RWANDA ENVIRONMENT MANAGEMENTAUTHORITY (REMA)

THE ASSESSMENT OF ECONOMIC IMPACTS OF THE2012 WET SEASON FLOODING IN RWANDA

Kigali, Rwanda

October, 2013

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ACRONYMS AND ABBREVIATIONS

CsPro:	Census and Survey Processing System
DS:	Down Stream
ECLAC:	Economic Commission of Latin America and Caribbean
EDPRS:	Economic Development for Poverty Reduction Strategy
FGD:	Focus Group Discussion
FONERWA:	National Fund for the Environment and Climate Change in Rwanda
GIS:	Geographic Information Systems
GPS:	Global Positioning System
Hh:	Household
KCC:	Kigali City Council
MINAGRI:	Ministry of Agriculture and Animal Resources
MININFRA:	Ministry of Infrastructure
MINIRENA:	Ministry of Natural Resources
MIDIMAR:	Ministry of Disaster Management and Refugee Affairs
MS:	Middle Stream
NISR:	National Institute of Statistics of Rwanda
REMA:	Rwanda Environment Management Authority
REDD:	Reducing Emissions from Deforestation and forest Degradation
RTDA:	Rwanda Transport Development Authority
SEI:	Stockholm Environment Institute
SPSS:	Statistical Package for Social Scientists
TOR:	Terms of Reference
TVET:	Technical and Vocational Education and Training
UNFCCC:	United Nations Framework on Climate Change Convention
UN-OHRLLS:	The UN Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and the Small Island
US:	Up Stream

EXECUTIVE SUMMARY

Floods and landslides are common natural calamities that Rwanda has been facing almost every year at different scales. Consequently, damages to property and misery due to destruction of infrastructure and property are enormous leaving adverse socio-economic effects on the victims. In particular, the main wet season of 2012 brought much higher rainfall in the country than expected, with most meteorological stations recording more than double rainfall amounts in the first 10 days of May 2012 compared with the long-term average for the same period. This climatic change and its effects are main cause of this study.

The literature review indicates scarce or limited studies that quantified the effects of climate change in Rwanda. This particular study adds value in this context and postulates the need by REMA to quantify in monetary terms the losses incurred during the 2012 wet season. Therefore, the overall objective of this study was to assess the economic impact of the 2012 wet season flooding in Rwanda. Specifically, the research evaluated the economic costs in monetary terms of the 2012 floods on agricultural production, household livelihoods, and development infrastructure in the study area.

Results from this assessment were expected to provide some evidences on economic losses resulting from climate change effects so that this can inform future adaptation and mitigation strategies, as articulated in the National Strategy for Climate Change and Low Carbon Development for Green Growth and Climate Resilience (REMA 2011).Data used for this assessment was collected in four stage process: the mapping with the Geographic Information System (GIS), field exploration, Focus Group Discussion (FGD), and individual household/farm surveys. The first three stages allowed researchers to fully understand the context of the study prospects while the last stage of individual households' interviews was helpful in quantifying some of the losses expressed during the mapping, exploratory visit and through the focus group discussions. For analytical purposes, a number of approaches were followed including the input-output approach and with or without approach.

The study area was stratified in three locations namely the upstream zone, the middle and downstream zone. In line of these three locations, 43% of losses are from the middle zone compared to 24% in the upstream and 33% in the downstream zones; respectively. Total land affected by the rain in the 2012 wet season was 1,019,298 m^2 or 101.93

hectares in the sampled households of 421 households that responded. There is some variation per location where the middle stream was highly affected (437,590m^2) followed by the downstream (340,639 m^2) and then upstream (241,073 m^2). One of the explanations is that in sampled households, they cultivate more in the middle zone than in the upstream and downstream. The upstream is made mostly with hill plots inappropriate for agriculture while the downstream is made mostly with the marshlands.

The study assessed mostly the costs related to agricultural losses and damages linked to destroyed infrastructures based on both primary and secondary data collected. Results indicate that the 2012 wet season caused negative effects in terms of agricultural losses and replacement costs of damaged infrastructures. With respect to agriculture, there is a total estimate of 31, 926,941 Rwf considered as losses of which 50% are for seed losses, 32 % for human labor losses, and 18% for fertilizers, in the sampled area. With respect to infrastructure, an estimate of 4,285,091,200 Rwf represents the costs of destroyed or damaged infrastructures mainly roads and buildings based on the information collected from the survey. Taking into account the secondary information from MIDIMAR 2012 that establishes the rehabilitation cost for Musanze, Mukamira and Ngororero at 2,443,000,000 Rwf, the estimated loss in infrastructure both the replacement and economic cost is 6,915,591,200 Rwf. On the other hand, the total MININFRA/RTDA, KCC and districts road programmes budget of 2013 - 2014 is equivalent to Rwf 24,300,000,000 which means that the estimated loss in infrastructure comes down to 28% of the whole budget.

Overall, the estimated total economic loss of 2012 wet season flooding in Rwanda [agricultural loss + Livestock loss + infrastructure (replacement and economic cost) loss] is **58,322,907,201 Rwf** which represented about 1.4% of the overall GDP of 2011/2012. This provides an indication of the economic costs once measures to control floods and landslides are not in place. This is a lot of money the country lost.

Based on causes of floods as indicated by the sampled population, the study proposed some flood-proof adaptation strategies, these include Integrated Water Resource Management (IWRM); setting up an information system for early warning of hydrological and agro- meteorological systems and rapid intervention mechanisms; promotion of intensive agro-pastoral activities; introduction of species resistant to extreme conditions; and development of alternative sources of energy to firewood.

Furthermore, policies and strategies to address the above areas are in place, together with the necessary institutional arrangement. There are locally, regionally, and internationally driven programs and responsible government and non-government agencies, as well their respective areas of interventions as already mapped out by MINIRENA. These form a basis on which further efforts for adaptation strategies can capitalize. Therefore, the remaining task is to ensure that existing efforts are strongly coordinated, monitored and evaluated to ensure that what is planned is implemented.

PARTNERS AND CONTRIBUTORS

This report is a result of an effort from REMA and its partner institutions such as MINIRENA, MININFRA, MINECOFIN, and other stakeholders.

AUTHOR

SESMEC Ltd

NOTICE

1 GENERAL INTRODUCTION

Floods are a common natural disaster that Rwanda has to face almost every year in varying degrees. Damage to property and misery caused due to destruction of infrastructure and property as a result of floods are enormous. Floods also cause substantial loss of human life, huge loss of cattle herds and agricultural output causing untold misery to a large section of people. Floods are a major disaster affecting many other countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems. The impact of floods has increased due to a number of factors, such as rising water levels and increased development in flood prone areas. Recurring losses due to floods have handicapped the economic development of both developed and developing countries.

The Rwandan economy is mainly dependent on agriculture. The agriculture sector in turn depends on its production. The agricultural production in Rwanda is mainly rain fed. Thus the quality of rain variability and temperature ranges are key determinants of agricultural production in Rwanda (Ngabitsinze et al. 2011). It is evident that climate change will be affecting economic growth, health indicators, water availability, food production and the fragile ecosystems in the Least Developed Countries including Rwanda (UN-OHRLLS, 2009) [1]. In Rwanda, effects of climate change are being documented. For example, a study by Stockholm Environment Institute (SEI) (2009)[2]maintains that the existing climate variability in Rwanda has economic costs. Accordingly, periodic floods and droughts already cause major socio-economic impact and reduce economic growth in Rwanda (SEI, 2009). Some major flood events documented in Rwanda are those of 1997, 2006, 2007, and 2009.Consequently, these have caused different types of damages economically, known as the damages on stocks – both physical and human capital.

The main wet season of 2012 brought much higher rainfall in the country than expected, with most meteorological stations recording more than double the rainfall amounts in the first 10 days of May 2012, compared with the long-term average for the same period. The May 2012 heavy rains caused widespread flooding, severe soil erosion, landslides,

[1]UN-OHRLLS (2009)The Impact of Climate Change on development prospects of the least developed countries and Small Island developing States.
[2]SEI (2009).Economics of Climate Change in Rwanda. A study funded by DFID, Kigali, Rwanda.

crop and livestock loss, destruction of road infrastructure and property around the country and in some parts, the highest cost of human life. It has also been established from the available 30-year meteorological data of Rwanda, that temperatures as well as rainfall quantity and intensity are increasing. However, the data reveals that the all-important no-of-rain-days statistic for agriculture is decreasing, indicating the erratic behavior of climate change (REMA, 2012)[3].

The 2012 wet season heavy rainfall hadindeed damaged various areas connected with the social-economic well-being of the Rwandan population. As already reported in the preliminary aerial report conducted by REMA, many sectors have been affected especially the agricultural sector.

Since agriculture is the main economic activity of Rwanda, it is expected that the losses related to agriculture have severely, adversely affected the livelihood of the Rwandan population in general, and particularly the population living in the hot spot areas that were directly affected. These include: Nyabihu, Ngororero and Nyamagabe districts as well as the agricultural valleys of Mukungwa, Nyabarongo, Akanyaru and Akagera rivers.

It is clear that the Mukungwa, Nyabarongo, Akanyaru and Akagera marshlands and connected watersheds as well as other minor marshlands in the country were affected in terms of the rice crop damage and other minor crops, including vegetables. Agriculture activities in the districts of Nyabihu, Ngororero and Nyamagabe were either directly or indirectly affected. The heavy rainfall directly destroyed the crops in lowland/marshland areas, as well as crops which were on soils subjected to strong soil erosion, land slide and/or land slumping were also severely damaged.

In regard to the above, there is need for more studies that quantify the effects of climate change in Rwanda. This particular study adds value in this context and postulates the need for REMA to quantify the losses incurred from the 2012 wet season rain damage in monetary terms in order to provide economically sound advice on future adaptation and mitigation actions as articulated in the National Strategy for Climate Change and

[3]REMA (2012). Tender Notice- REF: No.09/REMA-SPIU/2012-2013.

Low Carbon Development for Green Growth and Climate Resilience (REMA 2011)[4].The strategy was developed with the guiding principles from the Rwanda Vision 2020 and the first generation of Economic Development and Poverty Reduction Strategy (EDPRS 2008-2012) and has in turn been adopted and monitored within the second generation of EDPRS (2013-2017).

1.1 Conceptual links on floods

The real benefits of economic analysis of floods may be difficult to identify because some of these benefits are not immediately visible or tangible. "Accordingly, reliable assessment of flood damage is a critical issue in analysis of the economic aspects of flood damage reduction projects"(Yi et al, 2010)[5]. The analysis of economic costs of floods has been previously done in many parts of the world, especially in areas with high potential inundation. But the methodology is dynamic as it brings some complementary aspects as well as those that are different. For example the International Union for Conservation of Nature and Natural Resources (2009)[6] uses a methodology that involves mainly three components: assessment of the cost of immovable assets and stock damage, assessment of income foregone, and the secondary or macroeconomic effects. Accordingly a "With and Without"[7] approach is used to translate direct and indirect effects of floods into economic cost estimates. This approach takes into account the difference between 'with cases' and 'without cases'. The difference is attributed to the climate change events such as floods. The information used is obtained from a flood economic survey. The literature postulates potential differentials in the methodology for assessing the effects of climate changes due partly to differentials in purposes of assessment and data availability (for a review see Hallegatte and Przyluski, 2010, and

[4]REMA (2011) National Strategy for Climate Change and Low Carbon Development; Kigali, Rwanda Environment Management Authority (REMA), October 2011.

[5]Choong-Sung Yi, Jin-Hee Lee, and Myung-Pil Shim (2010). GIS-based distributed technique for assessing economic loss from flood damage: pre-feasibility study for the Anyang Stream Basin in Korea. *Natural Hazards*, Volume 55, Issue 2, pp 251-272.

6Lal, P.N., Rita, R. and Khatri, N. (2009). Economic Costs of the 2009 Floods in the Fiji Sugar Belt and Policy Implications. Gland, Switzerland: IUCN. xi + 52

[7]Economic Costs of the 2009 Floods in the Fiji Sugar Belt and Policy Implications

Lichter and Felsenstein, 2012)[8]. In this process of economic costs estimation of flooding socio-economic impact assessment techniques are combined sometimes with the GIS based approach (e.g. Lichter and Felsenstein, 2012).

1.2 Study Objectives and Deliverables

The overall objective of this study was to carry out an economic impact assessment of the 2012 wet season rainfall in Rwanda. Specifically, the research evaluated the economic costs in monetary terms of the 2012 floods on agricultural production, household livelihoods, and development infrastructure in the study areas. Results of this study informed on the development of strategies and programs towards the adaptation and mitigation against future losses within the EDPRS-II framework by respective institutions and organizations.

The following outcomes in the terms of reference were expected at the end of this study:

- Impacts and Economic losses due to the 2012 wet season rainfall in Rwanda are measured in monetary terms and documented.
- Flood-proofing adaptation strategies for agriculture and livestock activities, building structures and infrastructure are recommended for validation and application.
- A geo-referenced and statistical data base is developed and proposed as a baseline for future monitoring and evaluation as well as development strategies.
- A statistically quantified conclusions of losses;
- Recommendations for adaptive strategies with regard to agricultural and livestock practices, building structures and infrastructure in the studied areas.

2 RESEARCH METHODOLOGY

2.1 Description of the study area

2.1.1 Population, population density and main activities

There was a census of population and housing in 2012. Considering the eight sampled districts for the study, as in Table 1 below, the highest population of 530,907 inhabitants is in Gasabo district and the lowest of 295,580 inhabitants is in Nyabihu district.

8Hallegatte, S. and Przyluski, V. (2010). The Economics of Natural Disasters: Concepts and Methods. Policy Research Working Paper 5507. The World Bank, Sustainable Development Network, Office of the Chief Economist.

Kicukiro district has the highest population density of 1918 inhabitants per square kilometer and Bugesera district, the lowest density of 282 inhabitants per square kilometer.

Table 1: Population distribution by district 2012 census

District	Province	Population August 15, 2012	Population Density 2012 (sq km)
Gasabo	Kigali City	530,907	1237
Musanze	Northern Province	368,563	695
Bugesera	Eastern Province	363,339	282
Nyamagabe	Southern Province	342,112	314
Ngororero	Western Province	334,413	493
Kicukiro	Kigali City	319,661	1918
Muhanga	Southern Province	318,965	492
Nyabihu	Western Province	295,580	556

Source: NISR 2012

The survey on impact of wet season 2012 showed that the main sources of income of the population in the study area are: Job remuneration, Farming / Rearing animals / Fishing, Agriculture Production, Services / Selling (Commerce), House worker at someone's house, Home worker at own house and other unspecified sources. Table 2 shows that agricultural production is the main source of income in all districts in the study area.

Table 2: Main source of income

Districts	Job remuneration	Farming / Rearing animals / Fishing	Agriculture Production	Services / Selling (Commerce)	House worker at someone's house	Home worker at own house	Other
	%	%	%	%	%	%	%
Gasabo	20%	7%	54%	5%	0%	0%	15%
Kicukiro	8%	13%	72%	2%	0%	0%	5%
Nyamagabe	0%	40%	60%	0%	0%	0%	0%
Muhanga	0%	55%	42%	2%	0%	0%	2%
Nyabihu	8%	25%	63%	3%	0%	0%	0%
Ngororero	15%	15%	70%	0%	0%	0%	0%
Musanze	22%	37%	32%	0%	2%	0%	8%
Bugesera	7%	7%	66%	3%	3%	2%	12%

Source: Field study on impact of wet season May 2012

Table 3: Summary of losses in provinces

Province	Floods (Number of affected Sectors)	% of total affected Sectors by floods	Land Slides (Number of affected Sectors)	% of total affected Sectors by landslides
Kigali City	15	11	3	3
Eastern	33	24	13	14
Northern	28	20	24	26
Southern	34	24	29	32
Western	30	21	22	24
Total	140	100	91	100

Source: MIDIMAR, 2012[9].

A survey by MIDIMAR in 2011 shows that the Northern, Southern, and the Western Provinces are affected by both floods and landslides as indicated in the Table 3 above. It shows that about 60.6% of the country's sectors were affected by the floods compared to 39.4% affected by the land slides.

[9]MIDMAR (2012).Disaster High Risk Zones on Floods and Landslides.Ministry of Disaster Management and Refugees Affairs, Kigali, Rwanda

2.1.2 Relief (slope and valley)

Rwanda is divided in compartments varying from 1,000 m to 4,500 m of altitude. The country is essentially mountainous with over 70% of the cultivated land surface presenting slopes superior to 10%. The processes of erosion generated hills of various shapes on the major part of it. Mountains are generally separated by a network of valleys.

Rwanda relief can be divided into four following categories:

(i) The Congo Nile Watershed

The Congo Nile Watershed stretches from the north to the south on a length of about 160 km and a width varying between 20 km and 50 km. The Congo Nile watershed Starts on Mount Muhe from the North (3000 m), decreases to 1200 m in Rutsiro and ends at the South in Nyungwe forest where its altitude is 2,750 m. The mean altitude of the Congo Nile Watershed can be estimated to 2500m. It is a mountainous chain with sides highly dissected by a lot of valleys, with stiff slopes and pointed summits.

At the north, the Congo Nile Watershed is limited by Volcano Mountains. Those volcanoes are Karisimbi (4507 m), Bisoke (3711 m), Sabyinyo (3634 m), Gahinga (3474 m) and Muhabura (4127m). These volcanoes are all non-active.

At the southwest, the Congo Nile watershed spreads to Bugarama plain which is an extension of Imbo plain belonging to Burundi. This is a tectonic ditch filled of deposits. With its 900 m of altitude, Bugarama is the lowest region of the country.

The Congo-Nile Ridge is a range of mountains, with an altitude ranging between 2500-3000 m. Overhanging Lake Kivu; it divides Rwanda's waters in two parts: those which flow into the Congo basin in the west; and, those which flow into the Nile in the east.

Much of Musanze, Nyabihu, Ngororero and Nyamagabe are located in the Congo-Nile Watershed.

(ii) The Central Plateau:

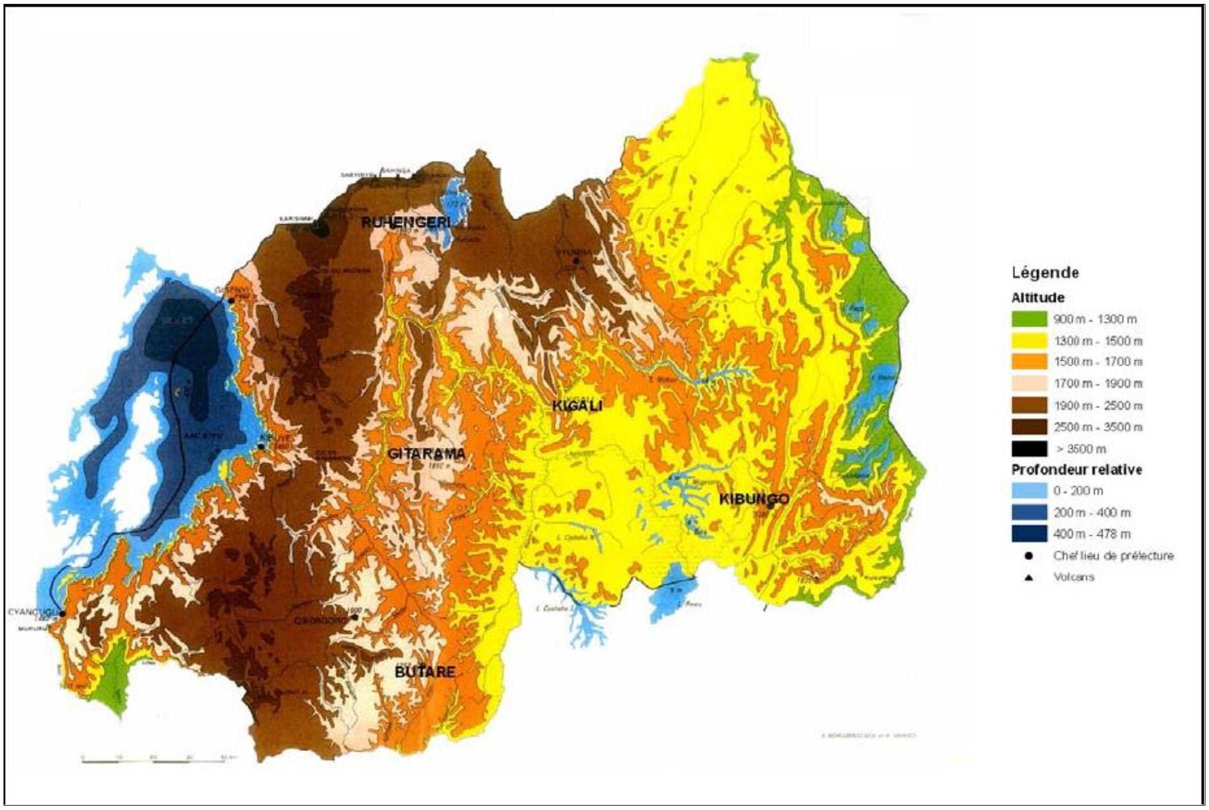
Extending from the south of Musanze to the border of Burundi, the Central plateau is made of hills separated by large valleys of 50-15 m often filled up with alluvial deposits. This topographic unit, whose altitude varies between 1500 m and 2000 m, large of about 80 km, spreads from the buttresses of the Congo Nile Watershed to Kigali and nearly covers a half of the country. This mountainous region gave to the country the nomination of " The Country of the A thousand Hills ".

This hilly region is dominated at the North by high lands of Buberuka and Gicumbi at an altitude of 2000 m, with long parallel watersheds, cashed valleys, long and strong slopes which make a truly mountainous region. The District of Muhanga and Gasabo are located in the Central plateau.

(iii) The lowlands of the East.

The lowlands are dominated by a depression of the relief, generally undulating between 1100 m and 1500 of altitude.Lowlands extend from the East of Akanyaru-Kigali-Gicumbi to the border of Tanzania. There develop basins of Umutara and Bugesera. The Districts of Bugesera and Kicukiro are located in the Lowlands of the East.

Figure 1: Rwanda topographic features



Source: Atlas du Rwanda, UNR, 1981

2.1.3 Lakes, Rivers and swamps

In Rwanda the abundance of water resources is reflected by the existence of a network of wetlands in various parts of the country. Wetlands and aquatic lands are generally represented by lakes, rivers and marshes associated with these lakes and rivers.

