ENVIRONMENTAL IMPACTS OF POPULATION AND CULTIVATED ECOSYSTEMS ON THE WATER RESOURCES OF THE LAKE VICTORIA BASIN: A REVIEW IN RELATION TO WATER RESOURCES PLANNING AND MANAGEMENT

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ABSTRACT
The Lake Victoria Basin spreads over 5 countries: Burundi, Kenya, Rwanda, Tanzania and Uganda. It has experienced a rapid growth in population and environmental degradation in the last 60 years. The study aimed to assess the major environmental impacts of the basin population especially as expressed in the cultivated ecosystems of the basin with respect to future contribution to the quantity and quality of water in the basin as it was part of a preliminary study leading to the formulation of a water resource management plan for the LVB. It involved mainly document review and field observations. Population estimation was based on 2012 estimated or reported district population, proportioning for the part of the district within the LVB. The basin population was estimated to be 40.4 million as of 2012, and projected to reach 88.8 by 2040 with constant growth rate; and population density was estimated to be 204 cap/km^2 in 2012 and projected to reach 449 cap/km^2 with constant growth rate by 2040. The population was found to be predominantly young, with people 14 years and younger accounting for 45% of the total. Three types of cultivated ecosystems were recognized: Mixed lowland smallholder subsistence rainfed cultivated systems, Mixed highland smallholder cultivated systems and Larger scale cultivated systems, all of which, together, covered about 13.9 million ha, or 70% of the terrestrial area of the basin. Smallholder subsistence rainfed system was found to be predominant, accounting for nearly 75% of the cultivated ecosystem. The study concluded that poverty was the defining driver of ecosystem degradation, and that reducing it requires a global integrated approach targeting poverty. It is clear that any effort to reduce ecosystems degradation may be nullified in the medium-term if it is not accompanied by a reduction in the growth of the population using agricultural land. Without this the quality of the basin's waters and livelihoods will be in jeopardy.
Keywords: Lake Victoria Basin, environmental impacts, population, cultivated ecosystems

INTRODUCTION

Lake Victoria is the second largest freshwater lake in the world. It is an international water body that offers the riparian communities many services. The Lake is shared by three countries: Kenya (6%), Uganda (42%), and Tanzania (52%). However, its catchment stretches further afield such that the Basin includes about 80% of Rwanda and 50% of Burundi, from where its principal affluent river, the Kagera River, originates (Figure 1). The Nile River, an extremely important freshwater resource for the downstream Nile Basin countries of Uganda, Sudan and Egypt, flows out of the lake at Jinja in Uganda. The terrestrial catchment of the lake, measuring approximately 197,700km^2 is 43% in Tanzania, 22% in Kenya, 17% in Uganda, 11% in Rwanda and 7% in Burundi (Table 1). Over the past six decades the basin has experienced explosive population growth (Table 2), leading to environmental changes in vegetative cover, from lush, thick tropical highland forests, savannah woodlands/shrublands/grasslands to a cultivated landscape. In addition to deforestation, the basin has come under increasing and considerable pressure from overgrazing, wetland conversion, overfishing of Lake Victoria, introduction of exotic species, unplanned, rapidly expanding urban areas, industrial pollution, eutrophication, and sedimentation. The impacts of global climate change, such as longer-than-normal dry spells, are also beginning to superimpose their impacts on the Lake Victoria Basin (LVB) environment. As the basin has experienced a rapid growth in population and expansion of cultivation in recent decades, this study focused on identifying and assessing key aspects of the LVB's population and the cultivated ecosystems that have negative environmental impacts in the basin with regard to the basin's quantity and quality of water in the long-term. It was part of a larger study on threats to the LVB ecosystems *vis-à-vis* their future contribution to the quantity and quality of water in the LVB to inform the development of a water resources management plan for the basin, a project of Lake Victoria Environmental Management Project (LVEMP II). The study reviewed literature on the LVB related to environment, population, agriculture and water resources.

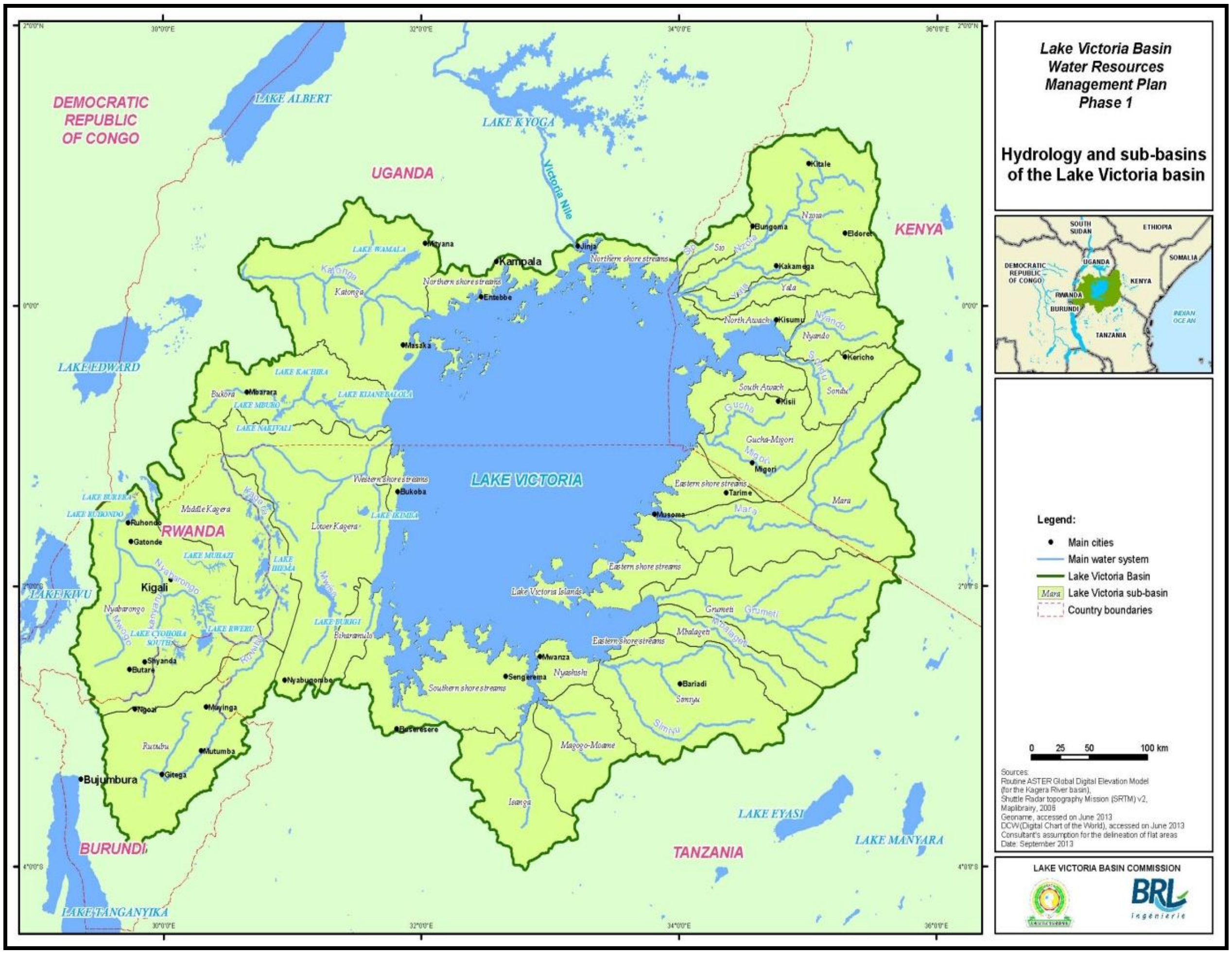


Figure 1: River sub-basins of the Lake Victoria Basin. *Source: Task C report (LVBC-c, 2014)*

