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

Final Report
Appendix Uganda

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Client
Nile Basin Initiative
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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: Fredrick Ssozi, Richard Cong, Michael Iwadra, amongst others. Their contribution is highly appreciated.

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1 Introduction

1.1 Background[1]

Uganda (Figure 1) is located in East Africa and occupies an area of 236,040 km^2, of which 15.4% consists of water. Based on the 2009 population estimate, a total of 32.4 million people live in Uganda. Uganda shares its borders in the east with Kenya, in the north with Sudan, in the west with the Democratic Republic of Congo, in the southwest with Rwanda, and in the south with Tanzania. A detailed map of the country is presented in Figure 1. The southern part of the country includes a substantial portion of Lake Victoria. Uganda lies almost completely within the Nile basin. The Victoria Nile drains from the lake into Lake Kyoga, and thence into Lake Albert on the Congolese border. From there it runs northwards into Sudan. One small area on the eastern edge of Uganda is drained by the Turkwel River, part of the internal drainage basin of Lake Turkana.

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

1.1.1 Socio-economy

Agriculture is arguably the most important sector of the Ugandan economy. It contributes up to nearly 20% of the GDP, accounts for 48% of exports (UBOS, 2008), and provides a large proportion of the raw materials for industry. Food processing alone accounts for 40% of total manufacturing. The sector employs 73% of the population aged 10 years and older (UBOS, 2005). Agriculture will be the key determinant in the country's efforts to reduce poverty in the immediate years ahead.

[1] Information in this chapter is among other sources based on: FAOSTAT, CIA world fact book, UNDP, phase 1 report. Ntamavukiro, 2007 and Niyongabo, 2007.

1.1.2 Millennium Development Goals, current status[1]

With the expiration of the Poverty Eradication Action Plan (PEAP), which had guided national development policy and public expenditure since 1997, the Government of Uganda has developed a comprehensive National Development Plan (NDP) covering 2010/11-2014/15. The Plan is the first of six five-year installments that seek to drive progress towards the long-term national vision, which sees Uganda transform from a largely peasant society to a modern and prosperous country over a 30-year period. The first NDP carries the theme of *'Growth, Employment and Socio-Economic Transformation for Prosperity'*, and proposes an ambitious range of initiatives that seek to boost household incomes and the availability of jobs, significantly expand the stock and quality of the country's physical infrastructure (roads, railways, power supply), increase access to public services and enhance human capital development, strengthen governance and the rule of law, and promote sustainable population and the use of the country's natural resources.

Uganda is making progress on many of the MDG's. With just over 30% of the goals, Uganda is on track to achieve them within the right time. Over 40% is proceeding slowly, and will not be reached in time without putting additional effort in it. The economic crisis, however, and the uncertainty about foreign aid are constraints which may slow down the rate of development in the coming years.

A quick overview will be given about the current status (2010 data) of the MDGs.

Goal 1: Eradicate Extreme Poverty and Hunger

Uganda is making good progress in reducing poverty. In 1990, 56% of the population lived under the poverty line of US$1 per day. In 2006 this was already reduced to 31%, and the government has set the target for 2015 to 25%, which would exceed the targets of the MDG's. The prevalence of underweighted children under five year is also on track, with a decrease of 10% compared to 26% in 1990.

Goal 2: Achieve universal primary education

Progress has been made with the introduction of the Universal Primary Education (UPE) in 1997. Enrollment rates tripled from the introduction until 2008. Nowadays, the net enrollment rate is 96% for boys, and 90% for girls. There is still a long way to go to reach the 100%. Besides that the dropout rate is high, the percentage of pupils finishing primary education is increasing slowly till 52% in 2009.

Goal 3: Promote gender equality and empower women

Good improvement can be seen. The ratio of boy to girls on primary schools is nearly 1:1. On secondary and tertiary education, however, the ratio decreases to 0.84 and 0.79 respectively. The amount of female seats in the parliament increased from 18% in 2000 to 30% in 2009. The amount of woman employed in the non-agricultural sector has decreased towards 28% between 2003 and 2006.

Goal 4: Reduce child mortality

The under-five year mortality rate has been reduced with 12% and the infant mortality rate with 6% between 1995 and 2005. When compared to the 67% reduction target by 2015, the only conclusion can be that the progress is slow.

Goal 5: Improve maternal health

[1] This section is based on the 2010 MDG status report.

The Maternal mortality ratio per 100,000 births is improving. It dropped from 506 in 1995 to 505 in 2000/2001, and further to 435 in 2005/2006. Despite the progress there is still a way to go to reach the 2015 target of 131/100,000. The proportion of births attended by skilled health personnel increased from 38% in 1995 to 42% in 2005/2006. Target 5.B, to achieve universal access to reproductive health by 2015, is progressing slowly.

Goal 6: Combat HIV/AIDS, malaria and other diseases
Uganda had a clear HIV infection peak in the 1990s, and thereafter infection rates dropped significantly. However, the data since the late 1990s show a concerning, upward trend in the number of new infections. It is estimated that more than 130,000 people have been infected with HIV so far in 2010. Based on this, the overall assessment is that, while Uganda may have been well under way to reverse or halt the spread of HIV, the situation today is deteriorating. The overall assessment of progress towards Target 6.A is therefore: reversal. The percentage of the population with access to adequate treatment of HIV increased from 44% in 2008 to 54% in 2009. Goal 6C, to halt and start to reverse the incidence of Malaria and other major diseases, is moving slowly.

Goal 7: Ensure environmental sustainability
The amount of people that have access to an improved drink water source, improved to 68% in 2005, and is getting close of the aimed 89%. However, the MDG has pushed the development of rural drinking water forward, from 51% (1999/2000) to 64% (2005/2006), while the percentage of urban people that have access to save drinking water remained constant at 87% within the same period. The proportion of the urban population living in slums decreased from 34% to 27% between 2002 and 2008. The integration of environmental issues into a sustainable development of the country is moving very slowly, and reversing on some points.

Goal 8: Develop a global partnership for development
This goal is especially measurable for the developed countries. Currently, the Overseas Development Aid (ODA) is at US$ 39 per capita, and this is expected to decrease to US$ 35 in 2015. This is comparable to 3.7% of the GDP.

1.1.3 Poverty reduction strategy

The information in this section is based on the ‘Poverty Reduction Strategy Paper’, published in May 2010, which looks back to results gained, and forward towards 2014/2015. This paper is mainly based on the results from the Uganda National Development plan (NDP), which contributes to the achievement of the MDGs as well. The NDP aims to transform Uganda from a peasant country towards a modern and prosperous country within 30 years.

From the independence in 1962 to 1971, GDP grew on average with 5.2% per year. Between 1971 and 1979 the GDP declined by 25%, due to the political situation and economic mismanagement. The decline in monetary growth, together with the growth in agriculture and food crop production, decreased the inflation from 200% in 1987 to approximately 7.1% in 1996. From that point onwards the GDP has grown with 7.3% on average. This GDP growth has contributed to a significant reduction in poverty levels.

Uganda’s trade deficit has been widening despite improvements in the composition and value of exports. The trade deficit, as a percentage of GDP, increased from an annual average of 12.9% for the period 2000/01 to 2003/04, to 13.5% for the period 2004/05 to 2007/08.

The share of agriculture in the GDP declined from 51.1% in 1988 towards 33.1% (1997), and declining further to15.4% in 2008. The forestry sector increased from 1.7% in 1988 to 3.4% in

2008. Manufacturing grew from 5.9% in 1988 to 7.2% in 2008, with a peak in 2002. Over the same period, tourism grew from 1.1% to 4%. Mining grew from 0.1% to 0.3% and ICT grew from 0.2% towards 3.8% in 2008. Construction is a large sector, growing from 4.1% in 1988 to 11.9%.

The population in Uganda is extremely young with nearly half of the population being under the age of 15. This means that the population is expected to increase rapidly. Already, Uganda has one of the highest dependency ratios in the world (above 1.5), which is expected to rise under the current growth trends.

Uganda was ranked 112th out of 183 in the "doing business survey 2010", with the main constraints for doing business being access to finance, infrastructure and corruption.

The approach for development is described within the NDP as follows: "A quasi-market approach, which includes a mix of government investments in strategic areas, and private sector market driven actions, will be pursued. The private sector will remain the engine of growth and development, while the Government, in addition to undertaking the facilitating role through the provision of a conducive policy, regulatory and institutional framework, will also actively promote and encourage public-private partnerships in a rational manner. Furthermore, the Government will continue to pursue outward-oriented policies by encouraging foreign investments and exports with high value addition, as well as pursuing sound macroeconomic policy and management."

1.1.4 Legal framework

The Government of Uganda created through the National Environment Management Policy (1994), the Water Statute 9/1995 and the National Water Policy (1999) a policy framework for the water sector. The policies have strategies to enhance property rights, to promote environmentally sound land use, to enhance water resources conservation and management; to improve wetland management, and to apply environmental economics and incentives. The statute established the National Environment Management Authority, which in consultation with the leading agencies is mandate to issue guidelines and prescribe measures and standards for the management and conservation of natural resources and the environment. The Water Statute 9/1995 has the objective to allow for the orderly development and use of the water resources for domestic, agricultural and industrial purposes in a manner that minimizes harmful effects to the environment. Domestic use included irrigation of subsistence gardens not exceeding 0.5 ha. Extraction of water from surface or ground water is prohibited unless authorized. The National Water Policy proclaimed the formation of a central authority, being the ministry responsible for water, whose role is to initiate national policies, to coordination between the line ministries, overseeing compliance and to provide technical support services. The policy aims to enhance the role of the private/voluntary sectors through the formulation of policy committees on environment & water at national and local level. These committees aim for active involvement of local authorities, private sector and NGOs in the development & management water supply & irrigation systems. Uganda has developed a framework for water resources management consisting of national legislations and by-laws for promoting sound water resources management and constrains potentially harmful practices. Water Resources Regulations, Water Supply Regulations and Waste Water Discharge regulations are all in place.

1.1.5 *Socio-economic context and institutional setting*

This section describes the socio-economic context and institutional setting for small scale irrigation development in Uganda. 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:

- Uganda retains a largely rural population (87%)
- Poverty levels are lowest among Nile Basin Countries within study (24.5% below national poverty line)
- On main social services: health expenditures (USD 43/ capita), population with access to improved source of drinking water (67%), electric power consumption (66 KWh per capita) and female illiteracy (37.9%) Uganda scores better than other countries in the same socio-economic bracket
- Agriculture is the main provider of jobs in Uganda (75%)
- In economic value Uganda is a net exporter of agricultural products (import to export is 0.73). The total value of agricultural exports is considerable (USD 878 M)
- With respect to food Uganda is a net importer (value of food imports USD 549 M)

Agricultural services

- Agricultural road density is low (13.6 km/1000 sq. km arable land) – affecting agricultural marketing
- Fertilizer use is at a minimum (3.4 kg/ ha)
- The use of mechanical equipment is minimal (9.04 tractors per 1000 sq km of arable land)

Irrigation and water use

- Irrigated land is only a small fraction of the arable land (0.13%)
- Total water abstraction is a small percentage of renewable resources (0.50%), the dependency ratio of renewable water sources is however quite high (40.91%)
- No data are available on groundwater usage
- Overall Irrigation Performance is high as compared with Nile Basin countries (3.45 on scale of 5) – agricultural water productivity is even highest of all (1/8) but crop consumption use is low (8/8)

Institutions

- *The institutional framework for irrigation and water development is stronger if compared to other studied countries. Main polices for irrigation and water resource development Water Sector Reform Strategies and Investment Plans includes (I) Rural Water and Sanitation Development, (II) Urban Water and Sewage, (III) Water for Production and (IV) Water Resources Management. Further policies include National Water policy (1999), Water Act (2000), Water Resources Regulation (1998), Constitution (1995)*
- Ministry of Water and Environment is the lead agency responsible for development, regulation and overall management of Uganda's water for production; as far as irrigation is concerned. However, its role is limited to the off-farm functions like assessment of water resources availability, design/construction off-farm infrastructure, operation and maintenance of hydraulic works, water infrastructures and reservoirs. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), responsible for on-farm works, including technical assistance design/construction on-farm irrigation schemes, as well as establish management structures for these and provide assistance in operation and management, for example through extension services.

UGANDA - INSTITUTIONAL	

Main guiding policies, act and ordinances (Meghani, M. et al. 2007)	• *Draft Final Irrigation Master Plan (2010-2035) published June 2011; aims to increase total irrigated area from 67,764 ha (2010-2013) till 355,668 ha (2024-2035) (GoU, 2011, pp. 4) It is mentioned that small scale irrigation schemes are not known at present, the Master Plan however aims at 483 ha small scale schemes in 2018, 1,202 ha (2023) and even 14,000 hectares in 2035.*
	• *The National Development Plan, provides a wider context for the Irrigation Master Plan. This Plan incorporates the Water Sector Reform Strategies and Investment Plans including (I) Rural Water and Sanitation Development, (II) Urban Water and Sewage, (III) Water for Production and (IV) Water Resources Management*
	    o *Water for Production Strategy and Investment Plan, targets surface water for water security, groundwater is mentioned for livestock watering, not as source for irrigation and also not promoted in the strategy. It is however mentioned that due to climate change impact on rain fed agriculture, relocation of water sources for small and medium scale irrigation need to be revised (Tindimugaya, C. 2010, pp. 31). In addition food security is prominent on the political agenda, especially in combination with high population growth*
	    o *Water Resources Management Strategy and Investment Plan, describes water demands and availability till 2015 (Ibid.)*
	    o *Rural Towns Water and Sanitation Program, includes planning for groundwater supply to sixty urban centres (Ibid.)*
	• *National Water policy (1999), Water Act (2000), Water Resources Regulation (1998), Water Action Plan 1995, Constitution (1995)*

Institutional mandate irrigation development	• *Ministry of Water and Environment is the lead agency responsible for development, regulation and overall management of Uganda's water for production; as far as irrigation is concerned however, its role is limited to the off-farm functions like assessment of water resources availability, design/construction off-farm infrastructure, operation and maintenance of hydraulic works, water infrastructures and reservoirs (GoU, 2011, pp. 20)*
	    o *Directorate of Water Resources Management*
	    o *Directorate of Water Development*
	• *Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), responsible for on-farm works, including technical assistance design/construction on-farm irrigation schemes, as well as establish management structures for these and provide assistance in operation and management, for example through extension services (GoU, 2011, pp. 20 and 21)*

Water Permit System – Drillers	• *Drilling permits, according to the Water Act (Cap. 152) and The Water Resources Regulation 1998, have to be obtained at the Directorate of Water Development.* • *36 driller companies have official licenses for drilling (DWRM, 2010, pp. 2 and 3). Stiff competition among them causing relocation to neighbouring countries, and*

	also induces high costs and often shoddy work (Meghani, M. et al. 2007)
Water Permit System – Users	• *Any use of surface water, including irrigation requires a permit, to be issued by the Directorate of Water Development. Application form is a 12 page specification list on the nature and objectives of the water withdrawal.* • *Users in rural areas of Uganda make a contribution towards maintenance of a groundwater sources and do not pay for groundwater as such. Users in urban areas supplied by piped water pay for groundwater (Meghani, M. et al. 2007)* • *In 2010 366 users had official license for water abstraction (DWRM, 2010)*
Other institutions involved in irrigation development (FAO, 2004)	• *International: World Vision, CARE, Oxfam, Catholic Relief Services (CRS) (especially groundwater development for drinking water), FAO (irrigation), African Development Bank, EU (agricultural projects)* • *Bilateral: JICA (feasibility study irrigation sites Namayala, Wairangala rivers); Arab Bank for Economic Development in Africa (finances Ministry of Water, Livestock and Environment); Denmark, Sweden and Belgium (Supporting Agri-Business Programme)*
Local organizations	• *Over 150 NGOs involved in groundwater development in Uganda, and these are coordinated under the Uganda Water and Sanitation NGO Network (UWASNET). These are mainly local NGOs. Limited knowledge of groundwater potential and catchment protection often leads to yield reduction and pollution of groundwater (Meghani, M. et al. 2007)* • *There are numerous NGO's active in the agricultural sector, many of them are church based and at very local level*
Private sector	• *Currently private sector irrigation involves production of flowers and horticultural crops (GoU, 2011, pp. 18)* • *Government aims at further inclusion of private sector in construction of commercial irrigation schemes (GoU, 2011, pp. 70)* • *The Agri-Business programme of the government, initiated in 2010, should guide private sector inclusion.*

Support to small scale irrigation development (vocational sector, land planning) (Infosysplus)	• *There are about sixty institutions related to agricultural research.*
	  ○ *Universities: Arapai College of Agriculture (Soroti), Bukalasa Agricultural College (Wobulenzi), Faculty of Agriculture at Univerity of Makerere (Kampala), Guru University of Agriculture an Environmental Science (Kampala), Uganda Martyrs University (Kampala)*
	  ○ *Institutes: e.g. Agricultural Engineering and Appropriate Technology Research Institute (Kampala), Association for Strengthening Agricultural Research in eastern and central Africa (ASARECA)(Entebbe), CIAT, Kwanada Agricultural Research Institute (Kampala)*

Land tenure (Place and Otsuka, 2002, pp. 106)	*There exist three types of land tenure systems in Uganda: mailo, customary and public land. "Some of the key land issues are the gulf between de jure state ownership of land (since 1975) and people's perceptions and actions; the issuance of leases to well connected individuals to public land occupied or used by earlier settler communities; perceived lack of tenure security for individual households under some customary systems; and the long standing problem of overlapping and competing rights of owners and long-term tenants on 'mailo land'"*
Government Effectiveness (percentile rank 0-100) (Worldbank, 2009)	*33.8*
Rule of Law (-2.5 – 2.5, in which high values represent effective enforcement of law (World Bank, 2009)	*-0.43*

SOCIO-ECONOMIC	
Food exports, FAO (current US$M) (FAO Statistical Yearbook 2010)	198.44
Food imports, FAO (current US$M) (FAO Statistical Yearbook 2010)	548.60
Imports/exports	2,77
Health expenditure per capita (World Bank, current US$, 2009)	43
Improved water source (% of population with access) (World Bank,	67
Improved water source, rural (% with access) (World Bank, 2008)	64
Improved water source, urban (% with access) (World Bank, 2008)	91
Poverty (% below national poverty line) (UNSTAT, 2009)	24.5
Illiteracy rate –Male (15+) (UNSTAT, 2006)	18.6
Illiteracy rate --Female (15+) (Ibid.)	37.9
Primary completion rate, total (% of relevant age group) (UNICEF,	54.4
Road density (road km/100 sq. km of land area) (IRF, 2008)	29
Road to arable land density (road km/1000 sq. km arable land) (IRF,	13.61
Roads, paved (% of total roads) (FAOSTAT, 2008)	23
Electric power consumption (kWh per capita) (CIA, 2005)	66
Country area (km2) (FAOSTAT, 2009)	241,550
Land area (km2) (FAOSTAT, 2009)	199,810
Population, Projected/Estimated (FAOSTAT, 2010)	33,425,000
Urban population (% of total population) (FAOSTAT, 2010)	13
Rural population (% of total population) (FAOSTAT, 2010)	87
Population density (pp/km^2) (World Bank, 2010)	170
AGRICULTURAL	
Agricultural exports (US$M) (FAOSTAT, 2008)	878.07
Agricultural Import (Current US$M) (FAOSTAT, 2008)	643.26
Import/export	0,73
Value added in agriculture, growth (%) (World Bank, 2010)	0
Value added, agriculture (% of GDP) (AQUASTAT, 2009)	24.68
Employment agriculture (% of population) (UBOS, 2007)	70
Agricultual machinery (tractors /100 square km arable) (World bank,	9.04
Agriculture value added per worker (Constant 2000 US$) (WB, 2009)	203
Fertilizer consumption (kg per hectare of arable land) (WB, 2008)	3.4
Cereal cropland (% of land area) (of which irrigated, %) (WB, 2009)	9
Agricultural area (FAO Resource Stat, 2009)	13,962,000
Arable land (FAO Resource Stat, 2009)	6,600,000

IRRIGATED AGRICULTURE	
Irrigated land (% of crop land) (Aquastat, 2002)	0.13
Irrigated land entire country (ha) Bastiaansen and Perry, 2009 and AQUASTAT, 1998)	9,000 – 30,017
Actually irrigated (ha) (GoU, 2011)	14,418[3]
Irrigation potential (entire country) (Bastiaansen and Perry, 2009; AQUASTAT, 2007 and GoU, 2011, pp. 43)	90,000-566,466
Irrigated Land Nile basin (ha) (potential) (Bastiaansen and Perry, 2009 and GoU, 2011, pp. 50)	25,131-550,000
Irrigation schemes in Nile Basin	See irrigation schemes below
Small schemes (<50ha) (national level) (ha) (GoU, 2011)	300
Medium schemes (50-500ha) (national level) (ha) (GoU, 2011)	190[4]
Large schemes (500ha<) (national level)(ha) (GoU, 2011)	13,928[5]
Potential schemes (Nile Basin) (Tindimugaya, C. 2010) (1982)	Bordering Nile
Water Sources (Tindimugaya, C. 2010)	Rainfed, surface water, no groundwater use
Water Sources - Names	River Rwizi catchemnt, Lake Victoria, Kyoga, Albert, George, Edward; Wamala Kafu river and Katonga River
Irrigated area per household (ha) (national level)	n.a.
SUSTAINABLE WATER ABSTRACTION RATES (AQUASTAT, 2000)	
Renewable resources (km3/year)	66
Overlap	29
Surface water	66
Ground water	29
Dependency ratio	40.91

[3] 50,000 ha non equipped informal irrigation for rice cultivation on wetland fringes in Eastern Unganda (Tindimugaya, C. 2010)

[4] Comprising Agoro (130ha) and Kige (60ha) irrigation scheme (GoU, 2011, pp. 19)

[5] Comprising Government Irrigation Schemes Mubuku (516ha), Doho Rice scheme (830ha), Olweny Swamp Irrigation Scheme (500 ha) and Commercial plantations: full irrigation (5,282 ha) and partial irrigation (Kakira)(6,800ha) (GoU, 2011, pp. 19)

ACTUAL WATER ABSTRACTION RATES	
Groundwater (km3/year)	n.a.
Surface (km3/year)	n.a.
Total water withdrawal (km3/year) (AQUASTAT, 2002)	0.3296
% of renewable water resources (calculated)	0.50
Water abstraction points	
Deep Motorized boreholes (Potential) (Tindimugaya, C. 2010)	20,000 (60,000)
Motorized boreholes	n.a.
Manual boreholes	n.a.
Protected shallow wells (Tindimugaya, C. 2010)	3,000 (23,000)
Windmill borehole	n.a.
Springs (Tindimugaya, C. 2010)	12,000
Water networks	n.a.

IRRIGATION PERFORMANCE (Bastiaansen and Perry, 2009)	
Overall Irrigation performance Large Scale Irrigation (0-5)	3.45
Result Oriented Performance	3.42
Sustainability Oriented Performance	3.06
Process Oriented Performance	3.75
Detailed Irrigation Performance Parameters	
Water Productivity (Performance 0-5) (Rank within Nile Basin 1-8)	2.9 (7)
Agricultural water Productivity	3.9 (1)
Crop consumptive use	1.8 (8)
Beneficial Water Use	3.6 (3)
Adequacy	4.1 (1)
Uniformity	4.3 (5)
Reliability	5.0 (1)
Sustainability	3.1 (7)
AGROPHYSICAL (Bastiaansen and Perry, 2009)	
Irrigated crops (ha)	Maize (5,000), sugarcane (4,000)
Cereal yield rainfed (kg/ha) (Nett yield)	1,539
Biomass production (satellites) (kg/ha) (Nett yield)	16,298
Cereal yield irrigated (kg/ha) (Nett yield)	7,064
Yield Increment	5,525
Net Increment	1,667

2 Countrywide irrigation potential

2.1 Terrain and soil

2.1.1 Relief, climate, and hydrography

Uganda is located on the East African plateau, and it averages about 1,100 MASL. The country slopes very steadily downwards to the Sudanese Plain to the north. The southern part of the country, however, is poorly drained. The center of Uganda is dominated by Lake Kyoga, which is surrounded by marshy areas.

Although generally equatorial, the climate is not uniform as the altitude modifies the climate. The southern part of Uganda is wetter with rain generally spread throughout the year. At Entebbe on the northern shore of Lake Victoria, most rain falls from March to June and during November-December. Further to the north a dry season gradually emerges. At Gulu, which is about 120 km from the Sudanese border, November-February is much drier than the rest of the year. The northeastern Karamoja region has the driest climate and is prone to droughts in some years. Rwenzori in the southwest on the border with DRC receives heavy rain all year round. Lake Victoria influences large parts of the south of the country.

Temperatures in Uganda show little variation throughout the year, with maxima ranging between 25-31°C for most areas. The rainfall distribution has generally been categorized as:

- High: over 1700 mm per annum – 4% of the land area
- Moderate: 1000-1750 mm per annum – 70% of the land area
- Low: under 1000 mm per annum – 26% of the land area

Rainfall distribution in southern Uganda is bimodal, allowing two crops annually, and adequate grazing for livestock throughout the year. Around Lake Victoria the annual rainfall averages 1200-1500 mm, and is well distributed. To the north, the two rainy seasons gradually merge into one. Dry periods at the end of the year become longer, with annual rainfall ranging between 900-1300 mm, this restricts the range of crops that can be grown. These conditions are not suitable for bananas, but favor extensive livestock production. The influence of soils, topography and climate on the farming systems in Uganda has led to the dividing of the country into seven broad agro-ecological zones. These zones are:

- The banana-coffee system
- The banana-millet-cotton system
- The montane system
- The teso system
- The northern system
- The West Nile system
- The pastoral system

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. 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.

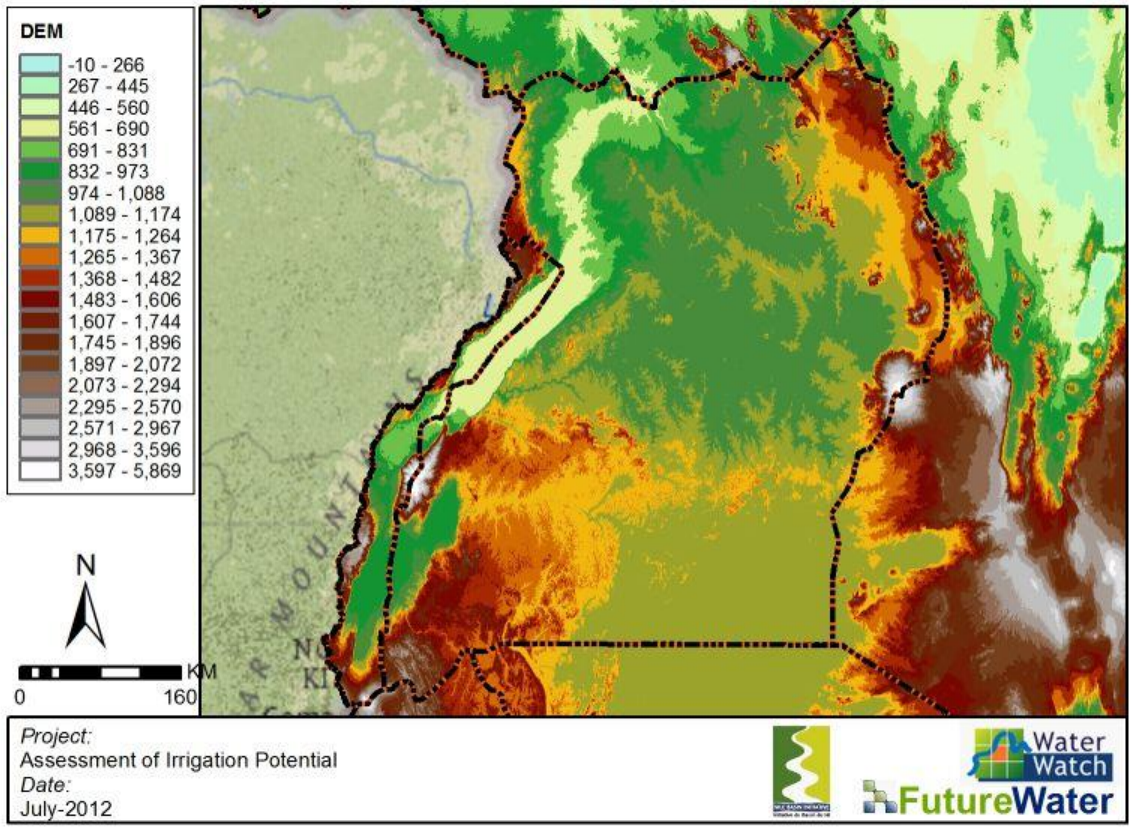
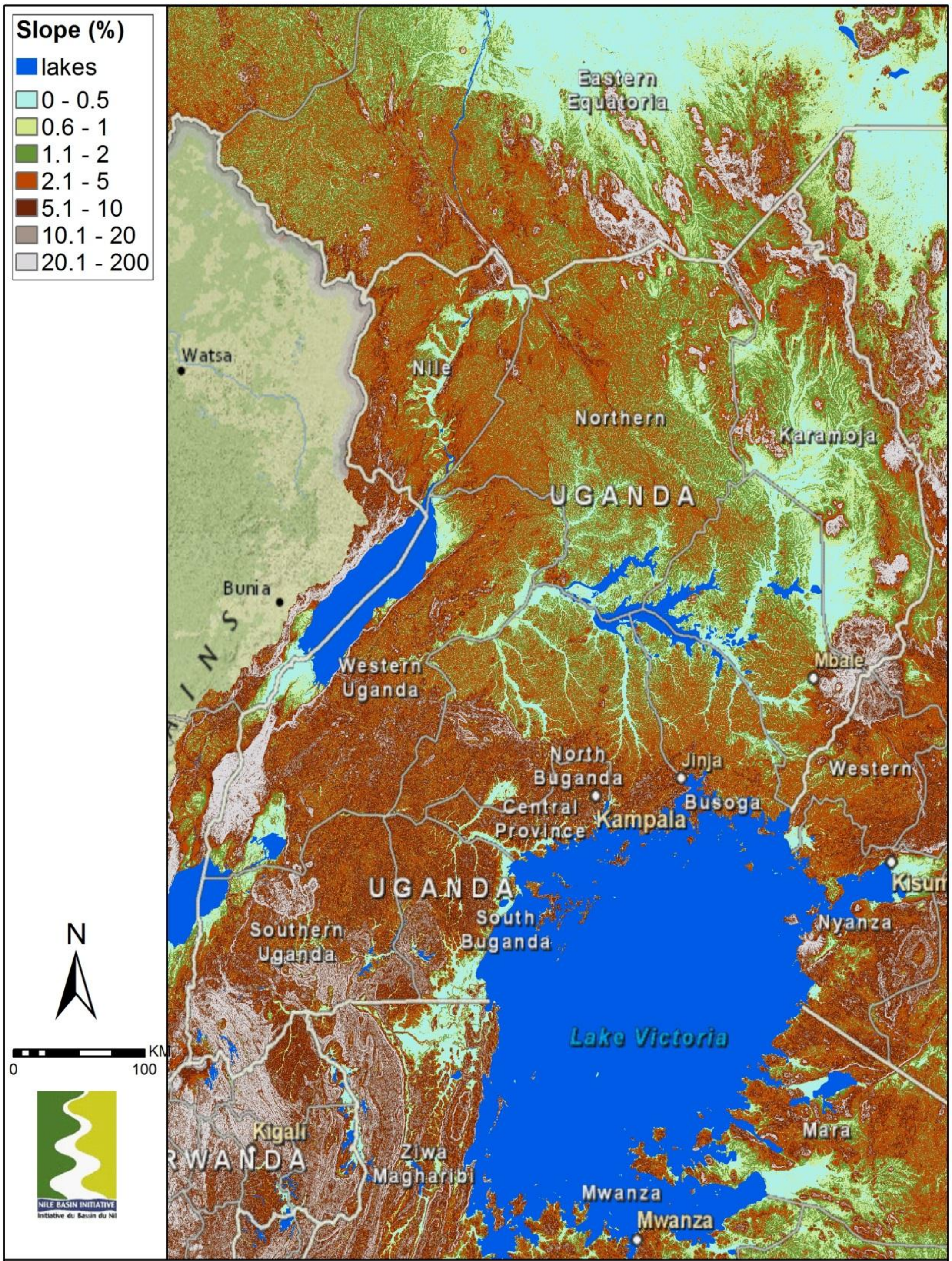


Figure 2: Digital Elevation Model of Uganda. (Source: ASTER)

In Figure 2 the DEM for the country is shown. Uganda in characterized by the high and steep mountains in the South west and at the Kenyan border. The plains surrounding the big lakes and the plains in the East would be highly suitable for surface irrigation. 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.



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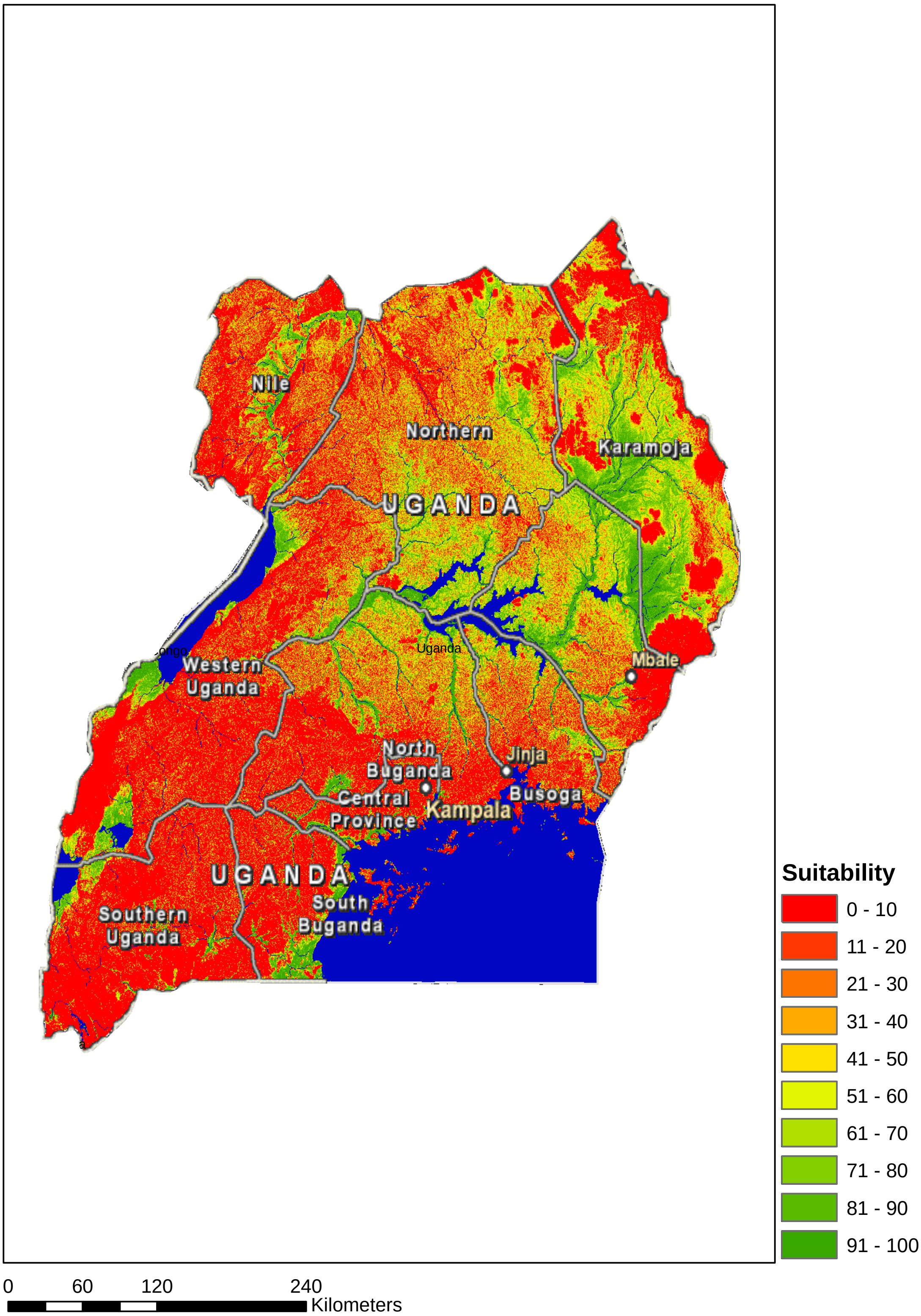
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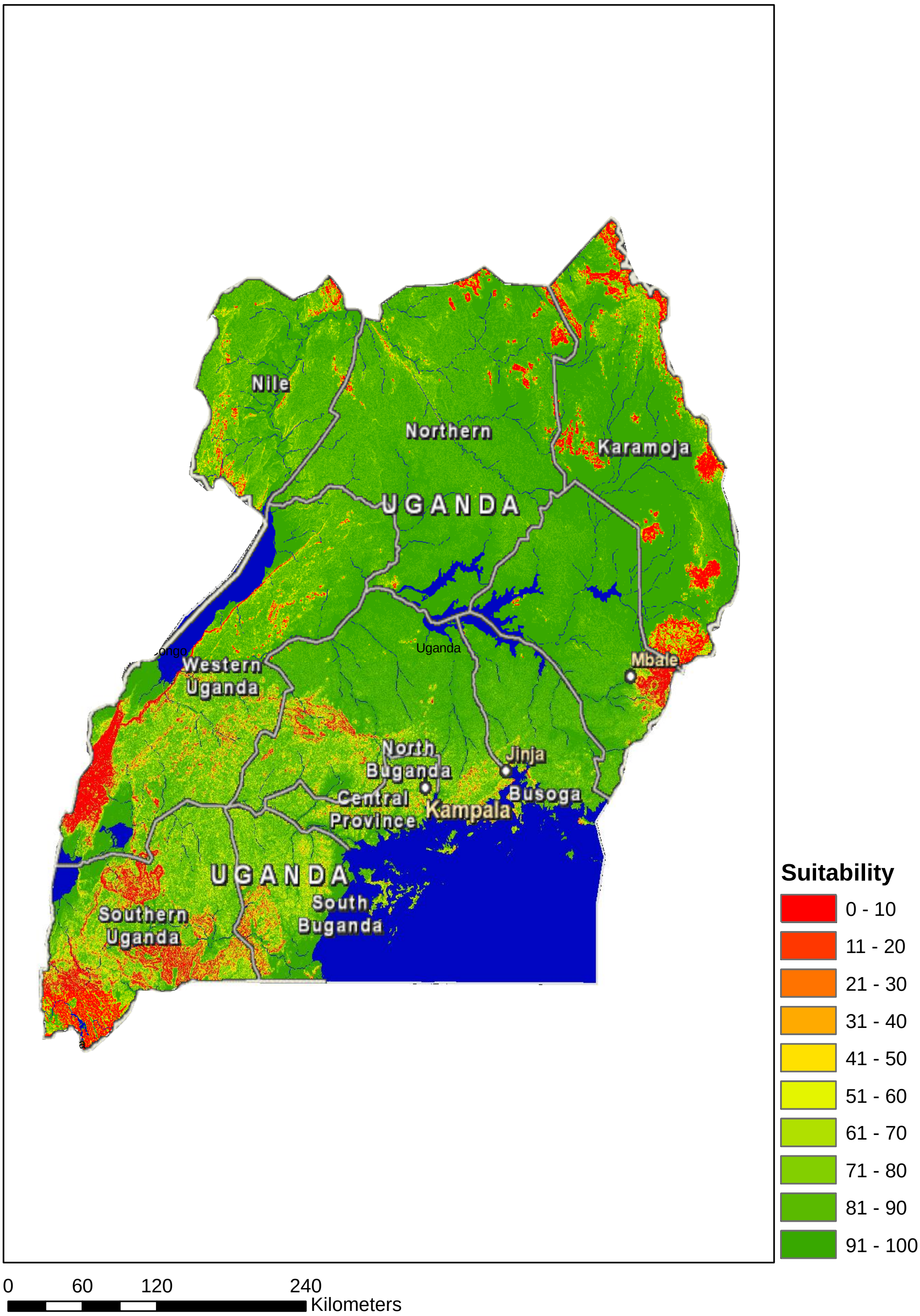
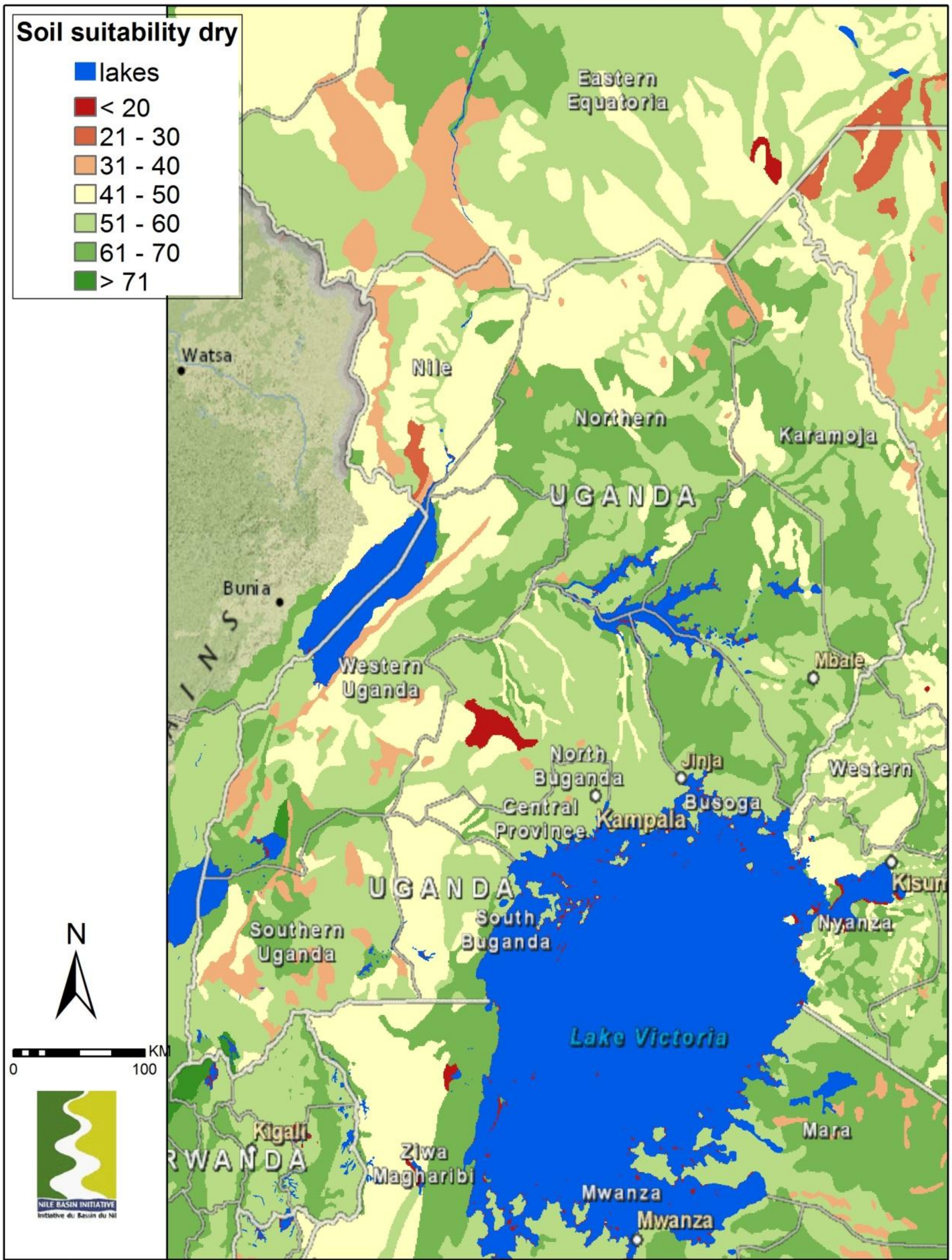


Figure 3: Terrain slope as percentage (top), surface irrigation (middle), and drip irrigation (bottom).

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.

Concerning the soil qualities the areas surrounding Lake Kyoga and lake Edward have the highest potential. For paddy a large potential area can be found East of Lake Kyoga. At the southern tip of Lake Albert some salinity problems occur, according to the soil map.



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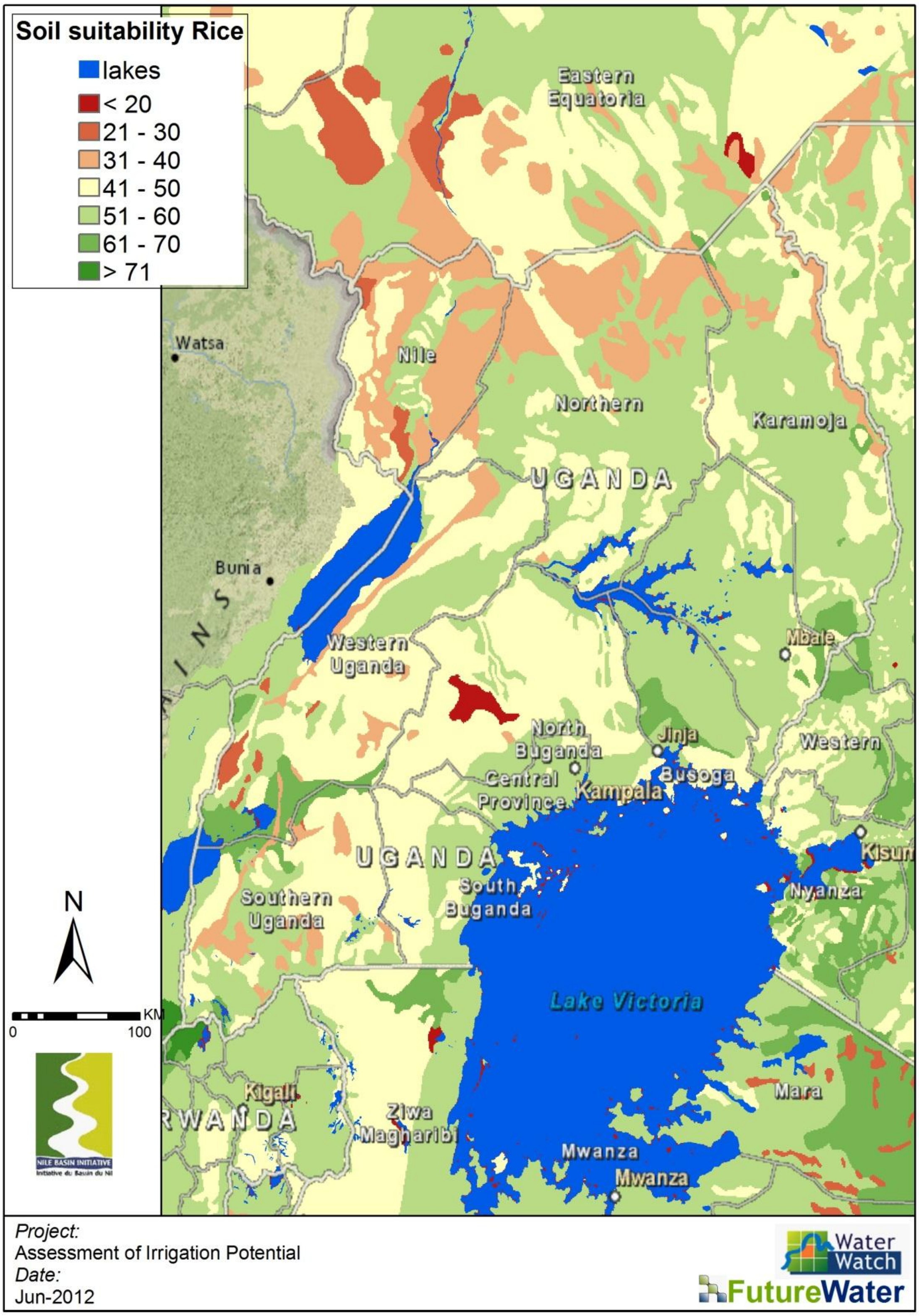


Figure 4: Soil suitability for dry crops (top) and rice/paddy (bottom) (Source: study analysis)

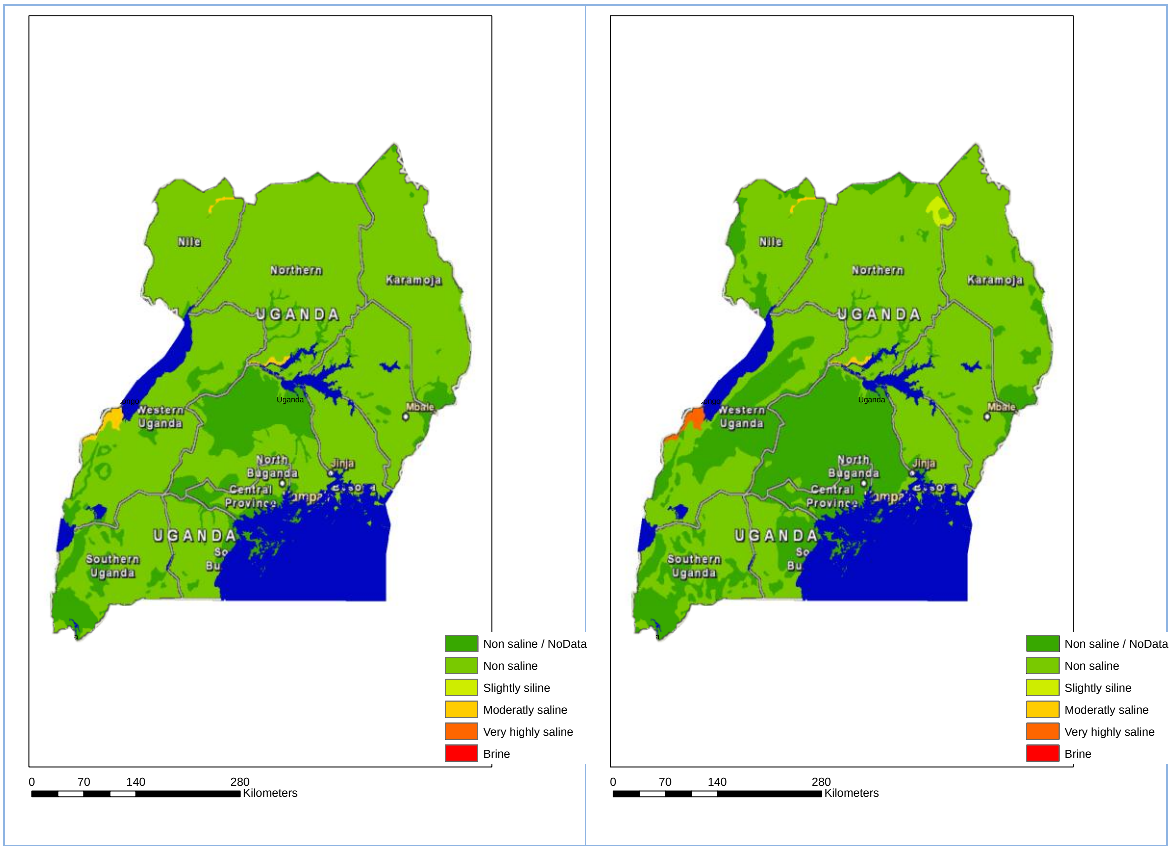


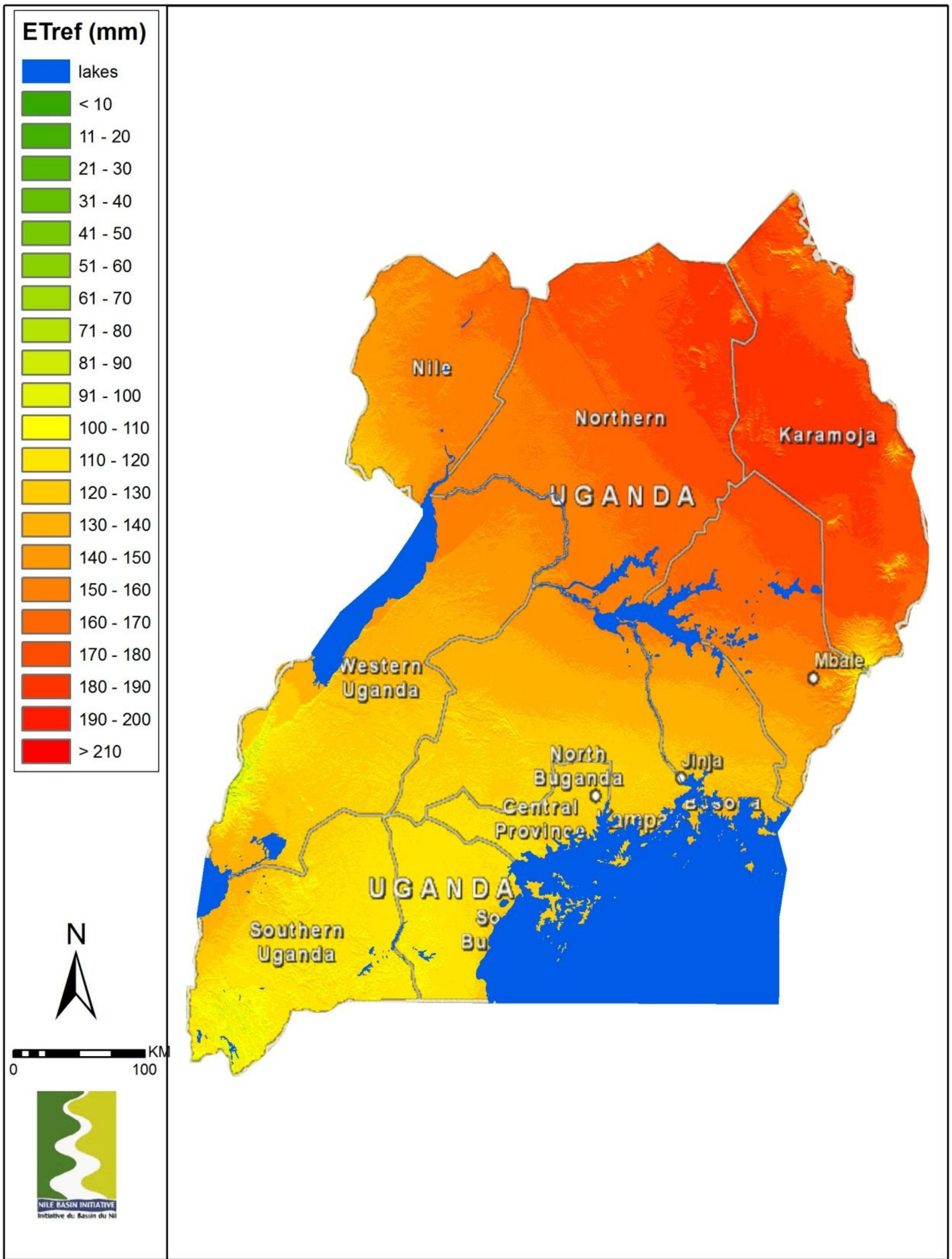
Figure 5: Salinity, top-soil (left) and sub-soil (right).

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. The irrigation water requirements are based on an innovative method using satellite information. 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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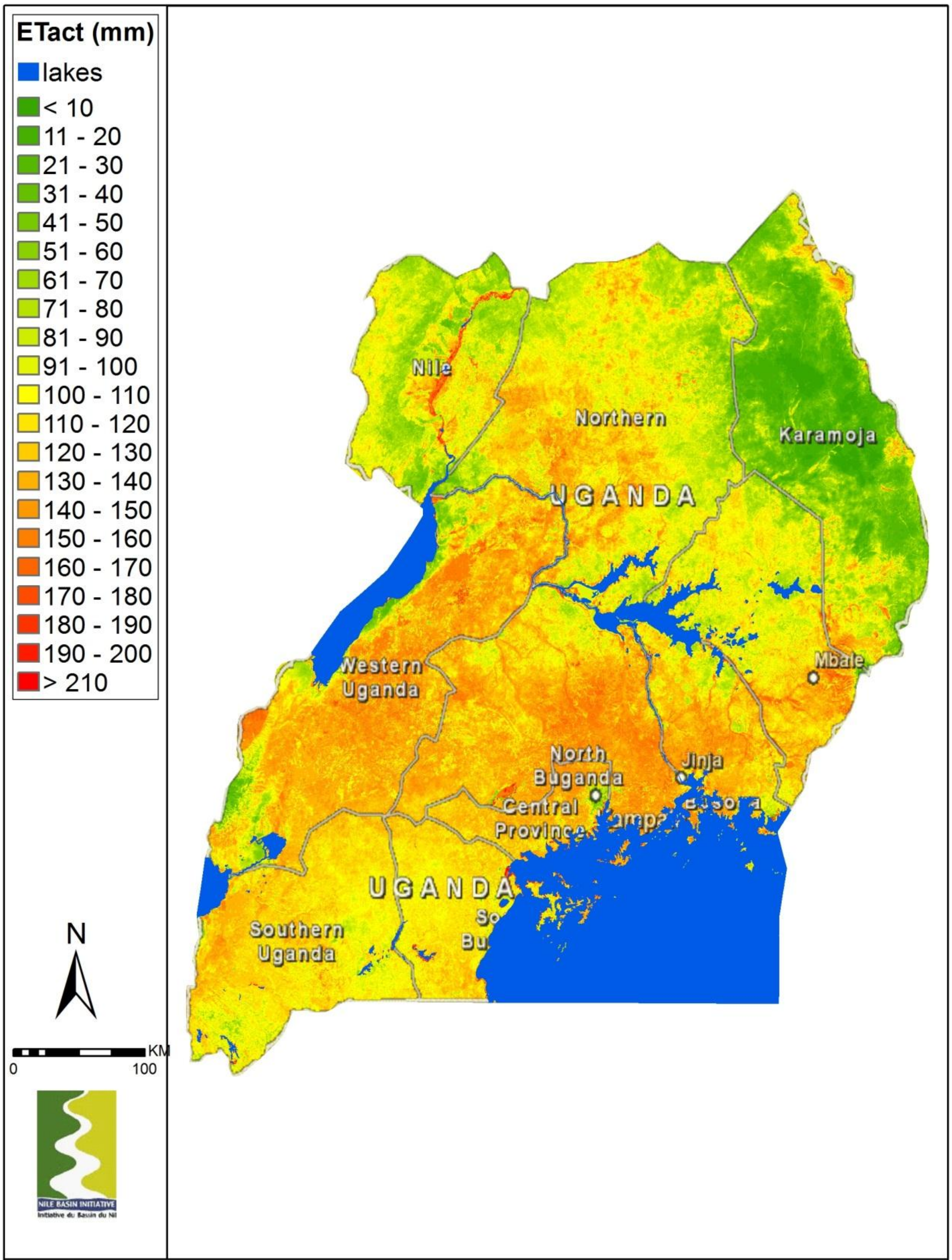

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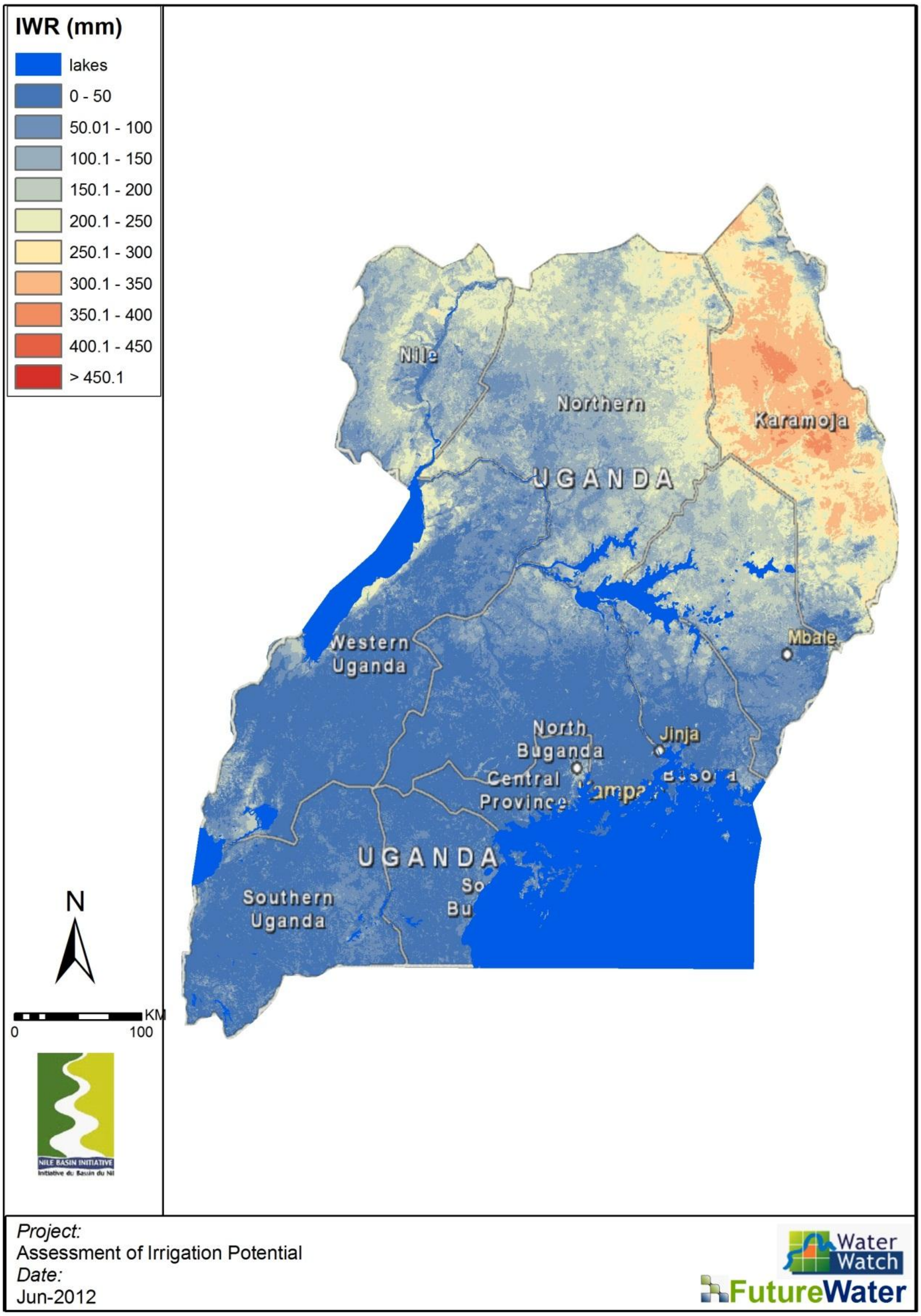
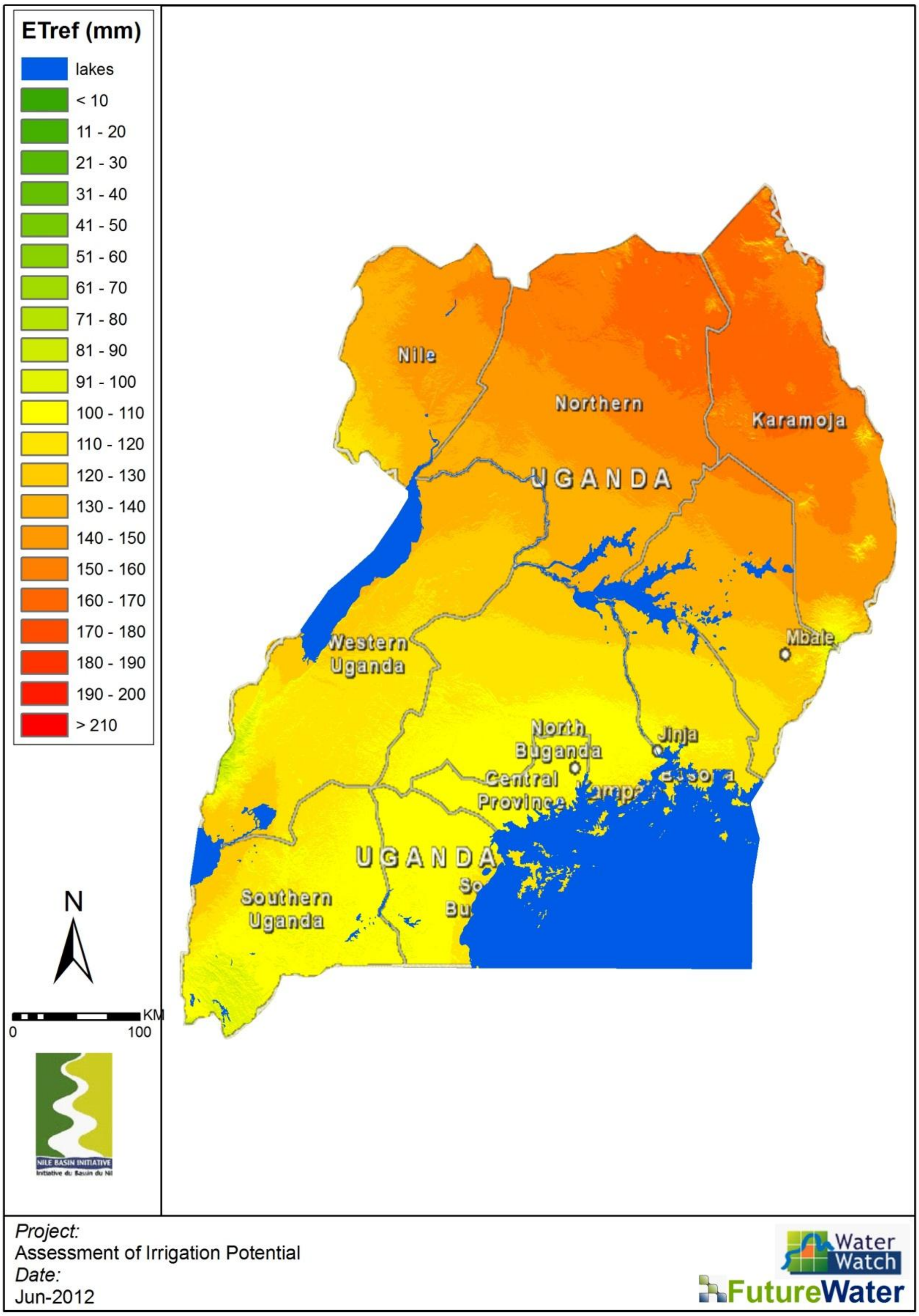


Figure 6: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for January (Average 2001-2010). (Source: study analysis).

February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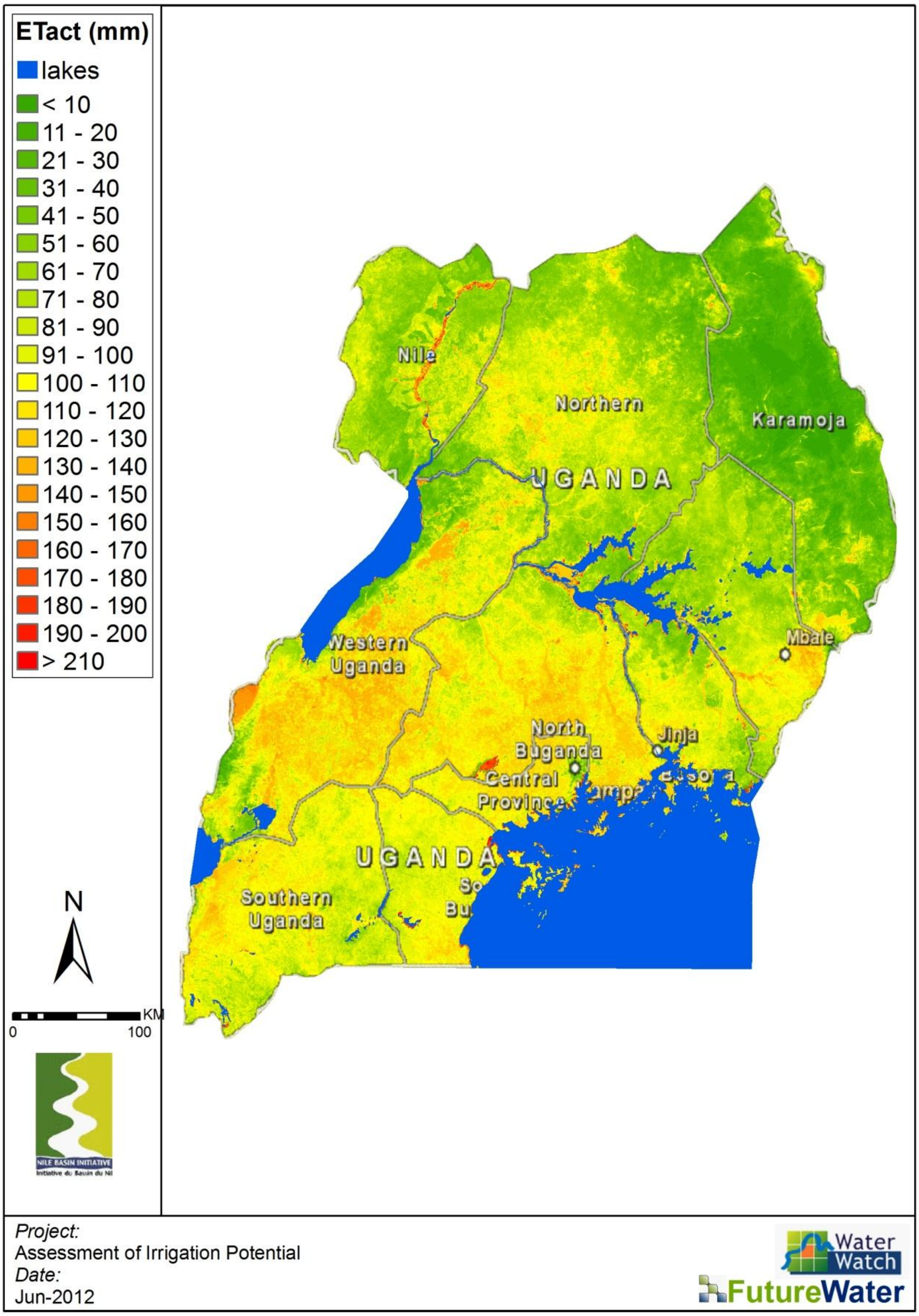
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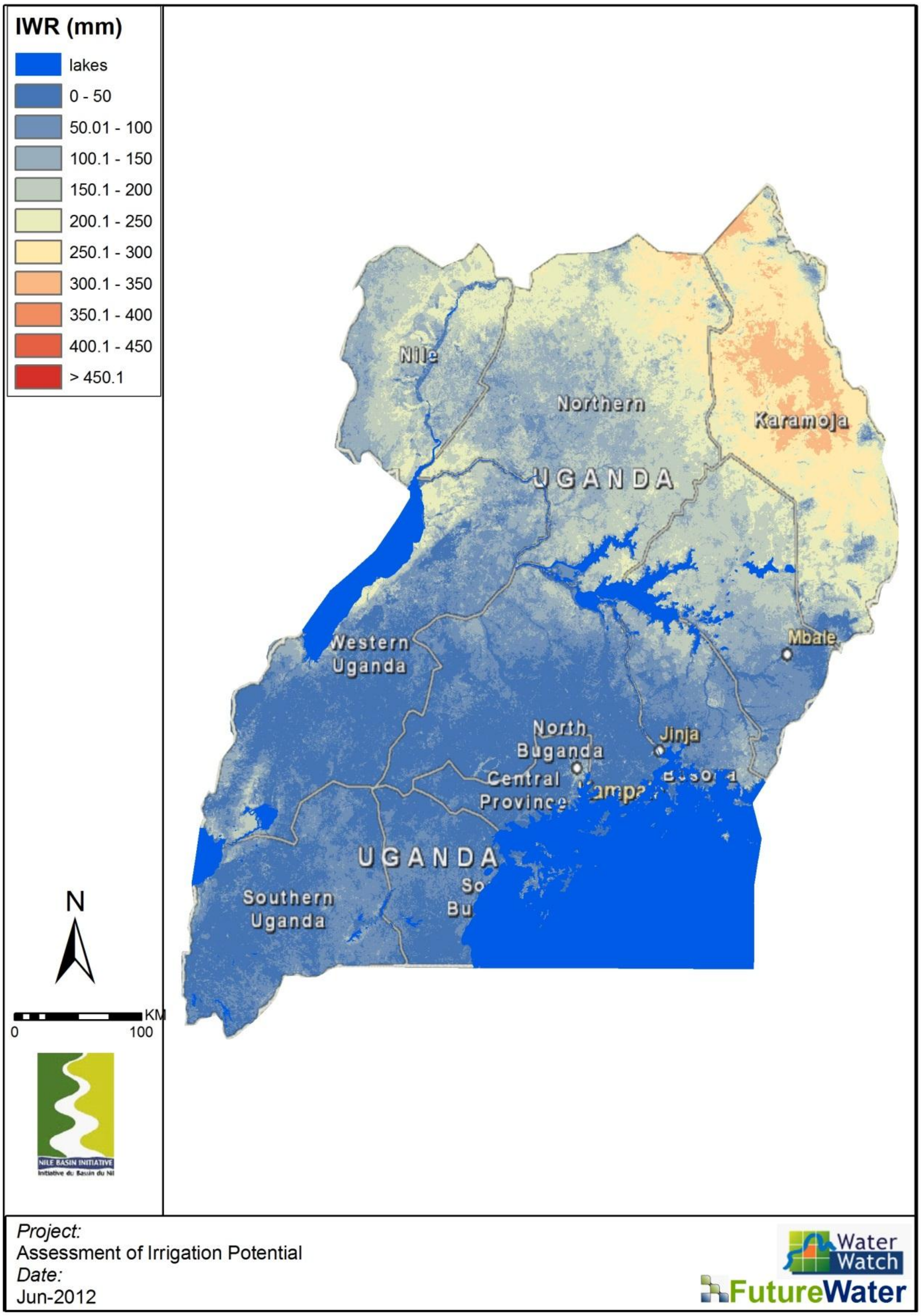
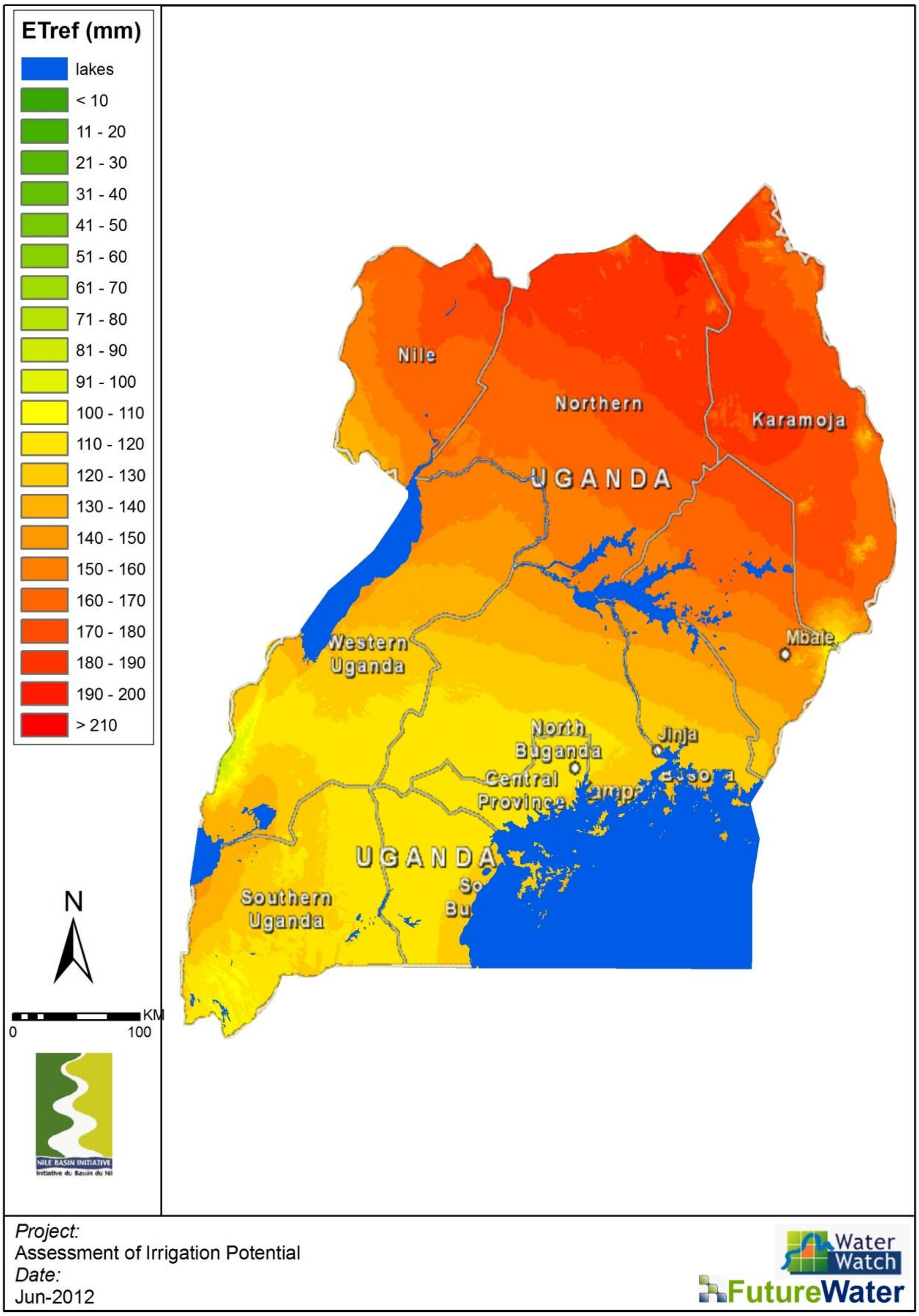


Figure 7: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for February (Average 2001-2010). (Source: study analysis).

