cloud analysis of titles from attendees in participant meetings also gives some indication of the range of potential users already engaged with RCMRD through the mapping process (Figure 5). For example, titles such as Senior, Officer, and Director appear more frequently (and thus appear larger in the word cloud), indicating many higher-ranking individuals have participated in GHG meetings. These higher-level officials are more likely to have access to policy-makers, which could facilitate knowledge around and uptake of GHG products in their institutions.

Figure 5: Word cloud displaying titles of stakeholders engaged during GHG LULC meetings in Rwanda, Malawi, and Namibia.

Source: RCMRD stakeholder participant lists from Rwanda, Malawi, and Namibia.

The delivered products will include the LULC maps for various dates, the Landsat TM imagery, the ancillary data employed in the mapping, reports, statistics, posters in pdf format, and the field validation data. In all countries visited, there was considerable interest in obtaining the RCMRD data. As mentioned previously, this case study focused on understanding the country specific situations and making recommendations to support enhanced dissemination and demand of these SERVIR-Africa data sets. These detailed recommendations are included in the section below.

DATA DISSEMINATION TO INCREASE DEMAND

RCMRD is currently contracted to hold one-two day workshops in each country, bringing together senior level policy makers and decision-makers from different ministries to explain the datasets, give context to the information being disseminated, and help users and beneficiaries understand what knowledge can be obtained from these datasets. These meetings are followed by a technical workshop to train local users in how to process the data independently in order to generate data for the UNFCCC reporting in the future.

Originally, the GHG focal point in each country planned to convene these meetings – including sending out the invitations and selecting whom to invite to the workshop. However, the ability of the focal points to convene and organize these workshops depends on how well networked they are, which varies greatly from country to country. Some are very involved and are actively looking for donor funding to augment the training RCMRD is planning. On the other hand, in one case the focal point is located within the

private sector and this presents a challenge to building linkages and fomenting connections with ministry officials. In this case, for instance, an email requesting attendance for an event from an unknown person is likely to be given less priority, or even ignored.

After meetings with the Demand team, it was recommended that RCMRD be given support (from the Demand team) to provide additional pre-meeting dialog with the relevant ministries to help explain the importance of these workshops, what will be disseminated, and why it would be important for them to attend. This upfront work with the end users and beneficiaries of the data will help sensitize the users to the information in ways the focal points may not be able to achieve alone, and will help ensure high attendance of the most appropriate users. It will also leverage the investment already undertaken to develop these maps and datasets to broaden the user base of these data. These pre-work one-on-one meetings will also allow for the ministries to help decide whom to send to the technical trainings to ensure the correct technicians attend.

While no data have been disseminated at this point, one exception to releasing maps did occur during the Demand team visit to Rwanda, where the GHG national team coordinator began to request initial maps or data since there was a case study team coming to visit. Due to his persistence, and RCMRD's involvement in a local visit, the USEPA decided to release initial LULC information to Rwanda. The approval process for data dissemination is still somewhat unclear, and there are definite political sensitivities surrounding how and when data are released by the USEPA, so it is beyond the direct authority of the SERVIR-Africa GHG Team.

Internet Data Posting

The Demand team recommends posting the primary RCMRD LULC map products to more than one site on the web. Possible options for this would include the SERVIR global site (www.servirglobal.net), the RCMRD regional site (www.rcmrd.org), as well as country specific ministries or country specific national spatial data committee sites. Making resources available on the web alone, however, will not necessarily ensure uptake and use. It was clearly indicated during the Demand team's field research that some organizations simply do not have the internet speed to download large spatial data sets. A partial solution is to simply post the metadata and a procedure where an interested organization or scientist could request data via physical media. Regardless of how the data is posted via the web however, by itself it is not a sufficient dissemination vehicle.

National Spatial Data Infrastructure Committees

It was initially expected that national spatial data infrastructure committees (there are other terms for these coordinating units, including RCMRD's National Geo-Information Committees) would have a useful role in the RCMRD LULC project data dissemination and raising awareness. These committees could also potentially serve as knowledge centers for spatial data standards and distribution policies. While several countries conducted initial committees meetings, they are generally in an early stage of development relative to time frame for the RCMRD project deliverables under the GHG Project.

Furthermore, data distribution policies or pricing structures were not identified as being a concern in the field visits. There was general agreement that data should be freely disseminated, which is consistent with SERVIR policy. From the Demand team meetings, it was determined that national spatial data infrastructure committees are not sufficiently established to be a sole repository for RCMRD LULC project data at this time, but this idea does hold some promise for the future.

Raster Versus Vector Data Format

The RCMRD LULC national maps are based on Landsat TM imagery and as such, are 30m raster-based. Most Geographic Information System (GIS) software is vector-based and thus potential users of the RCMRD data are vector-oriented. Raster to vector conversion is typically not considered complex, but there are nuances in the process (i.e. polygon size or minimum mapping unit and smoothing of the data, which requires evaluation).

A vector product is not part of the RCMRD statement of work but it would appear in the best interests of all parties to have RCMRD evaluate the best vector conversion method and provide both vector and raster LULC products to the countries. Defining a single vector conversion method would also remove the potential complication of multiple organizations within a country producing different versions of vector-based data. In addition, a number of visited organizations indicated a preference for these maps in vector rather than raster format. This is very reasonable expectation and should be given extensive consideration by SERVIR Program as an additional deliverable to expand the user base for the GHG Project data.

Competing National LULC Products

There are an increasing number of donors and international organizations producing satellite-derived LULC maps typically on a country, rather than a regional basis. These activities are generally not well coordinated, which has resulted in duplication of effort and inefficiencies. Countries are also increasingly producing LULC maps with internal resources. These competing efforts, while potentially useful, can actually be counterproductive as multiple maps create uncertainty and confusion within a country on how to harmonize multiple maps. Or worse still, duplicative maps can lead to using different maps for different purposes, such as agencies will use different maps for planning and decision-making.

For example, one country had four national LULC maps recently provided, including the maps to be delivered by RCMRD. Another country had an ongoing national LULC mapping effort using orthophotography. While it is not the responsibility of the Demand Activity to resolve these overlapping activities, it is important to note that the RCMRD LULC products may not be unique. In addition, if the SERVIR-Africa products are not seen to be the best for any specific purpose, growing the user base and strengthening demand may have additional challenges.

Posters and Flyers

RCMRD has produced excellent large-format posters of the LULC maps by country for individual years and for multiple years (see Figures 6– 8 in Appendix 2). These have also been prepared in PDF format for country dissemination. While RCMRD has not been called upon to produce physical posters and distribute them, this may be useful for some countries, as they may not have the resources, functioning hardware, supplies or budget, to produce multiple copies in country. With SERVIR-Africa support, it may be beneficial to distribute multiple copies of these posters at the end-of-project workshops to increase awareness and improve outreach. In addition, SERVIR-Africa or the Demand Activity may consider production simple one-page flyers by country for distribution at the national end-of-project workshops as well.

LULC Change Statistics

Many natural resource and economic development decisions are based upon change over time. Scientists and technocrats evaluate change over time for various parameters and then model or predict future changes under different scenarios or management constraints. The SERVIR-Africa LULC maps were produced for two to three epochs for the six countries. This provides the opportunity to obtain excellent LULC Change (LULCC) statistics. These statistics could be generated nationally and perhaps more

useful, would be to generate them at lower order administrative districts or even watersheds. While not within the current mandate of RCMRD, providing these detailed statistics would be extremely useful to decision-makers and relatively easy to generate.

Potential Scalability and Replicability

RCMRD will be delivering a variety of data products to each country, including the LULC maps, the original Landsat TM imagery, reconstructed ancillary data with metadata, reports, statistics, posters in pdf format, and the field validation information. While the primary data are the LULC maps, effort should be made to increase awareness and strengthen outreach around all of the deliverables and their potential uses.

Certainly, the Landsat imagery could potentially have multiple uses by different national organizations. The field validation data in particular could be very useful in future LULCC assessments, where a consistent sampling scheme might be employed. For those countries, which provided ancillary data to RCMRD to assist in the mapping effort, the return of those data sets with improved metadata and in some cases improved formatting, could assist in planning and multiple GIS applications. In addition to governmental organizations, these additional products could be useful for university educational and research activities.

Distribution

The full RCMRD GHG country data sets are very large as they include not only the LULC maps but also the original Landsat imagery, ancillary data, reports and field validation data. It would not be efficient to distribute the full data sets to multiple agencies in each country. However, it was suggested during the country visits that a subset of the most useful data, the actual LULC maps, might be placed on a standard media (such as DVDs or flash drives) and distributed to multiple national organizations, including both governmental and academic. This would insure much wider availability and potential use of the data. The size of a LULC raster map for Rwanda is about 3.27 MB and for Namibia 2.04 GB. These are viable sizes for multiple distribution media and to increase broader use of these data, it is recommended that RCMRD distribute the primary LULC data on individual media to multiple organizations at the end-of-project workshops.

CAPACITY BUILDING FOR LULC MAPPING

RCMRD conducted LULC training in Nairobi for each of the six participating countries. Those training programs were two weeks in length and each country could nominate two participants. Some countries, using additional funding, sent more participants. The training was based upon either ERDAS IMAGINE or ENVI image processing software, depending upon the availability of software in the targeted country. The training manuals for this capacity building were excellent. The intent was that each country would establish internal capacity to produce their own maps in 2014 according to the IPCC requirements.