Table 1: Estimated Lake Victoria surface area, LVB area and Lake Victoria Shore-line length

Country	Average Lake Victoria surface area		LVB terrestrial area		Lake shoreline length	
	km²	%	km²	%	km	%
Kenya	3,900	6%	44,500	22%	550	16%
Uganda	28,200	42%	33,500	17%	1,750	51%
Tanzania	34,700	52%	85,800	43%	1,150	33%
Burundi	-	-	13,200	7%	-	-
Rwanda	-	-	20,800	11%	-	-
Total	66,800	100%	197,700	100%	3,450	100%

Source: Task C report (LVBC-c, 2014)

Table 2: Estimated population (000') in LVB countries in 1950 and 2010

Year	Burundi	Kenya	Rwanda	Tanzania	Uganda
1950	2,456	6,077	2,072	7,650	5,158
2010	8,383	40,513	10,624	44,793	33,425

Source: World Bank estimates - http://data.worldbank.org/indicator/SP.POP.TOTL accessed 26 March 2015; Lury (1966)

METHODOLOGY

The area of study (Figure 1) is all of the Lake Victoria Basin, spread over the 5 countries of the East African Community: Burundi, Kenya, Rwanda, Tanzania and Uganda. The basin is bordered to the east by the well-defined western rim of the Great Rift Valley in Kenya and Tanzania, and to the west by the eastern rim of the Western Rift Valley, which defines the Nile River/Congo River water divide. The southern and northern boundaries of the basin are not as well defined by prominent geomorphological features. The basin is very narrow in the low-relief south-central Uganda area which also provides the only surface outlet for Lake Victoria at Jinja - the "Victoria Nile" River. The terrestrial area of the basin, excluding Lake Victoria itself, measures approximately 197,700 km2, and the lake occupies an area of approximately 66,800 km2, with a shoreline of approximately 3,450 km. The LVB lies astride the equator (Lat 01^{o}15'N to 04^{o}05'S, and Long 29^{o}20'E to 35^{o}55'E), and has 19 major river sub-basins identified here with their major rivers (LVBC-c, 2014), (Fig 1; Table 5 below).The basin encompasses a variety of climates, including cool, humid temperate tropical highland climate, moist sub-humid highlands, and the warmer tropical dry sub-humid climates in its lower altitudes to the south and southeast. The average shoreline altitude of Lake Victoria is located at 1,133masl. Average annual rainfall in LVB varies from less than 500mm in the south-eastern end of the basin to more than 2000mm on the mountains on the eastern and western rims (LVBC-c, 2014). The predominant land use is agriculture (food-crop cultivation and livestock keeping), mainly of subsistence variety.

The literature reviewed covered LVB environmental status, population, agriculture, land use/land cover changes, and their impact on water quality/quantity, and were sourced from Lake Victoria Basin Commission (LVBC) documentation center, consultants' reports, peer reviewed journal publications, SIDA/SAREC/IUCEA/VicRes reports/ studies, unpublished studies/reports, and internet. In methodology, the study involved mainly literature review, internet research and field observations in selected sub-basins in all the five countries (Nzoia, Yala, Nyando, Gucha/Migori, Mara, Grumeti, Simiyu, Katonga, and Kagera/ Nyabarongo), assessing the major environmental impacts of cultivation and population on the ecosystems of the basin. The literature was sorted according to subject (population/agriculture/environmental issues). The data collected on environmental issues was tabulated and collated according to identified ecosystems and river basins. Prior experience of the authors with some of the river basins in previous studies contributed greatly to this study. The population was estimated based on the 2012 estimated or reported district populations from each country. Where the whole district did not fall within the LVB catchment the basin population was estimated based on the proportion of the district in the basin, complemented by information received in discussions with relevant government officials regarding population distribution as well as the researchers' own knowledge of the localities. The population was then tabulated according to selected parameters (age-groups, rural/urban).

RESULTS AND DISCUSSION

Population/Agriculture

As mentioned above, the study focused on the key characteristics of the LVB population related to water resources and water management, especially with regard to their impact on future water quantity and quality of the basin. The 2012 population of the LVB was approximately 40.4 million, comprising 5.0 million in Burundi, 9.6 million in Kenya, 8.8 million in Rwanda, 9.0 million in Tanzania and 8.0 million in Uganda (Table 3). The mean estimated population density of the basin was found to be 204 cap/km², which is around 5.6 times the average of 36 cap/km² for Sub-Saharan Africa, indicating the magnitude of the pressure the basin is already experiencing (Table 3). UNEP (2006) also pointed out that the growth of population in the LVB was significantly higher than the rest of Africa and that the lake area was the most densely populated rural region in the world. According to the demographic growth rate, this gap is even getting wider every year (around 2.8% for the LVB against 2.5 % in Sub-Saharan Africa, World Bank, 2011). The total basin population was projected to reach 88.8 million by 2040 with constant population growth, with a density of 449 cap/km^{2}.

This high density is not, however, shared equally by the five countries of the LVB: it is 5 times higher in Burundian and Rwandan hills (the two countries share the highest population density in Africa) than in some lower lands especially where there are some protected areas. In fact, it is possible to distinguish two zones of high population density in the LVB, as shown in Figure 2: (i) the highlands of the upper Kagera River basin and uplands of western Kenya, preferred probably due to cooler climate, lower prevalence of water related and other diseases and better soil fertility (dark brown); (ii) the large cities on the Lake Victoria shores (Kampala, Kisumu, Mwanza, Musoma) where water availability presents a good opportunity for urban growth.

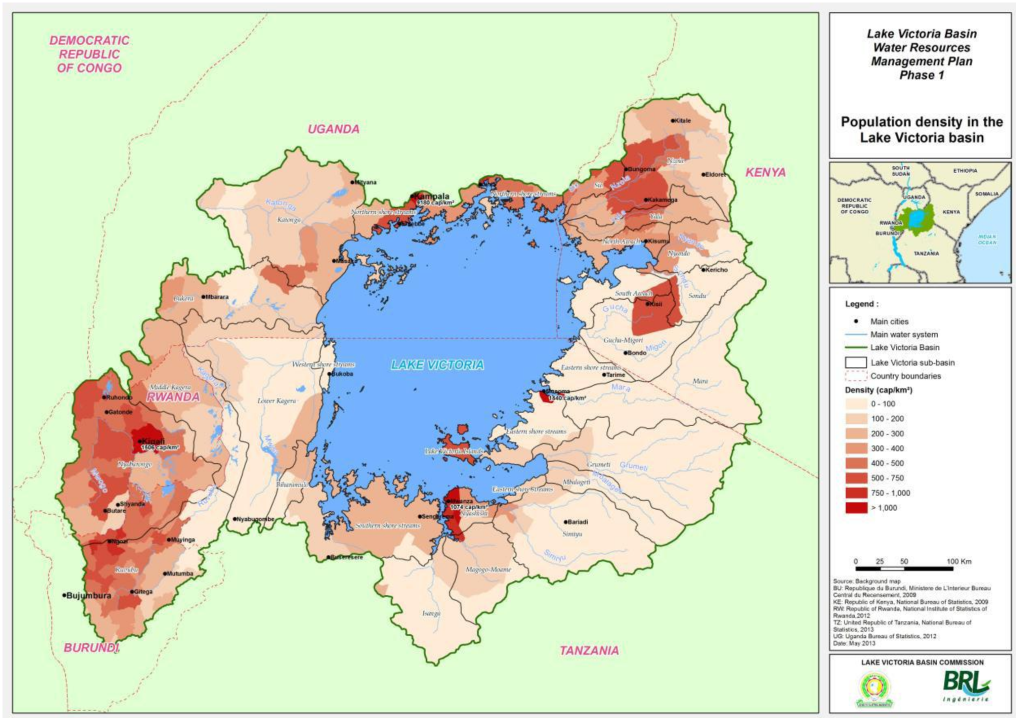


Figure 2: Population density in the LVB (ppl/km2). *Source: Task D report (LVBC-d, 2014)*

