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

Final Report
Appendix DR Congo

July 2012

Client
Nile Basin Initiative
NELSAP Regional Agricultural Trade and Productivity Project

Report FutureWater: 114

FutureWater
Costerweg 1V
6702 AA Wageningen
The Netherlands

+31 (0)317 460050

info@futurewater.nl

www.futurewater.nl

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: Henri Okitolembo (NLO), Bruno Matata (RPCS member), Isaac Mutela (contact person in Goma), Pitchou Mwana Katya (Field assesor), Alitum Ukelo (Field assesor), Grace Baruka (Field assesor), Pierrot Kasende Taombo (Field assesor), Christian Kambale Sukayamolo (Field assesor), amongst others. Their contribution is highly appreciated.

Authors of this report are:

- Dr. Peter Droogers[1] (Project Leader / Water Resources Specialist)
- Prof. Dr. Pascal Nkurunziza[1] (Assistant Team Leader)
- Prof. Dr. Wim Bastiaanssen[2] (Senior Irrigation Specialist)
- Dr. Walter Immerzeel[1] (Senior Water Modeler)
- MSc. Wilco Terink[1] (Data Analyst, Hydrologist)
- MSc. Johannes Hunink[1] (Data Analyst, Hydrologist)
- Dr. Wouter Meijninger[2] (Remote Sensing Specialist)
- Prof. Dr. Petra Hellegers[3] (Water Economist)
- MSc. Simon Chevalking[4] (Environmental Expert)
- Dr. Frank Steenbergen[4] (Social Geographer)
- BSc. Jaïrus Brandsma[1] (Data and GIS Analyst)

[1]FutureWater, [2]WaterWatch, [3]LEI, [4]MetaMeta

Contact: Peter Droogers; p.droogers@futurewater.nl; +31 317 460050; www.futurewater.nl

Table of contents

1 Introduction 10
1.1 Background 10
1.1.1 Socio-economy 10
1.1.2 Millennium Development Goals, current status 11
1.1.3 Poverty reduction strategy 12
1.1.4 Legal framework 13
1.1.5 Socio-economic context, legal framework and institutional setting 13

2 Countrywide irrigation potential 23
2.1 Terrain and soil 23
2.1.1 Relief, climate, and hydrography 23
2.1.2 Terrain suitability 23
2.1.3 Soil suitability 28
2.2 Water 31
2.2.1 Irrigation water requirements 31
2.2.2 Water availability for irrigation 68
2.2.3 Access to a potential water source 75
2.3 Land use 79
2.3.1 Current land use 79
2.3.2 Current land productivity (NDVI) 82
2.4 Agriculture 86
2.4.1 Background 86
2.4.2 Potential crop yield assessment 86
2.5 Infrastructure 89
2.5.1 Access to transportation 89
2.5.2 Access to markets 92
2.6 Population density 95
2.7 Irrigation potential 96
2.7.1 Focal areas 99

3 Bilukwa focal area 101
3.1 Introduction 101
3.2 Land suitability assessment 103
3.2.1 Terrain 103
3.2.2 Soil 106
3.2.3 Land productivity 108
3.2.4 Potential cropping patterns 108
3.3 Water resource assessment 108
3.3.1 Climate 108
3.3.2 Water balance 109
3.4 Assessment of irrigation water requirements 114
3.4.1 Irrigation water requirements 114
3.4.2 Irrigation systems and irrigations efficiencies 114
3.4.3 Water source 115
3.5 Potential crop yield assessment 115
3.5.1 Yield gap analysis potential dominant crops 116
3.6 Environmental and socio-economic considerations 119
3.6.1 Population displacements 119
3.6.2 Social 119
3.6.3 Upstream downstream consideration 119
3.6.4 Protected areas 119

	3.6.5 Institutional and legal framework	120
3.7	Benefit-cost Analysis	120
4	**Boga focal area**	**122**
4.1	Introduction	122
4.2	Land suitability assessment	124
	4.2.1 Terrain	124
	4.2.2 Soil	127
	4.2.3 Land productivity	127
	4.2.4 Potential cropping patterns	129
4.3	Water resource assessment	129
	4.3.1 Climate	129
	4.3.2 Water balance	130
4.4	Assessment of irrigation water requirements	135
	4.4.1 Irrigation water requirements	135
	4.4.2 Irrigation systems and irrigations efficiencies	135
	4.4.3 Water source	136
4.5	Potential crop yield assessment	136
	4.5.1 Yield gap analysis potential dominant crops	137
4.6	Environmental and socio-economic considerations	140
	4.6.1 Population displacements	140
	4.6.2 Social	140
	4.6.3 Upstream downstream consideration	140
	4.6.4 Protected areas	141
	4.6.5 Institutional and legal framework	141
4.7	Benefit-cost Analysis	141
5	**Abia- Tungudu focal area**	**143**
5.1	Introduction	143
5.2	Land suitability assessment	145
	5.2.1 Terrain	145
	5.2.2 Soil	148
	5.2.3 Land productivity	148
	5.2.4 Potential cropping patterns	150
5.3	Water resource assessment	150
	5.3.1 Climate	150
	5.3.2 Water balance	150
5.4	Assessment of irrigation water requirements	155
	5.4.1 Irrigation water requirements	155
	5.4.2 Irrigation systems and irrigations efficiencies	155
	5.4.3 Water source	156
5.5	Potential crop yield assessment	157
	5.5.1 Yield gap analysis potential dominant crops	157
5.6	Environmental and socio-economic considerations	160
	5.6.1 Population displacements	160
	5.6.2 Social	160
	5.6.3 Upstream downstream consideration	160
	5.6.4 Protected areas	161
	5.6.5 Institutional and legal framework	161
5.7	Benefit-cost Analysis	161
6	**Kitoba-Lubango focal area**	**163**
6.1	Introduction	163
6.2	Land suitability assessment	165

6.2.1 Terrain 165
6.2.2 Soil 168
6.2.3 Land productivity 168
6.2.4 Potential cropping patterns 170
6.3 Water resource assessment 170
6.3.1 Climate 170
6.3.2 Water balance 171
6.4 Assessment of irrigation water requirements 176
6.4.1 Irrigation water requirements 176
6.4.2 Irrigation systems and irrigations efficiencies 176
6.4.3 Water source 177
6.5 Potential crop yield assessment 178
6.5.1 Yield gap analysis potential dominant crops 179
6.6 Environmental and socio-economic considerations 181
6.6.1 Population displacements 181
6.6.2 Social 181
6.6.3 Upstream downstream consideration 181
6.6.4 Protected areas 181
6.6.5 Institutional and legal framework 182
6.7 Benefit-cost Analysis 182

7 Rutshuru Mutabo focal area 184
7.1 Introduction 184
7.2 Land suitability assessment 186
7.2.1 Terrain 186
7.2.2 Soil 189
7.2.3 Land productivity 189
7.2.4 Potential cropping patterns 191
7.3 Water resource assessment 191
7.3.1 Climate 191
7.3.2 Water balance 192
7.4 Assessment of irrigation water requirements 197
7.4.1 Irrigation water requirements 197
7.4.2 Irrigation systems and irrigations efficiencies 197
7.4.3 Water source 198
7.5 Potential crop yield assessment 199
7.5.1 Yield gap analysis potential dominant crops 199
7.6 Environmental and socio-economic considerations 202
7.6.1 Population displacements 202
7.6.2 Social 202
7.6.3 Upstream downstream consideration 202
7.6.4 Protected areas 202
7.6.5 Institutional and legal framework 203
7.7 Benefit-cost Analysis 203

Tables

Table 1: Agro-climatic zones in DRC (Iessime, 2007). 23
Table 2: Area equipped for irrigation in DR Congo according to FAO-Aquastat. 86
Table 3. Area harvested in ha for the 10 most dominant crops. 87
Table 4. Suitability classes. 99
Table 5: Focal areas Eastern DRC 100

Table 6: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season. 114
Table 7: Benefit-cost analysis for Bilukwa area. 121
Table 8: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season. 135
Table 9: Benefit-cost analysis for Boga area. 142
Table 10: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season. 155
Table 11: Benefit-cost analysis for Abia- Tungudu area. 162
Table 12: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season. 176
Table 13: Benefit-cost analysis for Kitoba-Lubango area. 183
Table 14: Irrigation water requirements for the selected crops in the focal areas. All units are given in mm per growing season. 197
Table 15: Benefit-cost analysis for Nsida-Mutaboarea. 204

Figures

Figure 1: Map of DR Congo (source: CIA Factbook). 10
Figure 2: Digital Elevation Model of Eastern DRC. 24
Figure 3: Terrain slope as percentage (top), surface irrigation (bottom left), and drip irrigation (bottom right). 27
Figure 4: Soil suitability for arable crops (left) and rice/paddy (right) 30
Figure 5: Salinity, top-soil (left) and sub-soil (right) 31
Figure 6: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 34
Figure 7: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 37
Figure 8: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 40
Figure 9: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 43
Figure 10: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 46
Figure 11: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 49
Figure 12: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 52
Figure 13: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 55
Figure 14: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 58
Figure 15: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 61
Figure 16: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 64
Figure 17: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom). 67

Figure 18. Water availability for irrigation. Total coverage (top left), coverage from surface water (top right), coverage from ground water (bottom left), and from potential reservoirs (bottom right). 72
Figure 19: Annual groundwater storage trends for Eastern DRC, based on GRACE satellite observations (Source: UoC, 2011). 73
Figure 20: Annual groundwater recharge based on NELmod. 74
Figure 21. Average distance to a natural stream, lake or reservoir (top left), elevation above natural stream, lake or reservoir (top right), and access to water suitability score. 78
Figure 22: Land use in Eastern DRC, based on AfriCover 79
Figure 23. Irrigated (left) and rainfed cropping intensities (right) as percentage of cells of about 10 x 10 km (Source: Mirca2000). 81
Figure 24: Current land productivity based on NDVI. Average NDVI (top left), average monthly coefficient of variation (top right), and the land productivity scores based on average NDVI (bottom left) and monthly coefficient of variation (bottom right). 85
Figure 25. Trend in yields per ha for the five most dominant crops. Average of first five years has been indexed to 100%. 87
Figure 26. Yield comparison for the five dominant crops in the country. 88
Figure 27: Distance to transportation (left), and suitability (right). 91
Figure 28: Distance to major towns (top left), distance to other towns (top right), and combined suitability index (bottom). 94
Figure 29: Population density distribution (source: CIESIN). 95
Figure 30: Irrigation suitability score 97
Figure 31. Final map indicating areas suitability for irrigation. 98
Figure 32: Overview focal areas Eastern DRC 100
Figure 33: 3D impression of Bilukwa focal area, Eastern DRC 101
Figure 34: Bilukwa focal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC 102
Figure 35: DEM Bilukwa focal area. Resolution 1 arc second (+/- 30m). 104
Figure 36: Slope map Bilukwa focal area (source: ASTER). 105
Figure 37: Yearly average NDVI values. 107
Figure 38: Average climate conditions for the focal area. 109
Figure 39: Water balances for the area based on the high resolution data and modeling approach. 110
Figure 40: Water balances for the area based on the high resolution data and modeling approach. 113
Figure 41: Typical example of AquaCrop input and output screens. 114
Figure 42: Yield gap Bilukwa (source: FAOSTAT). 117
Figure 43: Landsat True Color (top) and False Color Composite (bottom) indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC 118
Figure 44: Filled radar plot indicating expert knowledge score to develop irrigation in the Bilukwa focal area (1 = negative, 10 = positive) 121
Figure 45: 3D impression of Boga focal area, Eastern DRC. 122
Figure 46: Boga focal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC 123
Figure 47: DEM Boga focal area. Resolution 1 arc second (+/- 30m). 125
Figure 48: Slope map Boga focal area (source: ASTER). 126
Figure 49: High resolution NDVI 128
Figure 50: Average climate conditions for the focal area. 129
Figure 51: Water balances for the area based on the high resolution data and modeling approach. 131
Figure 52: Water balances for the area based on the high resolution data and modeling approach. 134
Figure 53: Typical example of AquaCrop input and output screens. 135
Figure 54: Yield gap Boga (source: FAOSTAT). 138

Figure 55: Landsat True Color (top) and False Color Composite (bottom) indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC 139
Figure 56: Filled radar plot indicating expert knowledge score to develop irrigation in the Boga focal area (1 = negative, 10 = positive) 142
Figure 57: 3D impression of Abia- Tungudu focal area, Eastern DRC 143
Figure 58: Abia- Tungudu focal area, Eastern DRC Shapes contributed by: LABO-DIAF/DRC 144
Figure 59: DEM Abia- Tungudu focal area. Resolution 1 arc second (+/- 30m). 146
Figure 60: Slope map Abia- Tungudu focal area (source: ASTER). 147
Figure 61: High Resolution NDVI 149
Figure 62: Average climate conditions for the focal area. 150
Figure 63: Water balances for the area based on the high resolution data and modeling approach. 151
Figure 64: Water balances for the area based on the high resolution data and modeling approach. 154
Figure 65: Typical example of AquaCrop input and output screens. 155
Figure 66: Yield gap Abia- Tungudu (source: FAOSTAT). 158
Figure 67: Landsat True Color (top) and False Color Composite (bottom) indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC 159
Figure 68: Filled radar plot indicating expert knowledge score to develop irrigation in the Abia-Tungudu focal area (1 = negative, 10 = positive) 162
Figure 69: 3D impression of the Kitoba-Lubango focal area, Eastern DRC 163
Figure 70: Kitoba-Lubango focal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC 164
Figure 71: DEM Kitoba-Lubango focal area. Resolution 1 arc second (+/- 30m). 166
Figure 72: Slope map Kitoba-Lubango focal area (source: ASTER). 167
Figure 73: High resolution NDVI 169
Figure 74: Average climate conditions for the focal area. 170
Figure 75: Water balances for the area based on the high resolution data and modeling approach. 172
Figure 76: Water balances for the area based on the high resolution data and modeling approach. 175
Figure 77: Typical example of AquaCrop input and output screens. 176
Figure 78: Yield gap Kitoba-Lubango (source: FAOSTAT). 179
Figure 79: Landsat True Color (top) and False Color Composite (bottom) indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC 180
Figure 80: Filled radar plot indicating expert knowledge score to develop irrigation in the Kitoba-Lubango focal area (1 = negative, 10 = positive) 183
Figure 81: 3D impression of the Nsida-Mutabo focal area, Eastern DRC. 184
Figure 82: Nsida-Mutabofocal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC 185
Figure 83: DEM Nsida-Mutabofocal area. Resolution 1 arc second (+/- 30m). 187
Figure 84: Slope map Nsida-Mutabofocal area (source: ASTER). 188
Figure 85: High resolution NDVI 190
Figure 86: Average climate conditions for the focal area. 191
Figure 87: Water balances for the area based on the high resolution data and modeling approach. 193
Figure 88: Water balances for the area based on the high resolution data and modeling approach. 196
Figure 89: Typical example of AquaCrop input and output screens. 197
Figure 90: Yield gap Nsida-Mutabo(source: FAOSTAT). 200

Figure 91: Landsat True Color (top) and False Color Composite (bottom) indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC 201
Figure 92: Filled radar plot indicating expert knowledge score to develop irrigation in the Nsida-Mutabofocal area (1 = negative, 10 = positive) 204

Abbreviations and acronyms

ASTER	Advanced Spaceborne Thermal Emission and Reflection
CEC	Cation Exchange Capacity
CIESIN	Center for International Earth Science Information Network
CNAEA	Comité National d'Action de l'Eau et de l'Assainissement
DEM	Digital Elevation Model
DRC	Democratic Republic of the Congo
ET	EvapoTranspiration
ETact	Actual ET
ETref	Reference ET
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GIZ	German Development Agency
GPRS	Growth and Poverty Reduction Strategy
IFPRI	International Food Policy Research Institute
IMF	International Monetary Funds
IWRM	Integrated Water Resource Management
MDG	Millennium Development Goal
NDVI	Normalized Difference Vegetation Index
ODA	Overseas Development Aid
PRSP	Poverty Reduction Strategy Paper
SRTM	Shuttle Radar Topography Mission
SSA	Sub Saharan Countries
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
WCS	Water Content Saturated
WSS	Water Supply and Sanitation

1 Introduction

1.1 Background[1]

The Democratic Republic of Congo (Figure 1) is the third largest country in Africa after Sudan and Algeria. The country lies on the southwestern fringes of the Nile Basin, and the Nile portion constitutes less than 2% of the national land area. It contributes to flow into the equatorial lakes region, lying along the border with Uganda. DRC has a vast central basin in a low-lying plateau with mountains in the east. In order to distinguish it from the neighboring Republic of Congo to the west, the Democratic Republic of Congo is often referred to as DRC. The DRC borders the Central African Republic and Sudan to the north, Uganda, Rwanda, and Burundi in the east, Zambia and Angola to the south, and the Atlantic Ocean to the west, and it is separated from Tanzania and Burundi by Lake Tanganyika in the east. The Democratic Republic of Congo has a total area of 2,344,585 km2, of which 2,267,048 km2 is occupied by land, and 77,810 km2 is occupied by water. Current estimates of the country's population are 71.7 million.

Figure 1: Map of DR Congo (source: CIA Factbook).

1.1.1 *Socio-economy*

Agriculture occupies an important place in the economy of the DRC. It contributed to 58% of GDP in 2002 against 35% in 1985 and less than 10% in the 1970s. But since then, exports of cash crops have plummeted. The agricultural sector provides a living for 70% of the population since the year 2002 against 63% in 2000.

The largest economic activity still occurs in the informal sector. Renewed activity in the mining sector, the source of the most export income, boosted a GDP growth from 2006-2008. The government's review of mining contracts that began in 2006, however, combined with a fall in world market prices for the DRC's key mineral exports temporally weakened output in 2009,

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

leading to a balance of payment crisis. The recovery of mineral prices, beginning in mid-2009, boosted mineral exports, and emergency funds from the IMF boosted foreign reserves.

The country faces several issues: water pollution, deforestation, soil erosion, wildlife poaching, and mining of minerals, which cause significant environmental damage.

1.1.2 Millennium Development Goals, current status[1]

The Millennium Development Goals (MDG) report, published in 2010, is not only giving an update about the current state of the MDGs, but also looks back to 50 years independence. To achieve the objectives of the MDGs, the government implemented a strategy for growth and poverty reduction. This strategy contains clear guidelines and an action plan to bring it into practice. Besides this, each province has developed a provincial poverty reduction strategy paper (PRSP).

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

Goal 1: Eradicate Extreme Poverty and Hunger
DRC makes very slow process with poverty and hunger reduction. The targets set for 2015 are: 40% of the population that live on less than one dollar per day, and 14% of underweighted children under 5 years. Nowadays, poverty has slightly decreased, from 80% in 1990 to 70% in 2007. However, the average dietary intake decreased from 2190 cal/per/day to 1500 cal/per/day in 2005. Numerous people eat one meal a day, and 71% of the population does not get the required 2500 cal/per/day.

Goal 2: Achieve universal primary education
Till 2001 the enrollment rate dropped due to armed conflicts, and increased from 2001 onwards to the year 2010. Overall, the enrollment rate increased from 56% in 1990 to 75% in 2010. Therefore, the target of 100% in 2015 is slightly unrealistic, but good progress can be seen within the last years. In 2007 the literacy rate of boys over 15 is 85%, and for girls over 15 59%. Regarding the progress from 1995 onwards, there is still a long way to go to reach 100% literacy.

Goal 3: Promote gender equality and empower women
Some improvement can be seen, although very slowly. In primary and secondary education the ratio girls to boys is 0.93 and 0.81. The percentage of females working in the non-agricultural sector increased from 11% in 1990 to 34% in 2007. This makes it possible to reach the targeted 50%. Female seats in parliament, however, are scarce with only 7.7% in 2007. This percentage changes slightly over time, but has never been close to the desired 50%.

Goal 4: Reduce child mortality
The under-five mortality rate has been reduced from 220/1000 to 158/1000 in the period 1995 - 2010. The target for 2015 is set to 60 per 1000 births. The infant mortality rate increased after 1990, to decrease again after 1995. However, the current level is still above the 1990 level with 97/1000.

Goal 5: Improve maternal health
Maternal health deteriorated first towards 2001, towards 1289 mortalities per 100,000 living births, just to improve afterwards to 549 mortalities per 100,000 births. The target is set to 322, which is still a long way to go. The percentage of births attended by skilled medical staff increased from 68% to 74% during 1995-2007. In 2007, 80% of the woman does not use any

[1] Section based on: rapport national des progress des OMD 2010.

contraceptive methods. Accordingly, target 5.B, to achieve universal access to reproductive health by 2015, progresses slowly.

Goal 6: Combat HIV/AIDS, malaria and other diseases
The infection rate of HIV decreased slightly from 5% in 1990 to 4.3% in 2010.The prevalence among woman is higher than among man, with a ratio of 1.25 in 2005. This ratio used to be 1.11 in 1990. The problem is much worse in the East of DRC, where systematic use of sexual violence by combatants contributes to the spreading of HIV. Malaria is still endemic within DRC, and remains the first major morbidity source. About 150,000-200,000 children under 5 years are estimated to die each year from Malaria. The percentage of children that sleeps under a mosquito net is rather low, with 3.4% in 2007 and a target of 15% in 2015.

Goal 7: Ensure environmental sustainability
Within DRC the forest cover was 55% in 1990, and this decreased to 52% in 2000 and even further towards 44.6% in 2006. The pressure on resources is high especially around urban areas. Access to an improved drinking water source is low, despite the abundant water resources. Only 47% of the population has access to an improved drinking water source in 2010, which is a 5 percent progress compared to 1995. The targeted 71% in 2015 seems a long way ahead. The percentage of people that have access to an improved sanitation system peaked in 1995 with 48%, and declined afterwards to 17.6% in 2007.

Goal 8: Develop a global partnership for development
This goal is especially measurable for the developed countries. The Overseas Development Aid (ODA) represented 5.49% of GDP in 1990, 4.48% in 1999 and rose after 2000 towards 40% in 2005. ODA decreased again to 10.7% in 2009. In July 2010 DRC has benefitted from the cancelation of about 90% of its public external debts.

1.1.3 Poverty reduction strategy[1]

The government of DRC has made a Growth and Poverty Reduction Strategy (GPRS). This is a paper which plans and describes on how to develop. In order to monitor the development and the achievements made with the GPRS, indicators were defined within the priority sectors: education, health, agriculture, rural development, transportation infrastructure, and water and sanitation.

In 2009, the economic growth slowed down to 6% compared to previous year. This resulted in a real GDP growth of 2.8%, which was slightly above expected. Annual average inflation reached 46.1%. The account deficit increased significantly to 15.9% of the GDP in 2008, due to increased imports and a drop in prices of export commodities. In 2009, the deficit decreased slightly to 12.9% of the GDP.

Public expenditures are divided into three strategic pillars: i) promoting good governance and peace, ii) promote access to basic social services, and iii) supporting sectors with growth potential. These sectors receive 60%, 24% and 16%, respectively, of the primary expenditure budget. The first pillar is equally divided among political and administrative governance, security governance and economic governance. The second pillar supports the transport, and agricultural and fishing sector. The third sector, which is only 16% or 4.6% of the GDP in 2009, supports the basic social services, such as education, health, water, electricity, science and environment.

---

[1] Section based on DRC PRSP progress report. IMF 2010.

The governance focuses on creating a save country and strengthen the judicial system. On political level the government tries to decentralize to allow the public to participate and to solve problem more on the local level. Economical governance focusses on the implementation of an efficient fiscal and customs policy, creating transparency, and public debt management.

Policies supporting economic growth include: i) agriculture and rural development, ii) forest and environment, iii) mines and hydrocarbons, iv) energy, v) transportation and infrastructure, vi) industry, and vii) trade. The government's aim is to restore food production to meet the national demand. They have actively contributed to agricultural and rural development by supplying seeds, trainings and other agricultural necessities. The government's policy concerning forest and environment is to promote sustainable management, which increases the contribution to economic, social and cultural development, currently, and in the future. Mining will be developed to increase the contribution from the mining sector to the economic growth. Energy access is planned to increase from 6% to 12.5% in 2015 (MDG), and further to 60% in 2025. Objectives for the industry sector are: make the sector competitive, create jobs, and integrate the sector in regional and international trade. For the improvement of the basic and social services, the targets are the same as for the MDGs.

1.1.4 Legal framework

The Government of the Democratic Republic of Congo has no unified official water policy in place. Efforts to develop a water policy or a water code with support of UN-organizations have been less successful. There is no single organization responsible the governance functions of water resources management. The functions are shared over various Ministries and the Directorate of Water Resources within the Environmental Department of the Ministry of Environment, Water and Forest is responsible for the development of water policies. However the administrative and managerial capacities of the directorate are limited for its constitutional function. The National Action Committee on Water and Sanitation is responsible for coordination between the ministries and for balancing competing interests in water uses. The committee cannot take the function of water administration that has overall responsibility. The Committee could take an advisory role, however the compromises between conflicting interests would require an organization that has a clear mandate.

1.1.5 Socio-economic context, legal framework and institutional setting

This section describes the socio-economic context and institutional setting for small scale irrigation development in the Democratic Republic of the Congo. 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:

- The rural population (65%) of Congo, DR is among the lowest in the region
- Poverty levels remain high – even slightly upwards of neighboring countries (71.3% below national poverty line)
- On main social services: health expenditures (USD 16/ capita), population with access to improved source of drinking water (46%), electric power consumption (91 KWh per capita) and female illiteracy (43%) Congo DR, scores slightly better than other countries in the same socio-economic bracket except for drinking water facilities
- Agriculture employment (61%) in Congo DR is lower than other Nile Basin countries
- In economic value Congo, DR is a net importer of agricultural products (import to export is 16.97), indicating low productivity of agricultural sector. The total value of agricultural exports is low (USD 56 M)

- With respect to food Congo, DR is a net importer (value of food imports USD 830 M)

Agricultural services

- Agricultural road density is low (22.91 km/1000 sq. km arable land) – affecting agricultural marketing
- Fertilizer use is at a minimum (0.9 kg/ ha)
- The use of mechanical equipment is minimal (3.63 tractors per 1000 sq km of arable land)

Irrigation and water use

- Irrigated fraction of arable land is nihil (0.14%) only two irrigation schemes for rice and sugarcane exist, totaling a 13,500 hectares. In official irrigation with waste water in urban centers is however provides health problem
- Total water abstraction is a small percentage of renewable resources (0.05%)
- No data are available on groundwater usage
- Irrigation performance is of less importance than scale of irrigation

Institutions

- The institutional framework for irrigation and water development is weak. Main polices for irrigation and water resource development are the Water Code Draft 2010 and the water Sector reform Draft 2006. The Water Code Draft 2010 is the guiding document for irrigation and water management. It includes the national strategy on water and includes principles of IWRM, Polluter/User Pay Principles, as well as defines the institutional framework on district level.)
- The institutional mandate for irrigation development is mainly shared between the Ministry of Environment, Nature Conservation and Tourism and the Ministry of Energy. The National Action Committee for Water and Sanitation under the Ministry of Planning provides interdepartmental coordination between the ministries for water sector management.
- Water license have to be obtained from the Ministry of Energy, water fees are not mentioned specifically.
- All land belongs officially to Congo, DR, in practice however access to land is granted by customary chiefs as life estate or freehold
- On indicators of government effectiveness (1.9) and rule of law (-1.7) Congo, DR scores among the lowest of all SSA countries.