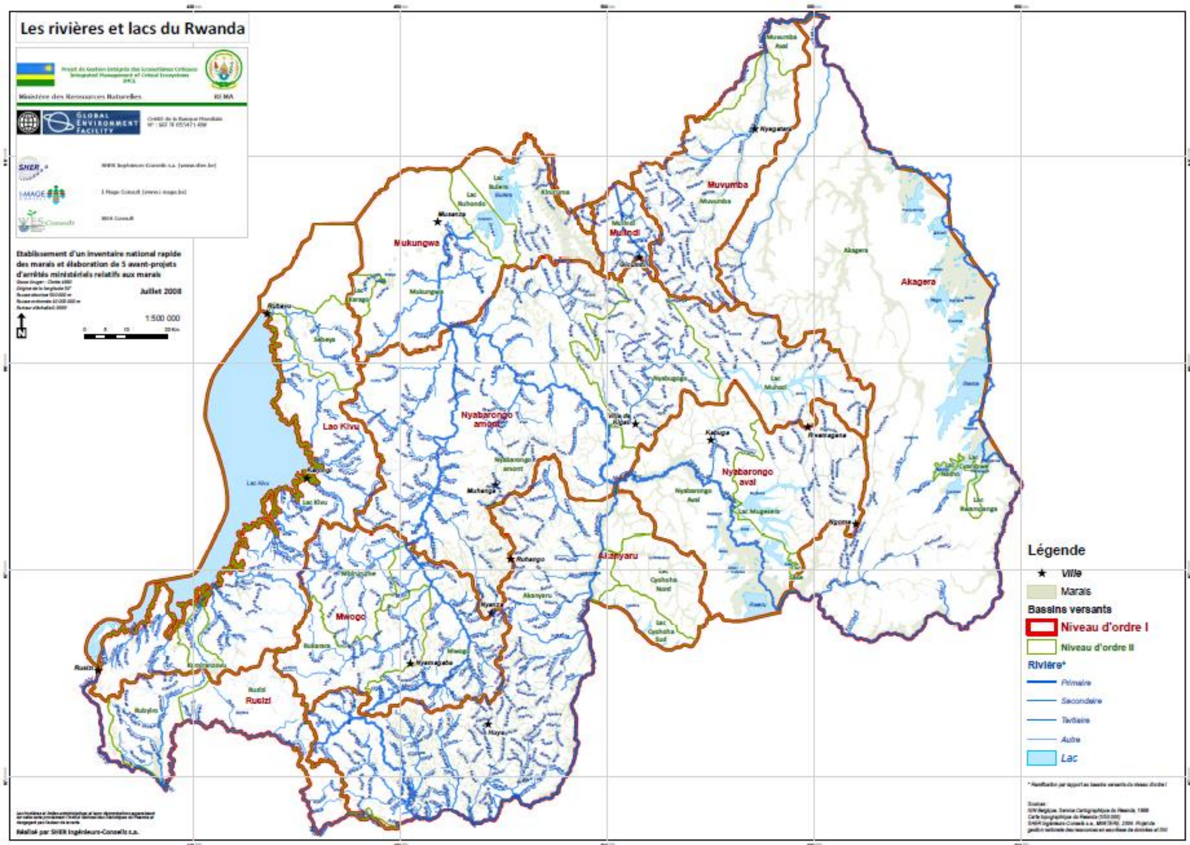
Rwanda is divided into two major drainage basins: the Nile to the east covering 67 per cent and delivering 90 per cent of the national waters and the Congo to the west which covers 33 per cent and handles the remaining 10 per cent of national waters.

A recent inventory of marshlands in Rwanda conducted in 2008 identified 860 marshlands, covering a total surface of 278,536 ha, which corresponds to 10.6% of the country surface, 101 lakes covering 149,487 ha, and 861 rivers totaling 6,462 km in length (REMA 2008).

The Congo Nile Watershed, especially Nyungwe forest, constitutes a real water reservoir of the country because a good number of country rivers take their source there. The other sources of water supply come from the mountains of Gishwati forest as well as in mountainous chains of Gicumbi-Buberuka.

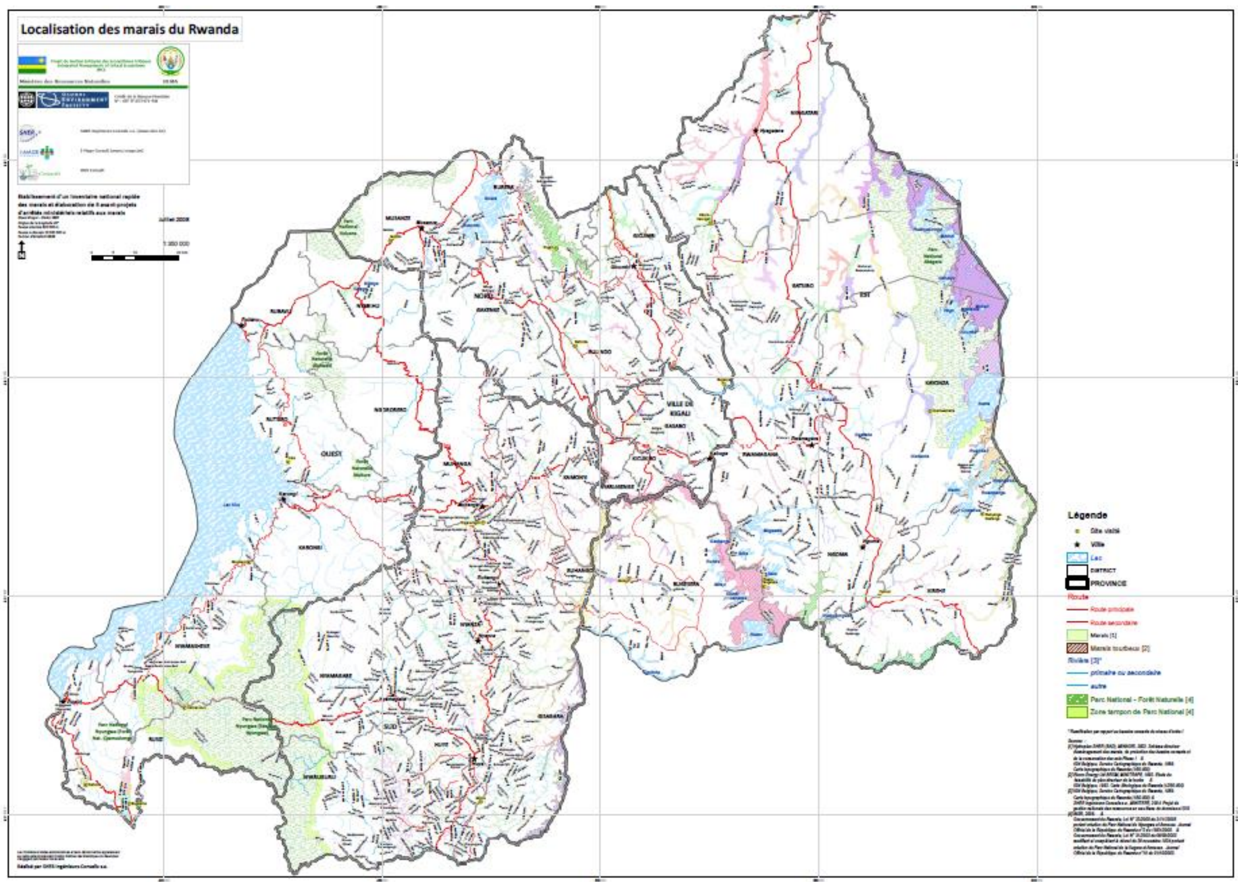
The drainage density varies from 0.75 km/km² in Nyungwe forest, in the Congo Nile Watershed, in the southwest of Muhanga, the region of Huye and in the region of Gicumbi, to less than 0.25 km/km² in low lands of the east notably in Umutara where the out-flow is often temporary.
Following maps indicate Lakes, Rivers and Marshlands of Rwanda.

Figure 2: Lakes and Rivers of Rwanda



Source: REMA, 2009

Figure 3: Marshlands of Rwanda



Source: REMA, 2009

2.1.4 Climate conditions

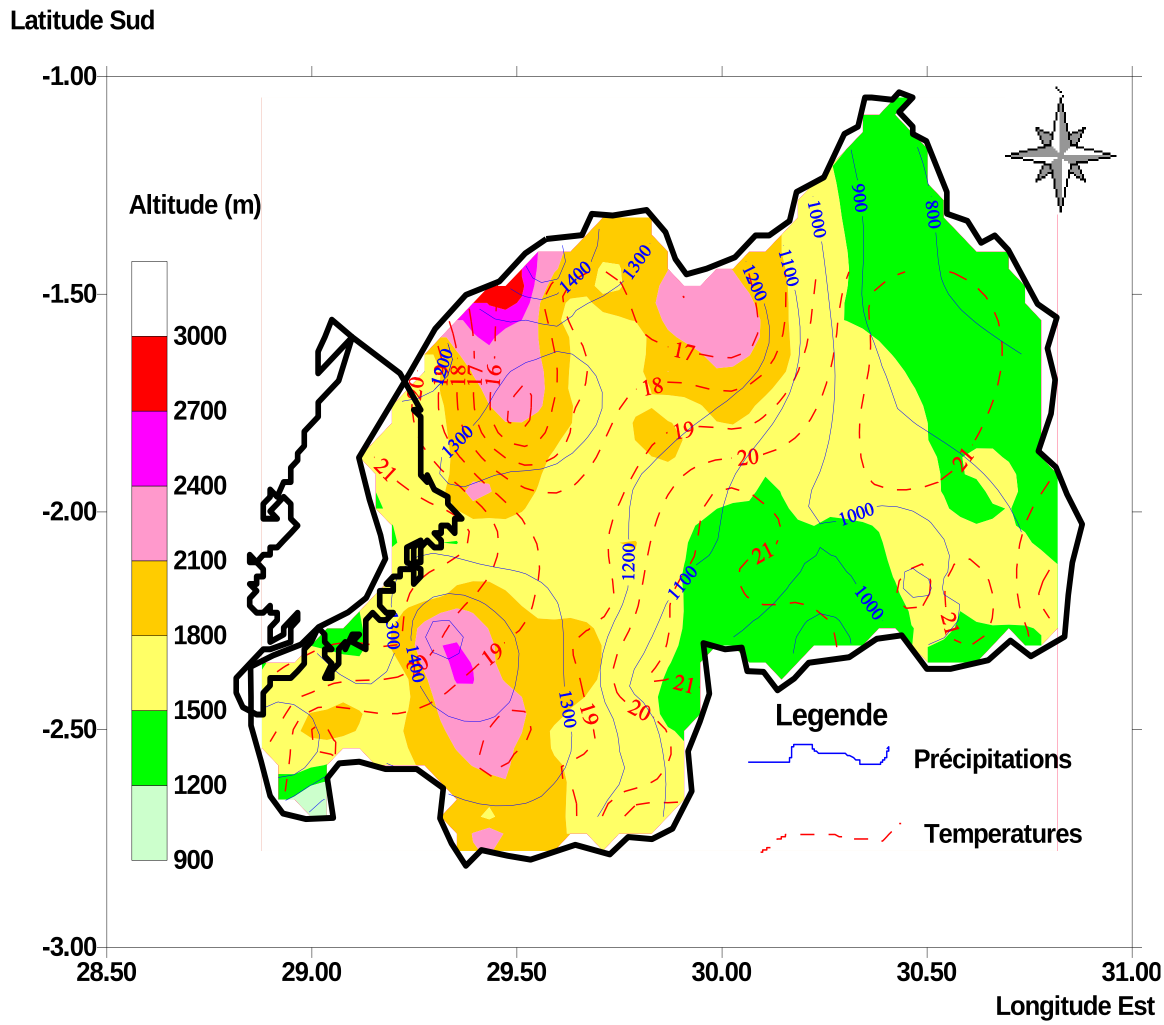
Depicting two main climate parameters, the annual mean rainfall totals varies westward from 700 mm to 1,600 mm following the topographic features while the annual mean temperature varies eastward from 15°C to 21° from western highland to eastern lowland.

Considering rainfall, Rwanda experiences two rainy seasons, the major one centered on March – May and the other one is from mid-September to December. The peak rainfall months for the seasons are April and November respectively.

Rwanda can be divided in four rainfall zones:

- Low lands of the East receive between 800mm to 1000mm of rains per year (Bugesera, Kicukiro);
- Hills of the center from Musanze to the border with Burundi receive between 1100 mm and 1200 mm;
- Highlands of the Congo Nile Watershed, the volcanoes region and highlands of Gicumbi and Buberuka receive between 1200mm and 1600 mm of rains per year (Musanze, Nyabihu, Ngororero);
- Lake Kivu sides and Bugarama receive precipitations varying between 1100mm and 1200mm per year.

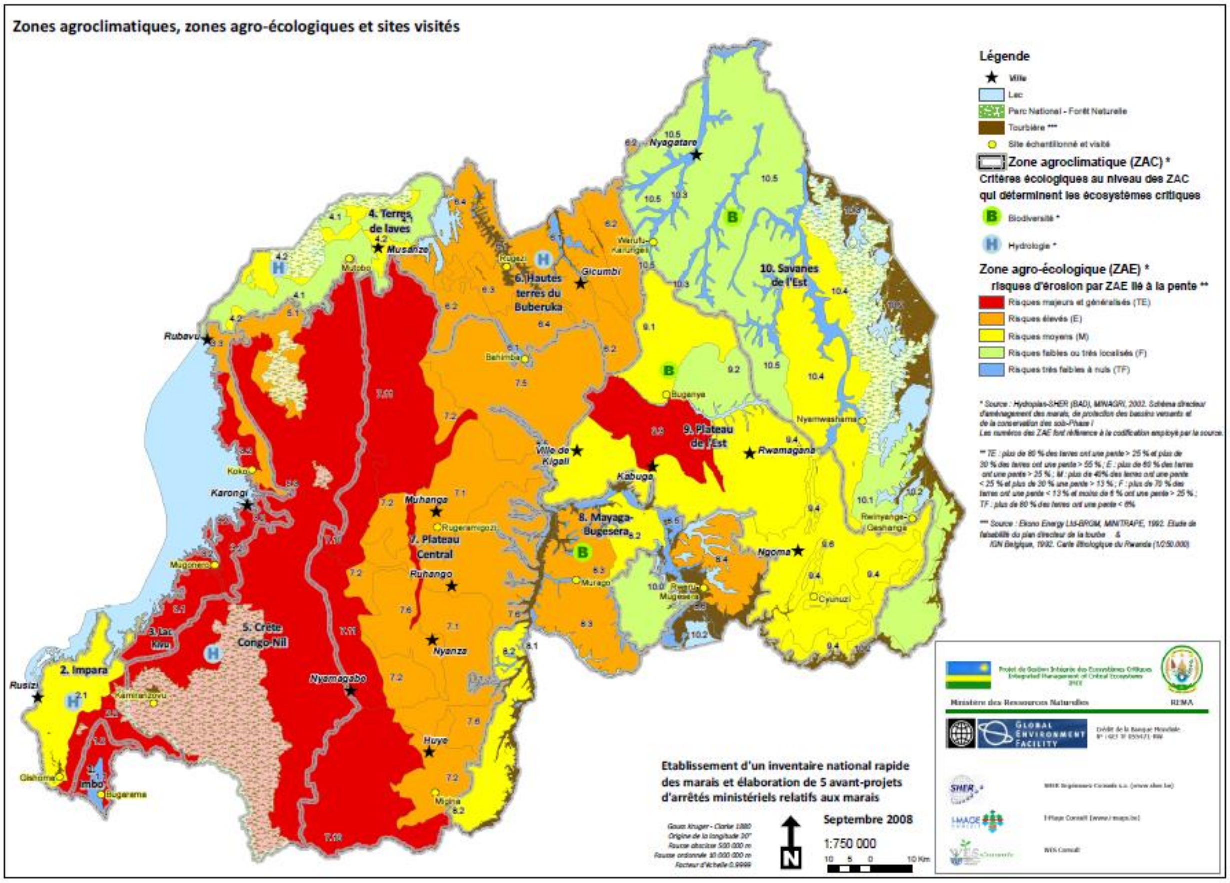
Figure 4: Map showing relief and climate elements



Source: Rwanda Second National Communication, 2012

The following maps indicates agro-climatic and agro-ecologic zones. Nyabihu and Musanze are located in lava lands (Terres de laves), Ngororero and part of much Nyamagabe are in the Congo-Nile Crest (Crête Congo Nil), Kicukiro is in Eastern Plateau and Bugesera is in Mayaga-Bugesera zone.

Figure 5: Agro climatic and agro-ecological zones



Source: REMA, 2008

2.1.5 Floods Description

In recent years natural disasters due to floods and landslides are becoming more observed due to several factors.

The first factor is the climate change.

According to Mutabazi (Mutabazi, 2011), recent testimony on climate change in Rwanda indicates that:

- Temperature increased with high frequency of warm days exceeding 30°C; this is likely to impact on increase of malaria and other diseases related to warm weather;
- The number of annual rain days decreased and this is likely to impact negatively on agricultural productivity as crops requires the quantity of water within the given number of days;
- At the same time the frequency of torrential rain increased with daily rainfall quantity sometimes exceeding the total monthly rainfall; this is natural disaster causing floods including soil erosion;
- The number of dry spells during rainy season increased affecting poor performance of crops;

In most cases we are observing late onset of rainfall and/or early rainfall cessation during rainy season and this also affect poor performance of agriculture productivity.

The second factor is the setup of Rwanda's topography, traditional agriculture practice and non-protection of Rivers banks, Lake shores and poor management of marshlands:

In Rwanda, due to high population density, most of agricultural lands are over exploited and are located on slopes. The traditional agricultural practices are observed, over exploitation of land (as result of lack of off-farm jobs), non-protected river banks and lake shores as well as poor managed marshlands. These combined factors are responsible for intensive soil erosion, landslides and floods.
According to the recent UNEP document on Rwanda Post Conflict Environmental Assessment (UNEP, 2011), floods is among the most destructive disaster which kills and affect a considerable number of people. The tables below show recent trend of disasters with the total number of people killed and affected.

Table 4: Disaster occurred in last 10 years and Number of people killed

Disaster	Date	Killed
Epidemic	24/06/2002	83
Flood	26/04/2002	69
Earthquake	17/01/2002	45
Earthquake	March 2008	48
Epidemic	01/09/1999	44
Earthquake	03/02/2008	36
Epidemic	janv-06	35
Epidemic	janv-99	27

Slides	28/11/2006	24
Flood	12/09/2007	20
Flood	22/09/2001	10

Source: UNEP, 2012

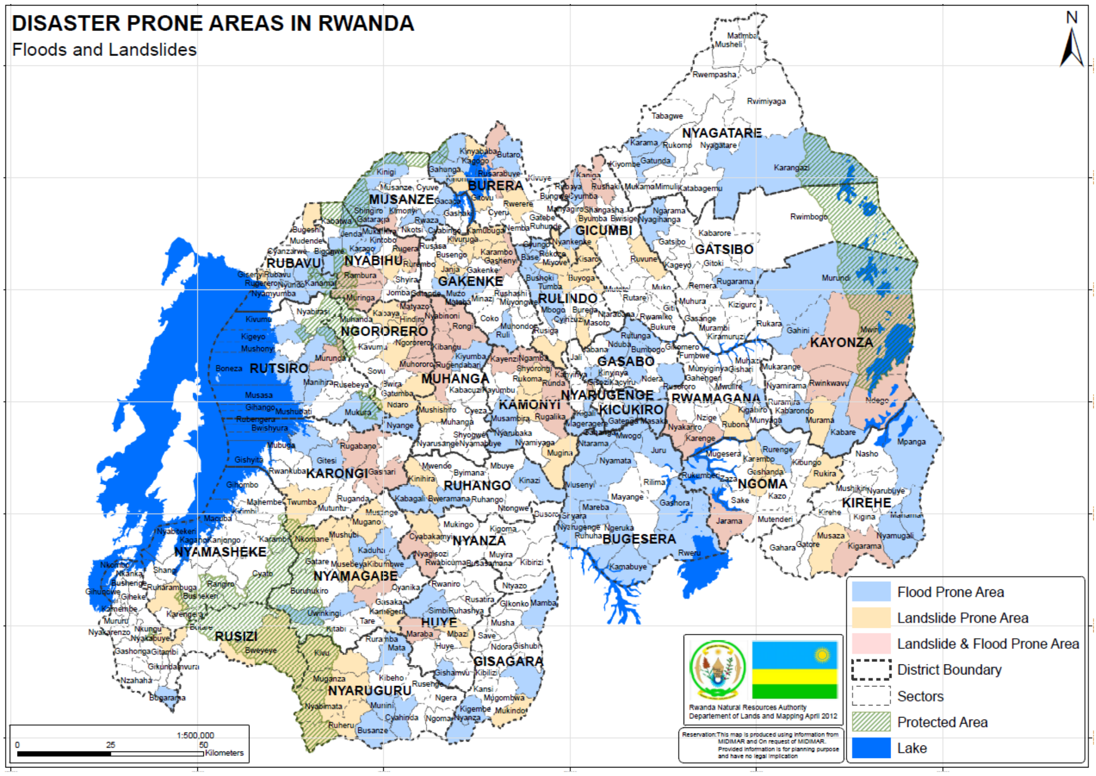
Table 5: Disaster occurred in last 10 years and Number of people affected

Disaster	Date	Total Affected
Drought	mars-03	1000000
Drought	nov-99	894545
Flood	26/04/2002	20000
Flood	30/10/2003	7016
Flood	12/09/2007	4000
Flood	30/10/2001	3000
Slides	28/11/2006	2000
Earthquake	17/01/2002	1643
Earthquake	03/02/2008	643
Epidemic	24/06/2002	636

Source: UNEP, 2012

With reference to recent mapping of floods and landslides, Rwanda is a country with multiple disasters.

