Review of the Economic Impacts of Climate Change in Kenya, Rwanda and Burundi

Ecosystems Chapter, Rwanda

Final Draft

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October 2009

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1. NATIONAL OVERVIEW: RWANDA

Section I gives a brief description of main ecosystems services in Rwanda, and analyses current exposure of ecosystems to different stresses and the associated effects on ecosystems services. This section describes first the ecosystem and ecosystem services in Rwanda and then explains briefly the value of ecosystems for Rwanda's economy and population well-being

1.2 Mapping Ecosystems in Rwanda

Rwanda is located in Central Africa between latitudes 1°04' and 2°51' south and longitudes 28°45' and 31°15' east. Rwanda's topography is considered hilly and mountainous with an altitude ranging between 900 m and 4.507 m (average 1700m), and has a tropical temperate climate due to this high altitude.

Rwanda has volcanic mountains at the northern fringe and has rolling hills in most of the central plateau. However, the eastern part of the country is relatively flat with altitudes well below 1500metres.

The average annual temperature ranges between 16°C and 20°C, without significant variation with average rainfall of about 1,250 mm per annum. (Figure.1)

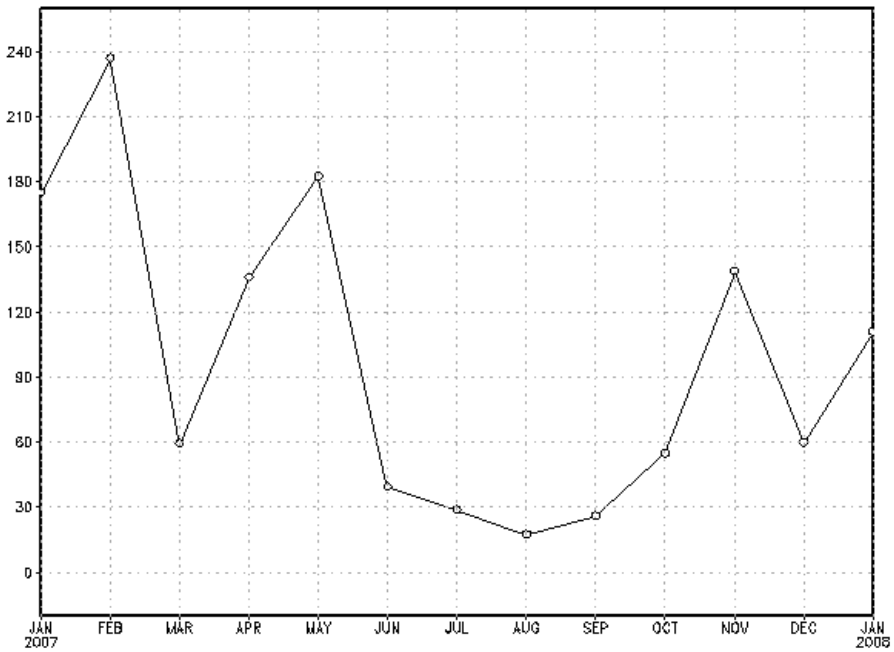

Figure 1. Monthly accumulated rainfall in mm, year 2007 near Kigali (NASA, 2009).

On the landscape there are five distinct ecosystems: cropland and natural vegetation (47 % of total land); scrubland, savannah and grasslands (32 % of total land); forest (12 % of total land); wetlands and water bodies (8 % of total land); and sparse/barren vegetation (1 % of total land) (USAID 2008) (see Figure 2). It is agreed that these ecosystems contain a wide variety of different habitats and species due in part to varied topography, which is responsible for diverse regional climatic conditions.

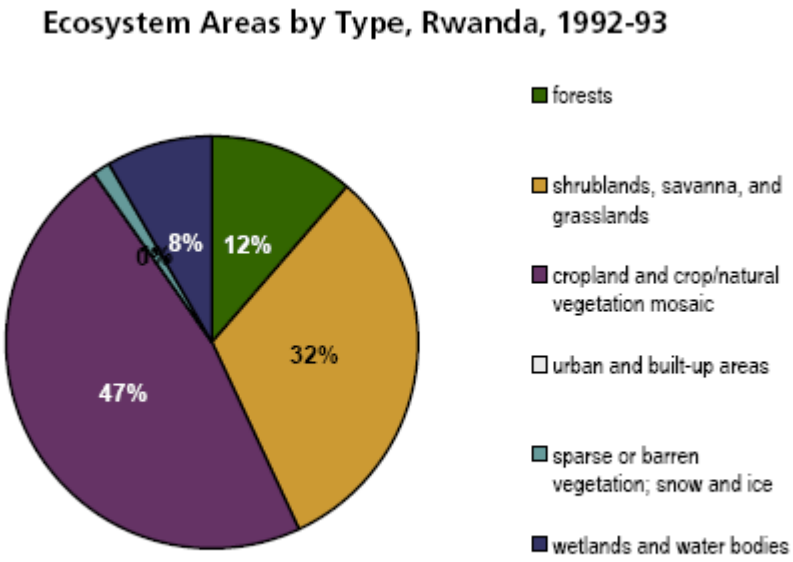

Figure 2. Ecosystem areas by type in Rwanda

Source: WRI, 2009

Protected areas: Protected areas are mainly the three national parks (see Figure 3):

Volcanoes National Park which is famous worldwide due to the presence of mountain gorillas (*Gorilla gorilla beringei)* and its variety of plant and animal species. It constitutes Rwanda's northern border with the Democratic Republic of Congo and Uganda.

At present, its surface area is 12,760 hectares and is characterized by an altitudinal layering of vegetation, from bamboo forest (at 2300 – 2600 m) to the afro-alpine vegetation resembling that of the tundra from 4200 m up to the summit of Karisimbi (4507m).

The Volcanoes National Park is home to 245 species of plants, 115 species of mammals, 185 species of birds, 27 species of reptiles and amphibians and 33 species of invertebrates Some of these species are endemic and others are internationally protected.

Nyungwe National Park has more than 1,200 species of flora, 275 species of birds. adjacent to the national park of Kibira in Burundi, is probably the largest mountain rainforest in the whole of Africa, with a surface area of 970 km2 in 1997. It stretches at an altitude ranging between 1600 and 2950 m and shelters a complex mosaic of types of vegetation. This rich variety of flora is accompanied high percentage of these species are endemic and are found only in the surrounding forests.

Thirteen types of primates have been identified, representing among which is the most threatened, namely the "monkey with an oval face" (*Cercopithecus hamlyni*) and the golden monkey (*Cercopithecus mitis kandti*) by an equal variety of fauna, including several species

of birds and primates. One of the remaining biggest populations of chimpanzees of the east (*Pan troglodytes schweinfurtii*) is to be found here.

Nyungwe is a large water catchment basin, shelters 60% of the country's waters and is one of the sources of the Nile River.