CONGO, DEMOCRATIC REPUBLIC OF THE - INSTITUTIONAL	
Main guiding policies, acts and ordinances (UNEP, 2011, pp. 21)	• *The Water Code Draft 2010 is the main guiding document for irrigation and water management. It includes the national strategy on water and includes principles of IWRM, Polluter/User Pay Principles, as well as defines the institutional framework on distrcit level.* • *Water Sector Reform Draft 2006 (EMAN)* • *Agricultural Code 2, including enhancement of agricultural productivity and modernization of production systems (SADC, 2011, pp. 72)* • *New constitution 2006, defines decentralization*[1] • *PRSP 2006 and CAF (Country Assistance Framework)*

Institutional mandate irrigation development (Meghani, M. et al. 2007; UNEP, 2011, pp. 22-23 & SADC, 2011, pp. 64 and 65)[2]	• *Ministry of Planning*
	  ○ *National Action Committee Action for Water and Sanitation (CNAEA). Provides interdepartmental coordination of the water sector and functions as gateway for development partners (UNEP, 2011, pp.23)*
	  ○ *Platform for Aid Management and Investment (PGAI)*
	• *Ministry of Environment, Nature Conservation and Tourism (MECNT)*
	  ○ *Dir. of Water Res., incl. development of watershed management plans*
	• *Ministry of Energy*
	  ○ *National Commission of Energy (including hydropower)*
	  ○ *Department of Water and Hydrology*
	• *Ministry of Agriculture*
	• *Ministry of Rural Development*
	  ○ *The national Service of Rural Hydraulics (Service National d'Hydraulique*

[1] Still multiple 'individual' laws and ordinanances are in circulation, originating from the period prior to the water reforms. The Water Code Draft 2010 is however meant as overarching institutional framework for these (UNEP, 2011). Few of these old ordinances are mentioned in Meghani, M. et al. 2007. For instance: Ordinance law No 52/443 of December 24, 1952: it describes measures to protect sources , aquifers, streams and rivers, wastage of water and control of right to use water and ownership; Ordinance law No 74/569 of December 3, 1958 is related to irrigation & The Ministerial act No E/SG/O/0133 C2/93 0f 7 Mars 1993 describes conditions for obtaining a ground water and surface water permit, as well as conditions for carrying out a drilling in an aquifer and exploiting ground water.

[2] The institutional mandat is described in the UNEP 2011 report as follows: "The management of the water sector is divided between seven several departments and organizations. Overlapping jurisdictions and conflictual mandates have led to a competition. The two key departments at the head of the sector water are the Ministry of Environment, Conservation and Tourism (MECNT) and the Minstry of Energy (MoE)"(UNEP, 2011, p.22) and "The institutional capacity for natural resources management and climate change adaptation is assessed to be very weak in general"(SIDA, 2008, pp.11).

	Rural – SHNR)
	• *Ministry of Public Works*
	  ○ *The service of drainage (Office de Voirie et Drainage – OVD)*
	• *Ministry of Agriculture, Fisheries and Livestok: including small scale irrigation schemes*
	• *Ministry of Transport*
	  ○ *METTELSAT and agencies perform an important role in the collection hydrological and meteorological data, but lack human and financial capacity.*

Water Permit System – Drillers *(Mghani, M. et al. 2007, pp. 51)*	• *No specific water permit system for drillers mentioned in one of the guiding policies of Congo DR. Drilling companies in Congo DR are REGISESO (state) and private companies such as MIDRILCO, FOLECO, SFA and ADIR. As long as the demand for groundwater supply is low, the existing companies are able to meet the demand. However, the low demand of water supply is mainly due to high cost of drilling.* • *India and China are increasingly involved in the drilling sector (UNEP, 2011)*
Water Permit System – Users *(Mghani, M. et al. 2007, pp. 27)*	*Congo DR has developed comprehensive regulations restricting groundwater abstraction without permit.* On national level permits have to be obtained from the general secretary (Large projects) or at representative (local level) of the Ministry of Energy

Other institutions involved in irrigation development *(UNEP, 2011, pp.25)*	• *GTZ (German Development Agency) provides overall guidance to the water reforms.*
	• *International institutions: World Bank and African Development Bank, UN (particular FAO and UNDP), EU (SIDA, 2011, pp. 11 and SADC, 2011, pp. 69)*
	• *Bilateral involvement in the agricutural sector: USAID, Canada, Belgium, Italy, Sweden, Japan, The Netherlands and Switzerland (SADC, 2011, pp. 69).*
	• *Loan facilities:*
	  ○ The Banque de Crédit Agricole, PROCREDIT, Trust Merchant Bank are institutions porviding loans in between 1,000-8,000 US$ (SADC, pp. 69)
	  ○ Microfinance loans in between 50-400US$ (ADEKOR, ACCCO Microcredit, CEDEKOC and Hope DRC) (SADC, pp. 69)

Local organizations	• *Included in the decentralization policy is creation of provincial councils, local governments, local water committees, water user associations and cooperatives (UNEP, 2011, pp. 23)* • Farmers often form cooperatives to provide training and assistance in marketing and agricultural inputs (seed, equipment). The farmers are organised at all levels

	of the production chain (SADC, 2011, pp. 68)
Private sector *(Meghani, M. et al. 2007, pp. 23)*	• *MIDRILCO, ADIR and C.D.I. operate in the groundwater sector with lucrative objectives* • *NGO/Companies Lovoi sustainable villages (development of organic agriculture and irrigation), Wright Rain (Sprinklers)*
Support to small scale irrigation development (vocational sector, land planning) (SADC, 2011, pp. 67)	At the higher education level, 52 institutes and universities, of which 25 are public and 27 are private approved establishments, are exclusively devoted to technical agricultural education
Land tenure (USAID, 200X)	• The land tenure system in the DRC is governed by Law N° 73/021 of 20 July 1973, as amended and supplemented by Law N° 80/008 of 18 July 1980 which makes the Congolese State the sole proprietor of all land and mineral resources. In practice, access to land is first granted by the customary chiefs who allocate plots as life estate or —freehold to applicants. The authorities have initiated consultations with all the stakeholders aimed at amending the land tenure system in order to make it more equitable and more attractive to private investors. (SADC, 2011, pp.73) • The current system provides little security to landholders and does not foster productive and sustainable use of the land (USAID, 200X)
Government Effectiveness (percentile rank 0-100) (Worldbank, 2009)	*1.9*
Rule of Law (-2.5 – 2.5), in which high values represent effective enforcement of law (World Bank, 2009)	*-1.7*

CONGO, DEMOCRATIC REPUBLIC OF THE - SOCIO-ECONOMIC	
Food exports, FAO (current US$M) (FAO Statistical Yearbook 2010)	10.86
Food imports, FAO (current US$M) (FAO Statistical Yearbook 2010)	829.82
Imports/exports	76,43
Health expenditure per capita (World Bank, current US$, 2009)	16
Improved water source (% of population with access) (World Bank, 2008)	46
Improved water source, rural (% of rural population with access)(WB, 2008)	28
Improved water source, urban (% of urban population with access)(Ibid.)	80
Poverty (% below national poverty line) (UNSTAT, 2005)	71.3
Illiteracy rate –Male (15+) (UNICEF, 2009)	22.6
Illiteracy rate --Female (15+)(UNICEF, 2009)	43.4
Primary completion rate, total (% of relevant age group) (UNICEF, 2006)	63.9
Road density (road km/100 sq. km of land area) (IRF, 2004)	7
Road to arable land density (road km/1000 sq. km arable land)(Ibid.)	22.91
Roads, paved (% of total roads)(Ibid.)	1,82
Electric power consumption (kWh per capita) (World Bank, 2009)	91
Country area (km2) (FAOSTAT, 2009)	342,000
Land area (km2) (FAOSTAT, 2009)	341,500
Population, Projected/Estimated (FAOSTAT, 2010)	67,827,000
Urban population (% of total population) (FAOSTAT, 2010)	35
Rural population (% of total population)(100-Urban Popuation)	65
Population density (pp/km^2) (World Bank, 2010)	29
AGRICULTURAL	
Agricultural exports (US$M) (FAOSTAT, 2008)	56.55
Agricultural Import (Current US$M) (FAOSTAT, 2008)	959.33
Import/export	16,97
Value added in agriculture, growth (%) (World Bank, 2009)	3
Value added, agriculture (% of GDP) (Ibid.)	42.91
Employment agriculture (% of population) (USAID)	61
Agricultual machinery (tractors /100 square km arable) (World bank,	3.63
Agriculture value added per worker (Constant 2000 US$) (WB, 2009)	168
Fertilizer consumption (kg per hectare of arable land) (WB, 2008)	0.9
Cereal cropland (% of land area) (of which irrigated, %) (WB, 2009)	1
Agricultural area (ha) (FAO Resource Stat, 2009)	22,450,000
Arable land (ha) (FAO Resource Stat, 2009)	6,700,000

IRRIGATED AGRICULTURE	
Irrigated land (% of crop land) (Aquastat, 1997)	0.14
Irrigated land entire country (ha) (AQUASTAT, 1995)	10,500
Actually irrigated (ha) (SADC, 2011)[1]	13,500
Irrigation potential (entire country) (AQUASTAT, 2007)	7,000,000
Irrigated Land nile basin (potential)	n.a.
Irrigation schemes in Nile Basin	n.a.
Small schemes (national level)	n.a.
Medium schemes (national level)	n.a.
Large schemes (national level)	n.a.
Potential schemes (Nile Basin)	n.a.
Water Sources	Rivers, Lakes
Water Sources – Names	n.a.
Irrigated area per household (ha) (national level)	n.a.
SUSTAINABLE WATER ABSTRACTION RATES (AQUASTAT, 2000)	
Renewable resources (km3/year)	1,283
Overlap	420
Surface water	1,282
ground water	421
Dependency ratio	29.85
ACTUAL WATER ABSTRACTION RATES	
Groundwater (km3/year)	n.a.
Surface (km3/year)	n.a.
Total water withdrawal (km3/year) (AQUASTAT, 2000)	0.622
% of renewable water resources (AQUASTAT, 2002)	0.05
Water abstraction points[2] (UNDP, 2010)	
Deep Motorized boreholes	n.a.
Motorized boreholes	707
Manual boreholes	1000
Protected shallow wells	13,056
Windmill boreholes	n.a.
Springs	n.a.
Canalized water systems	7126

[1] Only 13,500 ha of sugar cane and rice are irrigated (SADC, 201, pp. 66)

[2] Indicates number of abstraction points needed to be installed in 2020 to arrive at 60% water access for the population (UNDP, 2010)

IRRIGATION PERFORMANCE	
Overall Irrigation performance Large Scale Irrigation (0-5)	n.a
Result Oriented Performance	n.a.
Sustainability Oriented Performance	n.a.
Process Oriented Performance	n.a.
Detailed Irrigation Performance Parameters	
Water Productivity (Performance 0-5) (Rank within Nile	n.a.
Agricultural water Productivity	n.a.
Crop consumptive use	n.a.
Beneficial Water Use	n.a.
Adequacy	n.a.
Uniformity	n.a.
Reliability	n.a.
Sustainability	n.a.
AGROPHYSICAL	
Irrigated crops[8] (ha) (USAID)	Generally (irrigated and
Cereal yield rainfed (kg/ha) (Nett yield)	n.a.
Biomass production (satellites) (kg/ha) (Nett yield)	n.a.
Cereal yield irrigated (kg/ha) (Nett yield)	n.a.
Yield Increment	n.a.
Net Increment	n.a.

[8]The crop distribution per region is as follows: “Wheat, beans, potatoes and cash crops of coffee, tea, and quinine are grown in eastern regions (now Ituri and North Kivu provinces).Rice and groundnuts are grown in Maniema Province. Shifting cultivation is practiced in northern provinces (formerly Equateur Province), and, in addition to maize and manioc, subsistence farmers grow groundnuts and squash. In the north-central forest-savannah region (formerly Province Orientale, now Tshopo, Bas-Uele, and Haut-Uele) farmers grow rice, bananas, and groundnuts. Prior to the war, the province also had commercial coffee, cocoa, and rubber farms. The southwestern provinces (Kinshasa, Kongo Central, and Kwango), which serve Kinshasa markets, produce fruits, vegetables, and beef (WCS 2003).” (USAID)

1.1.5.1 Water treaty agreements

The Constitution provides that the state owns all of the natural resources, including water. The government has been working on a comprehensive water law for several years. The DRC does not have a formal water law. Various draft water laws have included objectives to conserve common resources, reconcile different uses, prevent pollution and harmful effects from floods, treat water as an economic resource, and prevent over-exploitation. The 2002 Mining Code (Law No. 007/2202 of 11 July) gives holders of mineral exploitation permits, the right to use subsurface water resources within the extent of land or perimeter granted. Under customary law, land rights include use-rights to surface and groundwater.

Overall, the DRC's Water Supply and Sanitation (WSS) sector is dominated by a maze of overlapping institutional jurisdictions. Although key government agencies are working with technical assistance from outside donors to develop a national water code and re-organize their duties around the code, many greater barriers to technical, managerial, and financial adequacy must first be assessed and improved after institutional reforms. Among this broad need for institution building, the DRC's infrastructure is degraded or under-utilized, funding is inadequate, and water service providers are weak in terms of human resources and the ability to manage, monitor, and evaluate system developments and operations.

The responsibility for water resources and water management in the DRC is fragmented among at least seven different ministries, coordinated by the National Action Committee on Water and Sanitation (Comité National d'Action de l'Eau et de l'Assainissement (CNAEA)). The primary ministries exercising authority over water resources are the Ministry of Energy, Ministry of Agriculture, Ministry of Rural Development, and Ministry of the Environment, Nature Conservation, and Tourism.

The DRC, Cameroon, Republic of the Congo, and Central African Republic ratified an accord in 2003 to establish the International Commission of the Congo-Oubangui-Sangha Basin (CICOS). The Commission is the first step in an effort to coordinate use and protection of the shared water basin resources and strengthen cooperation in the areas of shipping and water pollution control. Besides, DRC joined the Nile Basin Initiative for the part of DRC located within the Nile basin.

1.1.5.2 Land ownership rights

Under formal law, the state owns all the land in the DRC; people and entities desiring use-rights to land can apply for concessions in perpetuity or standard concessions. Concessions in perpetuity (concessions perpétuelles) are available only to Congolese nationals, and are transferable and inheritable by Congolese nationals. The state can terminate concessions in perpetuity through expropriation. The state can grant standard concessions (concessions ordinaires) to any natural person or legal entity, whether of Congolese or foreign nationality. Standard concessions are granted for specific time periods, usually up to 25 years with the possibility of renewal. Renewal is usually guaranteed as long as the land is developed and used in accordance with the terms of the concession (Musafiri 2008).

Although the formal law applies to all land in the DRC, as a practical matter, application of the DRC's formal law relating to concessions tends to be restricted to urban areas and large holdings of productive land in rural areas. In most rural areas, customary law governs. Under customary law, groups and clans hold land collectively, and traditional leaders allocate use-rights to parcels. Rural land used for agricultural and residential purposes has become highly individualized in some areas over the years. Community members have the authority to loan, lease for cash, or sharecrop their individualized plots of communal land, but in most areas they cannot sell or permanently alienate the communal land to people outside the community. As areas have become commercialized, the prohibition against the sale of land to outsiders has relaxed (GODRC Constitution 2005; Musafiri 2008; Leisz 1998; Vlassenroot and Huggins 2005).

In the colonial period, the DRC followed a Torrens system, in which land held by Europeans was surveyed, titled, and titles were registered in centrally maintained land books. At the independence in 1960, all holders of registered land were required to re-register their land, and prove that the land was put to appropriate and productive use. The percentage of land that was originally registered or re-registered is unknown, as is the extent of concessions granted by the government under the 1973 General Property Law. Concessions can be granted in the name of an individual or group of individuals. The frequency of married couples registering concessions in the names of both spouses is unknown (Leisz 1998; Coutsoukis 1993).

Most Congolese obtain land-rights through inheritance, customary land-allocations from chiefs, or concessions from government officials. Concessions are most common in urban and semi-urban areas and agricultural areas with large commercial landholdings. Customary tenure systems dominate in rural areas and in informal settlements in urban and semi-urban areas. In some areas, particularly areas affected by conflict and those where natural resources are extracted, the state government has posted local representatives who impose taxes on locals and business interests. Traditional authorities in many areas have retained their authority by forming alliances with local government officials; both chiefs and government administrators allocate land, often in exchange for political loyalty and without reference to requirements of the formal law. Particularly in regions where there are inadequate numbers of government officials, chiefs may serve as local representatives, blurring the distinction between formal and customary authority. In some areas, chiefs granting land-rights are issuing a type of concession document, but there are no established forms and no procedures for recording the documents (Leisz 1998; Coutsoukis 1993; Vlassenroot and Romkema 2007; Vlassenroot and Huggins 2005).

Since independence, successive governments have both granted and denied foreigners the right to be treated as nationals for purposes of obtaining land-rights. Most recently, in an effort to address tensions over land claims asserted by immigrants from Rwanda who have ties to the land in the eastern provinces, the government defined Congolese nationals as those descending from a tribe that can trace its roots to the DRC to a time period before 1885. With support of the chiefs, government administrators in some areas (especially the eastern provinces) evicted occupants of communal land and plantations and sold the land to a growing class of rural elite, including large numbers of immigrants from Rwanda. The formal law does not recognize private land-ownership (only perpetual or standard concessions), and the legal status of the rights obtained through these land transfers is ambiguous (Vlassenroot and Huggins 2005; Reynolds and Flores 2008; Leisz 1998).

Chiefs continue to grant rights to forest land for hunting and gathering in many areas, and community members may obtain rights to forest through clearing the land for agriculture. By some reports, in some areas where communities are structured on a principle of reciprocity and the exchange of social capital as opposed to ethnicity or lineage, newcomers may be able to integrate into communities and obtain individualized land-allocations available to community members; those who do not integrate into a community can often rent land from community members for cash. However, in other areas chiefs and other traditional authorities may preserve homogeneity in their control over land and deny people access to land based on their ethnicity, lineage, or gender (Leisz 1998; Musafiri 2008; Vlassenroot and Huggins 2005; WCS 2003).

2 Countrywide irrigation potential

2.1 Terrain and soil

2.1.1 Relief, climate, and hydrography

Eastern DR Congo is an area characterized by rolling hills, and plans along the rivers and the valley from Lake Kivu until Lake Albert. The climate in the DRC is hot and humid in the equatorial river basin, and cooler and drier in the southern highlands. North of the Equator we have a wet season (April-October) and a dry season (December-February). South of the Equator we also have a wet season (November-March), and a dry season (April-October).

According to Iessime (2007), the country is divided into three agro-climatic zones: equatorial, tropical wet, and mountain climate. A summary of these agro-climatic zones is represented in Table 1.

Table 1: Agro-climatic zones in DRC (Iessime, 2007).

Zones agro- climatiques	**Province ou contrées de province**	**Pluviométrie annuelle (mm)**	**Durée des saisons (en mois)**		**Végétation**
			Pluies	Sèches	
Equatoriale	Equateur	1800 - 2000	>11	<1	Forêt équatoriale
(cuvette centrale)	Nord Bandundu	1500- 2000	>11	<1	Forêt équatoriale
	Nord Maniema	1800- 2300	>11	<1	Forêt équatoriale
	Sud Prov Orientale	1700- 2000	>11	<1	Forêt équatoriale
Tropicale humide	Kasaï Or. & Occ.	1500	8-10	2-4	Savane+ forêt sec
	Sud Maniema	1300	8-9	3-4	Savane+ forêt sec
	Nord Prov Orientale	1400-1600	9-10	2-3	Savane+ forêt sec
	Sud Bandundu	1100-1500	8-9	3-4	Savane+ forêt sec
	Kinshasa	1200 - 1500	7-8	4-5	Savane+ forêt sec
	Bas-congo	1200 - 1500	7-8	4-5	Savane+ forêt sec
	Katanga	1200 - 1500	6-9	3-6	Savane+ forêt sec
	Ouest Kivu	1200-1400	9	3	Savane +forêt
Zones	Est prov Orientale	1400	8-9	3-4	Savane +forêt sec
des montagnes	Nord Est Katanga	1200	6-7	5-6	Savane +forêt mon
	Est Kivu	1200-1900	9	3	Savane +forêt mon

2.1.2 Terrain suitability

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

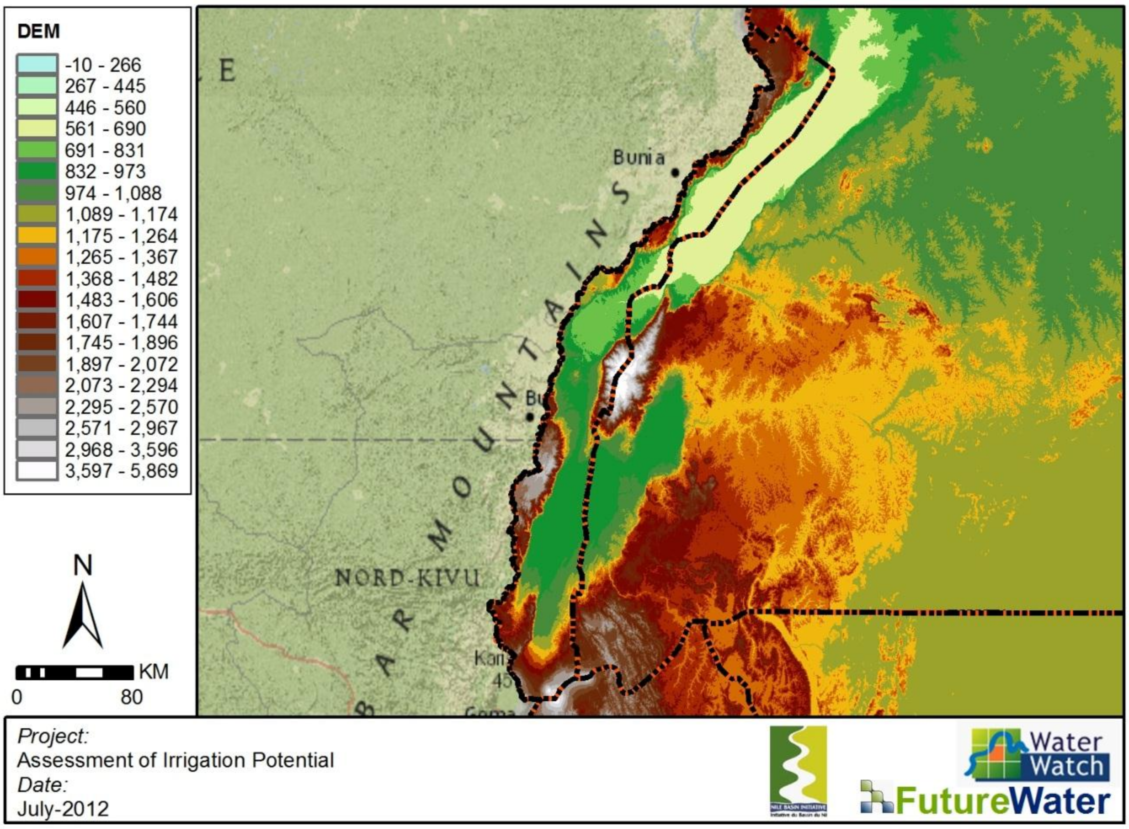
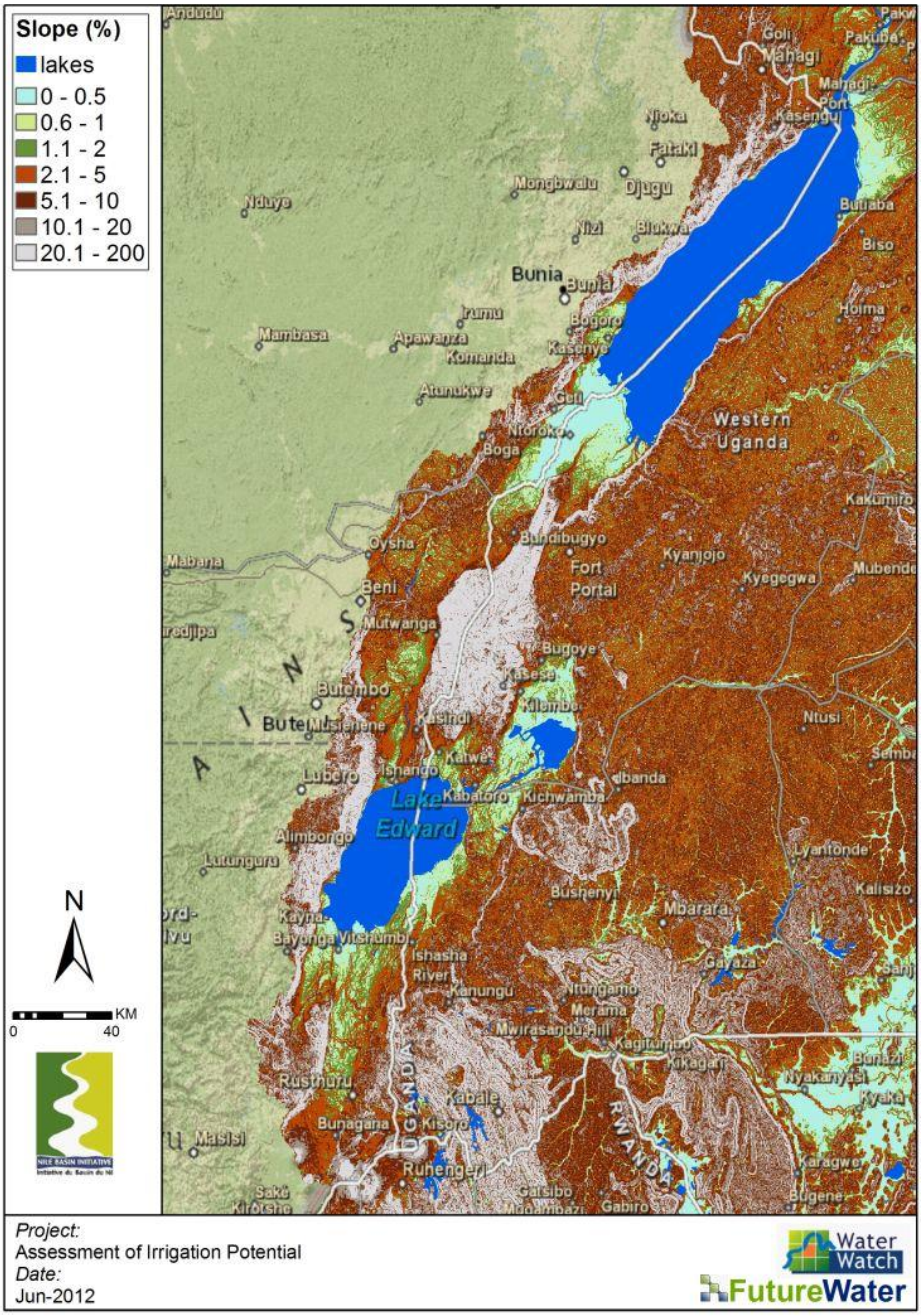
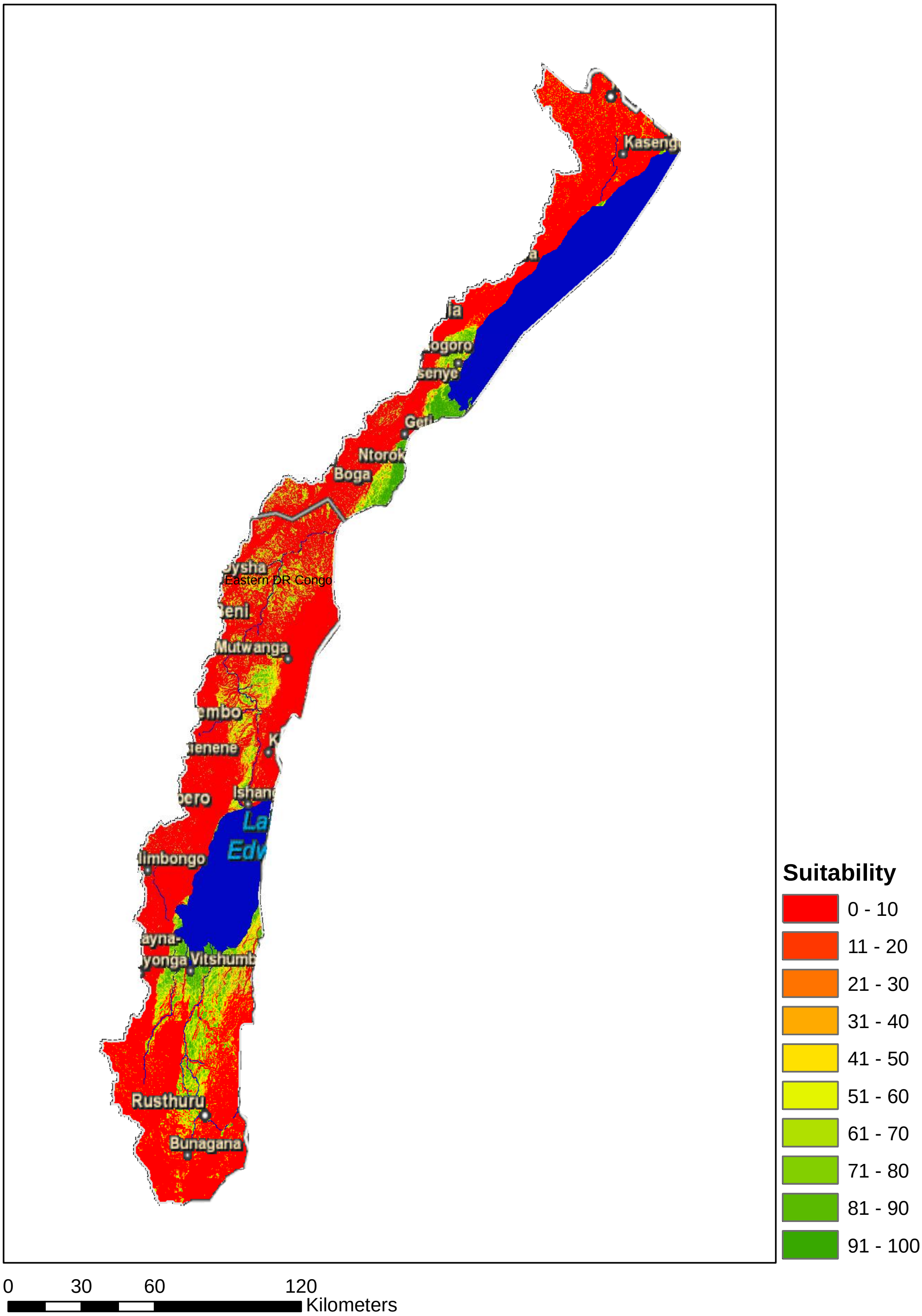


