Assessment of the Irrigation Potential in Burundi, Eastern DRC, Kenya, Rwanda, Southern Sudan, Tanzania and Uganda

Final Report
Appendix Burundi

July 2012

Client
Nile Basin Initiative
NELSAP Regional Agricultural Trade and Productivity Project

Report FutureWater: 114

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PREFACE

The Nile Basin Initiative (NBI), under the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) and the project Regional Agricultural Trade and Productivity Project (RATP) announced a Request for Proposals (RFP) entitled “Assessment of the Irrigation Potential in Burundi, Eastern DRC, Kenya, Rwanda, Southern Sudan, Tanzania and Uganda” in July 2010 (RATP/CONSULTANCY/04/2010). The study was categorized as “preparation for a development program” and has therefore a strategic perspective.

FutureWater, in association with WaterWatch, submitted a proposal in response to this RFP. Based on an independent Technical and Financial evaluation FutureWater, in association with WaterWatch, has been selected to undertake the study.

The consulting services contract was signed between the “Nile Basin Initiative / The Regional Agricultural Trade and Productivity Project” and “FutureWater in association with WaterWatch” entitled “Consulting Services for Assessment of the Irrigation Potential in Burundi, Eastern DRC, Kenya, Rwanda, Southern Sudan, Tanzania and Uganda”. This contract was dated 5-Feb-2011 and total project duration is 16 months. The Contract Reference Number is: NELSAP CU/RATP2/2011/01

Tangible outputs of this study area:

- Inception report
- Phase 1 report
- Seven country reports phase 2
- Final report

The Consultants wish to acknowledge the support, fruitful discussions and useful comments from all NBI-RATP staff and stakeholders in the countries. In particular Dr. Innocent Ntabana and Dr. Gabriel Ndikumana are acknowledged for starting this initiative and their support and advice on the study.

Various people and institutions have contributed to this specific country/focal area report: Emmanuel Ndorimana (NLO),Christophe Majambere (Field assessor), amongst others. Their contribution is highly appreciated.

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1 Introduction[1]

1.1 Background

Burundi (Figure 1) is situated in the Great Lakes region, Central Africa. Burundi has a total area of 27,834 km^2, of which 25,200 km^2 consists of land, and 2,634 km^2 is covered with lakes (Niyongabo, 2007). A detailed map of the country is presented in Figure 1. The natural and planted forests are of major importance in maintaining the ecological and hydrological balances, covering an area of almost 2,000 km^2. This area, however, tends to decrease as a result of population growth. The mountainous terrain of Burundi gives it a tropical altitude climate, which is hot and humid on low altitudes, and temperate and wet on the mountains. The country's river system is divided into two major watersheds: the Nile and the Congo basins.

Statistical projections, based on the census of people in 1979 and 1990, indicate a current population estimated around eight million. The average population density would be 317 inhabitants per km^2. In densely populated areas, like e.g. Buyenzi, Kirimiro, and Mimirwa, this would peak to 400-500 inhabitants per km^2.

Figure 1: Map of Burundi (source: CIA Factbook).

1.1.1 Socio-economy

In Burundi the majority (more than 90%) of the population depends on extensive agriculture. In 2003, agriculture was providing 95% of the total food supply, and contributed to 49% of the Gross Domestic Product (GDP) (95 USD per person per year), and 90% of foreign exchange earnings (FAO, 2005). According to socio-economic indicators, Burundi belongs to the five poorest countries in the world.

[1] Information in this chapter is among other sources based on: FAOSTAT, CIA world fact book, UNDP and phase 1 report.

The assessment of the irrigation potential project comes at the right time. This will certainly improve the living circumstances of the local population by increasing the agricultural productivity.

1.1.2 Millennium Development Goals, current status

Burundi is working on the Millennium development goals (MDG) with the Poverty reduction strategy paper (PRSP) as a major reference, which highlights the steps to be taken. Besides the PRSP, the vision Burundi 2025 is used as reference, and to create a political environment in which the MDGs can be achieved.

The instable political situation in Burundi at the end of the 20th century and the first years of this century has not contributed to a continuous development of the MDGs. Despite of the improvements made in education and health, Burundi is lacking behind on most targets. The lack of reliable statistical data on Burundi is a serious handicap for a correct assessment.

A quick overview will be given about the current status of the MDGs.

Goal 1: Eradicate Extreme Poverty and Hunger
In 1990 the poverty rate in Burundi was 35%. The poverty line is set on 820 FBU/day in the urban areas and 525 FBU/day (+/- $0.40) in the rural areas. Based on these thresholds, and 2008 numbers, 67% of the population is living beneath the poverty line. This means a poverty increase of 32% over those years. The persistence armed conflicts and civil war, together with a drop in production and public aid, have contributed to this increase.
Food insecurity is a chronic problem in Burundi, with 35.2% of underweighted children under 5 years. Figures from 2007 show that 44.2% of the population is not food balanced. Only 17.1% have a diet which is addressed as acceptable.

Goal 2: Achieve universal primary education
Good progress has been made. For the school year 2008-2009 the enrollment rate was 89.7%. There is a significant increase compared to the 1990 level of 52.8%. The Gross enrolment rate reached to 130% in 2009, as also older children could enroll for the free education from 2005 onwards. For the same year the rate of completion reached 46%. Literacy in the age of 15-24 increased from 53% in 1990 to 78% in 2007. There is a possibility that this MDG will be achieved, as there are high level political commitments taken over the last years by the government.

Goal 3: Promote gender equality and empower women
For public primary education the rate girls/boys in 2009 was almost equal at 97%. For secondary education the ratio is 72%, and for higher education the rate was about 36% in 2006. These numbers suggest that the dropout rate for girls is much higher. Effort should be taken to implement the positive trend from the primary education further into secondary and higher education. Over the last years, female positions in politics have increased slightly to 31% of the cabinet members and 32% of parliament in 2006 (12% in 1993). There is still a long way to go before full female emancipation can be reached.

Goal 4: Reduce child mortality
The mortality rate of children under five was 168 per thousand births in 2008, compared to 203 in 1990. This is a decrease of 17%. The overall goal is to reduce this with two thirds to 33% of the 1990 values, which would be 67 or lower. The measles vaccination program has been

effective; with 84% of the children immunized in 2008 the disease was no longer within the top ten causes of infant mortality.

Goal 5: Improve maternal health
The maternal mortality ratio is improving, but not fast enough to reach the goal of decreasing this with 75% by 2015. The maternal mortality rate was estimated in 2007 to be 620 deaths per 100,000 births compared to 800 in 1990, which is a decrease of 23%. The births attended by skilled medical staff were 56% in 2008.

Goal 6: Combat HIV/AIDS, malaria and other diseases
The prevalence of HIV/aids in Burundi increased over the last years. In urban areas it increased from 4.0% to 4.59%, and in rural areas from 2.2% to 2.82%. Malaria is still the first cause of death in Burundi and Tuberculosis is noted as third. The incidence rate from malaria decreased over the years from 46.5% in 2000 to 24.6% in 2008. For malaria good steps have been set, and the distribution of more mosquito nets can help to decrease infections further. Combating HIV/aids is more complicated, and many social structures and ideas push the increase of HIV. More awareness is needed to decrease HIV.

Goal 7: Ensure environmental sustainability
National resources are under great pressure as the population density is high. Deforestation is a problem, especially during the crisis. Nowadays there is a light improvement in re-forestation, but compared to 1990 forest decreased by 1.9% of the land area. Over 90% uses wood and coals as primary energy source. Greenhouse gas emissions decreased by 15% from 1990. Accessibility to drinking water was estimated to be 95% in 2008, which is close to the target of 100%. 93.8% uses latrines in 2008, but only 36.3% of these latrines are in good condition.

Goal 8: Develop a global partnership for development
Burundi tries to use the aid efficiently. In 2008, 40% of the GDP came from grants and aid with a total of $457 million. The Official Development Assistance (ODA) increased over time, starting with the Arusha agreement in 2000, when more effort was put on stable governance. Burundi tries to diversify exports and increase markets, and therefore joins international trade organizations. In 2007 nearly all of Burundi's 106 pharmacies are located around Bujumbura, Gitega and Ngozi. Therefore, access to medical assistance remains poor in most of the country. Mobile phone subscribers increased from 100,000 in 2003, to 484,314 in 2008 (60 out of 1000). From all the people that have access to electricity 4% can access a computer.

1.1.3 Poverty reduction strategy[1]

Within the 'Growth and Poverty Reduction Strategy Framework' (GPRSF) there are four principal objectives: (i) good governance, (ii) equitable and sustainable growth, (iii) development of human capital, and (iv) combating HIV/AIDS.

The first objective enhances a stable security situation that includes former rebels to be demobilized and disarmed; and to provide integration for this group. Besides this, the defense and security corps is being professionalized. Reform of the judicial system has been inadequate over the last years (2006-2009).

Economic growth reached four percent from 2006-2009, which is not sufficient to reduce the poverty rate of 67% in 2006. The agricultural production growth rate is low (<3%), while 97% of

[1] This section is based on the PRSP progress report 2011, IMF.

the poorest Burundians work in this primary sector. Production of electricity is extremely weak, and reaches only 3-4% of the population. No substantial growth can be seen over the years.

Most progress has been made with the development of Human resources. As described under the MDGs, the area of education has made good progress. There is free healthcare for woman giving birth, and the mortality of children under the age of five decreased maternal. In order to reduce poverty further, it is advised to put more effort in rural development, agriculture and livestock. The export crops must be reformed and diversified and infrastructure should be developed. The development of the private sector has a high priority in order to provide a strong impetus to growth.

1.1.4 Legal framework

The Government of Burundi formulated it first National Master Plan in 1992. The National Water Policy (NWP) and Strategic action plan was completed in 2001 to manage the national water resources in an integrated and sustainable manner. The accompanying Action Plan indicated objectives, actions, performance indicators, institutional responsibilities, budgets and an implementation calendar. The Ministry of Land Management, Environment and Tourism were the overall coordinator, and the Geographical Institute of Burundi was the technical coordinator of the Action Plan that anticipates participation by public sector and local communities through communal administration. However the NWP has never been presented to the Parliament to be accorded to a legal status. The NWP defined rivers, lakes, springs, groundwater, swamps permanently covered with water, islands, hydraulic structures constructed for the purpose of public benefit as public domain resources managed by the Ministry of Land Management, Environment and Tourism. No water intake or water effluent as well as the related water structures can be built in this public hydraulic domain without an authorization or a concession of the national water administration. However water can be abstracted freely from the ground or surface water for domestic purposes (human food supply, hygiene, washing, plant and animal production for domestic consumption). The law also establishes a priority order for the different water uses. Domestic water use enjoys the highest priority, followed by agricultural uses. The later cover water demands of livestock, fisheries and irrigation. These uses are followed by industrial, environmental and recreational water uses in declining order of priority. The holders of the water use rights have to use the water in a rational and economic way as well as to respect the rights of the other legitimate users. The water administration manages the water release of reservoirs on the basis of water needs, hydrologic and meteorological data and can decrease the discharge in case of water shortages.

1.1.5 Socio-economic context and institutional setting

This section describes the socio-economic context and institutional setting for irrigation development in Burundi. The main parameters and their sources are summarized respectively in the table on socio-economic context and institutional setting. The highlights are:

Socio-economic context:

- Burundi retains a largely rural population (89%)
- Poverty levels remain high – even slightly upwards of neighbouring countries (67% below national poverty line)
- On main social services: health expenditures (USD 20/ capita), population with access to improved source of drinking water (72%), electric power consumption (24 KWh per capita) and female illiteracy (39%) Burundi scores slightly better than other countries in the same socio-economic bracket
- Agriculture is the main provider of jobs in Burundi (90%)

- In economic value Burundi is a net exporter of agricultural products (import to export is 0.86). The total value of agricultural exports is modest though (USD 56 M)
- With respect to food Burundi is a net importer (value of food imports USD 44 M)

Agricultural services:

- Agricultural road density is low (12.5 km/1000 sq. km arable land) – affecting agricultural marketing
- Fertilizer use is at a minimum (2.2 kg/ ha)
- The use of mechanical equipment is minimal (1.7 tractor per 1000 sq km of arable land

Irrigation and water use:

- Irrigated land is a small fraction of arable land (1.6%)
- Total water abstraction is a small percentage of renewable resources (2.3%)
- No data are available on groundwater usage
- Irrigation performance is median as compared with Nile Basin countries (rank 4 out of 8) – agricultural water productivity is relatively low (7/8) but crop consumption use is relatively high (2/8)

Institutions:

- The institutional framework for irrigation and water development is weak. Main polices for irrigation and water resource development is National Water Policy 2009, its implementation however needs further political, organizational and institutional measures. These are mainly addressed in ProSecEau Project (2007-2015). The cohesive institution is the National Commission for Water: an inter-ministerial body for managing water resources under authority of Ministry of Energy and Mines.
- The institutional mandate for irrigation development is shared between the *Ministry of Water, environment, Planning and Urban Affairs (MEEATU)*, the Ministry of Agricultural and Livestock, *Ministry of Water, Energy and minerals,* the National Commission for Water and the National Project Implementation Agency
- There is no water licensing system in place or payment of water fees
- Only a small portion (5%) of land ownership is registered but reforms are underway

On indicators of government effectiveness (12.9) and rule of law (-1.7) Burundi scores low – in line with other SSA countries.

BURUNDI - INSTITUTIONAL	
Main guiding policies, act and ordinances	• *National water Policy (2009), overall objective is to ensure sustainable water for all users by a harmonious development of the national water resources needs….before implementation it needs however further policy, organizational and institutional measures which are aso described (USAID, 2010, pp. 73)* • *ProSecEau Project (2007-2015)… includes partnership between GTZ and GoB to bring reform in the water sector, including its policies, laws, and regulations to further strategic planning and integrated management of water resources (USAID, 2010, pp. 38)* • *Guiding policies towards a cohesive policy on water control and use are: Strategy Paper 2008-2011 (AFDG), Poverty Reduction Strategy Paper 2006 (Cadre Strategique de Croissance et de Lutte contre la Pauvrete 2006), Burundi 2025, National Environment Strategy 2000* • *National Action Plan for Adaptation to climate change (2007)* • *National Strategy of Sustainable Land Use (2007)*

Institutional mandate irrigation development (Aquastat, if not indicated otherwise)	• *MEEATU (Ministry of Water, environment, Planning and Urban Affairs),their activities incude design and monitoring of irrigation schemes, structures and farm buildings (sheds, barns, dipping tanks, etc.)*
	    o *Directorate of Water (USAID, 2010, pp. 39)*
	    o *Directorate of land (USAID, 2010, pp. 40)*
	• *Ministry of Agriculture and Livestock, their activities include operation and usages of water resources*
	• *Ministry of Water, Energy and minerals, their activities inlude operations and usages of water resources within their sector*
	    o *National Commision for Water: an inter-ministerial body for managing water resources*
	• *National Project Implementation Agency*

Water Permit System – Drillers *(Meghani, M. et al. 2007, pp. 26)*	*There is no permit system, due to lack of Legal base for it. There is only one drilling company in country with little equipment. However, it is able to meet the demand. No training capacity available in the country.*
Water Permit System – Users (Ibid., pp 47 and 62)	*No user payments for water*
Other institutions involved in irrigation development (Ibid.)	• *UNICEF, PNUD, FAO, BTC(Belgium). Their main concerns are development, protection and management of groundwater resources* • *BAP (Burundi Agribusiness Program) and ADC (Agent de developpement communautaire): Small scale irrigation Programss* • *Lake Tanganyika Authorithy (LTA), trandboundary issues around the lake, for Burundi specfically wastewater production and pollution*
Local organizations	*Unknown*
Private sector	*Poorly developed*

Support to small scale irrigation development (vocational sector, land planning)[3]	• *"Burundi's vision for Agricultural policy for market oriented agriculture includes promotion of small scale irrigation (World Bank, 2009, issue 81)*
	• *Examples are:*
	  ○ *the* granting of 280 pedal pumps to irrigate 158ha in Lac du Nord marhes, Kirundo Province; rehabilitaion of Murambi channel and Rugombo irrigation networkare mentioned (World Bank, 2008, issue 146)"
	  ○ *Irrigation development in Nyavymo, Rugamira and Kabyenge Marshlands (2,000 ha) and Lake Cohoha irrigation (500 ha) ADF (2008)*

Land tenure	• *Officially land has to be registered, actually less than 5% of all land is registered and ownership is rather based on oral testimony. Land reforms are underway, current performance of land tenure rights is low* (USAID, 200XX) • *"To solve the land problem, Burundi needs to (i) restore land to returnees or offer commensurate compensation and, through a process of land reform, (ii) address the issue of security of tenure"(African Development Bank Group, 2008, pp. 2)* • *Currently CLOP (Commission on Land and Other Properties) is appointment by the government to settle land issues*
Government Effectiveness (percentile rank 0-100) (Worldbank, 2009)	*12.9*
Rule of Law (-2.5 – 2.5, in which high values represent effective enforcement of law (Ibid.)	*-1,7*

[3] Current programs in irrigation development include (I) *NELSAP Kagera River Basin Transboundary Integrated Water Resources Development Project (TKTIWRDP) of which one component focuses on preparation of IWRM plans for the lakes and marhlands of Lacs du Nord (Bugesera) (USAID, 2010, pp. 38); (II) Infrastructure rehabilitation in Lacs du North and Bugesera area, especially to increasse rice production (World Bank PRASAB Project, 2004-2010); (III) Integrated Watershed Management Projects in eight water sheds south of Bujumbura through French Cooperation (USAID, 2010); (IV) Agricultural Intensification and Value-enhancing Support Project (IFAD), covering six provinces north and east of the capital Bujumbura, including marshland development and rehabilitation for improved rice production (IFAD); (V) USAID Food for Peace Project/ Multi Year Assistance Program (MYAP) and (VI) GEF (Global Environment Facility) small grant programs*

BURUNDI SOCIO-ECONOMIC	
Food exports, FAO (current US$M) (FAO Statistical Yearbook 2010)	2.44
Food imports, FAO (current US$M) (FAO Statistical Yearbook 2010)	43.67
Imports/exports (calculated)	17,88
Health expenditure per capita (World Bank, current US$, 2009)	20
Improved water source (% of population with access) (World Bank, 2008)	72
Improved water source, rural (% of rural population with access)	71
Improved water source, urban (% of urban population with access)	83
Poverty (% below national poverty line) (UNSTAT, 2006)	66.9
Illiteracy rate –Male (15+) (UNICEF, 2009)	37.4
Illiteracy rate --Female (15+)(UNICEF, 2009)	39.1
Primary completion rate, total (% of relevant age group) (UNICEF, 2005)	34.6
Road density (road km/100 sq. km of land area) (IRF, 2004)	44
Road to arable land density (road km/1000 sq. km arable land)	12.51
Roads, paved (% of total roads)	10,4
Electric power consumption (kWh per capita) (CIA, 2005)	24
Country area (km2) (FAOSTAT, 2009)	27,830
Land area (km2) (FAOSTAT, 2009)	25,680
Population, Projected/Estimated (FAOSTAT, 2010)	8,383,000
Urban population (% of total population) (FAOSTAT, 2010)	11
Rural population (% of total population)(calculated)	89
Population density (pp/km^2) (World Bank, 2010)	326
AGRICULTURAL	
Agricultural exports (US$M) (FAOSTAT, 2008)	56.81
Agricultural Import (Current US$M) (FAOSTAT, 2008)	48.69
Import/export (calculated)	0,86
Value added in agriculture, growth (%)	0.95
Value added, agriculture (% of GDP) (AQUASTAT, 2005)	34.85
Employment agriculture (% of population)	90
Agricultual machinery (tractors /100 square km arable) (World bank,	1.72
Agriculture value added per worker (Constant 2000 US$) (WB, 2005)	70
Fertilizer consumption (kg per hectare of arable land) (WB, 2008)	2.2
Cereal cropland (% of land area) (of which irrigated, %) (WB, 2009)	9
Agricultural area (ha) (FAO Resource Stat, 2009)	2,150,000
Arable land (ha) (FAO Resource Stat, 2009)	900,000

IRRIGATED AGRICULTURE	
Irrigated land (% of crop land) (Aquastat, 2002)	1.59
Irrigated land entire country (ha) (Bast. and Perry, 2009; AQUASTAT and WB,	11,793-21,430
Actually irrigated (ha) (World Bank, 2008)	5,000
Irrigation potential (entire country) (FAO, 1997a and AQUASTAT, 2007)	105,000 - 215,000
Irrigated Land nile basin (potential) (Bastiaansen and Perry, 2009)	14,625-215,000
Irrigation schemes in Nile Basin	n.a.
Small schemes (national level) (Ibid.)	800
Medium schemes (national level) (Ibid.)	500
Large schemes (national level) (Ibid.)	5660
Potential schemes (Nile Basin)	n.a.
Water Sources	Rivers and lakes
Water Sources - Names	n.a.
Irrigated area per household (ha) (national level) ((Ibid.)	0.5
SUSTAINABLE WATER ABSTRACTION RATES (AQUASTAT, 2000)	
Renewable resources (km3/year)	12.54
Overlap	7.47
Surface water	12.54
ground water	7.47
Dependency ratio	19.75
ACTUAL WATER ABSTRACTION RATES	
Groundwater (km3/year)	n.a.
Surface (km3/year)	n.a.
Total water withdrawal (km3/year) (AQUASTAT, 2000)	0.288
% of renewable water resources (AQUASTAT, 2002)	2.30
Water abstraction points[45]	n.a.
Deep Motorized boreholes	n.a.
Motorized boreholes	n.a.
Manual boreholes	n.a.
Protected shallow wells	n.a.
Windmill boreholes	n.a.
Springs	n.a.

[4] *There is no significant use of groundwater for irrigation (Meghani, M. et al. 2007, pp. 38)*

[5] More information should be available at *Groundwater competency centre (University of Burundi) (Meghani, M. et al. 2007, pp. 29)*

IRRIGATION PERFORMANCE (Bastiaansen and Perry, 2009)[6]	
Overall Irrigation performance Large Scale Irrigation (0-5)	3.6
Result Oriented Performance	2.9 [7]
Sustainability Oriented Performance	4.25[8]
Process Oriented Performance	3.7[2]
Detailed Irrigation Performance Parameters	
Water Productivity (Performance 0-5) (Rank within Nile Basin 1-8)	3.0 (4)
Agricultural water Productivity	2.8 (7)
Crop consumptive use	3.4 (2)
Beneficial Water Use	2.8 (7)
Adequacy	3.1 (5)
Uniformity	4.4 (4)
Reliability	3.9 (4)
Sustainability	3.5 (3)
AGROPHYSICAL (Bastiaansen and Perry, 2009)	
Irrigated crops (ha)	Maize (43,000), Rice (17,000), Vegetables (9,000), Sorghum (18,000), Sugarcane (3,000)
Cereal yield rainfed (kg/ha) (Nett yield)	1,249
Biomass production (satellites) (kg/ha) (Nett yield)	9,755
Cereal yield irrigated (kg/ha) (Nett yield)	4,228
Yield Increment	2,979
Net Increment	894

6 Specific recommendations for improvement of irrigation performane, as mentioned in Bastiaansen and Perry (2009): Increase transpiration instead of unproductive evaporation through intercropping methods for example, use of fertilzer and improved feed stock

7 Referred to as low in Bastiaansen and Perry (2009) should become more output oriented

8 Referred to as good in Bastiaansen and Perry (2009), no comments

2 Countrywide irrigation potential

2.1 Terrain and soil

2.1.1 Relief, climate, and hydrography

Burundi is a mountainous area with some plains in the Imbo, Buragane, Mosso and Bugesera natural regions. The climate is tropical and tempered by altitude. Average temperature ranges between 15 and 24 degrees Celsius. However, extreme high temperatures of 33 degrees Celsius during the day are not an exception. Despite the climate challenges currently observed within the Eastern Africa region, Burundi detains an important potential for irrigation. Unfortunately this is currently underused at the moment. The average annual rainfall in Burundi is sufficient, ranging from 700 to 2000 mm per year. It is partly for this reason that rainfed agriculture is by far more dominant than irrigated agriculture. Agricultural activity is marked by two rainy seasons: the first season from February to May, which provides 60% of the total precipitation, and the second season from September to December, delivering 40% of the total precipitation.

Burundi is divided into eleven natural regions and five agro-ecological zones. The plain of Imbo: lowlands (774-1000 m) with a warm tropical climate (23°C average temperature), a low amount of rainfall (annual 800-1000 mm), and a dry season of 5-6 months. The west slope of the Congo-Nile ridge: a mountainous area with elevations ranging from 1000 to 2000 m, Annual rainfall ranges from 1100 to 1800 mm and temperatures vary between 23 and 17°C. The Congo-Nile ridge: elevations range from 2000 to 2670 m, and the annual rainfall varies between 1500 and 2000 mm, and mean annual temperatures ranging between 12 and 16°C. The central plateau: elevation varies between 1500 and 2000 m, while the average annual rainfall varies between 1150 and 1500 mm, and temperatures between16 and 18°C. The East and Northeast depressions: altitude varying between 1320 and 1500 m, rainfall between 600 and 1100 mm, and temperature around 20^{o}C.

2.1.2 Terrain suitability

The terrain slope is a key characteristic for assessing the irrigation potential. Steeper slopes evidently are less suitable for irrigation. Different types of irrigation also have different associated slope suitability. Three different irrigation types are included in the suitability analysis: border/furrow, sprinkler irrigation, drip irrigation, and hill-side irrigation (see main report). The base of this analysis is the digital elevation model of the 90-meters SRTM. This DEM was used to derive slopes and to undertake the suitability analysis.

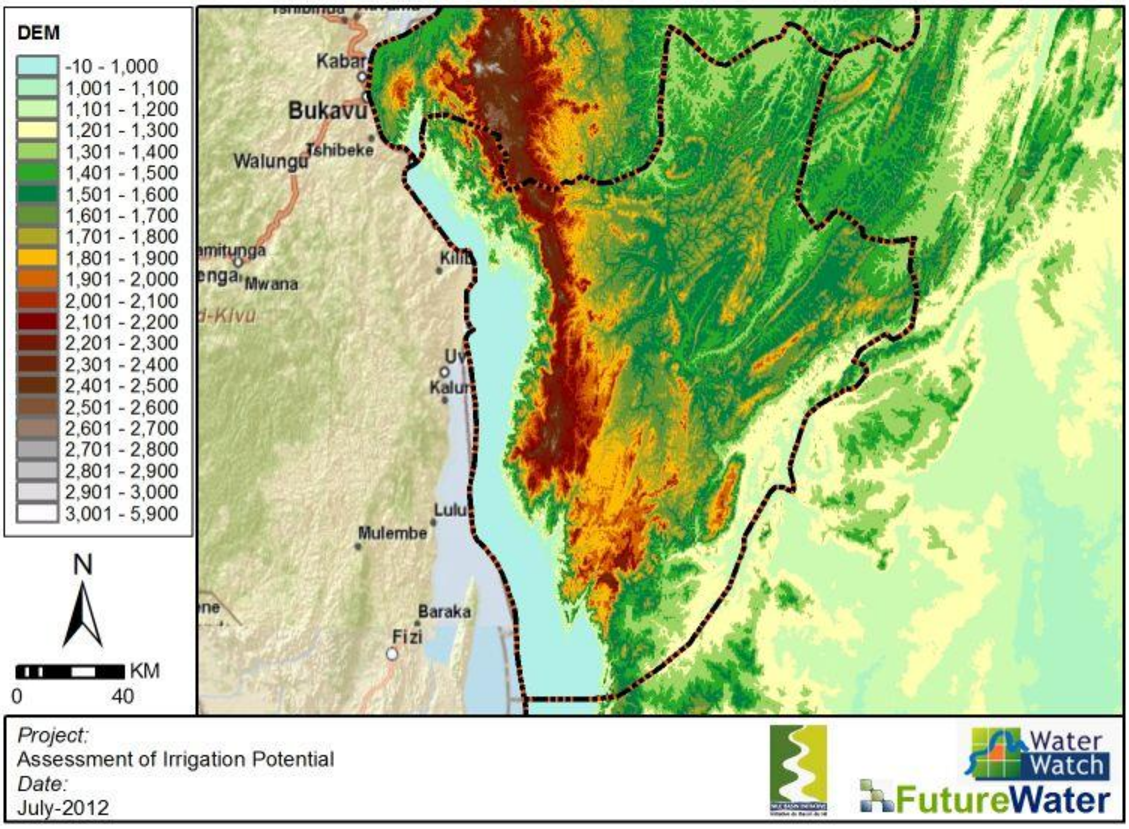
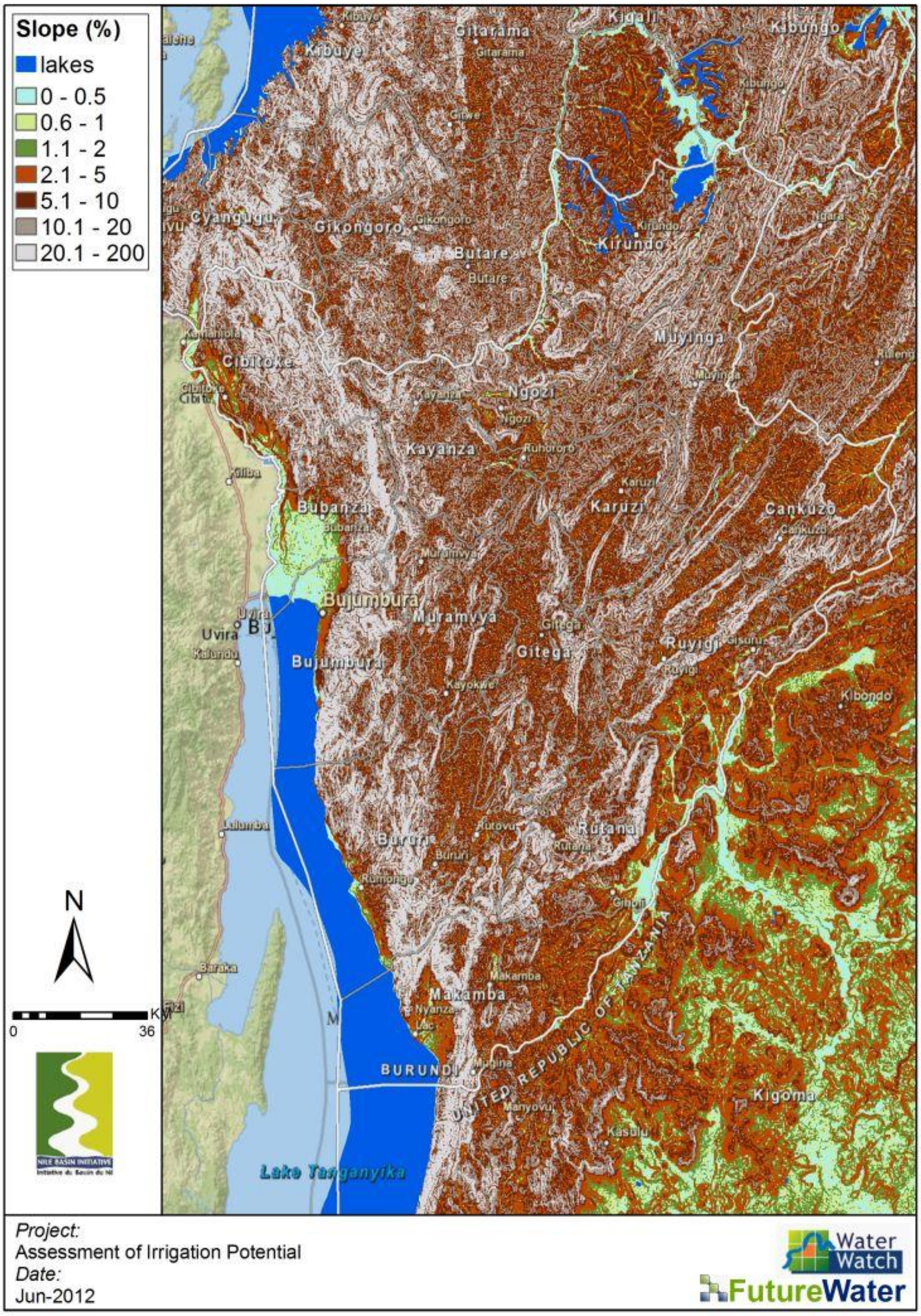


Figure 2: Digital Elevation Model of Burundi. (Source: ASTER)

In Figure 2 the DEM for the country is shown. Burundi is characterized by quite some mountains throughout the country with lowland areas along Lake Tangayika and the boder with DRC. Associated slopes can be seen in Figure 3. Based on these slope classes for each of the three irrigation types suitability for irrigation has been determined. It is clear that suitability for surface irrigation is very limited in the country and that is why Burundi is promoting hill-side irrigation.



Slope (%)
lakes
0 - 0.5
0.6 - 1
1.1 - 2
2.1 - 5
5.1 - 10
10.1 - 20
20.1 - 200
N
0
36
KM
Kigali
Kibungo
Gitarama
Kibuye
Cyangugu
Gikongoro
Butare
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Karuzi
Cankuzo
Bubanza
Bujumbura
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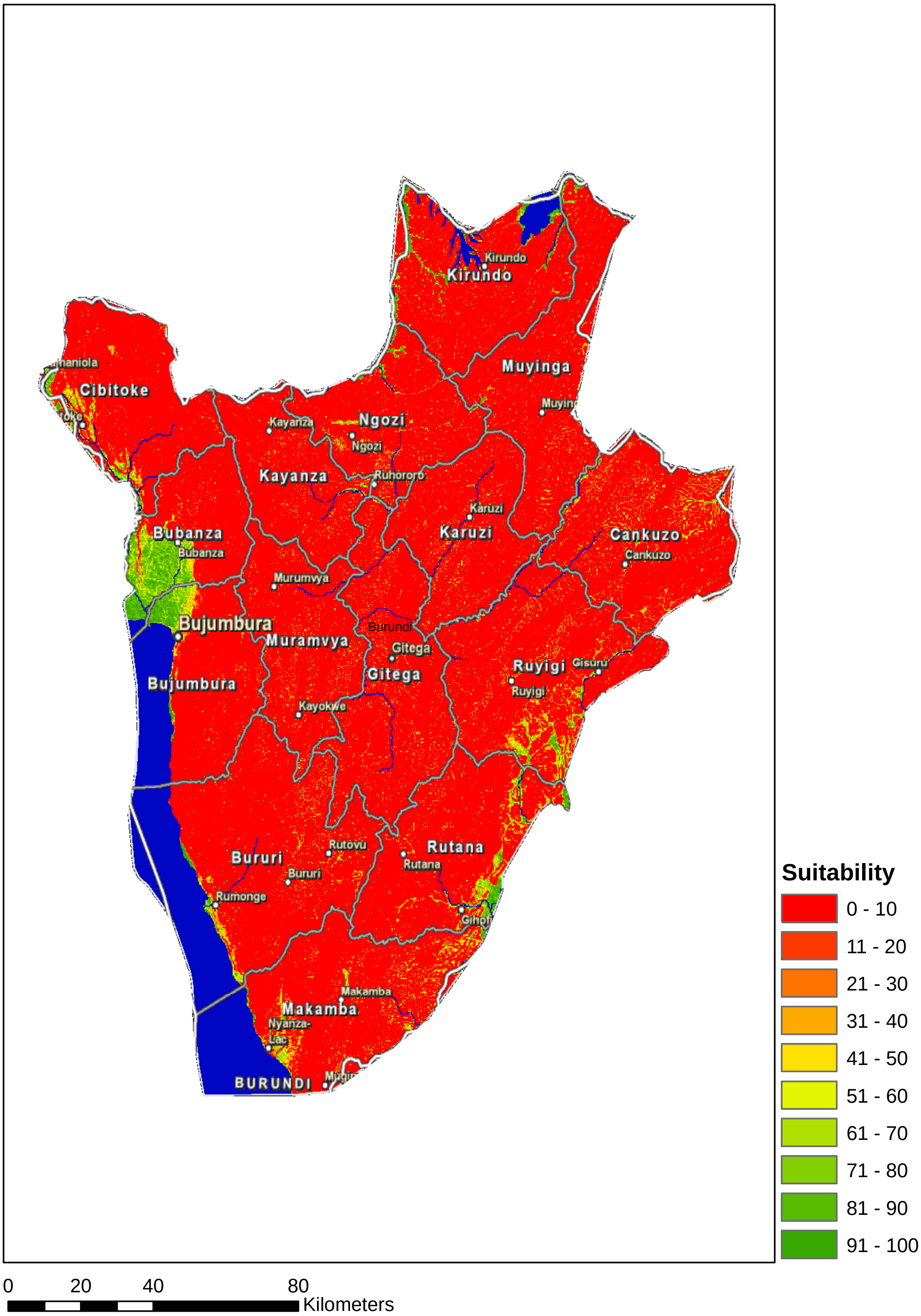

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Karuzi
Cankuzo
Cankuzo
Bubanza
Bubanza
Murumvya
Bujumbura
Muramvya
Burundi
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
Bujumbura
Kayokwe
Bururi
Rutovu
Rutana
Bururi
Rutana
Rumonge
Makamba
Makamba
Nyanza-Lac
BURUNDI
Suitability
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
0 20 40 80
Kilometers

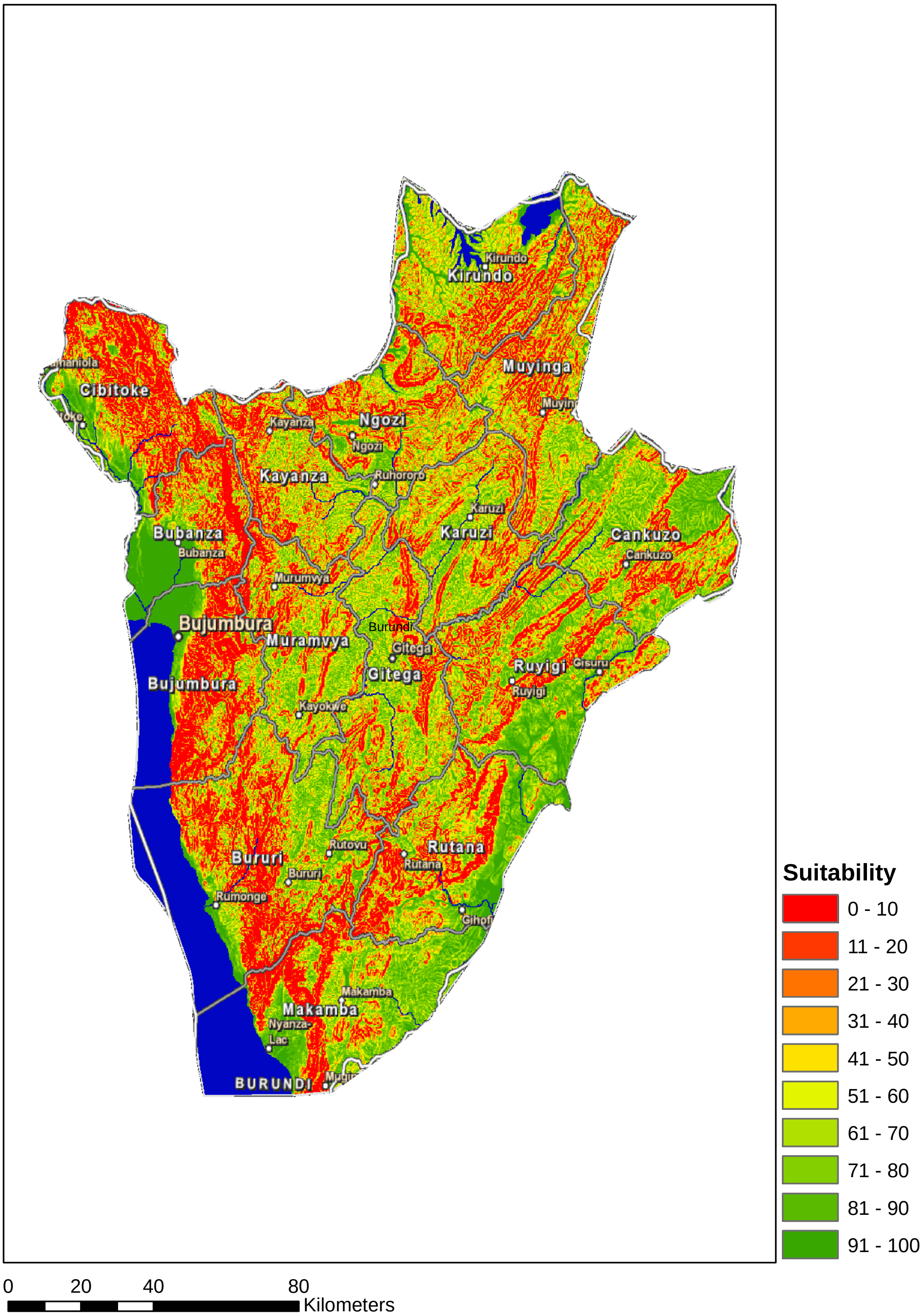
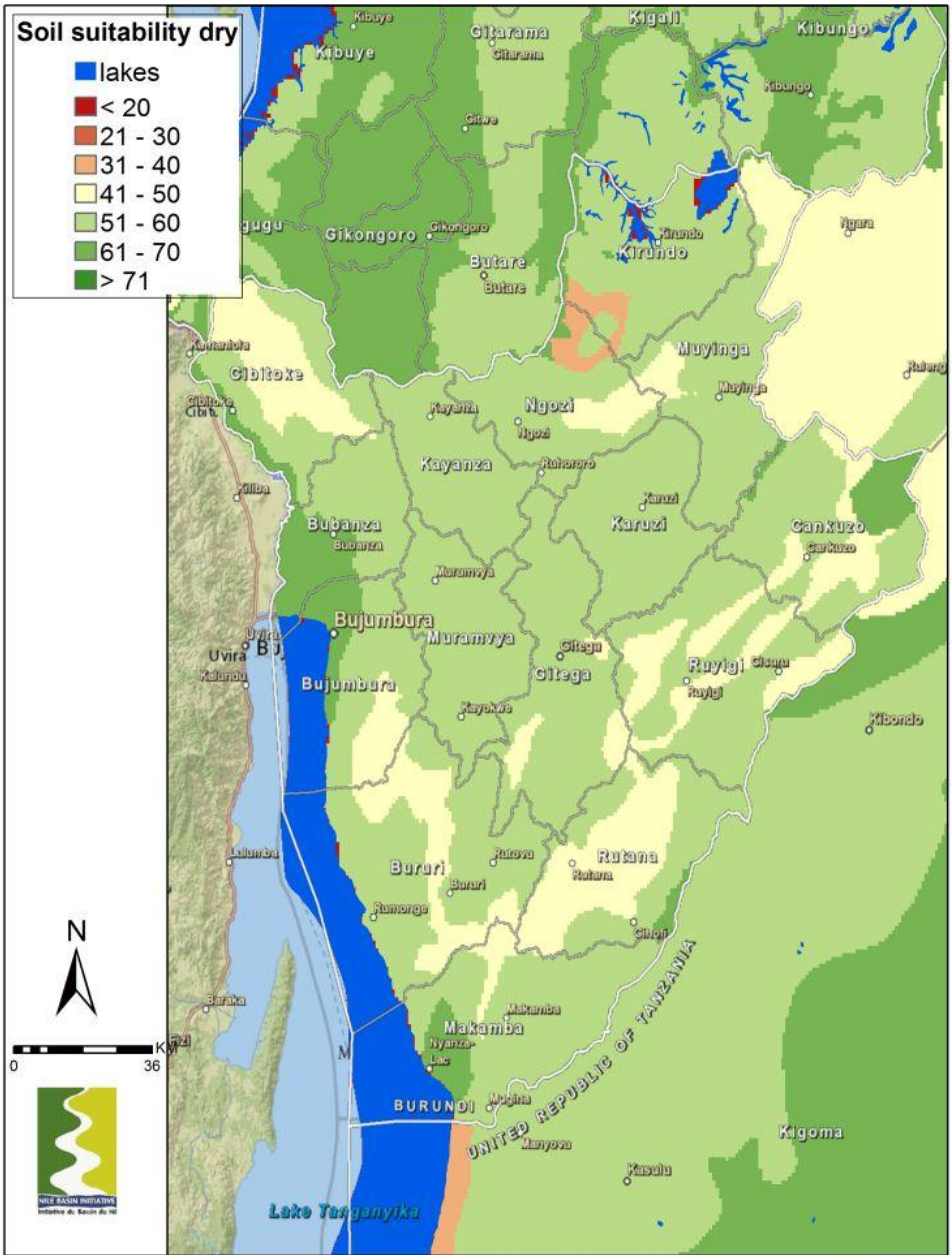


Figure 3: Terrain slope as percentage (top), surface irrigation (middle), and drip irrigation (bottom).

2.1.3 Soil suitability

Based on local soil maps as combined in the Harmonized World Soil Database (HWSD) soil suitability for irrigation has been assessed based on the FAO methodology (for details see main report). The following characteristics are included in the soil suitability assessment: (i) organic carbon, (ii) soil water holding capacity, (iii) drainage capacity, (iv) soil texture, (v) pH, and (vi) soil salinity. Given the quite different characteristics for rice crops, two suitability maps were created.

It is clear that soils in Burundi are by enlarge reasonable suitable to develop irrigation based on soil characteristics. Some major salinity problems occur in the western part of the country according to the soil map.



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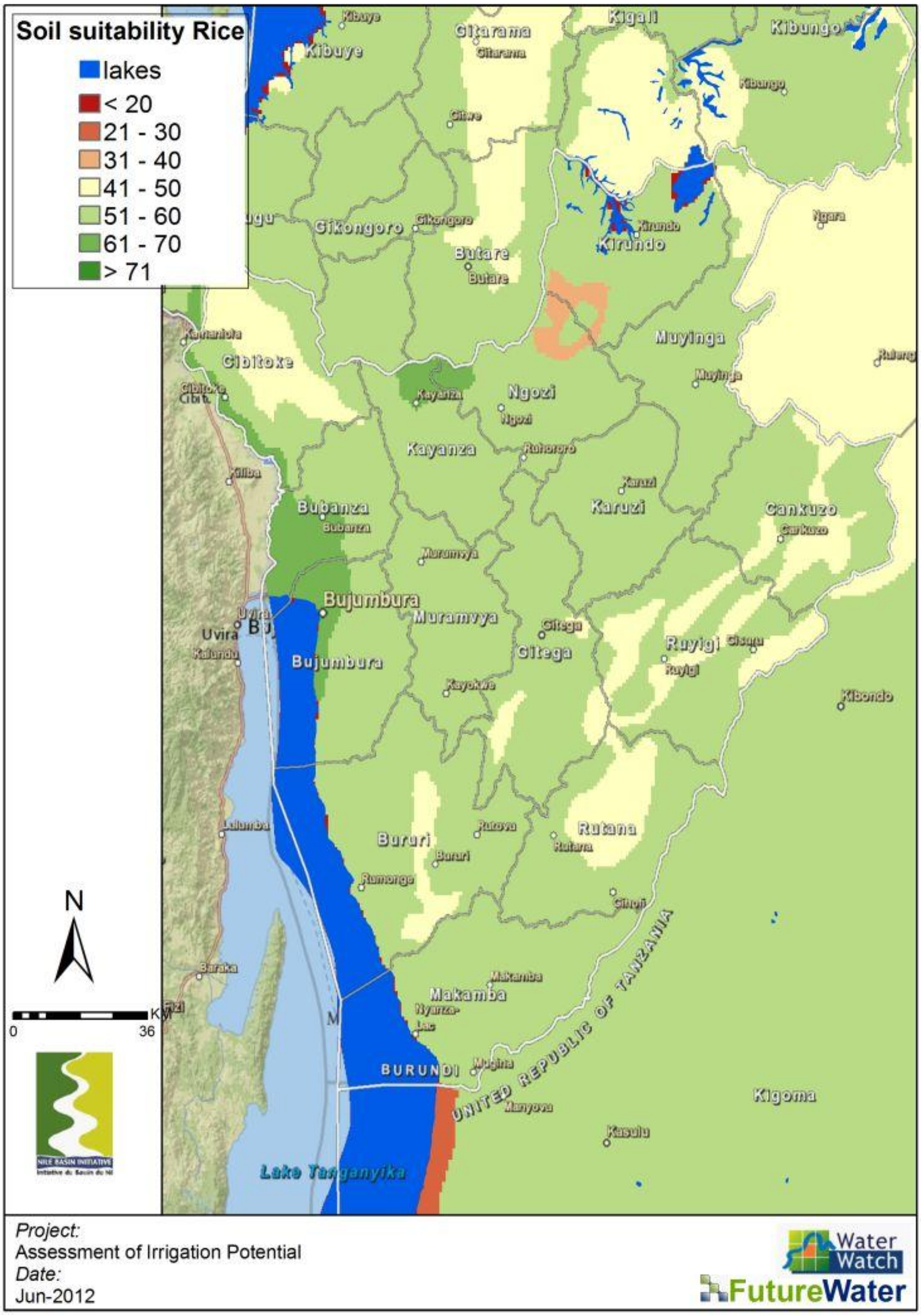
Soil suitability Rice
lakes
< 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
> 71
N
0
36
KM
Kigali
Kibungo
Gitarama
Kibuye
Gikongoro
Butare
Kirundo
Muyinga
Ngozi
Cibitoke
Kayanza
Bubanza
Karuzi
Cankuzo
Bujumbura
Muramvya
Gitega
Ruyigi
Uvira
Bururi
Rutana
Makamba
BURUNDI
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Kigoma
Lake Tanganyika
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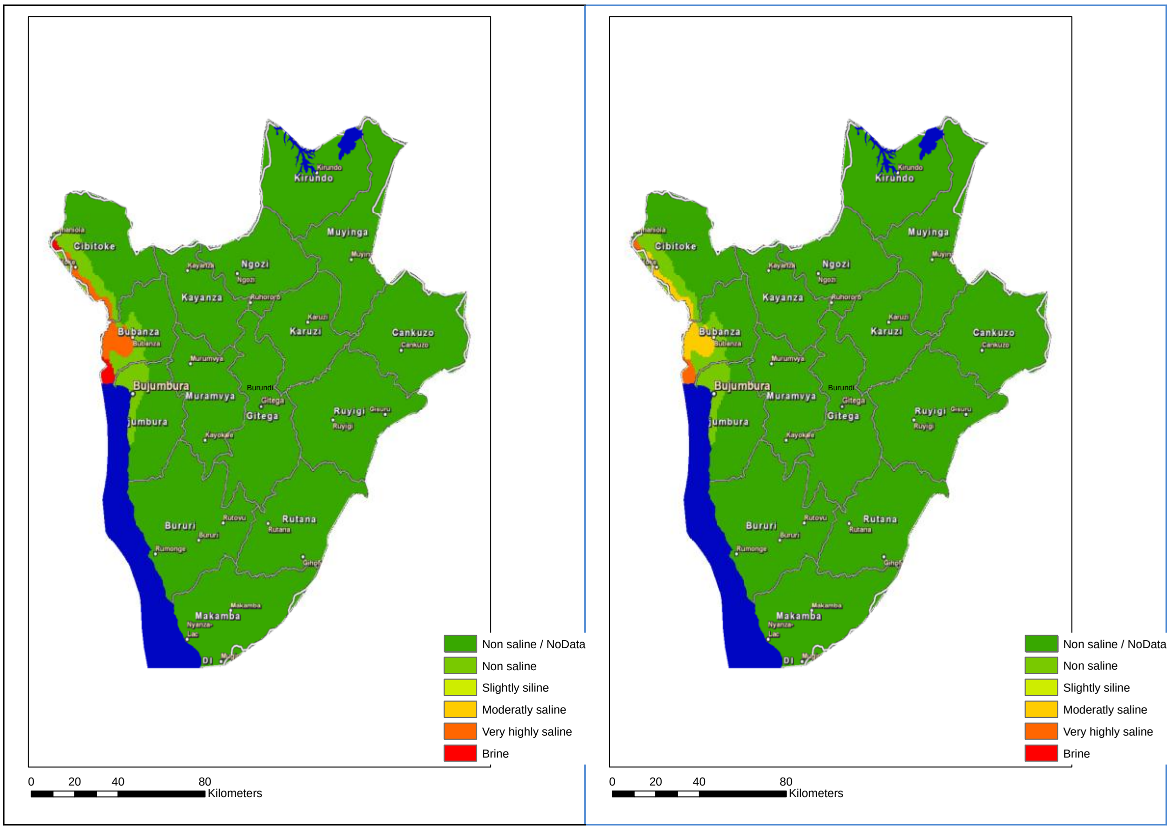


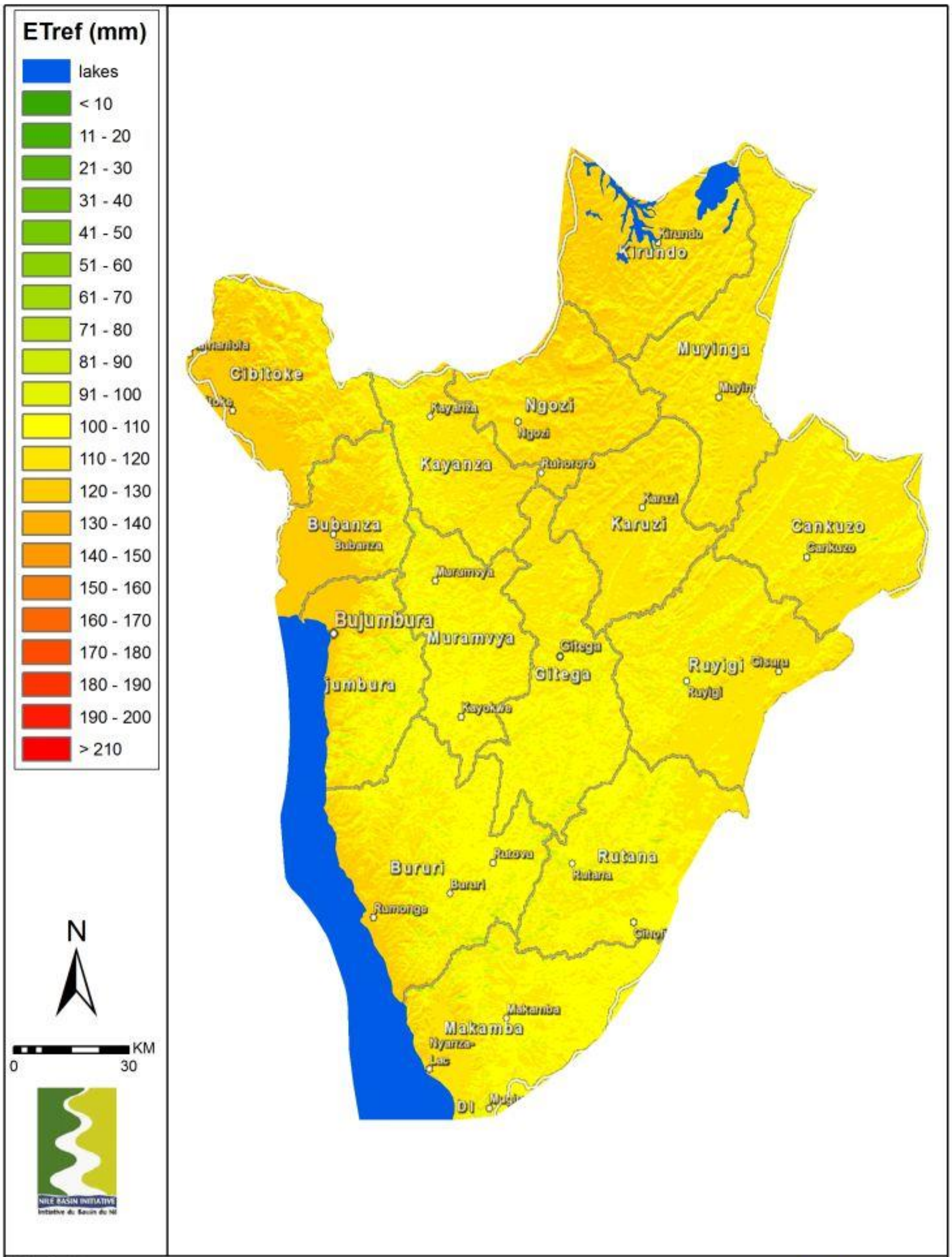
Figure 4: Soil suitability for arable crops (top) and rice/paddy (middle) and salinity, top-soil (bottom left) and sub-soil (bottom right) (Source: study analysis)

2.2 Water

2.2.1 Irrigation water requirements

The amount of water needed during a growing season depends on the crop, yield goal, soil, temperature, solar radiation, and other bio-physical factors. The amount of water required for irrigation is also a function of rainfall and irrigation efficiencies. During Phase 1 of this study the irrigation water requirements are based on an innovative method using satellite information (see main report for details). The following maps provide for each month the reference evapotranspiration (= evaporative demand of the atmosphere), the actual evapotranspiration under current conditions and the final irrigation water requirements.

January



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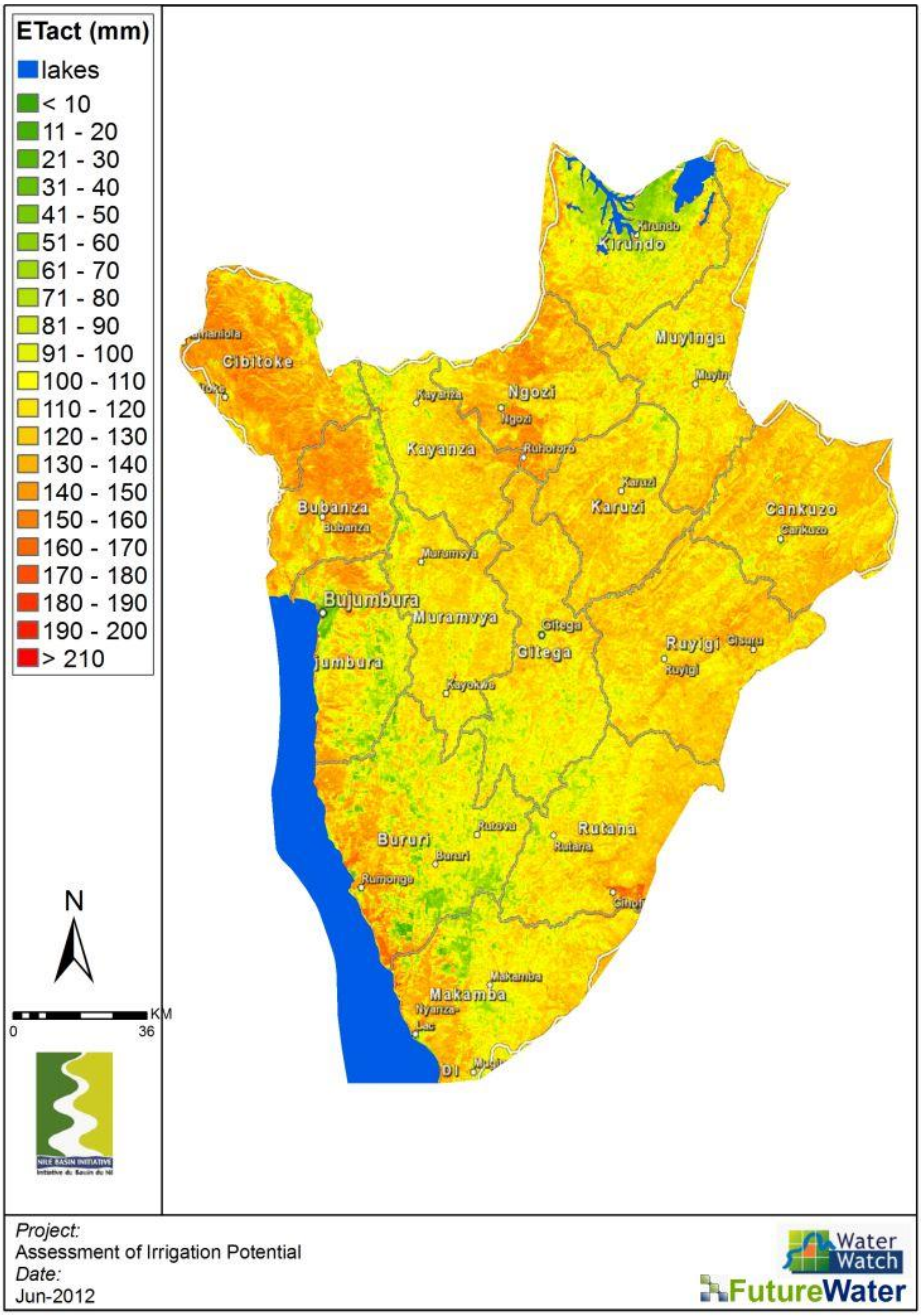
ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
36
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Karuzi
Cankuzo
Bubanza
Bujumbura
Muramvya
Gitega
Ruyigi
Bururi
Rutana
Makamba
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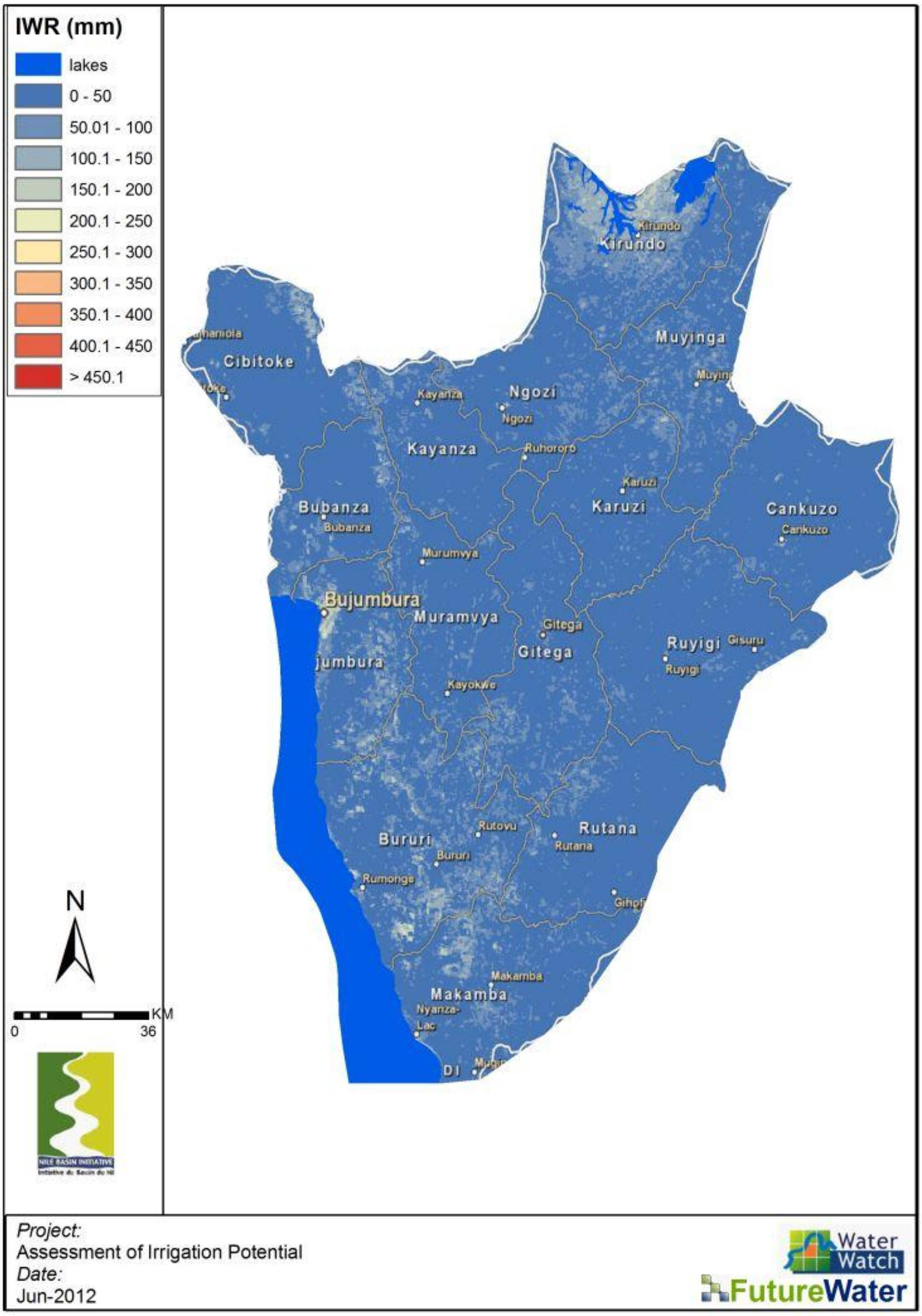
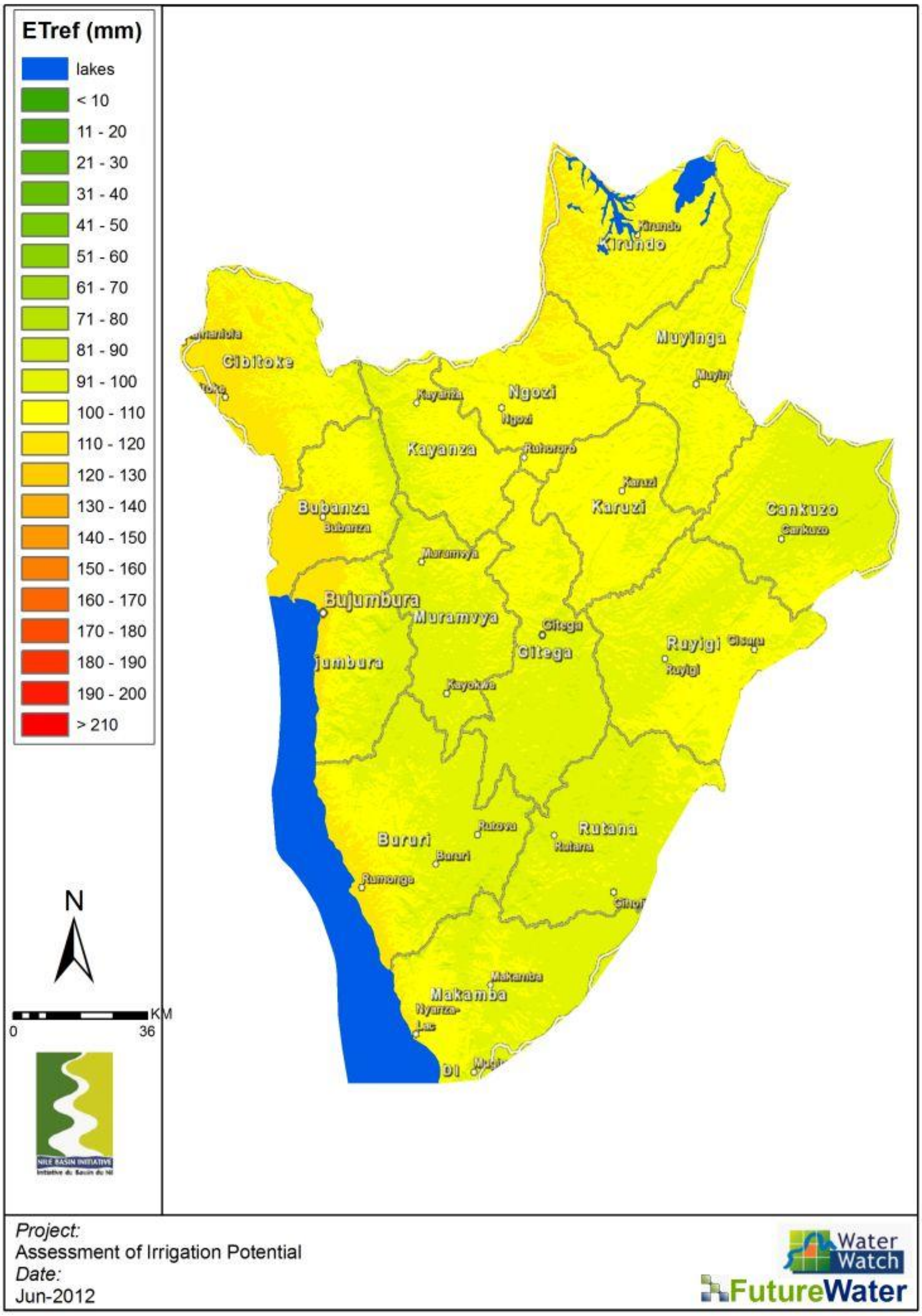


Figure 5: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for January (Average 2001-2010). (Source: study analysis).

February



ETref (mm)
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61 - 70
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160 - 170
170 - 180
180 - 190
190 - 200
> 210
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0
36
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Karuzi
Cankuzo
Bubanza
Bujumbura
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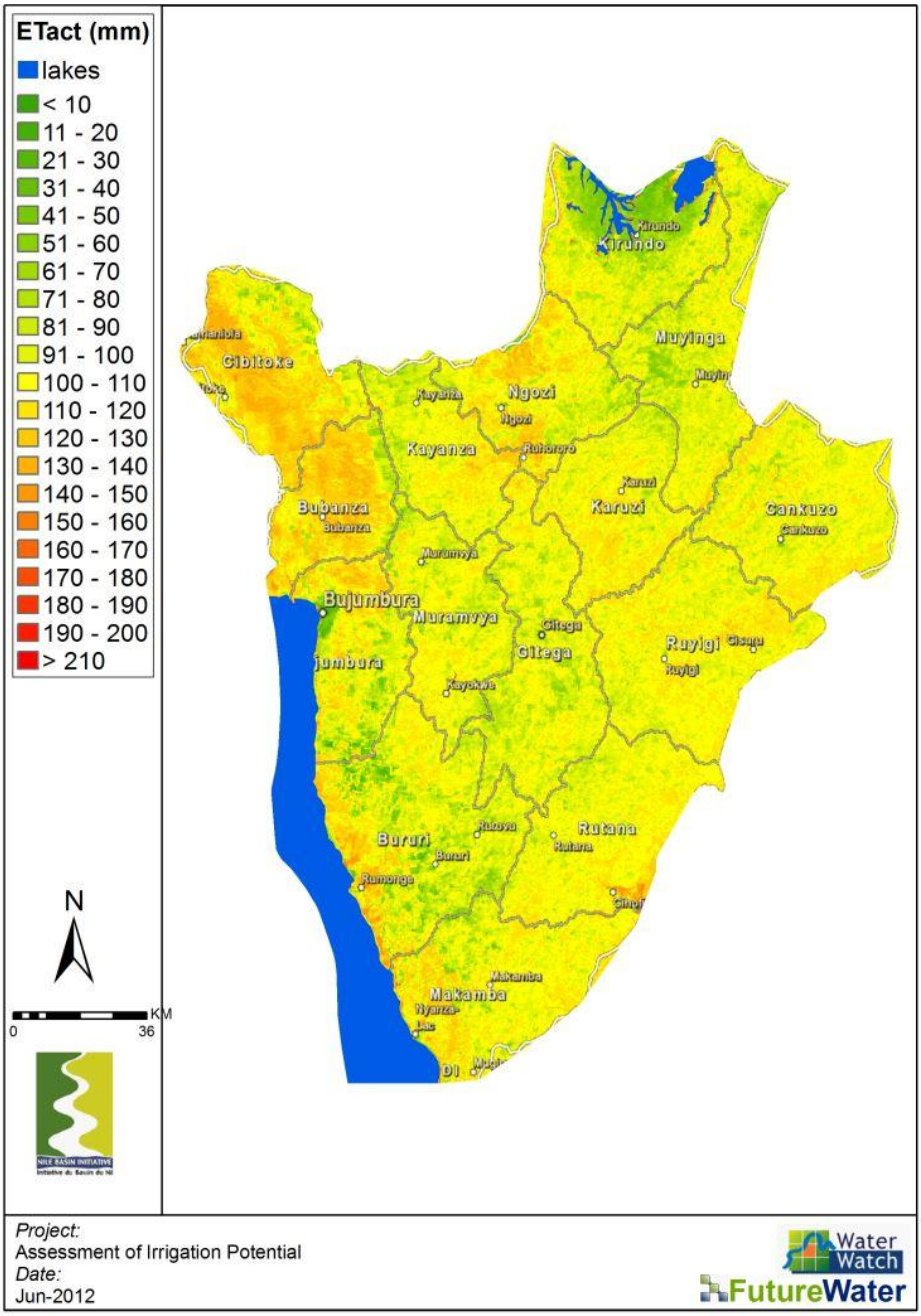
ETact (mm)
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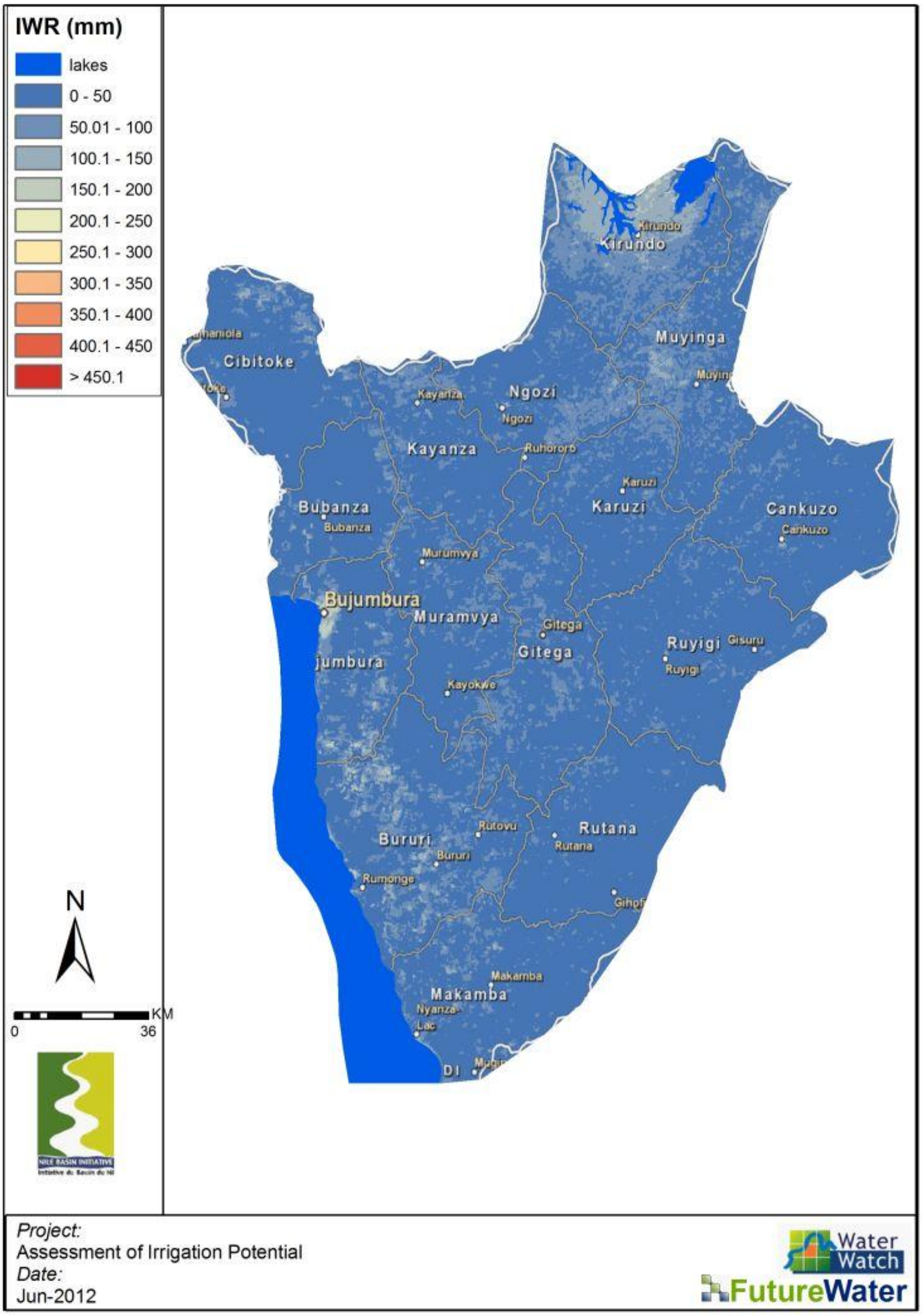
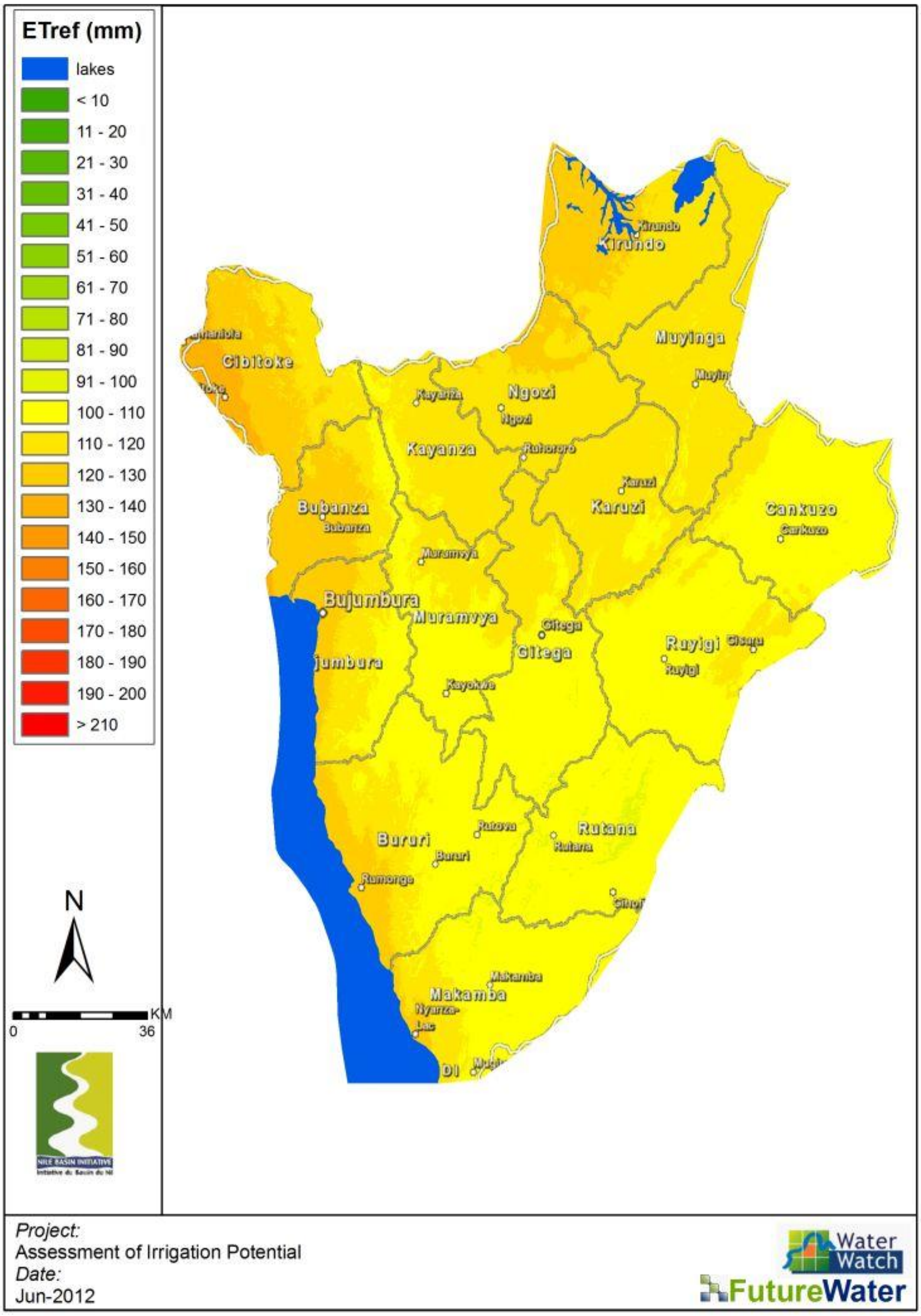


Figure 6: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for February (Average 2001-2010). (Source: study analysis).