Akagera National Park covers a surface area of about 90,000 ha and is a unique ecological zone situated between 1,300 m and 1,825 m of altitude. More than 900 species of plants have been identified in the park. *Acacia senegal* dominates, *A. combretum* is also present with *A. polycantha* and *A. Sieberana* found in lesser number. Grassy savannas consist mainly of Themeda, Hyparrhenia, Sporobolus and Botriochloa.

The fauna comprises 47 species of big mammals, more than 500 species of birds, 9 species of amphibians and 23 species of reptiles.

Figure 3. National parks in Rwanda.

Source: USAID, 2008

Forests

Rwanda has a total of 480,000 ha of forested land (19.5%) of total land area. Almost all of Rwanda's remaining forested lands of any significance are found within the borders of its national parks and two forest reserves (see Figure 4). A few small gallery forests and remnant forests also exist.

Gallery forests are strips of swampy forests that were extensive in times past. These forests are all found in the eastern part of the country, mainly in the Akagera river-lake system. They cover a surface area of about 163 ha. Despite their small size, these gallery forests, have

high levels of biodiversity including endemic and rare species. The most important of these gallery forests is the Ibanda Makera forest.

Relict forests and savannahs of the Eastern Province situated around Akagera National Park have a variety of endemic and rare species of plants most of which are used in traditional medicine.

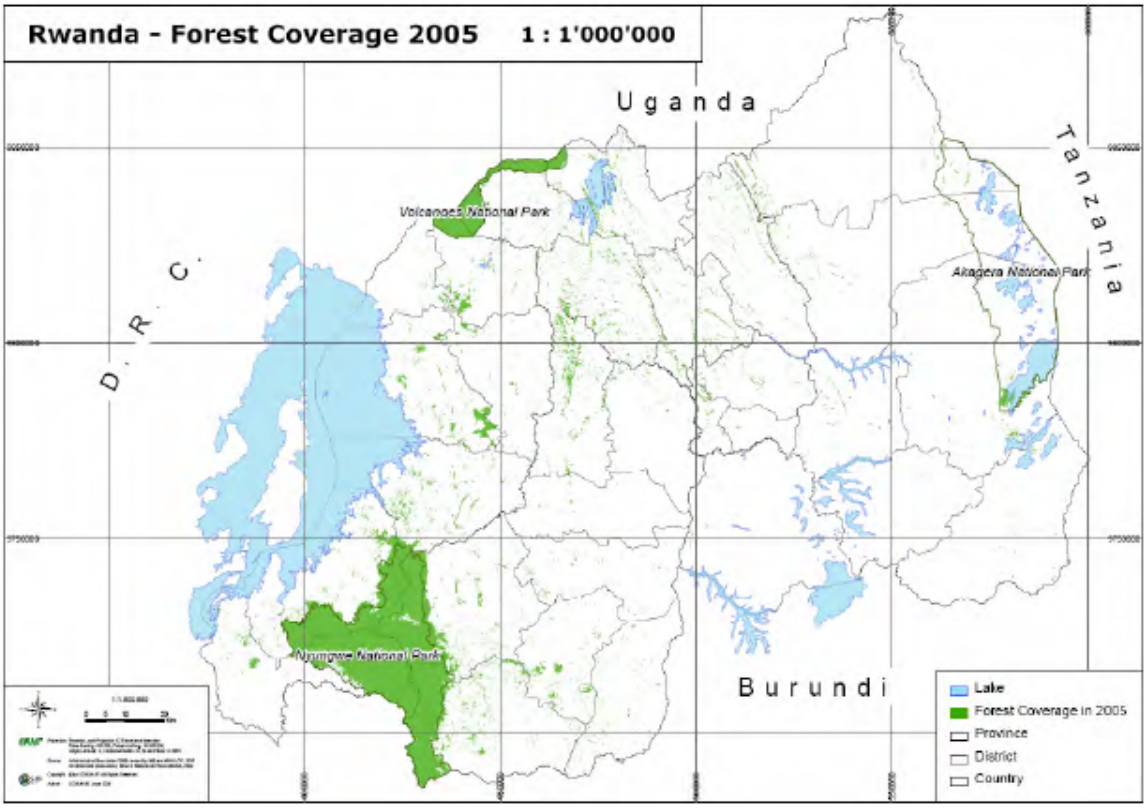

Figure 4. Forest Cover in Rwanda

Source: USAID, 2008

Hydrology

Rwanda's hydrology is characterized by a dense network of lakes, rivers, and wetlands. Water is, without a doubt, Rwanda's most valuable natural resource. Approximately 210,000 ha, 8% of the entire country, are under water; lakes occupy about 128,000 ha, rivers about 7,260 ha, and water in wetlands and valleys about 77,000 ha (USAID 2008).

The country is divided into two major drainage basins, the Nile to the east and the Congo to the west. The Congo basin covers 33% of Rwanda and handles 10 percent of all national waters. The Nile basin covers 67% and delivers 90 % of the national waters. The forested area of Nyungwe National Park is Rwanda's major watershed for both the Nile and the Congo basins. The waters of the Nile basin flow out through the Akagera river system, which contributes 8 to 10% to the Nile drainage system (USAID 2008).

The network includes numerous lakes: In the Congo basin Kivu is the only lake. However, the Nile basin has six groups of lakes, namely:

- the lakes of the north, lakes Bulera and Ruhondo and other small lakes
- the lakes of the centre: Muhazi

- the lakes of Bugesera: Rweru, Cyohoha (south and north), Kidogo, Gashanga, Rumira, Kilimbi, Gaharwa
- the lakes of Gisaka: Mugesera, Birira and Sake
- the lakes of the Nasho basin: Mpanga, Cyambwe and Nash
- the lakes of the Akagera National Park: Ihema, Kivumba, Hago, Mihindi, Rwanyakizinga

The lakes of the Akagera National Park are among the richest in fish species in the whole country. The most dominant species is the haplochromis and other fluvial species. Other lakes like Muhazi, Nasho, Rwampanga, lakes of Gisaka and Mugesera are also very rich in fauna and flora. In addition to lakes, the major rivers are the Akagera, Nyabarongo, Akanyaru, Ruhwa, Rusizi, Mukunga, Kagitumba, and Muvumba (see Figure 5).