While not directly related to the Demand Activity, the capacity building effort by RCMRD was a significant component of their involvement in the broader GHG Project. As such, some consideration on the status and potential enhancement of this capacity building effort was included in the field research and in-country interviews.

Organizational Mandates

The most critical issue in building a sustainable capacity for national LULC mapping is a clearly provided and accepted mandate by an organization within the governmental structure of each country. These institutional arrangements have not occurred in all of the countries that have received RCMRD training

and support. This has resulted in an inefficient expenditure of resources as many organizations without an institutional mandate to continue LULC mapping have sent scientists to receive training.[6] A related issue is that at least one country, and perhaps others, contracts to the private sector to implement much of their geospatial activity. Therefore training to governmental scientists may not be useful in cases such as these.

Going forward, the Demand team recommends that a condition of capacity building and training support provided by SERVIR-Africa should be that a clear mandate be provided and accepted by a specific governmental unit for this task be made. Capacity building should be coordinated with that unit.

Internet Speed and Capacity

Internet speed varies from country to country and between organizations within a country. Limited internet capacity is an issue for data dissemination from the LULC mapping activity, as previously described, but also for future in-country mapping. Landsat TM data have been identified as the preferred data source for the LULC mapping for a variety of reasons, but primarily because it is free and can be downloaded from the USGS web site. However, these are large data sets. A single image is greater than 300 MB and multiple scenes are needed per country.

A solution to this potential difficulty is for RCMRD to be retained as a technical center of excellence to support future GHG LULC national mapping in the regions. In this role, their primary responsibility would be to disseminate imagery as necessary, which could be done on physical media.

Hardware and Software

Image processing of country data sets (such as those based on Landsat TM) is a very data-intensive activity, which requires large data storage capacities and considerable processing speeds for most approaches. These hardware requirements are becoming less of an issue in many countries, but are still important factors for capacity building efforts. Viable hardware provided by each country should be a consideration or requirement for future capacity building. To some degree, lower capacity hardware can be viable if there are multiple platforms and simpler data analysis procedures are employed.

Software, on the other hand, is of greater concern for capacity building efforts in national LULC mapping. The RCMRD training was provided on either ERDAS IMAGINE or ENVI, both commercial packages which are expensive and require annual license renewals. Many countries do not have these packages or the ability to maintain the licenses. For example, the Demand team visited one governmental organization with excellent hardware and software provided under a bilateral project which had recently closed. The organization requested license renewals from their administration for their suite of software, but were not optimistic about receiving the over $34,000 USD in funding. These issues should be anticipated and avoided. There are open source software packages both in image processing and GIS that could be employed for national LULC mapping. They would use different procedures than ERDAS or ENVI, but they are viable methods.

For future capacity building efforts, RCMRD should determine the hardware and software capacities in the national organization mandated to do the mapping and tailor training to those capacities – including

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[6] Zambia is one of the clear exceptions in the region, as they have internally created the 1990 LULC map after receiving RCMRD capacity building and other external support.

the potential to use open source software. The software could then be packaged with training materials and some data sets for dissemination.

Accuracy Assessments

One of the strengths of the RCMRD LULC mapping was their rigorous scientific assessment of the accuracies of the maps. This was done with extensive field visits for validation. Typically hundreds of points were visited and in one country, about 1400 points. These are excellent procedures, but complex and typically expensive to implement.

The methods and costs of future national mapping accuracy assessments should also be considered in capacity building as there are several options. The best, but most expensive, would be for the mandated national organization to have the budgetary resources to replicate these field validations. A second option might be to create a network of collaborating governmental officers, such as district forestry or agricultural staff, to assist in the field work – which would likely be less expensive and perhaps more accurate that use of a national office. A third, but less desirable option, might be to establish surrogates for field validation. Some examples of surrogates could include third party interpretation of the original imagery or possible use of other sources, such as Google Earth. Future effective LULC mapping may require that national capacity building for map accuracy assessments be placed in the context of individual country resources, and not simply a regional solution.

Timing and Staff Availability

As mentioned previously, the lack of organizational mandate as well as the availability of hardware and software affects the sustainability to conduct LULC mapping at the national level. Another critical factor in the efficacy of capacity building efforts is the timing. For instance, there was a considerable lag between when the RCMRD training occurred and when the national mapping would occur, typically in 2014.

One suggestion proposed during the in-country interview process was to distribute the mapping responsibilities to a more local level, such as administrative districts. This has the advantage of an increased number of scientists with more local knowledge and in proximity to the field for calibration and validation efforts. It has the disadvantages of potentially more complex management, more issues in consistency, data distribution of the original imagery, and availability of software and hardware at the local administrative levels. Clearly, there are various models for training for LULC mapping, but they need to be tailored by RCMRD based upon individual country situations.

CONCLUSIONS

RCMRD produced excellent LULC maps for multiple dates for six countries. The scientific rigor was exceptional as was the willingness of the analysts to vary their approach from one country to another. The overall thematic classification accuracies of over 80% are indicators of the quality of this work. RCMRD also produced multiple detailed country-specific reports on all phases of this activity and all work was accomplished in a remarkable short time. Because of this excellent work, there is no surprise that the Demand field team encountered high interest in obtaining products from this project in Rwanda, Malawi, and Namibia.

As mentioned previously, as of the preparation of this report no final products had been delivered. That effort is slated to occur during the end-of-project workshops in each country, most likely starting in February 2014 (though the Demand team's experience in Rwanda is an indication that it is possible for countries to obtain the data earlier). In order to strengthen and enhance demand among these national-level users, the Demand team plans to support pre-work visits to encourage participation in these workshops. The goal of these additional consultations will be to explain the benefits of these datasets to the right end users and support RCMRD to augment and leverage USAID and other donor's investment in the GHG Project. Both RCMRD and the Demand team are hopeful that these user engagement activities, conducted prior to the end-of-project workshops, will serve to expand the potential user base across many ministries that may not know to take advantage of the information now available through the LULC maps.

Based on the field research and in-country interviews, the Demand team identified several other opportunities to enhance data dissemination and strengthen demand for the project data. Those suggestions include creating vector LULC maps in addition to the raster version, determining lower level administrative district LULCC statistics, distributing copies of the primary data to multiple ministries and academic organizations in each country as well as distributing large format LULC maps and awareness flyers at the end-of-project national workshops.

There is also a need for continued and focused national capacity building for future country-driven LULC mapping. In order for this effort to succeed however, each country will require a clearly mandated organization for these mapping initiatives in order to receive assistance. Finally, future capacity building should be county-specific based upon available resources and as appropriate, include open source software.

The primary responsibility and mandate of RCMRD for this project was to produce data for the GHG Inventory and to provide software training, not to work with national governments to disseminate the LULC mapping products and ensure their utilization. As such, RCMRD's role is limited to providing support to the countries to submit their findings to USEPA and the UNFCCC. Most of the opportunities listed above to strengthen demand and improve capacity building efforts are not funded under RCMRD's mandate.

That said, the Demand team suggests that RCMRD maintain continued engagement in the project to provide additional deliverables to strengthen demand and increase awareness, as well as to serve as a technical backstop for future country-based LULC mapping mandated under the UNFCCC. It would be advantageous for these funding decisions to be resolved soon, preferably before the end-of-project data distribution workshops.

Finally, while the main purpose of this study was information gathering for the Demand Activity, one of the key takeaways and unexpected outcomes was that this process served to encourage or facilitate data sharing among partners on the GHG project. In fact, more open dialog and continuous partner to user engagement may serve to encourage data sharing practice in this type of collaboration.

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APPENDIX 1: CASE STUDY CONCEPTUAL FRAMEWORK

During the initial visit to RCMRD in June 2013, the Demand Team conducted interviews with members of the GHG team to gain insight into the history and methodology of the project, the current user groups, and any background documentation that has been produced that was unavailable to the team previously. A conceptual framework for the case study was used during the initial meetings, and was also the basis for the country protocols found in Appendix 5.

I. History/Background

a) How did it originate? When and why did the Hub accept this task? What problem or challenge does the project address?
b) Who are the intended users and beneficiaries of the products generated by the project?
c) Who funded it?
d) What organizations or partnerships are involved, including NGOs, research institutes, donors, etc.? (What are the roles of NASA Coordination Office, and others?)
e) Who does training/capacity building? What activities have been held?
f) How did the project leverage SERVIR?
g) What workshops/activities/meetings have been held? Country specific and regional?

II. Methods

a) What procedures are being employed by Hub and what by methodological documents (if any) are being accessed/developed for this?
b) What is the role of users in the project at various stages? (E.g., scoping, data acquisition, methodology development, "requirements" setting, etc.) What tools (e.g., workshops, exchanges, meetings, etc.) have been used to engage users? (Similar to I (g) above, but specific to user-analyst interactions)
c) How are data being classified and is it consistent across all dates and countries? What is the hierarchical structure? (Note: Will look at data sources, Landsat MSS and TM, relative balance. Specific date/anniversary or multidate). (RCMRD specific)
d) Was there any inclusion of any ancillary data such as DEMs, etc. (RCMRD specific)
e) How have the following been performed: Image preprocessing, mosaicking, rectification, resampling, atmospheric correction or compensation. (RCMRD specific)
f) What classification procedures have been used? (pixel or object based, calibration signature extraction methods, decision rule, data mining?) (RCMRD specific)
g) What was the minimum mapping unit? (RCMRD specific)

h) What validation/accuracy assessment methods were used and what were the results? (RCMRD specific)

III. Current Users

a) Who has access?
b) Who is using it?
c) In what department or unit do these users work, and under which Ministries or agencies?
d) How are they using it? What for? Impacts resulting from use of the products? (Again, maybe too early, in which case, desired impacts)
e) Have any user profiles been developed?