Figure 2: Digital Elevation Model of Eastern DRC.

In the previous figure the DEM for Eastern DRC is shown. The region is characterized by quite some mountains throughout the country with lowland areas along the big lakes. Associated slopes can be seen as well. Based on these slope classes for each of the three irrigation types, suitability for irrigation has been determined. It is clear that suitability for surface irrigation is somewhat restricted to the lower areas along the big lakes.



Slope (%)
lakes
0 - 0.5
0.6 - 1
1.1 - 2
2.1 - 5
5.1 - 10
10.1 - 20
20.1 - 200
N
KM
0
40
Lake Edward
Western Uganda
Bunia
Fort Portal
Mbarara
Kabale
Kisoro
Ruhengeri
Beni
Butembo
Mahagi
Hoima
Bundibugyo
Kyenjojo
Kyegegwa
Mubende
Bushenyi
Ntungamo
Rutshuru
UGANDA
RWANDA
Project:
Assessment of Irrigation Potential
Date:
Jun-2012


Boga
Eastern DR Congo
Mutwanga
Rusthuru
Bunagana
Suitability
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
0 30 60 120
Kilometers

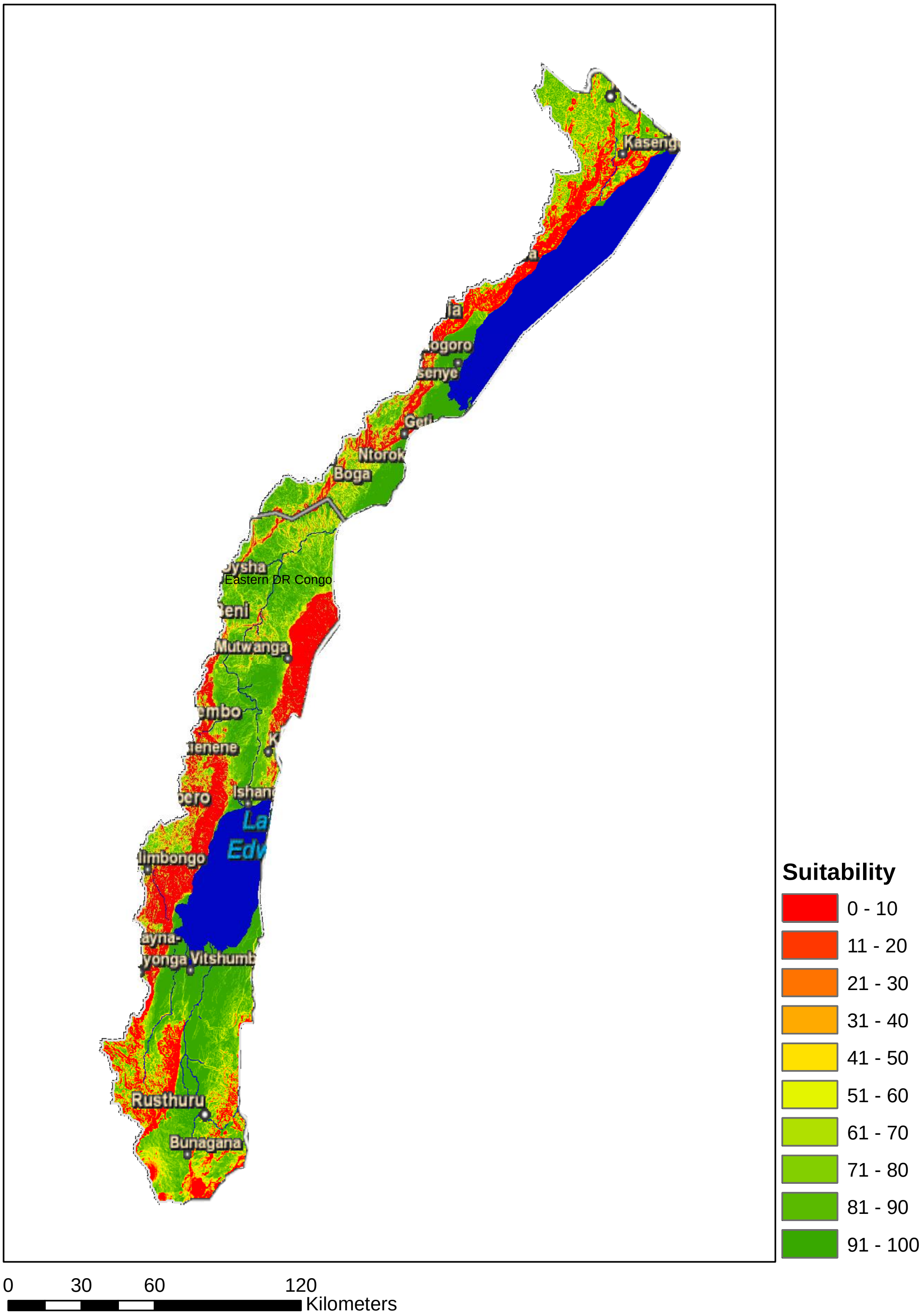
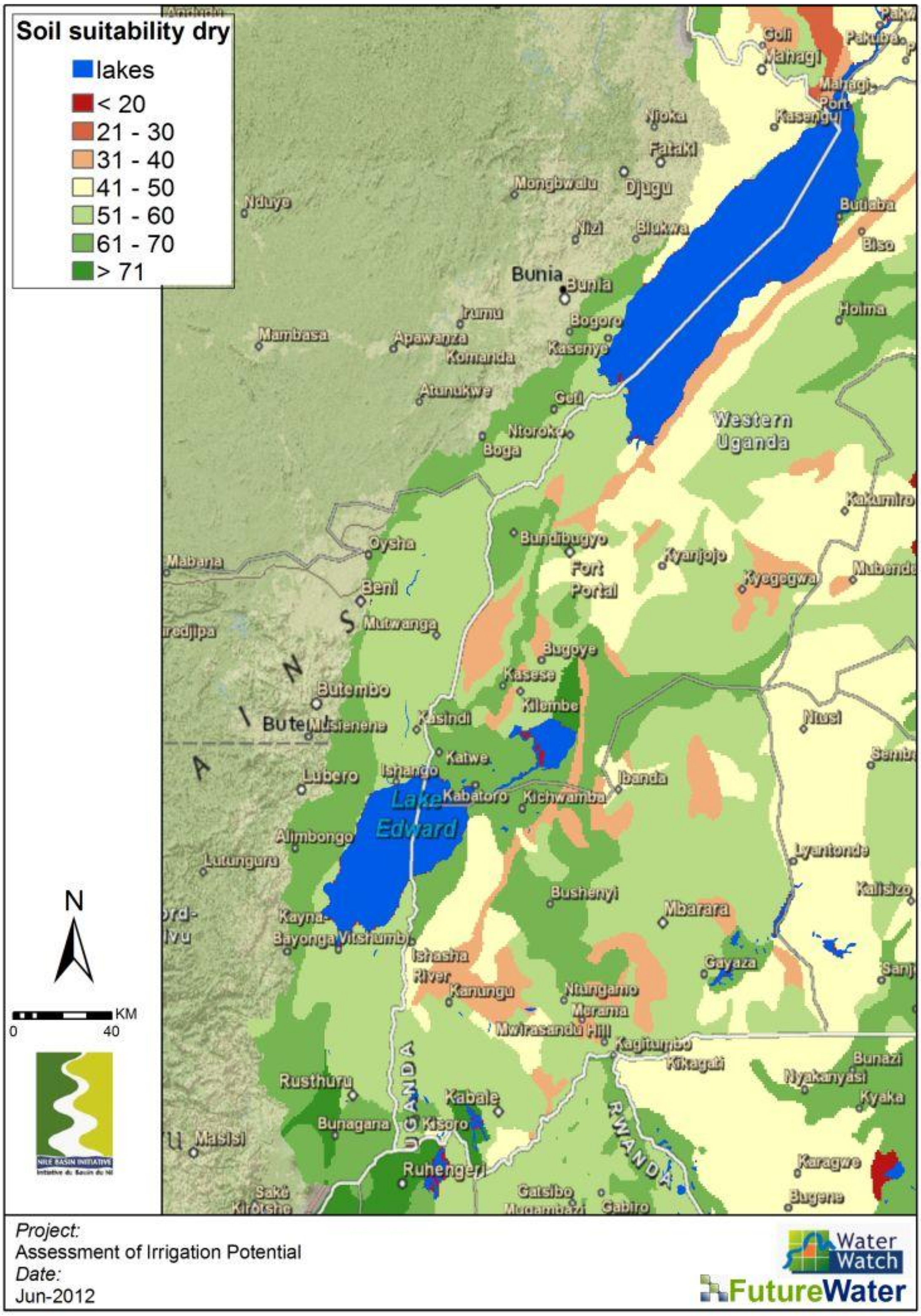


Figure 3: Terrain slope as percentage (top), surface irrigation (middle), and drip irrigation (bottom).

2.1.3 Soil suitability

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

It is clear that soils in Eastern DRC are by enlarge reasonable suitable to develop irrigation based on soil characteristics. Salinity problems are very rear in the country according to the soil map.


Soil suitability dry
lakes
< 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
> 71
N
KM
0
40
Lake Edward
Western Uganda
UGANDA
RWANDA
Bunia
Fort Portal
Beni
Butembo
Kasese
Mbarara
Kabale
Hoima
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

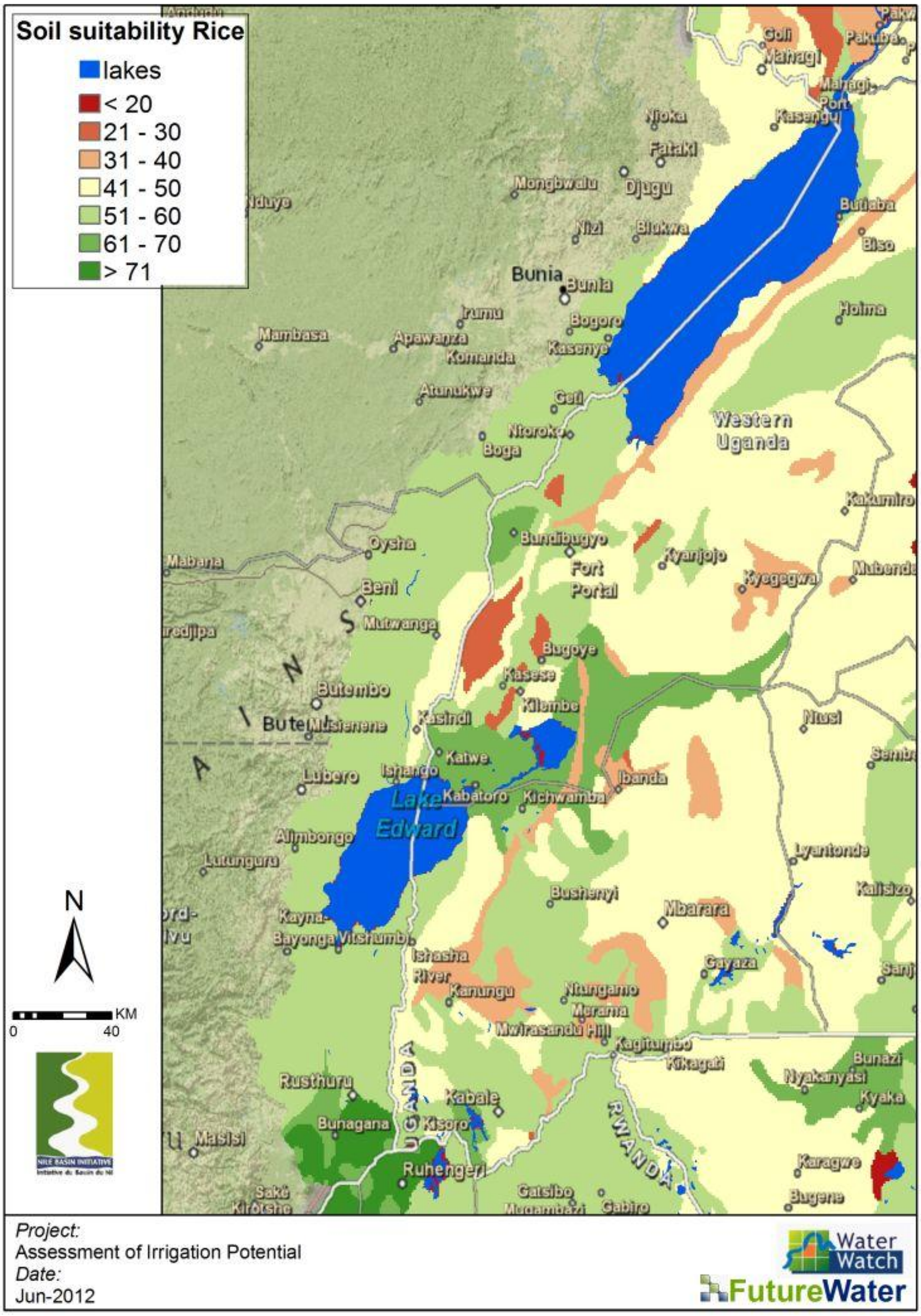


Figure 4: Soil suitability for arable crops (top) and rice/paddy (bottom)

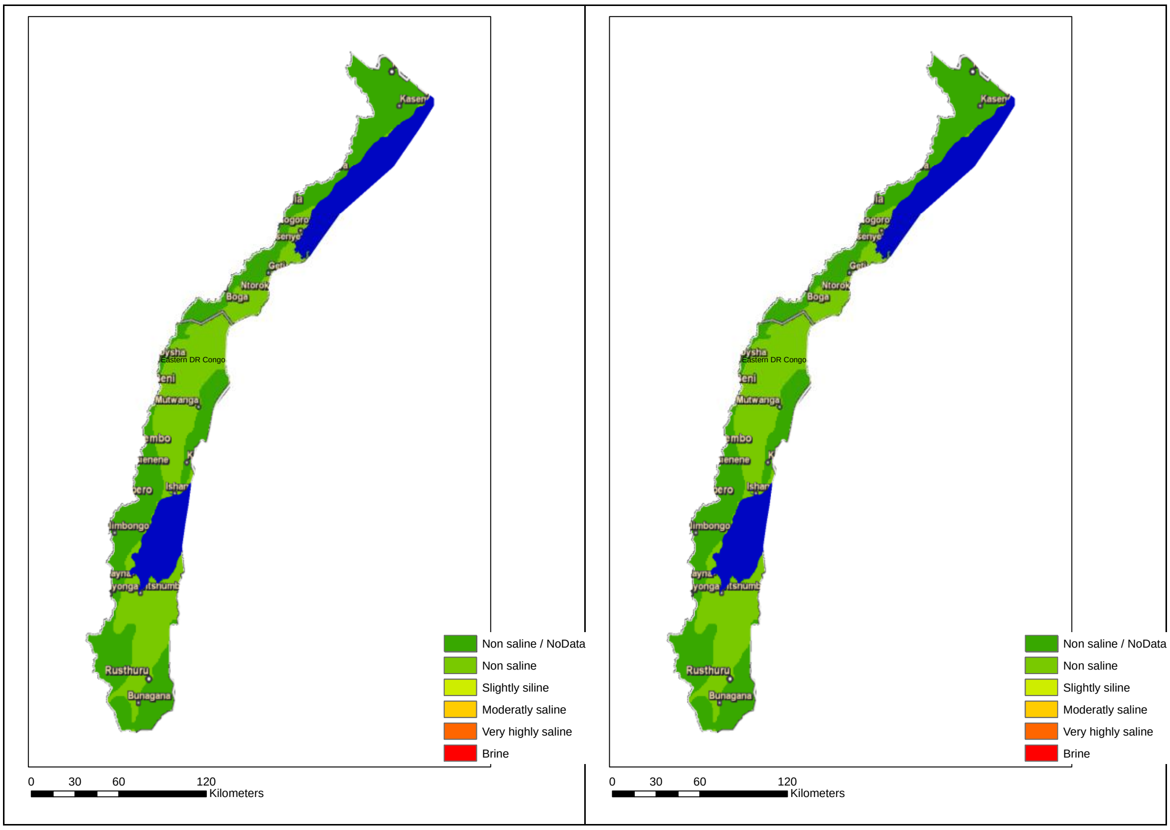


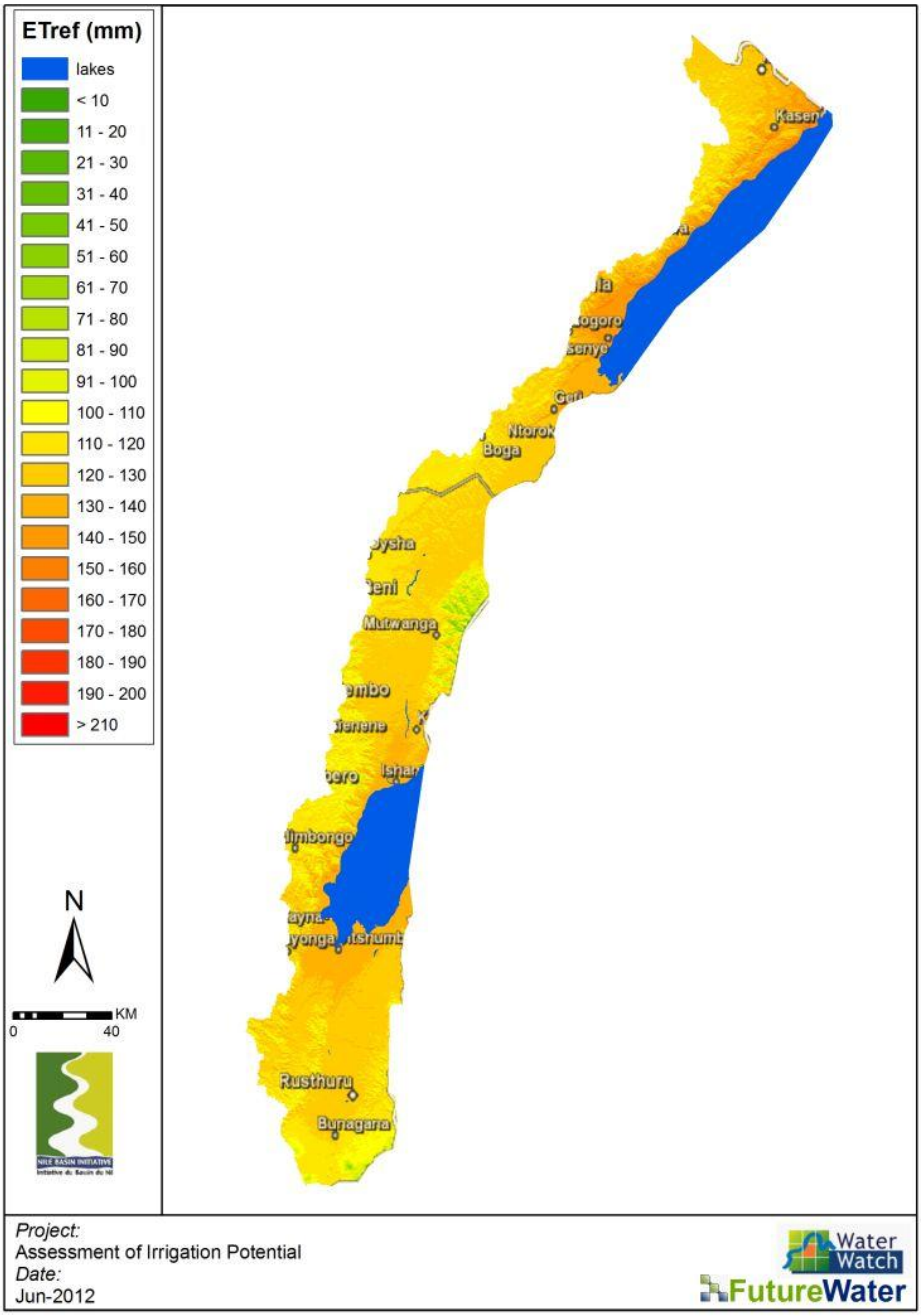
Figure 5: Salinity, top-soil (left) and sub-soil (right)

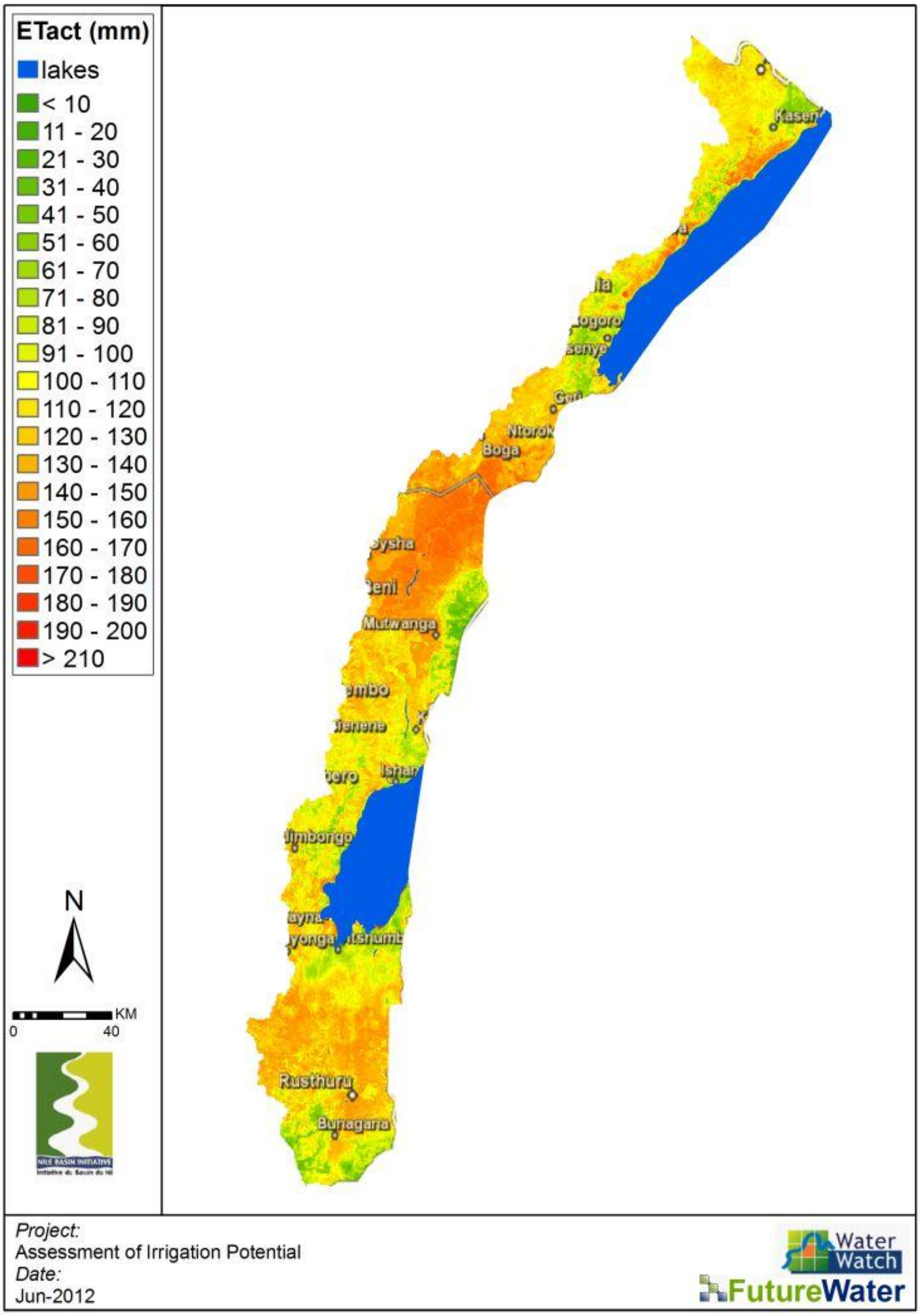
2.2 Water

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. During Phase 1 of this study the irrigation water requirements are based on an innovative method using satellite information (see main report for details). The following maps provide for each month the reference evapotranspiration (= evaporative demand of the atmosphere), the actual evapotranspiration under current conditions and the final irrigation water requirements.