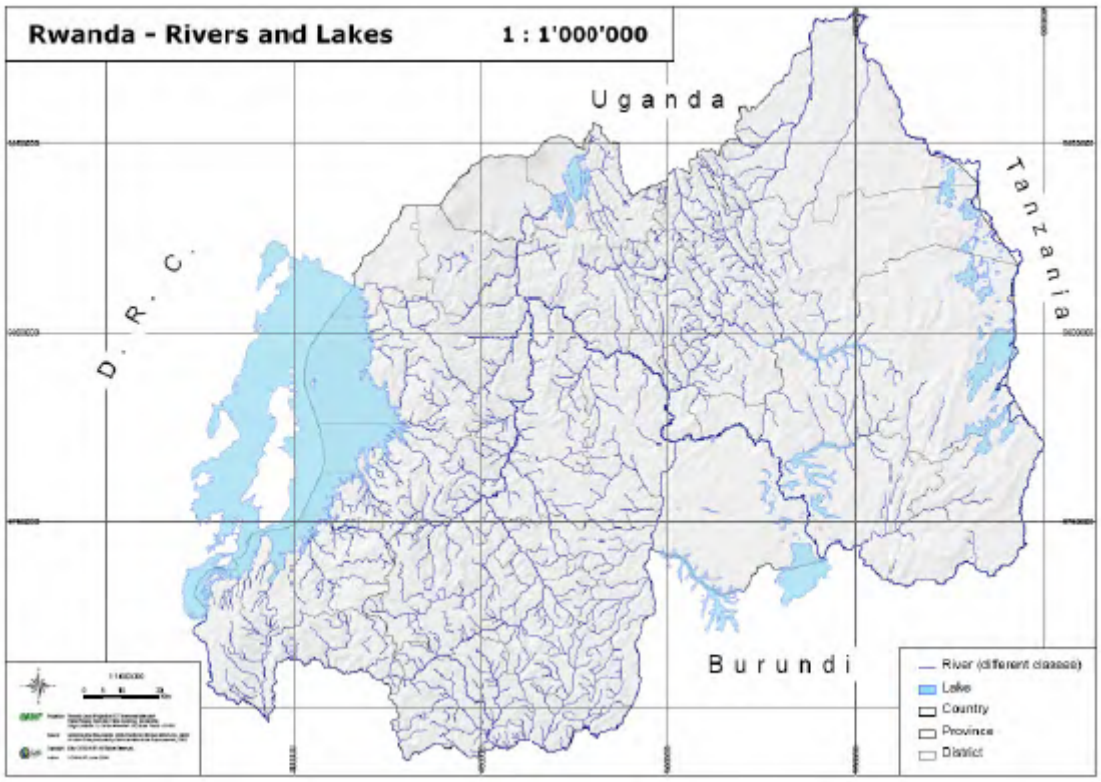

Figure 5. Rwanda rivers and lakes

Source: USAID, 2008

Wetlands

Wetlands of Rwanda are composed of marshlands, lakes, rivers and streams and represent about 14.9% of the national territory (approx. 254,847 ha) (WRI 2007). 6.3% are marshlands and 8.6% are lakes, streams that are permanent or seasonal. Rwanda's wetlands are extremely important. They act as a buffer in flood or overflow plains reducing maximal flow

rates during the rainy season and maintaining relatively high flow rates during the dry season.

The wetlands and marshlands, which occupy about 10% of the country, are comprised of three large swamps and small wetlands scattered among the country's many hills. The main swamps are Akanyaru (12,546 ha) on the border with Burundi, Kagera along the Tanzania border to the east (12,227 ha), and the Nyabarongo (24,698 ha) and Rugezi wetlands (6,294 ha) to the north (see Figure 6).

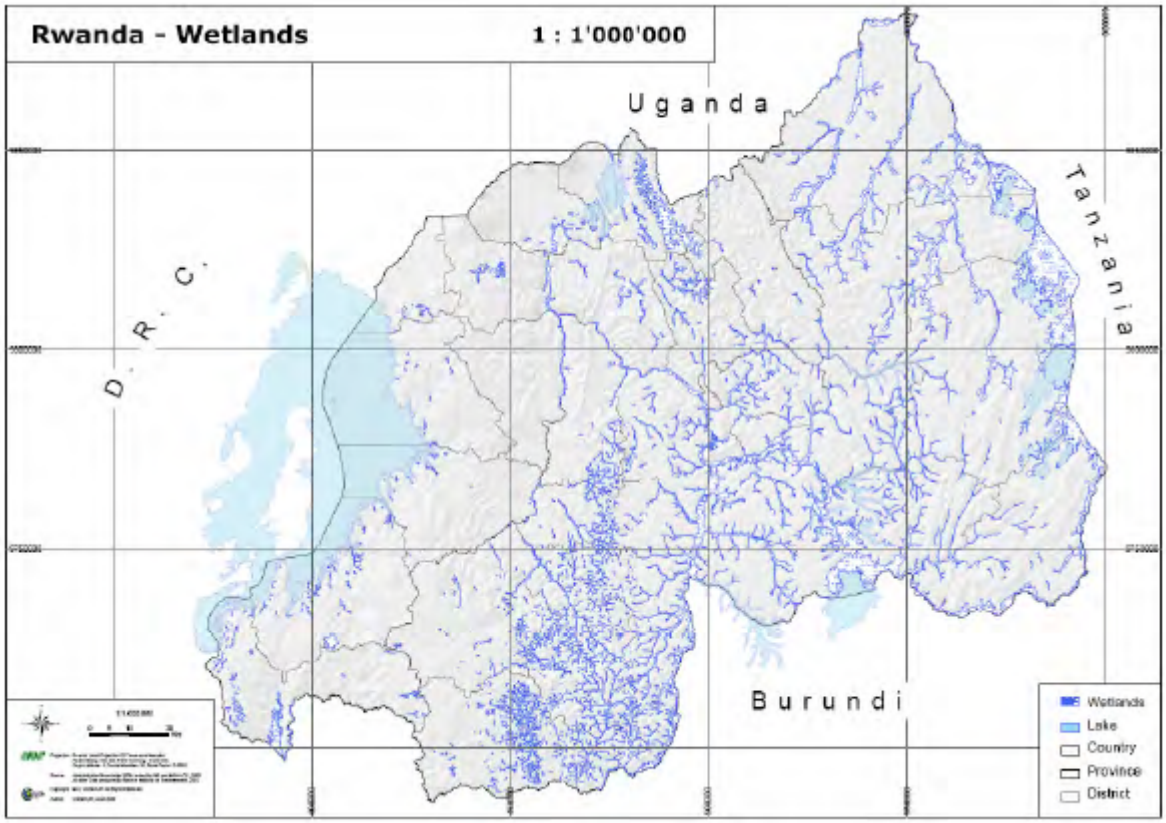

Figure 6. Rwanda wetlands

Source: USAID, 2008

Soils

Rwanda's soils come from the physical-chemical alteration of schistose, quartzite, gneissic, granite and volcanic rocks, which make up the superficial geology of the country. There are six groups of soil:

The Rwandan pedology is characterized by six types of soils namely; soils derived from schistose, sandstones and quartzite formations (50%); found in the Congo-Nile Ridge, part of the Central Plateau and on highlands in Byumba. Soils derived from granite and gneissic formations (20%) are found around Gitarama (Central Plateau) and in the Mutara plains. Soils derived from intrusive basic rocks in the north of Kigali and west of Byumba. Alluvial and colluvial soils of marshes and valleys which comprise mineral soils found in the valleys of the east and the organic soils of the valleys of Akagera, Nyabarongo and Rugezi. Soils derived from recent volcanic materials found at the piedmont of volcanoes. Soils derived from old volcanic materials found in the plateau of Cyangugu in the south west of the country (MLRE 2003).