March


ETref (mm)
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Ngozi
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Karuzi
Cankuzo
Bubanza
Bujumbura
Muramvya
Gitega
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Bururi
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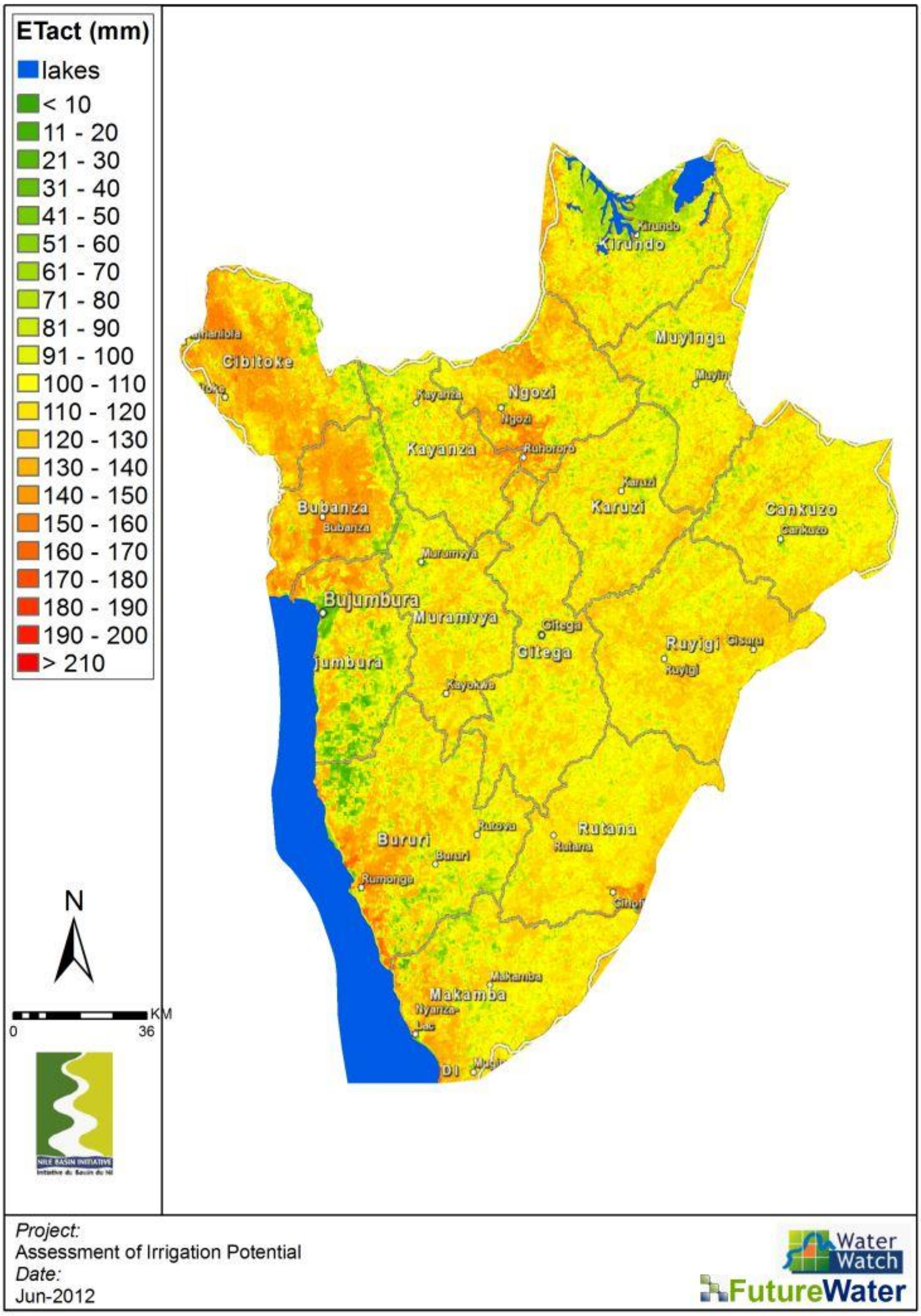
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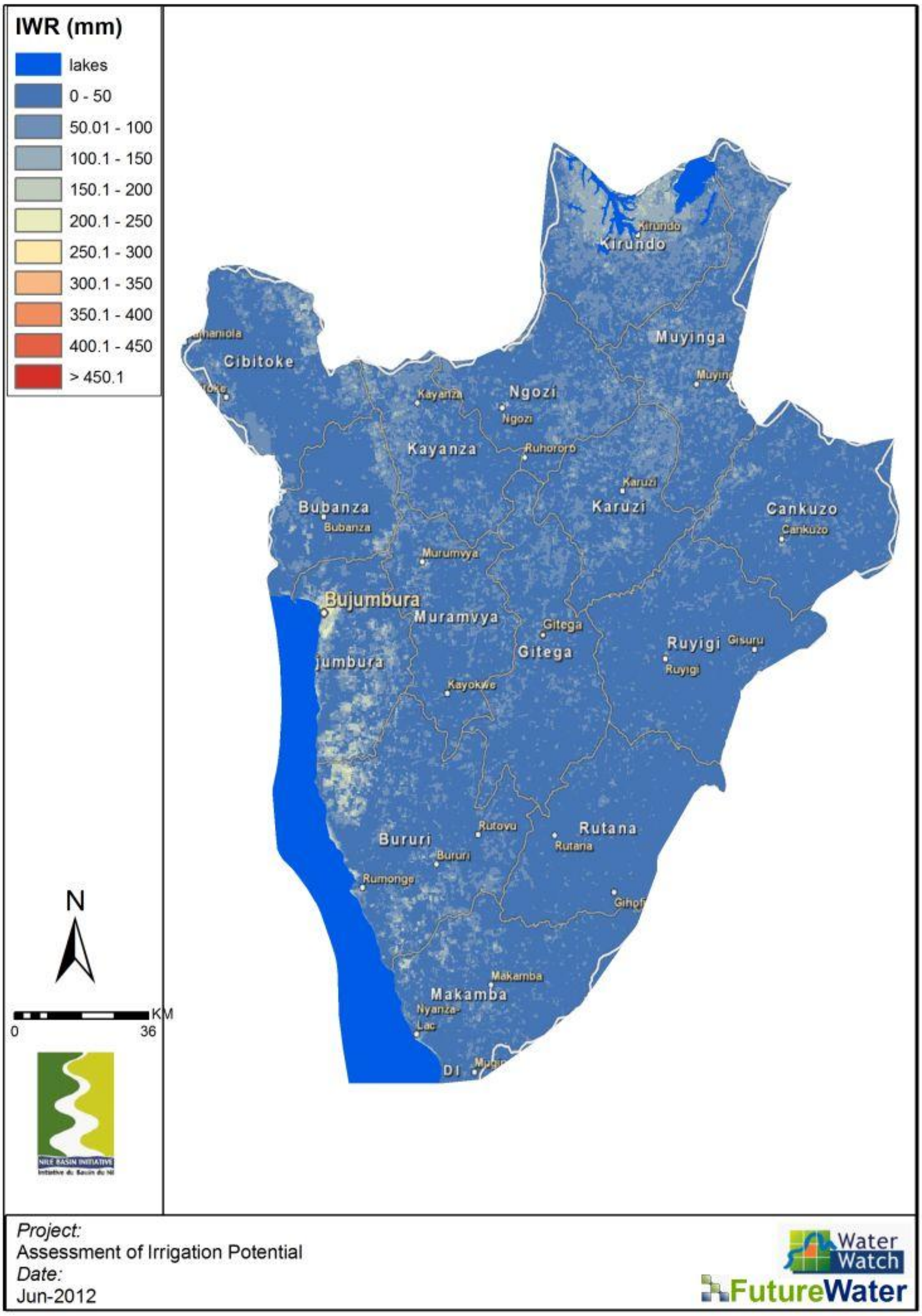
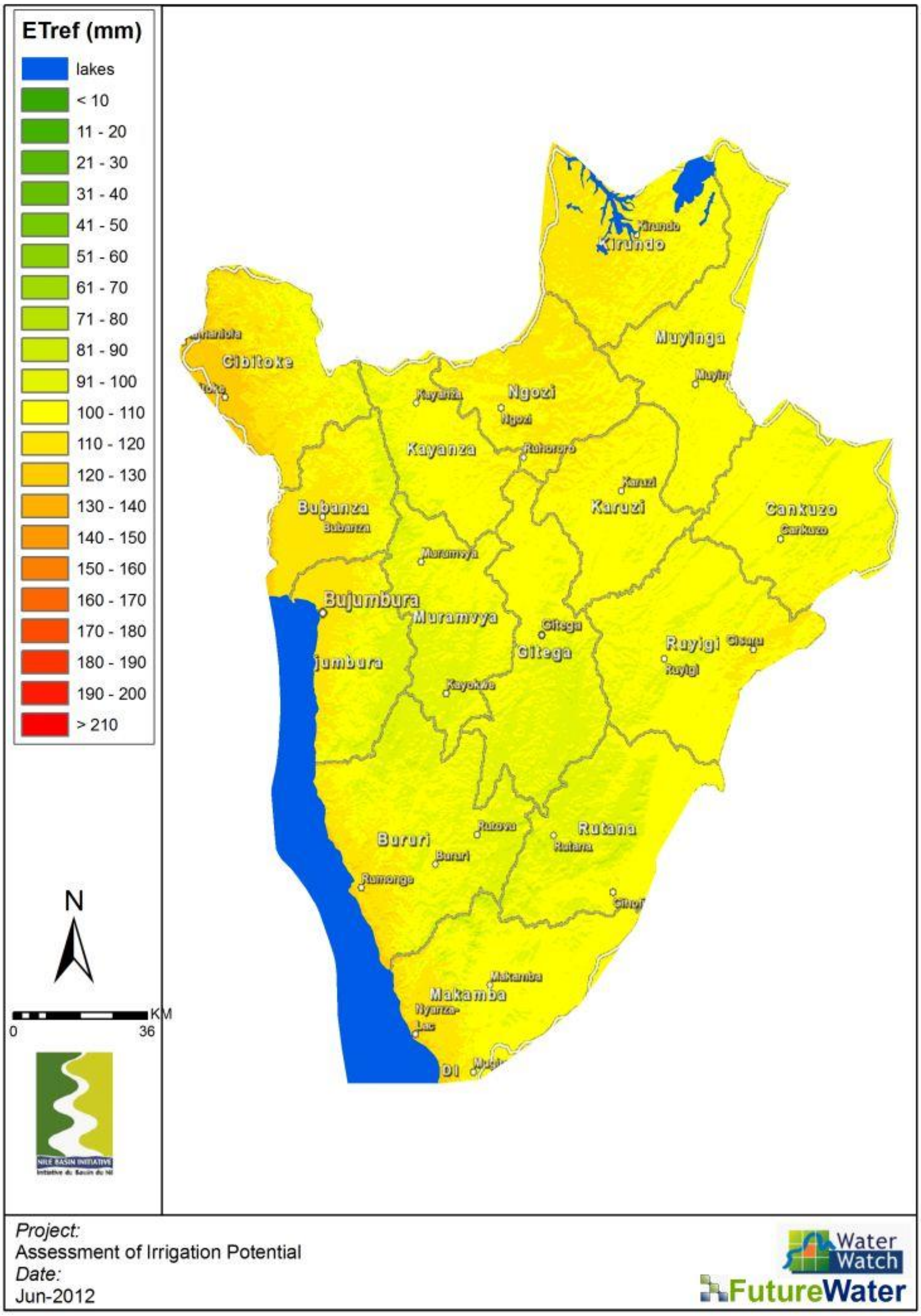


Figure 7: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for March (Average 2001-2010). (Source: study analysis).

April


ETref (mm)
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180 - 190
190 - 200
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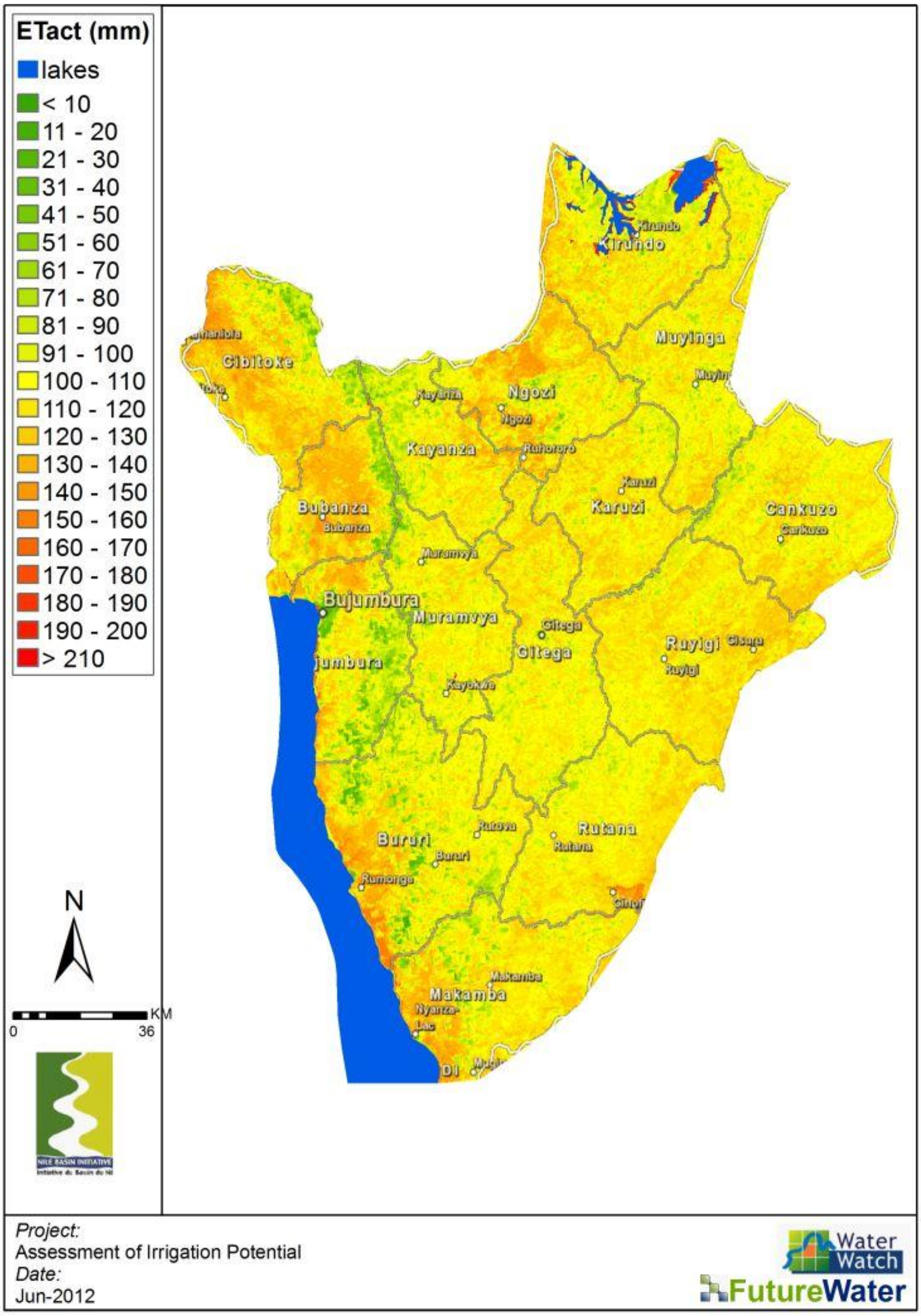
ETact (mm)
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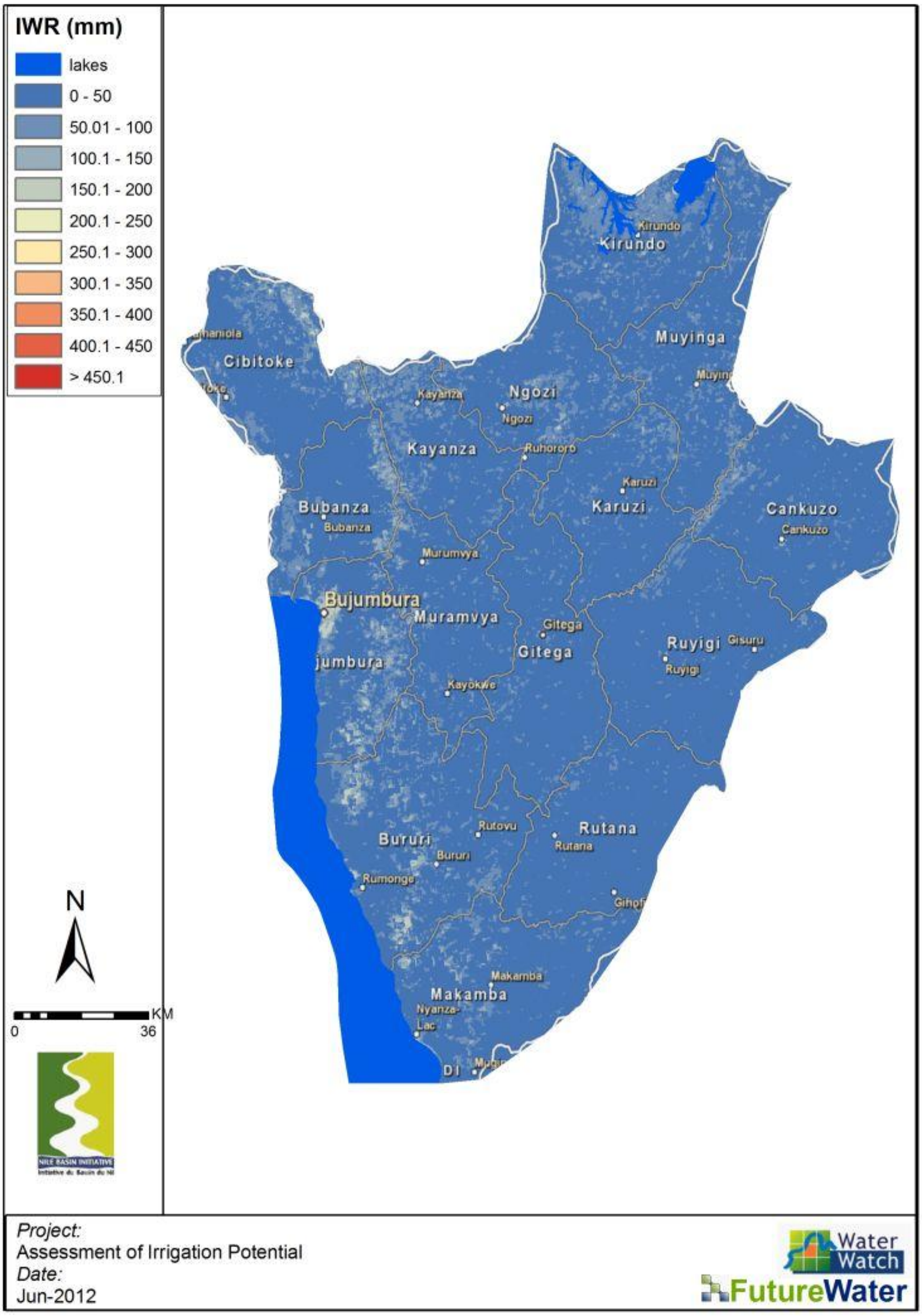
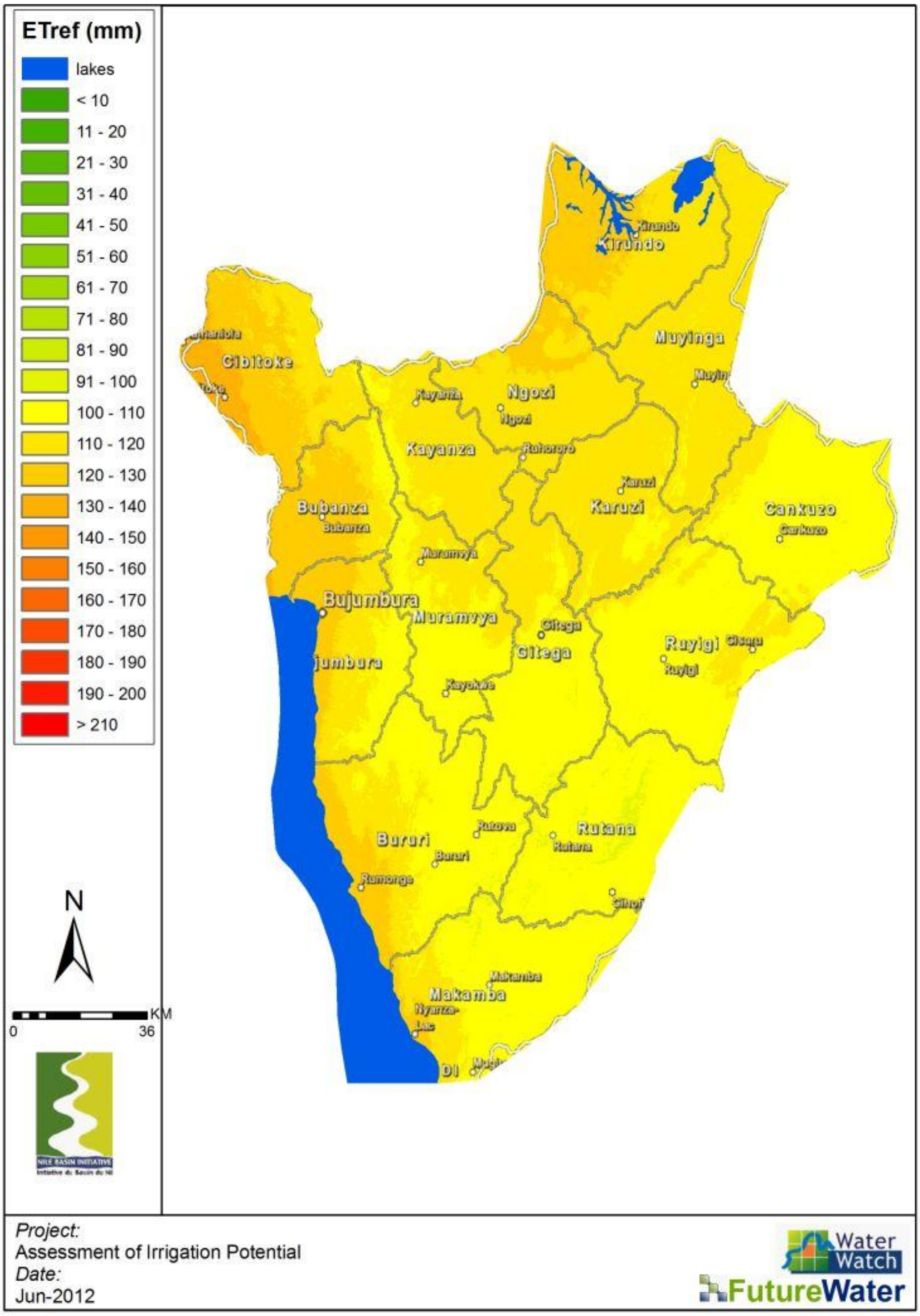


Figure 8: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for April (Average 2001-2010). (Source: study analysis).

May


ETref (mm)
lakes
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11 - 20
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81 - 90
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160 - 170
170 - 180
180 - 190
190 - 200
> 210
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Cankuzo
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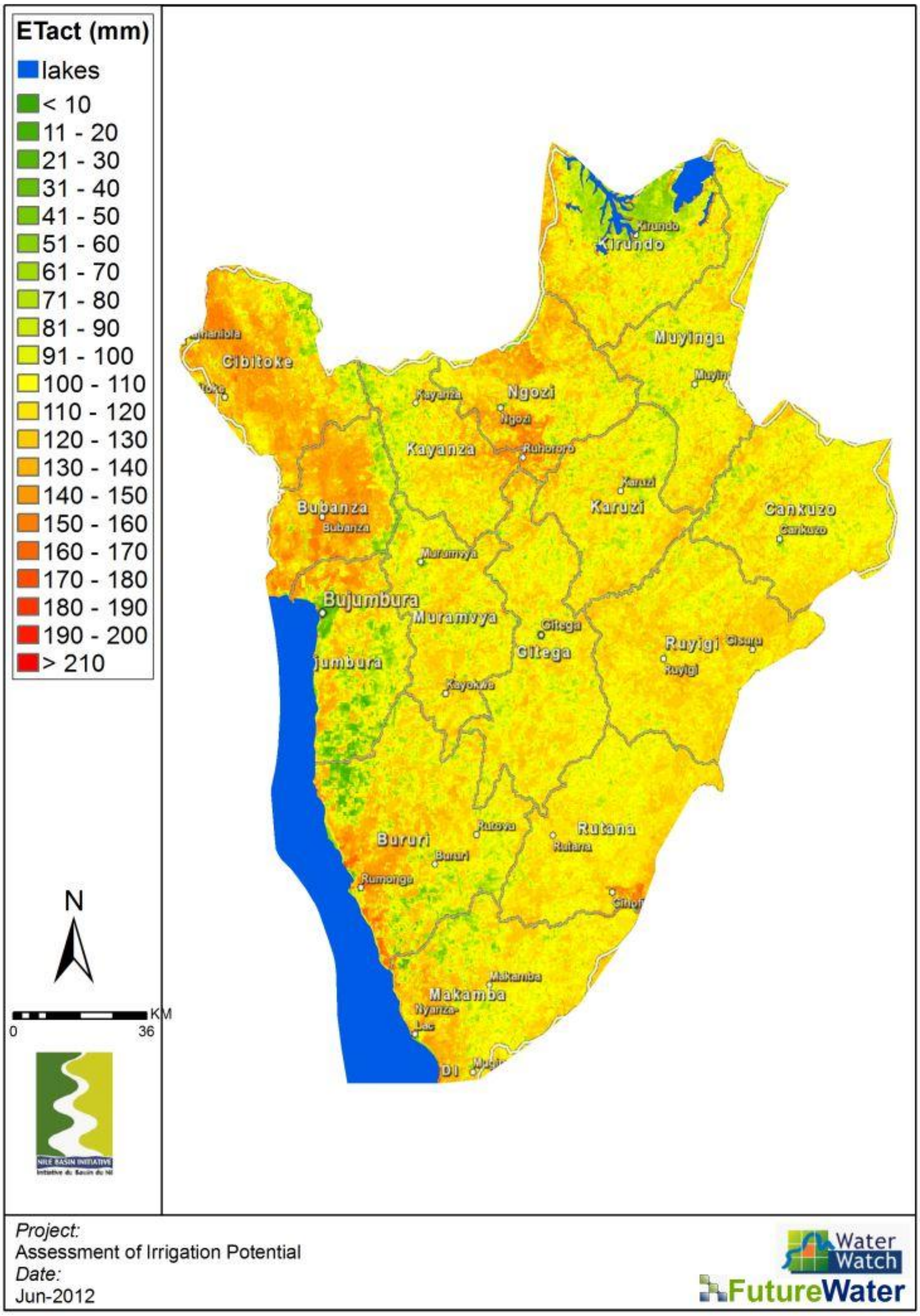
ETact (mm)
lakes
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100 - 110
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130 - 140
140 - 150
150 - 160
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170 - 180
180 - 190
190 - 200
> 210
Kirundo
Kirundo
Muyinga
Cibitoke
Kayanza
Ngozi
Ngozi
Kayanza
Ruhororo
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Cankuzo
Cankuzo
Bubanza
Bubanza
Muramvya
Bujumbura
Muramvya
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
Kayokwe
Rutovu
Rutana
Rutana
Bururi
Bururi
Rumonge
Makamba
Makamba
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Lac
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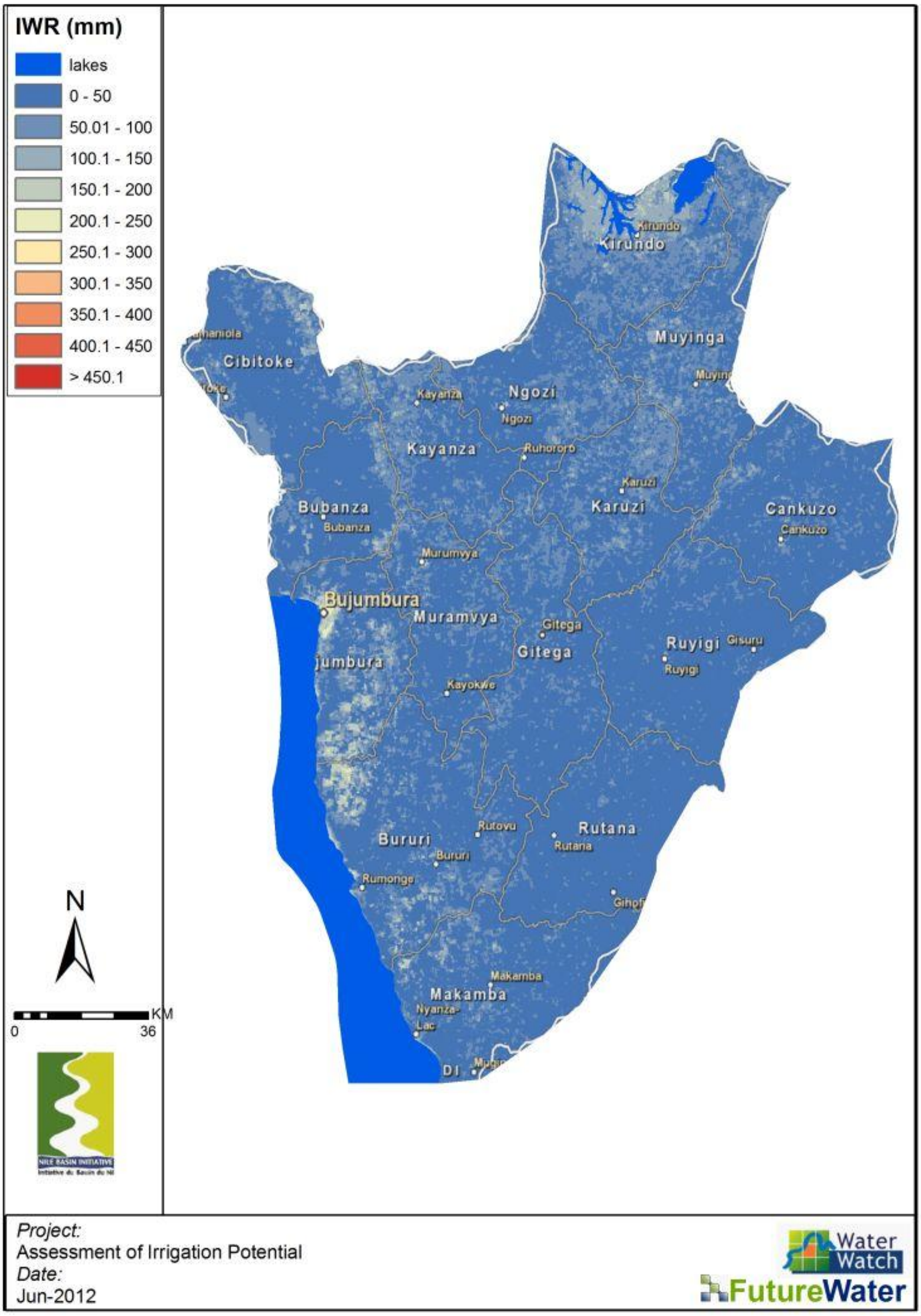
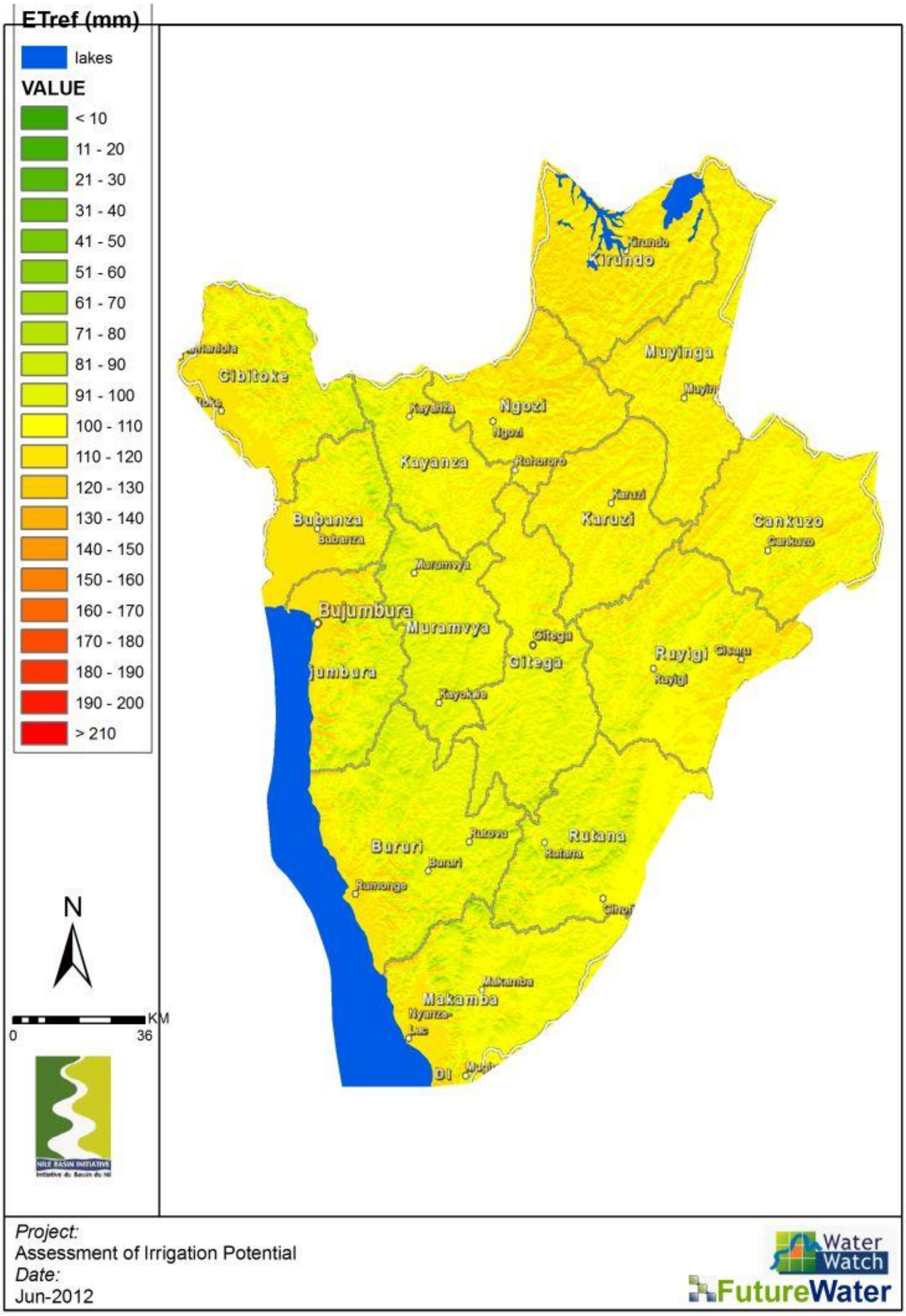


Figure 9: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for May (Average 2001-2010). (Source: study analysis).

June



ETref (mm)
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61 - 70
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81 - 90
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160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
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0
36
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Karuzi
Cankuzo
Bubanza
Bujumbura
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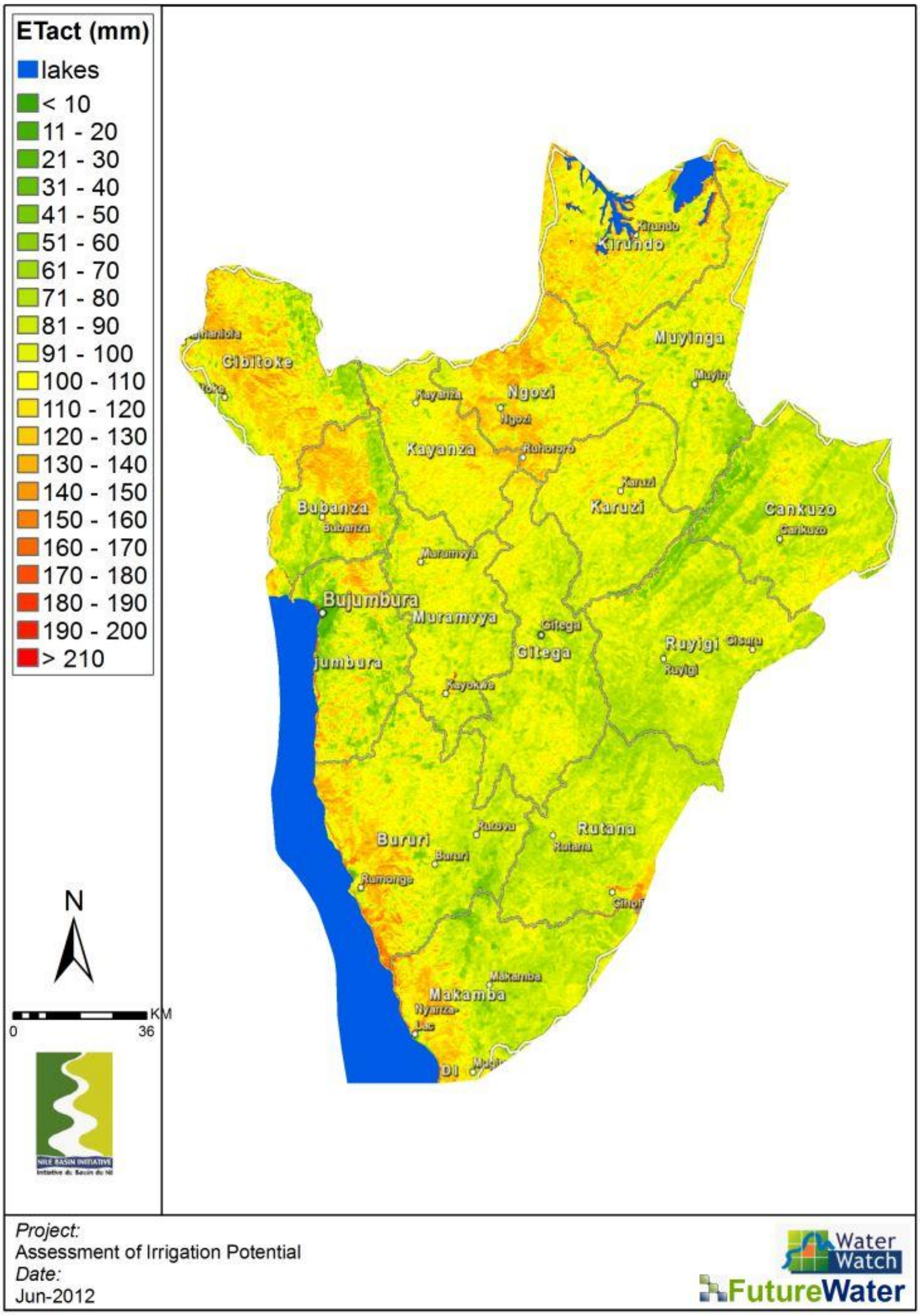

ETact (mm)
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140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Ruhororo
Karuzi
Cankuzo
Bubanza
Muramvya
Bujumbura
Gitega
Ruyigi
Gisuru
Kayokwe
Bururi
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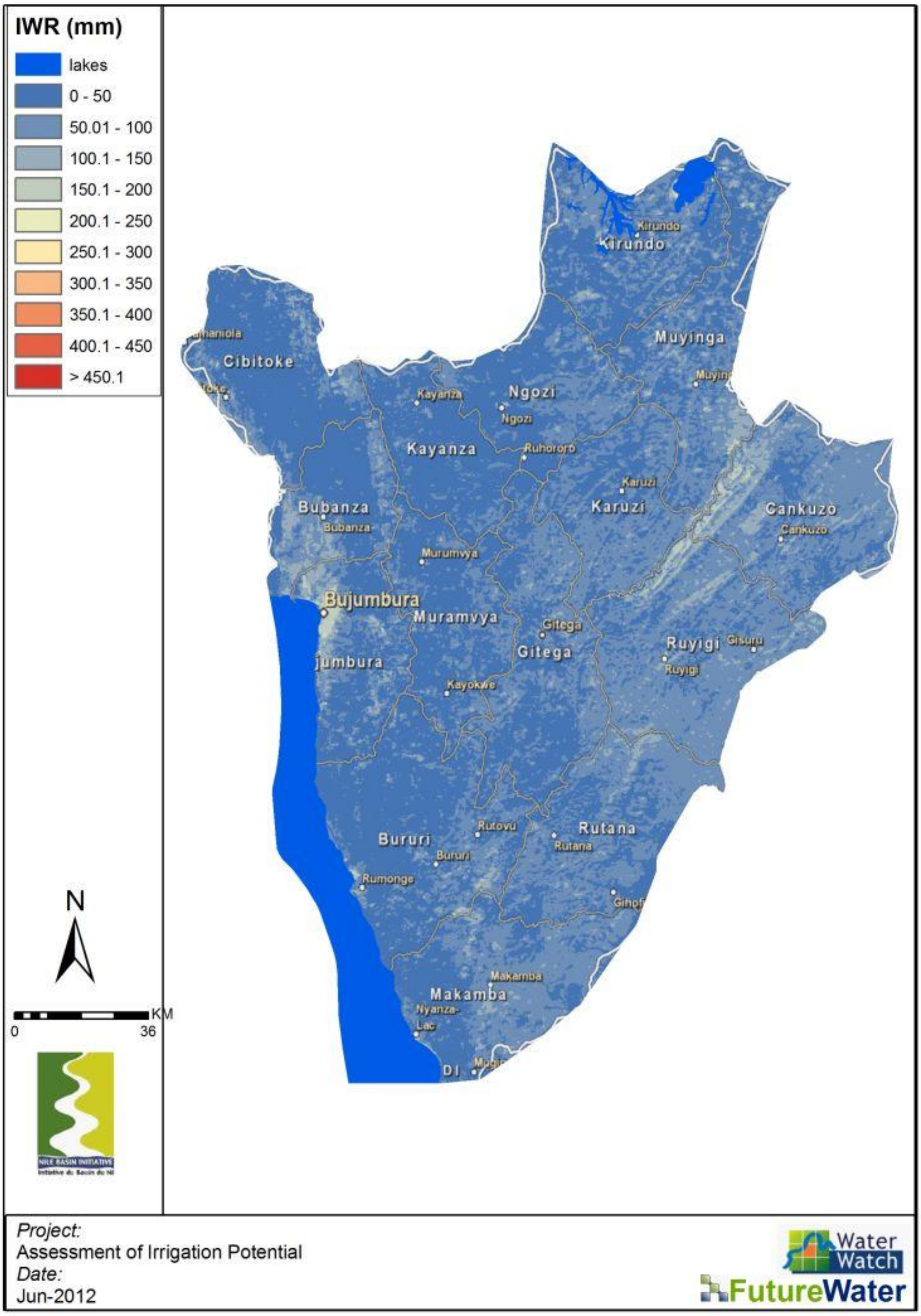
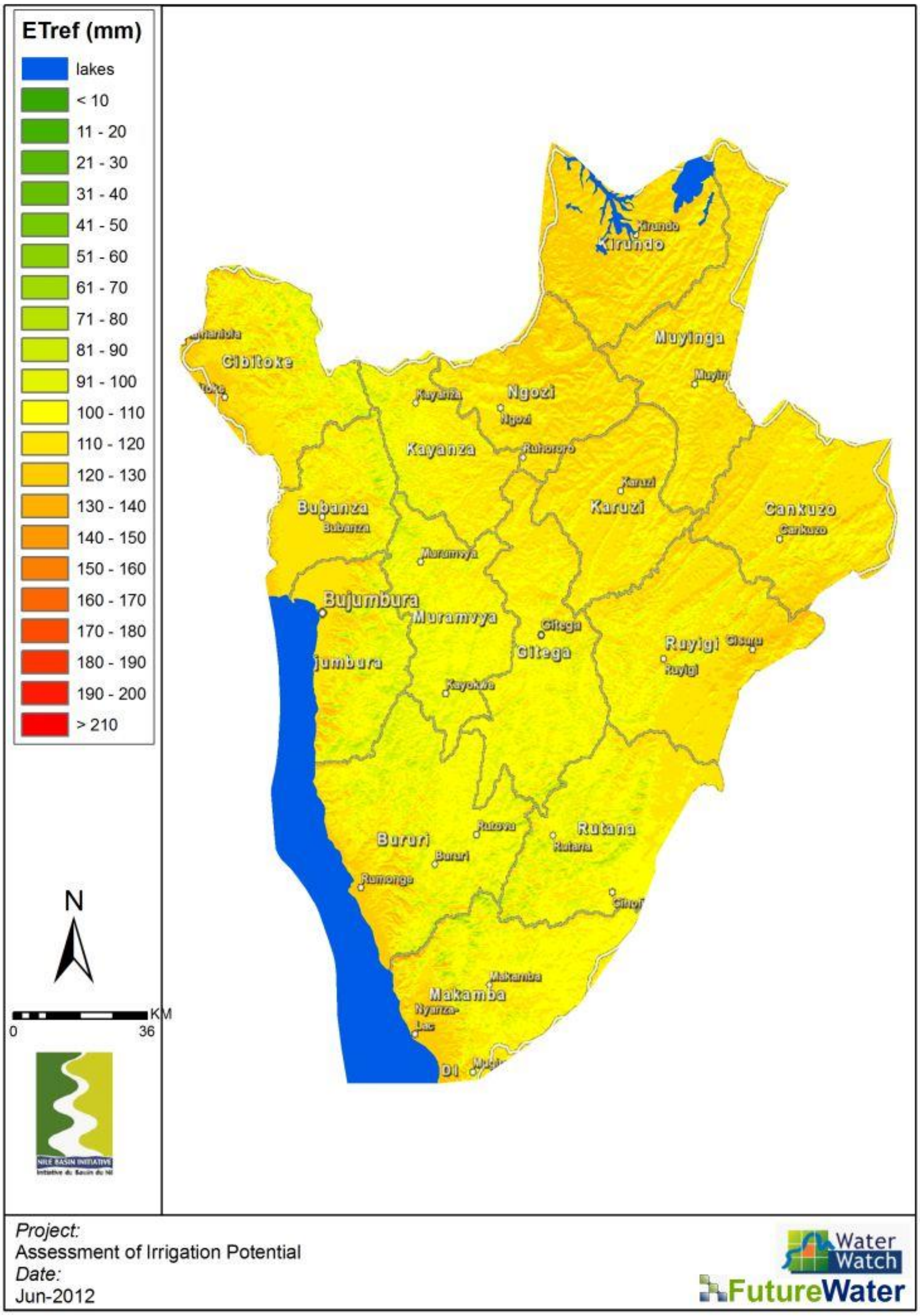


Figure 10: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). For June (Average 2001-2010). (Source: study analysis).

July



ETref (mm)
lakes
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31 - 40
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61 - 70
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81 - 90
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170 - 180
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190 - 200
> 210
N
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36
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Ruhororo
Karuzi
Cankuzo
Bubanza
Muramvya
Bujumbura
Gitega
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Gisuru
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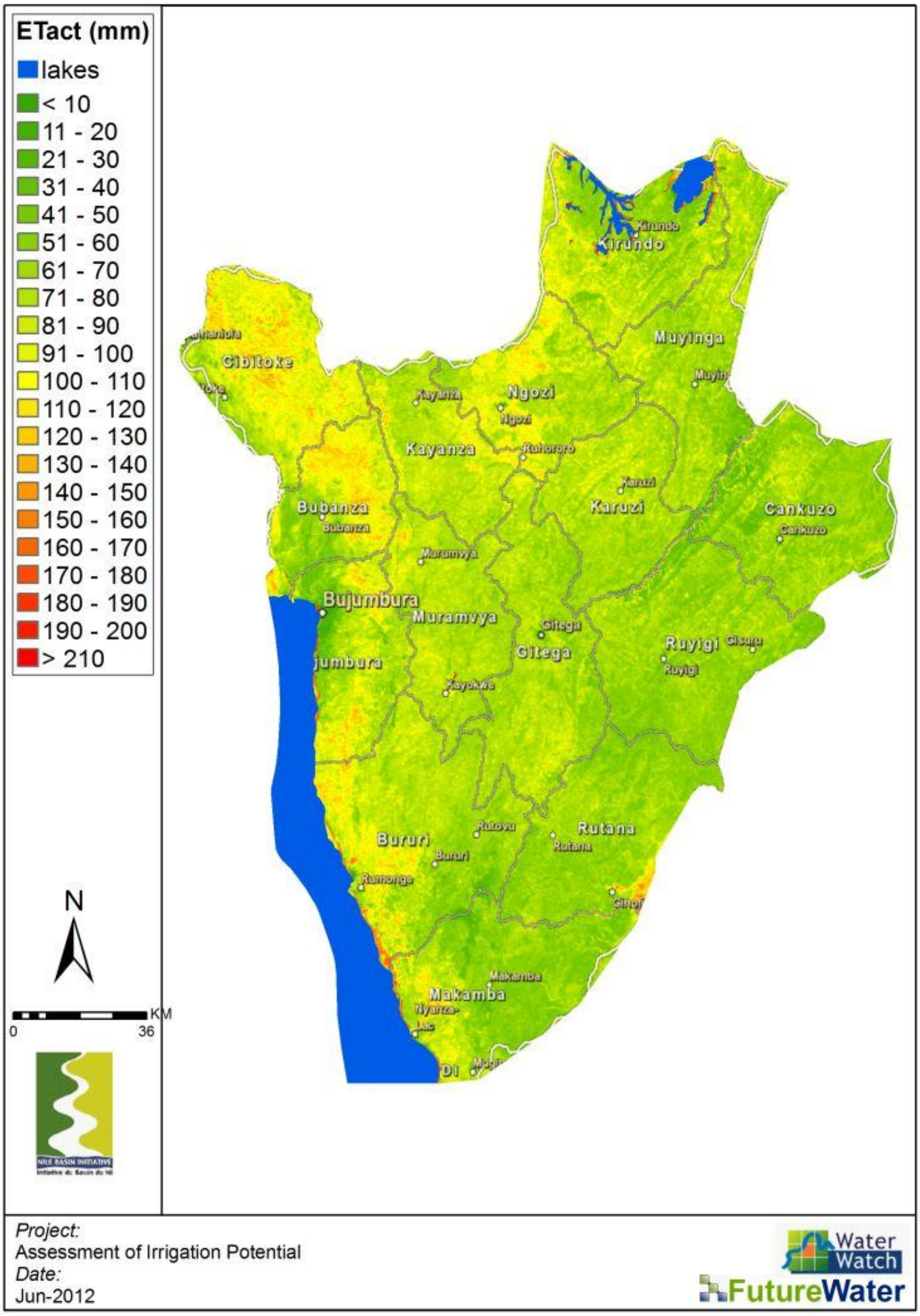
ETact (mm)
lakes
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Cankuzo
Bubanza
Muramvya
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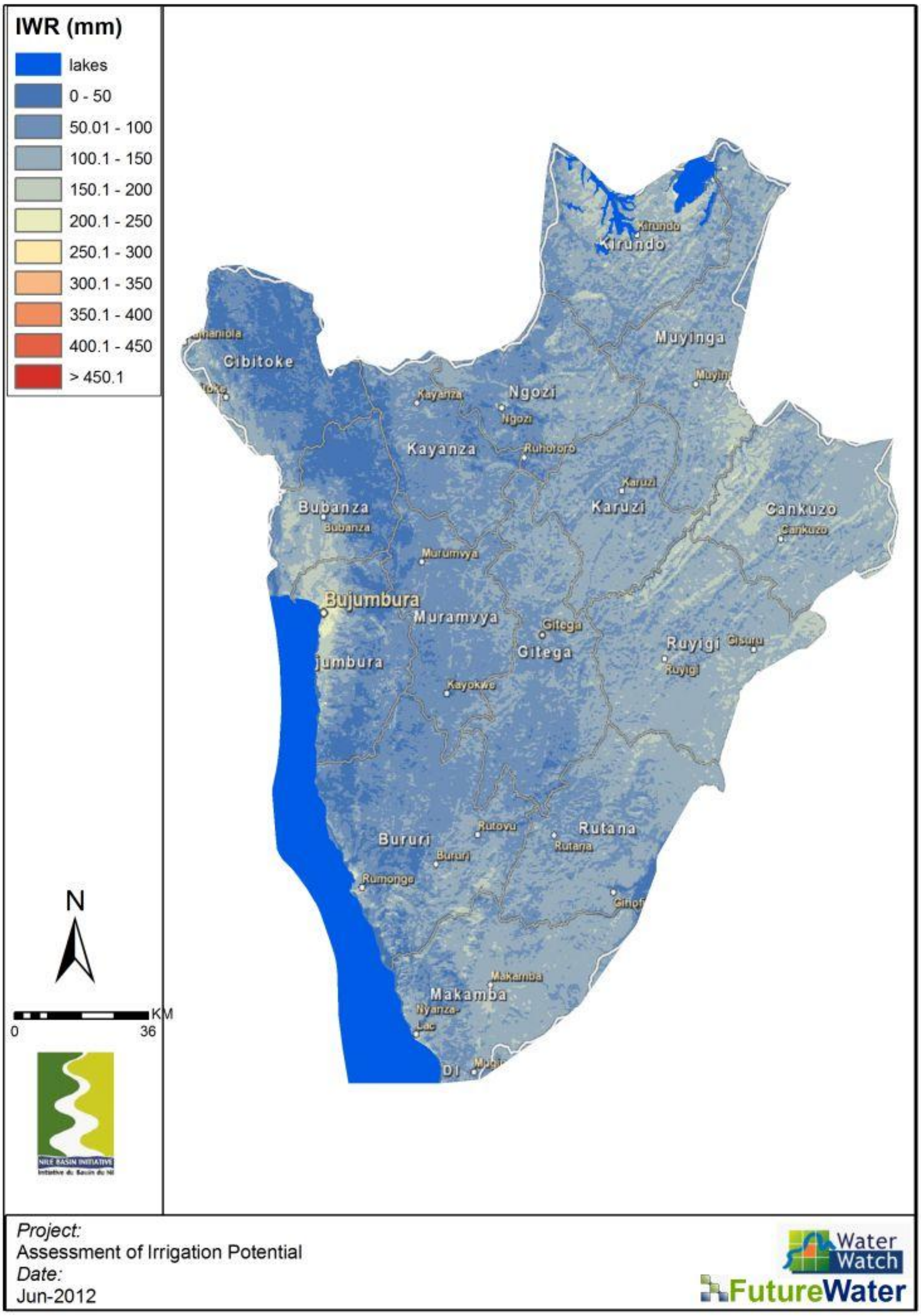
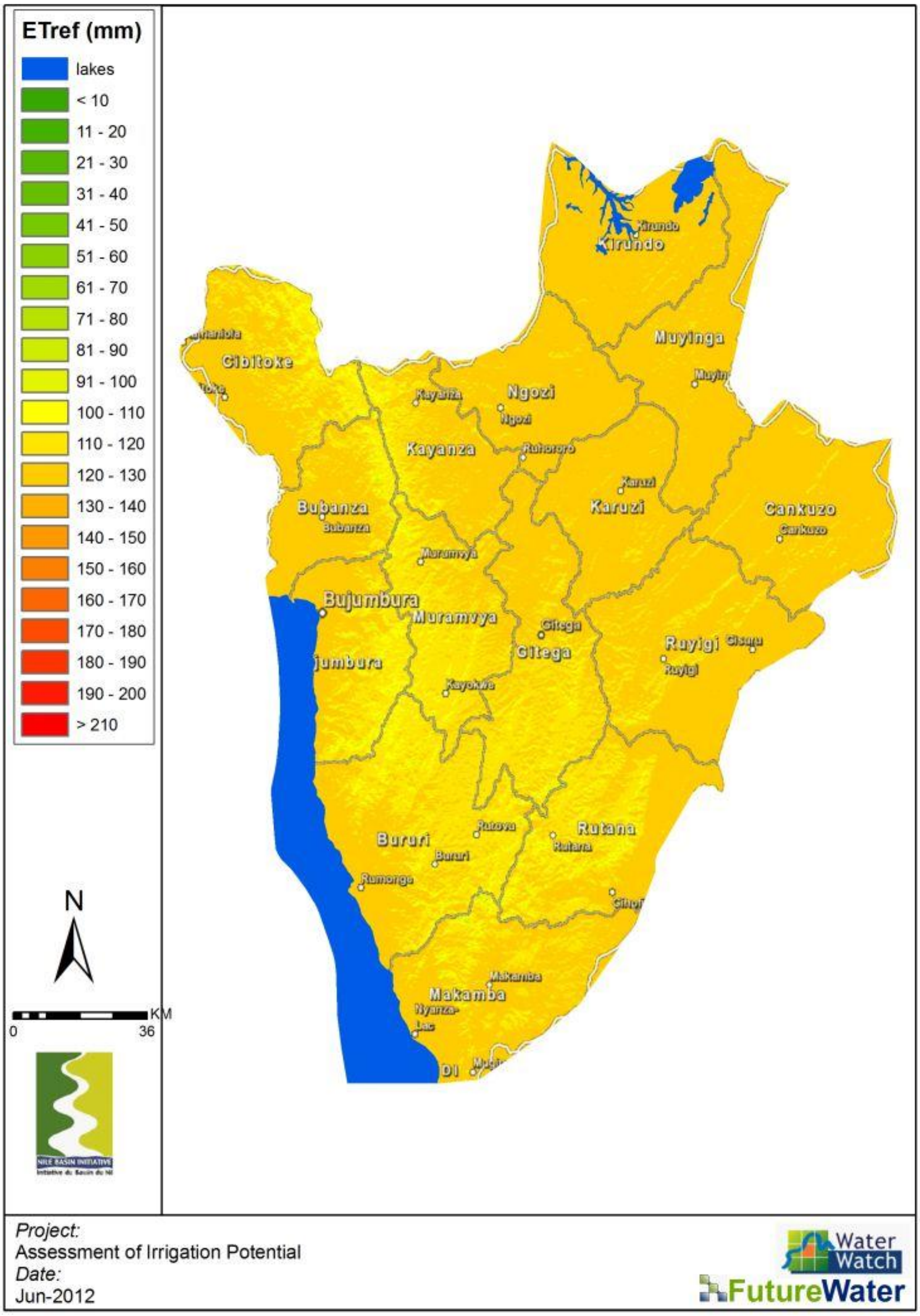


Figure 11: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for July (Average 2001-2010). (Source: study analysis).

August



ETref (mm)
lakes
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11 - 20
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31 - 40
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51 - 60
61 - 70
71 - 80
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160 - 170
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190 - 200
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Kirundo
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Cankuzo
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Muramvya
Gitega
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Bururi
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Jun-2012
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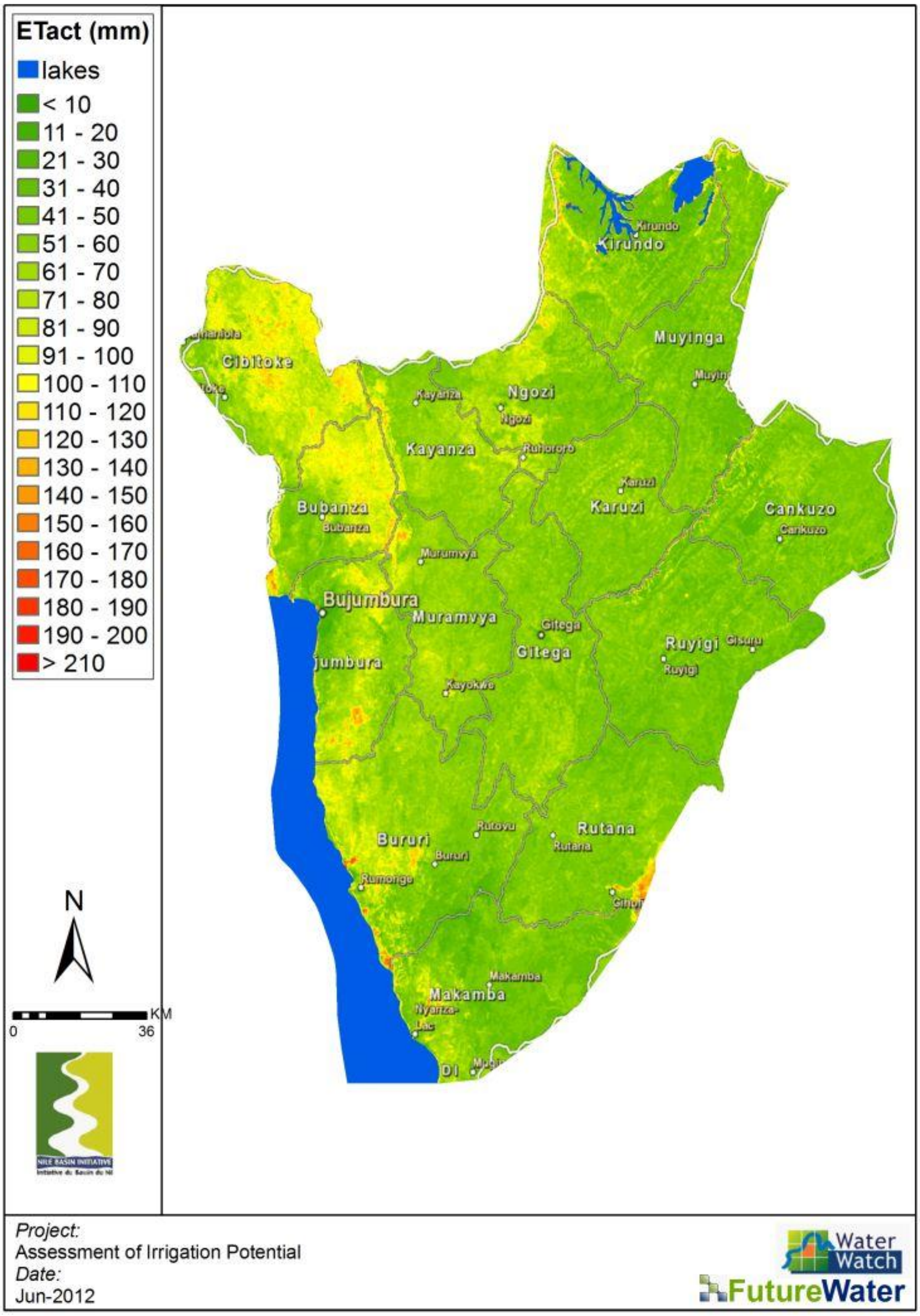
FutureWater


ETact (mm)
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Karuzi
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Cankuzo
Cankuzo
Bubanza
Bubanza
Murumvya
Bujumbura
Muramvya
Gitega
Gitega
Ruyigi
Ruyigi
Gisuru
jumbura
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NILE BASIN INITIATIVE

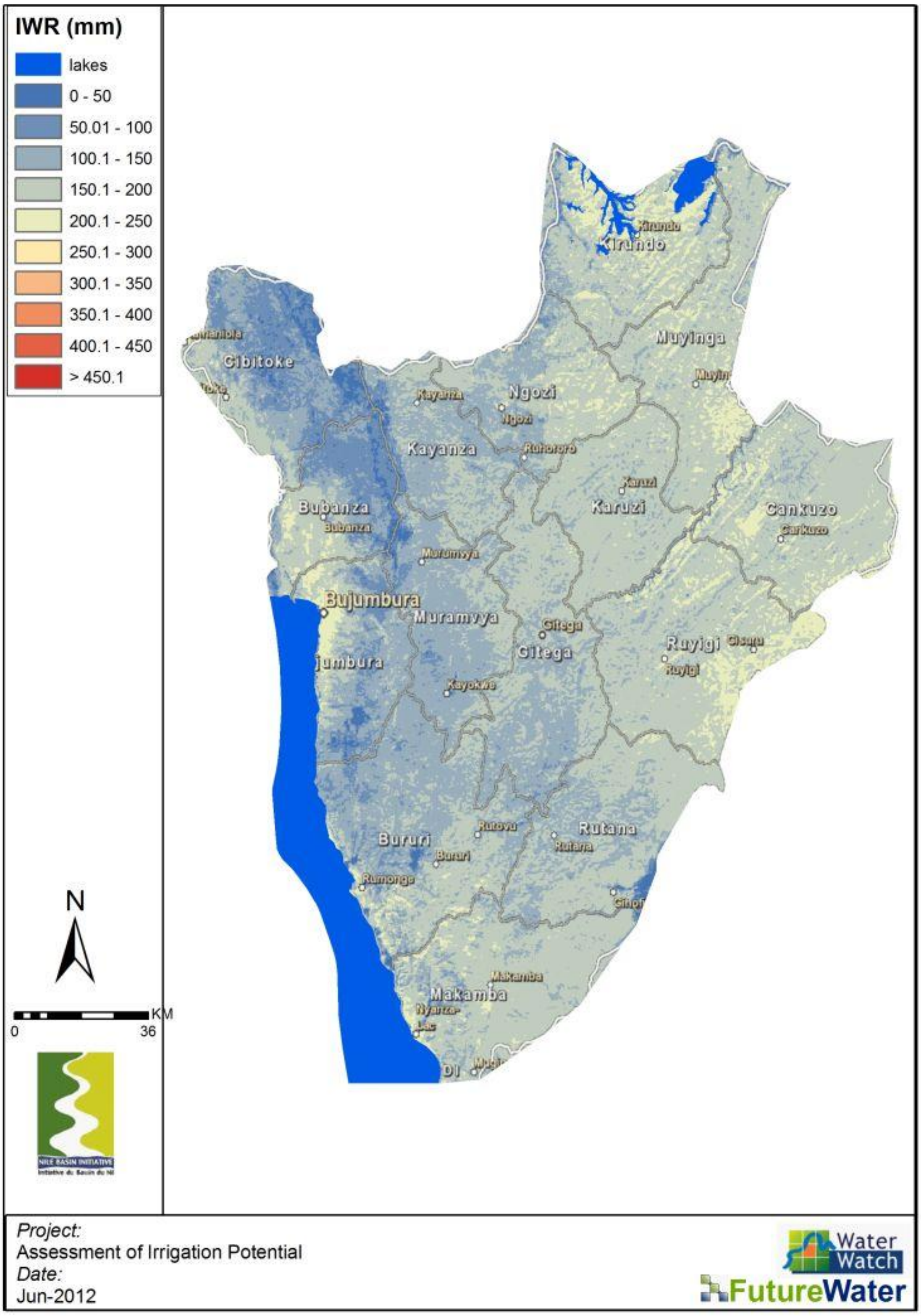
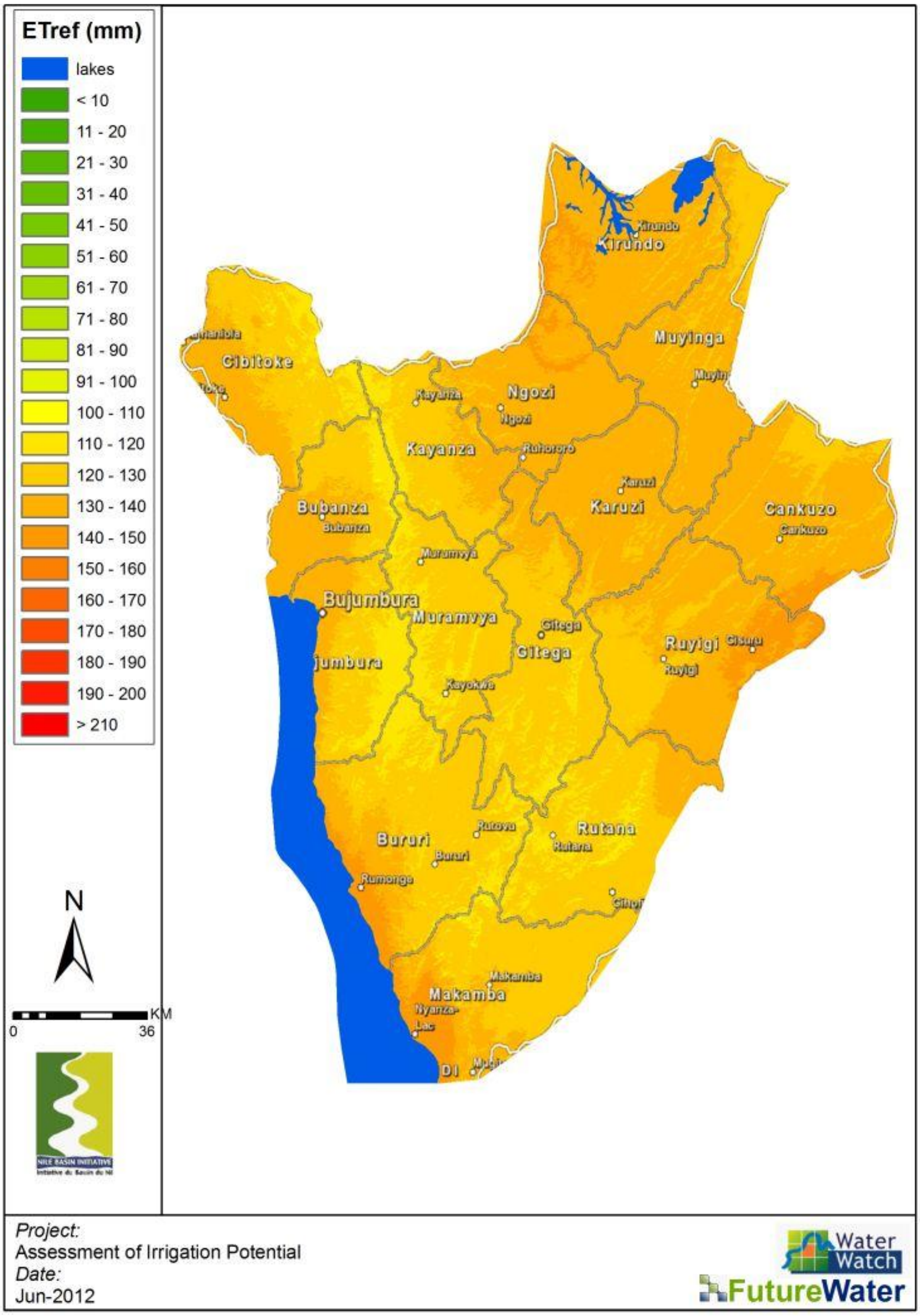


Figure 12: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for August (Average 2001-2010). (Source: study analysis).

September


ETref (mm)
lakes
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31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
36
Kirundo
Kirundo
Muyinga
Cibitoke
Ngozi
Ngozi
Kayanza
Kayanza
Ruhororo
Karuzi
Karuzi
Cankuzo
Cankuzo
Bubanza
Bubanza
Muramvya
Bujumbura
Muramvya
Gitega
Gitega
Ruyigi
Ruyigi
Kayokwe
Bururi
Bururi
Rutovu
Rutana
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Project:
Assessment of Irrigation Potential
Date:
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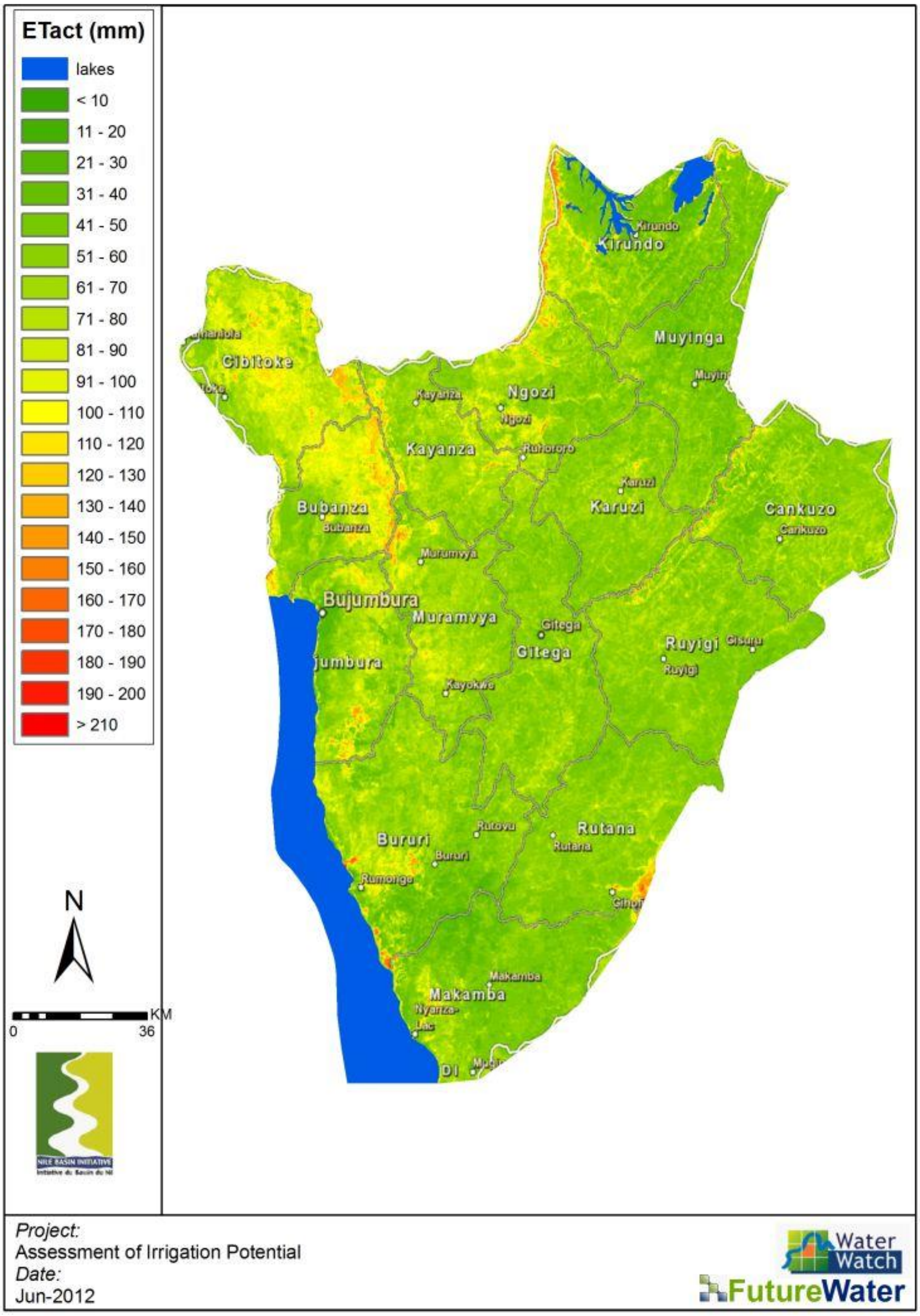
FutureWater


ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
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Bubanza
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Muramvya
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Gitega
Ruyigi
Gisuru
Gitega
jumbura
Ruyigi
Kayokwe
Rutovu
Rutana
Bururi
Rutana
Bururi
Rumonge
Makamba
Makamba
Nyanza-
Lac
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36
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
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FutureWater

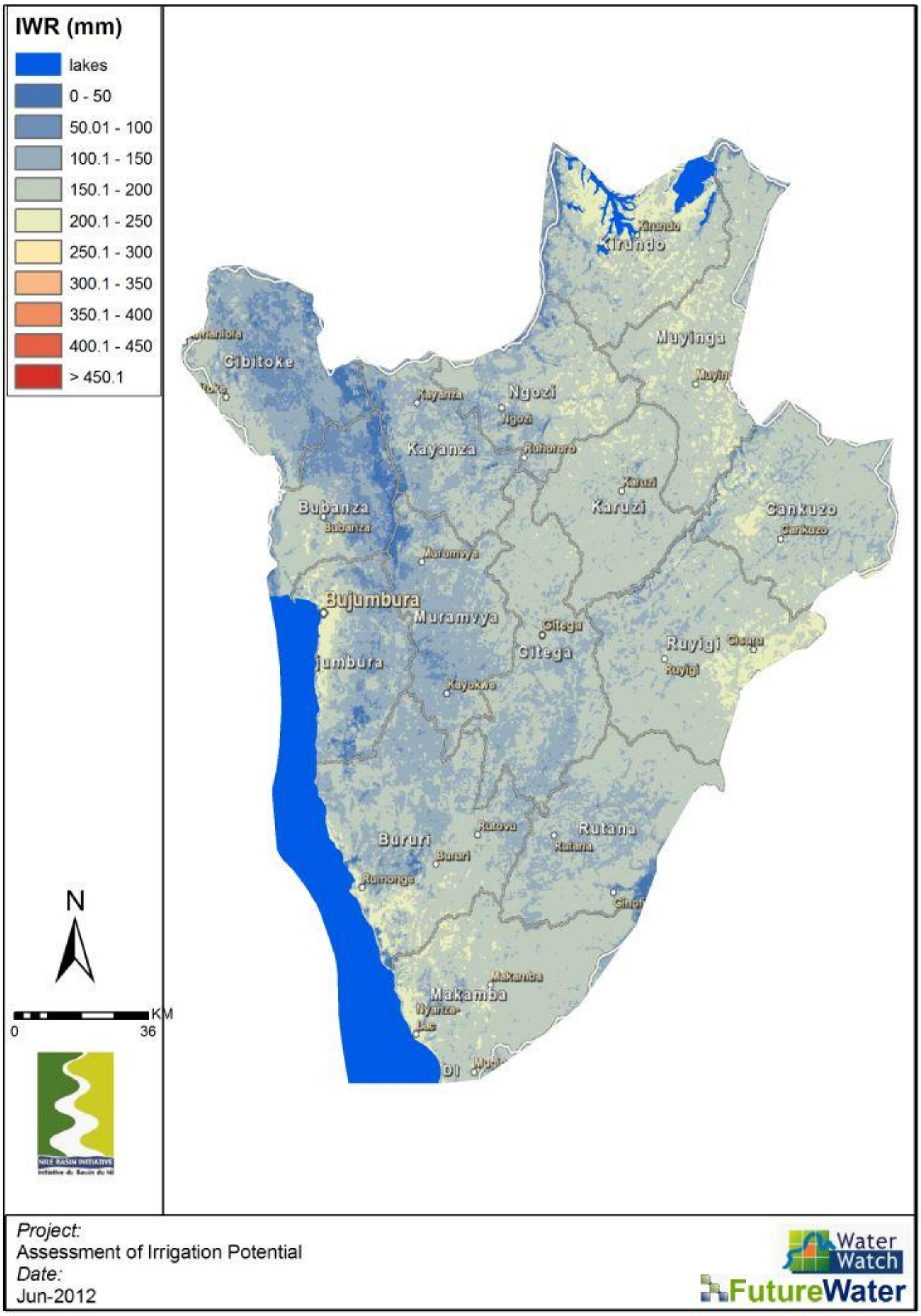
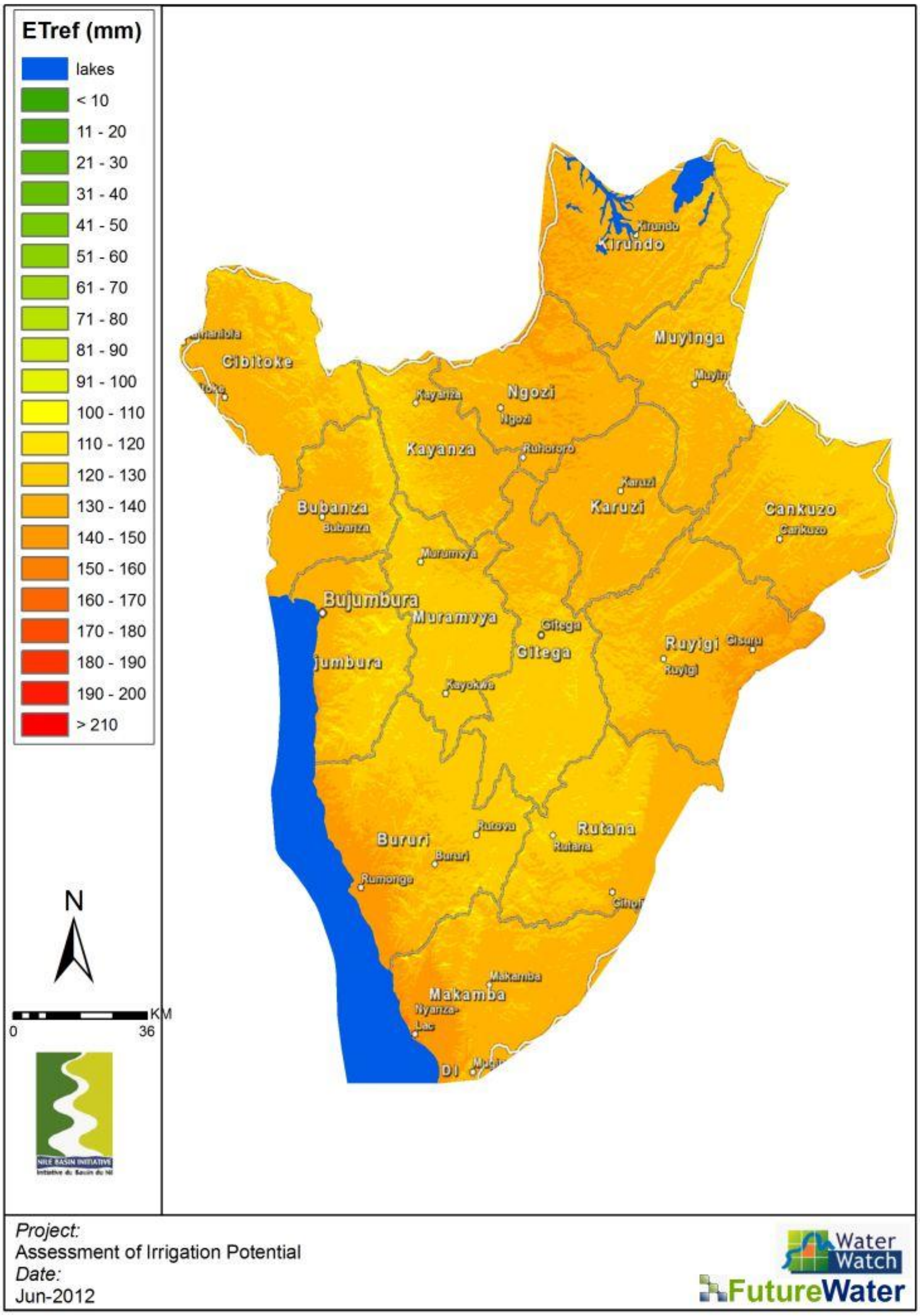


Figure 13: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for September (Average 2001-2010). (Source: study analysis).