January


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Boga
Mutwanga
Rusthuru
Bunagana
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

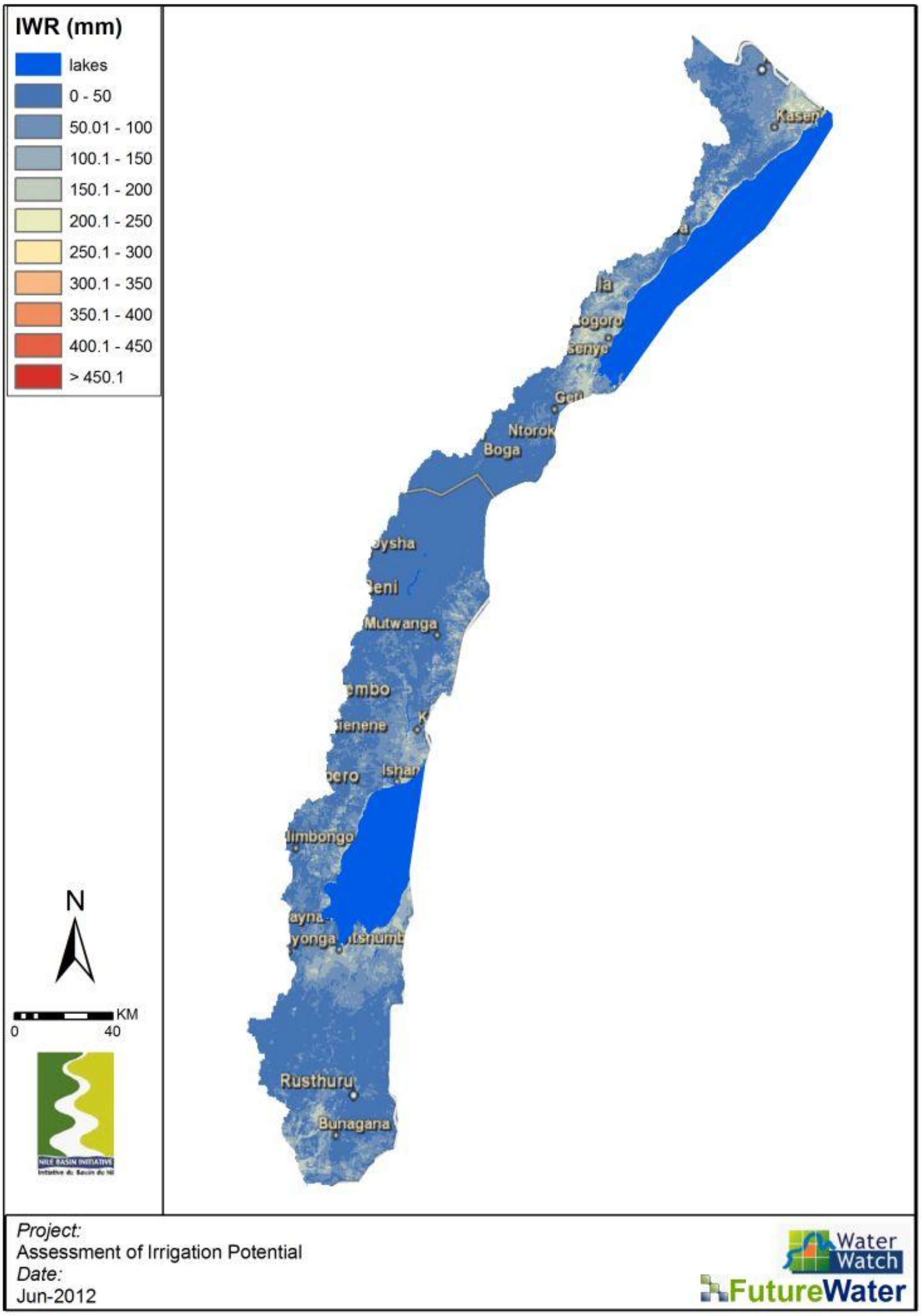
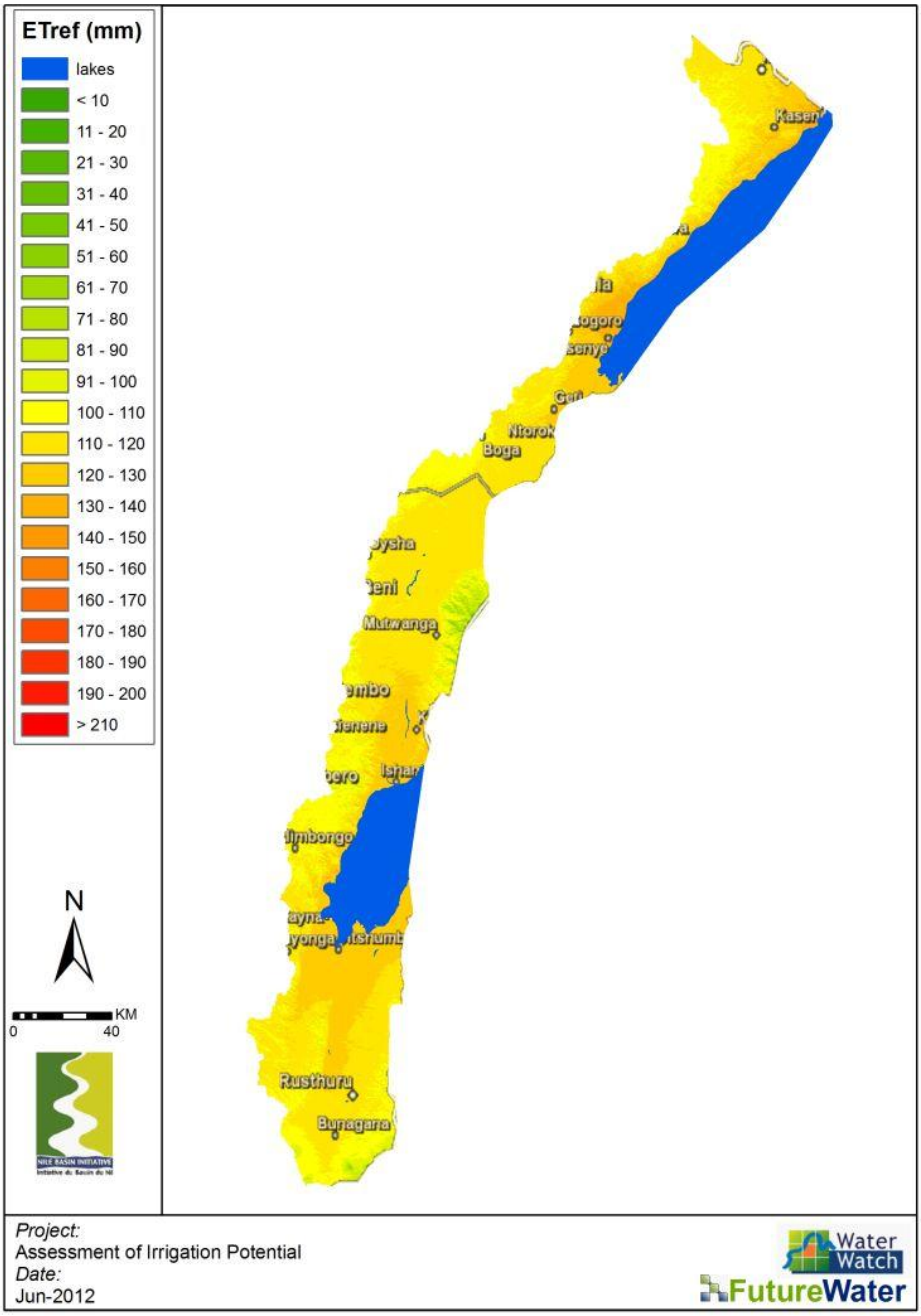
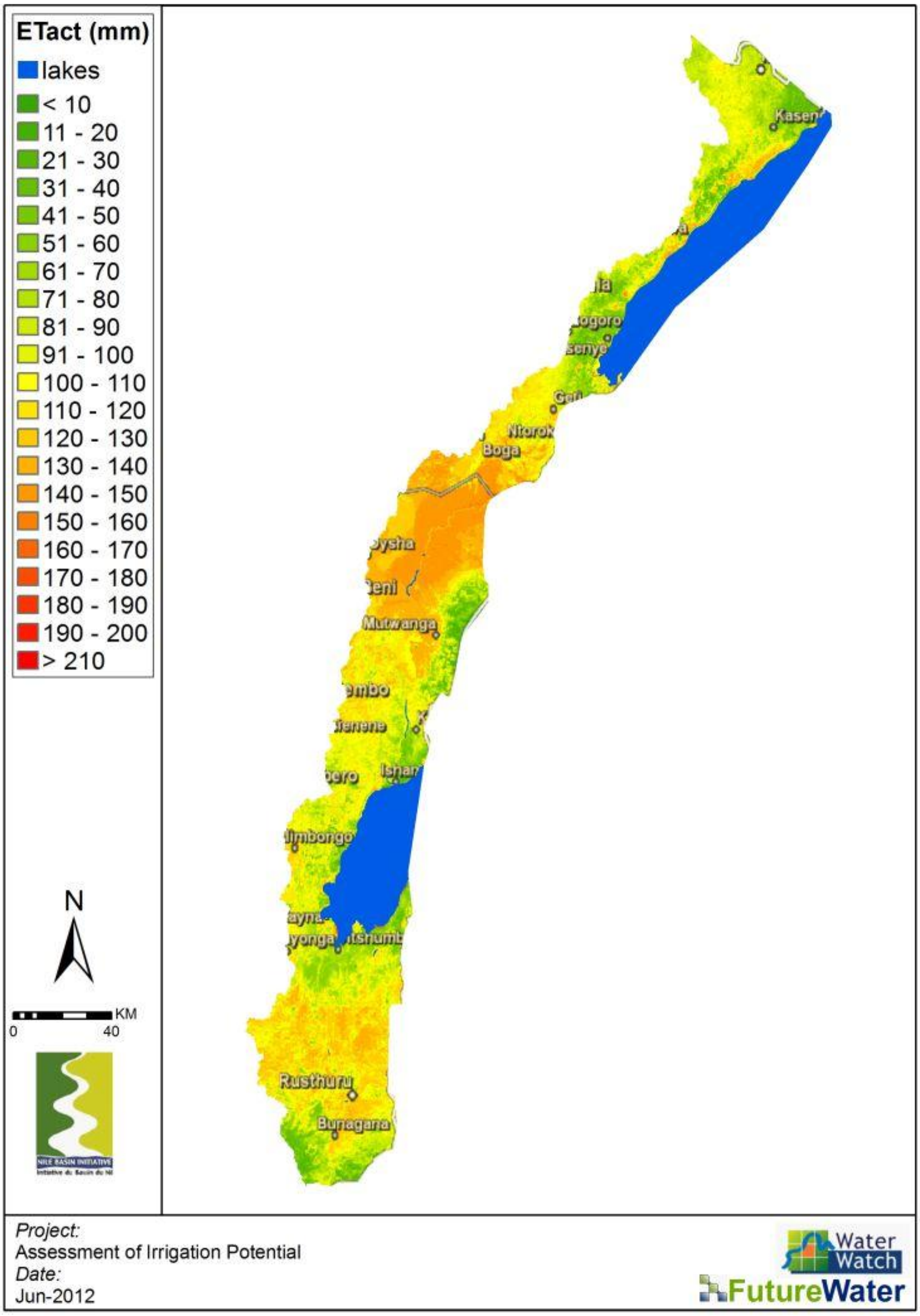


Figure 6: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

February


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Boga
Mutwanga
Rusthuru
Bunagana
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

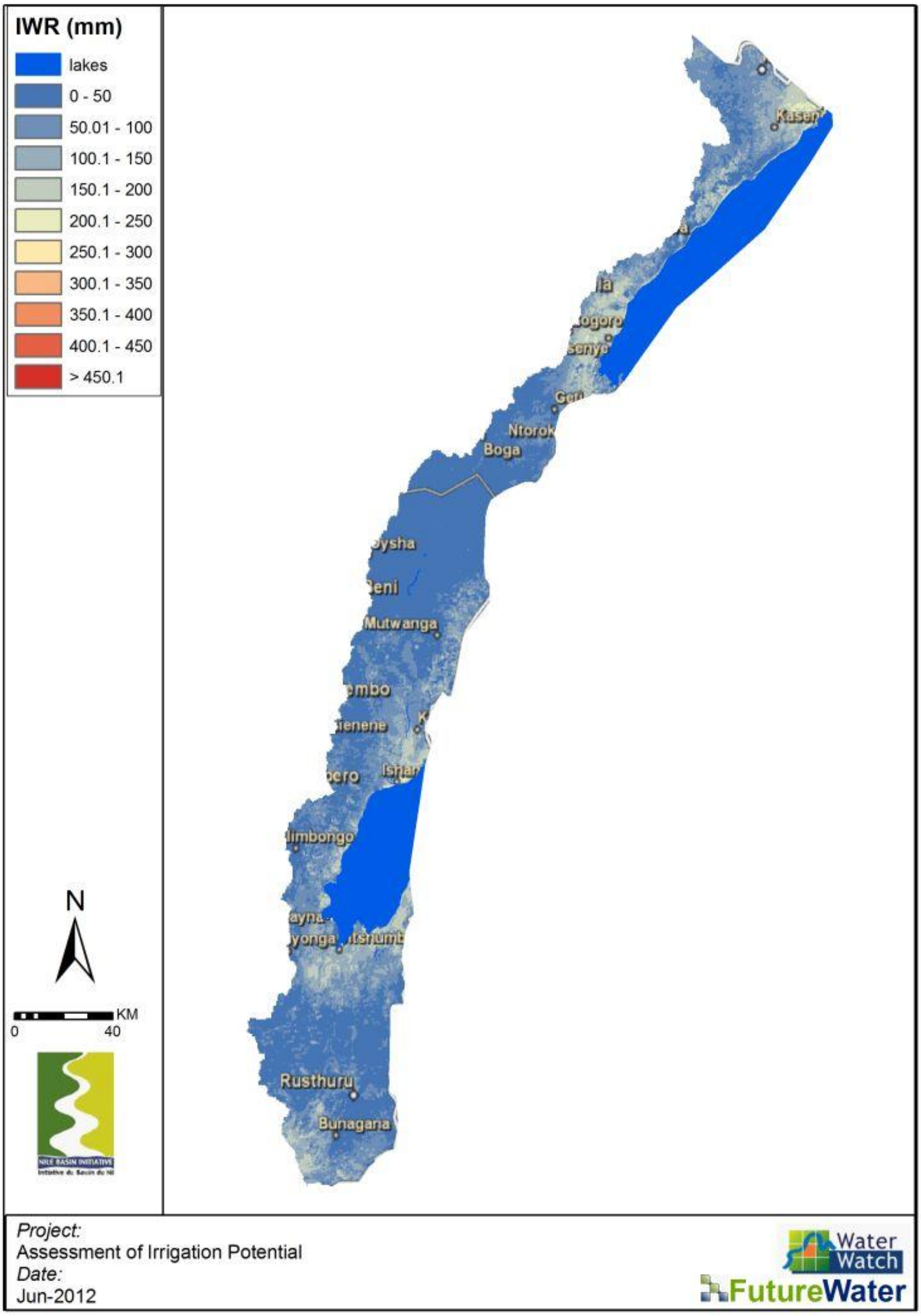
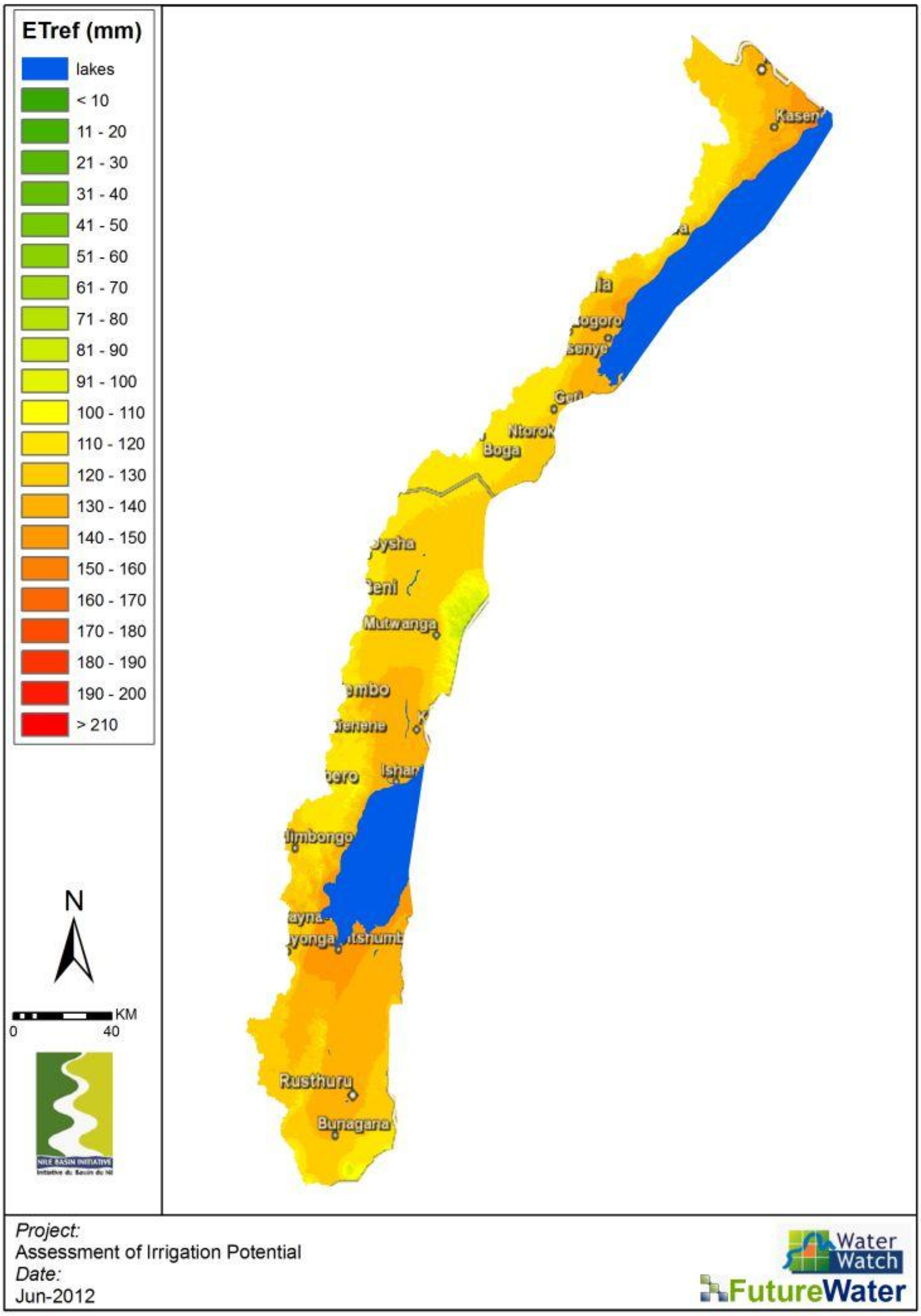
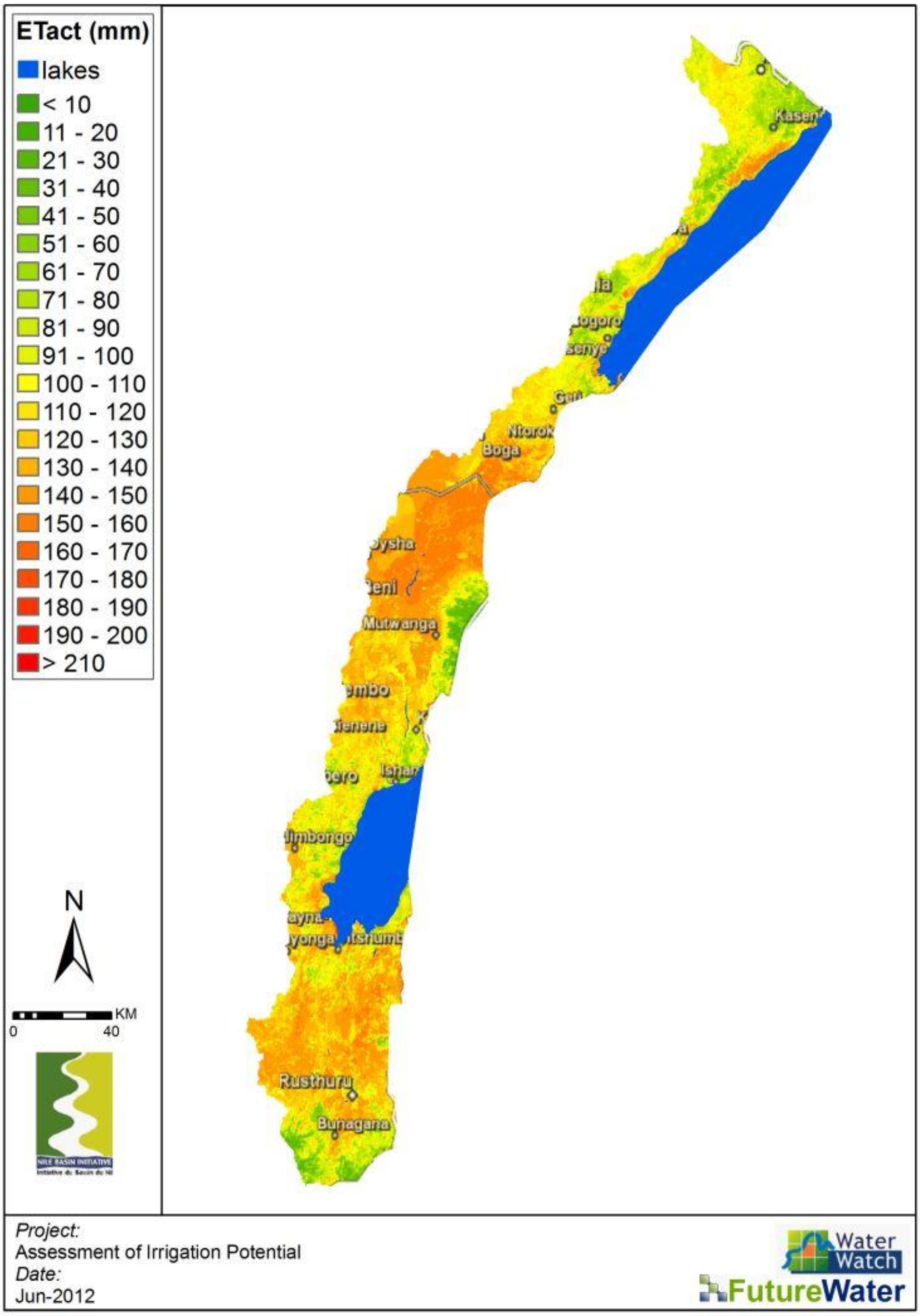


Figure 7: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

March



ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Mutwanga
Boga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012


ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

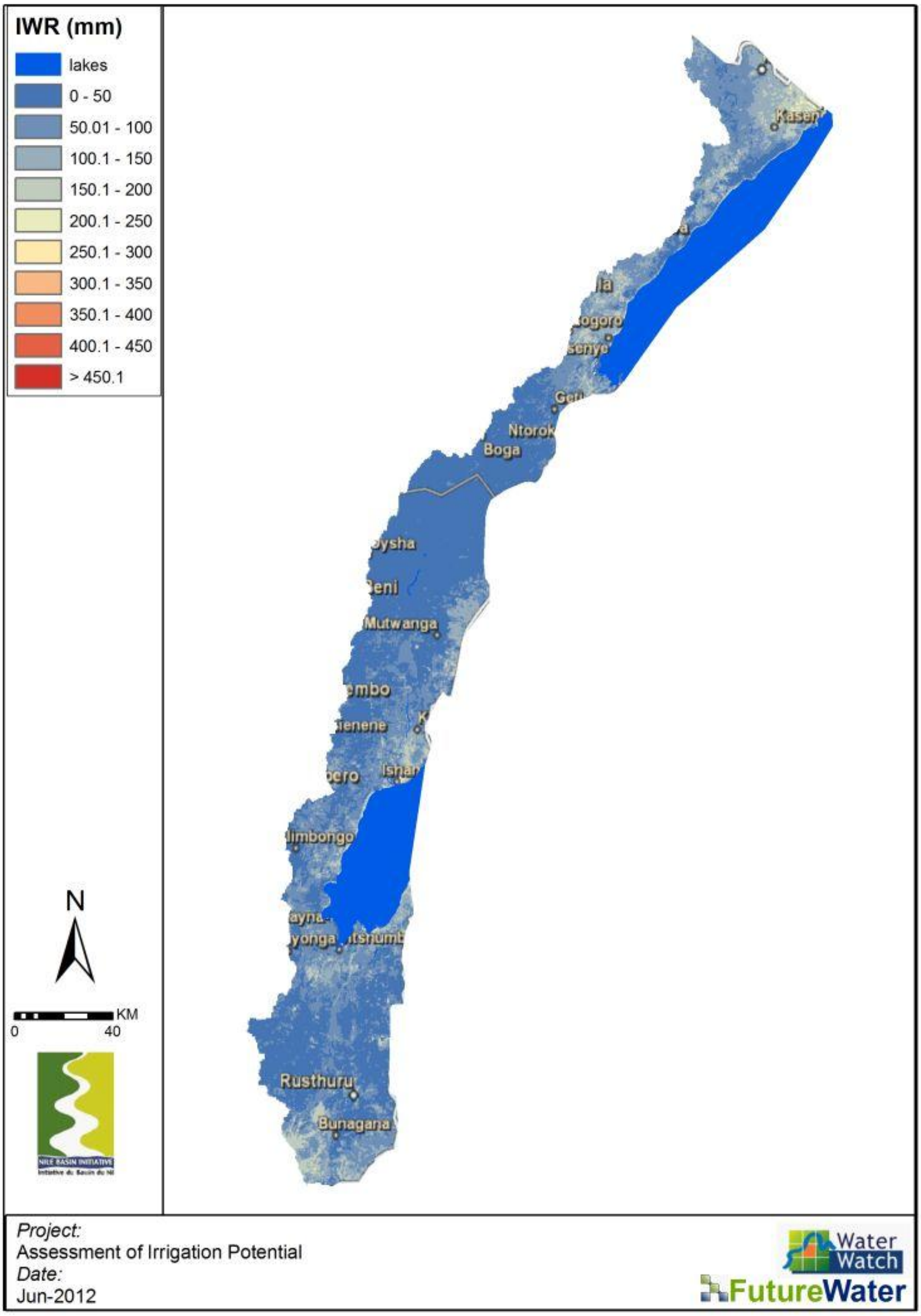
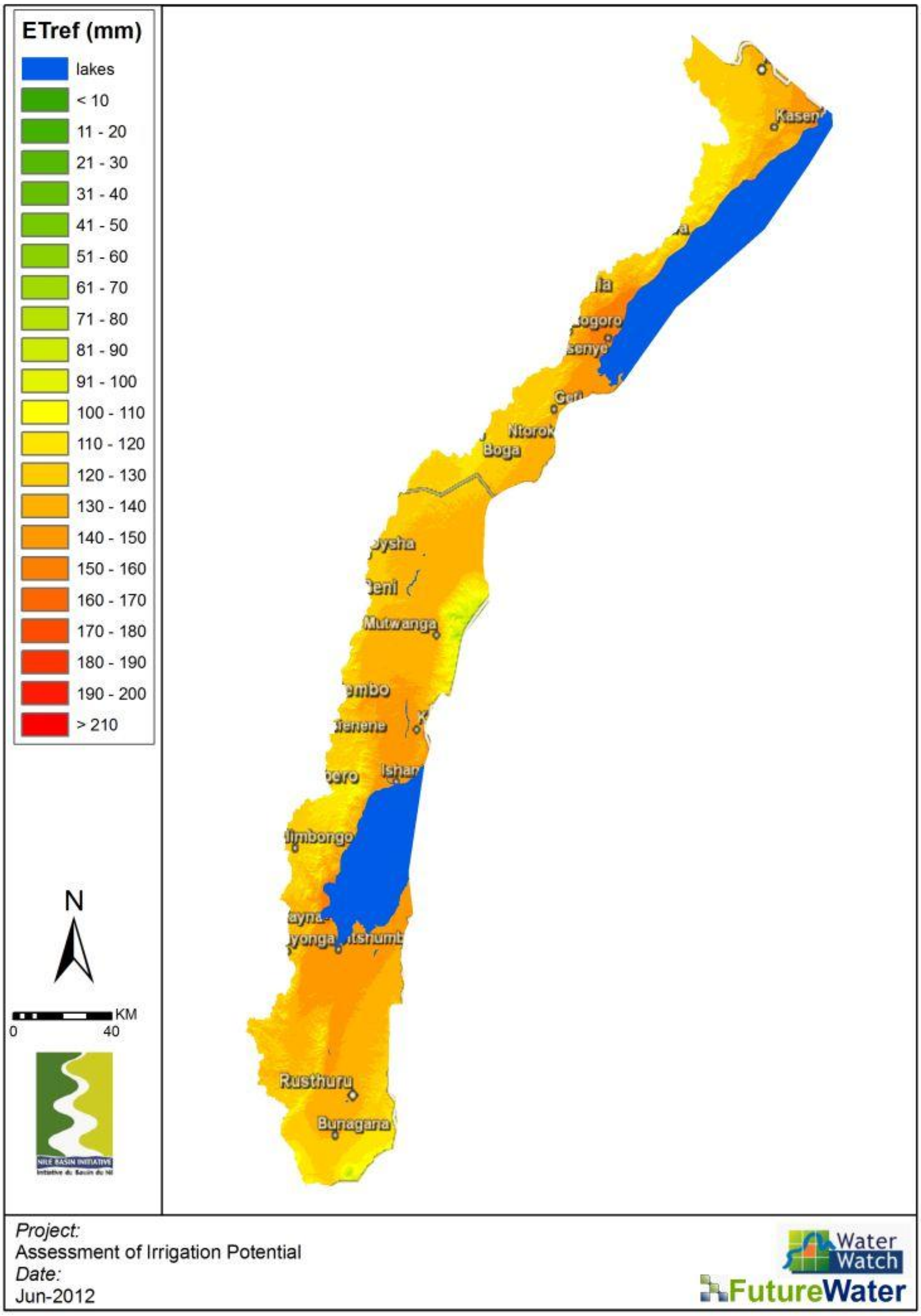
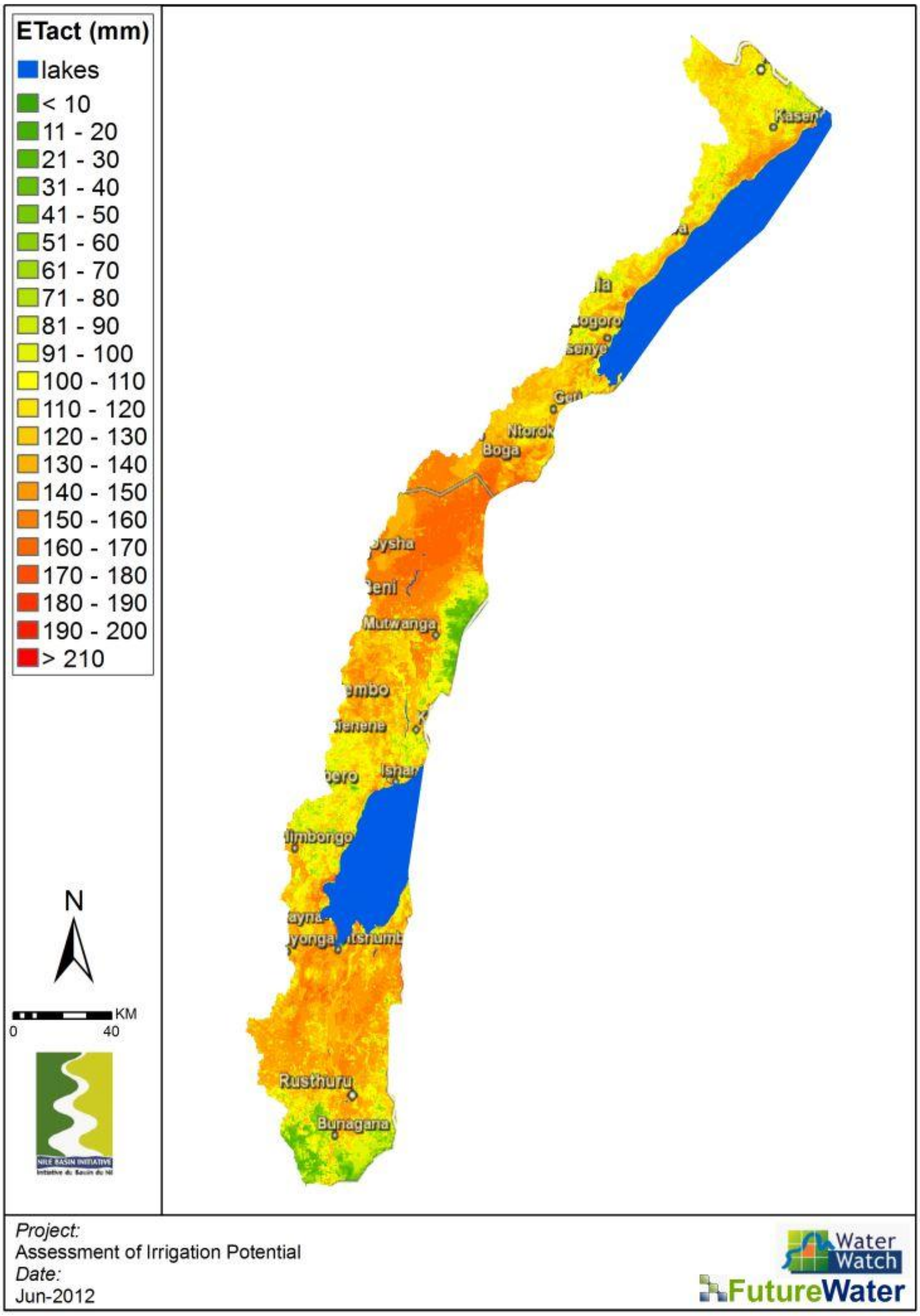


Figure 8: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

April


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Kasen
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

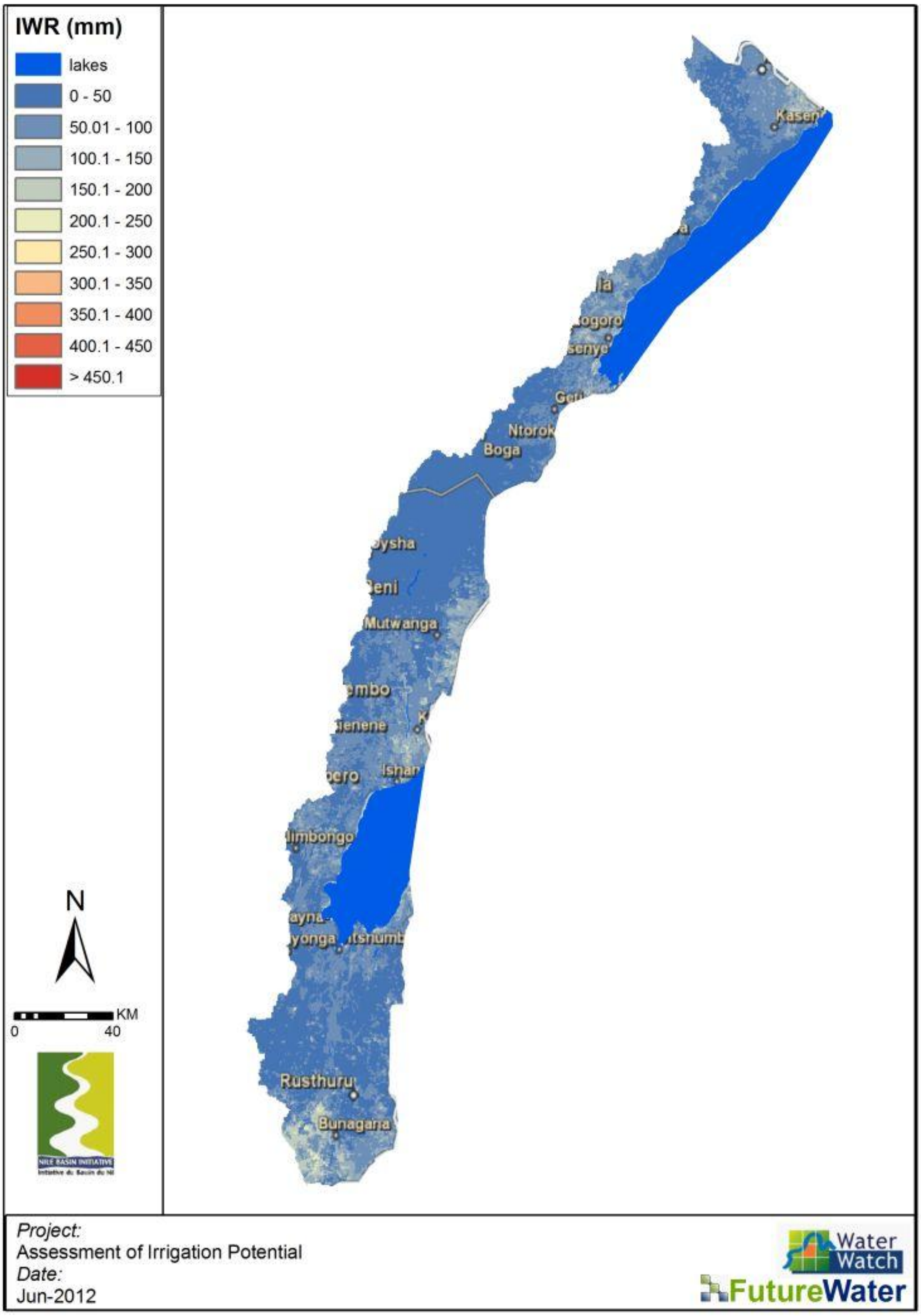
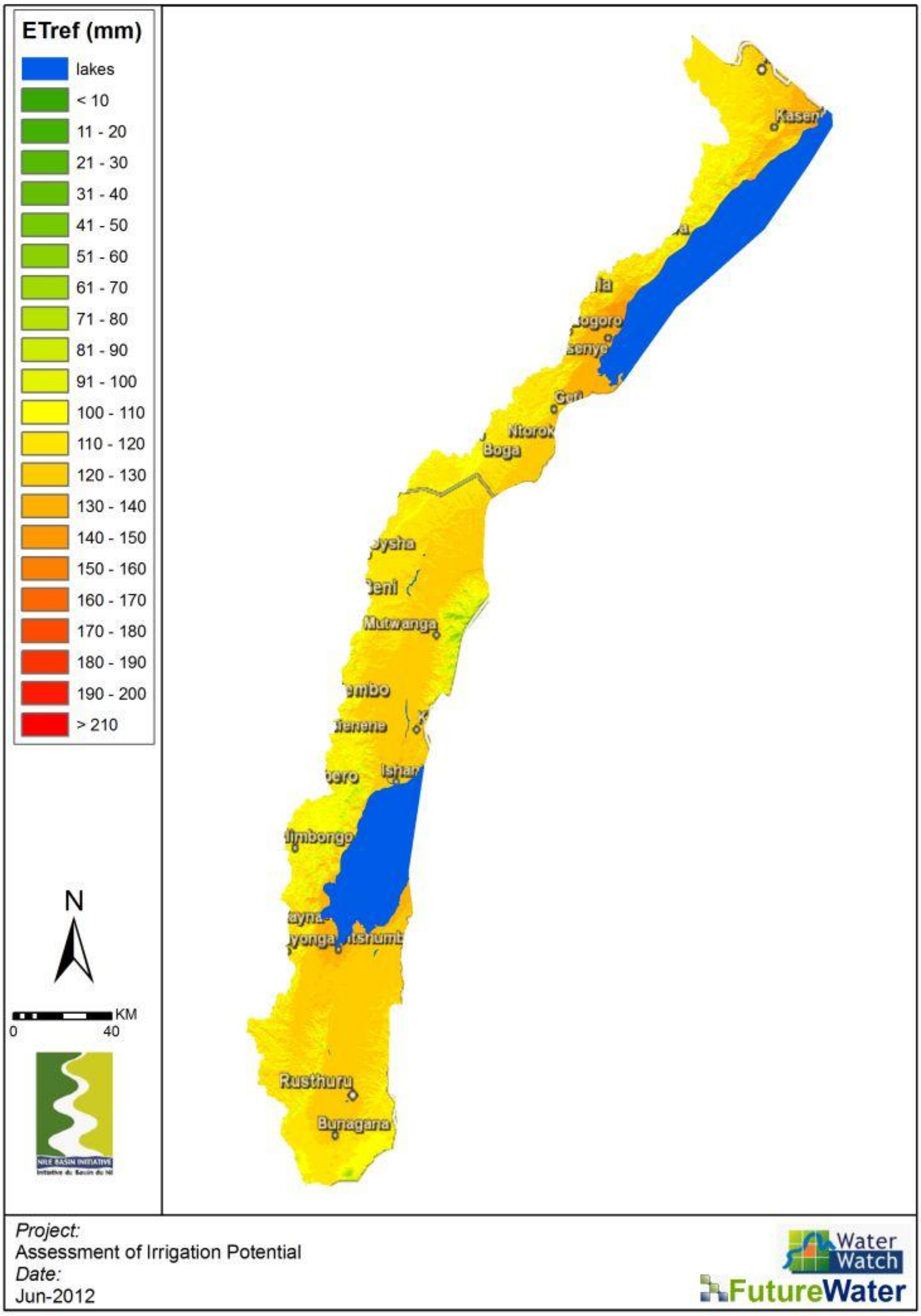
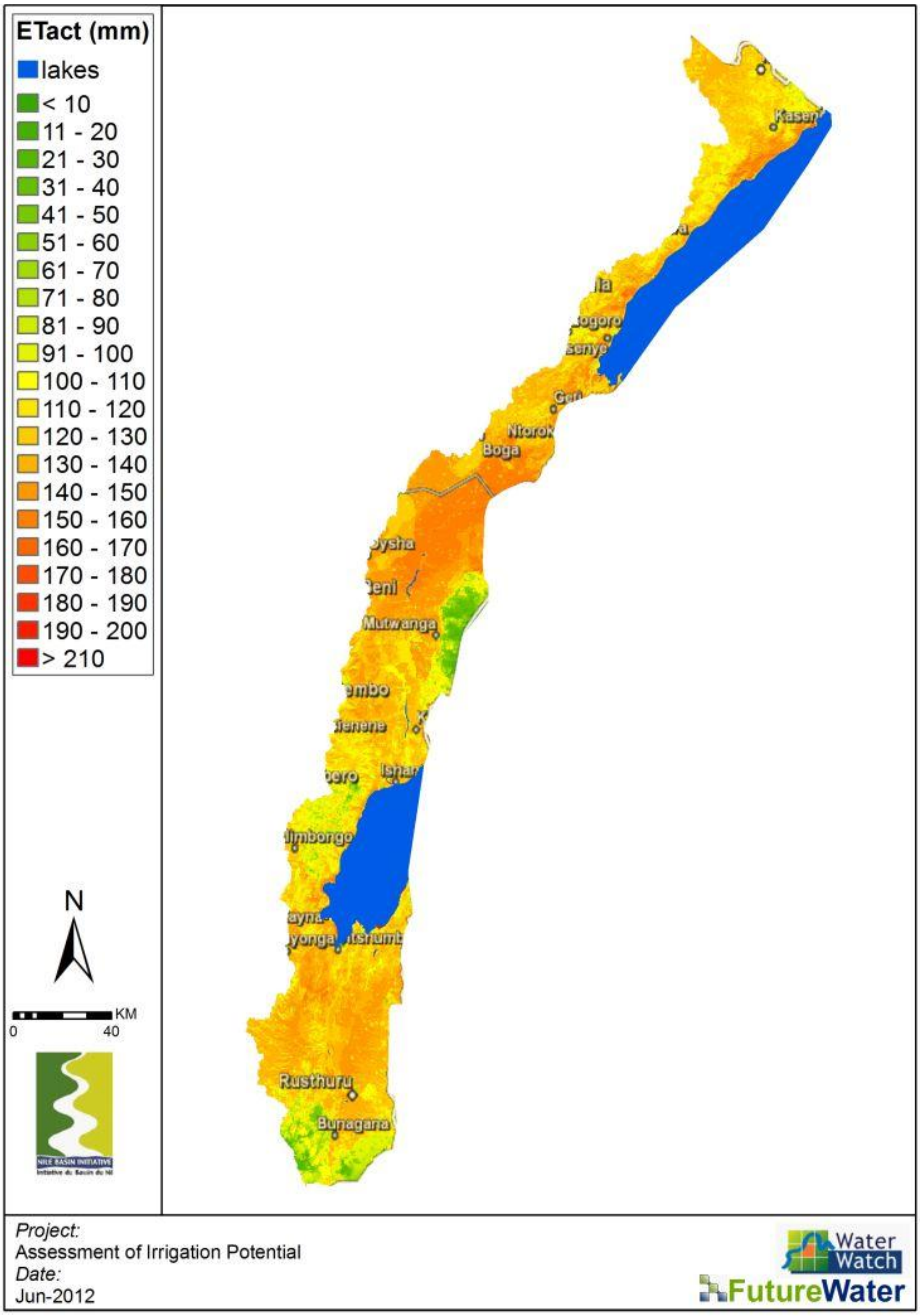


Figure 9: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

May



ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
Boga
Mutwanga
Rusthuru
Bunagana
N
KM
0
40
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

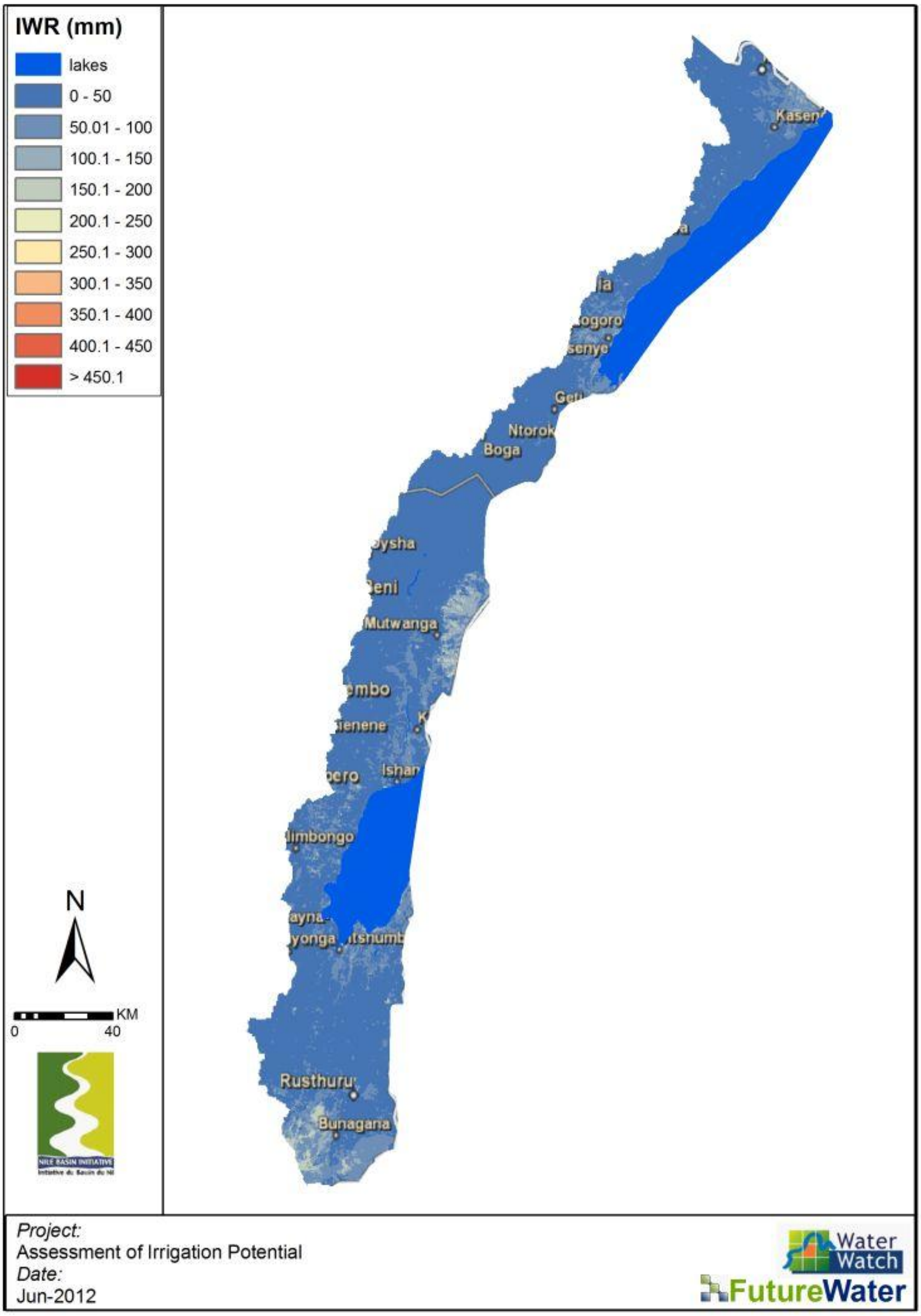
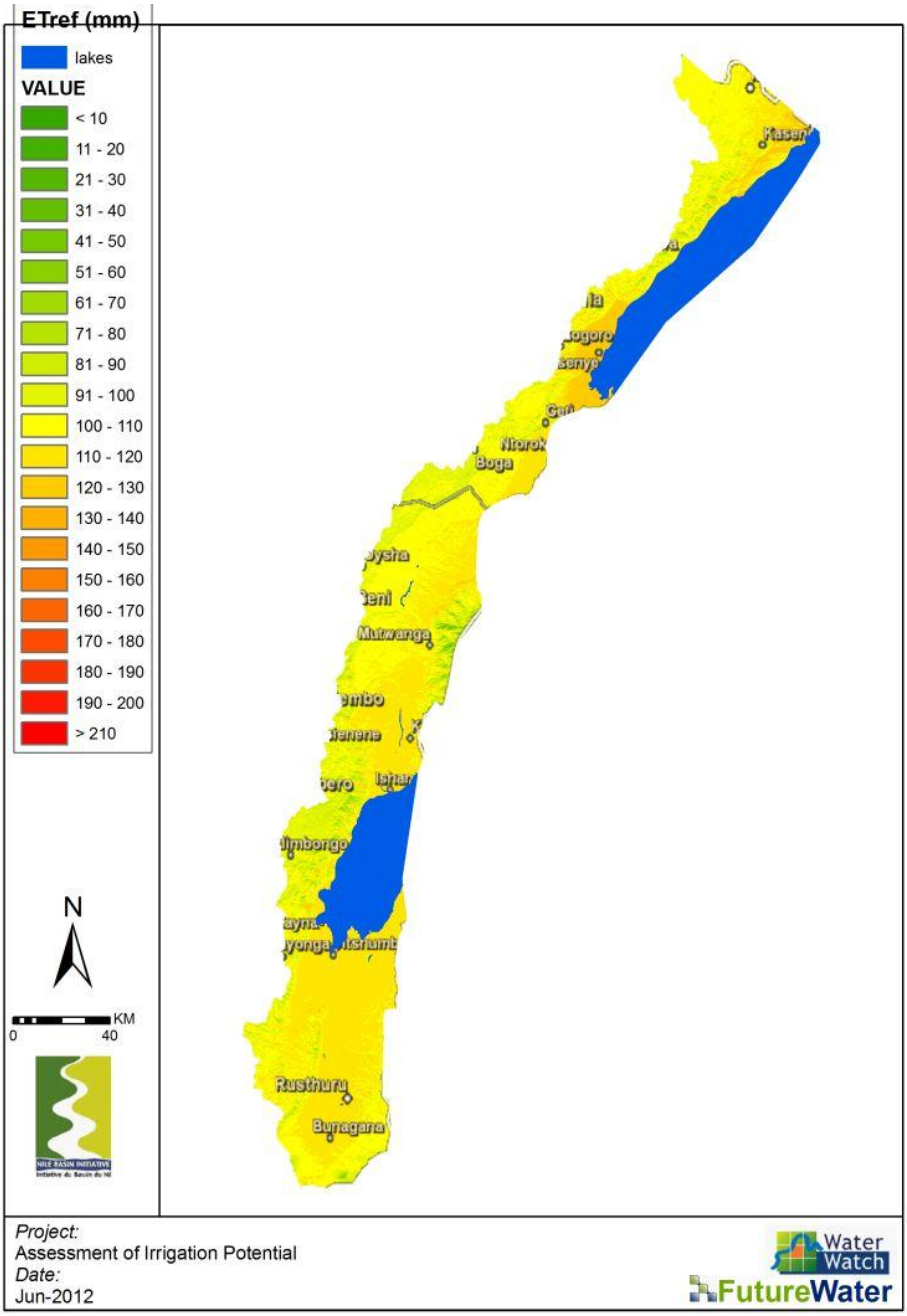
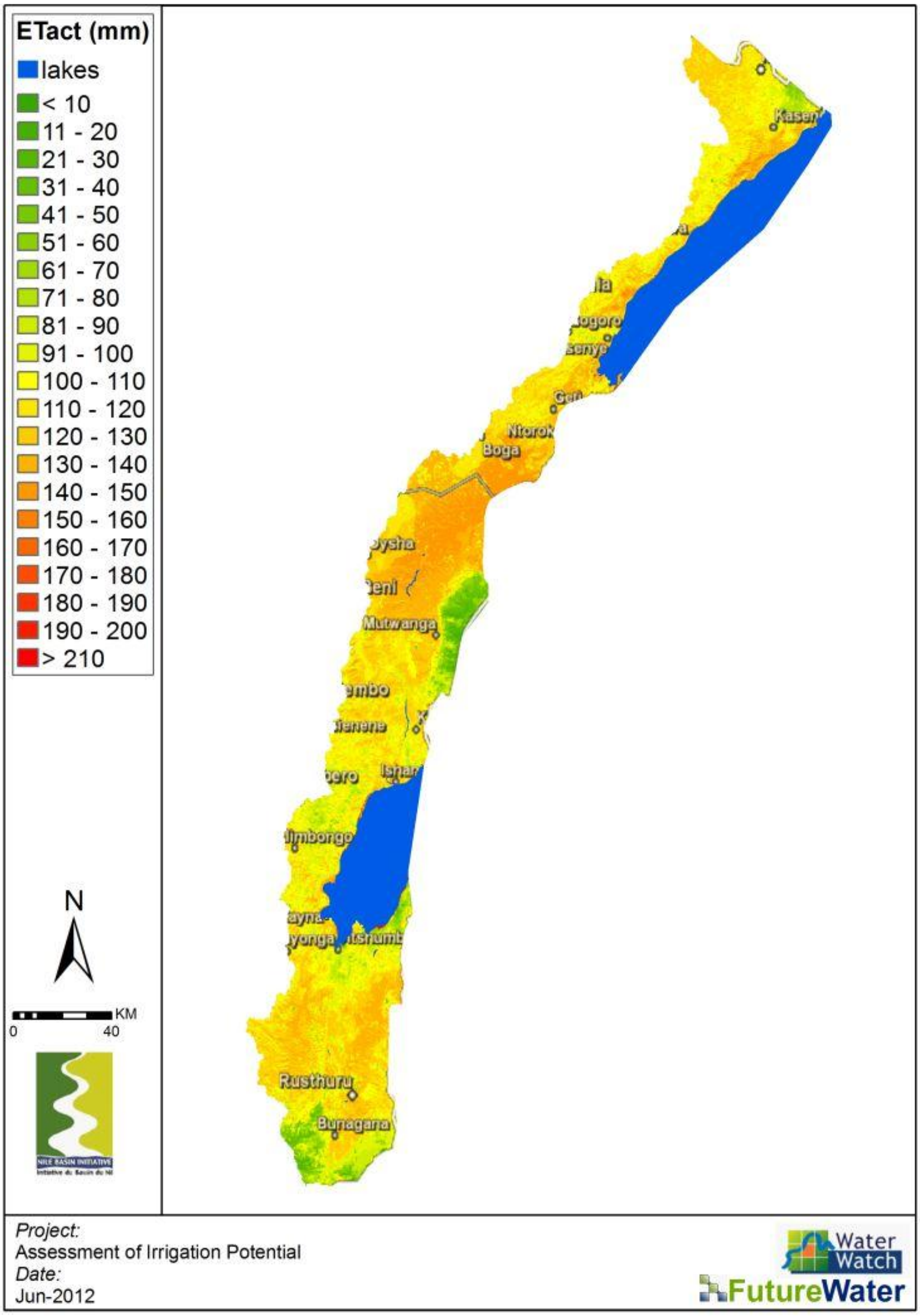