IV. Product(s) Description

a) What does the Hub consider to be the "products"?
b) What are the services coming out of this?
c) What are the "tools"?
d) What is the data/product format? (map? raw data? etc.)

V. Distribution

a) How is the product being distributed?
b) Is it being tracked?
c) Is the distribution active or passive?
d) Will the imagery and LULC maps as well as documentation be available for all maps and data from the RCMRD website? When? Will there be search mechanisms such as Landsat path/rows, administrative units or watersheds? For how long and under what arrangements will this be maintained? (RCMRD specific)
e) What data will be provided to each country and in what format? Will this include imagery, maps, statistics, reports, metadata? What is the process/media of delivery?
f) How might other organizations utilize the SERVIR data in each country? Discuss a process of involvement and/or dissemination.
g) Other data applications?

VI. Opportunities

a) What opportunities and constraints do they envision for the future of the project/product?
   i) Expanding upon existing
   ii) Developing new
b) Identify new users? New ministries to make the data available based on identified applications.

VII. Status

a) What is the timeline?
b) Where are they right now? (Status by country of mapping completion and data delivery, SMS, training, etc.)
c) What's next? End date?

d) Staffing changes/challenges? (mostly an RCMRD issue)

VIII. Future Activities

a) Is it (the product) sustainable?[7]
b) Any new plans on the horizon?
c) What additional capacity building and technical assistance will RCMRD conduct in the future and under what time frame? Web support, software dissemination, etc.

IX. Recommendations

c) Data distribution and data sharing policies

Note: Most of this section will come out of the data gathered, so there are not specific questions to be asked.

[7] This is a broader question the Demand Team will be looking into based on information received from the case study based on staffing, methodology, capacity, etc.

APPENDIX 2: RCMRD LULC MAPPING PROCEDURES

RCMRD produced with national counterpart input a lengthy report for each county (typically about 80 pages) describing in detail the process for the LULC mapping. This appendix is a condensation of the mapping procedures as extracted from one of those country reports.

DEVELOPMENT OF CLASSIFICATION SCHEMES

One of the most important and difficult steps in planning a LULC classification effort is selection of the categories to be discriminated in the mapping effort. The classification scheme should be compatible with the existing systems and yet represent the unique country characteristics. Numerous existing classification schemes were studied to help guide the structure and categorical detail of the GHG scheme and most importantly, the classification scheme used was informed by country specific interests, definitions, descriptions, mapping goals and policy statements and documents.

The IPCC guidelines played an overarching role in developing the classification scheme that meets the country specific mapping standards and that can be related to the IPCC categories. The following are the IPCC categories with their respective codes.

Scheme I: Six IPCC Classes as the bare minimum—tier 1, (All sub-categories gets rolled up to the bare minimum)

10 – Forest lands

30 – Grasslands

40 – Croplands

50 – Wetlands

60 – Settlements

70 – Other Lands

255 – No Data

The sub-categories were agreed upon by the national teams in consultative forums and workshop sessions and were based on either the government policies or on previous classifications in the event of a lack of or inadequate policy provisions. The following are the most common sub-categories used to create level II discriminations for this project.

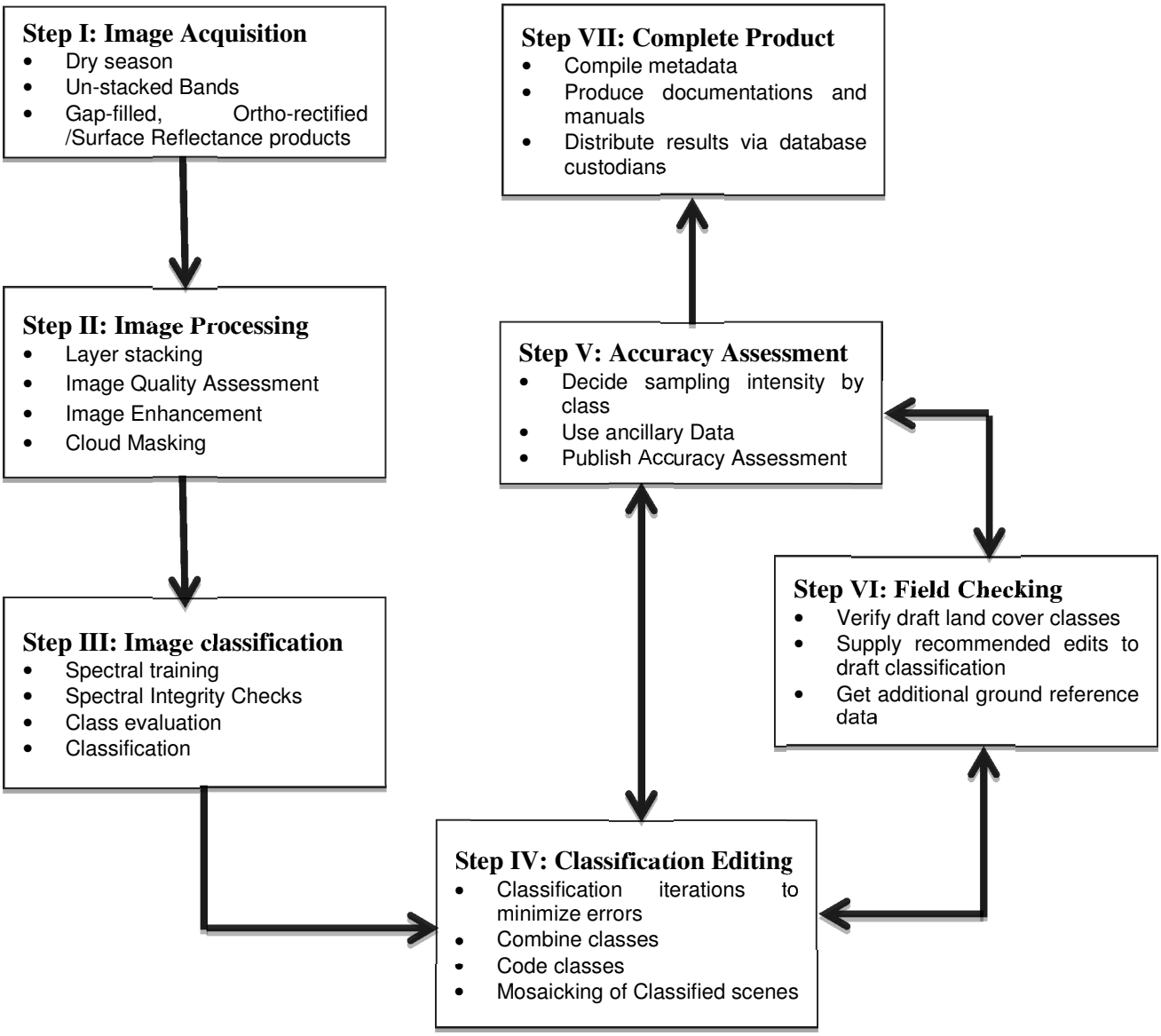
Schema II: national sub classification categories agreed upon with countries; 12 to 15 classes, and keeping them consistent with IPCC guidelines.

- 10 – Forest lands
  - 01 – Dense Forest
  - 02 – Moderate Forest
  - 03 – Sparse Forest
  - 04 – Planted Forest
- 30 – Grasslands
  - 31 – Closed Shrub lands
  - 32 – Open Shrub lands
  - 33 – Closed Grasslands
  - 34 – Open Grasslands
- 40 – Croplands
  - 41 – Perennial Crops
  - 42 – Annual Crops
- 50 – Wetlands
  - 51 – Wetlands
  - 52 – Water Bodies
- 60 – Settlements
- 71 – Other Lands
- 255 – No data
  - 81 – Clouds
  - 82 – Shadow

Remote Sensing Data Acquisition

The decision to use Landsat TM and ETM imagery was a function of the existence of a historical archive of the data and that the data were freely available and accessible from the USGS web site. For each country, RCMRD acquired images for 1990, 2000, and 2010 epochs for classification. Careful attention was made to acquire scenes with consistent seasonality. Quality checks of the images were based on established detailed radiometric, atmospheric and geometric integrities.

Figure 1. Primary RCMRD LULC mapping procedures.



Source: Project Implementation Guide: Rwanda, RCMRD, Nairobi, 2013.