March



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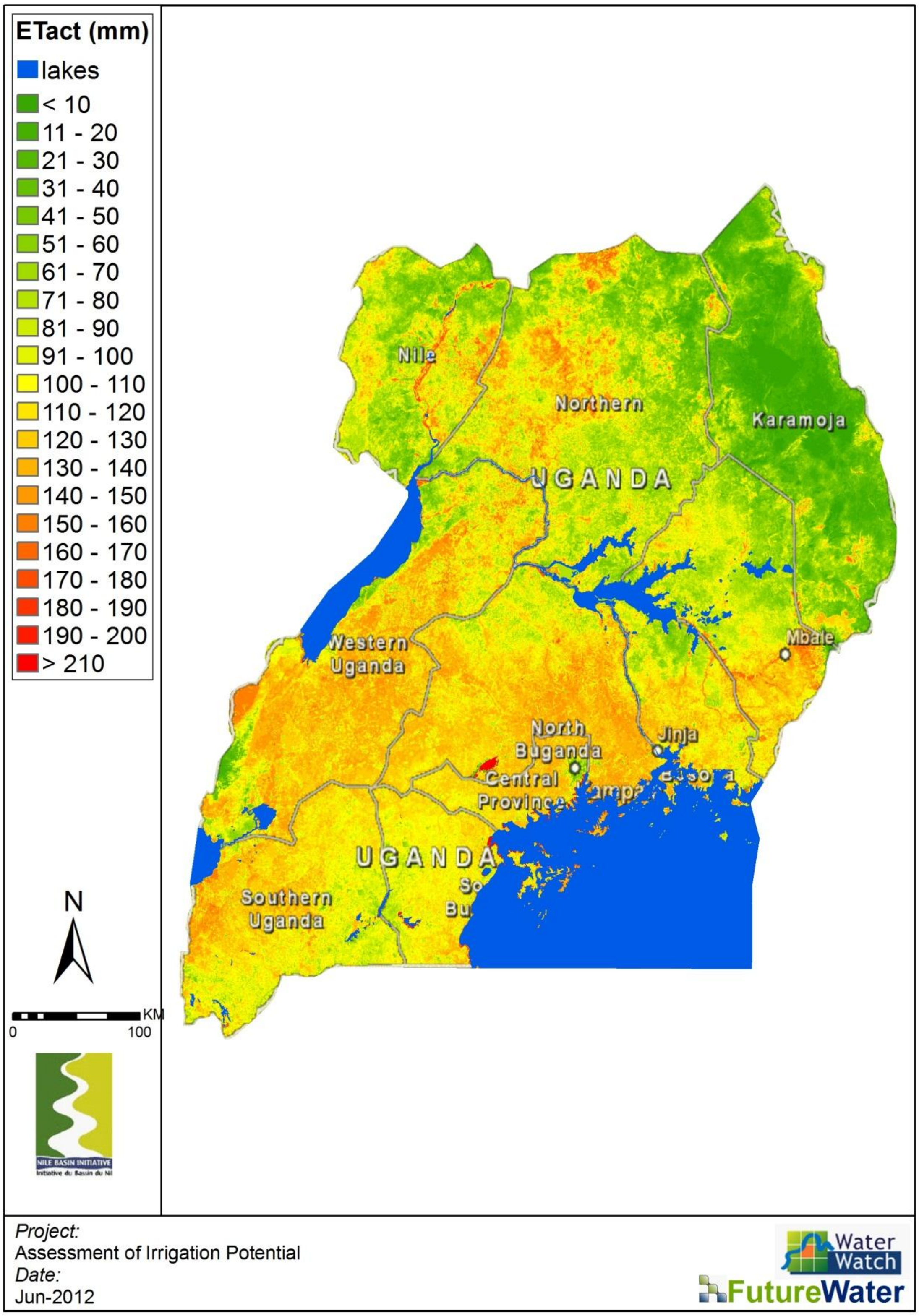
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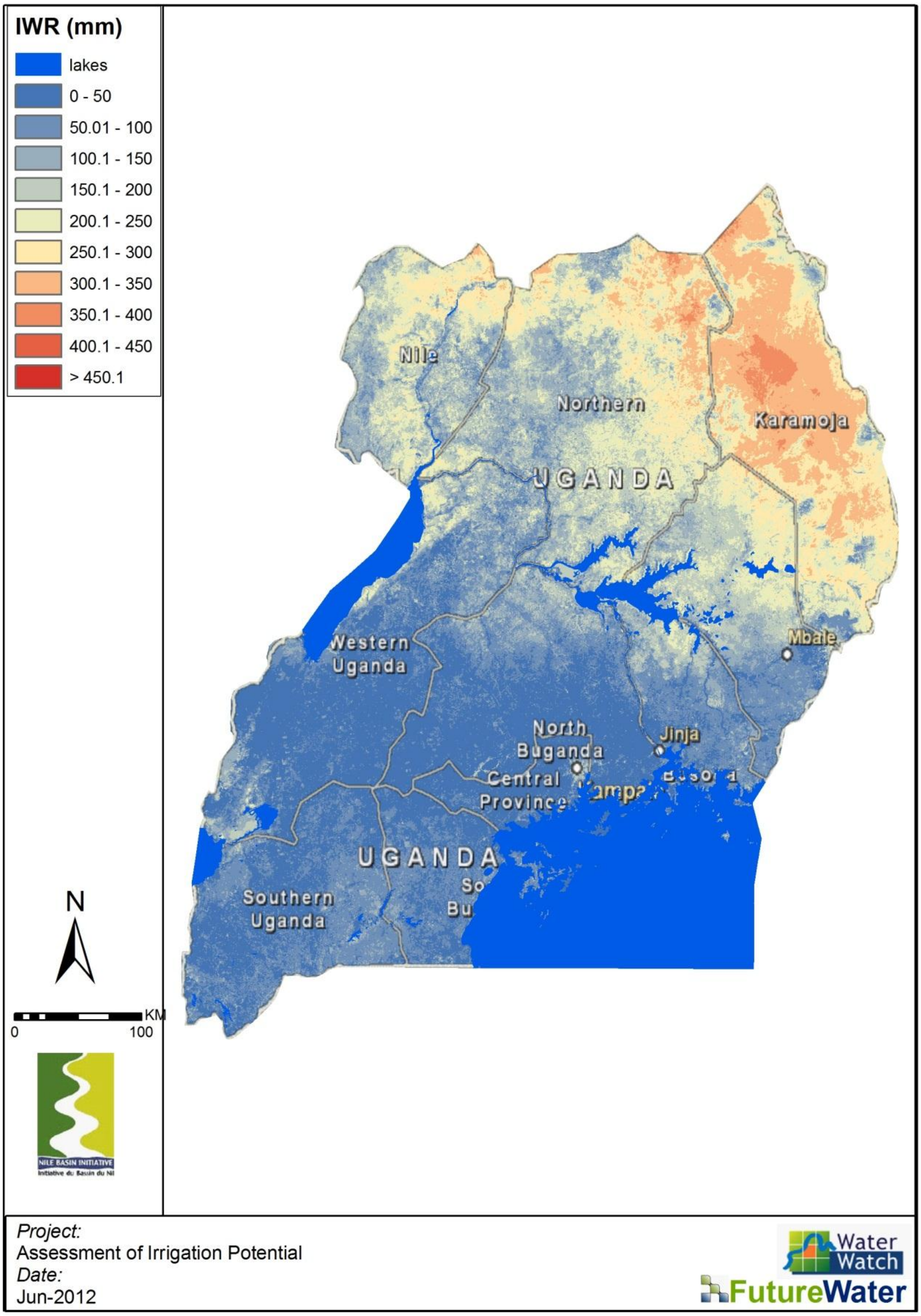
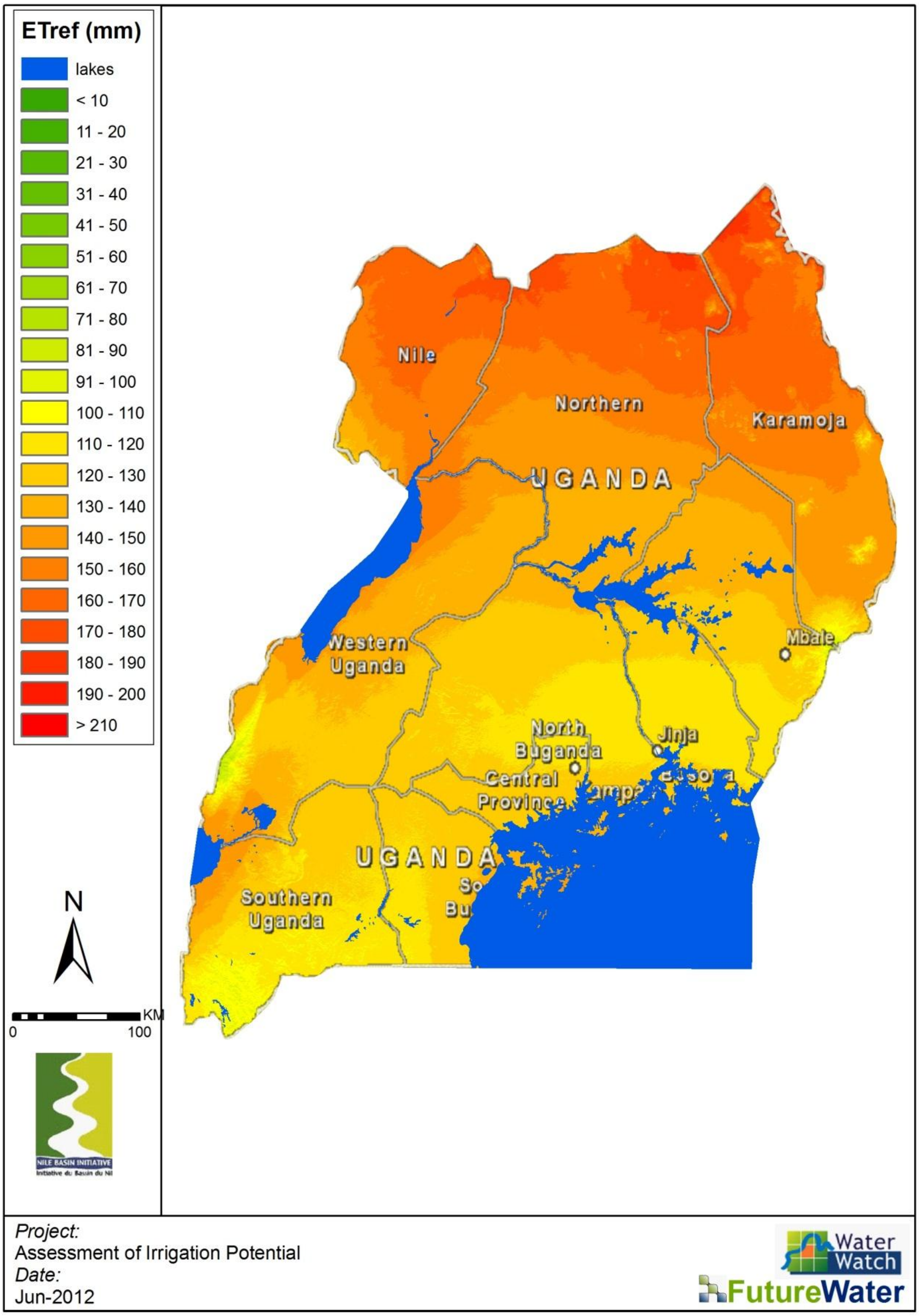


Figure 8: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for March (Average 2001-2010). (Source: study analysis).

April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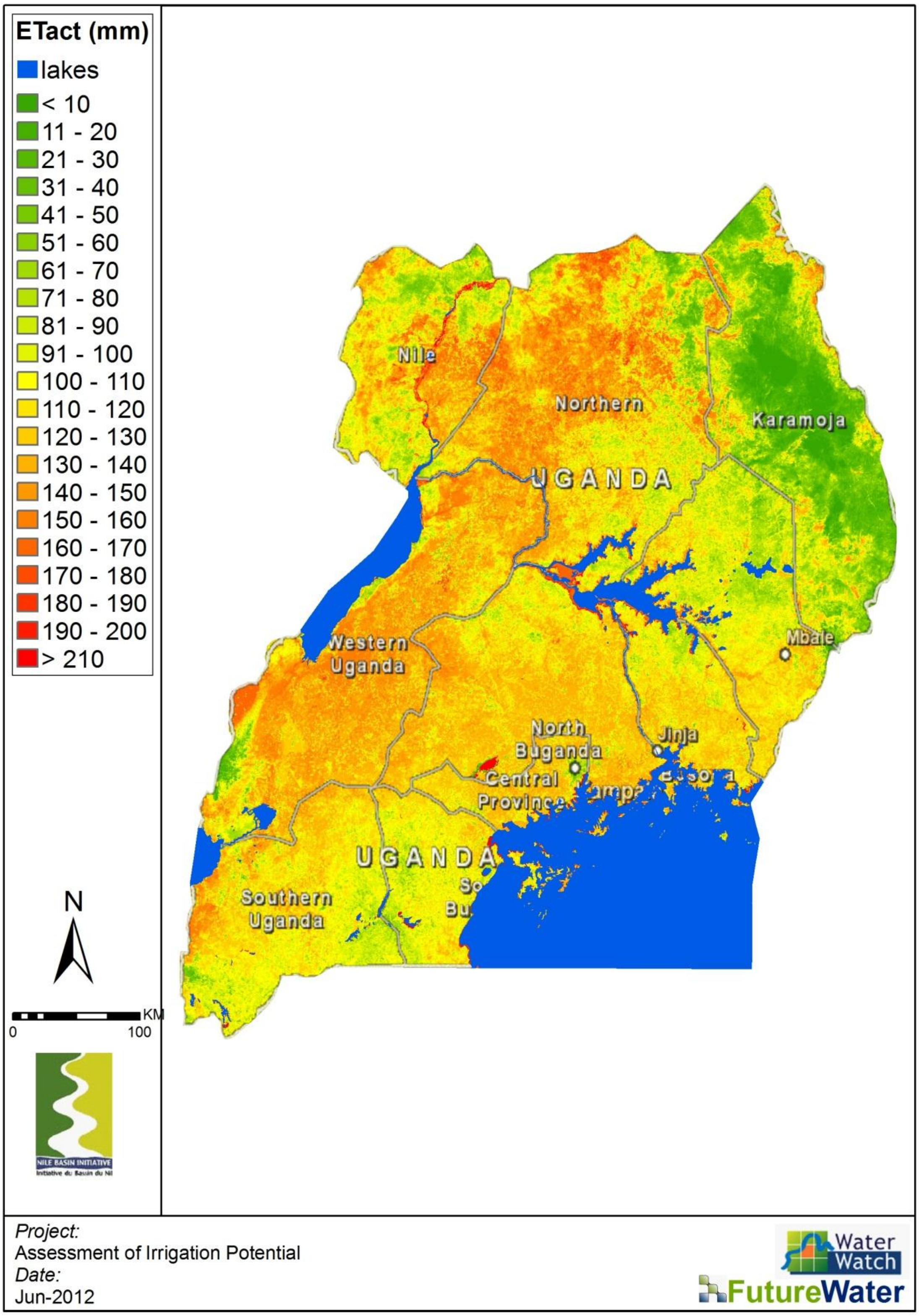
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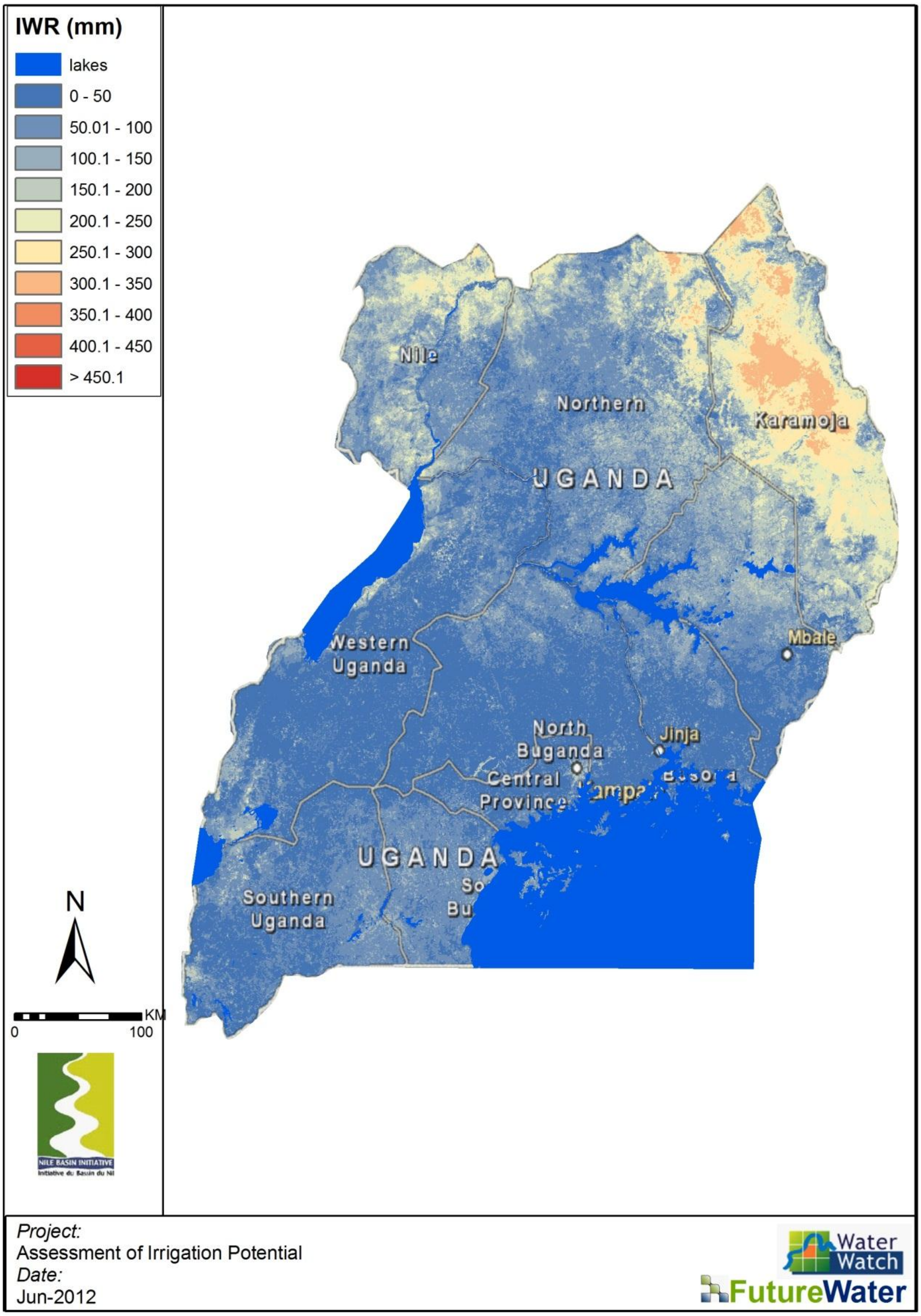
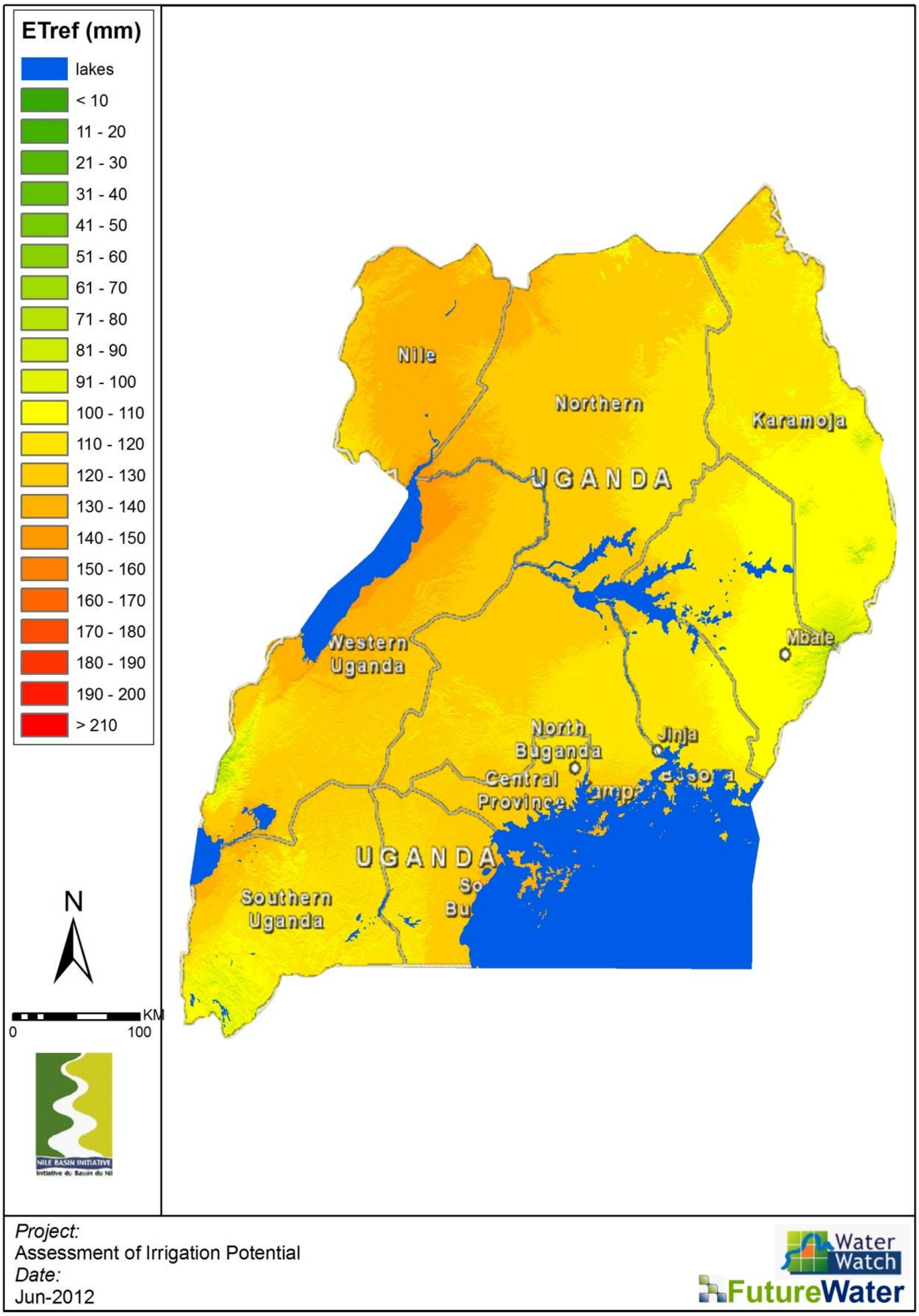


Figure 9: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for April (Average 2001-2010). (Source: study analysis).

May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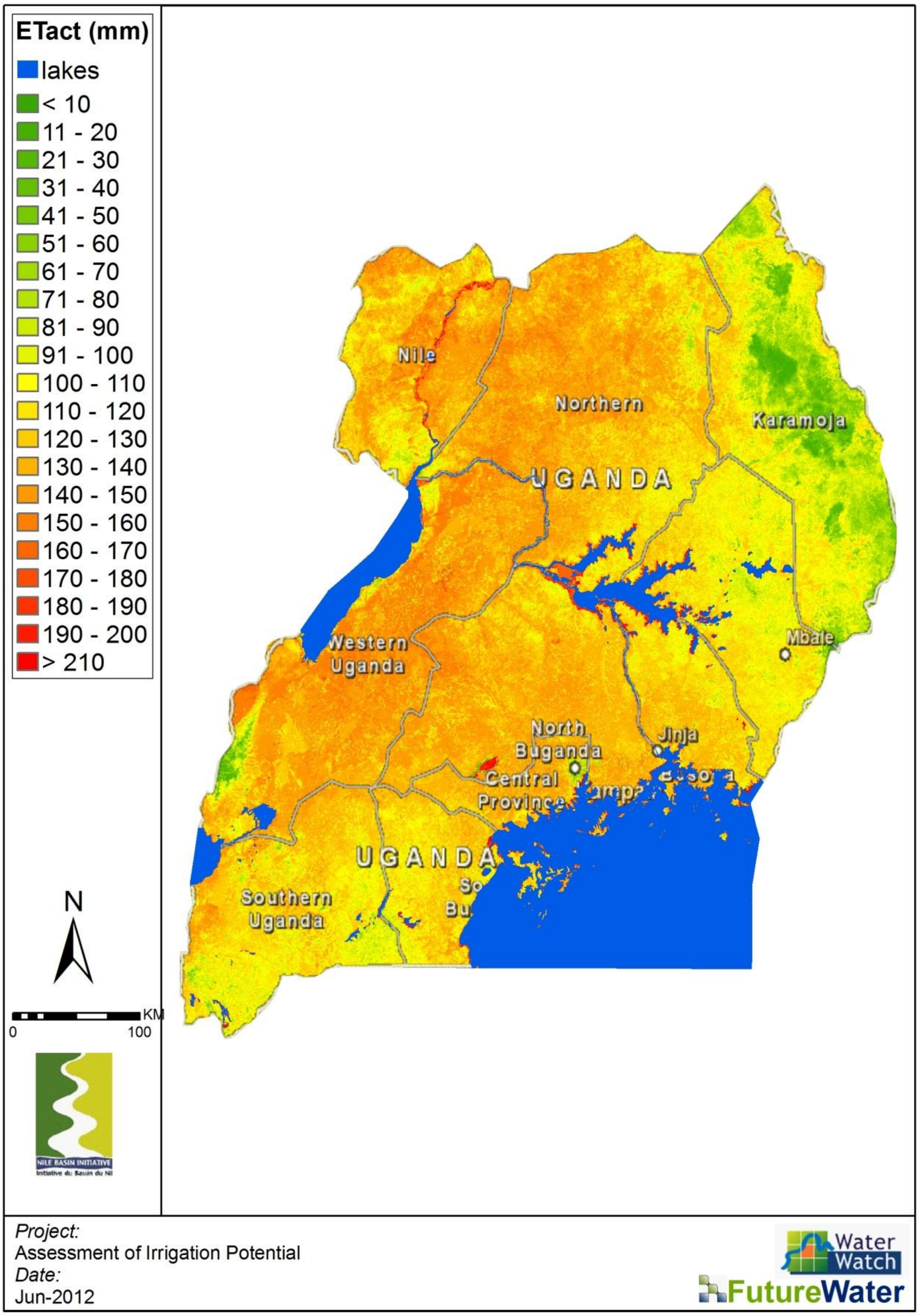
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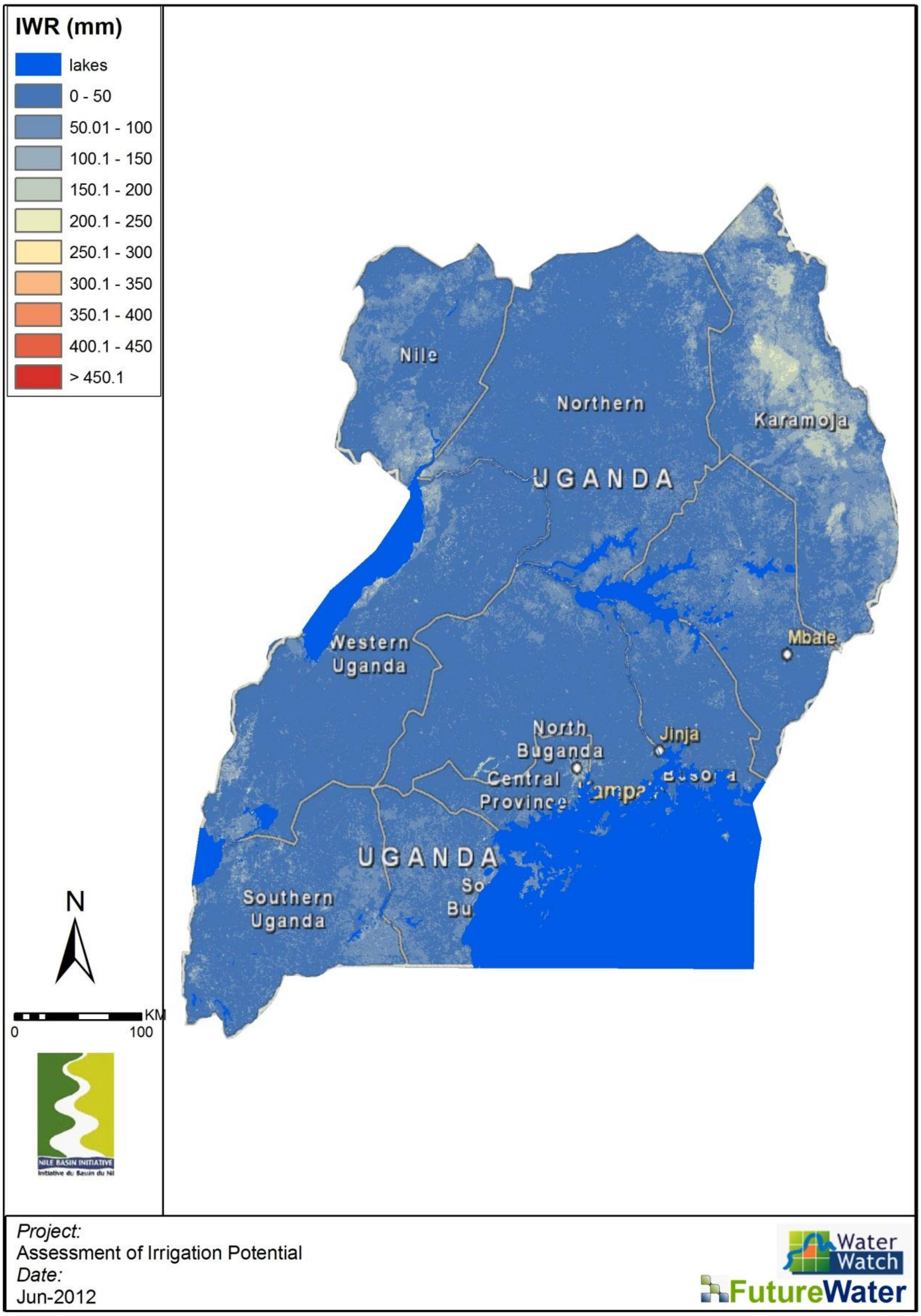
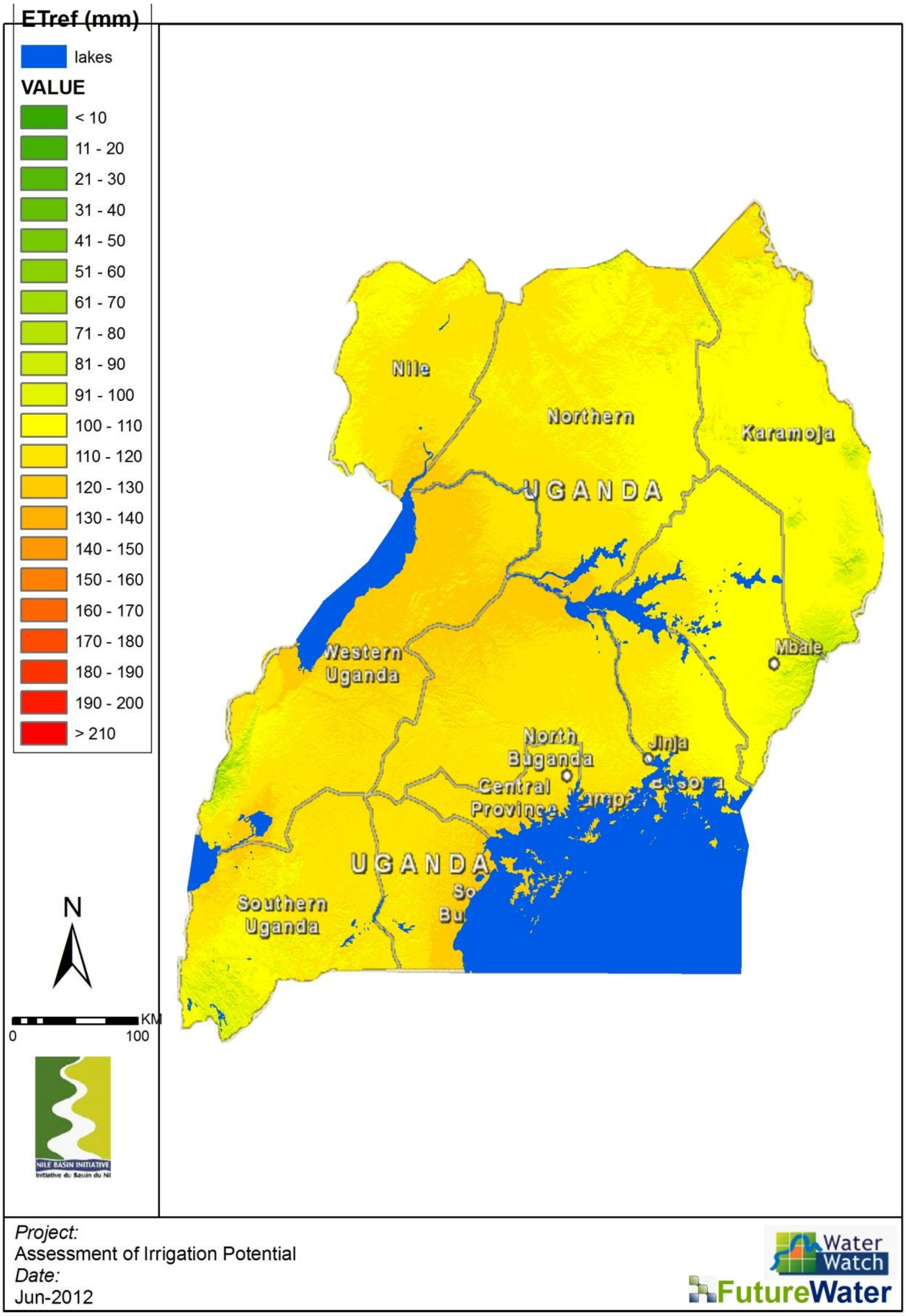


Figure 10: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for May (Average 2001-2010). (Source: study analysis).

June



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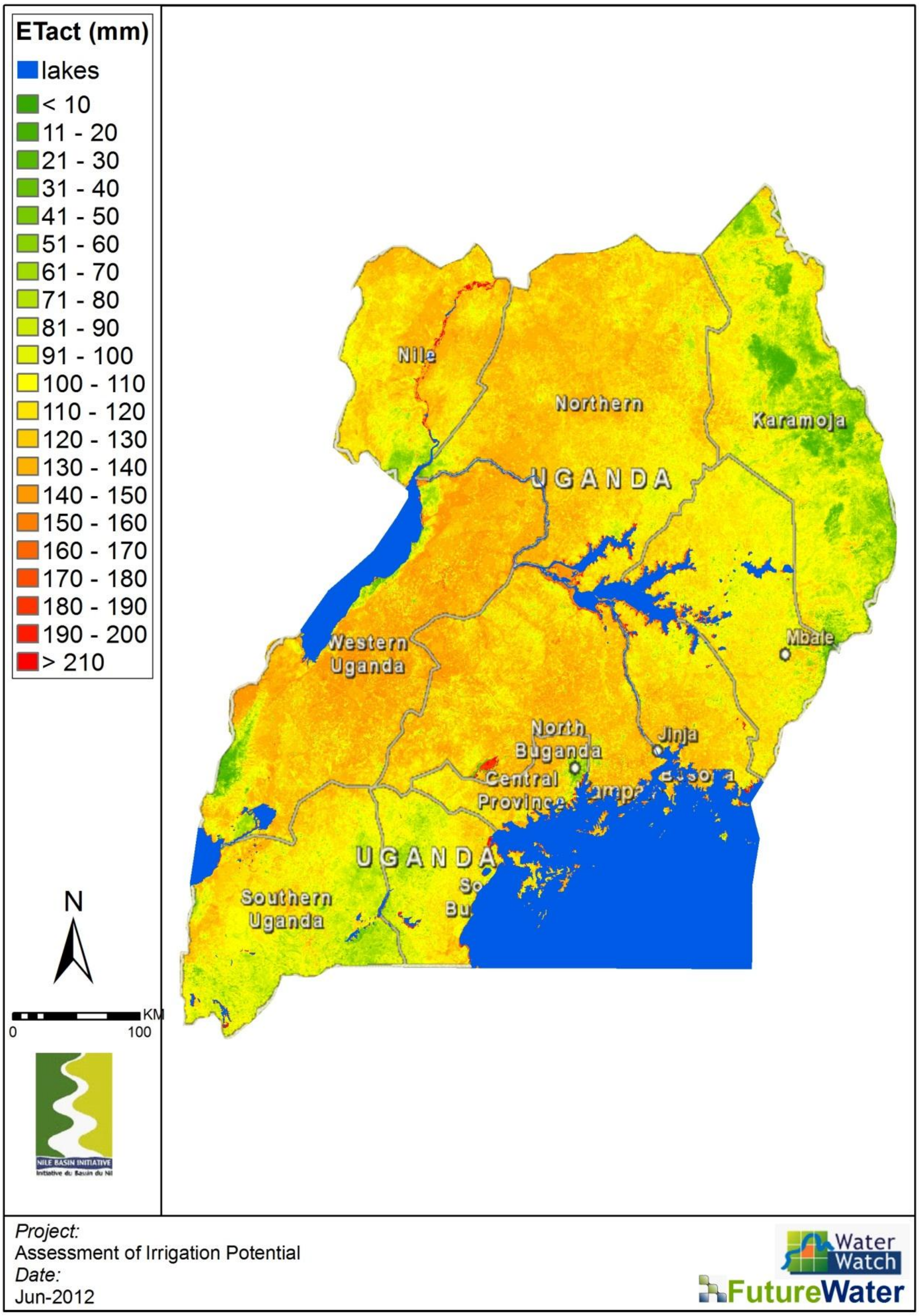
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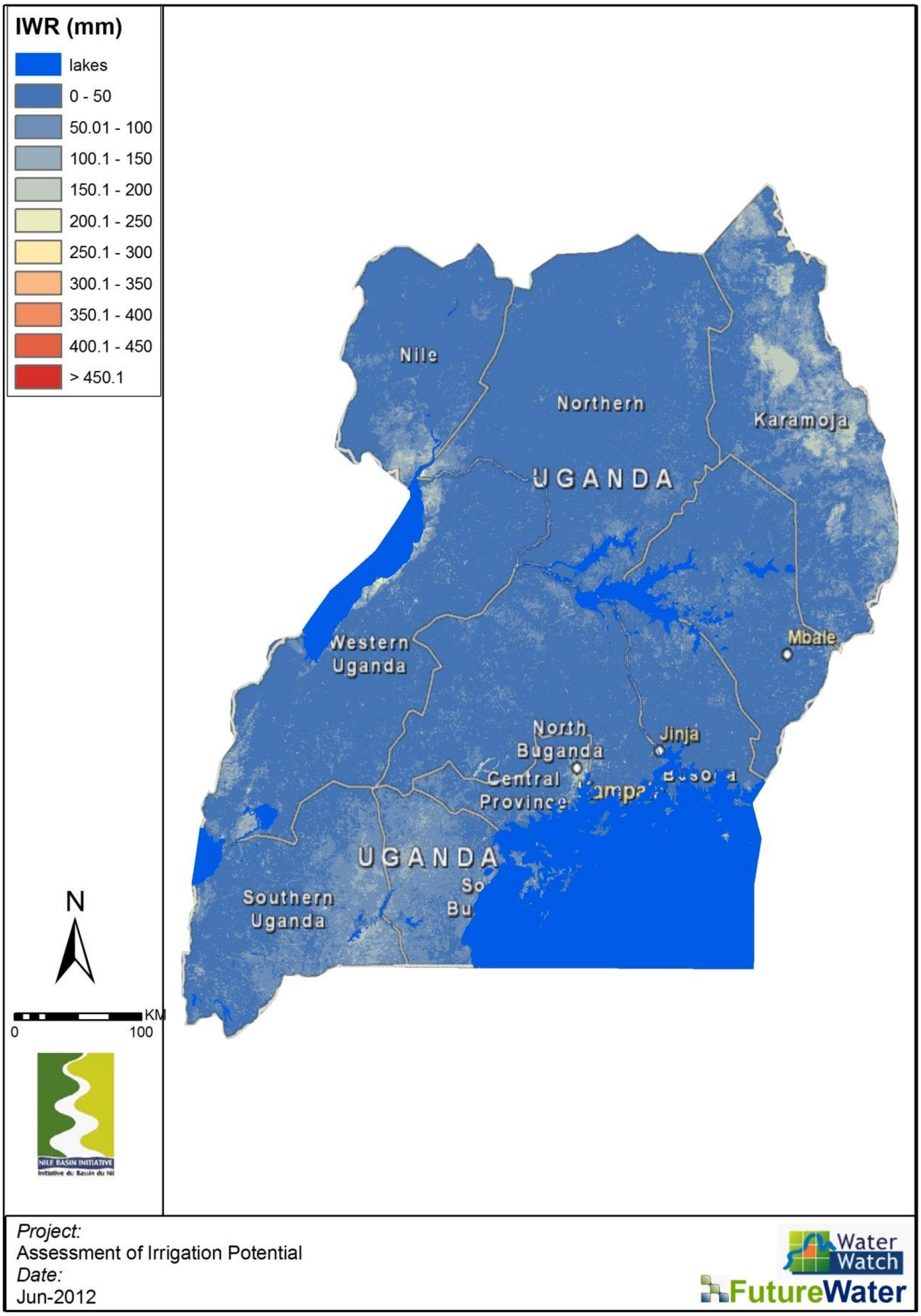
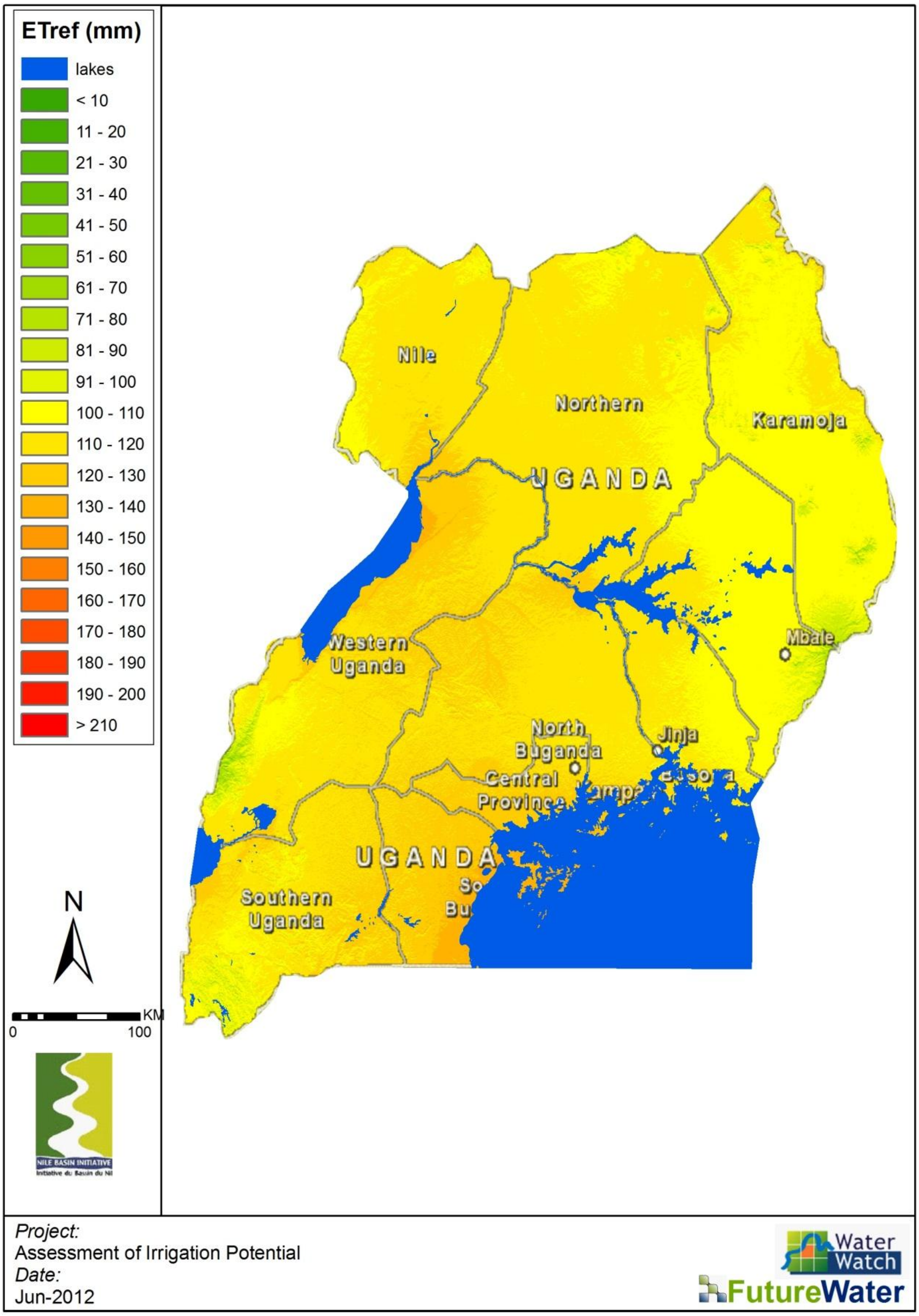


Figure 11: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). For June (Average 2001-2010). (Source: study analysis).

July



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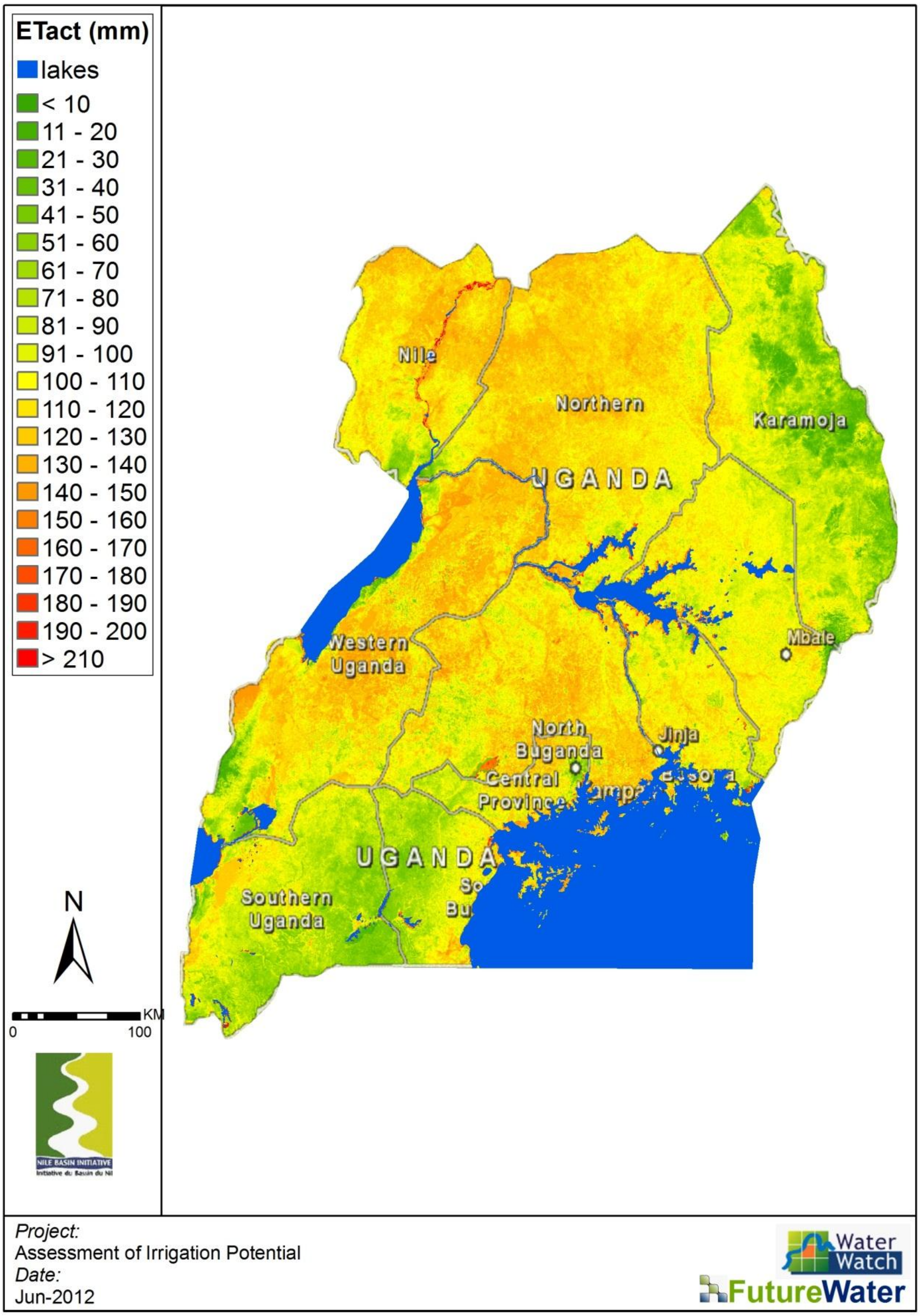

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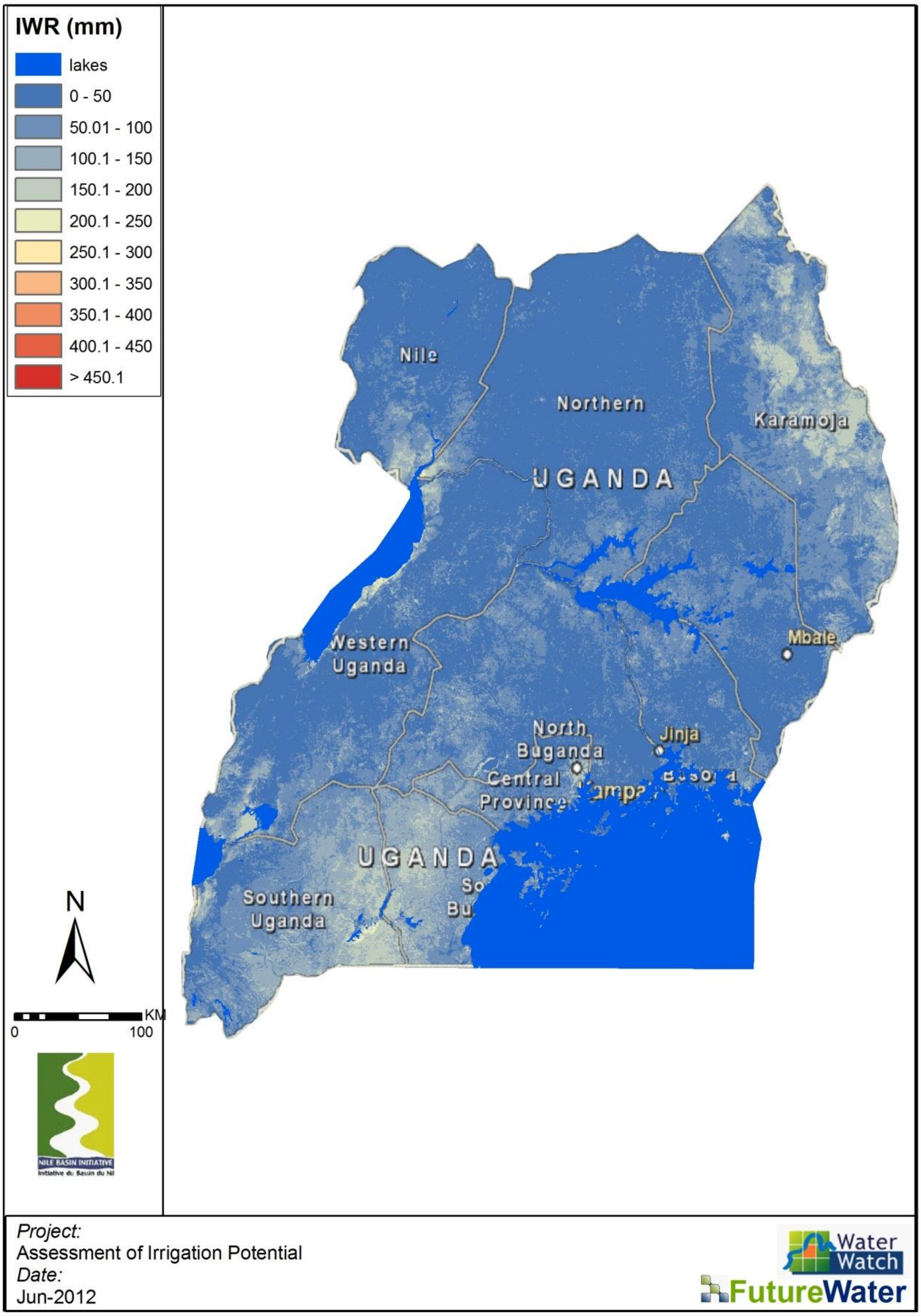
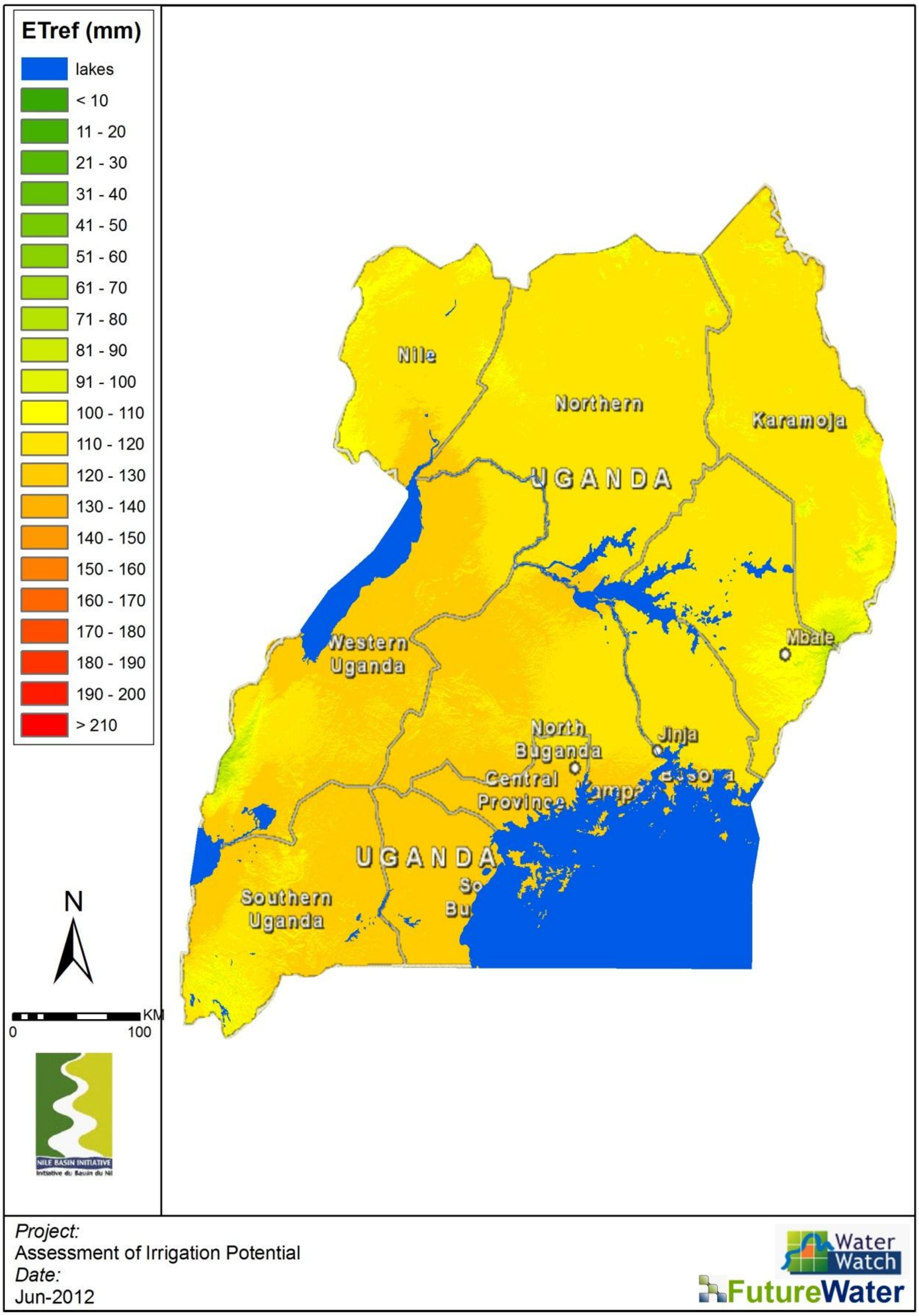


Figure 12: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for July (Average 2001-2010). (Source: study analysis).

August



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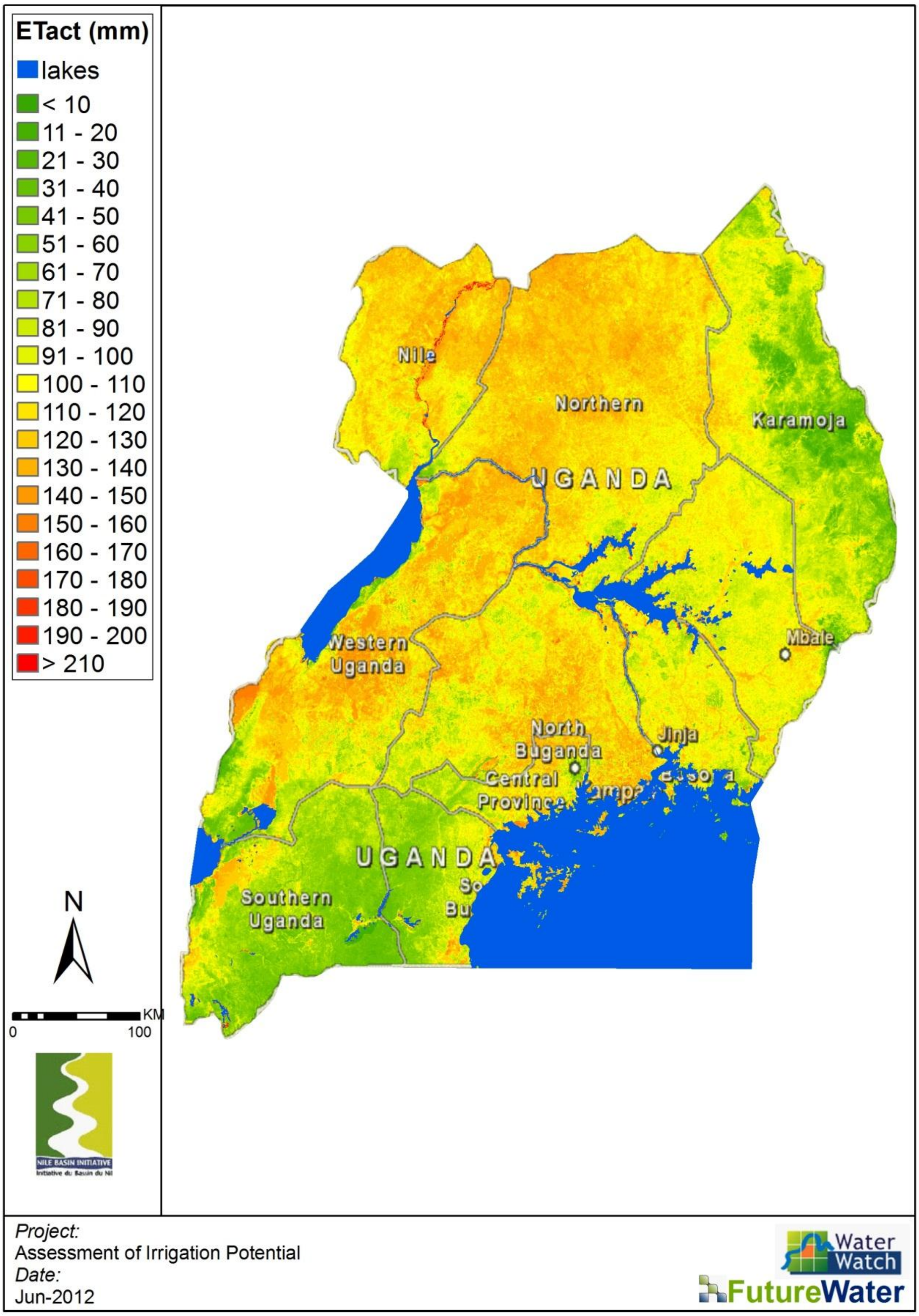
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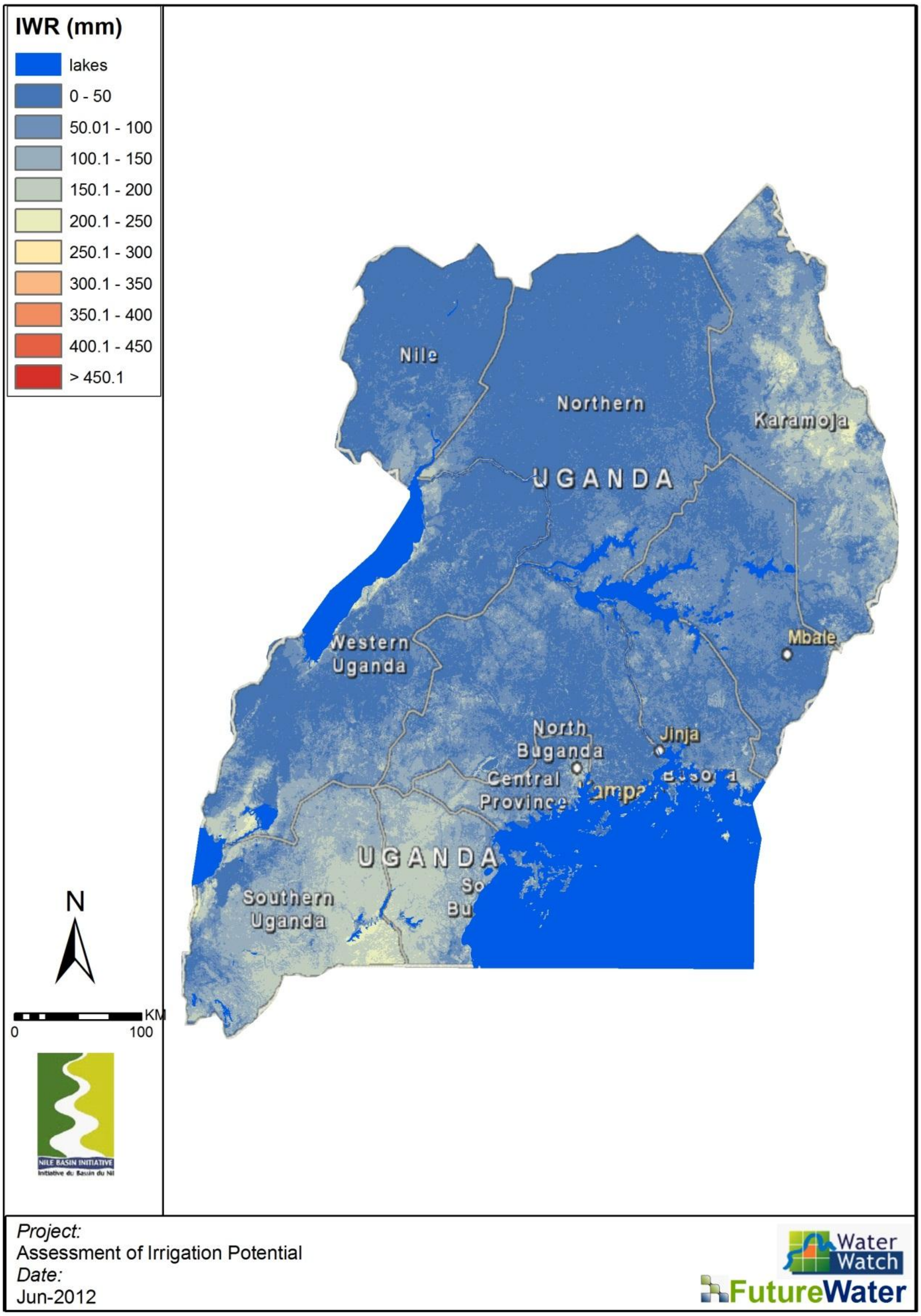
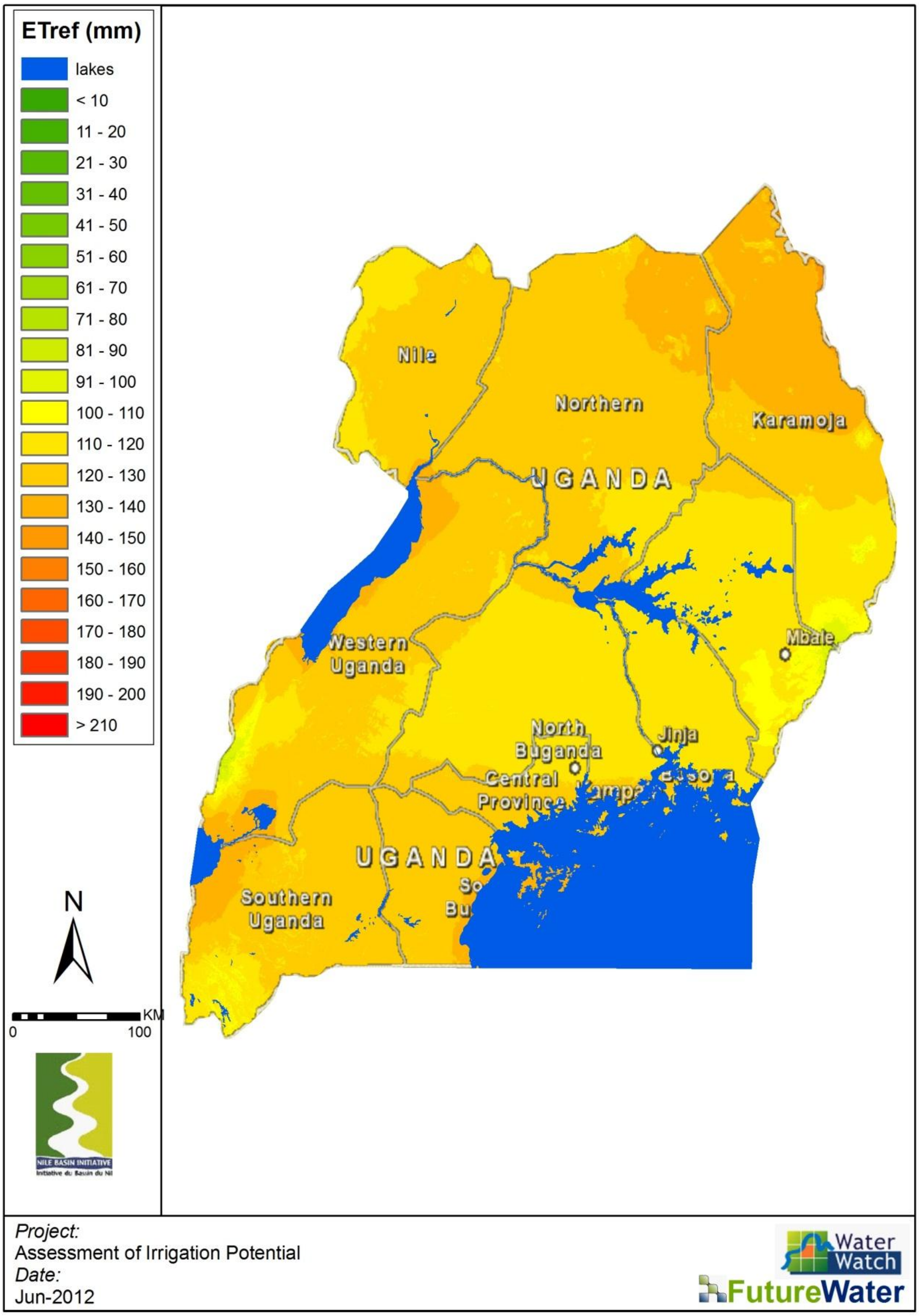


Figure 13: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for August (Average 2001-2010). (Source: study analysis).