Table 3: Estimated population of the LVB. *Source: Task D report, LVBC-d, 2014*

Country	Burundi	Kenya	Rwanda	Tanzania	Uganda	LVB
2012 population in the LVB (million)	5.0	9.6	8.8	9.0	8.0	40.4
2012 population density (ppl/km^2)	379	216	421	105	239	204
2012 Population growth (%)	2.39	2.67	2.87	2.73	3.30	2.82
2020 population (million) with constant population growth	6.0	11.9	11.0	11.2	10.4	50.4
2020 population density (ppl/km^2) with constant population growth	457	267	529	130	310	255
2040 population (million) with constant population growth	9.6	20.3	19.8	19.3	19.9	88.8
2040 population density (ppl/km^2) with constant population growth	736	455	951	224	593	449

The LVB population is also predominantly young and rural, with children under 14 representing 45% of the total (LVBC-c Report, 2014). Additionally, whereas the rural-based population has decreased steadily in the recent three decades, 75 – 90% of the people are still based in rural areas (Table 4). However, in Uganda about 94% of its LVB population is urban-based. This is because Ugandan population density is highest in the southern regions of the country, as well as the fact that seven of the 15 largest towns/cities, including the capital city, Kampala, are located in the LVB and the terrestrial area of Uganda in the LVB is small (Table 1). A significant challenge to this young generation with regards to water use is that they need professional qualifications that would enable them get out of the subsistence agriculture, where land holdings cannot be fragmented any more. Furthermore, the high population growth (Table 3) coupled with the predominance of the young means that the need for supplementary infrastructure development will increase, further impacting the environment. With respect to current and future water quantity and quality of the LVB, it is significant that the agriculture is predominantly small scale subsistence farming and not mechanized (Gitau, Kasisira and Mganilwa, 2010) as discussed further below. Except for Uganda, which is much more urbanized in the LVB than in the country as a whole, the agricultural sector is currently the economic backbone of the LVB, employing most of the working population. Table 5 shows that the part of agricultural workers in the LVB countries still varies between 60% and 80% even if these figures were around 10% higher 10 years ago (NBI/NELSAP, 2008).

Lastly, the LVB countries are among the world's poorest countries, with the UNDP listing Burundi at 178, Kenya at 145, Rwanda at 167, Tanzania at 152 and Uganda at 161 out of 186 countries listed for 2012 (Table 6, UNDP, 2012). Their situation, however, is roughly the same as the average situation in Sub-Saharan Africa. The per capita GDP is very low in the LVB countries since (i) agriculture accounts for a large share in it, (ii) most of the population is employed in the agricultural sector and (iii) agriculture in the LVB countries is mainly subsistence farming with:

(a) a small mean cultivable area per employee in the agricultural sector (0.2 to 0.8 ha, Table 9),
(b) a low agricultural productivity (< 2.1 t/ha whereas it is 5.7 in China, and 7.2 in Egypt),
(c) a relatively low use of fertilizers (from 1 to 38 kg/ha/year, compared for instance to 56, 239, 432 and 448 kg/ha/year in South Africa, Chile, Korea and Egypt respectively (KIPPRA, 2009).

Table 4: Rural/urban ratios in the LVB

	Burundi	Kenya	Rwanda	Tanzania	Uganda	LVB
2006 rural population (%)	95.0%	92.2%	90.0%	87.0%	6.0%	73.8%
2006 urban population (%)	5.0%	7.8%	10.0%	13.0%	94.0%	26.2%

Source: LVBC, 2006a

Table 5: Distribution of employed persons by occupation in the LVB countries (per cent - %)

Occupation	Burundi	Kenya	Rwanda	Tanzania	Uganda
Agricultural workers (farmers, livestock keepers, Fishermen)	80.2	60.0	72.6	74.7	70.0
Service and shop sales workers	7.3	26.0	7.5	9.1	9.3
Elementary occupations and non-agriculture unskilled workers	3.2		8.3	7.6	9.6
Non-agriculture skilled workers (craft…)	5.8	14.0	7.9	5.4	6.7
Professionals, legislators and administrators	3.0		2.8	2.7	3.6
Office clerks	0.6		0.9	0.4	1.0

Source: Task D report (LVBC-d, 2014)

Table 6: LVB countries human development indicators. *Source: Task D report (LVBC-d, 2014)*

	HDI rank in 2012 (over 186 countries)	Human Development Index (HDI)	Life expectancy at birth (years)	Adult literacy rate (in % ages 15 and older)	GDP per capita (in 2013 USD)
Burundi	178	0.36	50.9	67	271
Kenya	145	0.52	57.7	87	808
Rwanda	167	0.43	55.7	71	583
Tanzania	152	0.48	58.9	73	516
Uganda	161	0.46	54.5	73	487
Sub-Saharan Africa		0.48	54.9	63	1,447
World		0.69	70.1	81	10,040

Cultivated ecosystems

Human transformation of natural ecosystems to produce food, fibre, and fuel has occurred on a massive scale in the Lake Victoria Basin. UNEP (2005, 2006http://www.unep.org/maweb) points out that the LVB, together with the Great Lakes region of East Africa, has faced one of the major cropland expansions in the world during the last 3 decades. This is buttressed by the growth in population in the five countries of the basin in the past six decades, 1950 - 2010 (Table 2). As stated above agriculture is the most important activity for the LVB population (Table 4). Lundgren (2010) observed that “more than 80% of the population in the LVB is engaged in agricultural production, the majority as small scale farmers and livestock owners producing maize, vegetables and cash crops such as sugar, rice, tea, coffee, cotton, milk and meat”. Much of this agriculture is made up of mixed small-holder subsistence systems, mostly rainfed both in the lowlands and in the highlands. However, there are other systems in select locations, including large-scale commercial mechanized systems (Figure 3).