October



ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Karuzi
Bubanza
Cankuzo
Muramvya
Bujumbura
Gitega
Ruyigi
Bururi
Rutana
Rumonge
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0
36
Project:
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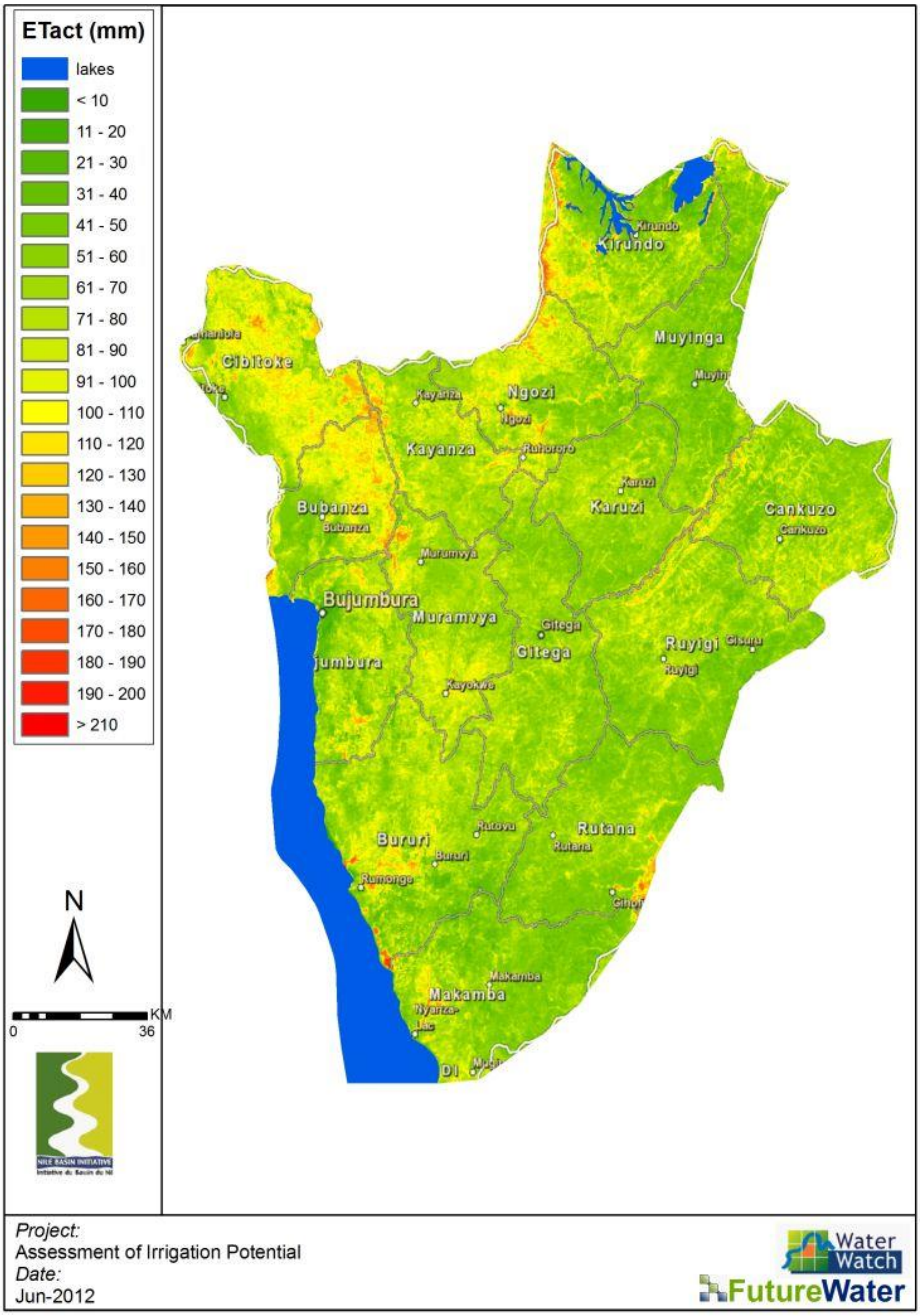
ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
36
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Ruhororo
Karuzi
Cankuzo
Bubanza
Muramvya
Bujumbura
Gitega
Ruyigi
Kayokwe
Rutovu
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Bururi
Rumonge
Makamba
Project:
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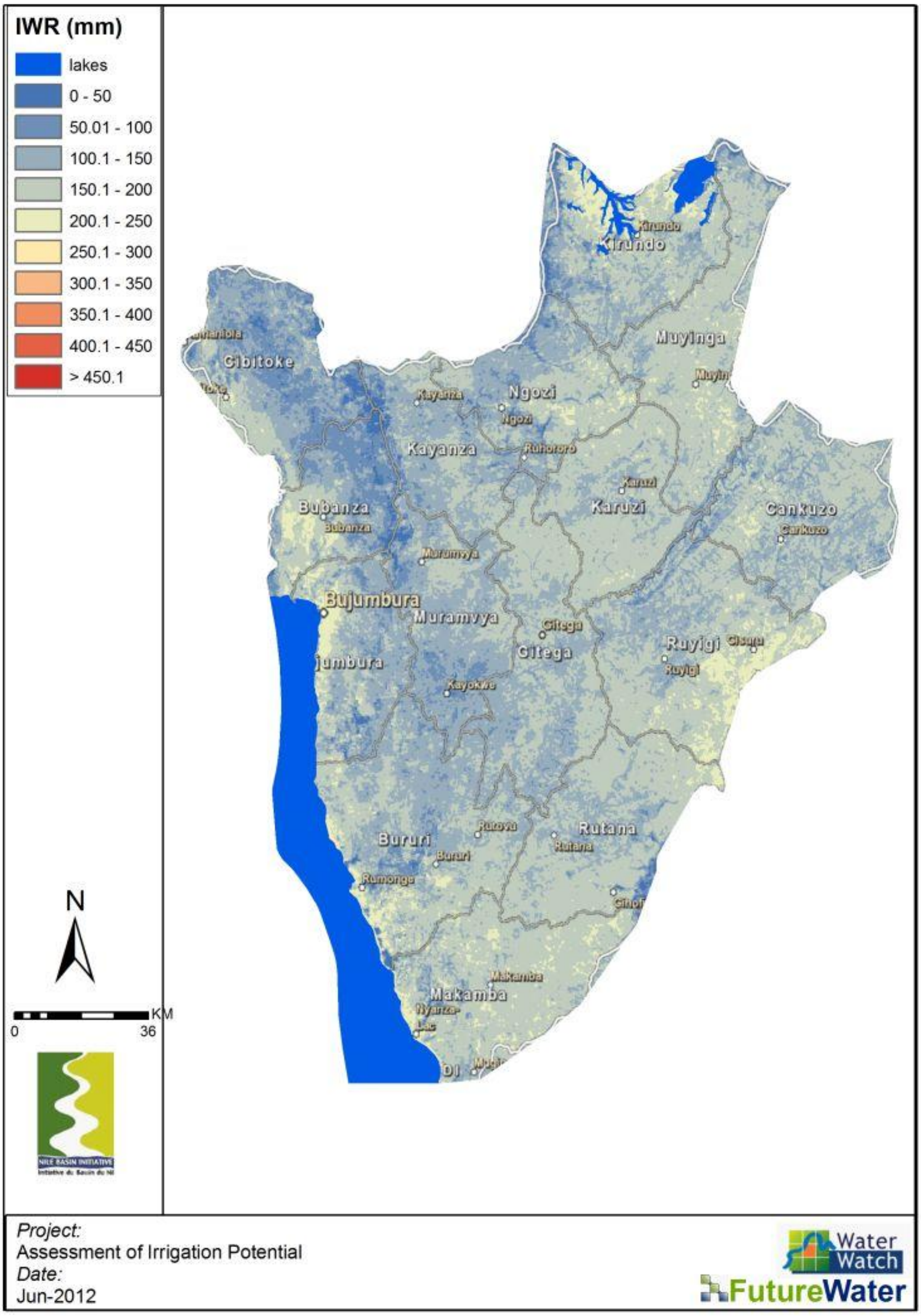
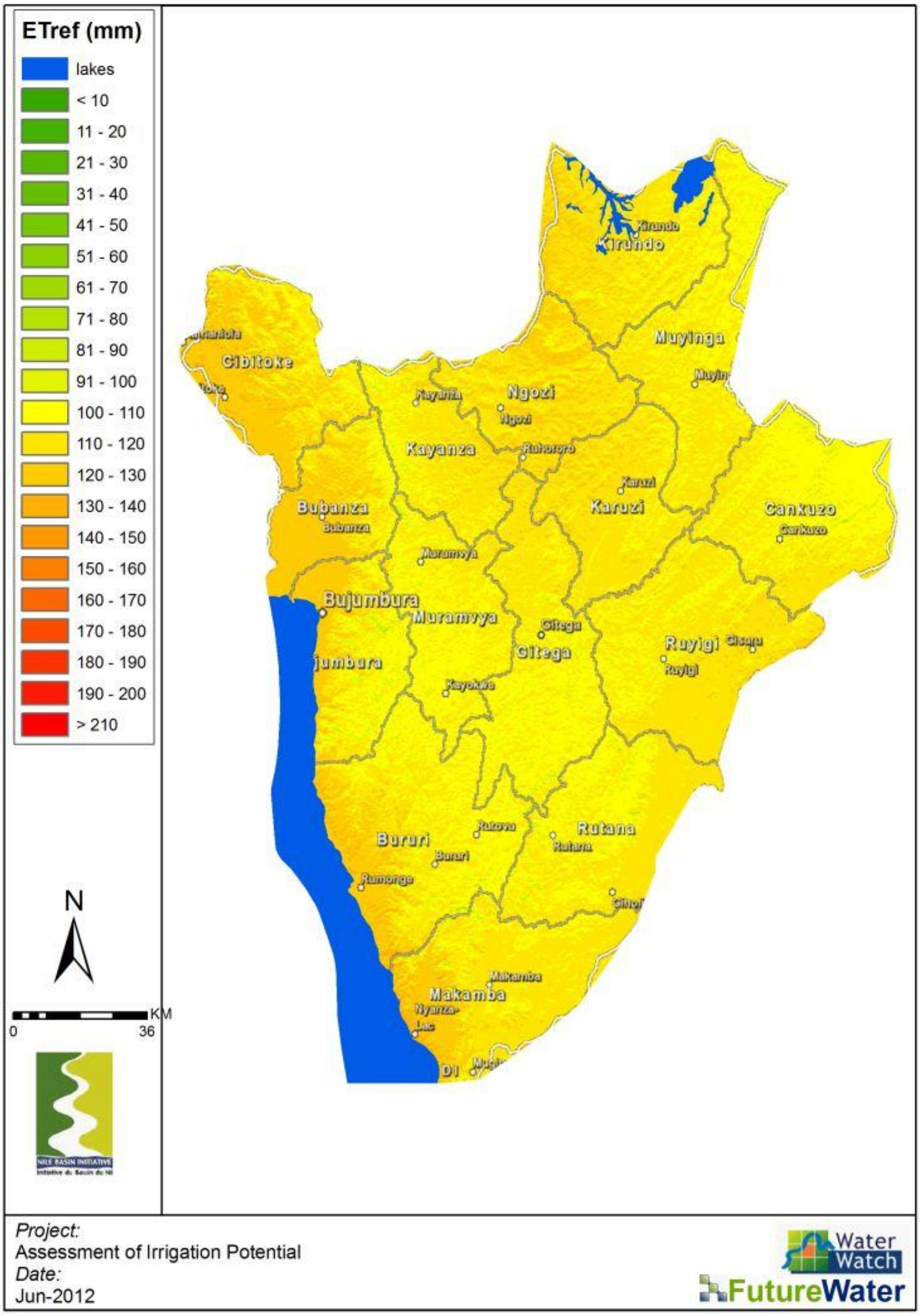


Figure 14: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for October (Average 2001-2010). (Source: study analysis).

November



ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Karuzi
Cankuzo
Bubanza
Muramvya
Bujumbura
Gitega
Ruyigi
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36
Project:
Assessment of Irrigation Potential
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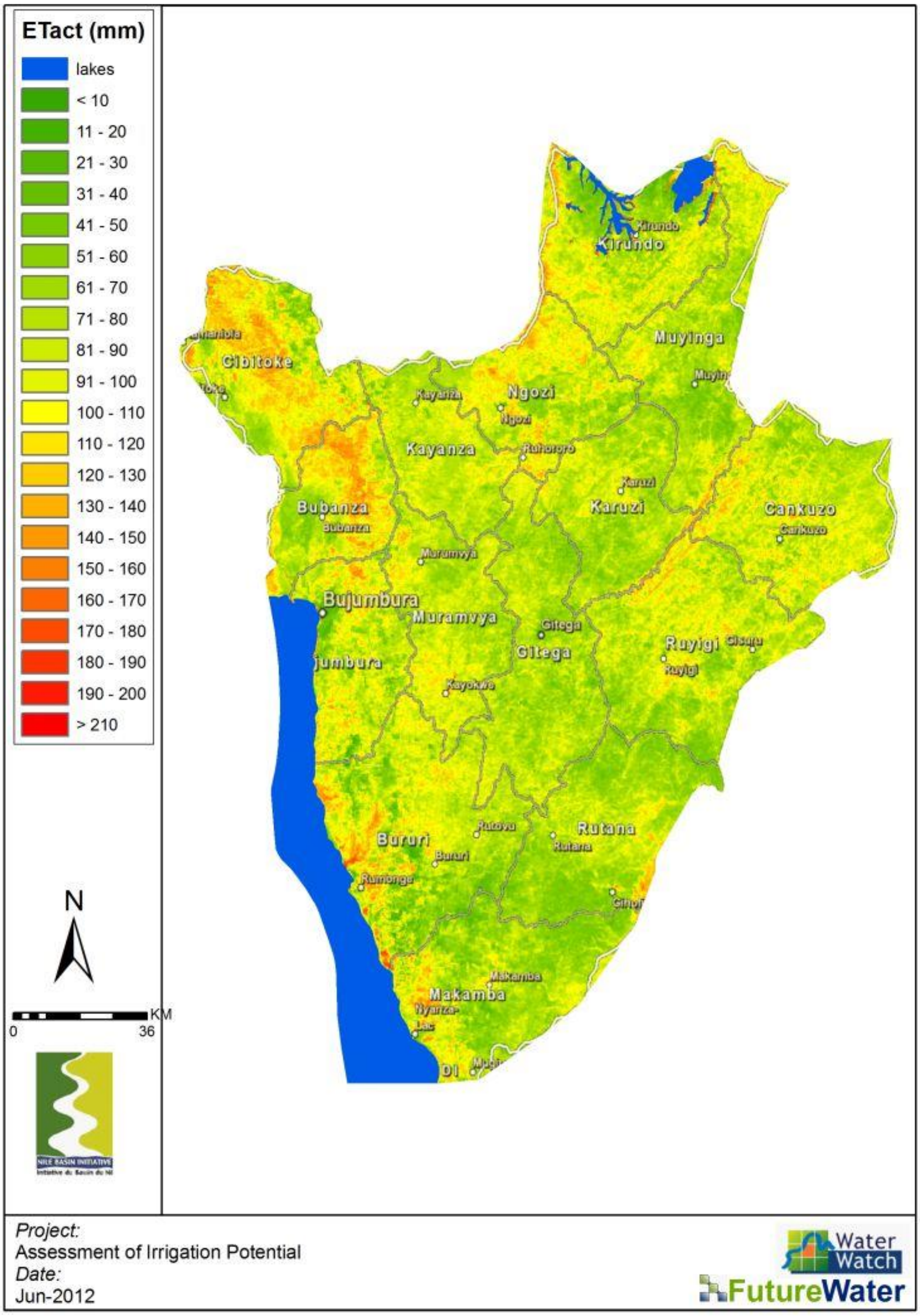
FutureWater


ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
36
Kirundo
Muyinga
Gibitoke
Ngozi
Kayanza
Karuzi
Cankuzo
Bubanza
Muramvya
Bujumbura
Gitega
Ruyigi
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Rutana
Makamba
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
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FutureWater

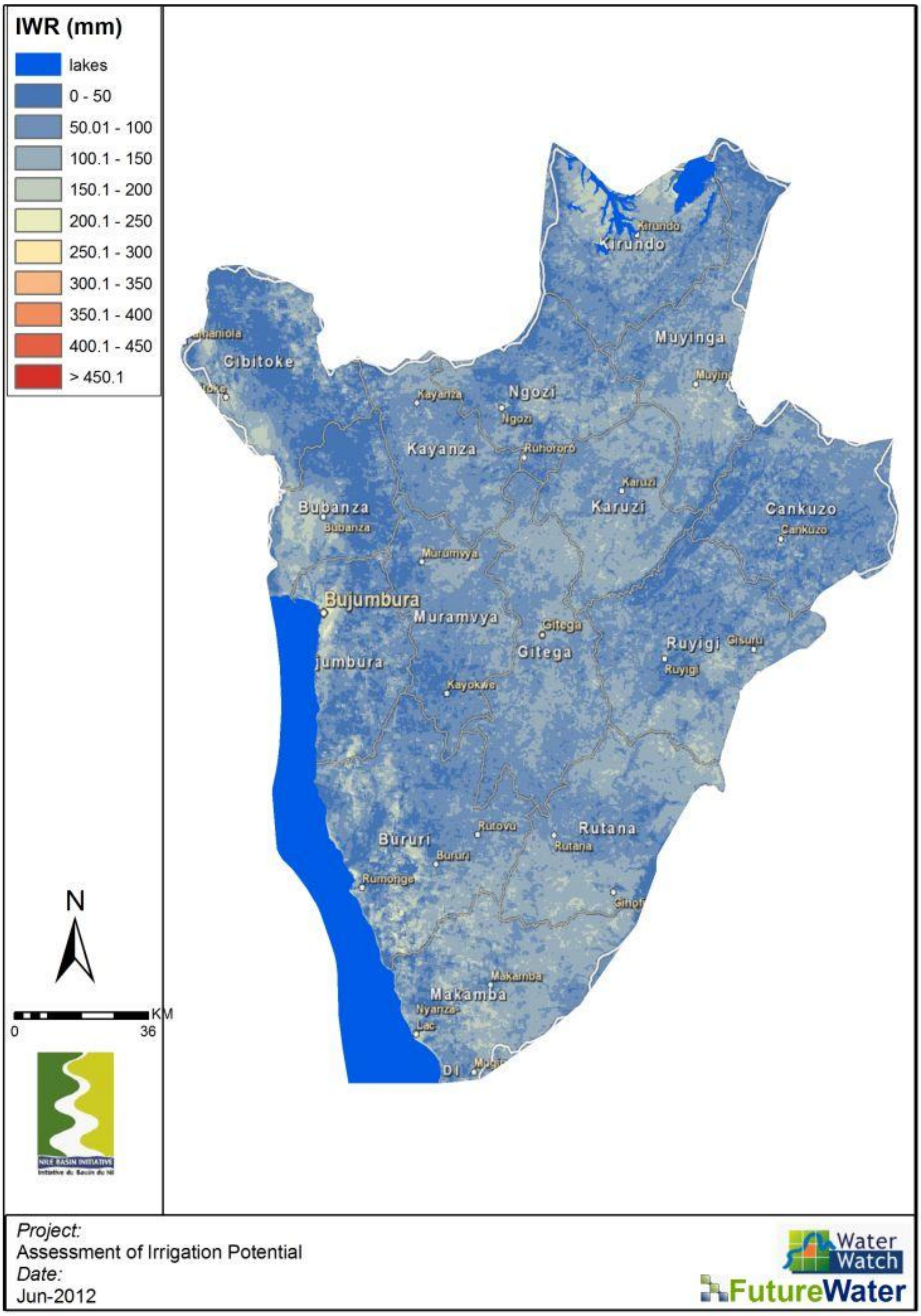
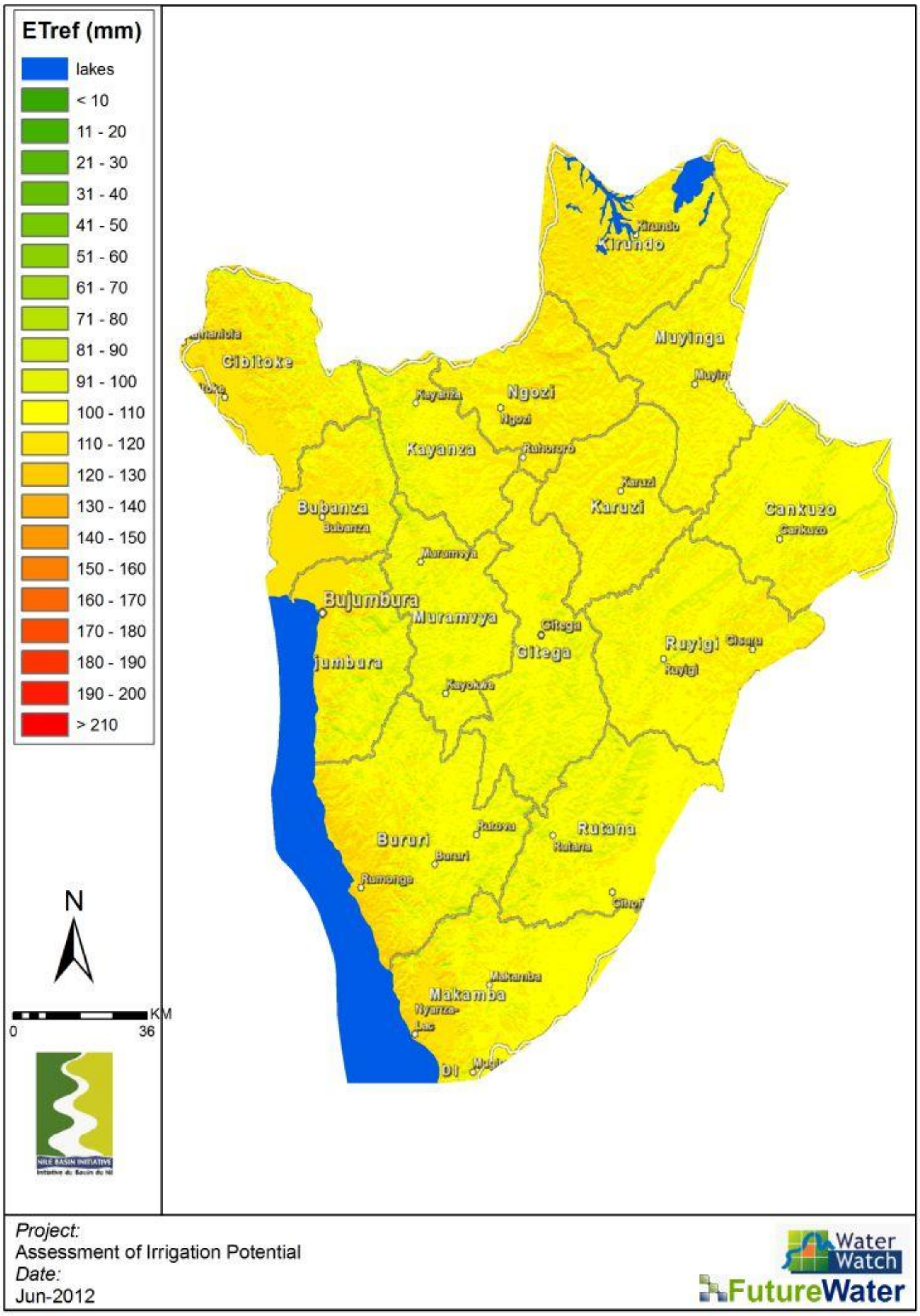


Figure 15: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for November (Average 2001-2010). (Source: study analysis).

December


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
Kirundo
Muyinga
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Kayanza
Karuzi
Cankuzo
Bubanza
Bujumbura
Muramvya
Gitega
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Project:
Assessment of Irrigation Potential
Date:
Jun-2012
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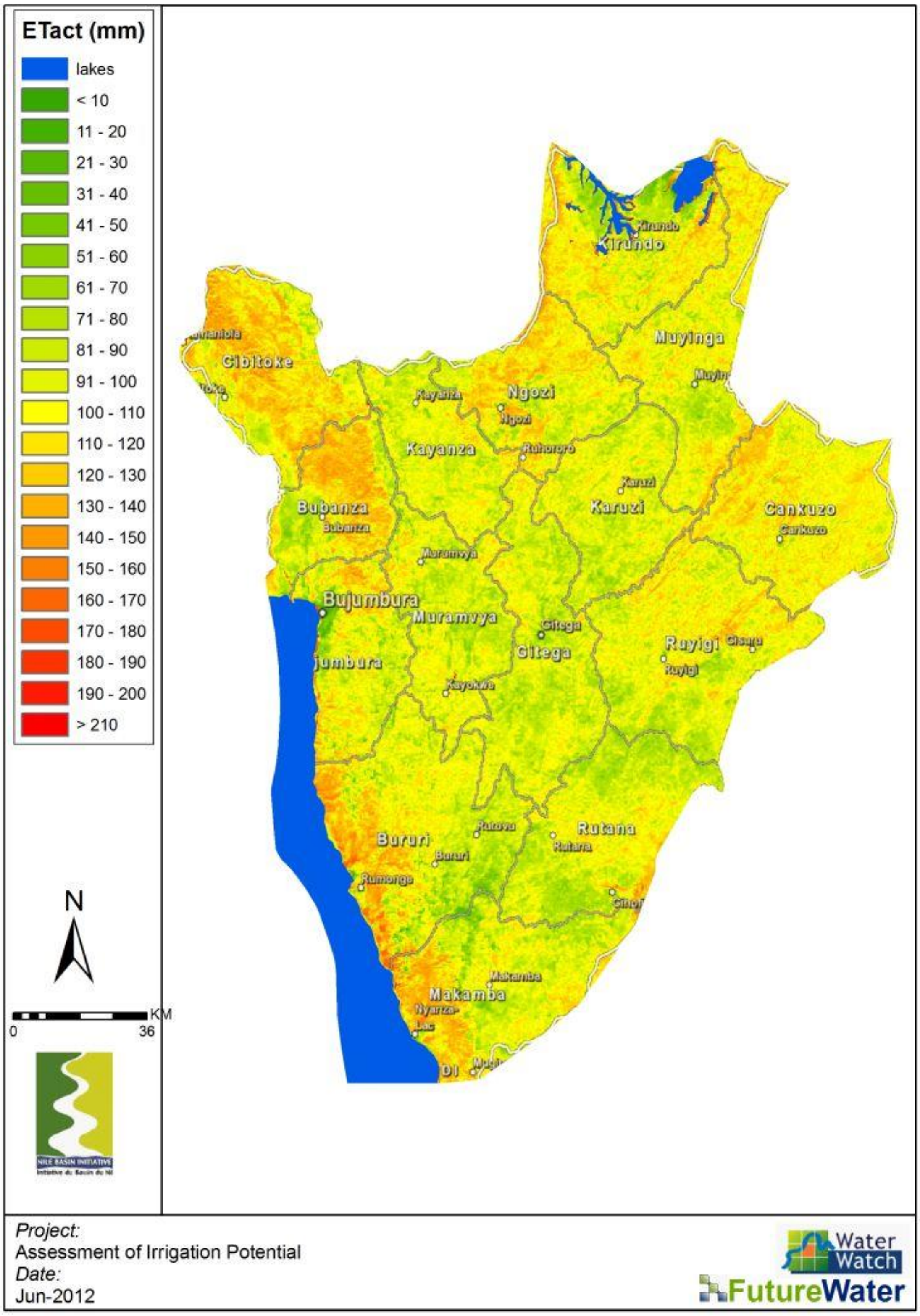
FutureWater


ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
36
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Ruhororo
Karuzi
Cankuzo
Bubanza
Muramvya
Bujumbura
Gitega
Ruyigi
Gisuru
Kayokwe
Bururi
Rutovu
Rutana
Rumonge
Makamba
Nyanza-Lac
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

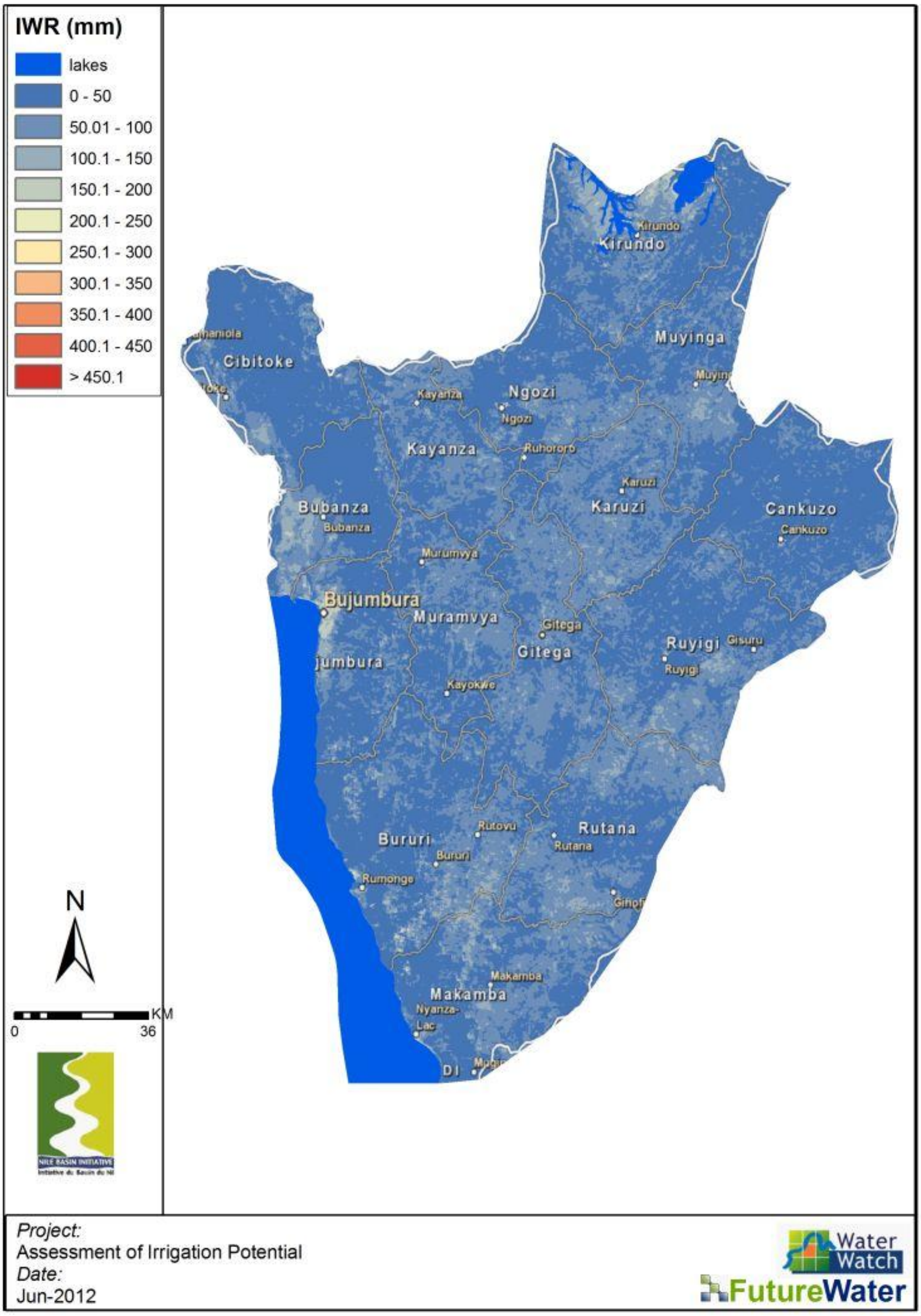


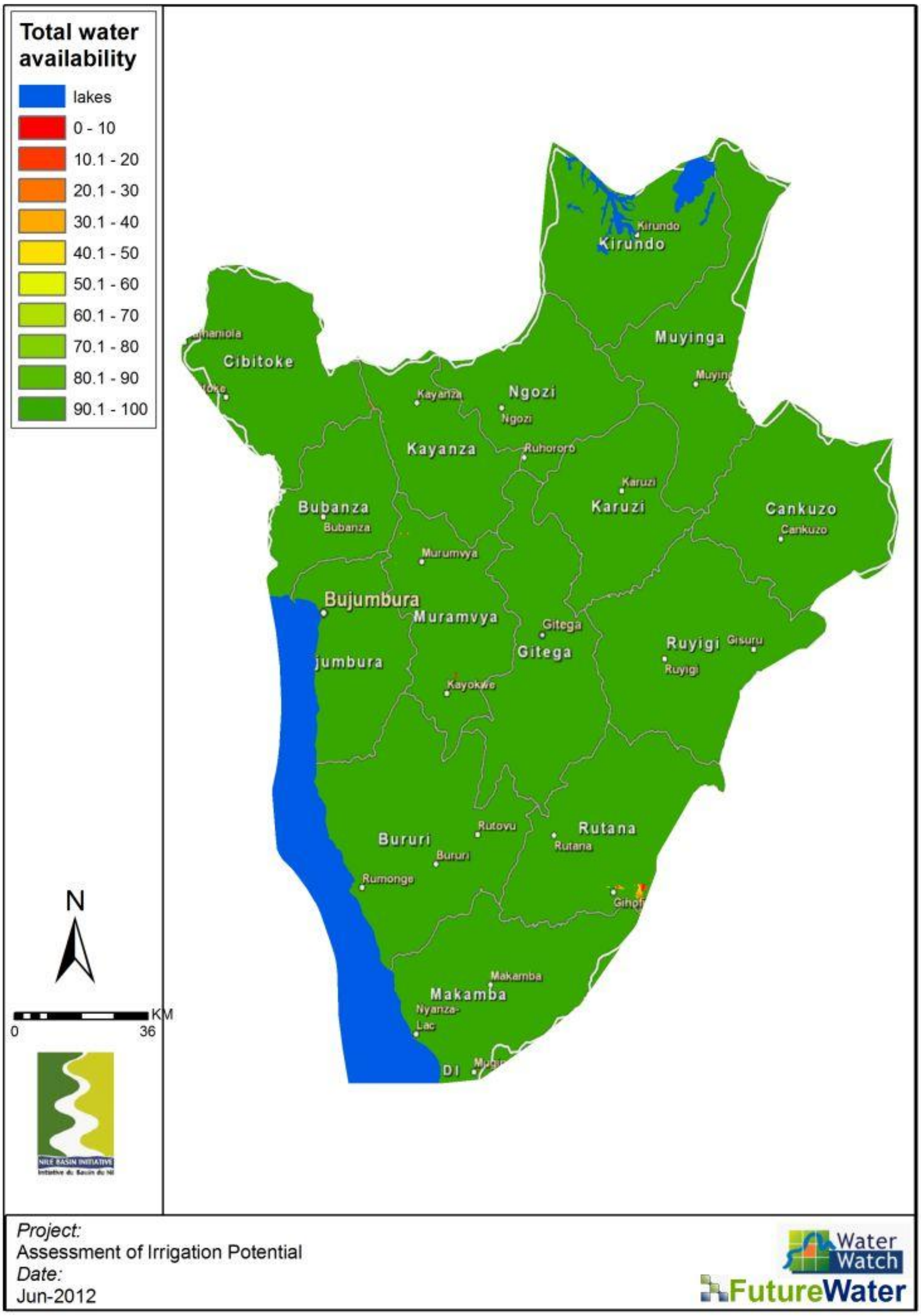
Figure 16: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for December (Average 2001-2010). (Source: study analysis).

2.2.2 *Water availability for irrigation*

2.2.2.1 NELmod

Water for irrigation can originate from three main sources: surface water, groundwater, and reservoirs. Based on the water availability (NELmod results), and irrigation demands (ETLook/SEBAL results) coverage of irrigation water requirements has been made (for details see main report). As explained in detail in the main report this water availability reflects only the need for irrigation, e.g. if rainfall occurs the irrigation water requirement is lower. Also the assumption that reservoir water can be used is based on the long-term annual flow rather than on restrictions for construction of a reservoir.

Results indicate that water availability for irrigation in the country is very high. Main sources are the potential reservoirs and water from existing streams.



Total water availability
lakes
0 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 90
90.1 - 100
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Bubanza
Karuzi
Cankuzo
Murumvya
Bujumbura
Muramvya
Gitega
Ruyigi
Gisuru
Kayokwe
Bururi
Rutovu
Rutana
Rumonge
Makamba
Nyanza-Lac
N
KM
0
36
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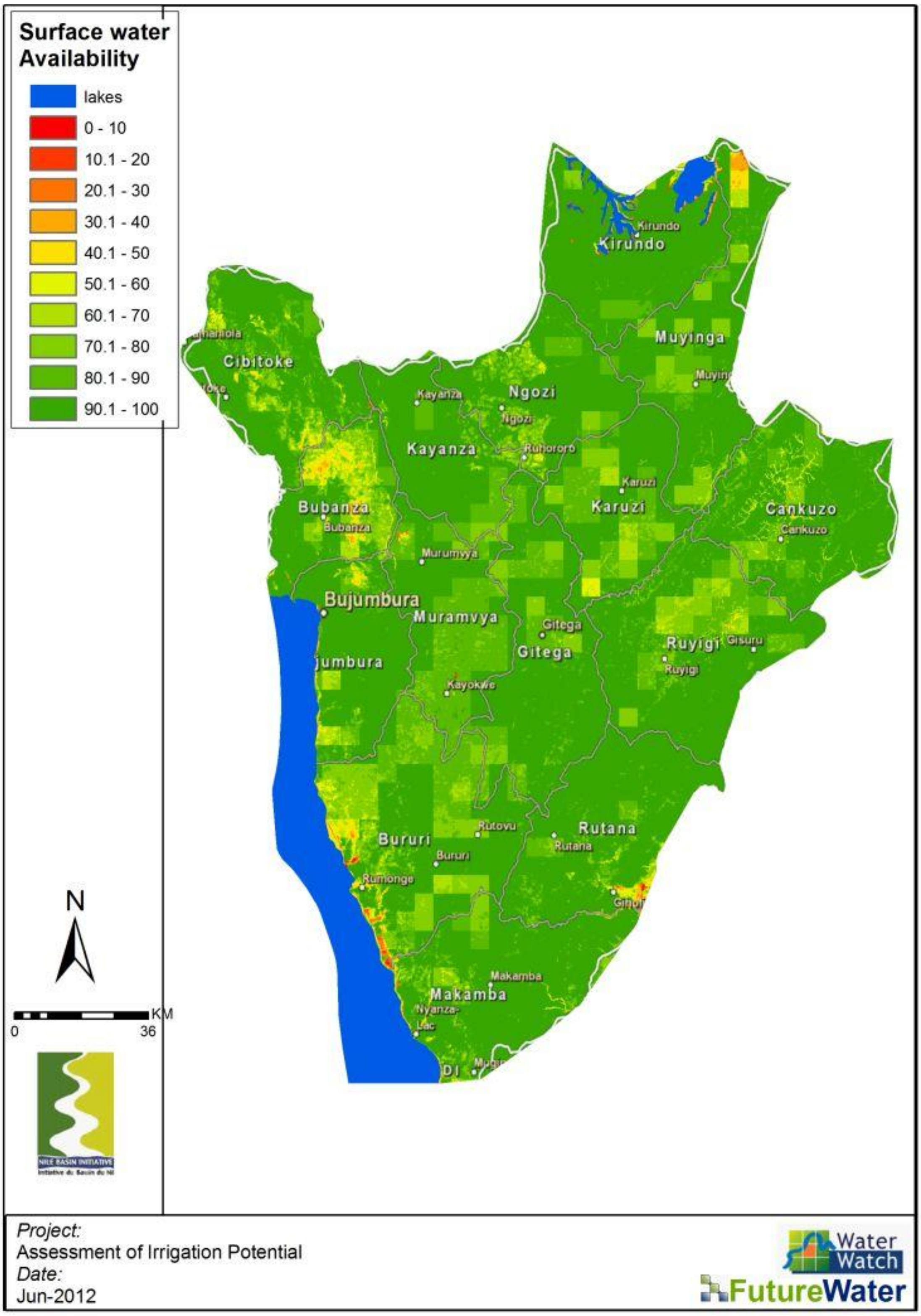
Surface water Availability
lakes
0 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 90
90.1 - 100
N
KM
0
36
Kirundo
Kirundo
Muyinga
Cibitoke
Kayanza
Ngozi
Ngozi
Kayanza
Ruhororo
Karuzi
Karuzi
Cankuzo
Cankuzo
Bubanza
Bubanza
Murumvya
Bujumbura
Muramvya
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
jumbura
Kayokwe
Rutovu
Rutana
Rutana
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Project:
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Date:
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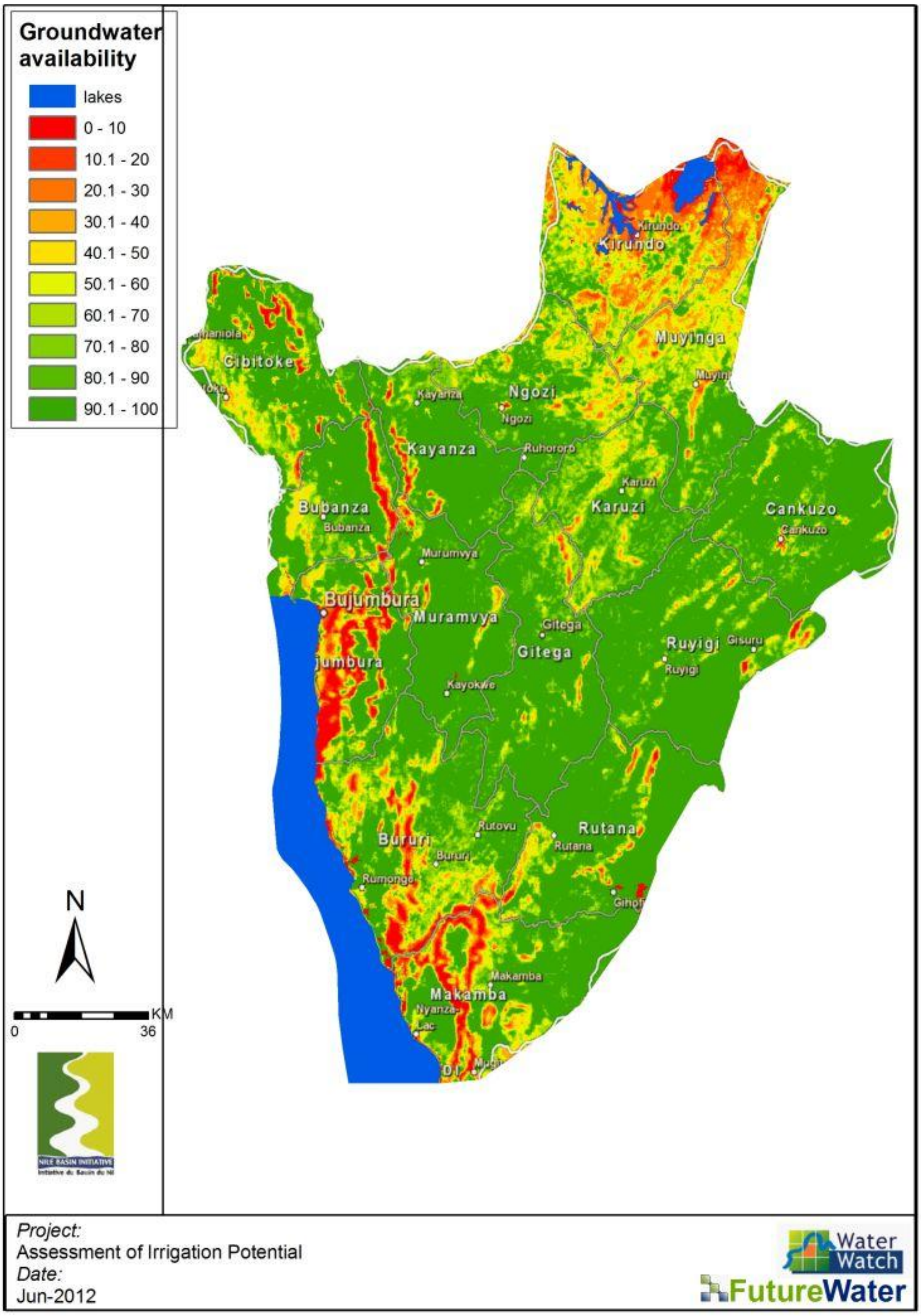
FutureWater


Groundwater availability
lakes
0 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 90
90.1 - 100
Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Karuzi
Bubanza
Cankuzo
Bujumbura
Muramvya
Gitega
Ruyigi
Bururi
Rutana
Makamba
N
KM
0
36
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

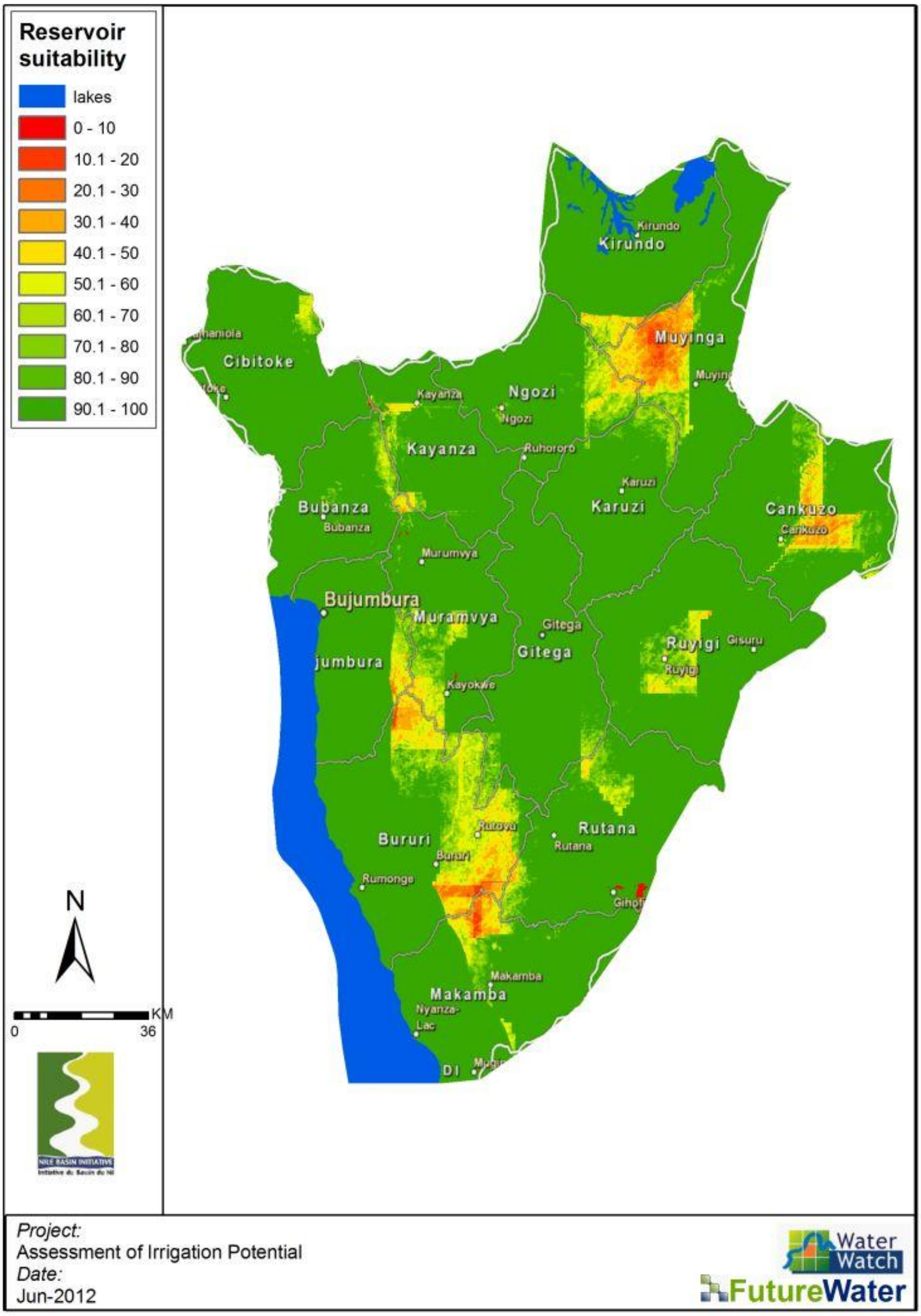


Figure 17: Water availability for irrigation. Total coverage (top), coverage from surface water (second), coverage from ground water (third), and from potential reservoirs (bottom).

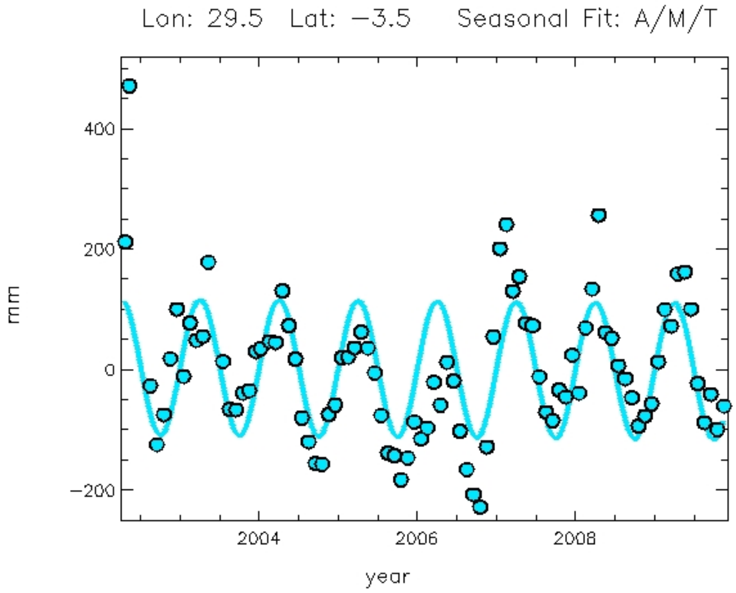


Figure 18: Annual groundwater storage trends for Burundi, based on GRACE satellite observations (Source: UoC, 2011).

2.2.2.2 Groundwater Trends

Large scale groundwater trends can also be observed from the GRACE satellite. This twin-satellite detects on a monthly base groundwater fluctuations over rather large areas (for details see main report). Long term groundwater trends can be seen in Figure 18. Groundwater recharge has quite some regional differences (Figure 19). Overall, groundwater recharge is quite high especially in the eastern part and in the valleys.

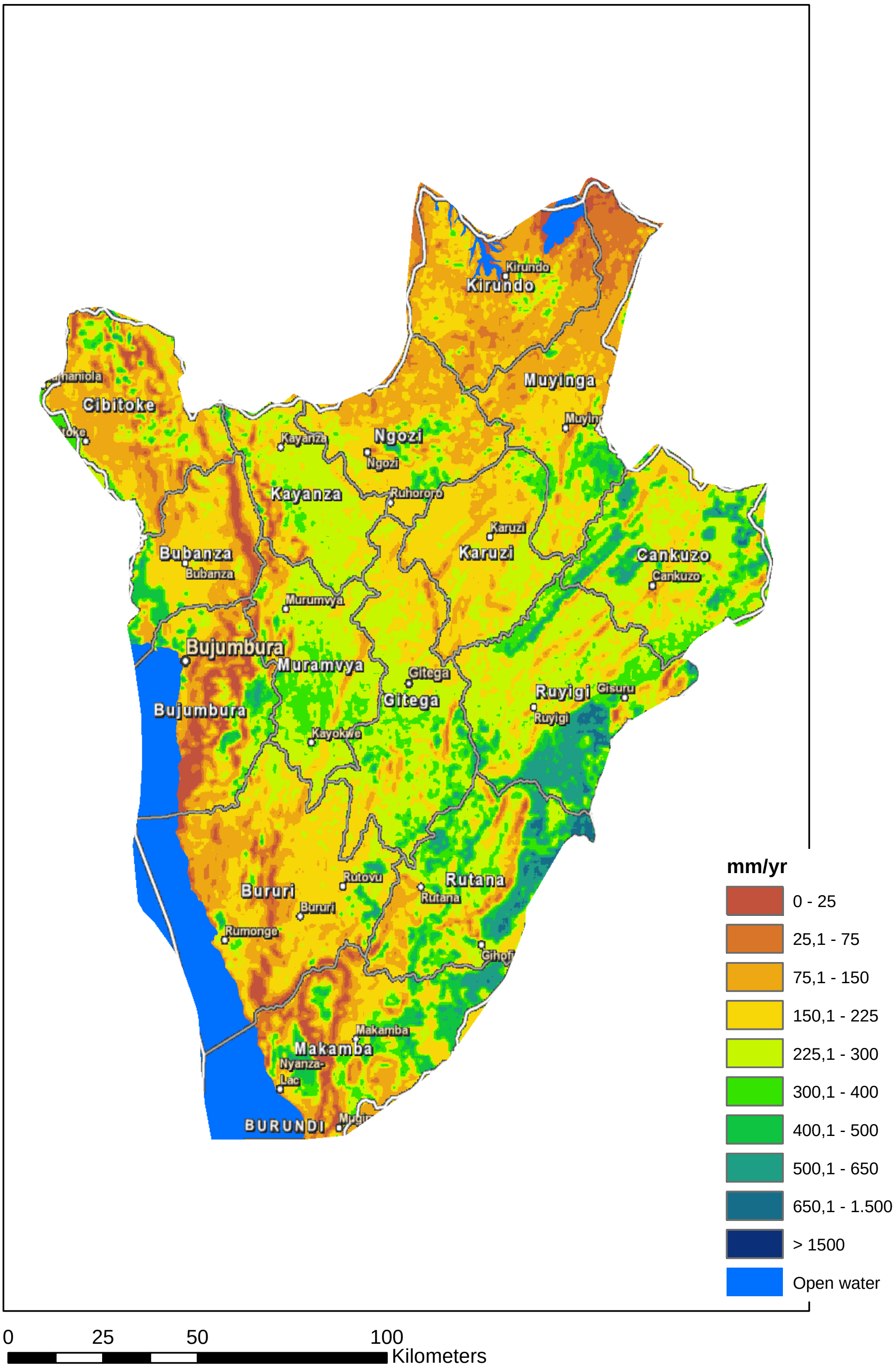
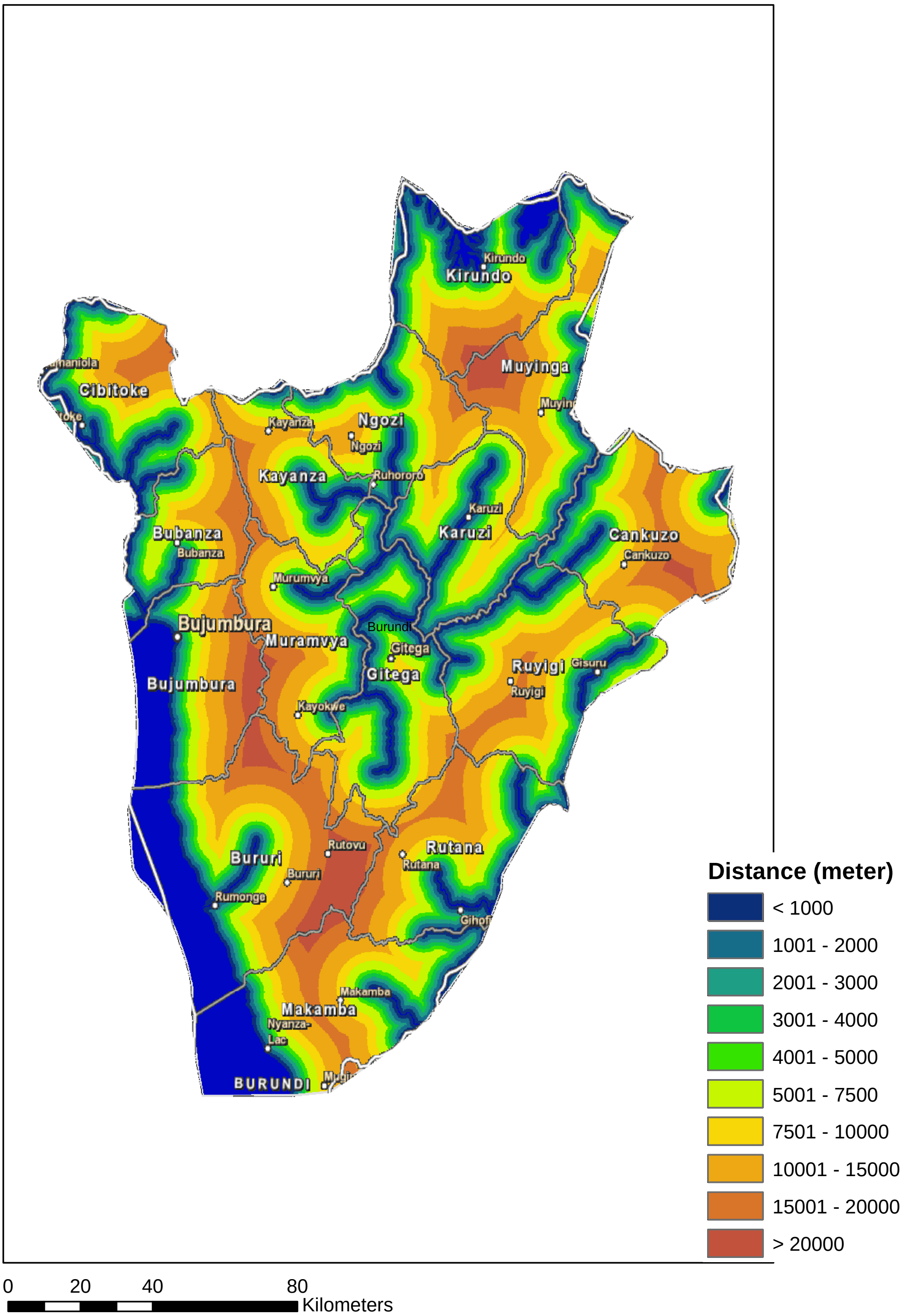


Figure 19: Annual groundwater recharge based on NELmod.

2.2.3 Access to a potential water source

A crucial component in assessing the potential for irrigation is the distance from the potential irrigation scheme to natural course of a river, stream or lake or to an existing reservoir. Based on various distance classes and elevation this suitability in terms access to a potential water source is defined (for details see main report). Although there are many streams in the country, overall access to water is quite low, mainly because of the high elevations in the country.


Kirundo
Kirundo
Muyinga
Cibitoke
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Ngozi
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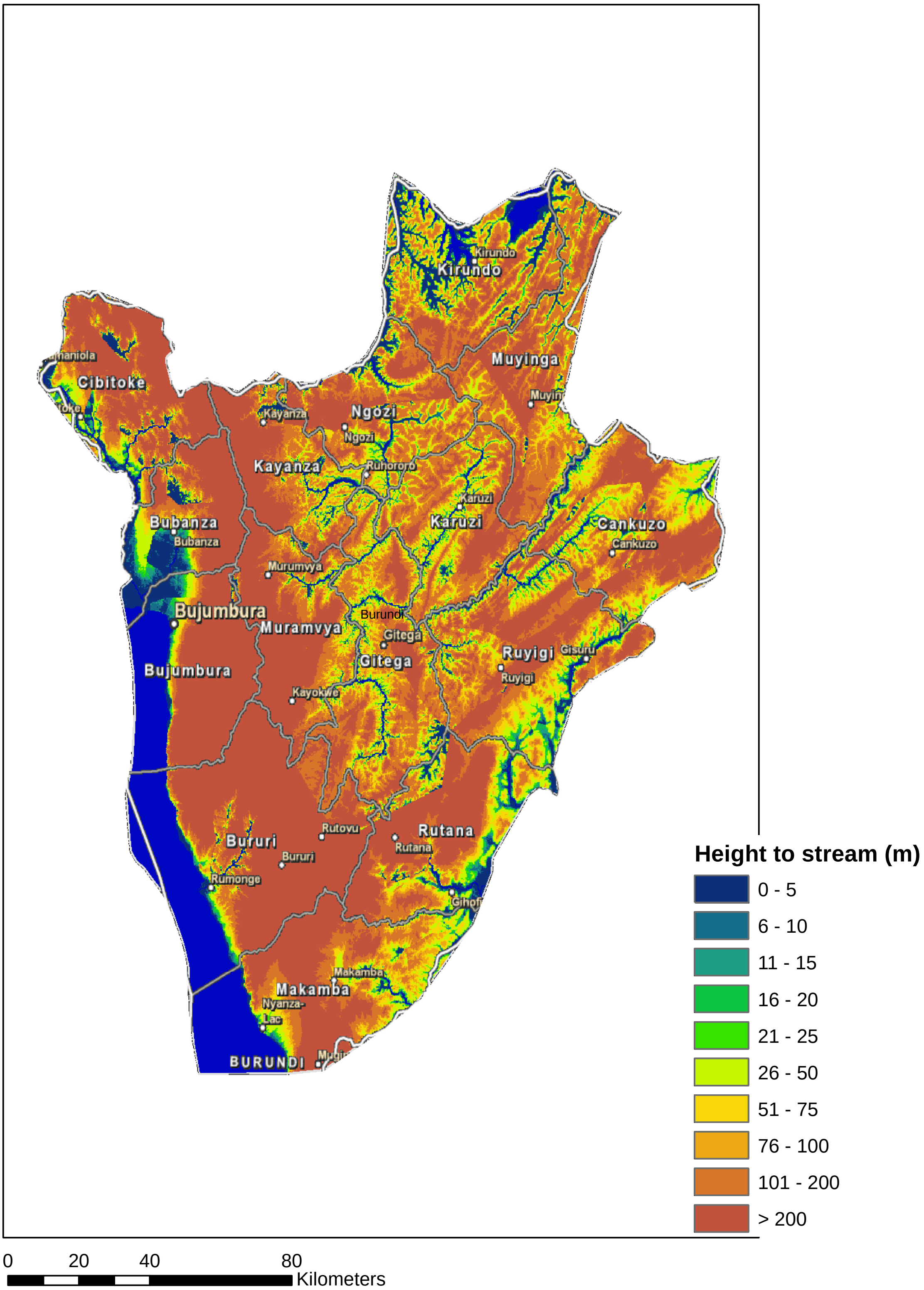
Karuzi
Bubanza
Bubanza
Cankuzo
Cankuzo
Murumvya
Bujumbura
Muramvya
Burundi
Gitega
Gitega
Bujumbura
Ruyigi
Gisuru
Ruyigi
Kayokwe
Rutovu
Rutana
Bururi
Rutana
Bururi
Rumonge
Makamba
Makamba
Nyanza-
Lac
BURUNDI
Distance (meter)
< 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 7500
7501 - 10000
10001 - 15000
15001 - 20000
> 20000
0
20
40
80
Kilometers


Kirundo
Kirundo
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Ngozi
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Ruhororo
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Karuzi
Cankuzo
Cankuzo
Bubanza
Bubanza
Murumvya
Bujumbura
Muramvya
Burundi
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
Bujumbura
Kayokwe
Rutovu
Rutana
Rutana
Bururi
Bururi
Rumonge
Gihofi
Makamba
Makamba
Nyanza-Lac
BURUNDI
Height to stream (m)
0 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 50
51 - 75
76 - 100
101 - 200
> 200
0
20
40
80
Kilometers

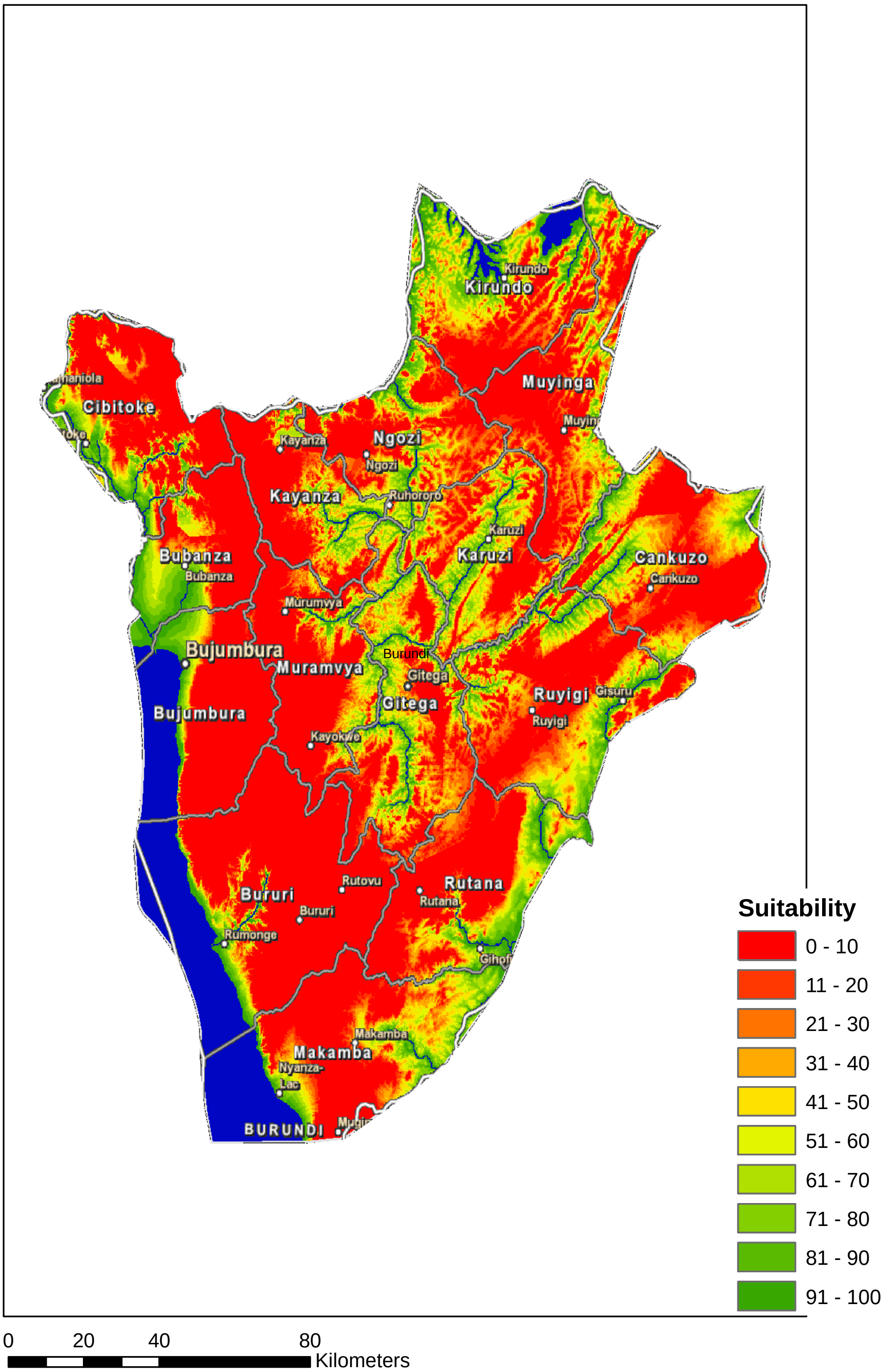


Figure 20: Average distance to a natural stream, lake or reservoir (top), elevation above natural stream, lake or reservoir (middle), and access to water suitability score (bottom).

2.3 Land use

2.3.1 Current land use

Actual land cover based on AfriCover is shown in Figure 21. Distribution of irrigated and rainfed crops are shown in Figure 22. Specific maps for 26 crops are included in the database attached to the report.

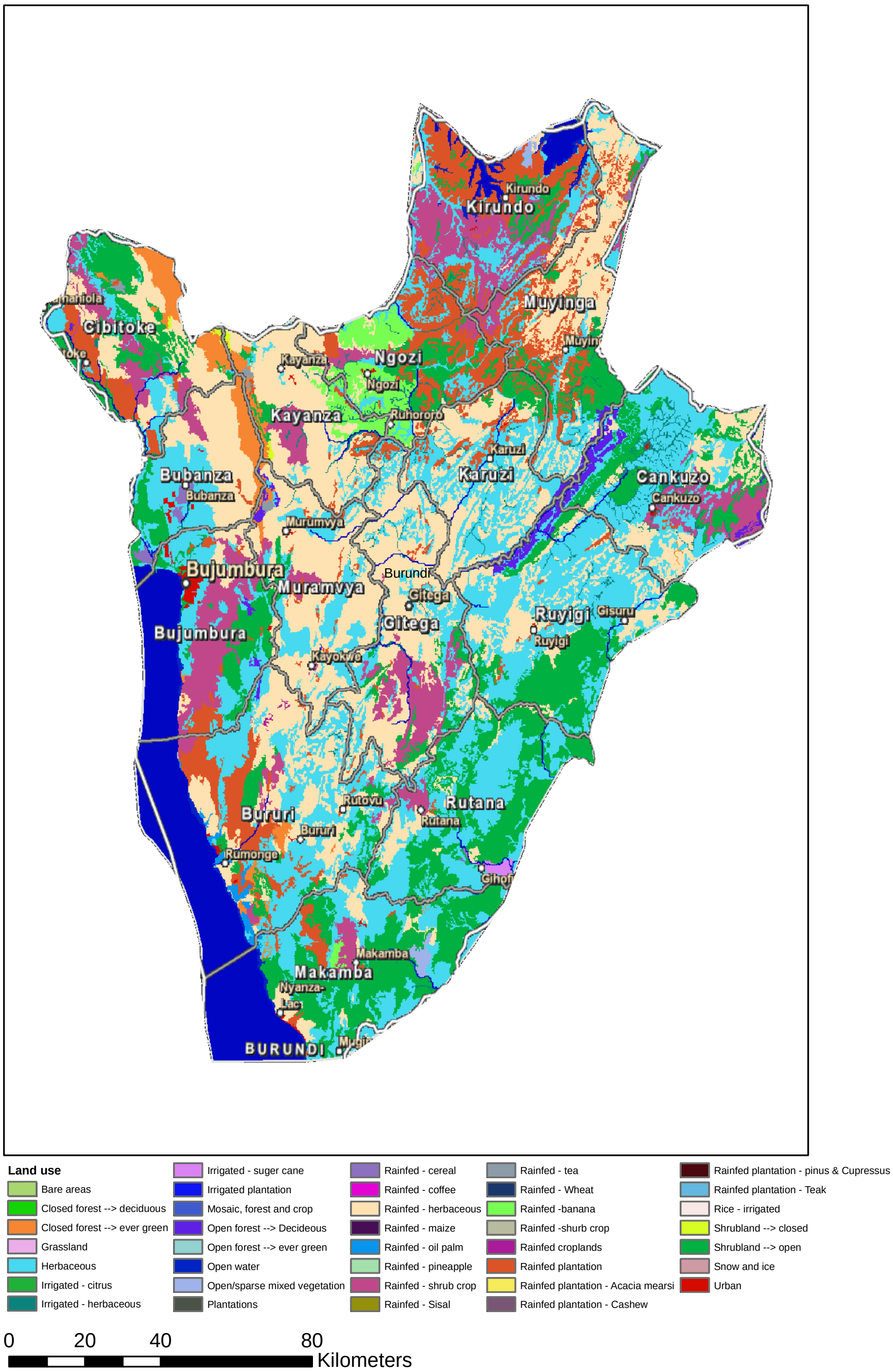
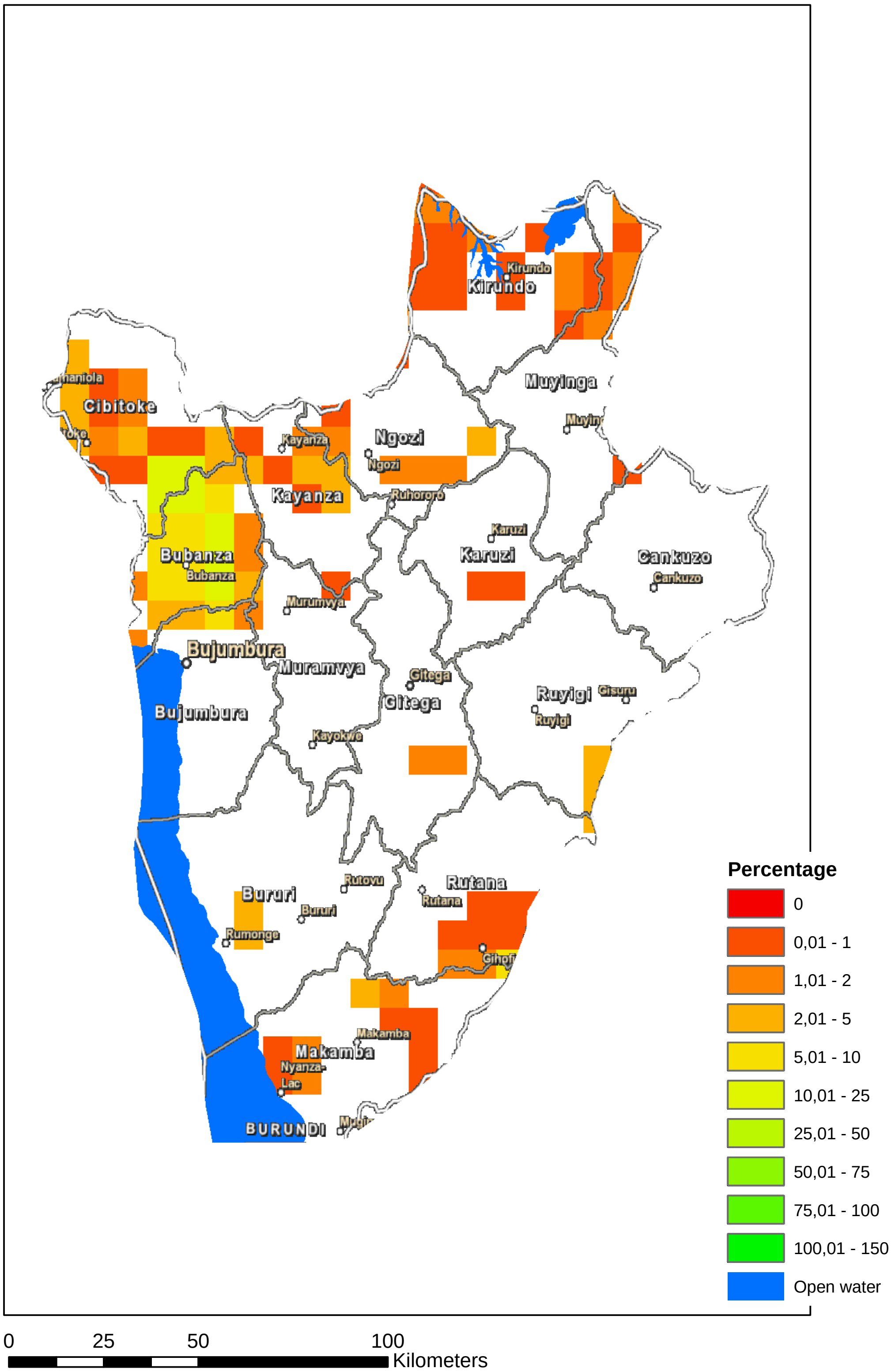


Figure 21: Land use in Burundi, based on AfriCover.