September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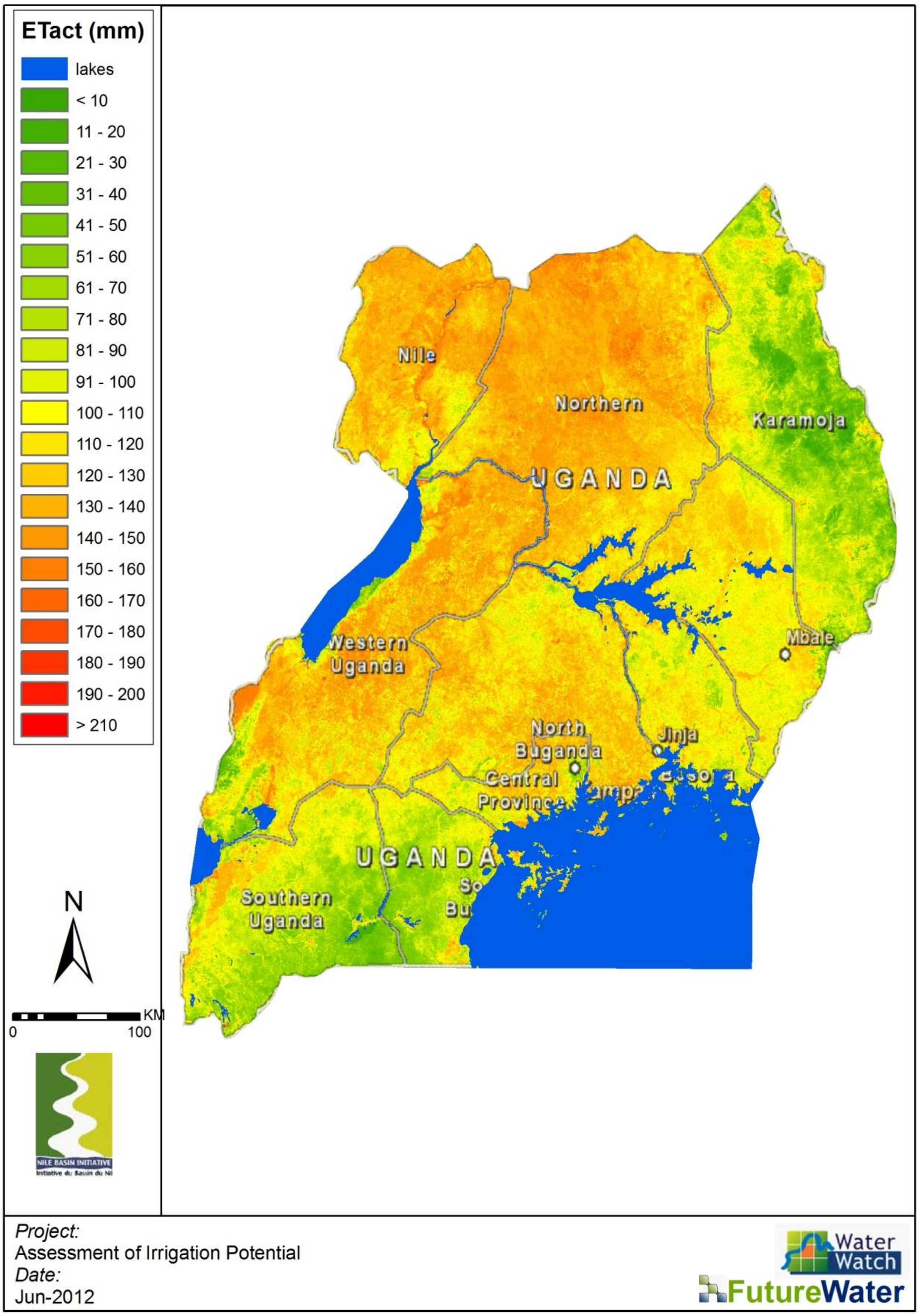
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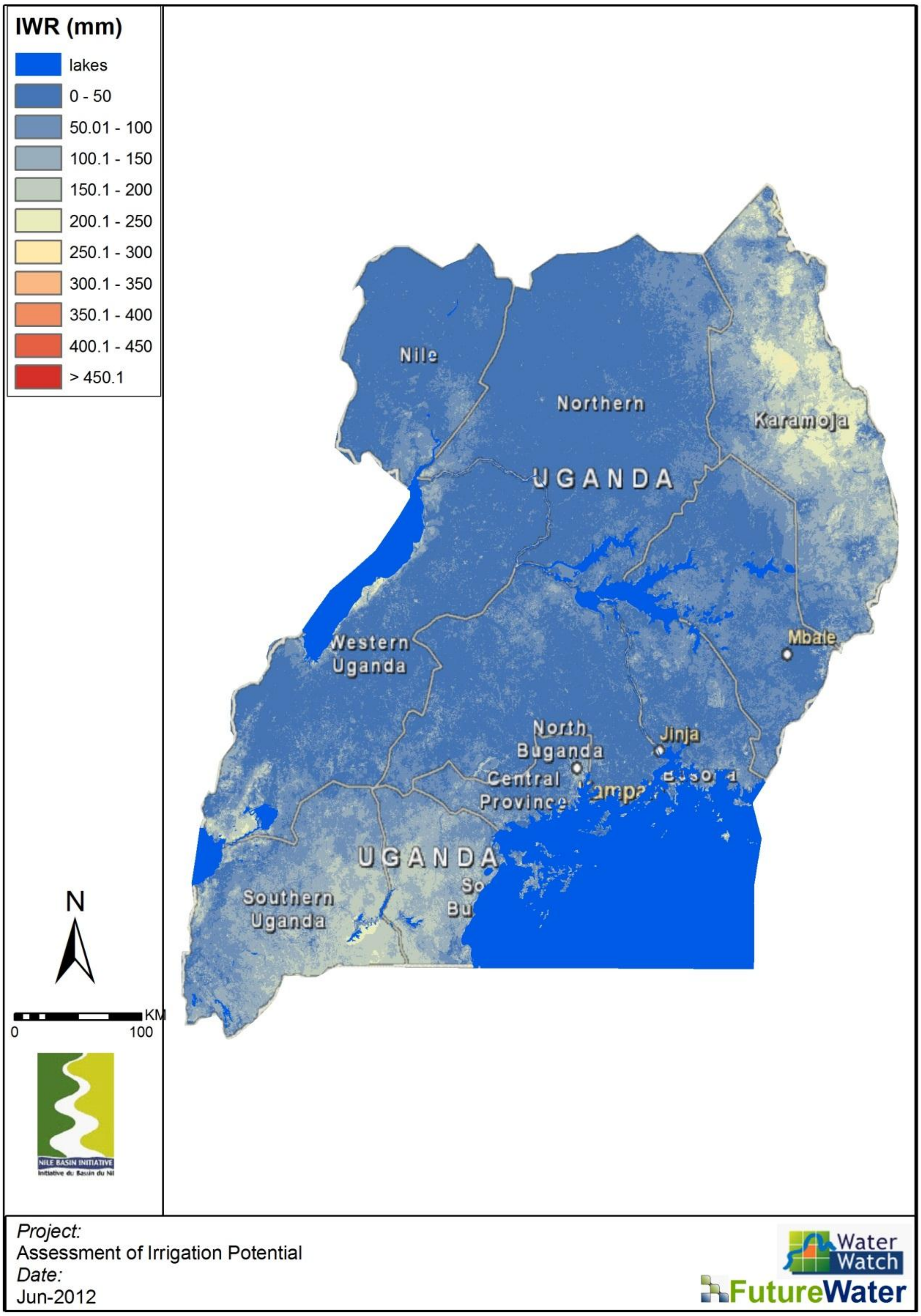
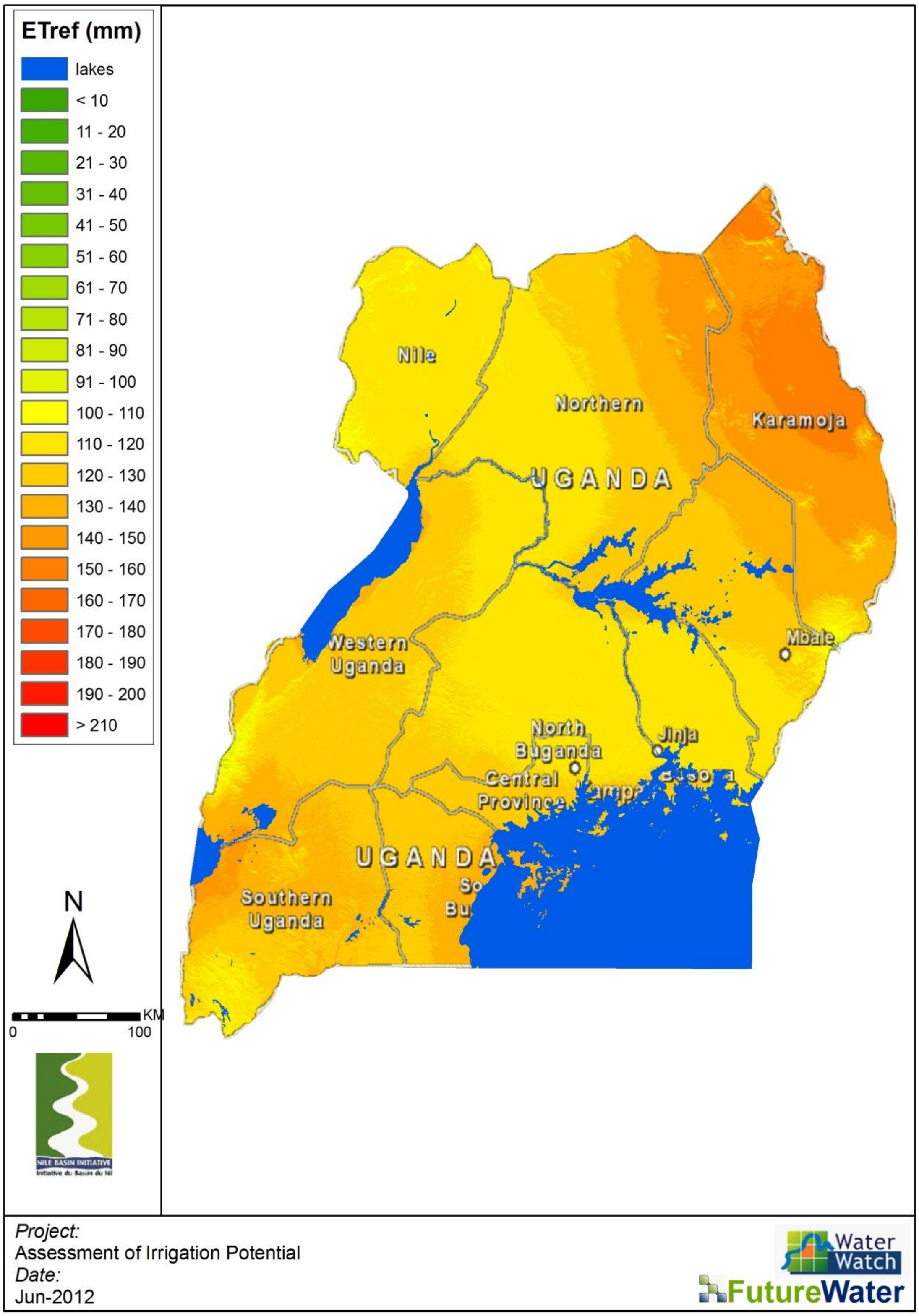


Figure 14: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for September (Average 2001-2010). (Source: study analysis).

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
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160 - 170
170 - 180
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> 210
N
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Nile
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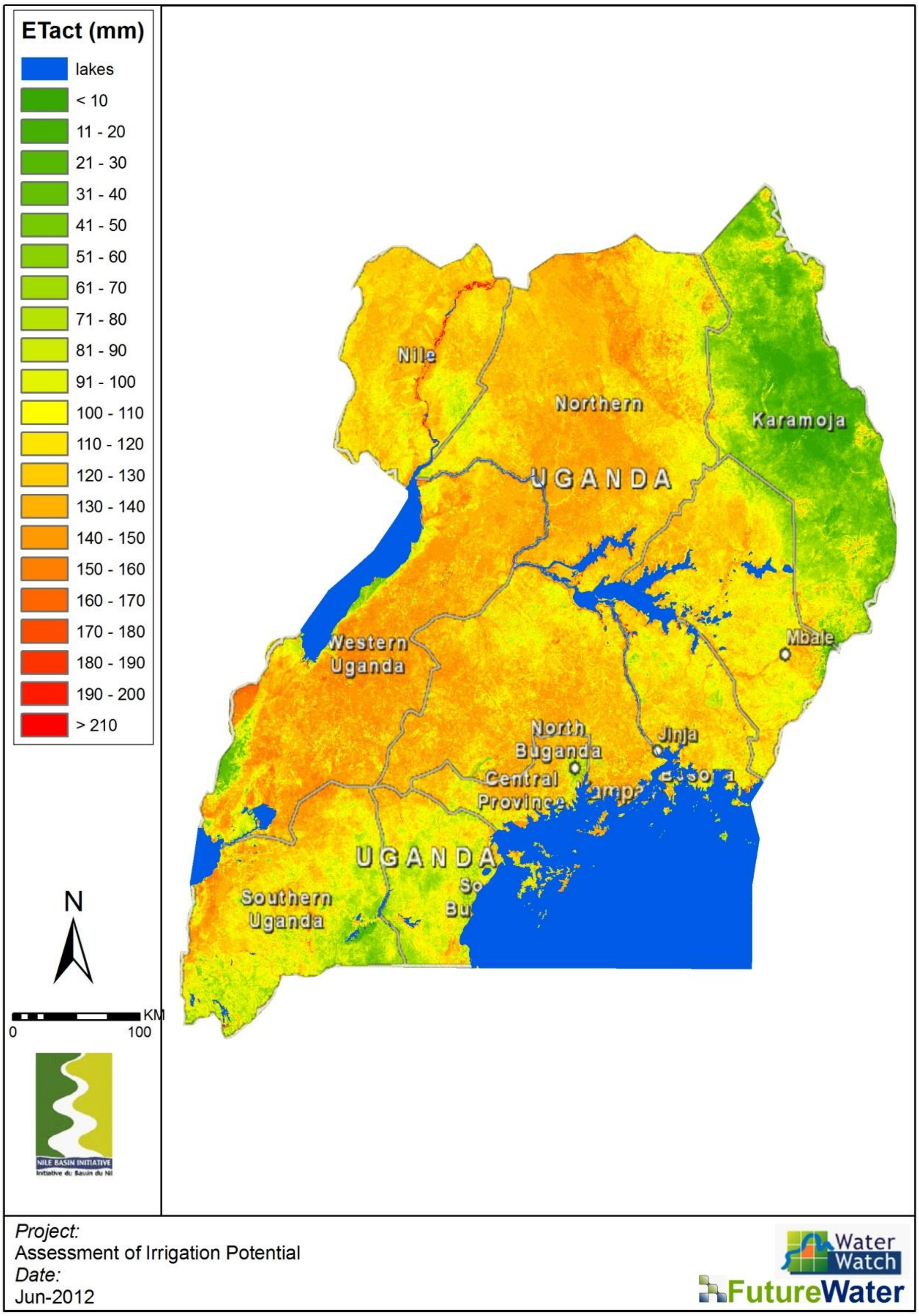
Project:
Assessment of Irrigation Potential
Date:
Jun-2012


ETact (mm)
lakes
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11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
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100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
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Project:
Assessment of Irrigation Potential
Date:
Jun-2012

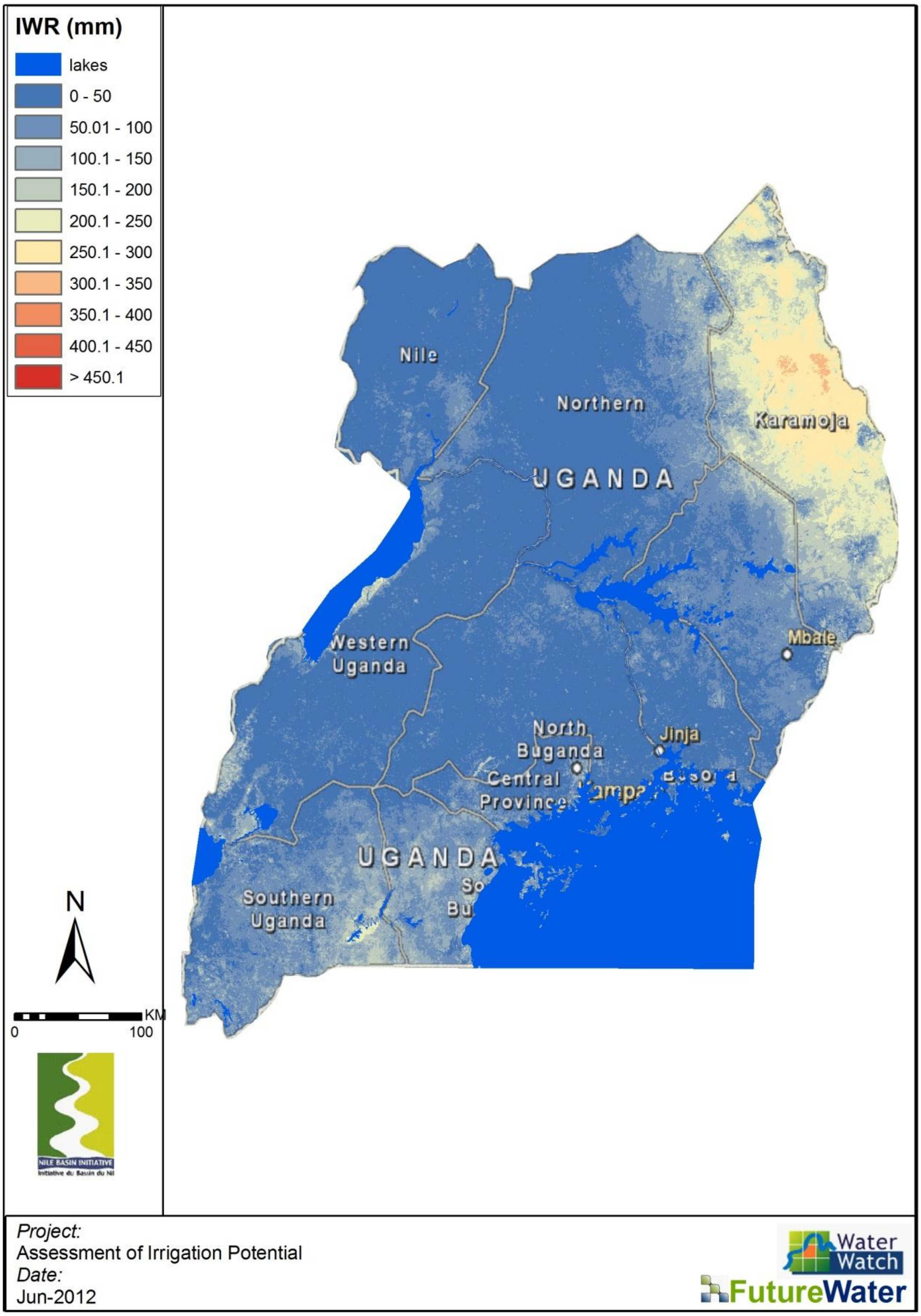
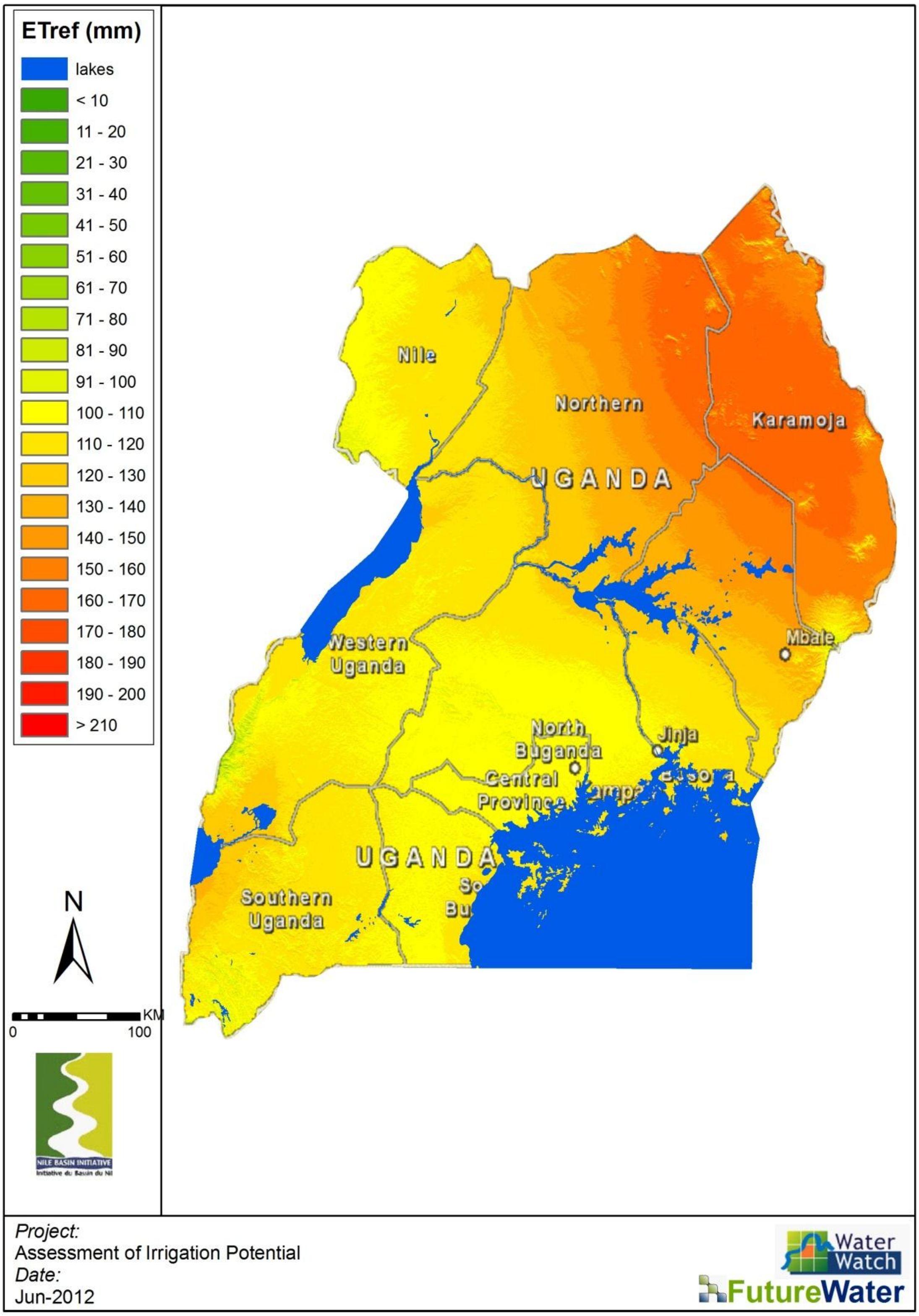


Figure 15: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for October (Average 2001-2010). (Source: study analysis).

November



ETref (mm)
lakes
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11 - 20
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31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
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130 - 140
140 - 150
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160 - 170
170 - 180
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190 - 200
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Western Uganda
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Central Province
UGANDA
Southern Uganda
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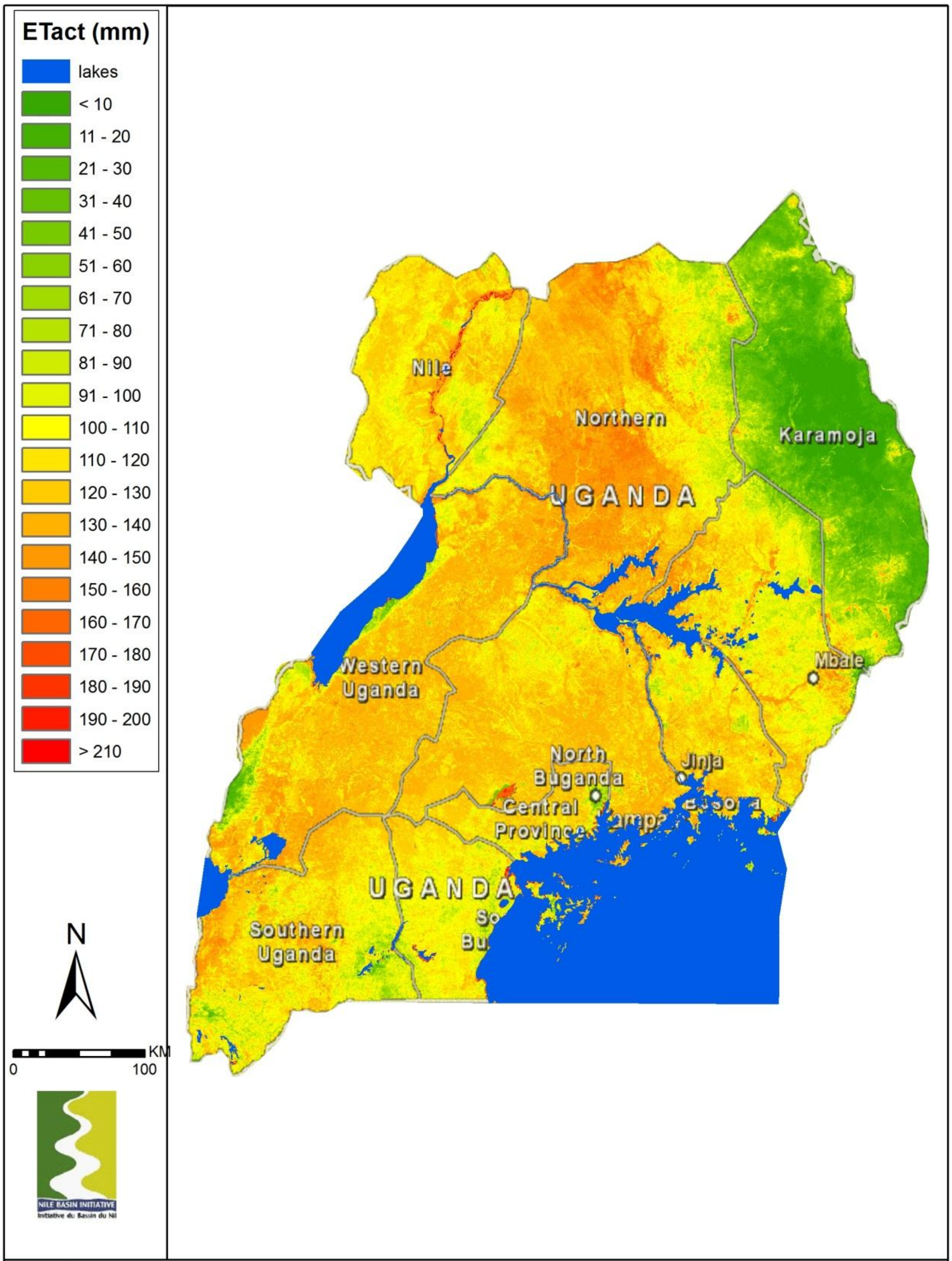
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater



Project:
Assessment of Irrigation Potential
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Water Watch
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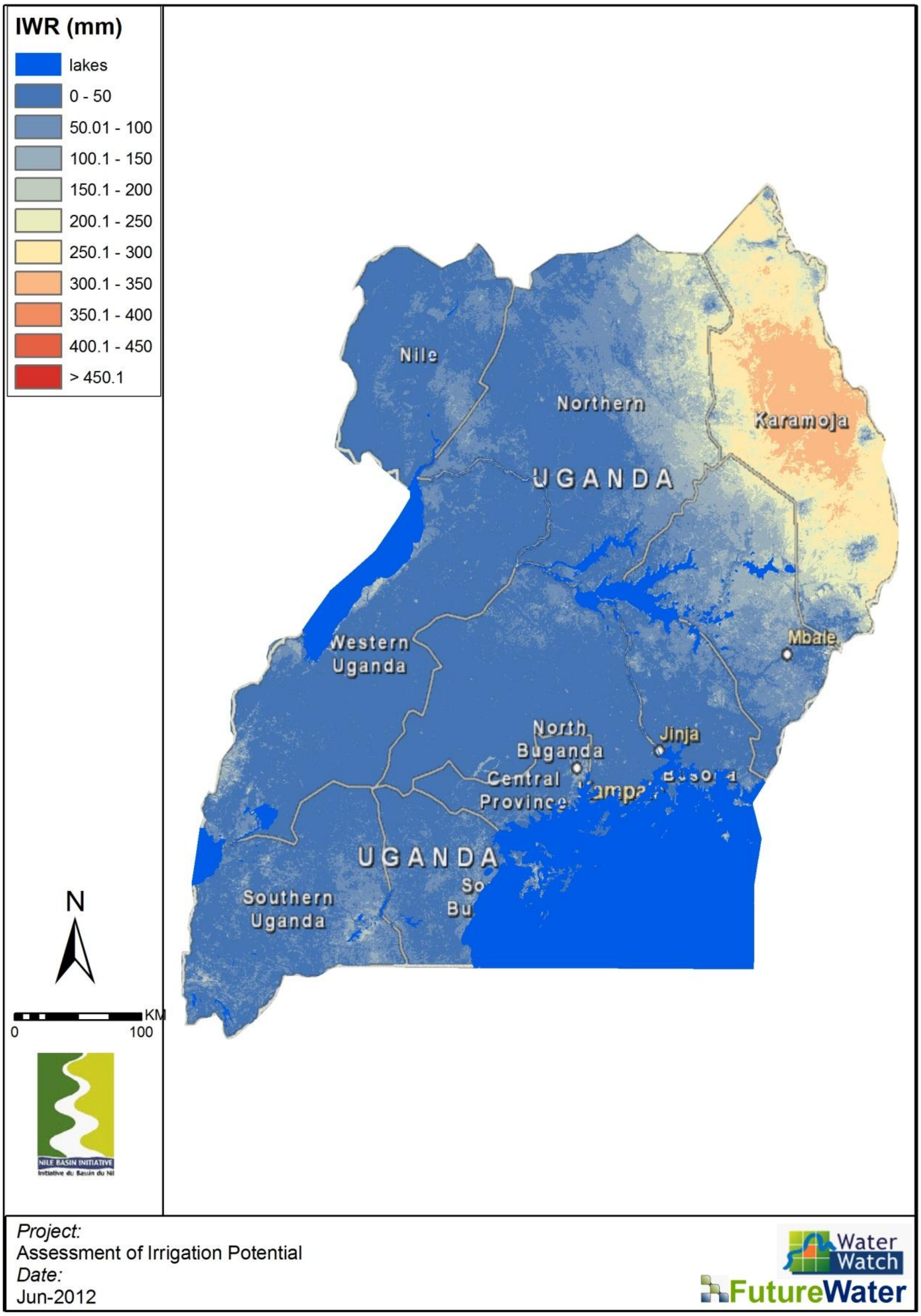
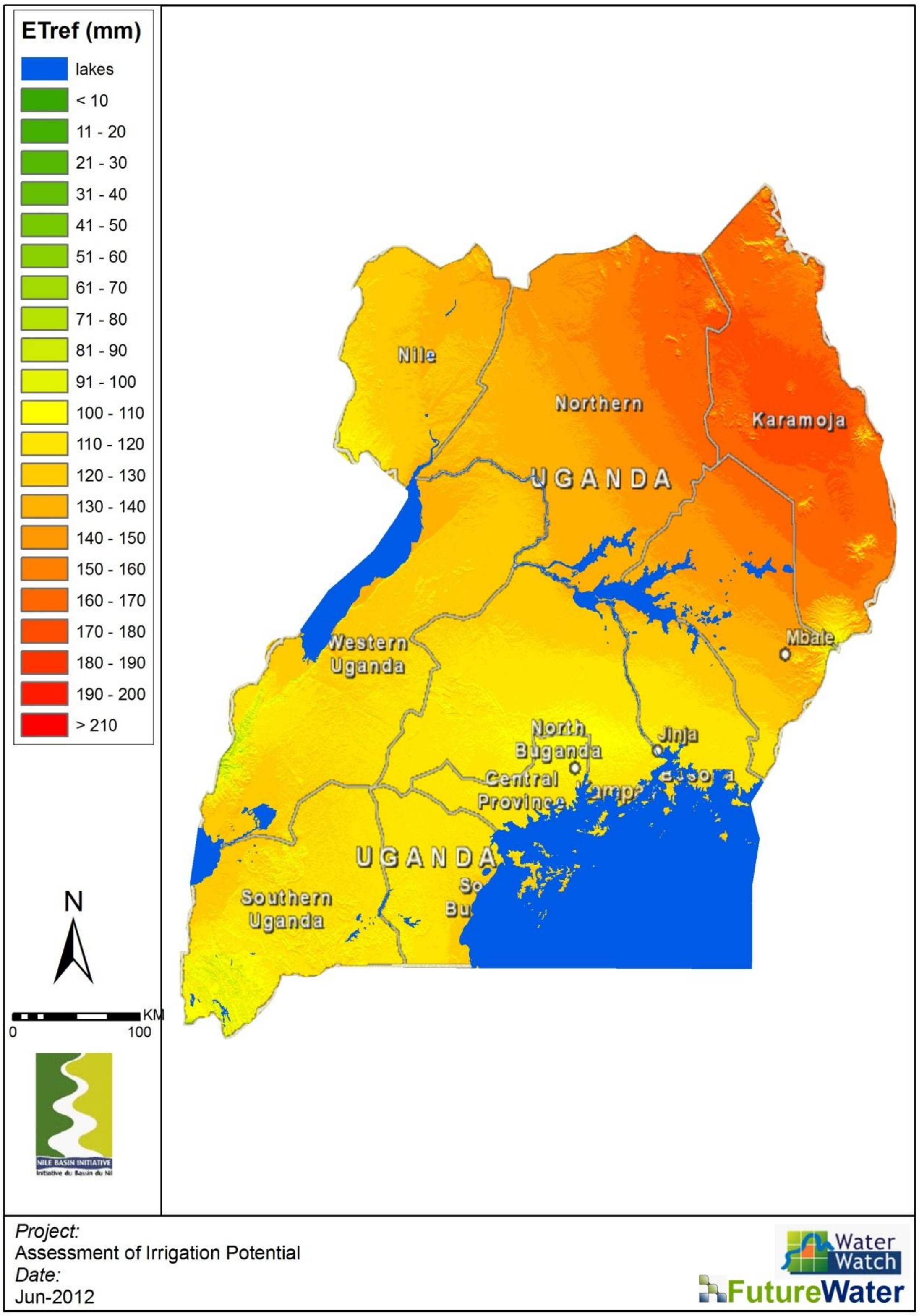


Figure 16: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for November (Average 2001-2010). (Source: study analysis).

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
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Nile
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Karamoja
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Western Uganda
Mbale
North Buganda
Jinja
Central Province
UGANDA
Southern Uganda
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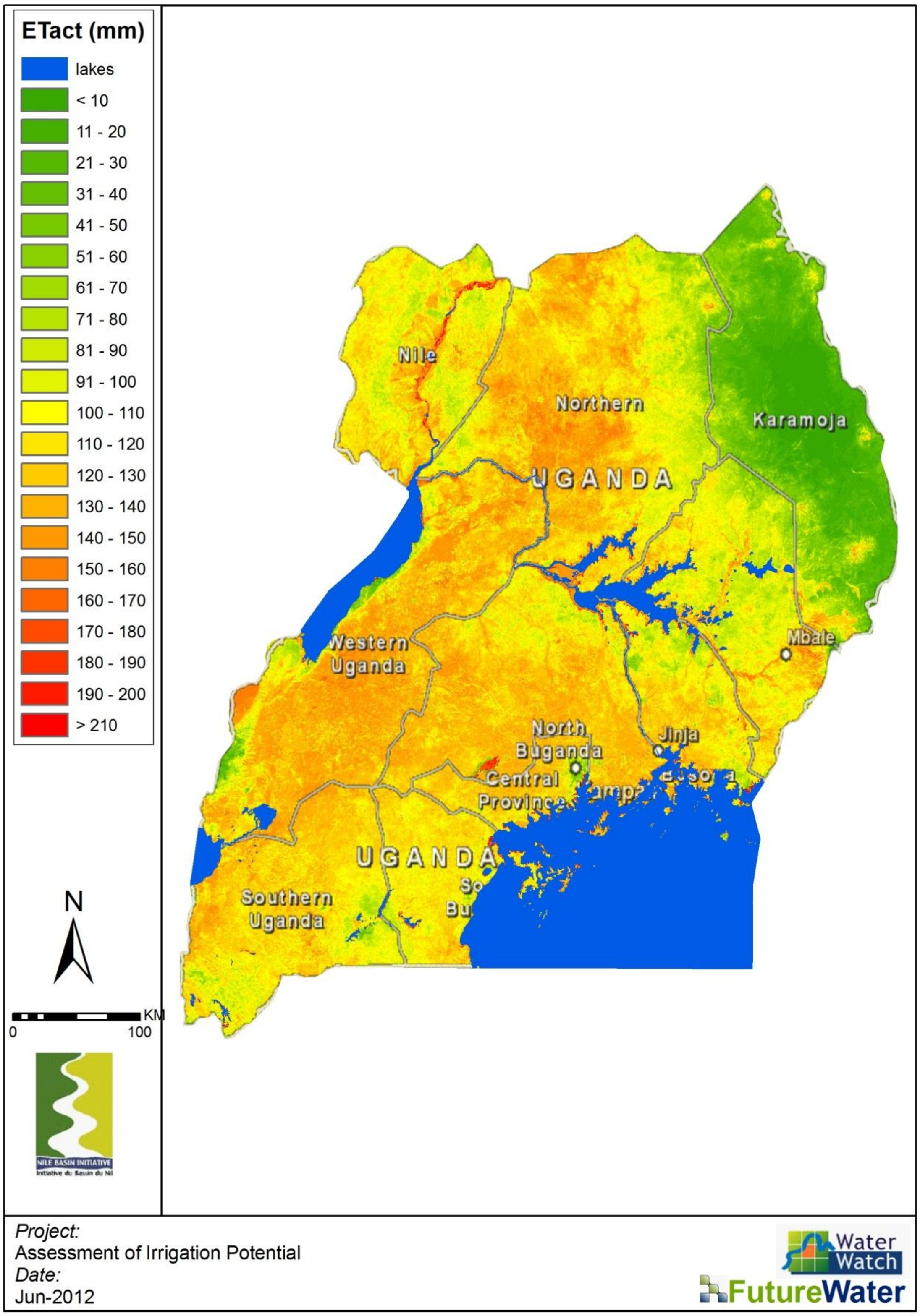
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater



ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
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110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
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Water Watch
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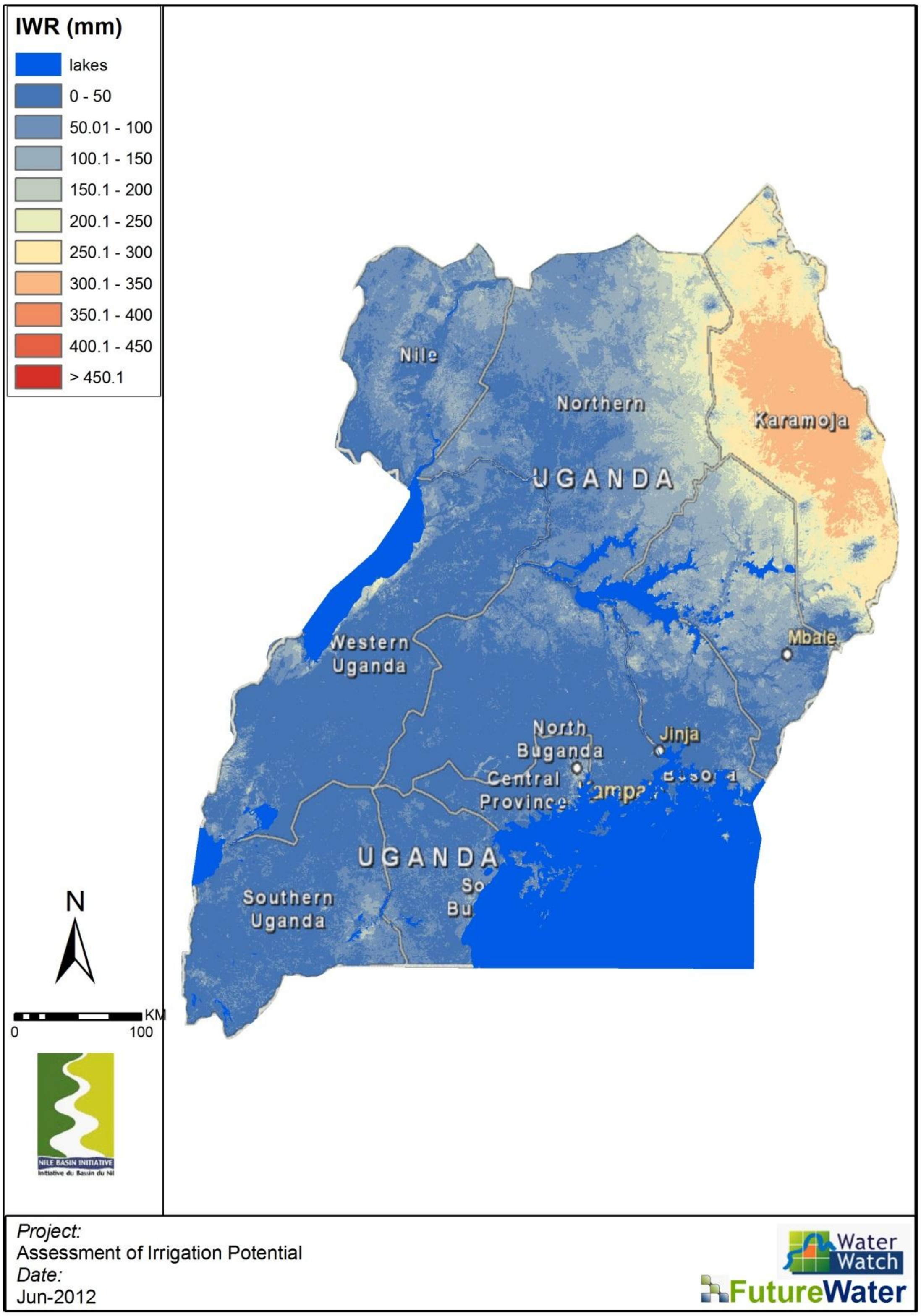


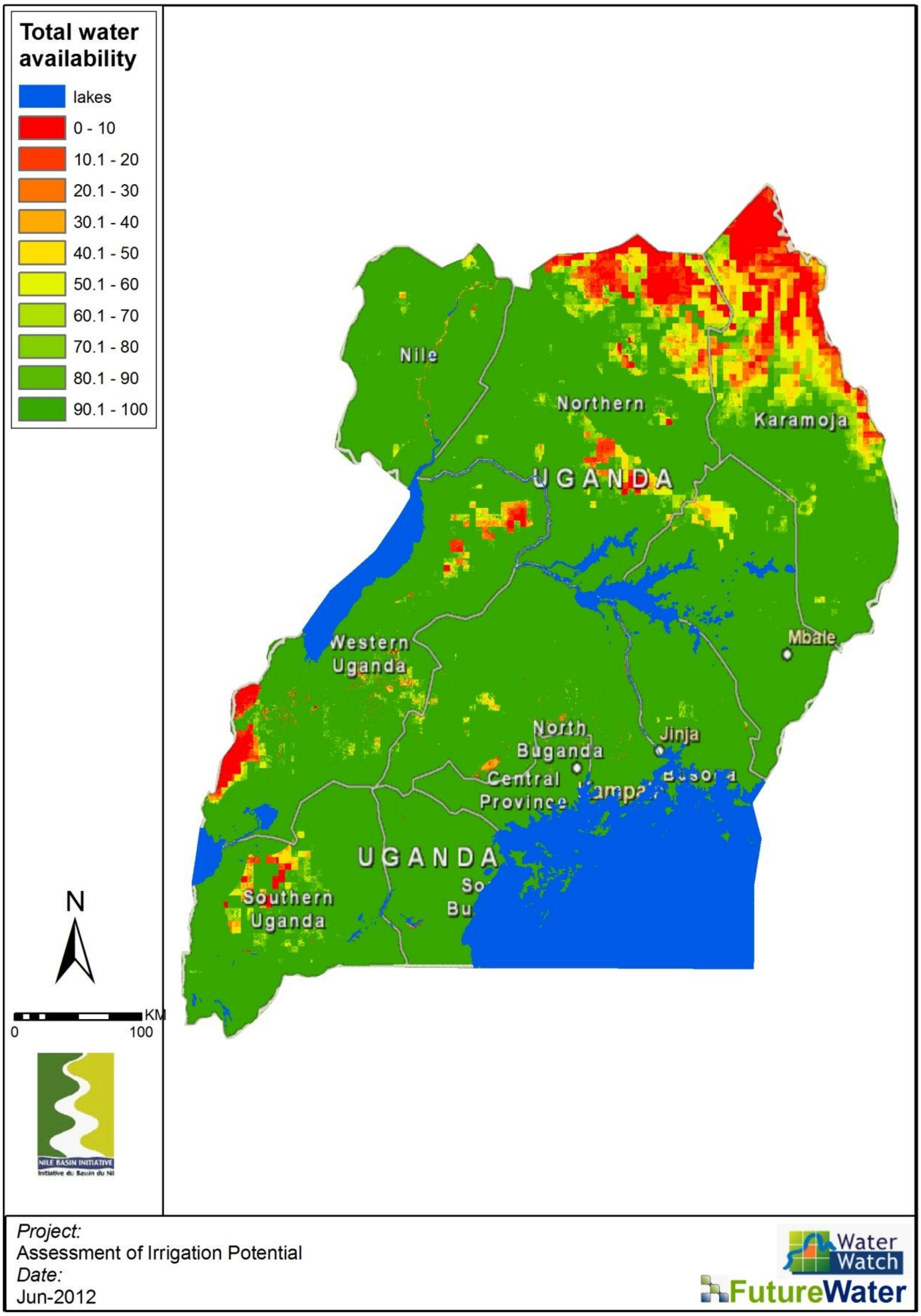
Figure 17: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for December (Average 2001-2010). (Source: study analysis).

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 is available for irrigation in most of the country. 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
N
KM
0
100
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Nile
Northern
Karamoja
UGANDA
Western Uganda
Mbale
North Buganda
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Central Province
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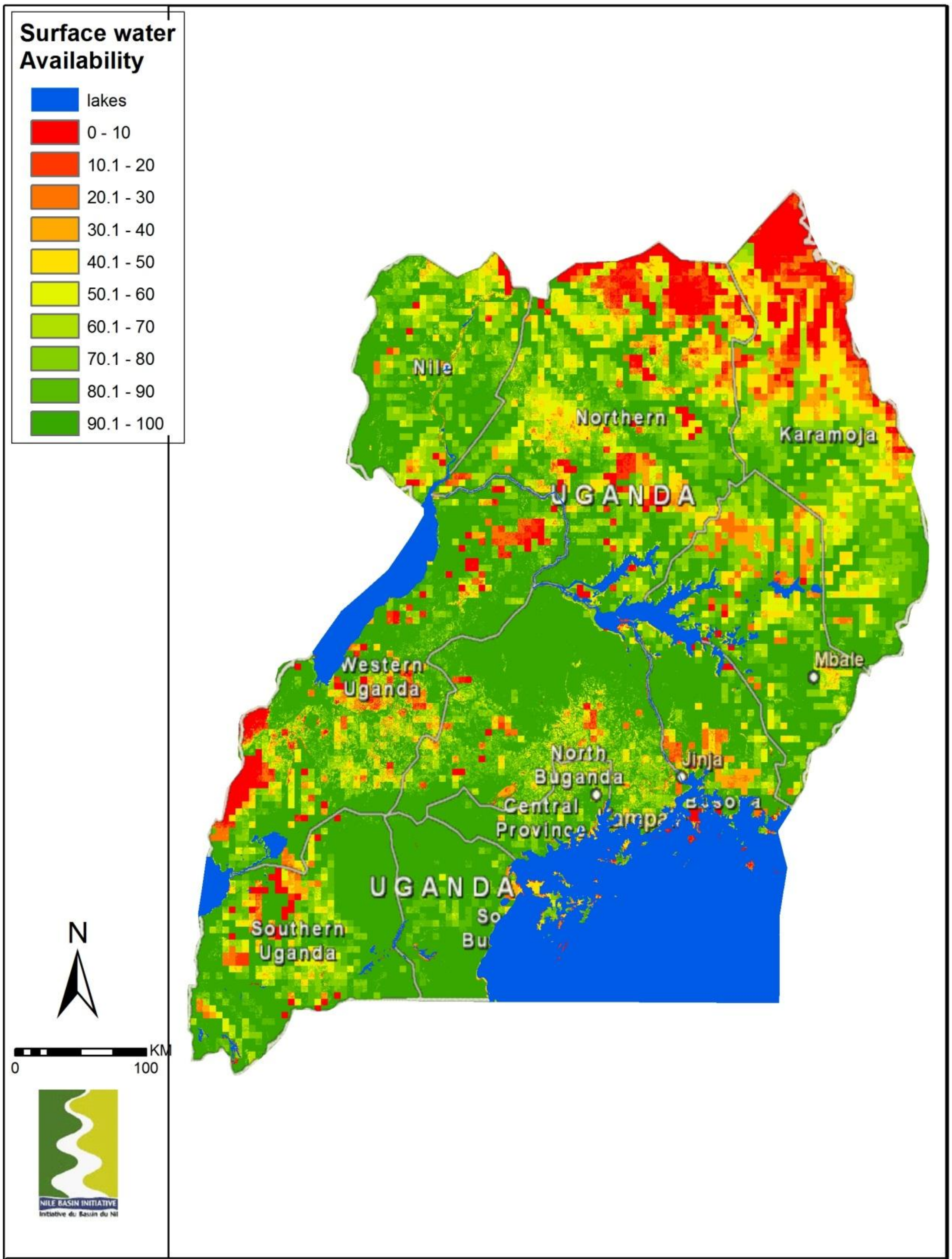
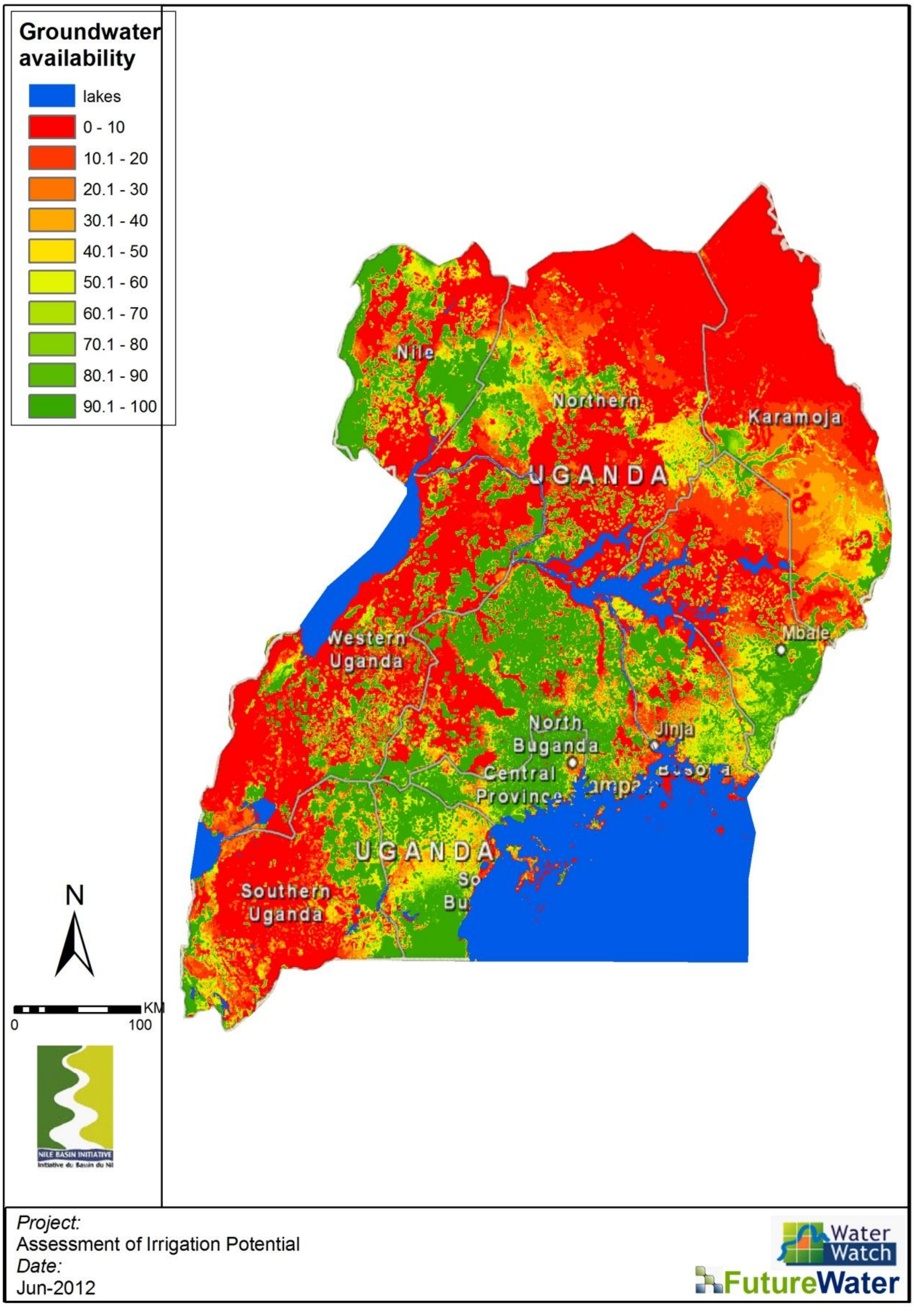
Southern Uganda
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater



Project:
Assessment of Irrigation Potential
Date:
Jun-2012


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
Nile
Northern
Karamoja
UGANDA
Western Uganda
Mbale
North Buganda
Jinja
Central Province
UGANDA
Southern Uganda
N
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NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

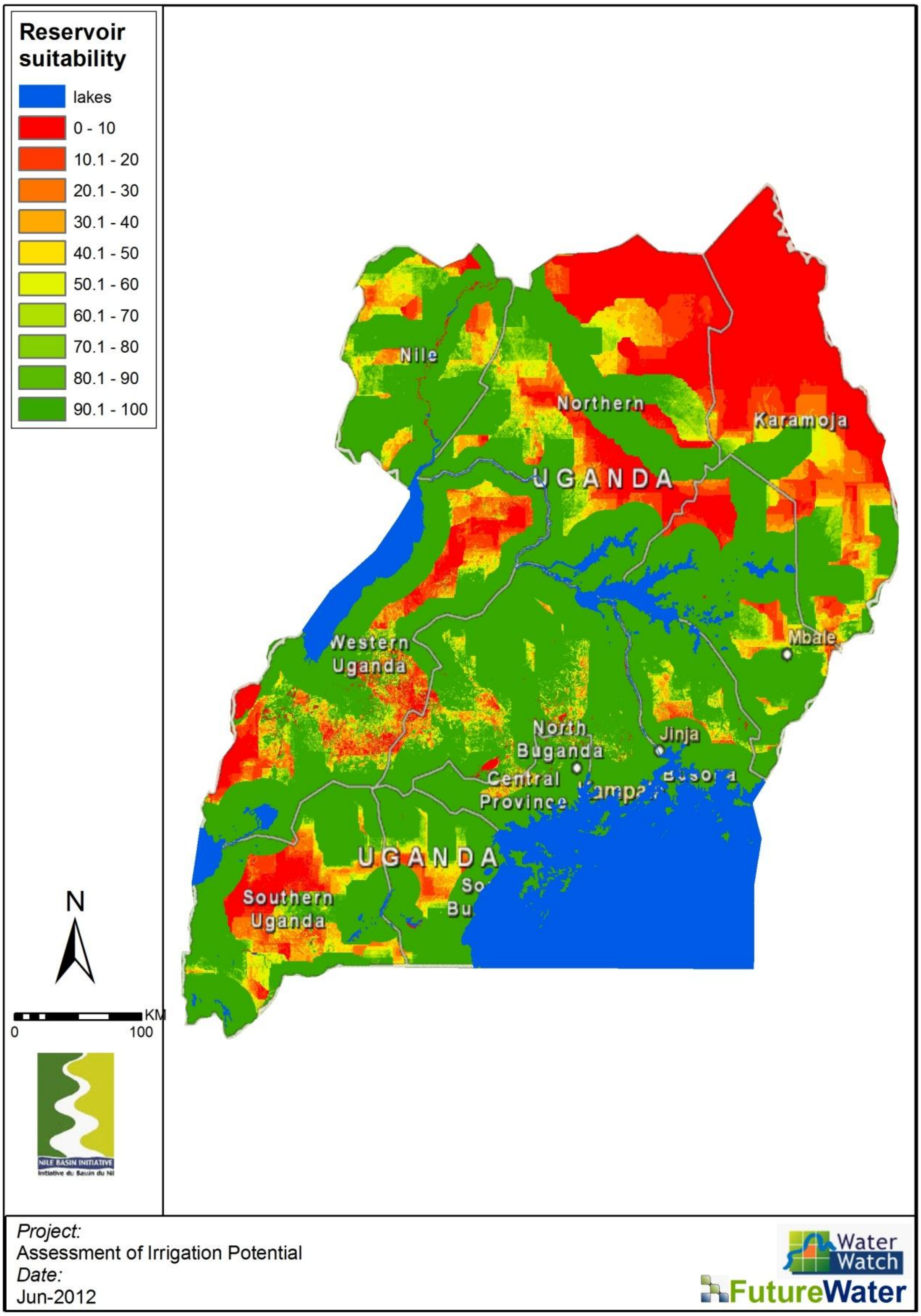


Figure 18: Water availability for irrigation. Total coverage (top), coverage from surface water (second), coverage from ground water (third), and from potential reservoirs (bottom). (Source: study analysis).

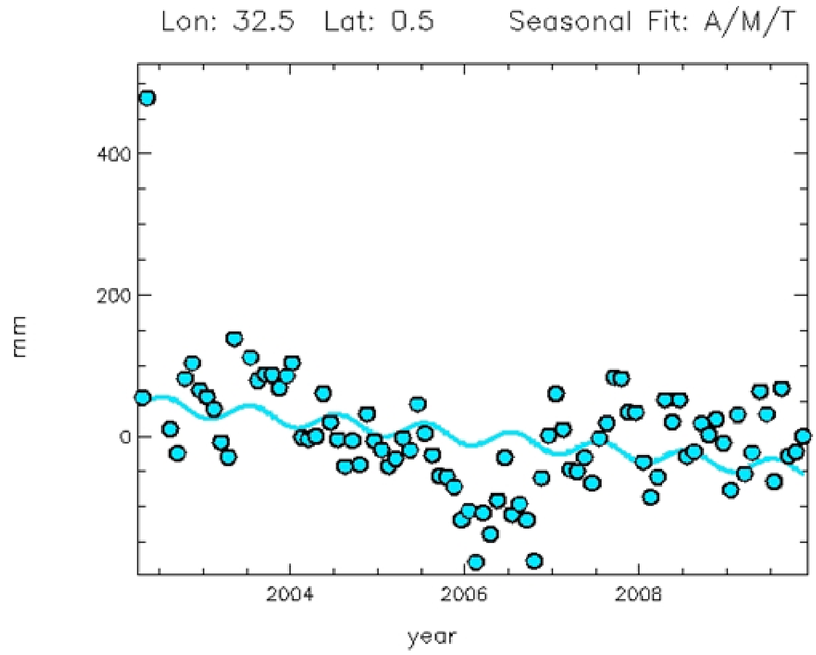


Figure 19: Annual groundwater storage trends for Uganda, based on GRACE satellite observations (Source: UoC, 2011).

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 19. Groundwater recharge has quite some regional differences (Figure 20). Overall, groundwater recharge is highest in the valleys.

Table 4.5 Uganda's Water Resources Potential (WfP-SIP 2009)

	Water availability (mill m3/year)			
Region	**Rivers**	**Lakes**	**Ground water**	**Runoff**
Central	2,504	10,600	588	9,365
Eastern	1,956	15,200	303	7,775
Northern	4,926	4,600	1,265	12,075
Western	3,210	7,700	1,189	11,753

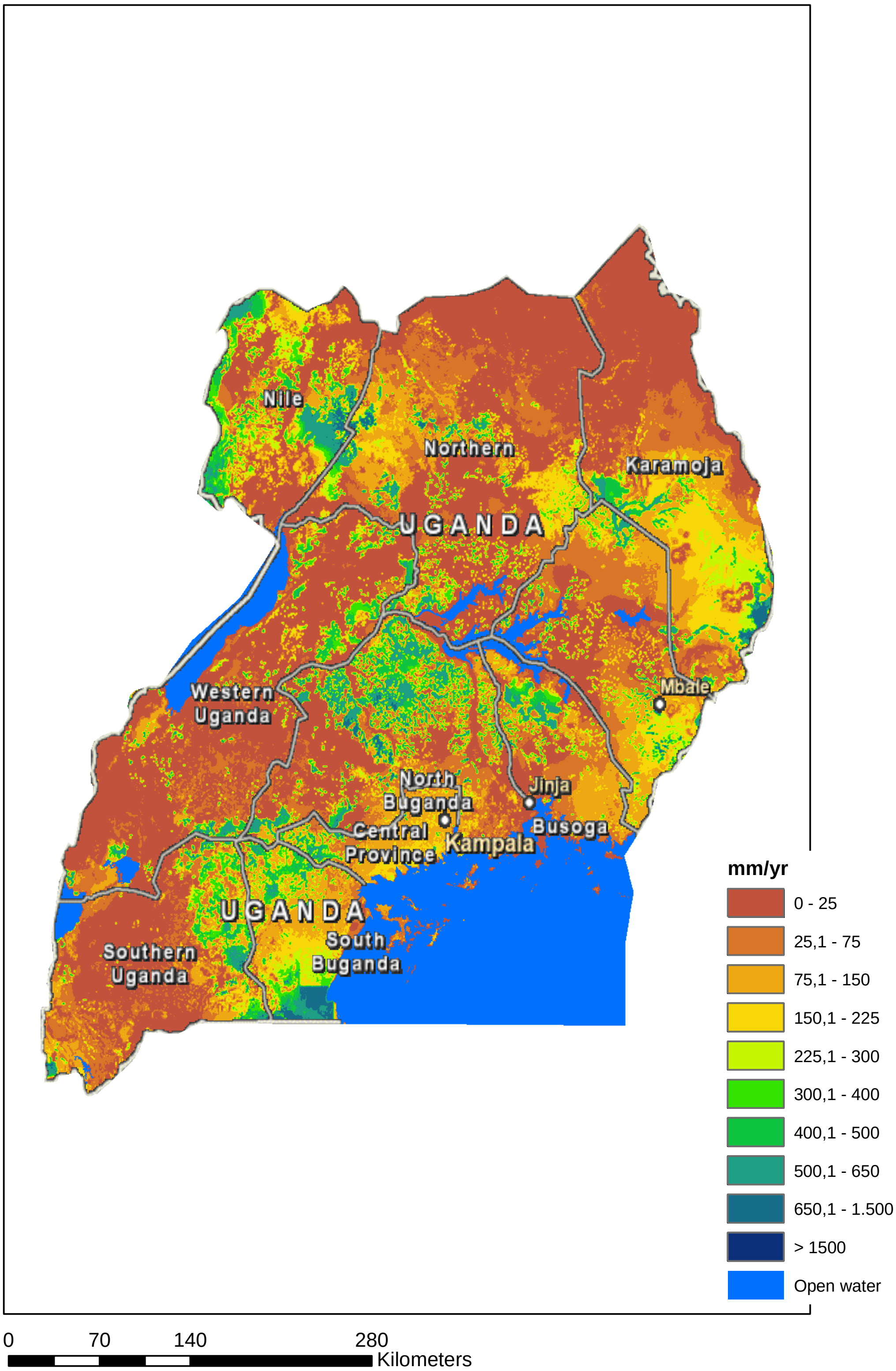
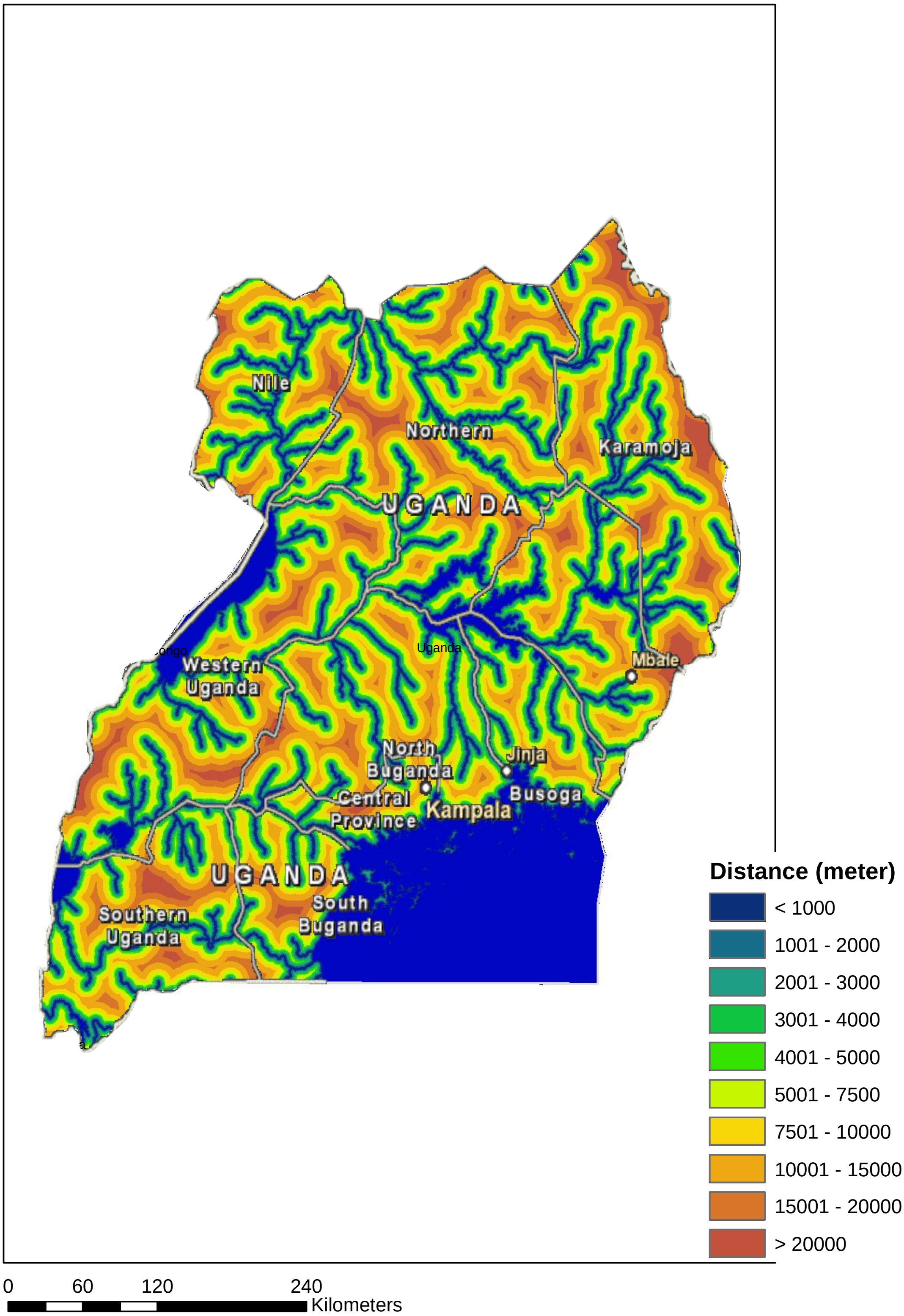
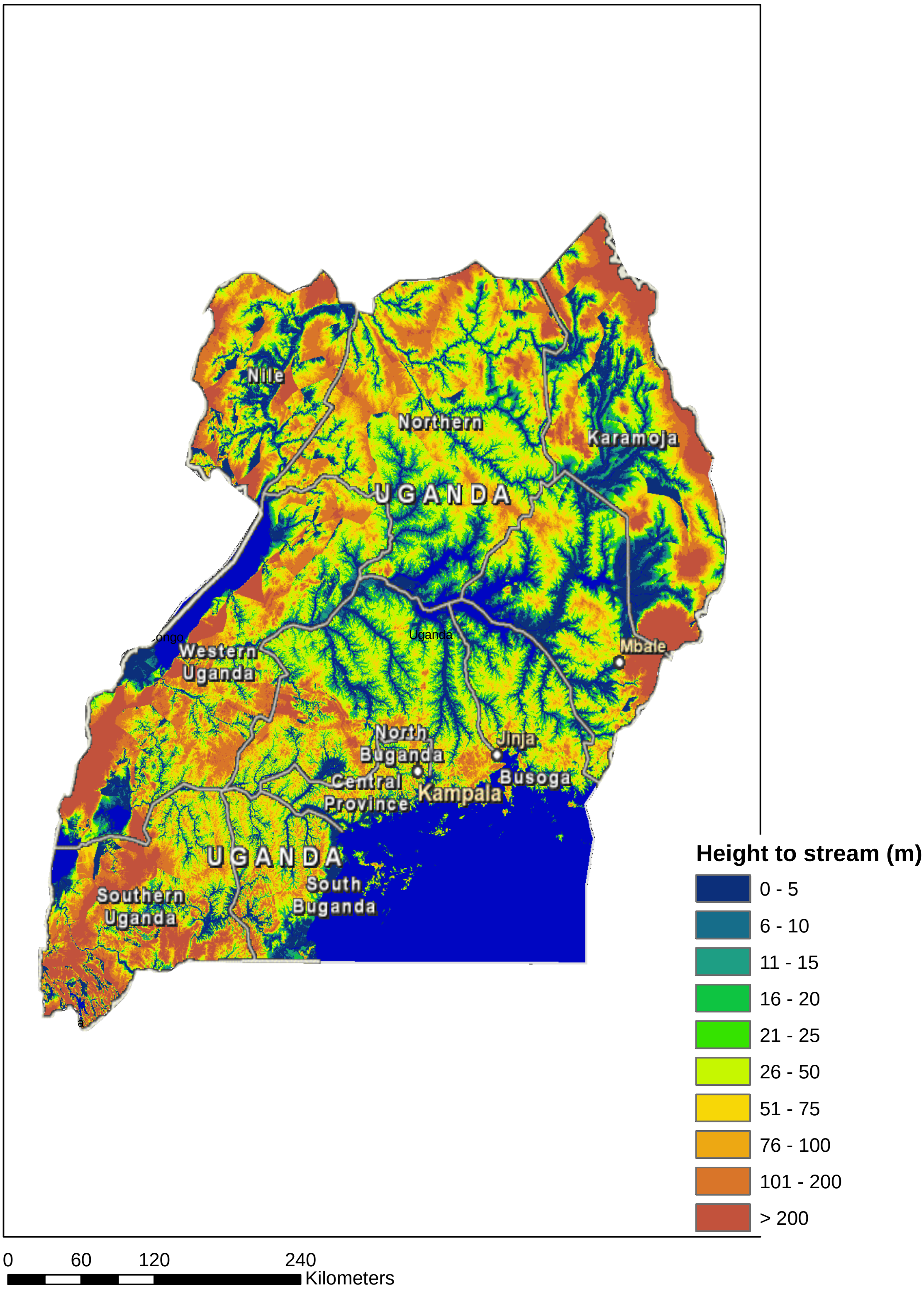


Figure 20: Annual groundwater recharge based on NELmod.

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).




Nile
Northern
Karamoja
UGANDA
Western Uganda
Uganda
Mbale
North Buganda
Jinja
Central Province
Kampala
Busoga
UGANDA
South Buganda
Southern Uganda
Height to stream (m)
0 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 50
51 - 75
76 - 100
101 - 200
> 200
0
60
120
240
Kilometers

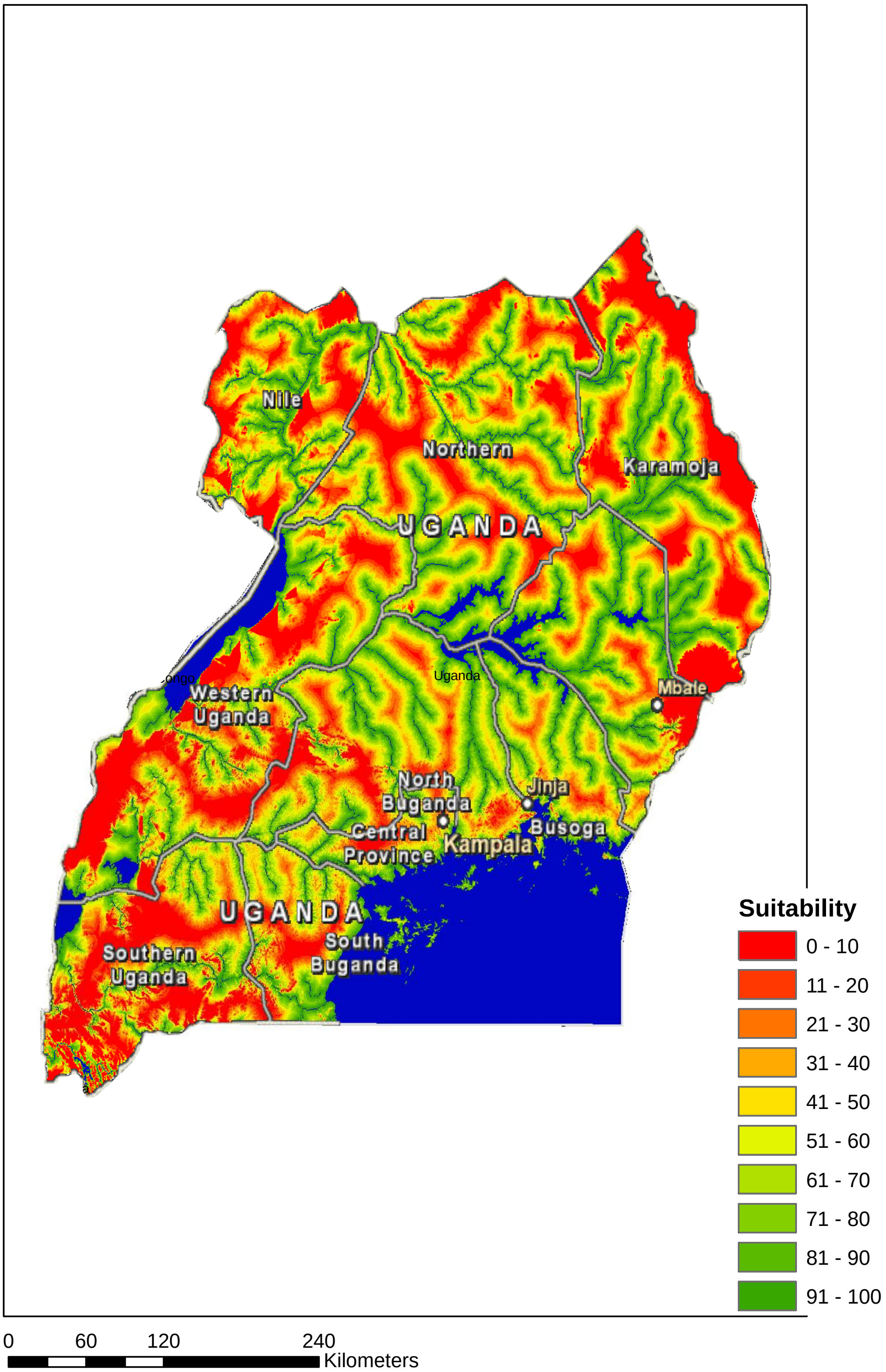


Figure 21: Average distance to a natural stream, lake or reservoir (top), elevation above natural stream, lake or reservoir (middle), and access to water suitability score (bottom). (Source: study analysis).