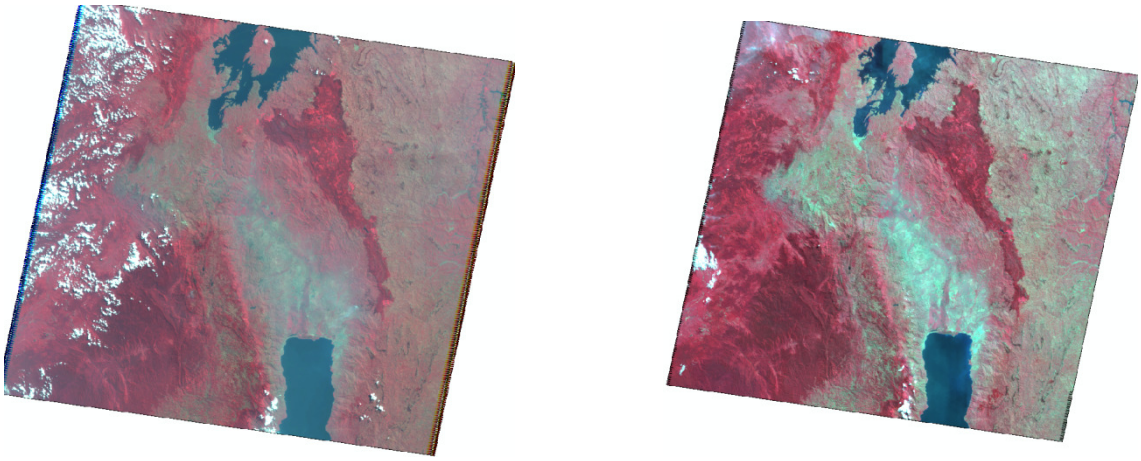
Image Processing

After image acquisition, the following processing steps were conducted before image classification; selection or creation of cloud free scenes, computation of image statistics, varied band combinations and establishment of derived image products and enhancements. Once these steps were completed, class signatures were extracted and evaluated prior to application of the maximum likelihood decision rule for classification. Figure 1 is a summary of the steps carried out from image acquisition to the final classification product and the following sections contain brief descriptions of the principle analysis processes.

Computing Image Statistics. The Landsat images with less cloud cover were selected for classification and employed for general statistical evaluations. The image processing software was used to generate statistical reports and display plots of histograms, mean spectra, eigenvalues, and other statistic information for each image file. Calculation of basic statistics and/or tabulated histogram information (frequency distributions) for single-band or multi-band images was conducted to evaluate the spectral quality of the imagery.

Cloud Masking. A major challenge encountered by RCMRD in some countries was the high cloud cover on the images selected for classification. In an effort to reduce the cloud cover percentage, Landsat data from the USGS site were used for filling gaps in the cloud masked images. Figure 2 shows an ortho-rectified scene before and after cloud masking and filling.

Figure 2. Landsat image before and after cloud masking and filling.

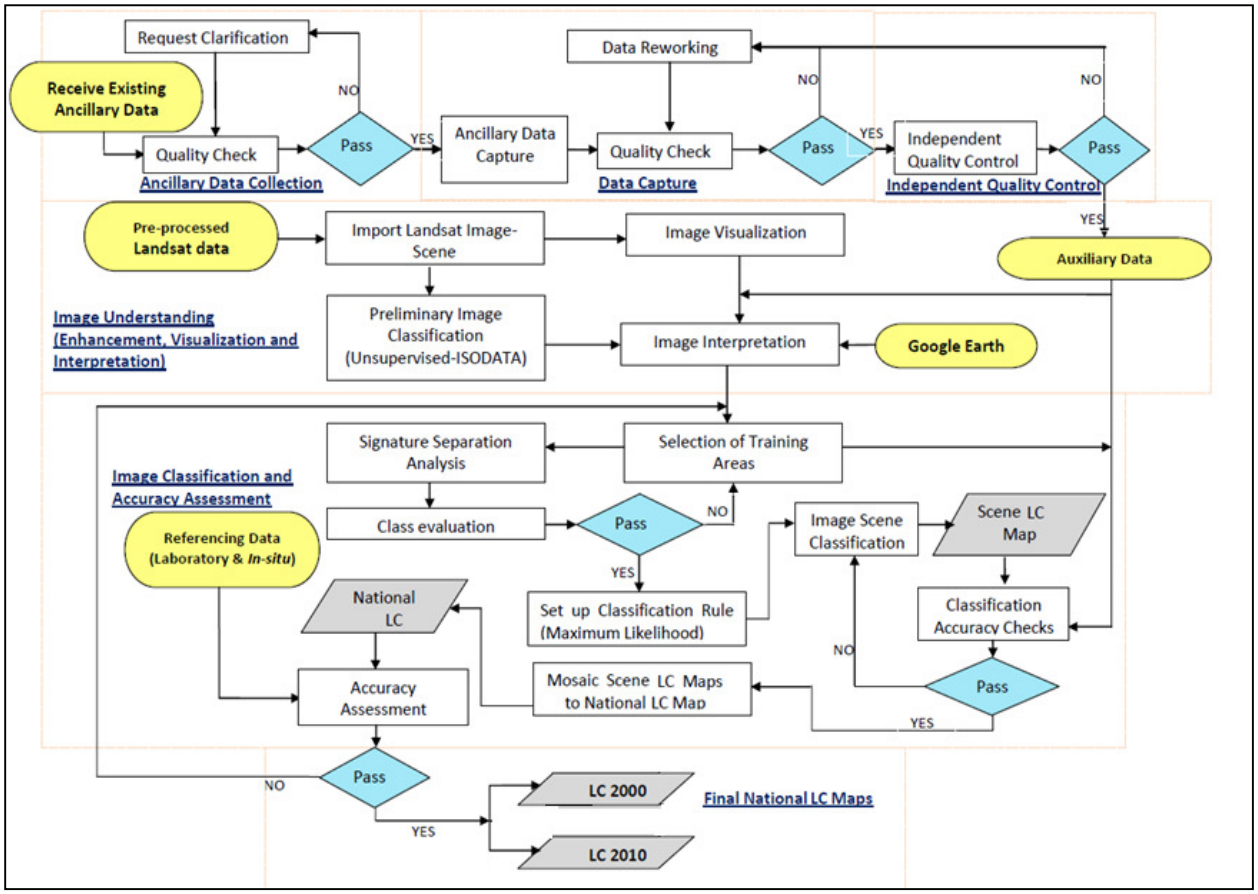


Source: Project Implementation Guide: Rwanda, RCMRD, Nairobi, 2013.

Classification Method. Image classification is the categorization of all the pixels in a digital image into one of several LULC classes. The majority of image classification is based on the detection of the spectral response patterns of surface classes. As a result classification depends on distinctive signatures for the classes in the data set being used, and the ability to reliably distinguish these signatures from other spectral response patterns that may be present.

Landsat scenes for this project were classified individually and merged after classification. A process of supervised and unsupervised signature extraction and application of a decision rule together with post classification editing methods were employed in the project. Figure 3 provides a detailed workflow of image classification for the RCMRD LULC project.

Figure 3. Detailed work flow for RCMRD LULC image classification.



Source: Project Implementation Guide: Rwanda, RCMRD, Nairobi, 2013.

The following primary processing steps were implemented.

a) Image Interpretation using Ancillary Data and Google Earth - The individual country provided ancillary data were used in image interpretation to help in selection of training areas for signature extraction. This was done by performing overlays of the selected ancillary data and the Landsat data on Google Earth. The ancillary data were also overlain on the imagery to interpret the various features on the images. Using the very high spatial resolution imagery on Google earth, it was possible to verify various features that are not clear on the Landsat imagery for interpretation

b) Vegetation Delineation Tool - The Vegetation Delineation tool enables quick identification of the presence of forest and the density subcategories and to visualize the levels of vigor. This tool was used for delineating forest sub-categories in terms of dense, moderate and sparse categories.

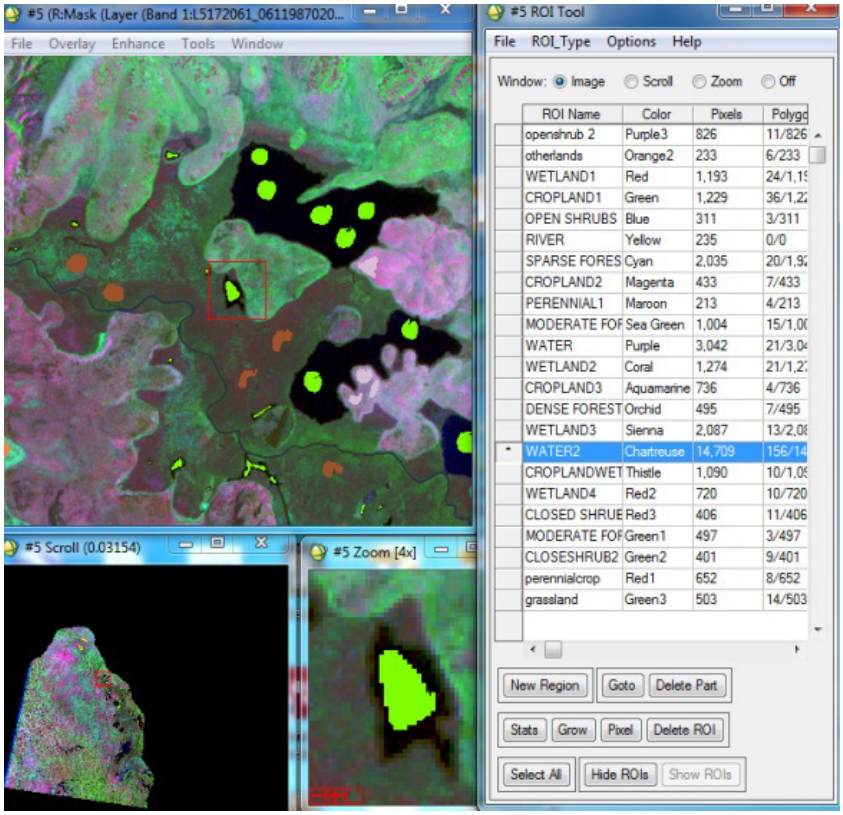
c) Separability Analysis - Jeffries Matusita distance measures were employed for the separation of the six IPCC and 12-15 country specific class scheme categories. Separability analyzes were conducted to ensure that all classes were distinct from each other during classification. This process involves viewing an image, selecting training or calibration areas for each class and computing a separability measure.

d) Classification Using Maximum Likelihood - Maximum likelihood is a statistical decision rule for examining the probability function of a pixel for each of the classes, and assigning the pixel to the class with the highest probability. The classifier assumes that the training data for each class has a normal or 'Gaussian' distribution. The classifier uses training data statistics to compute a probability value of whether it belongs to a particular LULC class.