The underground earth contains deposits of minerals such as tin, wolfram, colombo□tentalite and gold. There are quarries which extract clay, sand, building stones, limestone, and peat.

Population

Rwanda, with an estimated population of over 9 million inhabitants has a surface area of 26,338 km². and which makes it the most densely populated country in Africa, with about 397 inhabitants/km². With an annual growth rate of 2.9%, the population of Rwanda is currently estimated at 9.2 million (2006) with an urban population of up to 17%.

The population is expected to grow to around 16 million by 2020. The government aims to reduce this to 2.2% by 2012. The ensuing rise in population density has put pressure on the physical environment and induced labour migration between rural areas as well as from the countryside to the towns. The population age profile is relatively young with 67% of the total population below the age of 25 most of whom are unemployed (MINECOFIN 2003).

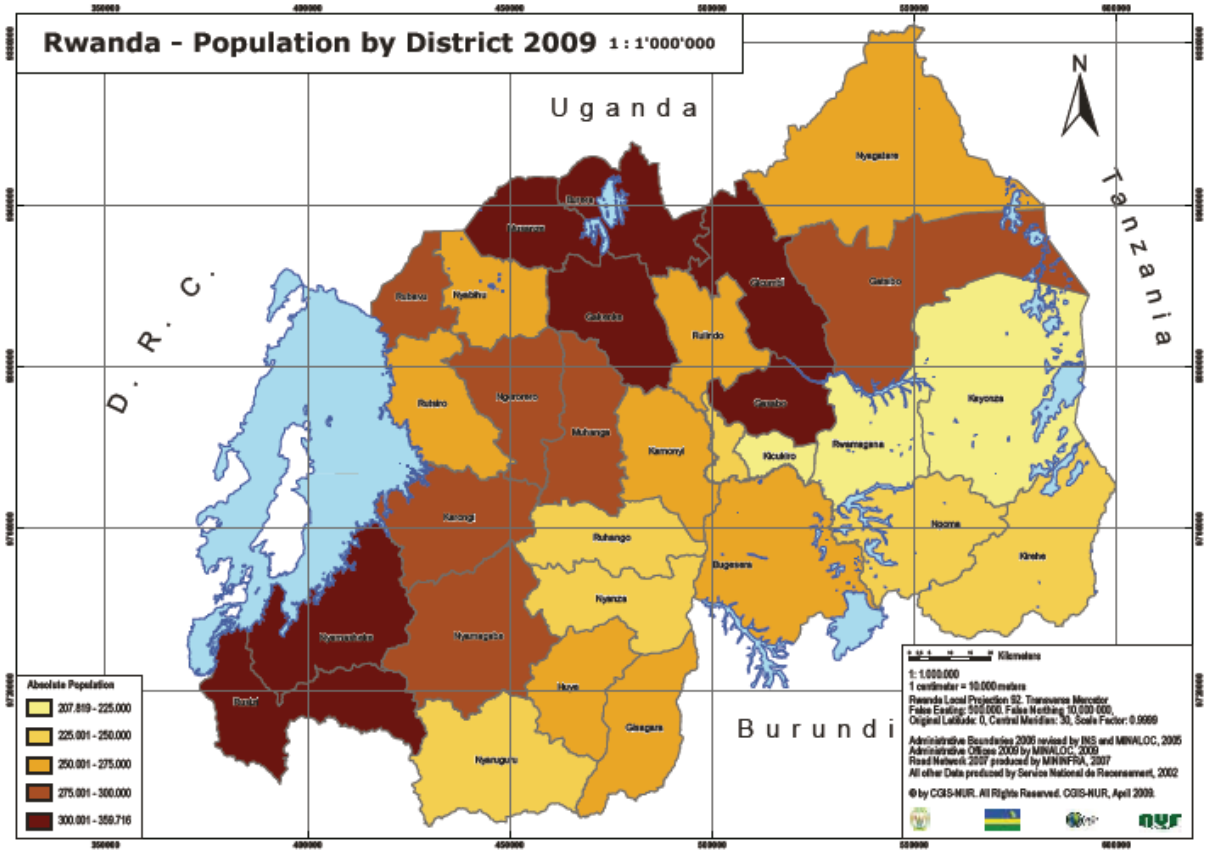

Figure 7. Population in Rwanda by district.

Source: (USAID, 2008)

1.2 Current Stresses Affecting Ecosystem Services

It is clear that ecosystems in Rwanda are currently particularly vulnerable to a number of significant stressors. These include natural threats such as erosion, floods, drought, invasive species, diseases and pests and social pressure including population pressure, forced

resettlement, overexploitation of biological resources, poaching, human induced fire, conflict and insecurity (DFID & MINITERE, 2003).

The strong dependency on natural resources in Rwanda makes economic activities directly dependent on climate conditions. In addition, because of overuse of natural resources, the ecosystems are more vulnerable. (NAPA-Rwanda, 2006)

The Rwandan NAPA undertaken in 2006, outlined that periods of vegetation growth, the duration and frequency of dry and rainy periods, risks of floods, erosion and risks of drought all play a part in biophysical vulnerability. Social vulnerability, including the level of education, income, poverty and diversification of the means of existence were also taken into account.

Freshwater

The large hydrological network in Rwanda has been made vulnerable by the fact that there are inconsistency of precipitation and incidence of drought in the country. Drought which involves a remarked rainfall deficit, a reduction of the water level in lakes, rivers and the depletion of water sources have been noticed recently in Rwanda (MINITERE 2004). Prolonged drought affects ecosystems and leads to a drastic reduction of varieties and species, hampering the proliferation of indigenous species to regenerate and may offer opportunity for invasive species. In particular, drought, combined with the high degradation of land, contributes to the rapid progress of the desertification process in the eastern region.

During extremely heavy rains, rain water causes floods in the valleys and depressions. Ecosystems are seriously affected and threatened during extreme weather events, including pressure on species due to inundation cutting off of air supply (i.e plants) or are carried away by water (MINITERE 2004).

This has been particularly noticed in wetter ecosystems (marshes, gallery forests,…). Siltation of lakes such as North Cyohoha resulting from floods and erosion constitutes also a serious threat to aquatic ecosystems. It causes a rising of the water level which, later, may flow out above the alluvial barrier, particularly for the lakes in the east and the destruction of fish spawning grounds (MINITERE 2004)

As seen in the majority of the region in East Africa, population pressure has caused huge implications for the availability and management of natural resources. Rwanda, as mentioned has a very high population density with exceptional growth putting pressure on natural ecosystems.

As with growing population in the entire region, this effect of this pressure is an increased demand on water and freshwater but also natural resources in general (land, energy, foodstuffs, etc), land clearing for agriculture and grazing, house building, removal of species for traditional medical purposes, etc, modification and destruction of habitats and deforestation which, ultimately, lead to the extinction of some species.