Figure 6: Areas Prone to multiple climate-related disaster risks in Rwanda



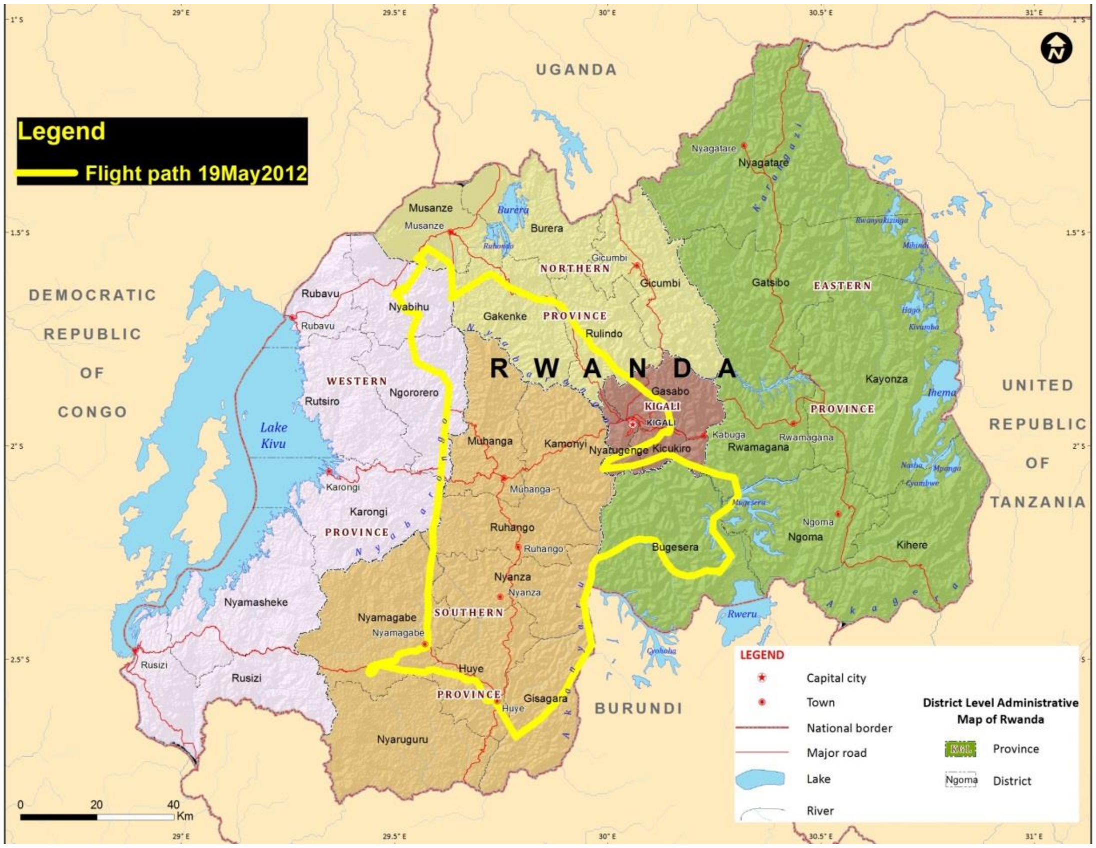
Source: Department of Lands and Mapping, RNRA, 2012.

2.1.6 Floods of May 2012

In May 2012, severe floods occurred in Rwanda and affected mostly 8 Districts: Nyabihu, Musanze, Ngororero, Nyamagabe, Muhanga, Kicukiro, Gasabo and Bugesera. This floods were associated with heavy rains and overflow of Mukungwa, Nyabarongo, Akanyaru and AkageraRivers.

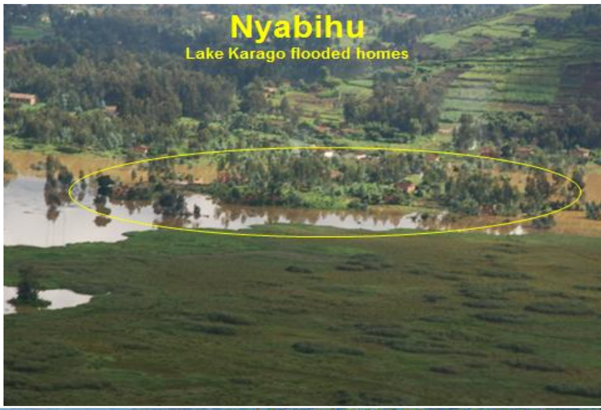
The impacts of these floods were: crop destruction and failure, Water quality regarding pathogens and sediment, water stagnation with vector disease risk, especially malaria, infrastructure destruction, loss of properties, death of people etc…

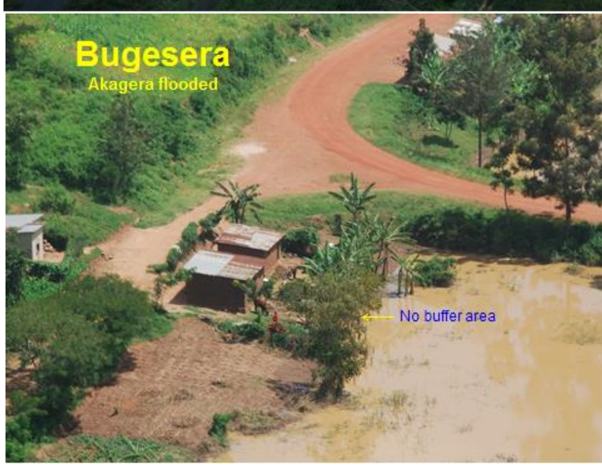
Figure 7: Aerial Survey Route, 19th May 2012



Source: REMA, 2012

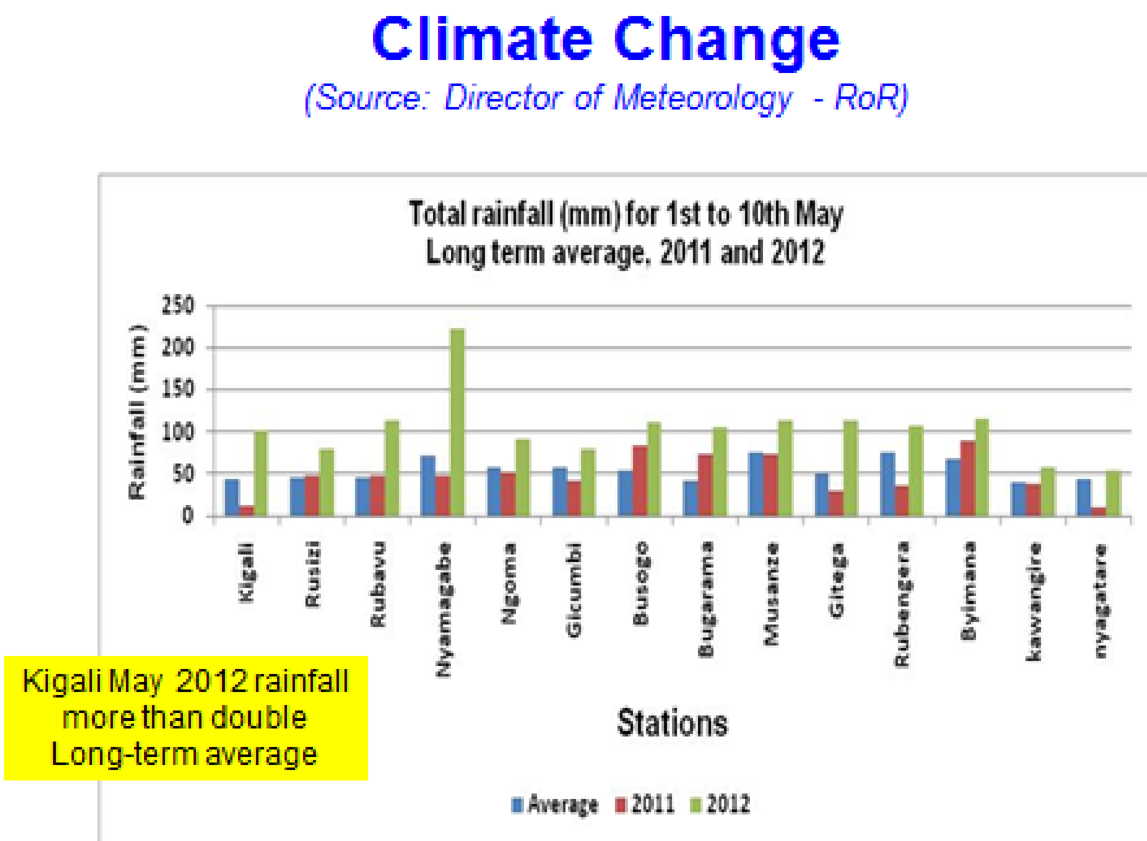
Figure 8: Aerial photographs taken during the period of 2012 wet season





During the period, the rainfall observed on different meteorological stations across Rwanda indicated that the rainfall in 10 days (1st to 10th May 2012) were above normal and in most of stations, the rainfall was double than long-term average.

Figure 9: Rainfall measurement in wet season 2012



2.2 Data Collection Techniques

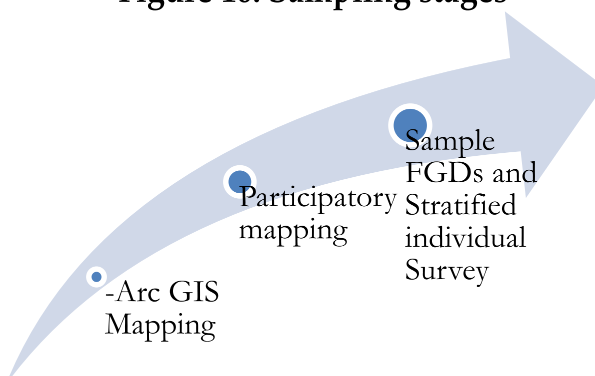
This section deals with the details techniques of data collection.

2.2.1 Sample design

The sampling approach was a two stage process. The first stage was a purposive selection of Districts to be considered. These Districts were Kicukiro, Gasabo, Bugesera, Musanze, Nyabihu, Ngororero, and Nyamagabe. From these Districts a stratified sampling of respondents was applied in three categories, upstream, mid-stream and downstream. The first step was the mapping of all areas with greater likelihood of being affected by the floods in the above eight purposely selected Districts. In the second step, a participatory GIS approach was used to map, together with local population, areas that were highly, moderately, and less likely to be affected by the May

2012 wet season. From these participatory maps, sample areas for the FGDs and individual household/farm survey were identified and jointly validated with the client before the primary data collection at the field started. In this case GPS Astch Mobile mapper 100 was used with real time RTK (Accuracy specifications real time RTK 30m), promark 500 (with real time accuracy horizontal 10 mm, real time accuracy vertical 20 mm, RTK Initialization range 40 km) and Trimble Juno SB. other software used include the GNNS solutions; map Source, and Arc PAD 10. The following figure summarizes the sampling stages.

Figure 10: Sampling stages



The sample size proposed for the household survey was 480 households but the effective sample was 421 as illustrated in the frequency tables in the annex 1: Agriculture losses. The proposed sample size was based on the above Districts but also following major valleys and wetlands with greater probability of being flood prone. These included Gikondo Valley, Nyabugogo Valley, Nyabarongo River Valley, Akagera Valley, Rugende Valley, and Kanombe–Masaka Wetlands. Given that there was no secondary data to give respective weight of the sample size per District, the proposed size was equitably divided among those Districts. The proposed households per District were 60 [10], assuming this to be sufficient to provide the necessary information. The following Table depicts the distribution of sample size across the study area.

[10] 60 households out of a total of 480 households

Table 6: Distribution of sample size

No	District	Sectors	Sample selected (HH)	Distribution of sample (HH)	Reasons of choosing	Enumerators
1	Kicukiro	Gahanga Gikondo Kanombe Kicukiro Masaka Nyarugunga	60	20 Upstream 20 Middle stream 20 Downstream	Nyabarongo Flood and Agriculture risk Industrial area	1
2	Gasabo	Gatsata Gisozi Jabana Kacyiru Kimihurura Remera Rusororo	60	20 Upstream 20 Middle stream 20 Downstream	Nyabugogo, Gatsata, Gikondo Industrial area Non-regulated sand mining Industrial area Nyabarongo: Flood and Agriculture risk Muyumbu Agriculture risk	
3	Bugesera	Gashora Juru Mwogo Ntarama Nyarugenge Rilima Rweru Shyara	60	20 Upstream 20 Middle stream 20 Downstream	Akagera Agriculture risk Nyabarongo Flood and Agriculture risk Nyabarongo Flood and Agriculture risk Akanyaru-Nyabarongo mix	2

No	District	Sectors	Sample selected (HH)	Distribution of sample (HH)	Reasons of choosing	Enumerators
					Akanyaru Agriculture risk	
4	Muhanga	Nyarusange Rugendabari	60	20 Upstream 20 Middle stream 20 Downstream	Nyabarongo Valley Hydro power construction Mining degradation	2
5	Musanze	Busogo	60	20 Upstream 20 Middle stream 20 Downstream	Mukungwa Valley Busogo - Mukamira 19 may 2012	1
6	Nyabihu	Jenda Jomba Karago Kintobo Mukamira Rugera Shyira	60	20 Upstream 20 Middle stream 20 Downstream	Landslide near Mukamira Landslide damadeKabaya Lake Karago Busogo - Mukamira 19 may 2012 Landslide near Mukamira Lake Karago Flooding, Vunga Wetland	2
7	Ngororero	Hindiro Kabaya Muhororo Nyange	60	20 Upstream 20 Middle stream 20 Downstream	Kabaya flood Landslide damage, Kabaya Mining degradation Hydro-power construction	2

No	District	Sectors	Sample selected (HH)	Distribution of sample (HH)	Reasons of choosing	Enumerators
8	Nyamagabe	Gasaka Kamegeri Kitabi	60	20 Upstream 20 Middle stream 20 Downstream	Landslide road damage	1
	Total		**480**	**160 US (33.3%)** **160 MS (33.3%)** **160 DS (33.3%)**		**12**

A sample population in the affected areas was drawn from the study population after the exploratory field visit to quantify in monetary terms damages that might have occurred due to the May 2012 wet season.

2.2.2 GIS Based Flood Mapping

Geographic Information System (GIS) can be understood in two parts "Geography and Information system". First "Geography"- It is a study of the relationship between man & the environment, and the key tool to study this spatial relationship is a map. Secondly "Information System"- It is a continuous chain of data collection, storage, analysis and use of the derived information in some decision-making.

GIS applications in flood risk mapping range from storing and managing hydrological data to generating flood inundation and hazard maps to assist flood risk management. GIS is a useful tool that enables different data sets to be brought together for flood mapping purposes. These include land use, buildings, environmental information, ground water, topographic details, etc. In this regard, an attempt was made to demarcate the flood prone areas in Rwanda using GIS. This helped to understand the general topography and the nature of soil and the kind of vegetation of the flooded areas; to demarcate the area of flood vulnerability and appreciate the effect of resultant floods; to prepare a flood hazard zonal map; to demarcate the river overflow and breaches that lead to free flow of water into the rural as well as urban areas; to collect information on flood damages using GPS which can then be integrated into GIS; to identify and detail those factors that are relevant to current and future flood risks; and to outline policies to be applied to such areas to minimize and manage flood risk in the most affected areas.

First of all, the topo sheets of Rwanda at a scale of 1:50,000 and the aerial photographs (at 25 cm of spatial resolution) above the flooded selected areas were acquired from Rwanda Natural Resources Authority and used for this study. The base map of administrative and villages' boundaries showing all the prominent geographic features of the river basins were prepared by integrating topo sheets and aerial photographs. Field visits to different parts of the river basins were conducted to observe the landforms. Based on the observations made from the field a base map was prepared. The amount of rainfall in the flooded areas for various seasons was collected from the meteorological department and an average of the annual total rainfall was calculated and mapped through GIS. The latter was used to show affected land uses, agriculture fields, physical infrastructure, and soils. It provided what kinds of property were affected when the actual flood occurred along the study area. This information and based on the accuracy can be linked with emergency response planning. A procedure to obtain final map products of flood impact analysis by overlaying the spatial data set, land use in points –vegetation, buildings, land use, and roads with flood hazards zones was used. Flood impact analysis was done to identify impact in flood prone areas with the help of the GIS system.

GIS-Based Data Collection and Processing

The study was carried out for a large catchment and long river reach of the flooded zone. The primary decision factors considered in this study are geomorphic features, elevation, vegetation, land cover and land use, physical infrastructure, human settlement, economic activities, distance to water channels, and population density. The main input data collected were therefore from the sub- catchment area, river gradient, land use, soil types and rainfall distribution over time (e.g. time series). Most of this data can be extracted from a topographical map, hydrological and meteorological stations. Using GIS, the following information was determined:

Division of sub-catchment: Various methods to delineate the sub-catchment are available but for this exercise the sub-catchment boundary was digitized manually from an elevation contour lines map and the river network layer using ArcGIS10.1.

River slope: the river slope was estimated using a simple approach, i. e., the difference of height divided by the length of the river. Both of this information was available from the contour layer and the river layer.

Soil distribution: the rainfall runoff requires the soil group to be defined for each sub-catchment. This information was combined with the land use layer from MINAGRI. The overlaying process was carried out to distribute the soil group to various sub-catchments.

Rainfall distribution: information on annual average rainfall distribution at country level and particular to the study area was collected. This information is regularly collected by the meteorology department under the Ministry of Infrastructure. The spatial interpolation by the kriging method was used to demonstrate the rainfall distribution map for Rwanda. This map was used to find possible correlation between the rainfall and the most flooded zones.

2.2.3 Focus Group Discussions

Qualitative approaches that help to understand the processes, behaviors and conditions surrounding natural resources management interventions were used. These tend to use open-ended designs for data collection, including focus group discussions, key informants surveys and participatory appraisals (Shiferaw et al. 2005). A number of focus group discussions were organized at Sector level to gain collective opinion from key informants, including local authorities representing different domains such as the Executive Secretary, the officer in charge of Agriculture and Environment, and that of Social Affairs. Choosing to collect information from local authorities and population was meant to provide information that was not available elsewhere in terms of secondary data, and to gain knowledge of the perceptions of individuals about rain flood damages and causes. From these FGDs we also obtained information on damages regarding public and community facilities (such as bridges, schools, churches, health facilities, etc.). Similarly, information from the FGDs contributed to the understanding of existing and potential adaptation measures to prevent adverse effects of floods and climate change. Finally, these approaches provided insights into the way in which households and communities perceive the climate change in the form of floods and its effects.

2.2.4 Household Survey

A team of 12 enumerators and 3 supervisors was trained before the field data collection and logistical arrangements was made for field data collection. This took 10 working days.A structured questionnaire was designed to gain baseline information on the socio-economic characteristics of the sample respondents and rain floods-related damages (both first and higher order damages). Each of these areas was unpacked to gain information on potential economic costs and /or losses.

To design an economic stratified survey, a number of steps were followed:

1. The first step was to identify, during the field exploration, (in the selected Districts) sectors affected by the May 2012 wet season. This exploration followed the proposed Districts in the TORs and major valley and wetlands as these are the most likely areas where floods can occur. These include Gikondo Valley, Nyabugogo Valley, Nyabarongo River Valley, Akagera River Valley, Rugende Valley, and Kanombe –Masaka Wetlands.
2. From these sectors, key informants, including local authorities and the in-charge of environment, were consulted to provide an indication of immediate or direct damages by the flood. Location of selected farms was mapped using participatory GIS.
3. A sample of affected farms was selected by considering geographical representation and the frequency of the floods in sample areas.
4. Each selected farm was visited by trained enumerators/ research assistants to elicit detailed information using a designed questionnaire, visited homeswere captured using a GPS.

Among the respondents, 52.7% were males and 47.3 % were females. Considering their locations, 24.8% were from the Upstream, 43.5% were from the Middle stream, while 31.7% were from the Downstream zones.

For data processing and analysis two software packages were used: CsPro and SPSS, for the development of the survey database. The choice was based on the analysis capacity of these packages, compared to the capabilities and limitations of other software options. The CsPro software was conceived specifically for entering, storing, cleaning and analyzing data from surveys and SPSS for cleaning cross tabulating and analyzing data. An important additional factor in favor of CsPro and SPSS is the fact that the National Institute of Statistics of Rwanda, (NISR), uses them for all its surveys, including the national census. Once a cleaned data file was produced and exported, tabulations were generated using SPSS statistical software and detailed analyses of results presented in the research report. The GIS data were entered and treated using Arc GIS 10.

2.3 Analytical Approaches

The analytical approach opted in this study lies within the overall methods for Natural Resources Management impact assessment (Shiferaw et al. 2005). The intention here is to have an approach that allows accounting monetary and non-monetary impacts of the 2012 wet season flooding in Rwanda. Approaches often used in the analysis of economic costs/losses due to natural phenomena (such as floods) are various. These include Input-output approach, Social Accounting Matrix, Spatial or GIS analysis, the "With -Without Analysis, and Econometrics (Okuyama and Sahin, 2009[11]; IUCN, 2009)[12]. Each approach has its merits, which in turn, informs on data requirements. With reference to the nature of this study and its expectations, input-output approach was adapted and this has been the most widely used in assessing the economic impacts of a disaster (Okuyama and Sahin, 2009).

Damages and losses brought by disasters such as earthquakes and floods can have significant and intense effects to the economy. Natural disasters, as above indicated, can cause physical destruction (e.g. transportation facilities) casualties and injuries to human lives. From economic perspective, these damages are known as 'damages on stocks', which include physical and human capitals (Okuyama, *undated*)[13]. The assessment of economic impacts of such damages requires that their respective economic costs are estimated.

11Okuyama, Y and Sahin, S (2009). Impact Estimation of Disasters: A Global Aggregate for 1960 to 2007. The World Bank , Sustainable Development Network Vice Presidency, Global Facility for Disaster Reduction and Recovery Unit &International University of Japan. WPS4963

[12]Impact Estimation Methodology: Case studies

[13] Okuyama Y (…). Impact Estimation Methodology: Case studies. Graduate School of International Relations, International University of Japan, Niigata, Japan[Internet]. http://www.gfdrr.org/sites/gfdrr.org/files/New%20Folder/Okuyama_Impact_Estimation.pdf. Accessed on: 4th October, 2013

2.3.1 Economic Cost Estimation methodsof floods

The quantification of economic costs/losses induced by natural disasters such as floods is crucial to inform on individual and community vulnerability, evaluate the worthiness of mitigation, determine the appropriate level of disaster assistance, improve recovery decisions, and inform insurers of their potential liabilities (Rose, 2004)[14]. Accordingly, the principle of welfare economics offers a starting point for an analysis of economic losses from natural hazards; leading to the estimate of costs in terms of the value of destroyed resources (Rose, 2004). The estimation of costs, in turn, brings the notion of direct and indirect effects of the natural disaster. The direct effects are also known as damages on stocks – these lead to interruption of economic activities namely production for consumption. While indirect effects are also linked to flow losses through inter-industry relationships (Okuyama and Sahin, 2009).Before attaching any monetary value to any of the above disaster effects, some guidance is needed. Nelson and Maredia (1999) provide such a direction in a five-step procedure:

1) Understanding the causes and impact of changes in the use of natural resources such as declining soil fertility, land degradation, deforestation, and loss of biodiversity
2) Identifying the main types of Economic costs: Economic costs may include the depletion of the stock of natural resources and loss of species. An important consideration is to identify the distribution of the burden of these costs over time and space and across affected communities.
3) Determining whether there is or isn't a means to measure the costs in monetary terms
4) Collecting data to estimate the impact of the environmental effects on indicators such as productivity, income, and human health.
5) Using economic techniques to place values on environmental changes or particularly on flood effects.

The above steps provided some guidance to assess the economic costs of the 2012 wet season flooding in Rwanda. We needed to understand the causes of the flooding occurred, identify the main economic activities or assets affected, looked at options of measuring the costs / impact in monetary terms, and collected both primary and

[14]Rose A (2004).Economic Principles, Issues, and ResearchPriorities in Hazard Loss Estimation. Department of Geography and Natural Hazards Research Center, The Pennsylvania State University, USA.

secondary data to estimate the economic impact of the 2012 wet season flooding as detailed in the next sections.