The maximum likelihood classifier was employed based upon the spectral signatures obtained from selected class specific training polygons. This technique is a per-pixel classifier, and therefore assigns a class value to each pixel based on its individual spectral response patterns. In this supervised classification method, images are classified using spectral signatures or training area reflectance values obtained from calibration samples (polygons that represent distinct sample areas of the different LULC types to be classified).

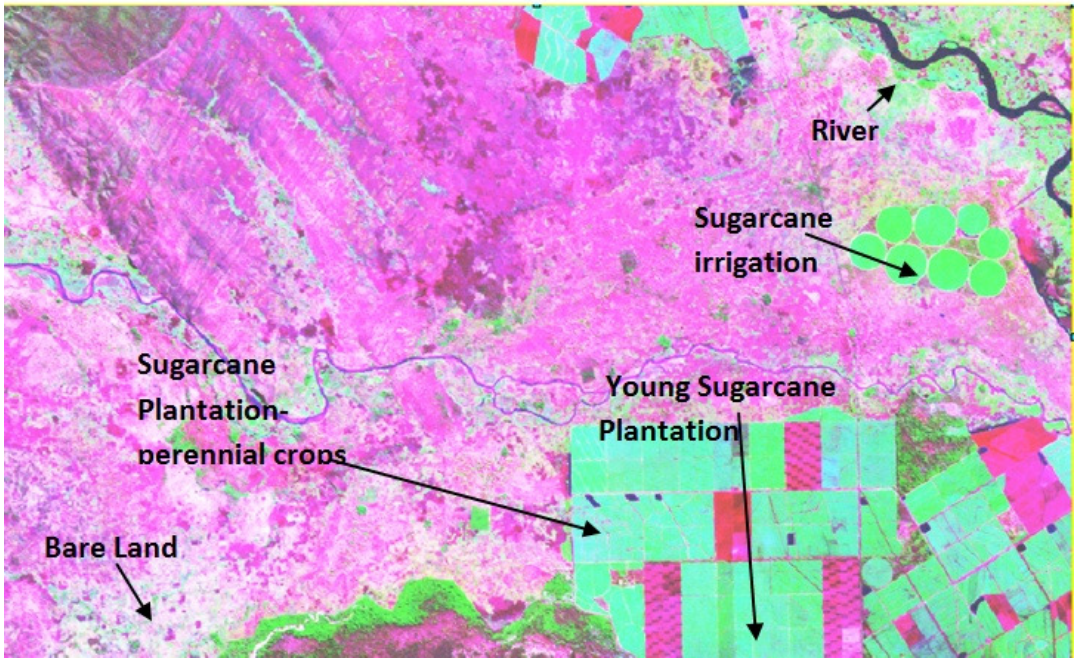
e) Regions of Interest or Polygons for Calibration - These are created by selection of the various training sites depending on the class identified on the image**.** Figures 4 and 5 shows calibration polygons selected for water and other classes.

Figure 4. Selected training or calibration areas for water bodies.



Source: Project Implementation Guide: Rwanda, RCMRD, Nairobi, 2013.

Figure 5. Examples of other class calibration features.

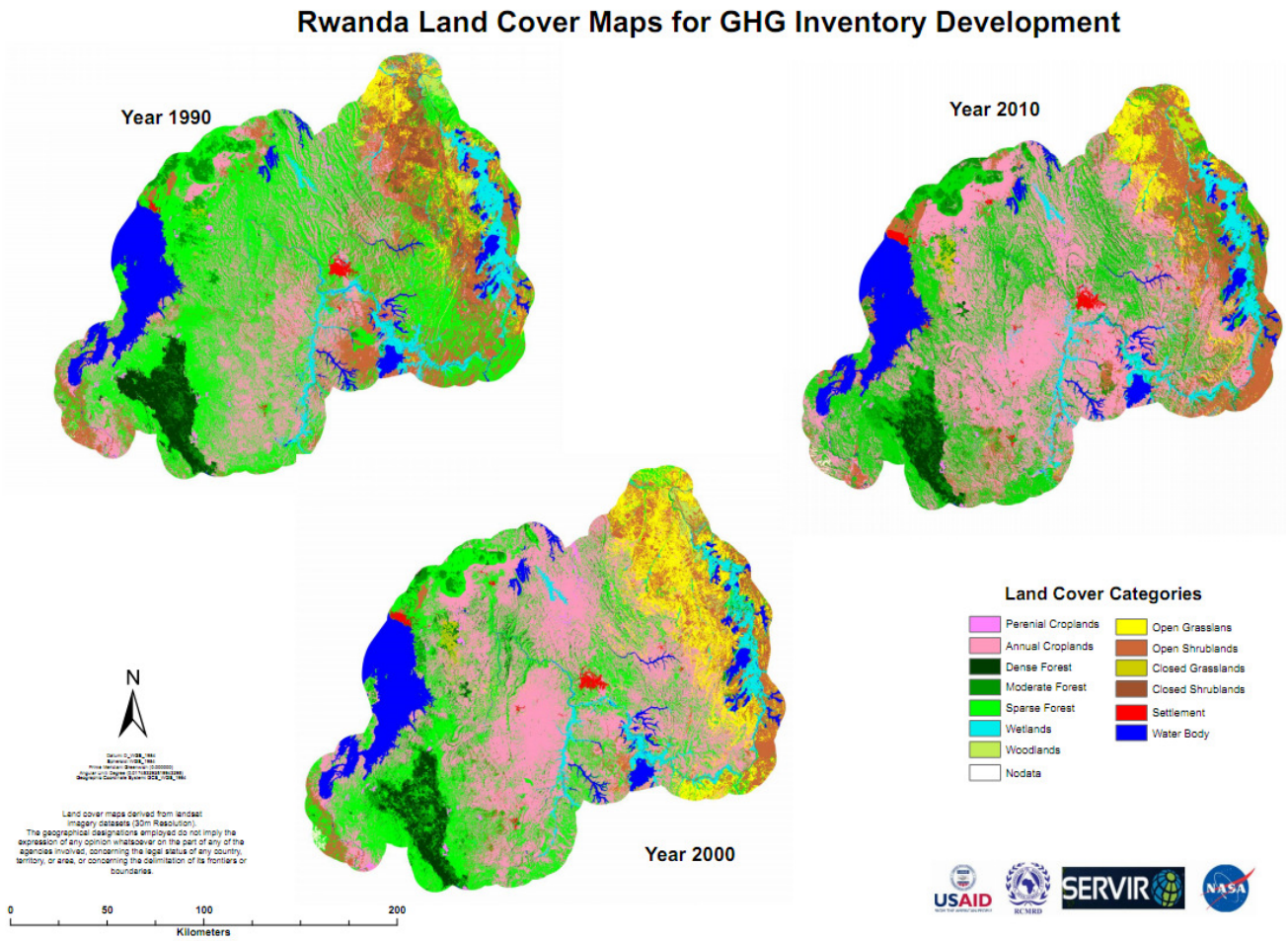


Source: Project Implementation Guide: Rwanda, RCMRD, Nairobi, 2013.

After the polygons are selected and evaluated, the classification is run based on the maximum likelihood classification decision rule. Correction of misclassified classes involves re-running the classification several times and/or moving to the post classification processing where various processes are used to improve the classification accuracy including extensive visual editing and also edge matching between scenes.