2.3 Land use

2.3.1 Current land use

Actual land cover based on AfriCover is shown in Figure 22. Distribution of irrigated and rainfed crops are shown in Figure 23. Specific maps for 26 crops are included in the database attached to the report.

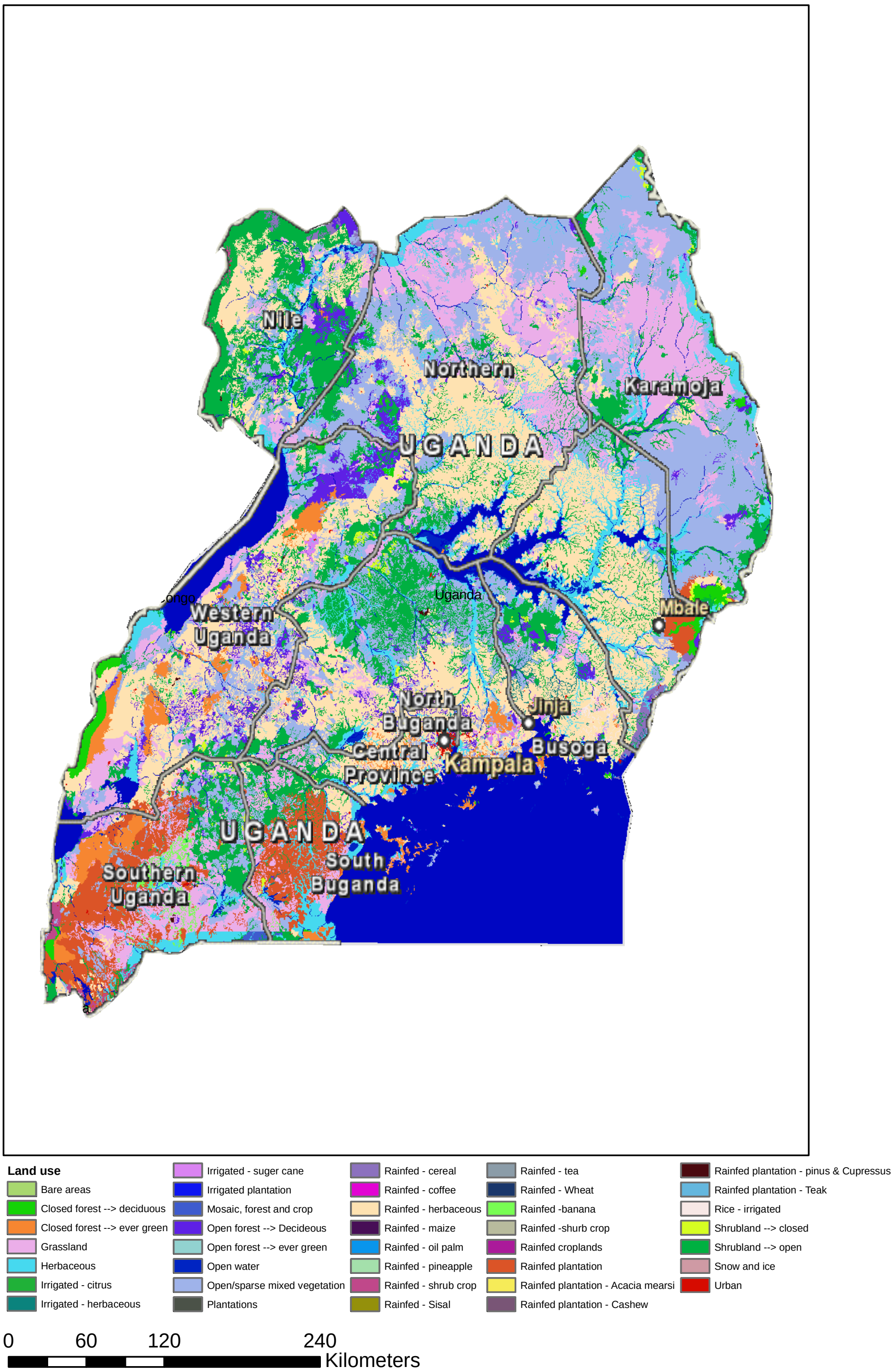
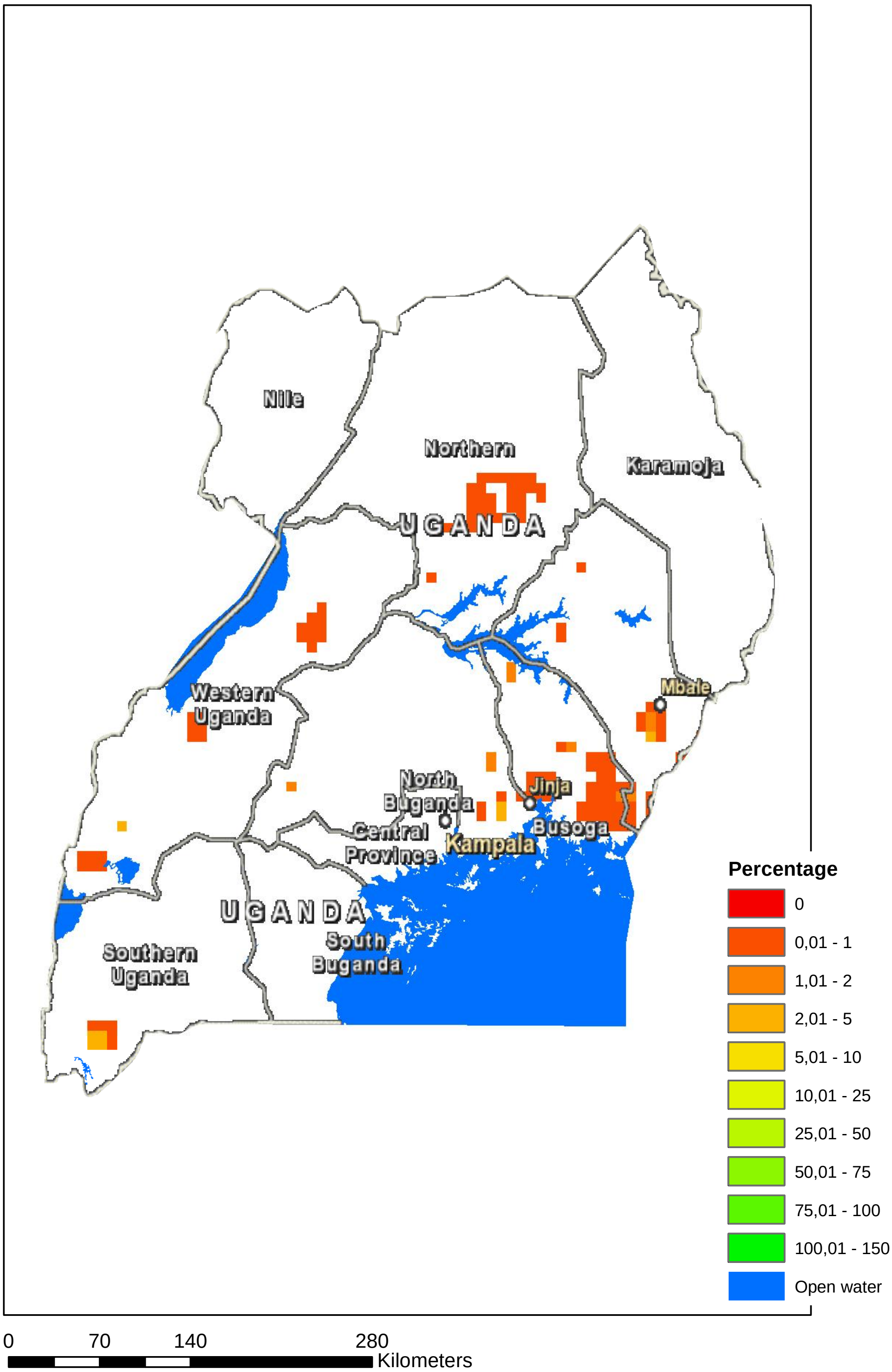


Figure 22: Land use in Uganda, based on AfriCover.


Nile
Northern
Karamoja
UGANDA
Western Uganda
Mbale
North Buganda
Jinja
Central Province
Kampala
Busoga
UGANDA
South Buganda
Southern Uganda
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 70 140 280
Kilometers

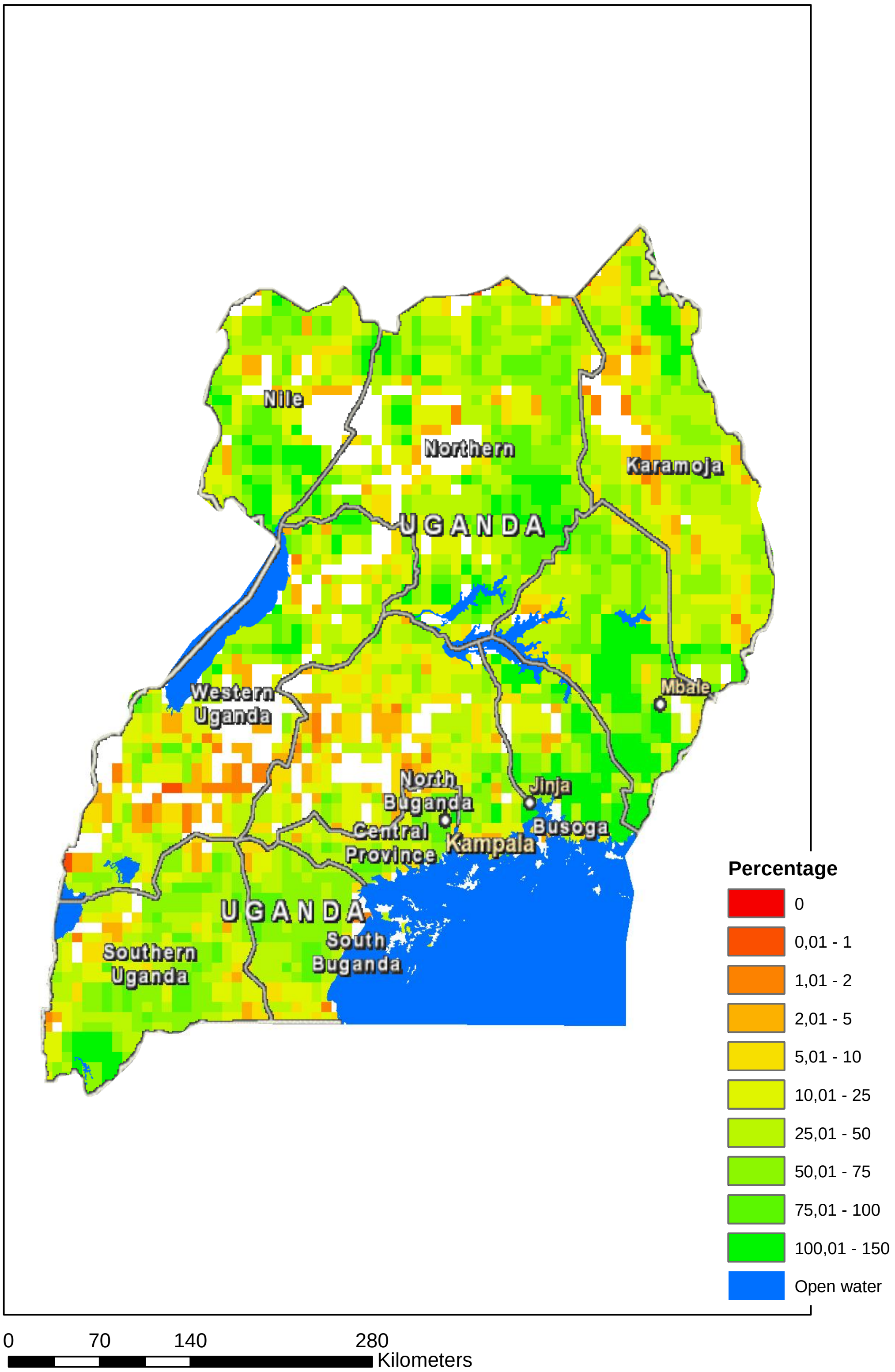


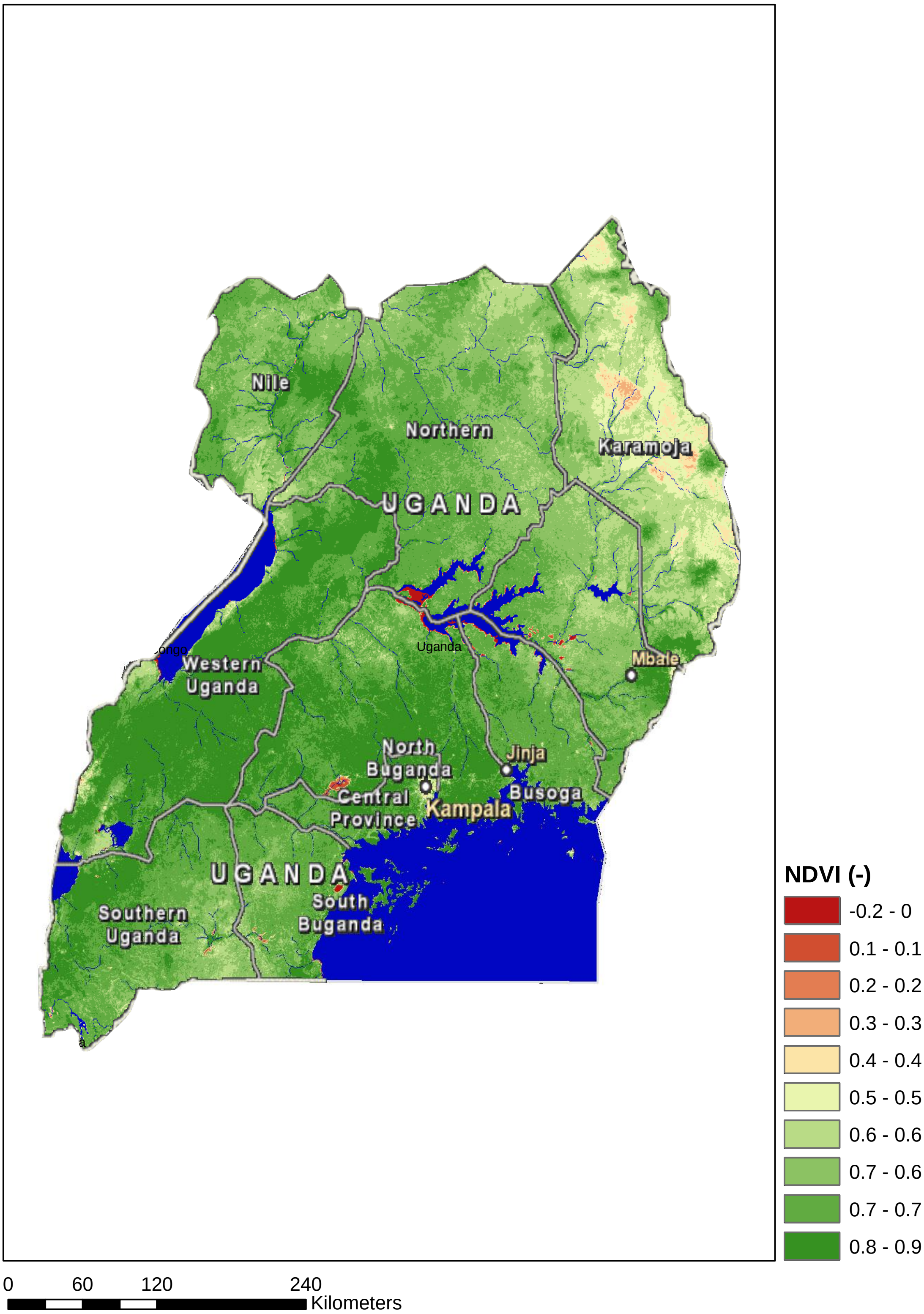
Figure 23. Irrigated (left) and rainfed cropping intensities[1] (right) as percentage of cells of about 10 x 10 km (Source: Mirca2000).

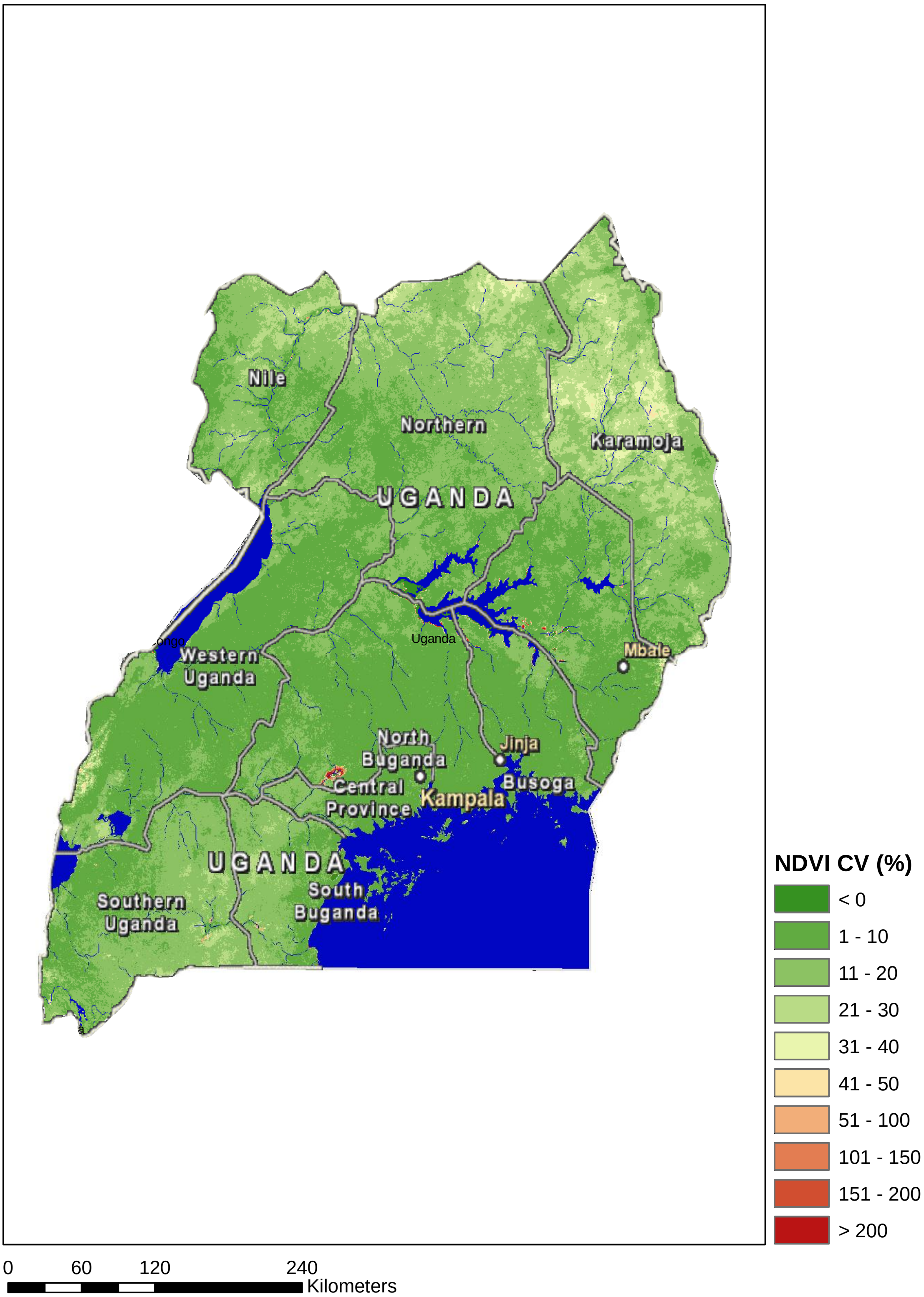
---

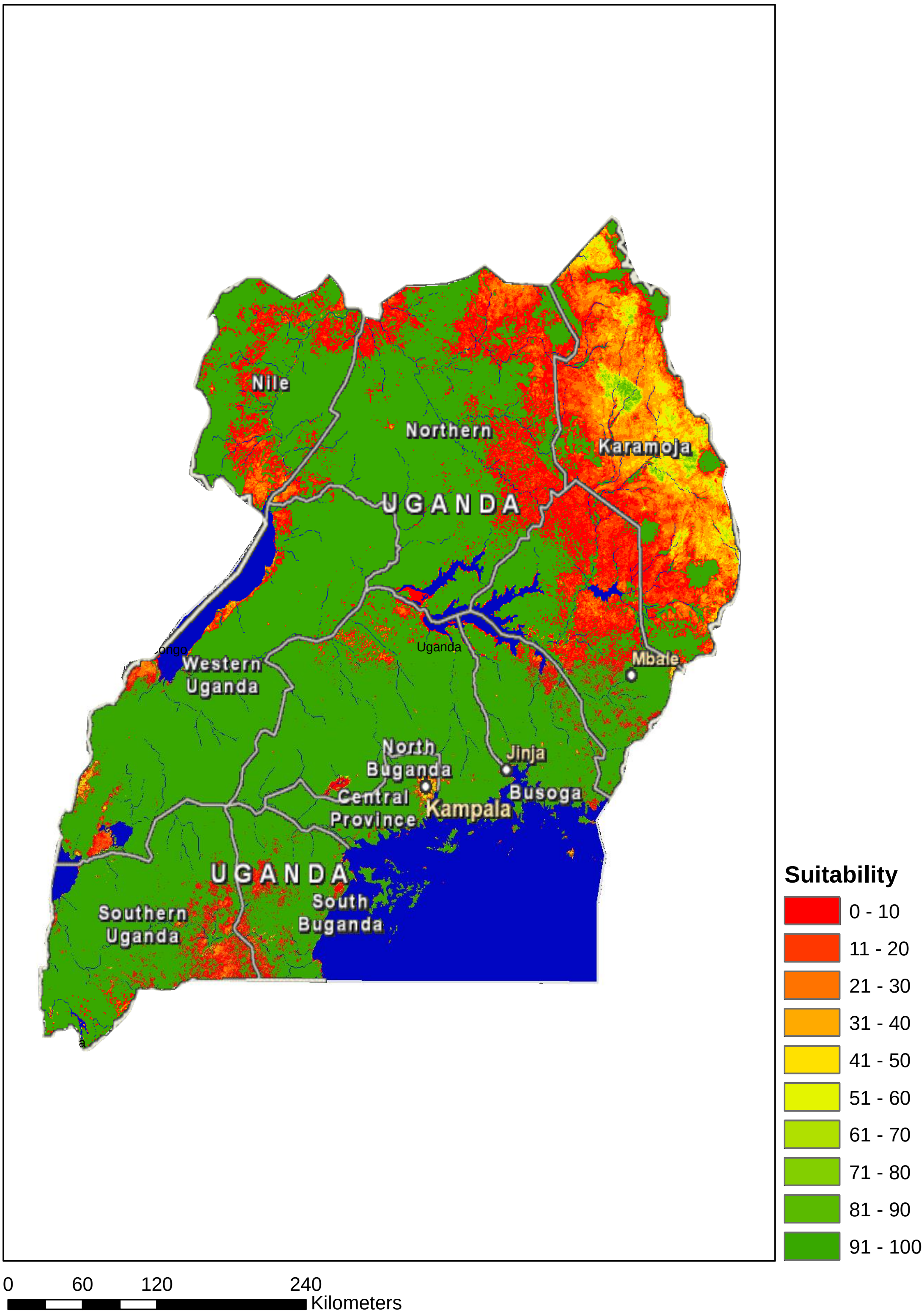
[1] Percentages can be above 100% as multiple cropping season might exist in one year.

2.3.2 *Current land productivity*

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.




Nile
Northern
Karamoja
UGANDA
Western Uganda
Uganda
Mbale
North Buganda
Jinja
Central Province
Kampala
Busoga
UGANDA
South Buganda
Southern Uganda
NDVI CV (%)
< 0
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 100
101 - 150
151 - 200
> 200
0
60
120
240
Kilometers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Province
Kampala
Busoga
UGANDA
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Uganda
South
Buganda
Suitability
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
0
60
120
240
Kilometers

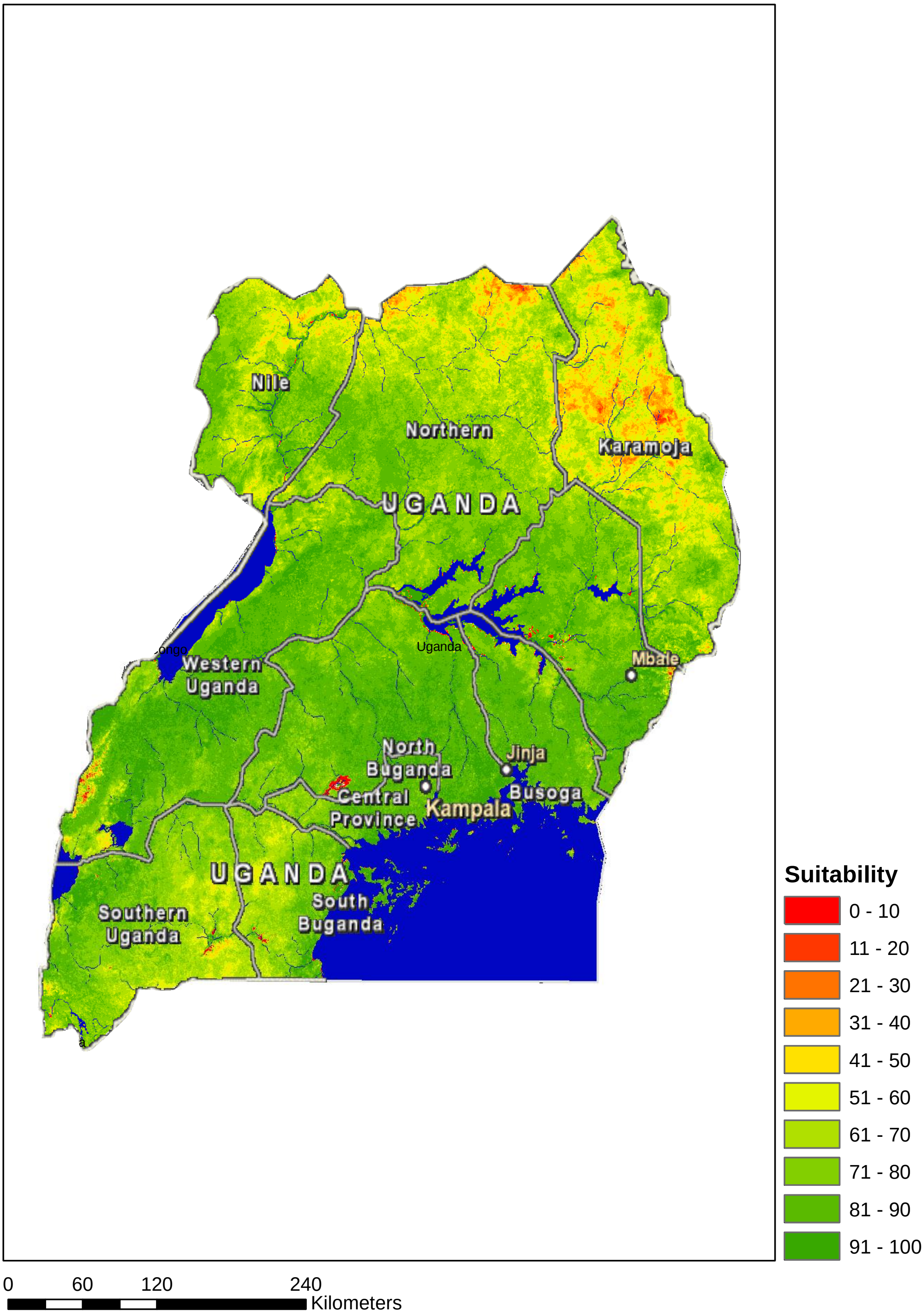


Figure 24: Current land productivity based on NDVI. Average NDVI (top), average monthly coefficient of variation (second), and the land productivity scores based on average NDVI (third) and monthly coefficient of variation (bottom). (Source: study analysis).

2.4 Agriculture

2.4.1 Background

The agricultural system in Uganda is based on the agro-ecological zones as mentioned previously. Between 1999/2000 and 2005/2006, the production trends of the major crops are inconsistent. Positive increases were recorded for cereals (maize, millet, rice and sorghum), beans and simsim, while significant declines were noted for root crops (cassava, Irish and sweet potatoes) and export crops (cotton and coffee).

Due to the fact that farmers can produce at least one crop or two per year using rain fed agriculture, irrigation development is rather low in Uganda although the need for irrigation is becoming increasingly serious due to unreliable rainfall and the effect of global warming.

2.4.2 Irrigation

Uganda is working on completing their Irrigation Master Plan as part of the current National Development Plan. Uganda considers irrigation as an important development path and the IMP mentions that the Overall Sector Objective is “Poverty Alleviation and Economic Growth as a result of the sustainable realisation of the country’s irrigation potential”.

The Irrigation Master Plans presents an estimate of Uganda’s irrigation potential in terms of land (around 570,000 ha made up of some 295,000 ha of easily irrigated “Type A” land situated close to reliable water resources and 275,00 ha of “Type B” land requiring storage and/or significant conveyance systems. The same section also concludes that full development of all this potential would have minimal effect on basin level water budgets. Markets are also considered once again before the section closes by concluding that a meaningful FMP would have to include several crop categories in order fully to respond to its objectives: food, industrial, seasonal, perennial, staple food, high value, upland and lowland.

Table 1: Area equipped for irrigation in Uganda according to FAO-Aquastat, 2010).

Uganda	ha
1965	3,000
1975	4,000
1985	9,000
1995	9,000
2005	9,000

2.4.3 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. 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.

Uganda's analysis shows a relatively stable yield development. Although agricultural area has developed over the last 20 years, the yields of the five dominant crops stick around the 1979 level. Except for dry Beans which yield has decreased since 1990 until 70% of the 1979 level. The largest yield gap can be observed for sweet potatoes and plantain, for which both neighboring countries, Kenya and Sudan/Rwanda have a higher yield. These yields should be doubled to reach the same level as neighboring countries. The yield gap is smallest for Millet, for which the current yield is higher than surrounding countries.

Table 2: Area harvested in ha for the 10 most dominant crops (FAOstat, 2010).

	1980	1990	2000	2005	2009
Plantains	1.173.000	1.388.000	1.598.000	1.675.000	1.682.000
Beans, dry	224.000	494.915	699.000	828.000	925.000
Maize	258.000	401.000	629.000	780.000	887.000
Sweet potatoes	231.000	412.835	555.000	590.000	609.000
Millet	279.000	373.000	384.000	420.000	460.000
Cassava	302.000	412.000	401.000	387.000	411.000
Sorghum	167.000	240.000	280.000	294.000	329.000
Coffee, green	224.000	270.000	300.991	263.000	320.000
Sesame seed	65.000	124.000	194.000	268.000	292.000
Groundnuts, with shell	95.000	186.000	199.000	225.000	253.000
Total	3.018.000	4.301.750	5.239.991	5.730.000	6.168.000

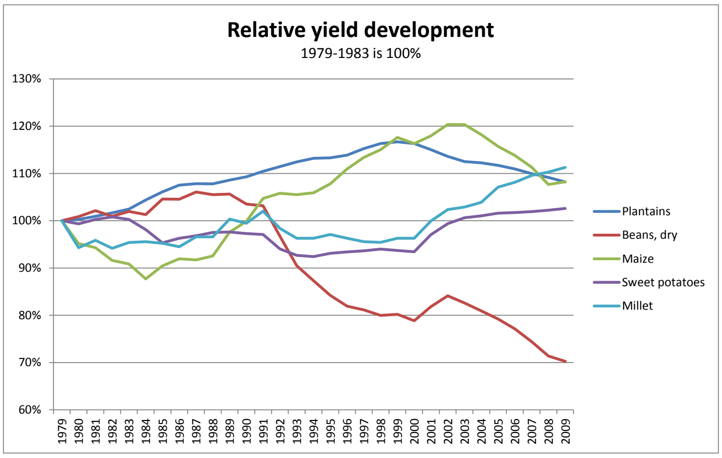


Figure 25: Yield per ha, development for the 5 most dominant crops (FAOstat, 2010)

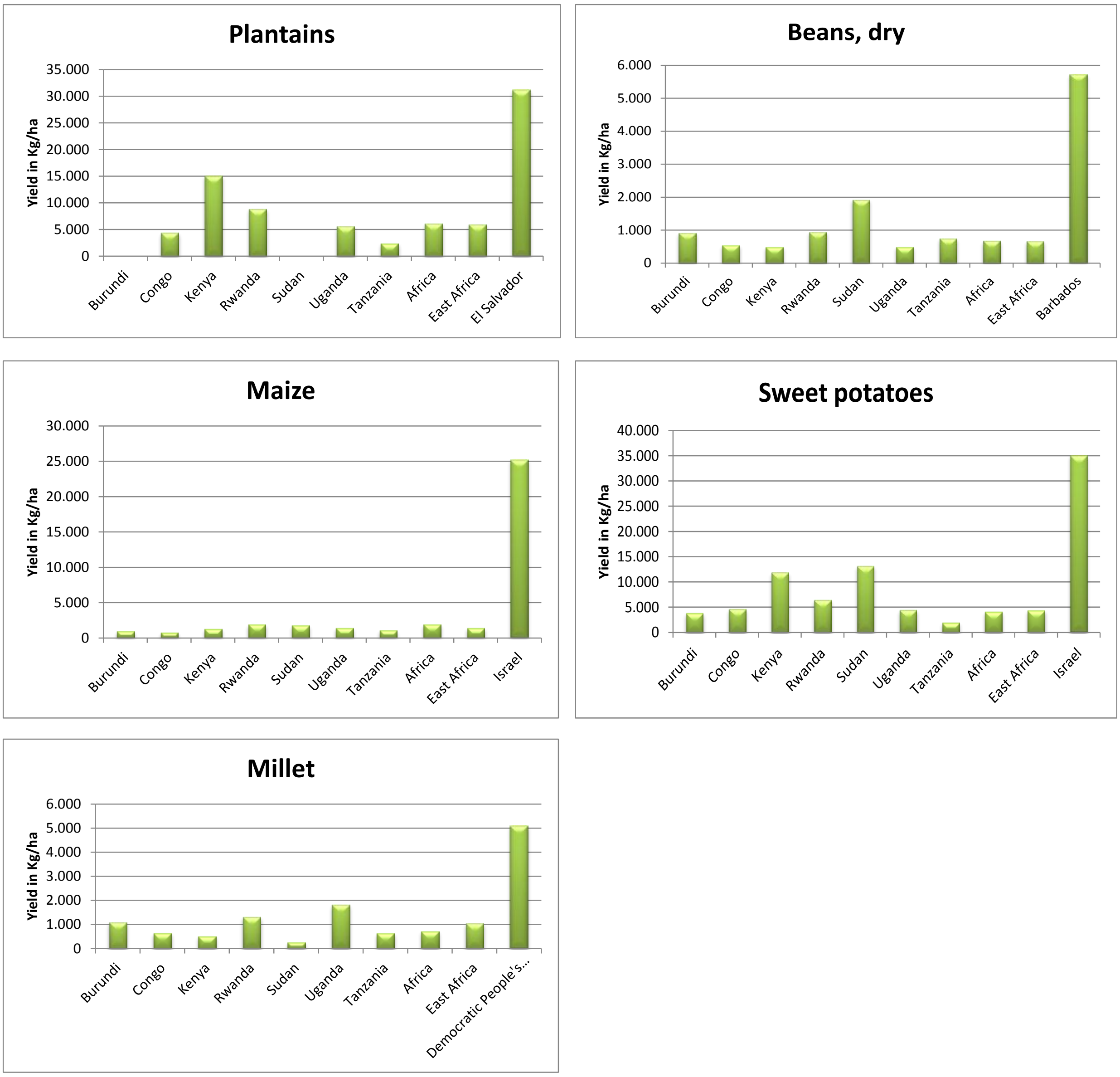
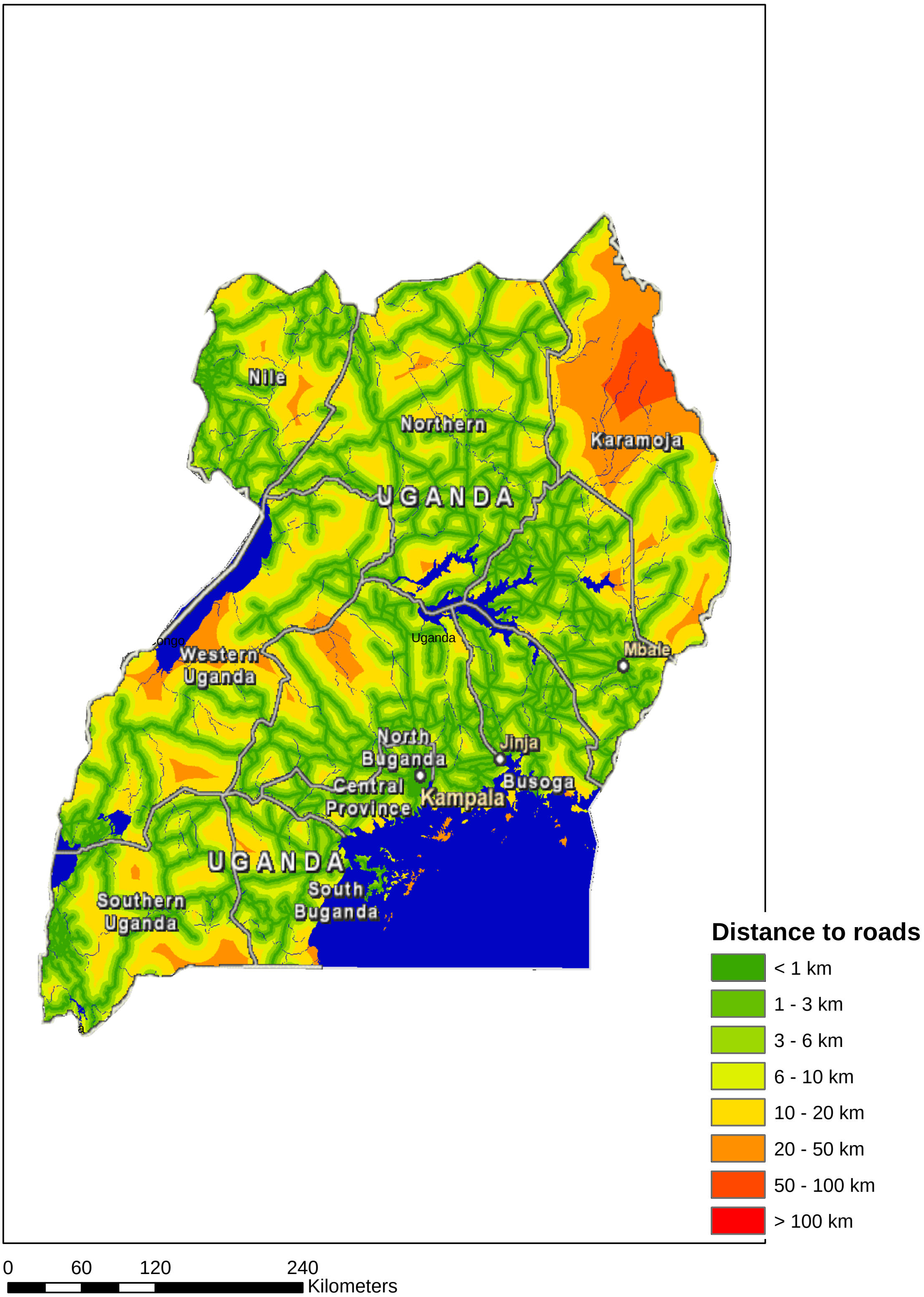


Figure 26: Regional and global yield gap: yield in Kg/ha in 2009 for the five most dominant crops (FAOstat, 2010).

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). Uganda has a relatively dense transportation network, only in north eastern part and some smaller areas towards the west the coverage is somewhat poor (Figure 27).


Nile
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Uganda
Western
Uganda
Mbale
North
Buganda
Jinja
Central
Province
Kampala
Busoga
UGANDA
South
Buganda
Southern
Uganda
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
60
120
240
Kilometers

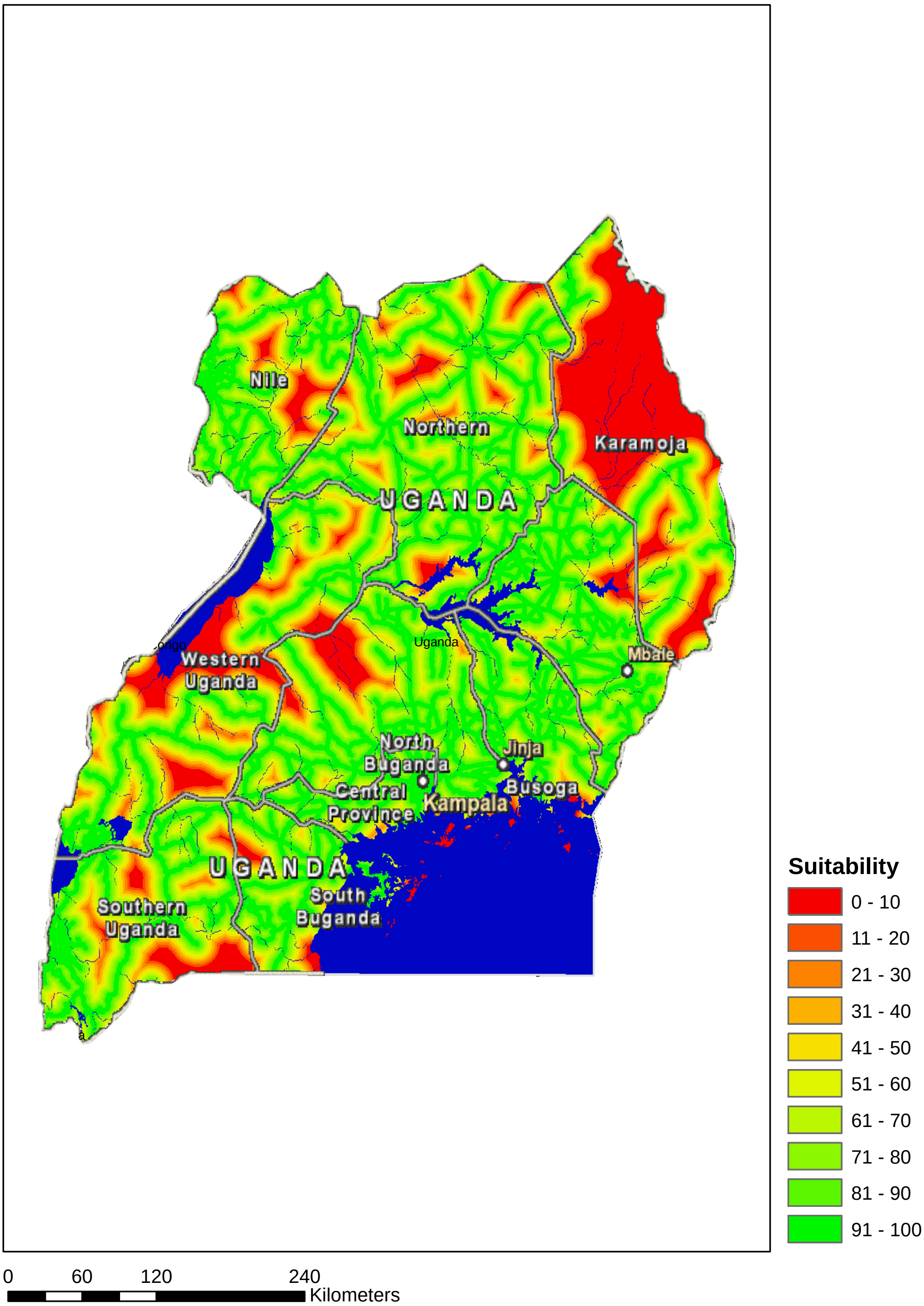
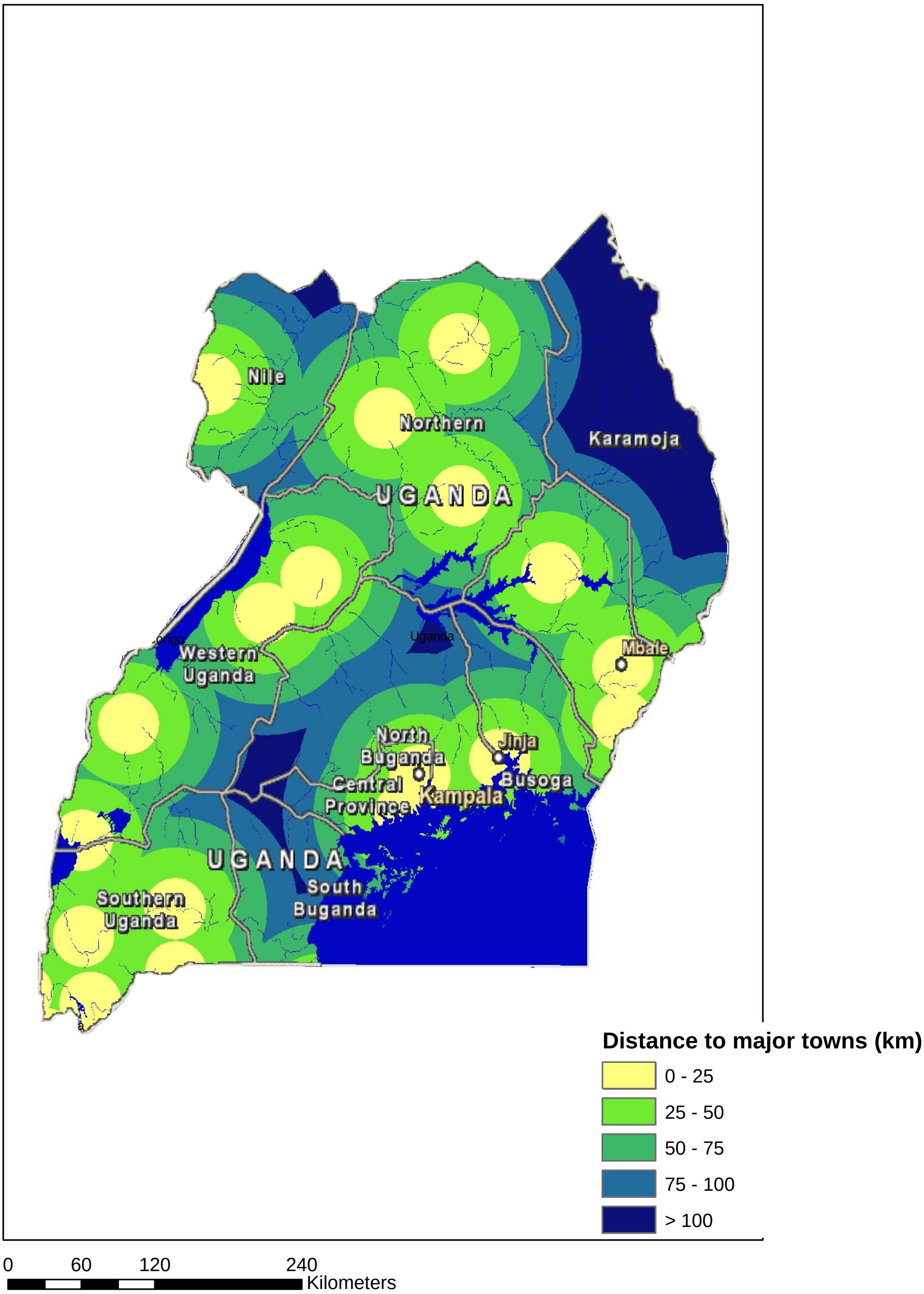
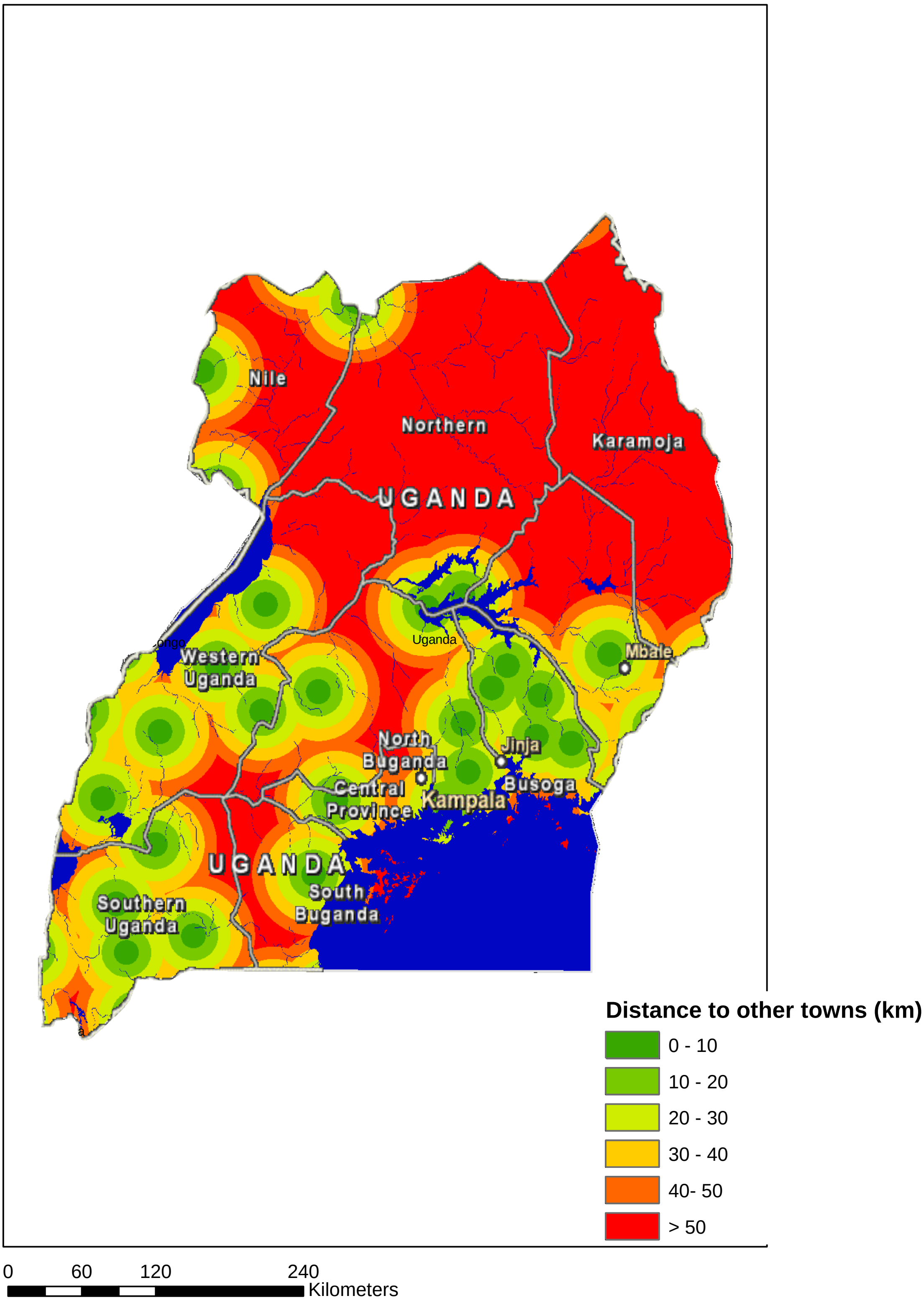


Figure 27: Distance to transportation (top), and suitability (bottom). (Source: study analysis).

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).

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Northern
Karamoja
UGANDA
Uganda
Mbale
Western Uganda
North Buganda
Jinja
Central Province
Kampala
Busoga
UGANDA
South Buganda
Southern Uganda
Distance to other towns (km)
0 - 10
10 - 20
20 - 30
30 - 40
40- 50
> 50
0
60
120
240
Kilometers

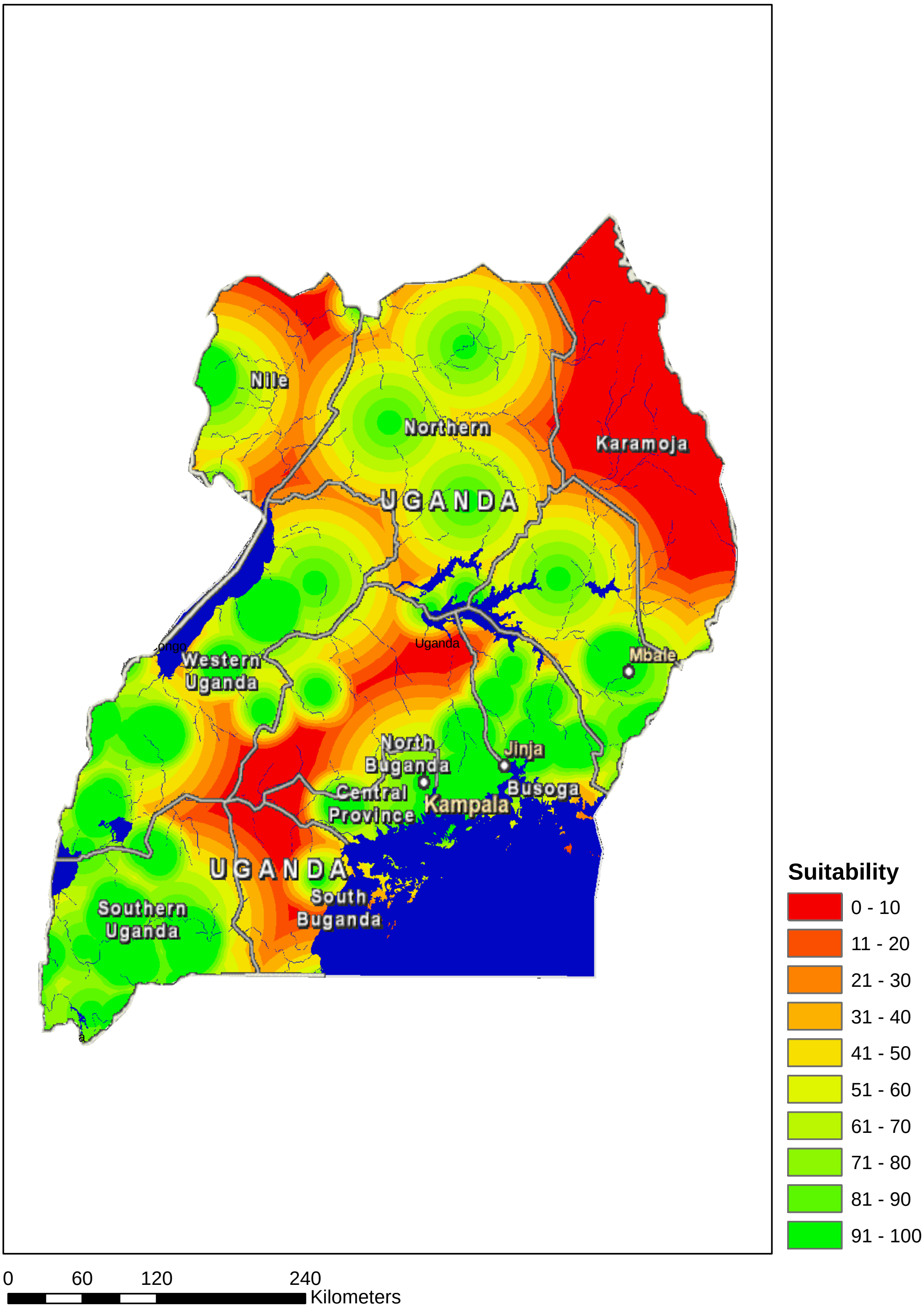


Figure 28: Distance to major towns (top), distance to other towns (middle), and combined suitability index (bottom). (Source: study analysis).

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 Uganda is about 32 million of which most live around Lake Victoria and near the southern border to Kenya. Population density can be observed in Figure 29.

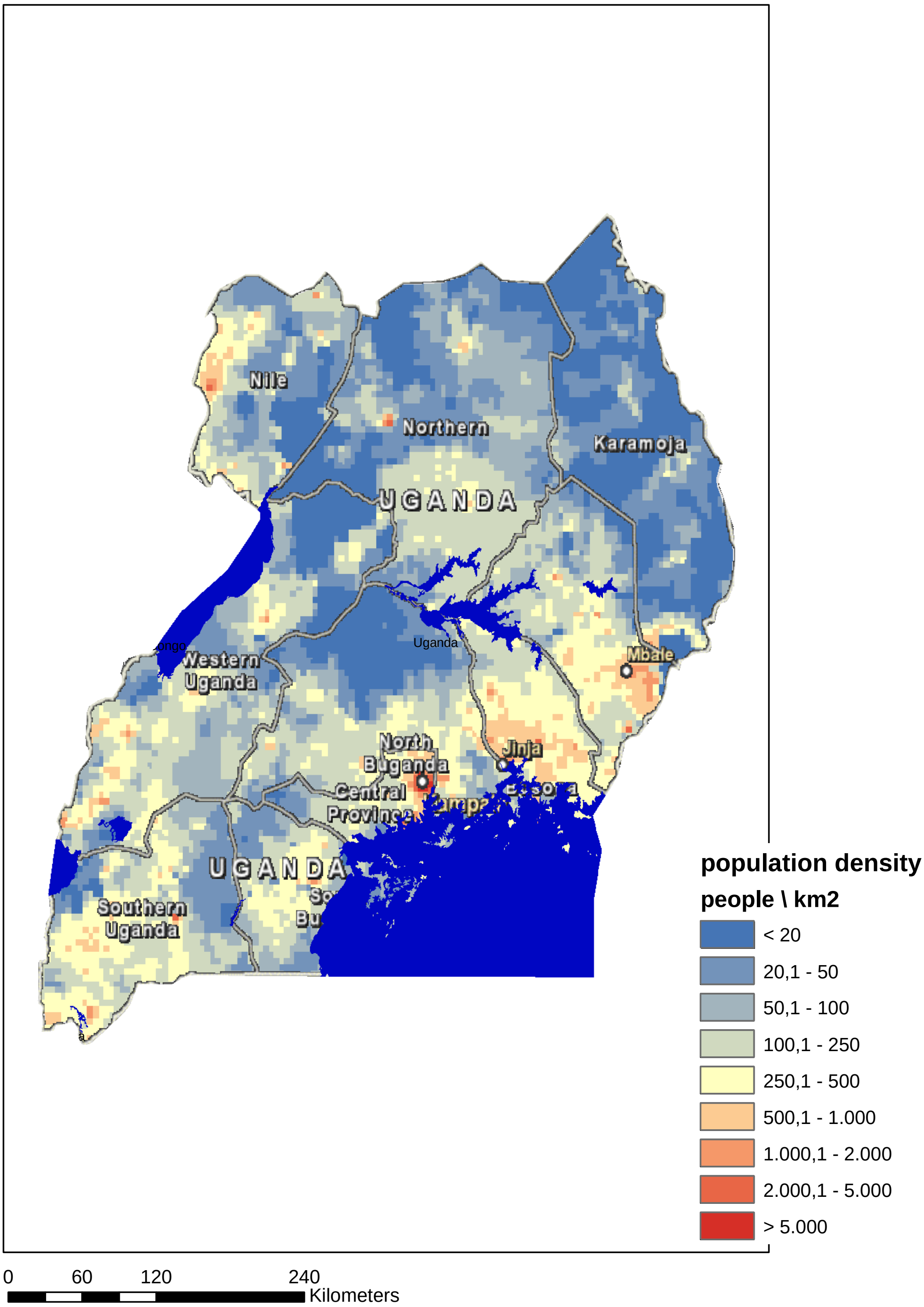


Figure 29: Population density distribution (source: CIESIN).

2.7 Institutional and legal framework[1]

2.7.1 Water treaty agreements

The Directorate of Water Development (DWD) (the ministry responsible for water), established in 1993, is the lead government agency responsible for water resources management, the provision of water supplies in rural areas and urban centers (excluding the country's 15 large urban centers), the granting of water use permits, and the coordination and regulation of all sector activities. The Directorate also provides support services to districts, towns, lower local governments and other service providers. Local governments and communities are responsible for implementing, operating and maintaining water supply and sanitation facilities in their area of jurisdiction. The Directorate and National Environment Management Authority (the ministry responsible for water) ensure that water resources are not over exploited or polluted—setting standards for water quality and discharge of effluent, granting wastewater discharge permits, setting limits on the use and development of lakes and riverbanks, and reviewing environmental impact assessments.

The National Water and Sewerage Corporation (NWSC), established in 1972, is an autonomous parastatal entity (the ministry responsible for water) responsible for water supply and sewerage services in 15 large urban centers, including Kampala, Jinja/Njeru, and Entebbe. The Ministry of Agriculture, Animal Industries and Fisheries affects water resources management: agriculture through irrigation and land use practices in relation to soil erosion; veterinary services through run-off of chemicals from cattle dips; and fisheries through the intake and discharge of fish ponds. The East African Community, Nile Basin Initiative, and other regional bodies have responsibilities for the management of trans-boundary water bodies and water ways.

Small towns between 5,000 and 30,000 inhabitants control their own WSS services, and have often times created Water Authorities, which contract out operations to local private firms. The local private sector currently serves 61 towns, and has achieved water supply coverage rates of 67%, often through local operations which operate under performance contracts to NWSC.

Uganda does not have an autonomous WSS regulator, but it is creating a transparent regulatory system through legal contracts. There are performance contracts between the Water Authorities and the MWLE, and there is a performance contract between NWSC and MWLE/Ministry of Finance, Planning and Economic Development. The Water Act of 1995 puts the DWD in charge of technical regulation in the sector, and it oversees these contracts through a performance contract review committee. In turn, the NWSC and the Water Authorities oversee and report on progress and achievements against their contracts with local operators.

2.7.2 Land ownership rights

The Constitution (1995, amended in 2005) vests land in the citizens of Uganda: “Every person has a right to own property either individually or in association with others” (Section 26[1]). Some scholars and advocates have argued that the principle of public trust applies to all national resources and public land. Under the public trust doctrine, the government has an obligation to manage national lands and resources in a manner that doesn't prejudice the interests of all Ugandans (Tumushabe, 2003).

[1] Section based on USAID

The Land Act (1998) recognizes the four historic forms of land tenure in Uganda (customary, leasehold, freehold, and mailo); grants all lawful and bona fide occupiers (legally defined) property rights; decentralizes land administration; and establishes land tribunals.

The (10-year) Land Sector Strategic Plan (2001) was developed to implement the Land Act. The National Land Use Policy (2008) provides guidelines on effective land use for socio-economic development and on minimizing land degradation. In January 2007, the government issued a third draft of the National Land Policy, which attempts to address all aspects of land in the national development context. The draft policy was vetted for review and comments, and a fourth working draft was released by the Ministry of Lands, Housing and Urban Development in September 2009.

In 2007, the government prepared a Land (Amendment) Bill designed to curb rampant, often forced, land evictions of occupiers lacking full ownership rights (especially problematic in urban/peri-urban areas). The Land (Amendment) Bill enhances the security of bona fide and lawful occupants. Under the proposed bill, a person claiming an interest in land held under customary tenure can only be evicted by a court order; and tenants on registered land can only be evicted for non-payment of rent. The Bill has generated strong opposition from landlords, some parliamentarians, the Buganda, Acholi and other ethnic groups, bankers, many churches, NGOs, and citizens who argue that it will weaken property rights and jeopardize the ability of landowner to use lands as collateral for loans. The bill was passed in November 2009.

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 the Figure 30 and Table 3 . 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 (Figure 31). The overall suitability for the country is determined at about 3 million 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.

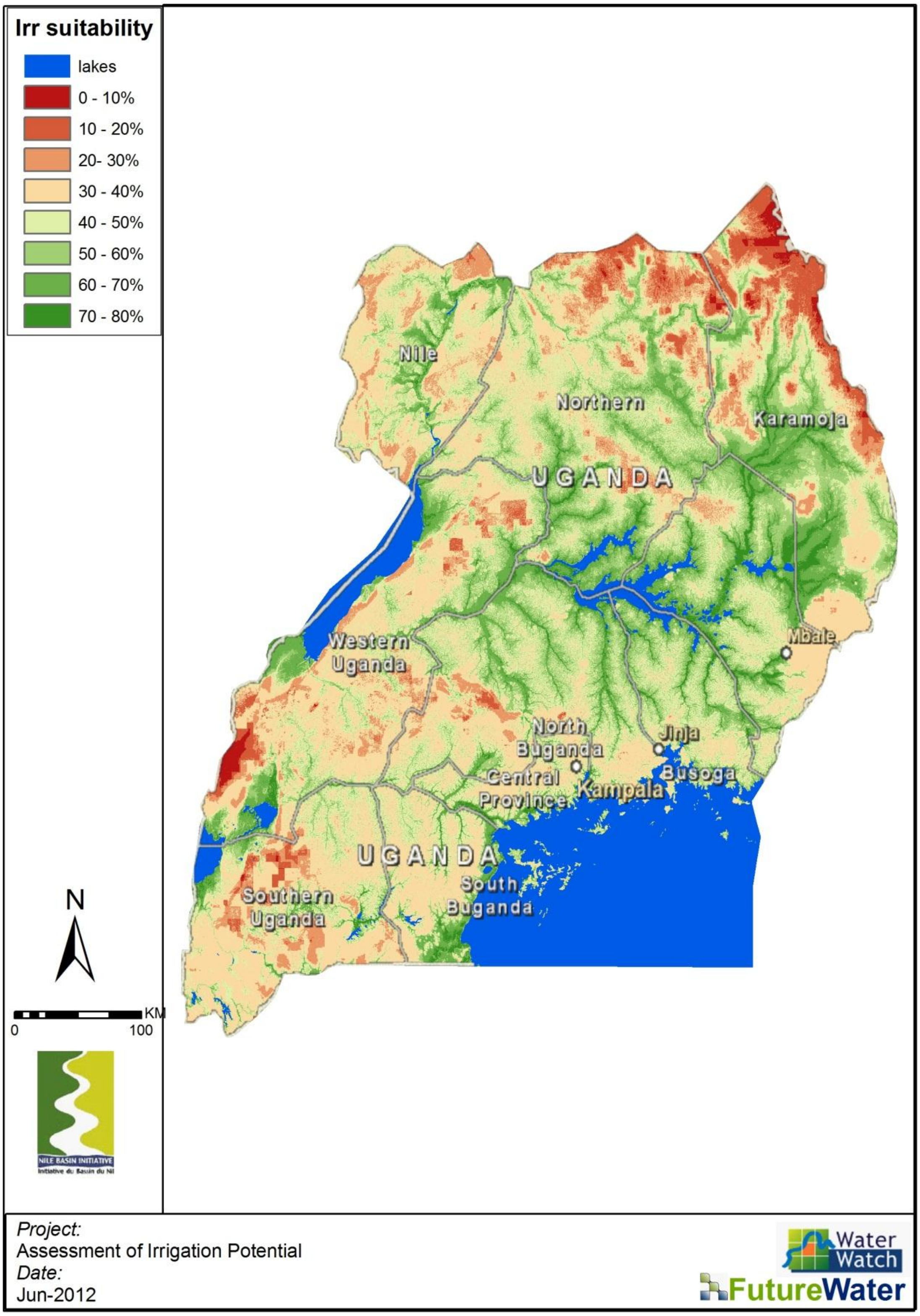


Figure 30: Irrigation suitability score.

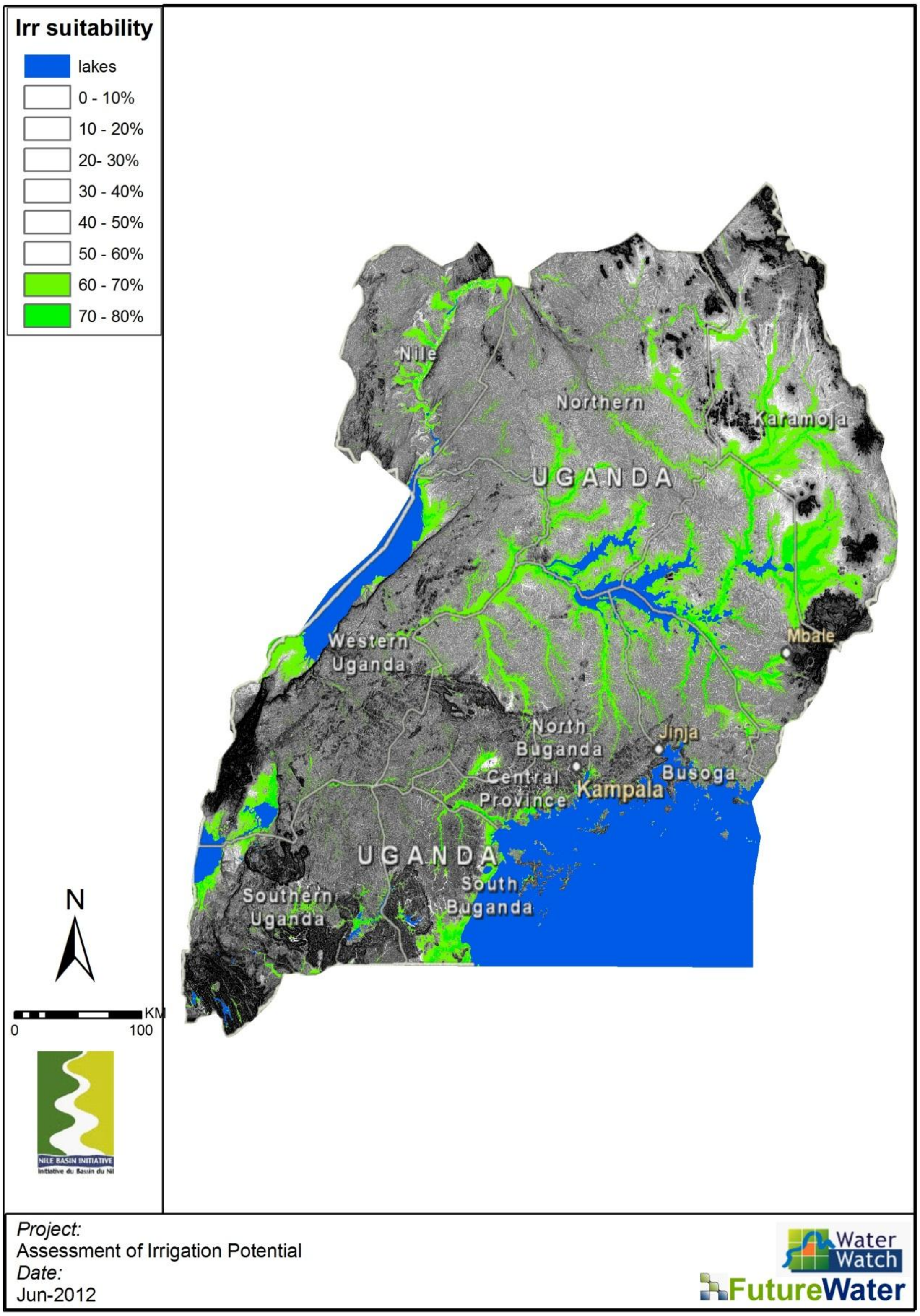


Figure 31: Final map indicating areas suitability for irrigation.

Table 3: Suitability classes.

Suitability	Irrigation potential (ha)
0 - 10%	143,306
10 - 20%	765,638
20 - 30%	1,493,463
30 - 40%	6,069,881
40 - 50%	5,315,163
50 - 60%	3,860,081
60 - 70%	2,481,694
70 - 80%	546,094
80 - 90%	0
90 - 100%	0
Total >60%	3,027,788

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 4 the names and areas are given, and in Figure 32 a map is supplied on which the focal areas are shown. Final selection and agreement on focal areas have been done by experts from the country attached to various ministries and institutions.

Table 4: Focal areas Uganda.

	Acaba	Bigasha/Omumukura	Rwimi	Lumbuye	Soroti
Area in ha	4327	1942	4415	9812	6620

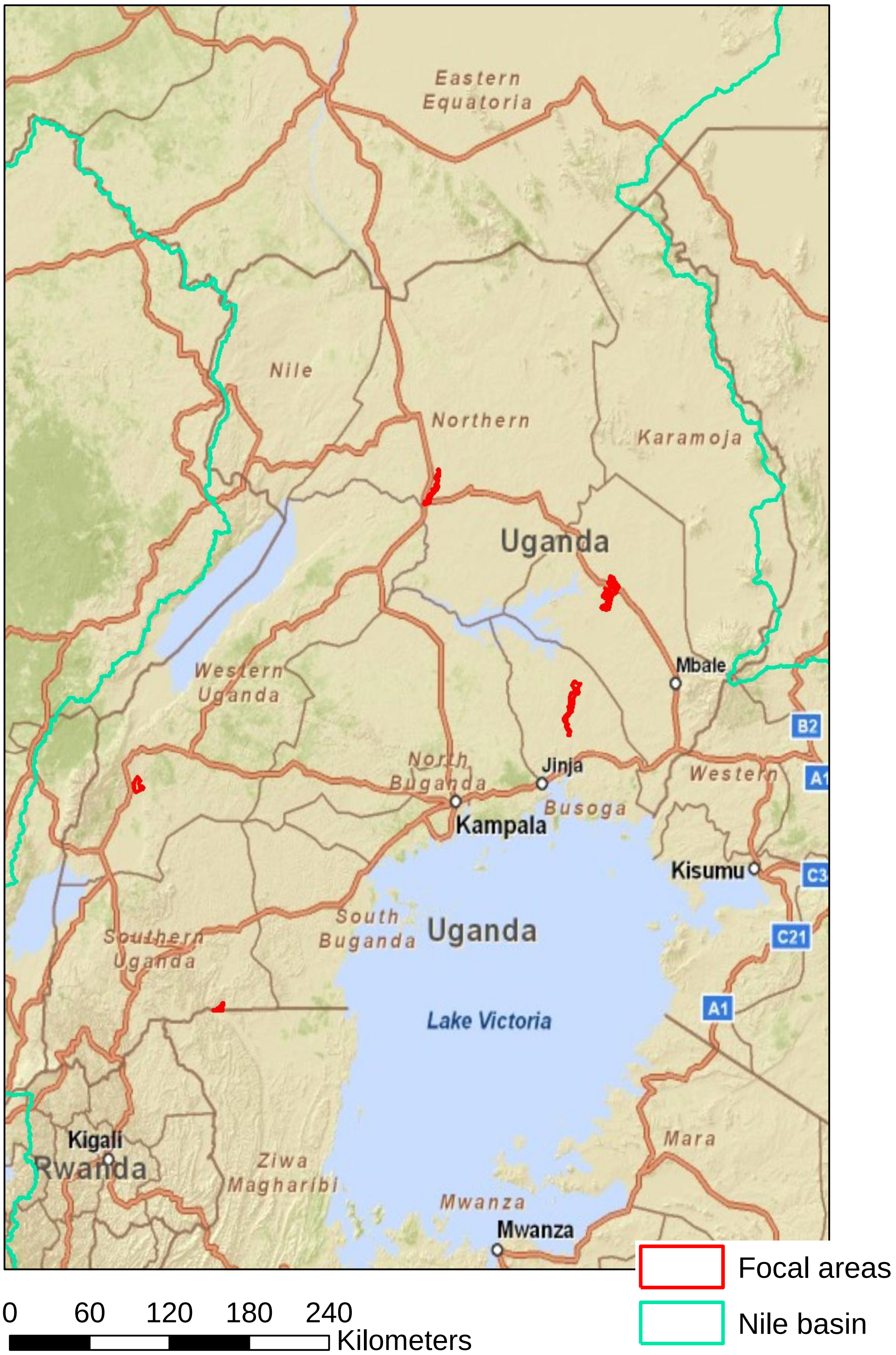


Figure 32: Overview focal areas Uganda.