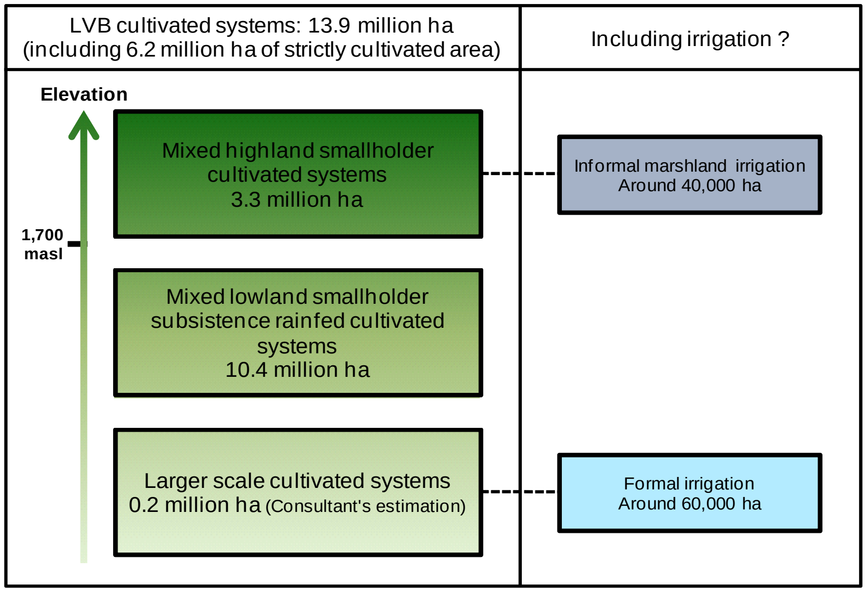


Figure 3: Main LVB agricultural systems: a traditional use of water. *Source: Task D report (LVBC-d, 2014).*

It is estimated that 6.2 million ha is cultivated in the LVB (Figure 3). However, when buildings, access roads, scattered trees and mainly pasture land are included, the GIS estimates that 13.9 million ha (138,938 km^2), or more than 70% of the LVB's terrestrial area can be considered as cultivated systems, if one considers that one hectare covered by more than 50% of crops or pasture land is part of a cultivated system (Table 7). Cultivated ecosystems are very important with respect to water resources management, as agriculture is by far the most consumptive human use of fresh water. Both the quantity and quality of water resources can be affected, as well as the timing and distribution of water flows. The impact of cultivation on freshwater quantity is much larger in irrigated than in rainfed systems. Deforestation tends to increase the amount of water available for agriculture because of reduced transpiration losses. Impoundments for irrigation can regulate downstream flows, while seasonally bare soil and field drainage systems, in very gentle slopes, can accelerate runoff and reduce infiltration, resulting in more severe local flooding and decreased dry weather flows. Distribution of cultivated ecosystems in the sub-basins is shown in Table 7.

All forms of cultivation have been reported to affect water quality, including confined livestock systems and aquaculture, but the nature and magnitude of the impact can vary substantially. Poorly managed cultivation, which is typical of subsistence systems, particularly on sloping lands, is often associated with increased soil erosion, high silt loading, and downstream sedimentation. Intense, high-input cultivation systems can result in water pollution or leaching, or runoff that carries nutrients, pesticides, or animal wastes to waterways. The negative impact of cultivation on water resources can limit options for, and increase the cost of downstream water use. It can also have additional negative effects on the supply of other ecosystem services, such as reducing aquatic biodiversity and increasing nutrient flows, and on the conditions of other ecosystems (UNEP, 2005). Broadly, three types of cultivation systems are recognizable in the LBV. They are discussed below.

Mixed Lowland Smallholder Subsistence Rainfed Cultivated Systems

These systems represent the predominant land using activity in the LVB on which rural livelihoods are based. They are spread throughout the LVB, at an elevation generally lower than 1,700 m asl (Figure 3). Mixed lowland smallholder subsistence rainfed systems are agricultural production systems characterized by small land holdings (usually less than 1 hectare), where cultivation is mostly by hand, operated by single households, with a low cropping intensity (usually the area is only cultivated during the high rainy season) and with minimal innovative farming techniques. Households usually also maintain a few livestock. These systems are rainfed and completely dependent on the rains. The dominant crops are various but pulses are exclusively secondary crops, as shown on the Figure 4. They contribute to high sediment production during the early part of the growing season when the land is bare but encourage significant infiltration in mid-season when crops are growing and there is good crown cover. After harvesting, surface flow increases and sediment yield rises again because vegetation cover is reduced, and also because livestock graze freely on the harvested fields and loosen the soil. UNEP (2006) estimated that 150,000km2 of the LVB was affected by soil degradation of which 13% was severely degraded.

The systems are dominated by cultivation of annual food crops and are essentially part of the desertification process as they often represent a degradation of the natural savannah ecosystems. There is little crop rotation, the soil becomes agriculturally exhausted, weeds increase, yields go down, and generally the soils degrade. Rapid rise in population and land subdivision are of course exacerbating this phenomenon.

Mixed Highland Smallholder Cultivated Systems

They are similar to the lowland systems described above, except that: (i) they are generally located at higher altitudes (more than 1,700 m asl), (ii) the land holdings are usually a little larger, often ranging between 2 and 10 ha, (iii) there is a mix of hand cultivation and use of mechanized implements, (iv) they are semi-commercial, with cash crops prevalent in addition to food crops and (v) the cropping intensity is higher and can reach 2 cultivated seasons per year. In fact, these two categories of mixed smallholder cultivated systems are not clearly separated and there is a continuity of various systems, including highland very small farms or lowland semi-commercial ones (Plate 1, Table 7). They are separated here to show that there is a variety among the smallholder cultivated systems in the LVB.

Table 7: Distribution of LVB cultivated ecosystems per sub-basins
Source: Modified from Task B report (LVBC-b, 2014)

Region (in km²)	Cultivated (>50%) ecosystems	
	Lowland	Highland
Western shore streams	308	-
Biharamulo	704	
Southern shore streams	6,854	-
Isanga	4,984	-
Magogo-Moame	5,133	-
Nyashishi	1,585	-
Simiyu	8,313	-
Eastern shore streams	5,636	47
Mbalageti	607	-
Grumeti	1,874	1,344
Mara	3,146	4,638
Gucha-Migori	4,070	2,511
South Awach	2,327	156
Sondu	337	2,307
Nyando	1,510	1,180
North Awach	1,569	118
Yala	1,354	778
Nzoia	4,107	6,549
Sio	1,353	-
Northern shore streams	2,472	-
Katonga	11,031	-
Bukora	4,682	855
Lower Kagera	10,193	293
Middle Kagera	5,474	1,387
Nyabarongo	8,622	6,446
Ruvubu	6,922	4,521
Lake Victoria Islands	640	-
LVB	105,809 53.50%	33,129 16.80%