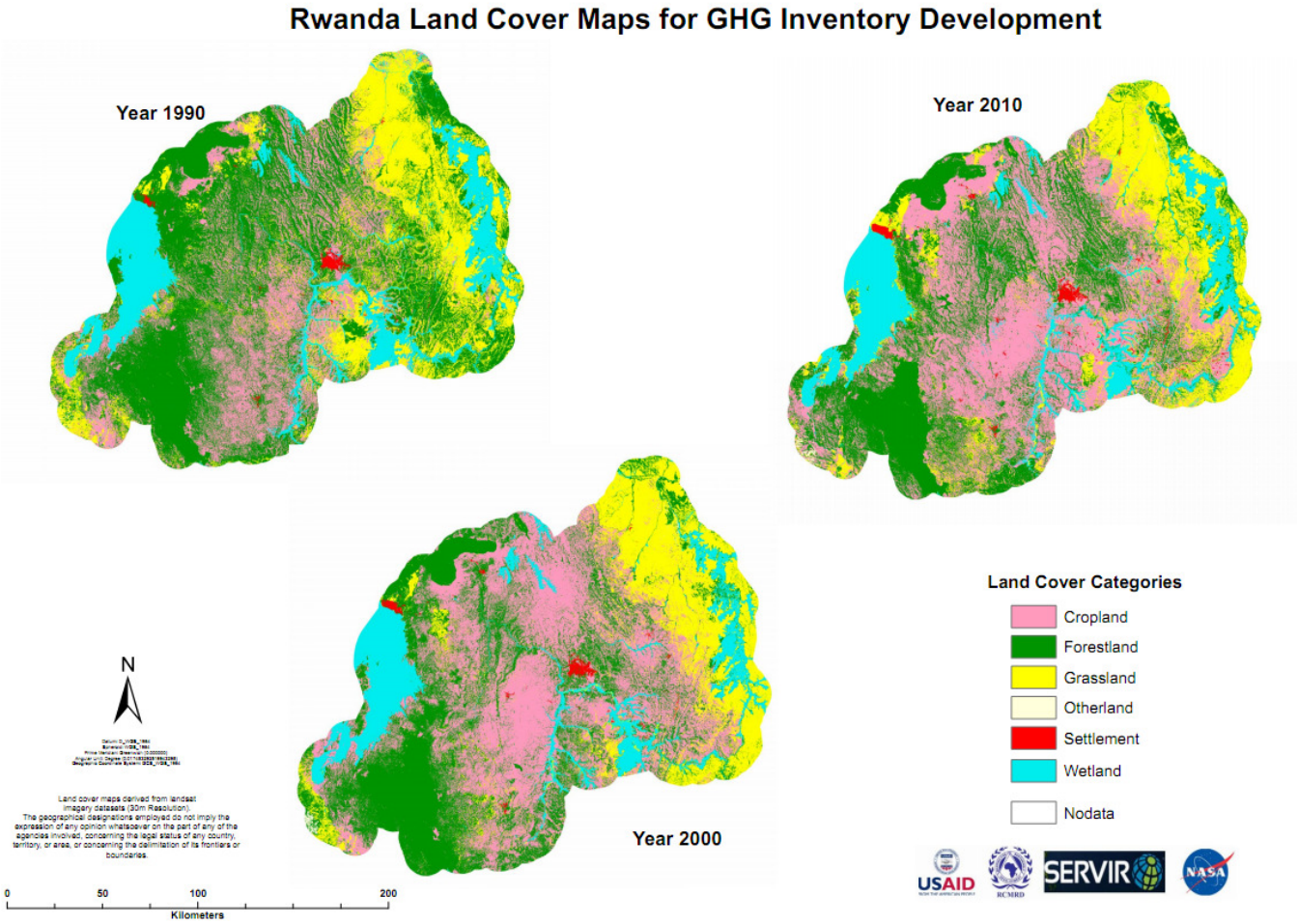
Figures 6, 7 and 8 are examples of the resulting LULC maps for Rwanda at two schemes or levels and for Malawi.

Figure 6. Rwanda scheme two LULC maps.



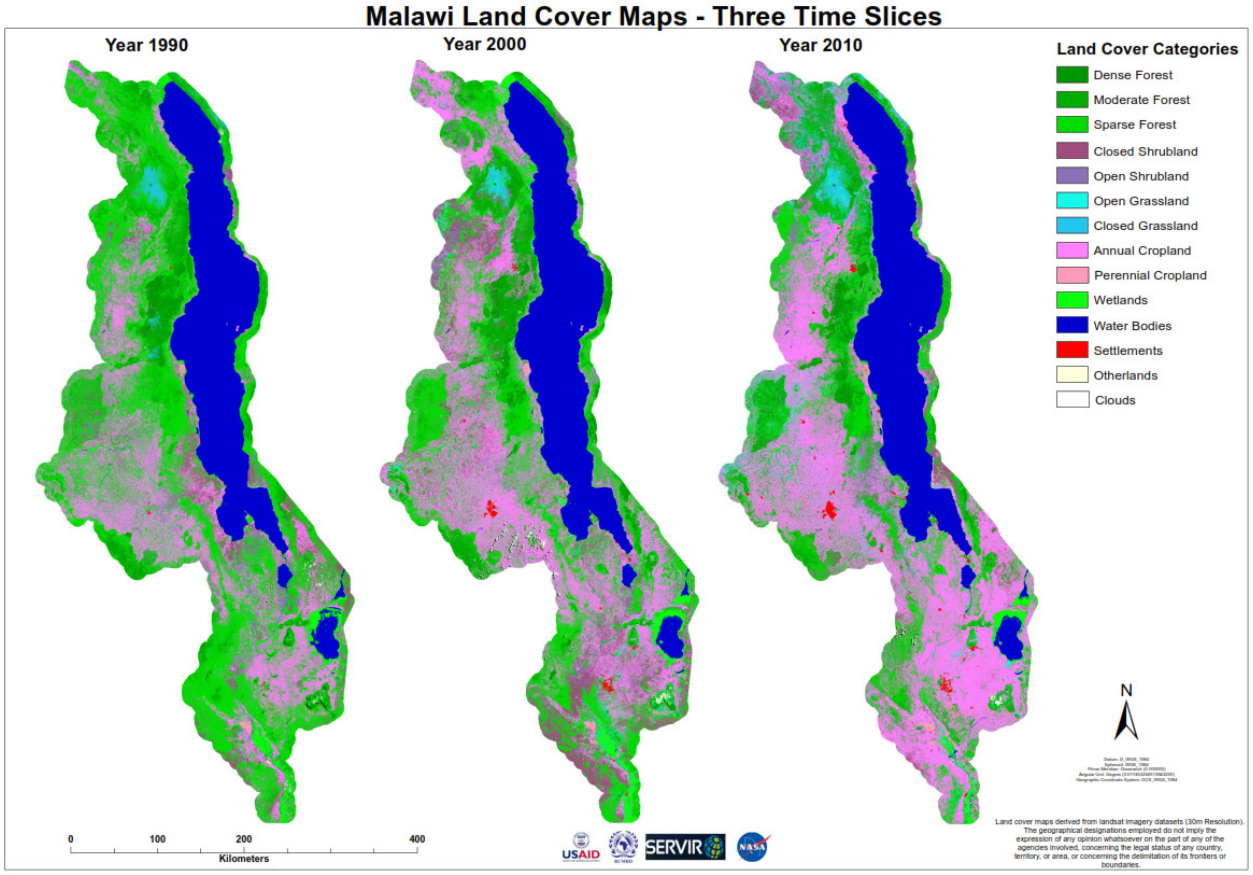
Source: U.S. EPA African Activities Supporting National GHG Inventory Mapping in Six ESA Countries, P.Odure RCMRD scientist, Presentation, International Symposium on Land Cover Mapping for the African Continent, Nairobi, 2013.

Figure 7. Rwanda scheme one LULC maps.



Source: U.S. EPA African Activities Supporting National GHG Inventory Mapping in Six ESA Countries, P.Odure RCMRD scientist, Presentation, International Symposium on Land Cover Mapping for the African Continent, Nairobi, 2013.

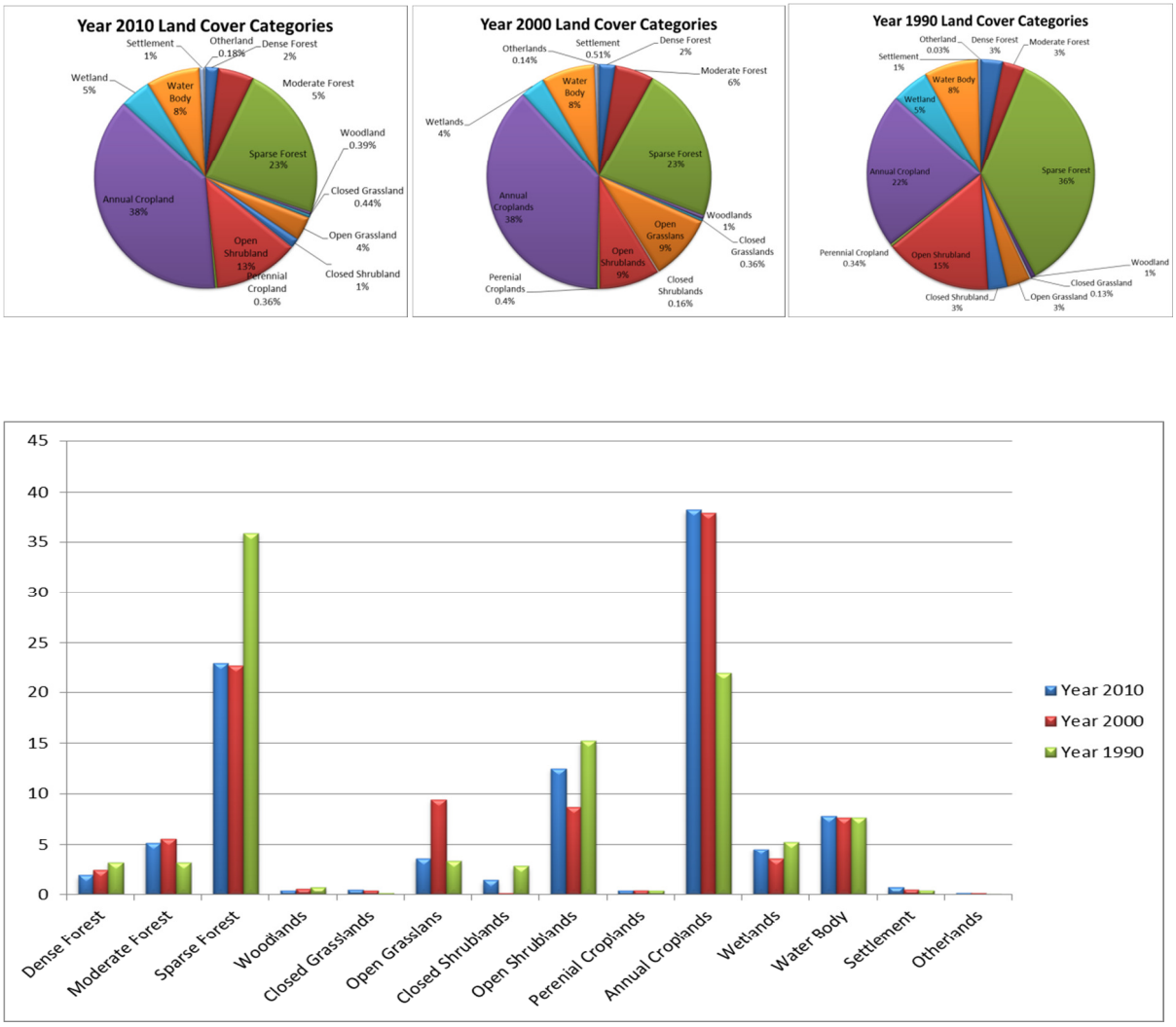
Figure 8. LULC scheme two maps for three dates in Malawi produced by RCMRD.