3 Acaba focal area

3.1 Introduction

This chapter will describe the current state of the Acaba 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 34 a detailed map of the area is given. Total area is 4327 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 Michael Iwadra and Fredrick Ssozi and Richard Cong as supervisor in March 2012.

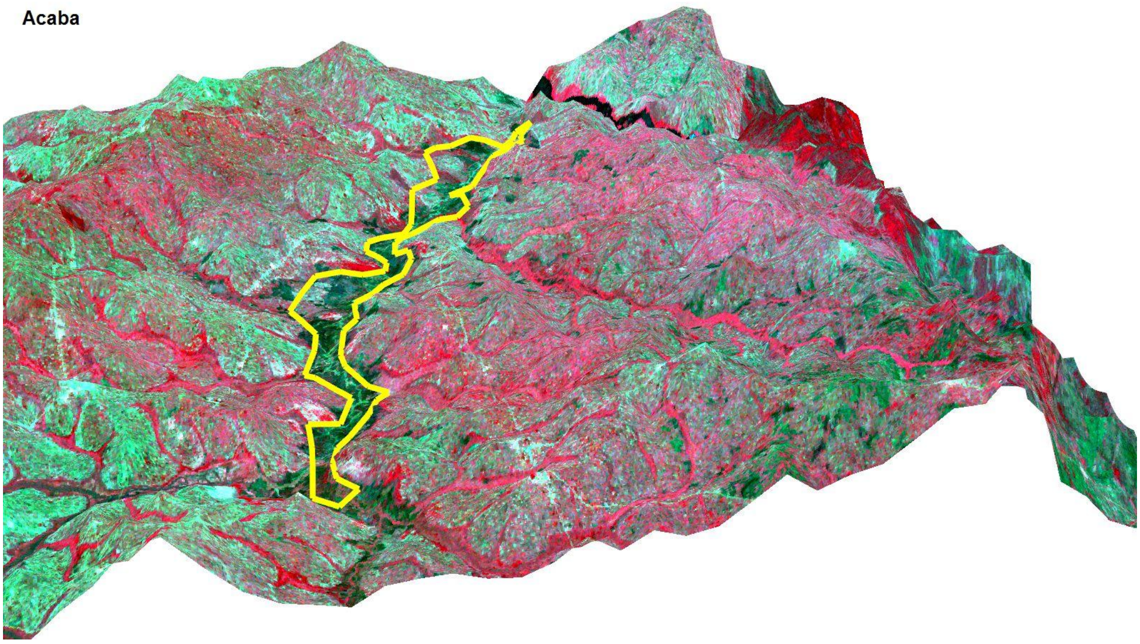


Figure 33: 3D impression of Acaba focal area, Uganda.

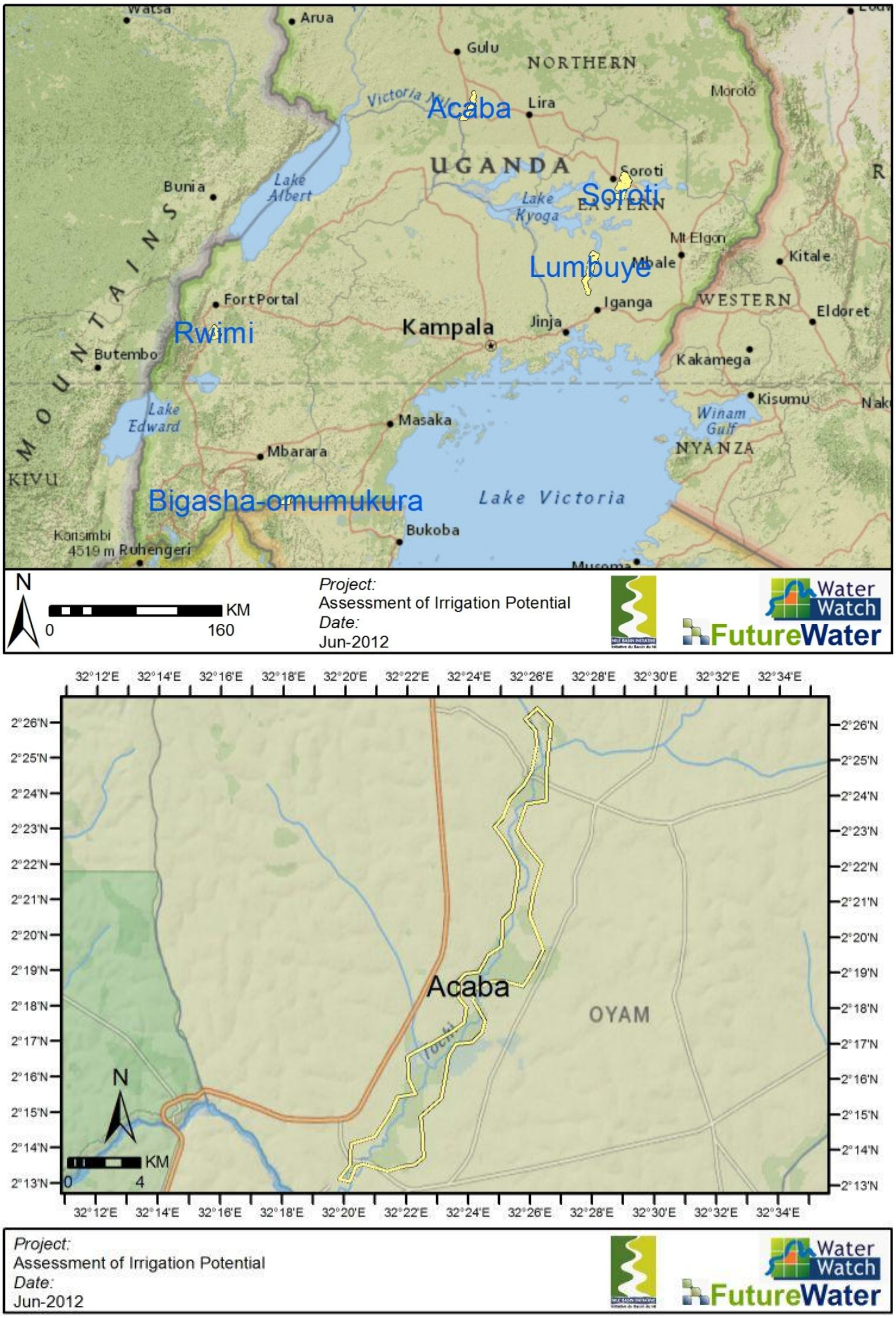


Figure 34: Acaba focal area, Uganda

3.2 Land suitability assessment

3.2.1 Terrain

This focal area is situated in Uganda's Northern region within the Apac district and Oyam district. The focal area covers the valley of one of the tributaries towards the White Nile. The total area of the focal area is 4327 ha, which includes the river and the flat land on the sides. Within the focal area the slopes are very limited. The area slightly descends from North to South, from 1047 m in the North to 1037 m in the Southern tip of the focal area. Within the cross section of the focal area, the elevation difference is very limited to a maximum of 3 meter (Figure 35). Based on the ASTER 30 m slope map (Figure 36), it becomes clear that slopes vary significantly on this small scale. Slopes are predominantly limited to 0-5%. On smaller scales, however, they may increase to values exceeding the 10%.

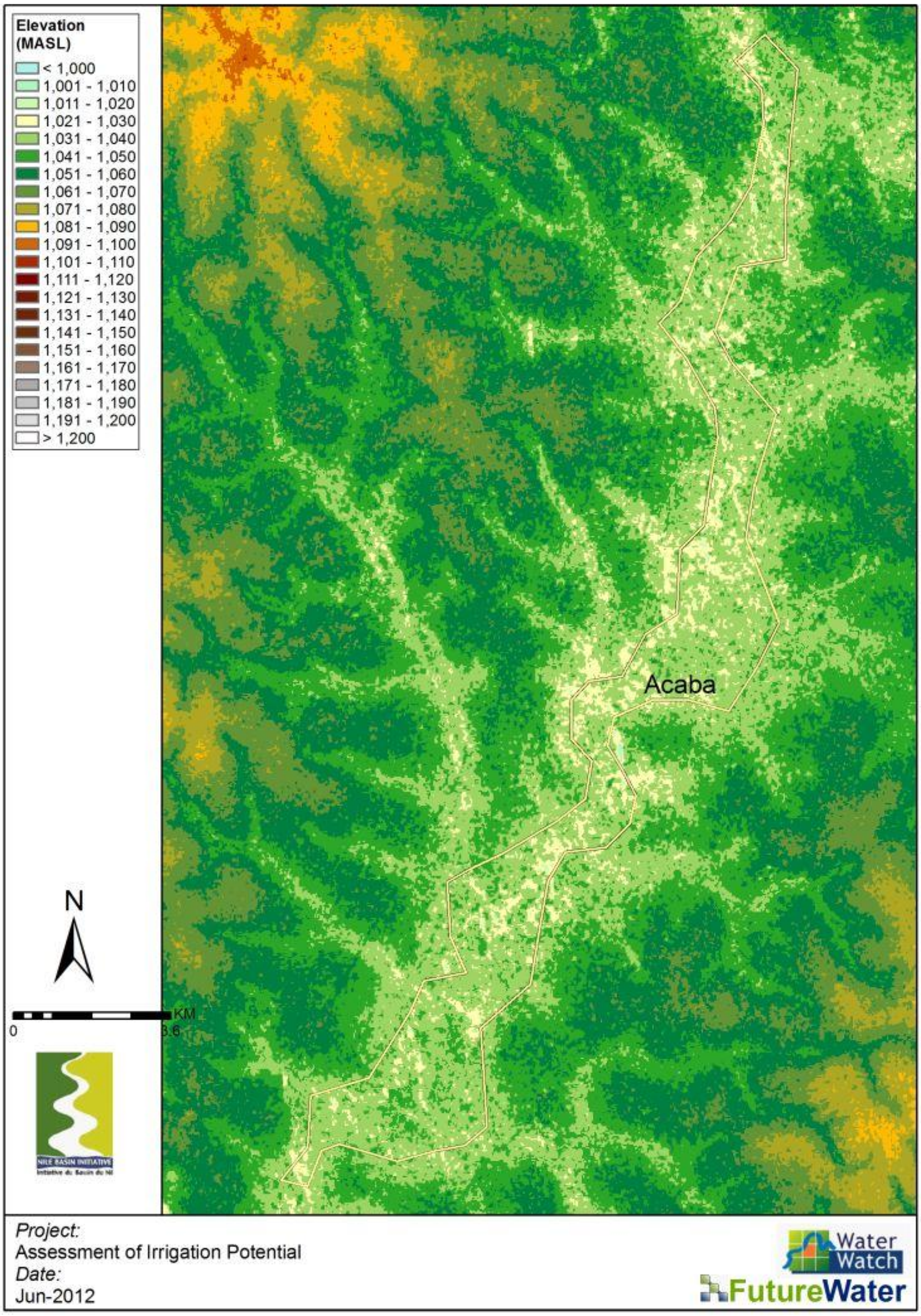


Figure 35: DEM Acaba focal area. Resolution 1 arc second (+/- 30m).

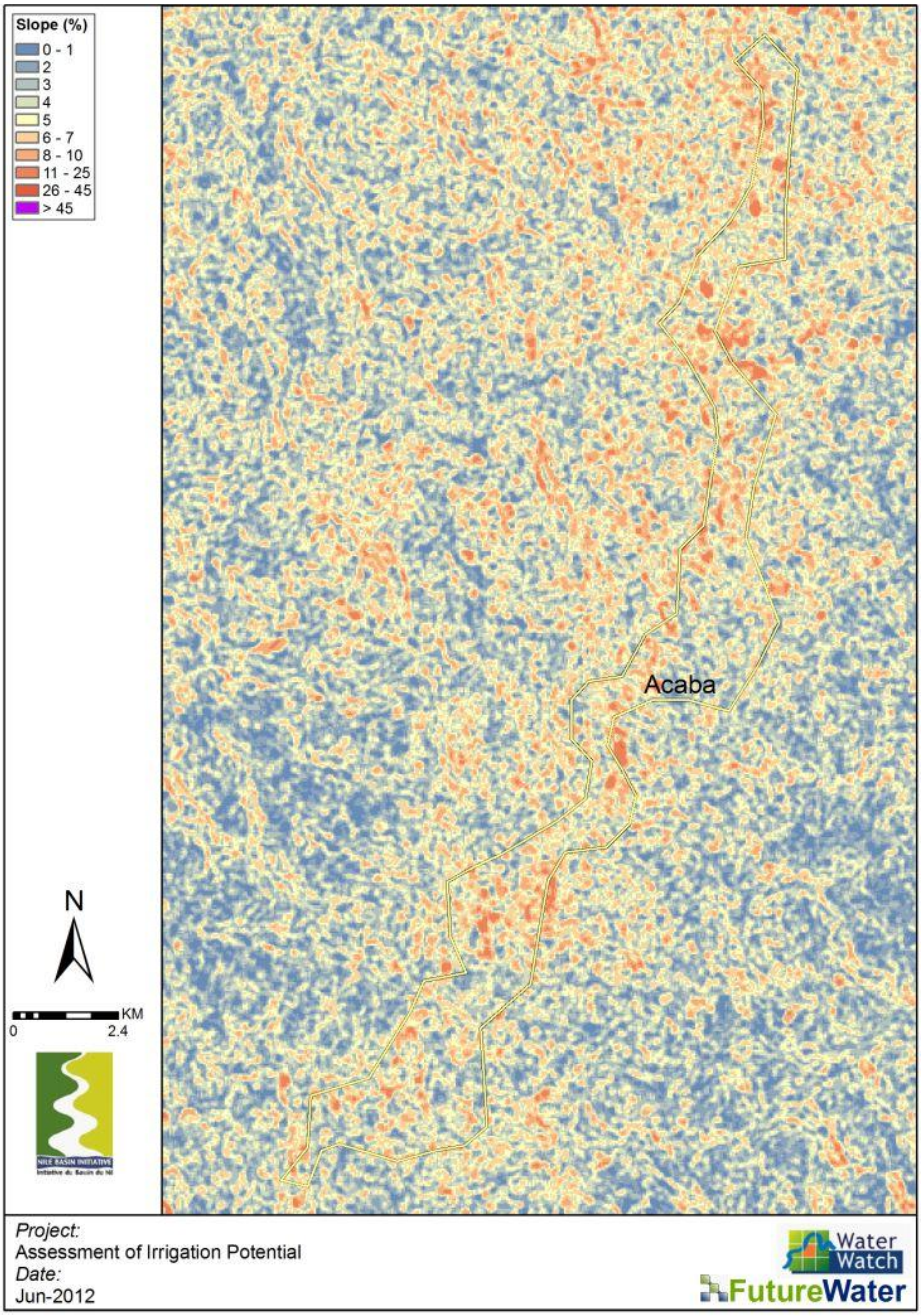


Figure 36: Slope map Acaba focal area (source: ASTER).

3.2.2 Soil

Soils in Acaba focal area are formed under fluvial processes. Apart from some small regional differences, the entire focal area has a Eutric Gleysol. Gleysols can be found in depressions and in low landscape positions, with shallow groundwater. Within the focal area, the groundwater is rather shallow indeed, and drainage is moderately to poor. The main obstacle to the utilization of Gleysols, is the necessity to install a drainage system to lower the groundwater table. Adequately drained Gleysols can be used for arable cropping, dairy farming and horticulture. The soil structure will be destroyed for a long period, if too wet soils are cultivated. Therefore, Gleysols in depression areas with insufficient possibilities to lower the groundwater table are best kept under a permanent grass cover or swamp forest. Gleysols are suitable for wetland rice cultivation. There are slight signs of erosion, thus erosion issues should be addressed when designing an irrigation scheme. Salinization is developing as a problem; a good drainage system can decrease the occurrence and development of salinization.

3.2.3 Land productivity

The land productivity (NDVI) in the five Ugandan focal areas ranges between 0.58 and 0.74. Compared to the Uganda average NDVI of 0.54, all of the focal areas have relative high land productivity values. Within the Acaba focal area the NDVI is 0.67 (Figure 38). The land productivity is slightly higher in the South. The variation in land productivity over the year is rather stable. With a coefficient-of- variation approaching close to zero, the land productivity is roughly 0.67 all-year-round. This could suggest that there is no particular difference between dry en raining season. Besides this, the low percentage of land used for agriculture explains the stability in NDVI.

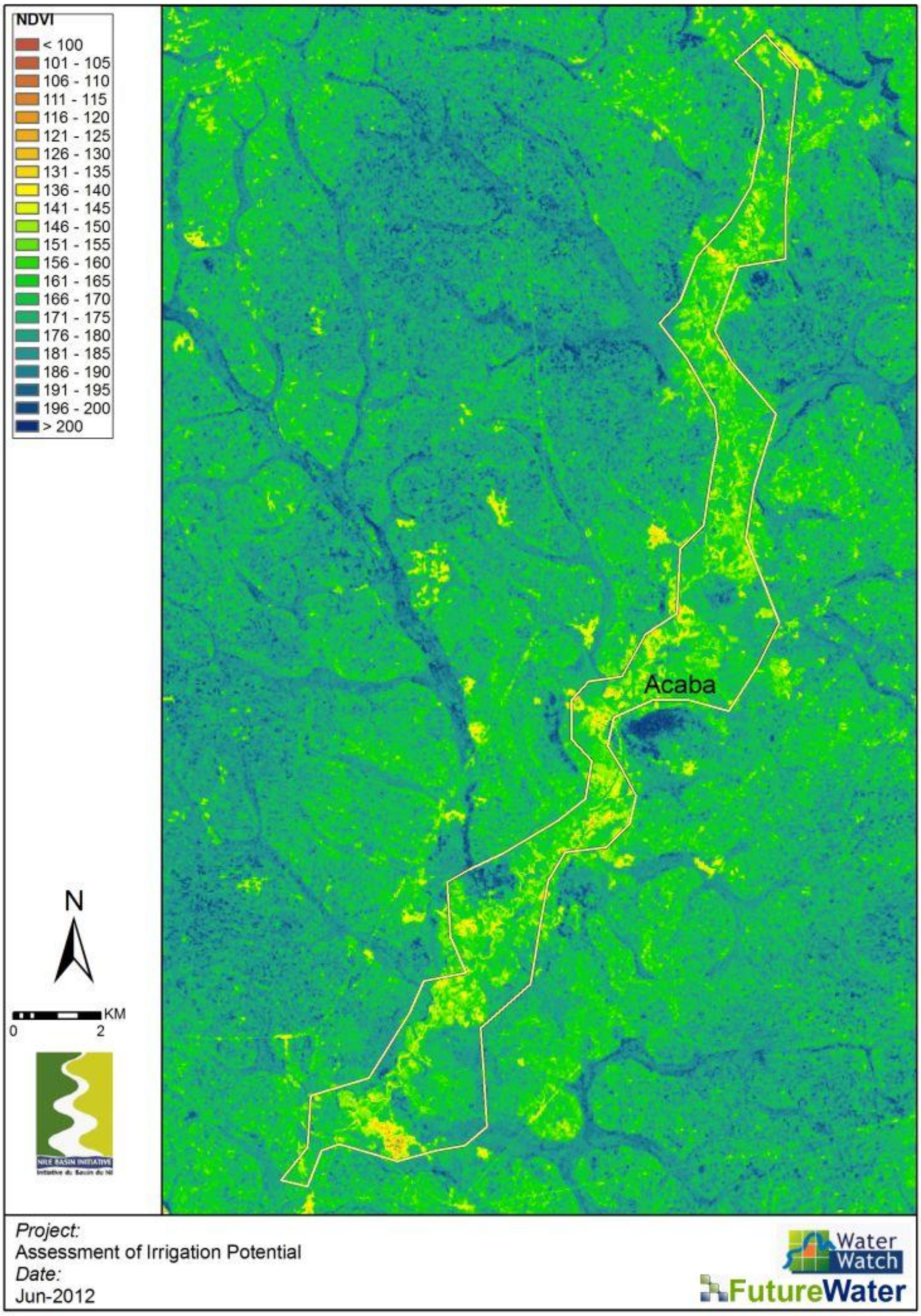


Figure 37: High resolution NDVI for Acaba focal area

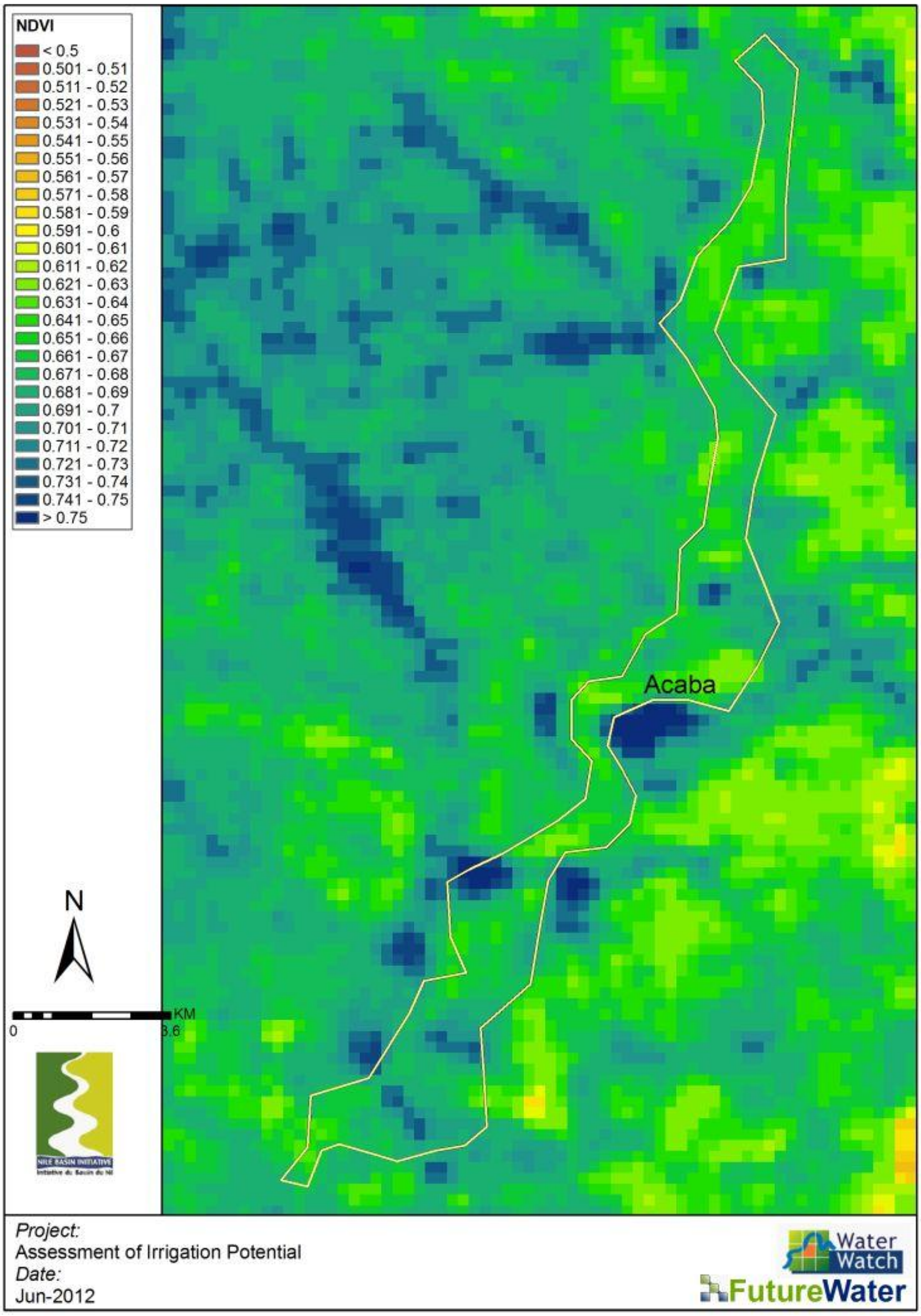


Figure 38: Yearly average NDVI values for Acaba focal area.

3.2.4 *Potential cropping patterns*

Within the Acaba focal area 30% of the land is used for agriculture. Dominant crops are Beans, which cover approximately 50% of the agricultural area, Soy beans (25% of the area), and Cassava and Maize (both 10% of the area). Minor crops include sunflowers, sugarcane, vegetables and sesame. Beans and soy beans, together with some minor crops, are grown in two growing cycles per year. The other crops grow once a year. Depending on the type of irrigation system to be developed, the government policy differs concerning future crops. However, the overall focus will be on high value crops which will strengthen the economic situation in the region and reduces poverty and hunger. Proposed crops for the Acaba focal area are Rice, fruit trees and to a lower extend bananas. Rice under a well-managed irrigation system has a high return rate, and can be grown in two or in rare occasions three growing cycles per year.

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 warm with temperatures during the year ranging from about 20°C to 31°C, with the hottest months being January, February, and March. Annual average precipitation is 1229 mm and reference evapotranspiration 1652 mm per year.

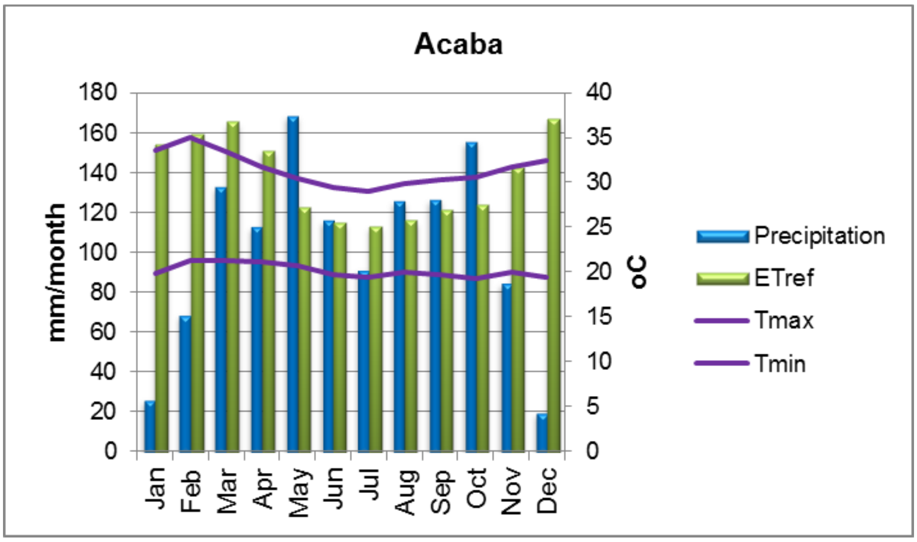


Figure 39: Average climate conditions for Acaba focal area.

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.

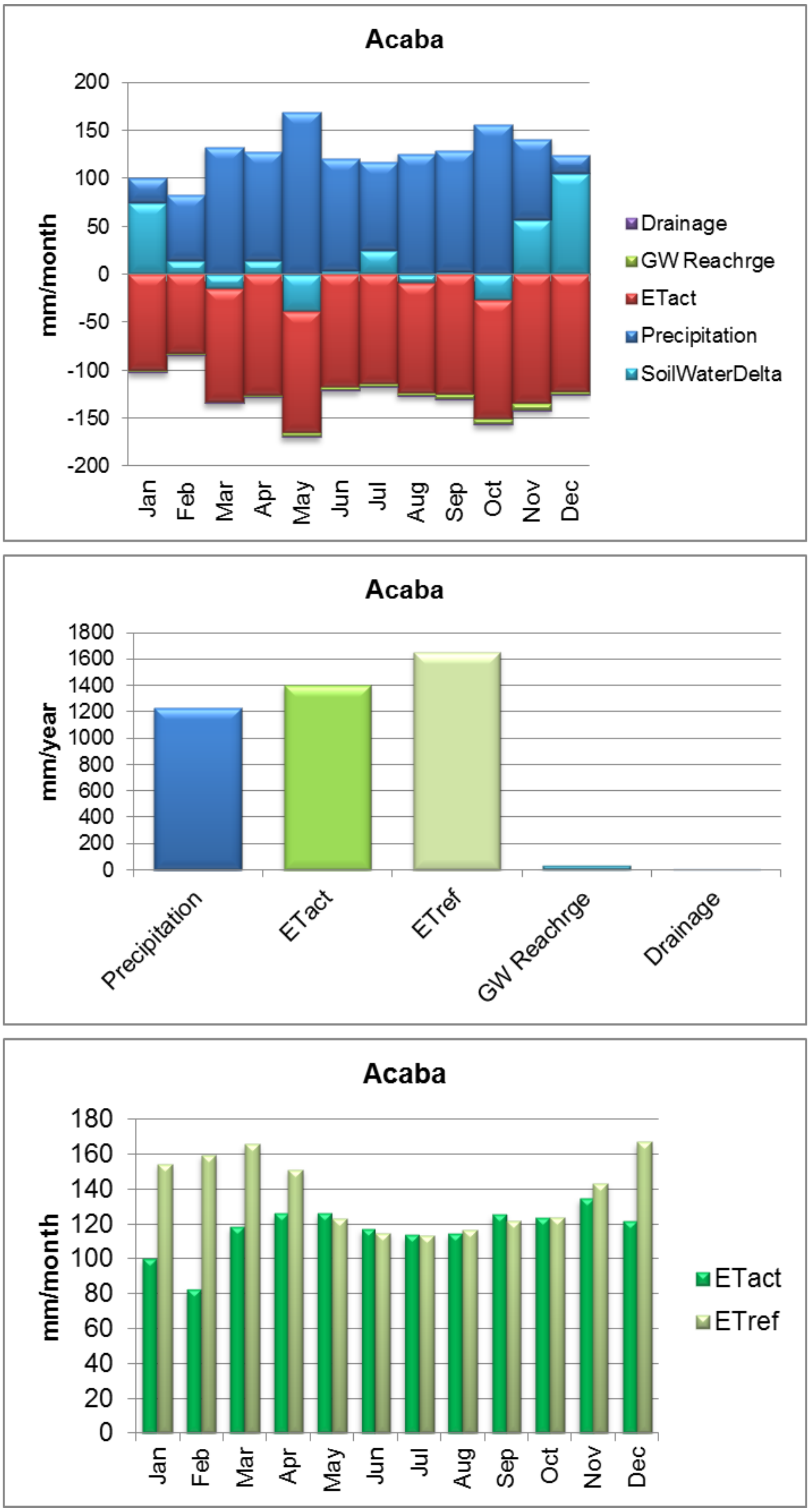
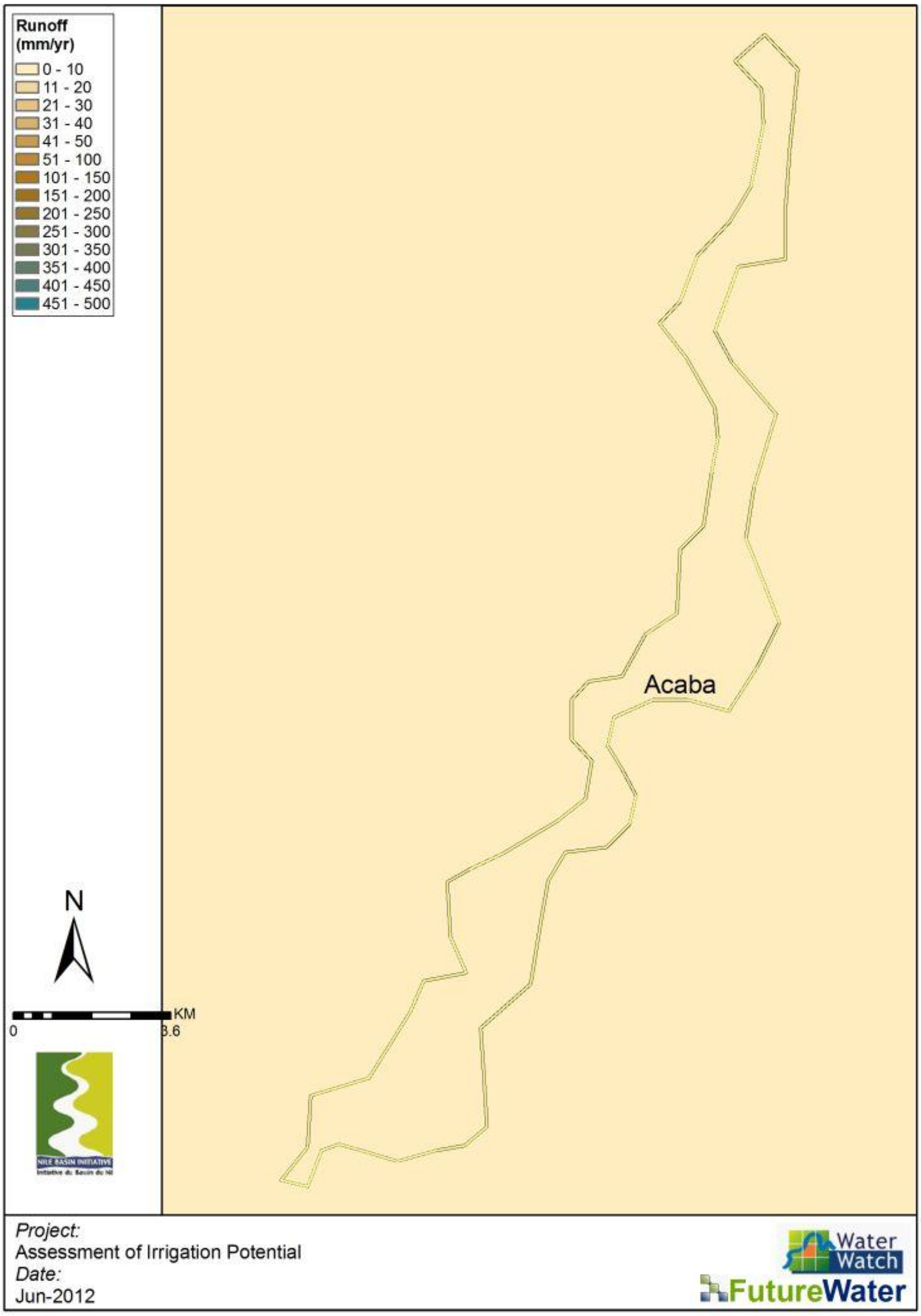
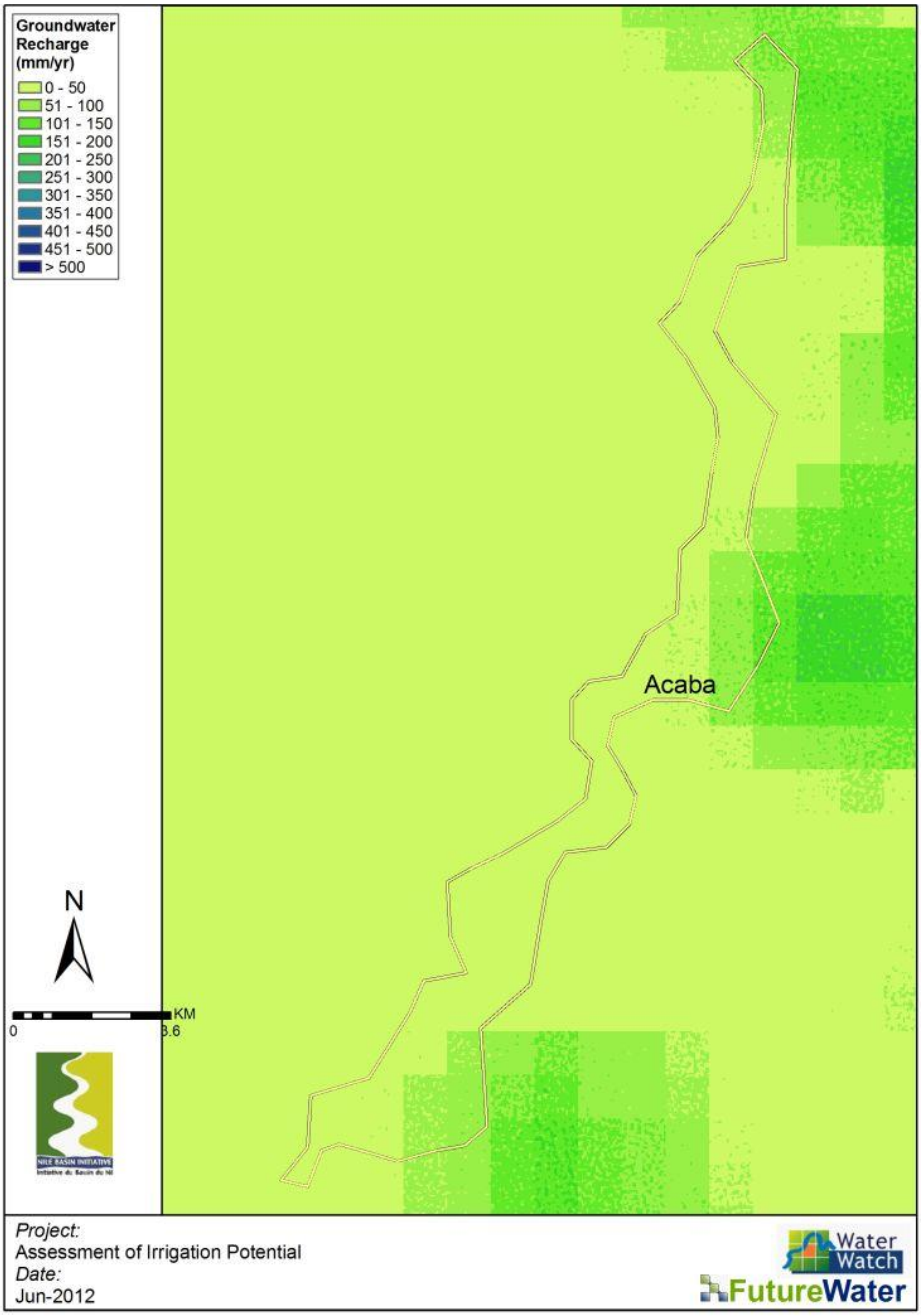


Figure 40: Water balances for the area based on the high resolution data and modeling approach for Acaba focal area.


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
Acaba
N
KM
0
3.6
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
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Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

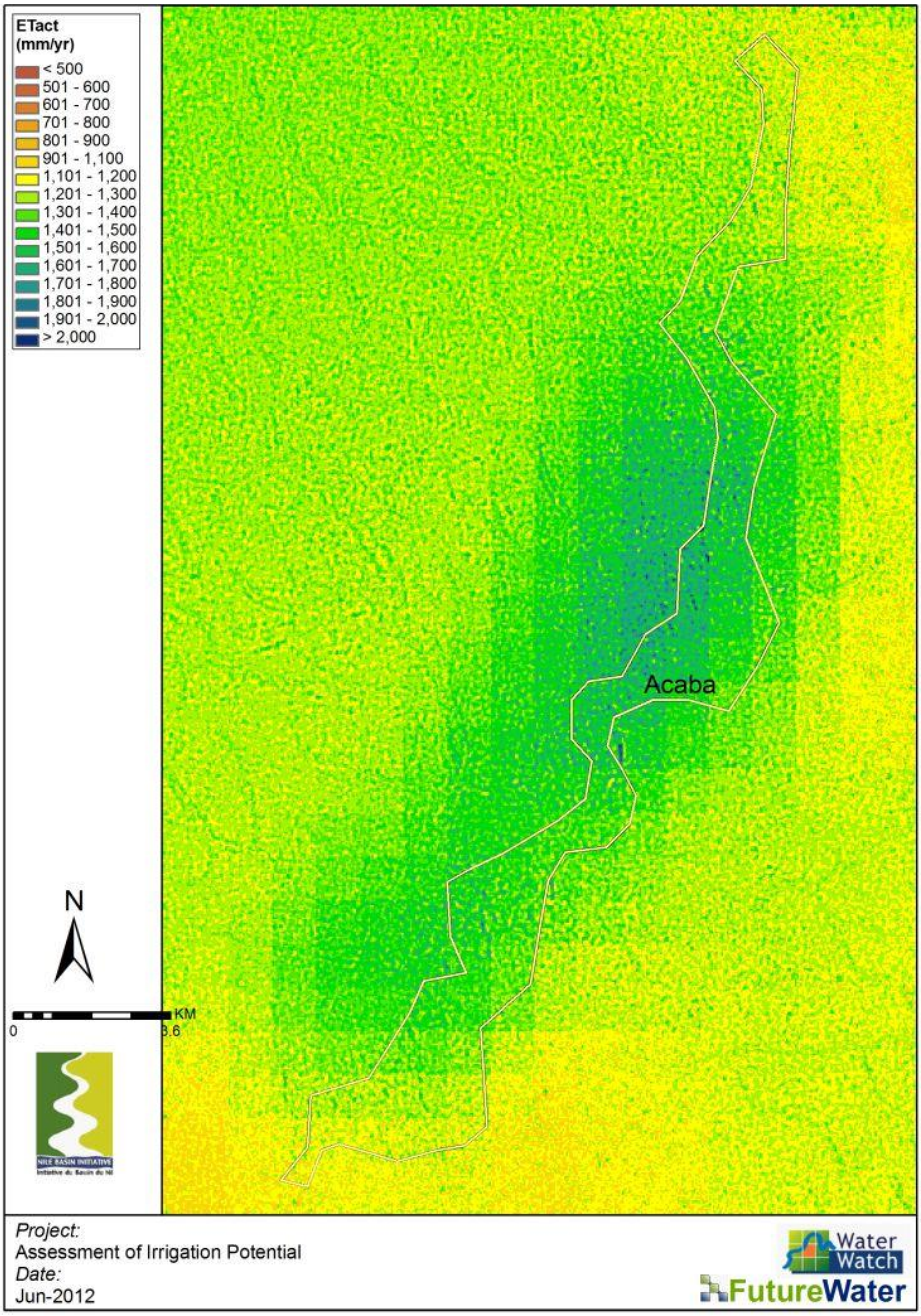


Figure 41: Water balances for the area based on the high resolution data and modeling approach for Acaba focal area.

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.

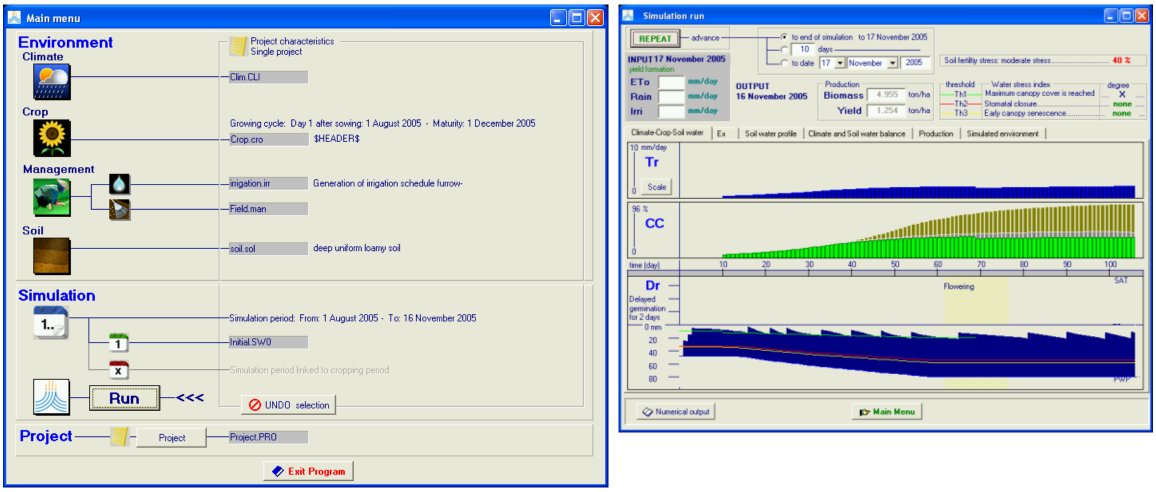


Figure 42: Typical example of AquaCrop input and output screens.

Table 5: 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	1229	1652	213	320	461	130	436	403
Bananas	1229	1652	1	365	1229	440	1646	1119
Fruit trees	1229	1652	1	365	1229	430	1646	1106

3.4.2 Irrigation systems and irrigations efficiencies

The river flowing through the area drains an approximate area of 1600 km^2. The water from this area can be sufficient for irrigating this area. The topography is very suitable for surface irrigation, since slopes are limited and the land descends slightly from North to South. In the North, the discharge is 4.5 m^3/s. For rice production in the valley border irrigation is recommended. Since abundant water is available and water requirements are low, the low water efficiency for border irrigation is not a problem. The water percolating in the soil will most likely become available downstream. Irrigation of the fruit trees and banana trees can best be done with drip irrigation. This will expand the possible irrigated area, since the slightly higher land can be used for irrigating the fruit trees. Efficiencies for drip irrigation are much higher as for border irrigation. But since drip irrigation requires pumping, the operational costs are higher as well as the initial development costs.

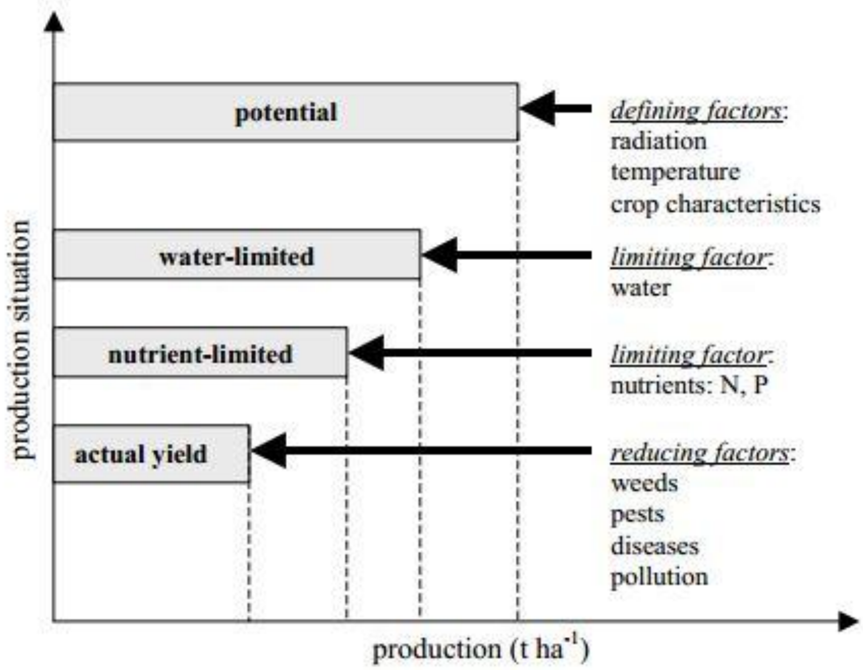
3.4.3 Water source

The river that flows through the area will be the main source for irrigation. The river has sufficient water year through, with an average discharge of 4.5 m^3/s in the upstream part of the focal area. This will be enough to irrigate an area of approximately 4500 ha with an average water requirement of 5 mm/day and an efficiency of 60%. In raining season the valley is flooded and therefore, to increase irrigation possibilities, it is recommended to build a reservoir. Potential locations for a reservoir include the confluence of the Olon River swamp and River Toch, and at the Awoo Bridge (GPS locations 0433709,0279094 and 0444428,0267933, 36N).

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 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.



3.5.1 *Yield gap analysis potential dominant crops*

Uganda has slightly higher yields compared to surrounding countries. Population pressure and the increasing food demand have been triggers for the intensification of agriculture. In Figure 43 the yield gap is shown relatively to the highest obtainable yield in the world, the world's average, and to Africa's average. The yields in the Acaba focal area are relatively high, with yields about 25% higher than the Ugandan average. The yields of bananas and rice are low compared to African, or East African standards. Fruit Fresh Nes, however, is giving high yields, surpassing the African and world's average, approaching 33% of the highest obtainable in the world. Especially for bananas and rice the yield gap is rather large, and a large improvement can be made to overcome the yield gap. Banana yields can increase from 7.9% to around 30% of the world's highest, and rice can double towards 30-35% of the world's highest. The combination of these three crops is very suitable, since farmers know how to obtain high fruit fresh nes yields, and banana and rice are rather new. The combination can supply the area with a continuous food supply and push development.

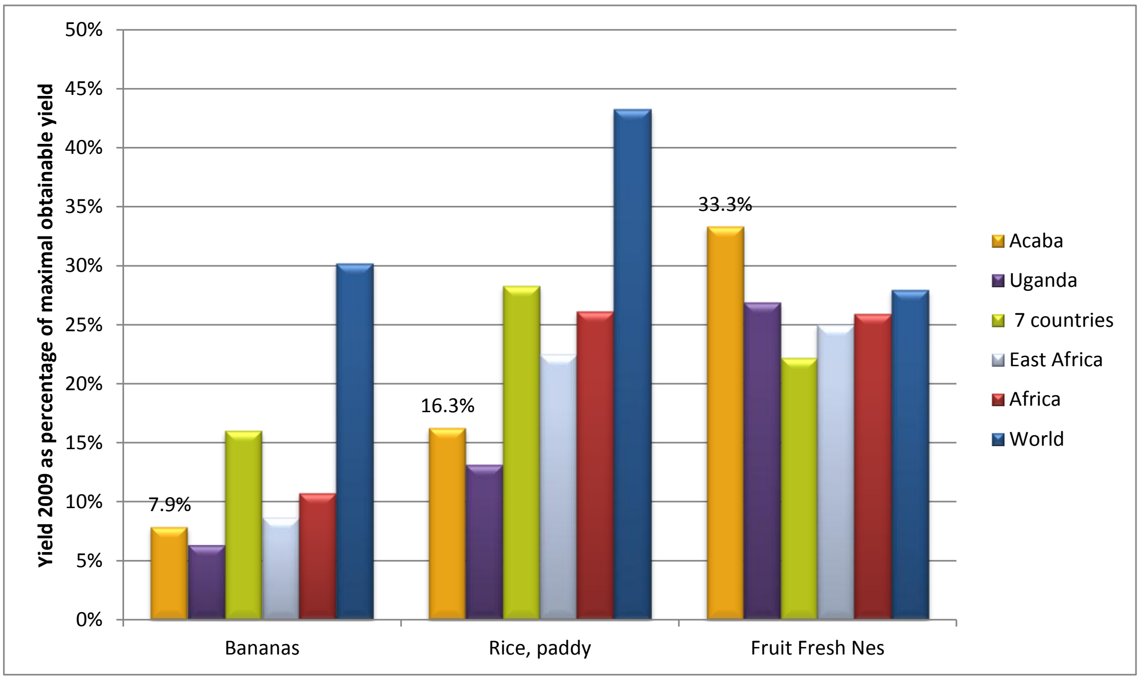


Figure 43: Yield gap Acaba (source: FAOSTAT, 2012).

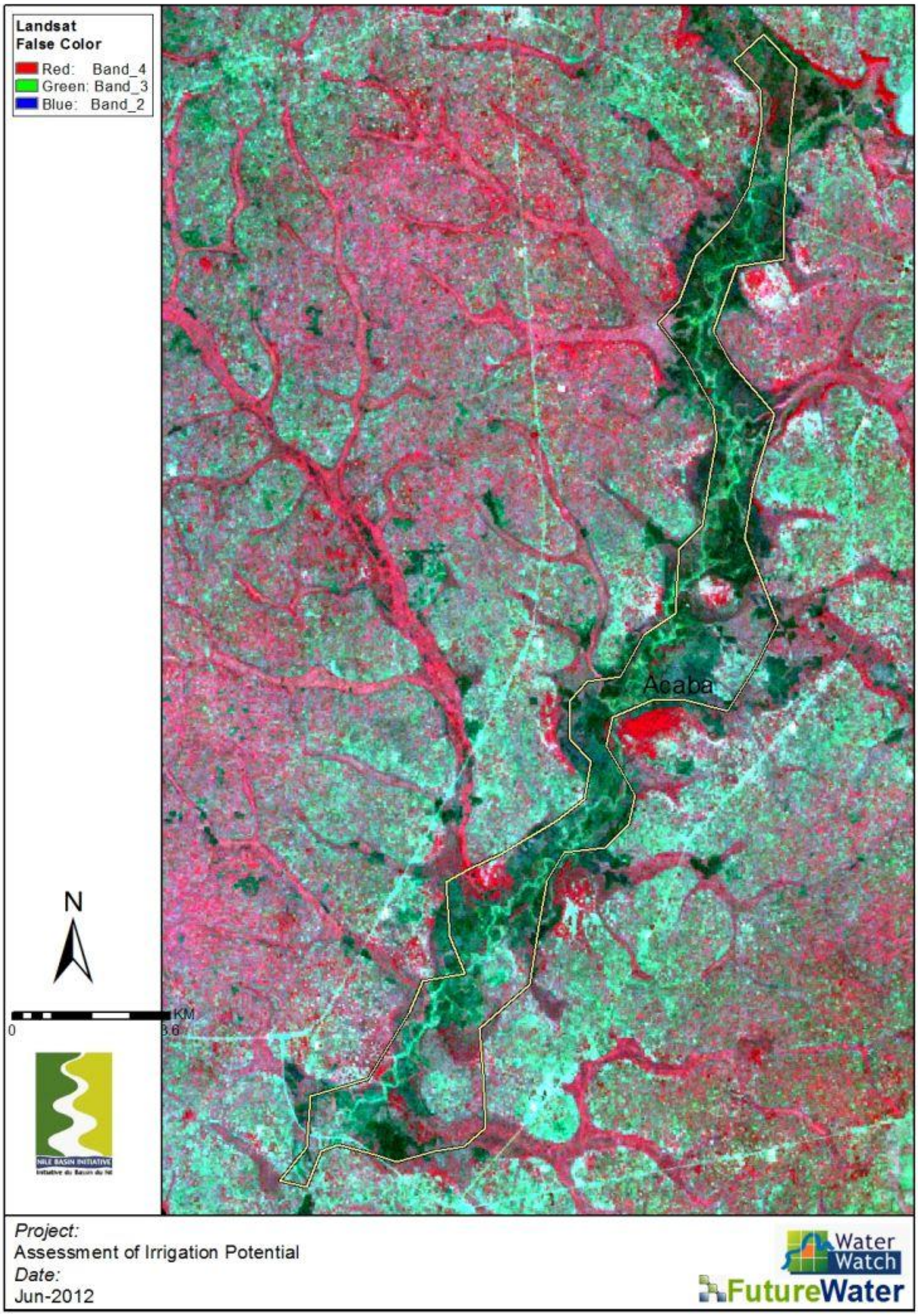


Figure 44: Landsat False Color Composite indicating current productivity of the area for Acaba focal area.

3.6 Environmental and socio-economic considerations

3.6.1 Population displacements

People in the focal area are living quite scattered around. Most houses can be found along the roads passing by on both sides of the focal area. Within the valley, which is mainly appointed as focal area, hardly anybody lives due to the high flood risks. When developing an irrigation scheme it is advised to design the scheme such that population displacement is not or hardly needed. However, due to the scattered houses in some areas, the irrigation possibilities will either be restricted, or minimal displacements are needed. People in the area have some experience with irrigation. This increases the coop capacity of the people, as they are aware of the benefits of irrigation. 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 of Acaba focal area is around 170 people/km^2. This is slightly above the Ugandan average of 150 people/km^2. Farmers have an average farming and irrigation knowledge, and have some experience in agricultural cooperatives. The area can easily be reached by road, as the Bobi-Masindi road is passing by on the Western side. Infrastructure within the area is poor, with a few dirt roads going through the area. Small markets are easy to reach, larger markets nearby include the markets in Oyam, Minakulu, Gulu and South Sudan. The area is inhabited by to main tribes, the Langi and the Acholi. Development in the area is continuing. On regional level, however, it can be said that 40-50% of the population is living beneath the poverty line.

3.6.3 Upstream downstream consideration

Since the upstream catchment (1600 km^2) and discharge are not enormously large, the water availability for irrigation should be considered well. Upstream and downstream of the focal area, people should still have enough water available to practice agriculture, and have water for 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 an irrigation system, extra attention should be paid to keep the soil in place. In some areas the slopes 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.

3.6.4 Protected areas

Within the focal area no protected areas are reported.

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 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: 5,250 kg/ha, 0.61 $/kg
    - Bananas: 60,000 kg/ha, 0.22 $/kg
    - Fruit trees: 210,000 kg/ha, 0.10 $/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, water availability is a great deal for the area that will foster an increase yields.

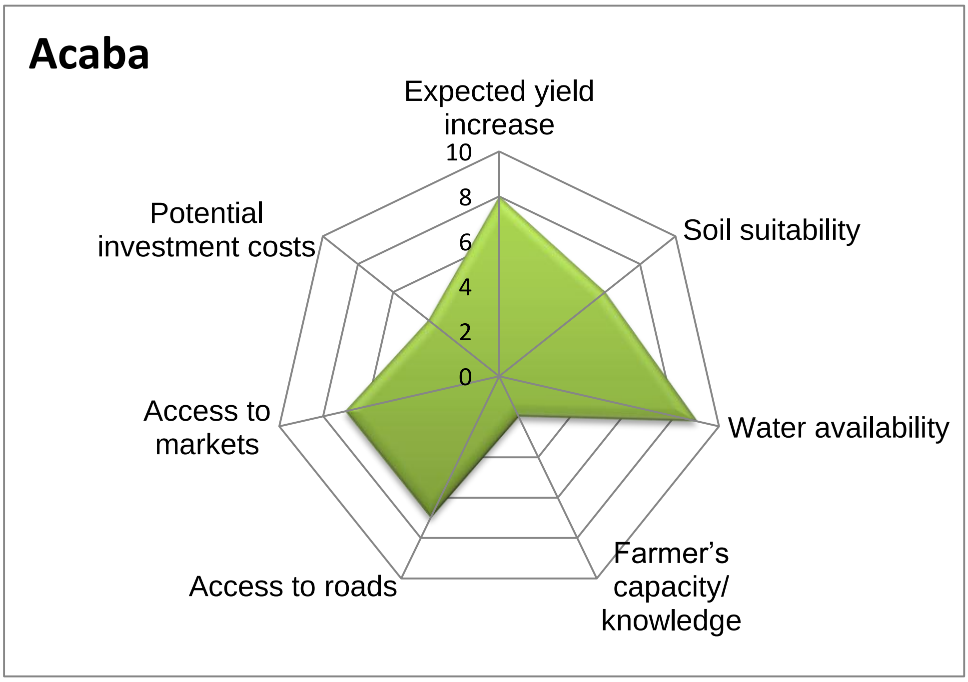


Figure 45: Filled radar plot indicating expert knowledge score to develop irrigation in the Acaba focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 6: Benefit-cost analysis for Acaba area.

Characteristics	
Irrigated land (ha)	3,000
Farmers	2,500
Investment Costs	
Irrigation infrastructure (US$/ha)	6,000
Social infrastructure (US$/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$)	21.3
O&M costs (million US$/yr)	0.245
Net benefits per year (million US$/yr)	22.432
IRR (Internal Rate of Return)	>100%

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 Soroti focal area

4.1 Introduction

This chapter will describe the current state of the Soroti 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 47 a detailed map of the area is given. Total area is 6620 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 Michael Iwadra and Fredrick Ssozi and Richard Cong as supervisor in March 2012.

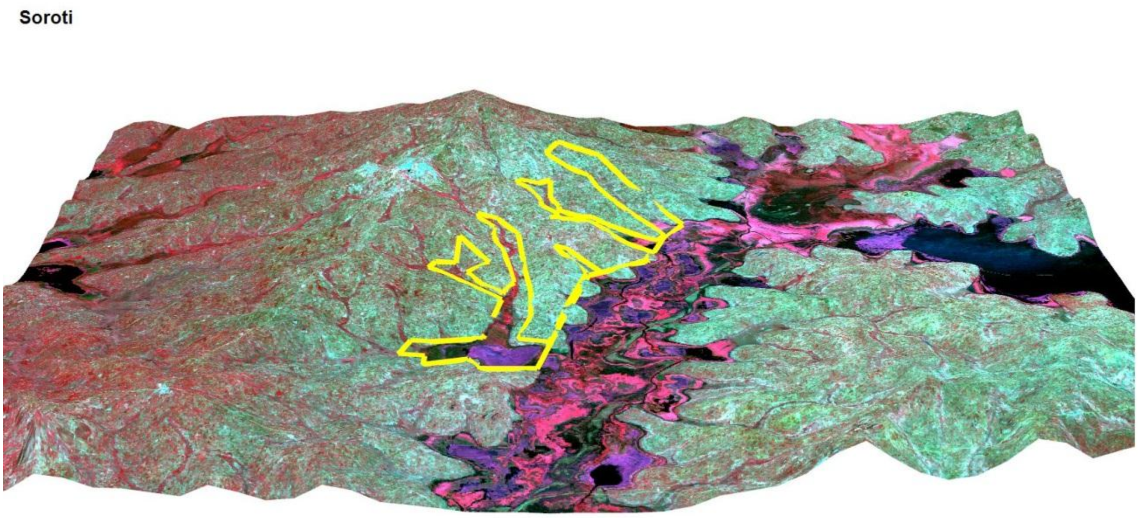


Figure 46: 3D impression of Soroti focal area, Uganda.

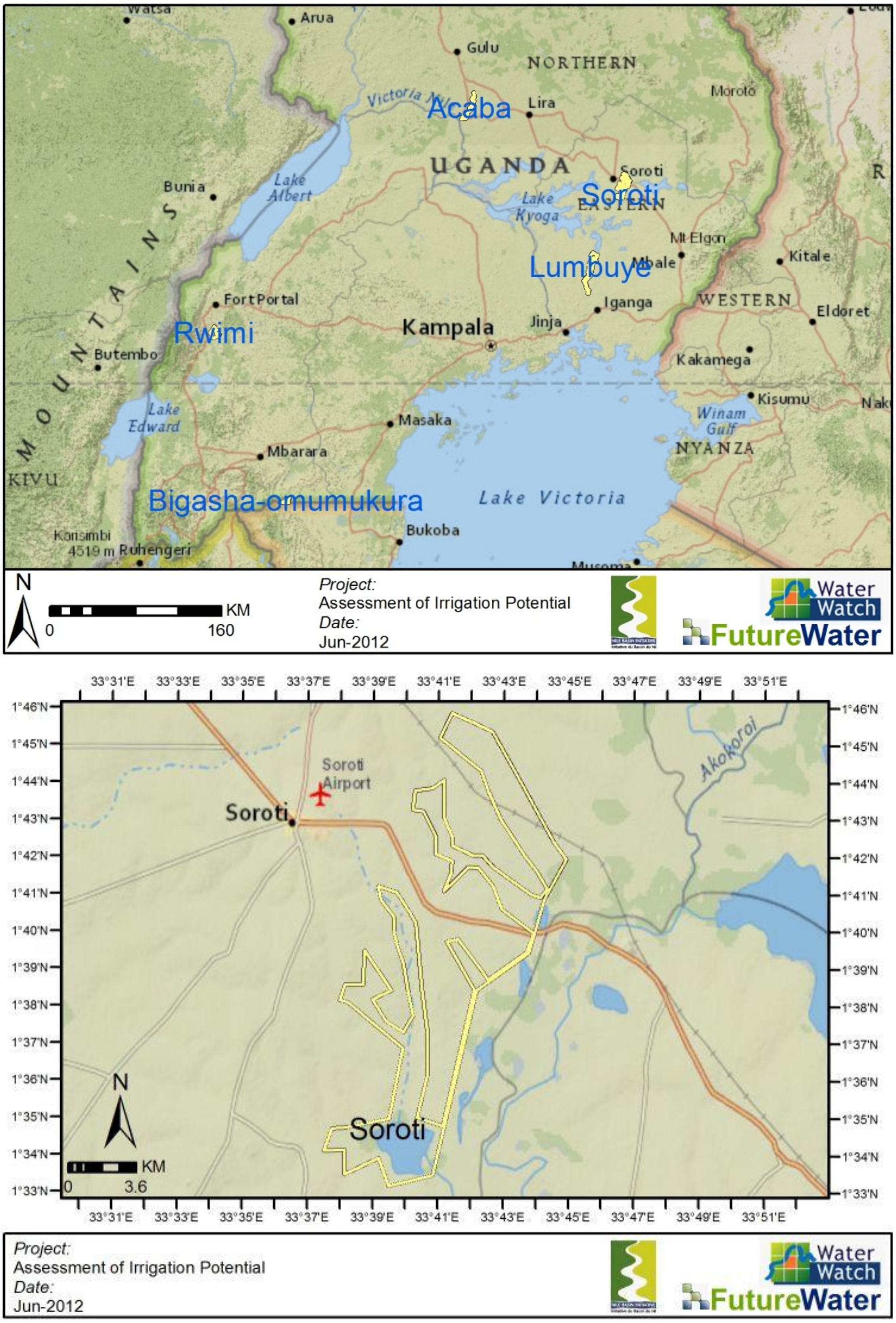


Figure 47: Soroti focal area, Uganda

4.2 Land suitability assessment

4.2.1 Terrain

Soroti focal area is situated in Uganda’s Eastern province within the Soroti district. The focal area covers four valleys East of Soroti town, which drain into the Okot River towards the East. Okot River drains an extremely large area, and therefore the water levels and discharge within the river valley are unpredictable. The four valleys within this focal area all have their highest point in the west, at elevations of approximately 1070 m above sea level. The valleys descend towards the East towards 1040 m (Figure 48). The slopes differ throughout the area. The Northern two branches have slopes ranging from 0% to more than 15%, with quite some emphasis on the steep slopes. The Southern two branches clearly have less steep slopes, with most of the area having slopes of 0-5% (Figure 49).

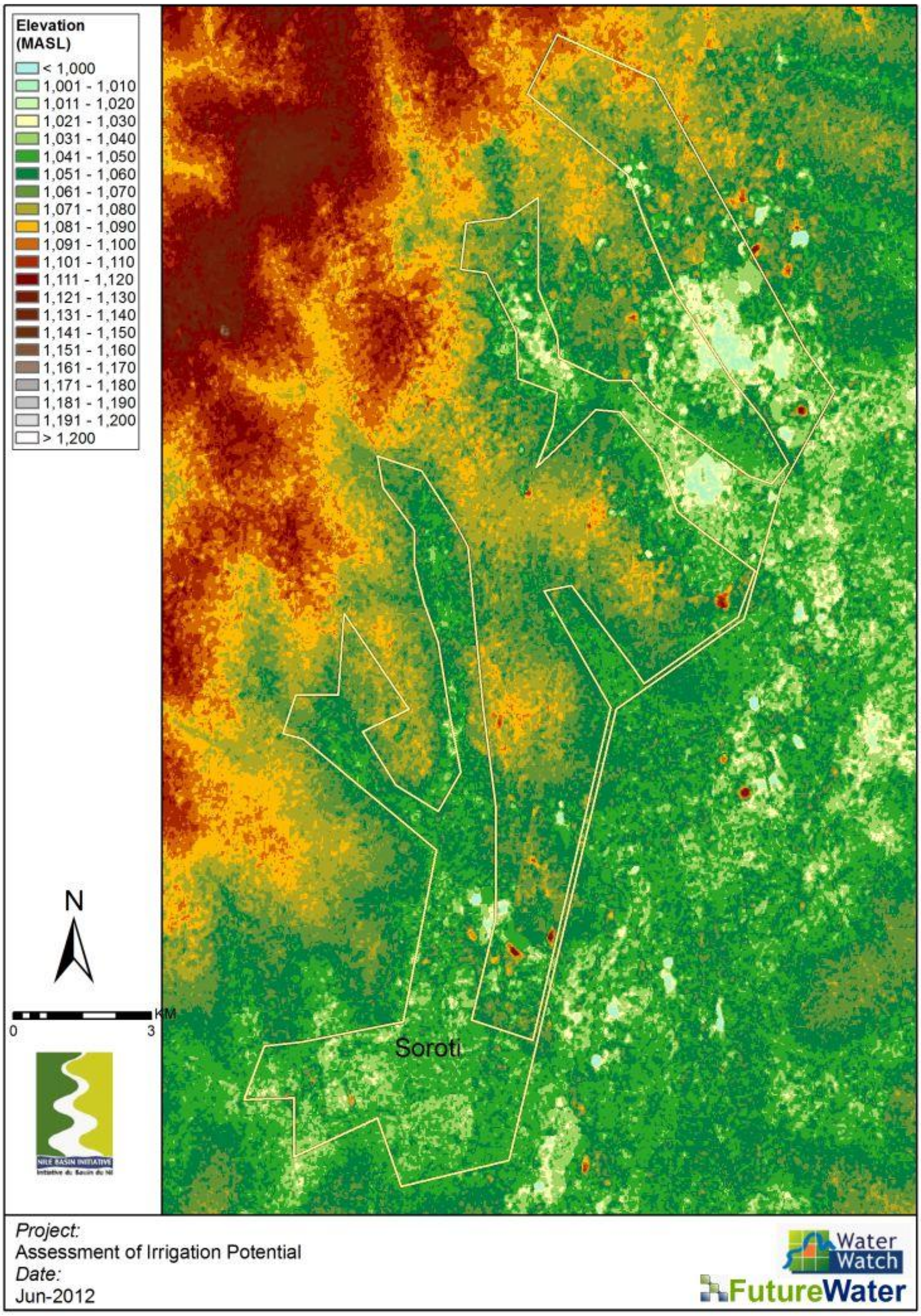


Figure 48: DEM Soroti focal area. Resolution 1 arc second (+/- 30m).

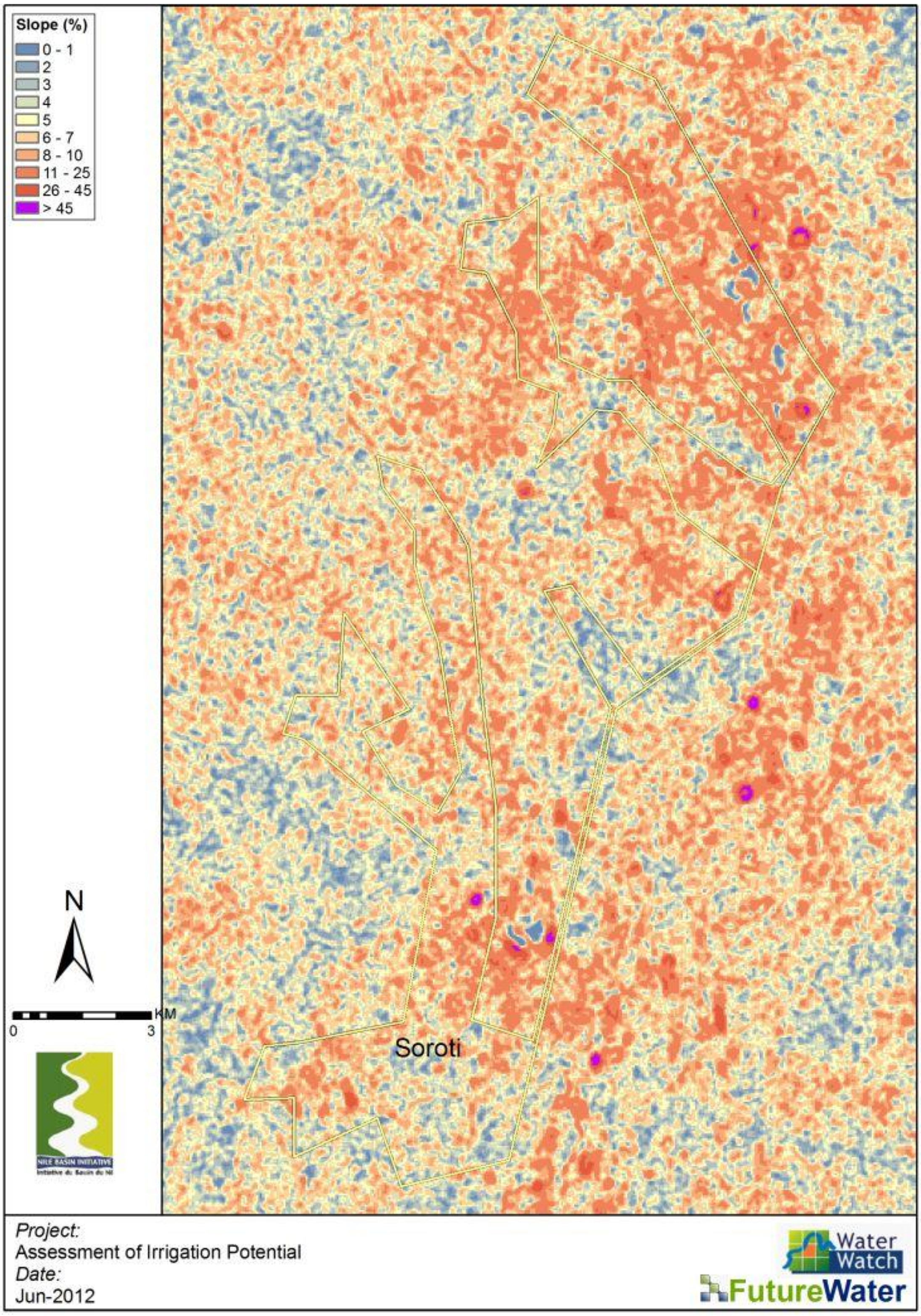


Figure 49: Slope map Soroti focal area (source: ASTER).