Kirundo
Kirundo
Muyinga
Cibitoke
Kayanza
Kayanza
Ngozi
Ngozi
Ruhororo
Karuzi
Karuzi
Cankuzo
Cankuzo
Bubanza
Bubanza
Murumvya
Bujumbura
Muramvya
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
Bujumbura
Kayokwe
Rutovu
Rutana
Bururi
Rutana
Bururi
Rumonge
Makamba
Makamba
Nyanza-Lac
BURUNDI
Percentage
0
0,01 - 1
1,01 - 2
2,01 - 5
5,01 - 10
10,01 - 25
25,01 - 50
50,01 - 75
75,01 - 100
100,01 - 150
Open water
0
25
50
100
Kilometers

z

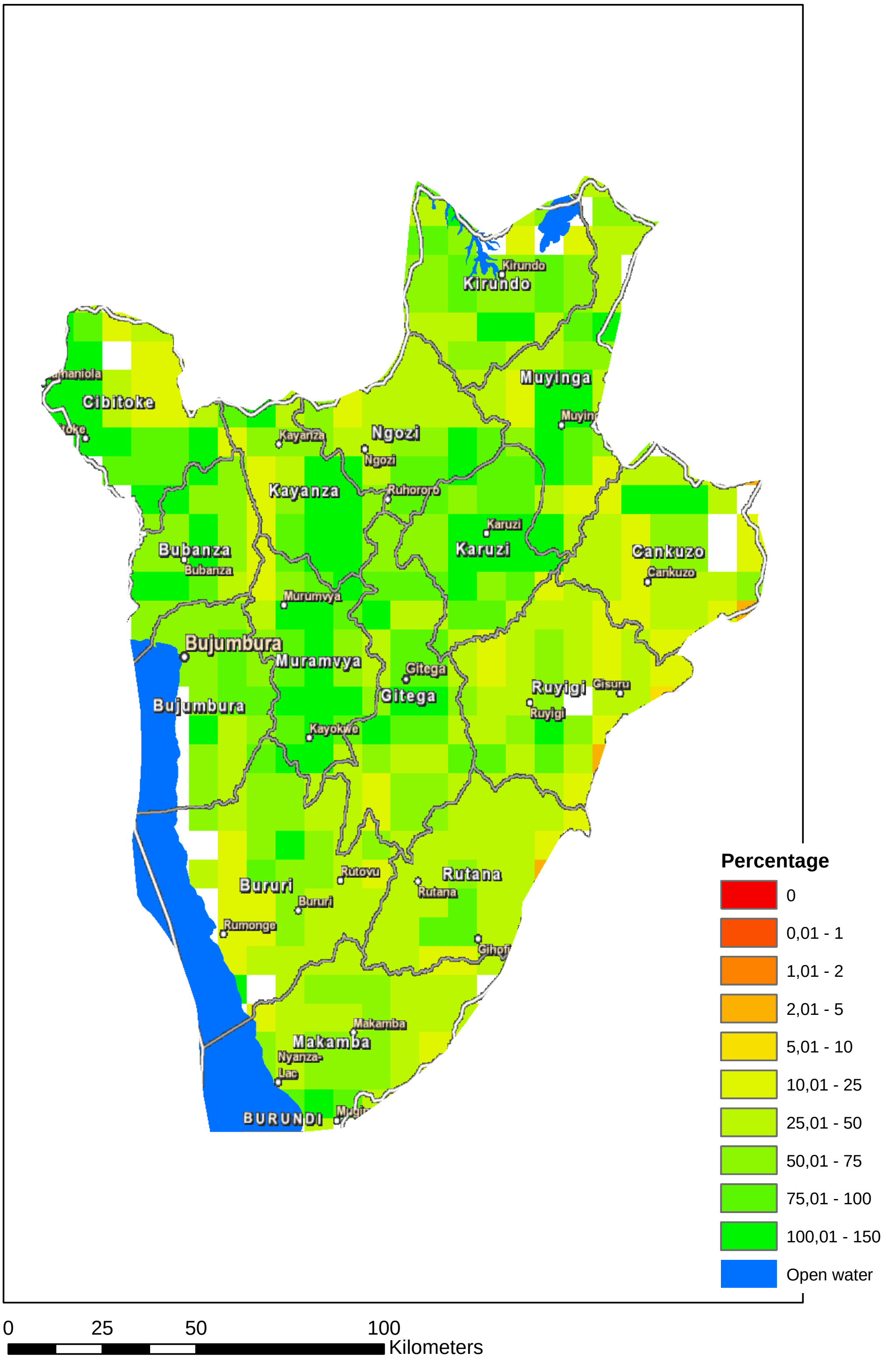


Figure 22. Irrigated (top) and rainfed cropping intensities[1] (bottom) as percentage of cells of about 10 x 10 km (Source: Mirca2000).

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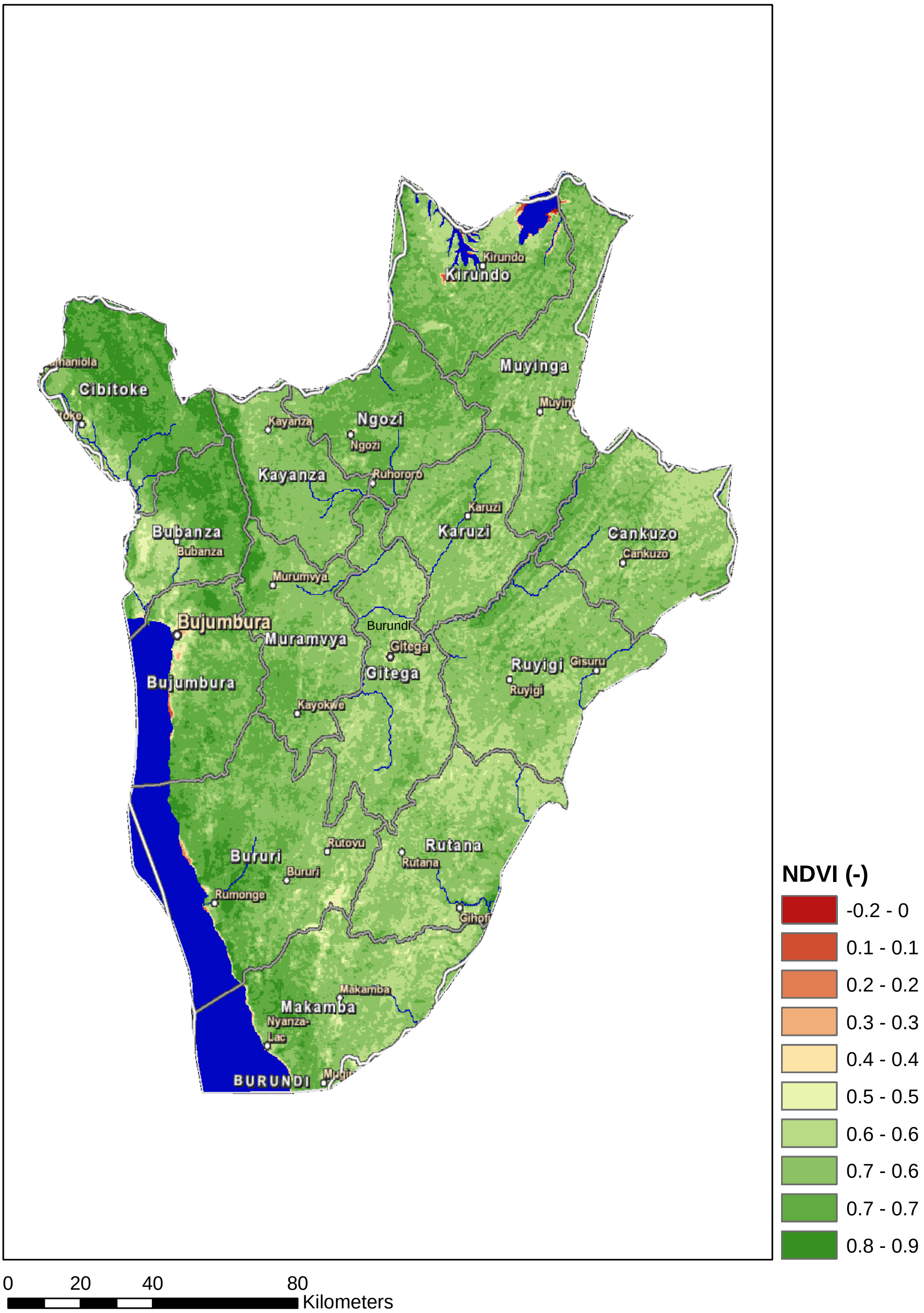
[1] Percentages can be above 100% as multiple cropping season might exist in one year.

2.3.2 *Current land productivity (NDVI)*

Current land productivity is assessed based on satellite information and is a good proxy of all integrated features like soils, slopes, management, vegetation etc. Current land productivity in the country is high, although quite some regional difference exists, but monthly variation is limited.



Kirundo
Kirundo
Muyinga
Muyin
Cibitoke
Kayanza
Ngozi
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Ruhororo
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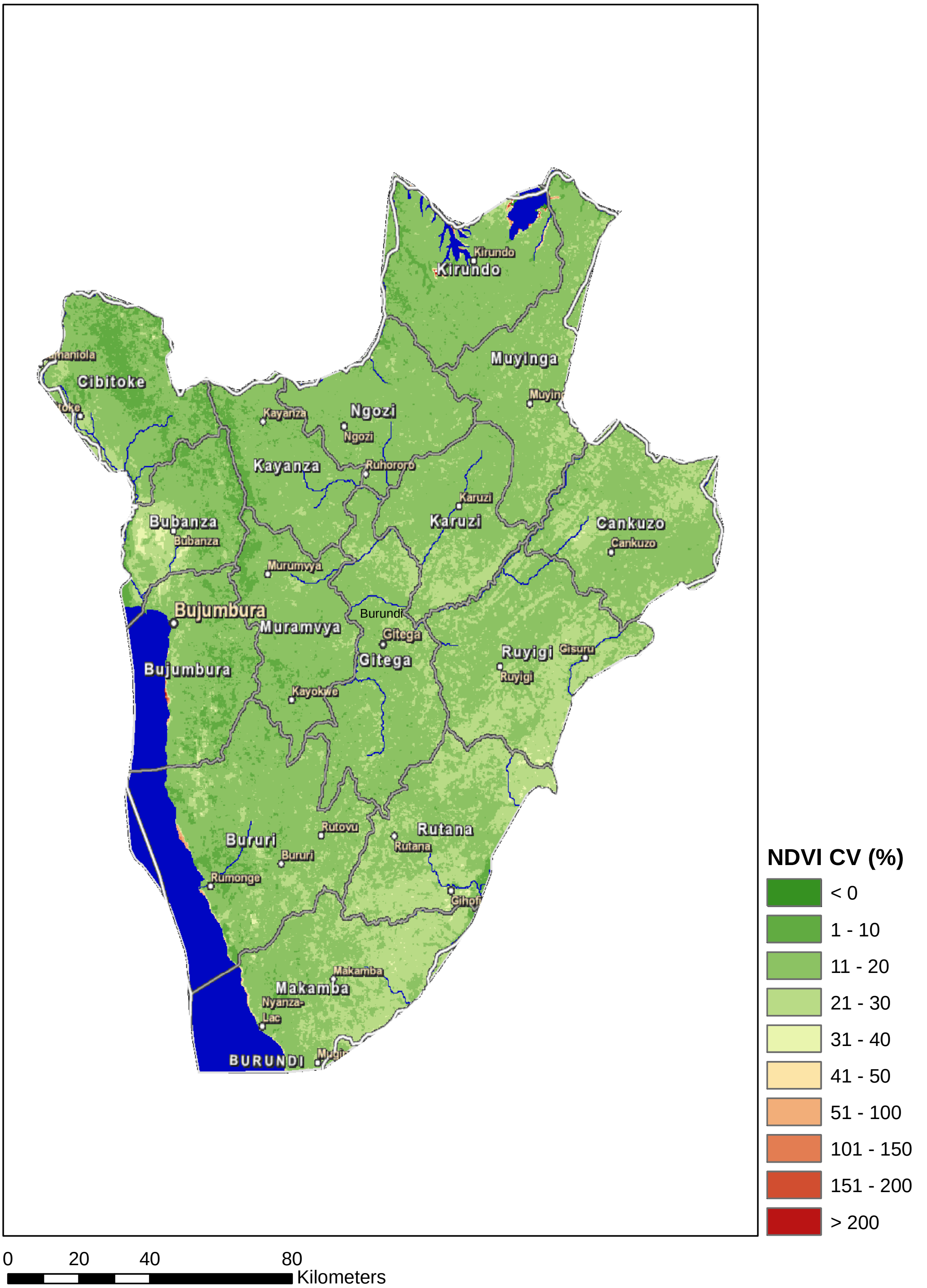
Karuzi
Cankuzo
Cankuzo
Bubanza
Bubanza
Murumvya
Bujumbura
Burundi
Muramvya
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
Bujumbura
Kayokwe
Rutovu
Rutana
Rutana
Bururi
Bururi
Rumonge
Gihofi
Makamba
Makamba
Nyanza-
Lac
BURUNDI
NDVI (-)
-0.2 - 0
0.1 - 0.1
0.2 - 0.2
0.3 - 0.3
0.4 - 0.4
0.5 - 0.5
0.6 - 0.6
0.7 - 0.6
0.7 - 0.7
0.8 - 0.9
0
20
40
80
Kilometers


Kirundo
Kirundo
Muyinga
Cibitoke
Ngozi
Ngozi
Kayanza
Kayanza
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Karuzi
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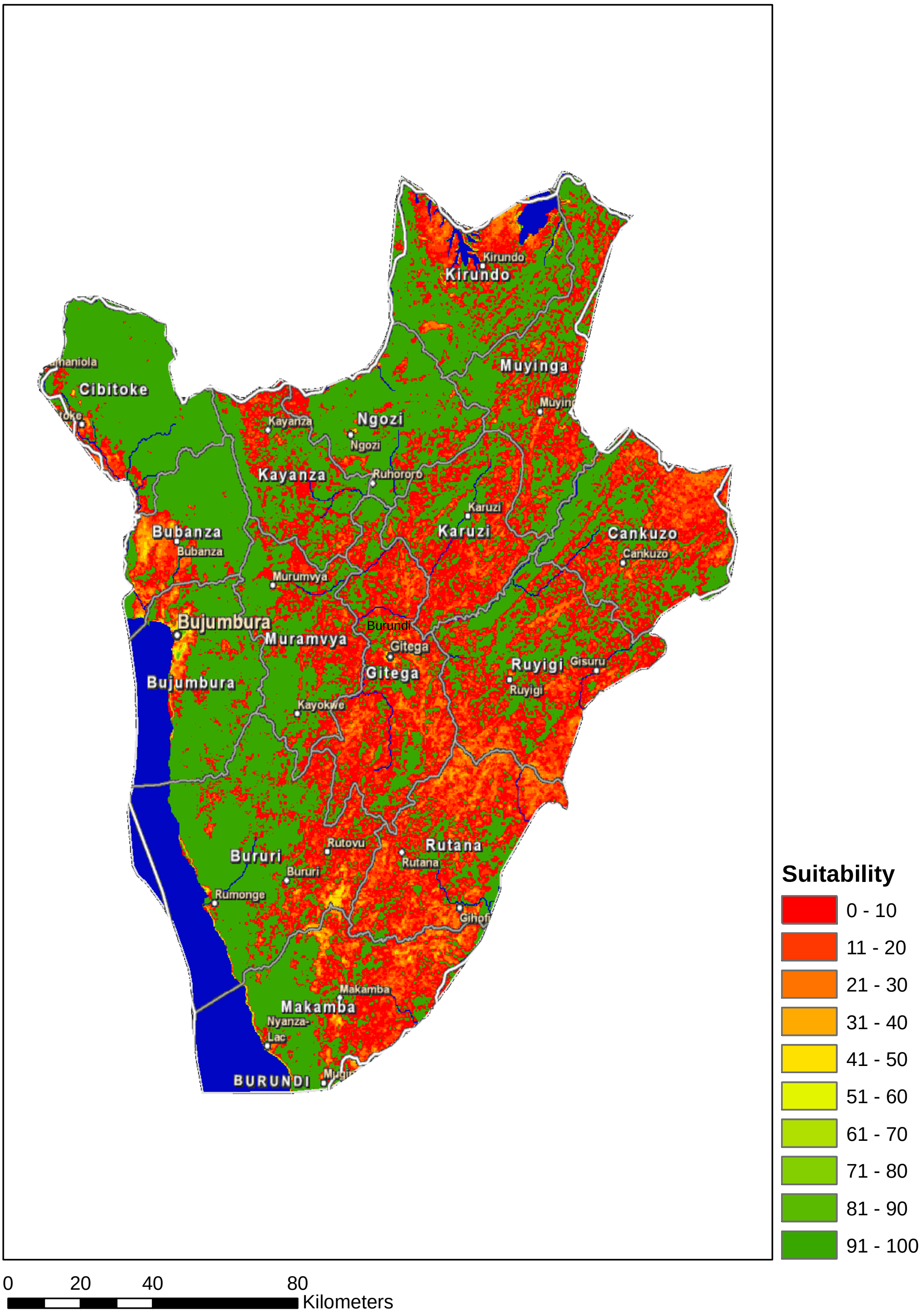
Bubanza
Bubanza
Cankuzo
Cankuzo
Murumvya
Bujumbura
Muramvya
Burundi
Gitega
Gitega
Bujumbura
Ruyigi
Ruyigi
Gisuru
Kayokwe
Rutovu
Rutana
Rutana
Bururi
Bururi
Rumonge
Makamba
Makamba
BURUNDI
NDVI CV (%)
< 0
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 100
101 - 150
151 - 200
> 200
0
20
40
80
Kilometers



Kirundo
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Muyinga
Muyinga
Cibitoke
Kayanza
Ngozi
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Ruhororo
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Cankuzo
Cankuzo
Bubanza
Bubanza
Murumvya
Bujumbura
Burundi
Muramvya
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
Bujumbura
Kayokwe
Rutovu
Rutana
Bururi
Bururi
Rutana
Rumonge
Makamba
Makamba
Nyanza-
Lac
BURUNDI
Suitability
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
0
20
40
80
Kilometers

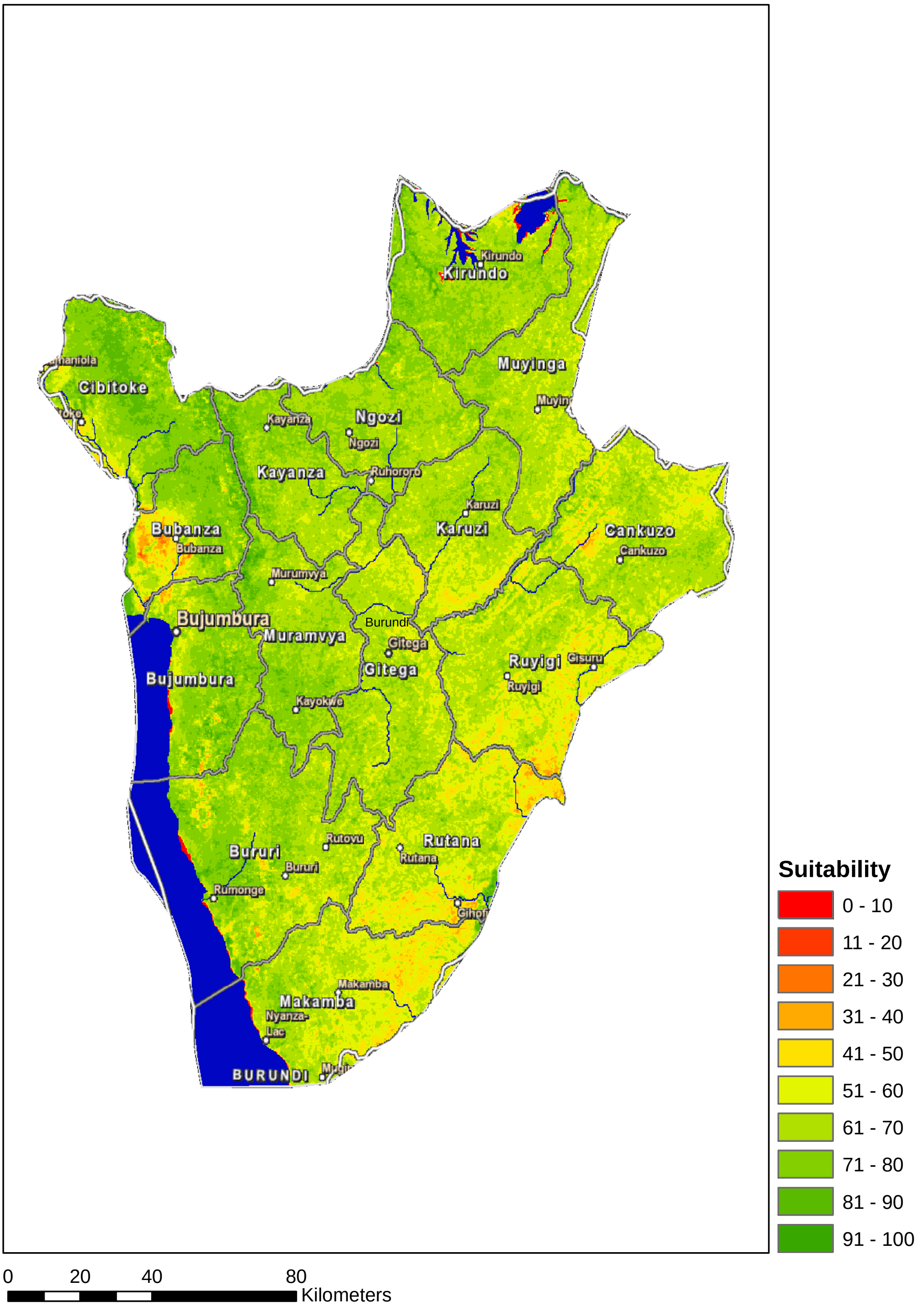


Figure 23: Current land productivity based on NDVI. Average NDVI (top), average monthly coefficient of variation (second), and the land productivity scores based on average NDVI (third) and monthly coefficient of variation (bottom).

2.4 Agriculture

2.4.1 Background

It is estimated that Burundi has about one million farms, with an average size of 0.8 ha. In these farms they practice mixed crops (mainly food crops) incorporating more or less breeding and afforestation. In the more densely populated regions (Buyenzi, Kirimiro, and Mumirwa center), the average size of farms is 0.5 ha. The largest holdings (2 to 5 ha) are located in the plains of Imbo and Moso where population densities are lower. The three seasons of agricultural production allows the small producer, through cropping intensity, to develop a cultivated area multiplied by 1.5 to 2 of the real size of the holding. An issue, however, is that without the input of organic matter and without refund of minerals, the soil fertility deteriorates, the production declines, and the small farm is insufficient to sustain the family.

The agricultural development in Burundi, mainly characterized by small private farms, has a lack of mechanization. This factor in combination with the mountainous terrain and the energy deficit are a major obstacle to practice large scale irrigation. Therefore irrigation is hardly developed in Burundi. Most of the irrigated fields (99%) are located in the plains of Imbo, Moso, Bugesera, and in the marshes. Mountain irrigation represents only a tiny fraction, less than 1% of the total irrigated area. It is known that the total irrigated area in Burundi represents only 0.65% of the total surface landmass, and only 1.57% of the total irrigable area. Table 1 gives an overview of the current irrigable and irrigated areas in Burundi.

Table 1: Overview of irrigable and irrigated areas in Burundi (Niyongabo, 2007).

AEZ	Area (ha)		Irrigation		
	Total	Irrigable (ha)	Irrigated (ha)	Irrigated (% of total)	Irrigated (% of irrigable)
1	176400	123500	8739	4,95	7,08
2	252000	68595	260	0,10	0,38
3	378000	149915	910	0,24	0,61
4	1108800	406180	2286	0,21	0,56
5	604800	300140	4309	0,71	1,44
Total	**2520000**	**1048330**	**16504**	**0,65**	**1,57**

2.4.2 Main crops

The agricultural sector is the dominant activity in Burundi with arable land under permanent crops occupying 12,000 km^2, which is 43% of the total area of Burundi. The agricultural products are mainly food crops (46% of GDP), fish products, and oilseed crops (7% of GDP and 98% of exports). The climatic conditions prevailing in the country is encouraging for a variety of food crops of which the most important in volume are:

- Bananas
- Tubers (sweet potatoes, potatoes, cassava)
- Legumes (beans)
- Cereals (sorghum, rice)
- Vegetables
- Fruits

Oil crops which are essentially made of peanuts, palm oil and cotton produce about 19,000 tons of oil per year. The industrial crop production (coffee, tea, cotton, palm oil, sugar cane, tobacco, rice, and cinchona) is organized into the agro-industrial sectors. This agricultural sector provides the main export products of the country and is the main source of foreign currency. That is why it has benefited from a preferential treatment while allocating financial resources for agricultural development.

Burundi has a total land area of 25,200 km^2, of which 23,500 km^2 is considered as potentially agricultural. Currently, the cultivated area covers about 14,000 km^2, which is split up in peasant mountain farms, culture in marshes and industrial crops.

2.4.3 Irrigation

A typical example of development in irrigation in the country is the development in the Bugesera region. The governments of Burundi and Rwanda have decided to design an integrated rural development project for the Bugesera region shared by the two countries. The two governments and ADF concluded that it would be necessary to launch the following studies during the project preparation process: (i) for Rwanda: study on irrigation development on an interior marshland (1,500ha) and feasibility study on the irrigation of 1,000 ha with water from Lakes Rweru and Gaharwa; (ii) for Burundi: irrigation development on 3 interior marshlands (2,000 ha) and feasibility study on the irrigation of 500 ha with water from Lake Cyohoha. The priority given to the development of irrigation is justified by the acute food shortage affecting the populations living along the borders between the two countries in Bugesera area where natural resources are limited. The inter-annual climate variability, as well as the irregular and low rainfall currently constitute a significant obstacle to the development of agriculture. (African Development Fund (2008) Multinational: Rwanda-Burundi. Integrated rural development project of Bugesera)

The Bugesera Agricultural Development Support Project (PADAB) aims at increasing agricultural production in the Bugesera Region by setting up irrigation infrastructure in a 650-hectare valley. It also seeks to protect water catchment basins and improve rain-fed farming on nearly 5 000 hectares of hills, as well as build the capacity of farmers and supervisory institutions. Overall, the project aims at strengthening food security in Rwanda. The project involves irrigation and development of the catchment basin, agricultural development and project management.

To evaluate the project’s economic viability, the internal rate of return was calculated. The economic analysis makes a general assessment of the project’s direct economic benefits. Those benefits are quantified by comparing the “no-project” and “with project” situations.

At full development, the project will contribute to increased production (agricultural production will increase substantially by 25,000 tons), generating additional substantial income as a result (to 13,500 rural households). The project’s internal rate of return is estimated at nearly 15.2 percent. In addition, the project will create close to 2,500 permanent jobs, the use of the labor-intensive work in implementing the development works will generate two million works days. It is therefore well-worth investing in it.

Table 2: Area equipped for irrigation in Burundi according to FAO-Aquastat (2012).

Burundi	ha
1965	14,000
1975	14,000
1985	14,000
1995	18,000
2005	23,000

2.4.4 *Potential crop yield assessment*

Potential crop yield assessment is based on the so-called yield-gap analysis. Yield-gap is defined as the difference between the actual yield and the maximum obtainable yield. The yield-gap analysis is essential to show what might be an obtainable yield if all factors are optimal. Instead of using a so-called theoretical yield assuming that no restrictions exist, yield-gap analysis are based on realistic and attainable yields (details see main report). The analysis will therefore compare all countries involved in this study as well as the average of the continent and the highest value obtained somewhere in the world. Moreover, a trend analysis per country will indicate whether improvements can still being made.

The regional and global yields for the five dominant crops in Burundi are shown in Figure 25. For dry beans and sorghum, Burundi has a relative high yield compared to the region. The yield of sorghum has increased continuously by about 30% from 1979 to 2009. The yields of dry beans and maize have increased, since 1979, with a peak around 1990 and are decreasing ever since, and dropping beneath the 1979 level over the last 10 years. The yield of sweet potatoes has been relatively stable in the last 30 years. The yield of bananas however has been decreasing gradually, and ends up just above 80% of the 1979 level. In summary the yield gap is largest for bananas and sweet potatoes, for which the current yield is below the regions average. This relates directly to a higher potential to increase yields for these crops.

Table 3. Area harvested in ha for the 10 most dominant crops (FAOstat, 2010).

	1980	1990	2000	2005	2009
Beans, dry	290.000	250.600	210.000	275.000	220.000
Bananas	220.600	290.000	345.852	325.000	200.000
Sweet potatoes	79.000	103.000	110.000	130.000	125.000
Maize	130.000	124.000	112.000	116.000	120.000
Sorghum	52.000	58.000	50.965	55.000	63.000
Cassava	44.000	64.000	73.000	89.000	54.000
Peas, dry	44.800	60.000	48.000	58.939	53.000
Vegetables fresh nes	23.000	27.202	22.000	39.230	51.843
Coffee, green	30.000	42.229	21.000	9.000	25.000
Rice, paddy	4.254	12.000	17.000	19.900	24.000
Total	917.654	1.031.031	1.009.817	1.117.069	935.843

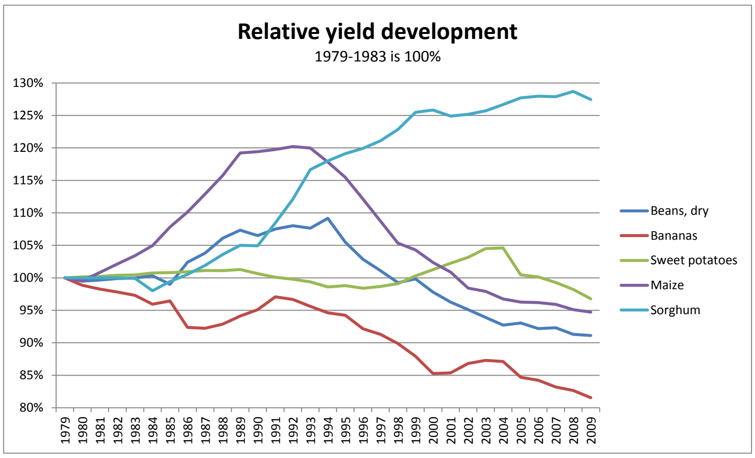


Figure 24. Trend in yields per ha for the five most dominant crops. Average of first five years have been indexed to 100%. (FAOstat, 2010)

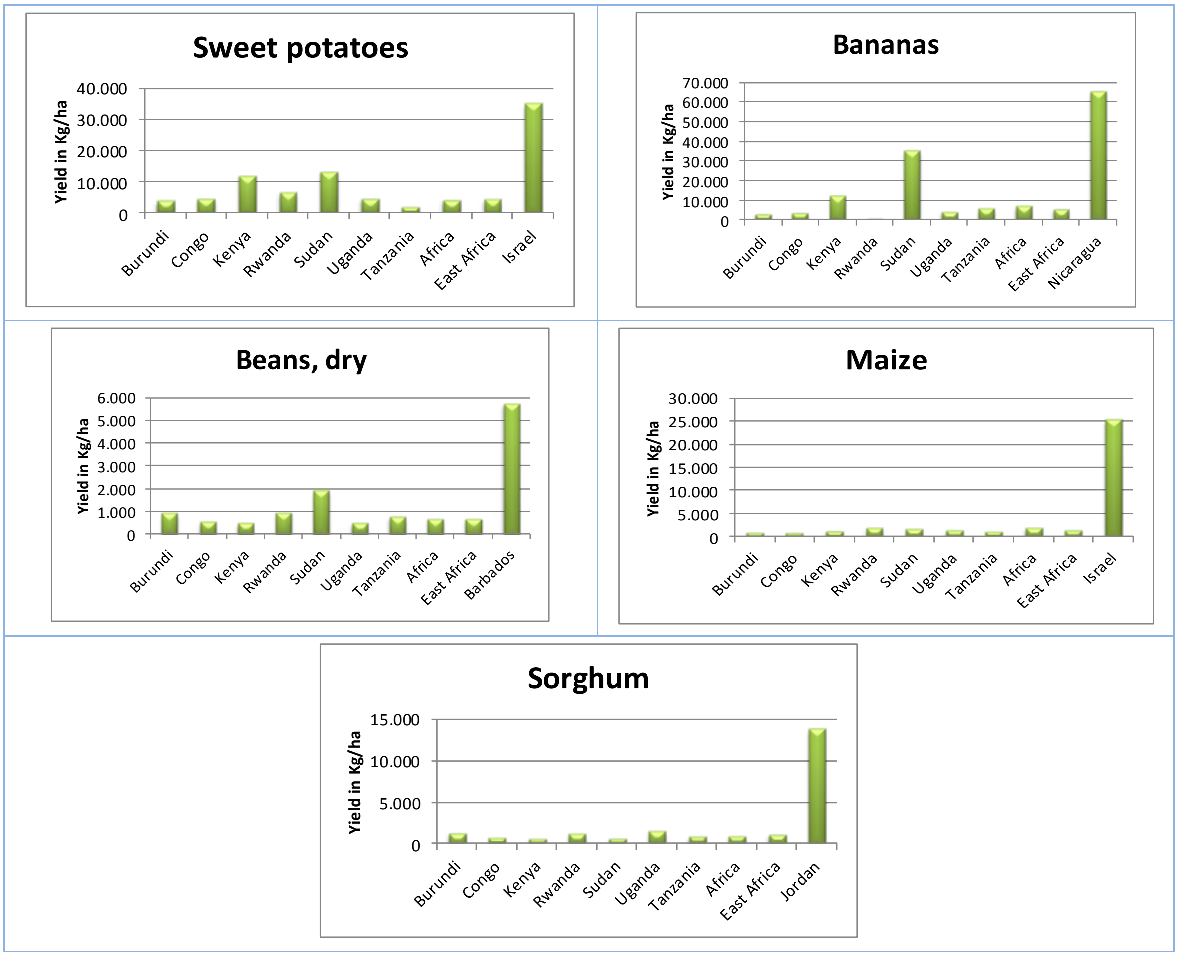
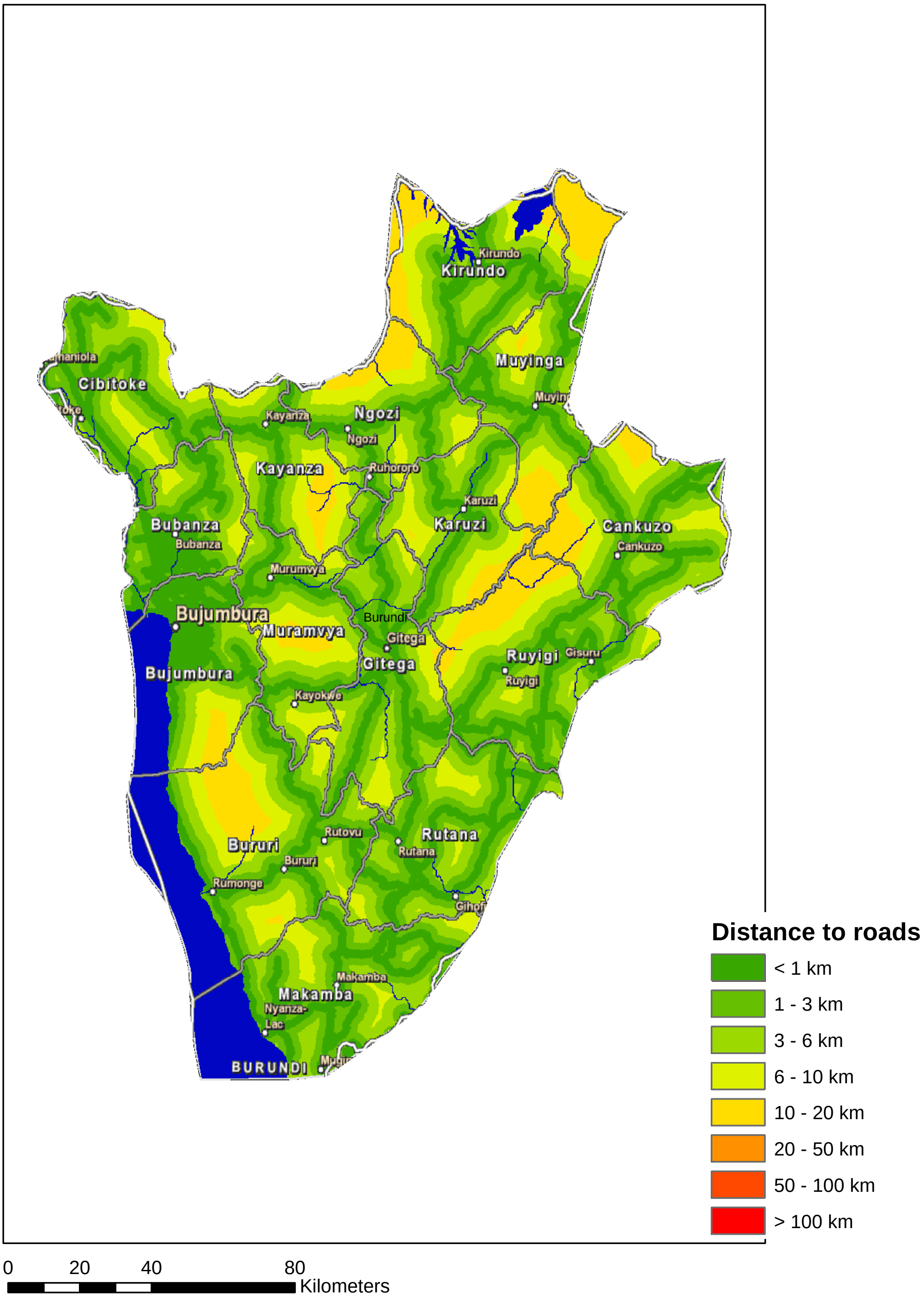


Figure 25. Regional and yields for the five dominant crops in the country. (FAOstat, 2010)

2.5 Infrastructure

2.5.1 Access to transportation

Access to transportation is an important factor to be considered for irrigation development. Harvested products should be transported to markets and also supply of seeds, fertilizer and machinery require close distances to transportation means. Distances to roads, railways and/or waterways are taken as input to determine the suitability in this respect (for details see main report). Overall most regions in the country have excellent access to transportation. Only some more mountainous areas are lacking proper transportation.



Kirundo
Muyinga
Cibitoke
Ngozi
Kayanza
Ruhororo
Karuzi
Cankuzo
Bubanza
Murumvya
Bujumbura
Muramvya
Burundi
Gitega
Ruyigi
Gisuru
Kayokwe
Rutovu
Rutana
Bururi
Rumonge
Makamba
Nyanza-
Lac
BURUNDI
Distance to roads
< 1 km
1 - 3 km
3 - 6 km
6 - 10 km
10 - 20 km
20 - 50 km
50 - 100 km
> 100 km
0
20
40
80
Kilometers

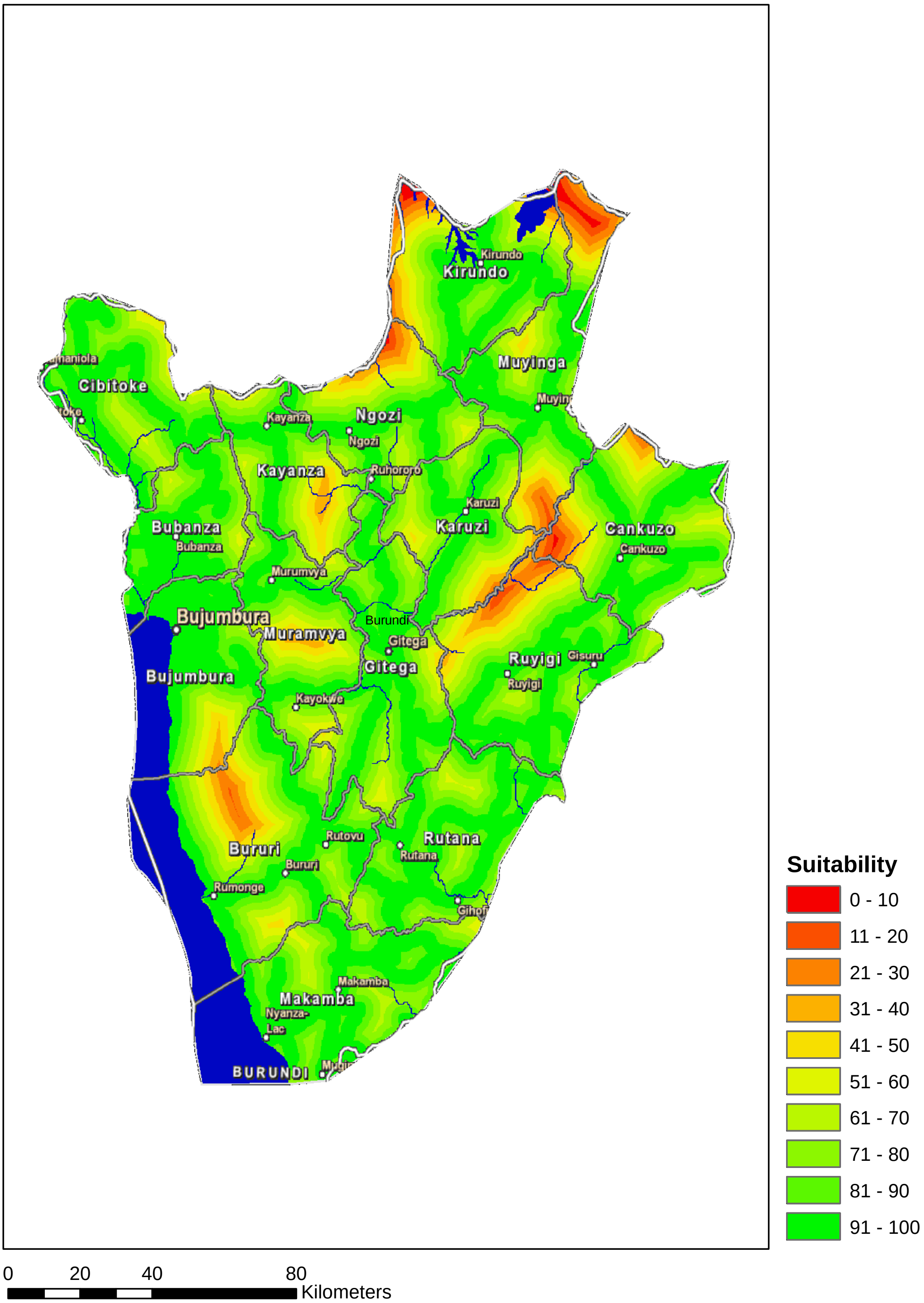
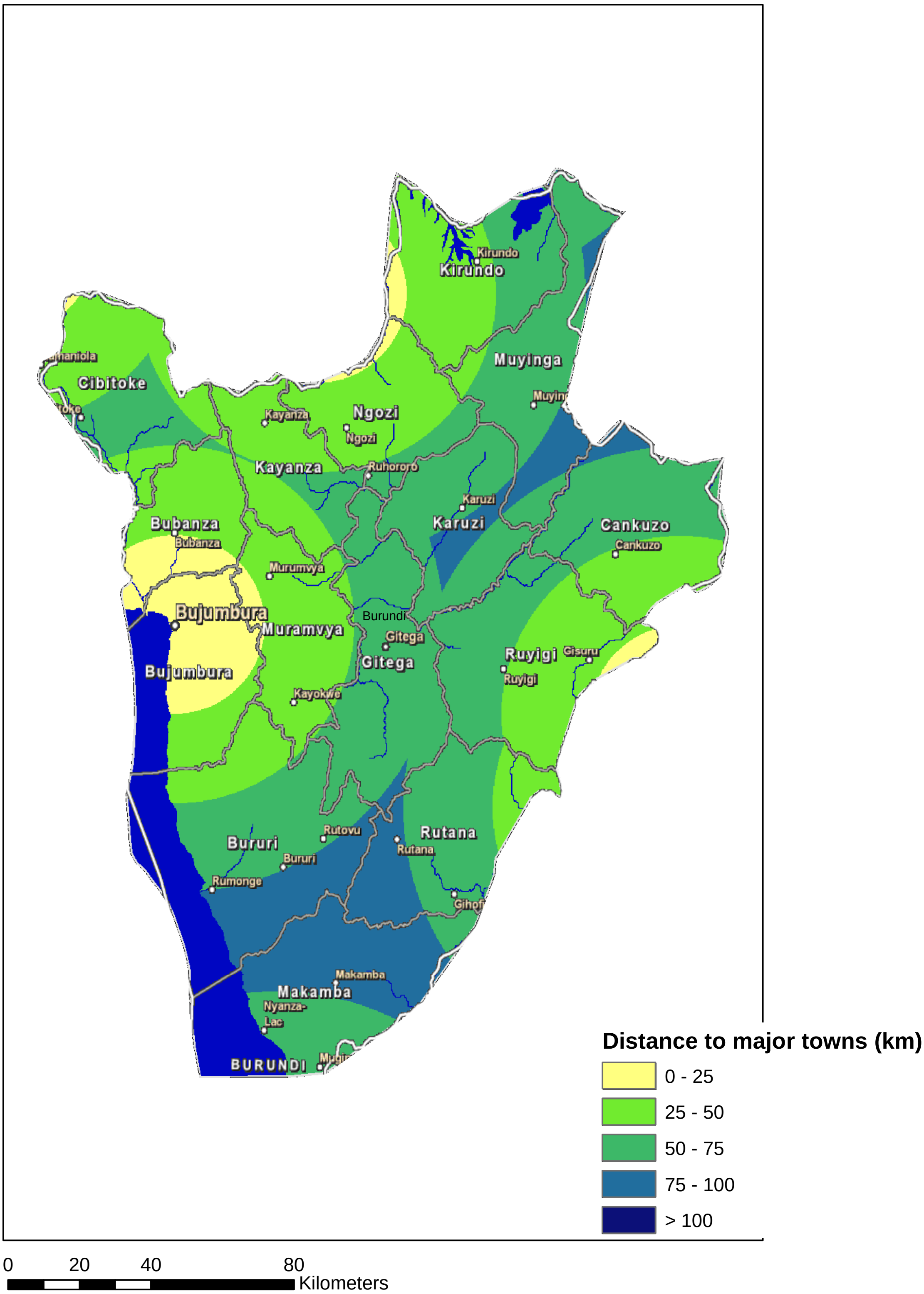
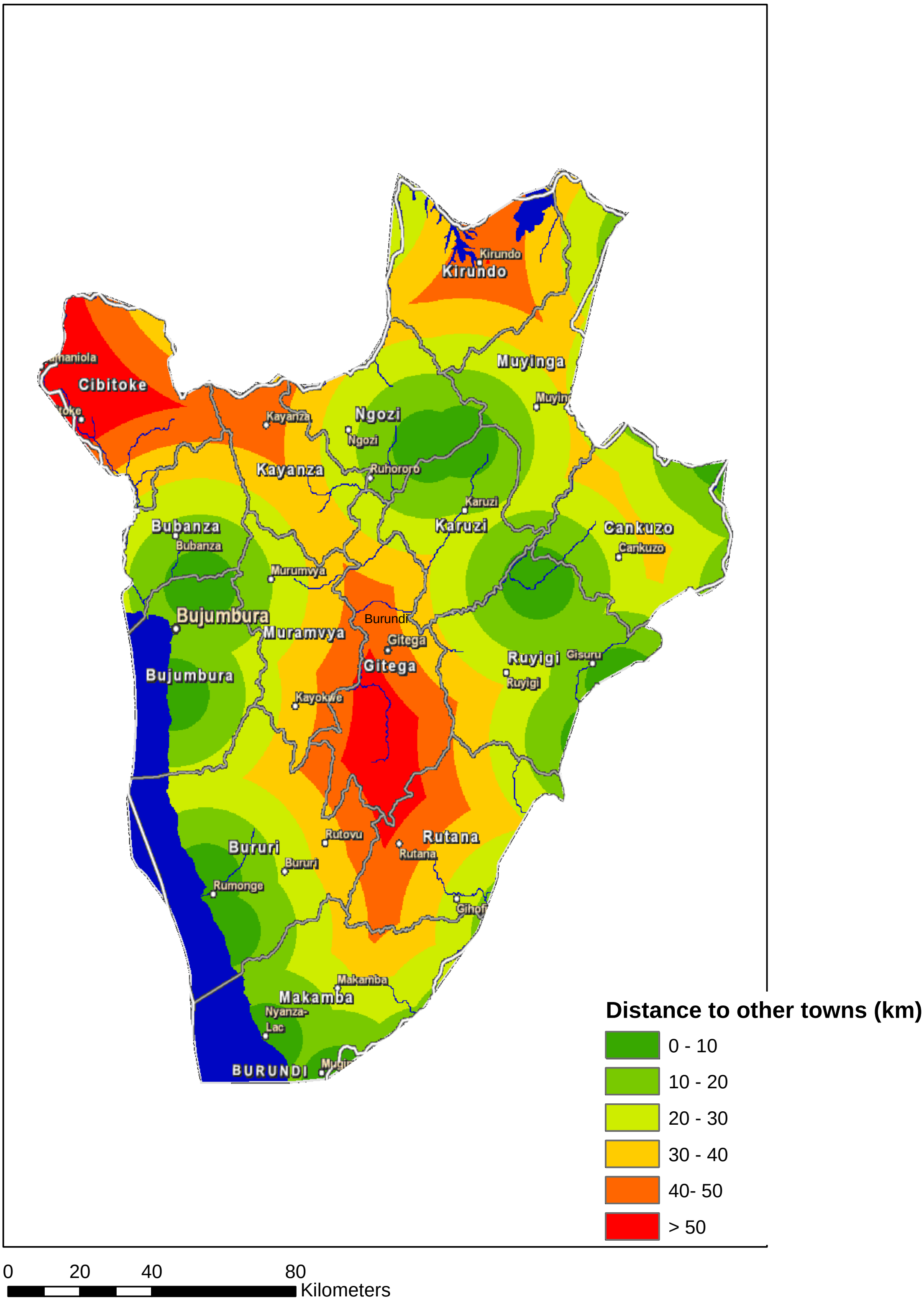


Figure 26: Distance to transportation (top), and suitability (bottom).

2.5.2 Access to markets

Access to markets is an important factor if irrigated agriculture would be developed. Harvested products should be sold to the local, regional, national or world market. Distance to nearest markets is therefore an important factor to determine suitability for irrigated agriculture. Analysis is based on the distances to the nearest smaller cities and larger towns (see for details main report).


Kirundo
Kirundo
Muyinga
Cibitoke
Kayanza
Ngozi
Ngozi
Kayanza
Ruhororo
Karuzi
Karuzi
Bubanza
Bubanza
Cankuzo
Cankuzo
Murumvya
Bujumbura
Muramvya
Burundi
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
Bujumbura
Kayokwe
Rutovu
Rutana
Bururi
Rutana
Bururi
Rumonge
Makamba
Makamba
Nyanza-Lac
BURUNDI
Distance to major towns (km)
0 - 25
25 - 50
50 - 75
75 - 100
> 100
0 20 40 80
Kilometers


Kirundo
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Ngozi
Ngozi
Kayanza
Ruhororo
Karuzi
Karuzi
Cankuzo
Cankuzo
Bubanza
Bubanza
Murumvya
Bujumbura
Muramvya
Burundi
Gitega
Gitega
Ruyigi
Gisuru
Ruyigi
Bujumbura
Kayokwe
Rutovu
Rutana
Rutana
Bururi
Bururi
Rumonge
Makamba
Makamba
Nyanza-
Lac
BURUNDI
Distance to other towns (km)
0 - 10
10 - 20
20 - 30
30 - 40
40- 50
> 50
0
20
40
80
Kilometers

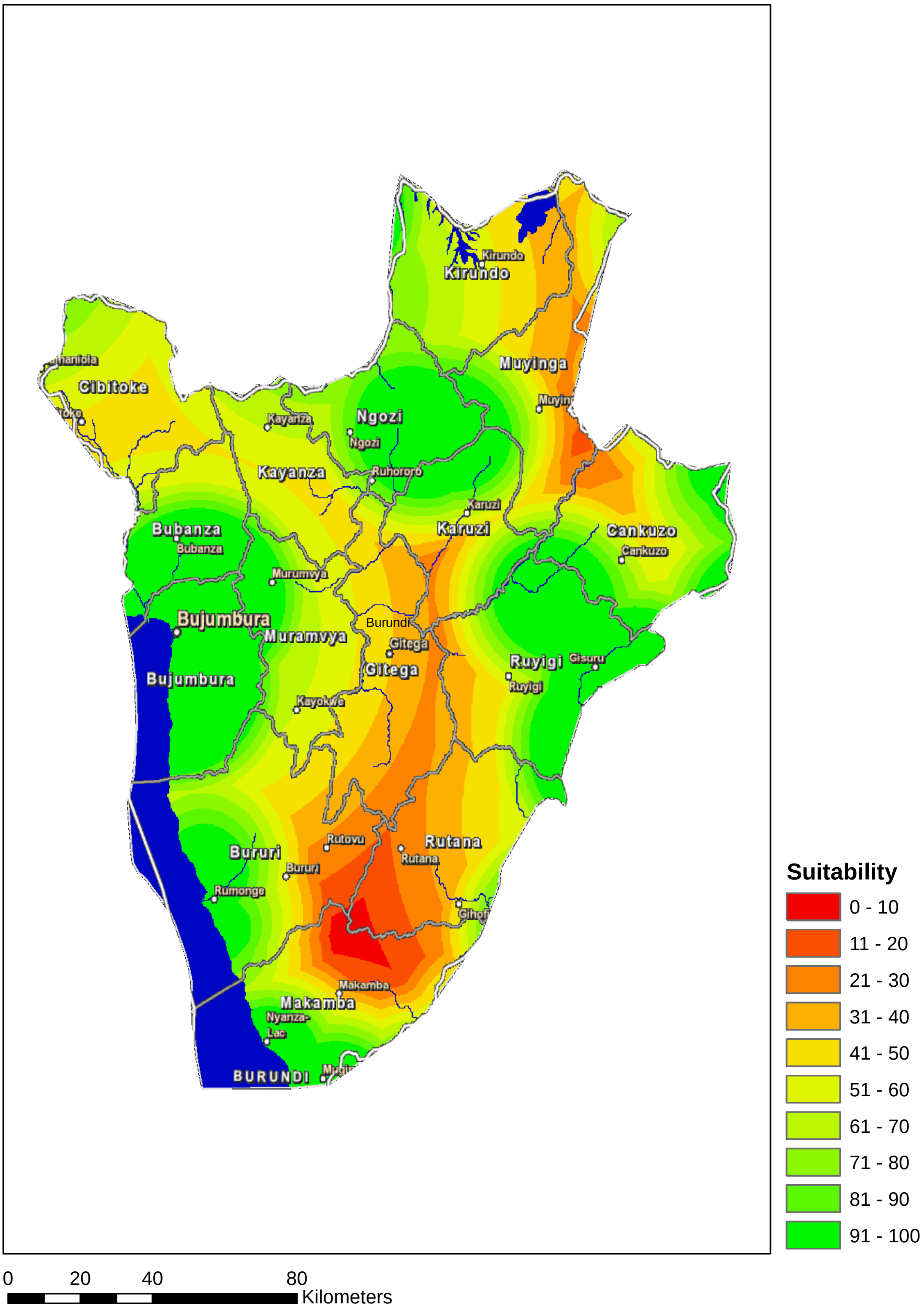


Figure 27. Distance to major towns (top), distance to other towns (middle), and combined suitability index (bottom).

2.6 Population density

Population density should be considered in the context of irrigation. Highly-dens populated areas are not suitable for irrigation. On the contrary, areas where hardly anybody lives might face difficulties in terms of labor and markets. Total population of Burundi is about 8 million of which most live in the capital Bujumbura and in the northern part. Population density can be observed in Figure 28.

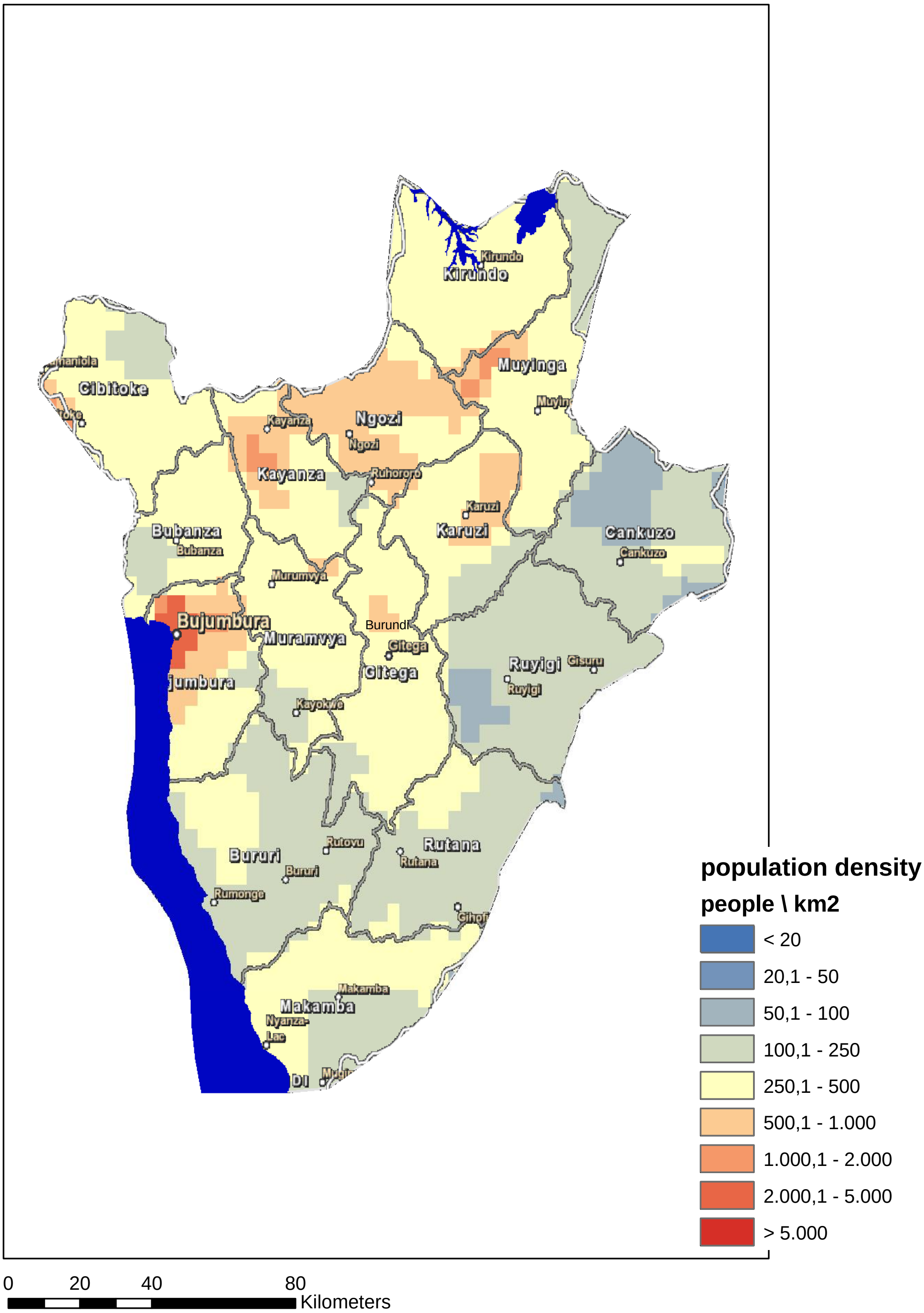


Figure 28: Population density distribution (source: CIESIN, 2010).

2.7 Institutional and legal framework[1]

2.7.1 Water treaty agreements

A number of institutions are involved in the management of water resources, resulting in overlapping responsibilities in some areas. The Ministry of Water, Energy and Mines (MWEM), through its Directorate General for Water and Energy (DGEE), heads up policy formulation and the administrative functions of the central government as they relate to the WSS sector. In the rural areas, the Directorate General of Rural Water and Electricity (DGHER), an entity under MWEM, oversees and coordinates drinking water and sanitation.

The Water and Electric Authority (REGIDESO), a public utility with autonomous legal and financial status that operates under the supervision of the MWEM, and 34 Communal Water Authorities (RCEs) undertake actual service provision. REGIDESO is responsible for catchment, treatment, and distribution of drinking water in the urban or urbanizing centers. The RCEs supply drinking water to the rural areas.

SETEMU (Services Techniques Municipaux) is responsible for sewerage and wastewater treatment services, but only covers 38 percent of the Bujumbura's needs. Other cities and towns do not have a sewerage system or wastewater treatment facility. Sanitation services in rural areas are limited; only 23 percent of the population uses functional facilities.

The government of Burundi remains the principal financier of the water supply and sanitation (WSS) sector in spite of its scarce budgetary resources. Donor contributions are increasing, but private sector investments remain absent.

At the moment of writing the New Partnership for Africa's Development (NEPAD) action plan (2004), the Nile Basin Initiative (NBI) is the only active organization which is internationally managing and developing the trans-boundary rivers within the Nile basin. Another organization, the Kagera Basin Organization (KBO) was established in 1977, but is hardly active anymore nowadays. Under the Nile Equatorial Lakes Subsidiary Action Program (NELSAP) several programs take place on (trans-boundary) basin scale, of which the Kagera Basin project is one of them. Currently, the 1929 agreement and the subsequent 1959 agreement signed by Egypt and Sudan are still in place. This 1959 agreement is purely bilateral; it seeks to apportion the entire flow of the Nile to Egypt and Sudan, excluding the interests of any other riparian countries. Currently, under the NBI new negotiations take place to come to an agreement with all the Nile countries. At the time of writing the results from these negotiations are not yet published.

2.7.2 Land ownership rights

The Post-Transition Interim Constitution of the Republic of Burundi, ratified by popular vote in 2005, guarantees every Burundian the right to property. Specific legislation and policy with regard to land, however, do not support this constitutional right. The Constitution grants foreigners equal protections to person and property, without restrictions on foreign ownership of land (GOB Constitution 1992a; USDOS 2009).

The 1986 Land Code and the customary tenure system provide parallel structures for governing access to land. The goal of the Land Code was to encourage the country's development and increase agricultural production, while the customary system provides for local administration of

[1] Based on USAID country profile

lands. However, the Land Code recognizes customary rights to land, including fallow land. Under the customary, community-based system, land is held by individual heads of households. The Code, by contrast, requires that land held customarily be registered in order to be officially recognized. The registration process, however, is extremely complex and infrequently followed. The result is that community-based tenure systems have a quasi-legal status, but are not formally recognized (Leisz, 1996).

At the conclusion of the civil war, the Arusha Agreement on Peace and Reconciliation in Burundi (2000), called for revision of the 1986 Land Code to resolve unspecified land management problems. Article IV of the Accords promises that returning refugees will be able to access their land, or will receive adequate compensation (GOB Constitution 1992a; Kamungi et al. 2005; Leisz 1996).

After several years of starts and stops, in 2008 the GOB made significant progress on three land-related fronts. First, initiated by an inter-ministerial technical committee, the GOB adopted a National Land Policy Letter, which identifies four government priorities: (1) amendment of land legislation and modernization of land administration services; (2) restructuring and modernization of administrative bodies responsible for land management; (3) decentralization of land administration; and (4) inventory of state lands (Freudenberger and Espinosa, 2008; Freudenberger, 2010, pers. comm.).

Second, in 2008, the GOB held public consultations on land tenure issues and revised the Land Code with assistance from USAID and the European Union (EU). Issues addressed included: revocation of governors' authority to allocate state land (only the central Ministry of Environment would hold such authority); ownership and management of marshlands; and rights to lands of 1972 refugees (but apparently not to lands of 1993 refugees). The draft Code makes no reference to land rights of women and girls. The GOB sent the draft to Parliament for a vote in spring 2009, but withdrew it in spring 2010, without a vote, just prior to the elections (Freudenberger and Espinosa, 2008).

Third, the GOB adopted a Five-Year Action Plan to Implement the Land Code. The GOB estimates that implementation of the new code will cost US $17–20 million. The prospects for adoption of the draft land code and action plan for implementation are uncertain (Freudenberger and Espinosa, 2008).

2.8 Irrigation potential

Based on information as presented in the previous sections, suitability for irrigated agriculture can be determined. Some information is more qualitative and presented as general reference to support decision making. Other information is quantitative and will be used to create maps to be used to support decisions to select areas that can be studied more in-depth

Results of the analysis are used to create an overall map of "suitability for irrigation". These maps (determining factors) are all scaled between values of 0 (not suitable) to 100 (very suitable). Note that many of these individual maps are composed by combining various other sources. By combining this information a total suitability map per country is produced. The following maps are used to this end:

- Terrain suitability
- Soil suitability
- Water availability
- Distance to water source
- Accessibility to transportation

Based on these maps, the final score indicating suitable for irrigation can be observed in Figure 29 and Table 4. Scores above 60% can be considered as potential suitable for irrigation, while scores above 70% can be considered as very suitable with only minor limitations. The overall suitability for the country is determined at about 105 thousand hectare. In order to assess what limitations are in a certain areas, information from the previous sections can be used.

The suitability map as presented should be considered as the final map for irrigation potential. This map reflects the situation for surface irrigation and non-rice crops. The database attached to the report includes the digital version of these maps allowing zooming in. Moreover, this database includes also the maps with the determining layers that can be used to explore the limitations for a specific area.

It is important to realize that the suitability map has to be considered using other (non-determining) information and maps. Moreover, other factors like expert knowledge, existing policies etc. should play an integrated role as well.

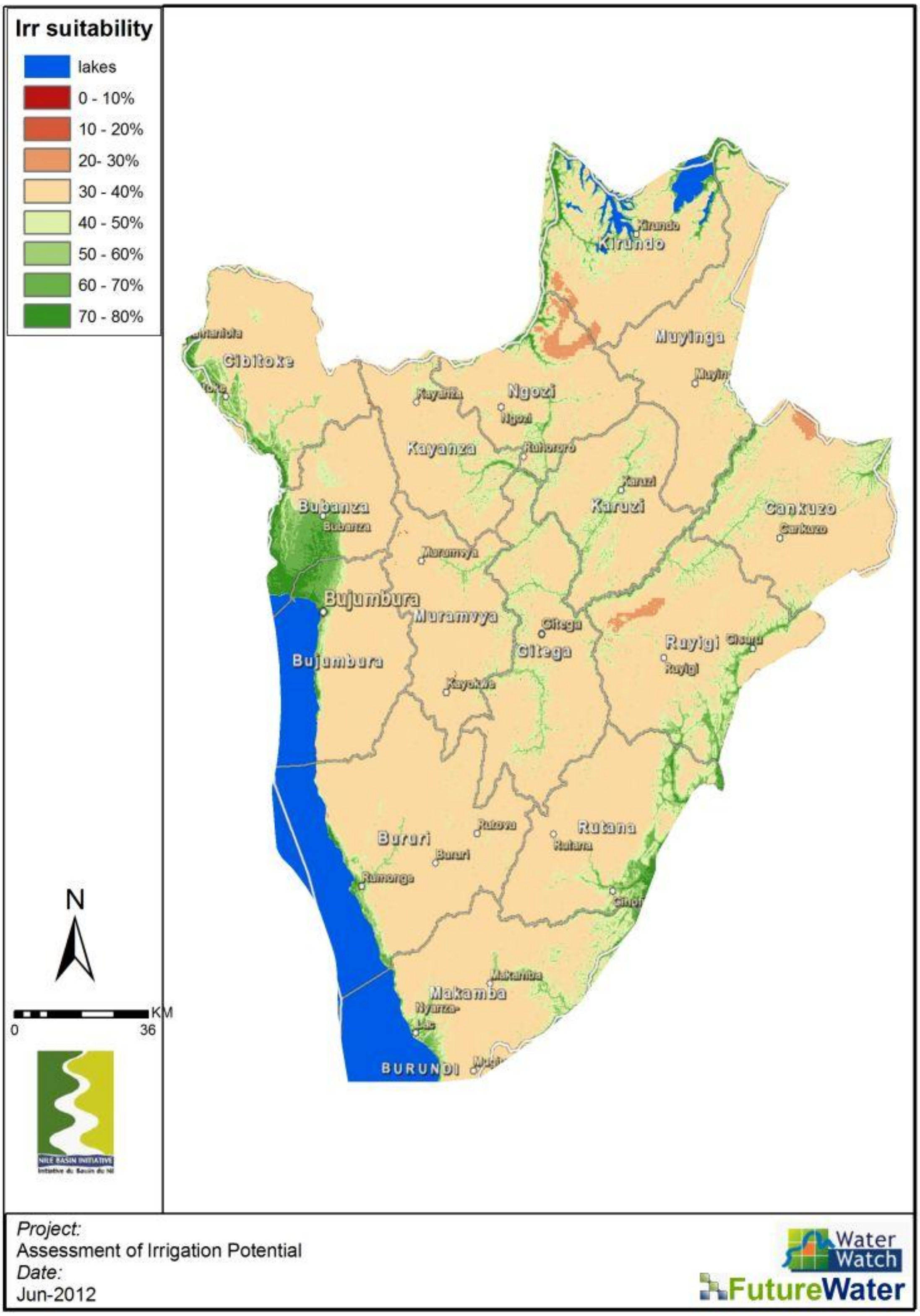


Figure 29: Irrigation suitability score

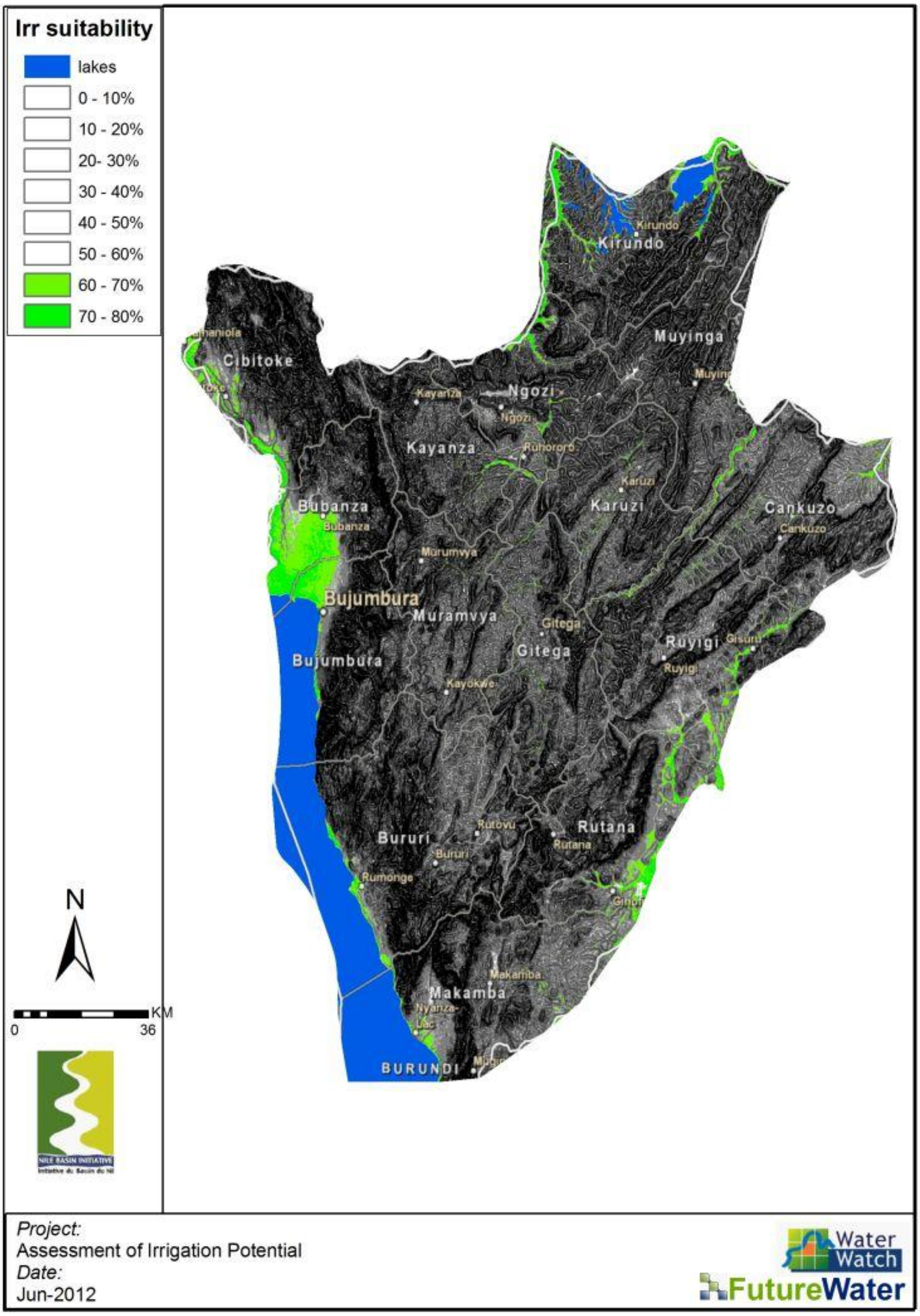


Figure 30. Final map indicating areas suitability for irrigation.

Table 4. Suitability classes.

Suitability	Irrigation potential (ha)
0 - 10%	0
10 - 20%	388
20 - 30%	19,944
30 - 40%	1,910,731
40 - 50%	352,863
50 - 60%	133,094
60 - 70%	70,531
70 - 80%	34,838
80 - 90%	0
90 - 100%	0
Total >60%	105,369

2.8.1 Focal areas

Based on the results from the first phase of the irrigation potential study and the local available expert knowledge and political considerations five focal areas have been delineated on which the second phase will focus. In the following chapters these focal areas will be studied on a more detailed level, and the possibilities for irrigation development will be described. In Table 5 the names and areas are given, and in Figure 31 a map is supplied on which the focal areas are shown.

Table 5: Focal areas Burundi

	Nyanza lac	Nyamuswaga	Ruvubu river	Ndurumu	Moso
Area in ha	8616	3644	5265	4905	12784

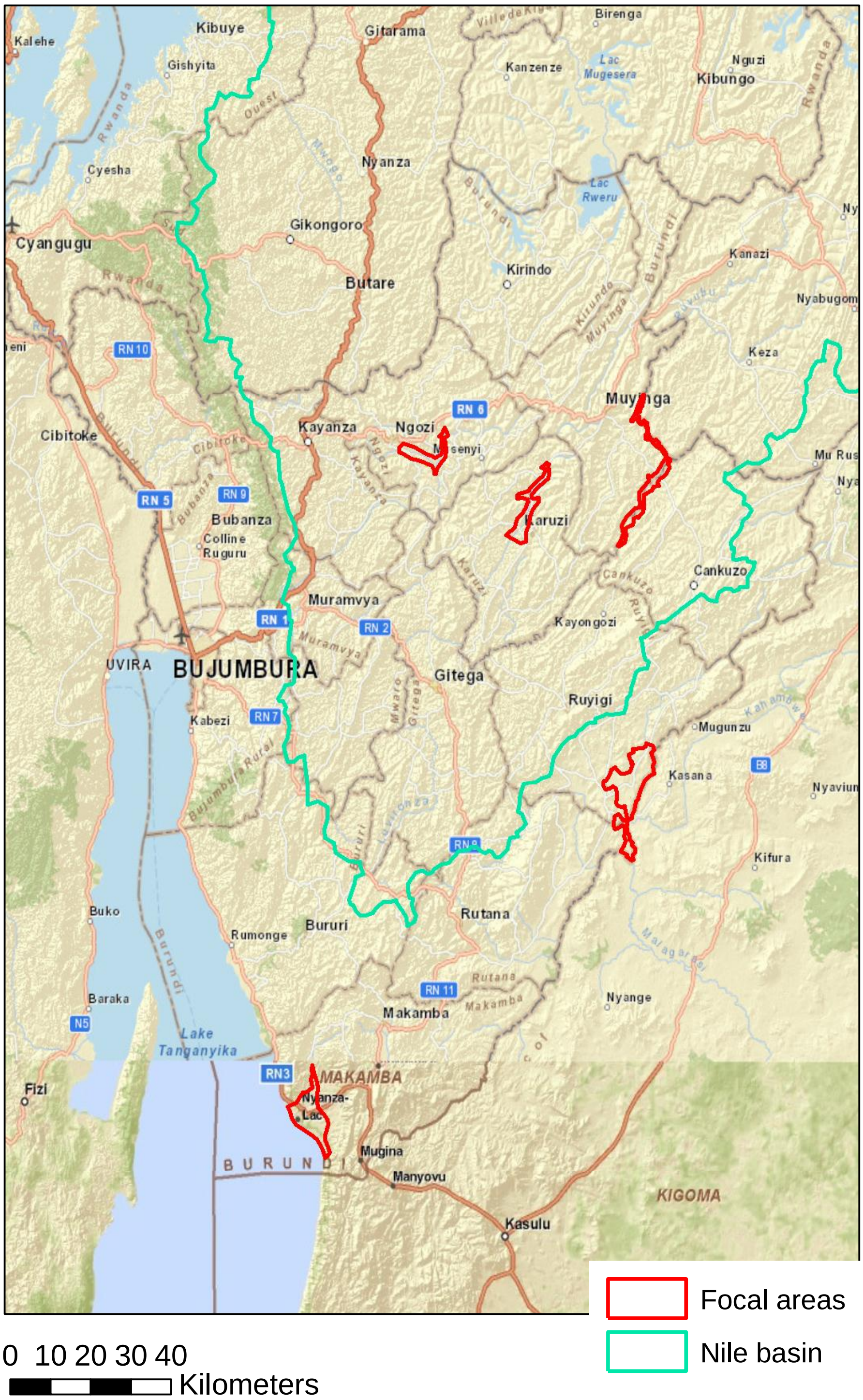


Figure 31: Overview focal areas Burundi

3 Nyanza lac focal area

3.1 Introduction

This chapter will describe the current state of the Nyanza lac focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations and institutional frameworks. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 33 a detailed map of the area is given. Total area is 8616 ha.