The cost-estimation methods used include production, replacement, and opportunity cost methods (IUCN, 2009)[15]. The following Table 7 below shows the cost estimation method and its area (s) of application in the context of this study as well as the source of information used to inform the costing.

Table 7: Economic Estimation Methods

Cost estimation method	Item to consider	Sources of information
Production Method	Gross value of loss in crop production	Economic Stratified survey
	Gross value of loss in livestock	Economic Stratified survey
Replacement costs	Cost to replace the lost house items – or other infrastructures	Local authorities, civil engineers and MININFRA offices
	Costs used or needed to repair damaged facilities and infrastructures	Local authorities, civil engineers and MININFRA offices
Opportunity Costs	Costs for treatment of diseases with high linkages to floods.	Hospitals/ Health Centres in the neighborhoods
	Value of Humanitarian Assistance	Local Authorities
		Local and International Humanitarian organizations operating in Rwanda or particularly in the study area
Social Capital Costs	Equivalent costs of collective actions such as loss of membership value within a farmer cooperative due to	Local authorities (social affairs and the person in charge of

[15]Padma NarseyLal, Rashmi Rita and NeehalKhatri (2009).Economic Costs of the 2009 Floods in the Fiji Sugar Belt and Policy Implications. IUCN, Gland, Switzerland

displacement or resettlement.	cooperatives)

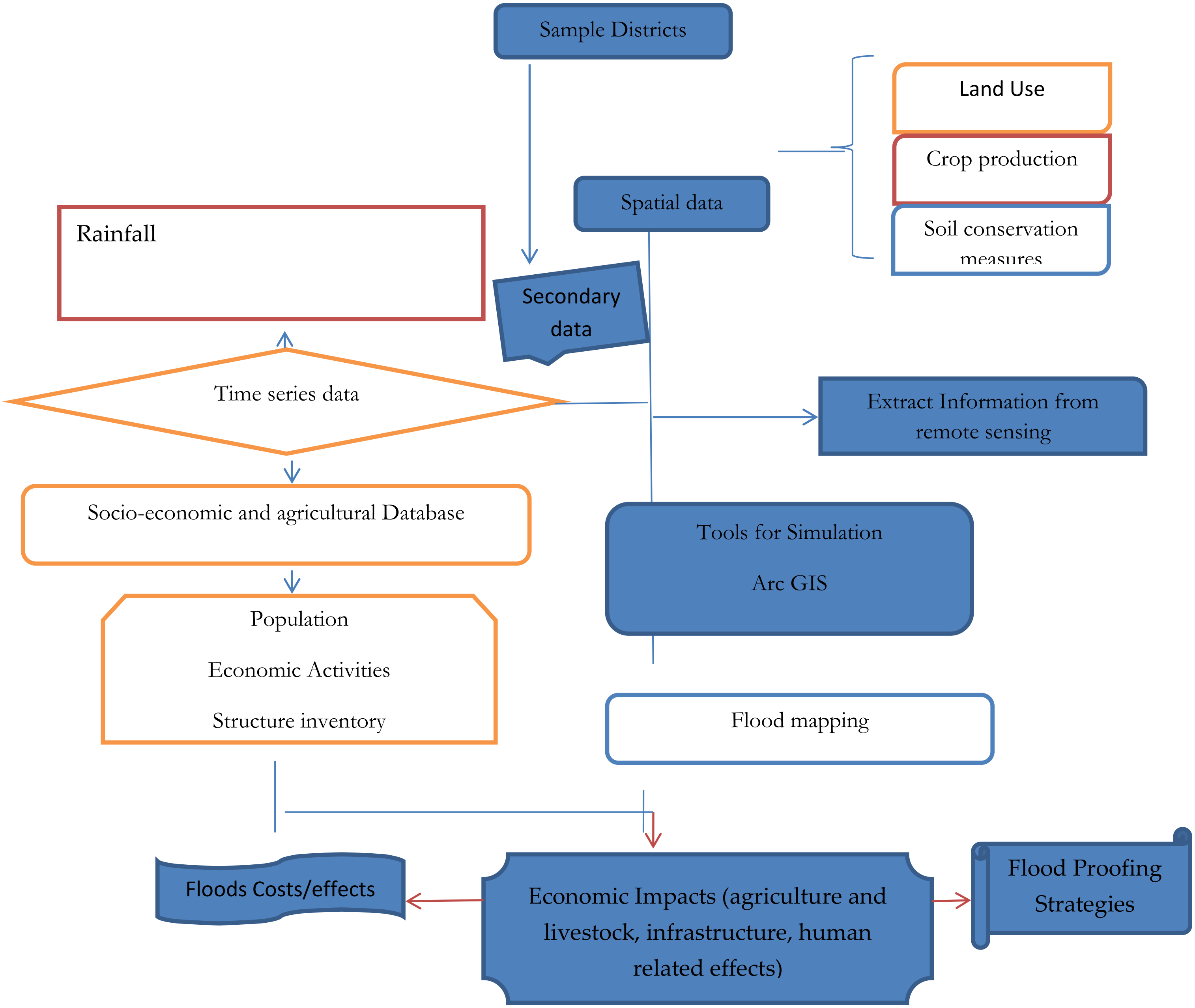
Adapted from ICUN (2009)

The flood effects can be measured by its indicators. The main flooding indicators include the area(s) affected, frequency and duration of flooding. These indicators are used to characterize and measure the extent to which temporary or seasonal flooding upstream affects downstream parts or reaches of streams and their tributaries. Seasonal flooding causes human miseries, loss of property, destruction of standing crops and loss of agricultural productivity, silting of lands in the course of rivers and waste of rain water (McCracken, 1990; Wasson, 2003; *cited in*Shiferaw et al. 2005: 81).

From the above, data required in terms of flood indicators include upstream, middle, and downstream flood frequency records and estimates of damage, the extent to which land and water management practices are implemented, river banks protection measures, the number of water storage and flood control structures in a given area, landslides, roads destruction, existence and respect of the buffer zones, color of the rivers, presence and maintenance of road retainer walls, number of rain days, and the implementation of other vegetative control measures, (Sharma et al. , 1991; cited in Shiferaw et al., 2005: 81).

In this study, change in productivity, replacement cost, opportunity cost methods used actual market values to appreciate costs in their respective categories. However, some costs such as the opportunity costs were not documented making it difficult to distinguish at health centres treatment costs induced by the flooding of 2012 wet season. The following framework shows theanalytical process opted for this study.

Figure 11: Analytical Framework



3 ECONOMIC IMPACTS OF 2012 WET SEASON

To measure the economic impact of the 2012 wet season in Rwanda the production and replacement costs methods were followed. This section presents loss estimates that are related to agricultural and livestock, infrastructures and human losses. A summary of direct and indirect costs as reflected by the above cost areas is presented.

3.1 Agricultural and Livestock Losses

The economy of Rwanda is highly dependent on agriculture and animal resources. Agriculture is strongly rain-fed making the sector to be highly vulnerable to climate change. Since 1970, Rwanda has experienced a temperature increase of 1.4°C, higher than the global average, and can expect an increase in temperature of up to 2.5°C by the 2050s, from 1970[16]. Projections for East Africa over Rwanda and Burundi show an increasing trend in rainfall intensity for both rainy seasons which are likely to cause floods and storms that can result in landslides, crop losses, health risks and damage to infrastructure.

Agriculture and livestock are, therefore, the economic activities with greater likelihood of being affected by the floods. The production method was used to quantify the gross value of losses in agriculture and livestock incurred from the 2012 wet season rain damage in monetary terms. Data used to compute these losses are from a sample household survey as indicated above and some secondary data sources. Results obtained in this section are beneficial to future adaptation and mitigation actions as far as agriculture is concerned. Furthermore, this is consistent with the National Strategy for Climate Change and Low Carbon Development for the Green Growth and Climate Resilience. The strategy is also in line with national development frameworks such as the Vision 2020 and EDPRS.

Findings of the survey show that 81% of the respondents indicated that flooding occurred in their locations in year 2012, and 62.5% confirmed that flooding occurred mainly between March and May of the same year.

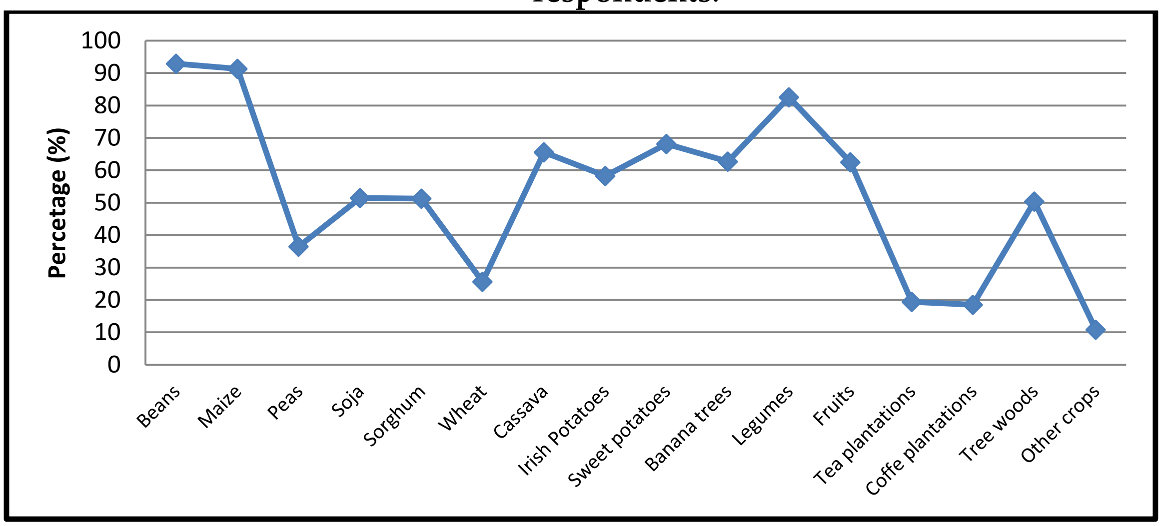
Agricultural activities (crop production, livestock, and fish farming) are the main source of income of sampled respondents as confirmed by the most of respondents (82%). Those involved in off- farm activities are fewer and represent only 18% of which 10% are found in job remunerative activities. Looking at the stratified study areas (up-stream, middle-stream, down-stream) the same agricultural activities dominate. In the up-stream, about 54.6% revealed that they practice crop production, rearing animals, and fishing as their main activities. Out of the 27% of respondents from the mid-stream, 64.1% of them carry out agricultural production, while 22% of them rear animals and practice fishing activities. In the downstream area, 50% indicate that they practice agricultural production, while 26.3% practice rearing animals and fishing

[16] TOR

activities and 13.16% have job remuneration as their source of income. From the above descriptive, it is clear that agricultural production remains the major economic activity and hence the main source of the respondents' income and livelihoods.

With respects to types of crops cultivated in the study areas, more than 15 crop varieties are cultivated although their dominance vary from the up-stream, middle stream, and down-stream. Wheat, coffee plantations and tree woods were found to be dominant in the up- stream areas; Irish potatoes and tea plantations are dominant in the downstream zone; while crops like soya, maize, peas, sorghum, cassava, Irish and sweet potatoes, other legumes, as well as fruits are dominant in the mid-stream zone. Figure 12 below portrays the percentage of respondents who indicated what crops were grown in the main 2012 wet season. It is clear that beans, maize and legumes were grown by a high percentage of respondents during this period and therefore have a greater likelihood to have been the most affected by the floods.

Figure 12: Crops grown in the main 2012 wet season, as indicated by percentage of respondents:



Source: Field study on impact of wet season May 2012

The gross value of agricultural and livestock losses was obtained by estimating the losses in investments for agricultural production (inputs lost) and livestock units lost (number and their monetary value). In other words, estimates of agricultural inputs and livestock units lost from sample population give an indication of gross agricultural and livestock losses.

The 2012 wet season flooding caused tremendous losses in crops and livestock in Rwanda. Out of the 421 households' respondents, 21% reported agricultural losses during the May 2012 wet season due to flooding, especially those located in the hillsides and near the marshlands from both the upstream and the downstream zones. This is supported by the fact that 21% of respondents that live in the Upstream, 38% in Middle stream and 28% in Downstream had spent money to purchase inputs like seeds, fertilizers, and to hire workers and land used for their agricultural activities. Causes and the losses incurred are specific to location and to types of crops invested in. For example respondents from the volcanic region reported to have been badly affected by heavy rain coming from the volcanic park, leading to soil erosion and land damages.

The estimate of agricultural losses during the wet season was based on all crops cultivated in sample areas. Seasonal crops such as Irish potatoes, beans, maize, sweet potatoes, as well as other legumes are the most vulnerable to flooding, compared to perennial crops such as tea and coffee. This is, perhaps, mostly because such perennial crops are part of soil erosion control measures and hence less likely to be affected by floods. The most affected seasonal crop was found to be Irish Potatoes. For example, about 23.5% of sampled respondents reported that they incurred seed losses, 22.3% lost fertilizers and 21% lost labor. In addition land losses due to the 2012 main wet season by respondents growing Irish potatoes were estimated on an average of 585.7 m^2, the highest loss being 50,000m^2 (5 hectares). Details about losses for each crop are provided in Annex 1.

The gross value of agricultural losses in the main wet season is estimated based on information provided by 74.4 % of total sample respondents who reported being affected by the 2012 wet season flooding. The total estimated losses are 31, 926,941 RwF, of which 50% accounts for seed loses, 32% for human labor losses, and 18% for fertilizers. Looking at the three locations surveyed, 43% of losses were from the middle stream zone, compared to 24% in the upstream and 33% in the downstream zones, respectively. Table 8 below gives an estimate of 1,019,302 m^2 or 101.93 hectares of the total land affected by floods in the 2012 wet season. There is some variation per location where the middle stream was highly affected (437,590m^2) followed by the downstream (340,639 m^2) and then upstream (241,073 m^2).

Table 8: Agricultural losses during 2012 wet season

Inputs	Stream			Total Cost (Rwf)
	Up	Middle	Down	
Seeds	3764676	6833556.1	5319531.2	15,917,763
Fertilizer	1353610	2457042.2	1912666.3	5,723,318
Labor	2432687	4415758.9	3437414.8	10,285,860.4
Total	7,550,972	13,706,357	10,669,612.28	31,926,941.4
Mean Loss	28,915	51,805	39,758	120,478
Indiv. Mean loss	82,076	82,074	82,074	82,074
Land (m2)	241,073	437,590.4	340,639	1,019,302.5
Indiv. Mean loss (land in m2)	2620.4	2620.3	2620.3	2620.3

Source: Field study on impact of wet season May 2012

Among 389 sample households who faced flood problems, only 48 declared that they lost some units of livestock. About 3% were from the upstream, 5% from the middle stream, while 4% are from the downstream zones. Units of animals lost vary per individual, from 1 to 16. The total gross value of livestock losses is estimated at more than 2.5 million Rwf, of which 34% represents losses of goats and 16% of cattle.

Table 9: Livestock losses during 2012 wet season

Livestock	Number	Total Loss Value (Rwf)
Cattle	13	670,000
Goats	42	858,000
Sheep	13	288,000
Pigs	27	439,500
Poultry	43	142,500
Others	57	118,500
Total	195	2,516,500

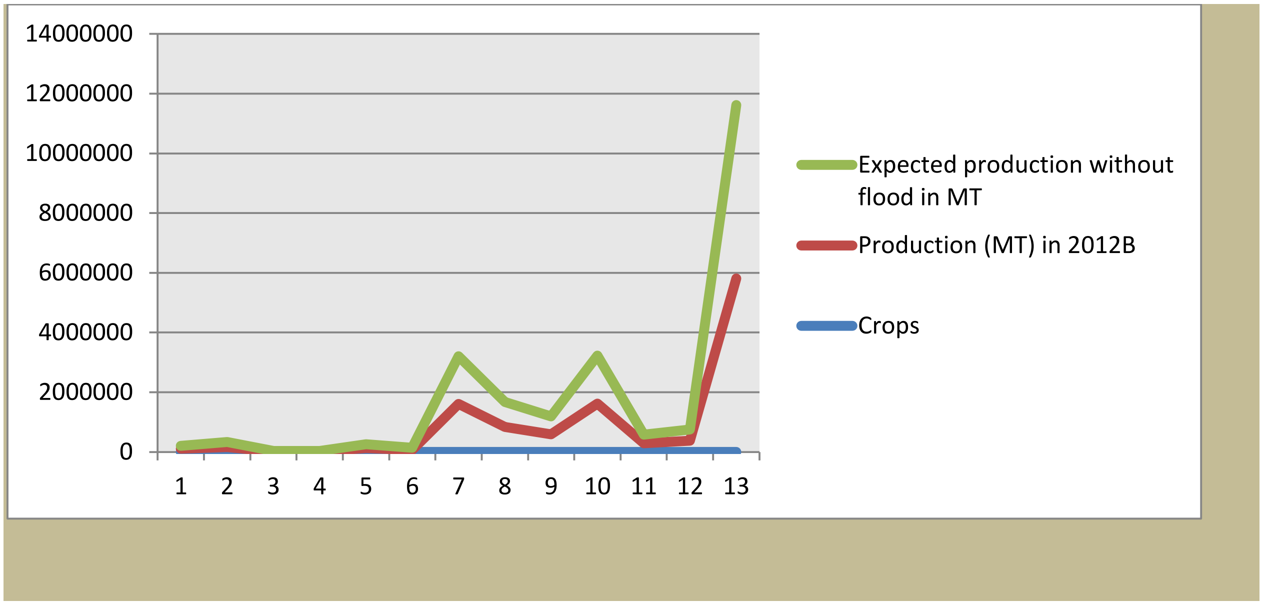
Stream	Up	Middle	Down	Total
Total losses	595,174.9	1,080,336	840,989.1	2,516,500
Mean loss	6,469	6,469	6,469	6,469

Source: Field study on impact of wet season May 2012

3.2 Opportunity losses

An alternative option to compute the economic impact of the 2012 wet season is to estimate the expected crop production losses. We compared the obtained production in Season B consistent with the 2012 Wet Season and compared this with the expected crop production without floods. From the Table below the loss crop production is estimated at 580.5 Metric Tons which represents 0.01 percent of the total production at national level. Assuming a replication period of 5 years, as evidenced in the flood recurring circle shown in table 4 and 5, Rwanda is likely to lose similar amount every 5 years if no measures are put in place. We also performed the T-test (is used to determine if two sets of data are significantly different from each other, and is most commonly applied when the test statistic would follow a normal distribution if the value of a scaling term in the test statistic were known) to compare the two means (crop production and expected production without floods). The estimate shows that the mean difference is statistically significant at 10% level of significance [mean (diff) > 0 (Pr (T > t) = 0.0518)].For details (see Figure13 and Table10)

Figure 13: Trends of crop production (with Floods) and Expected Production (Without Floods)



Source: MINAGRI Crop assessment 2012

Table 10: Estimates of Crop losses and Expected crop Production

Crops	Loss in area (m²)	Loss in Area Ha	Average Yield (kg/ha)*	Crop Production in (MT) 2012B****	Expected crop production without flood in MT
Bean**	274597	27.4597	791.5	103819	103,840.73
Maize	105597	10.5597	1965	166649	166,669.75
Peas	1263	0.1263	793	16256	16,256.10
Soja	27689	2.7689	708	14782	14,783.96
Sorghum	14454.5	1.44545	1450	126590	126,592.10
Wheat	7345	0.7345	2270	68026	68,027.67
Cassava	16814	1.6814	17795	1604366	1,604,395.92
Irish potato	281147	28.1147	11625	836110	836,436.83
Sweet potato	22652	2.2652	9616	593517	593,538.78
Banana	23883	2.3883	9428	1615317	1,615,339.52
Legumes***	99111	9.9111	12987	289924	290,052.72
Fruits	1865	0.1865	13178	373327	373,329.46
Tree wood	2520	0.252	n.a	n.a	n.a
Other plantation	140360	14.036	na	n.a	n.a

Source: MINAGRI Crop assessment 2012

Notes:* 2012B Yield (National level),

** Mean (Ordinary beans + Climbing beans)/2
*** Vegetables
****Source: Agric. Statistics
MT (1MT=1000Kg)

3.3 Infrastructure losses

The 2012 Wet season in Rwanda had a considerable impact on the range of agricultural infrastructure and other facilities. The approach used to estimate the infrastructure related losses was varied and singled out each affected facility. The main cost estimation approach used is the replacement cost method. The infrastructures in this estimation were considered to be buildings (residential, school classrooms, hospital rooms), roads, bridges, electricity and water supply lines and telecommunication routes. The intensity of damage and destruction caused by floods differs per infrastructure, but in terms of monetary value can be arranged in descending order from bridges, roads, buildings, electricity and water supply lines, and telecommunication routes. Only severe effects were considered and grouped into damages that need major repairs and rehabilitation as well as destruction requiring entire replacement.

3.3.1 Cost consideration

Costs considered in this estimation include replacement cost for lost/damaged buildings and/or infrastructure; cost of repairing damaged facilities and infrastructure; and cost of loss of production, business, income, and livelihood. The evaluation made a reference of information from quantity surveying cost analysis consultancy databank and the Institute of Real Property Valuers in Rwanda data bank. Each category of infrastructure is analyzed separately due to different intensity of damage, with the intensity determined by the type of infrastructure. We also made assumptions for computation of the costs for each category of infrastructure as detailed below:

Table 11: Cost consideration

Type of Infrastructure	Areas considered
Houses	▪ A typical lost residential house has an average floor area of $38m^2$, ▪ Replacement cost to replace new residential house is average of 78,500Rwf /m^2, ▪ The typical damage of residential house is 40% of replacement cost.
Class room Buildings	▪ A typical lost class room has an average floor area of $42m^2$, ▪ Replacement cost to replace new class room is average of 160,000Rwf /m^2, ▪ The typical damage of classroom is 30% of replacement cost.
Gravel road:	▪ A typical gravel road in flooded areas has an average width of 6m, ▪ Replacement cost to replace 1 km of road is 80,000,000Rwf, ▪ The typical damage of gravel road is 60% of replacement cost.
Stone road	▪ A typical stones paved road in flooded areas have an average width of 6m, ▪ Replacement cost to replace 1 km of road is 160,000,000Rwf, ▪ The typical damage of stones road is 60% of replacement cost.
Tarmac road	▪ A typical tarmac road in flooded areas have an average width of 6m, ▪ Replacement cost to replace 1 km of road is 350,000,000Rwf, ▪ The typical damage of tarmac road is 40% of replacement cost.
Bridges:	▪ A typical gravel road bridge in flooded areas have an average width of 8m, ▪ Replacement cost to replace 8m long bridge is 32,000,000Rwf, ▪ The typical damage of gravel road bridges is 60% of replacement cost.
Water supply pipe network	▪ Replacement cost for 1km of water supply pipe network is 20,000,000Rwf, ▪ The typical damage of 1 km water supply pipe network is 20% of replacement cost
Electrical distribution network:	▪ Re-erecting cost to re-fix 1electrical distribution pole is 40,000Rwf

3.3.2 Estimates of infrastructure losses in the 2012 wet season

The following Table 12gives an overview of numbers of damaged and destroyed infrastructure based on information collected in the study area. The residential houses damaged are 306 with 28 destroyed. Eight classrooms were damaged compared to one totally destroyed. About 31 kilometers of feeder gravel road were damaged and more than26 kilometers of the same type road were totally destroyed. Six feeder road bridges were destroyed.