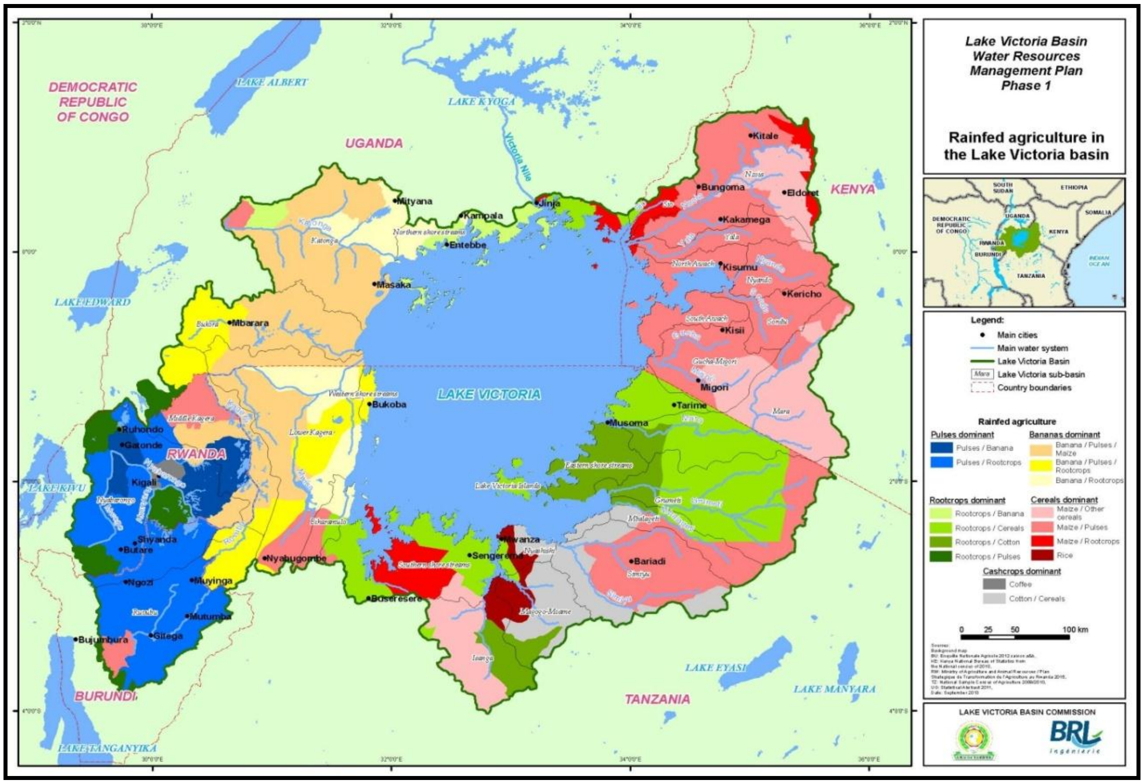


Figure 4: Rainfed agriculture in the LVB, classified by dominant crop. *Source: Task B report, LVBC-b, 2014.*

Plate 1: Mixed highland smallholder cultivated systems in the Middle Kagera sub-basin (Mukungwa River sub-basin). *Source: Task B report, LVBC-b, 2014.*

The mixed highland smallholder systems are mostly located in the mid sections of the highlands of the Middle Kagera, Nyabarongo and Ruvubu sub-basins and the Kenyan highlands (middle/upper catchments of Mara, Gucha/ Migori, Sondu, Nyando, Yala and Nzoia sub-basins, Table 7). They are located on higher rainfall/elevation zones and there is often better soil conservation measures practiced. Cash crops (often coffee and tea) provide crown cover throughout the year and, with the soil conservation measures, reduce soil erosion and river sediment loads. Therefore, their ecological quality is generally stable, but rural population pressure is continuing to force land subdivision, leading to “more subsistence” agriculture. However, a large part of these cash crops is not cultivated by smallholders but in larger-scale systems. Within these mixed highland smallholder systems, some informal irrigation systems can be found, implemented by farmers in order to cope with drought risks in the dry season: the marshland irrigation is a particular type of irrigation encountered in the Middle Kagera, Nyabarongo and Ruvubu sub-basins where farmers do handmade infrastructures in the wetlands to drain water or irrigate depending on the season. Usually, cropping is not possible on these sites during the rainy season because of flooding. Cultivation is done only during the dry season with remaining water of the plains augmented perhaps with some sub-surface flow. The area under marshland irrigation is about 40,000 ha in the LVB currently, around 0.9% of the total LVB cultivated area, almost exclusively in the three sub-basins.

Larger Scale Cultivated Systems

These are large to very large farming systems with large land holdings, generally highly mechanized, where cash (or industrial) crops are the main target. They are characterized by large household land holdings (in hundreds to thousands of hectares) and are often government owned or company-owned farming estates typically in the thousands of hectares. The crops are coffee, tea, cotton, flowers, cereals or sugarcane, sometimes including horticultural crops. Because they are large-scale systems, the risk management is different from the subsistence agriculture and improved techniques are used.

There is a higher use of fertilizers, pesticides and herbicides in these farming systems and therefore there are nutrient and pesticide residues finding their way into the rivers of LVB and ultimately Lake Victoria. Also, many of the large operations have processing factories (coffee, tea, sugar, rice) which release contaminated effluents into the rivers.

Supplementary formal irrigation is sometimes used in these systems to reduce the drought risk and therefore the water abstractions can become significant. Formal irrigation means that the control of water is possible in the schemes, with proper irrigation and/or drainage infrastructures. The source of water is diverse (pumping, gravity from a lake or a river, dam, water harvesting). Usually, double cropping is possible in these schemes. Also these irrigation systems are usually concentrated on the lower part of the LVB (rice, other cereals, sugarcane, and flowers in greenhouses) but are also present at altitudes above 2,000masl, for example in the hills irrigation systems in tea or coffee plantations in the Middle Kagera, Nyabarongo and Ruvubu sub-basins. The area currently under formal irrigation is estimated to be less than 60 ha (around 1.3% of the total LVB cultivated area). More than 80% of the formal irrigation is located in Kenya and Tanzania (LVBC-d, 2014). Table 7 shows how the lowland and highland cultivated systems are distributed in the LVB sub-basins.

Pressure on Water Resources Is Unsustainable

All the factors discussed above combined (young, high-density, fast-growing, rural and poor population) point to an unsustainable pressure on the ecosystems, resulting in deforestation, wetland degradation and soil erosion (Table 8). These degraded ecosystems will not be able to play their role of water filtration and regulation any more. Their degradation also leads to poor water and soil productivity which ultimately leads to new degradation of neighbouring ecosystems and perpetuates the poverty cycle as illustrated in Figure 5. For instance, poor land management and unsustainable land uses (Makalle, Obando and Bamutaze, 2008) have been reported as the key contributing factors to the poverty of farmers in LVB, while the rapid population growth has been associated with the massive land degradation, and declining human health and water quality (Onywere, Getenga, Mwakalila, Twesigye, Nakiranda, Kirui, and Letema, (2005), (Lundgren, 2010).

High population growth has caused increased pressure on land and some small scale farmers have resorted to cultivating in areas with steep slopes, riverbanks, forests, and wetlands. Overgrazing has also contributed significantly to soil erosion in the LVB. A synthesis of cultivated ecosystems showing what and where they are, their current quality and relationship with water resources, and key threats to their sustainability is summarised in Table 8.

Table 8: Synthesis of LVB cultivated ecosystems conditions and key threats. *Source: Modified from Task B report (LVBC-b, 2014)*