For example, most of the marshes in Rwanda have been reclaimed without appropriate facilities for good water management (irrigation - drainage), which resulted in the extinction of some aquatic plant species. The phytoplankton and spawning grounds have been destroyed, in many areas (DFID & MINITERE 2003).

Ecosystems Degradation and Biodiversity Loss

Rwanda's relief consists of high mountains, steep-sloped hills and depressions. High altitude regions are the wet and water runoff on steep slopes, coupled with the natural fragility of the soil, carries along easily eroded soils towards valleys and depressions.

Soil degradations affect a large part of the territory, particularly fragile ecosystems of mountain regions in the North and in the West. Whether by wind or by water, erosion causes a reduction of soil fertility by removing the arable layer and, consequently, it contributes to the extinction of some plant formations and to the loss of faunal habitat (DFID & MINITERE 2003).

Biophysical threats such as landslides result in vertical infiltration of rain water which is facilitated by the low cohesion structure of the soil. When land is dampened and reaches a point of saturation, it may lead to the movements of parts of the hills towards valleys and depressions, part of which is carried away outside the country. There is significant damage and losses of biodiversity. This is particularly noticeable in the area of mountains in the north and south west of the country.

Anthropogenic influences have also seen the proliferation of certain competitive and invasive species. For example, *Sericostachys scandens* in the forest of Nyungwe has for a long time, been living in balance with other ligneous plants thanks to herbivores which grazed it; today, with the extinction of these herbivores, this creeper, with some varieties of the fern, have become intrusive and destructive.With regard to wild plant species, there is for example the invasion of the water hyacinth (*Eicchornia crassipes*), introduced in river Mukungwa, which has spread rapidly including into lake Mihindi in the Akagera National Park where is now extremely widespread.

In Rwanda, due to a myriad of social problems, overexploitation of biological resources has been one of the most important threats to ecosystems. The immediate economic interest of certain biological resources has increased their overexploitation by the population living in the vicinity who often neglect or ignore other alternative sources of income. For example, the fish wealth of lakes is threatened by the use of nets with very fine meshes which hold the fries. Poaching has become widespread and selective and intensive hunting for commercial purposes has today led to the extinction of some animal species such as the elephant and the mountain buffalo in the forest of Nyungwe and the porcupine in the Akagera National Park. The unrestrained search for high value timber (*Entandophragma excelsum, Faurea saligna, Prunus africana, Polyscias fulva*) in certain ecosystems has led to selective felling. It is believed that poaching has exacerbated the local extinction of leopards in Volcanoes National Park and the forest of Nyungwe, the increased rarity of hyena, elephant and the buffalo in the same areas. The local extinction of the giant forest pig and wildcat from the Akagera National Park and the increased rarity of the chimpanzee, the potto, the green monkey, the bush baby and the harnessed bushbuck in the same park. There is also evidence of a drastic reduction of the most targeted animal species, which are sought out as trophies, such as the elephant, the Royal antelope, the sitatunga, the buffalo, the gazelle, the boar, the porcupine, the partridge and the colobus monkey (MINITERE 2003)

Fire has also been pointed out as a serious problem in Rwanda and has in some cases resulted in a serious threat to the countries ecosystems. Periodically, protected and non protected areas are devastated by deliberate, criminal or accidental fires. Areas that are mostly affected by these fires are: the forest of Nyungwe, the Akagera National Park and the savannas of the east, the valleys of Nyabarongo, Akagera and Akanyaru.

Population pressure

Rwanda has experienced conflicts and social crises since 1959, and these have resulted in the loss of human lives and the destruction of ecosystems. The recent and most obvious case is the war that prevailed since 1990 and culminated in the 1994 genocide and massacres with the following consequences on ecosystems, including encroachment, loss of skills in the field of environment and biodiversity; discontinuance of protection of formerly protected areas and use of areas for domestic animals.

Resettlement of the population during and after the 1994 genocide, lead to considerable movement of people in the country. The country faced the resettlement of the returnees and internally displaced persons. This resettlement which was carried out in an emergency situation constituted a serious threat to biodiversity, particularly forests through serious deforestation. For lack of other public land, community administrations were often made to sacrifice whole forests to accommodate resettlement sites.

At the same time, spontaneous occupation of these natural ecosystems aggravated this deforestation: the cases of Gishwati (in the north of the country), Umutara hunting fields and the Akagera National Park (in the east of the country) were the most critically affected. In fact, these two ecosystems which are naturally fragile were forced to accommodate considerable numbers of people and cattle greatly exceeding their environmental capacity. Furthermore, it has been observed in these ecosystems that there was serious pressure on biological resources and increased demand of water and land. Eventually, the occupation of the forest of Gishwati and part of the Akagera National Park has caused considerable damage to Rwanda's biodiversity.

Population pressure has also led to the depletion of arable land. In fact, arable surface area per capita has fallen from 47 ares in 1970 to 13 ares in 2000 when in Sub-Saharan Africa, the average was estimated at 26 ares in the same year.

1.3 Value of Ecosystem Services in Rwanda

Since the livelihoods of about 90% of people are linked to land (State of environment report 2009, Unpub.) and the agricultural sector is the backbone of the economy and contributes about 41% of GDP and more than 72% of all exports (REMA 2003), it is imperative for Rwanda to have a good economic understanding of its natural resources.

It has been noted that there are little if any data on the contribution to the economy of other natural and environmental resources. Some estimates have been developed, for example Table 1. However, it is widely agreed that tourism has been the third largest earner of foreign exchange for Rwanda.

Table 1. Estimation of the economic value of ecosystem services in Rwanda and beneficiaries

Ecosystem services	Economic Value ($US/year)	Beneficiaries
Watershed protection	117,757,583	Local communities, OCIR THE, Electrogaz, Regideso/Burundi
Biodiversity protection	2,000,000	Global community
Carbon sequestration and storage	162,080,000	Global community
Recreation and tourism	3,372,313	Global community, ORTPN and tour operators
Total	285,209,896	

Source: (USAID, 2008)

Rwanda is considered to be one of the poorest countries in the world and current estimates put GNP per capita at $250, population growth rate at 2.8%, life expectancy at 41 years and literacy rates at 48.3% (GoR 2002a).

A review carried out by UNEP and IISD (2005) identified four critically stressed ecosystem services in Rwanda (based on the Millennium Assessment categorization of ecosystem services, see section I): maintenance of biodiversity; food provision; water supply, purification and regulation; and energy resources. This section will describe each one of these ecosystem services.

Maintenance of Biodiversity

Rwanda is a country that is exceptional in its biodiversity. However, rapid deforestation and conversion of natural habitats to agricultural systems has caused a loss in the variability of ecosystems. Biodiversity loss in Rwanda is severe and mainly due to the progressive disappearance of national parks and large-scale habitat destruction. Specifically, natural forests have declined by 78 per cent since 1990 and the country is also experiencing a loss of its agrodiversity and wetland biodiversity.