4.2.2 *Soil*

Within the Soroti focal area the soils are quite uniform in the valleys, consisting of sandy clay loam. More upland the texture changes towards sandy loam. Within the FAO classification, the soils in the largest southern part of the focal area are Eutric Plinthosols, and in the North Eastern part Eutric Leptosols can be found. Field observations showed that the area is drained well, and that slight erosion is present. Plinthosols are iron rich, and developed under changing groundwater regimes. The repeatedly drying and wetting of the soil hardened it. Plinthosols present considerable management problems. Poor natural soil fertility, caused by strong weathering, waterlogging in bottomlands, drought on Plinthosols with Petroplinthite, Pisoliths or gravels, are serious limitations. Leptosols, which can be found in the North East of the focal area, are very shallow and extremely stony. Therefore, they are mainly used for grazing, and have limited fertility for agriculture. Erosion is the greatest threat to these soils. A few good crops may be grown on such slopes, but at the price of severe erosion. Steep slopes with shallow and stony soils can be transformed into cultivable land through terracing, the removal of stones by hand and their use as terrace fronts. Agroforestry (a combination of rotation of arable crops and forest under strict control) holds promise, but is still largely in an experimental stage. The excessive internal drainage and the shallowness of many Leptosols can cause drought even in a humid environment.

4.2.3 *Land productivity*

The land productivity (NDVI) in the five Ugandan focal areas ranges between 0.58 and 0.74. Compared to the Uganda average NDVI value of 0.54, all of the focal areas have relative high land productivity values. Within the Soroti focal area the average NDVI is 0.58, which is rather low (Figure 51). The two southern valleys have a significant higher NDVI value than the northern two. The variation in land productivity is low in the focal area, despite the fact that the area is rather intensively used for agriculture. This low variation could suggest that many perennial crops are crown, or that crops are grown in continuous cropping cycles.

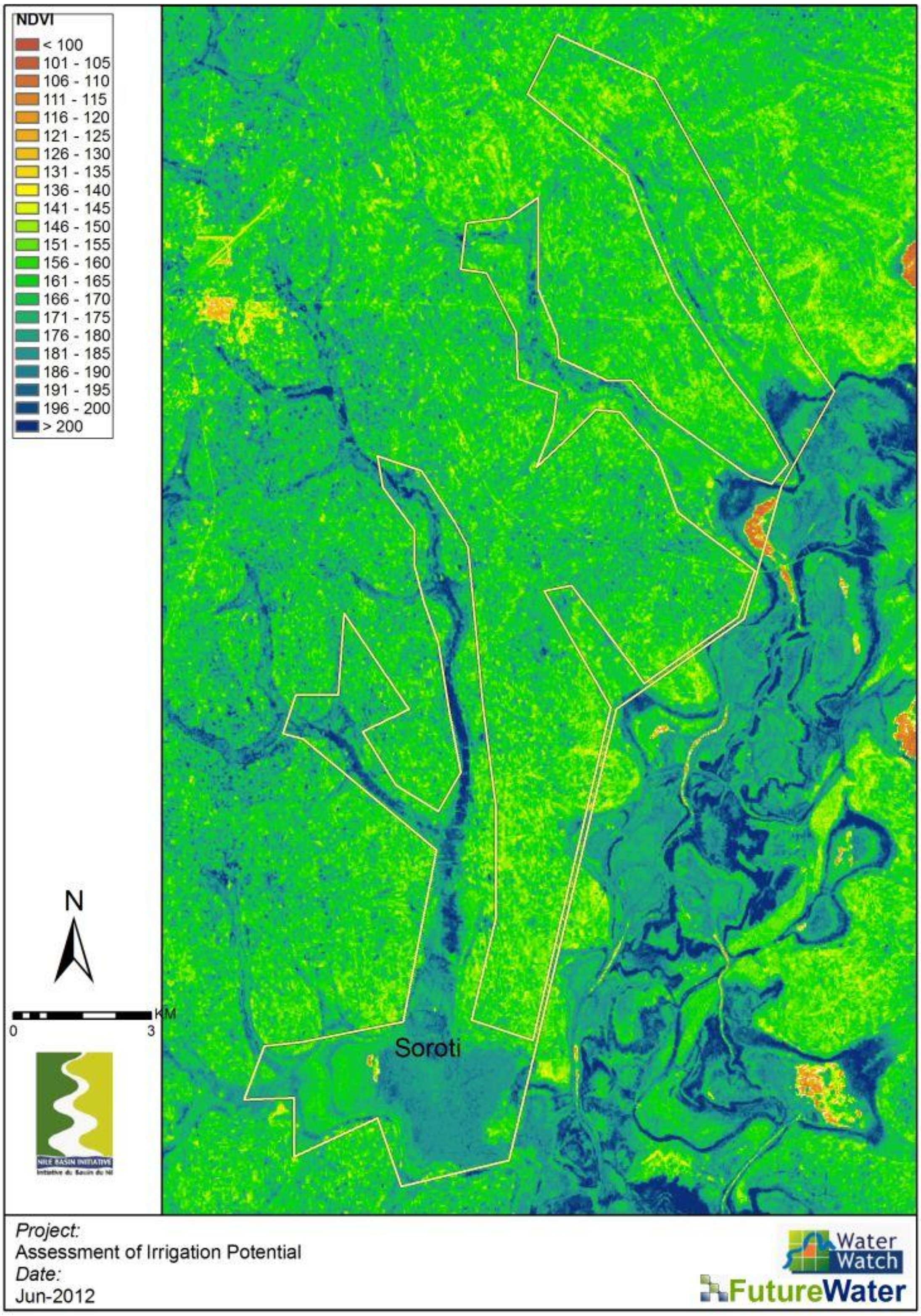


Figure 50: High resolution NDVI for Soroti focal area

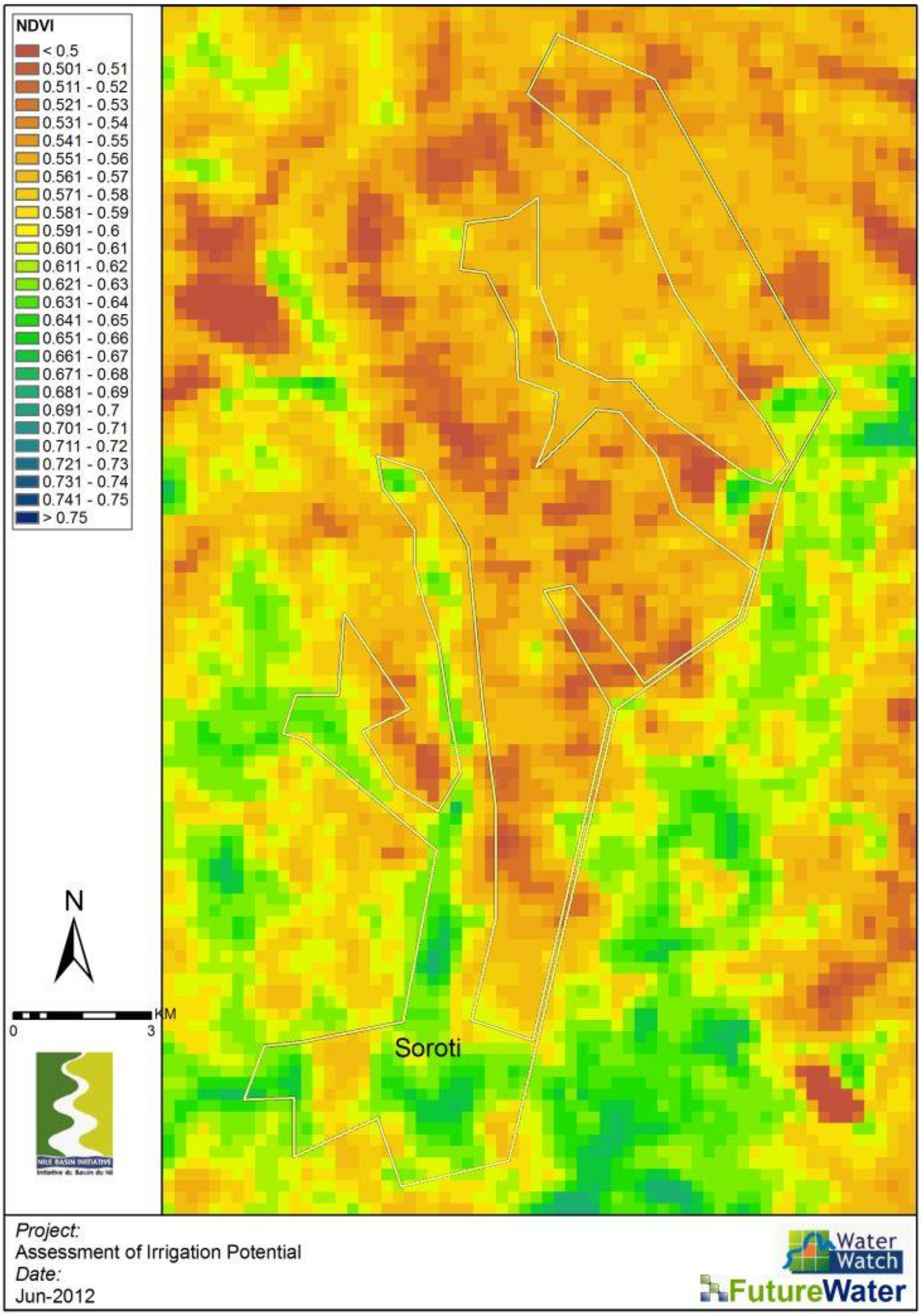


Figure 51: Yearly average NDVI values for Soroti focal area.

4.2.4 *Potential cropping patterns*

Soroti focal area is already used intensively for agriculture, with more than 70% of the land being used for agricultural production. Dominant crops include cassava, groundnuts, rice, millet and sorghum. If possible, these crops are already grown in two growing cycles per year. Depending on the type of irrigation system to be developed, the government policy differs concerning future crops. However, the overall focus will be on high value crops which will strengthen the economic situation in the region and reduces poverty and hunger. Potential future crops include rice, vegetables and fruit trees. Currently, pilots for rice irrigation are going on in the area of Omugenya, by the Japanese International Cooperation (JICA). Rice is a high potential crop, which can be grown in at least 2 growing cycles per year, and in some occasions even three 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 warm with temperatures during the year ranging from about 20^{o}C to 32^{o}C, with the hottest months being December, January, February, and March. Annual average precipitation is 1232 mm and reference evapotranspiration 1644 mm per year.

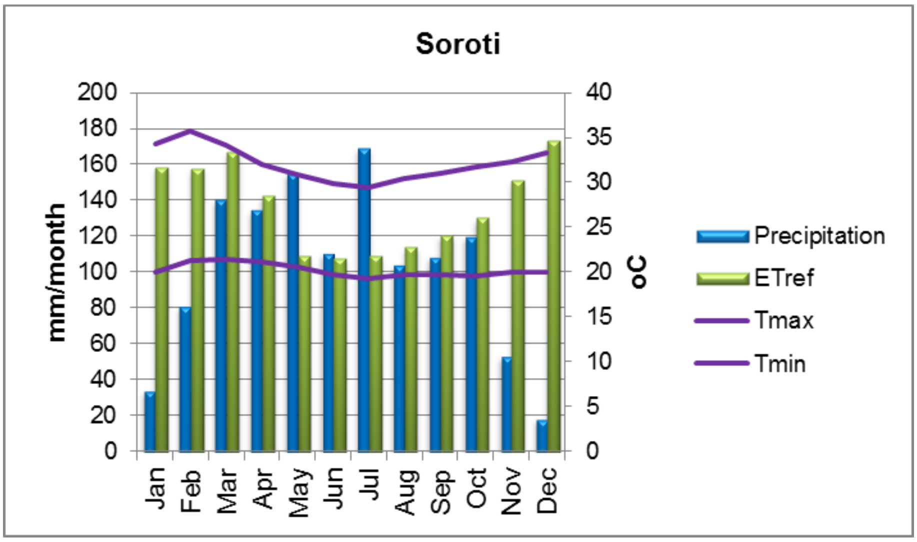


Figure 52: Average climate conditions for Soroti focal area.

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.

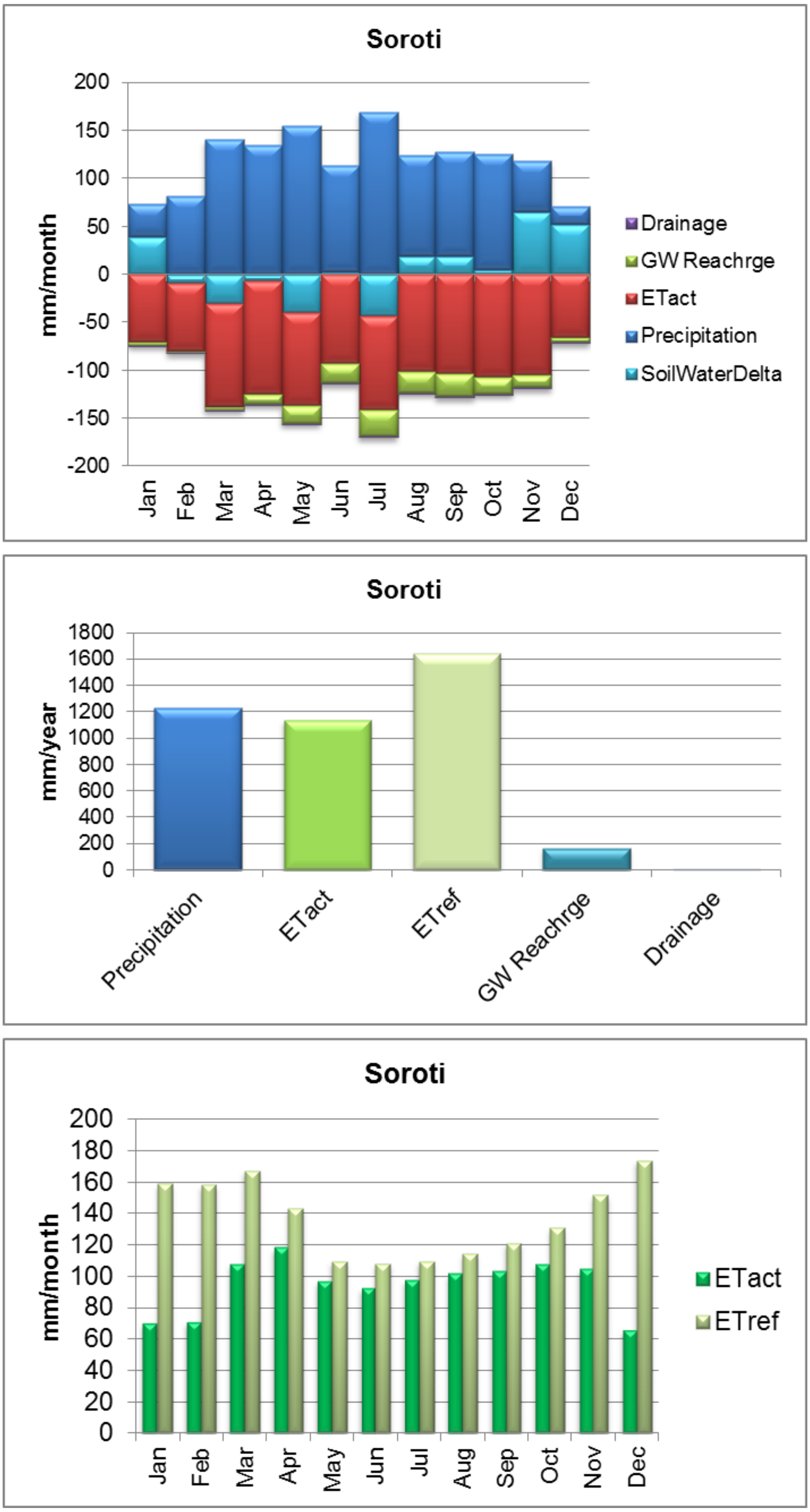
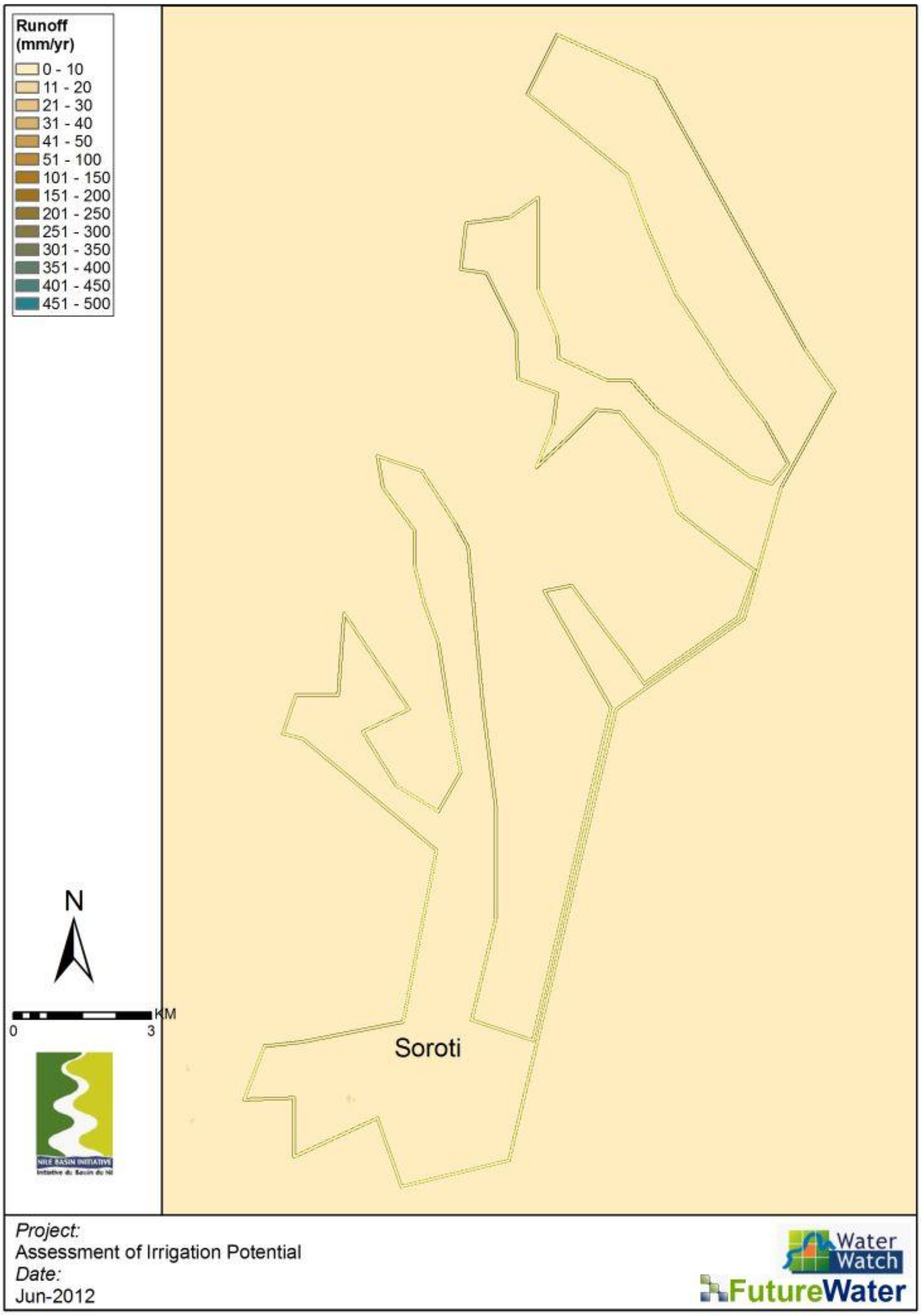
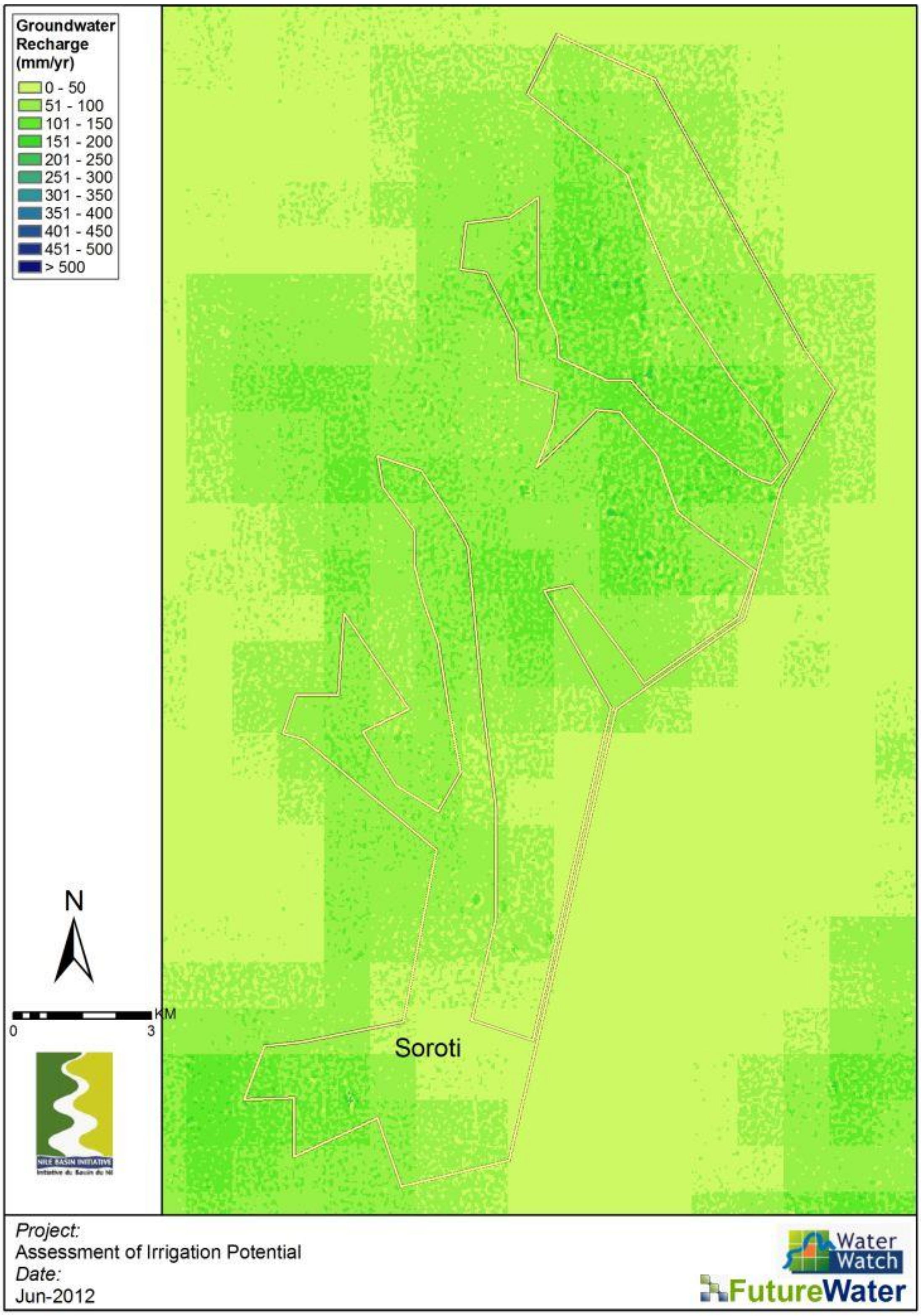


Figure 53: Water balances for the area based on the high resolution data and modeling approach for Soroti focal area.


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
N
KM
0
3
Soroti
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
N
KM
0
3
Soroti
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

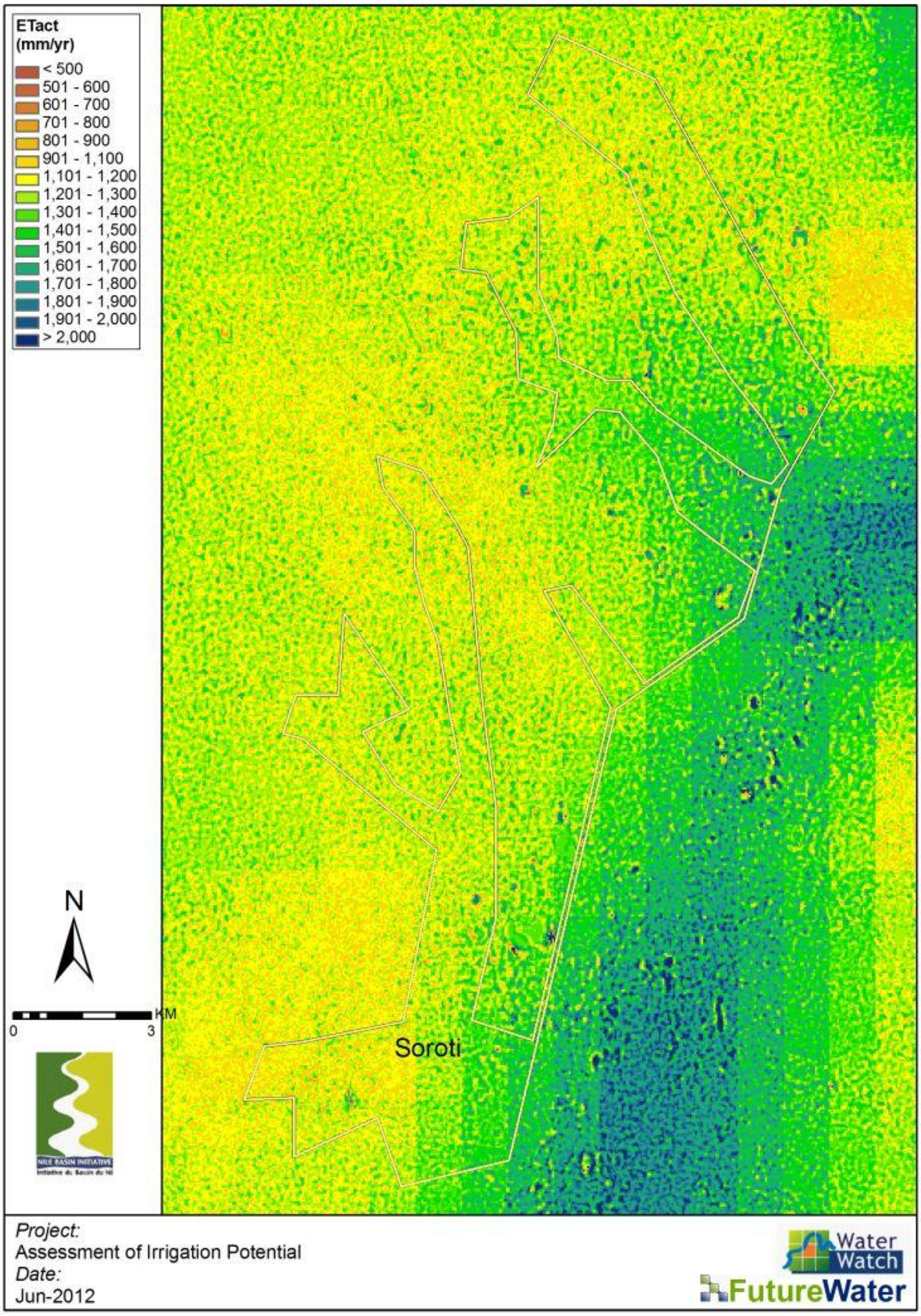


Figure 54: Water balances for the area based on the high resolution data and modeling approach for Soroti focal area.

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.

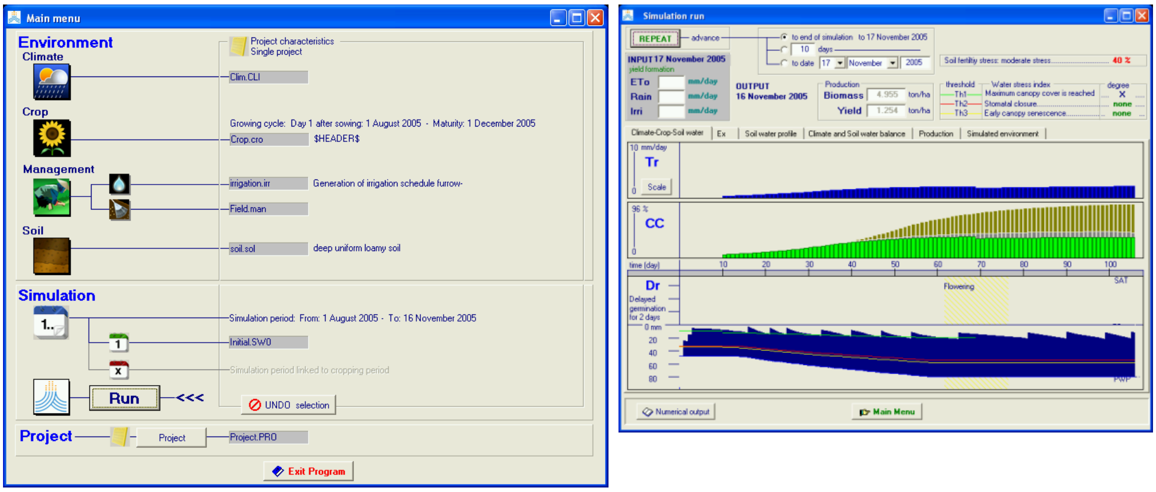


Figure 55: Typical example of AquaCrop input and output screens.

Table 7: 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)
Fruit trees	1232	1644	1	365	1232	380	1638	1015
Vegetables	1232	1644	1	365	1232	310	1638	1031
Rice	1232	1644	213	320	368	220	445	411

4.4.2 Irrigation systems and irrigations efficiencies

This focal area is split up into four smaller separate areas. The Northern three branches of the focal area are not as suitable for irrigation as the Southern one. Therefore, it is recommended to focus initially on the southern branch, and eventually decide whether it's worth and possible to develop the other branches too. In the Southern branch it is advised to use border or furrow irrigation. Rice can be grown with border irrigation, and vegetables and fruit trees with furrow irrigation. Both of these irrigation techniques require a relatively low initial development cost, and are easy to use as farmers already have some experience with these techniques. The only constraint is that the upstream catchment is very small with roughly 35 km^2. This limits the irrigation possibilities. An average yearly flow of 0.1 m^3/s enters the focal area, which would just be enough to irrigate 100 ha. Using another irrigation technique, such as drip or sprinkler irrigation, could enlarge the irrigable area as efficiencies are much higher. However, the development costs are much higher and the farmers have limited knowledge on these techniques.

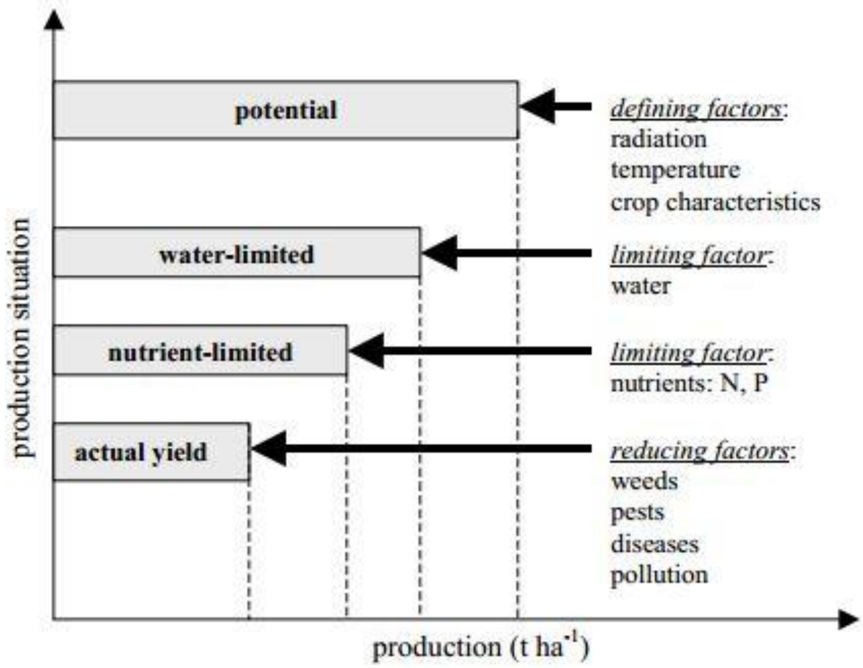
4.4.3 Water source

The water source for irrigation will be the streams coming from the west, and drain into Okot River in the East. These streams all have a very small catchment area, and a very limited discharge. Small reservoirs can be a solution, which can slightly stretch the growing period. Alternative water sources include groundwater, which is a very realistic source within all the valleys, and the Okot River and wetland. Water can be pumped up from the river, which is especially feasible for the lower parts of the valleys. The lifting height is very limited and distance feasible. Most likely, a combination of all water sources is needed for a total irrigation development in the valleys. Therefore, a detailed cost analysis should be made within the scope of a feasibility study.

4.5 Potential crop yield assessment

The yield gap describes the difference between the current yield, and the maximum possible yield. Generally, 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

Uganda has slightly higher yields compared to surrounding countries. Population pressure and the increasing food demand have been triggers for the intensification of agriculture. In Figure 56 the yield gap is shown relatively to the highest obtainable yield in the world, to the world's average, and to Africa's average. Within the Soroti focal area the yields are with an average of 7% slightly higher than the Ugandan average yields. Uganda keeps good records for fruit fresh nes growing. Therefore, it is being introduced in many new areas. A change to fruit fresh nes will probably result in relatively high yields compared to Africa standards and even world standards. This can be a good move, but it should be kept in mind that with fruit trees the first years will not give abundant harvest. The yield gap for rice and vegetables is quite large. Rice currently gives yields of 1500 kg/ha, which is about 14-15% of the world's highest. The potential for rice is enormous, and yields under a good managed irrigation system can increase towards 5000 kg/ha. Vegetables currently give a yield of about 6000 kg/ha. Under a good managed irrigation system this can be increased towards 20,000 kg/ha.

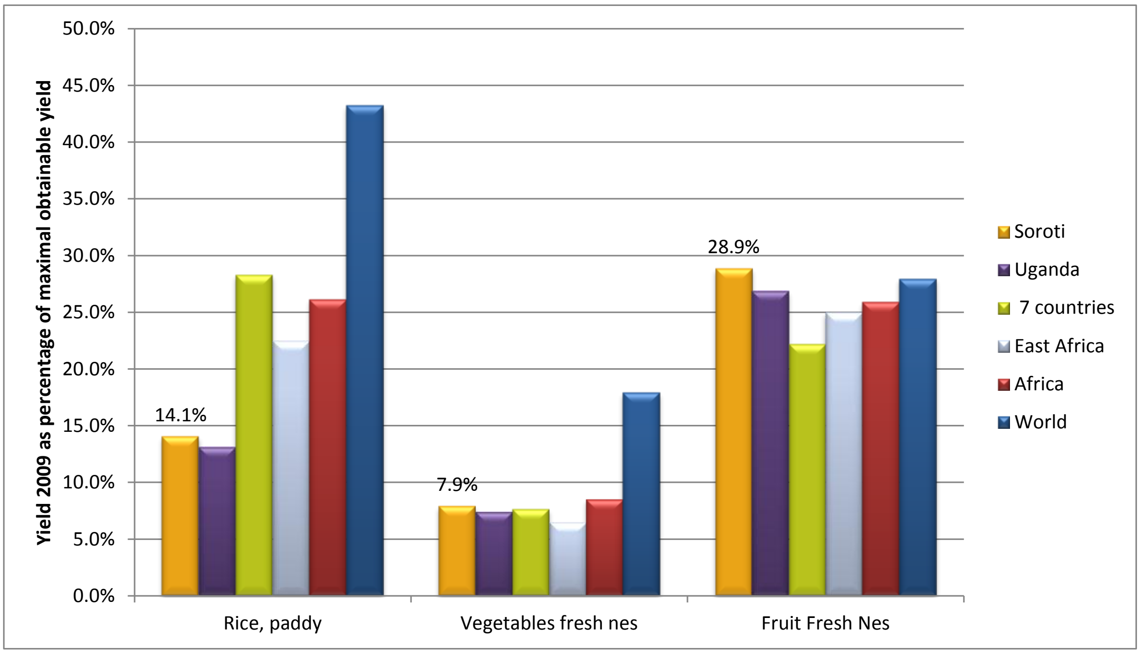


Figure 56: Yield gap Soroti (source: FAOSTAT, 2010).

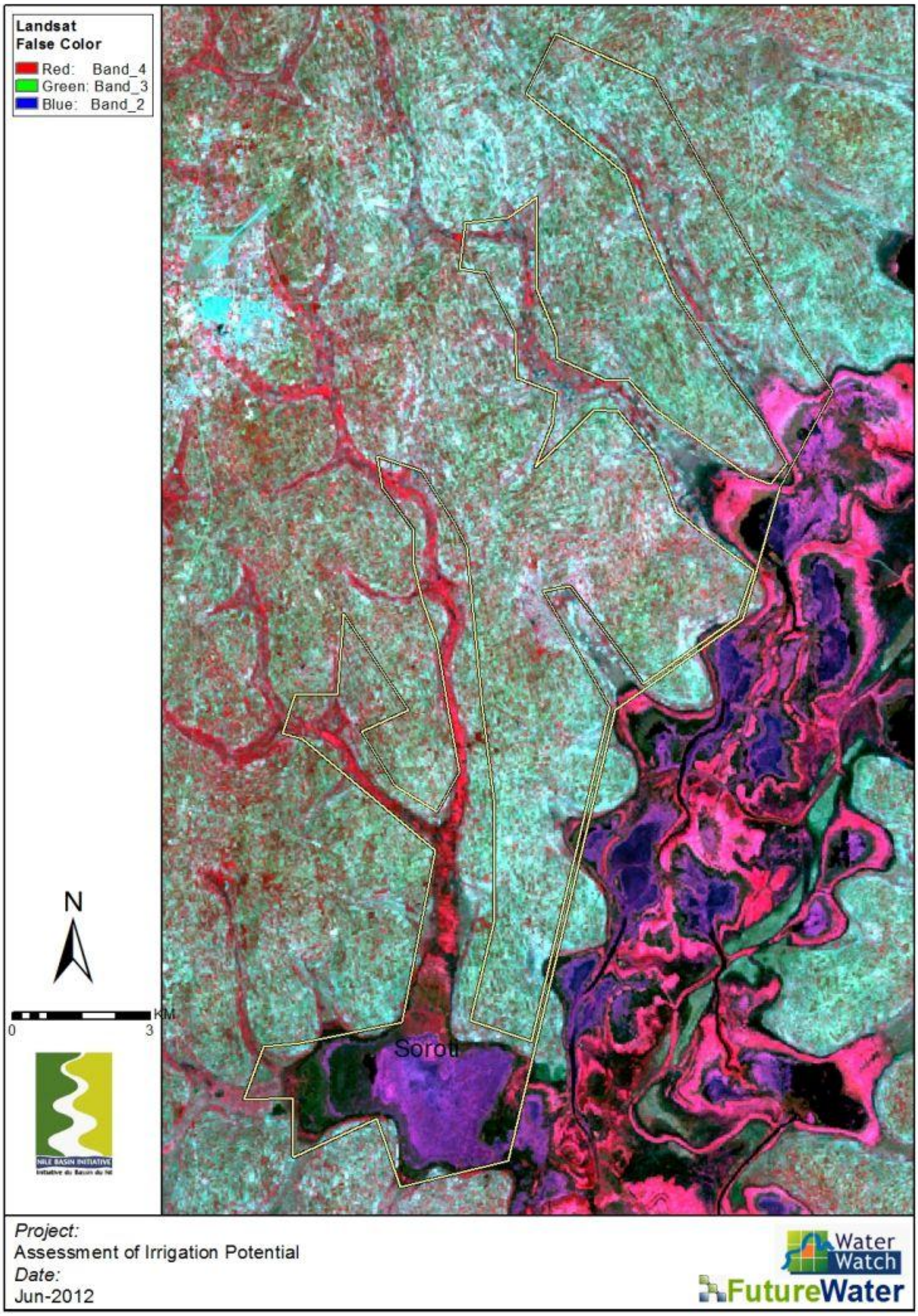


Figure 57: Landsat False Color Composite indicating current productivity of the area for Soroti focal area.

4.6 Environmental and socio-economic considerations

4.6.1 Population displacements

People in the focal area live quite scattered around on the banks of the valley and on the upward slopes. Within the valley, which is mainly appointed as focal area, hardly anybody lives due to the high flood risks. 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, due to the scattered houses in some areas, the irrigation possibilities will either be restricted, or minimal displacements are needed. People in the area have some experience with irrigation. This increases the coop capacity of the people as they are aware of the benefits that irrigation brings. 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

The population density in the extended Soroti focal area is 150 people/km^2, which is roughly the Ugandan average. Within the focal area itself, which mainly covers the valleys, the population density is much lower. The focal area is accessible by the Mbale highway, which passes through the focal area and connects to Soroti town, which is 15 km away. Quite some dirt roads are present within the focal area, but if irrigation will be developed, the infrastructure should be strengthened. The area is inhabited by the Iteso,Bagisu, Kumam and Japadola tribes. The farmers have average expertise in farming and irrigation, and farmer's cooperatives do exists, but need to be strengthened. Poverty in the region is severe, with 50-60% of the population living beneath the poverty line.

4.6.3 Upstream downstream consideration

Since the upstream catchment is very small, the water availability for irrigation should be considered with care. Upstream and downstream of the focal area, people should have enough water to practice agriculture and have water for 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 an 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 the focal area no protected areas are reported.

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):
    - Fruit trees: 210,000 kg/ha, 0.10 $/kg
    - Vegetables: 50,000 kg/ha, 0.16 $/kg
    - Rice: 2,500 kg/ha, 0.61 $/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.

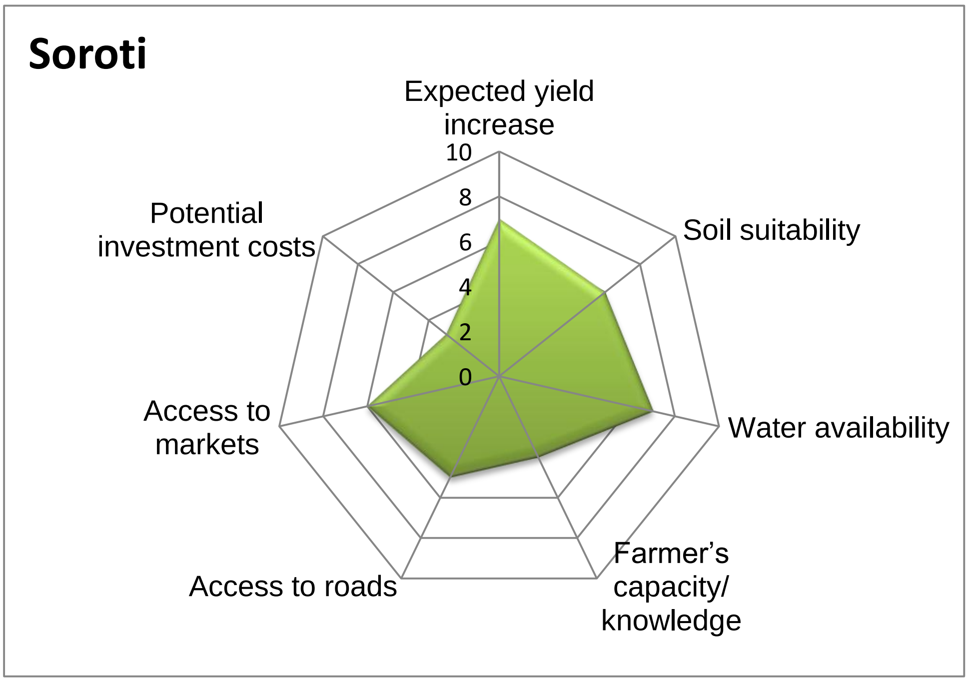


Figure 58: Filled radar plot indicating expert knowledge score to develop irrigation in the Soroti focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 8: Benefit-cost analysis for Soroti area.

Characteristics	
Irrigated land (ha)	2,400
Farmers	3,000
Investment Costs	
Irrigation infrastructure (US$/ha)	8,000
Social infrastructure (US$/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$)	23.7
O&M costs (million US$/yr)	0.234
Net benefits per year (million US$/yr)	14.694
IRR (Internal Rate of Return)	100.0%

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 Bigasha/Omumukura focal area

5.1 Introduction

This chapter will describe the current state of the Bigasha/Omumukura 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 60 a detailed map of the area is given. Total area is 1942 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 Michael Iwadra and Fredrick Ssozi and Richard Cong as supervisor in March 2012.

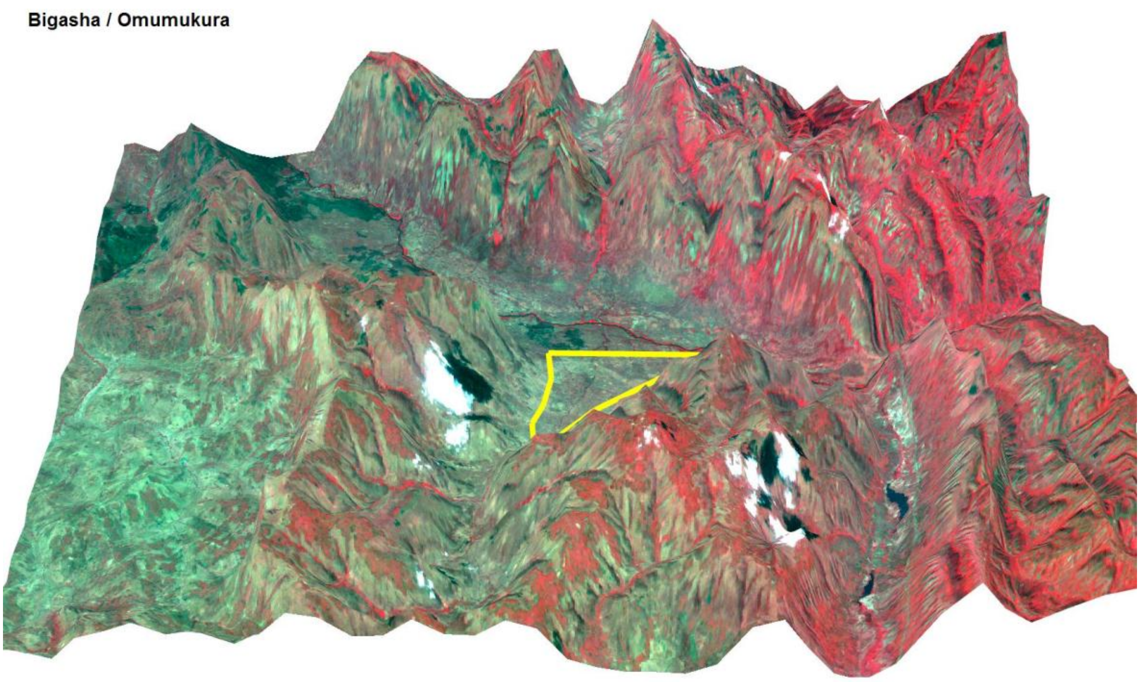


Figure 59: 3D impression of Bigasha/Omumukura focal area, Uganda

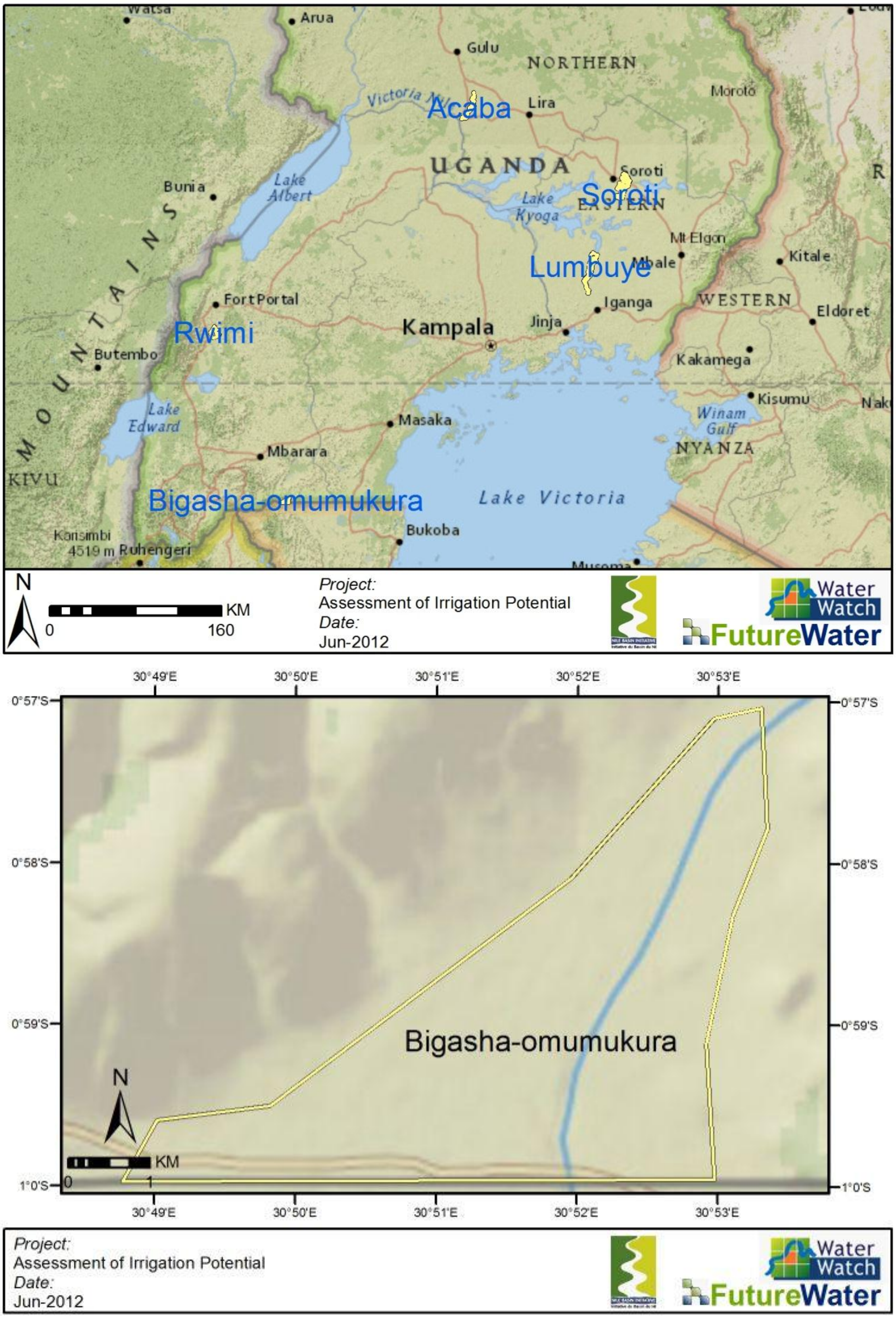


Figure 60: Bigasha/Omumukura focal area, Uganda

5.2 Land suitability assessment

5.2.1 Terrain

This focal area is situated in the absolute South of Uganda, in the Southern province, Isingiro district and Ngarama sub-county. Omukura River flows through the focal area from North to South. With 1942 ha, this focal area is the smallest of the five selected in Uganda. The area is rather flat, and descends gradually from 1260 m in the North to 1230 m in the South. The stream flowing through the area drains into the Kagera River, which flows from Tanzania (Figure 61). Compared to the areas nearby, the focal area can be classified as a plain, with most slopes under 5% and a few small places with slopes exceeding 10% (Figure 62).

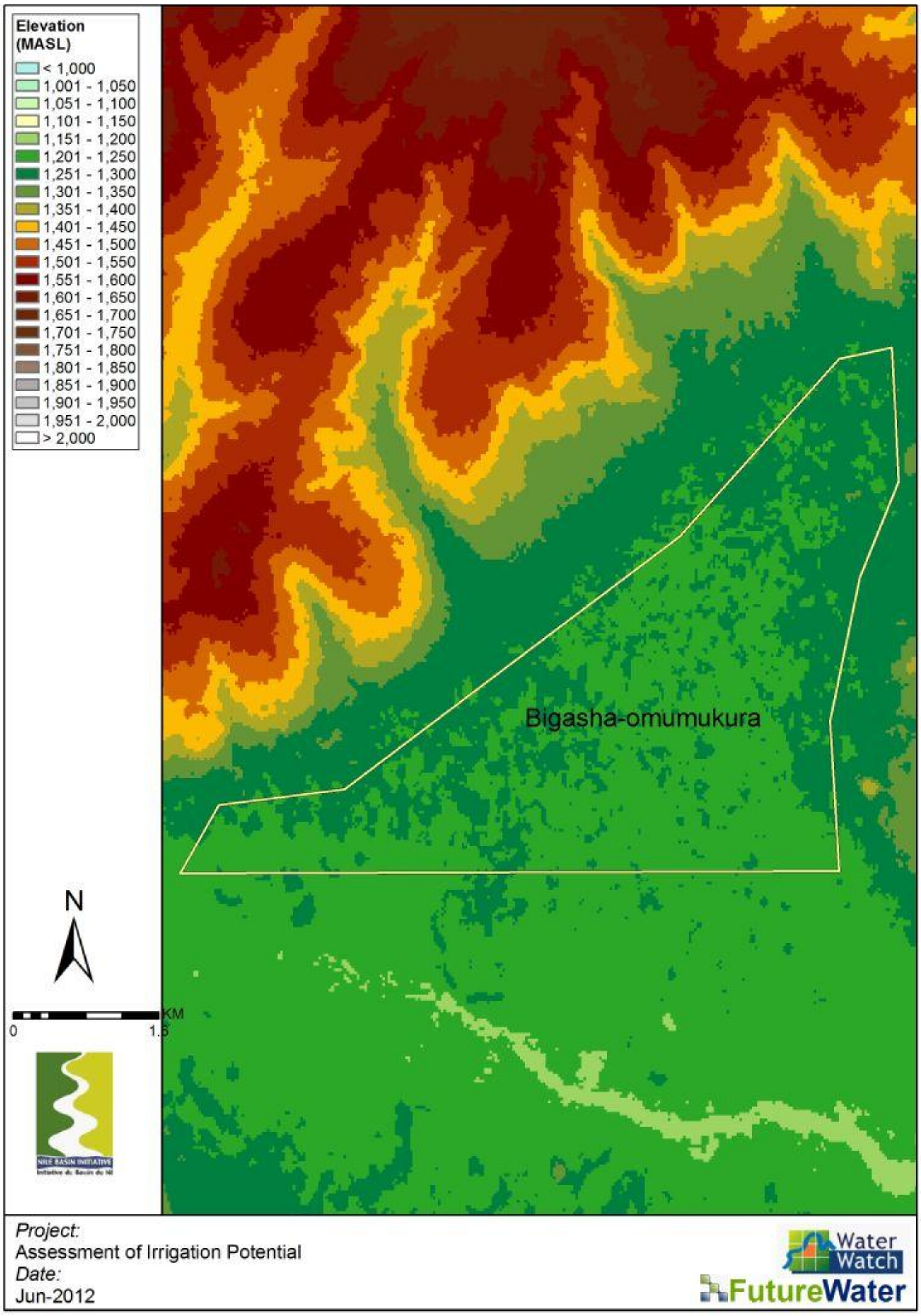


Figure 61: DEM Bigasha/Omumukura focal area. Resolution 1 arc second (+/- 30m).

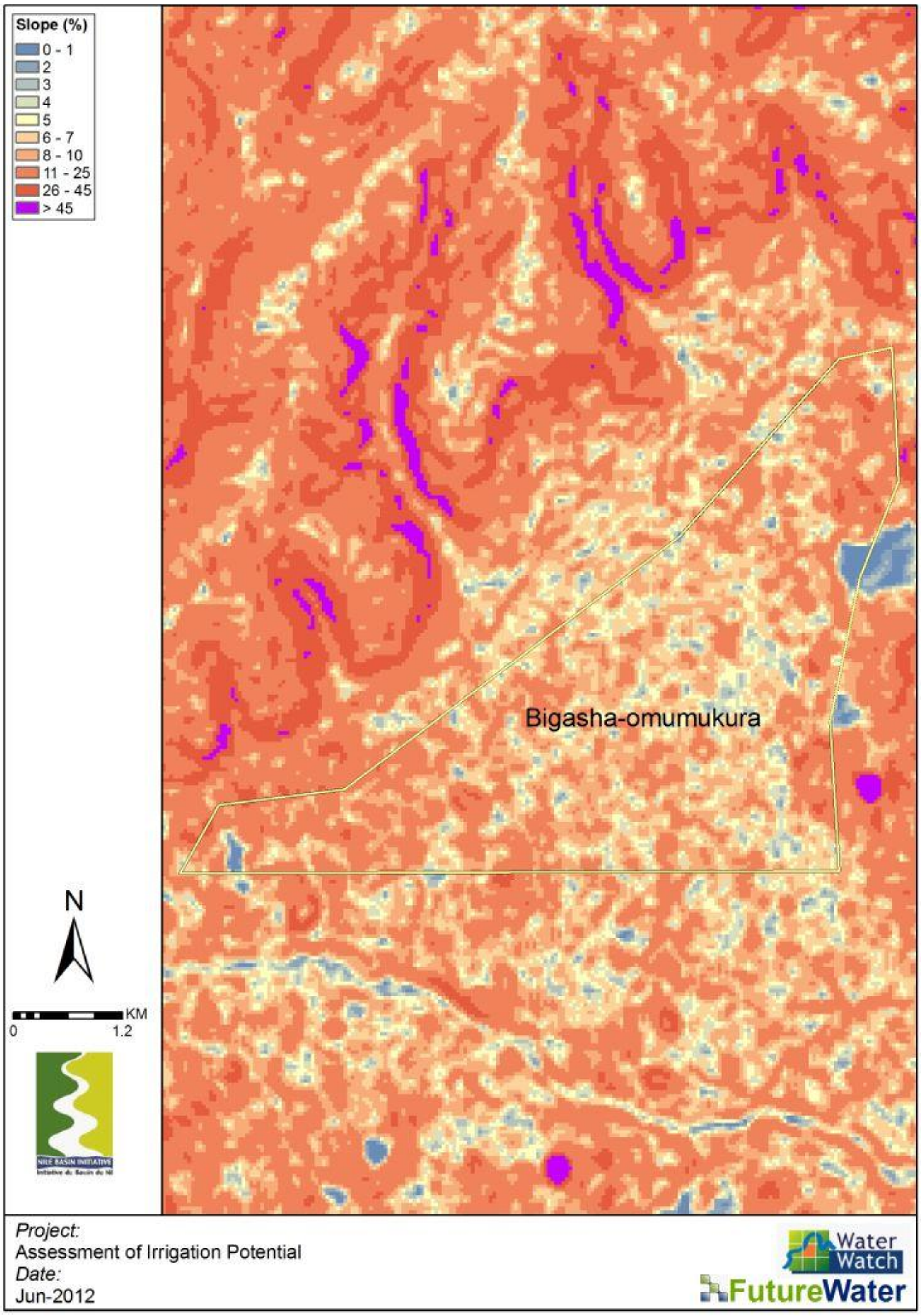


Figure 62: Slope map Bigasha/Omumukura focal area (source: ASTER).

5.2.2 Soil

The focal area has clay based soils, due to a continuous process of sedimentation. The soils in the valley are moderately drained, while upland the soils are more sandy clay, and well drained. According to the FAO classification, the soil in the valley is a Haplic Ferralsol, which is a classic deeply weathered, tropical red or yellow soil. Ferralsols have good physical properties. Great soil depth, good permeability and stable microstructure make Ferralsols less susceptible to erosion than most other intensely weathered tropical soils. Moist Ferralsols are friable and easy to work. They are well drained, but may in times be dry because of their low available water storage capacity. The chemical fertility of Ferralsols is poor; weatherable minerals are scarce or absent. Maintaining soil fertility by maturing, mulching and/or adequate (i.e. long enough) fallow periods or agroforestry practices, and prevention of surface soil erosion, are important management requirements.

5.2.3 Land productivity

The land productivity (NDVI) in the five Ugandan focal areas ranges between 0.58 and 0.74. Compared to the Uganda average NDVI of 0.54, all the focal areas have relative high land productivity values. Within this focal area the average NDVI is 0.6 (Figure 64). This is rather low, but higher values can be found in the center of the focal area. The variation over the year is quite diverse within the area. The center part, with the higher land productivity has also the lowest variation in land productivity over the year. The eastern end western parts of the focal area have a higher coefficient-of-variation. These are mainly the areas which receive least of the water and are therefore relying on seasonal precipitation.

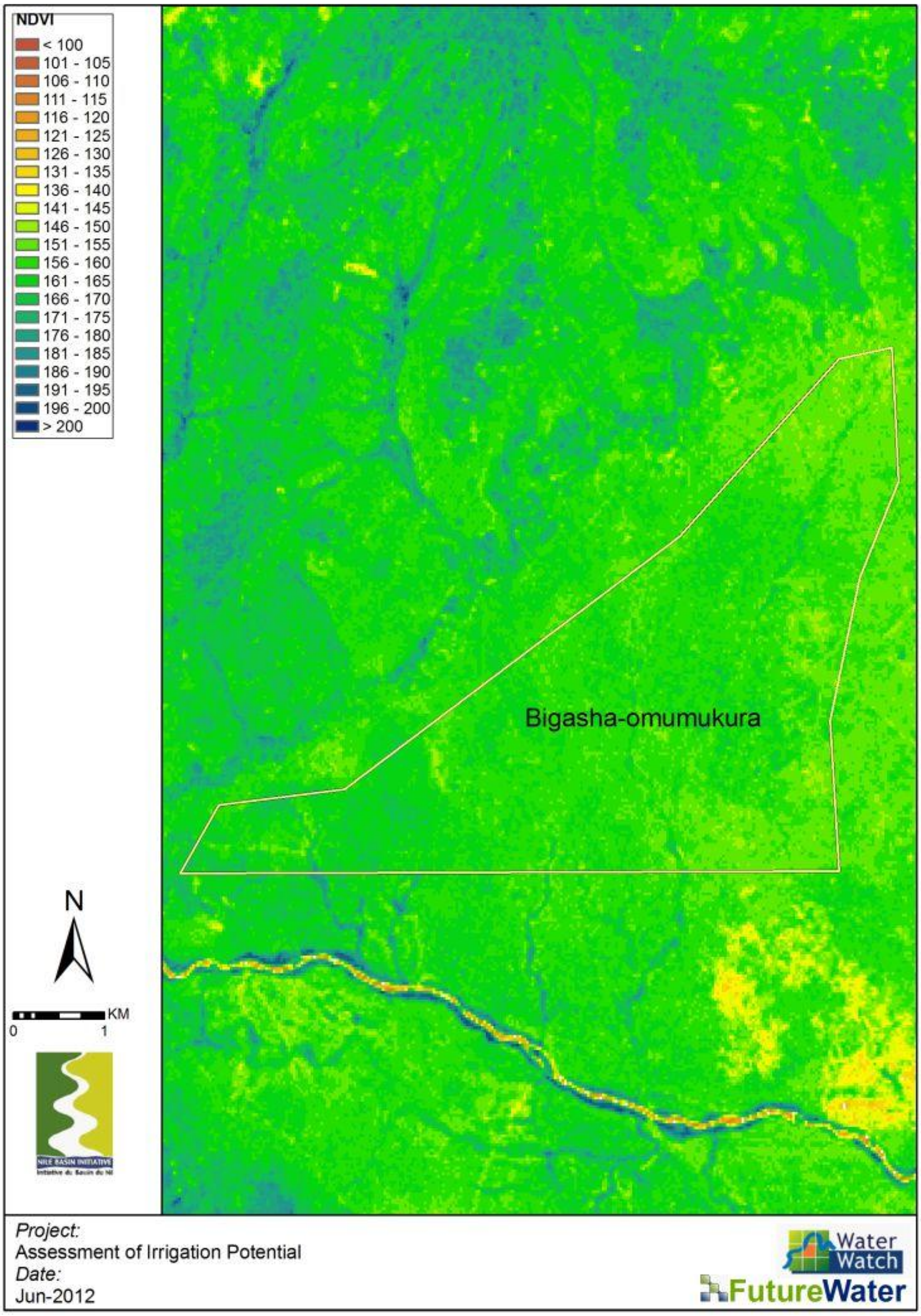


Figure 63: High resolution NDVI for Bigasha-Omumukura focal area

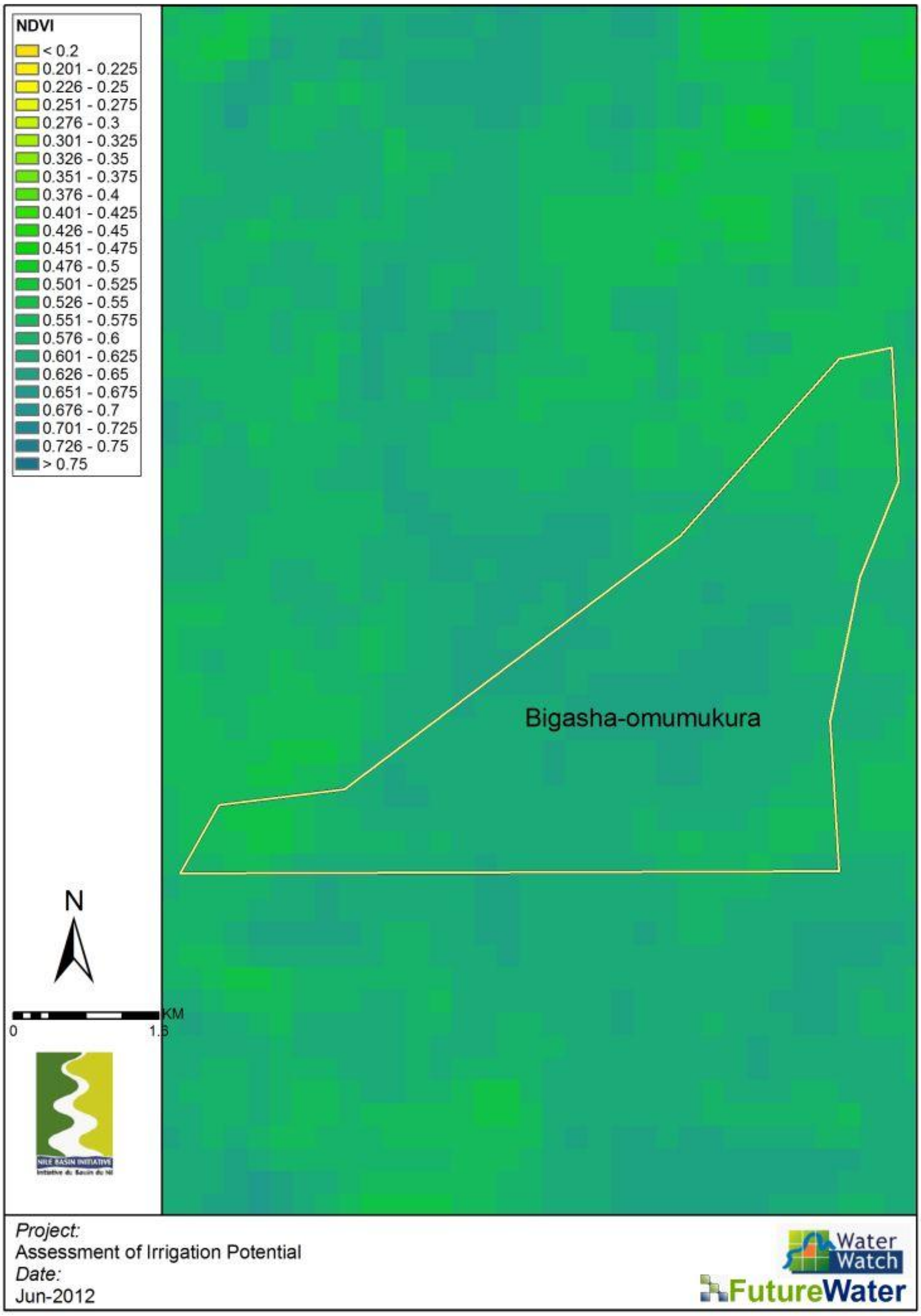


Figure 64: Yearly average NDVI values.for Bigasha-Ommumukura focal area

5.2.4 *Potential cropping patterns*

This focal area is used for both agriculture and livestock. However, 65% of the land is used for agriculture. A dominant crop includes bananas, which occupies about 70% of the agricultural land and is a perennial crop. Other crops include beans, cassava, millet and maize, which all occupy about 10% of the agricultural area. These crops area all grown in two growing cycles per year. Depending on the type of irrigation system to be developed, the government policy differs concerning future crops. However, the overall focus will be on high value crops, which will strengthen the economic situation in the region and reduces poverty and hunger. Future potential crops therefore include fruit trees, vegetables and coffee. These are all perennial crops with a high economical return.

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 temperatures during the year ranging from about 15^{o}C to 27^{o}C. Annual average precipitation is 1247 mm and reference evapotranspiration 1439 mm per year.

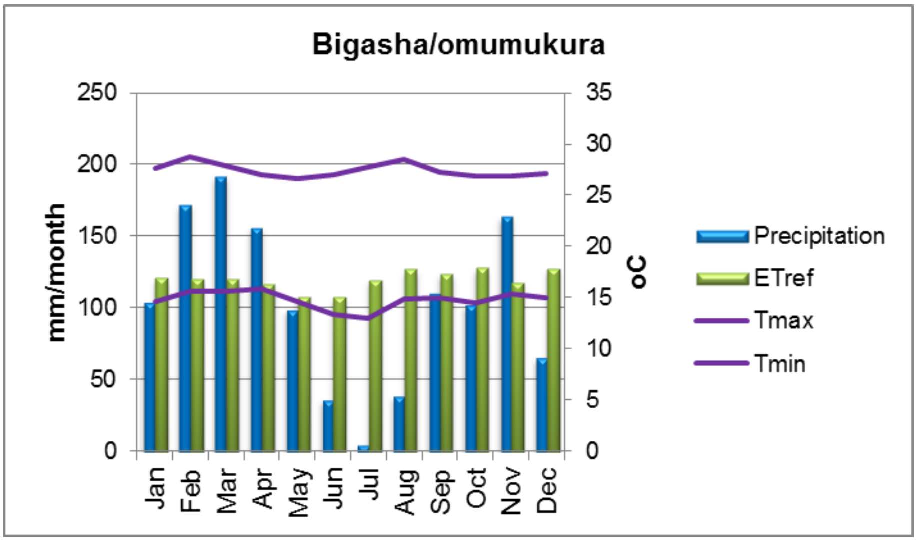


Figure 65: Average climate conditions for Bigasha-Omumukura focal area.