Source: U.S. EPA African Activities Supporting National GHG Inventory Mapping in Six ESA Countries, P.Odure RCMRD scientist, Presentation, International Symposium on Land Cover Mapping for the African Continent, Nairobi, 2013.

The LULC datasets developed for Rwanda for 2000 and 2010 indicate an increase in cropland as sparse forest coverage decreases over the years. The statistical results of the Rwanda LULC classifications are summarized in Figure 9.

Figure 9. Percentage coverage of Year 2010, 2000 and 1990 LULC categories for Rwanda.



Source: Project Implementation Guide: Rwanda, RCMRD, Nairobi, 2013.

Accuracy Assessment. Sampling in conjunction with ground reference surveys is one of the commonly expected approaches in LULC mapping accuracy assessments. Ground reference data generally cannot be collected for large portions of the entire project area therefore; representative samples are frequently employed. For the RCMRD LULC mapping accuracy assessment effort, extensive field visits were conducted in each of the six countries. Those efforts included determination of a sampling method and sample size prior to field visits. The field or validation visits included scientists from each country.

Random points were generated for accuracy checks of the produced LULC maps. The accuracy assessment of each LULC map was accomplished through the construction and analysis of an error matrix and an overall accuracy of not less than 75% was required. Initial consistency checks were obtained by

comparing the LULC products with ancillary data including the imagery on Google Earth and other imagery and identified errors corrected.

Accuracy assessments were constructed using ground referencing data collected from the field. The point data were overlaid on the classification data set for each country and year and assigned a LULC attribute by the reviewer based on automatic interpretation and comparison. The results from the accuracy assessment are summarized using the confusion matrix. Figure 10 provides accuracy assessments for several of the countries in this project.

Figure 10. RCMRD LULC example national mapping accuracies.

Country	Scheme I	Scheme II
Malawi	Kappa: **0.7871** Overall Accuracy: **85.2399**	Kappa: **0.7439** Overall Accuracy: **79.5203**
Rwanda	Kappa: **0.8077** Overall Accuracy: **86.4253**	Kappa: **0.7643** Overall Accuracy: **80.0454**
Zambia	Kappa: **0.7409** Overall Accuracy: **80.415**	Kappa: **0.7163** Overall Accuracy: **75.5167**

Source: U.S. EPA African Activities Supporting National GHG Inventory Mapping in Six ESA Countries, P.Odure RCMRD scientist, Presentation, International Symposium on Land Cover Mapping for the African Continent, Nairobi, 2013.

RCMRD LULC MAPPING SUMMARY

The RCMRD GHG LULC mapping activity is an excellent example of LULC mapping using a classic textbook approach but with appropriate understanding of variations of conditions in the six participating countries. One of the strengths of the approach by RCMRD was the willingness and ability of the scientists to understand the conditions in each country and appropriately vary procedures. The use of visual quality control and quality assurance editing was appropriate and necessary. The extensive field verifications to obtain scientifically rigorous accuracy assessments and the quality of those accuracies,

generally over 80%, were other examples of good methodologies. The multiple and extensive country specific reports were excellent.

APPENDIX 3: RCMRD LULC NATIONAL ORGANIZATIONAL CONTACTS[8]

BOTSWANA

Mauritius Workshop 7-9 March 2011
University of Botswana Physics Department
Botswana Meteorological Department
Department of Forestry and Range Resources

Initial Classification and Ancillary Data Workshop 29 April-6 May 2013
University of Botswana
Surveys and Mapping
Statistics
Botswana Meteorological Department

LULC Mapping Participants
Surveys and Mapping
University of Botswana
Crop Production
Town and Regional Planning

GHG Mid-Term Review Meeting Namibia March 2013
University of Botswana
Environmental Statistics Unit
Department of Meteorological Services

MALAWI

Mauritius Workshop 7-9 March 2011
University of Malawi College of Agriculture
Environmental Affairs Department
Environmental District Officer
Department of Forestry

Initial Classification and Ancillary Data Workshop 24-27 April 2012
Chief Environmental Officer – GHG National Coordinator
Land Resources Conservation Department

[8] Information on National GHG Team members and GHG ALU training participants has not been obtained.

Lilongwe City Council
Bunda College
Surveys Department
Department of Animal Health and Livestock Development
Ministry of Natural Resources, Energy and Environment
Forestry Research Institute of Malawi
Crop Production Department
National Climate Change Programme, Ministry of Finance and Development Planning
Land Resources Conservation Department

LULC Mapping Participants
Department of Forestry
Environmental Affairs Department

GHG Mid-Term Review Meeting Namibia March 2013
Department of Forestry
Lilongwe City Council
Ministry of Agriculture
Lilongwe University of Agriculture and Natural Resources
Environmental Affairs Department

NAMBIA

Mauritius Workshop 7-9 March 2011
Directorate of Forestry
Ministry of Environment and Tourism
Ministry of Agriculture, Water and Forestry

Initial Classification and Ancillary Data Workshop 6-9 February 2013
Third National Communication to UNFCCC
Ministry of Environment and Tourism Department of Environmental Affairs – Multilateral Environmental Agreements
Ministry of Agriculture, Water and Forestry, Department of Forestry
Ministry of Agriculture, Water and Forestry, NRCS
Ministry of Environment and Tourism
Namibia Statistics Authority
Ministry of Mining and Energy

LULC Mapping Participants
Namibia Statistics Agency
National Remote Sensing Center, Forestry

GHG Mid-Term Review Meeting Namibia March 2013
UNDP Namibia
Ministry of Environment and Tourism
Ministry of Agriculture, Water and Forestry

RWANDA

Mauritius Workshop 7-9 March 2011
None

Initial Classification and Ancillary Data Workshop 19-22 June 2012
Rwanda Environmental Management Authority
Rwanda Agriculture Board
National University of Rwanda
World Agroforestry Centre
National Institute of Statistics of Rwanda
Rwanda Natural Resources Authority

LULC Mapping Participants
Rwanda Agriculture Board

GHG Mid-Term Review Meeting Namibia March 2013
None

TANZANIA

Mauritius Workshop 7-9 March 2011
Division of Environment

All other workshops in planning phase

GHG Mid-Term Review Meeting Namibia March 2013
None

ZAMBIA

Mauritius Workshop 7-9 March 2011
None

Initial Classification and Ancillary Data Workshop 10 -14 September 2012
Centre of Energy for Engineering
Ministry of Lands, Energy and Water Department (MLEWD), Department of Survey
MLEWD – Department of Natural Resources and Environmental Protection
MLEWD – Department of Forestry
Zambia Wildlife Authority
Ministry of Agriculture
University of Zambia, Department of Soil Science
University of Zambia
University of Zambia, School of Agriculture

LULC Mapping Participants
Ministry of Lands, Energy and Water Department, Forestry
Ministry of Lands, Energy and Water Department, Department of Survey
National Remote Sensing Centre

GHG Mid-Term Review Meeting Namibia March 2013
Centre for Energy, Environment and Engineering
Environmental Management Agency
Ministry of Lands, Natural Resources and Environmental Protection
Forestry Department

APPENDIX 4: INTERVIEWEES AND ORGANIZATIONS VISITED

Title or Expertise	Ministry or Organization	Country
Director - Climate Change Unit	Rwanda Environmental Management Authority	Rwanda
Climate Change Program Manager	Rwanda Environmental Management Authority	Rwanda
Coordinate - GHG ESA Project - Climate Change Unit	Rwanda Environmental Management Authority	Rwanda
Director of Land Use Management & Spatial Planning	Rwanda Natural Resource Authority	Rwanda
Director of Livestock Research and Extension	Rwanda Agriculture Board	Rwanda
Livestock Expert	National University of Rwanda	Rwanda
Forest Expert	Rwanda Agriculture Board	Rwanda
GIS Expert	Rwanda Agriculture Board	Rwanda
GIS Expert	World Agroforestry Center - Rwanda	Rwanda
Forest Expert	Rwanda Agriculture Board	
GHG National Coordinator	Environmental Affairs Department, Ministry of Environment and Climate Change Management	Malawi
Environmental Affairs	Environmental Affairs Department, Ministry of Environment and Climate Change Management	Malawi
Statistician	Environmental Affairs Department, Ministry of Environment and Climate Change Management	Malawi
GIS Specialist	Department of Surveys	Malawi
Photogrammetrist	Department of Surveys	Malawi
Principle Surveyor	Department of Surveys	Malawi
GIS Specialist	Department of Surveys	Malawi
Mapping Section	Department of Surveys	Malawi
Environmental Inspector	Department of Surveys	Malawi
GIS specialist	Land Resources Conservation Department	Malawi
GIS Scientist Waste Management	Lilongwe City Council	Malawi
Assistant Director of Forestry for Biodiversity and Ecosystems	Forestry Department, Ministry of Natural Resources, Energy and Environment	Malawi
GIS Specialist	Forestry Department, Ministry of Natural Resources, Energy and Environment	Malawi
Director	Ministry of Economic Planning and Development	Malawi
Assistant Director	Ministry of Economic Planning and Development	Malawi