Table 12: Overview of the impact

№	Infrastructures	Number damaged	Number Destroyed
1.	Residential houses	306	28
2.	School classrooms	8	1
3.	Feeder gravel road (Kilometers)	30.9	26.73
4	Feeder road bridges	0	6

Source: Field study on impact of wet season May 2012

Replacement costs for all these damaged and destroyed infrastructures were computed and estimates are presented in Table 13 below. It must be noted that we used proxy method to estimate the economic loss due to the flooding of Masaka and Mukamira - Ngororero roads. and this isexplained by the fact that information of this study was collected one year after the occurrence. Information collected was from a sample population drawn from50% of total districts prone to floods. The report by REMA (2009)[17]indicates that floods and landslides are the main disasters in the high altitude regions mainly in the rain seasons. Reference to Rwanda's topography, the potential for flash flooding in many parts of the country is ever present.

[17] Rwanda State of Environment and Outlook Report (2009).

Table 13: Estimated cost damages on infrastructure

DISTRICT	INFRASTRUCTURE NAME	UNITS	QUANTITY	COST (RWF)	TOTAL AMOUNT (RWF)
Ngororero	Damaged houses	Nr	34	1,193,200	40,568,800
	Destroyed roads	Km	3.35	80,000,000	268,000,000
Nyabihu	Damaged houses	Nr	40	1,193,200	47,728,000
	Damaged roads	Km	7	48,000,000	336,000,000
	Destroyed bridge	Nr	1	32,000,000	32,000,000
Musanze	Damaged houses	Nr	26	1,193,200	31,023,200
	Damaged road	Km	18	48,000,000	864,000,000
Nyamagabe	Destroyed houses	Nr	11	2,983,000	32,813,000
	Damaged houses	Nr	56	1,193,200	66,819,200
	Destroyed road	Km	5.38	80,000,000	430,400,000
	Destroyed bridges	Nr	5	32,000,000	160,000,000
	Damaged class rooms	Nr	4	2,016,000	8,064,000
Muhanga	Destroyed houses	Nr	17	2,983,000	50,711,000
	Damaged houses	Nr	9	1,193,200	10,738,800
	Damaged road	Km	2	48,000,000	96,000,000
	Damaged class rooms	Nr	4	2,016,000	8,064,000
Gasabo	Damaged houses	Nr	25	1,193,200	29,830,000
	Damaged road	Km	3.3	48,000,000	158,400,000

Kicukiro	Damaged house	Nr	1	1,193,200	1,193,200
	Damaged roads	Km	0.6	48,000,000	28,800,000
Bugesera	Damaged houses	Nr	115	1,193,200	137,218,000
	Destroyed road	Km	18	80,000,000	1,440,000,000
	Destroyed class room	Nr	1	6,720,000	6,720,000
	TOTAL LOSS				**4,285,091,200**

Source: Field study on impact of wet season May 2012

Damaged or destroyed roads and bridges have implications on the flow of goods and services. The economic costs of such destruction was based on information from key informants given that there was no secondary data that was collected after May 2012 flooding. For example information collected from Masaka area shows that transport costs doubled due to the damaged road and bridge during the one month flood period when travelling from Masaka to neighbouring town centres (Mulindi and Kigali). Before the floods the return cost was 500 Rwf which was doubled to 1000 Rwf. Considering an average of 5000 people travelling daily, the extra cost was estimated at 75,000,000 Rwf for the duration of the month. This extra cost could have been allocated to other livelihood expenses. In addition, this extra cost gives an indication on how other areas like Muhanga - Ngororero - Mukamira might have been affected. Furthermore, there was no significant change in price levels for commodities that was reported. A remote estimate of economic loss for the Muhanga - Ngororero - Mukamira road could be 1.5 times[18] that of Masaka which is about 112,500,000 Rwf.

Making reference to existing secondary data, the total MININFRA/RTDA, KCC and districts road programmes budget of 2013 - 2014 is equivalent to Rwf 24,300,000,000, when you compare the estimated loss in infrastructure both the replacement and economic cost of 6,915,591,200 Rwf(6,728,091,200 + 75,000,000 + 112,500,000) , it comes down to 28% of the whole budget. Furthermore, analysis of climate change effects requires a long-term time series,of up to about 30 years in order to appreciate dynamics of the climate. It was difficult to have this information also complicatingthe assessment

[18] The flow of traffic of Muhanga - Ngororero - Mukamira is approximately 1.5 times of that of Masaka

of macro and indirect cost impact of the 2012 flooding; hence these are not included in the estimated total losses. An earlier study by the SEI (2009) on the economics of climate change in Rwanda postulates that the 2007 floods in Nyabihu, Musanze and Rubavu Districts led to estimated measurable direct economic costs (e.g. household damage, agricultural losses,animal and human fatalities) of $4 to $22 million, equivalent at the time to 0.1 – 0.6 % of the GDP for the two districts alone. This does not include the wider economic costs from infrastructure damages, water system damages and contamination, soil erosion and direct and indirect effects on individuals. Accordingto the Government of Rwanda (2013) reports, additional net economic costs resulting from climate change is estimated to at least 1% of the country's GDP each year up to 2030.

In addition to the above, secondary data from MININFRA showed that the replacement costs for the damaged Muhanga-Ngororero-Mukamira road was estimated at RwF2,443,000,000[19].This cost would involve mainly the clearing the road of flood debris and bridge repairs. This is an estimate and can be higher, depending to other replacements activities that could be discovered.Estimates from MINIRENA show that about Rwf247,500,000 is needed to repair some of the infrastructures affected by the floods in Nyabihu District. An estimate of Rwf278, 000, 000 is also required to support flood-proofactivities in NyabihuDistrict.Assuming that all the ten districts have almost the same condition as Nyabihu, we can roughly deduce using, the simple expansion formula, for the ten districts that were affected by the floods 2012 wet season, the estimate would be ten times which comes to Rwf 2,470,500,000 and Rwf 2,780,000,000 for infrastructure repairs and support flood proofing respectively.

3.4 Human losses

Impact of natural disasters like floods on human can be captured in terms of the number of people deceased, missing, casualties, and persons injured. Among 389 householdswho faced flood problems, 4.4% declared that they lost some family members during the main wet season 2012 compared 95.6 % who reported no death cases in their respective families. During the 2012 wet season, 18 families lost 37 peopleas confirmed by the respondents: 2 are from Kicukiro, 1 in Nyamagabe, 1 in Nyabihu, 1 in Ngororero, 31 in Musanze, and 1 in Bugesera.

The economic costs related to these people who died are also enormous although it is difficult to compute their value. Considering the average age 43.7 for the sample

[19] Department of Maintenance, MININFRA 2013

population and the per capita GDP of 595 USD (at current market price) and the life expectancy for these people of 52.8 years old (NISR, 2012)[20]; the death of one person implies a loss of 595 USD per year, all else equal. The total loss for these people who died is estimated at 22,015 USD per year. Assuming that they were supposed to live for another period of 9 years that implies that the loss for their remaining life period is 198,135 USD at constant price. There are other costs not easy to capture such as increased family dependency due to orphans and widows.

Making reference to existing secondary data collected by MIDIMAR in 2012, it is indicated that 25 persons were lost and 32 were injured; 1,163 houses and 1,883.5 ha of land were damaged during the 2012 wet season. On the other hand, 1,275 families were assisted with food and non-food items during the floods events of that year as shown in the table below.

Table 14: Estimates of Damages by disaster types (Jan –Dec 2012) by MIDMAR

Disaster Type	Died	Injured	Individual Houses Damaged and destroyed	Land (Ha)
Land slides	14	1	177	399
Floods	25	32	1163	1883.5
Fire	----	----	1	20
Heavy rains and storms	7	3	2004	277.6
Thunderstorms and Lightning	29	93	1	
Total	75	129	3,346	2580.1

Source: MIDIMAR, Assessment reports, 2012

3.5 Direct and Indirect Effects of 2012 wet season

As already indicated in the analytical framework section (above), natural disasters can cause direct, indirect and macro-economic impacts. This categorization is important as

[20] NISR (2012). Statistical Year Book. National Institute of Statistics of Rwanda , Kigali, Rwanda.

it guides in development and policy actions needed for both short and long run prospects.

For the direct damages, these are mostly those recorded above, including the agricultural losses (31,926,941.4Rfw), the livestock losses (2,516,500 Rfw), and land related losses (estimate of 1,019,302.5 square meters), infrastructure related costs (4,285,091,200 Rfw). Other direct costs include the destruction of agricultural assets such as irrigation channels, mostly in the valleys; no record was provided.

With respect to indirect costs, these include costs that are linked to the flow of goods and service(such as those extra costs linked to the damage of roads and bridges), increment of the price levels due to crop losses, extra income allocated to payment of food for home consumption, and planted area (Merz et al. 2010).During the survey, respondents mentioned that agricultural outputof staple crops hadreduced as cause of floods. In addition, the focus discussions revealed also that the reduction in crop and livestock productivity has induced many other problems in rural areas, with many of the affected people leaving their areas to seek jobs in other districts[21].

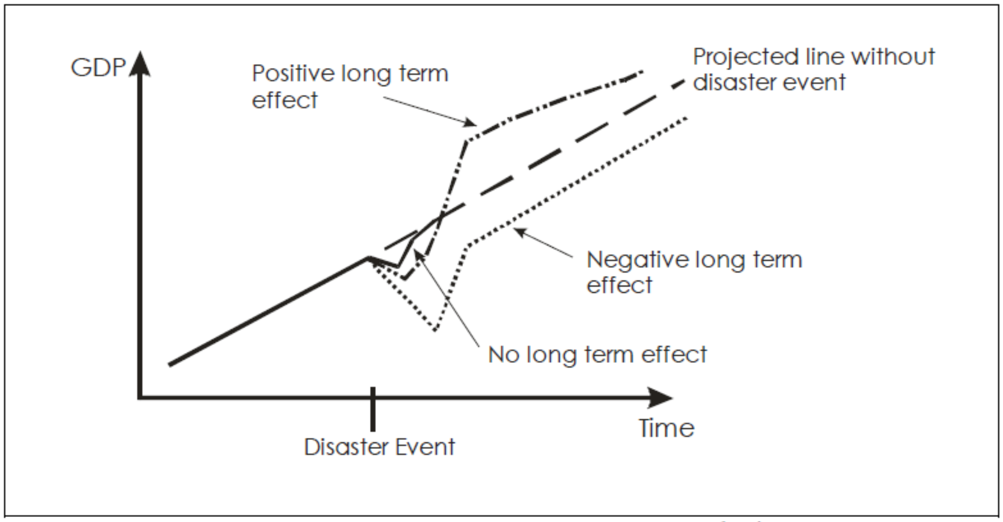
3.6 Macro-economic Effects of the 2012 wet season

There is a growing literature in the last few years on the macro-economic and development impacts of natural disasters. This literature provides two entry points in the analysis of the impactof the natural disasters namely short-to- medium term (1 to 5 years of economic analysis) and the longer term (beyond 5 years); the short-term perspective being the dominant(see Figure14) (Hochrainer, 2009)[22]. Hochrainer provides also two entry points for the analysis of the macro-economic effects of the natural disasters: The first is to look at counterfactual vs. observed GDP; the second entry point is to assess disaster impact as a function ofhazard, exposure of assets (human, produced, intangible), and, importantly vulnerability.

Figure 14: The macro-economic and development impact of natural disasters

21 There is no quantitative information; it was a result of FGD.

22 Hochrainer, S (2009). Assessing the macroeconomic impacts of natural disasters: are there any? International Institute for Applied Systems Analysis (IIASA). Policy Research Working Paper 4968



Source: Possible trajectories of GDP after a disaster. Source: Hochrainer, 2006; *cited* in Hochrainer, 2009.

The main macro-level effects of the floodingare those which have an impact on the level of the overall and sector gross domestic product, such as the growth rate of per capita GDP, growth rate of real per capita agricultural value added and growth rate of real per capita non-agricultural value added (Cuñado and Ferreira, 2011)[23]. Depending on the nature of the disaster, it is also usually relevant to estimate the secondary effects on inflation, employment levels and household incomes. It is clear that these macro-level aggregates require a minimum of 5 year time series data for projections and reflect a trade-off between data requirement and number of samples.

The 2012 wet season is one year old making it difficult to obtain accurate time series for projections. But we adapted the counterfactual vs. observed approach by comparing gross agricultural production, planted/harvested area, Gross Domestic Product (GDP) for the period 2011 (counterfactual) and 2012 as observed period.

In terms of harvested area, the annual harvested area in 2012 (448, 294 ha) as reported in the crop assessment dataset of MINAGRI (2011-2012) is a little bit greater than that of 2011 (438,607) in all aggregated sample Districts. A possible reason for no flood effect in terms of harvested area could be the fact that the cultivated area in 2012 was much

[23]Cuñado J. and Ferreira S, 2011. The Macroeconomic Impacts of Natural Disasters: New Evidence from Floods. Selected Paper prepared for presentation at the Agricultural and Applied Economics Association's 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011

greater than in 2011, thus making it difficult to materialize the 2012 flood effect on the overall affected area. But, from the respondent's views and key informants, the 2012 flooding had a negative effect on crop production.. The analysis of the crop assessment data on crop production at macro-level did not show the impact of the 2012 wet season on the overall crop production. Part of the explanation can be attributed to the crop intensification program of MINAGRI which has led to overall increment in crop production and hence overshadowing expected negative impact of May 2012 wet season. It was also reported from the survey respondents and key informants that the May 2012 flooding has caused some secondary effects included the increase in food prices and other goods' prices, and caused a fall in household incomes in the affected areas. The May 2012 wet season flooding affected districts normally that produce high quantities of agricultural products, for instance Musanze and Nyabihu districts in the case of Irish potatoes. Due to the fall in output, food prices might have rose, and this had a ripple effect onprices of other goods and services.

Looking at GDP aggregate and comparing the two periods 2010/2011 and 2011/2012, the GDP for the former is estimated at 3, 484 billion Rfw comparedto 4,121 billion Rfw of 2012 (NISR,2013) . There is evidence of positive difference between the two periods in terms of overall GDP. Alternatively there is also positive difference between agricultural GDP of 2010/2011 estimated at 1091 billion Rfw against 1328 billion Rfw for 2011/2012. Looking at the two aggregates, there is no evidence of negative difference that could be attributed to the 2012 wet season. Possible explanation is that effects of natural disasters like floods on macro-economic aggregates may react with some lags (Hochrainer, 2009). Therefore, the effects of the 2012 wet season on GDP needs further consideration after 5 years after taking into account the lag effects.

3.6.1 Extrapolated agricultural and livestock losses

Extrapolation is an estimation of a value based on extending a known sequence of values or facts beyond the area that is certainly known. In the process of obtaining an estimate of economic cost, the sample estimate of the economic loss was extrapolated at national level under the following conditions:

- We considered the highlands part of Rwanda, where most of the prone flood districts are found. The geographic set up of Rwanda is categorized with highlands, Midland, Plateau Central and the lowlands. The area of interest in this case is the highlands, where the sample fell, they are comprised of Karongi, Rutsiro, Ngororero, Nyabihu, Rurindo, Gicumbi, Gakenke, Burera, Nyaruguru and Part of Rusizi districts.

- Using the recent census of population of 2012, we calculated the weights to be applied on the sample results of our survey by considering that an average size of a household is 5 persons[24] .
- The extrapolation assumes no major topographical differences in the above areas.

Table 15: Highland Districts

District	Province	Population August 15, 2012	Number of Households	Value of Agricultural loss	Value of Livestock loss
Rusizi	Western	202,139	40,428	3,065,898,319	241,655,729
Gicumbi	Northern	397,871	79,574	6,034,574,870	475,648,387
Gakenke	Northern	338,586	67,717	5,135,387,268	404,773,944
Burera	Northern	336,455	67,291	5,103,081,127	402,227,557
Ngororero	Western	334,413	66,883	5,072,140,034	399,788,764
Karongi	Western	331,571	66,314	5,028,989,343	396,387,603
Rutsiro	Western	323,251	64,650	4,902,798,218	386,441,152
Nyabihu	Western	295,580	59,116	4,483,121,724	353,362,029
Nyaruguru	Southern	293,424	58,685	4,450,436,402	350,785,754
Rulindo	Northern	288,452	57,690	4,374,979,570	344,838,207
TOTAL		3,141,742	628,348	47,651,406,875	3,755,909,126
TOTAL VALUE OF CROP and LIVESTOCK				**51,407,316,001**	

Source: NISR 2012

The table 15 above shows the distribution of population from the last Population and Housing Census of the highland districts. The population of Rusizi is divided by two because part of it is lowland. The number of households in the highlands was estimated at 628,348 households representing about 30% of the total households in Rwanda. Looking at agricultural losses only, assuming all conditions the same, the extrapolation of the loss on 421 households can be extended to 628,348 households. The total

[24] NISR 2012

estimation of agricultural losses is 31, 926,941 Rwf for 421 households according to the result of our survey.

If this loss is extended to 628,348 households, it will be 31, 926,941 Rwf / 421 households X 628,348 households and it is equivalent to **47,651,406,875 Rwf** for 628,348 households.

This value is only for crops losses. With regard to the livestock, following the same procedure, the estimate of livestock loss is **3,755,909,126 Rwf.**
The total loss isestimated at**47,651,406,875 Rwf + 3,755,909,126 Rwf = 51,407,316,001 Rwf.** Whenwe compare the total agriculture loss of May 2012 with agriculture GDP 2011/2012 estimated at 1,323 Billion Rwf (NISR 2012), the former represents about 4% of the agriculture GDP at current price.

3.6.2 Computation of overall estimate of economic Impacts of 2012 wet season

Due to the data requirements and the need to estimate the overall economic impacts of the 2012 wet season; an alternative option was to compute the proportional weight of the estimated economic losses compared to the overall GDP and the agricultural GDP in particular. In this case, the proportion is made of direct losses, the costs of replacing and reconstructing damaged infrastructure(houses, bridges, and roads) and reflects only a fraction of total cost of a such disaster, particularly in the case of a large- scale event (Hallegatte, S. *et al*. (2010)[25]. Consequently, we used extrapolation as indicated in the chapter on extrapolation. Considering that the infrastructure is not be extrapolated, the replacement costs and economic costs for infrastructure loss is added to the agriculture losses and the estimated total economic costs for flood losses is **6,915,591,200Rwf** + **51,407,316,001 Rwf = 58,322,907,201 Rwf** which represents about 1.4% of the overall GDP of 2011/2012, which is a lot of money. This figure implies that if no appropriate

[25]Hallegatte, S. et al. (2010), "Flood Risks, Climate Change Impacts and Adaptation Benefits in Mumbai: An Initial Assessment of Socio-Economic Consequences of resentand Climate Change Induced Flood Risks and of Possible Adaptation Options", OECD Environment Working Papers, No. 27, OECD Publishing. http://dx.doi.org/10.1787/5km4hv6wb434-en

measures are taken to alleviate the flooding, the loss is likely to be more than 1.4%, all things remaining the same.

4 FLOOD PROOFING AND ADAPTATION STRATEGIES

“Wet flood proofing” includes permanent or contingent measures applied to a structure and/or its contents that prevent or provide resistance to damage from flooding by allowing flood waters to enter the structure.Generally, this includes properly anchoring the structure, using flood resistant materials below the Base Flood Elevation (BFE), protection of mechanical and utility equipment, and use of openings or breakaway walls.

4.1 Overview of flood proofing strategies

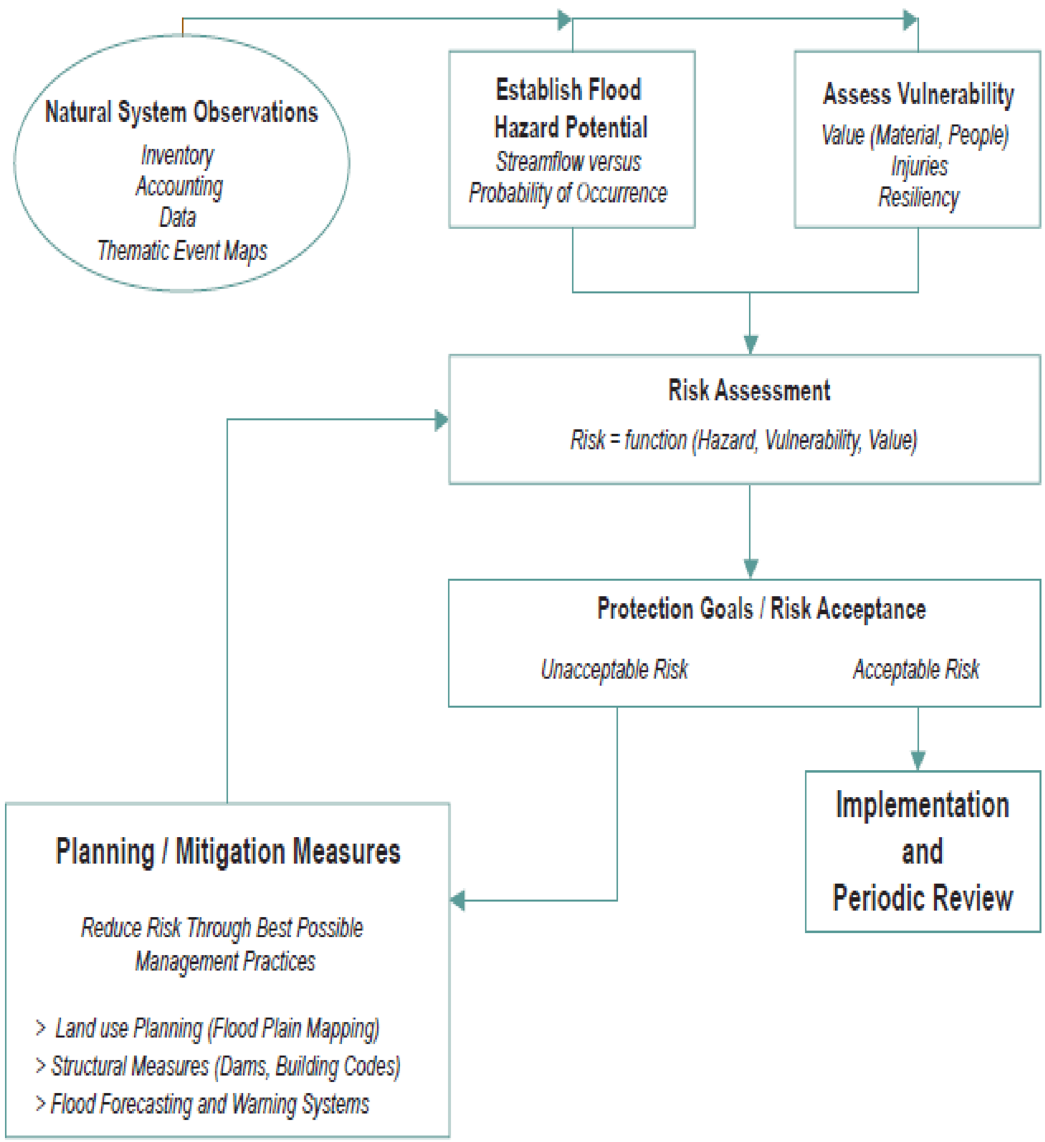
A change to proactive management of natural disasters requires an identification of the risk, the development of policies and strategies to reduce that risk, and elaboration of programs and activities to put these strategies into effect.