Selection of this specific focal area was based on results of Phase 1 of this study, while final selection was the responsibility of the relevant country representatives. Results presented hereafter have been obtained from a broad range of sources: Phase 1, previous other studies and reports, modeling results, remote sensing, expert knowledge and field visits by Christophe Majambere and Emmanuel Ndorimana as supervisor in March 2012.

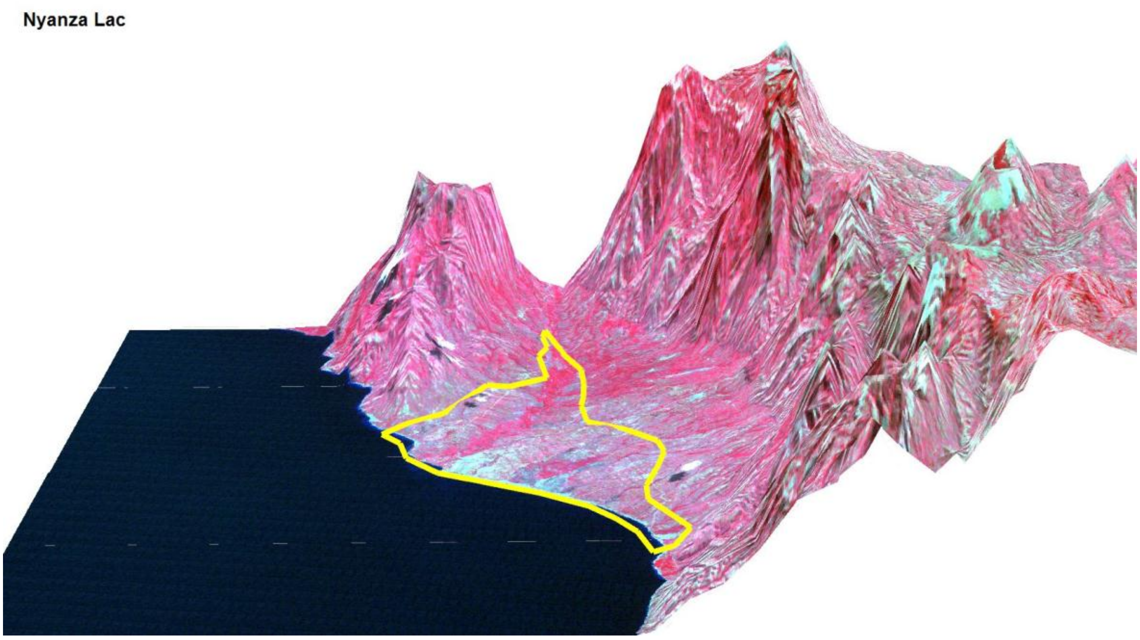


Figure 32: 3D impression of Nyanza lac focal area, Burundi

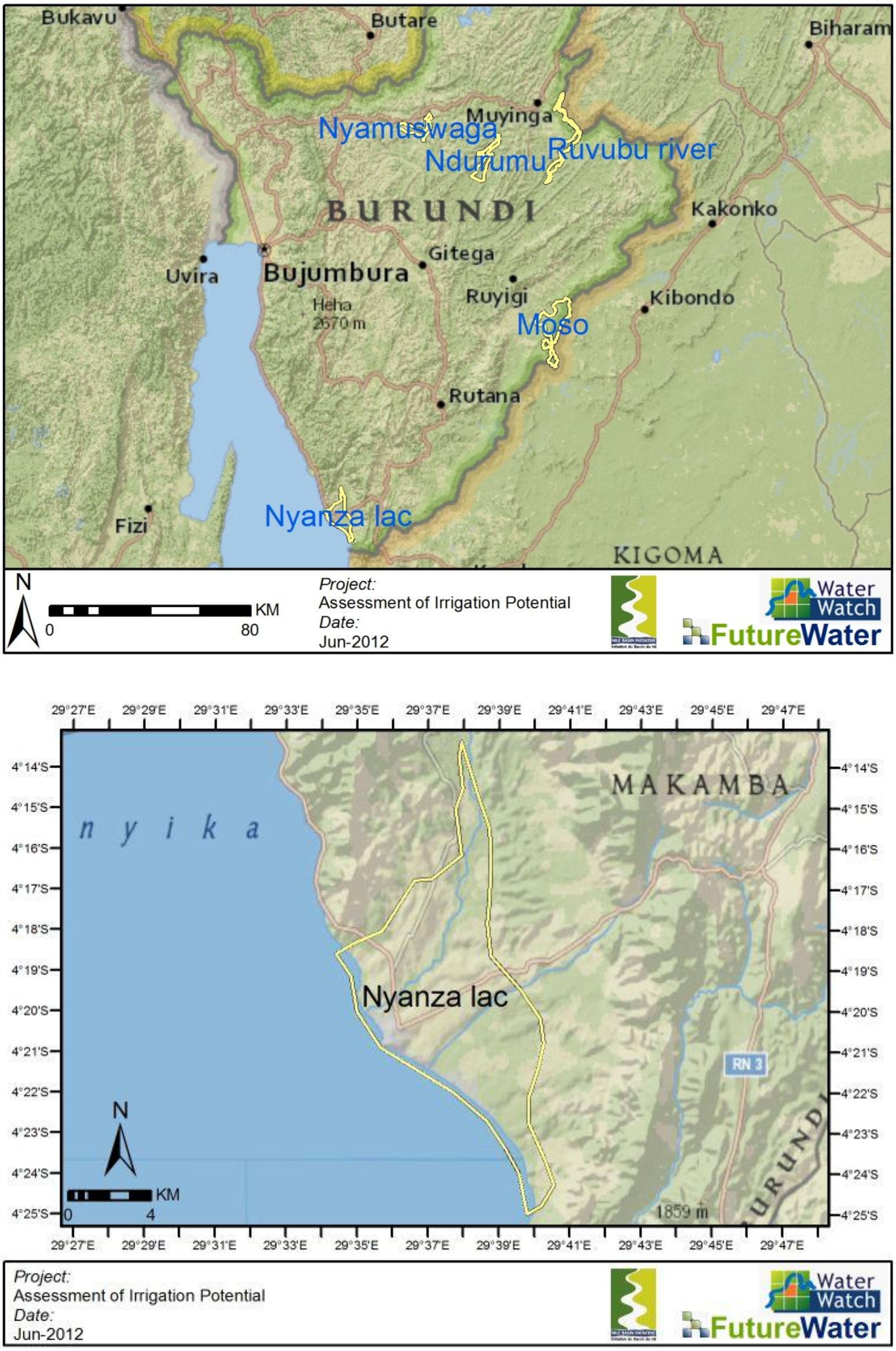


Figure 33: Nyanza lac focal area, Burundi

3.2 Land suitability assessment

3.2.1 Terrain

Nyanza lac focal area is situated in the southern point of Burundi within Makamba province. The southern point of the focal area is tipping at the border with Tanzania. The area covers the plains going slightly up from Lake Tanganyika towards the mountains in the East. The elevation varies from 830 m above sea level at the eastern and northern part, towards 767 m at the lake (Figure 34). Overall the area is ascending gradually from West to East, with the exception of some prolonged foothills, reaching completely towards the lake. Slopes vary between 0 and 10%, but on average slopes are under three percent (Figure 35).

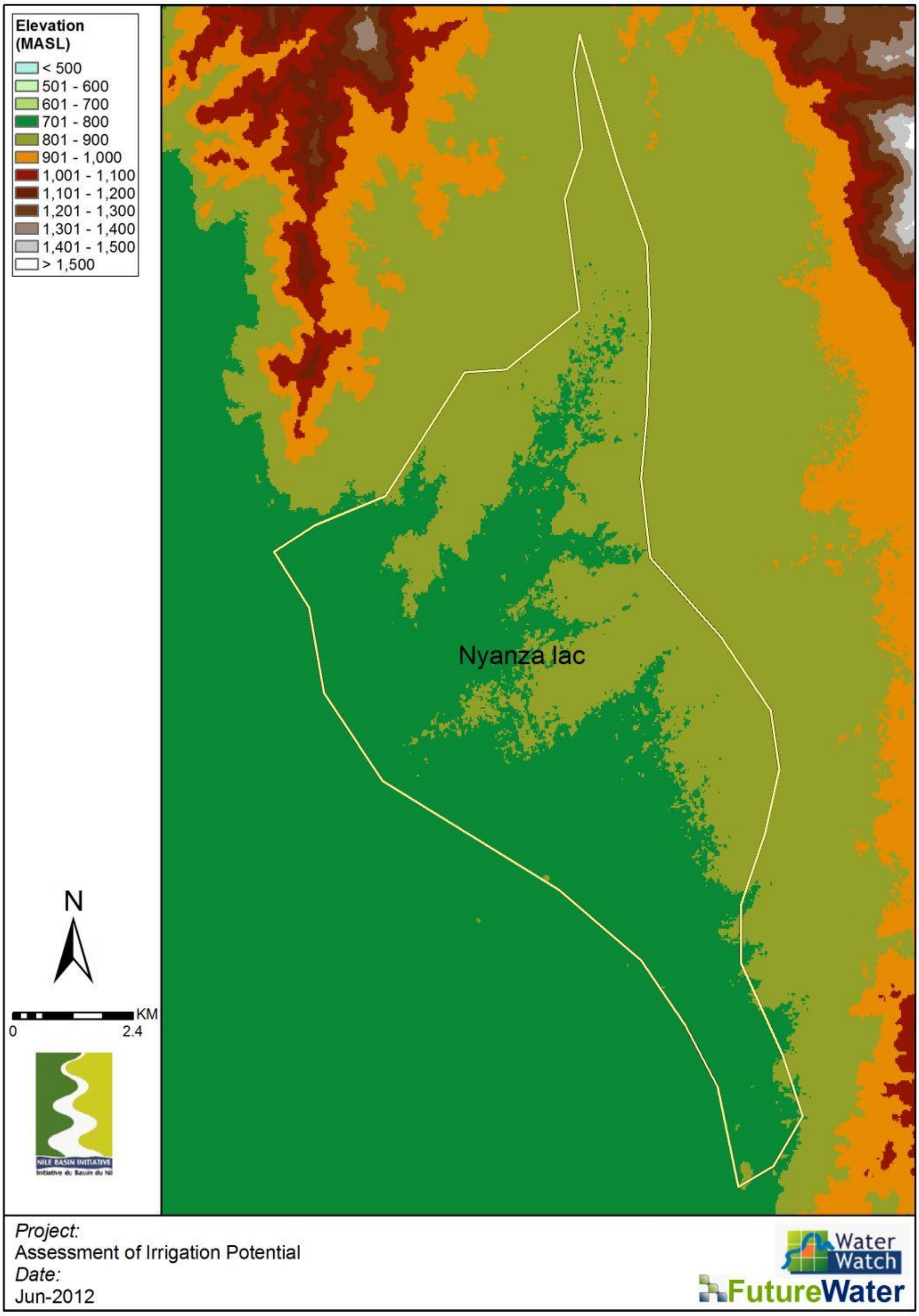


Figure 34: DEM Nyanza lac focal area. Resolution 1 arc second (+/- 30m)

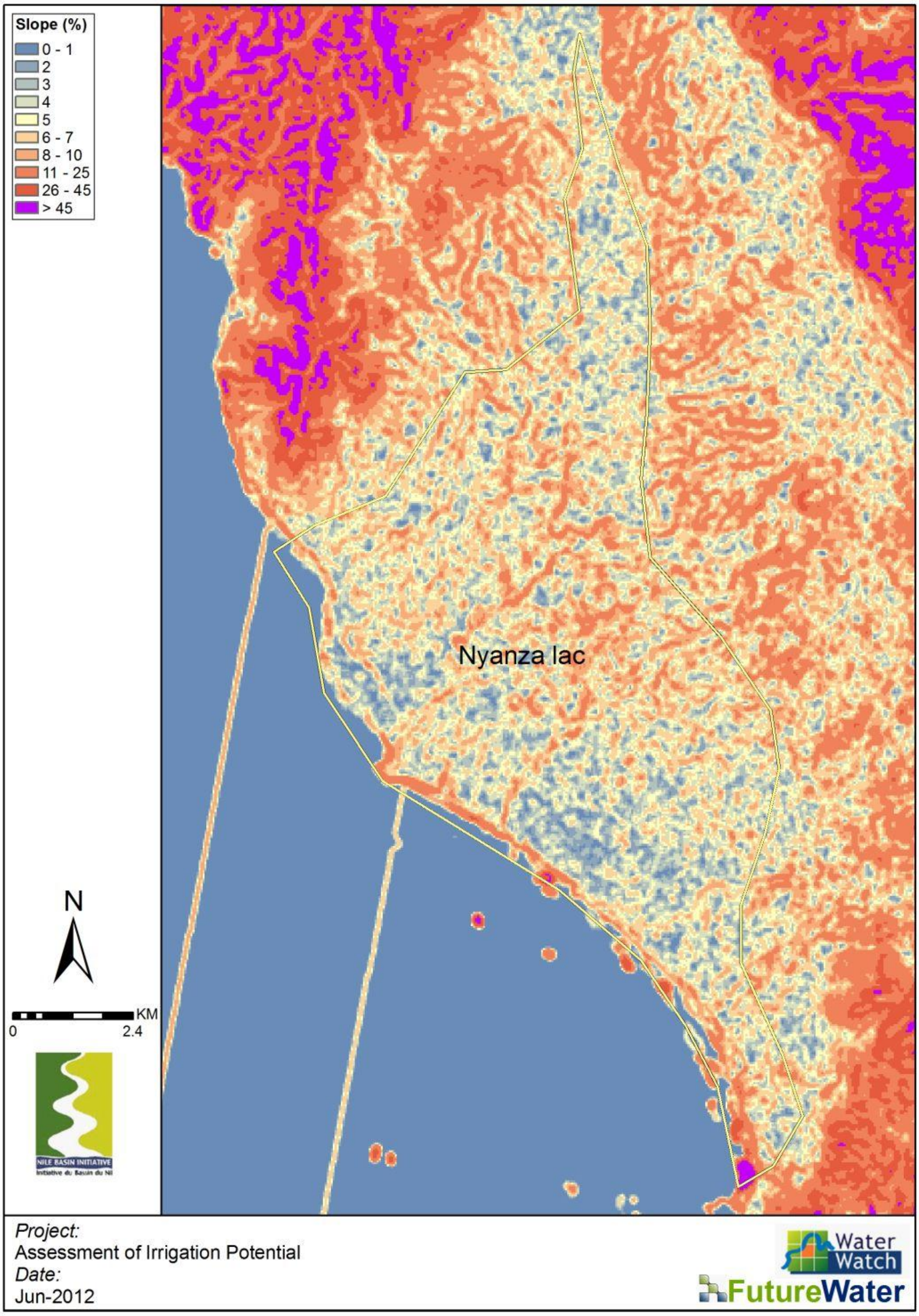


Figure 35: Slope map Nyanza lac focal area (source: ASTER).

3.2.2 Soil

Soils in Nyanza lac are mainly formed under Fluvial and Eluvial processes. Soils are sandy loam on the hills and foothills, and loamy clay in the lower areas. Soils in the lower areas have been used for agriculture for a long time, and are improved by repeated plowing and the humus runoff from the slopes of Mumirwa in the East. Therefore the topsoil has, with over 2%, a relative high percentage of organic carbon. Drainage is slightly poor in the lower areas, and the higher areas in the foothills are better drained. The topsoil is with a pH between 4-5.5 acid to slightly acid. The water holding capacity is large with over 150 mm/m. Erosion takes place as there are hardly any anti-erosion measures.

3.2.3 Land productivity

The land productivity in Nyanza lac is about 10% above the Burundian average. The whole area has an average NDVI of 0.61, which is higher than the Burundian average of 0.56. Average land productivity is highest in the upstream part of the focal area, and along the streams. In the very upstream part of the focal area, land is hardly cultivated and therefore the land shows stable land productivity over the year with an NDVI of 0.8. At the lake shores, around Nyanza lac town, and in the foothills the NDVI is lowest, with areas approaching NDVIs of 0.4 (Figure 37). The coefficient-of-variation is highest along the lake and in the North West of the area. These areas are under seasonal agriculture.

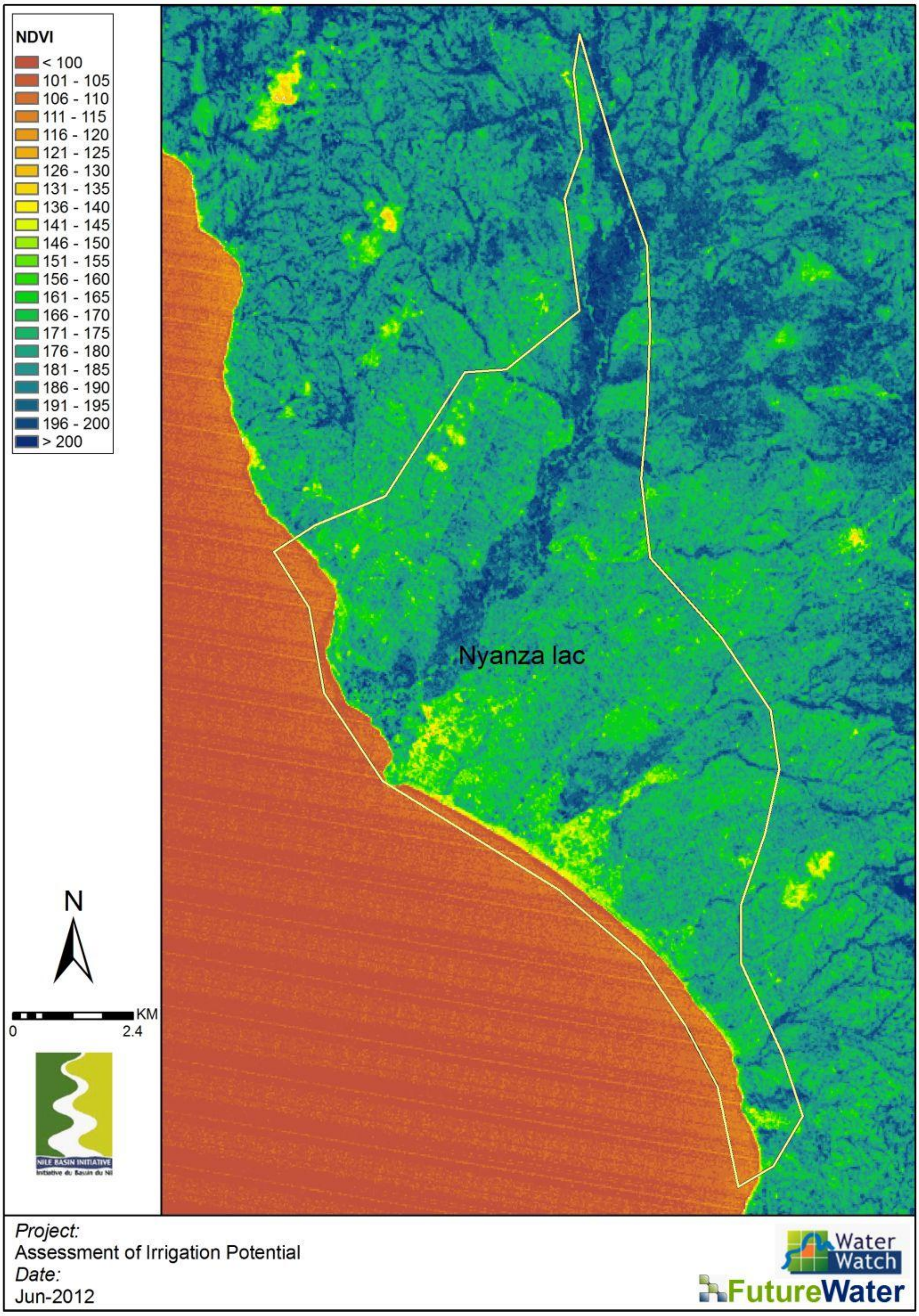


Figure 36: High resolution NDVI

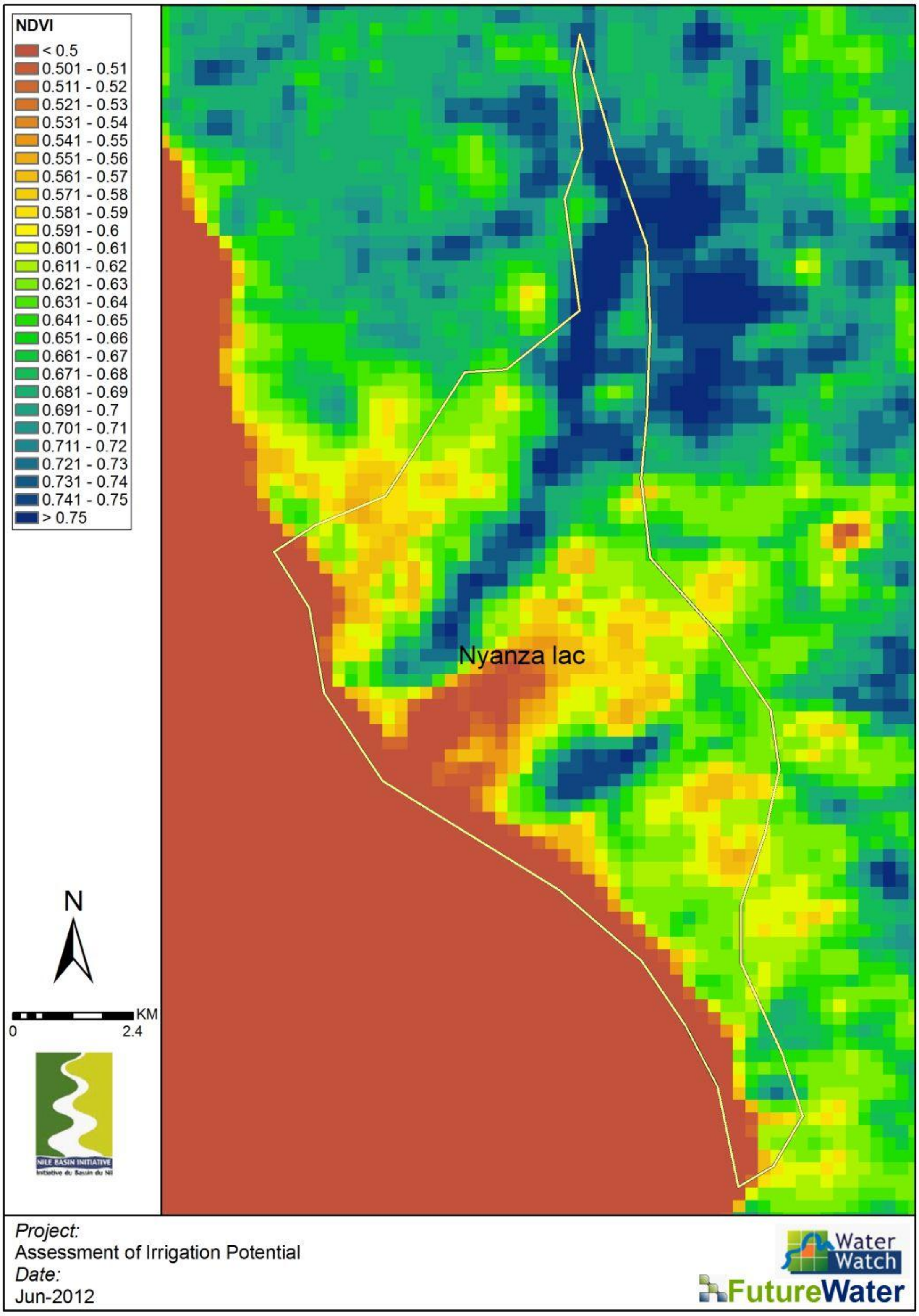


Figure 37: Yearly average NDVI values.

3.2.4 Potential cropping patterns

Currently over 90% of the lands is cultivated for agriculture. Palm oil trees are the most dominant crop, covering about 60% of the area. Besides this, Cassava is grown on about 20% of the area and tomatoes and eggplant both cover approximately 5%. On many places crops are grown in multiple layers underneath the palm trees. The governmental policy is to stimulate regional qualities and agricultural differentiation. Therefore Palm oil trees will remain the most important perennial crop, and cassava and eggplant will remain. Both will be grown in one cropping cycle per year. On small scale, bananas, vegetables and beans will be grown next to each other. Vegetables and beans can also be grown underneath the palm oil trees.

3.3 Water resource assessment

3.3.1 Climate

Average climate conditions for the area are shown in the figure below. Precipitation is based on an advanced calibration/validation algorithm using satellite derived precipitation and calibrated using local observations. Details can be found in the Phase 1 Report. Reference evapo-transpiration (ETref) is calculated using the well-known Penman-Monteith approach. Input data for ETref is based on local observations and an advanced spatial downscaling algorithm.

The climate of the area can be characterized as relatively warm with constant temperatures during the year ranging from about 17^{o}C to 27^{o}C, with lower minimum temperatures during June and July. Annual average precipitation is 1055 mm and reference evapotranspiration 1484 mm per year.

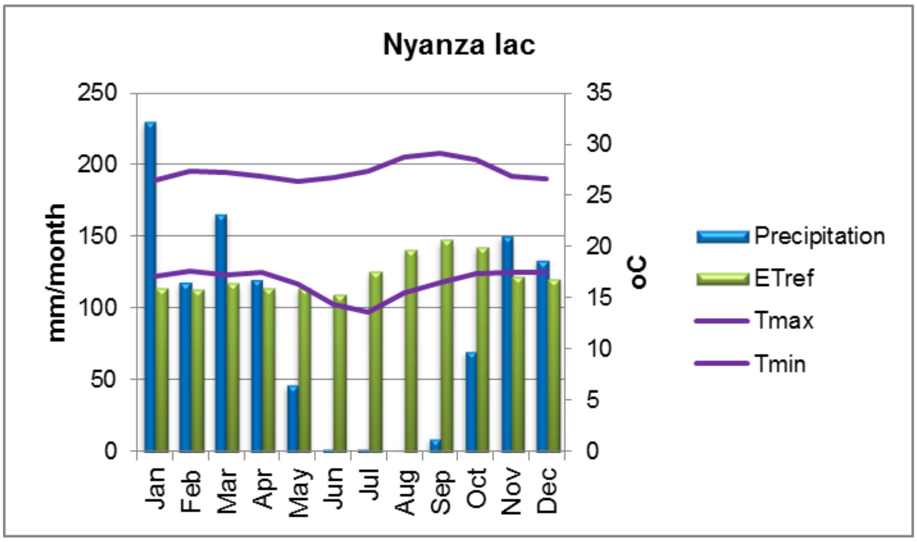


Figure 38: Average climate conditions for the focal area.

3.3.2 Water balance

A very detailed high resolution model was built for NEL countries (NELmod). For a detailed description see Phase 1 report. Results from NELmod were extracted for this specific focal area and are shown below.

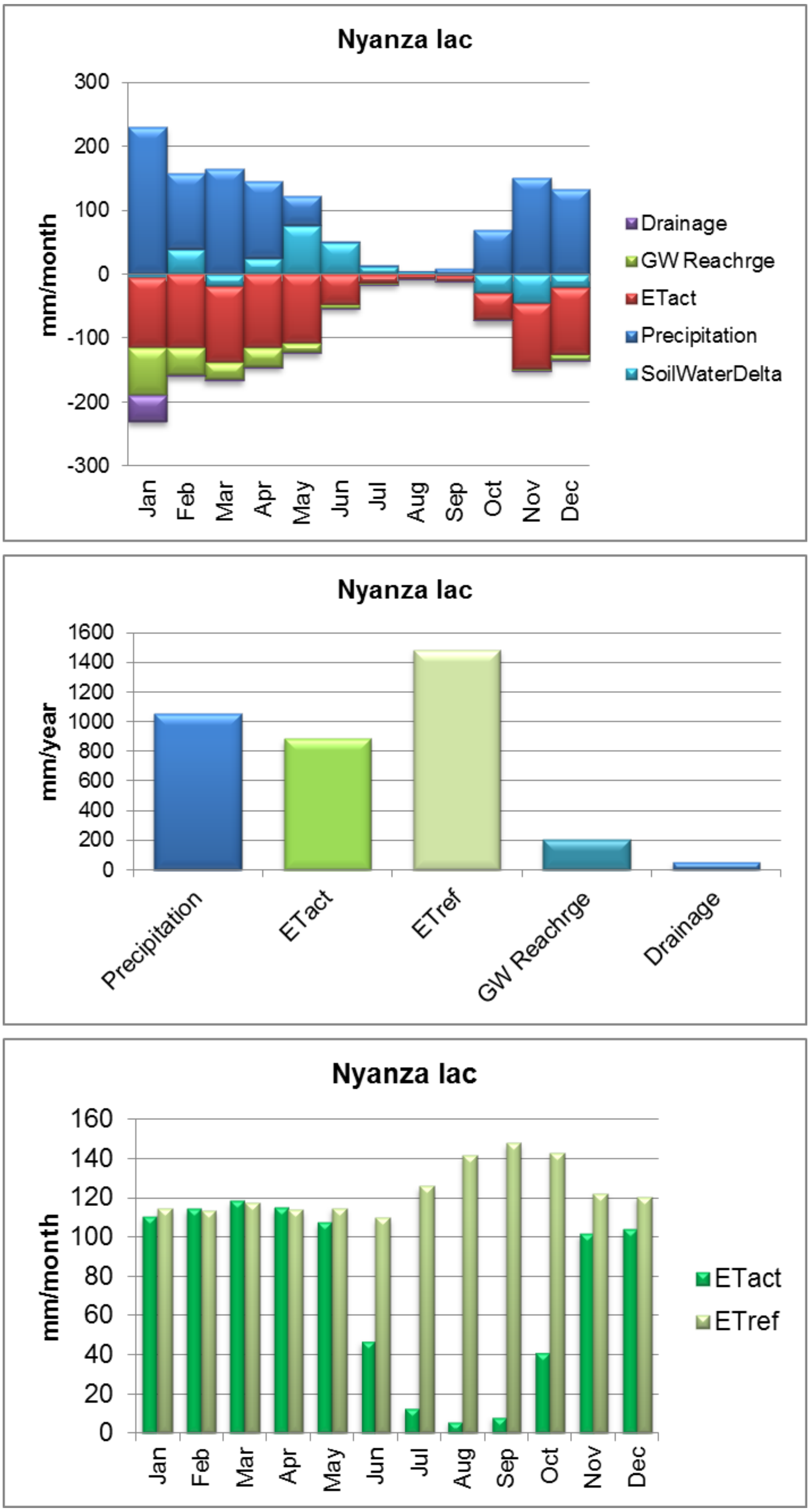
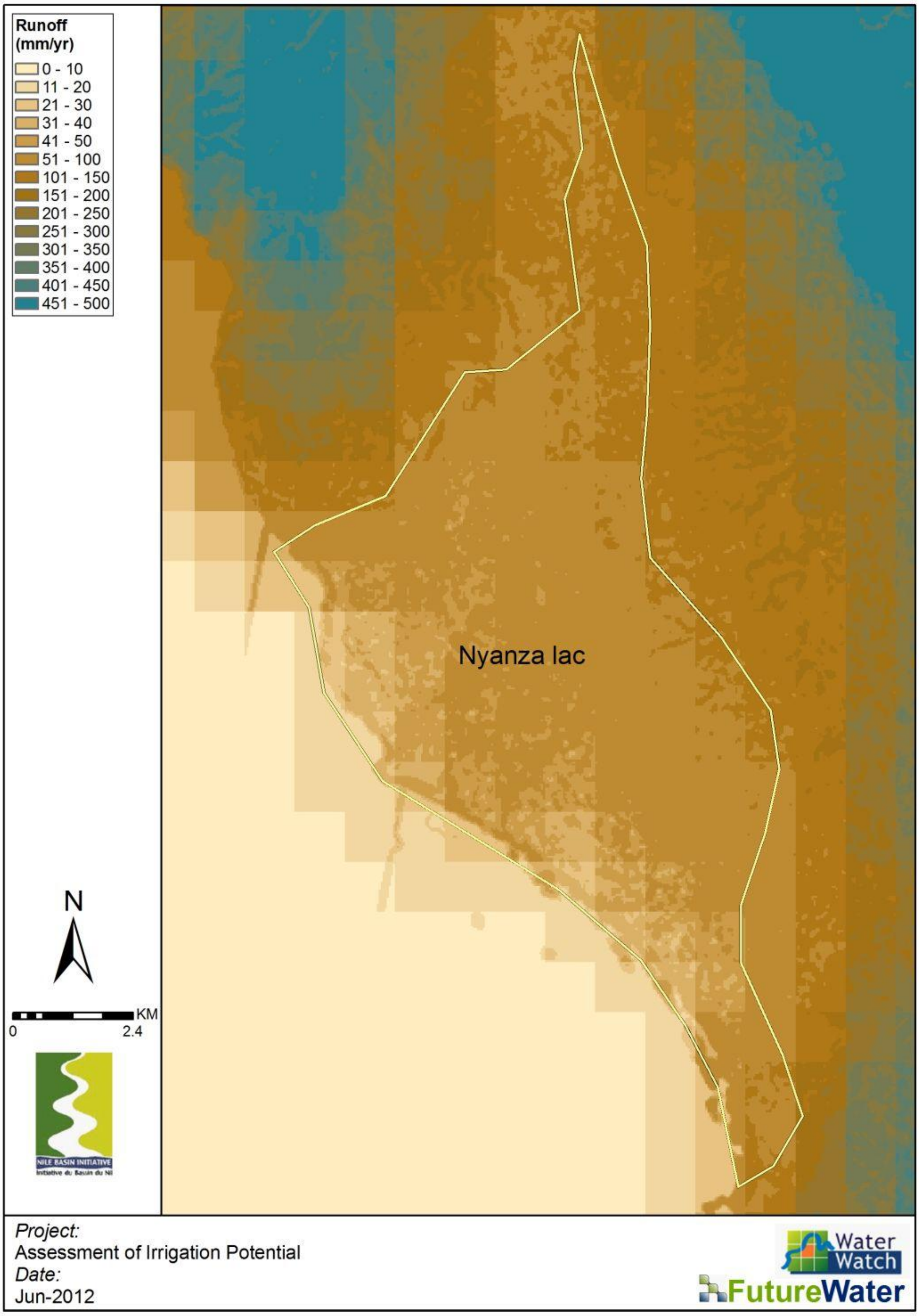
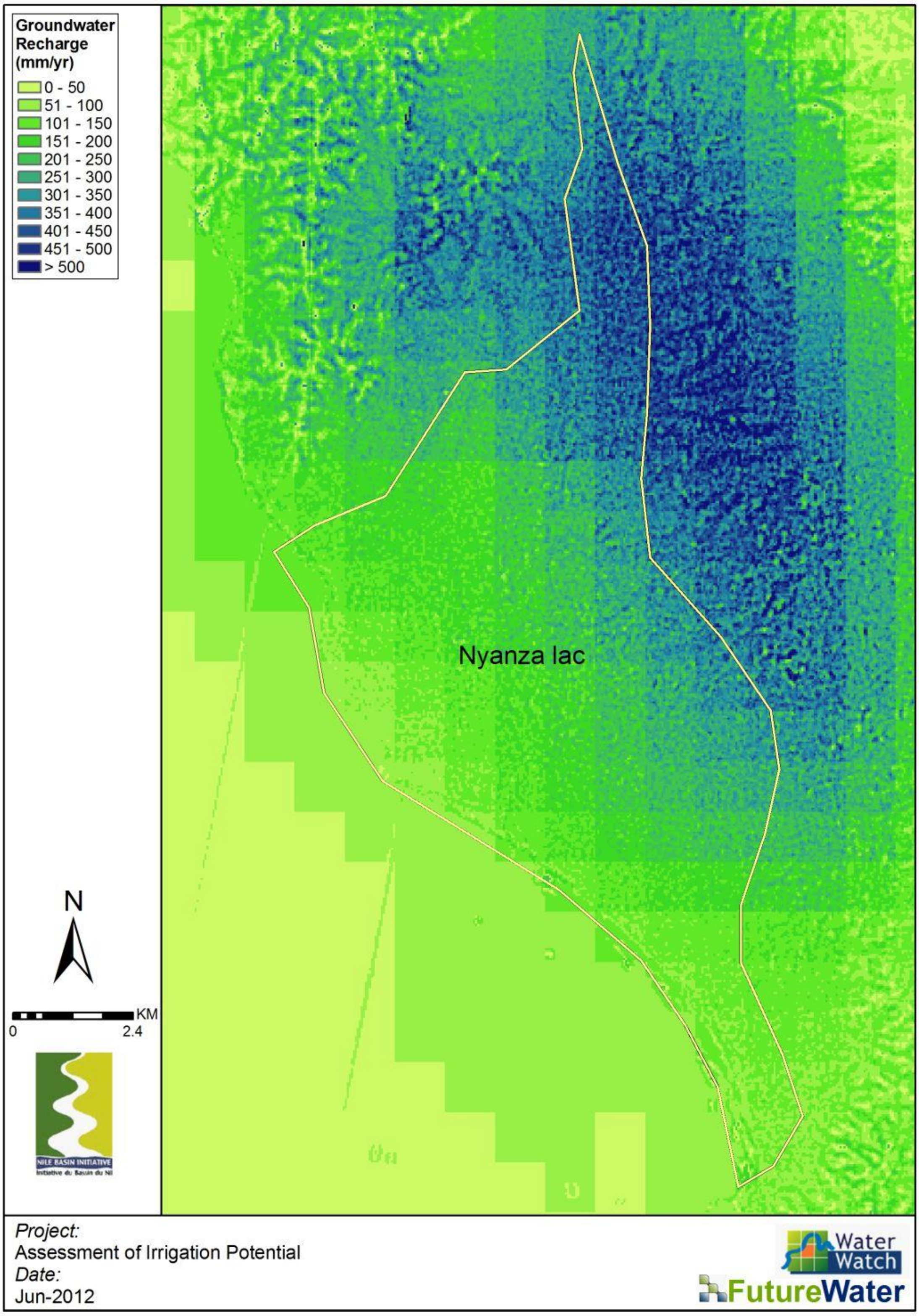


Figure 39: Water balances for the area based on the high resolution data and modeling approach.


Runoff (mm/yr)
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
Nyanza lac
N
KM
0
2.4
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
> 500
Nyanza lac
N
KM
0
2.4
NILE BASIN INITIATIVE
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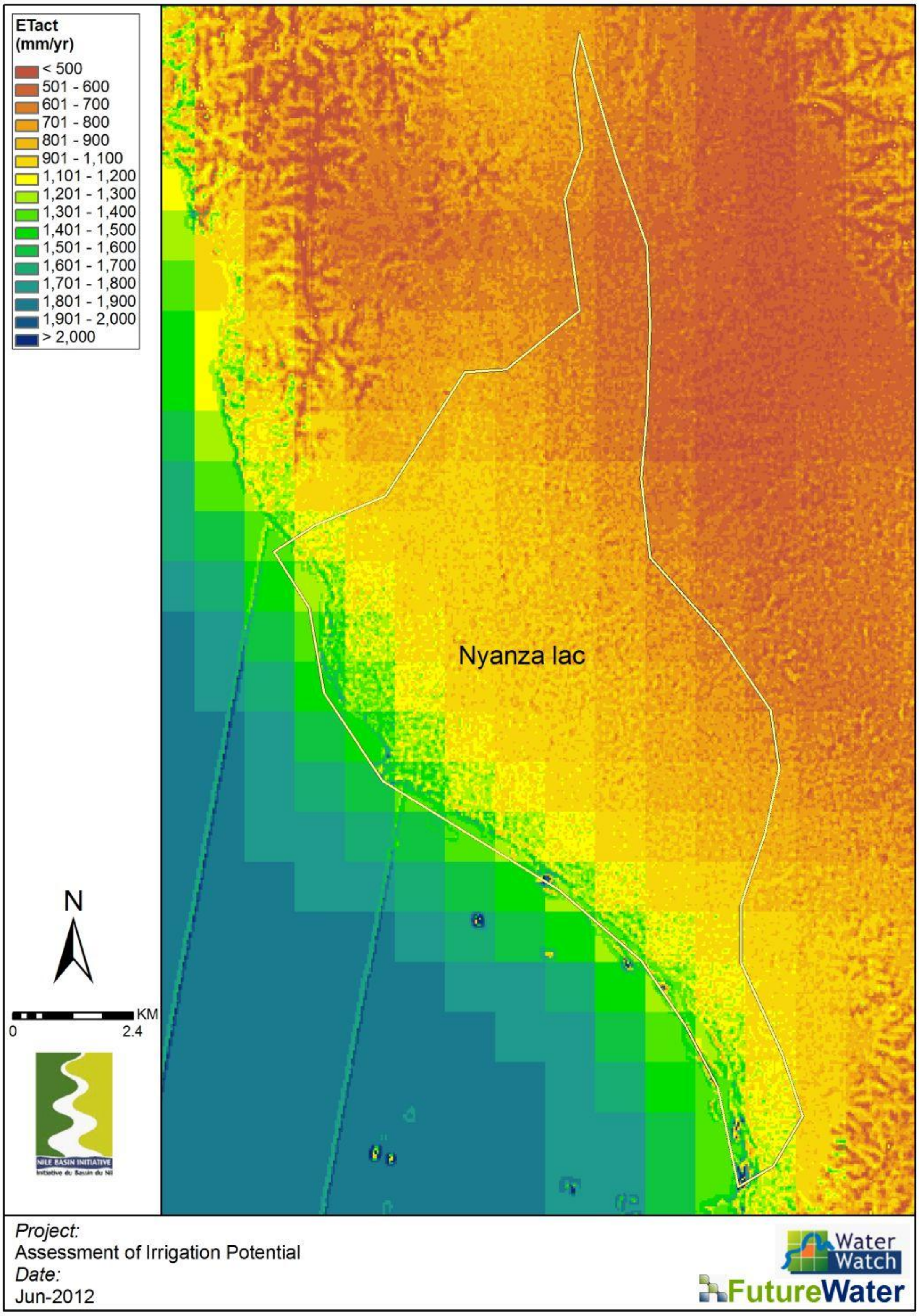


Figure 40: Water balances for the area based on the high resolution data and modeling approach.

3.4 Assessment of irrigation water requirements

3.4.1 Irrigation water requirements

Irrigation water requirements depend on many factors such as: climatic conditions, crop, growing season, irrigation practices etc. A first estimate of irrigation requirements could be based on the difference between rainfall and reference evapotranspiration. It was however selected for this pre-feasibility assessment to provide a first estimate of irrigation needs based on the most promising crops. To this end, FAO's AquaCrop, the successor of CropWat was setup for local and crop specific conditions.

In the table below the irrigation water requirements for each selected crop are provided based on AquaCrop calculations. All units are provided in mm per growing season for the specific crops. Note that for various crops, like vegetables and similar crops, multiple croppings per years might occur.

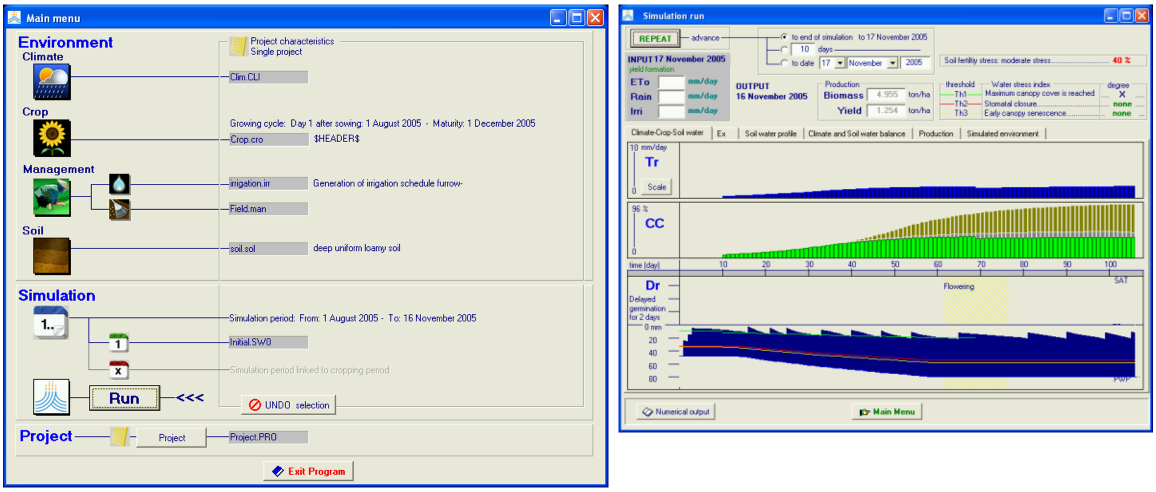


Figure 41: Typical example of AquaCrop input and output screens.

Table 6: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season.

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year	===	== (day of year) ==		======== growing season	=======		
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Palmoil	1055	1484	1	365	1056	80	1480	500
Aubergine	1055	1484	1	365	1056	80	1480	500
Cassava	1055	1484	349	167	758	90	687	469

3.4.2 Irrigation systems and irrigations efficiencies

Within the Nyanza lac focal area several irrigation techniques can be used. Border or furrow irrigation will be most suitable; however the water availability may not be sufficient to irrigate the full area with the upstream water. Since the catchment is small, the discharge of the streams coming from the east fluctuates over the year. There are however some possibilities for a small reservoir upstream to reduce peak flows, and store water for irrigation purposes. The efficiency of border and surface irrigation is quite low, and uses two to three times more water than advanced drip or sprinkler irrigation systems. Therefore, it may be considered to use the upstream water very economically and develop drip or sprinkler irrigation. The plain near the lake can be irrigated with drip or sprinkler irrigation with lake water. This requires some pumping, which increases the operation and maintenance costs; besides this the farmers should be trained on how to use the irrigation systems. A detailed cost analysis within a feasibility study will show which technique is most economically.

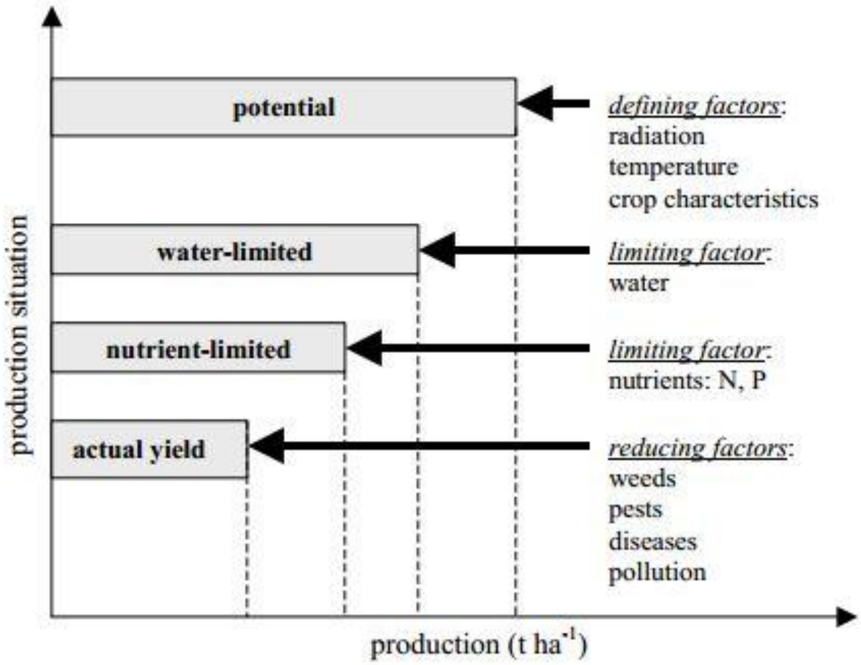
3.4.3 Water source

The water for irrigation comes from two sources. First of all, one main stream and two minor streams come from the slopes of Mumirwa hills in the East. A small reservoir can be build upstream for the major stream. Since the total catchment is rather small, with only 43,100 ha, the available water from runoff may not be sufficient to irrigate the whole area with water from the stream. Therefore, lake water can be used to irrigate the plains at the lake shores. This requires pumping, but the head is very limited.

3.5 Potential crop yield assessment

The yield gap describes the difference between the current yield, and the maximum possible yield. Mostly the maximum possible yield is defined as the highest yield in the world, but it can also be assessed against a regional background which makes the yield gap more realistic and the maximal yield possible to achieve under the given circumstances.

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximum possible yield is not reached can be the water availability, the soil and the available nutrients, or yield reducing factors like diseases, weeds or pollution.



3.5.1 Yield gap analysis potential dominant crops

Yields in Burundi are among the highest in the NELSAP countries. The topography, population density increase, and the increasing demand for food have been drivers for agricultural intensification. However, irrigation is not practiced much, and fertilizer is hardly used. In Figure

42 the yield gap is shown relatively to Burundian average yields, NELSAP average yield, East African yields, African yields, and world's average yields. Everything is scaled to percentage of the highest yields obtained somewhere in the world.

Yields in Nyanza lac are just above Burundi's average. However, the nearly unlimited water source of Lake Tanganyika creates a large potential for irrigated agriculture. The future potential crops include cassava, eggplant and oil palms. Yields of the most dominant crop, oil palm, are around the world's average, and can still increase slightly, but are expected to increase towards 65% of the world's highest obtainable yield. The production of cassava has a higher potential and it is expected that yields can increase towards the world's average, which means that yields can nearly triple. For eggplant no data is available within FAOstat, however, the area is assessed to be suitable for eggplant and it is expected that yields will reach just around the world's average when irrigated.

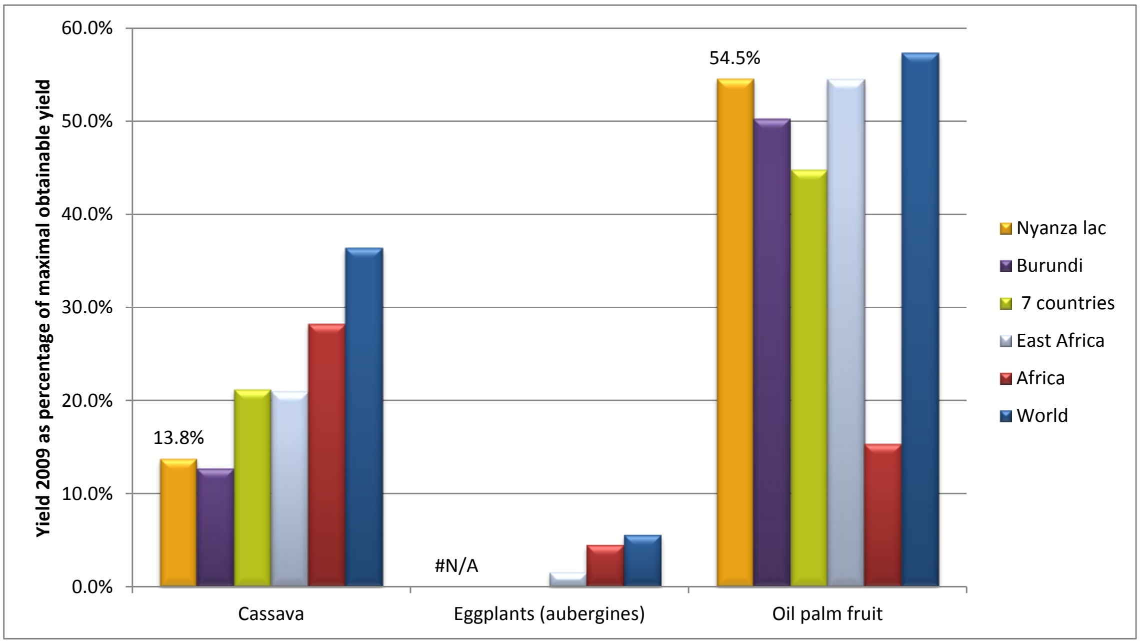


Figure 42: Yield gap Nyanza lac (Source: FAOSTAT 2012)

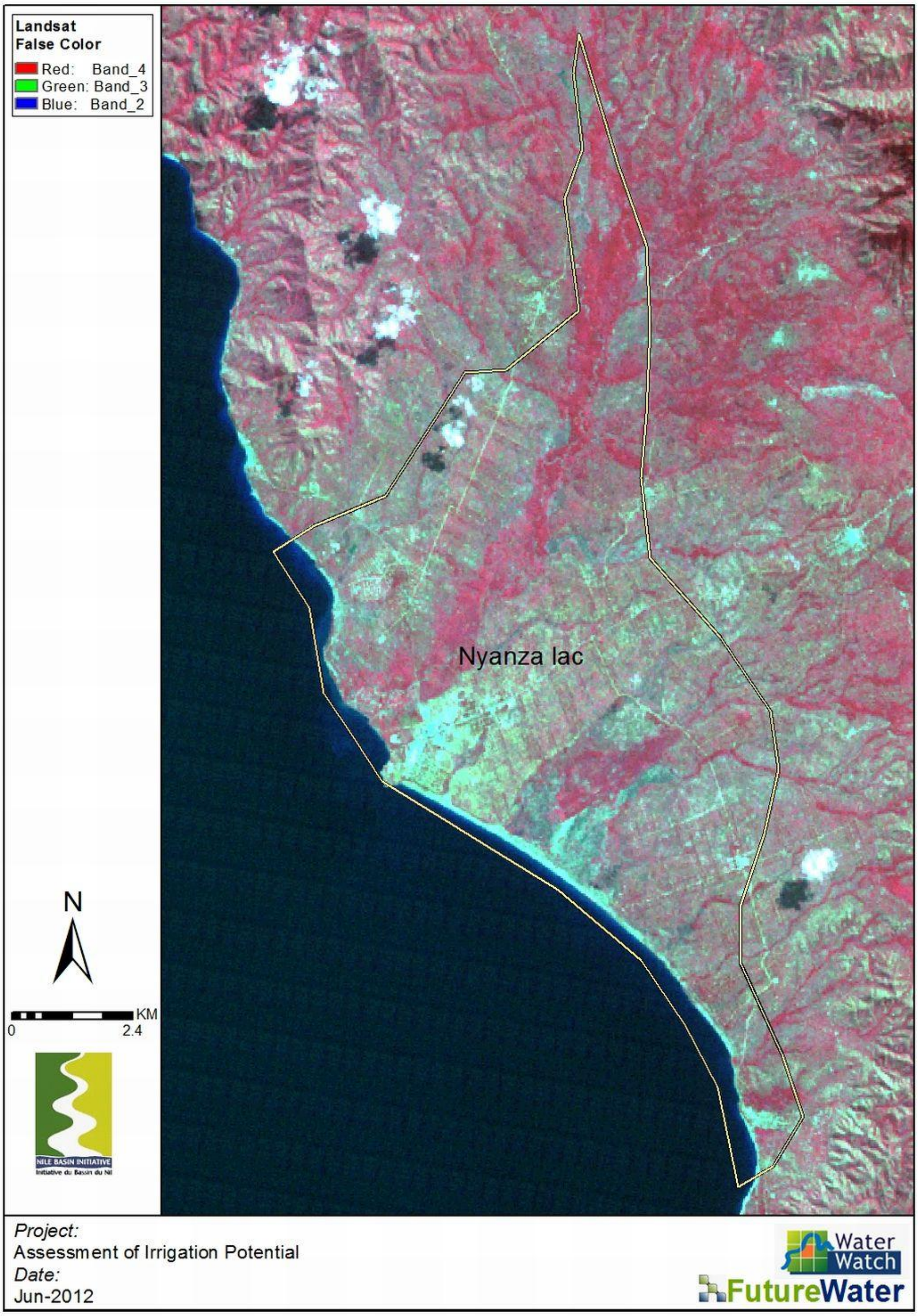


Figure 43: Landsat False Color Composite indicating current productivity of the area for NYANZA-Lac focal area.

3.6 Environmental and socio-economic considerations

3.6.1 Population displacements

People in the area are mainly living along the roads and in the villages. When developing an irrigation scheme it is advised to design the scheme in such a way that population displacement is not or hardly needed. However, the houses in some areas are scattered around, which will either restrict the irrigation possibilities, or minimal displacements are needed. People in the area have some experience with irrigation, as some irrigation schemes are already present. This increases the coop capacity of the people, as they are aware of the benefits that irrigation delivers. With the design of any irrigation scheme, it is advised to limit any population displacement. The exact numbers of effected houses can only be known after designing the scheme, which is beyond the scope of this pre-feasibility study.

3.6.2 Social

The population density within the Nyanza lac focal area is below the Burundian average, with only 266 people/km^2 (Mininter, 2006). Regarding the population distribution by age, it becomes clear that the people within Makamba province are extremely young, with approximately 67% of the population being under the age of 25. The active labor force in Nyanza commune is therefore less than half of the total population. The amount of male and female workers is nearly equal, which could suggest social equity between male and female.
The infrastructure in the area is quite good, but completely focused on Burundi. Tanzania is just a few kilometers away, but the road to the border is not continued on Tanzania's side. Besides agriculture, fishing is one of the other main activities.

3.6.3 Upstream downstream consideration

Since part of the water for irrigation is coming from Lake Tanganyika, in which the water is nearly inexhaustible, there are no issues concerning the equal distribution of the water. In this area more attention should be paid to erosion matters and anti-erosion measures. People should be aware of the risk from erosion, and the measures they can take to decrease erosion. Measures like contour ditches or vegetation that prevents erosion, should also be included in any irrigation design. Especially the upstream parts of the Nyanza lac focal area include slopes on which erosion takes place. The use of fertilizer is recommended, however, people should be aware of the influences that excessive use and leaching can have for the environment and the water quality in the lake.

3.6.4 Protected areas

Within Nyanza lac focal area there are no protected areas.

3.7 Benefit-Cost Analysis

A simplified benefit-cost analysis is undertaken for the area. Information for this is based on various sources such as FAO publications, IFPRI publications, local expertise and data. A full benefit-costs analysis has to be undertaken in a sub-sequent feasibility study for the area.

Note that this is a first-order benefit-cost analysis. A feasibility study can provide a more rigorous benefit-cost analysis, which is required before taking any implementation planning. However, the following table shows that based on this first-order analysis, investments in irrigation can have a very positive impact.

Main assumptions for the benefit-costs analysis includes:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Palmoil: 2,160 kg/ha, $0.85/kg
    - Aubergine: 5,000 kg/ha, $0.42/kg
    - Cassava: 7,000 kg/ha, $0.28/kg

Based on expert knowledge on the suitability to develop irrigation in the area scores between 1 (negative: low suitability or expensive) to 10 (positive: high suitability or low investments) have been marked. The filled radar plot below indicates the options for the focal area. Overall, the weak part of the site lies under farmers' capacity, accessibility to roads, to markets and the initial investment cost. This in-turn affects access to market as farmers cannot transport their yield easily and more importantly may not fetch golden prices. However, soil suitability and water availability is a great deal for the area that will foster an increase yields.

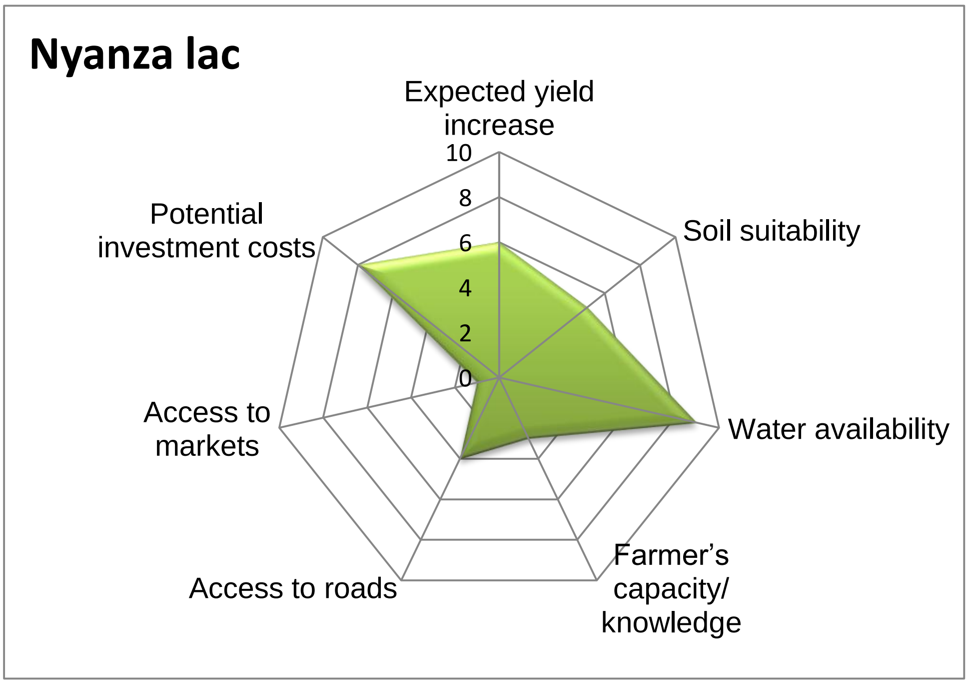


Figure 44: Filled radar plot indicating expert knowledge score to develop irrigation in the Nyanza lac focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 7: Benefit-cost analysis for Nyanza lac area.

Characteristics	
Irrigated land (ha)	6,000
Farmers	7,500
Investment Costs	
Irrigation infrastructure (US$/ha)	6,000
Social infrastructure (US$/farmer)	500
Accessibility infrastructure (million US$)	1.0
Operational Costs	
O&M irrigation (US$/ha/yr)	60
Extension service (US$/farmer)	10
O&M roads (US$/yr)	20,000
Summary	
Initial investments (million US$)	40.8
O&M costs (million US$/yr)	0.455
Net benefits per year (million US$/yr)	7.097
IRR (Internal Rate of Return)	19.2%

3.8 Recommendations

This pre-feasibility study describes the topics on a screening and scoping level. The available local data are included in the analysis and description, but final results give a first impression of the irrigation possibilities. Recommendations to be included in a detailed feasibility study are: i) possible design of the irrigation scheme ii) In depth analysis of possible reservoir sites iii) the implications of the legal framework and local law on irrigation development in the focal area iv) make an economic analysis per crop and irrigation system and v) a in depth cost benefit analysis, fully based on the local situation.

4 Nyamuswaga focal area

4.1 Introduction

This chapter will describe the current state of the Nyamuswaga focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 46 a detailed map of the area is given. Total area is 3644 ha.

Selection of this specific focal area was based on results of Phase 1 of this study, while final selection was the responsibility of the relevant country representatives. Results presented hereafter have been obtained from a broad range of sources: Phase 1, previous other studies and reports, modeling results, remote sensing, expert knowledge and field visits by Christophe Majambere and Emmanuel Ndorimana as supervisor in March 2012.

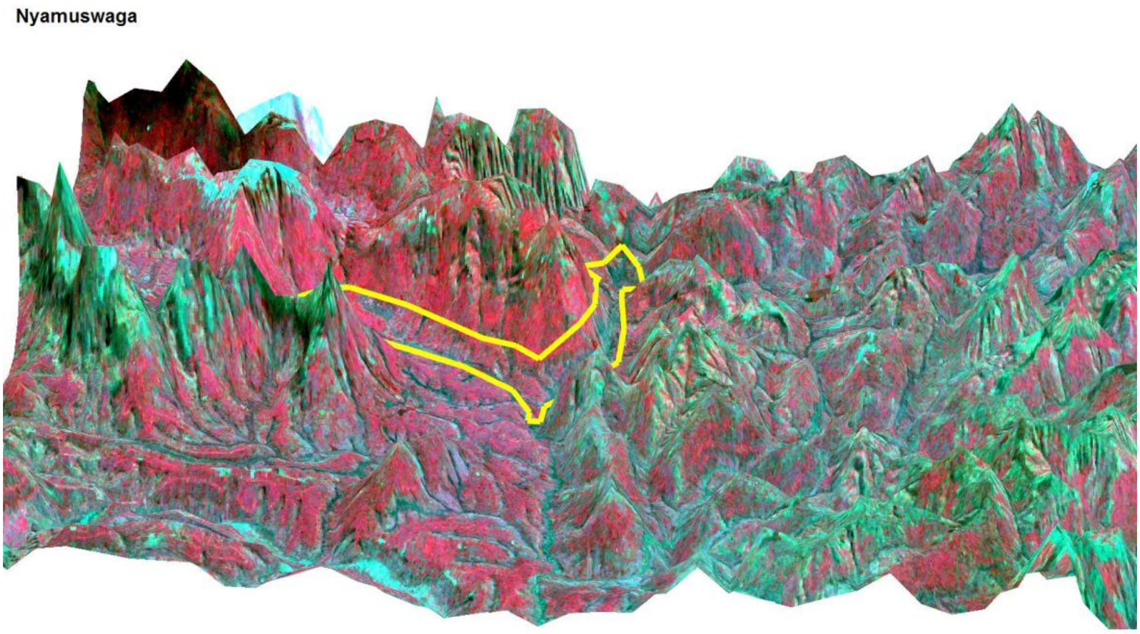


Figure 45: 3D impression of Nyamuswaga focal area, Burundi.

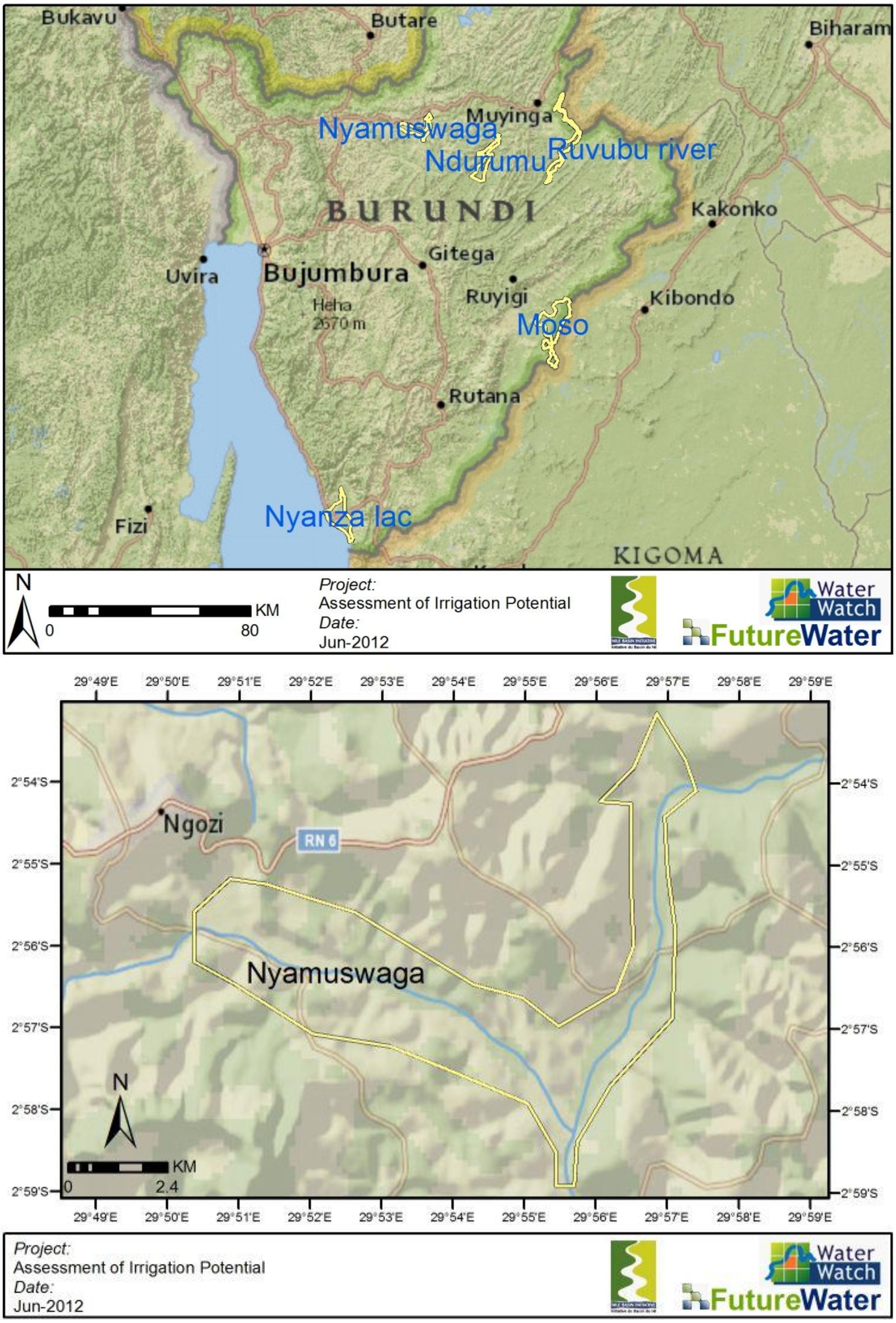


Figure 46: Nyamuswaga focal area, Burundi

4.2 Land suitability assessment

4.2.1 Terrain

Nyamuswaga focal area covers the upstream part of Nyamuswaga catchment. The focal area is wrapped in the valleys which are quite flat. The elevation difference from top to bottom of the valley is approximately 30 m, with elevations of 1560 m in the western end of the focal area, and 1530 in the south. Elevations increase more rapidly from the valley into the hills and foothills. Then the highest point approaches 1620 m (Figure 45 + Figure 47). These exceptional points, however, will not be considered for irrigation within this pre-feasibility study. In

Figure 48 the slopes are shown. Slopes in the valley are limited to 1-2%. Slopes at the side of the valley, going up to the hills are steep on most places, reaching over the 15%.

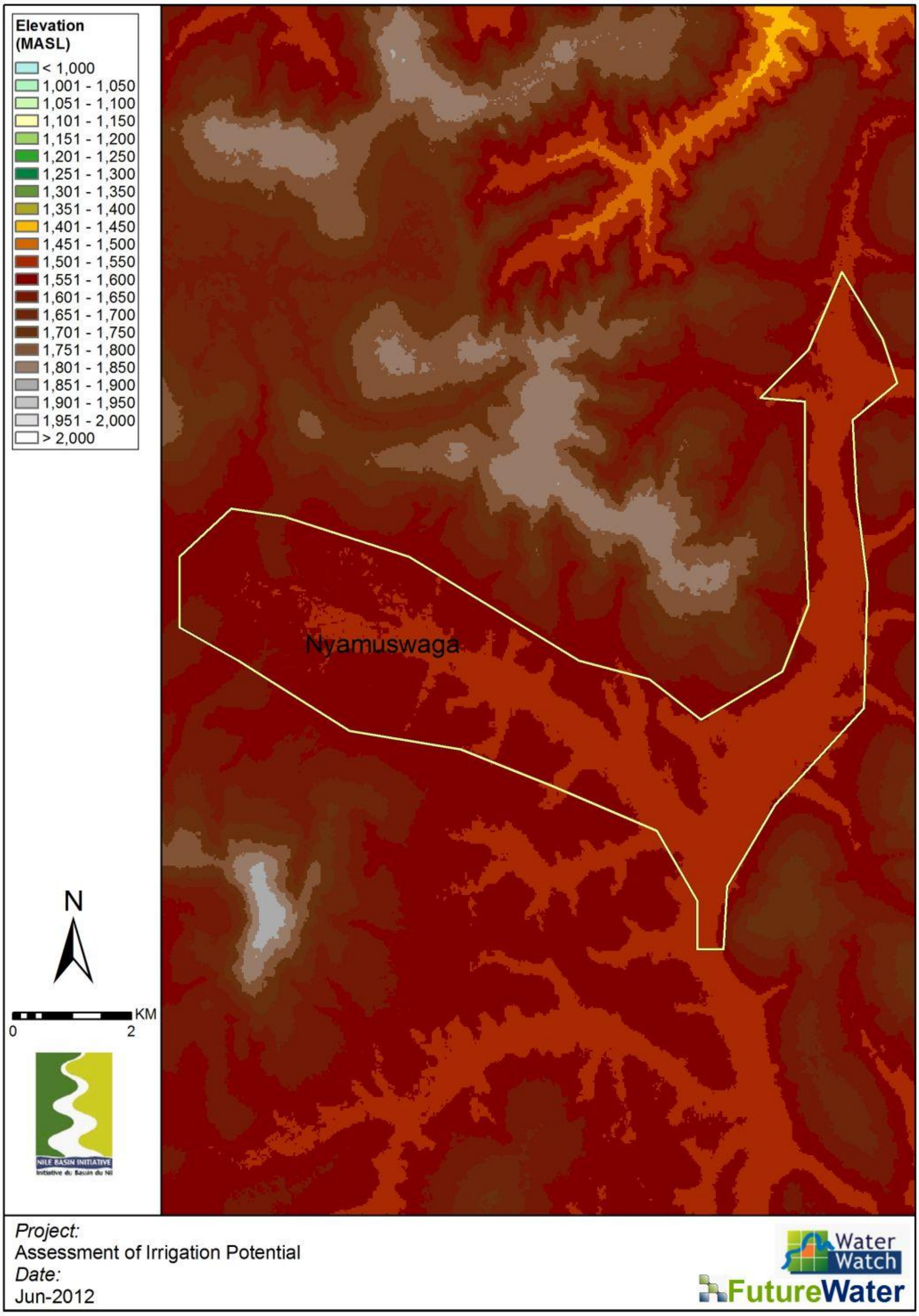


Figure 47: DEM Nyamuswaga focal area. Resolution 1 arc second (+/- 30m).

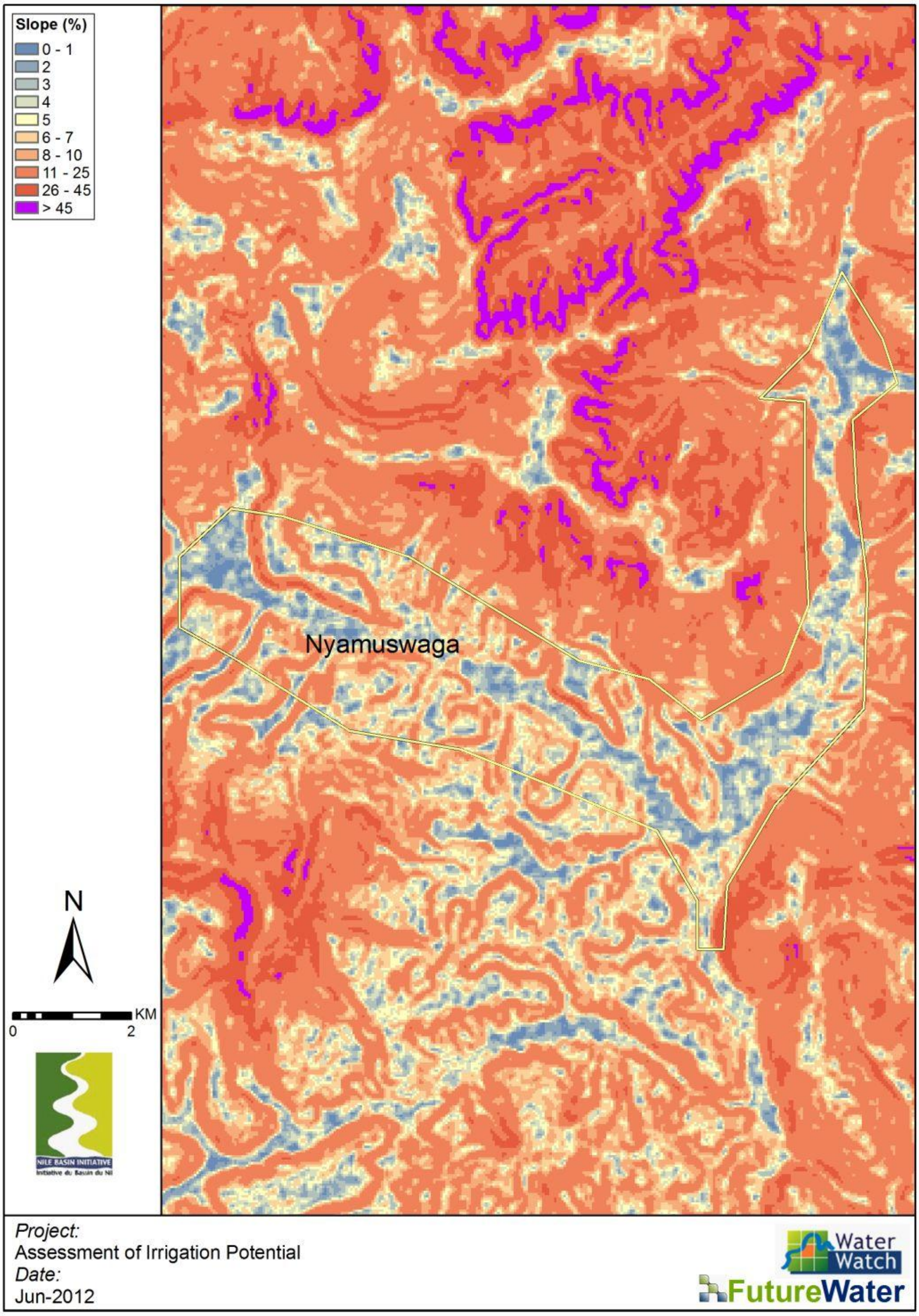


Figure 48: Slope map Nyamuswaga focal area (source: ASTER).

4.2.2 Soil

Soils are silty to clayey, heavy and fertile. On the slopes, soils are shallow and prone to erosion. Currently, there are no measures to prevent the soil from eroding. In the valley the soil is rather flat, deep, and poorly draining. The soil is non-saline and slightly acid. The available water holding capacity in the North of the area is more than 150 mm/m. In the South of the area the water holding capacity is limited to 125-150 mm/m. On the slopes with the more shallow soils, the water holding capacity is even more limited. The organic carbon in the top-soil is between 1.2 and 2% in the North, and over 2% in the Southern part.

4.2.3 Land productivity

Land productivity in Nyamuswaga is the highest from all the focal areas. On average the NDVI is 0.64 over the year, compared to a Burundian average of 0.56. Within the focal area there are just slight differences in land productivity. In the North and in the valley in the western branch, land productivity is a bit lower with averages around 0.6. On the slopes the NDVI is higher with averages around 0.67. The variation in land cover is most stable in the southern point, and the slopes in the west. A high NDVI means that intensive agriculture is practiced year round.