5.3.2 *Water balance*

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

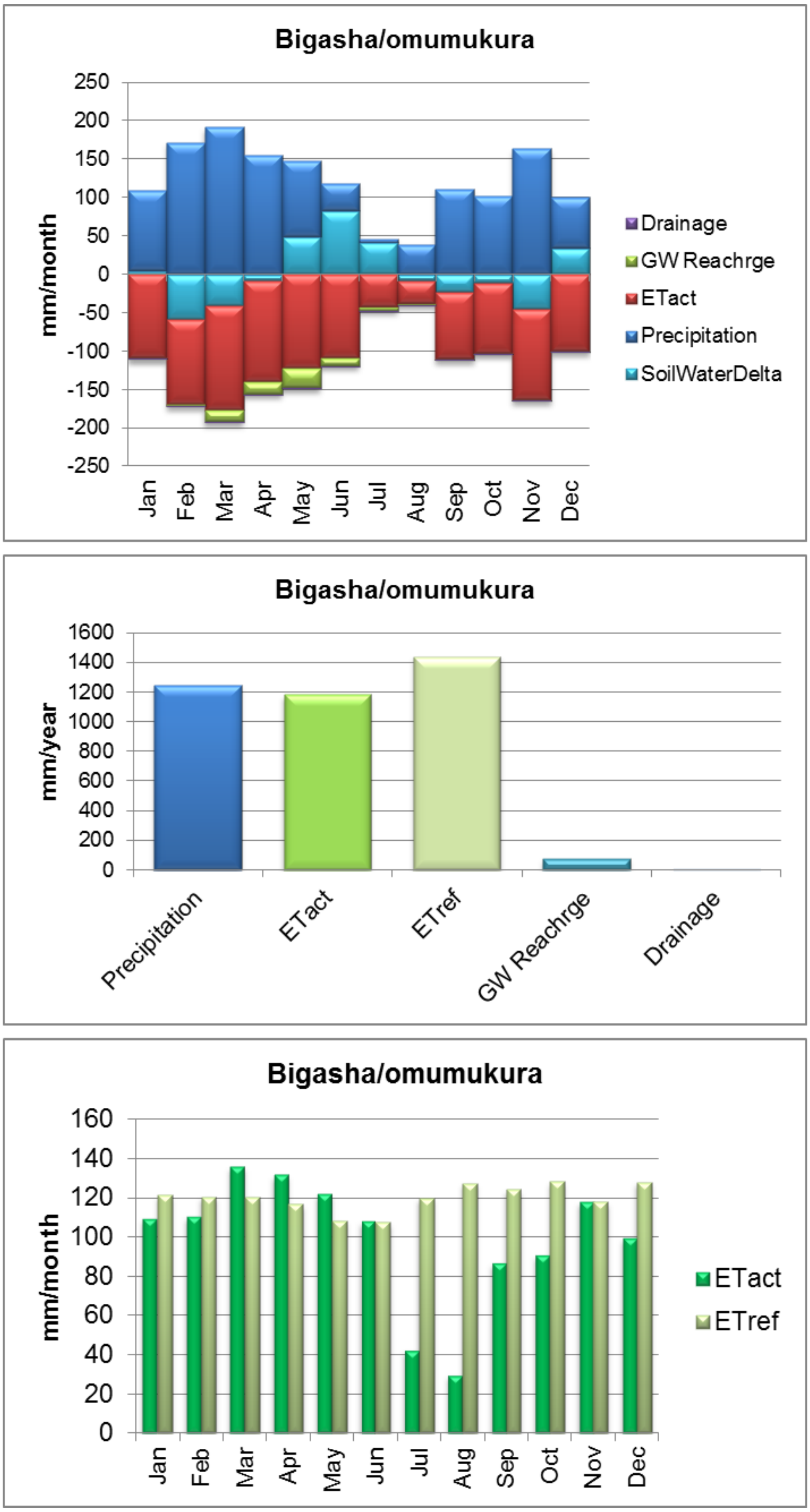
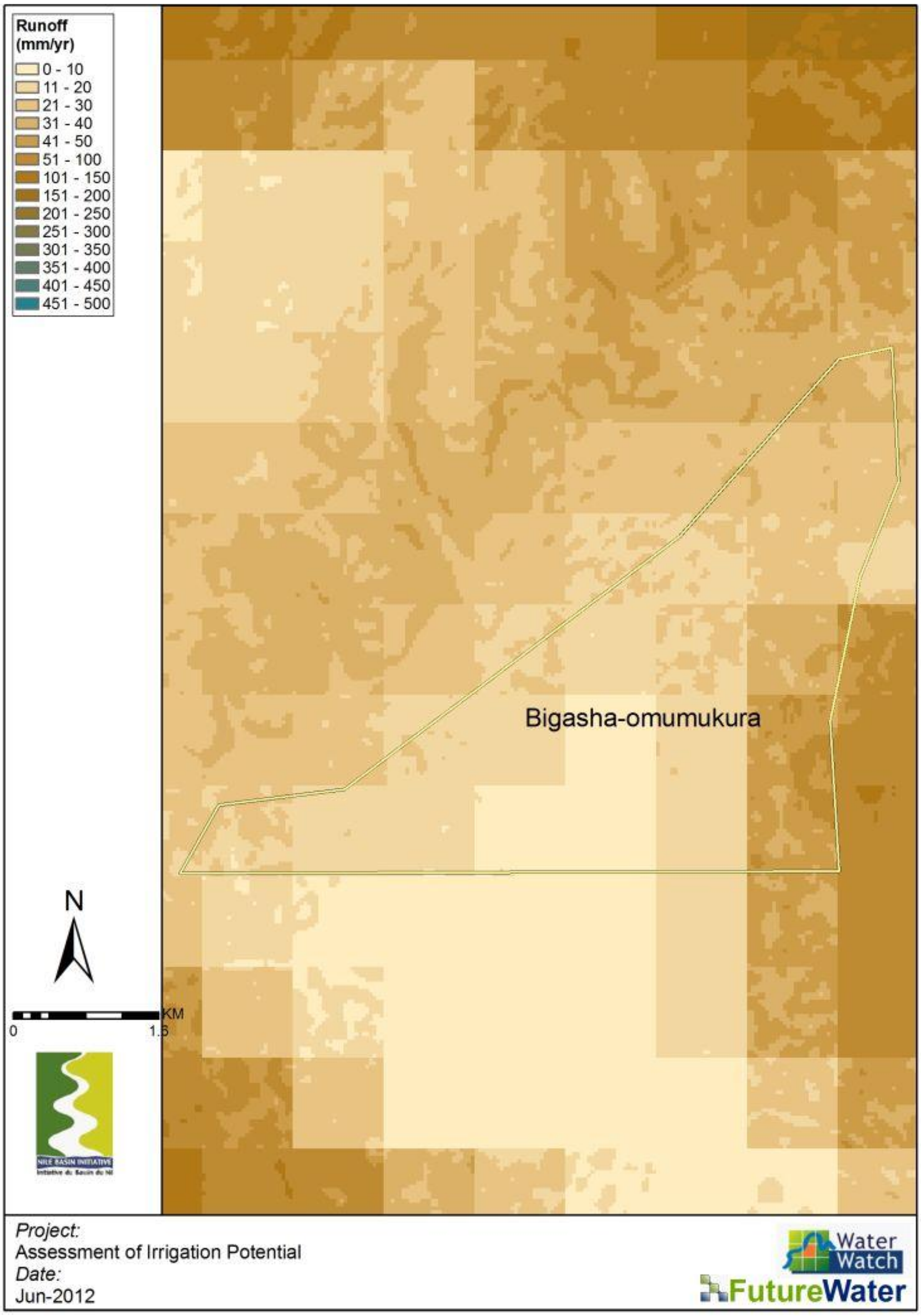
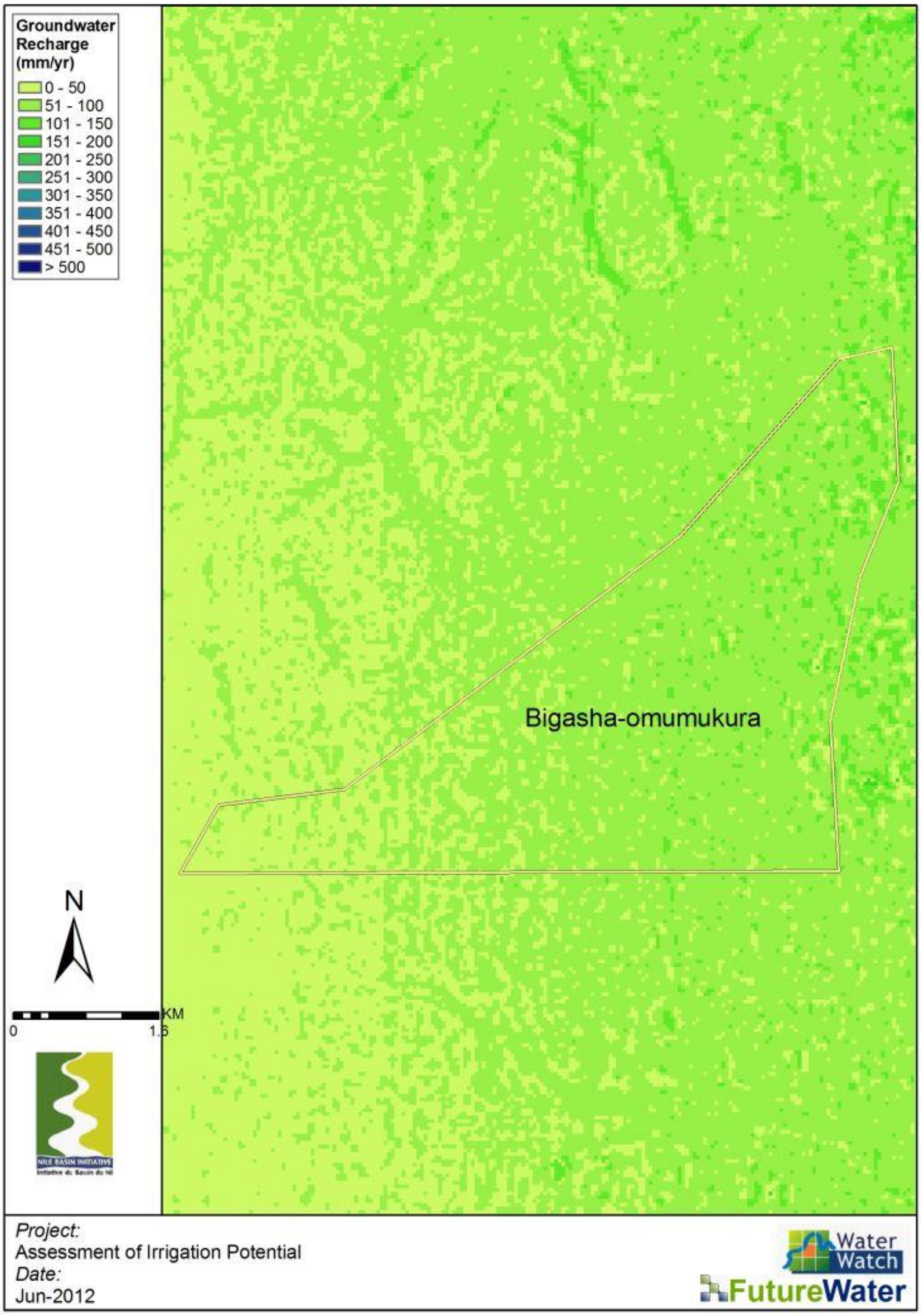


Figure 66: Water balances for the area based on the high resolution data and modeling approach for Bigasha-Omumukura focal area.



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
Bigasha-omumukura
N
KM
0
1.6
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
Bigasha-omumukura
N
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0
1.6
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Water Watch
FutureWater

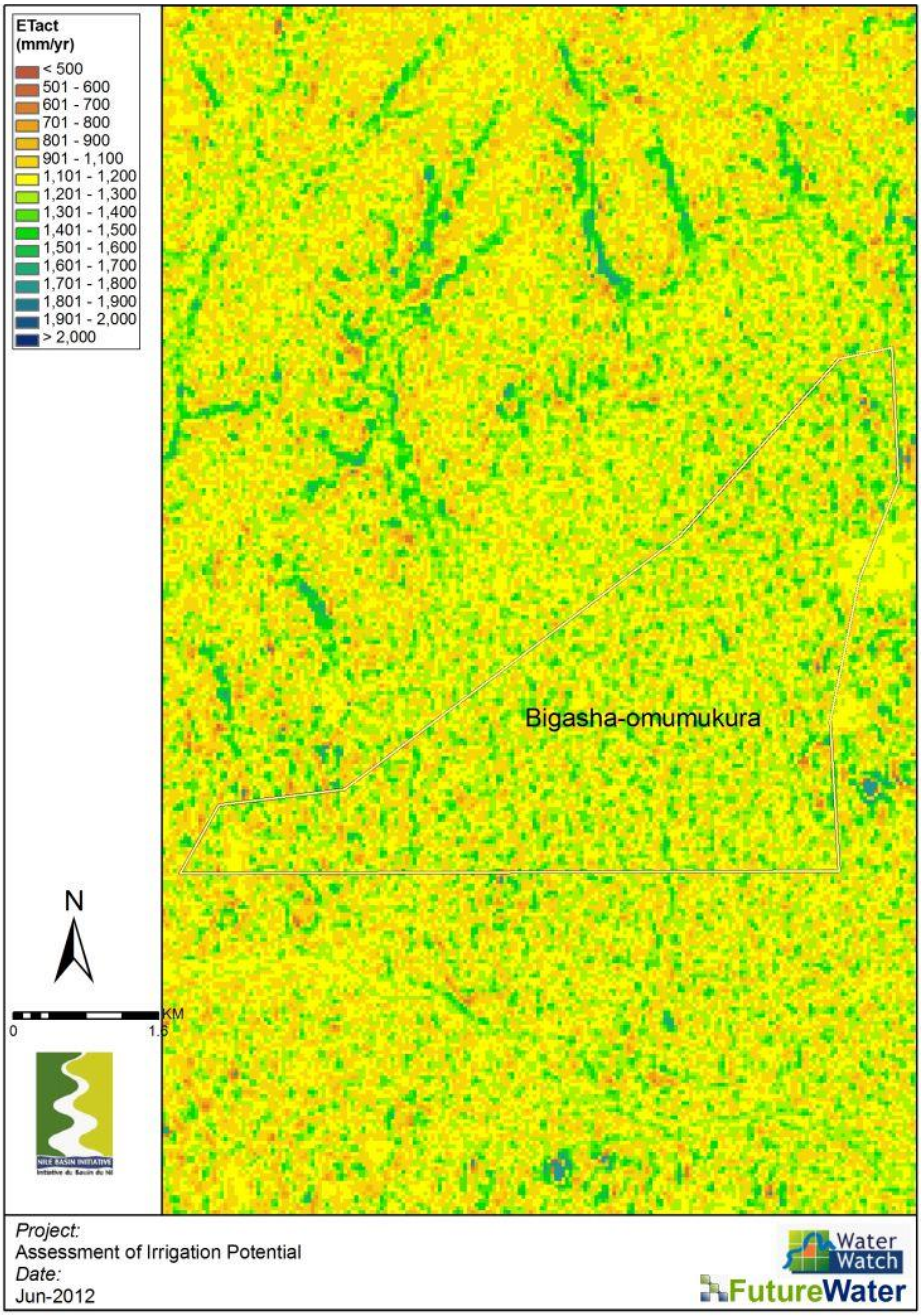


Figure 67: Water balances for the area based on the high resolution data and modeling approach for Bigasha-Omumukura focal area.

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.

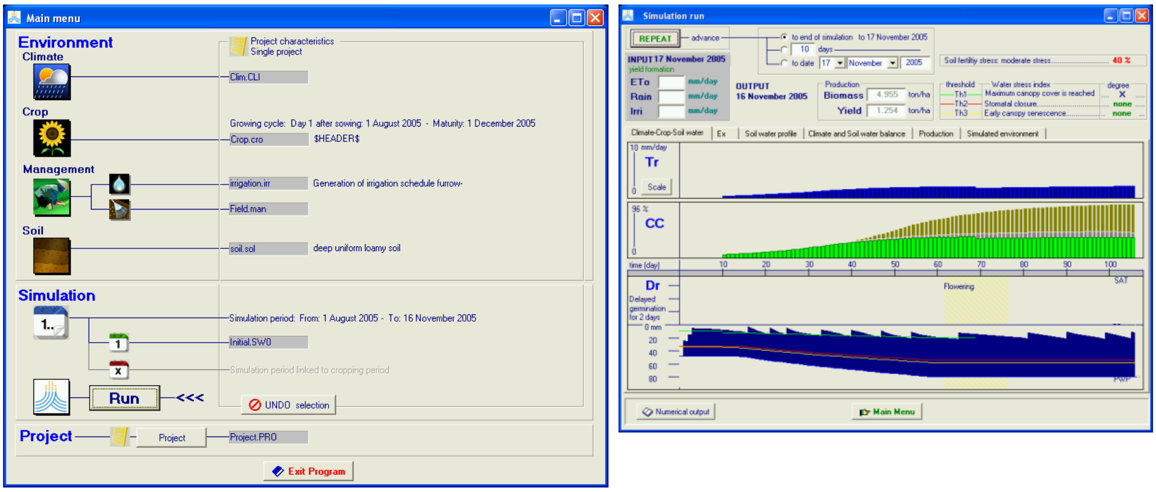


Figure 68: Typical example of AquaCrop input and output screens.

Table 9: 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)
Fruit trees	1247	1439	1	365	1246	150	1436	759
Vegetables	1247	1439	1	365	1246	120	1436	777
Coffee	1247	1439	243	76	829	190	799	690

5.4.2 Irrigation systems and irrigations efficiencies

The topography in this focal area is very suitable for surface irrigation, as most places can be reached by gravity. This focal area covers a total area of 1942 ha. With an annual average river flow of just above 0.5 m^3/s, the possible irrigated area becomes more limited. This discharge allows for approximately 500 ha to be irrigated. However, an upstream catchment of roughly 125 km^2 creates a potential for an upstream reservoir, which could expand the irrigable area and stretches the growing period. In case this project is partially transformed in a trans-boundary project with Tanzania, the Kagera River can easily be used to irrigate the lower part of the focal area. This requires pumping, which increases the operational costs, but ensures a year round water supply. Efficiencies of surface irrigation are rather low, with an average water use efficiency of 40%. Pressurized irrigation systems, such as drip or sprinkler irrigation, have a considerable higher efficiency, but require more knowledge and higher investments.

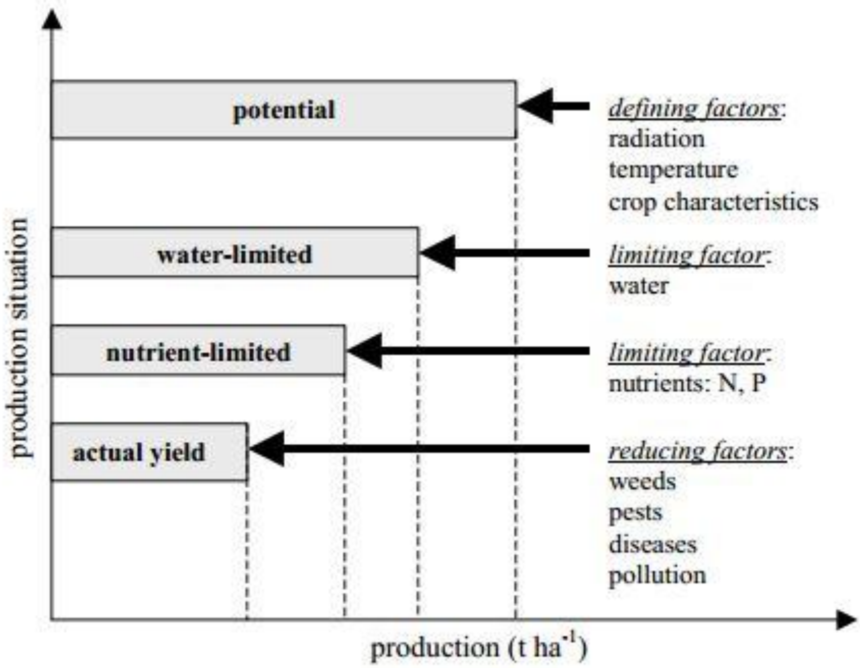
5.4.3 Water source

The source of water will be the Omukura River, which runs through the focal area. The stream drains a total upstream area of 125 km^2, and generates an annual average discharge of 0.5 m^3/s. The construction of a reservoir is suggested just upstream of the focal area, at an elevation of 1280 m (GPS coordinates - 02658887,9895454, 36S). An alternative water source, in case of a trans-boundary irrigation project, is the Kagera River, which has a large discharge all-year-round that can be pumped to the focal area.

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

Uganda has slightly higher yields compared to surrounding countries. Population pressure and the increasing food demand have been triggers for the intensification of agriculture. In Figure 69, the yield gap is shown relatively to the highest obtainable yield in the world, to the world's average, and to Africa's average. Yields in Bigasha/Omumukura focal area are 10% above Ugandan average. All three potential dominant crops are cash crops, which are hardly grown today. Uganda has a good record with growing coffee and fruit fresh nes, as yields are above African average, and for fruit fresh nes even above the world's average. The transition to start growing these mainly perennial crops ask for a large investment, as the harvests will be low in the first years. The return will be high, and will push development in this area. Vegetables are currently crown at 8.2% of world's highest, and are expected to increase to about 20% of the world's highest with irrigation.

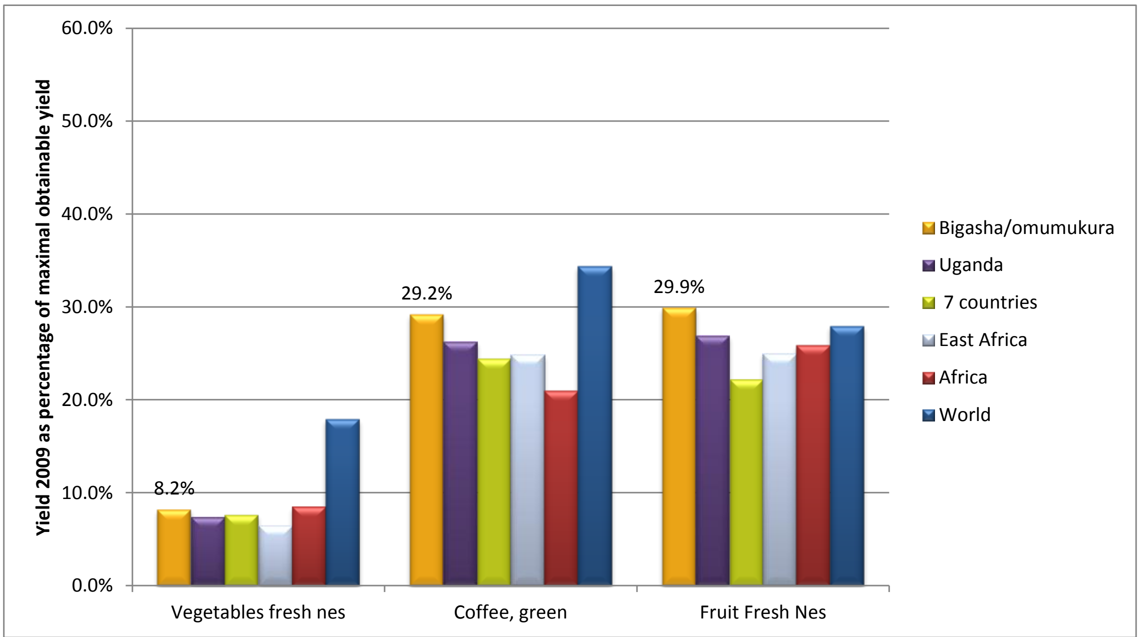


Figure 69: Yield gap Bigasha/Omumukura (source: FAOSTAT, 2010).

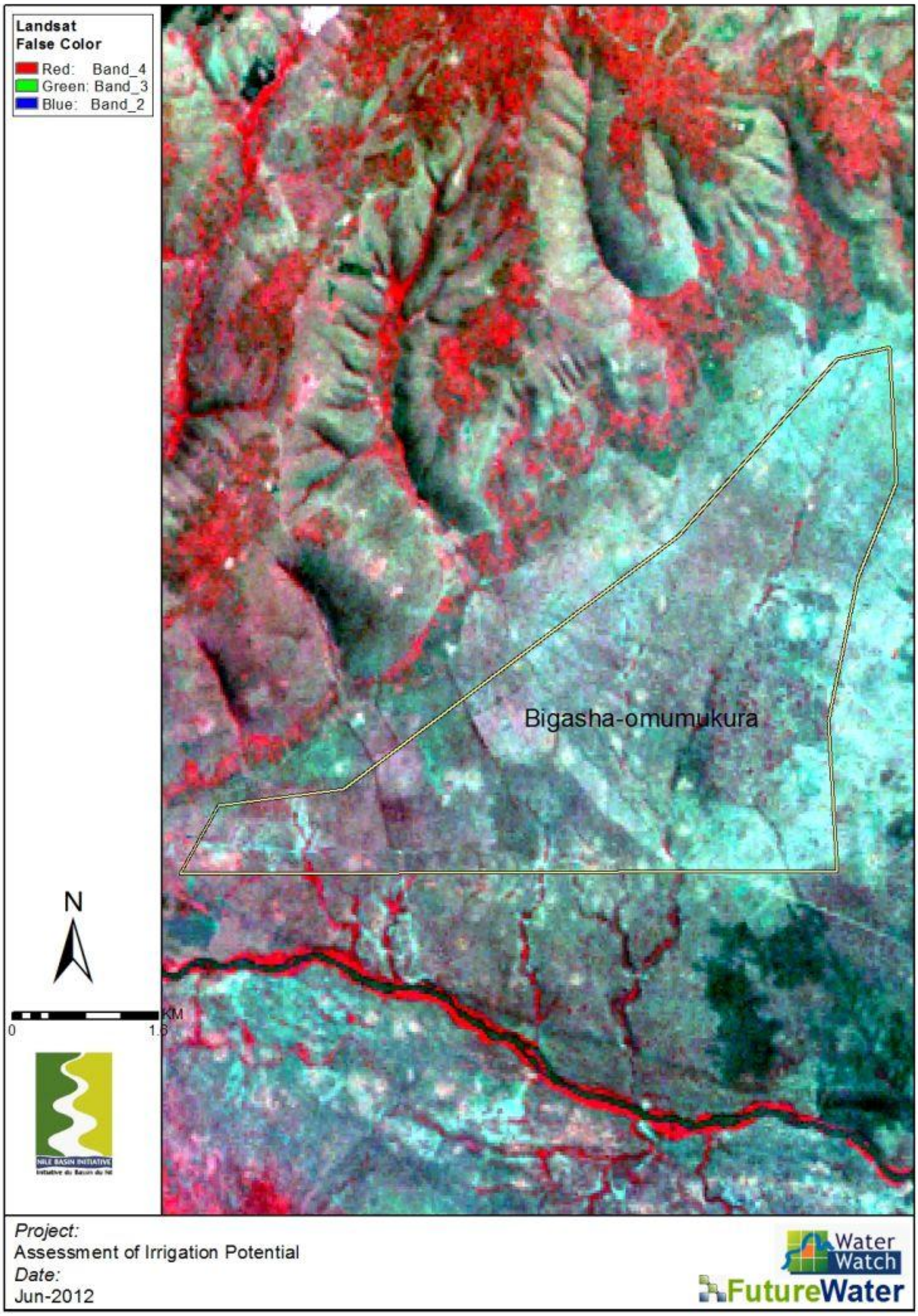


Figure 70: Landsat False Color Composite indicating current productivity of the area for Bigasha/Omumukura focal area.

5.6 Environmental and socio-economic considerations

5.6.1 Population displacements

People in the area mainly live at the transition between the flat land and the hills along the road on the western side of the focal area. Furthermore, some people live within the flat focal area, but they live quite scattered around. 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, due to the scattered houses in the low flat land, the irrigation possibilities will either be restricted, or minimal displacements are needed. People in the area have low experience with irrigation. This makes displacement also more difficult, as people are less aware of the advantages that irrigation brings. It is therefore very important to involve the people in irrigation development, and make them aware of the advantages, also on the longer term with coffee and fruit yields. 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

Within the extended focal area the average population density is 140 people/km^2, which is lower than the Ugandan average. The average age in Uganda is very young, with almost half of the population being younger than 15 years. This makes that the dependency ratio of the amount of people relying on one income is among the highest in the world. The positive side is that many people profit from irrigation development, and the increase of incomes in the area. The nearest highway is at approximately 10-20 km from the focal area. This Mwizi – Isingiro road is also important to transport goods to nearby markets, which include Mbarara and Isingiro and the markets in Tanzania. Tribes inhabiting the area include Banyankole, Banyarwanda, Bafumbira, Bakiga and Banyambu. Farmers' knowledge is low, but they are rather business oriented towards faming. Farmers do have some experience with farmers' cooperatives.

5.6.3 Upstream downstream consideration

Since the upstream catchment is rather small the water availability for irrigation should be considered well. Upstream and downstream of the focal area, people should have enough water to practice agriculture and have water for living. Currently, some erosion takes place on the slopes and in the flat areas. It is important to minimize erosion in order to keep the soil fertile, and to avoid downstream problems. Currently, some anti-erosion measures are in place, but whenever developing an 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. Heavy showers occur in the area, which may cause landslides. This can be avoided to grow plants and make ditches on the steeper slopes.

5.6.4 Protected areas

Within the focal area no protected areas are reported.

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):
    - Fruit trees: 210,000 kg/ha, 0.10 $/kg
    - Vegetables: 50,000 kg/ha, 0.16 $/kg
    - Coffee: 7,000 kg/ha, 4.44 $/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, water availability and the initial investment cost.

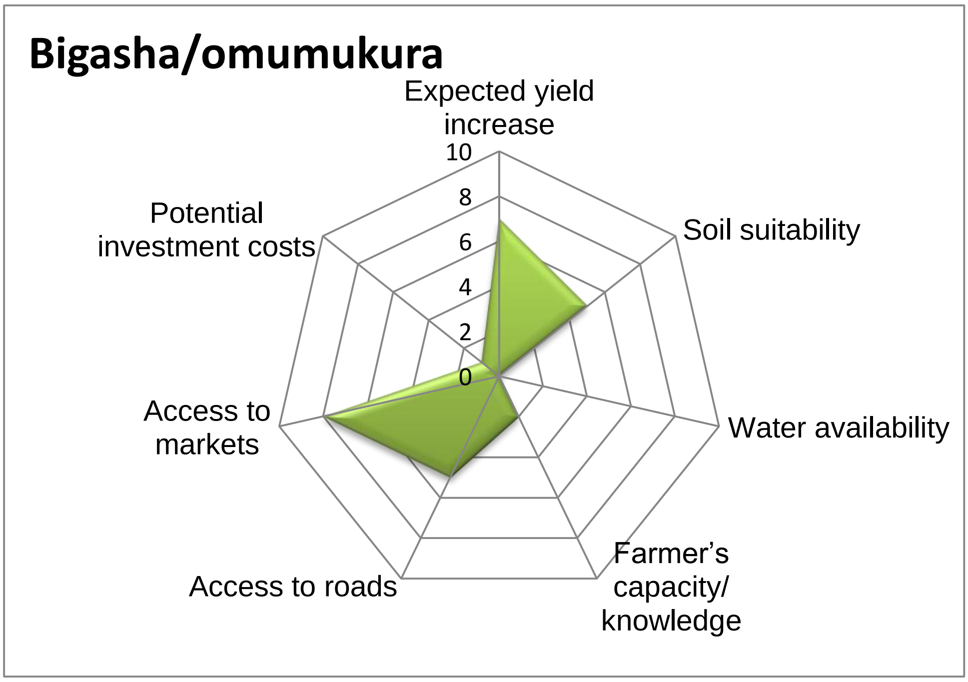


Figure 71: Filled radar plot indicating expert knowledge score to develop irrigation in the Bigasha/Omumukura focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 10: Benefit-cost analysis for Bigasha/Omumukura area.

Characteristics	
Irrigated land (ha)	1,500
Farmers	1,500
Investment Costs	
Irrigation infrastructure (US$/ha)	7,000
Social infrastructure (US$/farmer)	750
Accessibility infrastructure (million US$)	2.5
Operational Costs	
O&M irrigation (US$/ha/yr)	60
Extension service (US$/farmer)	15
O&M roads (US$/yr)	50,000
Summary	
Initial investments (million US$)	14.1
O&M costs (million US$/yr)	0.163
Net benefits per year (million US$/yr)	18.062
IRR (Internal Rate of Return)	#NUM!

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 Rwimi focal area

6.1 Introduction

This chapter will describe the current state of Rwimi 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 73 a detailed map of the area is given. Total area is 4415 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 Michael Iwadra and Fredrick Ssozi and Richard Cong as supervisor in March 2012.

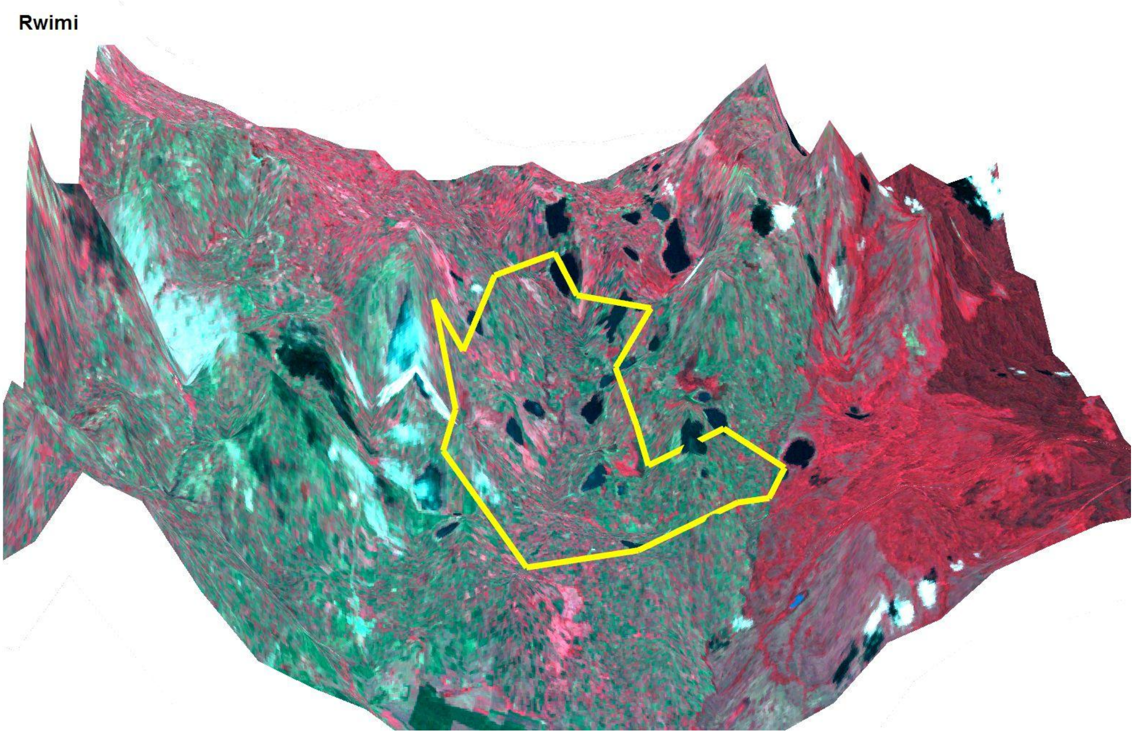


Figure 72: 3D impression of Rwimi focal area, Uganda.

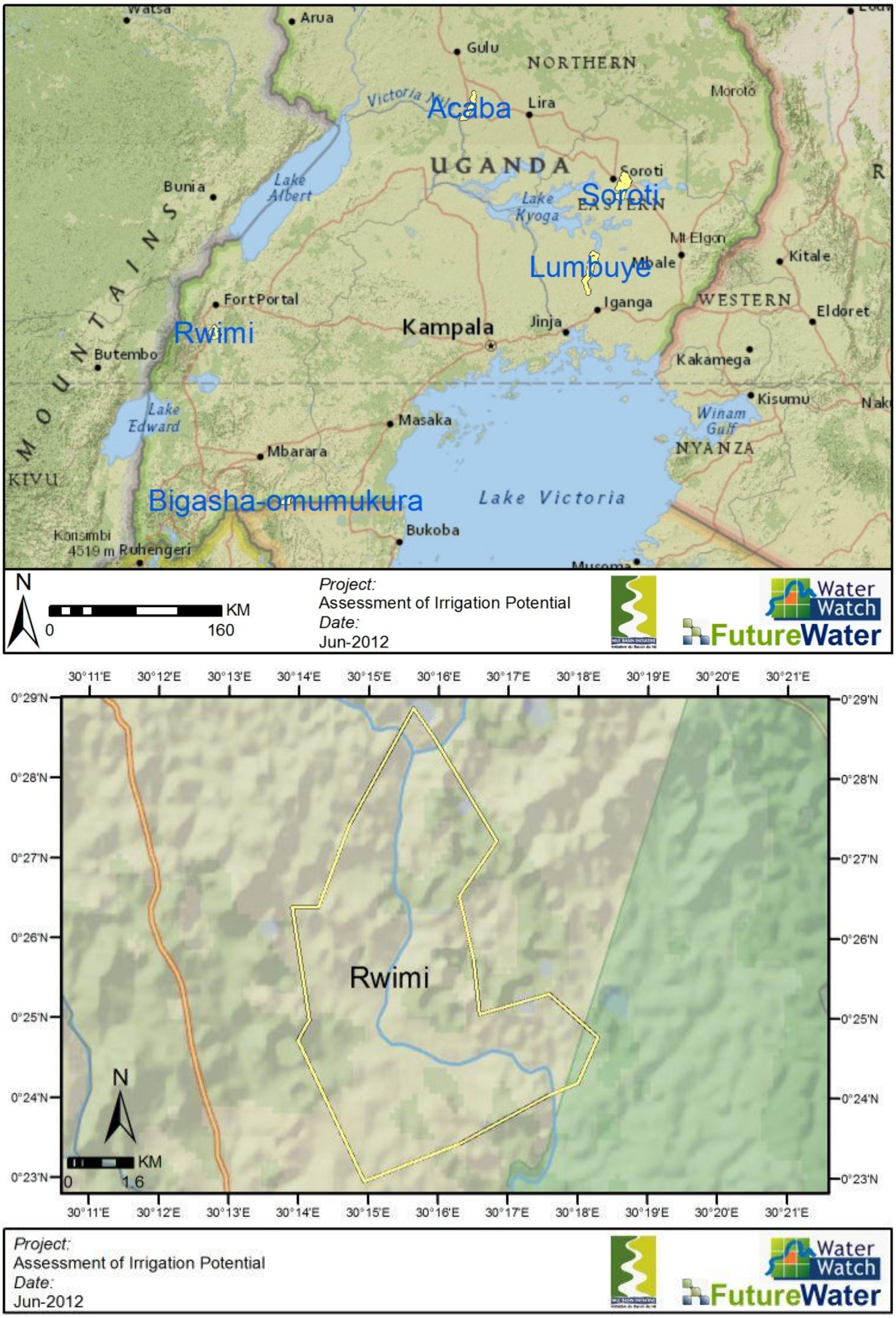


Figure 73: Rwimi focal area, Uganda

6.2 Land suitability assessment

6.2.1 Terrain

The Rwimi focal area is situated in Uganda's Western province in the Kabarole district and Rwimi sub-county. The river flowing through the area drains into the Katonga River. Elevation differences within the focal area are substantial. The river valley descends from North to South from 1290 m to 1120 m (Figure 74). In the Northern and Eastern part of the area the slopes ascend rather steep from the river valley. The area south of the stream is more flat. Slopes in the North-East range between 20-25%. Slopes in the Southern part of the area are moderately, and stay mainly under 10% (Figure 75).

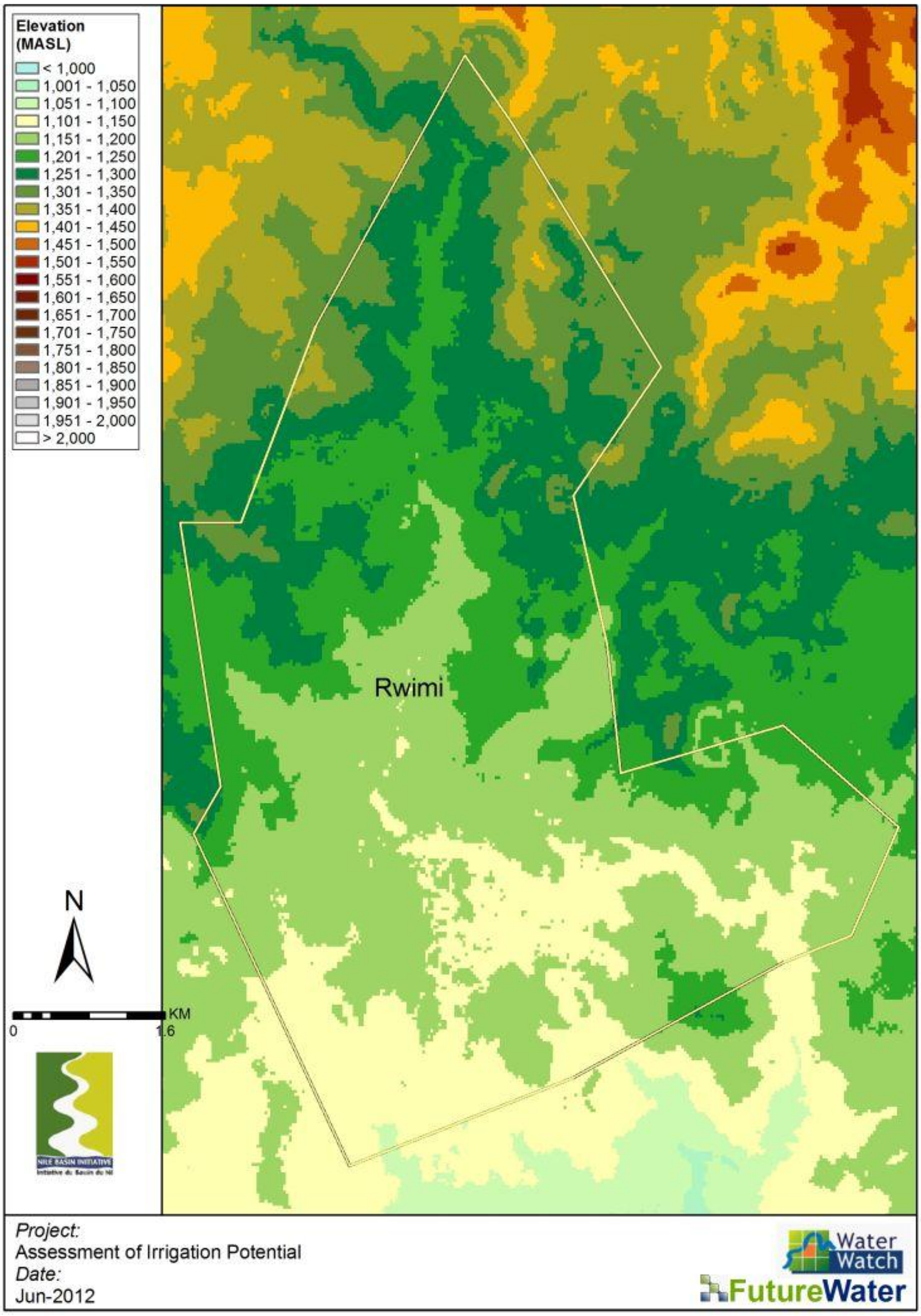


Figure 74: DEM Rwimi focal area. Resolution 1 arc second (+/- 30m).

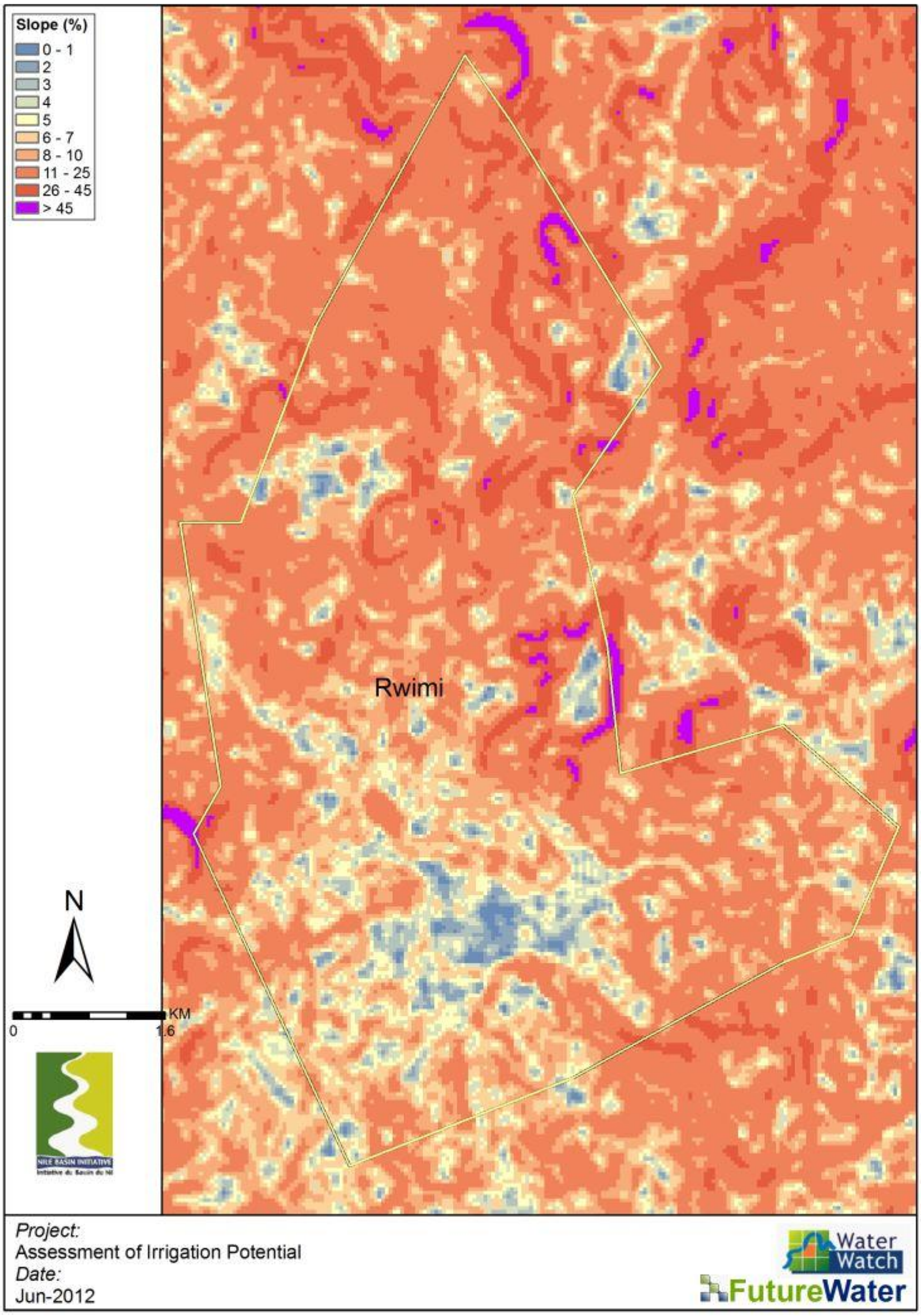


Figure 75: Slope map Rwimi focal area (source: ASTER).

6.2.2 Soil

The loamy soil in the focal area is originating from volcanic processes. The soil is very deep, and contains more than 3% organic carbon in the top soil. The available water holding capacity is between 125 and 150 mm/m. These Chromic Cambisols generally make good agricultural land and are used intensively. Cambisols with high base saturation in the temperate zone are among the most productive on earth. Cambisols on steep slopes are best kept under forest, which is particularly true for Cambisols in highlands. Cambisols on irrigated alluvial plains in the dry zone are used intensively for production of food and oil crops. Cambisols in the humid tropics are typically poor in nutrients, but are still richer than the associated Acrisols or Ferralsols, and have a greater CEC. Cambisols with groundwater influence in alluvial plains are highly productive paddy soils.

6.2.3 Land productivity

The land productivity (NDVI) in the five Ugandan focal areas ranges between 0.58 and 0.74. Compared to the Uganda average NDVI of 0.54, all focal areas have relative high land productivity. The Rwimi focal area has, with an NDVI of 0.74, the highest land productivity of the five Ugandan focal areas. The low NDVI spots, which can be seen on Figure 77, are the crater lakes that are scattered around the area. Apart from those spots, the NDVI values are quite similar over the area. Variation in land productivity is low, and increases slightly towards the South. This is largely explained by the large amount of perennial crops, and the continuous crowing seasons of maize and rice.

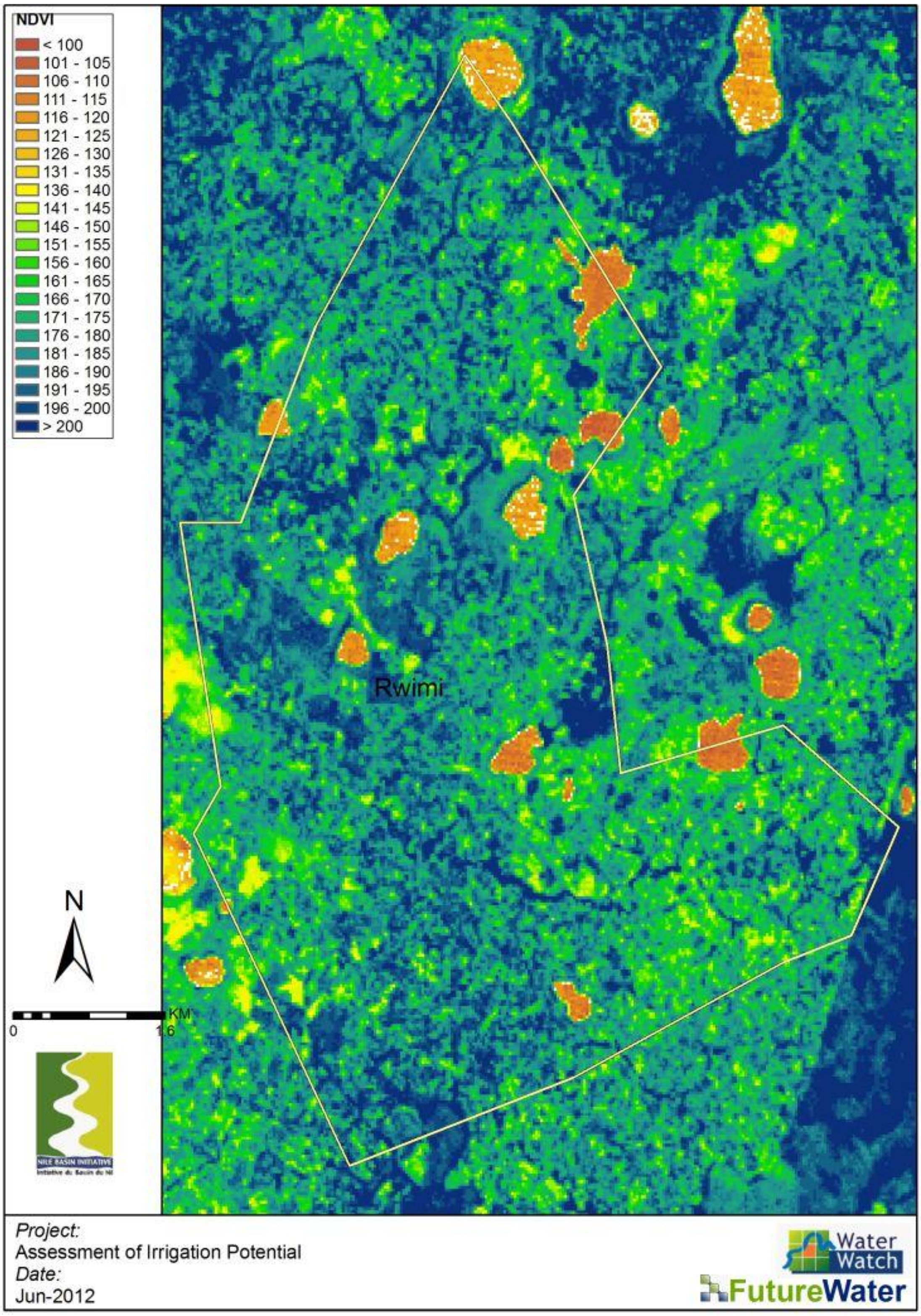


Figure 76: High resolution NDVI for Rwimi focal area

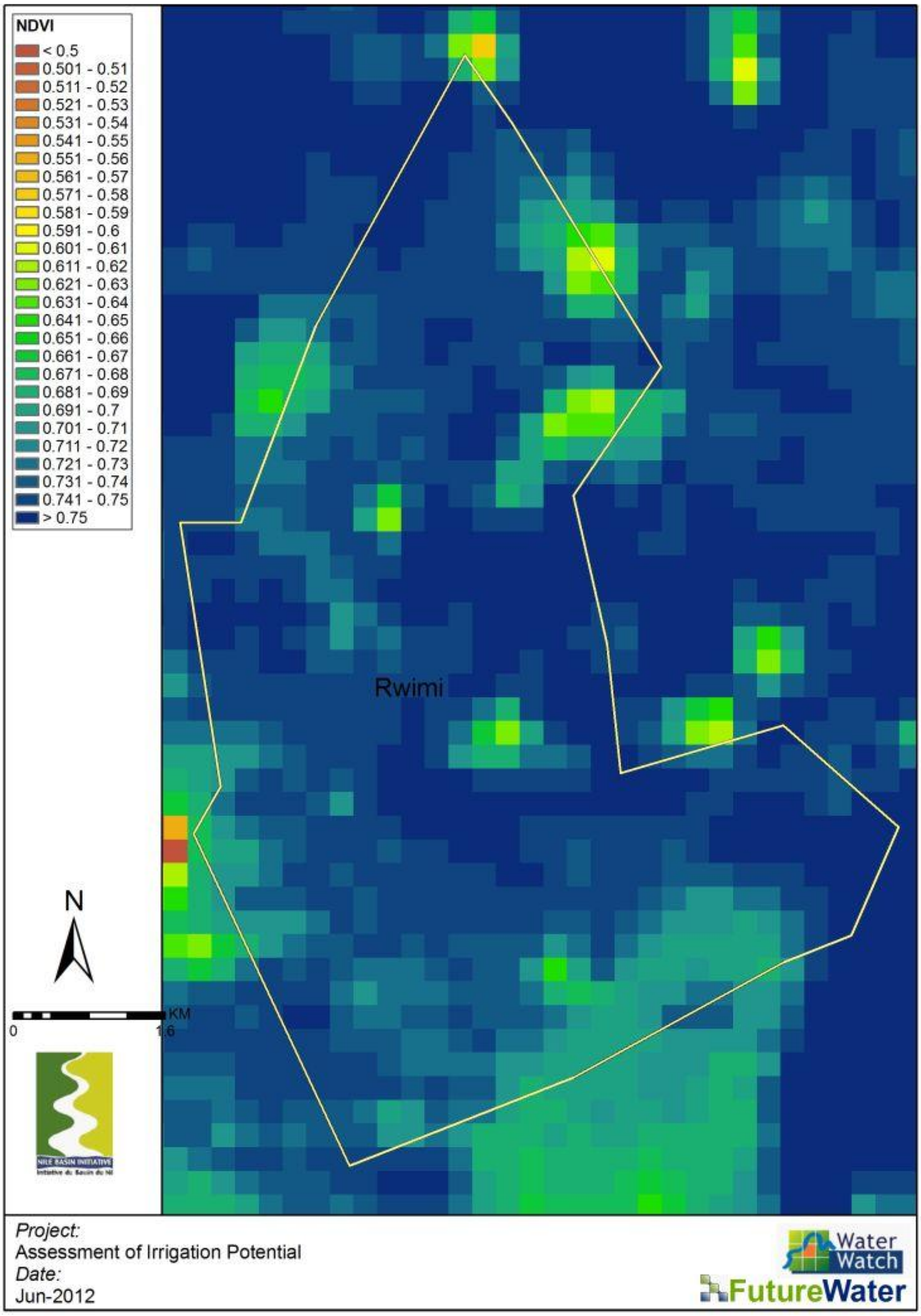


Figure 77: Yearly average NDVI values for Rwimi focal area.

6.2.4 *Potential cropping patterns*

Approximately 80% of the land is used for agriculture in this focal area. The most dominant crop is maize, which is grown twice a year. Upland rice is increasing rapidly, and reveals maize as the dominant crop. Other current crops include bananas and vegetables. Water is the limiting factor for the production of some of these crops in two growing cycles. Within the valleys farmers already practice informal irrigation. Depending on the type of irrigation system to be developed, the government policy differs concerning future crops. However, the overall focus will be on high value crops which will strengthen the economic situation in the region and reduces poverty and hunger. In the Rwimi focal area the focus for irrigated crops will be on upland rice, fruit trees and vegetables. Vegetables and upland rice can be grown twice a year under irrigation.

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 temperatures during the year ranging from about 18°C to 29°C, with the warmest months being January, February, and March. Annual average precipitation is 1187 mm and reference evapotranspiration 1476 mm per year.

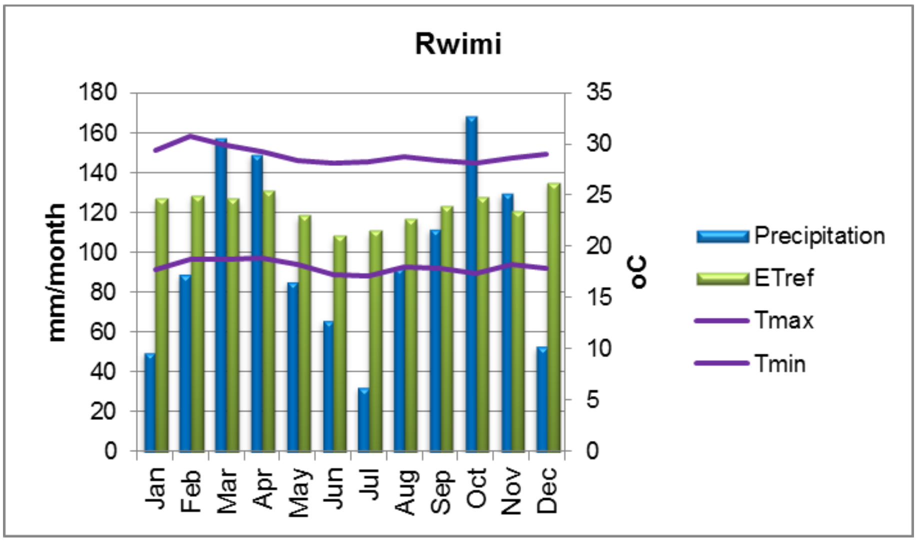


Figure 78: Average climate conditions for Rwimi focal area.

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.

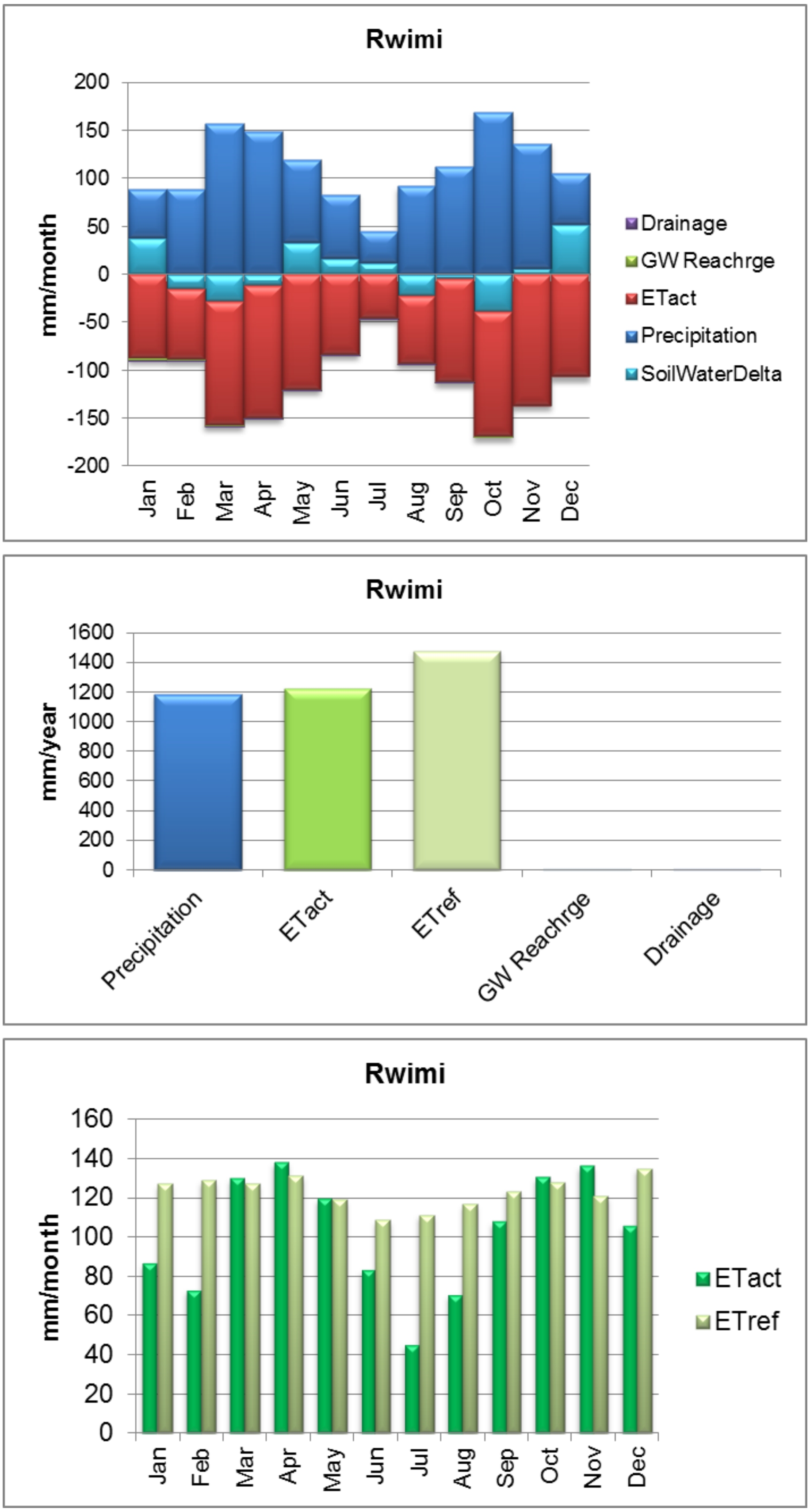
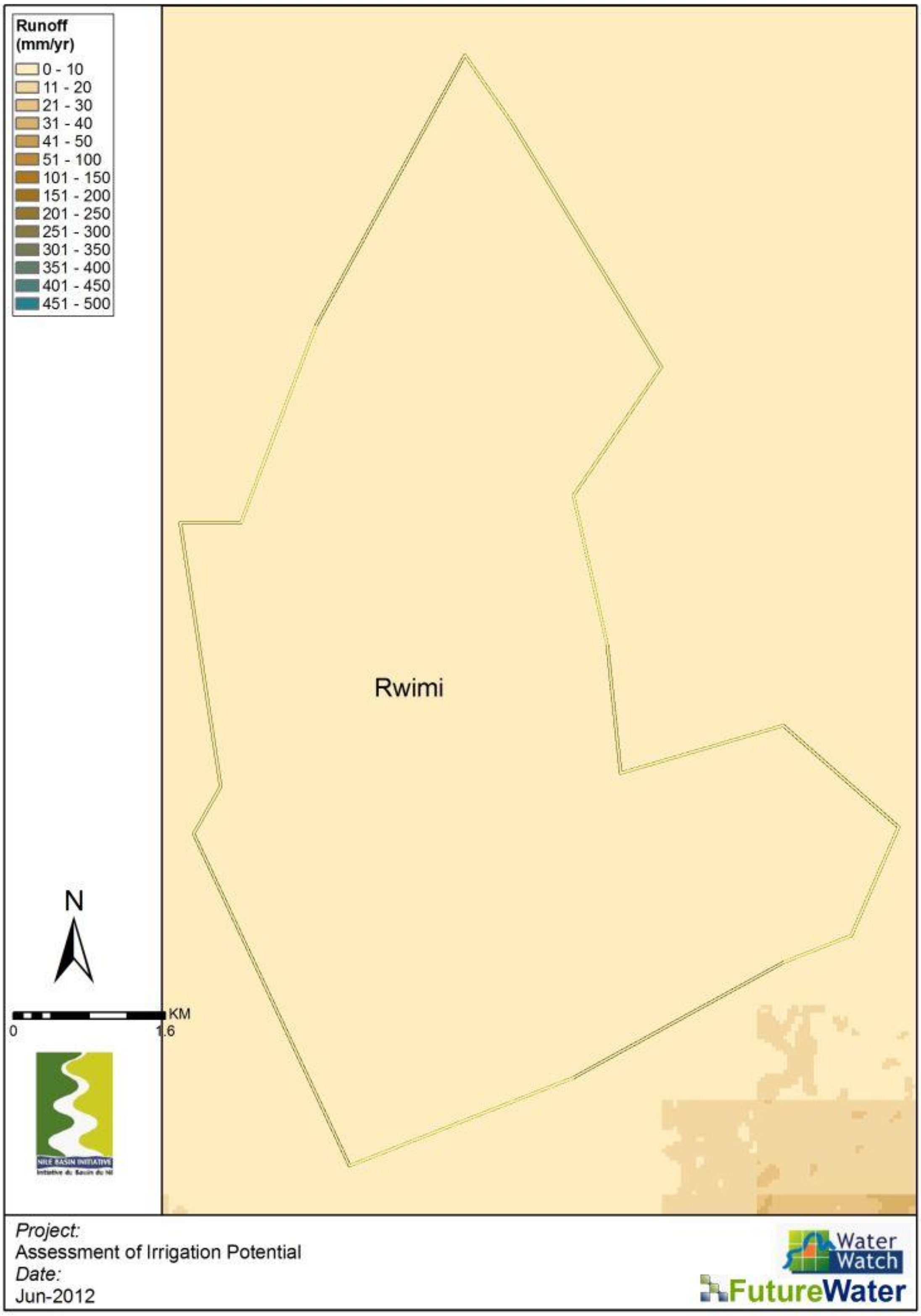


Figure 79: Water balances for the area based on the high resolution data and modeling approach for Rwimi focal area.


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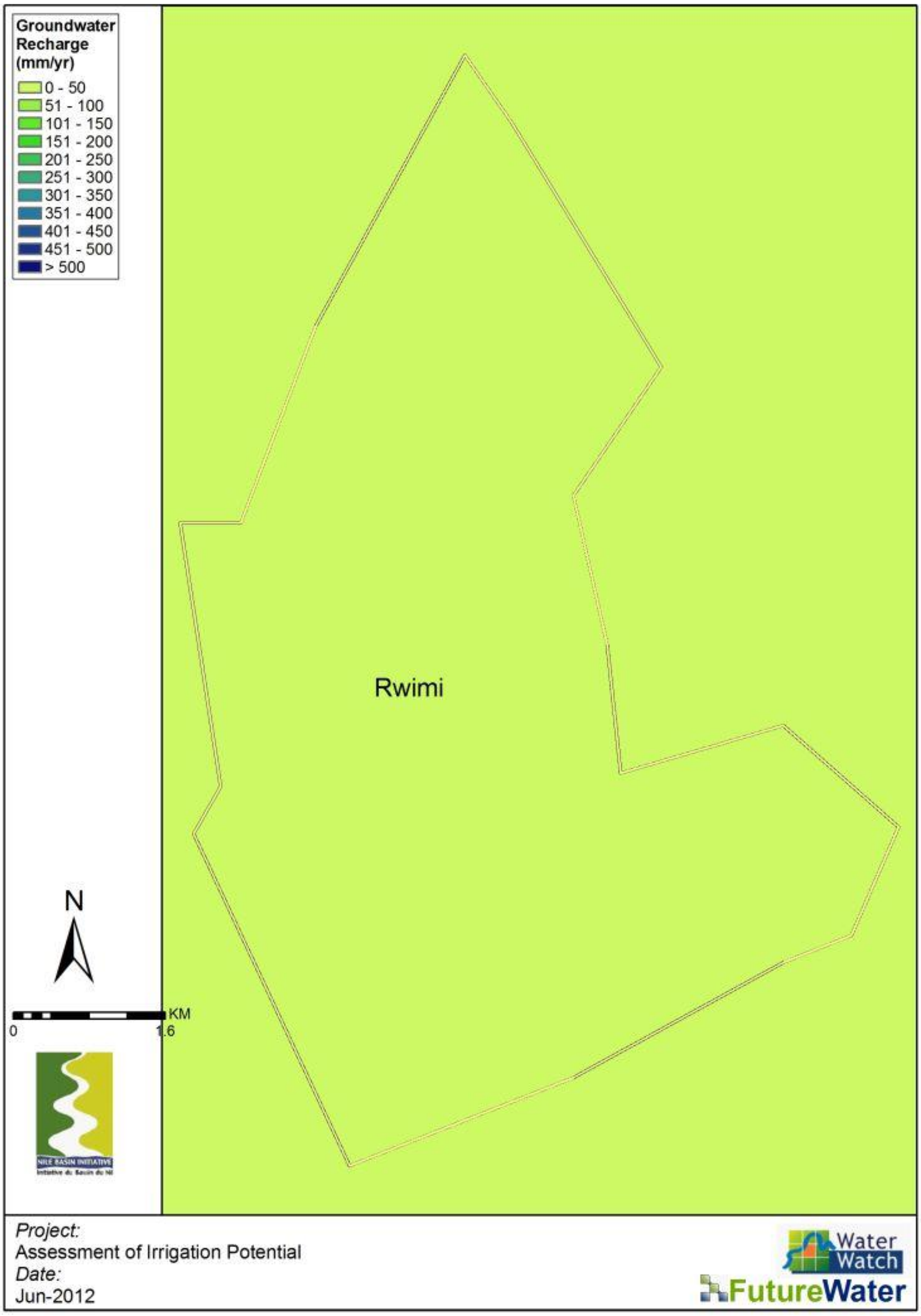
Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
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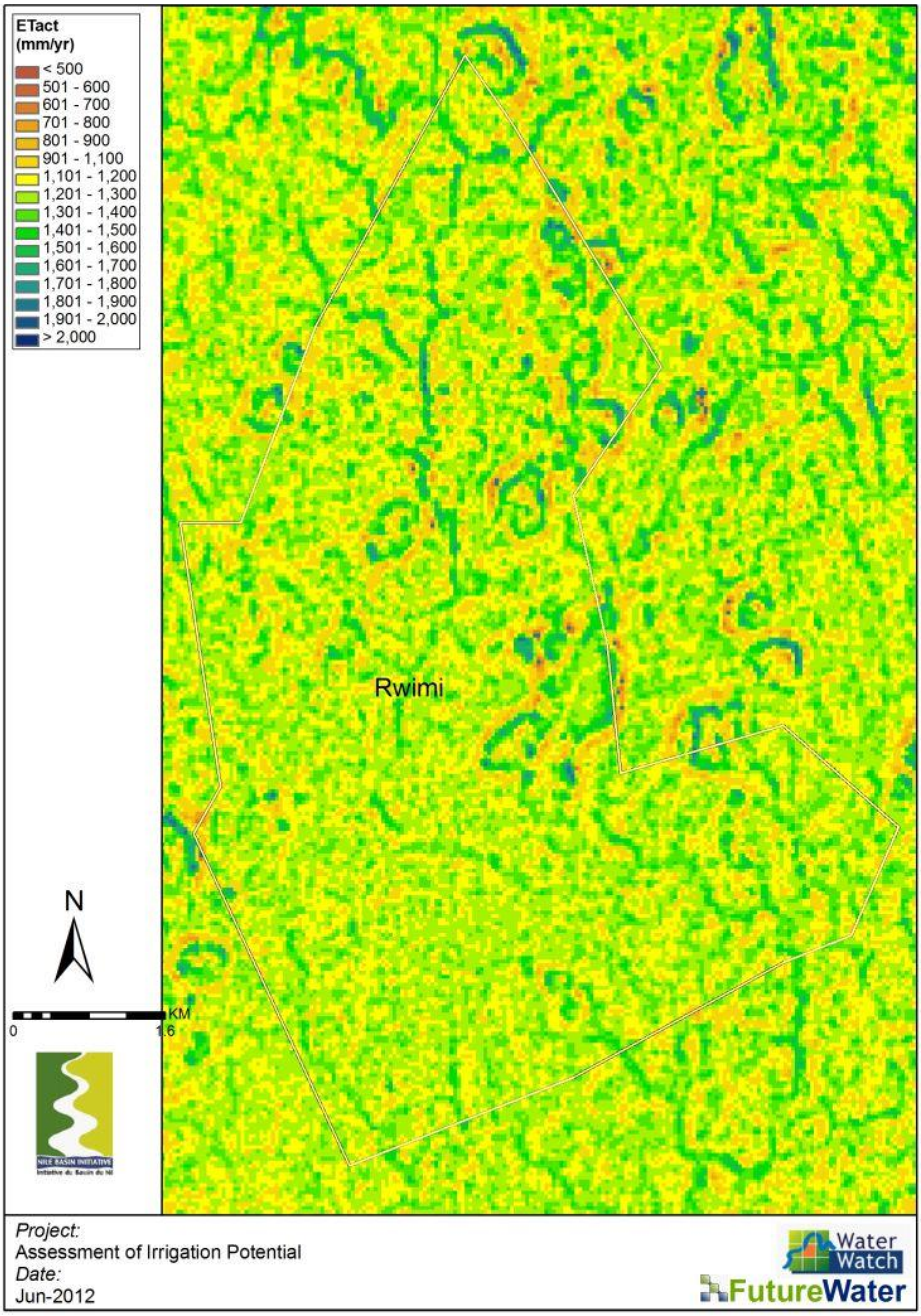


Figure 80: Water balances for the area based on the high resolution data and modeling approach for Rwimi focal area.

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.

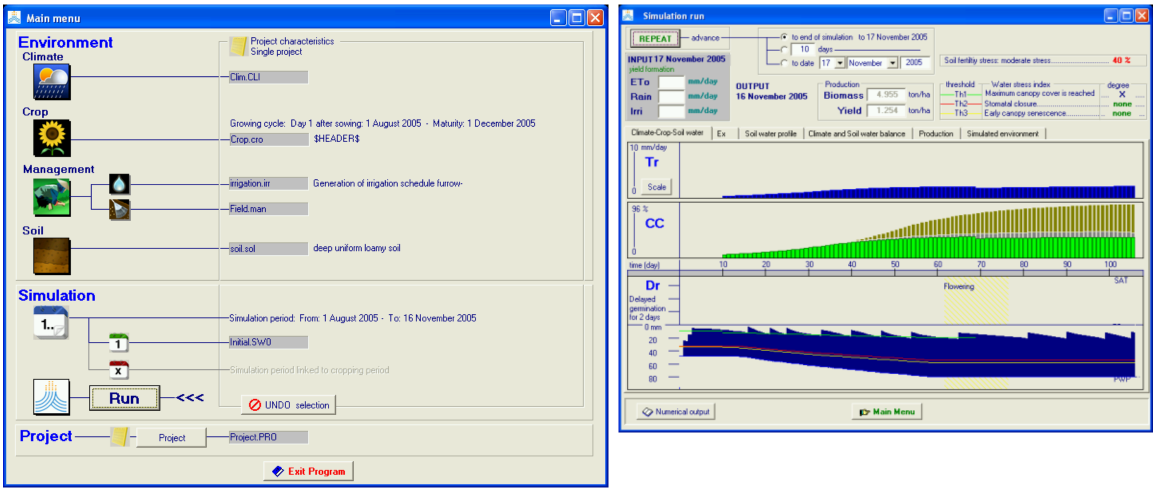


Figure 81: Typical example of AquaCrop input and output screens.

Table 11: 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)
Fruit trees	1187	1476	1	365	1187	270	1472	929
Rice	1187	1476	213	320	449	170	433	400
Vegetables	1187	1476	1	365	1187	200	1472	943

6.4.2 Irrigation systems and irrigations efficiencies

It is advised to irrigate this focal area with gravity irrigation systems, such as border or furrow irrigation. In the steeper parts of the area there is a possibility to use sprinkler irrigation under gravity, as the elevation difference is substantial. This would be a very good option, as the efficiency of sprinkler irrigation is much higher than the efficiency of border and furrow irrigation. This means that the irrigable area, which can be irrigated with the possible available water, will somehow be doubled compared to a surface irrigation system. The only two constraints can be the farmer's capacity to work with a pressurized system, and the higher investments costs.