Figure 10: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

June


ETref (mm)
lakes
VALUE
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Boga
Mutwanga
Rusthuru
Bunagana
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

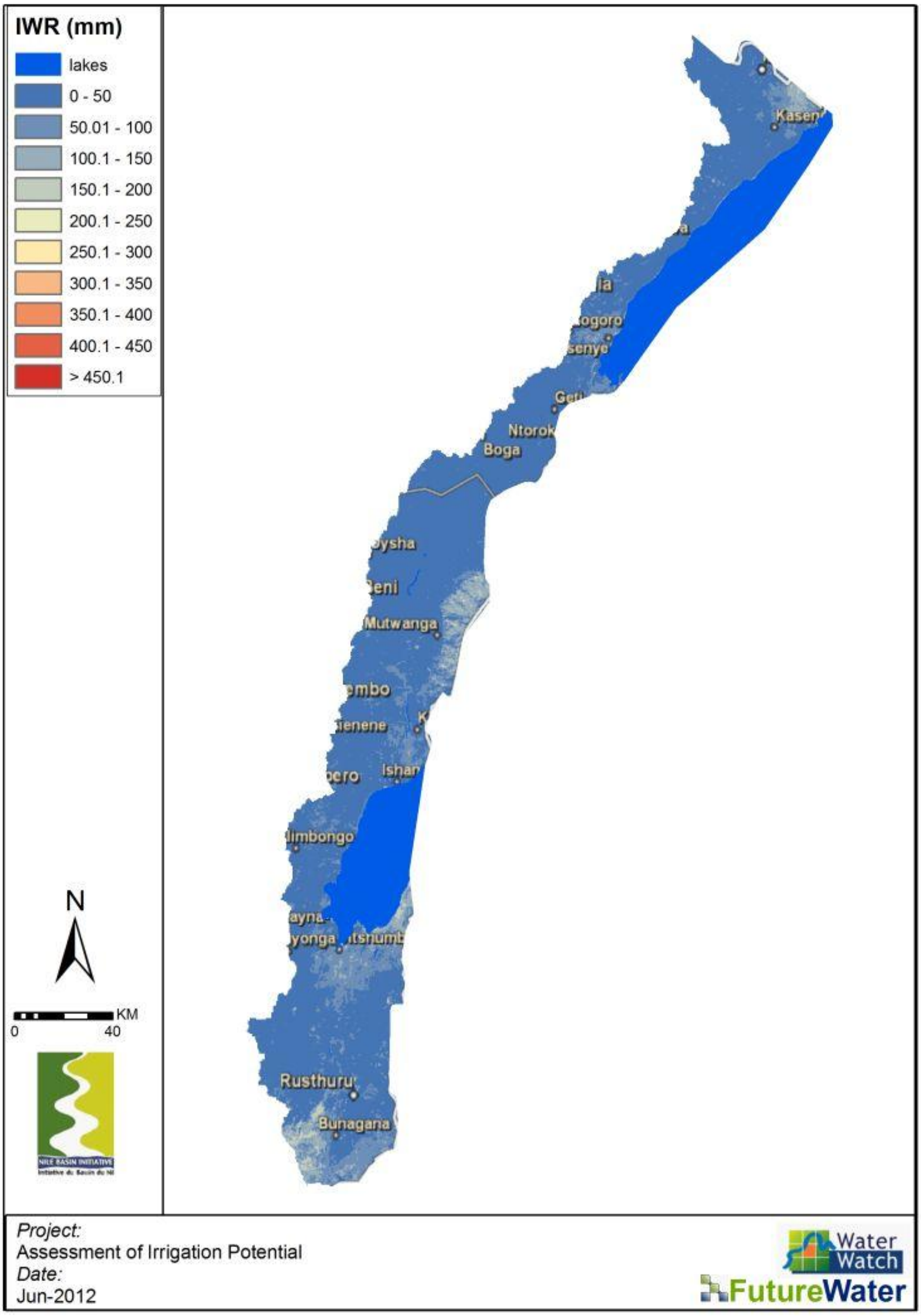
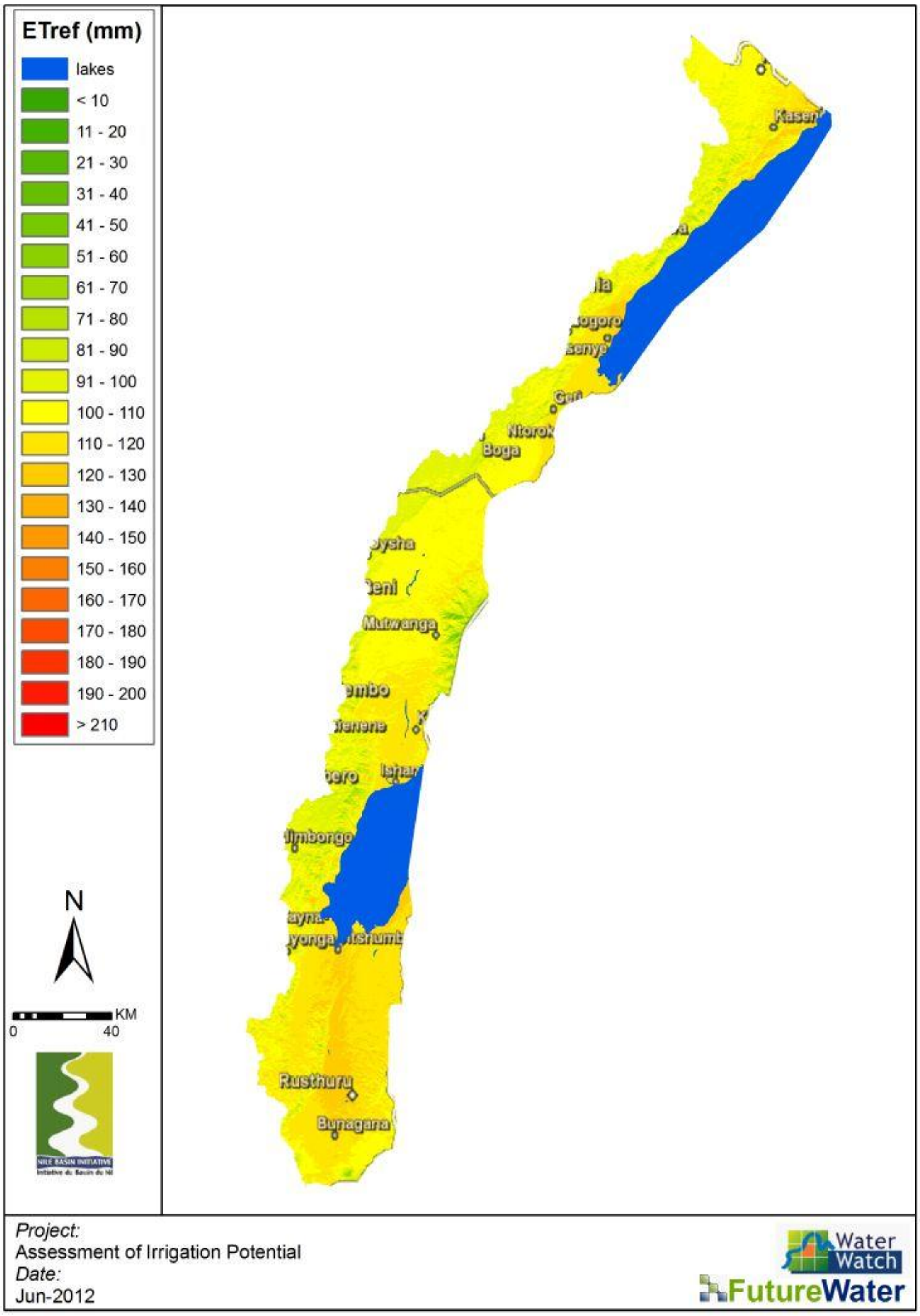
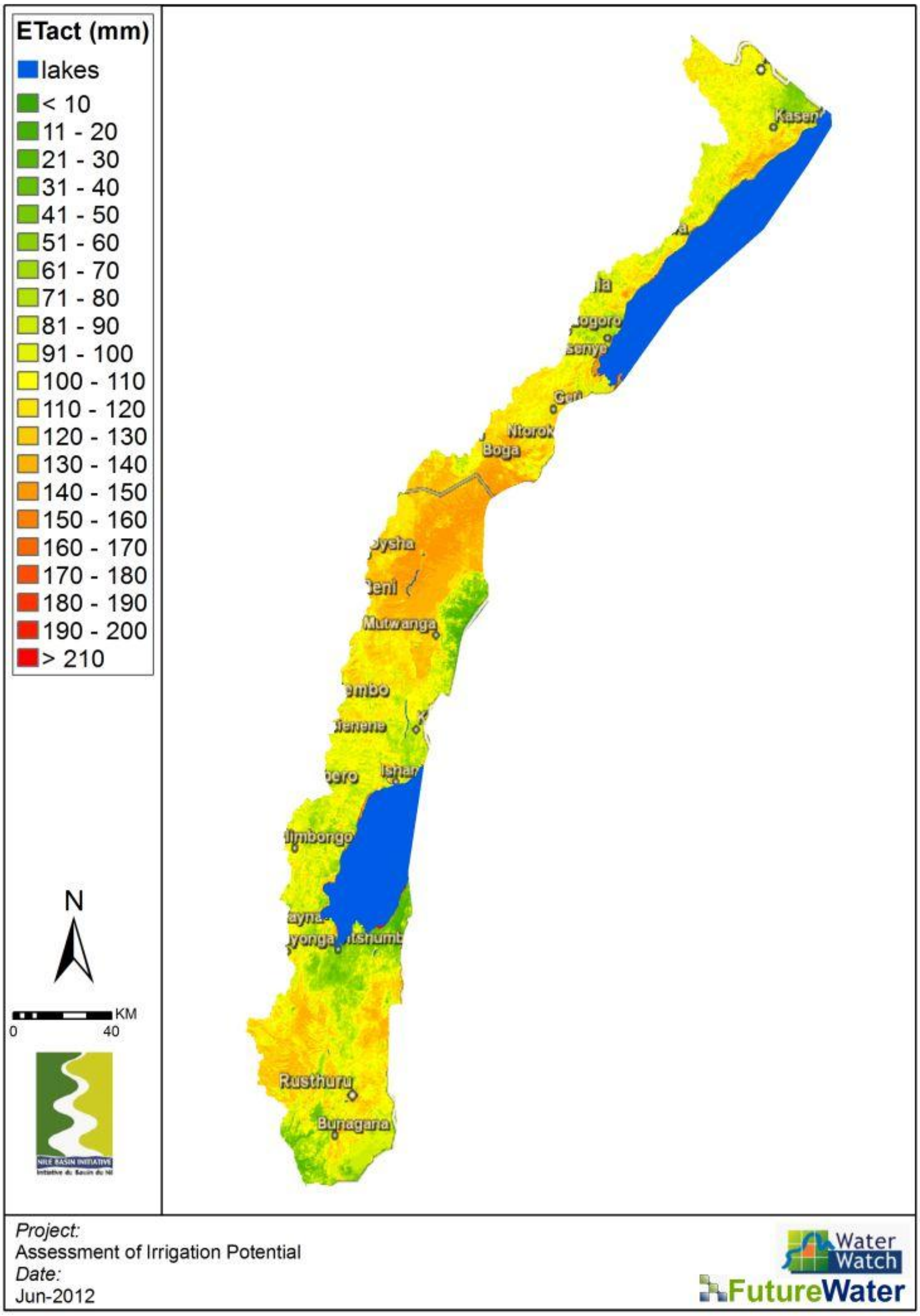


Figure 11: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

July


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
Boga
Mutwanga
Rusthuru
Bunagana
N
KM
0
40
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
N
KM
0
40
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

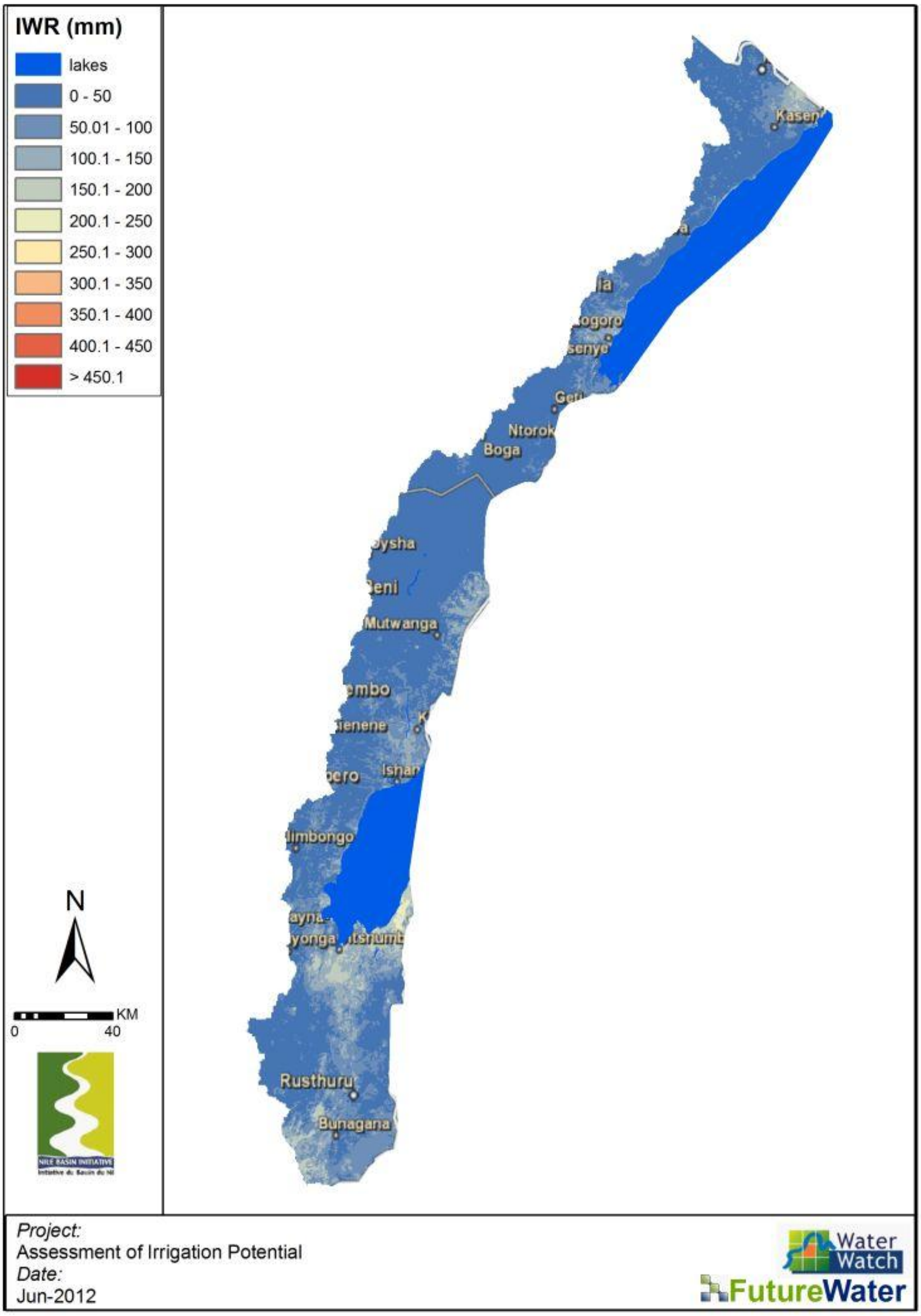
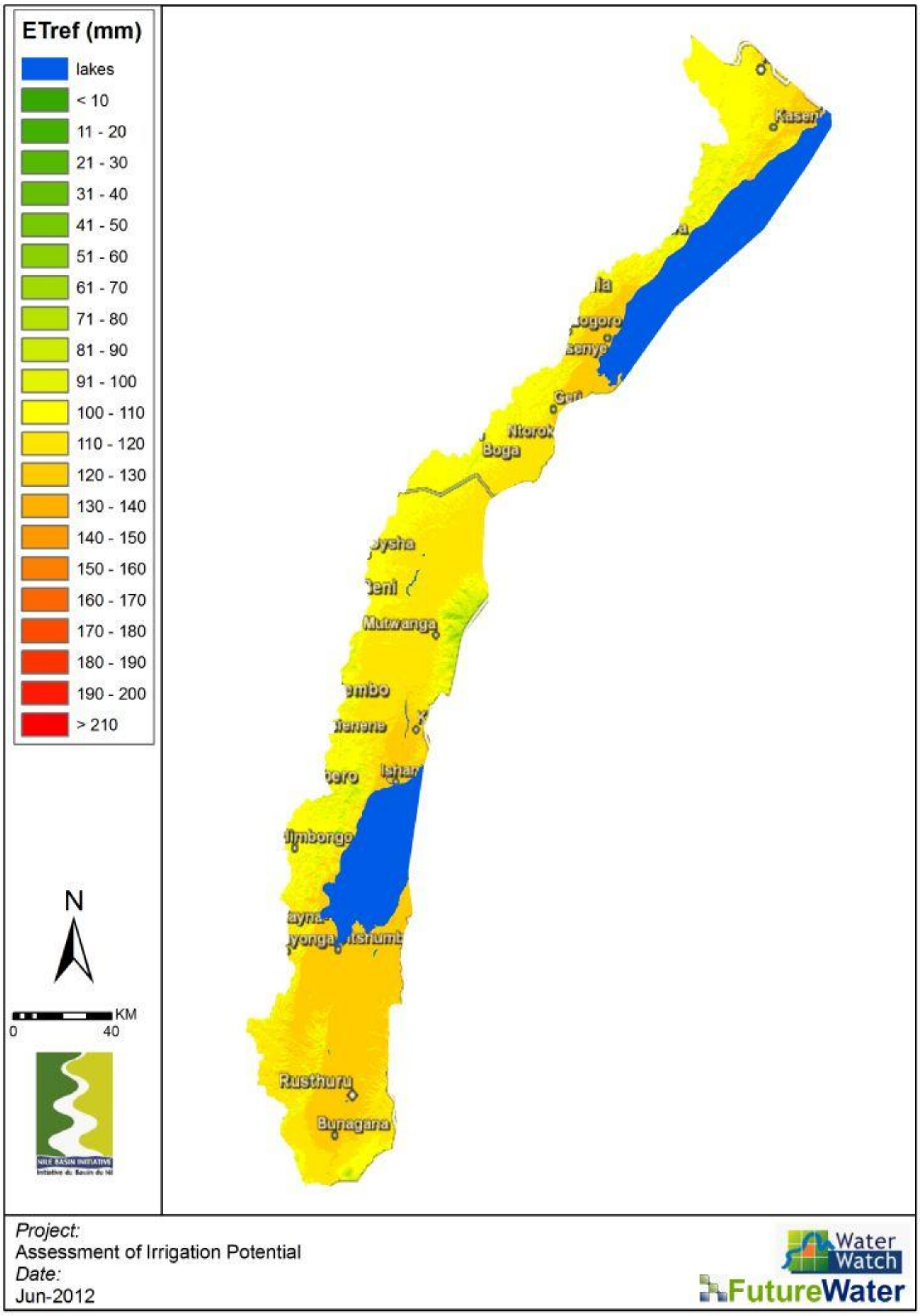
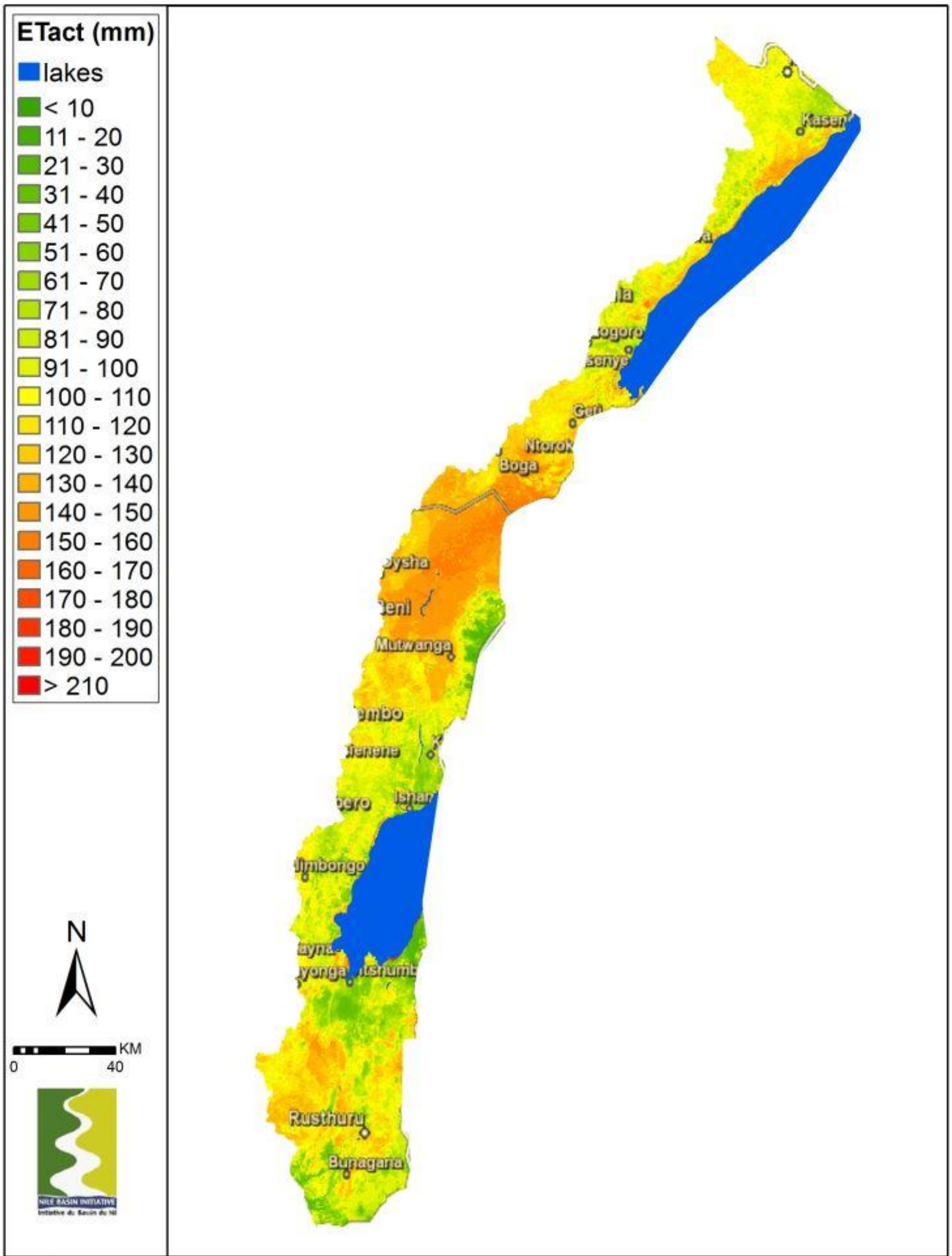