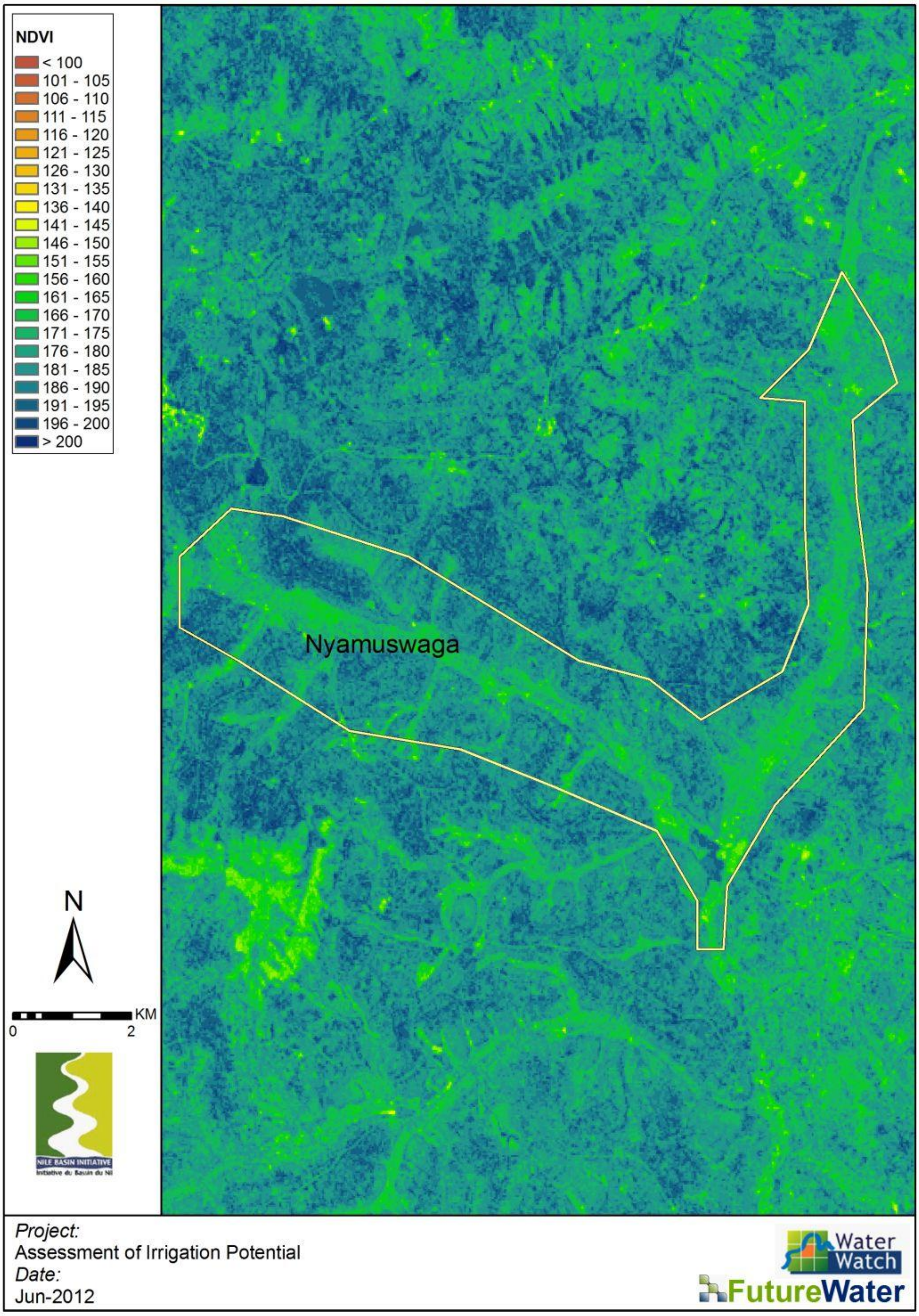


Figure 49: High resolution NDVI

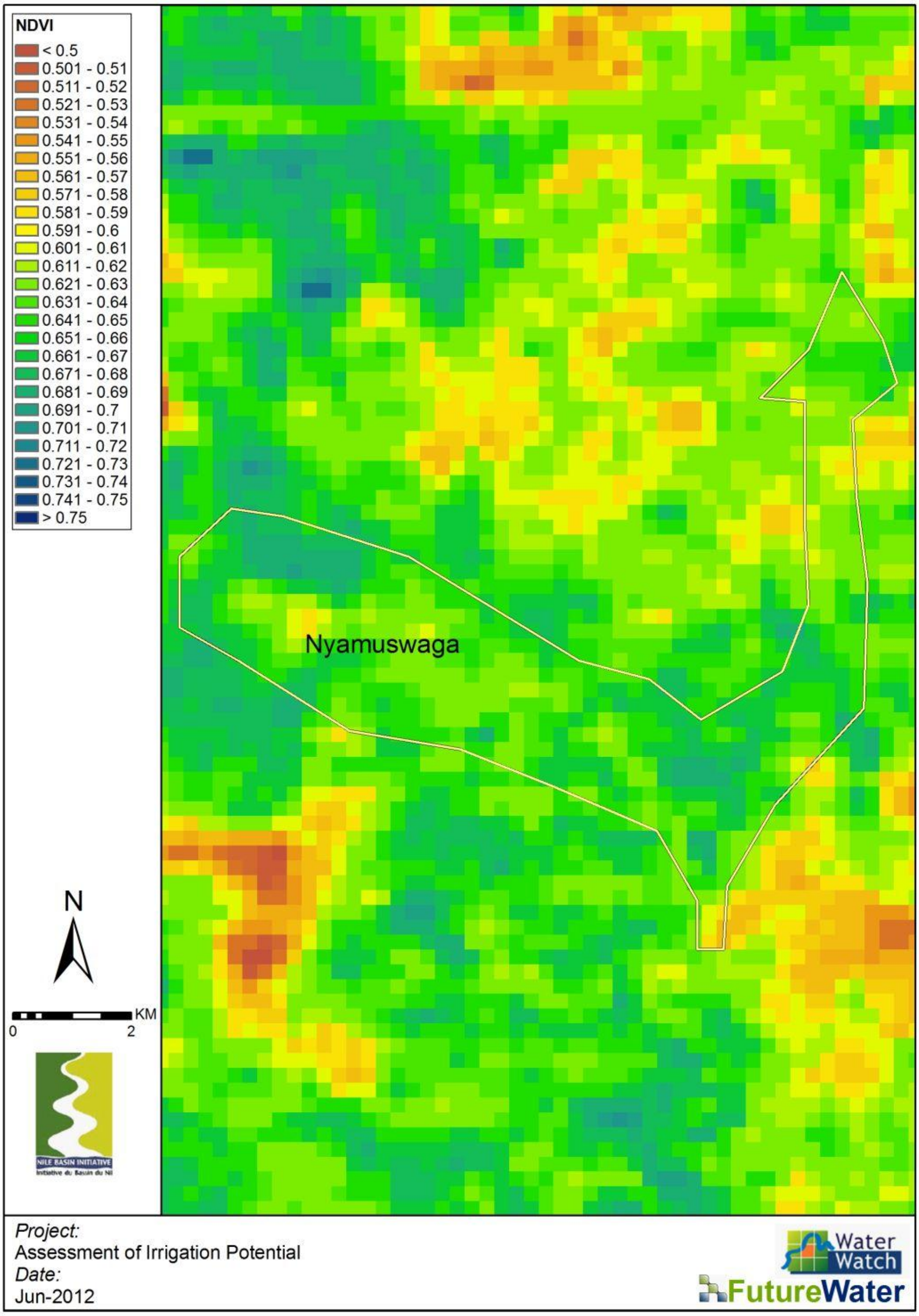


Figure 50: Yearly average NDVI values.

4.2.4 Potential cropping patterns

The current dominant crop is paddy rice. Besides rice, maize, beans and potatoes are grown. All crops are grown in one growing cycle per year. Rice is sown in December, and harvested in June or July. The other crops are sown later, and grown in the second half of the year. Thus, theoretically the land can reach a growing intensity of 200% as two crops can be grown after each other. The potential crops include rice, potato, cabbage, and tomatoes. It is advised to use the valley as much as possible for rice production, and grow the other crops on the foothills on the side in two growing cycles per year. When the area is irrigated, rice can be grown in two cropping cycles per year.

4.3 Water resource assessment

4.3.1 Climate

Average climate conditions for the area are shown in the figure below. Precipitation is based on an advanced calibration/validation algorithm using satellite derived precipitation and calibrated using local observations. Details can be found in the Phase 1 Report. Reference evapo-transpiration (ETref) is calculated using the well-known Penman-Monteith approach. Input data for ETref is based on local observations and an advanced spatial downscaling algorithm.

The climate of the area can be characterized as relatively warm with constant temperatures during the year ranging from about 15°C to 26°C. Annual average precipitation is 1195 mm and reference evapotranspiration 1426 mm per year.

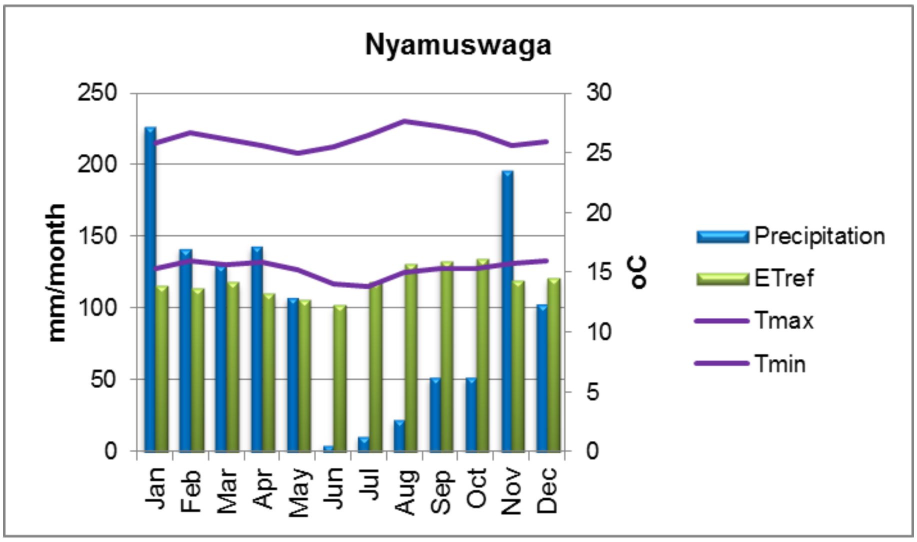
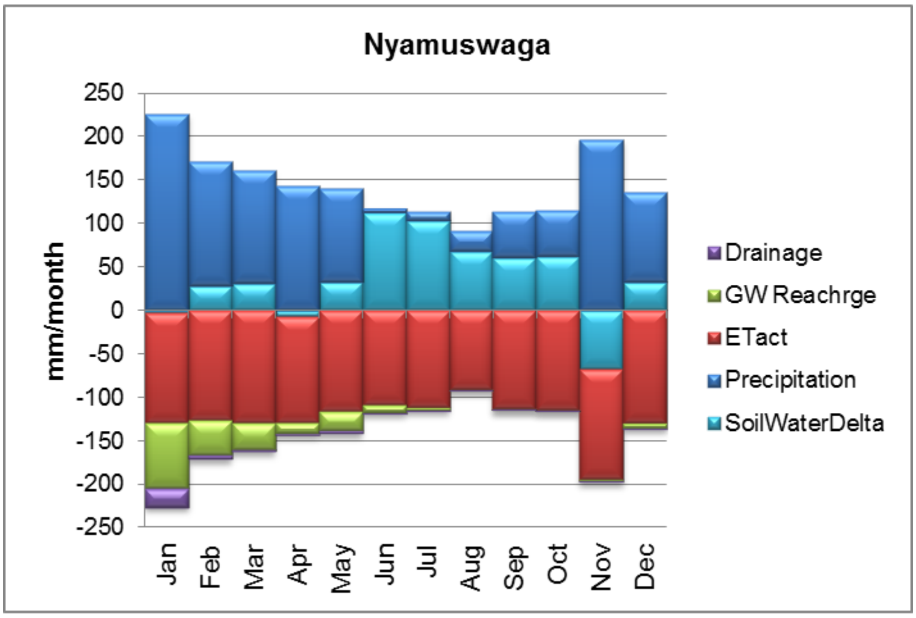
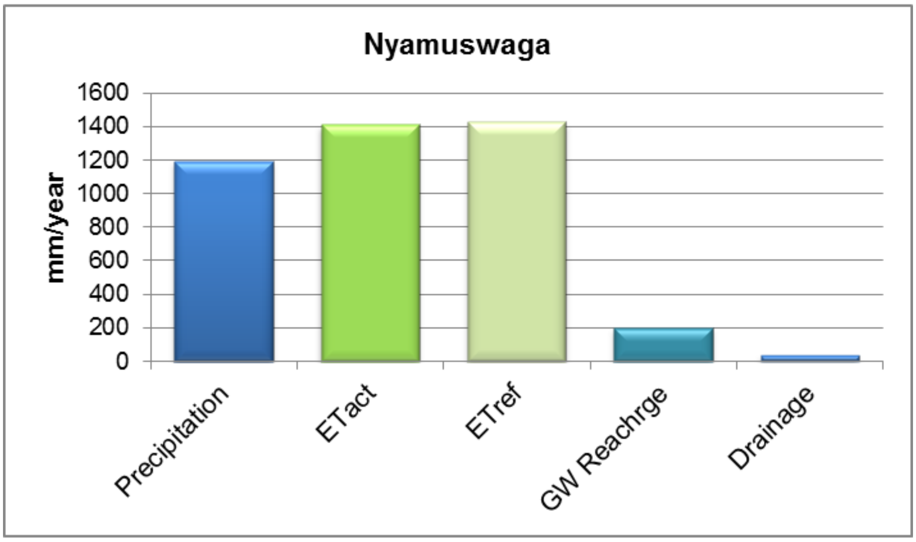


Figure 51: Average climate conditions for the focal area for NYAMUSWAGA focal area.

4.3.2 Water balance

A very detailed high resolution model was built for NEL countries (NELmod). For a detailed description see Phase 1 report. Results from NELmod were extracted for this specific focal area and are shown below.





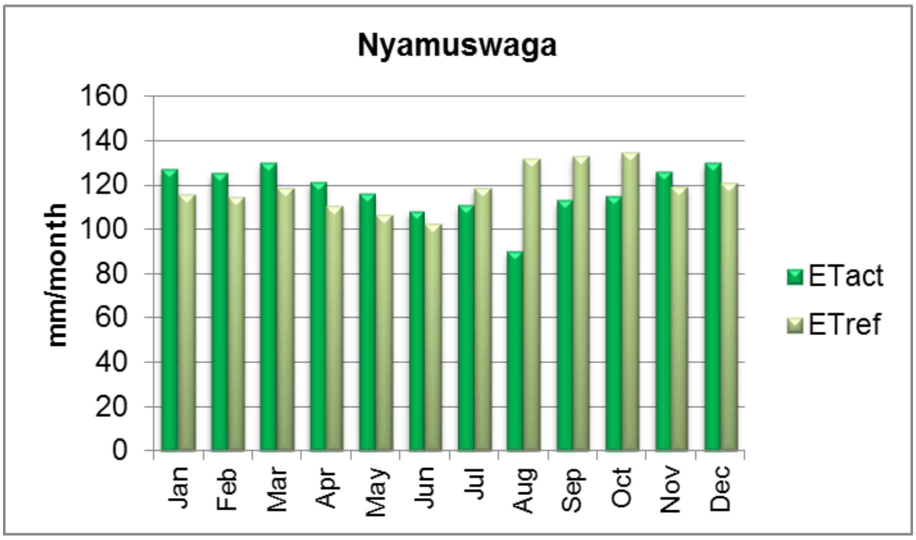
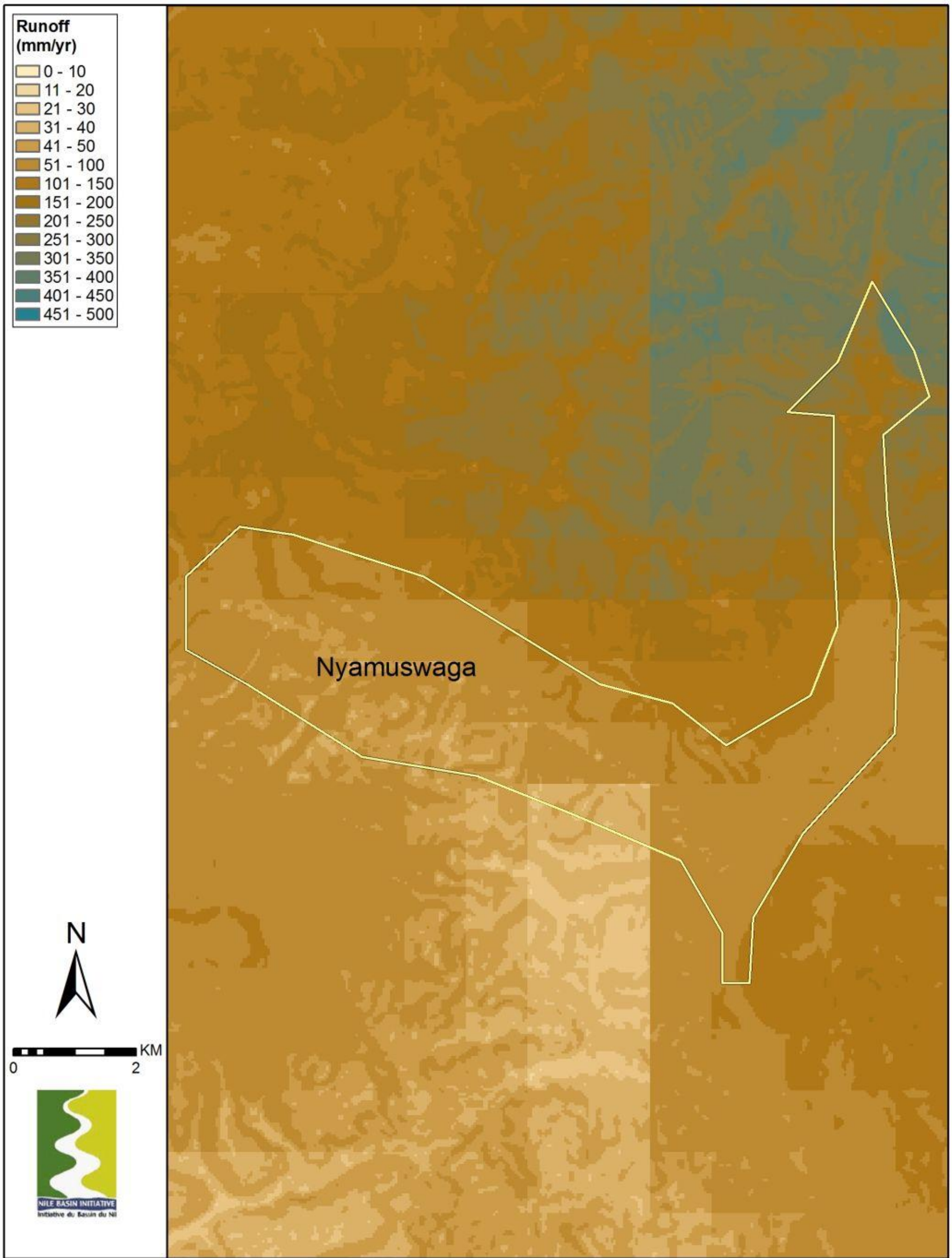


Figure 52: Water balances for the area based on the high resolution data and modeling approach for NYAMUSWAGA focal area.



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Date:
Jun-2012

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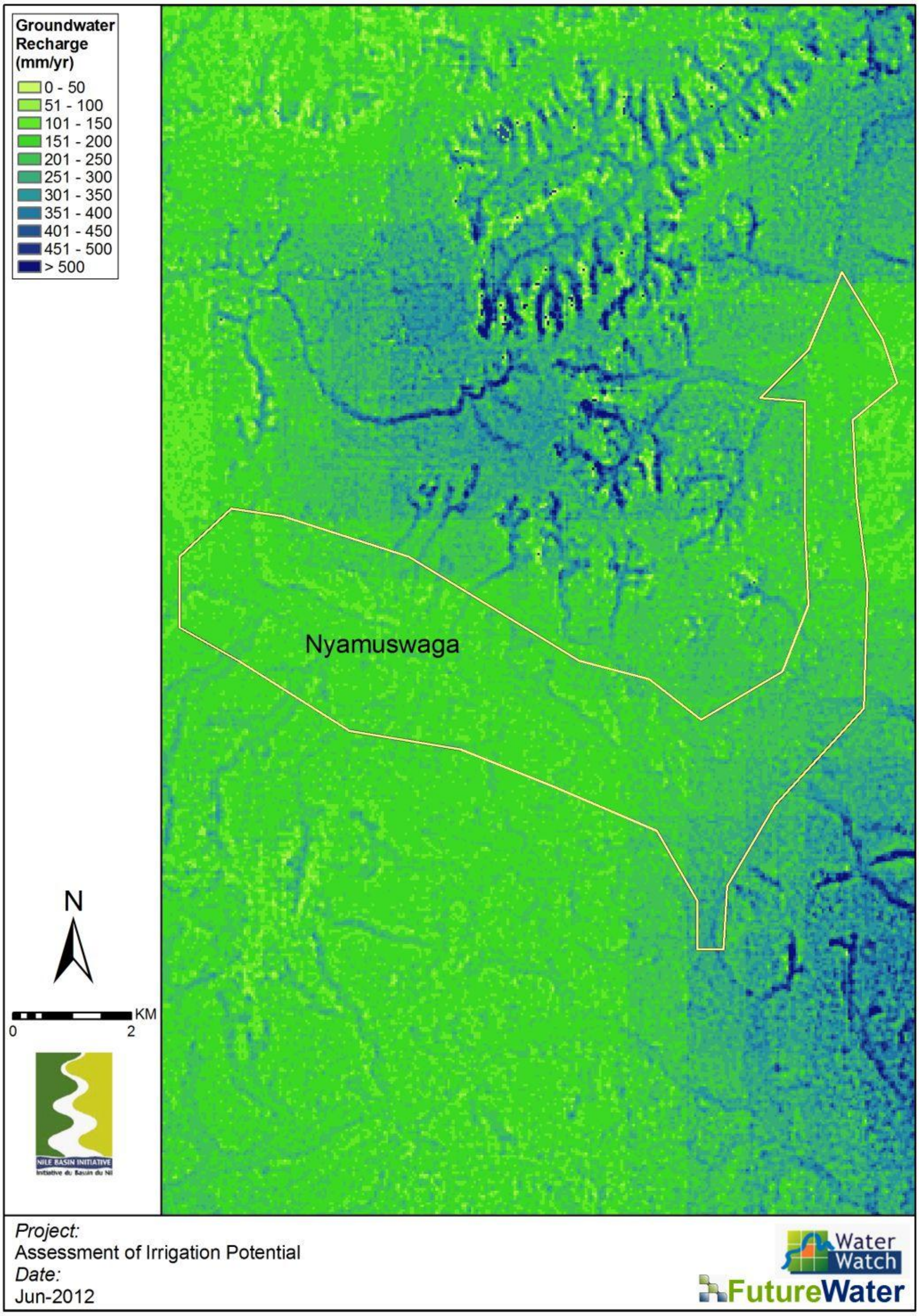
FutureWater


Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
> 500
Nyamuswaga
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NILE BASIN INITIATIVE
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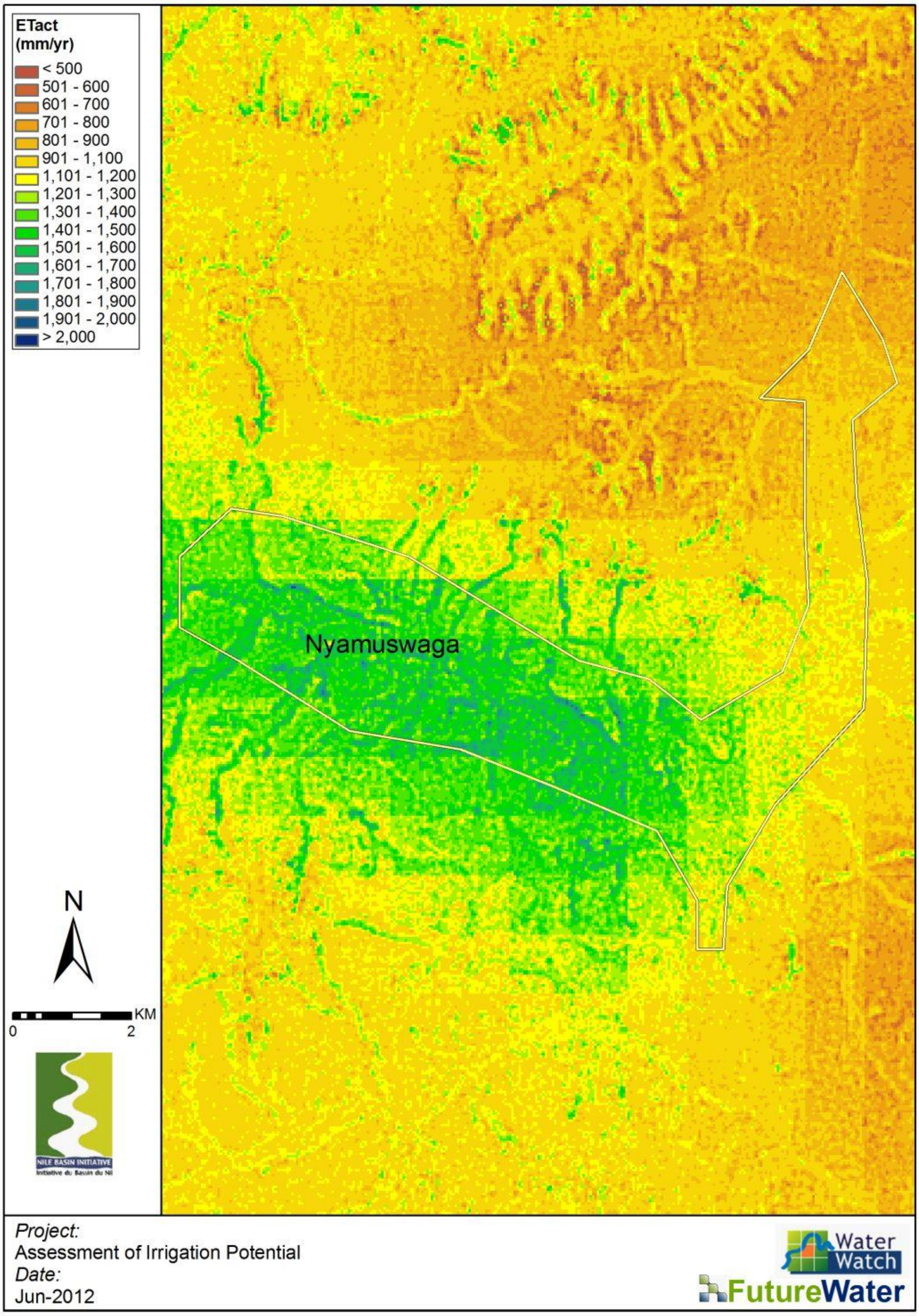


Figure 53: Water balances for the area based on the high resolution data and modeling approach for NYAMUSWAGA focal area.

4.4 Assessment of irrigation water requirements

4.4.1 Irrigation water requirements

Irrigation water requirements depend on many factors such as: climatic conditions, crop, growing season, irrigation practices etc. A first estimate of irrigation requirements could be based on the difference between rainfall and reference evapotranspiration. It was however selected for this pre-feasibility assessment to provide a first estimate of irrigation needs based on the most promising crops. To this end, FAO's AquaCrop, the successor of CropWat was setup for local and crop specific conditions.

In the table below the irrigation water requirements for each selected crop are provided based on AquaCrop calculations. All units are provided in mm per growing season for the specific crops. Note that for various crops, like vegetables and similar crops, multiple croppings per years might occur.

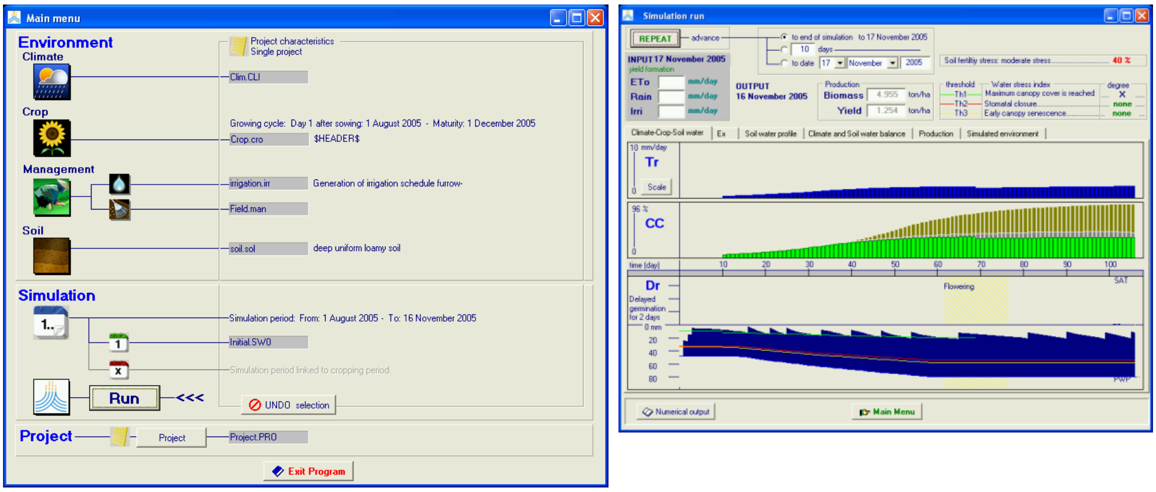


Figure 54: Typical example of AquaCrop input and output screens.

Table 8: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season.

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year ===		== (day of year) ==		======== growing season =======			
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Rice	1195	1426	1	136	711	90	511	469
Potatoes	1195	1426	243	76	848	290	797	702
Cabbage	1195	1426	1	365	1197	90	1423	623
Tomatoes	1195	1426	1	365	1197	90	1423	623

4.4.2 Irrigation systems and irrigations efficiencies

Within the Nyamuswaga focal area a combination of irrigation techniques is recommended. In the valley rice production under border irrigation is most suitable. The soil is very suitable for rice, and the irrigation water requirements are relatively low. Although the efficiency from border irrigation is rather low, this is not a significant issue, as most of the "lost" water will come available downstream again. For the slopes in the sided of the valley it is recommended to use sprinkler or drip irrigation, depending on the chosen crop. Since the water for irrigating the slopes has to be pumped, it is vital that the efficiency is as high as possible in order to reduce operation costs. Drip irrigation has very high application efficiency, and sprinkler irrigation is nearly as efficient. Lifting head is limited to about 50 m.

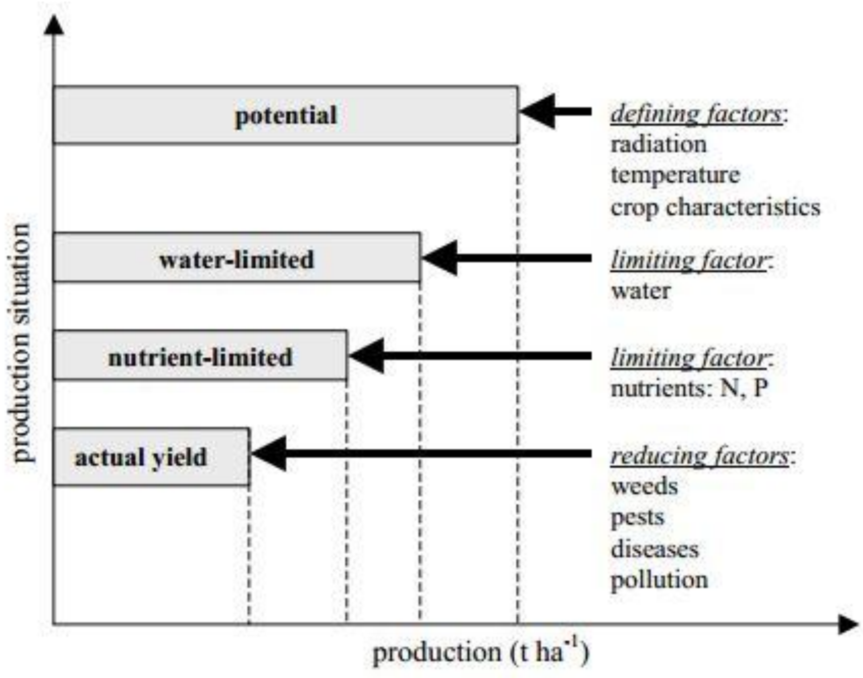
4.4.3 Water source

The water for irrigation will come from the two branches of the river. The North Eastern branch has an upstream catchment of approximately 32,200 ha, and the Western branch has an upstream catchment of 16,100 ha. For the Eastern branch there are possibilities to build an upstream reservoir. This can greatly improve the water management and reduce flooding risks, and as such enhance high level yields. The Western branch includes most irrigable land, but water availability is lower. A detailed feasibility study should include the water availability for hill slope irrigation within this branch. Within the valley just North of Ngozi, there may be a possibility for a reservoir, which would enhance all-year-round cultivation.

4.5 Potential crop yield assessment

The yield gap describes the difference between the current yield, and the maximum possible yield. Mostly the maximum possible yield is defined as the highest yield in the world, but it can also be assessed against a regional background which makes the yield gap more realistic and the maximum yield possible to achieve under the given circumstances.

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximum possible yield is not reached can be the water availability, the soil and the available nutrients, or yield reducing factors like diseases, weeds or pollution.



4.5.1 Yield gap analysis potential dominant crops

Yields in Burundi are among the highest in the NELSAP countries. The topography, population density increase and the increasing demand for food have been drivers for agricultural intensification. However, irrigation is not practiced much, and fertilizer is hardly used. In Figure 81, the yield gap is shown relatively to Burundian average yields, NELSAP average yields, East African yields, African yields and world's average yields. Everything is scaled to percentage of the highest yields obtained somewhere in the world.

Yields in Nyamuswaga are the highest of all focal areas, and reach to 115% of the average yields in Burundi. Within the area rice is the dominant crop, and will stay dominant. Within the valley rice, is currently grown under partial irrigation. However, improving the irrigation system will enhance productivity and may double yields. Depending on the water availability rice can be grown in two growing cycles per year, which could double the yields, and the yields will be much more stable. Potatoes have a rather low yield within Burundi, compared to Africa and the world. The potential to increase yields is high, and yields can easily increase towards 15-20% of the highest obtainable yields. Unfortunately, no data is available in FAOstat for cabbage and tomatoes. However it is expected that both crops do have a large potential.

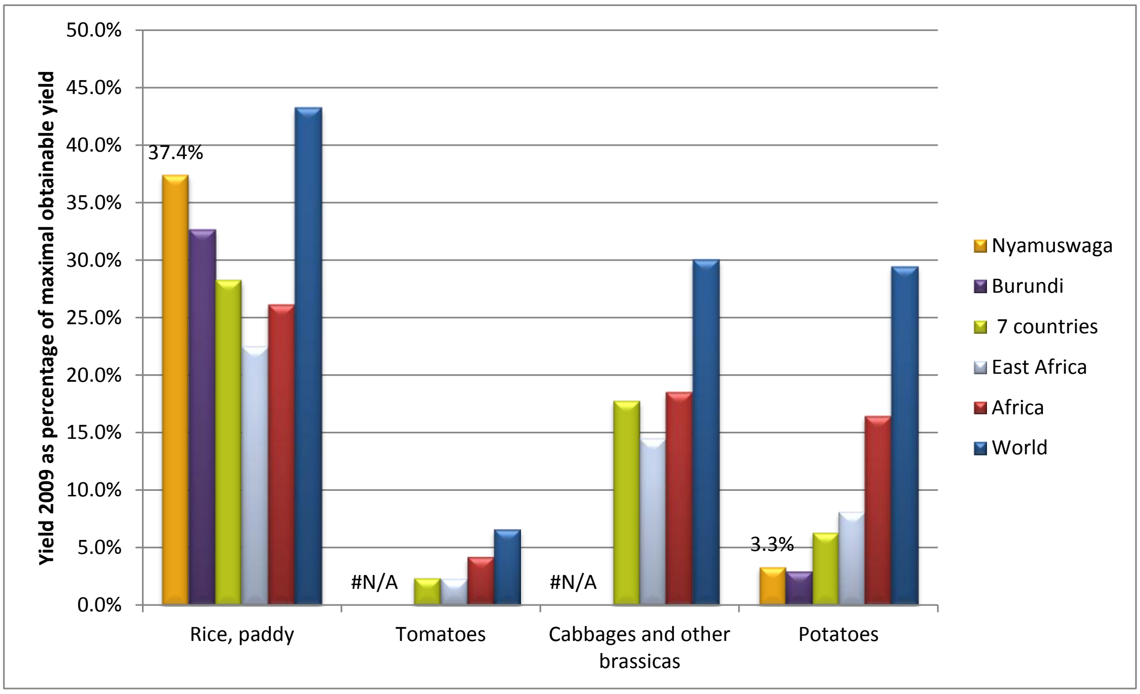


Figure 55: Yield gap Nyamuswaga (Source: FAOSTAT 2012).

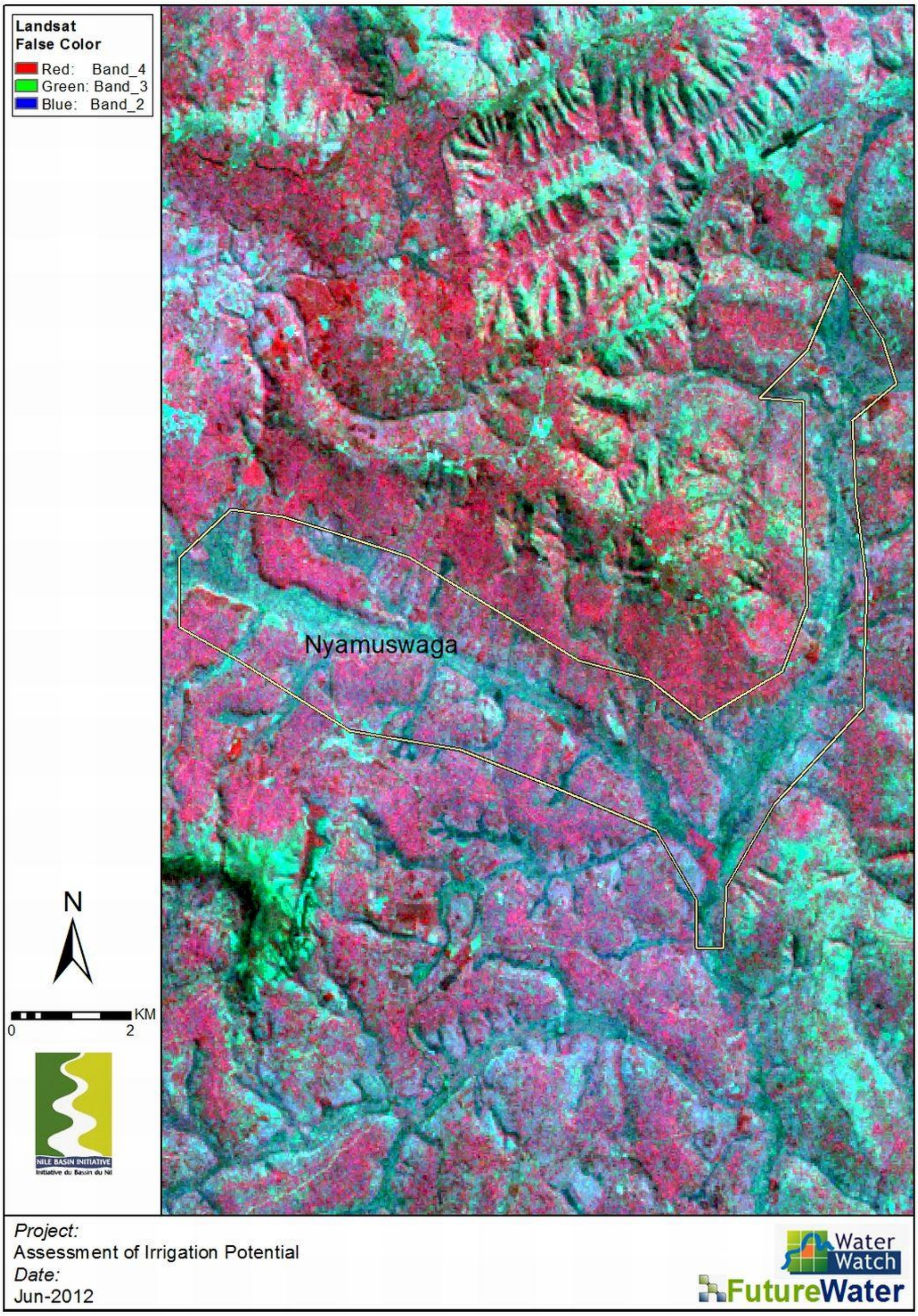


Figure 56: Landsat False Color Composite indicating current productivity of the NYAMUSWAGA focal area.

4.6 Environmental and socio-economic considerations

4.6.1 Population displacements

This focal area mainly covers the valleys and some slopes on the sides. Within the valley nobody is living due to the high flood risks. Just on the slopes going up, there are some houses build along the roads. These roads and houses are mostly build along the contour lines, and can be avoided when designing a pressurized irrigation system. People in the area have some experience with irrigation, as some partial irrigation schemes are already present. This increases the coop capacity of the people as they are aware of the benefits which irrigation will bring. With the design of any irrigation scheme it is advised to limit any population displacement. The exact numbers of effected houses can only be known after designing the scheme, which is beyond the scope of this pre-feasibility study.

4.6.2 Social

Within the Nyamuswaga focal area, the population density is above the Burundian average with 450 people/km^2 (MININTER 2006). Regarding the population distribution by age, it is clear that people within Ngozi province are extremely young, with about 65% of the population being under the age of 25. The active labor force in Nyamuswaga area is therefore less than half of the total population. The amount of male and female workers is nearly equal, which could suggest social equity between male and female. Infrastructure in the area is not developed well. Dirt roads are present, but these are often in poor condition. Tarmac roads are not far, and Ngozi is connected to the highway towards Rwanda. Farmers have average knowledge in irrigation, but poor knowledge about farmer's cooperation's.

4.6.3 Upstream downstream consideration

Since the upstream catchment is not enormously large, the water availability for irrigation should be considered well. Downstream of the focal area, people should still have enough flow to practice agriculture and have water for a living. Currently, some erosion occurs on the slopes and in the marshes. It is important to minimize erosion in order to keep the soil fertile and to avoid downstream problems. At the moment some anti-erosion measures are in place, but whenever developing irrigation system, extra attention should be paid to keep the soil in place. In some places the slope can be minimized by terracing, which will enhance irrigation possibilities as well. Within the marshes flow regulation is the most important measure, which will decrease erosion and enhance irrigation possibilities.

4.6.4 Protected areas

Within this focal area there are no protected areas.

4.7 Benefit-Cost Analysis

A simplified benefit-cost analysis is undertaken for the area. Information for this is based on various sources such as FAO publications, IFPRI publications, local expertise and data. A full benefit-costs analysis has to be undertaken in a sub-sequent feasibility study for the area.

Note that this is a first-order benefit-cost analysis. A feasibility study can provide a more rigorous benefit-cost analysis, which is required before taking any implementation planning. However, the following table shows that based on this first-order analysis, investments in irrigation can have a very positive impact.

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Rice: 6,000 kg/ha, 0.70 $/kg
    - Potatoes: 13,000 kg/ha, 0.21 $/kg
    - Cabbage: 4,000 kg/ha, 0.07 $/kg
    - Tomatoes: 1,500 kg/ha, 0.85 $/kg

Based on expert knowledge on the suitability to develop irrigation in the area scores between 1 (negative: low suitability or expensive) to 10 (positive: high suitability or low investments) have been marked. The filled radar plot below indicates the options for the focal area. Overall, the weak part of the site lies under farmers capacity, accessibility to roads, to markets and the initial investment cost. This in-turn affects access to market as farmers cannot transport their yield easily and more importantly may not fetch golden prices. However, soil suitability and water availability is a great deal for the area that will foster an increase yields.

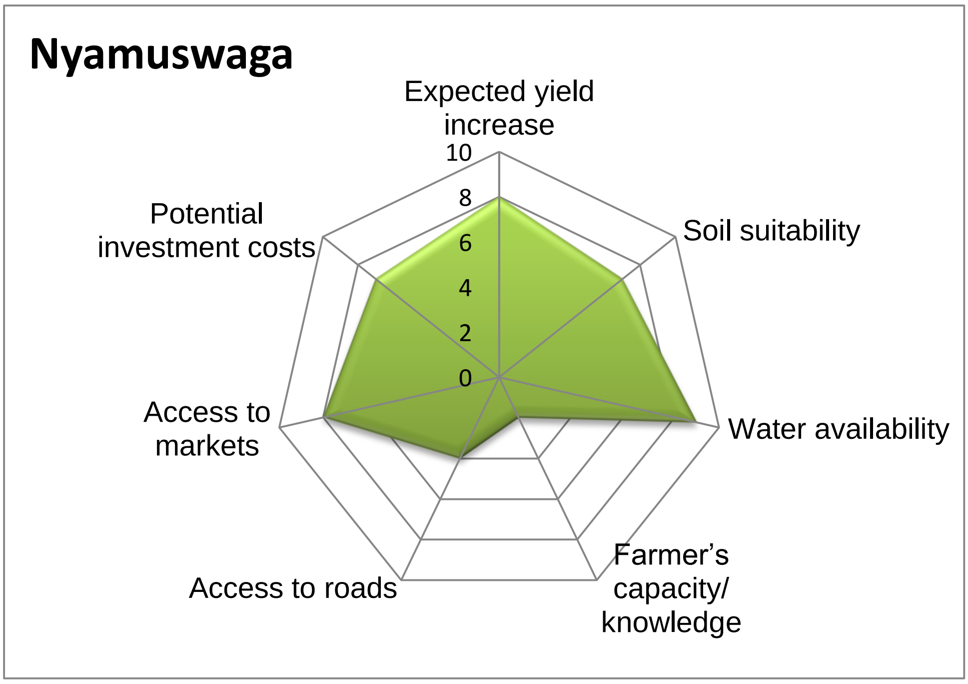


Figure 57: Filled radar plot indicating expert knowledge score to develop irrigation in the Nyamuswaga focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 9: Benefit-cost analysis for Nyamuswaga area.

Characteristics	
Irrigated land (ha)	3,000
Farmers	6,000
Investment Costs	
Irrigation infrastructure (US$/ha)	5,000
Social infrastructure (US$/farmer)	500
Accessibility infrastructure (million US$)	1.0
Operational Costs	
O&M irrigation (US$/ha/yr)	60
Extension service (US$/farmer)	10
O&M roads (US$/yr)	20,000
Summary	
Initial investments (million US$)	19.0
O&M costs (million US$/yr)	0.260
Net benefits per year (million US$/yr)	3.837
IRR (Internal Rate of Return)	23.0%

4.8 Recommendations

This pre-feasibility study describes the topics on a screening and scoping level. The available local data are included in the analysis and description, but final results give a first impression of the irrigation possibilities. Recommendations to be included in a detailed feasibility study are: i) possible design of the irrigation scheme ii) In depth analysis of possible reservoir sites iii) the implications of the legal framework and local law on irrigation development in the focal area iv) make an economic analysis per crop and irrigation system and v) a in depth cost benefit analysis, fully based on the local situation.

5 Ruvubu river focal area

5.1 Introduction

This chapter will describe the current state of Ruvubu river focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations and institutional frameworks. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 59 a detailed map of the area is given. Total area is 5265 ha.

Selection of this specific focal area was based on results of Phase 1 of this study, while final selection was the responsibility of the relevant country representatives. Results presented hereafter have been obtained from a broad range of sources: Phase 1, previous other studies and reports, modeling results, remote sensing, expert knowledge and field visits by Christophe Majambere and Emmanuel Ndorimana as supervisor in March 2012.

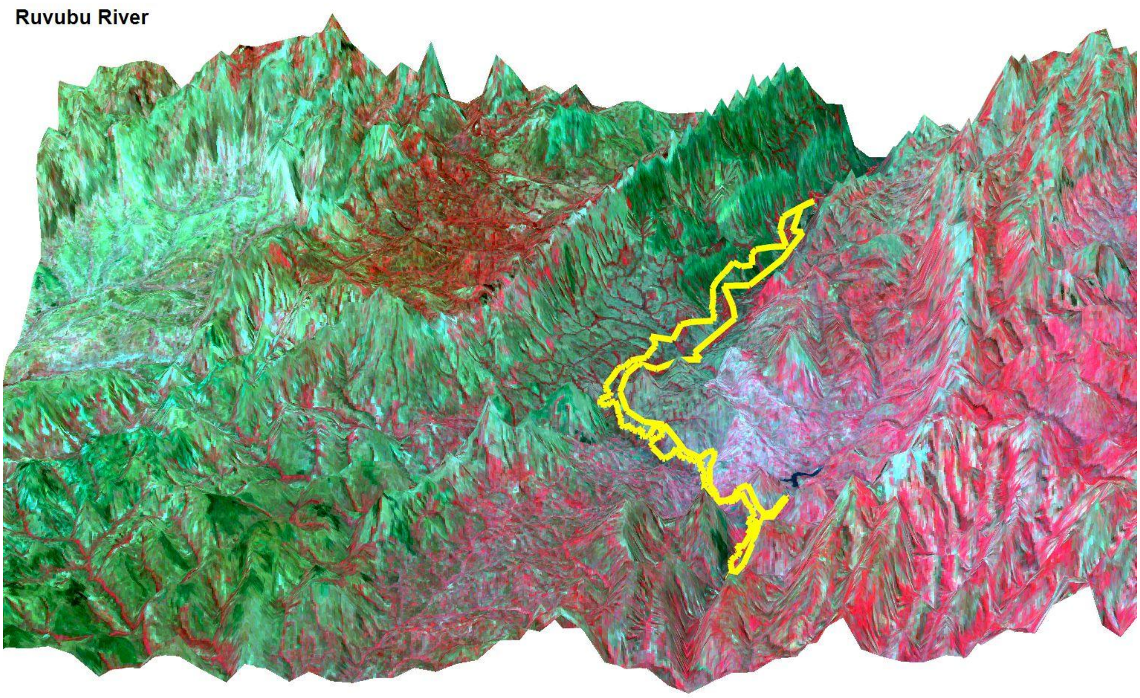


Figure 58: 3D impression of Ruvubu river focal area, Burundi.

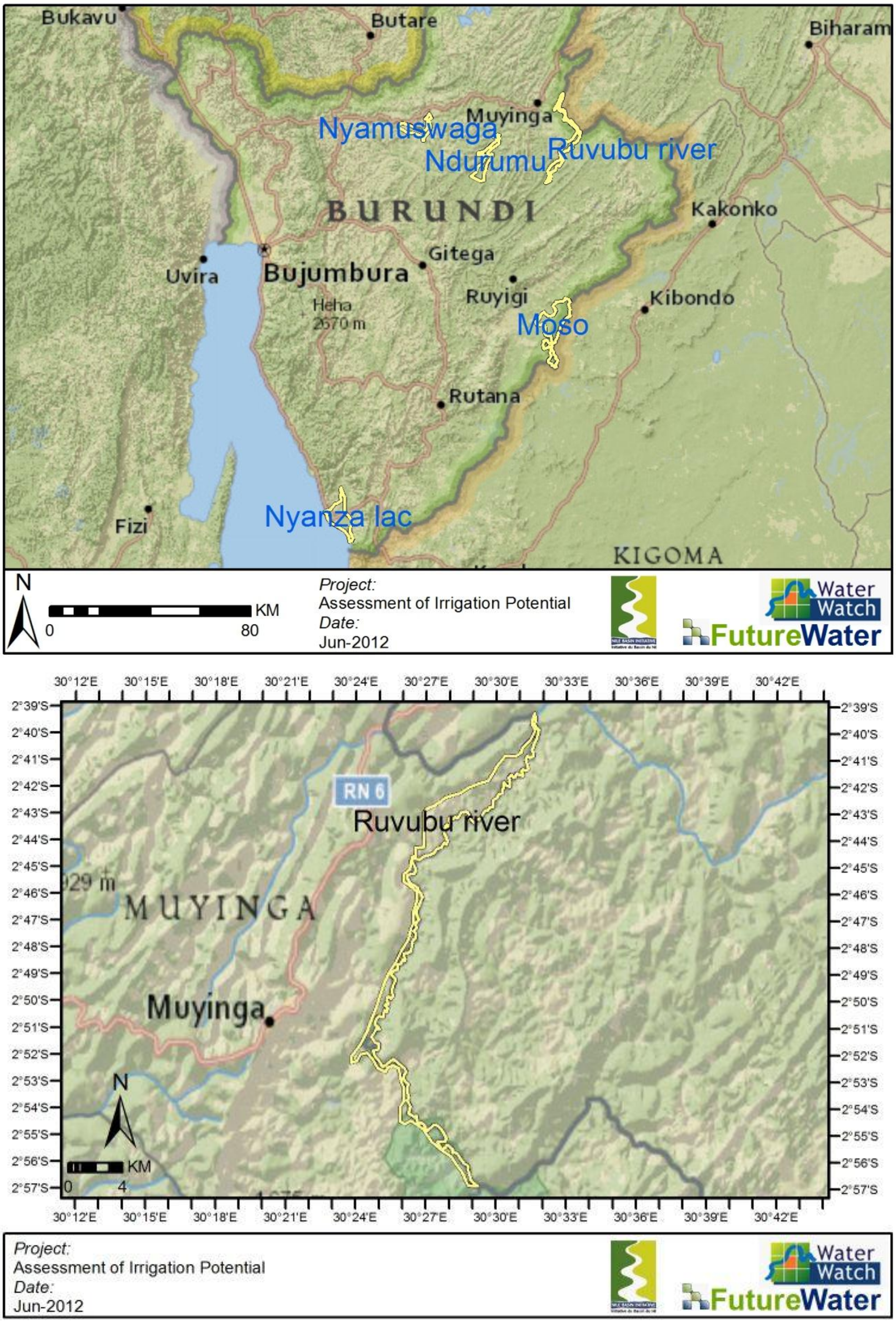


Figure 59: Ruvubu river focal area, Burundi

5.2 Land suitability assessment

5.2.1 Terrain

This long stretched focal area is situated at the Eastern side of Burundi, and covers the border region with Tanzania in the North, all the way along Ruvubu River. The area covers the Ruvubu Valley and is therefore relatively flat. Elevations vary between 1360 m in the South to 1345 m in the North. On both sides of the valley the land is ascending towards elevations over 1500 m. Slopes within the valley are low, with slopes limited to 4% (Figure 61).

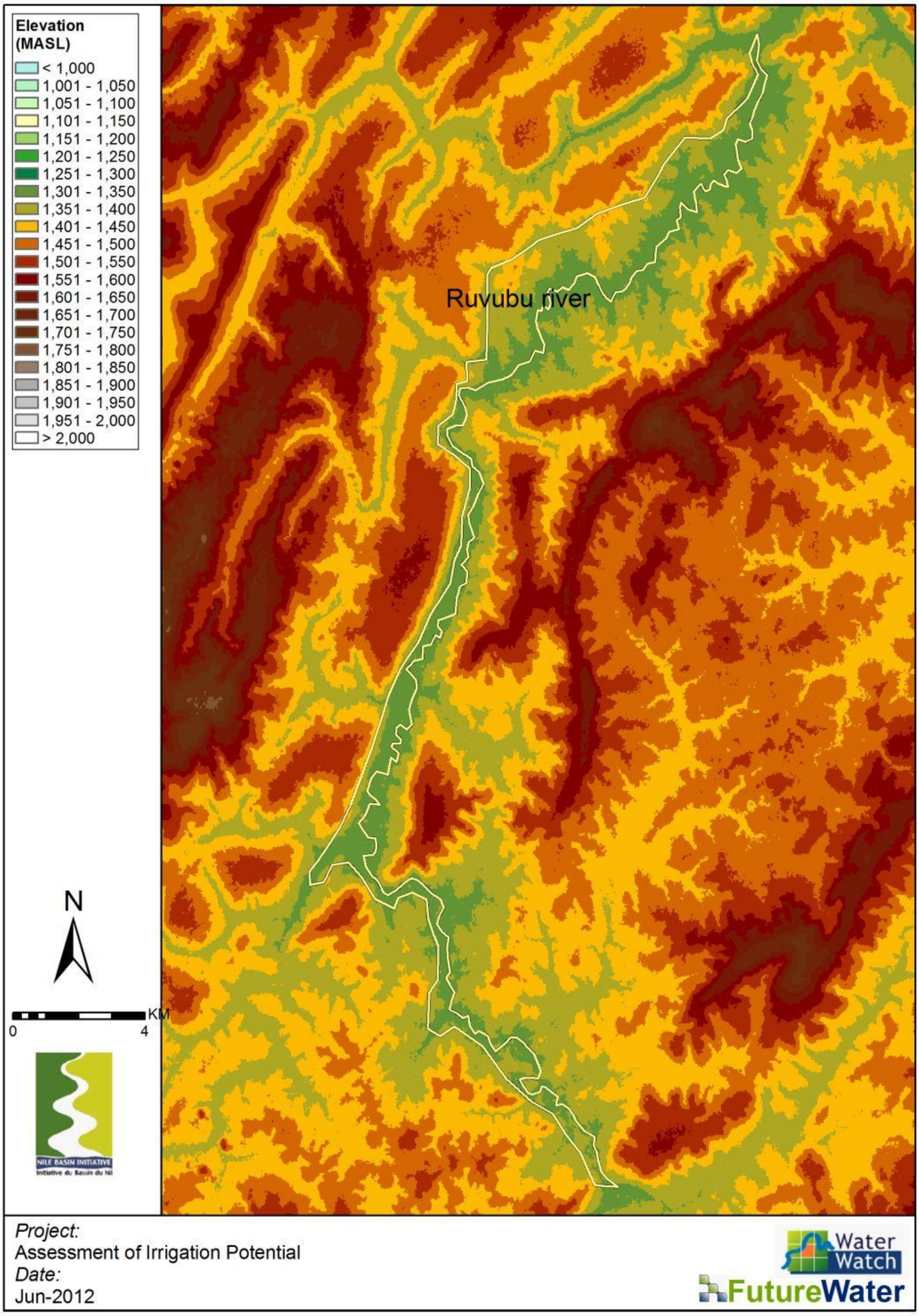


Figure 60: DEM Ruvubu river focal area. Resolution 1 arc second (+/- 30m).

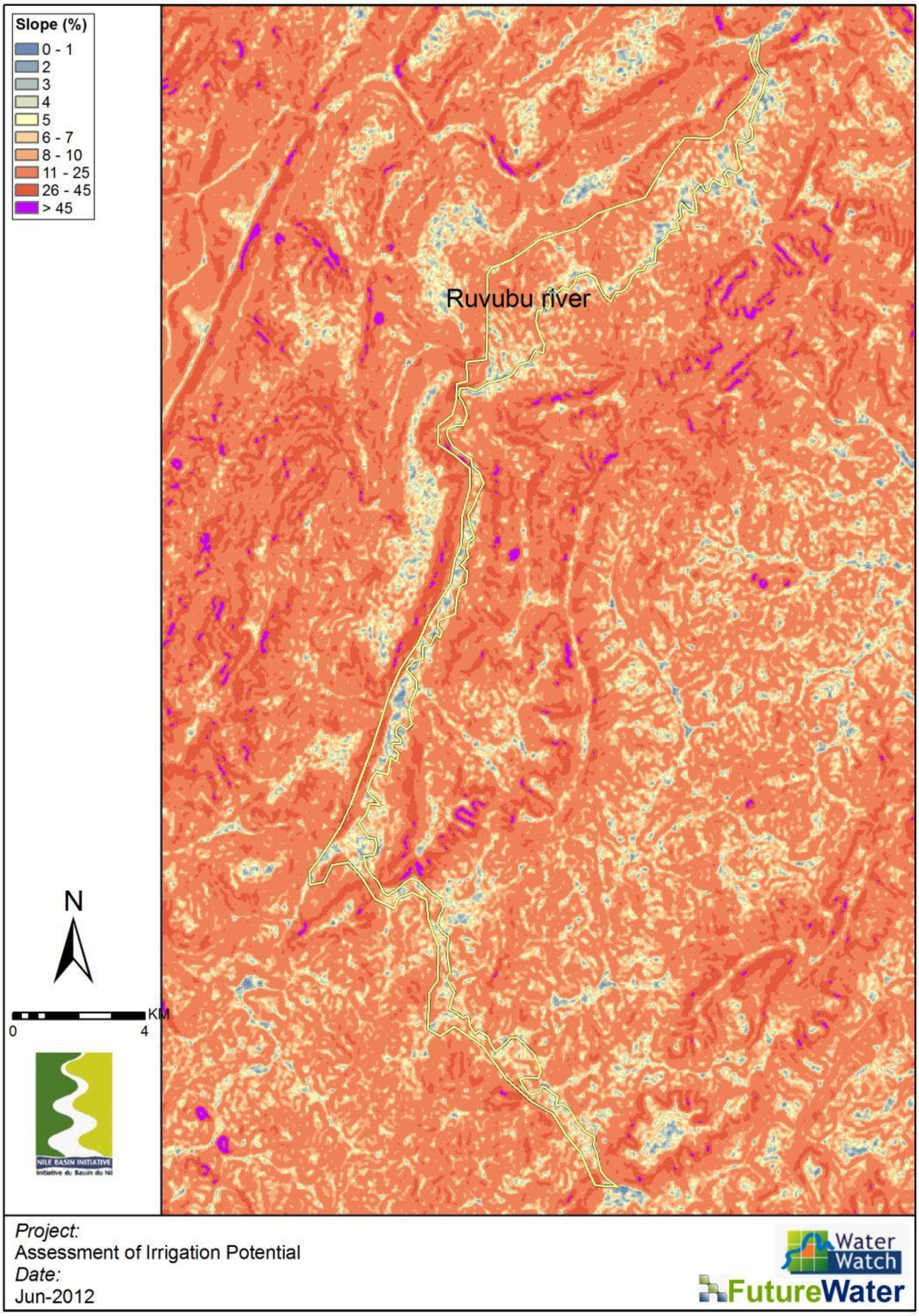


Figure 61: Slope map Ruvubu river focal area (source: ASTER).

5.2.2 Soil

This focal area is completely wrapped around the Ruvubu River, and soils are therefore formed through alluvial processes. In the river valley the soil is loamy, while on the foothills the soils are more silty clay. Drainage is somewhat poor on the slopes and moderate in the riverbed. The soil is non-saline and slightly acid. Organic carbon in the top soil can reach over the 2%. The available water storage capacity is very high with 150 mm/m. Moderate erosion is reported, however, due to the current land use and slope not much erosion is expected other than alluvial.

5.2.3 Land productivity

Ruvubu focal area has an above Burundian average NDVI of 0.62. The land directly bordering the river has lower land productivity compared to the land further away from the river. However, the land located on a short distance from the river has high NDVI values (0.75). The NDVI within the Northern tip of the area decreases to 0.5. The coefficient-of-variation is low nearby the river, and slightly higher towards the hills around.

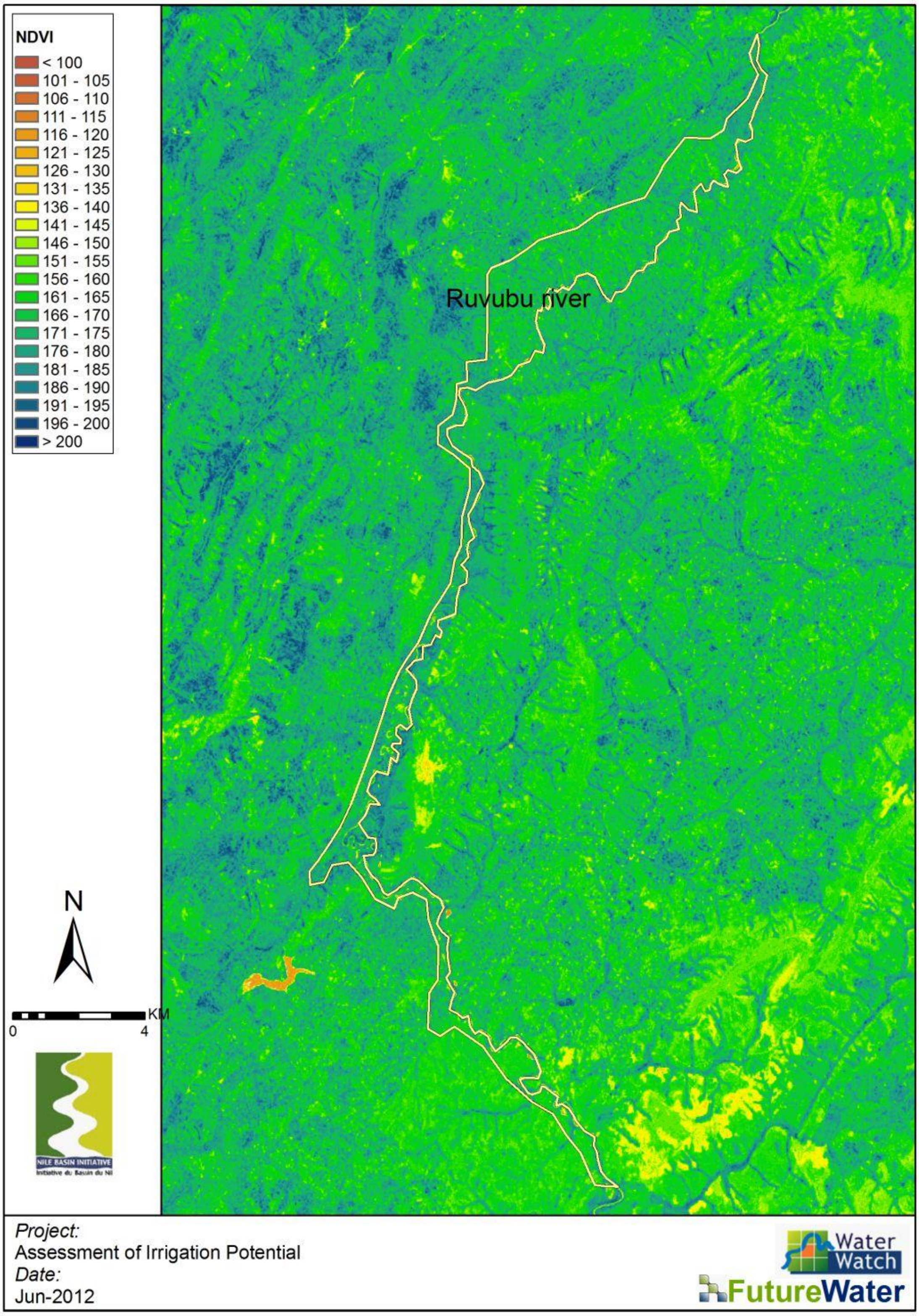


Figure 62: High resolution NDVI for RUVUBU focal area

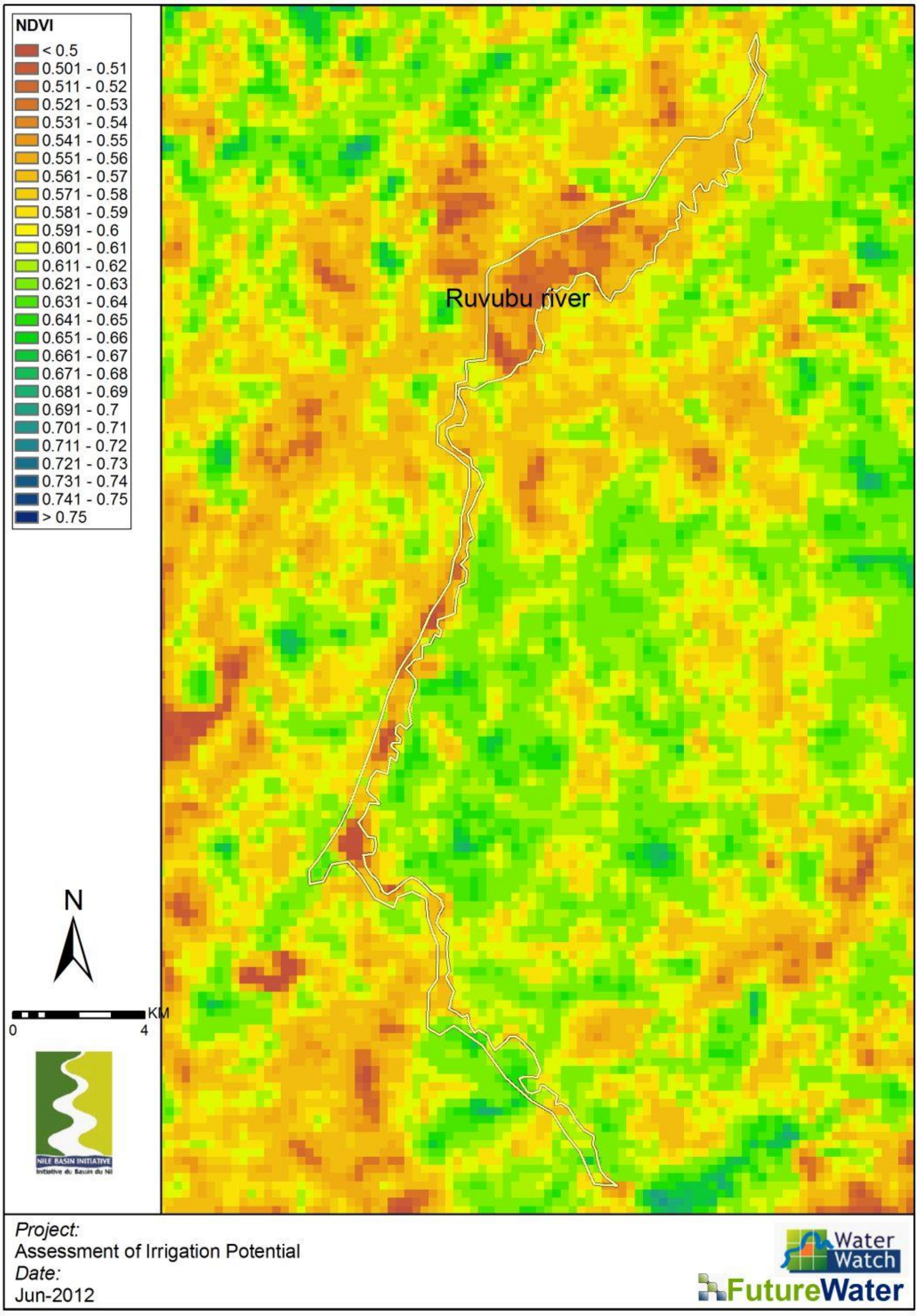


Figure 63: Yearly average NDVI values for RUVUBU focal area.

5.2.4 *Potential cropping patterns*

Currently, a part of the area is used for agriculture. Within this part, maize and beans are the dominating crops which cover both 40% of the area. Sweet potato covers approximately 30% and rice 10%. Sweet potato is grown between October and April. Beans are grown between June and September, and maize and rice both grow from July till December. All crops are grown once a year, which brings the cropping intensity on 120%. With irrigation the focus will shift more to rice. Besides rice, some vegetables are grown such as cabbage, leek, and potatoes. Under irrigation the land can be sown twice a year, which will increase the cropping intensity to at least 200%. In a detailed feasibility study the cropping patterns should be calculated based on growing period and water availability/requirements over the year.

5.3 Water resource assessment

5.3.1 *Climate*

Average climate conditions for the area are shown in the figure below. Precipitation is based on an advanced calibration/validation algorithm using satellite derived precipitation and calibrated using local observations. Details can be found in the Phase 1 Report. Reference evapo-transpiration (ETref) is calculated using the well-known Penman-Monteith approach. Input data for ETref is based on local observations and an advanced spatial downscaling algorithm.

The climate of the area can be characterized as warm with constant temperatures during the year ranging from about 17°C to 28°C. Annual average precipitation is 1110 mm and reference evapotranspiration 1381 mm per year.

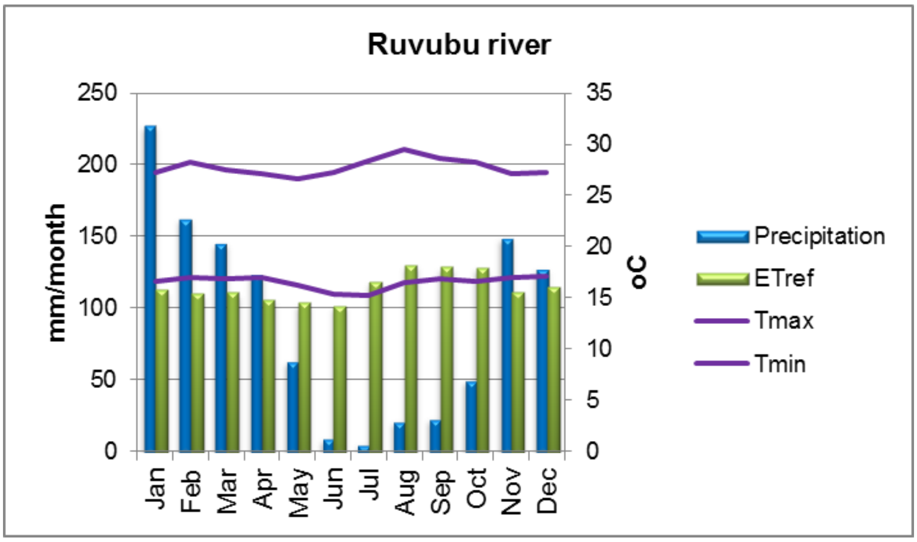
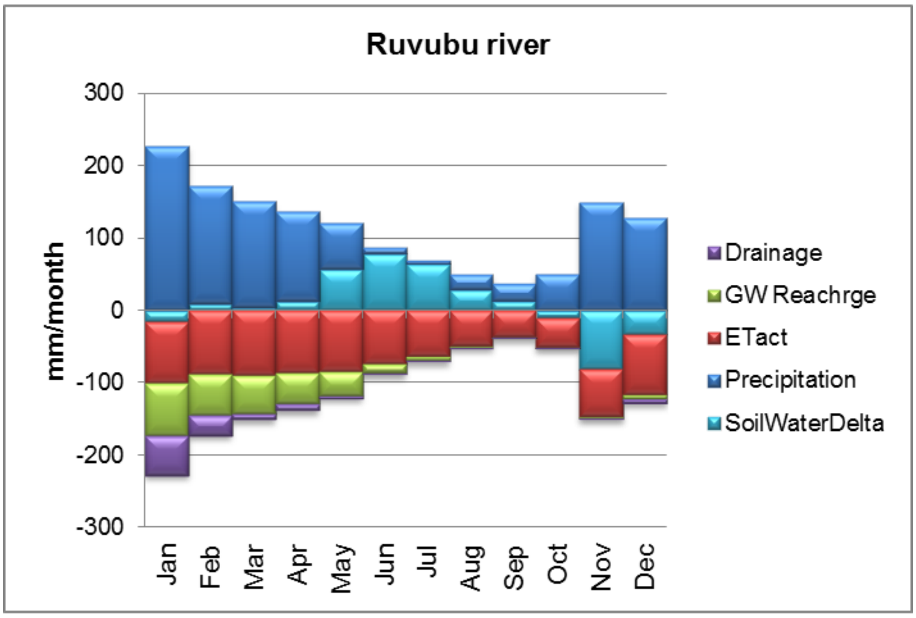
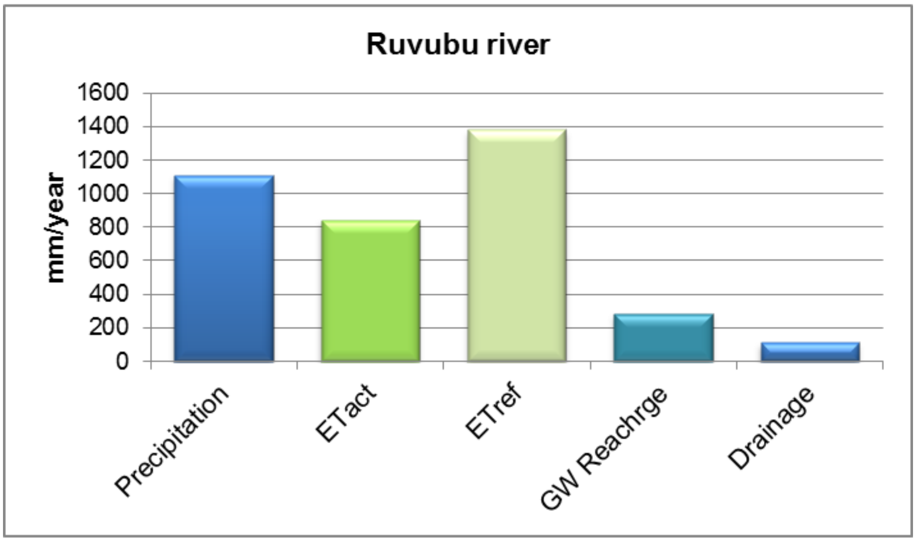


Figure 64: Average climate conditions for the focal area.

5.3.2 *Water balance*

A very detailed high resolution model was built for the 7 NEL countries (NELmod). For a detailed description see Phase 1 report. Results from NELmod were extracted for this specific focal area and are shown below.