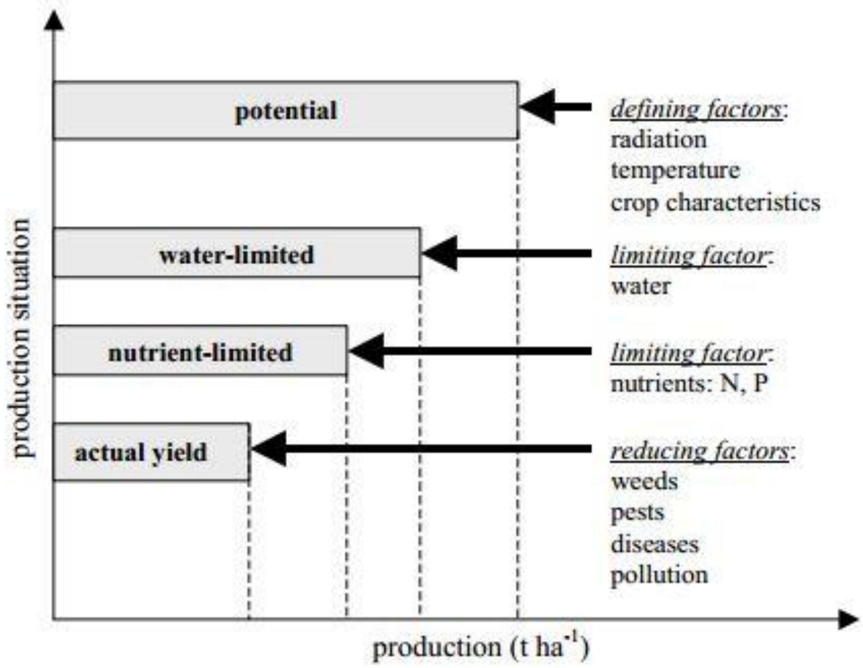
6.4.3 Water source

The water source for the Rwimi focal area can come from several streams and places. First of all, the Yerya River that flows through the focal area. It is advised to build an upstream reservoir such that the flow can be regulated, and the growing season prolonged. With an upstream reservoir, the gravity sprinkler irrigation system will be possible. The second possible water source is Rwimi River, which does not flow through the focal area. However, an upstream intake point can be created, which leads to an upstream reservoir from which the field can be irrigated under gravity. Rwimi River has an approximate flow of 1 m^3/s, while the Yerya River is smaller with approximately 0.35 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

Uganda has slightly higher yields compared to the surrounding countries. Population pressure and the increasing food demand have been triggers for the intensification of agriculture. In Figure 82 the yield gap is shown relatively to the highest obtainable yield in the world, to the world's average, and to Africa's average. Yields in the Rwimi focal area are very high, and reach nearly to 40% above Ugandan average. The area grown with upland rice has been expanded rapidly over the past year with good results. With irrigation the rice yields are expected to increase even further towards 5500-6500 kg/ha. This is approximately 50% of the world's highest yields per ha. Vegetables already have good yields, and are expected to increase even more towards 20% of the world's highest yields. Currently, fruit fresh nes is hardly growing in the area, and the introduction of fruit trees will take a large investment. However, the return will be very high and the investment can be earned back rapidly. The only constraint is that yields from the fruit trees will be limited in the first few years.

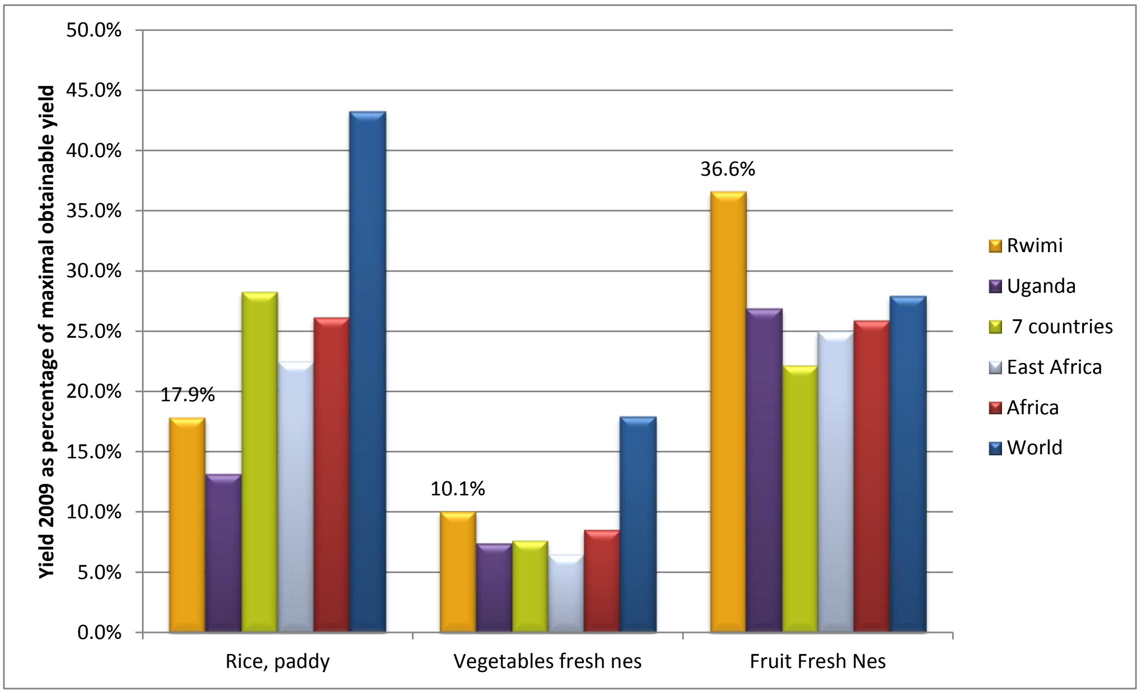


Figure 82: Yield gap Rwimi (source: FAOSTAT, 2010).

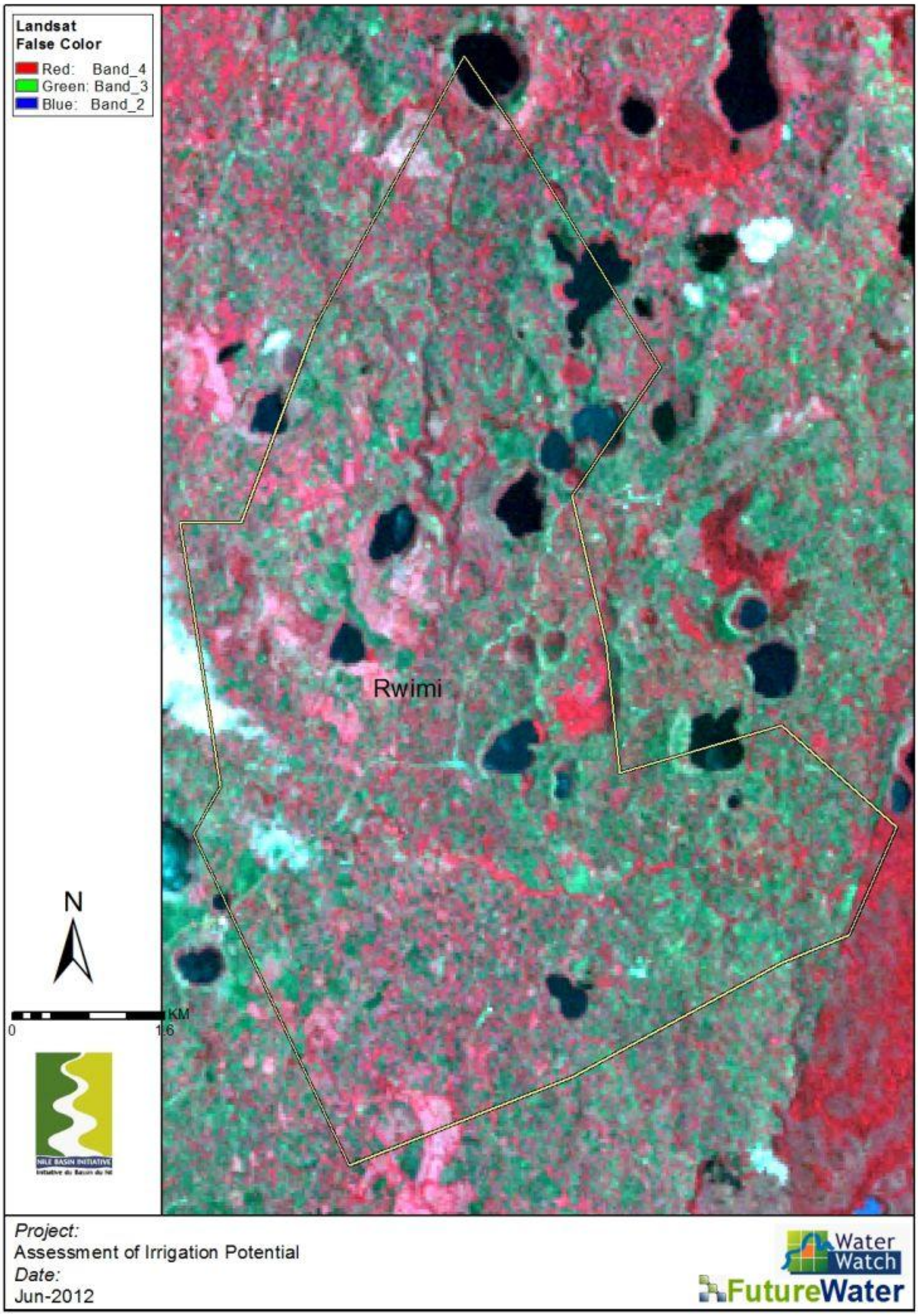


Figure 83: Landsat False Color Composite indicating current productivity of the area for Rwimi focal area.

6.6 Environmental and socio-economic considerations

6.6.1 *Population displacements*

People in the focal area live quite scattered around. Most small settlements can be found along the roads and road junctions. Furthermore, the houses are very scattered and equally distributed over the area. 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, due to the scattered houses and plots in some areas, the irrigation possibilities will either be restricted, or minimal displacements are needed. People in the area have good experience with irrigation. This increases the coop capacity of the people, as they are aware of the benefits that irrigation brings. 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.

6.6.2 *Social*

The population density in the Rwimi focal area is high, with about 235 people/km^2. This is far above the Ugandan average of 150 people/km^2. The average age in Uganda is very young, with almost half of the population being younger than 15 years. This makes that the dependency ratio of the amount of people relying on one income is among the highest in the world. Informal irrigation is already adapted by the farmers around water bodies. This makes the adaptation to an irrigation system very easy. The site has a good road infrastructure connection to the big markets in Fort portal, Kampala, etc., and even internationally. However, when developing irrigation systems, the current infrastructure in the area should be improved. Rwimi town is at approximately 13 km from the focal area. Tribes inhabiting the focal area include Batoro, Bakiga and Bakonzo. The area is reasonably well developed, with some of the lowest poverty rates from Uganda with less than 20% of the people living on an income beneath the poverty line.

6.6.3 *Upstream downstream consideration*

There are several constraints in this area. The water source can be dual, with an intake on the Yerya stream or an intake at the Rwimi River. However, both intake points are quite far away from the focal area, which increases transportation costs. Besides this, the people living close to the water source-abstraction point may also demand water of the project, which increases the water demand. The water quality of the Rwimi River is heavily compromised, as the upstream area is very much settled. A combination of irrigation and domestic water supply as desired by the local leadership may not be feasible. Slight erosion occurs within the focal area, and even more erosion takes place upstream. It is advised to minimize erosion by taking this topic very serious within any irrigation development plan. Currently, some anti-erosion measures are already in place as hill slope farming is practiced on many locations.

6.6.4 *Protected areas*

The focal area does include a part of Kibale Forest National Park. Therefore, it is really important that a feasibility study will show what the effects of an irrigation scheme in this area will be for the environment. 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. Another option is to allocate the focal area slightly, such that the entire focal area will be located outside of the National park.

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):
    - Fruit trees: 210,000 kg/ha, 0.10 $/kg
    - Rice: 7,000 kg/ha, 0.61 $/kg
    - Vegetables: 50,000 kg/ha, 0.16 $/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.

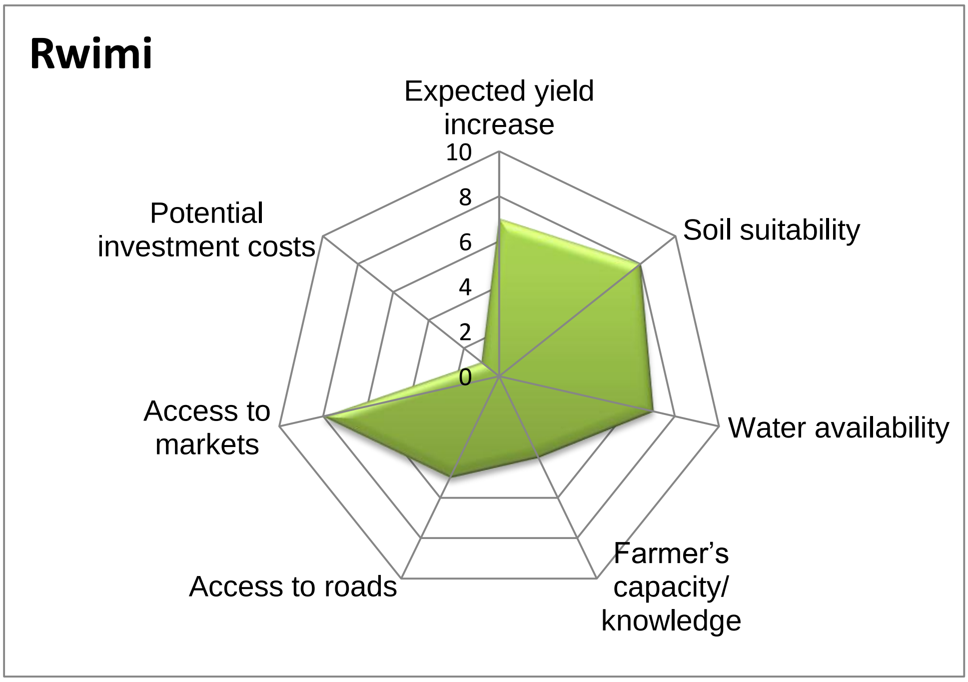


Figure 84: Filled radar plot indicating expert knowledge score to develop irrigation in the Rwimi focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 12: Benefit-cost analysis for Rwimi area.

Characteristics	
Irrigated land (ha)	2,500
Farmers	3,125
Investment Costs	
Irrigation infrastructure (US$/ha)	10,000
Social infrastructure (US$/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$)	27.6
O&M costs (million US$/yr)	0.201
Net benefits per year (million US$/yr)	16.672
IRR (Internal Rate of Return)	100.0%

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 Lumbuye focal area

7.1 Introduction

This chapter will describe the current state of Lumbuye 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 86 a detailed map of the area is given. Total area is 9812 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 Michael Iwadra and Fredrick Ssozi and Richard Cong as supervisor in March 2012.

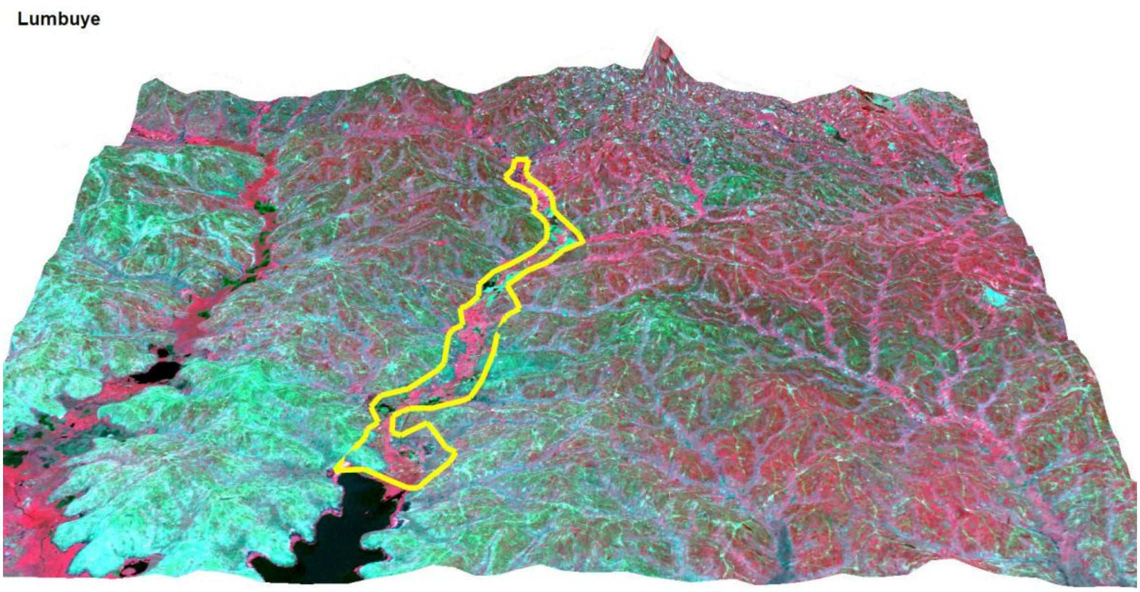


Figure 85: 3D impression of Lumbuye focal area, Uganda..

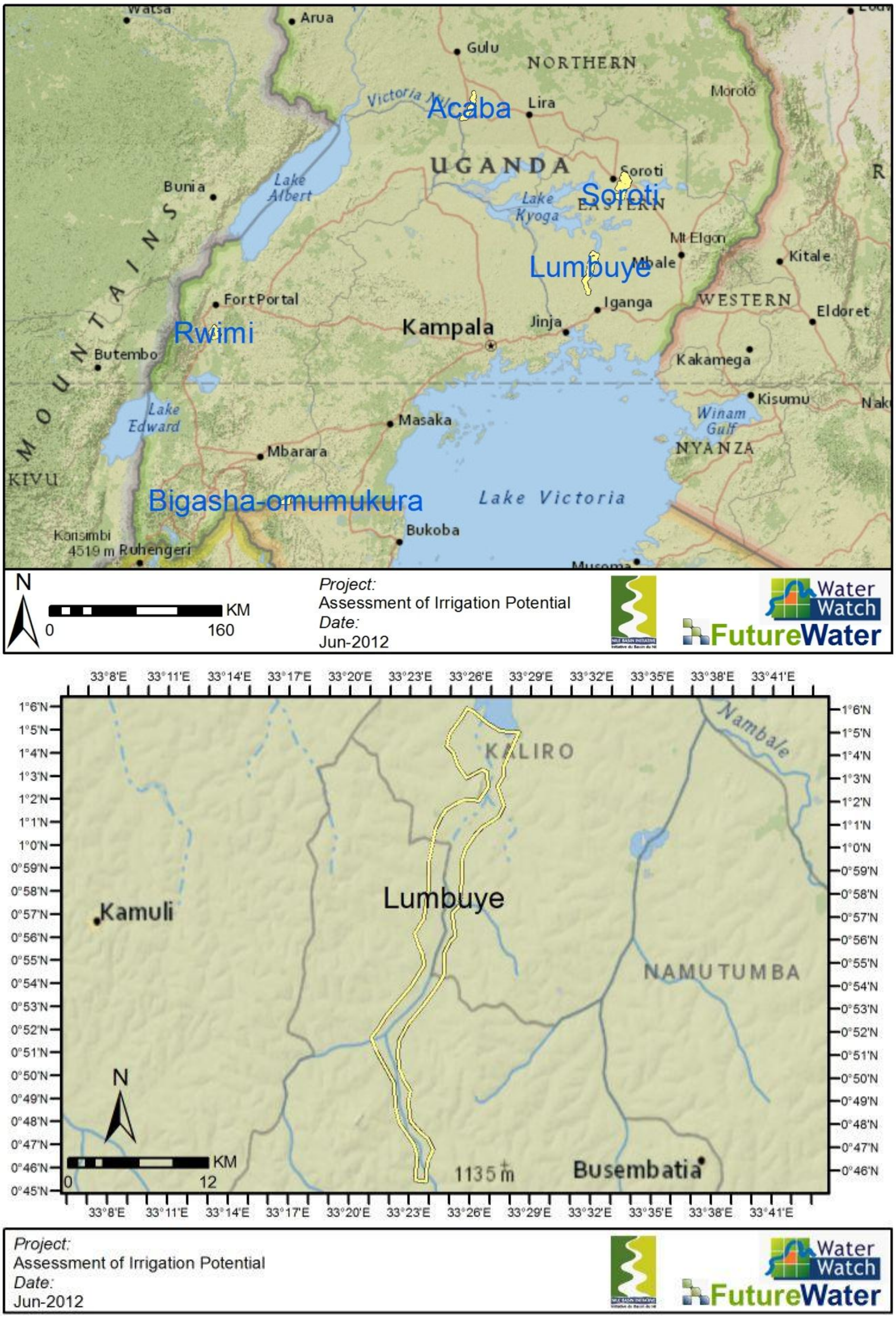


Figure 86: Lumbuye focal area, Uganda

7.2 Land suitability assessment

7.2.1 Terrain

Lumbuye focal area spreads out from Lake Victoria towards the Eastern tip of Lake Kyoga. The river that flows through the focal area finds its source just north of Lake Victoria. The focal area covers the Northern and downstream part, which are the last 40 km before the river drains into Lake Nakuwa. The river valley descends from South to North from 1065 m in the South to 1035 m in the North (Figure 87). The valley bottom is nearly flat and is slightly higher on the sides. Slopes are very limited and remain below 3% on most places, with some small exceptions where slopes locally reach over 10% (Figure 88). The terrain suggests that the area is very well suited for gravity irrigation.

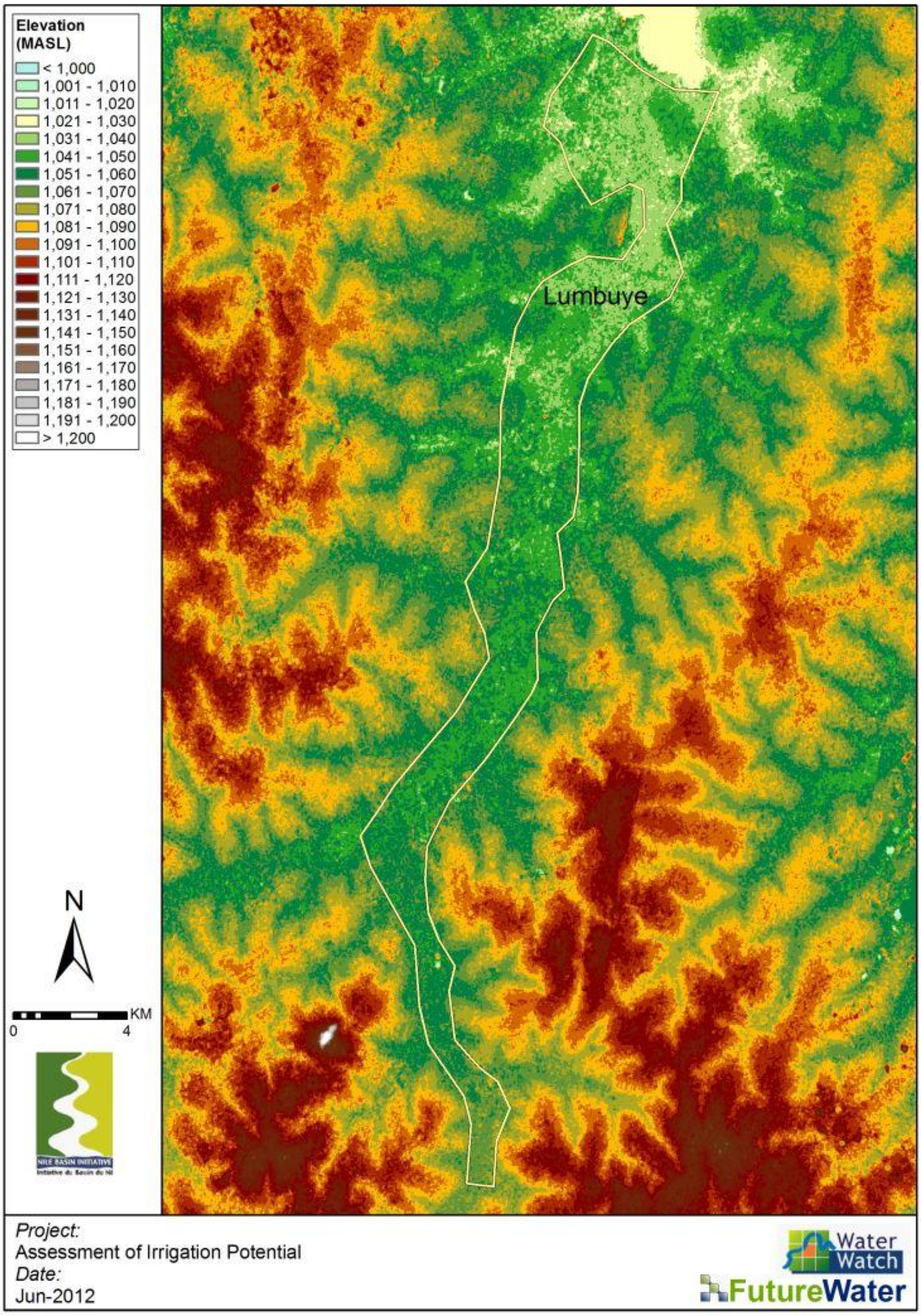


Figure 87: DEM Lumbuye focal area. Resolution 1 arc second (+/- 30m).

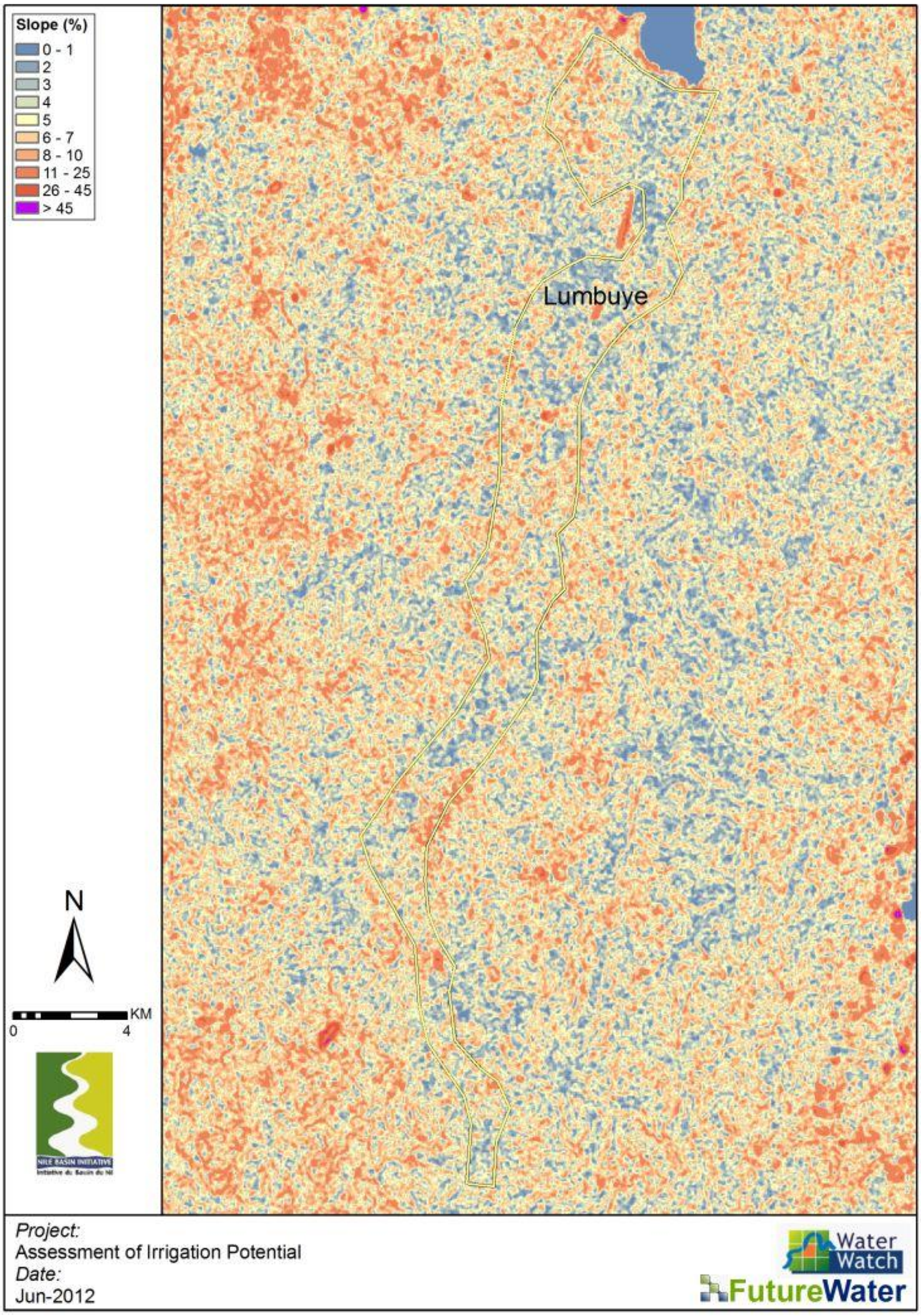


Figure 88: Slope map Lumbuye focal area (source: ASTER).

7.2.2 Soil

The soils in the Lumbuye focal area consist of silty clay loam, and drain poorly due to a dense and finer textured subsoil. Currently, only small parts of the area are used for agriculture. The water holding capacity is quite large with 125-150 mm/m. The area is mainly classified as a Planosol, combined with Vertisols, Gleysols and Umbric Fluvisols. Natural Planosol areas support sparse grass vegetation, often with scattered shrubs and trees that have shallow root systems and can cope with temporary waterlogging. Yields from Planosols are modest. Vertisols are often unused or only used for extensive grazing. These soils do have a considerable agricultural potential under adapted management and with a sustainable production. Crops with a vertical rooting system are preferred, as they coop easier with the severe cracking of the soil, which may occur on a yearly base. The main obstacle to utilization of Gleysols is the necessity to install a drainage system to lower the groundwater table. Adequately drained Gleysols can be used for arable cropping, dairy farming and horticulture. If the soils are cultivated too wet, then the soil structure will be destroyed eventually. Therefore, Gleysols in depression areas with inadequate possibilities to lower the groundwater table are best kept under a permanent grass cover or swamp forest. Fertilizer is used on very small scales, mainly by commercial farmers.

7.2.3 Land productivity

The land productivity (NDVI) in the five Ugandan focal areas ranges between 0.58 and 0.74. Compared to the Uganda average NDVI of 0.54, all of the focal areas have relative high land productivity values. The Lumbuye focal area has an average NDVI of 0.68, which is quite high. As can been seen in Figure 90, the land productivity in the valley is very high and decreases more at the sides. These sides are mostly used for agriculture, as drainage in the valley is poor, and water logging occurs in the valley. This can also be seen in the variation of the NDVI, which is low in the middle of the valleys, and much higher towards the side, where seasonal agriculture takes place.

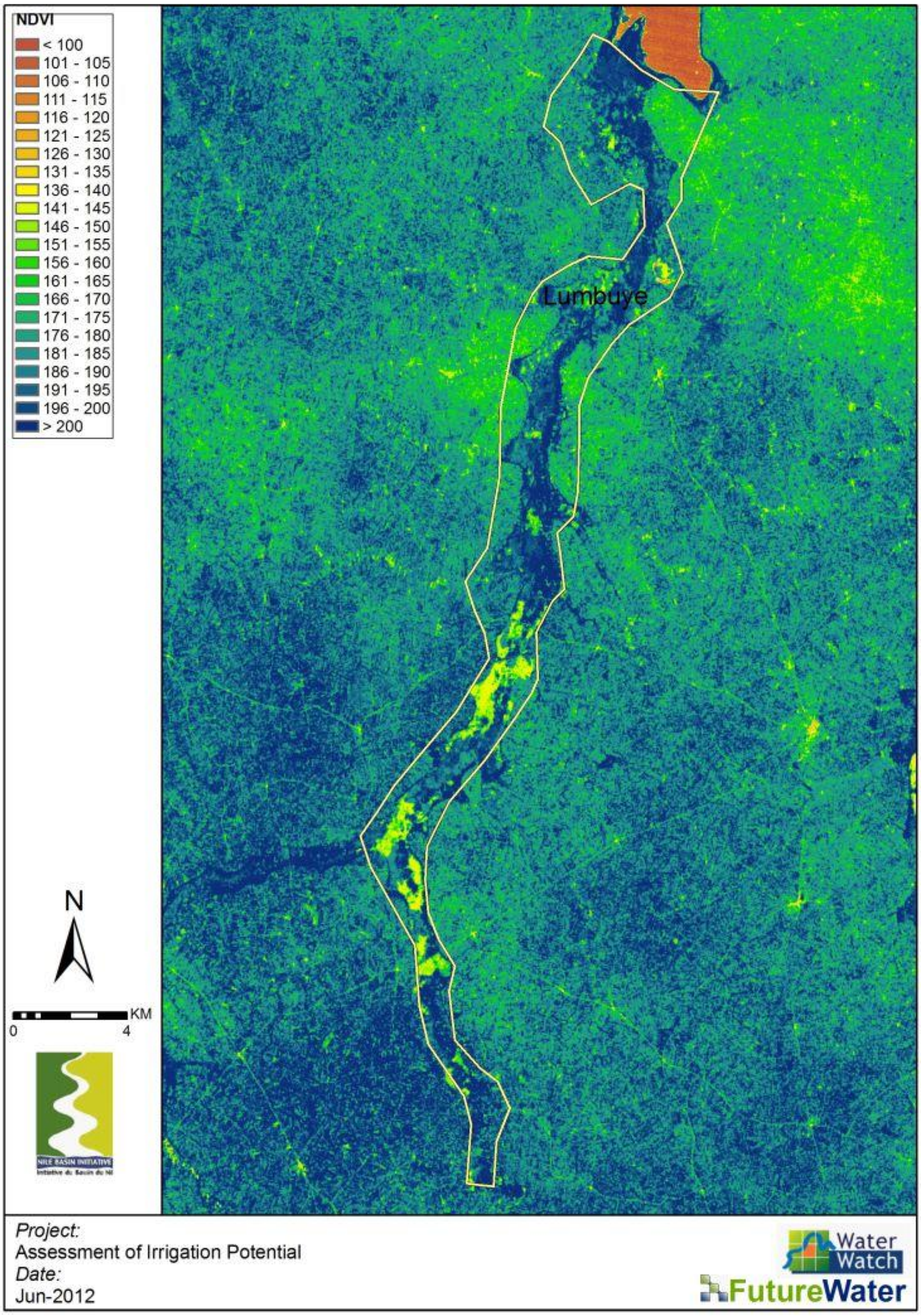


Figure 89: High resolution NDVI for Lumbuye focal area

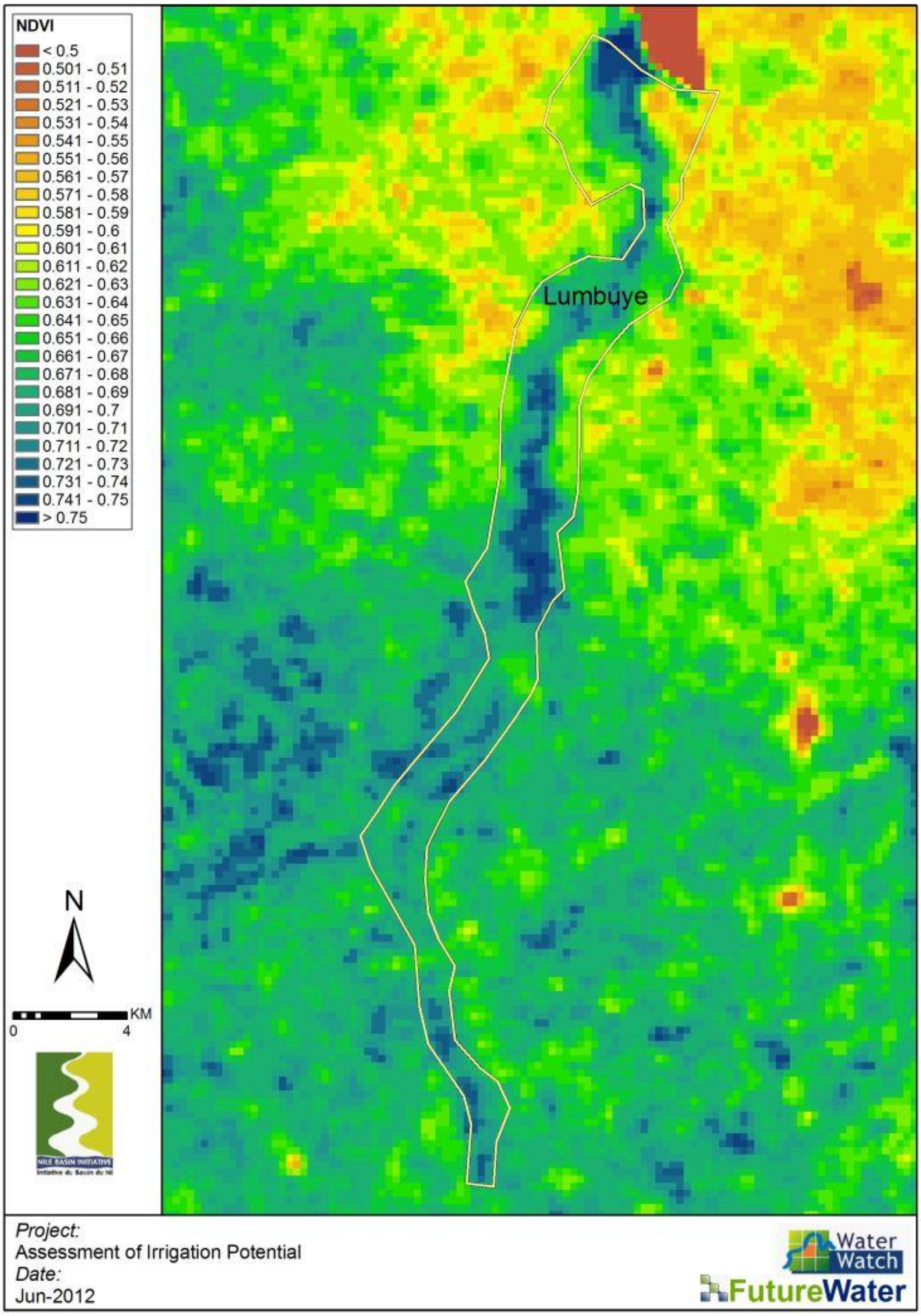


Figure 90: Yearly average NDVI values for Lumbuye focal area.

7.2.4 Potential cropping patterns

According to field observations, the land in the Lumbuye focal area is for 80% used for agricultural purposes. However, this may mainly be at the transition from the wetland valley to the more slope area. So far, agriculture in the valley is not developed well due to high groundwater levels and waterlogging. The main crops that are currently grown are paddy rice (70% of the agricultural area), maize and vegetables (both 10% of the agricultural area), and sugarcane. If possible, all crops are grown in two growing cycles per year. Depending on the type of irrigation system to be developed, the government policy differs concerning future crops. However, the overall focus will be on high value crops which will strengthen the economic situation in the region, and reduces poverty and hunger. Therefore, in the Lumbuye focal area the focus for irrigated crops will be on rice, fruit trees, pineapples and passion fruit.

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 temperatures during the year ranging from about 19°C to 31°C, with the warmest months being January, February, and March. Annual average precipitation is 1174 mm and reference evapotranspiration 1475 mm per year.

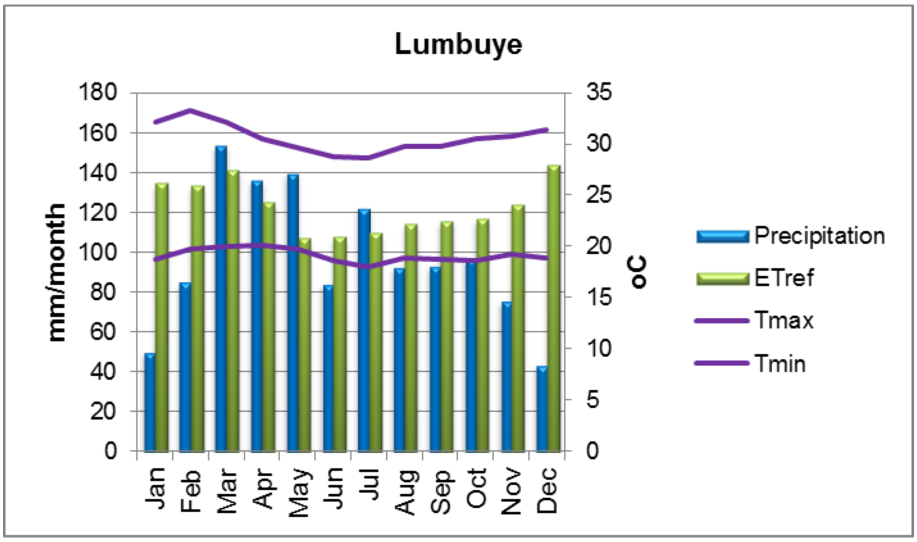


Figure 91: Average climate conditions for Lumbuye focal area.

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.

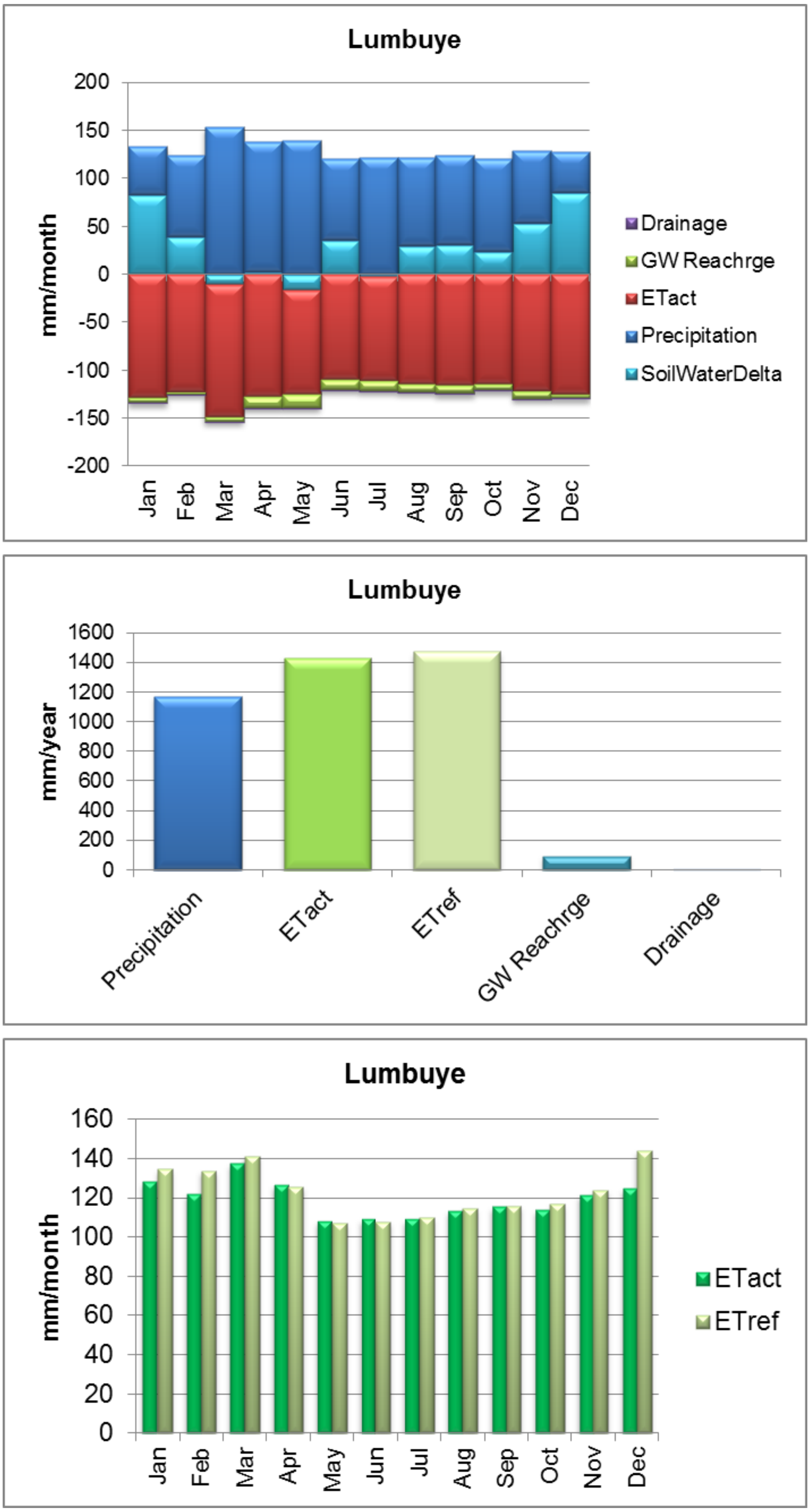
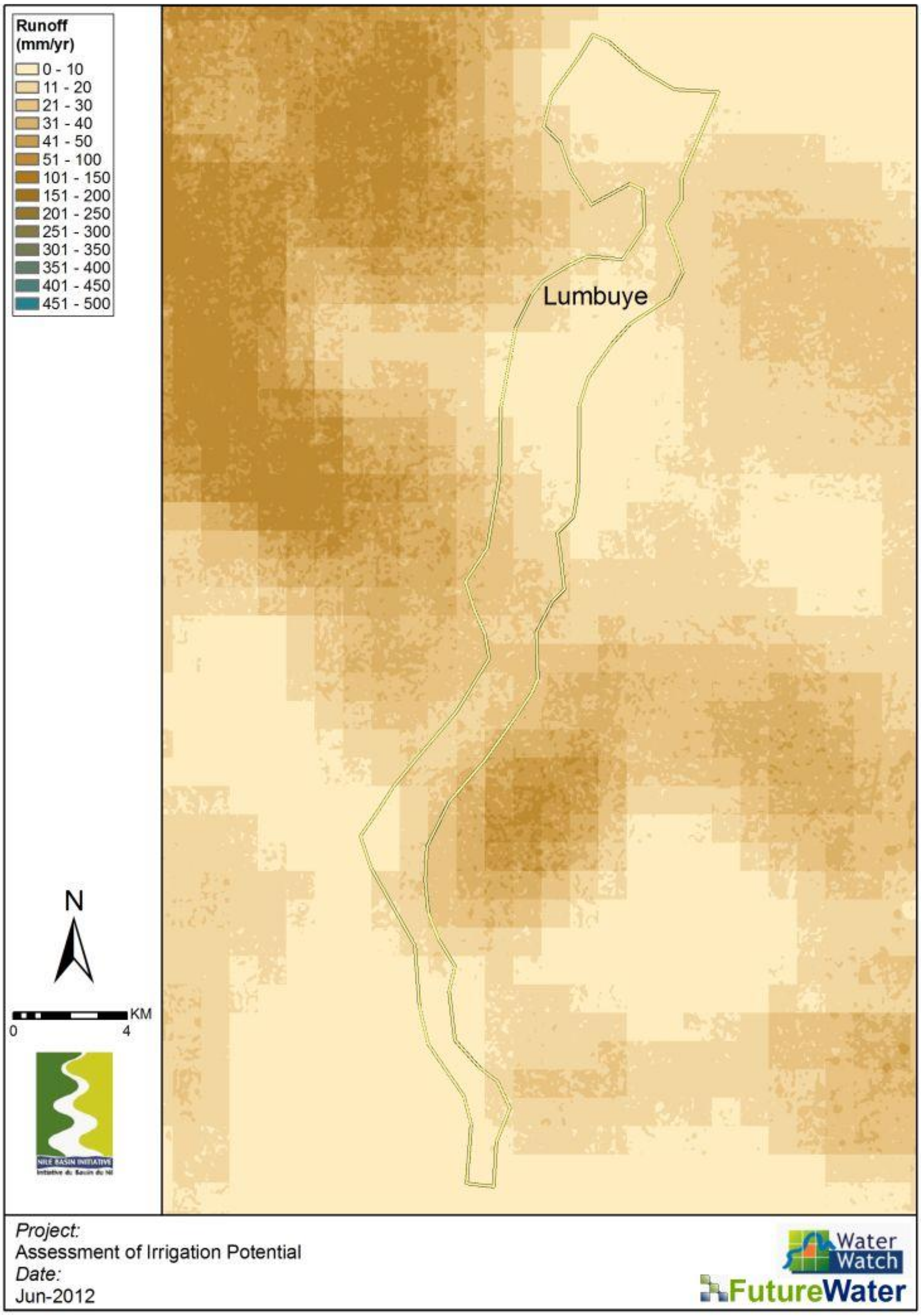


Figure 92: Water balances for the area based on the high resolution data and modeling approach for Lumbuye focal area.


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
Lumbuye
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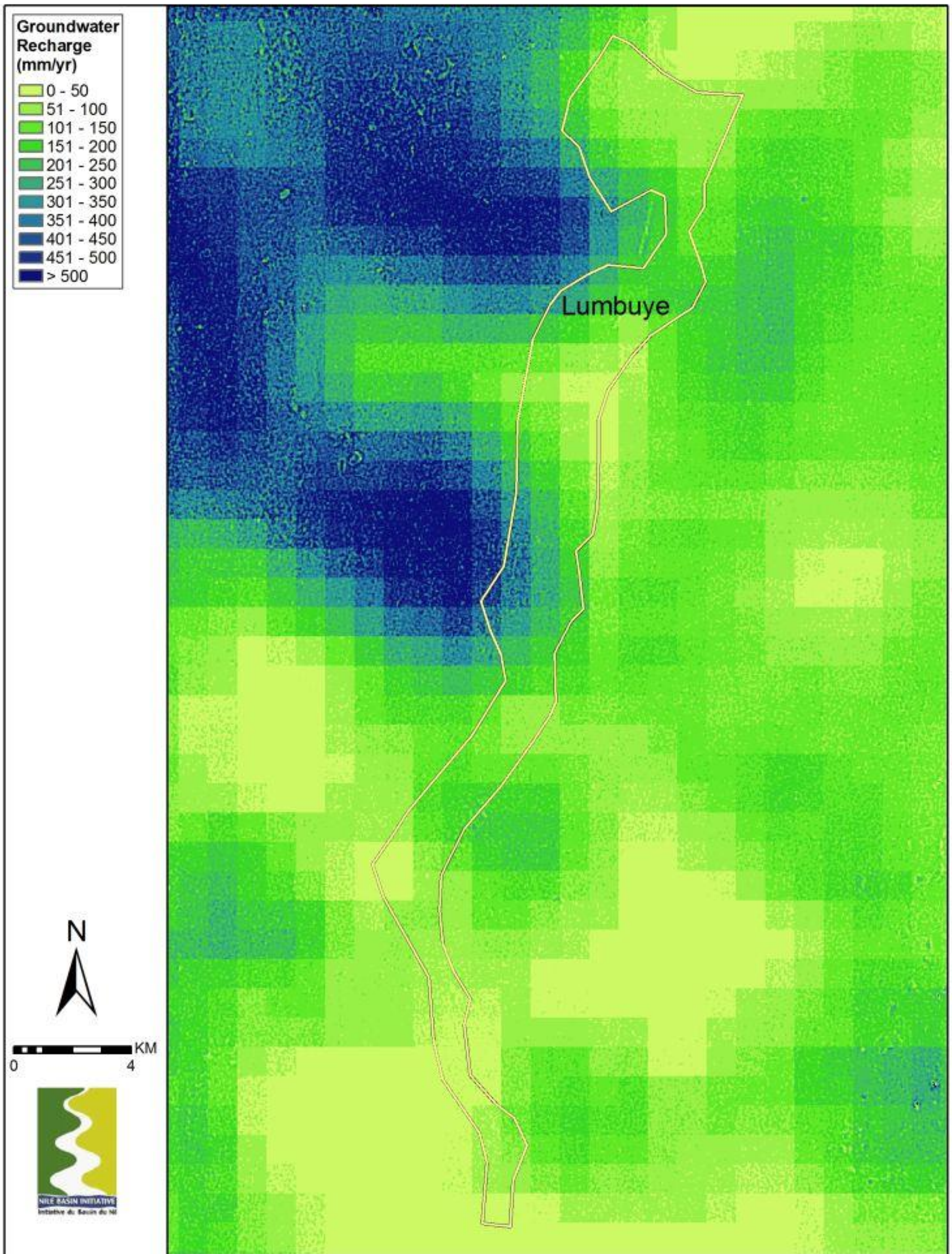

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Assessment of Irrigation Potential
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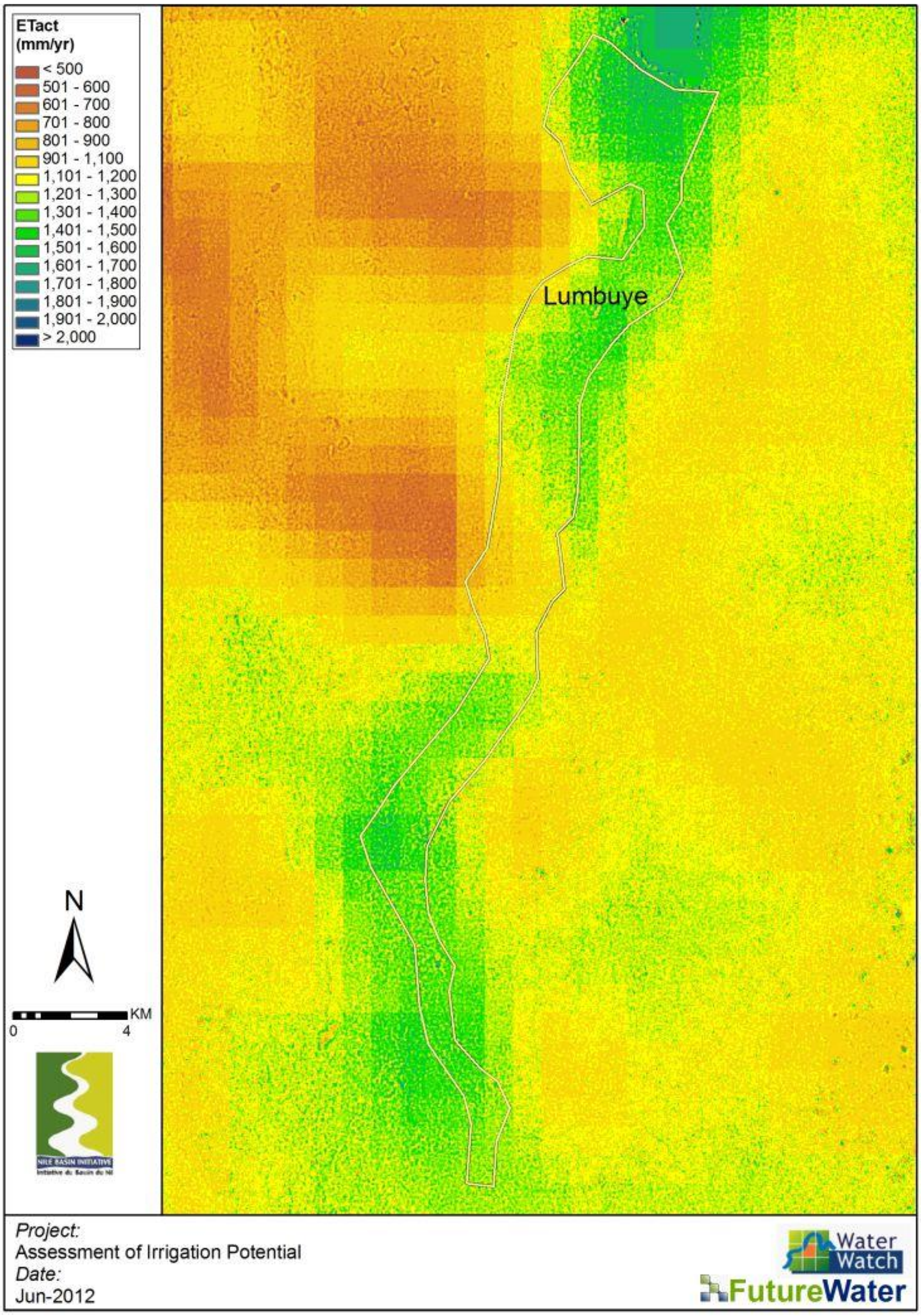


Figure 93: Water balances for the area based on the high resolution data and modeling approach for Lumbuye focal area.

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.

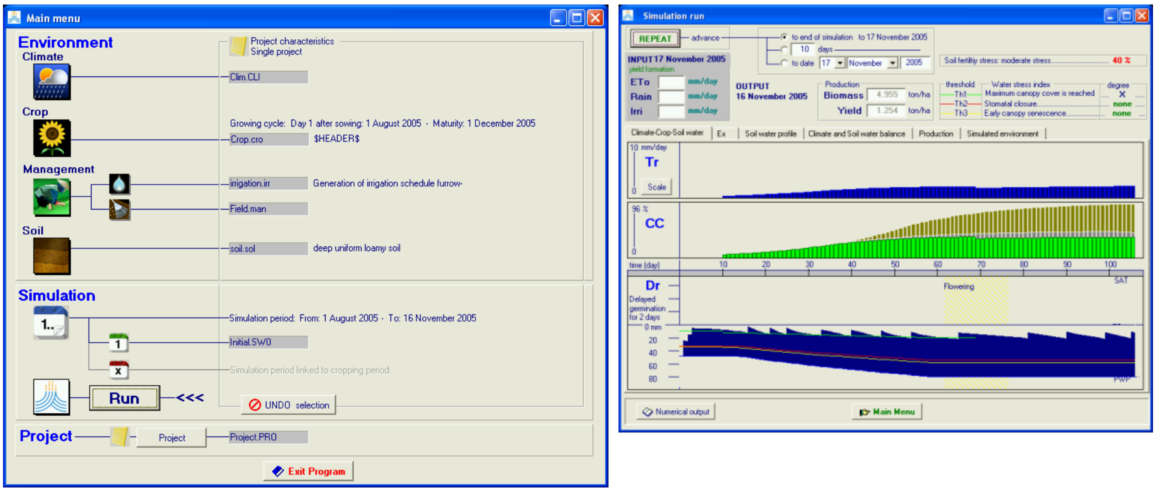


Figure 94: Typical example of AquaCrop input and output screens.

Table 13: 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)
Fruit trees	1174	1475	1	365	1174	290	1470	977
Pineapples	1174	1475	1	365	1174	330	1470	1000
Passion fruit	1174	1475	1	365	1174	250	1470	1000
Rice	1174	1475	213	320	327	230	413	381

7.4.2 Irrigation systems and irrigations efficiencies

The valley bottom in the area descends slowly and is therefore very suitable for surface irrigation. It is advised to create an intake point upstream of the focal area, and lead the water up from there following the contour lines along the focal area. In this manner gravity irrigation can be developed from the highest parts possible on the slopes of the valley, and extend further into the valley when water is abundant. The development of the irrigation canals will be rather costly, seen the topography of the area. Surface irrigation has a relatively low water application efficiency, and uses approximately 2-3 times more water than pressurized irrigations systems, such as drip or sprinkler irrigation. When water is the limiting factor for irrigation, the choice for sprinkler or drip irrigation would be better. This requires a higher investment and demands a higher farmers' knowledge, but will give a higher return.

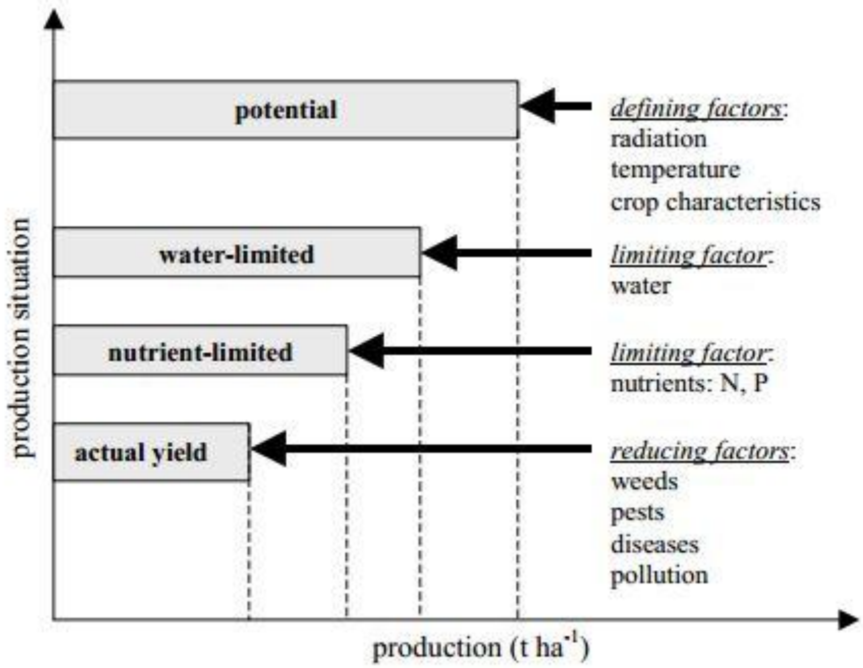
7.4.3 Water source

The source of the irrigation water will be Lumbuye River, which runs through the area. The annual average flow is about 0.7 m^3/s in the upstream part of the focal area, increasing towards 3.5 m^3/s in the most Northern part of the area. There is a large seasonal variation, which makes the construction of a dam mandatory for flow control and water storage. There are more possible locations for a reservoir, including the rehabilitation of the already existing Namadope dam.

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*

Uganda has slightly higher yields compared to surrounding countries. Population pressure and the increasing food demand have been triggers for the intensification of agriculture. In Figure 95 the yield gap is shown relatively to the highest obtainable yield in the world, to the world's average, and to Africa's average. Lumbuye has favorable conditions for agriculture, which shows off in yields being approximately 25% higher than the Ugandan average. The yield of rice is still lower than African standards. The unpredictable river conditions destroy the harvest partially every now and then. Rice grown in an area with a well-managed irrigation system can increase yields towards 6000-7000 kg/ha, which would triple the current yields. Pineapples and fruit trees are not common in the area, but are both good cash crops. Uganda has good experience with fruit trees, which result in yields exceeding the world's average. Planting of fruit trees does require a large investment. This will not be payed back in the first years, due to low yields in the first couple of years. Pineapple is a good cash crop that can stimulate together with fruit trees the agro-industry in the area.

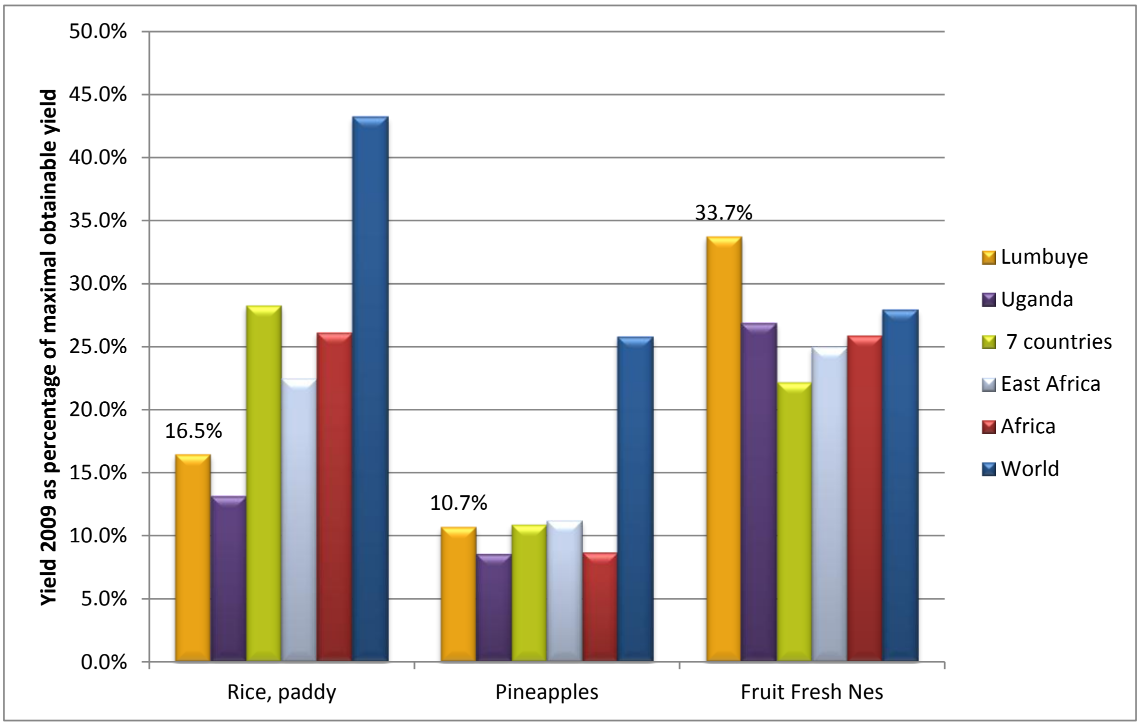


Figure 95: Yield gap Lumbuye (source: FAOSTAT, 2010), note that passion fruit is missing, but is considered under 'Fruit Fresh Nes'.

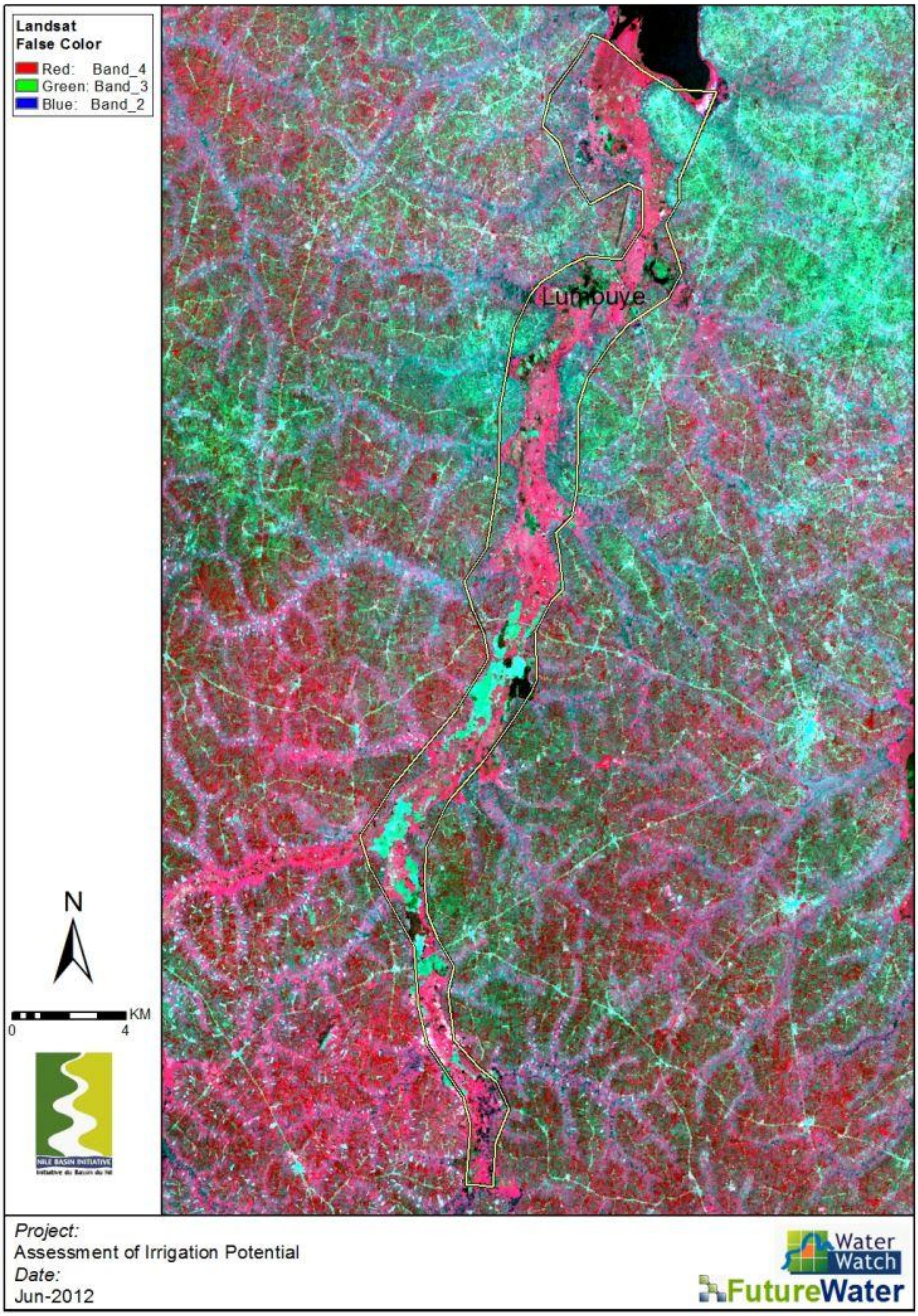


Figure 96: Landsat False Color Composite indicating current productivity of the area for Lumbuye focal area.

7.6 Environmental and socio-economic considerations

7.6.1 Population displacements

The population density in this area is among the highest in Uganda. People live in small communities along the roads, which mainly follow the contour lines of the hills surrounding the valley of the focal area. When developing an irrigation scheme, it is advised to design the scheme in such a way that population displacement is not or hardly needed. People in the area have average experience with irrigation. This would make displacement also easier, as people are aware of the advantages that irrigation brings. However, it is very important to involve the people in irrigation development. Within the valley itself hardly any people live and the focal area consists mainly of wetland. If the area and the foothills will be developed for irrigation, the need for displacements is very low. However, 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

The population density in the area is among the highest in Uganda and reaches 470 people/km^2. This is far above the Uganda average of 150 people/km^2. The area is quite well accessible, with an average distance of 6 km to the nearest tarmac road, and approximately 10 km to the town of Iganga from the Southern tip of the focal area. The town of Kaliro is located in the East of the focal area. The farmers already practice informal rice irrigation, which makes it easy to adapt to a more professional irrigation system. The development of an irrigation system will be very costly, as flood control requires dams which need to be quite wide. The area is inhabited by Basoga, Bagisu,Banyole, Japadolaa and Bagwere people. The farmers are not united in any cooperatives at the moment. During the field assessment it was reported that part of the area is leased to a private investor, but documents that support this statement have not been available so far.

7.6.3 Upstream downstream consideration

The water for irrigation comes from the river, which has a considerable upstream catchment. Erosion takes place on a small scale; on the slopes and in the river valley. The building of a dam can decrease the erosion in the valley, as the flow velocity can be reduced. Building dams in the river bed can enhance efficient water use, as water will be available during a longer season, which makes it available for irrigation in a later stage. These dams may also proof to be useful for hydropower generation. In the valley drainage is needed on most places, which lowers the groundwater table. The drained water will become available again for use downstream.

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):
    - Fruit trees: 210,000 kg/ha, 0.10 $/kg
    - Pineapples: 60,000 kg/ha, 0.22 $/kg
    - Passion fruit: 10,000 kg/ha, 0.20 $/kg
    - Rice: 3,000 kg/ha, 0.61 $/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.

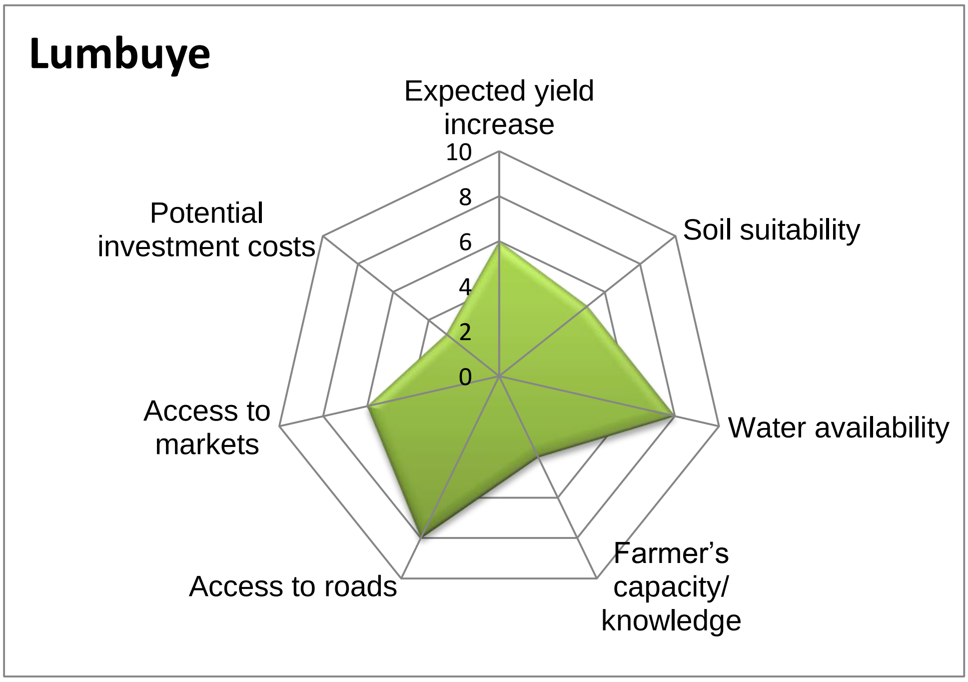


Figure 97: Filled radar plot indicating expert knowledge score to develop irrigation in the Lumbuye focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).

Table 14: Benefit-cost analysis for Lumbuye area.

Characteristics	
Irrigated land (ha)	9,812
Farmers	12,265
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$)	66.0
O&M costs (million US$/yr)	0.731
Net benefits per year (million US$/yr)	55.958
IRR (Internal Rate of Return)	100.0%

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.