As mentioned earlier ecosystems in Rwanda, the primary source of biodiversity, genetic resources and biochemicals, are composed of forests (12 % of total land area), savannah (32 %), wetlands (8%) and mixed cropland/natural vegetation (47 %). More recently, Rapid deforestation and conversion of natural habitats to agricultural systems, however, has caused a loss in the variability across them (World Resources Institute 2003d). Currently, Rwanda protects 7.7 per cent of its total land area and, thus, only a small proportion of its biodiversity (World Resources Institute 2003a).

Rwanda's protected areas, namely Volcano National Park, in the northwest (Gisenyi and Ruhengeri), Nyungwe Montane Forest Reserve in the southwest (Cyangugu), and Akagera National Park in the northeast (Umutara), hold exceptional biodiversity.

Today, Akagera is considered the most complex savannah ecosystem in eastern Africa, combining wetlands and savannah habitat, and is home to 12 species of primates (Kanyamibwa 1998). Volcanoes National Park is home to approximately half (320) of the world's population of mountain gorillas, which consume vegetation from more than 70 different plant species (World Bank 2004). Nyungwe's flora alone comprises more than 250 tree and plant species, including more than 100 orchid species, and is dominated by the bamboo *Arundinaria alpine* (Kanyamibwa 1998). It is also home to the owl-faced monkey *Ceropithecus hamylini* and 275 known bird species (Kanyamibwa 1998, World Bank 2004).

Biodiversity loss in Rwanda is severe and mainly due to the progressive disappearance of national parks and large-scale habitat destruction (World Bank 2004). They have been compounded by historical problems such as between 1958 and 1979, Volcanoes National Park lost 55 % of its natural habitat mainly for pyrethrum growing. The 1994 genocide resulted in direct fighting and bombs that killed wildlife throughout Rwanda. Furthermore large-scale fighting occurred inside Akagera National Park and soldiers killed many animals (Kanyamibwa 1998). Akagera National Park lost approximately 90 % of its megafauna, and approximately two-thirds of its original area.

Encroachment, grazing and agriculture since 1994 has resulted in Akagera National Park and Mutara Game Reserve being taken over by 700,000 grazing cattle from Uganda, with temporary and permanent buildings now widespread. Nyungwe Montane Forest Reserve is now fragmented by agriculture (Kanyamibwa 1998).

Illegal logging and deforestation has led natural forests to have declined by 78 % since 1990 (World Resources Institute 2003d). Rwanda's most recent biodiversity strategy (2003) mentions Mukura and Gishwati forests as having particularly high rates of deforestation (Rwanda Ministry of Lands, Resettlement and Environment 2003).

Riverine resources including fish diversity is also decreasing along with a loss of wetland biodiversity and habitat, though exact data is lacking.The invasive water hyacinth's presence in Lake Victoria has reduced water quality and threatened biodiversity, particularly along the Kagera River system, at the eastern border (Moorhouse, Agaba and McNabb 2000).

Tourism in Rwanda generates significant revenue. Each year, millions of tourists visit national parks and national reserves. In addition to admission fees to tourist sites, tourist taxes levied on different services (transport, accommodation, various purchases) contribute to the rapid development of the national economy. Approximately, revenue realized from tourism amounted to about 10 millions of US dollars in 1988 and to 110 thousands in 1999. Table 2 shows Virunga National Park, gate receipts from tourism is significant and it's loss would affect GDP if it were lost.

Table 2. Income from Virungu National Park(in US$) from 1974-2005.

Year	Visitors	Revenue	Year	Visitors	revenue
	Pax	US$		pax	US$
1974	449	10,400	1990	2,726	251,977
1975	923	3,062	1991	1,781	107,933
1976	661	2,351	1992	1,011	236,983
1977	970	4,509	1993	1,111	235,024
1978	1,444	7,353	1994	61	10,475
1979	1,653	10,237	1995	1,663	430,542
1980	2,593	31,377	1996	2,653	346,164
1981	3,693	80,002	1997	1,192	149,145
1982	4,217	100,955	1998	0	0
1983	4,905	119,476	1999	417	87,333
1984	6,010	235,462	2000	1,313	281,693
1985	6,571	266,973	2001	2,155	233,176
1986	5,524	315,896	2002	5,575	1,024,137
1987	5,356	-	2003	7,239	1,377,665
1988	5,282	278,755	2004	8,593	2,213,383
1989	6,952	448,545	2005	10,641	3,005,783

Source: REMA/PEI, 2008

Food and Fibre Provision

In Rwanda, 90 % of the population is engaged in subsistence farming, with the main subsistence food crops produced in 2001 being tubers (56 %), bananas (29 %), legumes (8 %), and cereals (seven per cent). Root and tuber crops, such as sweet potatoes, cassava and Irish potatoes account for 34% of the total cultivated land, while legumes, bananas and cereals took 25 %, 19 % and 17 % respectively of the remaining cultivated land

Commercial or cash crops are also grown and comprise 47 % of GDP. They consist of bananas, arabica coffee, tea, cattle (milk and meat hides and skin), and pyrethrum Although there is a continual downward trend in productivity overall, recent data show national-level

increases for cassava, Irish potatoes and sweet potatoes with decreases for legumes and cereals (Donovan, Mpyisi and Leveridge 2002). In 2004, it was shown that national crop production was 3,281,395 mt (similar to the same season in 2003). This production translates into 1,832 kilo calories (kcal)/person/day for Rwanda (or 87 % of the recommended daily requirements of 2,100 kcal/person).

Donovan, Mpyisi and Loveridge (2002) found that increases in Irish potato production are probably due to increased and better inputs including improved seed potatoes, while increased cassava production and yields can be attributed to new cassava varieties with better yields and its desirability as a drought- and flood-resistant crop.

Goats and cattle are raised in significant numbers by small-holder farmers (World Agroforestry Centre 2003). In mixed crop-livestock farming characteristic of Rwanda, there is a strong linkage between crop and livestock production, as crops provide unmarketable surpluses and by-products which livestock can convert into high-value products. While empirical data on the contribution livestock makes towards daily nourishment were not found, anecdotal information based on decreases in the supply of organic fertilizers implies a corresponding drop in livestock numbers. Existing data indicate that Umutara and Gitarama provinces have the largest number of livestock, while Ruhengeri Province has the highest density with 50–100 animals per sq km throughout the district (FAO 2005).

Fish protein comprises one per cent of the total protein supply, and the supply of fish and fisheries products was a one kg/person/year (World Resources Institute 2003b). Rwanda's freshwater fish catch in 2000 was 6,726 metric tons, up from 2,350 metric tons in 1990 (World Resources Institute 2003e). Freshwater aquaculture has also increased to 270 metric tons (World Resources Institute 2003b).

Food Production is constrained by topography, low soil suitability, climate (including frost, snow, drought), availability of small fish, soil erosion, declining soil fertility and declining water tables.