Figure 12: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

August


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater



Project:
Assessment of Irrigation Potential
Date:
Jun-2012

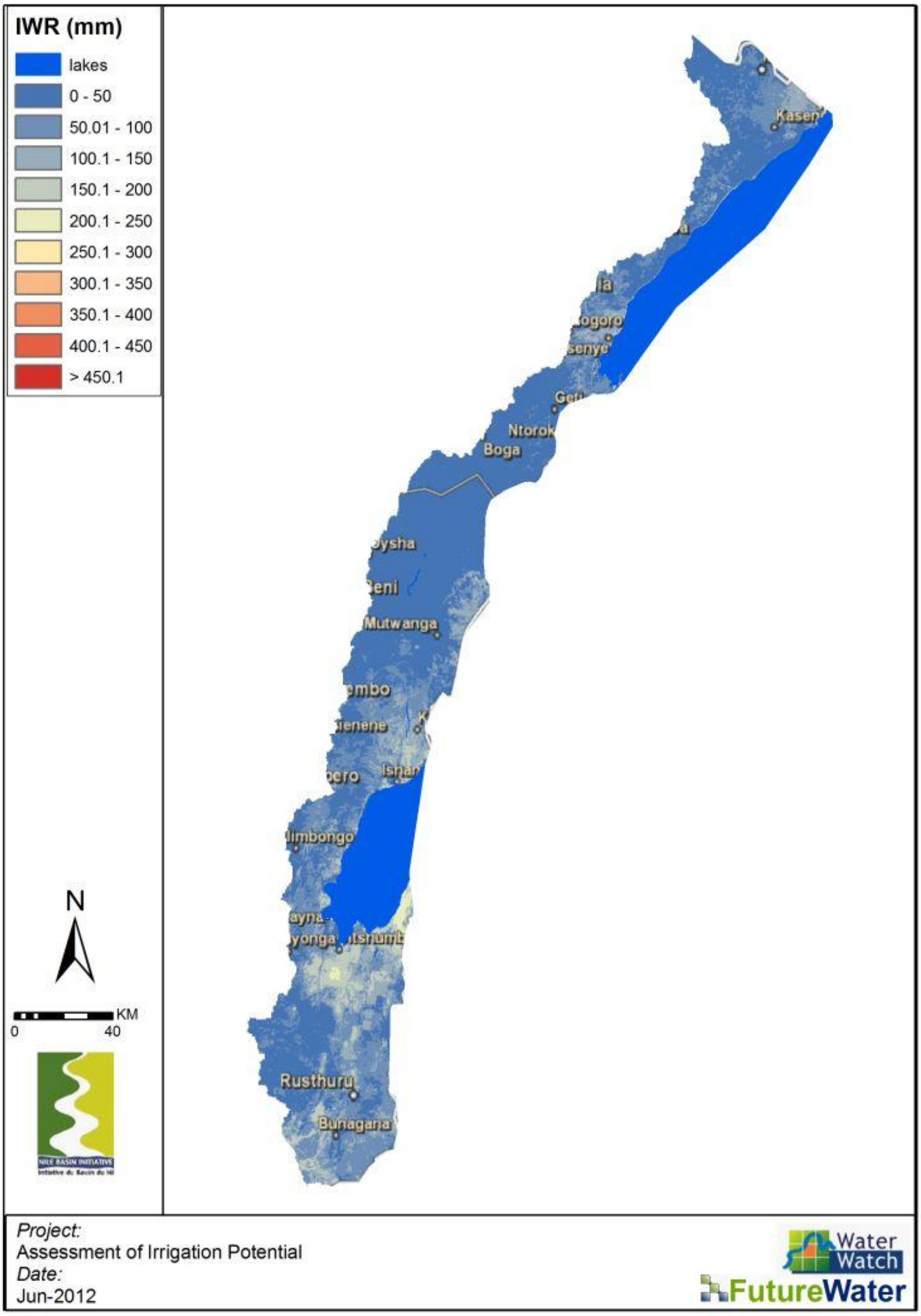
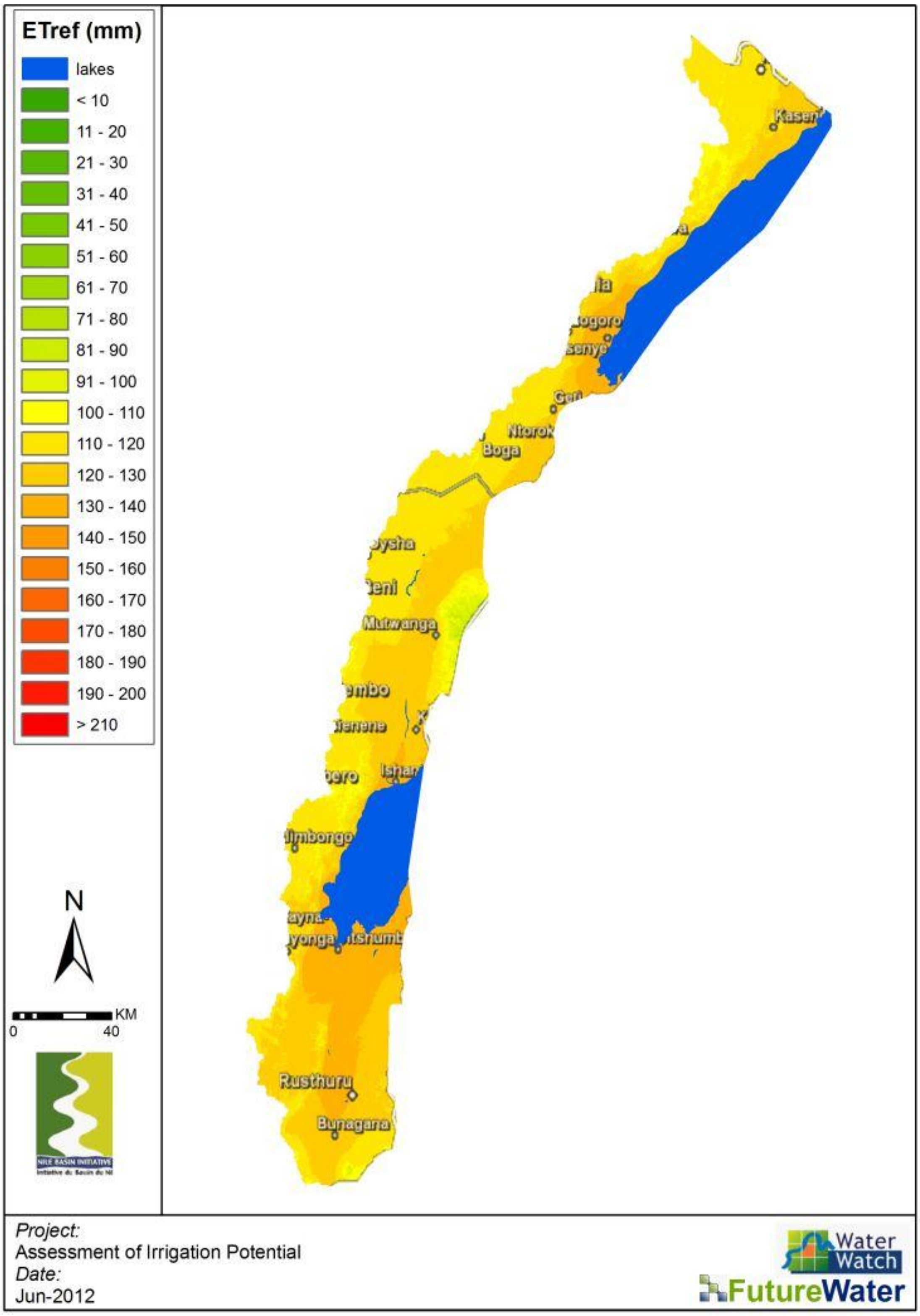
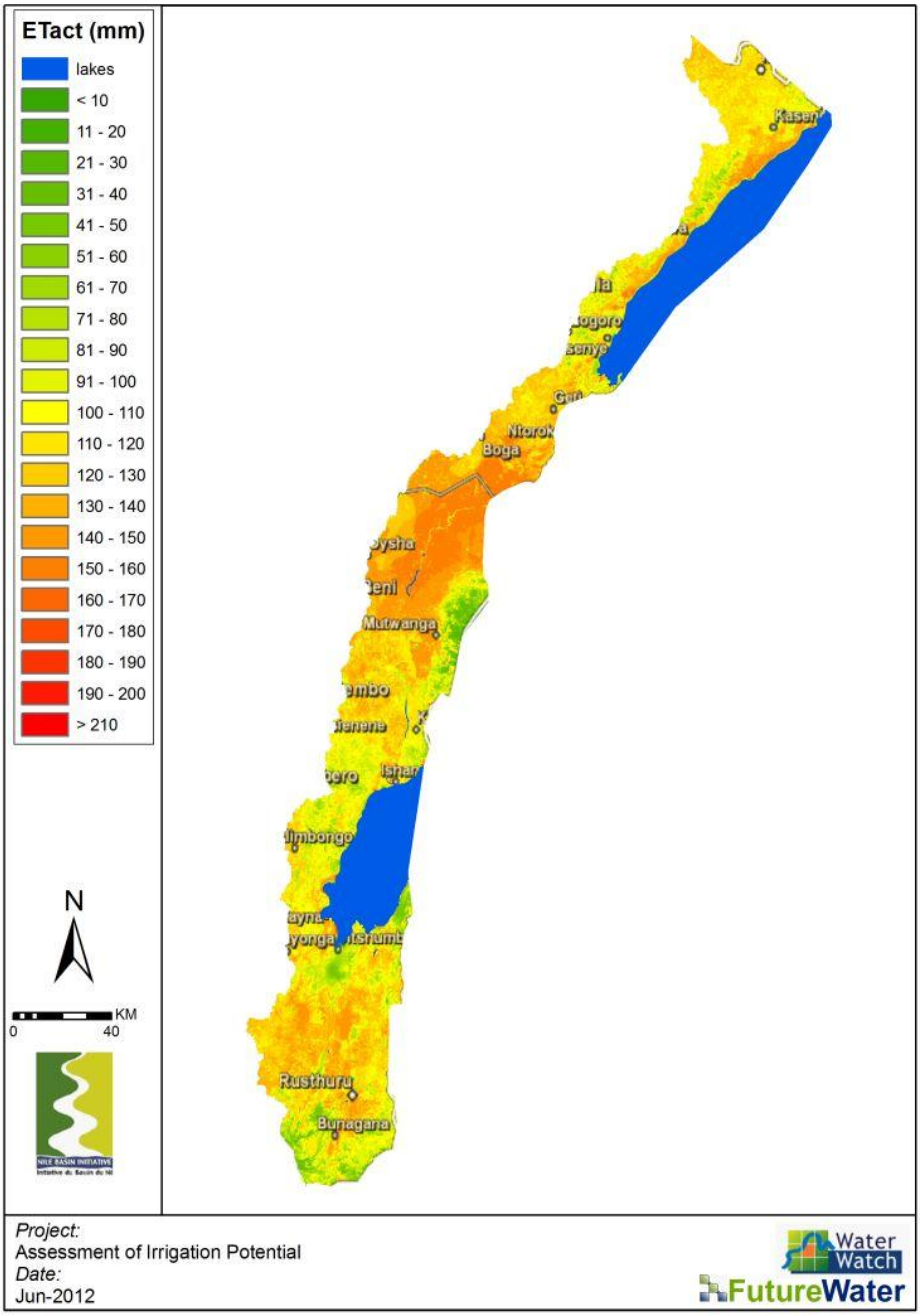


Figure 13: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

September


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
Boga
Mutwanga
Rusthuru
Bunagana
N
KM
0
40
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

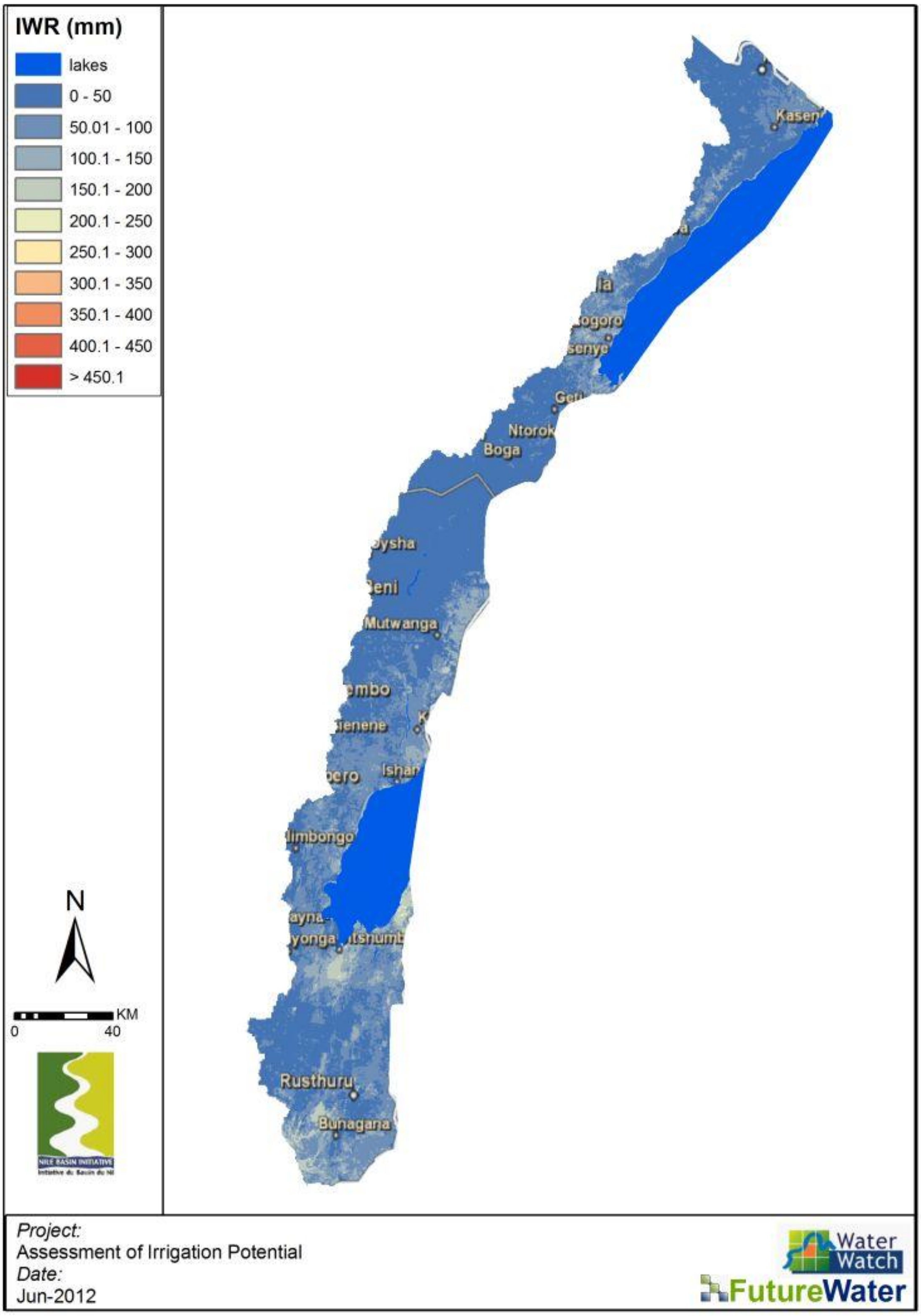
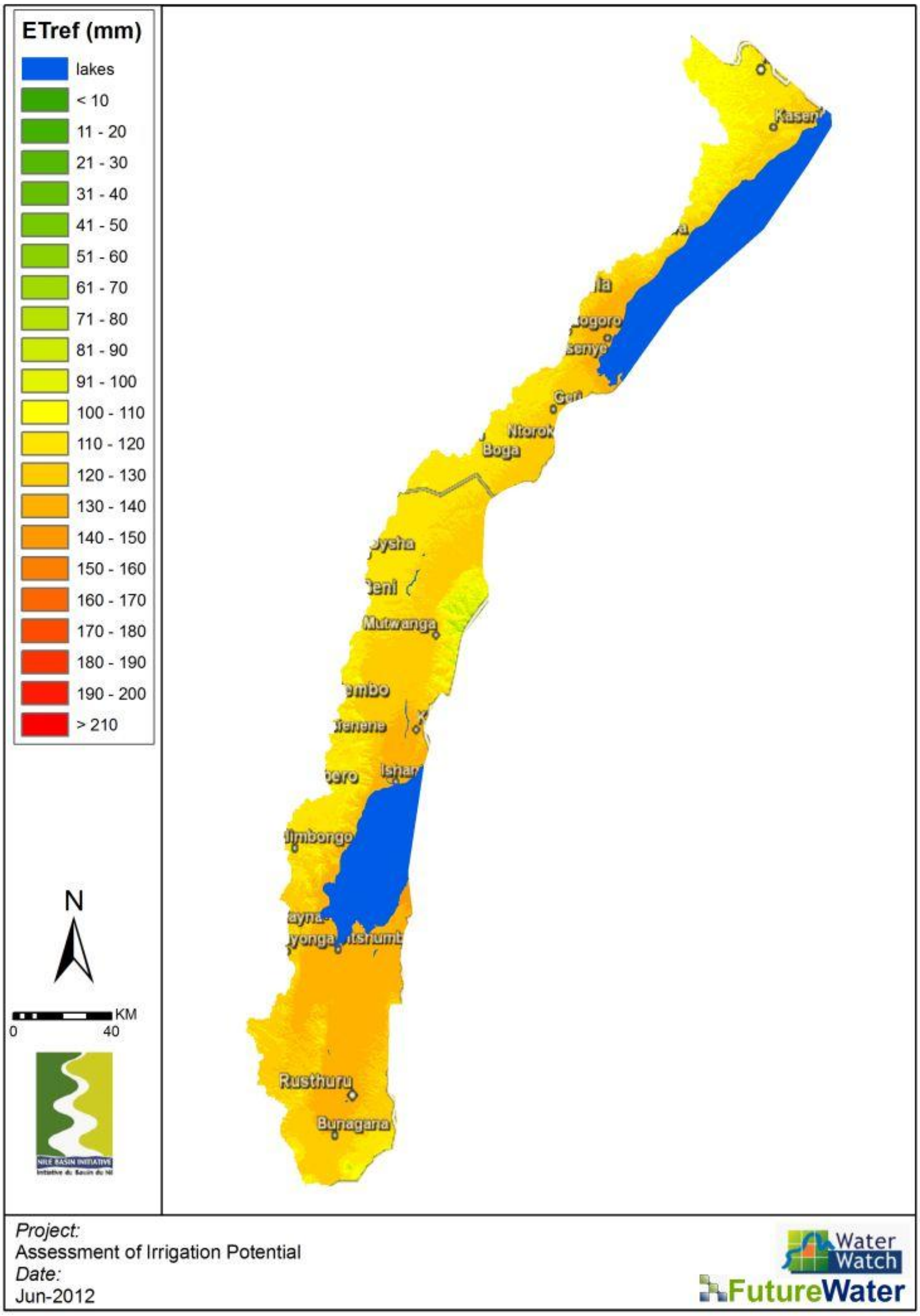
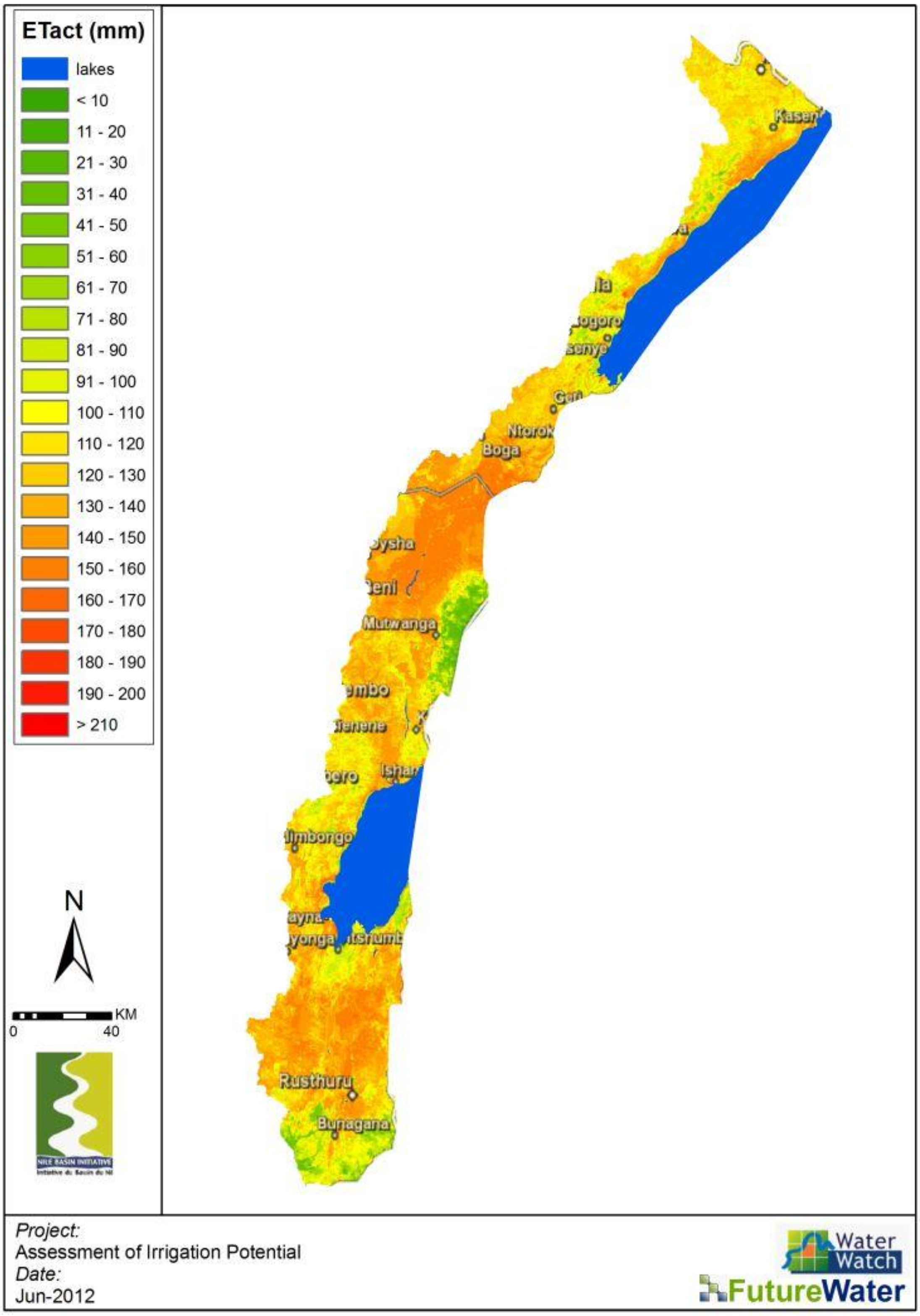


Figure 14: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

October


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Kasen
Gen
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