The sustainable floods risk management requires an adequate planning or mitigation measures which includes among others:

- ✓ Land planning (land use planning and floods plain maps);
- ✓ Structural measures (dams, building code)
- ✓ Agricultural adaptive strategies (erosion control, agroforestry practices, afforestation and reforestation, bench terraces)
- ✓ Ecological measures (i.e. wetland protection);
- ✓ Proper planning of road construction
- ✓ Etc..

The figure below shows the framework of floods risk assessment and risk management.

Figure 15: Framework for flood risk assessment and risk management



Source: Adapted from WMO, 1999

Following are floods proofing strategies documented in the guideline for reducing floods losses recommended by the International Strategy for Disaster Reduction:

4.1.1 Floodway and flood plain

The floodway is that portion of the flood prone area that is required to pass the design flood event without a significant rise in water levels compared to undeveloped conditions. "Significant" is normally defined as a rise in the range of 25 to 40 cm. The floodway is delineated using the flood frequency or extreme event information combined with a hydraulic analysis. Normally the floodway can be characterized as that part of the flood-prone area having high velocities, high potential for erosion and high exposure to significant flow of debris. Often the floodway encompasses the normal river channel and some expanded high water area. No structures, other than critical infrastructure such as bridges, should be allowed in the floodway. In simple terms, the floodway is reserved for the river, not for humans.

The flood plain is the residual area outside ofthe floodway where the water velocities areless and flood protection and flood-proofingmeasures can be considered. When both thefloodway and flood plain are identified, this is termed a two-zone approach. A simplified orone-zone approach is, at times, used whenthere is no existing incompatible developmentin the floodway and no new incompatibledevelopment will be allowed in the future. Insuch cases, only one designation of zone isused, and the entire area is treated as a floodplain. Under such circumstances, care wouldbe taken to ensure that no new incompatibledevelopment occurs in the zone.

Implications on existing investments would also be set by policy, which could consideroptions such as relocation of incompatibleuses, adoption of flood-proofing measures, orchanges in designation of vacant or unusedlands.

Areas beyond the defined flood plain may besubject to flooding by even rarer events,which are events that exceed the design event.Efforts should be made to ensure that"critical facilities" are flood proofed againstthese rarer events. Critical facilities includehazardous materials reduction, storage andwaste facilities; essential utilities such as waterand wastewater facilities and power plants;essential services such as hospitals, schoolsand airports; and emergency services such asfire stations or major computer centers. Forexample, if the 100-year flood is used todefine the flood plain for zoning purposes,then critical facilities could be flood proofedto higher standards as if they were in the 500-year flood plain.

4.1.2 Protecting flood-prone lands

Policies and programs to keep future flood damages from rising are based on the delineation and mapping of flood-prone areas. Generally the resulting programs will mean some form of control over new development in the flood-prone area combined with measures to reduce damages.

Alternate use of flood-prone land should be considered where possible. It is better tohave the land zoned and used for purposessuch as parks, nature areas or ecologicalreserves than to try and ensure that futuredevelopment is flood proofed. Zoning andflood proofing measures can be used tocontrol development and reduce future flooddamages, but the effectiveness of suchmeasures is highly reliant on enforcementand maintenance. Local authorities aresubject to developmental pressures andstandards have a tendency to "slip" as thememory of a flood event fades.

4.1.3 Construction of dams/diversions/storm channels/levees

Construction of protective works such asflood storage reservoirs, diversion of waterto side channel storage or other watersheds,construction of storm channels to carrywater around the area to be protected, andlevees along the floodway provide tools toreduce flood damages. Such works can beconstructed to various levels of protection,usually based on: 1) minimum standardsfor flood protection; 2) the optimum levelof costs and benefits based on an economicanalysis; or 3) to meet established levels ofacceptable risk.

Protective works should be considered when major infrastructure has already been developed and costs to protect existing investments are far less than those related to reconstruction, lost economic activity, disaster assistance, or relocation of existing structures and activities. For example, flood protection measures for the city of Winnipeg, Canada, were completed in the late 1960s at a cost of $US 92 million. A rough estimate of damages prevented in five large floods since then is approximately $US 2.0 billion.

Protective works have a tendency to increase the level of development in floodprone areas, as the assumption is made that it is now safe to build and invest in areas that are protected. However, it must be recognized that at some point in the future the design event will likely be exceeded and catastrophic damages will result. Levees and storage dams are particularly dangerous when design thresholds are exceeded in that unexpected failure can result in a rapid rise in water level and make evacuation and emergency protection extremely difficult. Diversions or storm channels are less prone to catastrophic failure and the level of protection can temporarily be increased by emergency measures if the lead-time of the flood warning is sufficient.

Flood control storage may be one component of a multi-purpose reservoir development. Over time the operation of the reservoir could be altered to enhance other beneficial uses of storage to the detriment of flood control. A commitment to "designated flood storage" and to reservoir operation procedures to achieve that storage is needed.

4.1.4 Flood proofing of new and existing structures

Any new construction permitted in the flood plain should be flood proofed to reduce future damages. Building codes can be developed that minimize flood damages by ensuring that beneficial uses of buildings are located above the design flood elevation. For example, buildingscan be raised above the design flood level by placement of fill; stilts or piles used to elevate the structure; and building utilities can be located above the flood level.

Buyout and relocation programs for aparticularly vulnerable development shouldform a component of flood proofinginitiatives. In many cases it may be moreeconomical to buy out and relocate theexisting use than to protect it.

A number of critical services such aswater lines, power pylons and telephoneservices often cross the flood plain.These utilities can be protected againstthe ravages of flooding at relatively lowcost through additional depth of burial,a higher design standard for exposedcomponents, and rising of componentsabove design flood levels.

Water supply and treatment plants areparticularly vulnerable. They are oftenlocated on the flood plain yet are criticalfor the protection of human healthduring and after a flood event. Suchstructures need to be protected againstextreme events and designed to preventcross-contamination from floodwaters orsewers.

4.1.5 Bridges and roads

Bridges generally constrict the flow of water,and they can act as artificial dams if debrisjams the structure. In all cases, theirhydraulic characteristics must be considered atthe design stage to prevent an un-acceptablerise of water levels upstream of the structure.

Bridges are important in terms ofmaintaining access for evacuation anddelivery of medical and other emergencyservices. Key transportation corridorsshould have high design standards that willwithstand extreme flooding events.However not all bridges require a high levelof protection, and the design criteria can beto a lesser standard that takes intoconsideration the possibility of overtopping.

Bridges are expensive, and difficult toreplace quickly after a flood event. Analternative strategy is to design the approachroads to be the weak link in the chain so thatextreme events wash out the road but do notdamage the bridge. Approaches can bequickly repaired after a flood event andtransportation corridors restored.

Road design, either parallel to the river orleading to bridges, must be given carefulconsideration. There is a temptation to raiseroads that have been overtopped by floodevents without giving adequateconsideration to the number and size ofopenings necessary to pass local drainage ortributary inflow. In such cases the road canartificially raise water levels upstream andcause additional flood damage. Roads canalso act as levees when they are parallel tothe river. This is a two-edged sword: whileflood protection is provided, the water levelupstream can increase, resulting inadditional flood damages there. Hydraulicstudies must be undertaken before roads areraised to fully establish the impacts of theseactivities.

4.1.6 Watershed Management

The water storage effect of vegetation, soil,shallow groundwater, wetlands and drainagehas a direct impact on the flood level indownstream areas. Each of these storagemedia retain certain quantities of water forvarious periods of time and can influencethe timing of tributary flows and hence theircontribution to a flood event. The storageeffect can be likened to a sponge and isdependent on the antecedent conditions andthe magnitude of the flood.

The impacts of land-use changes on floodevents can be both positive and negative, sopredictions are hard to make for a specificwatershed. Generally the removal of forestand other natural cover, and the conversionof land to agricultural uses, compacts thesoil and reduces infiltration rates, leading tohigher flood peaks. Deforestation isbelieved to have been a significant cause ofthe catastrophic flooding in the YangtzeRiver basin in China and in CentralAmerica from Hurricane Mitch, both in1998. Deforestation and other land-usepractices can also lead to greater incidencesof landslides and mud flows.

Natural water storage is also generallyreduced due to the gradual loss of organicmaterial and soil erosion, once an area isconverted to agriculture. Additionally,natural vegetation may transpire moisture tothe atmosphere at a greater rate thanreplacement crops, thereby affecting boththe amount of storage available in the soiland the amount of local rainfall.

Drainage of wetlands and marshescontributes directly to changes in the timingof runoff, the amount of natural storage inthe basin, and the vulnerability of thechannel to the erosive forces of water. Evenroad construction can contribute directly toincreased runoff rates through improveddrainage as well as the effect of reducedinfiltration through the road surface.

By far the greatest impact of land-usechange is associated with urbanization itself.The paving of surfaces significantly reducesinfiltration, natural storage is reduced byimproved drainage, and streams are oftenconstricted by development or crossings. Acity will frequently have significant floodingproblems that are local in nature, but willalso be impacted upon by major flood eventson larger streams or lakes that are not withinthe urban zone.

A general rule is that the impacts of landusechange will be greater for smaller basinsthan for larger ones. Increases in flood peakand runoff volume in the range of 15-25%for medium-sized basins (>5000 squarekilometers) have been estimated intemperate climates. However, more detailedstudies are required before makingpredictions for specific basins and theirconditions. Scaling small basin results up tolarger basins and vice versa remains a majorscientific challenge.

4.2 Proposed flood proofing strategies for Rwanda

For flooding events, there is a need to calculate the probability or likelihood that an extreme event will occur and to establish and estimate the social, economic and environmental implications should the event occur under existing conditions. Maps of the flood-prone areas should be prepared and detailed impacts outlined. A participatory process should be invoked, leading to the development of an acceptable level of risk. Measures can be evaluated and implemented to meet this level. This overall process assists the community in better understanding the various actions that can increase or decrease risk exposure, and can lead to greater community participation in the developed solutions to the flooding problem.

Before applying any flood proofing technique, the floods proofing strategies requires firstly to integrate floods management countrywide which should relate to the following practice:

- ✓ Protection of watersheds by afforestation and reforestation;
- ✓ Applied modern and nationally documented best practice techniques for anti-erosive measures, improved farming practice (agroforestry combined with zero grazing);

- ✓ Creation of off-farm activities like bee keeping, rearing small ruminants etc…;
- ✓ River banks and Lakes shores protection;
- ✓ Strict follow of regulation for marshland exploitation:
  - Marshland are in 3 categories: Marshlands under total protection, Marshlands for use under specific conditions, Marshlands for use without specific conditions)

However, whatever the type , each marshland presents specificities that a general classification never can reflect. It is therefore essential that each development project is carefully studied first, including not only an environmental impact assessment but also an assessment of erosion, at the catchment area level. Proposal of priority sites to fight against erosion and the most appropriate techniques needed to be done at that time.

4.2.1 Engineering (infrastructure & buildings)

- ✓ Review the Environmental impact assessment related to road construction due to the hazards that occur to many existing road infrastructures;
- ✓ Encourage grouped habitation(imidugudu), preferably located upstream;
- ✓ Enforce flood-resistant material for buildings, capable of withstanding direct andprolonged contact with floodwaters without sustaining significant damage;
- ✓ Enforce site buildings and workshops well above past flood levels and not on or near steep slopes that might destabilize during heavy rains;
- ✓ Wherever possible, design buildings to withstand strong winds;
- ✓ Avoid building on or near slopes at risk of mudslides or landslides;
- ✓ Wherever possible, design water and sanitation infrastructure;
- ✓ Review the existing building codes due to the destruction of many buildings during the flooding period;
- ✓ Relocate threatened buildings.
- ✓ Demarcate certain zones as off-limits.

4.2.2 Agricultural flood proofing strategies

- ✓ Construct radical or progressive terraces, depending on the appropriate agronomical conditions of the area;
- ✓ Reducing the speed of flood waters by planting bamboo trees in the ravins;
- ✓ Intensive agro forestry practice;
- ✓ Plant trees and grass in upstream and middle stream to reduce the amount of rain water that would otherwise increase the volume of flood water.

4.2.3 Ecological related

- ✓ Stop all exploitation activities in marshlands under total protection and marshlands for use under specific conditions (consult existing REMA marshlands maps for each districts);
- ✓ Carry out detailed environmental impact assessment when planning exploitation of marshland for use without specific conditions;
- ✓ Enforce the law on buffer zones for rivers, lakes and swamps.

4.3 Specific recommendations

Proposed floods proofing strategies for Rwanda are general strategies for 3 sectors: agriculture, building and infrastructure as required in ToRs. However, these strategies requires sector specific activities mainly related to Climate Change resilience and improving population liver hood.

Following are activities recommended in 8 District of study divided into 3 groups according to relief categories (Congo Nile Watershed, Central plateau and Lowland of the East) as described in 2.1.2 above.

Table 16: Agriculture: Develop adaptation framework for agriculture to improve agricultural productivity and enhance food security

N°	Strategic Interventions	Nyabihu, Ngororero and Nyamagabe	Muhanga and Gasabo	Kicukiro and Bugesera
1	Promote sustainable land management practices systems highland and mountainous regions (Progressive and radical terraces, agroforestry, woodlots plantation, planting grasses and fodder bank)	✓	✓	X
2	Promote sustainable land management practices systems lowland regions (Agroforestry, woodlots plantation, planting grasses and fodder bank)	X	X	✓
3	Promote development and implementation of irrigated	X	X	✓

N°	Strategic Interventions	Nyabihu, Ngororero and Nyamagabe	Muhanga and Gasabo	Kicukiro and Bugesera
	agriculture (water-efficient irrigation technology identified, Piloting and replication of best case practices			
4	Promote water availability and sustainable use practices and technologies in agriculture, livestock and aquaculture for efficient utilization of water especially (Investment in water capture and storage infrastructure to capture and store Rainwater for agricultural use)	✓	✓	✓
5	Promote agro processing and enhance food storage facilities (Creation of strategic grains reserves as a form of post-harvest management; Provision of mobile grain driers to respond to unusual wet conditions during harvesting)	✓	✓	✓
6	Promote efficient livestock and aquaculture production systems (Aquaculture, Chicken rearing, and beekeeping).	✓	✓	✓
7	Promote income generating and small space agriculture practice (mushroom, fruits and vegetables)	✓	✓	✓
8	Improve on the food management and distribution systems to ensure access and affordability;	✓	✓	✓
9	Strengthen agro-meteorological information generation for improved early warning	✓	✓	✓

N°	Strategic Interventions	Nyabihu, Ngororero and Nyamagabe	Muhanga and Gasabo	Kicukiro and Bugesera
	systems for agriculture and food security;			
10	Facilitate Creation/provision of special livestock and crops insurance schemes using weather insurance index	✓	✓	✓
11	Promotion of crops and livestock types and varieties able to withstand the changing climatic conditions such as early-maturing crops and livestock;	✓	✓	✓
12	Facilitate Creation of seed conservation programmes;	✓	✓	✓
13	Promote improved land productivity and soil fertility, inter alia, through; integrated nutrient management, improving soil quality, enhancing soil and water conservation measures to enhance physical, chemical, biological or economic properties	✓	✓	✓

Table 17: Social and physical infrastructure

N°	Strategic Interventions	Nyabihu, Ngororero and Nyamagabe	Muhanga and Gasabo	Kicukiro and Bugesera
1	Promote climate change integration in all planning and design of infrastructure; • Adopting the design and materials of construction of infrastructure that are able to withstand extreme weather events taking into account the future climate extrems; • Factoring in potential impact of any future climate change mitigation action(s) on infrastructural service during its design stage. • Continuing to use vulnerable areas or sites through innovative measures practicable under the new prevailing conditions;	✓	✓	✓
2	Build awareness and capacity of the architects, engineers and Environmental Assessment practitioners to take into accountClimate Change in their professional deliveries;	✓	✓	✓
3	Revise and harmonize structural/building codes and standards taking into account the expected changes in climate: • Factoring in climate change into building codes and practice. This will help in	✓	✓	✓

	ensuring that infrastructure is able to withstand extreme events associated with climate change;			
4	Relocation of population in vulnerable areas	✓	✓	✓
5	Design national plan for grouped habitation respecting Environmental Impact Assessment in all Districts mainly relating to expected climate change extremes	✓	✓	✓

5 CONCLUSION

The aim of this study was to assess the economic costs of the 2012 wet season to inform the policy makers on what measures to take in terms of coping with floods. The main wet season of 2012 brought much higher rainfall in the country than expected, with most meteorological stations recording more than double the rainfall amounts in the first 10 days of May 2012 compared with the long-term average for the same period. It caused widespread flooding, severe soil erosion, landslides, crop loss, destruction of road infrastructure and property around the country and in some parts, the high loss of human life. The study assessed mostly the costs related to agricultural losses and destroyed infrastructures, based on both primary and secondary data. Results substantiate that high negative effects on agricultural are observed, with estimated total losses of 31, 926,941Rfw, of which 50% are for seed losses, 32 % for human labor loses, and 18% for fertilizers.

Considering the three locations identified, 43% of losses are from the middle stream zone, 24% in the upstream and 33% in the downstream zone. Total land affected by the rain in the 2012 wet season was 1,019,298 m2 or 101.93 hectares in the sampled households of 421 households. There is some variation per location where the middle stream was highly affected (437,590m2) followed by the downstream (340,639 m2) and then upstream (241,073 m2).

With respect to infrastructure, an estimate of 4,285,091,200 Rwf represents the costs for destroyed or damaged infrastructures mainly roads and buildings based on the information collected from the survey. In addition , secondary information from MIDIMAR 2012 indicates the rehabilitation cost for Musanze, Mukamira and Ngororero is 2,443,000,000 Rwf. Therefore the total estimated loss of infrastructure of May 2012 is about 6,728,091,200 Rwf.

The total estimate of agricultural losses of 31, 926,941 Rwf for 421 households is equivalent to **47,651,406,875 Rwf** for 628,348 households. This value is only for crops losses. With regard to the livestock, following the same procedure, the estimate of livestock loss is **3,755,909,126 Rwf.** The total loss is**51,407,316,001 Rwf.** Whenwe compare the total agriculture loss of May 2012 with agriculture GDP 2011/2012 estimated at 1,323 Billion Rwf (NISR 2012), the former represents about 4% of the agriculture GDP at current price. Considering the replacement costs and economic costs for infrastructure plus the agriculture losses, the estimated total economic costs is **58,322,907,201 Rwf** which represents about 1.4% of the overall GDP of 2011/2012, which is a lot of money. This figure implies that if no appropriate measures are taken to alleviate the flooding, the loss is likely to be more than 1.4%, all things remaining the same. On the other hand, the total MININFRA/RTDA, KCC and districts road programmes budget of 2013 - 2014 is equivalent to Rwf 24,300,000,000, when you compare the estimated loss in infrastructure both the replacement and economic cost of 6,915,591,200 Rwf (6,728,091,200 + 75,000,000 + 112,500,000) , it comes down to 28% of the whole budget.

Based on causes of floods as indicated by the sample population, the study proposed some flood-proof adaptation strategies. Foremost is to ensure ownership of the proposed solutions by the relevant institutions and community. The local government authorities must take responsibility to ensure effective implementation of the proposed upstream solutions, through policy and regulations. The existing gaps between policy makers and implementers can be addressed by adequate coordination of all partners involved, particularly in domains of environment and climate change.

In order to adequately address the floods impacts due to climate change, a package of flood proofing including general strategies and specific intervention activities are identified. Proposed strategies are general measures and aiming to address floods as synergy of many activities considering engineering infrastructure, agriculture and ecological functions and these strategies are, at certain level, under implementation within the Government plans i.e. marshland protection, erosion control etc.

In order to concretize the identified general strategies, this study propose accompanying specific intervention activities for climate change resilience and improving population livelihood in 8 Districts of study which were classifiedinto 3 groups according to relief categories: Congo Nile Watershed, Central plateau and Lowland of the East. On the other hand, intervention activities in each grouped districts are also categorized as follows:

- ✓ Agriculture: Develop adaptation framework for agriculture to improve agricultural productivity and enhance food security
- ✓ Social and physical infrastructure: those should be designed to be flood proofing.

Overall results of this study are evaluation of the cost of economic impacts caused by floods and proposal of the floodproofing strategies to address the potential flood effects in Rwanda.