Instructor	Bunda College	Malawi
Director Environmental Economics Unit	Ministry of Environment and Tourism, Department of Environmental Affairs	Namibia
GHG National Coordinator	Ministry of Environment and Tourism, Department of Environmental Affairs	Namibia
Remote Sensing Analyst	Ministry of Agriculture, Water and Forestry, Directorate of Forestry, National Remote Sensing Centre	Namibia
Remote Sensing Analyst	Ministry of Agriculture, Water and Forestry, Directorate of Forestry, National Remote Sensing Centre	Namibia
Remote Sensing Analyst	Ministry of Agriculture, Water and Forestry, Directorate of Forestry, National Remote Sensing Centre	Namibia
Remote Sensing Analyst	Ministry of Agriculture, Water and Forestry, Directorate of Forestry, National Remote Sensing Centre	Namibia
Director	Ministry of Agriculture, Water and Forestry, Directorate of Forestry, National Remote Sensing Centre	Namibia
IT Specialist	National Statistical Authority	Namibia
GIS Analyst	National Statistical Authority	Namibia
Head: Energy and Environment Unit	United Nations Developmental Programme	Namibia
Division Mapping and GIS	Ministry of Lands and Resettlement	Namibia
GIS Specialist	Ministry of Lands and Resettlement	Namibia
GIS Specialist	Ministry of Lands and Resettlement	Namibia
ICT Specialist	Ministry of Lands and Resettlement	Namibia
GIZ/CIM Integrated Expert for Land Use Planning at Ministry of Lands and Resettlement	Ministry of Lands and Resettlement	Namibia
Surveyor General	Ministry of Lands and Resettlement	Namibia
Deputy Surveyor General	Ministry of Lands and Resettlement	Namibia
Acting Mission Director	USAID	Namibia
Program Development Specialist	USAID	Namibia

APPENDIX 5: INTERVIEW PROTOCOL

GHG Team (technical) INTERVIEW GUIDE

GHG Case Study

1August 2013

Name of Person Interviewed:

Position/title:

Department/Ministry: Country:

Name of Interviewer:

Name of Notetaker:

Date: Start time: End time:

Others present at interview:

Other Comments about the Interview:

Introduction: Persons, titles, etc.

Thank you for taking the time in your busy schedule, it is an honor for us to meet with you. We are here as part of the USAID-funded SERVIR project. SERVIR is a global program focused on strengthening the capacities of government institutions and other stakeholders to use Earth observations and geospatial data in environmental decision-making.

We are conducting a case study on the GHG Project at RCMRD on behalf of USAID. The objective of this case study is to better understand how the land use/ land cover product is being developed, shared, and any preliminary impacts of the project. We also hope to learn more about how to increase the awareness and utilization of the LULC data produced by RCMRD. The case study is intended to better inform USAID and their partners, particularly NASA, on the process in which institutions like RCMRD develop and disseminate SERVIR products, how users are engaged and benefit from the product, and some of the impacts these tools may have on decision-makers. It is not an evaluation of the project.

The interview consists of 7 focus areas: organizational information, status of deliverables, possible products, national LULC efforts, increasing demand, GHG national efforts, and GHG ALU activity. In order to get through the interview, we may ask that some responses be completed at the end of the interview if time allows. We expect the interview to last approximately45 minutes.

IF ASKED: The information shared with us will not be linked to any specific individuals by name.

Note to assessment team: The interview may take longer depending on the number of active participants, and this should be clarified at the beginning of the interview. As a semi-structured interview, this protocol is meant to guide the assessment and generate similar types of information across interviews. However, it is up to the interviewer to make the discussion as conversational as possible.

Questions are in normal font. Prompts for interviewer are in *italics.*

Questions

A. Organizational/individual backgrounds

1. Please tell us more about how the GHG team is organized in your ministry. *PROBE: Who are the members of the GHG team and what organizations/departments are represented?*
    a. Are the members entirely engaged in the GHG effort or is this one of their responsibilities?

2. What are the responsibilities of the GHG team?

3. Are the GHG efforts at your ministry / department funded by the ministry or through external funds (donors)?

4. What are the relationships or the team to SERVIR/RCMRD?
   PROBE: Can you give an example of how your GHG team interacts with RCRMD/SERVIR?

5. Tell me about the GHG team's spatial capacities (including software/hardware/staff/internet access/data hosting, etc.)

   PROBE: Does the GHG team have available other spatial data sets and data distribution policies?

   PROBE: Does the GHG team have an existing web site, the capacity to host spatial data, the ability to track access/users?

6. What internal capacity exists for future GHG LULC inventories? Are there additional needs or support required?

B. Status on RCMRD LULC deliverables

1. What products does the GHG team expect to receive from RCMRD (LULC maps, images, ancillary data, metadata, reports) and when?

Product	√	When is it expected?
LULC Maps		
Images		

Ancillary Data		
Metadata		
Reports		

2. Can you tell us what you know about the upcoming national workshop? *For example, the focus, who is attending, and when it will happen?*

For the following table, please check Y/N and any observations or comments about the answer. Ex: if you do not feel comfortable asking directly, try to discover during the conversation and then check Y/N. If you ask the question directly, and get an answer that seems it needs more depth, please probe and add comments.

Question	Y	N	Comments/Observations
Does the GHG team have the ability to archive/utilize RCMRD data including software, hardware and staff?			
Does the team have plans for increasing awareness or dissemination of the data or products?			
Does the team have the ability, or plan to track users of the RCMRD GHG deliverables?			
Does the GHG team want GHG products posted on the web? *If so, by whom (ex: SERVIR, RCMRD and/or national sites)? Are there limitations or needs necessary for this activity?*			

Does the GHG team need assistance in data dissemination such as flyers, maps or the web?			

C. Possible products from RCMRD LULC data

(Note: these questions might apply to some ministries and not others)

1. In what ways would change detection maps be helpful for your activities (if at all)?
   PROBE: Would having these maps better inform your work? Would they help you to make decisions? Give examples if needed.

2. In what ways would vector formatted LULC products be helpful for your activities (if at all)?
   PROBE: Would having these maps better inform your work? Would they help you to make decisions? Give examples if needed.

3. What other suggestions might you have for derived products from RCMRD based on the GHG project?

D. National LULC data

1. Can you tell me more about any national LULC efforts to date in this country?
   PROBE: What data sets have been previously produced, are currently being produced, or are scheduled in the future?

2. What were the mapping parameters for those maps including source data, classifications, scale, accuracies etc.?

3. Are those maps available, in what format and from whom?

4. What connections exit (if any) between national LULC initiatives and the GHG Project?

E. Increasing demand for RCMRD/SERVIR LULC data

1. What other country organizations including governmental, academic or NGOs might use the RCMRD GHG LULC data?

2. What do you see as potential applications of those products?
   PROBE: Have discussions been held about how to use these products for specific sectors? Has the GHG team discussed these products and where they could be beneficial?

3. What plans are there to increase awareness and distribution of those data? *PROBE: What additional assistance might increase demand?*

4. What would be your top three priorities/needs related to disseminating and marketing national LULC datasets and other GHG products to decision-makers *E.g., staffing, infrastructure, software, specific tools, web hosting, etc.*

F. GHG National LULC 2014 mapping capacity

This section gets at the sustainability of the GHG teams after the RCMRD project ends. This could be sensitive based on the GHG team's relationship to the UNFCCC. Proceed with caution during this section. If you feel the questions aren't really getting at useful responses I would skip it and make a note. SKIP IF TIME IS SHORT

1. Is this mandated by your government or international agreements?

2. Which national organization has this responsibility?

3. What are the organizational resources including staff, hardware, software and internet access suitable for image downloading?

4. How could this his organization benefit from additional support and capacity building by RCMRD and/or SERVIR?

G. GHG ALU activity/status

1. Has the national GHG ALU organization received any data from RCMRD?
    a. If so, what data and when?

2. Has the national team processed this data using the ALU software?

3. What is the organizational location and capacity of the GHG ALU scientists?
    a. Is additional support needed?

4. What plans exist for post-RCMRD GHG Project funding?

H. Is there anything else related to this that you would like to share with us?

Wrap up:

- *Thank them for their time.*
- *Ask if they can be contacted again in the future, if necessary (by email).*
- *Ask if there are other individuals, departments, and/or entities they feel are relevant to contact, (noting that we may not be able to contact at this point).*
- *We are happy to share the Case Study Report once finalized.*