Ecosystem	What they are	Where they are	Relationship with water resources	Their quality today	Key threats to the Ecosystem
Mixed lowland smallholder subsistence rainfed cultivated systems	Agricultural production systems characterized by small land holdings (< 1 ha), hand cultivated, operated by single households, low cropping intensity (usually cultivated during the high rainy season), minimal innovative farming techniques, dominated by annual food crops. Households also maintain few livestock.	Spread throughout the LVB, at elevation generally lower than 2,000 m asl. Represent the predominant land using activity in the LVB on which rural livelihoods are based.	Contribute to high sediment production during beginning of the growing season when the land is bare; encourage significant infiltration in mid-season when crops are growing and there is good crown cover. After harvesting, surface flow increases and sediment yield rises again because vegetation cover is reduced, and also because livestock graze freely on the harvested fields and loosen the soil	The systems are part of the desertification process, represent a degradation of the natural savannah ecosystems. Little crop rotation, soil becomes agriculturally exhausted, weeds increase, yields go down, and the soils degrade.	Rapid rise in population exacerbates degradation: over-grazing, reduction of vegetation cover, nutrient depletion, high soil erosion and high sediment loads in rivers. Conversion of wetlands in valleys to agriculture due to high demand in Middle Kagera, Nyabarongo, and Ruvubu sub- basins. Increasing land subdivi-sion, intensified cultivation with little conservation measures in all countries of the basin.
Mixed highland smallholder subsistence rainfed cultivated systems	Similar to the lowland systems described above, except: (i) they are located at higher altitudes (>2,000 m asl), (ii) land holdings usually a little larger (2-10ha), (iii) there is a mix of hand cultivation and use of mechanized implements, (iv) are semi-commercial, with cash crops prevalent in addition to food crops and (v) cropping intensity higher- can reach 2 cultivated seasons per year	Located in the mid sections of the highlands of the Middle Kagera, Nyabarongo, Ruvubu, Mara, Gucha/Migori, Sondu, Nyando, Yala and Nzoia sub-basins.	They are located on higher rainfall/elevation zones and there is often better soil conservation measures incorporated. Cash crops (often coffee and tea) provide year-round crown cover and, with soil conservation measures, reduce soil erosion and river sediment loads.	They are located on higher rainfall/elevation zones and there is often better soil conservation measures incorporated. Their ecological quality is generally stable	Rural population pressure is continuing to force land subdivision, leading to more “subsistence” agriculture
Large scale cultivated systems	Large to very large farming systems, highly mechanized, cash (or industrial) crops main target. Characterized by large household land holdings (in hundreds to thousands of ha) and company-owned or government owned farming estates typically in the thousands of hectares. The crops are coffee, tea, cotton, flowers, sugarcane or cereals and horticulture.	Both in the highlands and lowlands of LVB: In Middle Kagera, Nyabarongo, Ruvubu, Mara, Gucha/Migori, Sondu, Nyando, Yala and Nzoia sub-basins	Supplementary formal irrigation is sometimes used, which means that the control of water is possible in the schemes, with proper irrigation and/or drainage infrastructures. The source of water is diverse (pumping, gravity from a lake or a river, dam, and water harvesting) thus the system consumes large amounts of water.	There is better soil conservation measures incorporated. Therefore, their ecological quality is generally stable	There is a high use of fertilizers, pesticides and herbicides so nutrient and pesticide residues find their way into the rivers of LVB and ultimately Lake Victoria. Many large farming operations have processing factories (coffee, tea, sugar, rice) and these release effluents contaminating the rivers and Lake Victoria

DISCUSSION

Population

UNEP (2006) pointed out that the LVB area was the most densely populated rural region in the world and that the growth of population in the area was significantly higher than the rest of Africa. The 2012 population was approximately 40.4 million, and the mean estimated population density was found to be 5.6 times the 36 cap/km² average for Sub-Saharan Africa, indicating the magnitude of the pressure the basin is experiencing. With constant population growth the total basin population was projected to reach 88.8 million by 2040, with a density of 449 cap/km^2. The population density is 5 times higher in Burundian and Rwandan highlands and the large cities on the Lake Victoria shores than in some lower lands especially where there are protected areas. The population is also predominantly young, with children under 14 representing 45% of the total (LVBC-c Report, 2014), and 75 – 90% of the people are based in rural areas except in Uganda. A significant challenge to this young generation with regards to water use is that they need professional qualifications that would enable them get out of the subsistence agriculture, where land holdings cannot be fragmented any further. The high population growth coupled with the predominance of the young means that the needs for supplementary infrastructure development will increase, further impacting the environment. This young generation will have to carry on the future development of the LVB.

Agriculture/Cultivation

About 13.9 million ha, or more than 70% of the terrestrial area of the basin (Figure 3) is under subsistence farming (Gitau *et al*, 2010). The farmers do not have adequate economic means to implement soil and land conservation measures or improve yields through modern farming techniques. This is significant in respect to future water quantity and quality of the LVB. Poor households/families can only use hand or animal-drawn tools to cultivate, cannot afford fertilizers, and depend solely on rainfall. As a result, productivity (yield) is low (Table 9) and there is perpetual food insecurity. Subsistence farmers also keep livestock as a sustenance strategy, which also means that a large proportion of the LVB is exposed to accelerated erosion.

Table 9: Some characteristics of the agricultural sector in the LVB countries

Country	Agriculture value added in 2012 (in % of GDP)	Employment in agriculture in 2006 (in % of total employment)	Arable land per employee in the agricultural sector (in ha/cap)	Quantity of fertilizers used (in kg/ha/year)	Cereal yield (in t/ha)
Burundi	35.2	92.2	0.2	3.4	1.3
Kenya	28.5	61.1	0.6	38.0	1.5
Rwanda	31.9	78.8	0.3	1.1	2.0
Tanzania	27.7	76.5	0.7	10.0	1.4
Uganda	23.4	65.6	0.8	1.1	2.1

Source: Task D report (LVBC-d, 2014)

Even in Uganda, which is much more urbanized in the LVB than in the country as a whole, the agricultural sector is currently the economic backbone of the LVB, employing most of the working population. Table 6 shows that the portion of agricultural workers in the LVB countries still varies between 60% and more than 90% even if these figures were around 10% higher 10 years ago (NBI/NELSAP, 2008). The LVB countries are among the world's poorest, with the UNDP listing Burundi at 178, Kenya at 145, Rwanda at 167, Tanzania at 152 and Uganda at 161 out of 186 countries listed for 2012 (UNDP, 2012), a situation roughly the same as the average in Sub-Saharan Africa. The per capita GDP is very low since (i) agriculture accounts for a large share in it, (ii) most of the population is employed in the agricultural sector and (iii) agriculture is mainly non-mechanized (Gitau, 2010) subsistence farming with: a small mean cultivable area per employee in the sector (0.2 to 0.8 ha, Table 6); a low agricultural productivity (less than 2.1 t/ha (Table 6); and low use of fertilizers (1 to 38 kg/ha/year, compared for instance to 56, 239, 432 and 448 kg/ha/year in South Africa, Chile, Korea and Egypt respectively (KIPPRA, 2009)). Opere and Ogallo (2004) identified high levels of poverty as an important factor in environmental degradation and advocated wealth creation and poverty alleviation as issues that must be given prominence in efforts to tackle environmental degradation in LVB. This means that there is not even enough food to satisfy the basic nutritional needs of most of the households, so that in most of the cases, no monetary surplus from off-farm sales are possible. This is the cause of and the reason why the investments in fertilizers, improved seeds, pesticides, irrigation or soil conservation practices are low.

In summary, the predominantly young, poor, rural-based LVB population dependent on subsistence agriculture and not educated in modern farming methods is unlikely to improve farm input, soil conservation, or farm yield and income in the near future. Nevertheless, this young generation has to carry on the future development of the LVB, but they are particularly challenged by illiteracy, lack of professional qualifications and fragmentation of agricultural land, which is approaching its limits (EAC, 2016), Berg *et al* (2015), Adams (2006), Page (2013). A major challenge for them therefore will be to get professional qualification outside of agriculture, if they are to reverse the downward trajectory of environmental quality of the LVB.