It is notable to point out that erosion of land under cultivation (Table 3) has been estimated at considerable loss for Rwanda.

Table 3. Estimated loss per hectare against estimated total loss for land under cultivation in Rwanda.

	Area in ha	Estimate area under erosion	Estimate loss per ha	Estimate total loss
Land under cultivation	1,144,300	572,000	33,000 RWF	18,876,000,000
			US$	34, 320,000
			As % of GDP	1.9

Source: PEI, 2006

Water supply, purification and regulation

Rwanda's main source of freshwater comes from its yearly average precipitation of 1,200–1,280 mm/year. The main user of water in Rwanda is the agricultural sector (94 per cent) followed by the domestic sector (five per cent) and finally the industrial sector (two per cent). The total withdrawal rate is 0.8 cu km per year or 141 cu m per capita per year. This is

approximately 22 per cent of total allowable withdrawal based on the internal renewable water resource value (World Resources Institute 2003e).

In turn, ecosystems play a key role in the provisioning of clean freshwater, water flow regulation and water purification. The ability of ecosystems to provide these services is in part determined by the quality of the country's watersheds.

Rwanda's water systems cannot meet the demand for water if all individuals are given the minimum amount of 1,000 cu m as recommended by the United Nations.

Pressure for agricultural space, inappropriate marsh cultivation, wetland degradation and their reclamation, siltation, flood damage, invasive plant infestations and deforestation have been all linked with reducing the valuation of water resources in Rwanda

Fuel and Energy

Ninety-eight per cent of Rwandan households use wood or charcoal for cooking and these represent the country's main energy sources (Rwanda Ministry of Finance and Economic Planning 2002). In order to satisfy demands for fuel wood and charcoal production, Rwandans clear forests and vegetation (Odada et al. 2004). Since 1990–1994, however, Rwanda has one of the highest deforestation rates in Central Africa, and perhaps all of Africa, currently at four per cent per year (FAO Forestry Department 2003, FAO 2001). Partly as a result of genocide, displacement and repatriation, forested areas have been reduced by almost half in less than a decade.

2. IMPLICATIONS OF CLIMATE CHANGE EFFECTS ON ECOSYSTEM SERVICES IN RWANDA

2.1 Climate change and socio-economic futures

This section on Rwanda will continue to understand how will affect ecosystems in Rwanda under the two possible future development pathways, the "Business as Usual" pathway and the "Vision" pathway.

The Business as Usual pathway will see a continuation of current trends, while the Vision pathway will see the goals and targets of different strategies and initiatives developed for the sustainable development and stability in Rwanda.

Although Rwanda has made significant progress from the devastated nation that emerged from the 1994 genocide, it still remains a severely under-developed, agrarian based economy with around 60% of the population living under the poverty line. Climate change will compound some of the problems that exist in this country, but it is positive to see that many levels of the Rwandan government have developed a strong interest in addressing some of these issues.

2.2.1 Climate Change in Rwanda

Observed climate trends

As outlined in the regional overview, it is difficult to know what will happen directly to Rwanda and the ecosystems and ecosystem services which are recorded there due to the impacts of climate change. Rainfall patterns have been inconsistent as is the case in many places in East Africa and this makes clear scenario development, even under current conditions more difficult. Rwanda has always been affected by droughts and floods, but it is expected that such extremes could potentially increase.

Climate Projections

It has been noted that GCM's indicate that a warming of 2-5% is likely by 2050 in this region, however downscaling to a level where we can be fully sure what will happen to ecosystems is extremely difficult. This has been outlined clearly by Berry, 2009.

Although it is acknowledge that since the closing date for submissions to the AR4, wide-ranging surveys have been conducted and analysis suggest that ecological changes in the phenology and distribution of plants and animals are occurring in all well-studied freshwater, and terrestrial groups (UNEP 2009).There have not been notable studies found in this area from Rwanda and with high levels of biodiversity, there may be changes occurring presently.

Predicting precipitation change at a downscaled level such as that of a small country like Rwanda is made difficult as there is a lack of clear data from the country. MINITERE (2004), have documented droughts and it's impact at the species and ecosystem level but also flooding has been noted. This makes even weather prediction difficult let alone climate projections.

However, if the projections outlined in Hulme (2001) are used, it is likely that there will be dramatic changes to rainfall patterns in Rwanda.

2.1.2 Socio-economic Futures

The Business as Usual pathway

The A2 scenario used in the Business as Usual pathway assumes medium economic development, low per capita incomes, and weak globalization. This scenario would see Rwanda remaining a strongly agricultural economy and most likely a decrease in earnings from agriculture as input costs increase. It could also indicate a return to conflict over natural resources. This could also see rapid population expansion above predicted levels due to reduced financial resources available in the country. It would also mean a continuation of low education and high illiteracy rates in Rwanda, which would also compound poverty issues and subsequently pressure on natural ecosystems. These increased levels of poverty would increase the number of the population who earn less than US$1/day. Table 4 outlines projected population increases in Rwanda in all age sectors from 1997 to 2020.

Table 4. Projected population increases in Rwanda

Age bracket	1997	2002	2007	2012	2017	2020
00-04	1177	1456	1529	1519	1694	1889
05-09	1121	1110	1384	1462	1630	1818
10-14	611	1102	1093	1365	1522	1697
15-19	474	1052	1082	1077	1201	1338
20-24	445	865	1027	1059	1181	1317
25-64	2044	2340	2951	3693	4117	4590
65+	248	238	234	245	272	305
Total	**6120**	**8163**	**9299**	**10420**	**11617**	**12954**

Source: (RoR - MFEP, 2000)

The Vision pathway

The Vision 2020 document which governs broad planning objectives for Rwanda sees a number of consistent growth areas, notably GDP and agricultural sector development. They are summarised in Table 5 below.

Table 5. 2020 Planning objectives for Rwanda

	2005	2010	2015	2020
Population (Million)	8.65	9.88	11.29	12.90
Population growth rate	2.7%	2.7%	2.7%	2.7%
Nominal GDP (Billion)	1,218.75	2,147.85	3,957.28	7,291.04
GDP Growth Rate	7%	8%	9%	9%
GDP per Capita (Rwf)	140,915.87	217,369.10	350,540.18	565,298.46
GDP per Capita (USD)	231.39	336.48	542.63	875.08
Agriculture(billion)	560.63	923.58	1,582.91	2,376.88
Agriculture (%of GDP)	46%	43%	40%	33%
Services (Billion)	439	795	1,504	3,048
Services (% of GDP)	36%	37%	38%	42%
Industry (Billion)	219	430	871	1,867
Industry (% of GDP)	18%	20%	22%	26%
Gross Domestic Investment (GDI)	321.75	614.29	1,131.78	2,085.24
Public	124.19	163.26	314.35	605.25
Private	197.56	451.02	817.44	1,479.99
Gross Domestic Investment (GDI) % of GDP)	26%	29%	29%	29%
Public	10%	8%	8%	8%
Private	16%	21%	21%	20%
Total Capital Expenditure	124.19	163.26	314.35	605.25

Source: RoR – MFER, 2000

Economically, Rwanda is expecting a sectoral shift away from the dominant agricultural economy to one that integrates more service based earnings (see Figure 6). It is hoped that such a move will also result in less pressure on the natural environment. Growth rates are

expected to increase in terms of GDP as a whole. This will be aided by growth in the service sector, improvement in the agricultural sector and growth in the industrial sector.