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Annexes

a. Annex 1: Agriculture losses tables

Agricultural losses of the 2012 wet season flooding ***(Monetary value in Rwfr)***

Crop	Inputs losses	% Respondents	Mean	Std	Max	Min
Beans	Seeds	32.5	23229.83	21349.987	350,000	250
	Fertilizer	14	10046.15	8706.158	30,000	1,000
	Workers	24.6	27311.36	43982.86	200,000	400
	Plots (in M^2)	43.5	2020.338	4065.963	20,000	5
Maize	Seeds	20	12933.64	27465.01	150,000	150
	Fertilizer	22.9	13738.82	21679.41	90,000	500
	Workers	22.3	29828.44	87504.17	500,000	210
	Plots (in M^2)	20.6	1665.84	3714.967	20,000	10
Peas	Seeds	1.5	6350	5654.644	16,000	1,500
	Fertilizer	1	8100	7893.035	21,000	1,500
	Workers	1	5950	2264.95	8,000	3,200
	Plots (in M^2)	1.5	202.16	255.7658	600	3
Soya	Seeds	5.6	19255	66329.67	300,000	400
	Fertilizer	3.3	15536.36	25836.78	90,000	1,000
	Workers	4	59853.33	130218.7	500,000	2,000
	Plots (in M^2)	5.4	1408.368	3571.804	15,000	13
Sorghum	Seeds	4	5391.667	4172.956	15,000	1,000
	Fertilizer	2.9	6858.333	5502.968	21,000	1,500
	Workers	2.7	12290	13028.9	39,000	1,500
	Plots (in M^2)	4.6	773.8611	2321.008	10,000	1.5
Wheat	Seeds	1.9	5750	3811.988	12,000	1,000
	Fertilizer	1	6750	8215.838	21,250	1,000
	Workers	1.7	10425	10313.06	30,000	1,400
	Plots (in M^2)	2.9	464.09	443.581	1,200	25
Cassava	Seeds	6.5	13730.77	17549.47	60,000	1,000
	Fertilizer	6.5	7906.25	7994.204	30,000	500
	Workers	5.8	18935	43878.71	200,000	500
	Plots (in M^2)	10.6	399.46	683.77	3,000	4
Irish Potatoes	Seeds	23.5	84791.46	119770.4	600,000	600
	Fertilizer	22.3	33176.09	39721.28	220,000	650
	Workers	21	26390.91	61078.77	370,000	1,000
	Plots (in M^2)	24	3468.867	8189.268	50,000	7
Sweet potatoes	Seeds	9.2	31894.74	90111.29	400,000	500
	Fertilizer	6.2	6605.556	6709.473	21,000	500

	Workers	11	15314.29	33821.89	200,000	700
	Plots (in M²)	15.8	339.8	436.0152	1,650	2.5
Banana trees	Seeds	3.3	15042.86	18501.8	60,000	1,000
	Fertilizer	2.9	9300	7543.872	25,000	2,000
	Workers	3.3	22821.43	51814.82	200,000	700
	Plots (in M²)	5.8	984.43	1918.09	7,500	10
Legumes	Seeds	8.1	33530	66150.55	300,000	400
	Fertilizer	6	15734.21	24173.25	100,000	500
	Workers	5.8	22756.52	36104.15	150,000	700
	Plots (in M²)	8.3	3469.269	11669.35	60,000	1
Fruits	Seeds	0.4	51500	68589.36	100,000	3,000
	Fertilizer	0	0	0	0	0
	Workers	0.2	48,000	0	48,000	48,000
	Plots (in M²)	0.6	621.66	1020.543	1,800	20
Tree woods	Seeds	0.8	73633.33	109852.6	200,000	900
	Fertilizer	0	0	0	0	0
	Workers	0	0	0	0	0
	Plots (in M²)	0.6	1255	1760.696	2,500	10
Other crops	Seeds	8.5	46239.37	89149.09	400,000	500
	Fertilizer	4.2	21891.18	23652.9	67,500	1,000
	Workers	7.7	72448.15	127013.6	600,000	700
	Plots (in M²)	10	4343.667	14271.34	78,125	15

Livestock losses of the 2012 wet season flooding

Livestock	**% Respondents**	**Value of the livestock in Rwfr**		
		Mean	**Max**	**Min**
Cattle	1.5	816667	180,000	20,000
Goats	2.9	51800	120,000	12,000
Sheep	1.2	48,000	150,000	5,000
Pigs	2.7	33950	84,000	1,500
Chicken/Poultry	2.3	13833	30,000	3,000
Other Domestic animals	1.5	16100	36,000	2,000

Major causes of droughts and floods

Cause	Localization					
	Upstream		Middle stream		Down stream	
	Dry	Wet	Dry	Wet	Dry	Wet
Deforestation	25.1%	29%	46.5%	48%	28.4%	22%
Air pollution	31.1%	31%	48.5%	51%	20.4%	19%
Soil erosion	26.6%	28%	50.8%	47%	22.6%	26%
Manner of cultivation	29.9%	29%	47.8%	47%	22.3%	24%
Habitation	26.7%	26%	50.7%	51%	22.6%	23%

Major mitigation measures against drought and floods:

Cause	Localization					
	Upstream		Middle stream		Down stream	
	Dry	Wet	Dry	Wet	Dry	Wet
Reforestation	24.9%	29%	46.1%	48%	28.9%	24%
Air pollution	30.4%	30%	50.0%	51%	19.6%	18%
Soil erosion	26.7%	25%	50.6%	46%	22.8%	29%
Cultivation practices	29.3%	29%	47.1%	48%	23.6%	23%
Habitation	29.1%	26%	48.6%	48%	22.3%	26%

Agricultural losses per crop and input during the dry season

Crop	Inputs	Cost in Rwf
Beans	Seed	912,450
	Fertilizer	266,950
	Labor	1,189,300
	Land (M^2)	97,295
Maize	Seeds	97,590
	Fertilizers	444,025
	Labor	694,200
	Land (M^2)	40,752
Peas	Seeds	4,800
	Fertilizers	2,000
	Labor	9,600
	Land (M^2)	80
Soya	Seeds	89900
	Fertilizers	122250

	Labor	79200
	Land (M²)	1365
Wheat	Seeds	17100
	Fertilizers	32000
	Labor	15700
	Land (M²)	7500
Cassava	Seeds	192700
	Fertilizers	58500
	Labor	91100
	Land (M²)	7585
Irish Potatoes	Seeds	1824000
	Fertilizers	748250
	Labor	551100
	Land (M²)	116971
Sweet Potatoes	Seeds	112000
	Fertilizers	75000
	Labor	227100
	Land (M²)	7452
Bananas	Seed	584,500
	Fertilizer	78,000
	Labor	189,900
	Land (M²)	15,780
Legumes	Seed	3,400
	Fertilizer	34,000
	Labor	18,000
	Land (M²)	2,100
Fruits	Seed	3,000
	Fertilizer	1,000
	Labor	0
	Land (M²)	60
Other	Seed	123,800
	Fertilizer	136,800
	Labor	271,500
	Land (M²)	13,851

Agricultural losses per crop and input during wet season

Crop	Inputs	Cost (Rwf)
Bean	Seed	2,359,160
	Fertilizer	562,150
	Labor	1,933,700
	Land (M^2)	274,597
Maize	Seeds	838,780
	Fertilizers	689,720
	Labor	1,127,710
	Land (M^2)	105,597
Peas	Seeds	43,100
	Fertilizers	40,500
	Labor	28,800
	Land (M^2)	1,263
Soya	Seeds	402,800
	Fertilizers	181,400
	Labor	918,800
	Land (M^2)	27,689
Sorghum	Seeds	82,200
	Fertilizers	87,300
	Labor	149,400
	Land (M^2)	14,455
Wheat	Seeds	51,750
	Fertilizers	33,750
	Labor	83,400
	Land (M^2)	7,345
Cassava	Seeds	320,500
	Fertilizers	181,000
	Labor	462,700
	Land (M^2)	16,814
Irish Potatoes	Seeds	7,497,862
	Fertilizers	2,784,570
	Labor	1,743,200
	Land (M^2)	281,147
Sweet Potatoes	Seeds	819,500
	Fertilizers	199,600
	Labor	668,100
	Land (M^2)	22,652

Bananas	Seed	245,600
	Fertilizer	118,700
	Labor	354,500
	Land (M^2)	23,883
Legumes	Seed	1,183,850
	Fertilizer	451,450
	Labor	593,400
	Land (M^2)	99,111
Fruits	Seed	103,000
	Fertilizer	0
	Labor	48,000
	Land (M^2)	1,865
Tree woods	Seed	420,900
	Fertilizer	0
	Labor	0
	Land (M2)	2,520
Other	Seed	1,548,683
	Fertilizer	393,150
	Labor	2,174,100
	Land (M^2)	140,360

b. Annex 2: GPS coordinates of sampled respondents

NUMBER	X	Y	Z	Names	House No
1	461986	4785485	1521m	KANTARAMA Vestine	4 PHC 088/O81
2	446276	4836627	2708m	TUYISHIMIRE Eoutarie	
3	461931	4785480	1556m	NIYONSENGA Francine	
4	461937	4786170	1582m	GAHIRE Auronisdas	
4	461922	4799323	1668m	HAZAKIRABENSHI J.de Dieu	4 PHC 080/074
5	462021	4786690	1558m	NYIRANGIRABATWARE PERPETUE	
6	461681	4787164	1473m	MUHAWENIMANA Alphonse	4 PHC 094/097
7	461992	4786795	1542m	KANTAMAGE Jeannette	
8	462023	4786828	1542m	MUSENGIMANA Solange	
9	462009	4799396	1676m	KABANDA Paul	4 PHC 077/072
11	456753	4803323	1950m	NDIMUBANZI Faustin	
12	456716	4803359	1962m	RENZAHO Pascal	4 PHC 105/108
13	456956	4803438	1925m	NSENGIYUMVA Emmanuel	4 PHC 673/150
14	456793	4803365	1945m	TUGIRINSHUTI J.Pierre	
15	456613	4803282	1943m	BARAYAGWIZA Vestine	4 PHC 116/112
16	456746	4803320	1950m	HAKIZIMANA Boniface	4 PHC 607/000
17	456917	4803436	1923m	NZABONIMPA Mustafa	
18	456893	4803430	1924m	BARANYERETSE Sylver	4 PHC 155/148
19	456737	4803373	1965m	MAPENDANO Bonavanture	4 PHC 101/098
20	456709	4803403	1969m	MUSABYIMANA J.de Dieu	4 PHC 097/094
21	461945	4799121	1659m	NYIRABAPAGASI Godeleva	4 PHC 080/081
22	446276	4836627	2708m	NYIRANSABIMANA Fortune	4 PHC 076/077
23	444764	4821048	2324m	RUGIMBABAHIZI Emmanuel	4 PHC 078/075
24	444897	4834032	2496m	MUKANKUNSI Selaphine	4 PHC

NUMBER	X	Y	Z	Names	House No
					128/124
25	455960	4802372	1949m	MUKAGATARE Josephine	
26	456081	4802297	1932m	MBABAZI Hilarie	
27	436970	4820922	2400m	TWAGIRAMARIYA Judith	4 PHC 056/057
28	456613	4803220	1993m	GASORE NKUNSI Alphonse	4 PHC 109/110
29	456613	4803282	1943m	HABIYAREMYE Claude	4 PHC 111/107
30	443915	4821861	2333m	MUHAWENIMANA Josiane	4 PHC 018/019
31	447074	4825467	2233m	NIYITEGEKA Bernard	
32	456108	4802250	1932m	HABIMANA Marc	
33	436970	4820922	2400m	NYIRAFARANGA Josepha	4 PHC 057/055
34	462240	4786101	1441m	HAKIZIMANA J. d?Amour	4 PHC 190/191
35	462186	4785806	1430m	MUNYENTWALI Martin	4 PHC 190/185
36	461694	4787175	1475m	IYAKAREMYE Olivier	4 PHC 094/093
37	456128	4802220	1930m	KWIRINGIRA ThΦogene	
38	455752	4801801	1888m	NDAGIJIMANA Vincent	
39	443887	4821868	2335m	NSENGIYUMVA Viateur	
40	461626	4787118	1477m	NDARUYINGABO Gaspard	4 PHC 022/019
41	444022	4821599	2334m	HABINSHUTI Egide	
42	461863	4785220	1597m	NIYONZIMA Emmanuel	4 PHC 106/100
43	444022	4821599	2334m	MUKAMANA Vestine	
44	462297	4784967	1436m	MUTUMYINKA Josephine	4 PHC 174/159
45	444073	4821511	2333m	AKIMANA James	
46	461806	4785389	1594m	TUGIRIMANA Francis	4 PHC 098/000
47	461997	4785229	1549m	MUKAMBA Vestine	4 PHC 104/098
48	444247	4821466	2332m	MURERERE Anel	
49	461646	4785331	1601m	NGIRUNSANGA J.M.V.	4 PHC 019/018
50	461986	4785484	1521m	MUKARWEGO PhilomΦne	4 PHC

NUMBER	X	Y	Z	Names	House No
					088/083
51	436743	4821177	2410m	INGABIRE Alphonsine	
52	455960	4802372	1949m	HABIYAMBERE Appolinaire	
53	456099	4802150	1927m	NTAWUKIRASONGWA J. Claude	4 PHC 013/013
54	456081	4802297	1932m	NAMAHIRWE Chantal	
55	447074	4825467	2233m	NSABAGASANI Sylvestre	
56	456101	4802275	1931m	NDAHAYO Claude	4 PHC 021/021
57	456121	4802202	1925m	UWIZEYE Marie Gaurette	4 PHC 017/017
58	456108	4802250	1932m	MUTUYEMUNGU Eugenie	
59	446276	4836627	2708m	NTIBIRINGIRWA Seraphine	
60	447832	4834893	1551m	MBAHUNGIRE Vincent	4 PHC 003/003
61	434288	4818404	2363m	NYIRABUHIVU Mukandekezi	4 PHC 0122/125
62	434460	4818364	2362m	UWIMANA Theoneste	4 PHC 137/147
63	434398	4818446	2363m	RUTABAGISHA Edison	4 PHC 104/100
64	434395	4818429	2361m	MANIRAMPA Theogene	4 PHC 102/098
65	434527	4818306	2373m	NIKUZE Moise	4 PHC 143/155
66	434316	4818340	2364m	NYAGAPAPURO Sfora	4 PHC 125/120
67	434306	4818295	2359m	NDYANABANZI Manasse	4 PHC 127/130
68	456128	4802220	1930m	HABYARIMANA Ouziel	
69	455752	4801801	1888m	YABURE Emmanuel	
70	434282	4818518	2376m	DUSINGIZIMANA J.Marie	4 PHC 117/120
71	436860	4820943	2398m	MUSABYIMANA Pacifique	4 PHC 015/011
72	443887	4821868	2335m	BUHURU MUNYANGORORE J.Pierre	
73	436970	4820922	2400m	CYUMA Ruharaza	4 PHC 059/058
74	461986	4785485	1521m	HAKAMINEZA Antoine	4 PHC 086/083

NUMBER	X	Y	Z	Names	House No
75	436687	4820873	2391m	KAYISIRE Kalisa	4 PHC 183/175
76	444022	4821588	2334m	MUKARUGIZA IrΦne	
77	436891	4821087	2407m	NGANIZI Phenias	4 PHC 011/007
78	436790	4821011	2396m	NKURUNZIZA Bosco	4 PHC 163/142
79	456956	4803438	1925M	MURORUNKWERE	4 PHC 521/013
80	436912	4820961	2401m	SEBUTOZI Jean	4 PHC 025/015
81	448186	4834236	2494m	NIYIBIZI Ezeckiel	4 PHC 084/026
82	443948	4821948	2334m	NIZEYIMANA J.de Dieu	4 PHC 206/183
83	443874	4821860	2338m	MUGIRANEZA Emmanuel	4 PHC 015/016
84	461986	4785485	1521m	NDAYISHIMYE Olivier	4 PHC 189/190
85	444073	4821511	2333m	MUNYAWERA Pascal	
86	444247	4821466	2332m	MUKARURINDI Beatrice	
87	443934	4821860	2333m	RWABUKAMBA Mathias	4 PHC 019/020
88	436743	4821177	2410m	N.BAZIYAKA Martha	
89	443915	4821861	2333m	NYIRABURANGA FortunΘe	4 PHC 018/019
90	434374	4818164	2363m	MUKAMURENZI Ziripa	
91	436618	4820812	2388m	DUTUREHEZA Muhamudu	
92	436621	4820914	2390m	NIYODUSENGA Christine	
93	439580	4821481	2451m	MUKANDUTIYE Tamari	
94	439625	4821498	2449m	UMUHOZA Adeline	
95	439593	4821627	2455m	UZAMURANGE Antoinette	
96	439361	4821493	2456m	MUZAYIRE Laurent	
97	439318	4821992	2479m	MUNYARUKIKO Aminadabu	4 PHC 203/229
98	439412	4821308	2443m	NSANZINTWARI Amuzha	
99	439364	4821992	2486m	MANIRAGABA Didier	4 PHC 201/227
100	439105	4821997	2482m	NYIRASHYEREZO Rachel	4 PHC 251/282
101	444518	4820845	2328m	SEBAHIZI Aloys	4 PHC

NUMBER	X	Y	Z	Names	House No
					171/176
102	444519	4820780	2330m	NSHIZIRUNGU Pierre	4 PHC 169/174
103	444461	4820743	2332m	NYIRAMUGWERA Anastasie	4 PHC 166/172
104	444441	4821043	2339m	BIZIMANA J. Bosco	4 PHC 077/077
105	444429	4821056	2337m	N.NSUKIRANYA Esperance	4 PHC 076/076
106	444764	4821048	2334m	MUSEMINARI Alexis	4 PHC 081/084
107	444410	4821069	2331m	INGABIRE M. Chantal	4 PHC 075/075
108	461869	4799550	1672m	TUYISENGE Emmanuel	
109	443990	4821349	2330m	MUSHIMIYIMANA Pierre	4 PHC 007/008
110	462267	4784959	1456m	BARANIGIRIRA Celestin	
111	446991	4824542	2266m	MUNYEHARA Janvier	4 PHC 180/175
112	447174	4825074	2233m	N.BANUGANUZI Ziripa	4 PHC 152/150
113	447165	4825210	2234m	NSABIMANA Joseph	4 PHC 126124
114	447320	4825496	2235m	BIZIMANA Joseph	4 PHC 036/034
115	447088	4825531	2233m	NIYITEGEKA J.de Dieu	4 PHC 065/063
116	447342	4825152	2233m	AYINKAMIYE Souzan	4 PHC 176/171
117	447261	4825176	2235m	N. NSABIMANA Providance	4 PHC 194/152
118	447202	4825209	2337m	N.MANA Josephine	4 PHC 127125
119	447156	4825536	2233m	HAKIZIMANA d?Amour	4 PHC 068/066
120	461827	4785360	1608m	NZABONIMPA Samuel	
121	434540	4818212	2368m	NTAWIHA Bernadette	
122	450339	4833973	2208m	MUKANDUTIYE Jeanine	4 PHC 047/049
123	449322	4834524	2345m	N.NTEGUYE Martha	4 PHC 193/196
124	449461	4834647	2329m	N.KARAGIRE ImmaculΘe	4 PHC

NUMBER	X	Y	Z	Names	House No
					178/000
125	449557	4834447	2308m	N.NKUMI Dancille	4 PHC 145/148
126	449924	4834280	2234m	HABYARIMANA Theophille	4 PHC 124/128
127	449149	4834655	2357m	ABIYINGOMA	4 PHC 202/205
128	449361	4834436	2340m	N.MPFURUKIYE Keziya	4 PHC 185/188
129	450227	4833856	2199m	IZAKIZA Solange	4 PHC 060/062
130	450416	4833700	2190m	N.NGORAGORE FelicitΘe	4 PHC 031/032
131	447393	4836147	2556m	N.NTEREYE Daphrose	4 PHC 177/172
132	447055	4835804	2602m	NZABAKURIKIZA Aroni	4 PHC 153/148
133	461486	4785282	1625m	NSHYIRAKERA Francis	
134	450185	4834056	2214m	N.HABIMANA Florence	4 PHC 000/000
135	448140	4834314	2491m	N.MANONE Beatrice	
136	450326	4826730	2299m	KARUHIJE Dismas	
137	447082	4836507	2568m	NTAKWIRWAKAMO Vincentia	4 PHC 117/112
138	447932	4834364	2329m	NIKOBAHOZE Pelagie	
139	447182	4835861	2590m	NDAYAMBAJE Joseph	4 PHC 164/159
140	447141	4836180	2582m	N.MUTARUTWA Martha	4 PHC 139/134
141	447769	4834364	2568m	N.NDUGU Jeanne d'Arc	
142	447824	4834828	2563m	NDAGIJIMANA Gaspard	4 PHC 002/002
143	436687	4820873	2391m	UZANYIREMA Leonie	4 PHC 182/175
144	448097	4834032	2496m	NTEZIYAREMYE Cyprien	4 PHC 132/128
145	447700	4834751	2590m	HATEGEKIMANA Salomon	4 PHC 008/008
146	448183	4834183		N.HABIMANA Dative	4 PHC 184/177
147	462024	4799322	1670m	KABYIRUKE J. Damascene	

NUMBER	X	Y	Z	Names	House No
148	462220	4799337	1639m	NKUBUYIMANA LΘonard	
149	448141	4834018	2479m	SEBAHIZI Flugence	4 PHC 173/166
150	447771	4834339	2561m	NGIRABAKUNZI Etienne	4 PHC 093/091
151	459776	4798382	1718m	GODERIVA Godance	4 PHC 19/183
152	450109	4830485	2235m	HABIMANA Jean	4 PHC 188/179
153	450164	4830487	2234m	AKIMANIZANYE Joceline	4 PHC 193/184
154	450764	4830195	2183m	GASORE Gaspard	4 PHC 019/017
155	450683	4830189	2187m	N.MIGISHA Joceline	4 PHC 013/012
156	450753	4830221	2177m	UWIMANA Providance	4 PHC 018/016
157	450728	4830232	2184m	N.NDAJE Dina	4 PHC 020/018
158	450032	4830516	2230m	NSEBYUMUREMYI Charles	4 PHC 183/179
159	449992	4830298	2227m	N.NDARWEMEYE Anastasie	4 PHC 076/065
160	449974	4830489	2234m	BINEGURA Felicien	4 PHC 179/170
161	450192	4826840	2172m	N.BUNANI Clemantine	4 PHC 146/148
162	456709	4803403	1969m	HUMURA Honorine	4 PHC 167/115
163	450229	4826701	2171m	MUKANOHERI Angelique	4 PHC 178/181
164	450278	4826768	2182m	NIYONSABA Betty	4 PHC 688/000
165	456709	4803403	1969m	MUKANDEKEZI Anastasie	4 PHC 097/097
166	450428	4826857	2187m	MANIRAGABA Bernard	4 PHC 088/088
167	450386	4826793	2172m	TURIKUNKEKO Ouzieli	4 PHC 092/092
168	450375	4826777	2172m	NYIRAJERI Rahabu	4 PHC 094/095
169	450353	4826825	2165m	TUYIRINGIRE Gerard	4 PHC