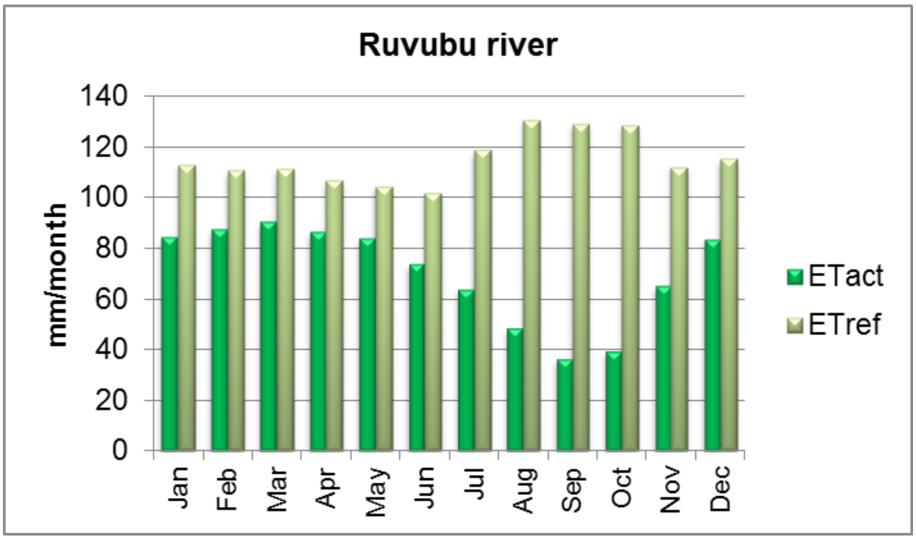
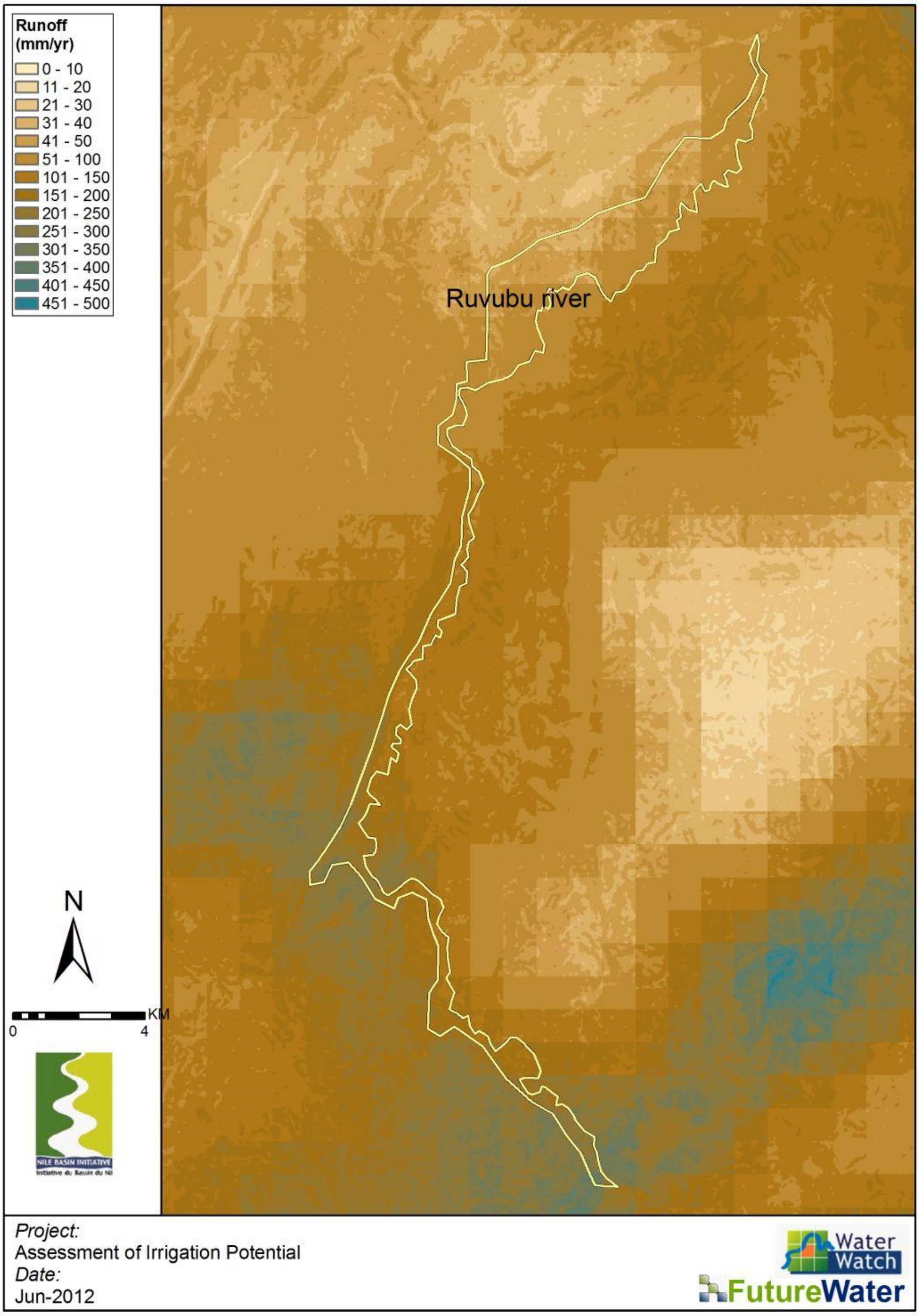
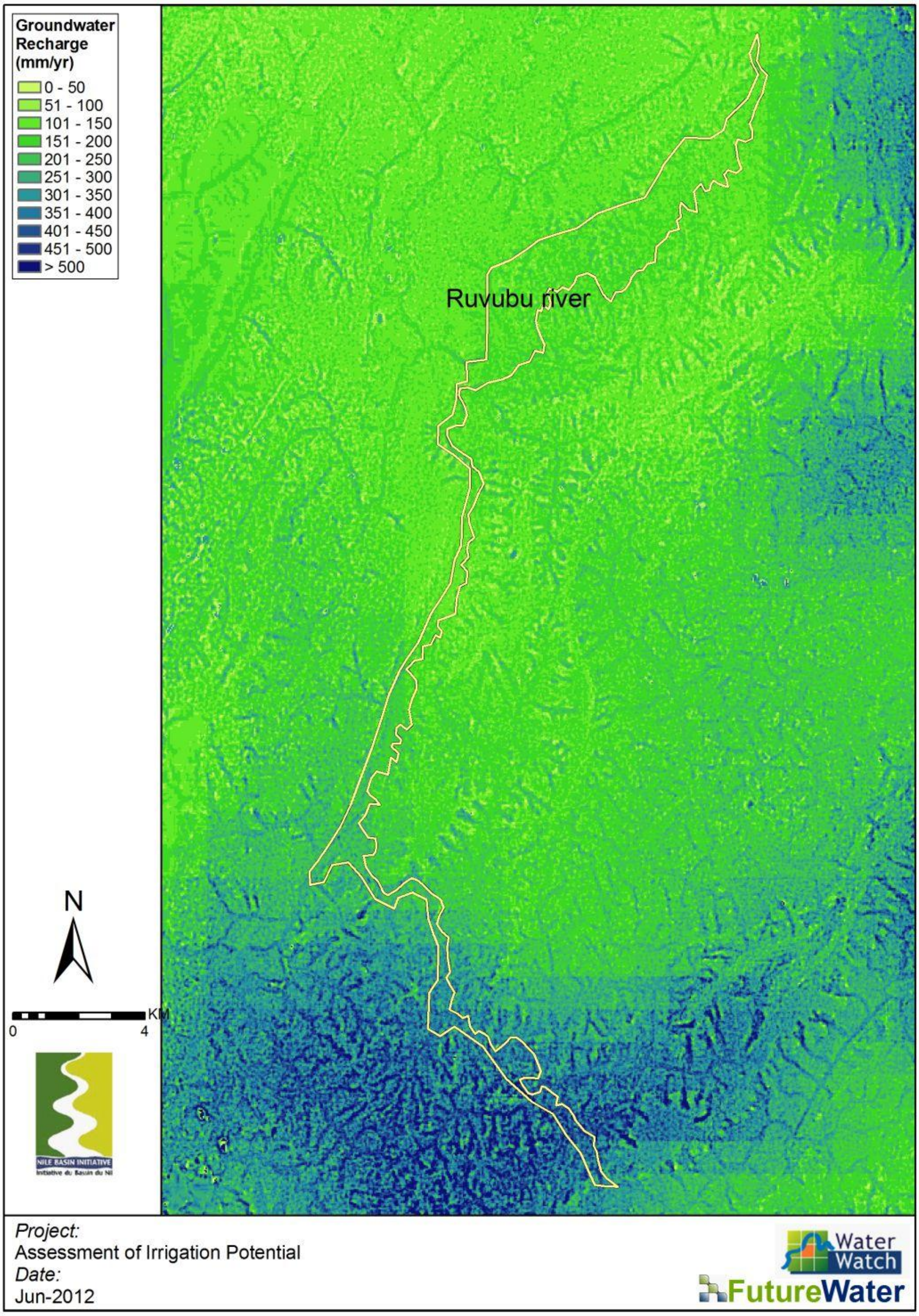


Figure 65: Water balances for the area based on the high resolution data and modeling approach for RUVUBU focal area.


Runoff
(mm/yr)
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
Ruvubu river
N
KM
0
4
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
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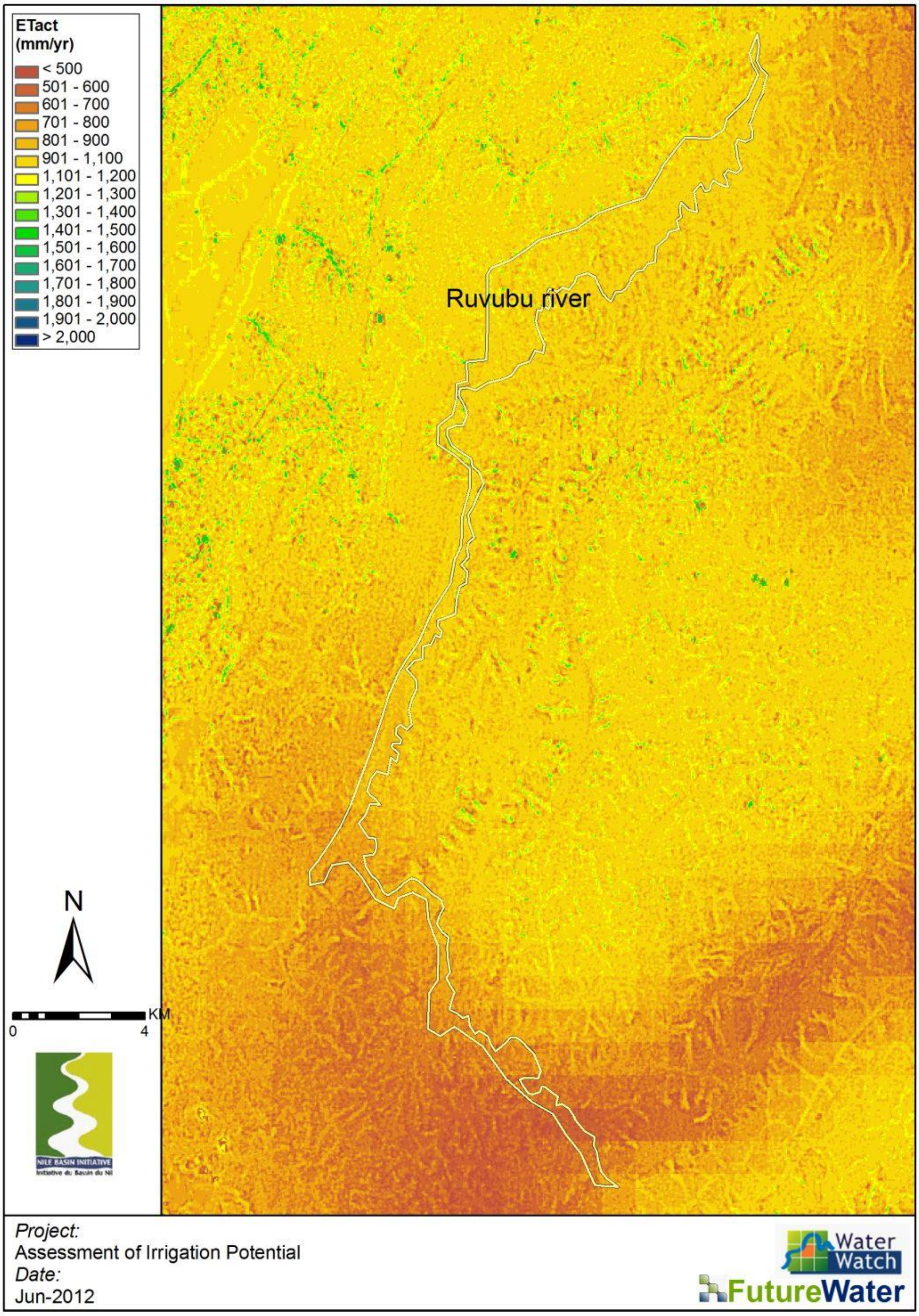


Figure 66: Water balances for the area based on the high resolution data and modeling approach for RUVUBU focal area.

5.4 Assessment of irrigation water requirements

5.4.1 Irrigation water requirements

Irrigation water requirements depend on many factors such as: climatic conditions, crop, growing season, irrigation practices etc. A first estimate of irrigation requirements could be based on the difference between rainfall and reference evapotranspiration. It was however selected for this pre-feasibility assessment to provide a first estimate of irrigation needs based on the most promising crops. To this end, FAO's AquaCrop, the successor of CropWat was setup for local and crop specific conditions.

In the table below the irrigation water requirements for each selected crop are provided based on AquaCrop calculations. All units are provided in mm per growing season for the specific crops. Note that for various crops, like vegetables and similar crops, multiple croppings per years might occur.

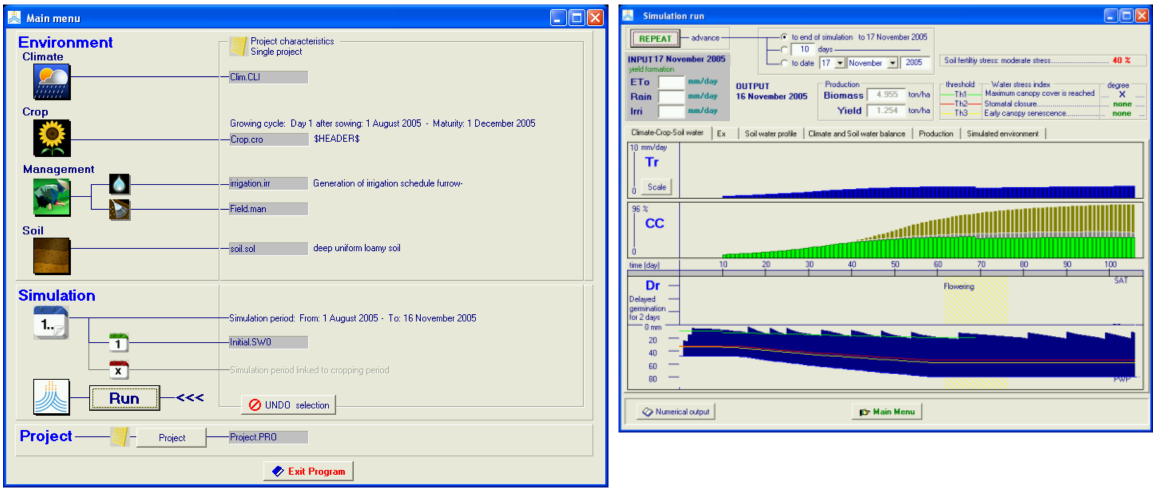


Figure 67: Typical example of AquaCrop input and output screens.

Table 10: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season.

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year ===		== (day of year) ==		======== growing season =======			
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Rice	1110	1381	1	136	702	90	493	446
Cabbage	1110	1381	1	365	1110	90	1378	533
Potatoes	1110	1381	243	76	826	290	763	653
Leek	1110	1381	1	365	1110	90	1378	533

5.4.2 Irrigation systems and irrigations efficiencies

This focal area is completely situated within the Ruvubu river valley. Water is available abundantly, but flood risks are high. Although water efficiency is not the most important factor in this area, it will hardly be possible to irrigate within the valley as the river is not regulated. In the best case the water can be diverted from the river and kept on elevation, so that the land can be irrigated with border or furrow irrigation, and flooding is not such a high risk. In the view of nature conservation, the best option is to pump the water from the river and irrigate the slopes on the sides of Ruvubu National park. In that case drip and sprinkler irrigation are most suitable as efficiencies are high. This limits the amount of water needed and operation costs accordingly. The Northern tip of the focal area is situated outside the Nation Park, however, slopes on the Western side are steep, and elevation differences easily reach 150-200 m. It is advised to focus on specific and rather small spots within and around this focal area for irrigation, to enhance local agriculture and to avoid destruction of the national park.

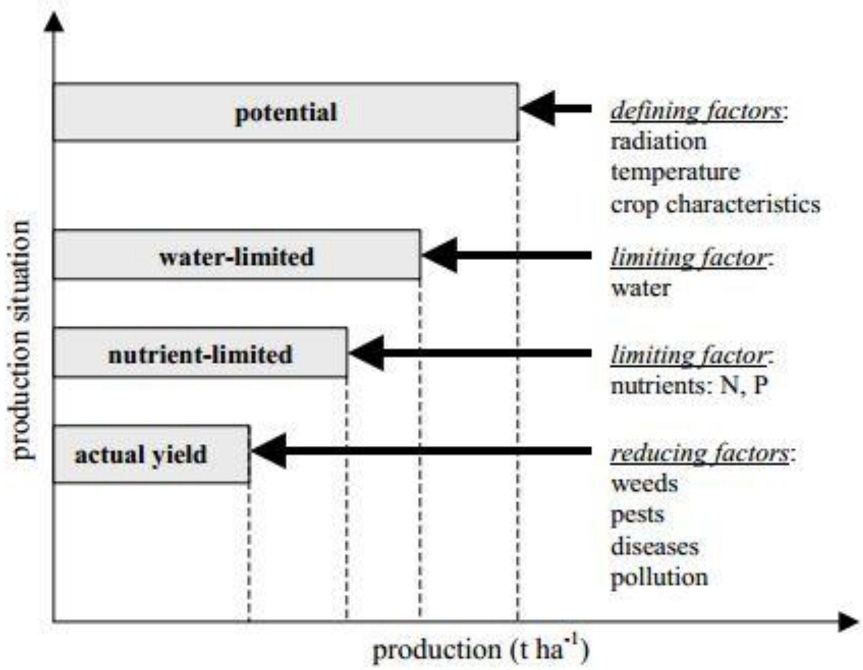
5.4.3 Water source

The water for irrigation will come from the Ruvubu River. The river drains a large part (9000 km^2) of Burundi, which is one third of the country size. Therefore flood risks are high, especially during raining season. Regulation of the river is needed for the development of large scale irrigation within the area, but this will be a very expensive project. Apart from river regulating costs, the environmental costs will be high as well, as there will be large impact on the ecosystem within the Ruvubu National Park.

5.5 Potential crop yield assessment

The yield gap describes the difference between the current yield, and the maximum possible yield. Mostly the maximum possible yield is defined as the highest yield in the world, but it can also be assessed against a regional background, which makes the yield gap more realistic and the maximum yield possible to achieve under the given circumstances.

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximum possible yield is not reached can be the water availability, the soil and the available nutrients, or yield reducing factors like diseases, weeds or pollution.



5.5.1 Yield gap analysis potential dominant crops

Yields in Burundi are among the highest in the NELSAP countries. The topography, population density increase and the increasing demand for food have been drivers for agricultural intensification. However, irrigation is not practiced much, and fertilizer is hardly used. In Figure

68 the yield gap is shown relatively to Burundian average yields, NELSAP average yield, East African yields, African yields and world's average yields. Everything is scaled to percentage of the highest yields obtained somewhere in the world.

Within the Ruvubu focal area the current yields are high; yields are well above Burundian average. Compared to the maximum obtainable yield, quite some improvements can be done to reach a realistic maximum yield. Currently the production of rice is about 35% of the maximum yield in the world, and at about 75% of the world's average. Depending on the chosen irrigation system and the level of flood control, the rice yield can double towards the 70% of the world's highest. This involves two growing cycles per year, and stable high yields over the years. Potatoes currently reach 3.2% of the world's highest, and approximately 11% of the world's average. It is expected that the yield of potatoes can increase towards the world's average, which means that yields can increase towards 20-25% of the highest obtainable yield. No data was available for cabbage and leek.

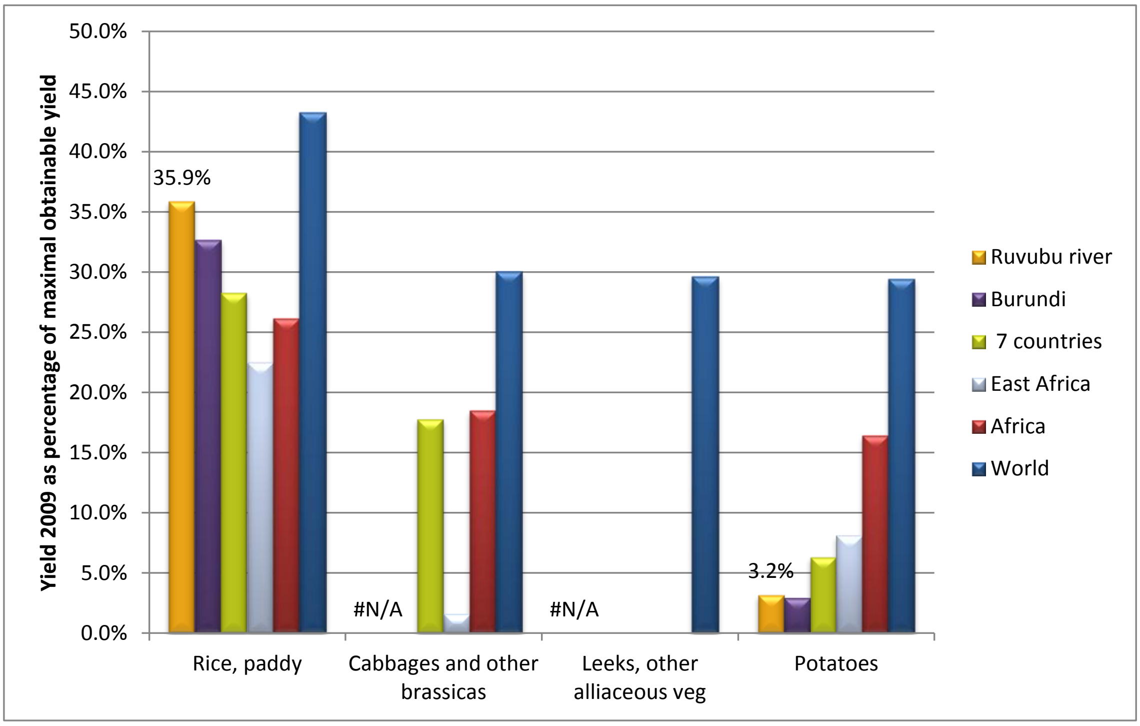


Figure 68: Yield gap Ruvubu river (Source: FAOSTAT 2012).

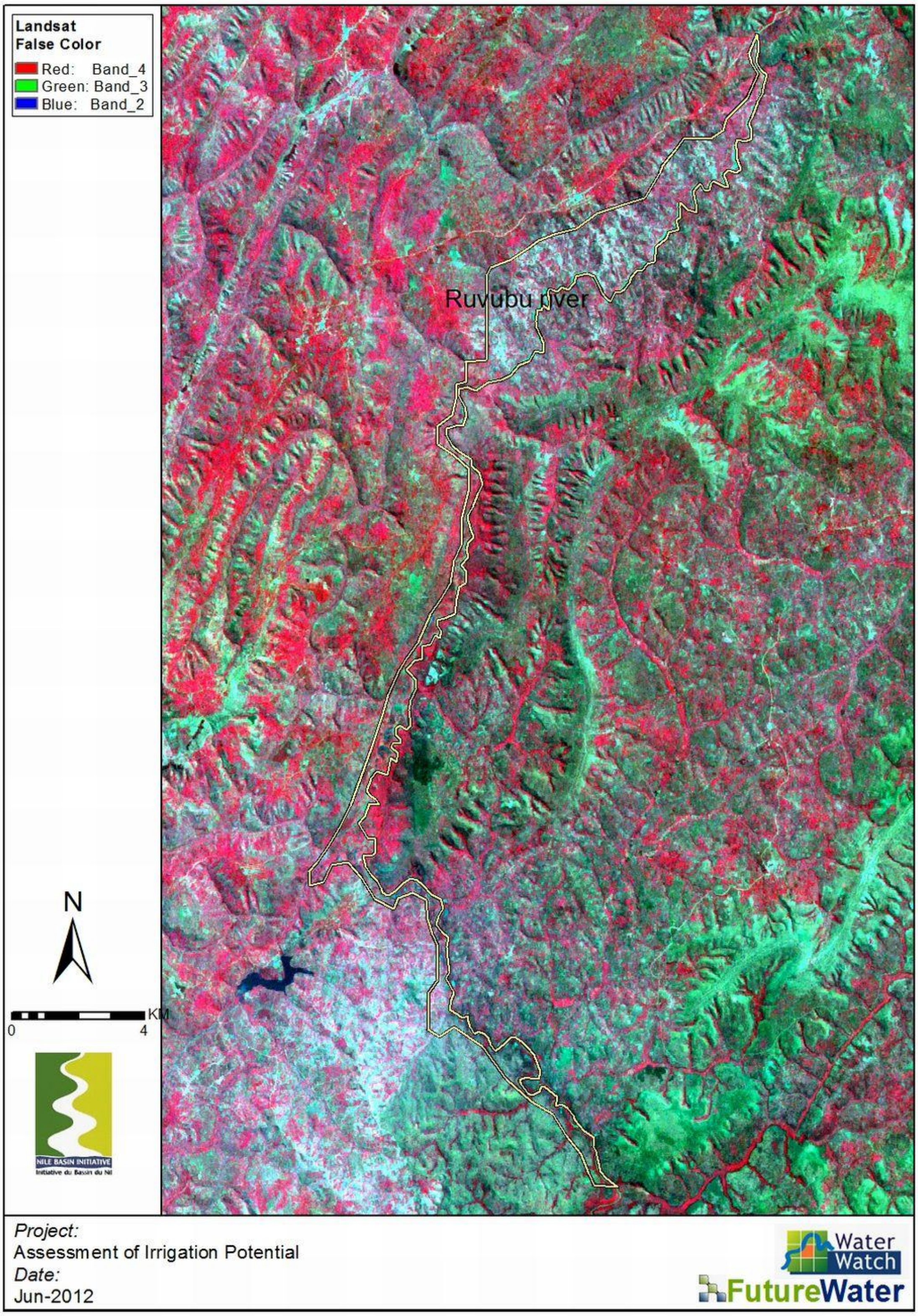


Figure 69: Landsat False Color Composite indicating current productivity of the Ruvubu focal area.

5.6 Environmental and socio-economic considerations

5.6.1 Population displacements

This focal area mainly covers the Northern part of the Ruvubu River in the valley going west along the border with Tanzania. Nobody lives within the valley due to the high flood risks. Just on the slopes going up there are a few houses build along the roads. These houses can be avoided when designing a pressurized irrigation system. With the design of any irrigation scheme, it is advised to limit any population displacement. The exact numbers of effected houses can only be known after designing the scheme which is beyond the scope of this pre-feasibility study..

5.6.2 Social

The Northern tip of the focal area has some inhabitants, but is still very sparsely populated with around 100 people/km^2. The average household has 5.5 children. Regarding the population distribution by age, it becomes clear that people within the province of Muyinga are extremely young, with approximately 67.3% of the population being under the age of 25 (MININTER 2006). The active labor force in Muyinga province is therefore less than half of the total population. The amount of male and female workers is nearly equal, which could suggest social equity between male and female. Infrastructure in the area is poor as the nearest tarmac road is going through Muyinga town, and further away the area is only connected to earth roads. The condition of these earth roads varies over the year. Farmers have average knowledge in irrigation and farmer's cooperation's.

5.6.3 Upstream downstream consideration

As agriculture is hardly practiced and population density is low, there is hardly any erosion and water quality is not affected. With irrigation development, however, this can easily change as farmers' knowledge is limited, which increases the chance on erosion or eutrophication. Erosion is a problem in the valley and on the slopes in the North of the area.

5.6.4 Protected areas

The focal area is situated close to the Ruvubu National Park. Therefore, it is really important that a feasibility study shows the effects of an irrigation scheme on the environment in this area. Although the pressure on land and resources is increasing rapidly, the added value from national parks and protected areas are studied and proven to be substantial. Therefore, a careful consideration should be made whether an irrigation scheme gives any added value to the region, in economic, social and environmental sense.

5.7 Benefit-Cost Analysis

A simplified benefit-cost analysis is undertaken for the area. Information for this is based on various sources such as FAO publications, IFPRI publications, local expertise and data. A full benefit-costs analysis has to be undertaken in a sub-sequent feasibility study for the area.

Note that this is a first-order benefit-cost analysis. A feasibility study can provide a more rigorous benefit-cost analysis, which is required before taking any implementation planning.

However, the following table shows that based on this first-order analysis, investments in irrigation can have a very positive impact.

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Rice: 4,000 kg/ha, 0.35 $/kg
    - Cabbage: 1,500 kg/ha, 0.07 $/kg
    - Potatoes: 11,000 kg/ha, 0.14 $/kg
    - Leek: 3,000 kg/ha, 0.63 $/kg

Based on expert knowledge on the suitability to develop irrigation in the area scores between 1 (negative: low suitability or expensive) to 10 (positive: high suitability or low investments) have been marked. The filled radar plot below indicates the options for the focal area. Overall, the weak part of the site lies under farmers capacity, accessibility to roads, to markets and the initial investment cost. This in-turn affects access to market as farmers cannot transport their yield easily and more importantly may not fetch golden prices. However, soil suitability and water availability is a great deal for the area that will foster an increase yields.

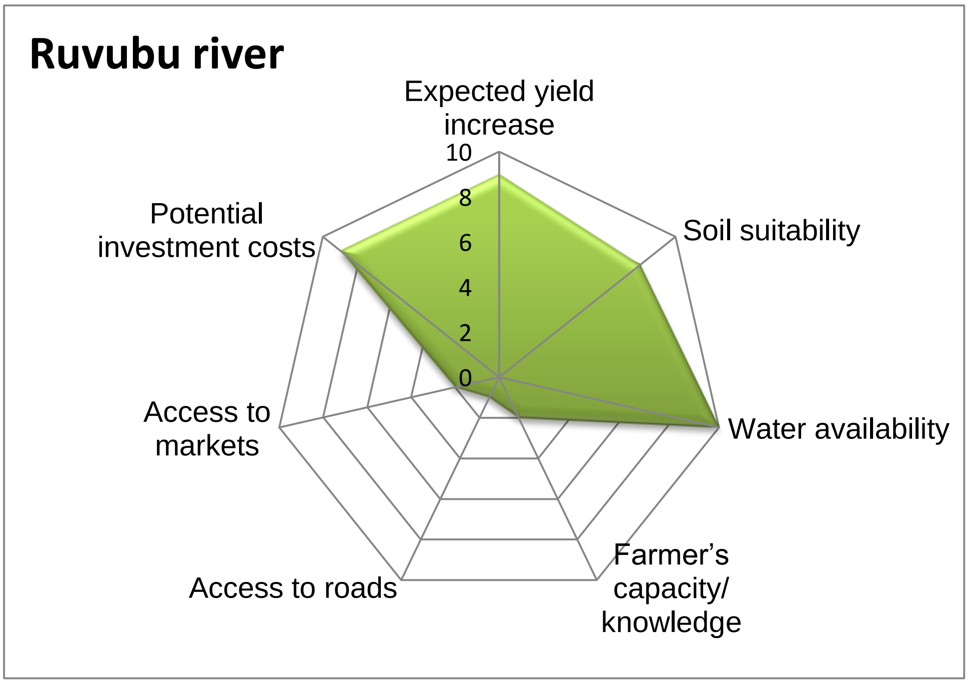


Figure 70: Filled radar plot indicating expert knowledge score to develop irrigation in the Ruvubu River focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 11: Benefit-cost analysis for Ruvubu area.

Characteristics	
Irrigated land (ha)	1,000
Farmers	1,667
Investment Costs	
Irrigation infrastructure (US$/ha)	12,000
Social infrastructure (US$/farmer)	500
Accessibility infrastructure (million US$)	3.0
Operational Costs	
O&M irrigation (US$/ha/yr)	60
Extension service (US$/farmer)	10
O&M roads (US$/yr)	60,000
Summary	
Initial investments (million US$)	15.8
O&M costs (million US$/yr)	0.137
Net benefits per year (million US$/yr)	0.745
IRR (Internal Rate of Return)	-0.3%

Characteristics	
Irrigated land (ha)	1,000
Farmers	1,667
Return on investments (yr)	25
Investment Costs	
Irrigation infrastructure (US$/ha)	12,000
Social infrastructure (US$/farmer)	500
Accessibility infrastructure (million US$)	3.0
Operational Costs	
O&M irrigation (US$/ha/yr)	60
Extension service (US$/farmer)	10
O&M roads (US$/yr)	60,000
Summary	
Initial investments (million US$)	15.8
Annualized investment costs (million US$/yr)	0.633
O&M costs (million US$/yr)	0.137
Total costs per year(million US$/yr)	0.770
Benefits per year (million US$/yr)	2.100
Total costs per year (US$/ha/yr)	770
Benefits minus costs per year (US$/ha/yr)	1330

5.8 Recommendations

This pre-feasibility study describes the topics on a screening and scoping level. The available local data are included in the analysis and description, but final results give a first impression of the irrigation possibilities. Recommendations to be included in a detailed feasibility study are: i) possible design of the irrigation scheme ii) In depth analysis of possible reservoir sites iii) the implications of the legal framework and local law on irrigation development in the focal area iv) make an economic analysis per crop and irrigation system and v) a in depth cost benefit analysis, fully based on the local situation.

6 Ndurumu focal area

6.1 Introduction

This chapter will describe the current state of Ndurumu focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 72 a detailed map of the area is given. Total area is 4905 ha.

Selection of this specific focal area was based on results of Phase 1 of this study, while final selection was the responsibility of the relevant country representatives. Results presented hereafter have been obtained from a broad range of sources: Phase 1, previous other studies and reports, modeling results, remote sensing, expert knowledge and field visits by Christophe Majambere and Emmanuel Ndorimana as supervisor in March 2012.

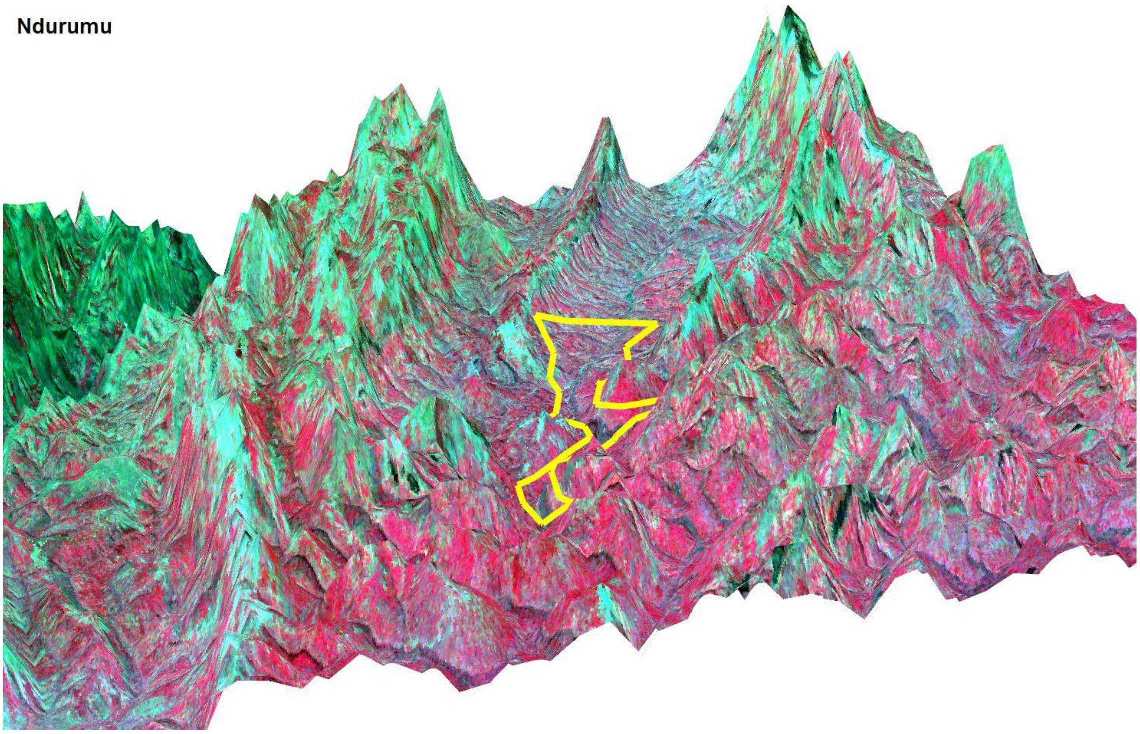


Figure 71: 3D impression of Ndurumu focal area, Burundi.

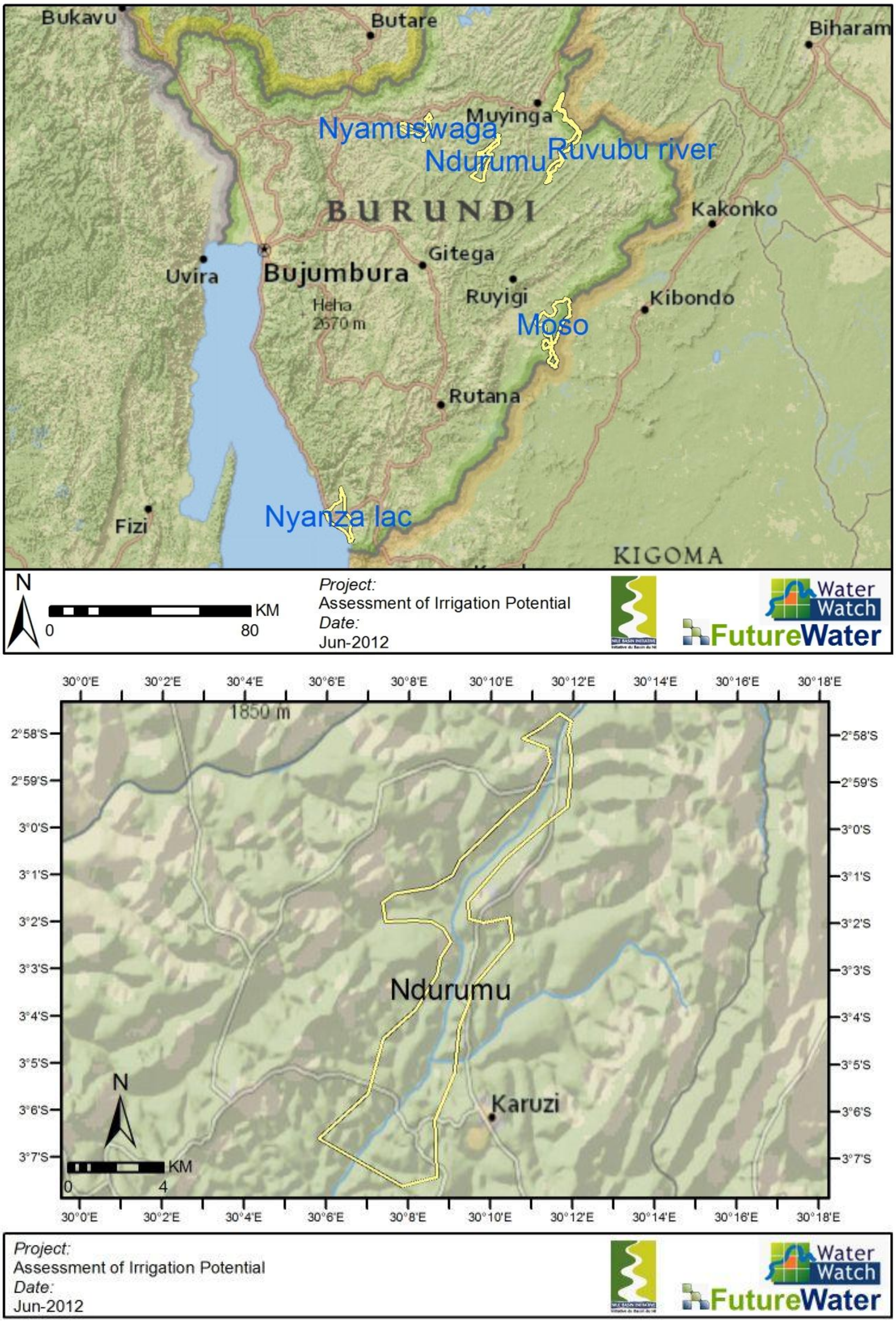


Figure 72: Ndurumu focal area, Burundi

6.2 Land suitability assessment

6.2.1 Terrain

Ndurumu Focal area is located within Karuzi Province and covers the upstream part of Murarangaro River. This area covers the valley and the foothills on the side. Within the focal area the valley descends 90 meters, from 1570 m to 1480 m above sea level. From the valley bottom to the sides the terrain is going up rather steeply, especially in the northern and narrow part of the focal area. Elevation difference is limited mostly to 50 meters within the cross section of the valley (Figure 71 + Figure 73). Slopes in the area are diverse. Most of the slopes are under the 5%. At some small ridges, however, slopes can increase to an occasional 20% (Figure 74).

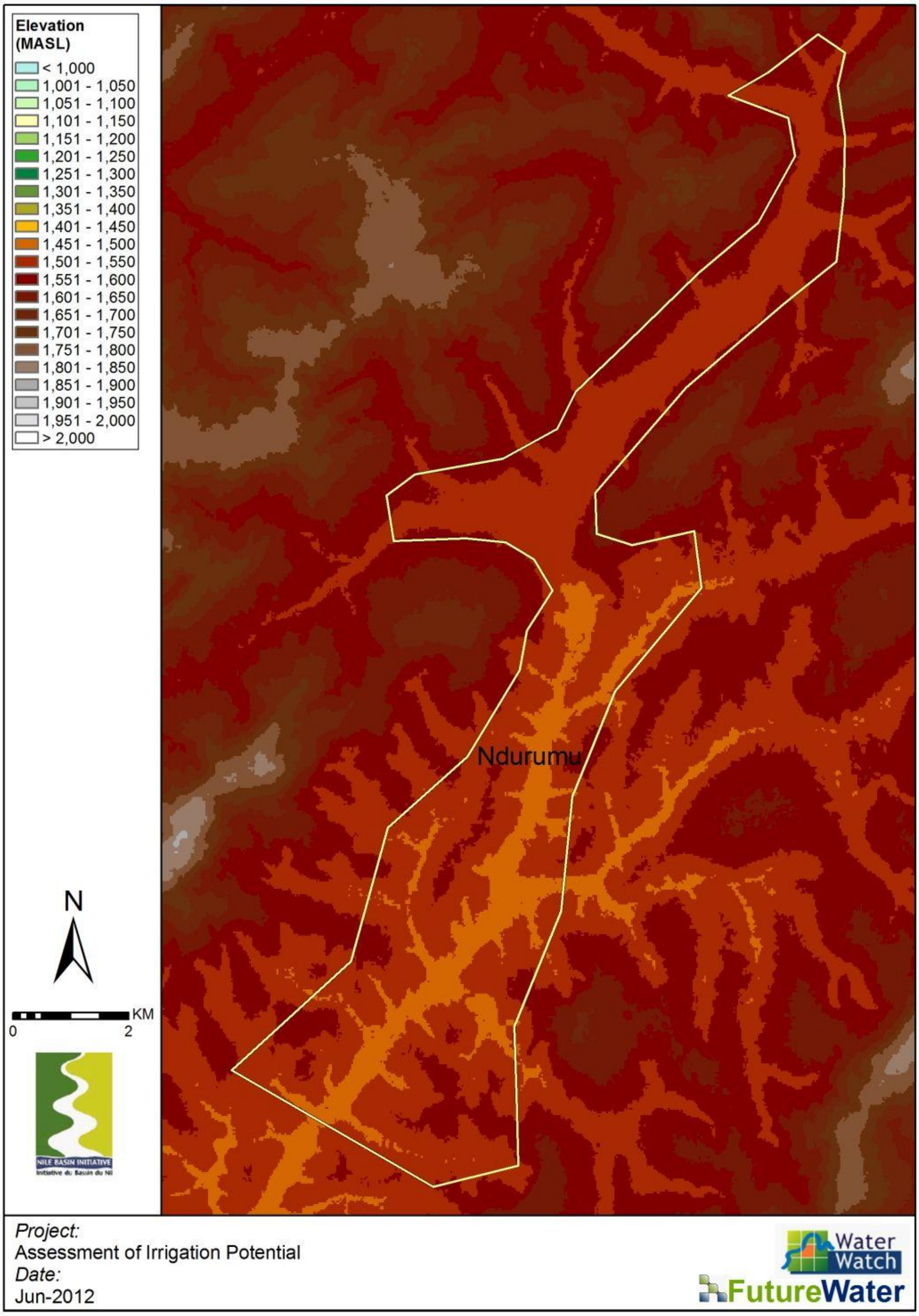


Figure 73: DEM Ndurumu focal area. Resolution 1 arc second (+/- 30m).

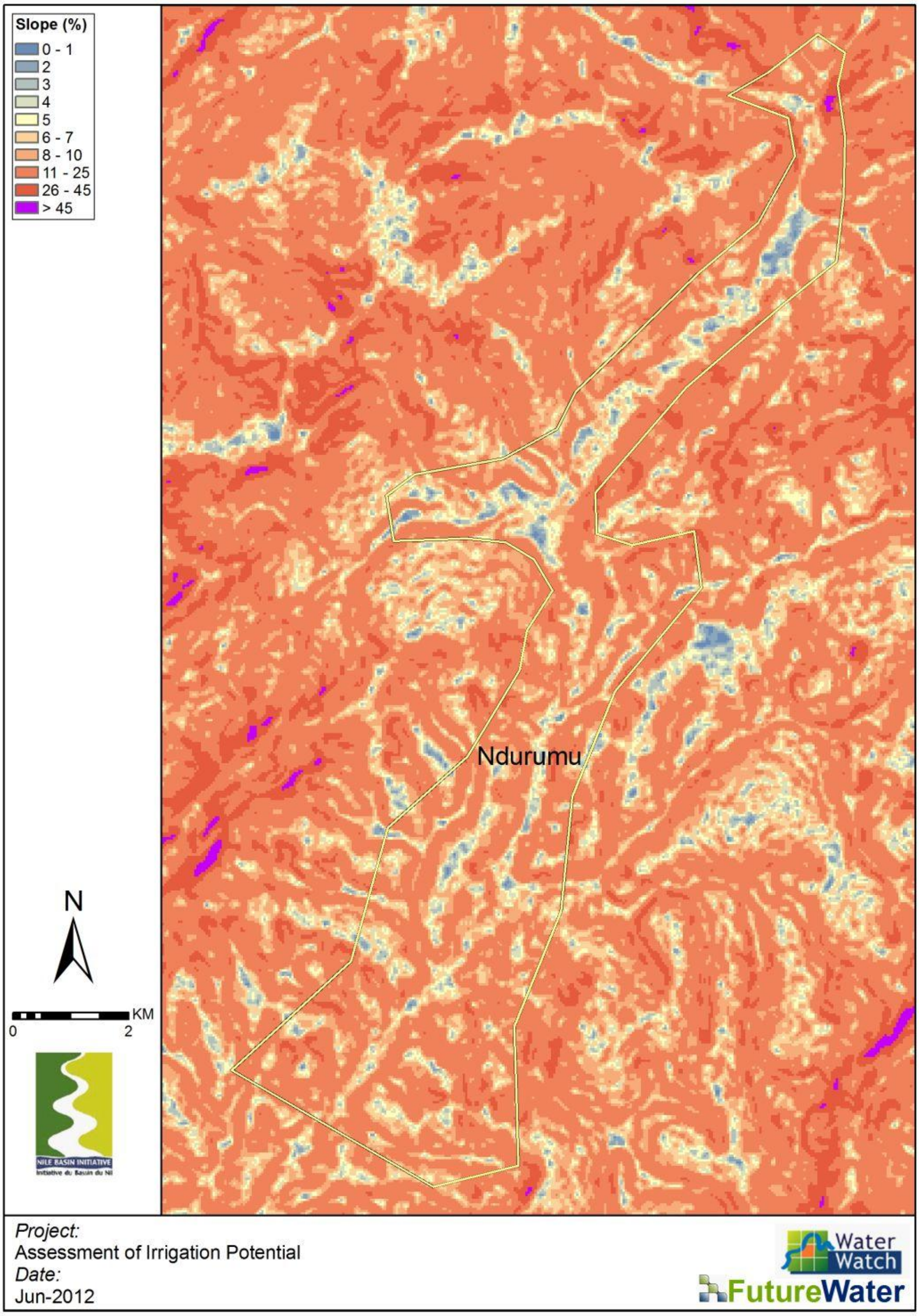


Figure 74: Slope map Ndurumu focal area (source: ASTER).

6.2.2 Soil

Soils in the area are silty clay loam, and formed by alluvial processes. The river flows through the area, and the change in discharge over the year causes quite some erosion and flooding. The area is originally swampy, and is subsequently poorly drained. The availability from organic carbon in the top soil increases from North to South. In the North carbon ranges between 1.2 and 2%, and towards the South more than 2% can be found. The available water storage capacity in the North is in the range of 125-150 mm/m and towards the South more than 150 mm/m. Furthermore, the soil is slightly acid. Erosion is a problem, and in the largest part of the area, no measures have been taken to prevent or reduce erosion. Some measurements are in place e.g. around Karuzi.

6.2.3 Land productivity

The Ndurumu marshland has a high land productivity with and yearly average NDVI of 0.62. This is roughly 10% above Burundian average. NDVI is highest on the slopes surrounding the swamp, with values that reach 0.67. In the Northern part of the area, and in the valley in the South, the land productivity is around 0.6 (Figure 76). Variation in land cover is quite low, and does not show specific patterns within the area.

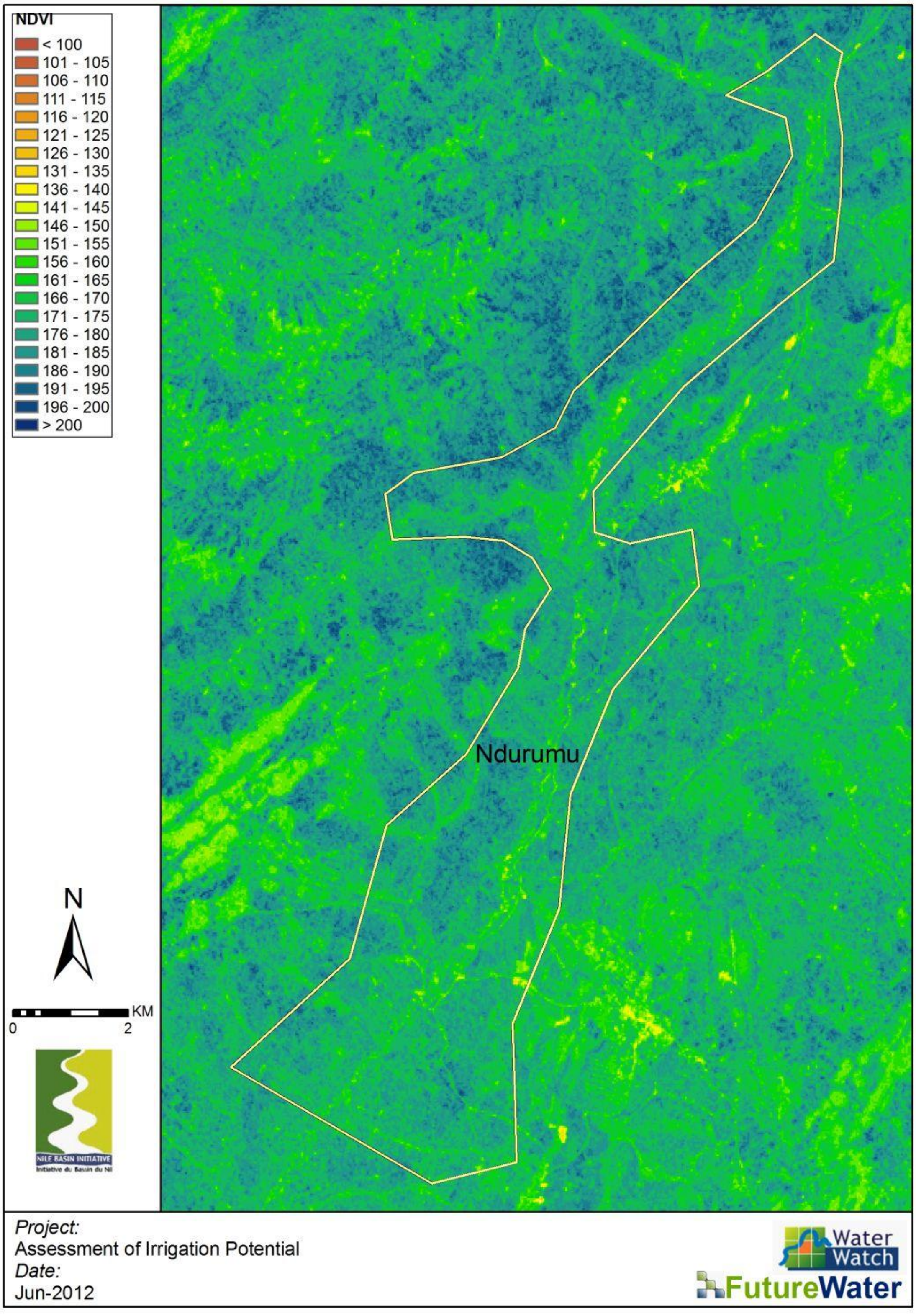


Figure 75: High resolution NDVI

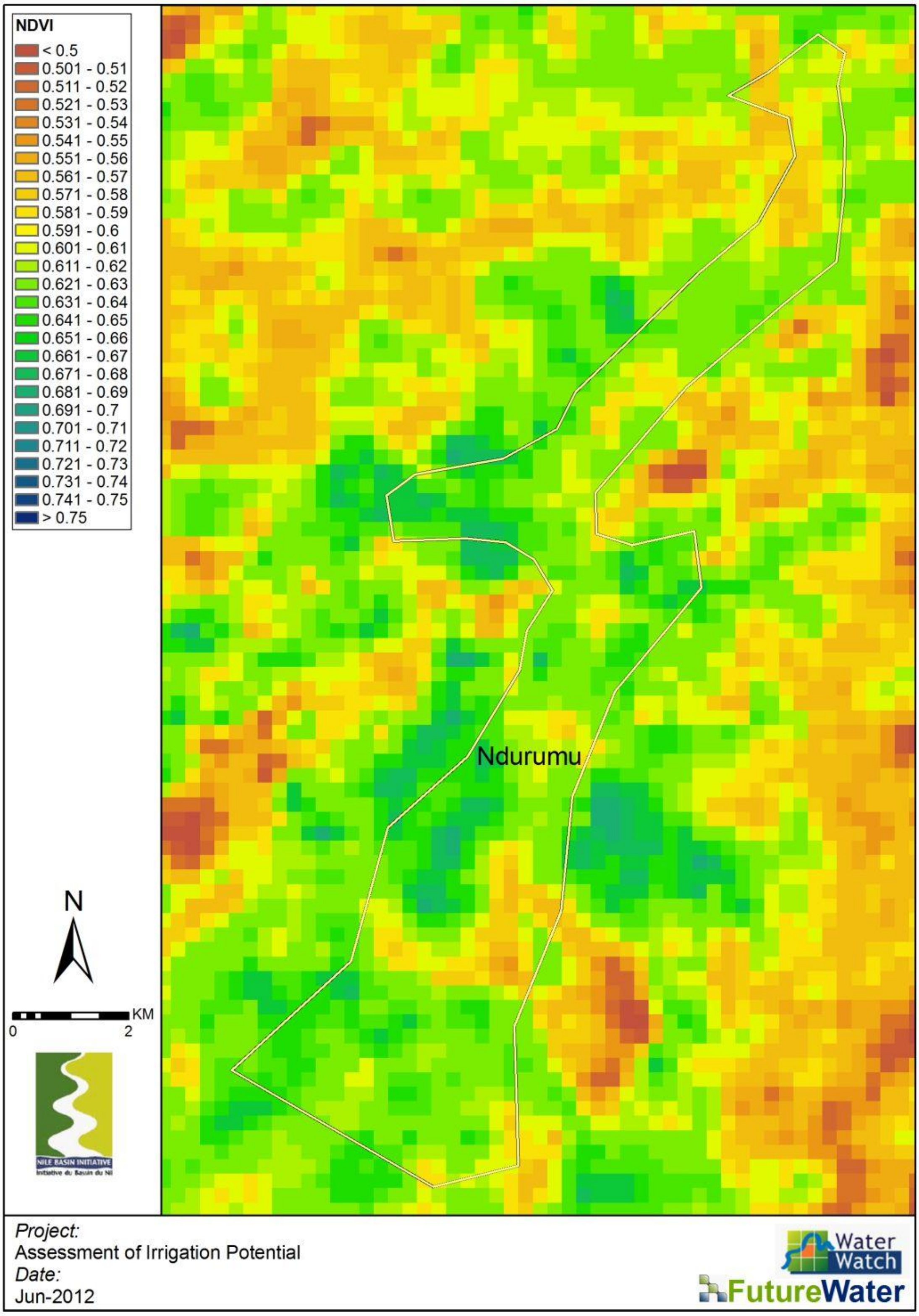


Figure 76: Yearly average NDVI values.

6.2.4 Potential cropping patterns

The government of Burundi has the policy to stimulate regional qualities and regional differentiation concerning agriculture. Within the Ndurumu focal area rice is the dominant crop, which covers approximately 60% of the area. Maize and beans cover both about 20% of the area, and cabbage is grown on 5% of the area. Rice and cabbage are grown in 2 growing cycles, and maize and beans once per year. Future cropping patterns enhance rice as dominant crop, and cabbage and eggplant will be grown besides. Water management in the Ndurumu swamp is poorly organized at the moment, but better management and flood protection will increase yields, and can increase the cropping intensity.

6.3 Water resource assessment

6.3.1 Climate

Average climate conditions for the area are shown in the figure below. Precipitation is based on an advanced calibration/validation algorithm using satellite derived precipitation and calibrated using local observations. Details can be found in the Phase 1 Report. Reference evapo-transpiration (ETref) is calculated using the well-known Penman-Monteith approach. Input data for ETref is based on local observations and an advanced spatial downscaling algorithm.

The climate of the area can be characterized as relatively warm with constant temperatures during the year ranging from 16^{o}C to 27^{o}C. Annual average precipitation is 1081 mm and reference evapotranspiration 1402 mm per year.

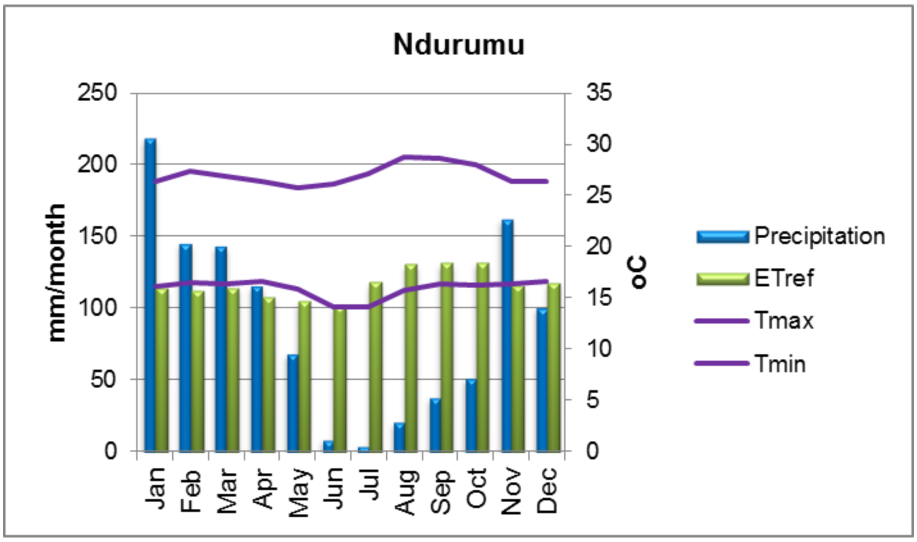


Figure 77: Average climate conditions for the focal area.

6.3.2 Water balance

A very detailed high resolution model was built for NEL countries (NELmod). For a detailed description see Phase 1 report. Results from NELmod were extracted for this specific focal area and are shown below.

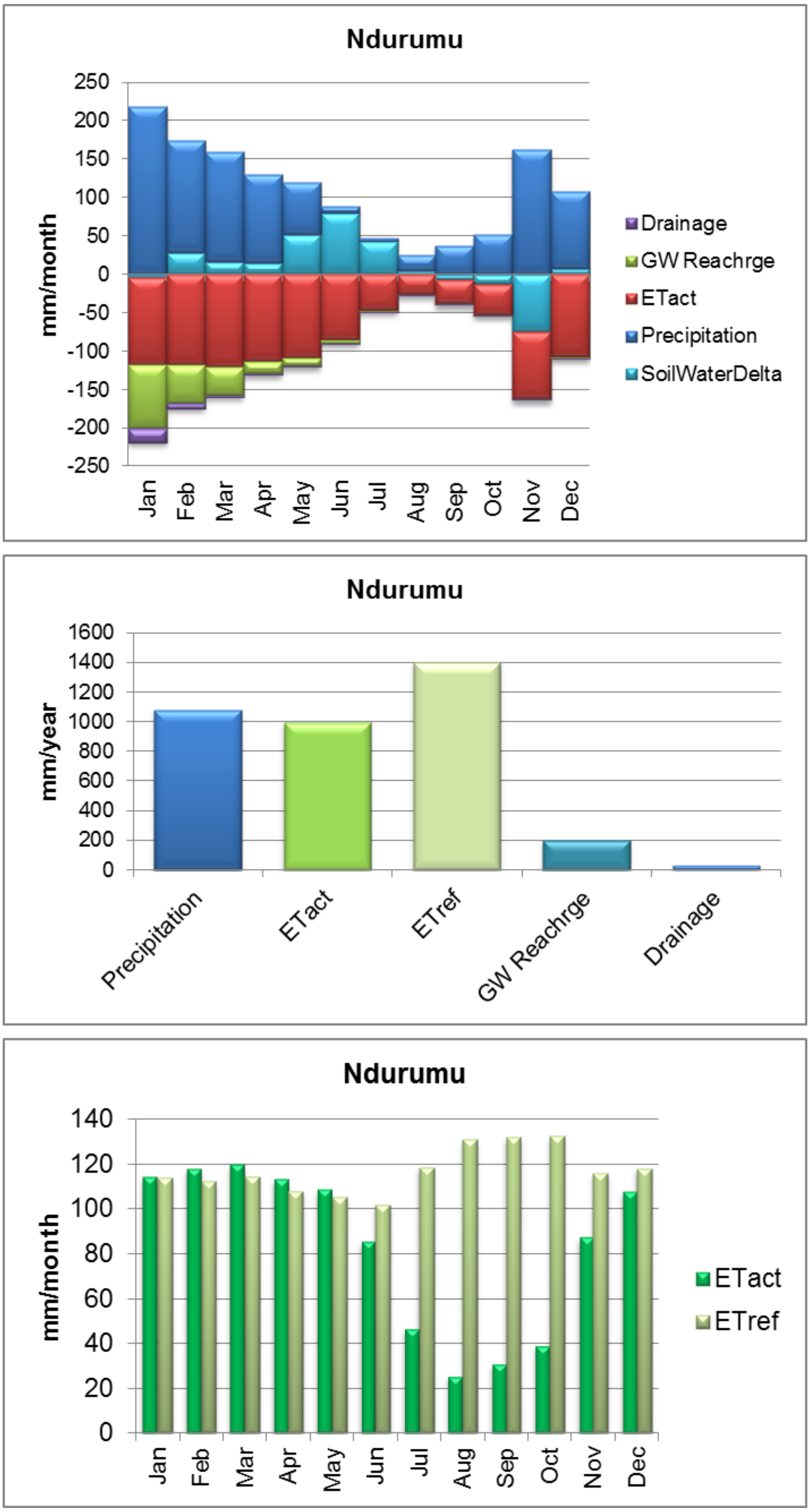
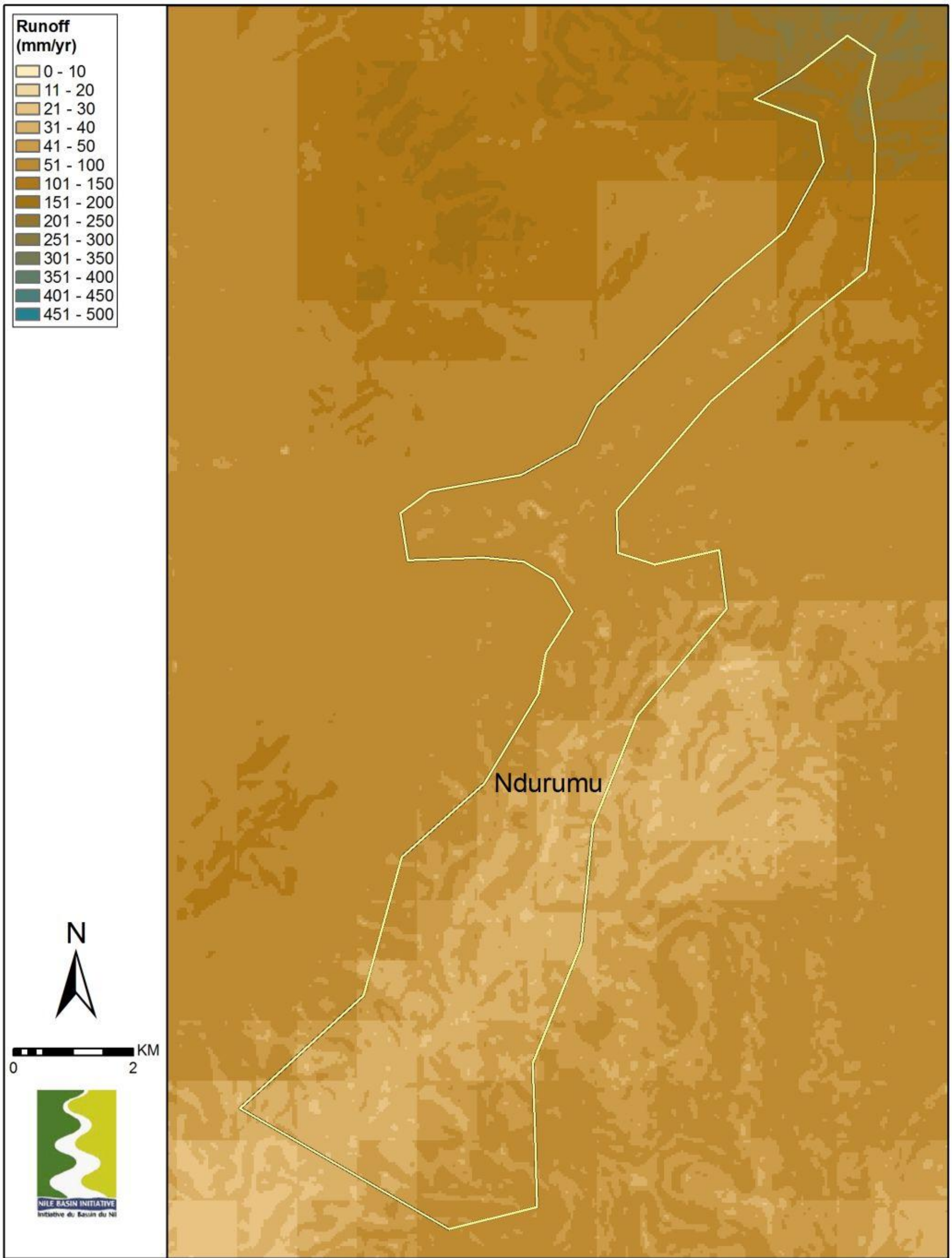


Figure 78: Water balances for the area based on the high resolution data and modeling approach for NDURUMU focal area.



Project:
Assessment of Irrigation Potential
Date:
Jun-2012

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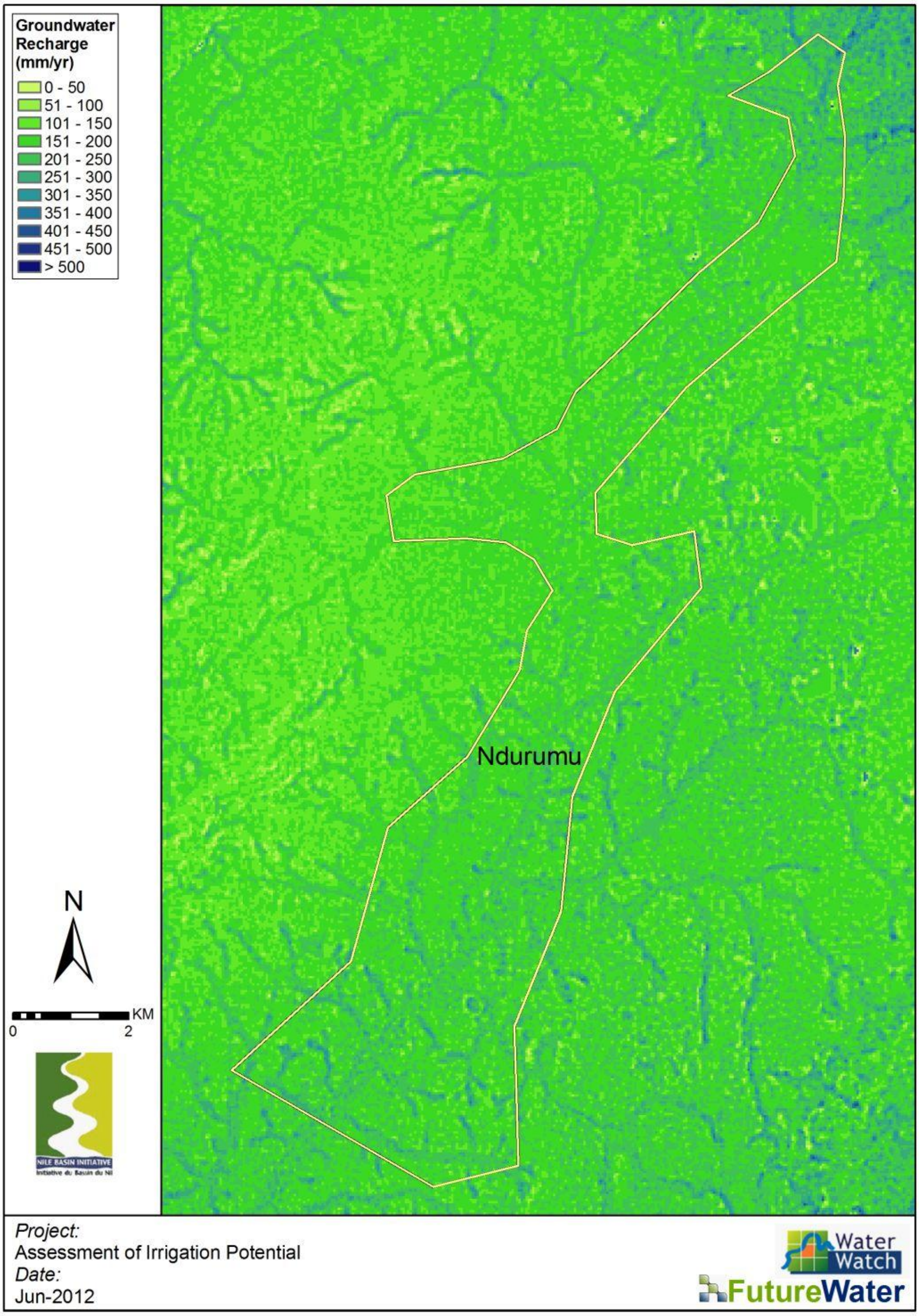
FutureWater


Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
> 500
Ndurumu
N
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Assessment of Irrigation Potential
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Water Watch
FutureWater

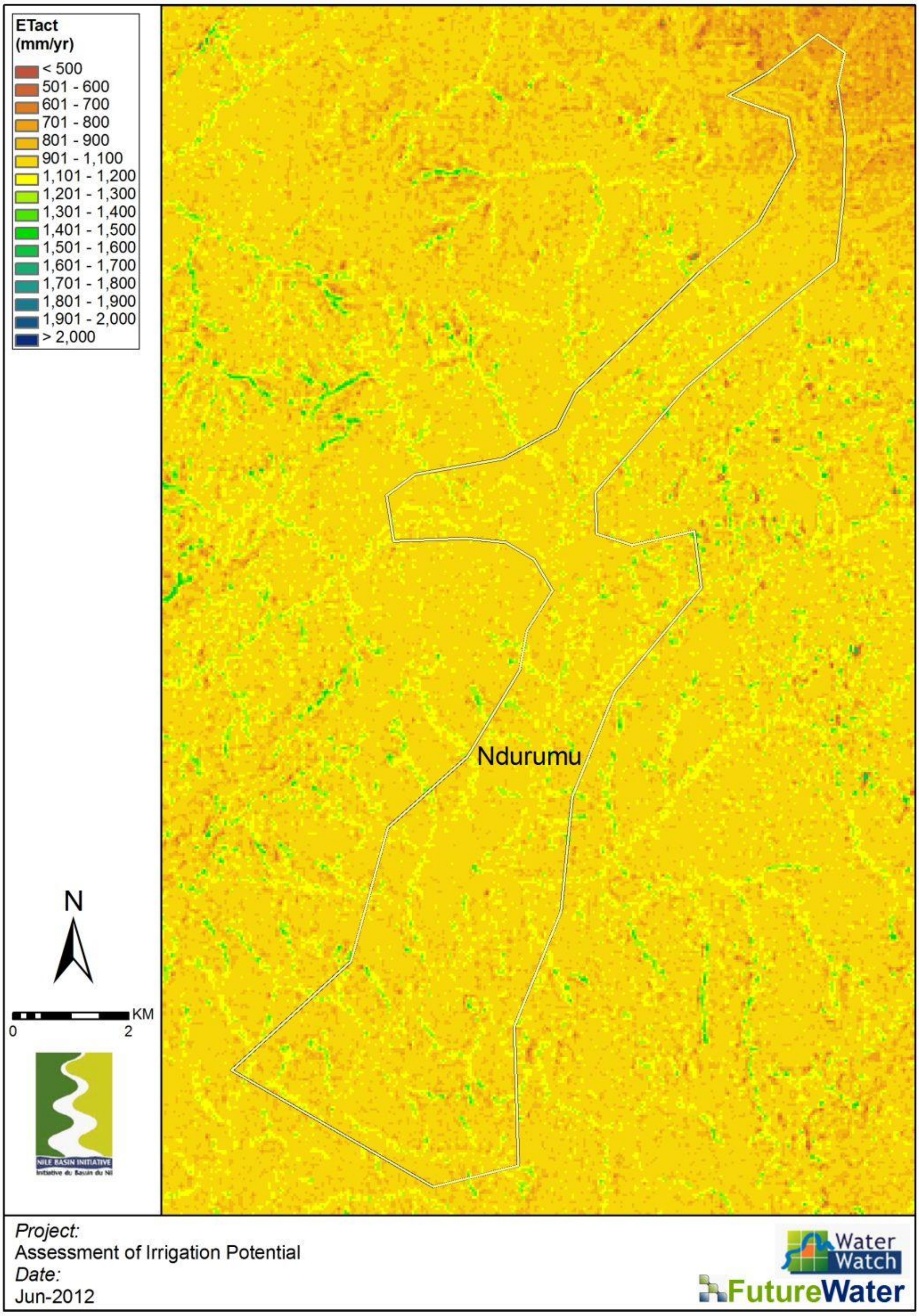


Figure 79: Water balances for the area based on the high resolution data and modeling approach for NDURUMU focal area.

6.4 Assessment of irrigation water requirements

6.4.1 Irrigation water requirements

Irrigation water requirements depend on many factors such as: climatic conditions, crop, growing season, irrigation practices etc. A first estimate of irrigation requirements could be based on the difference between rainfall and reference evapotranspiration. It was however selected for this pre-feasibility assessment to provide a first estimate of irrigation needs based on the most promising crops. To this end, FAO's AquaCrop, the successor of CropWat was setup for local and crop specific conditions.

In the table below the irrigation water requirements for each selected crop are provided based on AquaCrop calculations. All units are provided in mm per growing season for the specific crops. Note that for various crops, like vegetables and similar crops, multiple croppings per years might occur.

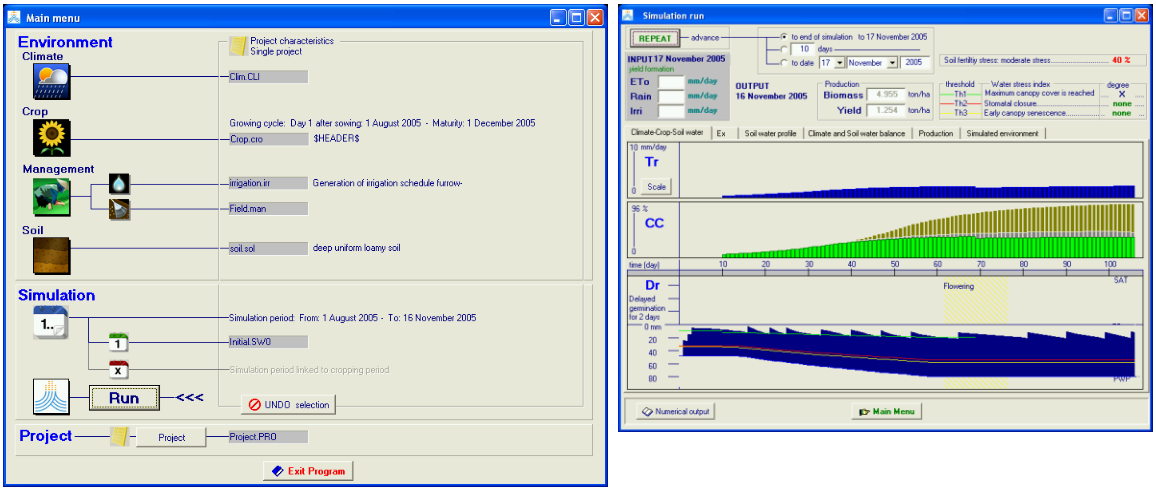


Figure 80: Typical example of AquaCrop input and output screens.

Table 12: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season.