Table 10: Major river sub-basins of Lake Victoria, their population density (cap/km^2), and major environmental issues/threats. *Source: Modified from Task B report (LVBC-b, 2014)*

River sub-basin	Country(ies)	Catchment area (km^2)	Population density (2012)	Projected pop density (2040)	Major environmental issues/threats
Biharamulo	Tanzania	1,990	123	294	Increased erosion
Isanga	"	7,080	78	153	Increased erosion
Magogo/Moame	"	5,400	129	283	Increased erosion
Nyashishi	"	1,690	537	1,228	Increased erosion
Simiyu	"	11,100	82	142	Wetland conversion, agricultural chemicals
Mbalageti	"	3,540	72	123	Increased erosion
Grumeti	Tanzania/Kenya	12,810	34	66	Increased erosion
Mara	Tanzania/Kenya	13,420	47	97	Deforestation, increased erosion, increased mine tailings
Gucha/Migori	Kenya	6,730	205	432	Agricultural chemicals
South Awach	"	2,180	182	383	Increased erosion
Sondu	"	3,530	165	348	Increased erosion
Nyando	"	3,790	185	390	Industrial pollution, agricultural chemicals, increased erosion
North Awach	"	2,180	280	591	Increased erosion
Yala	"	3,150	289	600	Wetland conversion, chemicals, increased erosion
Nzoia	"	12,785	313	661	Industrial pollution, agricultural chemicals, increased erosion
Sio	Kenya/Uganda	1,440	439	945	Increased Erosion
Katonga	Uganda	15,060	163	404	Increased Erosion
Bukora	"	8,330	200	497	Erosion
Lower Kagera	Tanzania/Uganda	16,930	109	266	Increased Erosion
Middle Kagera	Rwanda/Tanzania /Uganda	10,330	227	703	Wetland conversion, increased erosion, sedimentation
Nyabarongo	Burundi/Rwanda/ Tanzania/Uganda	18,340	474	972	Wetland conversion, erosion, sedimentation, pollution
Ruvubu	Burundi/Tanzania	12,210	302	561	Increased erosion, sedimentation
Western shore streams	Tanzania/Uganda	640	92	222	Agricultural chemicals
Southern shore streams	Tanzania	8,980	173	371	Increased erosion
Eastern shore streams	Kenya/Tanzania	6,680	123	242	Increased erosion
Northern shore streams	Uganda	4,260	589	1461	Increased industrial pollution, wetlands conversion
Lake Victoria Islands	Kenya/Uganda/Tanzania	2,460	288	449	Deforestation

Environmental Issues

Odada et al., (2004) identified unsustainable exploitation of fisheries and pollution as pressing environmental problems in the LVB. This study shows that the environmental issues are more extensive, as listed in Table 10 according to the river sub-basins. It is notable that increased erosion is a serious problem in all the sub-basins occasioned by deforestation and increased cultivation and accompanied by progressive loss of soil fertility and in some cases wetland conversion, sedimentation, industrial and agricultural chemicals pollution. Cultivation and erosion are likely to intensify with projected increase in population densities.

Yi-Hua Wu (2011, p. 31) used satellite imagery to study changes in forest cover in Mau forest between 1970 and 2009 and observed that the expansion of cultivation, and population growth were the major reasons for deforestation. Mathayo et al., (2006) estimated the suspended sediment load into Lake Victoria from the Tanzanian catchment (excluding Kagera River) to be 4,905.2kT/year, with Simiyu River carrying the largest proportion estimated at about 42.3% of the total "Tanzanian" load to the Lake (Plate 2), and Myanza, et al., (2006) estimated the suspended sediment load of the Kagera River to be 1,400kT/year (LVBC-b, 2014). In the Kenyan catchment, Okungu and Opango (2006) reported that ten rivers contributed 4,390.6kT/yr of total suspended solids, with river Nzoia contributing the highest at 2,504.4kT/year to the lake. River Nzoia has also been shown to carry substantial amounts of pesticides (*Organo-chlorines* and *Pyrethroids*) into the lake (Tarus et al., 2011) and persistent organic pollutants - *aldrin, dieldrin, endosulfan, DDT, and endrin* (Twesigye et al., 2011). Other Kenyan rivers (Gucha/Migori, Sondu, and Yala) were also found to carry substantial suspended sediments into the lake. It appears to be a one-way road towards desertification in many of these areas and an ongoing reduction of ecosystem services and functions in the LVB. Critical areas of these environmental threats are in the cultivated steep slopes of upper Mara sub-basin, Middle Kagera, Nyabarongo and Ruvubu sub-basins.

The highland degradation in the LVB, which is part of the vicious circle of poverty and ecosystems degradation as a whole (Figure 5), probably deserves particular emphasis because of its significance in the future stability of water resources availability in the LVB. This highland degradation is the consequence of vegetation cover clearing (mainly through deforestation and conversion to agricultural use, Plates 1 and 3) and its replacement by another vegetation cover (mainly cultivated area) that is not as efficient in water conservation.

Plate 2: Gully erosion in Malekano village Simiyu river catchment. *Source: GoT, 2012*

The most prominent highlands ring the LVB in the upstream Kagera River basin in Burundi and Rwanda and in Kenya (Figure 1). These highlands are generally high rainfall areas and because of this they have denser vegetation cover and deeper, richer soils. The rainfall in the highlands is also more reliable than in lower areas of the LVB. They are therefore ideal locations for rainfed agriculture and have thus attracted human settlement over time (Plate 1). The restraining factor to human settlement has been rugged and difficult terrain, and sometimes colder temperatures. However, this restraint has in the past four decades been "overcome", due mostly to demographic pressure, so that subsistence agriculture, generally without any soil conservation measure, has replaced highland vegetation in much of this landscape (Plate 3). The degradation effects of subsistence agriculture have been intensified by high demand for wood fuel and other wood products which have increased the rate of deforestation. Tolo et al., (2012) concluded that the changes were due to human factors and showed unsustainable utilization of natural resources as most of the changes made the land susceptible to degradation.

Efforts have been made at reforestation, but deforestation has hardly abated. Twagiramungu (2006) observed that "tree planting in Rwanda was limited to some plants around households such as *Ficus thoningii*, *Euphorbia tirucalli*…, but the cultivation of woody perennials for timber, energy generation or other services was not part of the people's customs. That resulted in a massive exploitation that quickly proved its limits". He pointed out that some of the species introduced in the forest plantations later proved to have allelopathic tendencies (reduction and even termination of undergrowth), which encouraged erosion.

In some places (such as the Kenyan highlands), an important driver for highlands degradation has been inappropriate policies implemented by the governments. These have encouraged de-gazettement of the forest and the conversion of forestland into settlements (GoK, 2013). This occurred through forest excisions, settlements and encroachments. Although some of the excised lands were turned into large commercial plantations incorporating soil conservation measures, the major part of the converted forestland was under subsistence agriculture and therefore subjected to continuing massive erosion.