NUMBER	X	Y	Z	Names	House No
					065/055
170	450299	4826821	2171m	N.MFITIKIJE Ereade	4 PHC 104/105
171	449267	4826666	2192m	N.NZAKUZWANIMANA Florence	4 PHC 030/027
172	448256	4825660	2199m	RYARIBOYE Ereade	4 PHC 191/183
173	448397	4826786	2200m	NYAKAMWE Fenias	4 PHC 131/122
174	449329	4826590	2191m	BANGIRIYEYO Samuel	4 PHC 025/024
175	449020	4826440	2194m	UWIMANA Mediatrice	4 PHC 240/233
176	449003	4826474	2195m	NIYITEGEKA Penina	4 PHC 074/042
177	448932	4826532	2193m	HarerimanaJ.Bosco	4 PHC 068/164
178	449438	4826515	2193m	N.NSENGIMANA Josephine	4 PHC 011/011
179	449329	4826432	2193m	NYIRABAKEZE Caisie	4 PHC 238/229
180	449404	4826710	2190m	N.MUTAMA Angeline	4 PHC 012/012
181	452449	4722872	1862 m	BANKUNDIYE Saverine	
182	452711	4723271	1807m	NYANDWI Celestin	
183	452498	4722912	1851m	NZABAHIMANA Gonzolve	
184	452581	4722984	1832m	MUKAGASHUGI Virginie	
185	452389	4722981	1876m	MVUYEKURE Pascal	
186	452605	4723054	1818m	NIRERE Alphonsine	
187	452572	4722938	1837m	NTIRENGANYA Anastase	
188	452528	4722907	1847m	MUKAMURAMBA Theresie	
190	452420	4722859	1864m	UWITONZE Alphonse	
191	445691	4724513	2115m	NYIRANSHIKAMA Venancia	
192	444962	4724577	2124 m	NYIRIBUMBA Juliette	
193	445670	4724654	2099	UZAMUSHAKA Verdiane	
194	445855	4724497	2085m	MUNGANYINKA Juliette	
195	445684	4724487	2121m	MUDACUMURA Faridah	
196	445739	4724470	2106m	MUKABURASA Catheline	4 PHC 017/017

NUMBER	X	Y	Z	Names	House No
198	444832	4724627	2122m	MUHONGAYIRE Josephine	
199	444925	4724618	2126m	NYIRANSABIMANA Esperanse	
200	444651	4724682	2124m	MUKARUGWIZA Marie	
201	433420	4744471	2337m	MUKANKUNDIYE Beatrice	
202	433466	4744458	2336m	MUKAGAKWAYA Beatrice	
203	433437	4744401	2341m	NIYOMUGABO Vincent	
204	432563	4744094	2327m	MUKAGATARE Violette	
205	433596	4744524	2336m	NIYIBIZI Shadrack	
206	433631	4744581	2320m	KARUGEMA Elaste	
207	433314	4744286	2378m	NDABARORA Ezechiele	
208	433358	4744653	2320m	NDAYISABA J.de Dieu	
209	433355	4744284	2364m	NTAWUMENYUMUNSI Wellars	
210	433067	4744378	2338m	MUNYARIHAMYE Emmanuel	
211	436348	4742078	1943m	ABARIKUMWE Laurent	
213	436343	4742079	1947m	KAZUNGU Pascal	
214	436247	4742317	1952m	RWABAHIZI Evariste	
215	436343	4742079	1947m	NTEGERI Pascal	
222	435876	4742735	2012 m	HATANGIMANA Fabien	
226	436368	4742073	1939m	UWITONZE Francois	4 PHC 045/042
227	437061	4735160	1999m	MUNYENTORE J.Claude	
228	438713	4736637	2219m	SEMAJANGWE Cyprien	
229	438614	4737638	2220m	NIRERE Julinne	
231	437625	4736401	2000m	AYISHYIZE Sylvestre	
232	437304	4736728	1976m	KAMURAMA Perusi	
233	437583	4736481	1987m	MUKANGANGO Laurence	
234	436999	4736128	2033m	NZEYIMANA Patrice	090/084
235	437237	4738002	1975m	NYIRAHABIMANA Jeanne d??Arc	
236	437309	4736546	1984m	MUKANTAGANDA Josephine	
237	437291	4736257	1989m	NSHIRIMPAKA Anastase	005/005
238	437954	4736750	1997m	NKURUNZIZA Pascal	069/065
239	437328	4736302	1989m	MBANGUKIRA Innocent	100/123
240	437320	4736190	2001m	MUKANGIRIMANDWA Marthe	
241	464687	4787902	1532 m	UWONKUNDA Leocatia	
242	464327	4788592	1531 m	UWMUKIJIJE Vestine	

NUMBER	X	Y	Z	Names	House No
243	463955	4788611	1527 m	SHIRIMITIMA Boniface	
244	464623	4787943	1540 m	MUKANDAYAMBAJE Donatha	
245	464617	4787945	1531 m	MUKABURANGA Speciose	
246	464043	4788481	1547 m	MUNYAGAJU Adrien	124/111
247	464775	4787857	1531m	NZABAGERAGEZA Samuel	4 PHC 120/106
248	464385	4788201	1550 m	NGENDAHIMANA Emmanuel	4 PHC 002/002
249	464059	4788610	1544 m	NAKURE Athanasie	
250	464145	4788616	1538 m	MUKAMANA Rebecca	
251	462710	4768006	1713m	NDAHAYO Evariste	
252	462722	4767921	1708m	TUYISENGE Drocelle	
253	472701	4768190	1736m	NDAHAYO Sylvaine	
254	462701	4768190	1729m	GAKWAYA Fidele	
255	462764	4768219	1750m	MUKANTABANA Flodia	
256	462764	4767818	1714m	HABIMANA J.Baptiste	
257	462731	4767785	1708m	DUSABEMARIYA Liberatha	
258	462791	4767640	1708m	GAKUMBA Cilile	
259	462835	4767600	1705m	MUKAMARARA Beatrice	
260	462709	4768039	1713m	NIZEYIMANA Fiacre	
261	460182	4767577	1545m	GAFARANGA Innocent	
262	459871	4767448	1566m	MUGWANEZA Alexis	
263	460114	4767909	1522m	NGABONZIZA Celestin	
264	460021	4768140	1516m	RUTAYISIRE Francois	
265	459941	4767119	1606m	DUSABEMARIYA Colette	
266	459500	4767051	1621 m	NYIRAMBARUBUKEYE Epiphanie	
267	460148	4767815	1526m	KANYARWANDA Joseph	
268	459536	4766860	1625m	HABIMANA Jean	
269	460098	4768006	1516m	UWIMANA Rose	
270	459447	4766524	1632m	HABYARIMANA J.Baptiste	
271	464044	4783593	1551 m	AHOBANTEGEYE Christine	4 PHC 189/184
272	464730	4783463	1636 m	KAMIRINDI Elias	

NUMBER	X	Y	Z	Names	House No
273	464916	4783351	1668 m	MUKANDANGA Dative	4 PHC 097/092
274	464620	4783522	1610 m	MUSHIRAGAHINDA Speciose	
275	464297	4783529	1567 m	MUKARUZIGA Priscille	
276	464005	4783579	1544 m	MUKANZIGIYE Donatille	
277	465081	4783393	1705 m	NYIRANSHIMIYIMANA Jeanne	
278	465010	4783598	1614 m	MUSHIMIYIMANA Patricie	
279	464205	4783595	1558 m	MUNGANYINKA Clesence	4 PHC 064/059
280	464368	4783499	1573 m	MUJAWIMANA Emelienne	
281	459455	4766521	1623m	MUKANYANDWI Odette	
282	459381	4766443	1634m	NZITONDA Longin	
283	459518	4766803	1634m	HAVUGIMANA Florent	
284	459481	4766378	1633m	MUSHIMIYIMANA Domitille	
285	459382	4766442	1627m	KAGIRANEZA Onesphore	
286	459825	4767253	1585m	NYANKUMI ImmaculΘe	
287	459633	4767075	1616m	MUKASHEMA Perpetue	
288	459430	4766821	1644m	NGENDAHIMANA Evariste	
289	459502	4767019	1618 m	NDAHAYO Zacharie	
290	459484	4766782	1636m	NYIRABUKEYE Epiphanie	
291	462772	4784880	1430 m	NTEZAYABO J.Damascene	4 PHC 007/007
292	463236	4784688	1457 m	NDAGIJIMANA Elias	4 PHC 082/079
293	463223	4785276	1558 m	DUFATANYE Marcel	4 PHC 044/044
294	463373	4785317	1580 m	MUKAMANA Bernadette	4 PHC 045/045
295	463506	4785350	1591 m	MUKANTABANA Theodette	4 PHC 035/035
296	462675	4784940	1434 m	MUREKATETE Clarisse	
297	462610	4784937	1430 m	NAMBAJIMANA Barthazar	4 PHC 007/007

NUMBER	X	Y	Z	Names	House No
298	463384	4785369	1574 m	NIYITEGEKA Aaron	4 PHC 061/061
299	463525	4784938	1561 m	NYIRANDIKUBWIMANA Eugenie	4 PHC 086/083
300	462773	4784923	1441 m	KANZIGA Donatile	
301	507398	4792211	1467	HABUFITE Jerome	
302	507412	4792241	1455	HAKIZIMANA Bernard	
303	507367	4792123	1470	RUSINE J.M.Vianney	
304	507476	4792187	1443	MUKARUSHEMA Franciste	
305	507456	4792125	1455	MURWANASHYAKA Jean Marie	
306	507076	4792089	1532	MUKANDEKEZI Vestine	
307	507394	4792153	1469	NSENGIMANA Emmanuel	
308	507091	4792036	1528	MUNYANGABE Straton	
309	507052	4792142	1537	KALISA Jean Damascene	
310	507028	4792209	1536	NTAWANGANYIMANA Jean Claude	
372	519405	4776091	1389	KABAGEMA Ildephonse	
373	519354	4776176	1375	MUKANTAMAGE Perpetue	
374	519217	4776101	1361	NYIRAMUGWERA Speciose	
375	519330	4776238	1377	MUKAMANA Valentine	
376	519211	4776112	1362	MUKAKALISA Olive	
377	519378	4776193	1378	UWAMARIYA Lucie	
378	519403	4776148	1375	BUSERUKA J.de Dieu	
379	519444	4776069	1376	MUKANDAYISENGA Ernestine	
380	519213	4778080	1368	NIWEMFURA Perpetue	
381	519494	4776144	1384	GATABAZI Michelle	
382	521146	4774536	1352	BAVAKURE	
383	521153	4774638	1358	NIZEYIMANA Daniel	
384	521263	4774536	1353	UWAMARIYA Valentine	
385	521233	4774548	1355	HAKIZIMANA Emmanuel	
386	520897	4774921	1375	RINDAYIMANA Valentine	
387	520962	4774622	1347	AHORUKOMEYE Joseph	
388	520959	4774925	1382	MUKASAFARI Anastasie	
389	521191	4774573	1351	MUSENGIMANA Annonciata	
390	521149	4774413	1341	MURINDAHABI Leonidas	
391	521071	4774851	1373	TWAHIRWA Emmanuel	
392	521551	4775929	1382	TWAGIRUMUKIZA Froterine	
393	521522	4776207	1381	MUKABODUWE Speciose	

NUMBER	X	Y	Z	Names	House No
394	521601	4776171	1399	BIZARYABANDI Clementine	
395	521481	4776080	1384	KAYITESI Josiane	
396	521442	4776121	1380	TWIRINGIYIMANA Theogene	
397	521519	4776147	1381	NYIRANSABIMANA Pascasie	
398	521596	4776104	1408	UWIZEYIMANA Feredia	
399	521498	4776148	1379	MUKAMAZERA Marie Louise	
400	521495	4776018	1381	SIBOMANA J.MarieVianney	
401	521560	4775978	1390	MUSHIMIYIMANA Angelique	
402	520905	4775059	1377	AHOBANTEGEYE Francine	
403	512008	4775412	1379	MUKAKALISA Constantine	
404	520927	4775248	1383	NYIRINKWAYA FidΘle	
405	520912	4775109	1381	MPUGUTO Jean	
406	521128	4775508	1382	UZAMUKUNDA Salima	
407	520924	4775054	1380	NYIRANDABONYE Adele	
408	521191	4774841	1377	NTEZIMANA Telesphore	
409	521004	4775371	1385	MURAGIJIMANA VΘlΦne	
410	520996	4775386	1377	HAKUZIMANA Elias	
411	520905	4774941	1380	MAGEZA Theoneste	
412	519723	4776259	1389	HAKUZIMANA Laurent	
413	519758	4776282	1384	NIYOYITA J. Bosco	
414	519782	4776271	1391	NTAKIRUTIMANA Xavier	
415	519796	4776238	1390	NYIRAMBONIMANA Belancilla	
416	519824	4776262	1390	NZAMUGURISUKA Salume	
417	519498	4775890	1379	MUJAWIMANA Dative	
418	519583	4775853	1379	MUHAYIMANA Venuste	
419	519711	4776241	1387	GASASIRA Felix	
420	519638	4775855	1379	KALIMANZIRA Jean Baptiste	
421	519885	4776343	1389	NDAYAMBAJE Gerard	

c.Annex 3:Household questionnaire

Introduction and consent /Guidance for introducing yourself and the purpose of the interview:

Hello. My name is ______________________________________. I am working with REMA. We are conducting a survey to assess the economic impact of the 2012 wet season flooding in Rwanda. The information we collect will help REMA to plan based on the data generated. Your household was selected for the survey. I would like to ask you some questions about your household. The questions usually take about 15 to 20 minutes. All the answers you give will be confidential and will not be shared with anyone other than members of our survey team. You don't have to be in the survey, but we hope you will agree to answer the questions since your views are important.

Household questionnaire ID……….. (Census code)

1. District………………………………………………………	/__/__/
2. Sector………………………………………………………	/__/__/__/__/
3. Cell………………………………………………………	/__/__/__/__/__/__/
4. Village ………………………………………………………	/__/__/__/__/__/__/__/__/
5. Localization (1= Upstream; 2= Middle stream; 3= Downstream)	/__/
6. Respondent's Name: ……………………………………………….	
7. Age (Year of birth)	
8. Sex *(1= Male, 2=Female)*	/__/
9. Marital status: *1.Single* *2.Married* *3.Separated* *4.Divorced* *5.Single Parent* *6.Widowed*	/__/
10. Level of Education: 1. *No Formal Education* *2. Primary* *3.Secondary* *4. Diploma* *5. Bachelors Degree* *6. Masters Degree* *7. PhD*	/__/
11. Religious affiliation:	/__/

1. Catholic *2. Muslim* *3. Protestant* *4. Jehovah's Witness* *5. Seventh Day Adventist.* *6. Traditional/Animist* *7. No Religion* *8. Other* **(**specify)**:**	

1. Sources of income

1.1 What is your main source of income?

1. Job remuneration …………
2. Farming/Rearing animals/Fishing
3. Agriculture Production
4. Trader in Goods/ Services(Commerce)
5. Domestic employee
6. Housewife
7. Other (Specify)..

1.2. How much do you spend in RwF on:

1. *Buying food*
2. *Buying clothes*
3. *Schools fees*
4. *Medical care*
5. *House rent*
6. *Renting land for cultivation*
7. *Social ceremonies/entertainment*
8. *Investment*
9. *Other (specify)*

2. What types of crops are grown in your area?

1. *Beans*
2. *Maize*
3. *Peas*
4. *Soya*
5. *Sorghum*
6. *Wheat*
7. *Cassava*
8. *Irish potatoes*
9. *Sweet potatoes*
10. *Bananas*
11. *Legumes*

12. *Fruits*
13. *Tea*
14. *Coffee*
15. *Tree woods*
16. *Other (Specify)*

3. Climate change aspects: drought
    3.1. Has any drought occurred in the area during the year 2012? Yes / No
    3.2. If yes, in which month this drought occurred (Between 1 and 12)

4. Agricultural and livestock losses caused by the drought:
    4.1. Did you lose any crops during the 2012 hot season drought? Yes / No
    4.2. If yes, which ones (in square meter)
        1. *Beans*
        2. *Maize*
        3. *Peas*
        4. *Soya*
        5. *Sorghum*
        6. *Wheat*
        7. *Cassava*
        8. *Irish potatoes*
        9. *Sweet potatoes*
        10. *Bananas*
        11. *Legumes*
        12. *Fruits*
        13. *Tea*
        14. *Coffee*
        15. *Tree woods*
        16. *Other (Specify)*
    4.3. Did you lose any livestock during the 2012 hot season drought? Yes / No
    4.4. If yes, how many of:
        1. *Cattle*
        2. *Goats*
        3. *Sheep*
        4. *Pigs*
        5. *Poultry*
        6. *Other domestic animals (Specify)*
    4.5. What do you perceive to be the major causes of the drought?
        1. *Human destruction of trees*
        2. *Air pollution*
        3. *Soil erosion*
        4. *Manner of cultivation*
        5. *Habitation*

6. *Other (Specify)*

4.6. Could you suggest any preventive measures?

1. *Reforestation*
2. *Air pollution control*
3. *Fighting against erosion*
4. *Revising the cultivation methods*
5. *Revising the habitation*
6. *Other (specify)*

5. Climate change aspects: Floods

5.1. How many times did flooding occur in this area during the year 2012? In which months did it occur? (Between January and December)

6. Agricultural and livestock losses due to floods:

6.1. Did you lose any of crops during the 2012 wet season flooding? Yes / No

6.2 If yes, which ones? (in square meter)

1. *Beans*
2. *Maize*
3. *Peas*
4. *Soya*
5. *Sorghum*
6. *Wheat*
7. *Cassava*
8. *Irish potatoes*
9. *Sweet potatoes*
10. *Banana trees*
11. *Legumes*
12. *Fruits*
13. *Tea*
14. *Coffee*
15. *Tree woods*
16. *Other (Specify)*

6.3. Did you lose any livestock during the 2012 wet season flooding? Yes / No

6.4. If yes, how many of?:

1. *Cattle*
2. *Goats*
3. *Sheep*
4. *Pigs*
5. *Poultry*
6. *Other domestic animals (Specify)*

7. Water supply system damages caused by the 2012 wet season flooding:

7.1. Did you lose any of the water system installations during the 2012 wet season flooding? Yes / No.

7.2. If yes, what is the estimated cost of the loss in RwF?

8. Infrastructures:

8.1. Did you lose any of the infrastructure installations during the 2012 wet season flooding? Yes / No.

8.2. If yes, which one among the following?

1. *Agricultural*
2. *Industrial*
3. *Service*
4. *Tourism*
5. *Transport*
6. *Telecommunication*
7. *Electricity*
8. *Water and sanitation*
9. *Water resources*
10. *Health and Nutrition*
11. *Education*
12. *Other (specify)*

8.3. What is the estimated cost for the damaged/lost infrastructures in RwF?

1. *Agricultural*
2. *Industrial*
3. *Service*
4. *Tourism*
5. *Transport*
6. *Telecommunication*
7. *Electricity*
8. *Water and sanitation*
9. *Water resources*
10. *Health and Nutrition*
11. *Education*
12. *Other (specify)*

9. Houses and building losses caused by the wet season floods:

9.1. Did you lose any houses/buildings during the 2012 wet season flooding? Yes / No

9.2. If yes, how much is the estimated loss in RwF?

10. Soil and water conservation measures used in area:

10.1. What measures of soil and water conservation do you use in this area?

1. *Upstream digs*
2. *Marshland drainage*

3. *Trees and grass*
4. *Other (specify)*

10.2. Did you lose any of the soil and water conservation installations during the 2012 wet season flooding? Yes / No

10.3. If yes, how long in meters?

11. Is there any other damage caused by the 2012 wet season flooding, such as the following?
    1. *Increased mosquito breeding in stagnant flood water*
    2. *Contaminated water due to flooding*
    3. *Gases from decomposing matter in submerged areas*
    4. *Other (Specify)*

12. What do you perceive to be the major causes of the floods?
    1. *Deforestation*
    2. *Air pollution*
    3. *Soil erosion*
    4. *Wrong cultivation practices*
    5. *Wrong habitation practices*
    6. *Other (Specify)*
13. Can you give mitigation measures?
    1. *Planting trees*
    2. *Fighting against air pollution*
    3. *Fighting against soil erosion*
    4. *Reviewing the cultivation practices*
    5. *Reviewing the habitation practices*
    6. *Other (specify)*
14. Did you lose anybody in the family due to the flooding of 2012? Yes / No

15. If yes/ how many?

c. Annex 4: Guide for Focus Group Discussions

The Executive Secretary of the Sector

1) What are the population trends, population density and demographic data?
2) What are the major sources of livelihood and income of the population?
3) What is the impact of the environmental effects on productivity, income, and human beings?
4) What are the fatalities during the 2012 wet season flooding?
5) What are the causes and impact of changes in the use of natural resources such as declining soil fertility, land degradation, deforestation, and loss of biodiversity?
6) What are the main types of economic costs? (Economic costs may include the depletion of the stock of natural resources and los of species).
7) Are there any means to measure the costs in monetary terms?
8) What are the direct damages and indirect effects during the 2012 wet season flooding?
9) How these effects are related to the nation's GDP.
10) What is the Geographical coverage in terms of area, and specific characteristics of flooded areas?

Officer in charge of Agriculture and Environment:

1. The Gross value of loss in crop production during the 2012 wet season flooding:
2. The Gross value of loss in livestock during the 2012 wet season flooding;
3. The Gross value of Agricultural losses during the 2012 wet season flooding;
4. The trend of agricultural production for major crops, (reference CIP);
5. The types of crops grown in sample areas;
6. Soil and water conservation measures used in sample areas;
7. The Infrastructures loses during the 2012 wet season flooding (e.g. bridges and loss of transport facilities);
8. Telecommunication infrastructure damaged/destroyed, during the 2012 wet season flooding;
9. Water system damages during the 2012 wet season flooding;
10. The variation of temperature and precipitation;
11. Any in-place climate change adaptation measures (e.g. early warning systems and disaster preparedness systems at the decentralized government level) and strategies as well as capacities;
12. Deforestation and reforestation measures in sample areas;
13. About the Land Use patterns;
14. Determinants of climate change variability in sample areas;
15. Development stakeholders are likely to contribute to in the adaptation strategies;
16. The existing land use , development and settlement plans of sample areas;
17. If there is land suitability studies /information in sample areas;
18. What adaptation alternatives/mitigation measures may be in place/ envisaged;

19. What are the Relief costs during the 2012 wet season flooding;
20. Was there any drought during the year 2012? (in which month and what was the impact);

The Officer in charge of Social Affairs:

1. The value of Humanitarian Assistance during the 2012 wet season flooding;
2. The Costs for treatment of diseases with high linkages to floods during the 2012 wet season flooding;
3. Houses and building losses during the 2012 wet season flooding;
4. The Cost to replace the lost house items – or other infrastructures during the 2012 wet season flooding;
5. The costs used or needed to repair damaged facilities and infrastructures;
6. The estimated equivalent costs of collective actions, such as loss of membership value within a farmers' cooperative organization due to displacement or resettlement;
7. Categorization of losses during the 2012 wet season flooding - first order losses (interruption of economic activities such as production and/or consumption) - and the losses from business interruption;
8. Any human fatalities during the 2012 wet season flooding (number of male, female, children under 18 years, adults below 65 years);