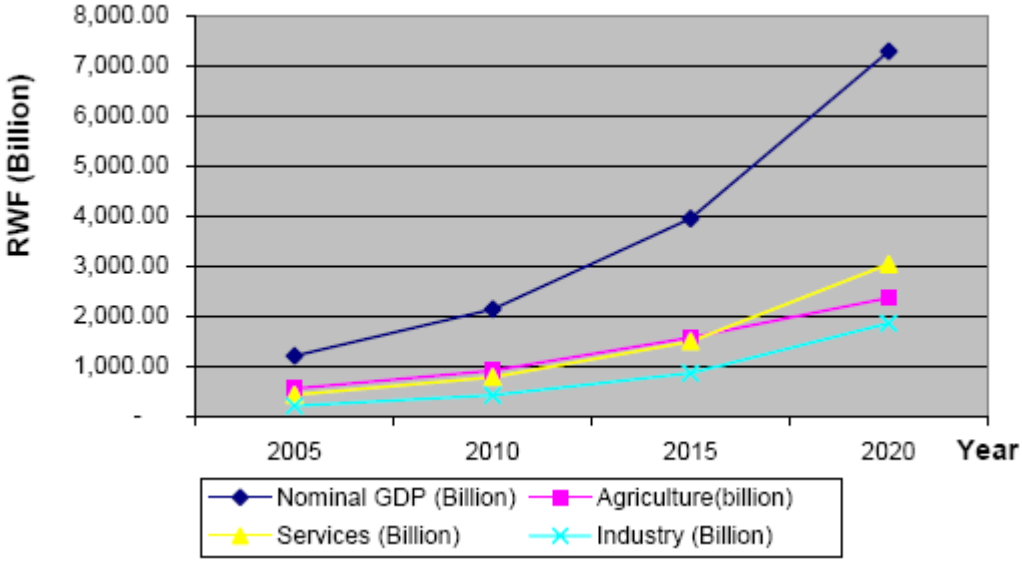

Figure 6. GDP growth for Rwanda by 2020
Source: RoR – MFER, 2000

2.2 Effects on Ecosystems and Ecosystem Services and Implications for Human Well-being and Economic Development at the Regional Level

This section analyses the effects of possible climate risks associated to future climate change on vulnerable ecosystems and ecosystems services in Rwanda. It will also look at the possible implications for human well-being and economic development.

It has been highlighted that ecosystems are vulnerable in Rwanda and some areas could be deemed as highly vulnerable and particularly climate-sensitive. This section will look at some of those areas which may be affected and the implications for human well-being, economic growth, and ecosystems resilience.

It is agreed that the climate risks outlined (see above) may have direct and indirect effects on ecosystems and ecosystem services in Rwanda. However it is acknowledged that the country is endowed with reserves that could provide enough water for both consumption and agricultural purposes.

These include substantial rainfall (between 900 and 1,800 mm per year) and the abundance of lakes, streams and watercourses. There is a plentiful supply of high altitude water in the western part of the country, which may be used in providing water by gravity to the southern and southeastern regions of the country that face water shortages.

Freshwater

The large hydrological network in Rwanda has been made vulnerable by the fact that there are inconsistency of precipitation and incidence of drought in the country.

Under a ***Business as Usual pathway***, it is clear that Rwanda would not be able to manage the water resources available to the country to provide quality clean water to its citizens. The present rate of only 52% of Rwandans having access to clean water would continue and possible be reduced (VISION 2020). Low daily consumption of water (estimated at 8.15 litres

per person presently) in rural areas would continue and put Rwanda far below the international standard of 20 litres.

Under a ***Vision pathway***, in order to achieve the goals for water, the country will have to increase the rate of access to potable water by 2.5 percentage points, annually from the current rate of 52% so that the whole of the Rwandan population will have access to drinkable water by 2020. This allows for potential increases in the management of entire catchment areas. Water management will also play an important role in Rwanda's aim of harnessing it's considerable hydroelectric potential and in understanding how to sustainably harvest the large deposits of renewable methane gas in Lake Kivu.

Ecosystems Degradation and Biodiversity Loss

Currently, Rwanda's land resources are utilized in an inefficient and unsustainable manner, which limits the profitability of land and infrastructure, whilst aggravating the national capacity to retain rainwater (Vision 2020).

Biodiversity will be affected by climate change and all species will have to adapt to changing conditions. Species composition will change in Rwanda under all climate change scenarios. This could lead to a shift in ranges. This may have consequences for the protected area network in Rwanda.

The local extinction rate may increase and put severe pressure on already vulnerable species. Keystone species may be lost. This may occur within plant and animal species.

In the ***Business as Usual pathway***, wood is the source of energy for 99 % of the population, which leads to massive deforestation and soil destruction. This would lead to further pressure on national parks and the small forestry sector in Rwanda.

Under a ***Vision pathway***, a land use plan is needed to ensure Rwanda's land optimal utilization in urban and rural development. To address this, a modern land law providing security of tenure and freedom of exchange will be instituted. Rwanda will pursue a harmonious policy of grouped settlements based on economic activity. Rural settlements organized into active development centres will be equipped with basic infrastructure and services. This system of settlement will serve as an entry point into the development of non-agricultural income generating activities.

Rwanda projects that by 2020, at least 35 % of the population will be connected to electricity (up from the current 6%) and the consumption of wood will decrease from the current 94% to 50% of national energy consumption.

Population pressure

The major problem in the field of environmental protection in Rwanda is the imbalance between the population and the natural resources (land, water, flora and fauna and non renewable resources, which have been degrading for decades).

This degradation is observed through massive deforestation, the depletion of bio-diversity, erosion and land slides, pollution of waterways and the degradation of fragile ecosystems, such as swamps and wetlands.

The average population growth of 3% per annum during the 80's to 90's period was faster than that of agricultural production, estimated at 2.2%. This has led to the occupation of more and more marginal areas and to the rapid and continuous soil degradation of the fragile ecosystems of the country. These environmental problems are exacerbated by the poor location of industries and the direct evacuation of their waste, without any treatment, into waterways and lakes. In order to ensure sustainable development, Rwanda will implement adequate land and water management techniques, coupled with a sound biodiversity policy.

Under a ***Business as Usual pathway***, there will continue to be large population growth and increased pressure on ecosystems.

Under a ***Vision pathway***, there is certainly an increase in population, however, it is hoped that that an improvement in human welfare will impact positively on ecosystem health.

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