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year ===		== (day of year) ==		======== growing season =======			
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Rice	1081	1402	1	136	668	90	500	454
Cabbage	1081	1402	1	365	1080	90	1399	556
Aubergine	1081	1402	1	365	1080	90	1399	556

6.4.2 Irrigation systems and irrigations efficiencies

Border irrigation will be the most used irrigation technique within the Ndurumu focal area. Currently, the farmers are used to this irrigation technique, thus the introduction of more professionalized border irrigation may proceed easily. The river has to be regulated in order to make irrigation possible, but due to the soil conditions the irrigation water requirements in the area is very low. Although border irrigation has low application efficiency, it is recommended here, as initial construction costs are relatively low per hectare, and operation costs are very limited. Besides this, the water that is "lost" will become available downstream, or recharge the ground water. This water may be available again later in the season. Based on the water availability within the upstream catchment it may be possible to have some pressurized hill slope irrigation. These sprinkler or drip irrigation systems are much more efficient, but have a high construction cost. Therefore it is advised only to install them if enough water is available to operate them around the year. A detailed feasibility study will show whether the upstream catchment of 26,300 ha will generate enough discharge. Since this is a trans-boundary river, involvement from Tanzania is essential.

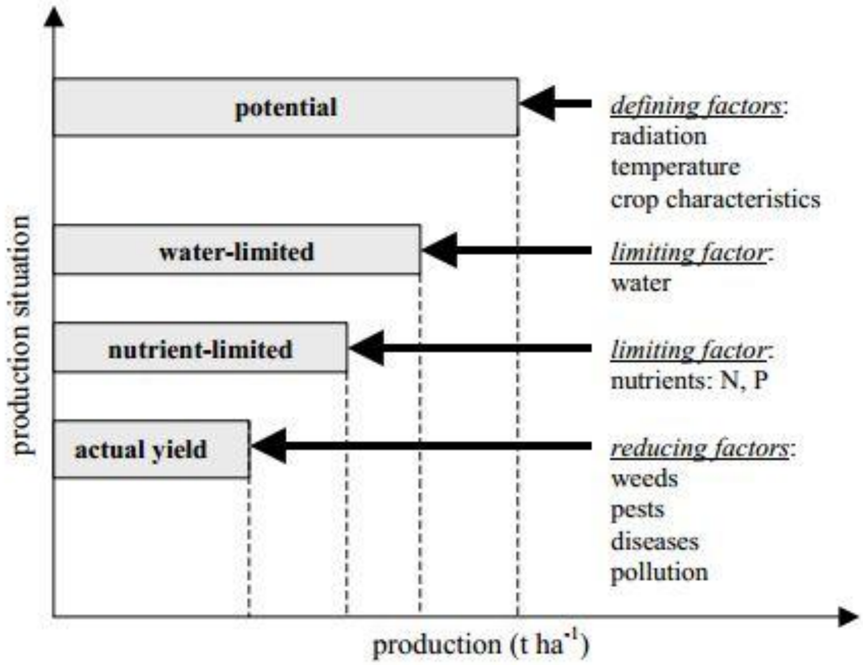
6.4.3 Water source

The water source will be the upstream part of Murarangaro River, flowing through Ndurumu swamp. There is a possibility for an upstream reservoir, but the catchment for a reservoir and the capacity accordingly will be rather small. The average annual discharge within the catchment is 3 m^3/s.

6.5 Potential crop yield assessment

The yield gap describes the difference between the current yield, and the maximum possible yield. Mostly the maximum possible yield is defined as the highest yield in the world, but it can also be assessed against a regional background which makes the yield gap more realistic and the maximum yield possible to achieve under the given circumstances.

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximum possible yield is not reached can be the water availability, the soil and the available nutrients, or yield reducing factors like diseases, weeds or pollution.



6.5.1 Yield gap analysis potential dominant crops

Yields in Burundi are among the highest in the NELSAP countries. The topography, population density increase, and the increasing demand for food have been drivers for agricultural intensification. However, irrigation is not practiced much, and fertilizer is hardly used. In Figure

81 the yield gap is shown relatively to Burundian average yields, NELSAP average yields, East African yields, African yields and world's average yields. Everything is scaled to percentage of the highest yields obtained somewhere in the world.

Within the Ndurumu focal area the yields are above Burundian average yields. Within the valley the stream is not much regulated, which does have a negative impact on yields. Professionalizing the current rice irrigation can nearly double the yields within one growing cycle. Besides this, yields will be much more stable over the years and rice can be grown twice a year, depending on the water availability. From cabbage and eggplant there are currently no statistics available in FAOstat. However, it is expected that, based on the field visits, potential yields for cabbage will be 30-40% of the highest obtainable, and for eggplant around 10% of the highest obtainable yield.

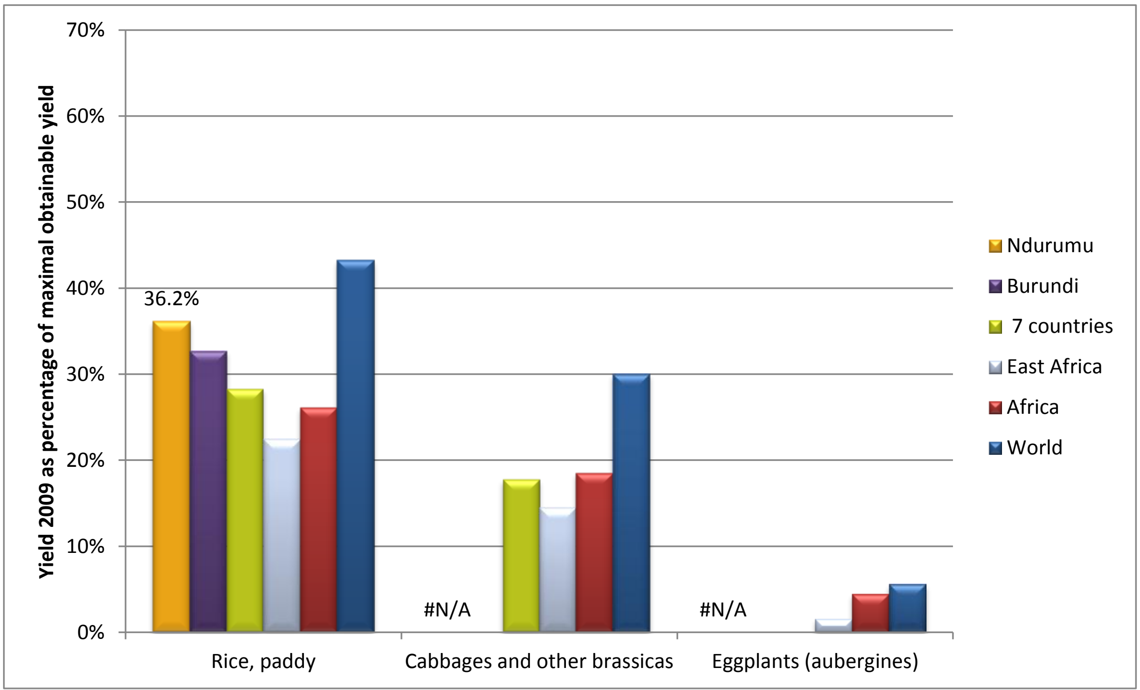


Figure 81: Yield gap Ndurumu (Source: FAOSTAT, 2012).

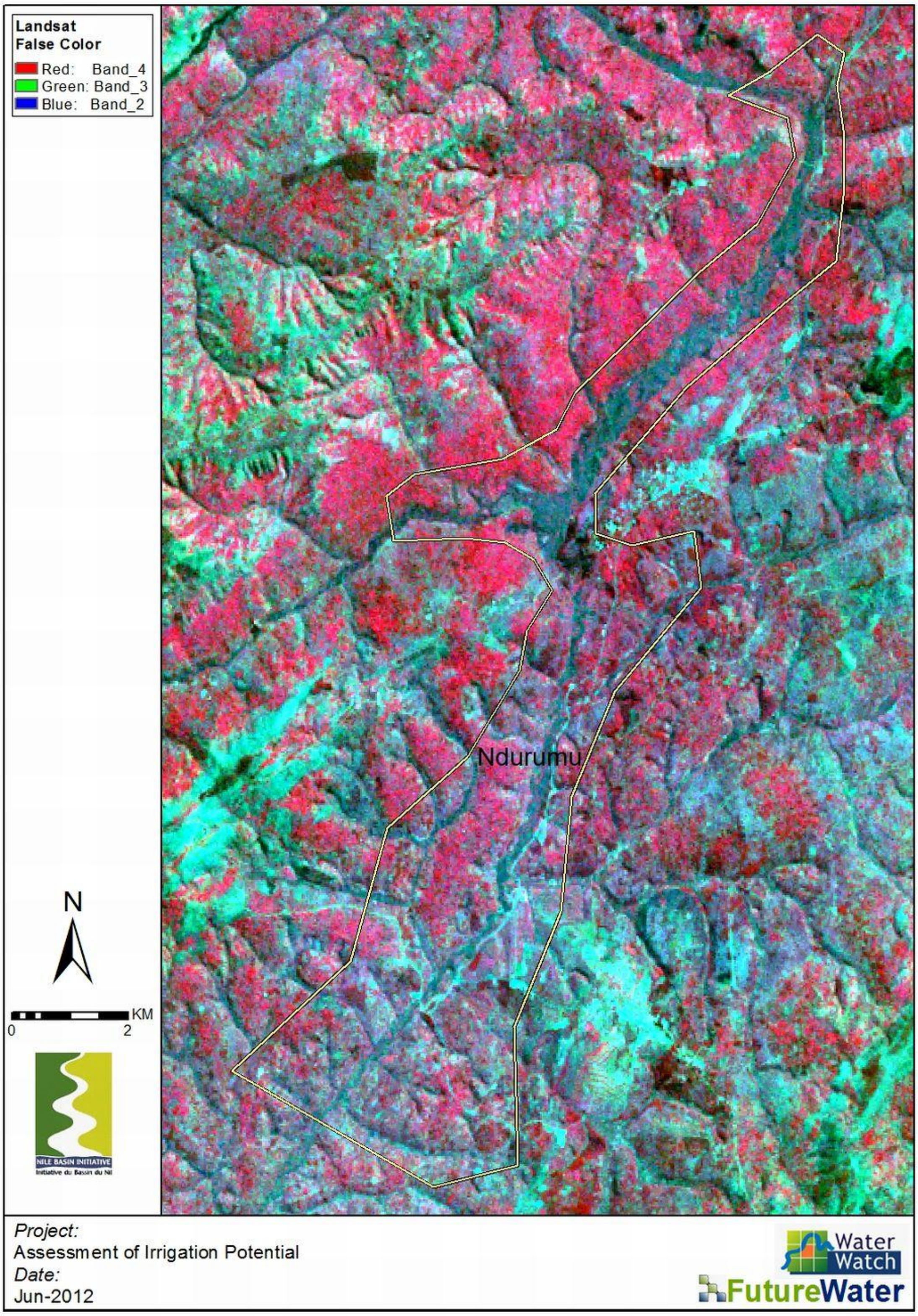


Figure 82: Landsat True Color (top) and False Color Composite (bottom) indicating current productivity of the area for NDURUMU focal area.

6.6 Environmental and socio-economic considerations

6.6.1 Population displacements

This focal area covers Ndurumu swamp and the hills on the sides. Within the swamp nobody lives, while on the slopes surrounding the swamp, houses are scattered around. These houses do limit the irrigation possibilities on the slopes. However, the valley should be irrigated first, and with the remaining water a certain area on the slopes can be irrigated. Preferably, the fields for pressurized irrigation are linked together. As the displacements of people will not have a positive impact on the people's involvement and contribution of the irrigation development, it is advised to look into this issue in more detail. The exact numbers of effected houses can only be known after designing the scheme, which is beyond the scope of this pre-feasibility study.

6.6.2 Social

The population density in Ndurumu focal area is quite low with 237 inhabitants per square kilometer (MININTER 2006). Regarding the population distribution by age, it becomes clear that people within Karusi province are extremely young, with approximately 64.9% of the population being younger than 25. The active labor force in Ndurumu area is therefore less than half of the total population. The amount of male and female workers is nearly equal, which could suggest social equity between male and female. However, if students of 15-25 years old are placed in the inactive category, the dependency rate of people depending on one working person reaches 2.24. Infrastructure is well to quite well developed, and the tarmac road from Gitega to Muyinga is passing by the area. This creates market opportunities and allows for an easy construction of an irrigation system.

6.6.3 Upstream downstream consideration

Since the upstream catchment is not enormously large, the water availability for irrigation should be considered well. Downstream of the focal area people should still have enough flow to practice agriculture and have water for living. Currently some erosion takes place on the slopes and in the marshes. It is important to minimize erosion in order to keep the soil fertile and to avoid downstream problems. At the moment some anti-erosion measures are in place, but whenever developing irrigation system, extra attention should be paid to keep the soil in place. In some places the slope can be minimized by terracing, which will enhance irrigation possibilities as well. Within the marshes flow regulation is the most important measure, which will decrease erosion and enhance irrigation possibilities.

6.6.4 Protected areas

There are no protected areas reported within the focal area.

6.7 Benefit-Cost Analysis

A simplified benefit-cost analysis is undertaken for the area. Information for this is based on various sources such as FAO publications, IFPRI publications, local expertise and data. A full benefit-costs analysis has to be undertaken in a sub-sequent feasibility study for the area.

Note that this is a first-order benefit-cost analysis. A feasibility study can provide a more rigorous benefit-cost analysis, which is required before taking any implementation planning. However, the following table shows that based on this first-order analysis, investments in irrigation can have a very positive impact.

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Rice: 4,000 kg/ha, 0.70 $/kg
    - Cabbage: 4,000 kg/ha, 0.07 $/kg
    - Aubergine: 3,000 kg/ha, 0.42 $/kg

Based on expert knowledge on the suitability to develop irrigation in the area scores between 1 (negative: low suitability or expensive) to 10 (positive: high suitability or low investments) have been marked. The filled radar plot below indicates the options for the focal area. Overall, the weak part of the site lies under farmers capacity, accessibility to roads markets and the initial investment cost. The score is contributed by the fact where roads entering to the very are rough un maintained roads which are very narrow and already eroded so much. This in-turn affects access to market as farmers cannot transport their yield easily and more importantly may not fetch golden prices. However, soil suitability and water availability is a great deal for the area that will foster an increase yields.

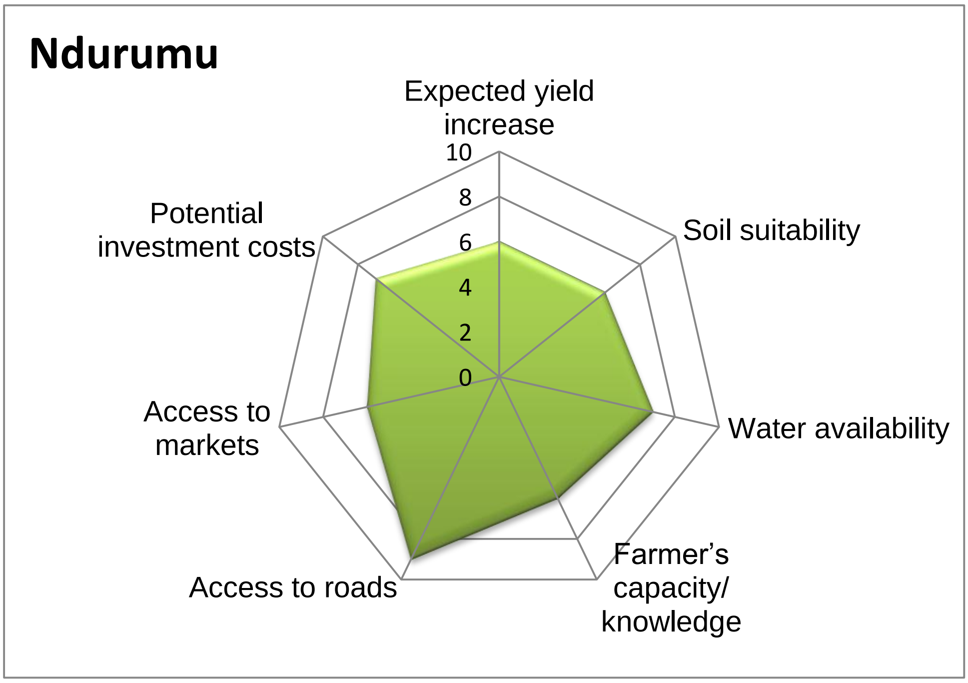


Figure 83: Filled radar plot indicating expert knowledge score to develop irrigation in the Ndurumu focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 13: Benefit-cost analysis for Ndurumu area.

Characteristics	
Irrigated land (ha)	4,000
Farmers	8,000
Investment Costs	
Irrigation infrastructure (US$/ha)	5,000
Social infrastructure (US$/farmer)	500
Accessibility infrastructure (million US$)	0.5
Operational Costs	
O&M irrigation (US$/ha/yr)	60
Extension service (US$/farmer)	10
O&M roads (US$/yr)	10,000
Summary	
Initial investments (million US$)	24.5
O&M costs (million US$/yr)	0.330
Net benefits per year (million US$/yr)	3.495
IRR (Internal Rate of Return)	14.2%

6.8 Recommendations

This pre-feasibility study describes the topics on a screening and scoping level. The available local data are included in the analysis and description, but final results give a first impression of the irrigation possibilities. Recommendations to be included in a detailed feasibility study are: i) possible design of the irrigation scheme ii) In depth analysis of possible reservoir sites iii) the implications of the legal framework and local law on irrigation development in the focal area iv) make an economic analysis per crop and irrigation system and v) a in depth cost benefit analysis, fully based on the local situation.

7 Moso focal area

7.1 Introduction

This chapter will describe the current state of Moso focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 85 a detailed map of the area is given. Total area is 12784 ha.

Selection of this specific focal area was based on results of Phase 1 of this study, while final selection was the responsibility of the relevant country representatives. Results presented hereafter have been obtained from a broad range of sources: Phase 1, previous other studies and reports, modeling results, remote sensing, expert knowledge and field visits by Christophe Majambere and Emmanuel Ndorimana as supervisor in March 2012.

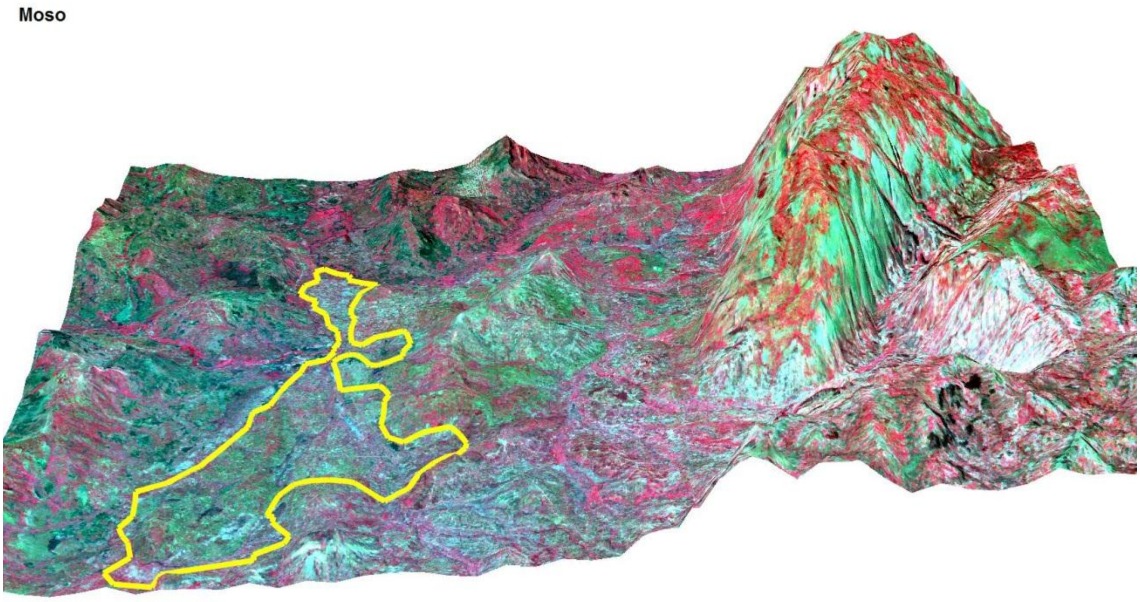


Figure 84: 3D impression of Moso focal area, Burundi

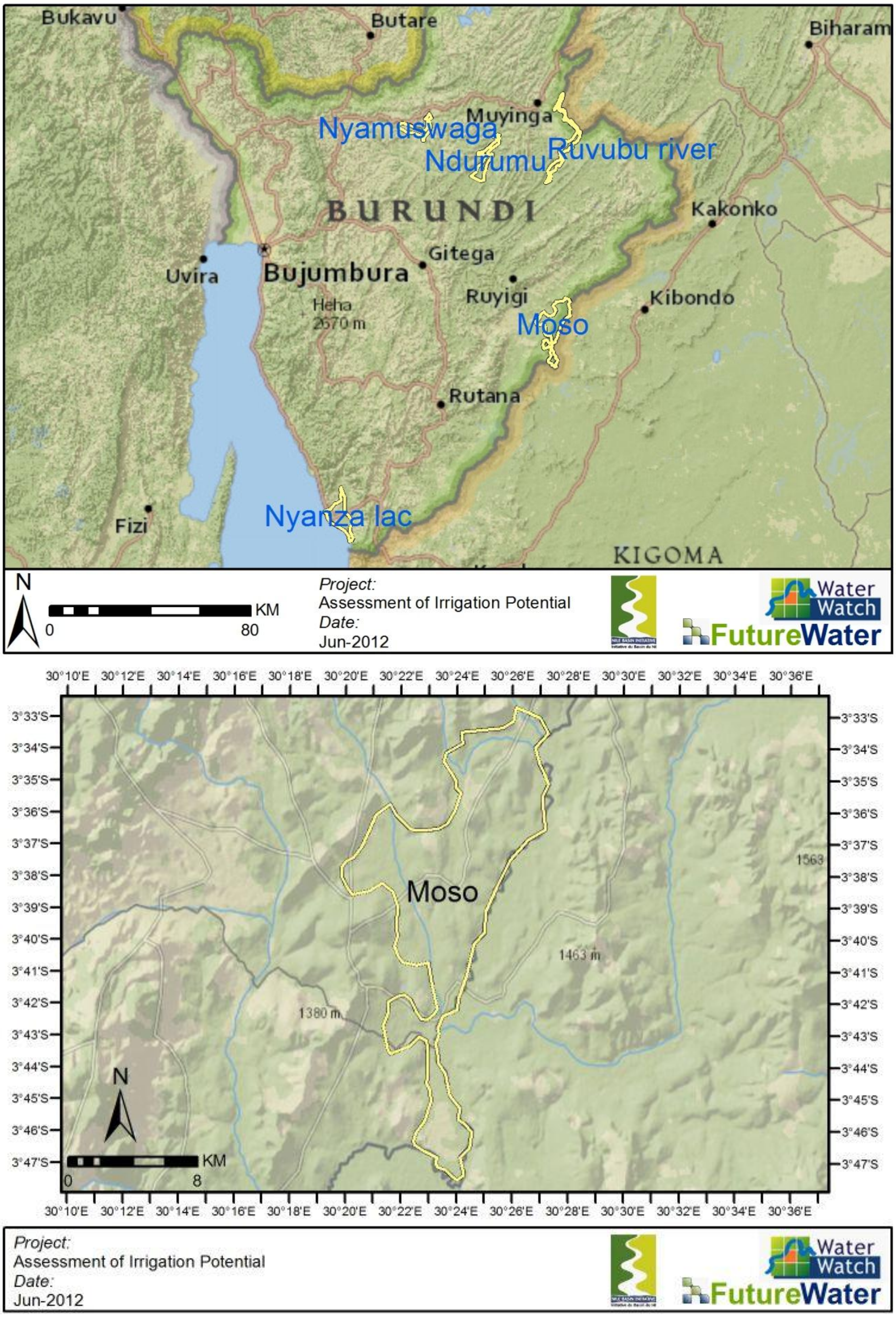


Figure 85: Moso focal area. Burundi

7.2 Land suitability assessment

7.2.1 Terrain

Moso focal area borders to Tanzania in the East. The area is partly situated in the Rutana province and the Ruyingi province. The focal area stretches along the Rumpungu River, which is the boundary between Burundi and Tanzania. Upstream the elevation of the valley bottom is around 1170 m and the valley descends towards the South towards 1140 m. The area includes the western banks of the Rumpungu River, and one branch coming from Buhonga village. The plains surrounding the river are nearly flat, and therefore very vulnerable for flooding. Hills on the North Western side go up towards a maximum of 1240 m (Figure 86). Slopes vary, but are limited in most of the area to 3%. The hills captured between the two branches of the river have some steeper slopes, but stay mostly under the 10% (Figure 84 + Figure 87).

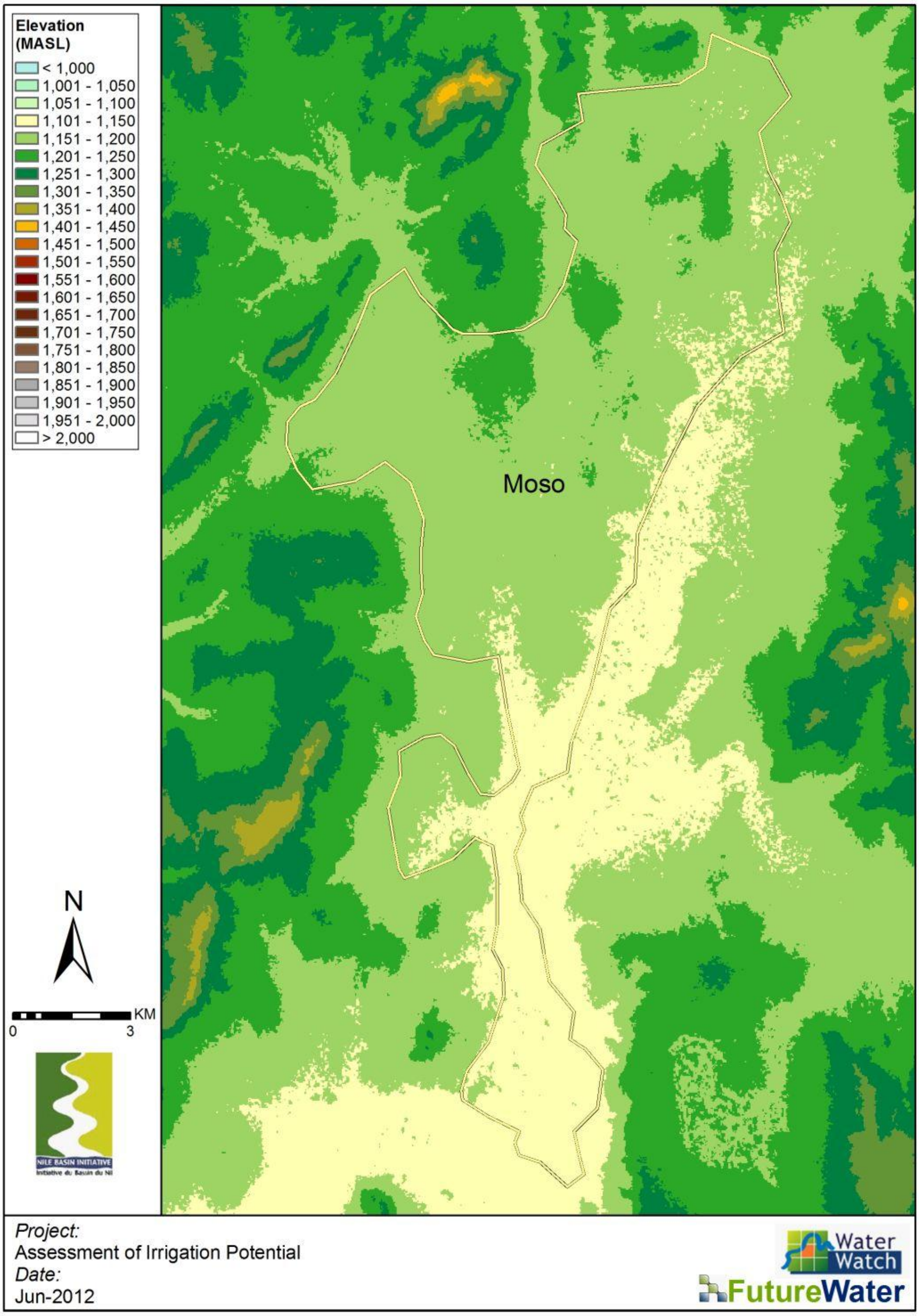


Figure 86: DEM Moso focal area. Resolution 1 arc second (+/- 30m).

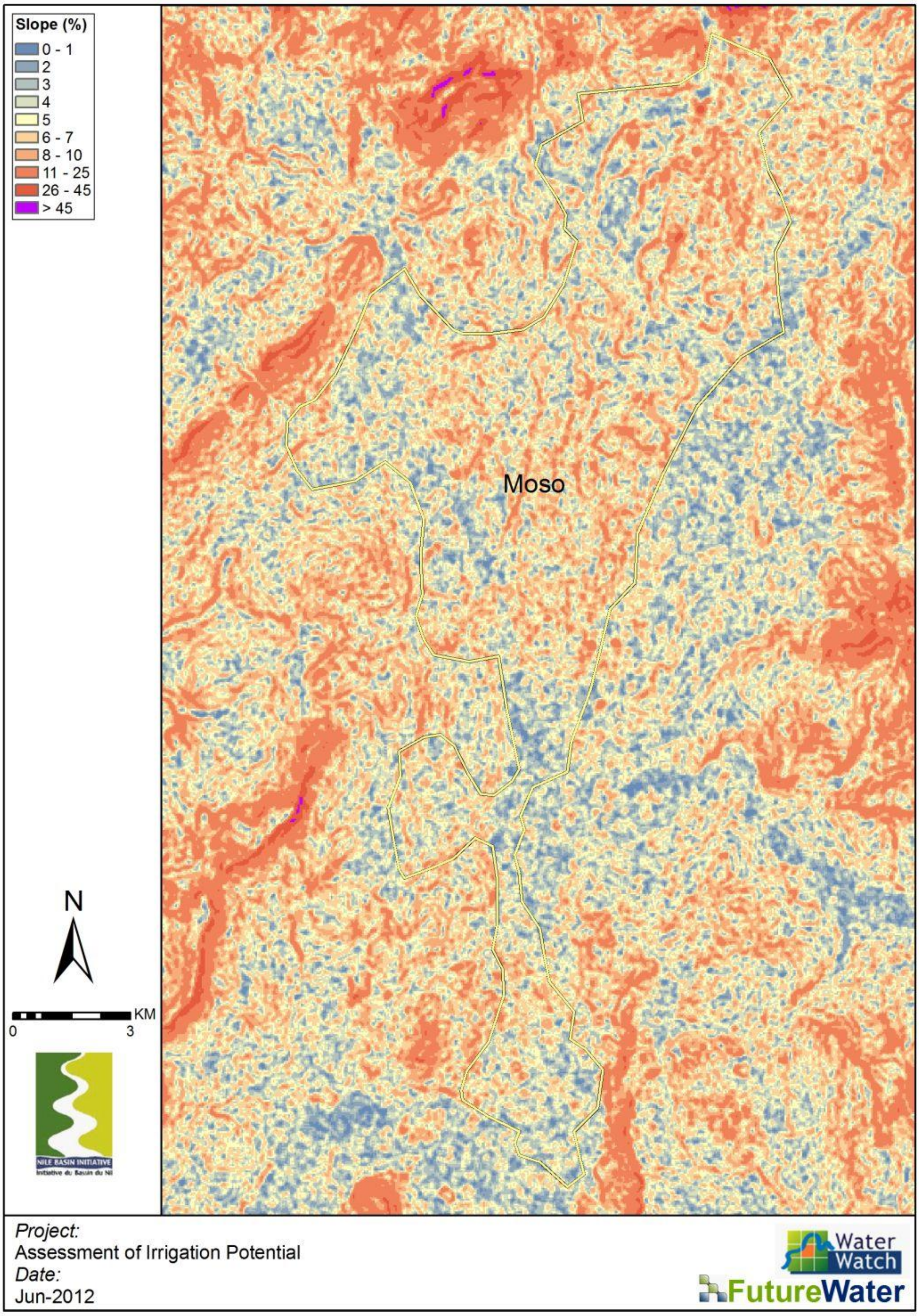


Figure 87: Slope map Moso focal area (source: ASTER).

7.2.2 Soil

Soils consist mainly of silty loam; build up from Schist-quartzite, sandstone and limestone. The steep slopes are generally much eroded, and have therefore a very thin soil. Soils in the valley are deep, and somewhat poorly drained. In the valley the percentage of organic material in the top soil is high, while on the slopes on the sides the organic material is limited to around 1%. Water storage capacity in the area is quite good with 125-150 mm/m. Soils tend to be very fertile.

7.2.3 Land productivity

Land productivity in Moso focal area is the lowest off all focal areas. NDVI values range from 0.45 in the mountains in the North, to 0.6 in the most Southern point and the North West (Figure 89). These low NDVI values can be explained by the sparsely vegetated hills and the high seasonal variation of land productivity. The coefficient-of-variation is very high, except directly along the river side. This indicates that agricultural activities depend very much on rainfall.

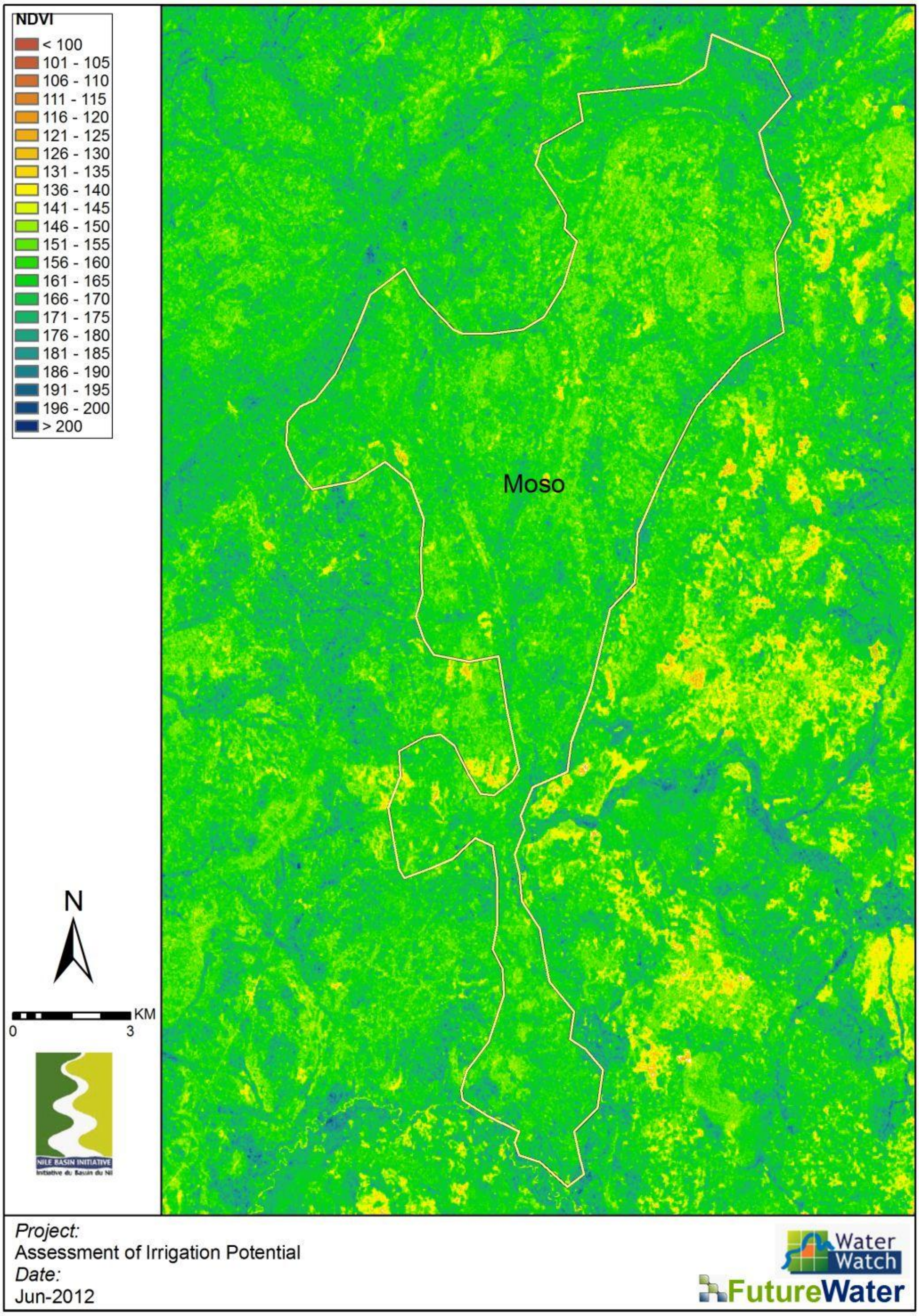


Figure 88: High resolution NDVI for MOSO focal area

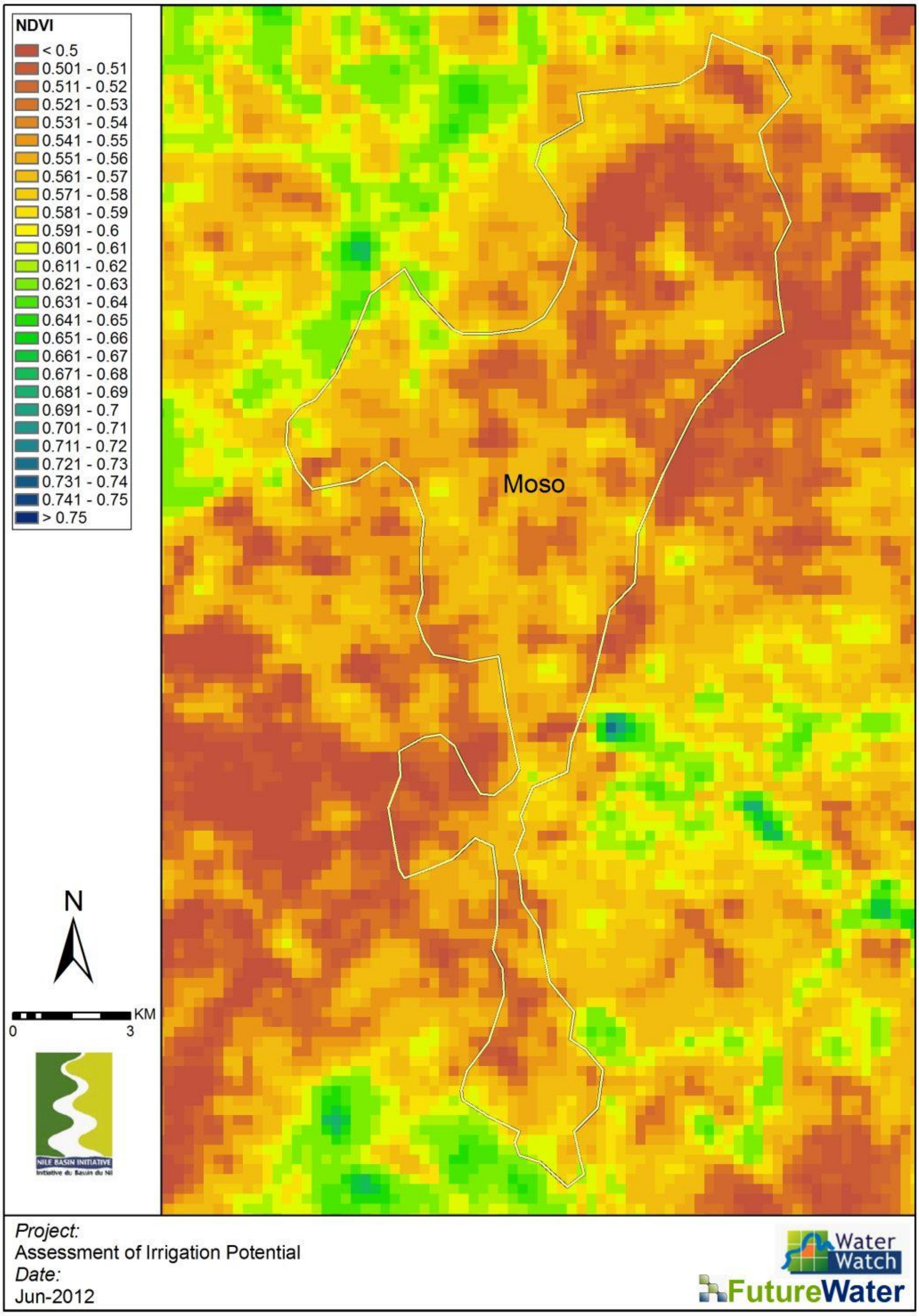


Figure 89: Yearly average NDVI values for MOSO focal area.

7.2.4 Potential cropping patterns

Currently, the Rumpungwe swamp is hardly cultivated due to high flood risks. On the slightly higher lands rice is grown once a year. On the western slopes a large variety of crops is grown; cassava, maize, sorghum, groundnuts and bananas. These lands depend on rainfall, and therefore crops are grown in one growing cycle per year. With irrigation, the swamp can be cultivated and prepared for rice growing. Subsequently, rice can grow on the valley bottom in at least two growing cycles per year. On the slopes maize and vegetables can be grown under irrigation. With irrigation the cropping intensity can increase to at least 200%.

7.3 Water resource assessment

7.3.1 Climate

Average climate conditions for the area are shown in the figure below. Precipitation is based on an advanced calibration/validation algorithm using satellite derived precipitation and calibrated using local observations. Details can be found in the Phase 1 Report. Reference evapo-transpiration (ETref) is calculated using the well-known Penman-Monteith approach. Input data for ETref is based on local observations and an advanced spatial downscaling algorithm.

The climate of the area can be characterized as warm with constant temperatures during the year ranging from about 17^{o}C to 28^{o}C, and lower minimum temperatures during June, July, and August, and higher maximum temperatures during August, September, and October. Annual average precipitation is 1176 mm and reference evapotranspiration 1379 mm per year.

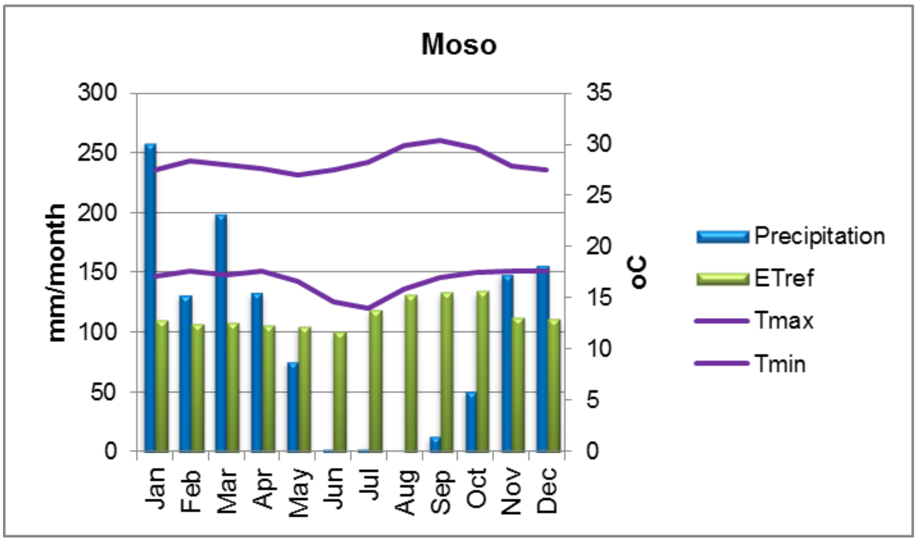


Figure 90: Average climate conditions for MOSO focal area.

7.3.2 Water balance

A very detailed high resolution model was built for NEL countries (NELmod). For a detailed description see Phase 1 report. Results from NELmod were extracted for this specific focal area and are shown below.

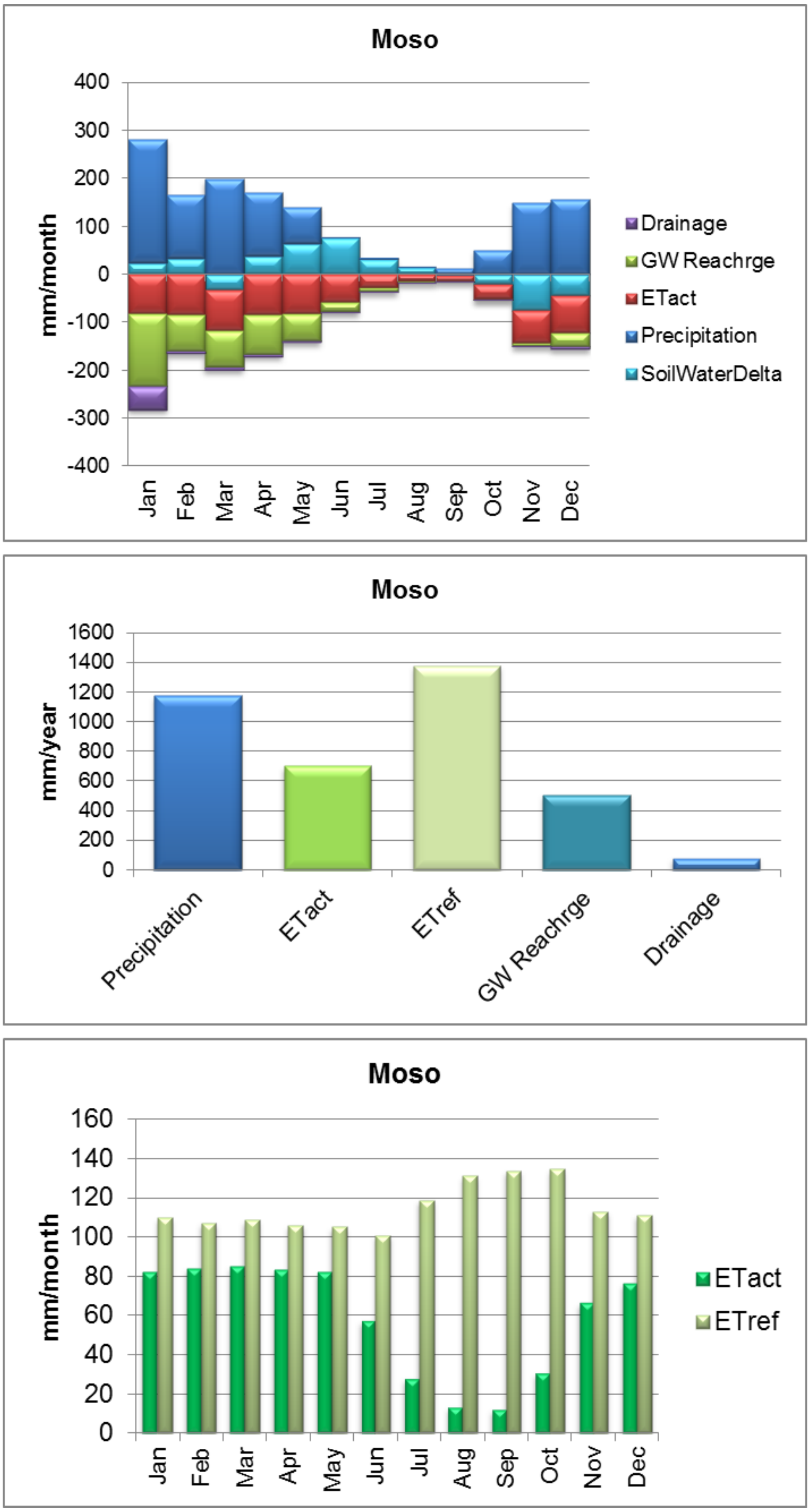
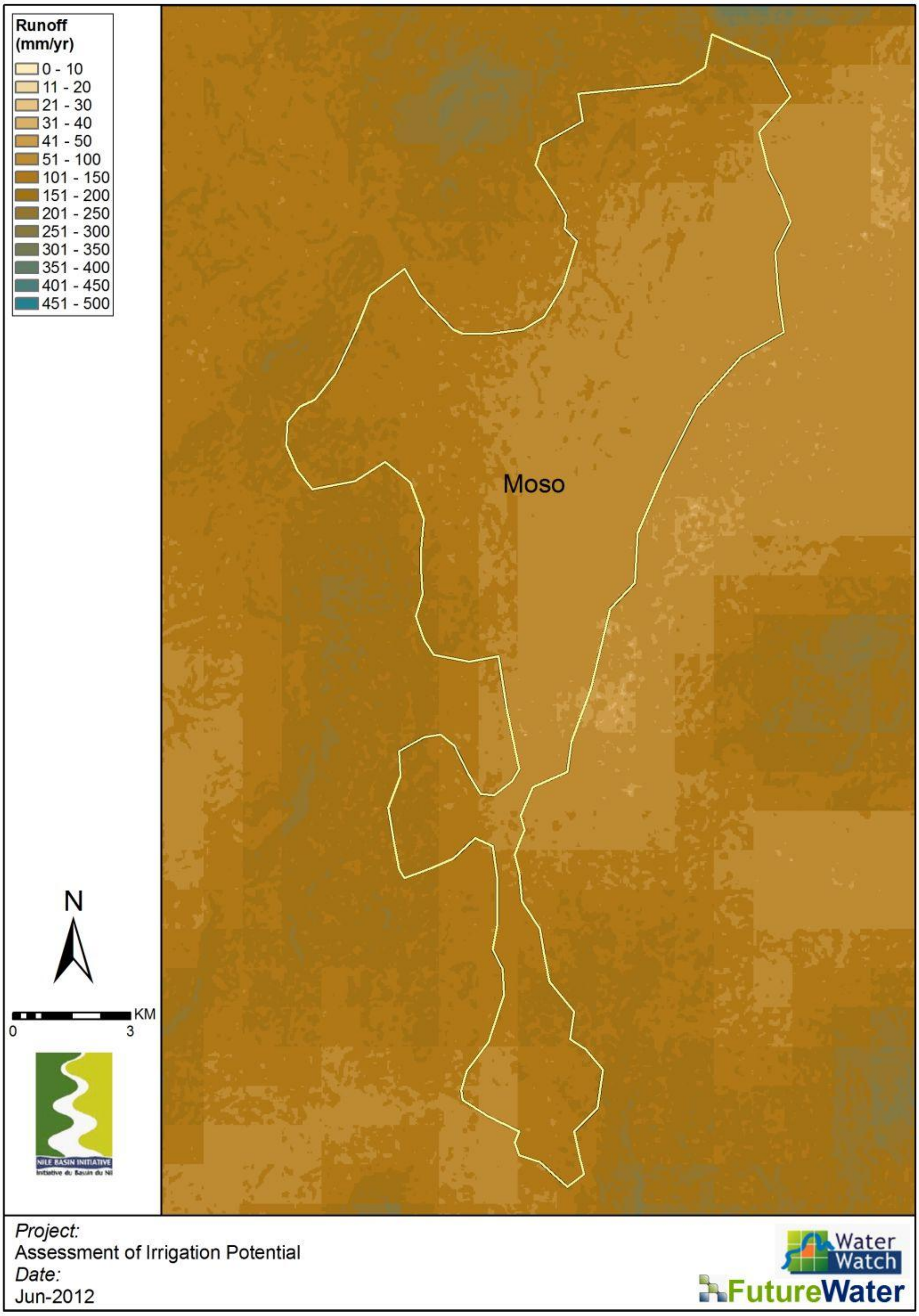


Figure 91: Water balances for the area based on the high resolution data and modeling approach for MOSO focal area.


Runoff (mm/yr)
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
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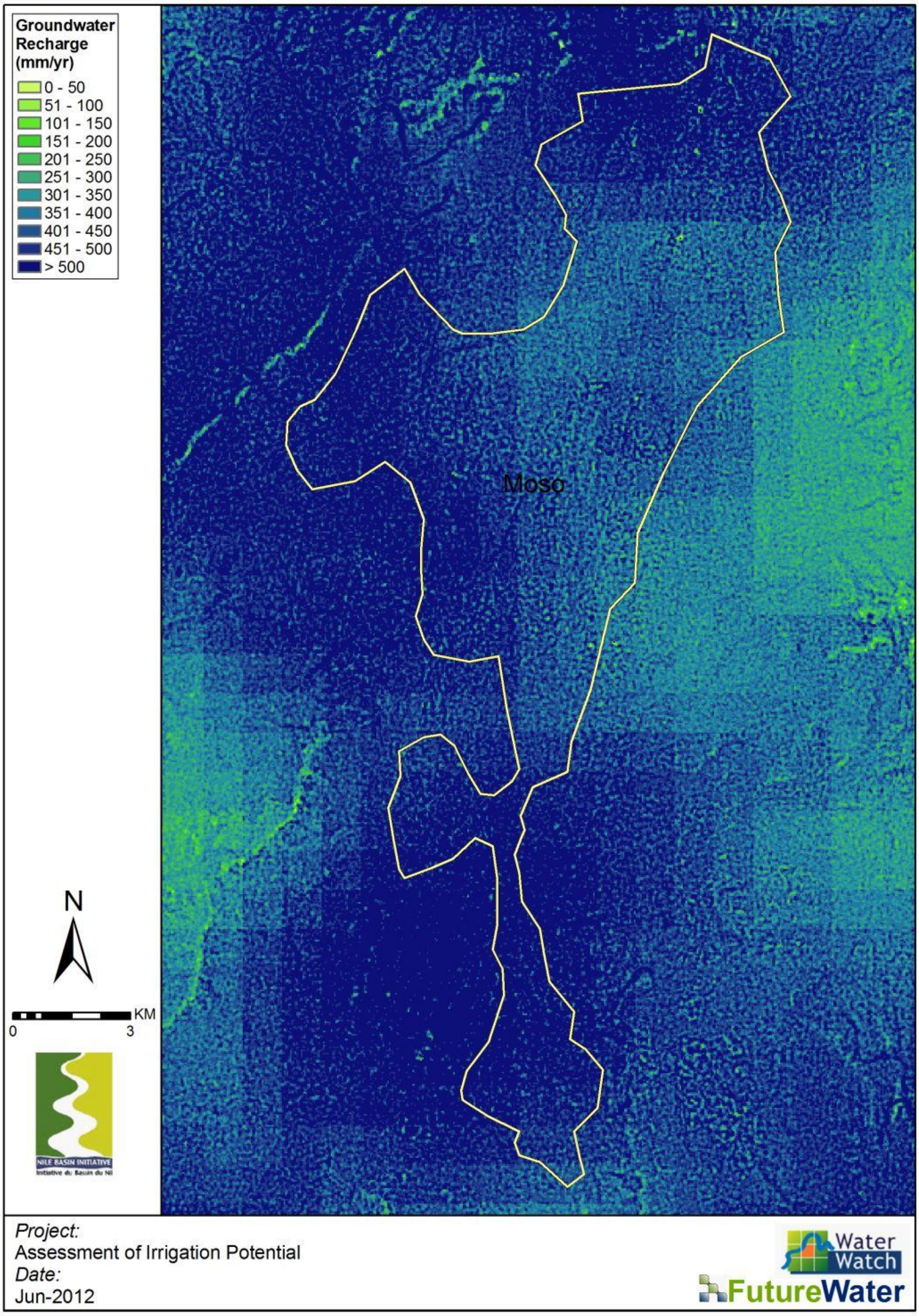
Jun-2012
Water Watch
FutureWater


Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
> 500
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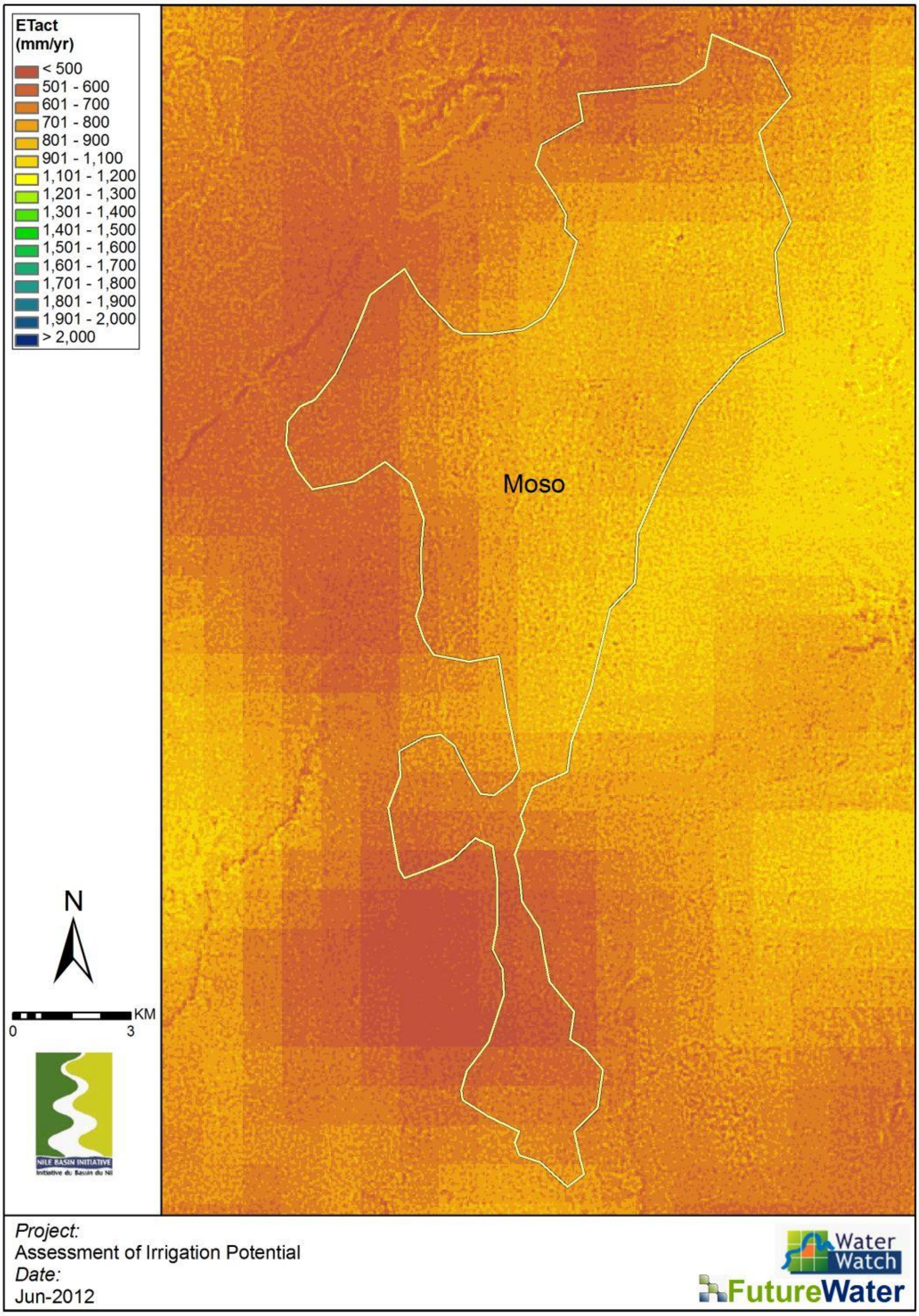


Figure 92: Water balances for the area based on the high resolution data and modeling approach for MOSO focal area.

7.4 Assessment of irrigation water requirements

7.4.1 Irrigation water requirements

Irrigation water requirements depend on many factors such as: climatic conditions, crop, growing season, irrigation practices etc. A first estimate of irrigation requirements could be based on the difference between rainfall and reference evapotranspiration. It was however selected for this pre-feasibility assessment to provide a first estimate of irrigation needs based on the most promising crops. To this end, FAO's AquaCrop, the successor of CropWat was setup for local and crop specific conditions.

In the table below the irrigation water requirements for each selected crop are provided based on AquaCrop calculations. All units are provided in mm per growing season for the specific crops. Note that for various crops, like vegetables and similar crops, multiple croppings per years might occur.

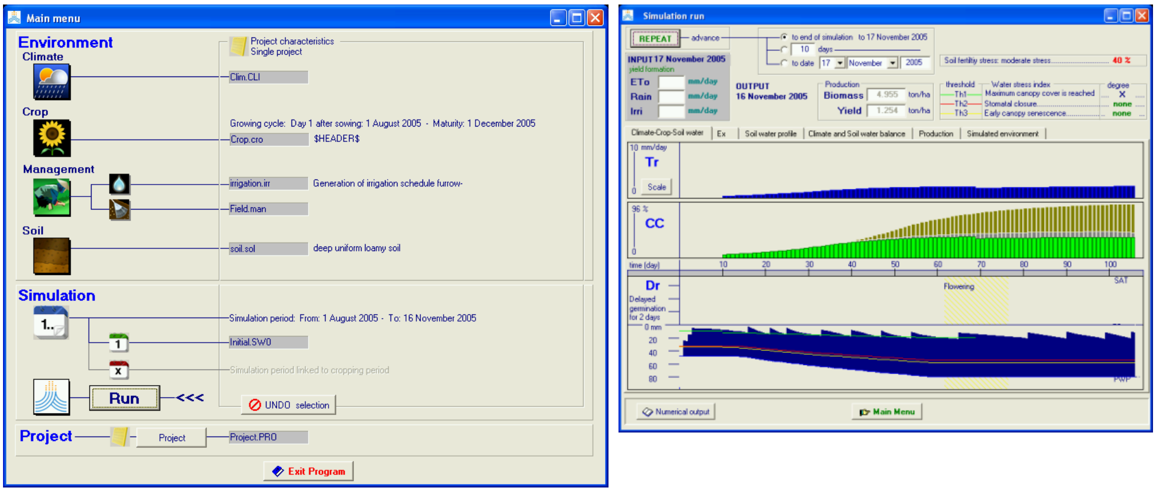


Figure 93: Typical example of AquaCrop input and output screens.

Table 14: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season.

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year	===	== (day of year) ==		======== growing season	=======		
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Rice	1176	1379	1	136	773	80	483	443
Vegetables	1176	1379	1	365	1179	80	1376	500

7.4.2 Irrigation systems and irrigations efficiencies

With a partly regulated river flow the high risk on flooding in the area will be reduced, and land can be prepared for border irrigation. Within the valley the land is rather flat, which increases the flood risks. According to the field visits the yield are lost in 30% of the cases due to excessive flooding of the land. The water application efficiencies for border irrigation are low, but since water is available abundantly that will not be a problem. The western foothills can be irrigated with pressurized irrigation systems such as drip or sprinkler irrigation. Those irrigation techniques have a high application efficiency, which is enhancing low operation and pumping costs. Knowledge for pressurized irrigation is not yet common, so it is advised to develop it slowly, with high farmer's involvement. Any irrigation development within the Rumpungwe valley is only possible when the flow is regulated. This requires a large investment, and large structures. Since this is a trans-boundary river, involvement from Tanzania is essential.

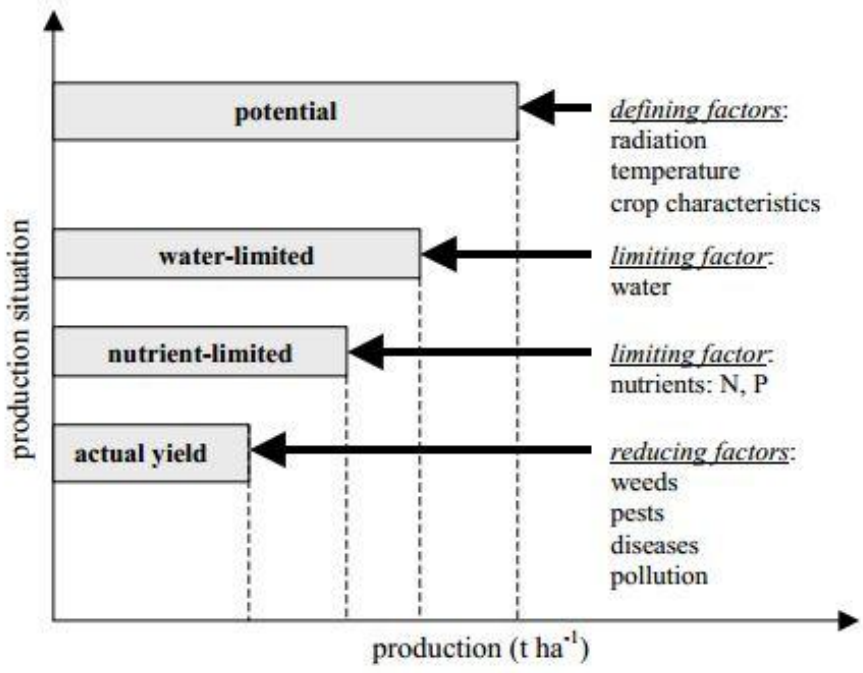
7.4.3 Water source

The water for irrigation will come from Rumpungwe River. The catchment upstream of the focal area covers an approximate 1000 km^2 and therefore accumulates a large discharge. The average discharge over the year is 13 m^3/s in the North, and increases to 105 m^3/s in the South. The Western branch of the river flowing through the area increases from 2 m^3/s in the North, to 3.5 m^3/s at the point joining the Rumpungwe River.

7.5 Potential crop yield assessment

The yield gap describes the difference between the current yield, and the maximum possible yield. Mostly the maximum possible yield is defined as the highest yield in the world, but it can also be assessed against a regional background which makes the yield gap more realistic and the maximum yield possible to achieve under the given circumstances.

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximum possible yield is not reached can be the water availability, the soil and the available nutrients, or yield reducing factors like diseases, weeds or pollution.



7.5.1 Yield gap analysis potential dominant crops

Yields in Burundi are among the highest in the NELSAP countries. The topography, population density increase and the increasing demand for food have been drivers for agricultural intensification. However, irrigation is not practiced much, and fertilizer is hardly used. In Figure 94 the yield gap is shown relatively to Burundian average yields, NELSAP average yields, East African yields, African yields and world's average yields. Everything is scaled to percentage of the highest yields obtained somewhere in the world. Although the large diversity of crops grown in the region, the average yields within the Moso focal area are just below Burundian average. Probably this can be blamed to the irregular yields within the valley, in which flooding is a major problem for stable high yields. However, compared to African standards, the yields in the Moso focal area for both rice and vegetables are above average. Yields within the focal area are expected to increase above the world's average when irrigated. Rice can at least double in yield towards 60% of the highest obtainable, and vegetables are expected to double and increase towards 25% of the highest obtainable in the world.

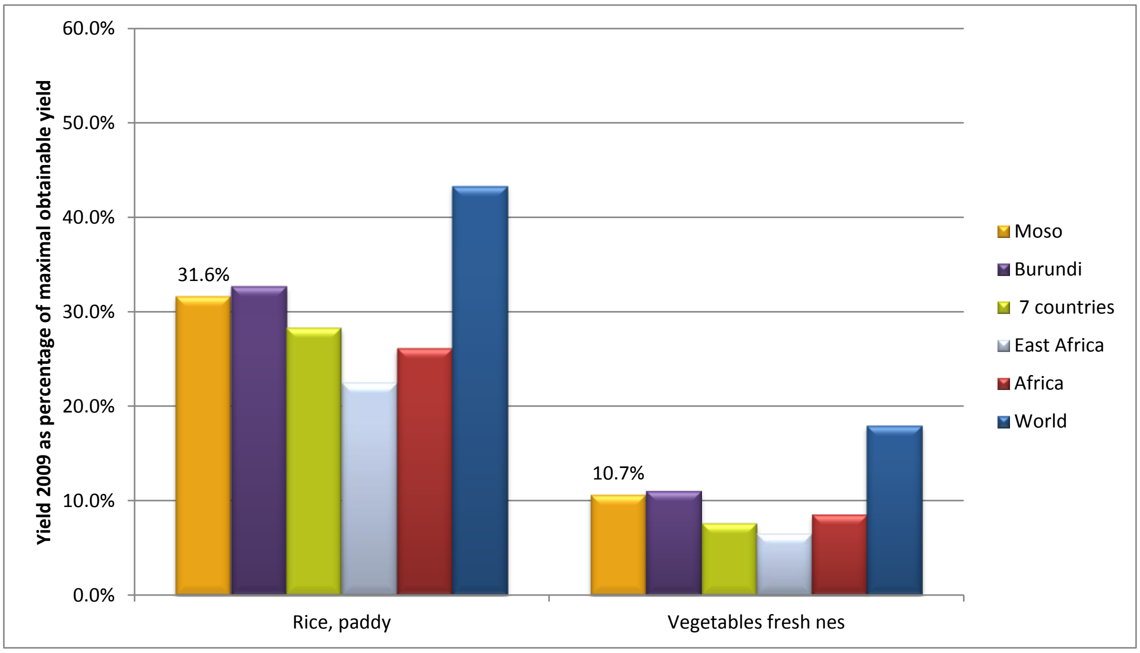


Figure 94: Yield gap Moso (Source: FAOSTAT, 2012).

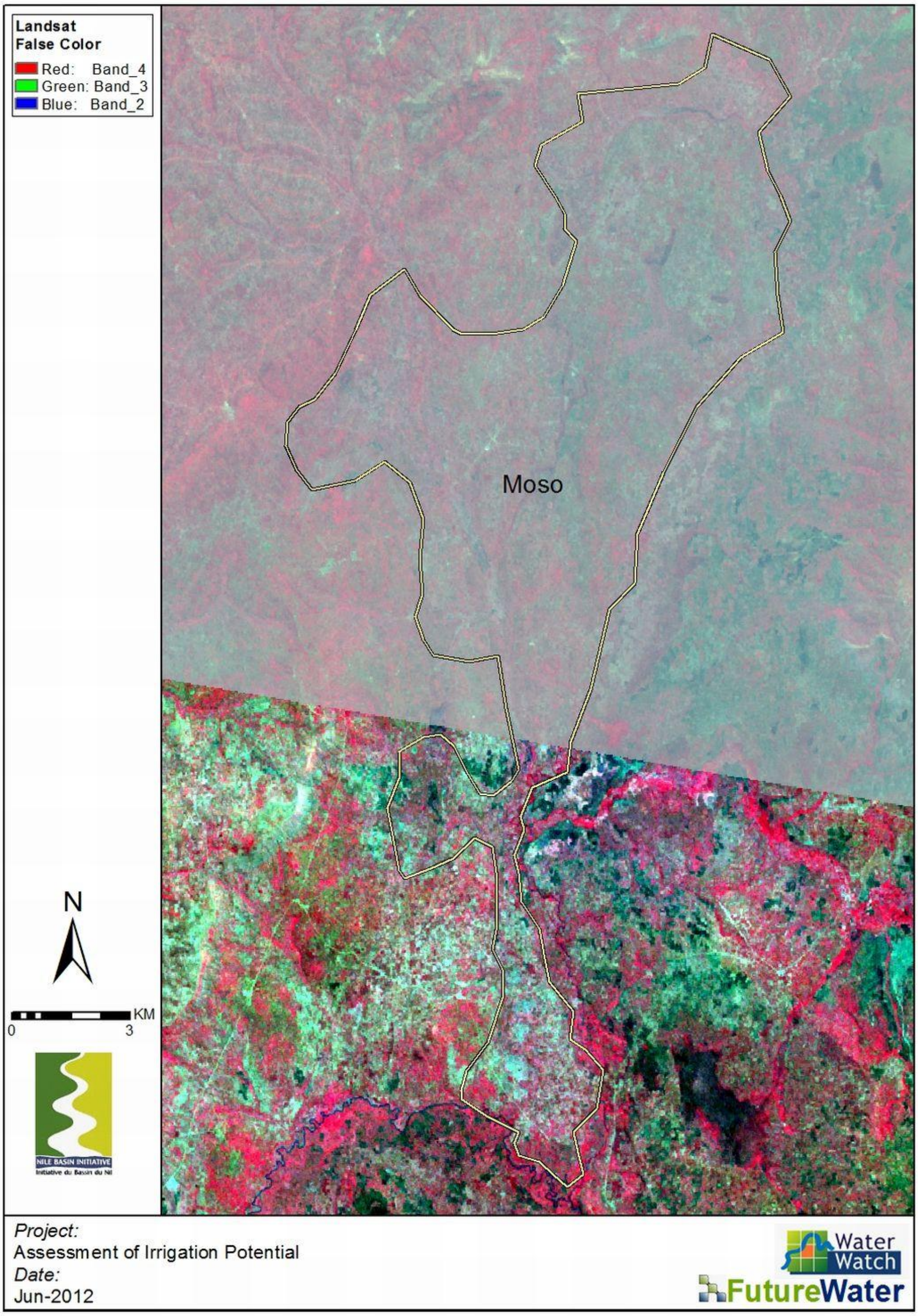


Figure 95: Landsat False Color Composite (bottom) indicating current productivity of the area for MOSO focal area.

7.6 Environmental and socio-economic considerations

7.6.1 Population displacements

This focal area covers the Western shores of Rumpungwe River and one of the tributaries. Within both valleys there are no settlements. Some houses are built on the slopes going up from the valleys. These houses are rather scattered, but since their number is small, it should be possible to work around when designing an irrigation system. With the design of any irrigation scheme, it is advised to limit any population displacement; as the displacements of people will not have a positive impact on the people's involvement and contribution to the irrigation development. The exact numbers of effected houses can only be known after designing the scheme which is beyond the scope of this pre-feasibility study.

7.6.2 Social

Most of the area is in Kinyinya commune, which has an average population density of 153 inhabitants per square kilometer (MININTER 2006). This is far under the Burundian average. Seen the population distribution by age, it becomes clear that people within Cankuzo-Ruyigi province are extremely young, with approximately 65% of the population being under the age of 25. The active labor force in Moso area is therefore less than half of the total population. The amount of male and female workers is nearly equal, which could suggest social equity between male and female. However, if students from 15-25 years old are placed in the inactive category, the dependency rate of people depending on one working person reaches 2.2. Infrastructure in the area is poorly developed. A tarmac road is crossing through Kinyinya, but the areas towards the river can only be reached by dirt roads, which are not always good accessible. Farmers have low knowledge in irrigation and farmer's cooperation's.

7.6.3 Upstream downstream consideration

The water for irrigation is directly coming from Rumpungwe River, which is a trans-boundary river at the border between Burundi and Tanzania. This is a major issue to consider before irrigation can be developed. Whenever creating flow regulating structures in the river upstream, erosion should be considered and the possible sedimentation at the dam side. Currently, some erosion takes place on the slopes and in the marshes. It is important to minimize erosion in order to keep the soil fertile and to avoid downstream problems. At the moment some anti-erosion measures are in place, but whenever developing irrigation systems, extra attention should be paid to keep the soil in place. In some places the slope can be minimized by terracing, which will enhance irrigation possibilities as well. Within the marshes flow regulation is the most important measure, which will decrease erosion and enhance irrigation possibilities.

7.6.4 Protected areas

Within the focal area no protected areas are reported.

7.7 Benefit-Cost Analysis

A simplified benefit-cost analysis is undertaken for the area. Information for this is based on various sources such as FAO publications, IFPRI publications, local expertise and data. A full benefit-costs analysis has to be undertaken in a sub-sequent feasibility study for the area.

Note that this is a first-order benefit-cost analysis. A feasibility study can provide a more rigorous benefit-cost analysis, which is required before taking any implementation planning. However, the following table shows that based on this first-order analysis, investments in irrigation can have a very positive impact.

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
  - Rice: 4,000 kg/ha, 0.85 $/kg
  - Vegetables: 8,250 kg/ha, 0.56 $/kg

Based on expert knowledge on the suitability to develop irrigation in the area scores between 1 (negative: low suitability or expensive) to 10 (positive: high suitability or low investments) have been marked. The filled radar plot below indicates the options for the focal area. Overall, the weak part of the site lies under farmers' capacity, accessibility to roads markets and the initial investment cost. This in-turn affects access to market as farmers cannot transport their yield easily and more importantly may not fetch golden prices. However, soil suitability and water availability is a great deal for the area that will foster an increase yields.

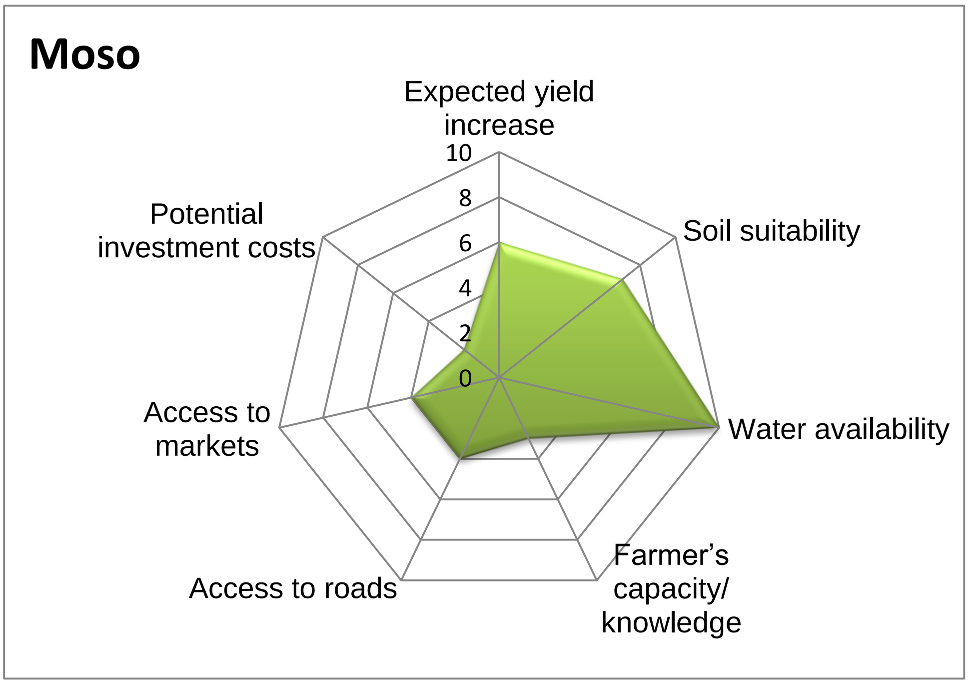


Figure 96: Filled radar plot indicating expert knowledge score to develop irrigation in the Moso focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 15: Benefit-cost analysis for Moso area.

Characteristics	
Irrigated land (ha)	7,000
Farmers	11,667
Investment Costs	
Irrigation infrastructure (US$/ha)	8,000
Social infrastructure (US$/farmer)	500
Accessibility infrastructure (million US$)	2.0
Operational Costs	
O&M irrigation (US$/ha/yr)	60
Extension service (US$/farmer)	10
O&M roads (US$/yr)	40,000
Summary	
Initial investments (million US$)	63.8
O&M costs (million US$/yr)	0.577
Net benefits per year (million US$/yr)	16.871
IRR (Internal Rate of Return)	34.2%

7.8 Recommendations

This pre-feasibility study describes the topics on a screening and scoping level. The available local data are included in the analysis and description, but final results give a first impression of the irrigation possibilities. Recommendations to be included in a detailed feasibility study are: i) possible design of the irrigation scheme ii) In depth analysis of possible reservoir sites iii) the implications of the legal framework and local law on irrigation development in the focal area iv) make an economic analysis per crop and irrigation system and v) a in depth cost benefit analysis, fully based on the local situation.