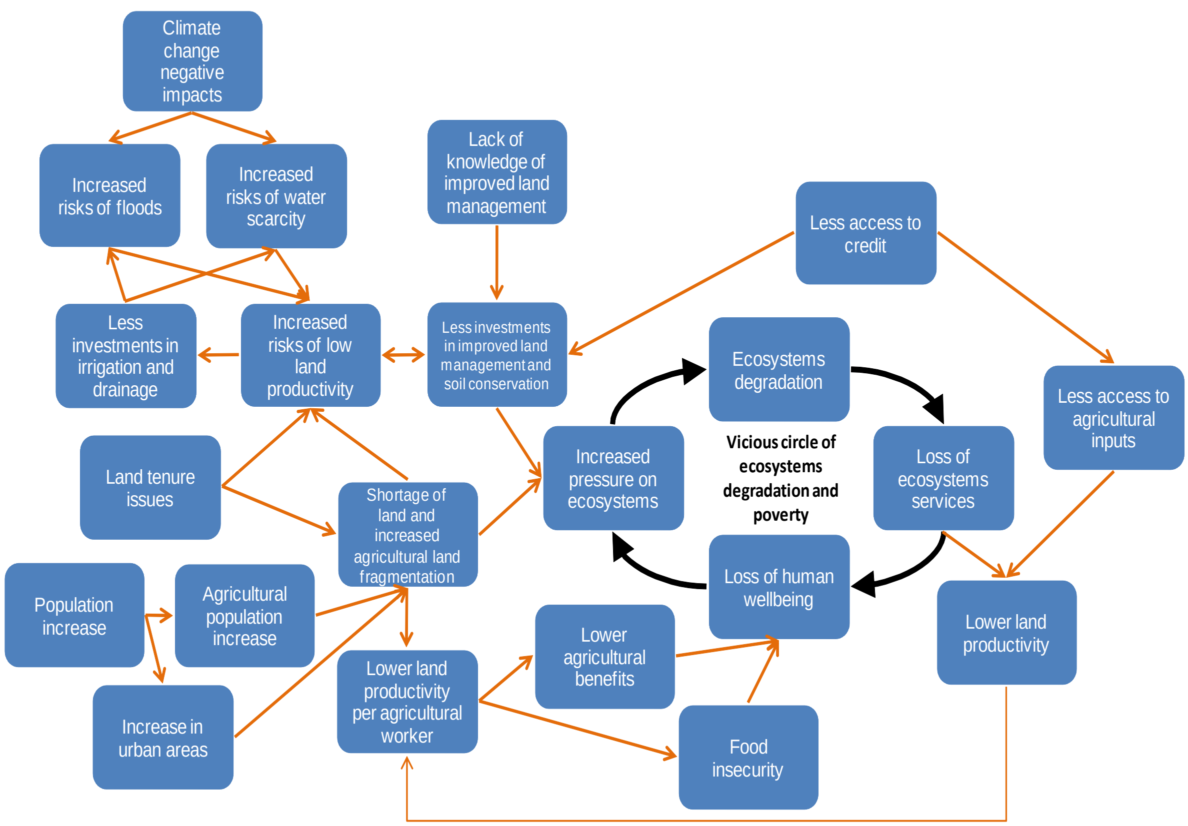
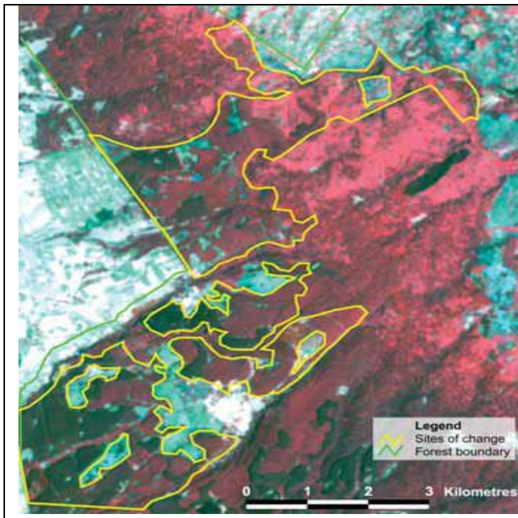
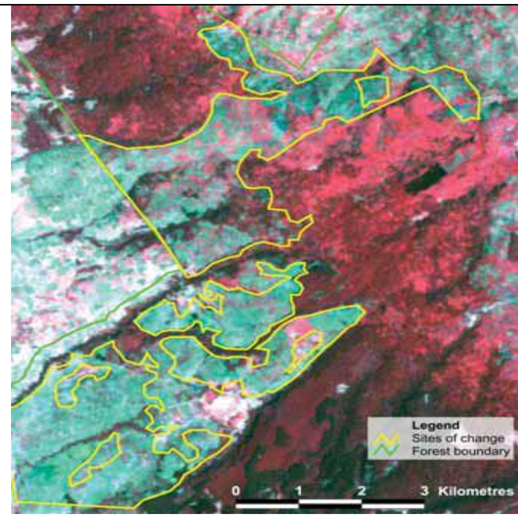


Figure 5: The various cycles of ecosystems degradation and poverty and it possible details. *Source: this study*



Situation in Year 2000; areas within the yellow outlined polygons are forested



Situation in Year 2003; areas within the yellow outlined polygons have been cleared and cultivated

Plate 3*: Deforestation in Kuresoi, South-West Mau, Kenya between 2000 and 2003.* *Source: Akotsi and Gachanja 2004*

CONCLUSION

The most affected catchments are the Middle Kagera, Nyabarongo and Ruvubu sub-basins in Burundi/ Rwanda, and the Mau Complex in Kenya, which is the origin of all but one of the Kenyan rivers in LVB. Figure 5 above shows that in order to reverse degradation of LVB ecosystems it is not sufficient to focus on activities directly targeting some of its causes without targeting the other key poverty causes. As the high population density is a key issue in the LVB, it is clear that any effort in reducing ecosystems degradation may be nullified in the medium-term if it is not accompanied by a reduction in the growth of the population using agricultural land. This will have to be achieved by a global reduction in population growth rate and/or by diversifying/providing alternative sources of livelihoods (mainly off-farm activities) to the population. Currently, a lack of control over resources, population growth, a lack of alternative avenues of livelihood, and inequity are contributing to the degradation of the region's resources.

The subsistence farming practices are closely entwined with the general rural poverty in the LVB and, in turn, environmental degradation perpetuates poverty, as the poorest attempt to survive on a diminishing resource base. This human-made “cultivated” ecosystem spreading throughout all the LVB, is an important hotspot almost in its entirety: because of the subsistence farming that does not incorporate any soil conservation/ sustainable land management practices, this ecosystem is likely to degrade rapidly in the future, especially given the rate of rural population growth and concomitant land subdivision. Olang’ and Kundu (2011, p. 260) concluded that “The negative environmental impacts on the MFC-Mau Forest Complex-have reached crisis level. It is imperative that the restoration and rehabilitation efforts are fortified by integrating with potential socio-economic activities that can support the survival of the riparian rural communities”.

Water conservation activities, i.e. any kind of activities that will improve the water resources quantity and quality in the LVB, are not sufficient. Land degradation, soil degradation and water degradation are interlinked processes but are also part of a more global vicious circle of poverty and ecosystems degradation in the LVB (see Figure 5). Unsustainable agricultural methods in the LVB are the most important human threat to the water resources quantity as they will reduce the natural water regulation and the filtration capacity of soil (notably through deforestation, which is spreading at an alarming rate (LVBC-b, 2014). They are also the main human threats to the water resources quality as they may cause pollution and sedimentation.

RECOMMENDATIONS

The following actions will be required if the environmental quality of the LVB is to be sustained:

The population growth rate must be reduced: As shown above, the mean LVB population density is 204 cap/km² and the mean annual growth rate is around 2.8. In 2040, there will be between 300 and 450 cap/km² depending on the growth rate changes. The pressure on the land will be higher than today and thus no reduction in the population growth rate would definitely lead to a land use crisis.

The share of the population working in the agricultural sector must be reduced: Through the reinforcement of the secondary and tertiary sectors at national and regional levels and diversification of economic opportunities (increased tourism, mining, manufacturing and others), the pressure on agricultural land could decrease. Land pressure within the agricultural sector must be reduced: This requires diversification of rural employment with additional occupations as full-time activities, such as bee keeping, agroforestry, fish farming, silk production, gathering and processing of medicinal plants, weaving, carving and pottery. In addition, there are possibilities for developing small-scale agro-industries to process/partly process, whatever is produced locally.

Implementing improved land management and land tenure regulations that encourage land consolidation to reduce land sub-division: This has been tried in the Rwandan highlands and has shown a measurable level of success with increased land consolidation, crop optimization and intensification and enhanced agricultural productivity (REMA, 2011, Kathiresan, 2012).

Restore and rehabilitate forests: It is imperative that the restoration and rehabilitation efforts of forest eco-systems are fortified through integration with potential socio-economic activities that can support the survival of the riparian rural communities. It is important that intervention efforts to reverse degradation situation consider local community perception and be of multiple nature to address technical, administrative and policy issues as recommended by Tenge, Mvuma, Baker, Mongi, Mwakijele, and Gabriel (2015).

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