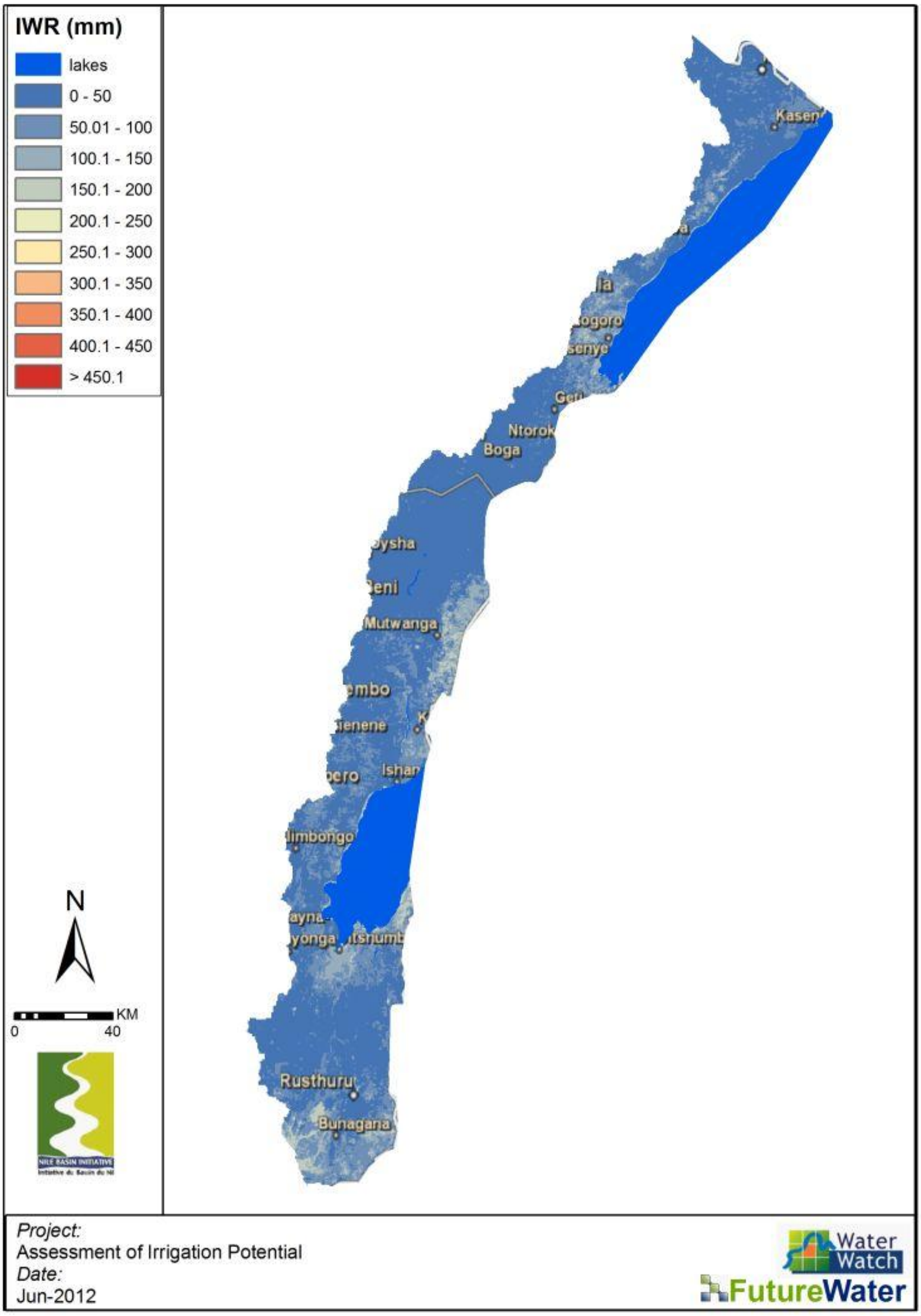
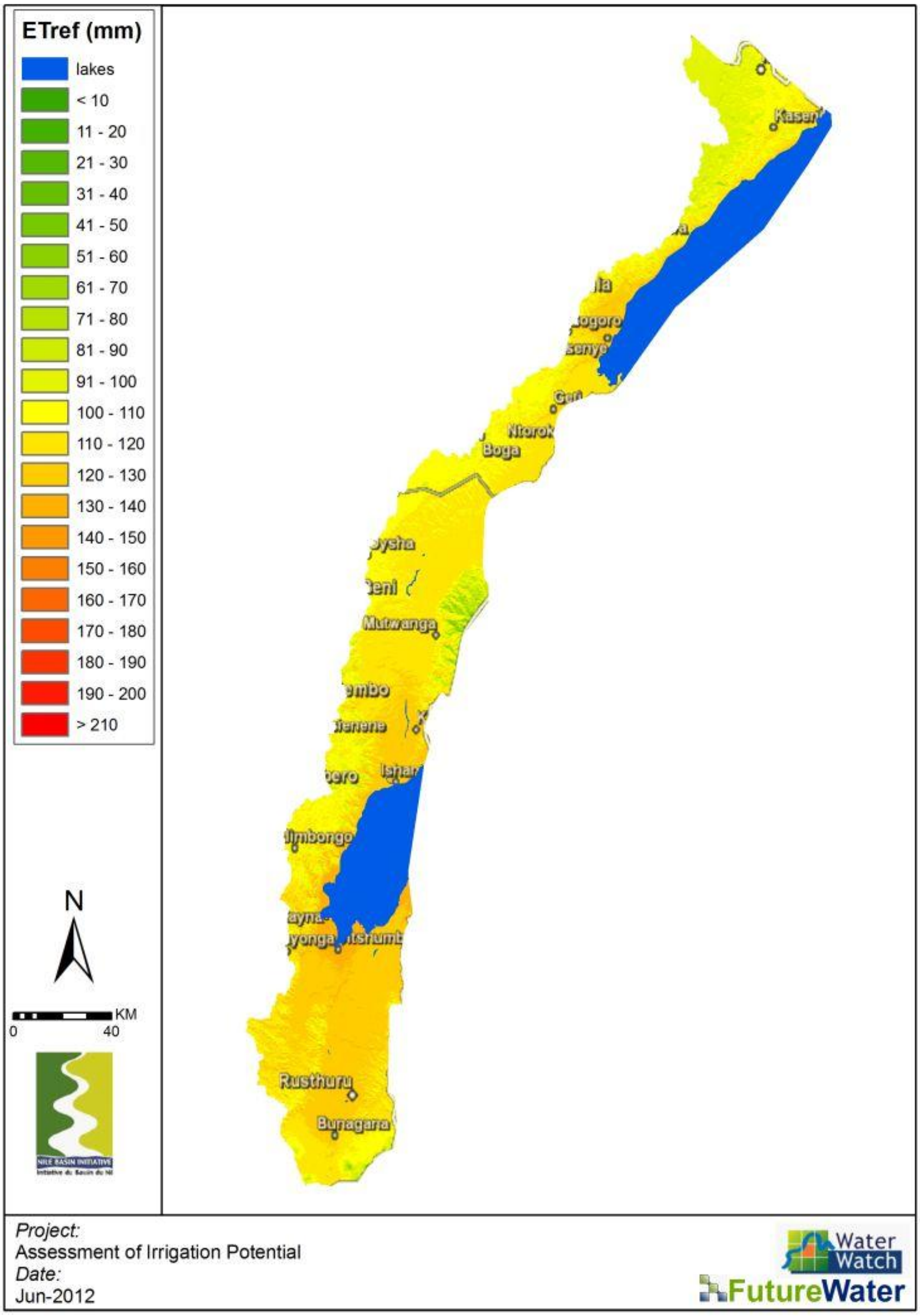
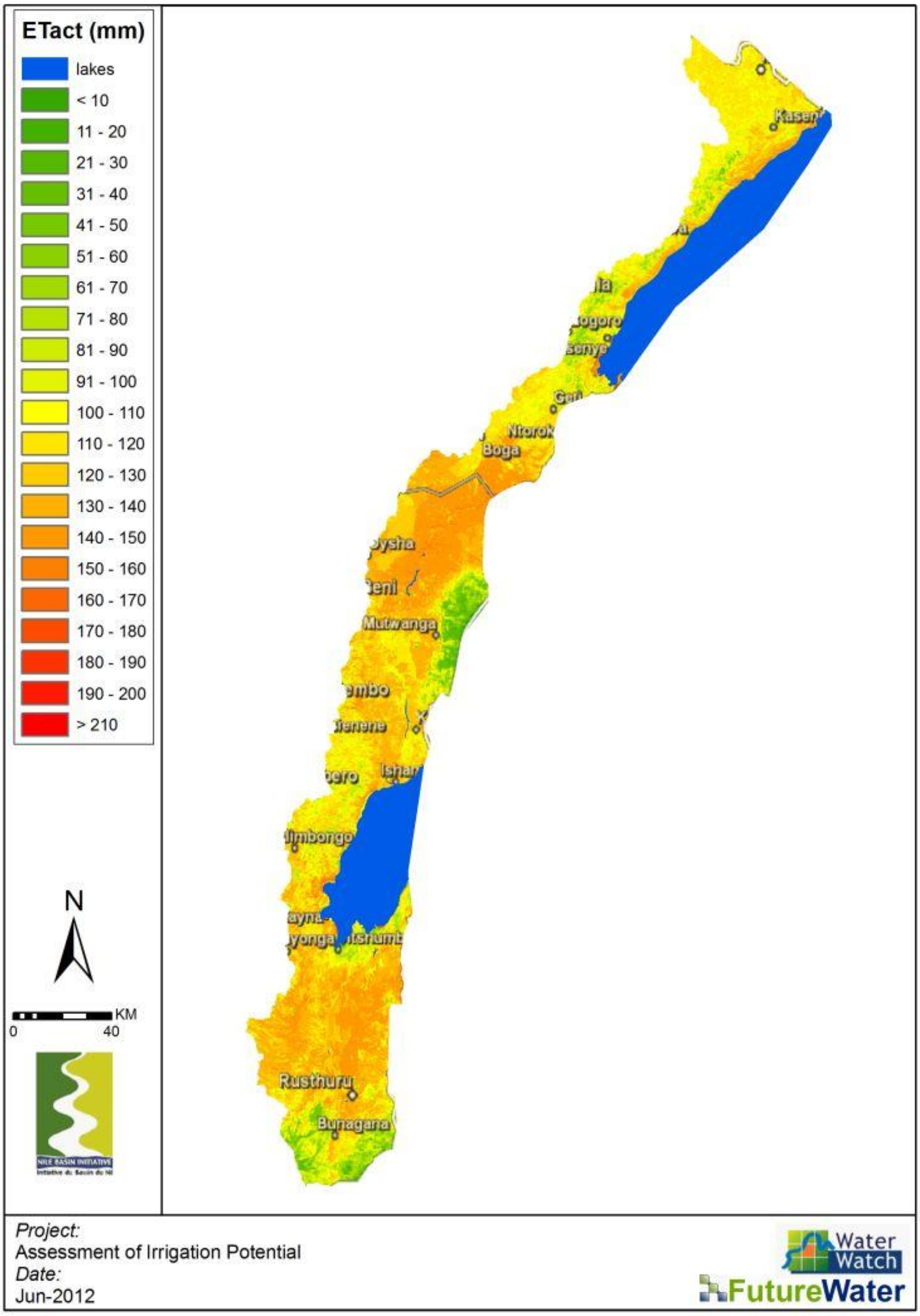


Figure 15: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

November



ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

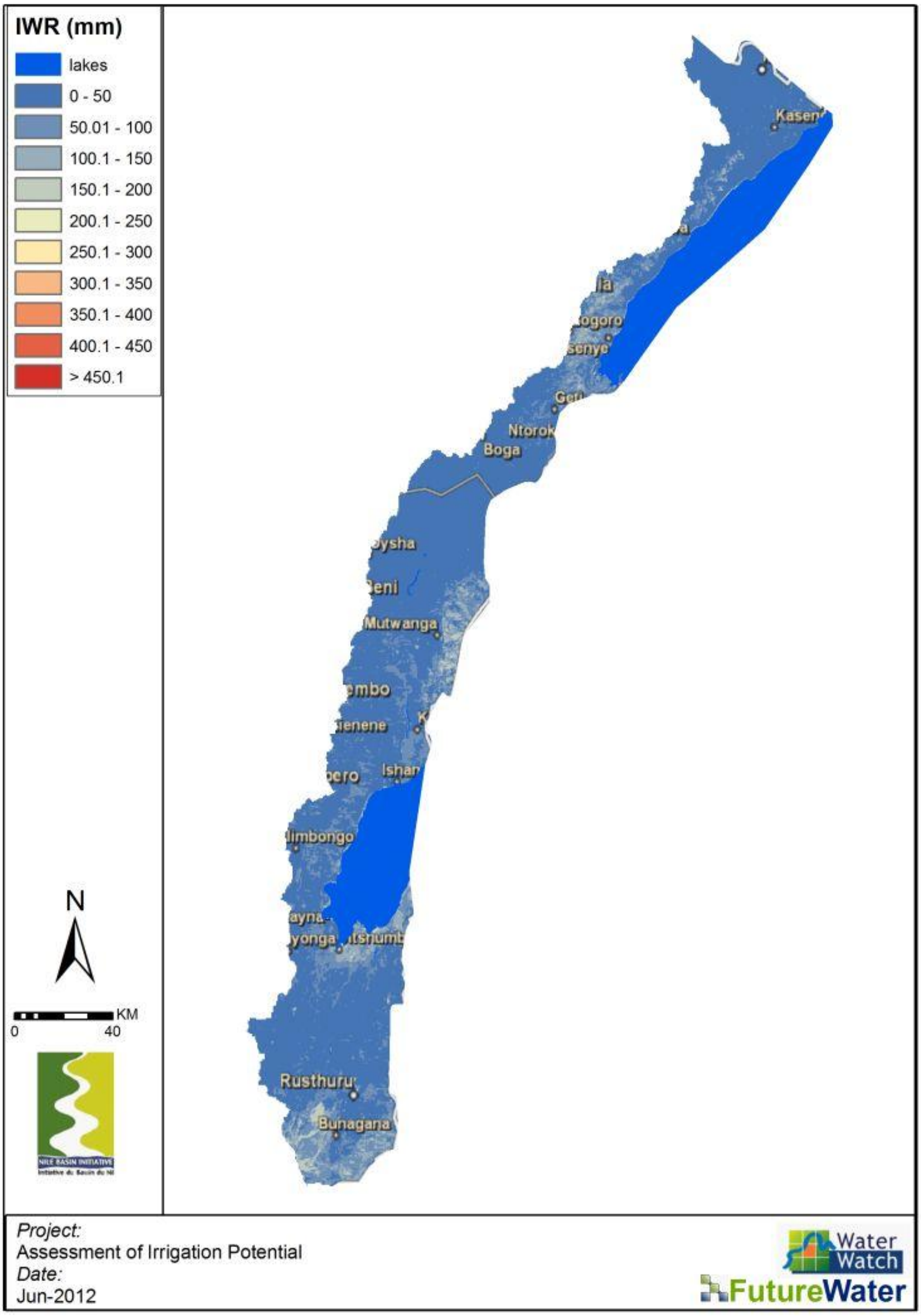
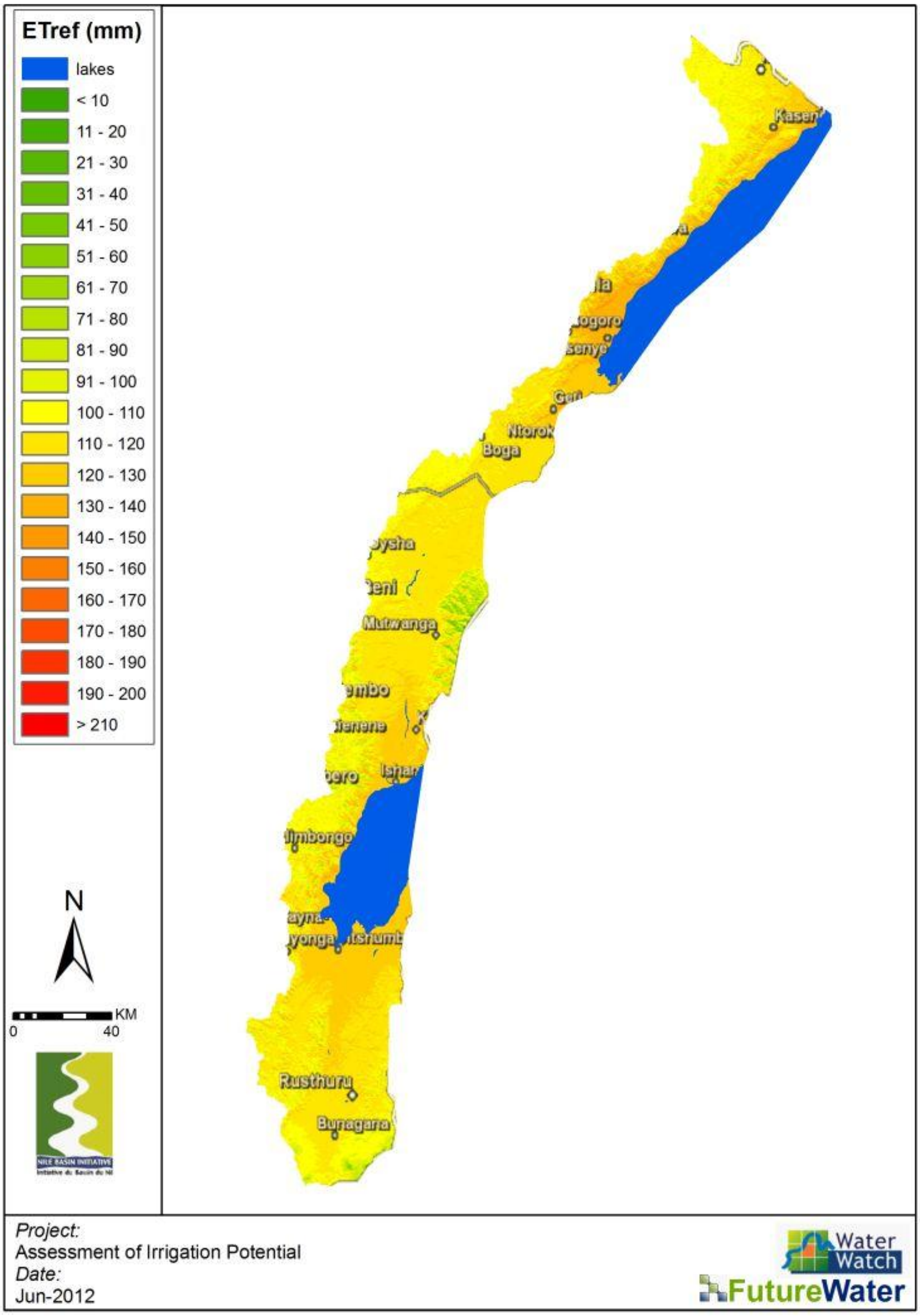
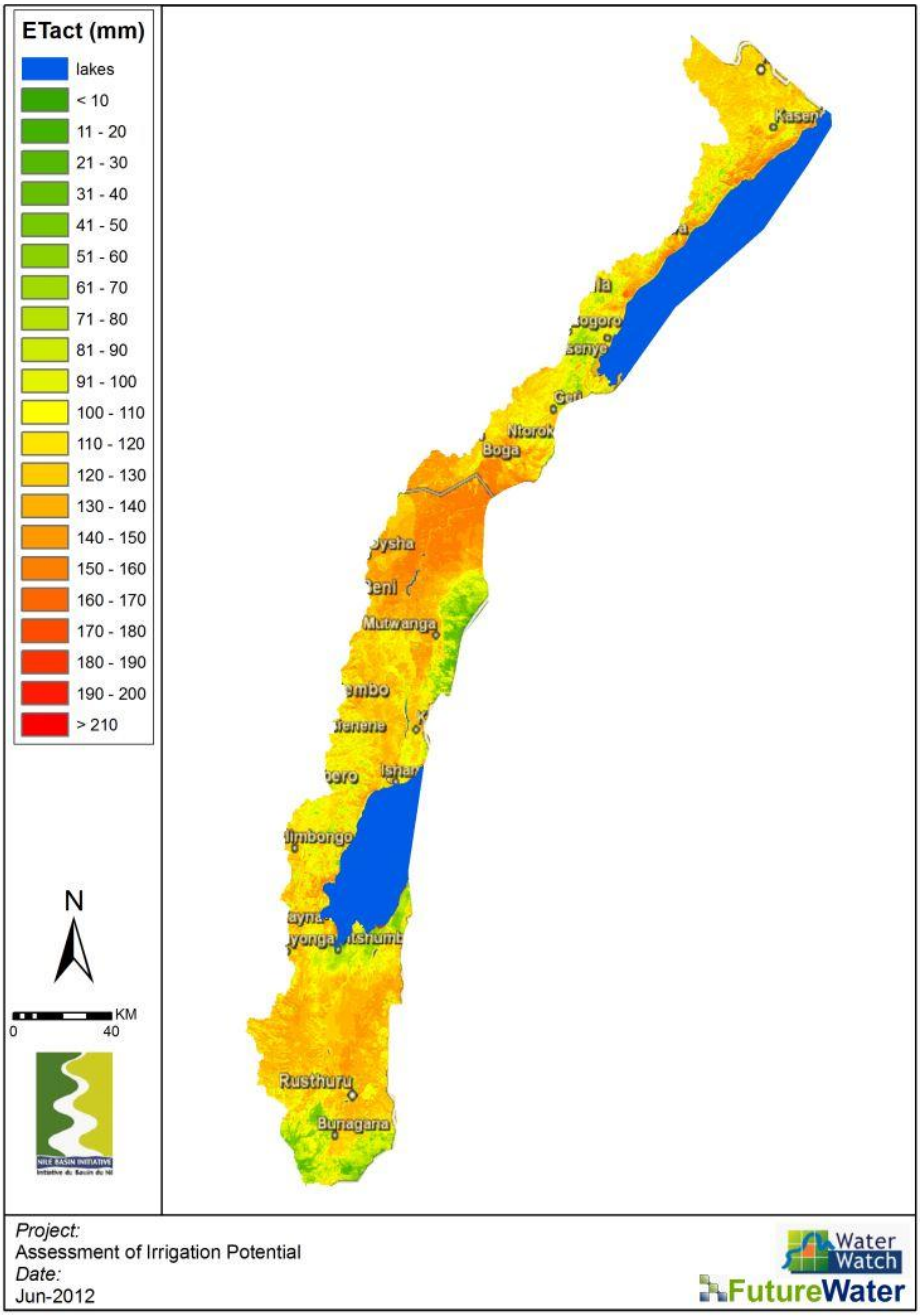


Figure 16: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

December


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Boga
Mutwanga
Rusthuru
Bunagana
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
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

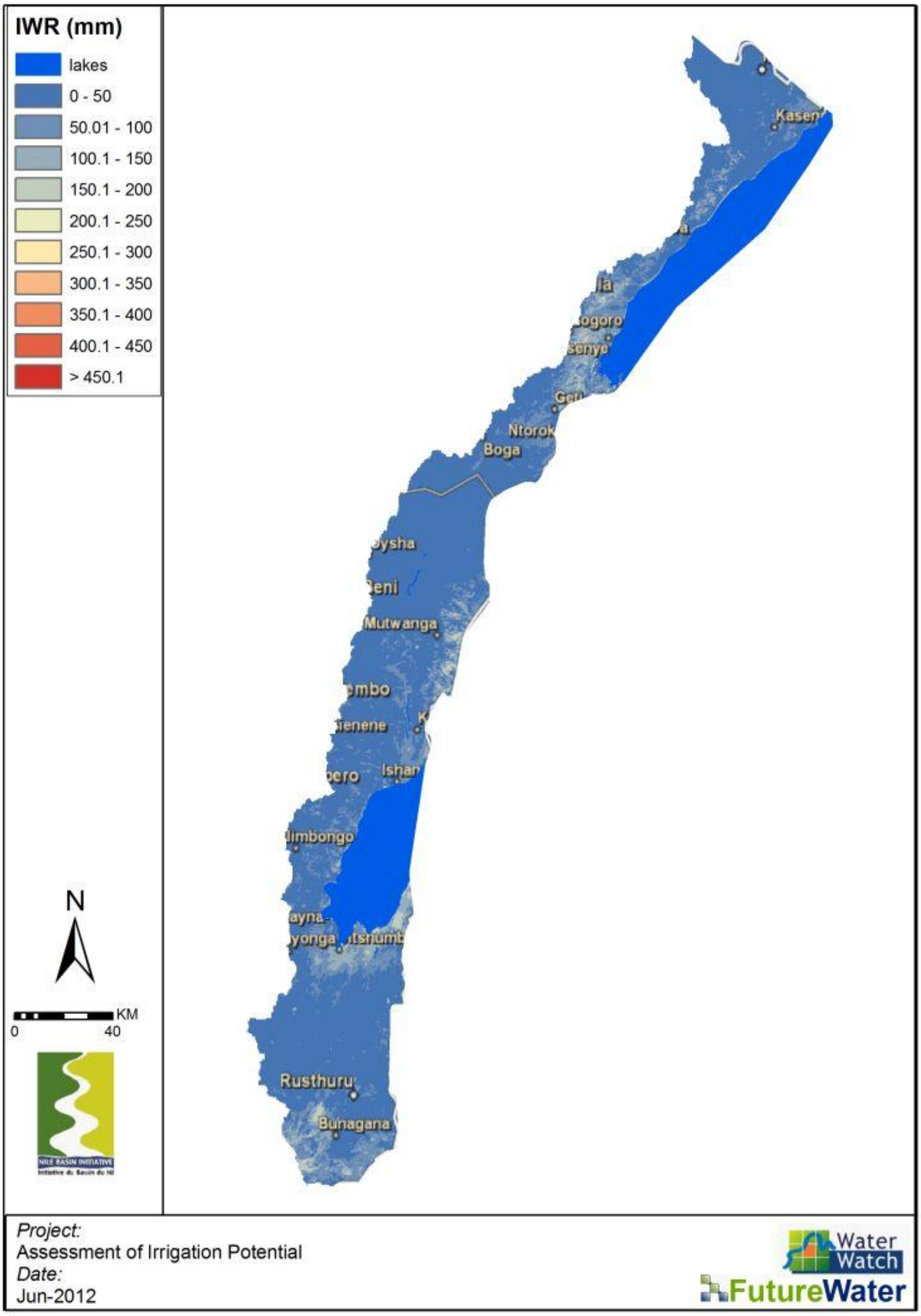


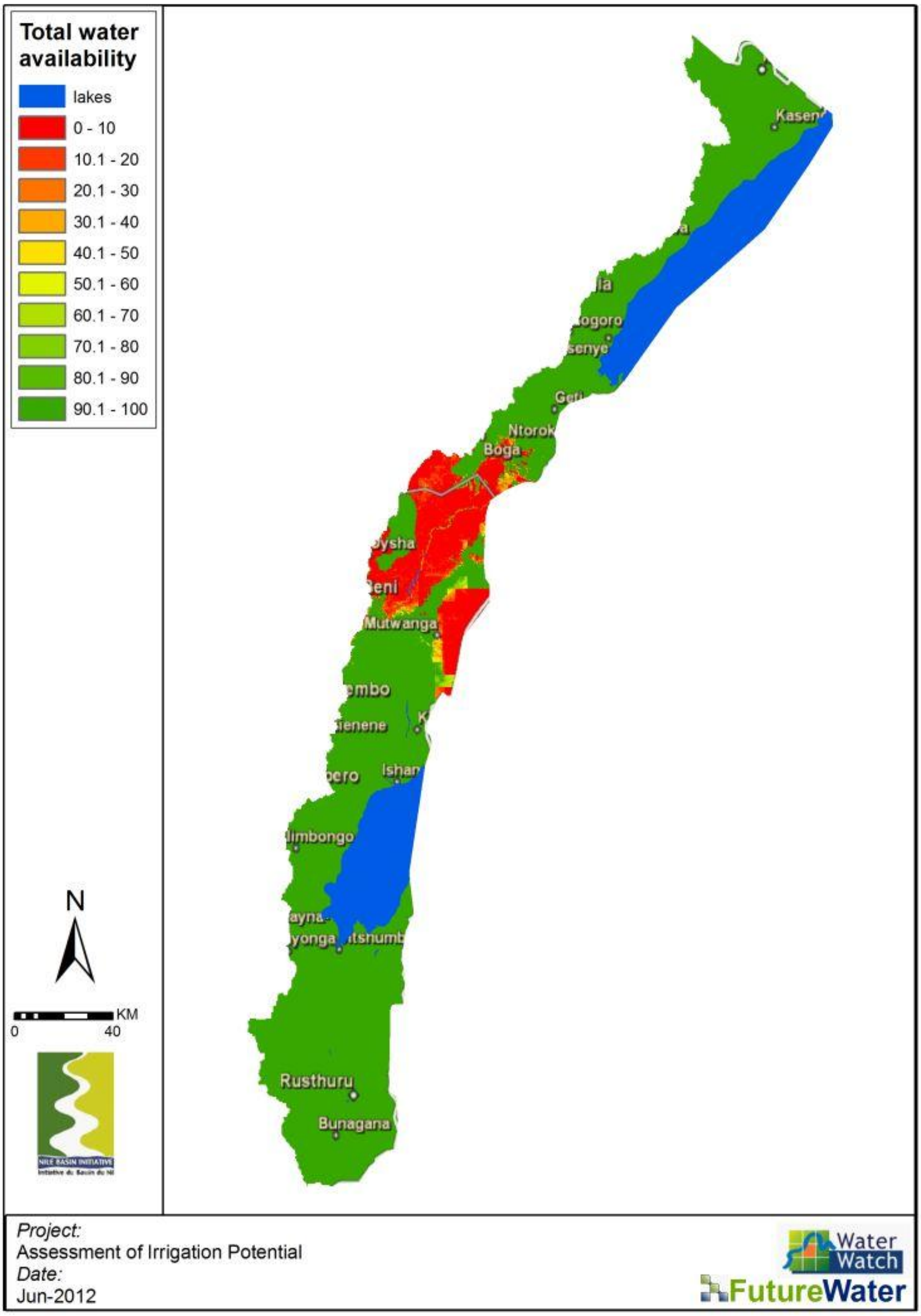
Figure 17: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom).

2.2.2 Water availability for irrigation

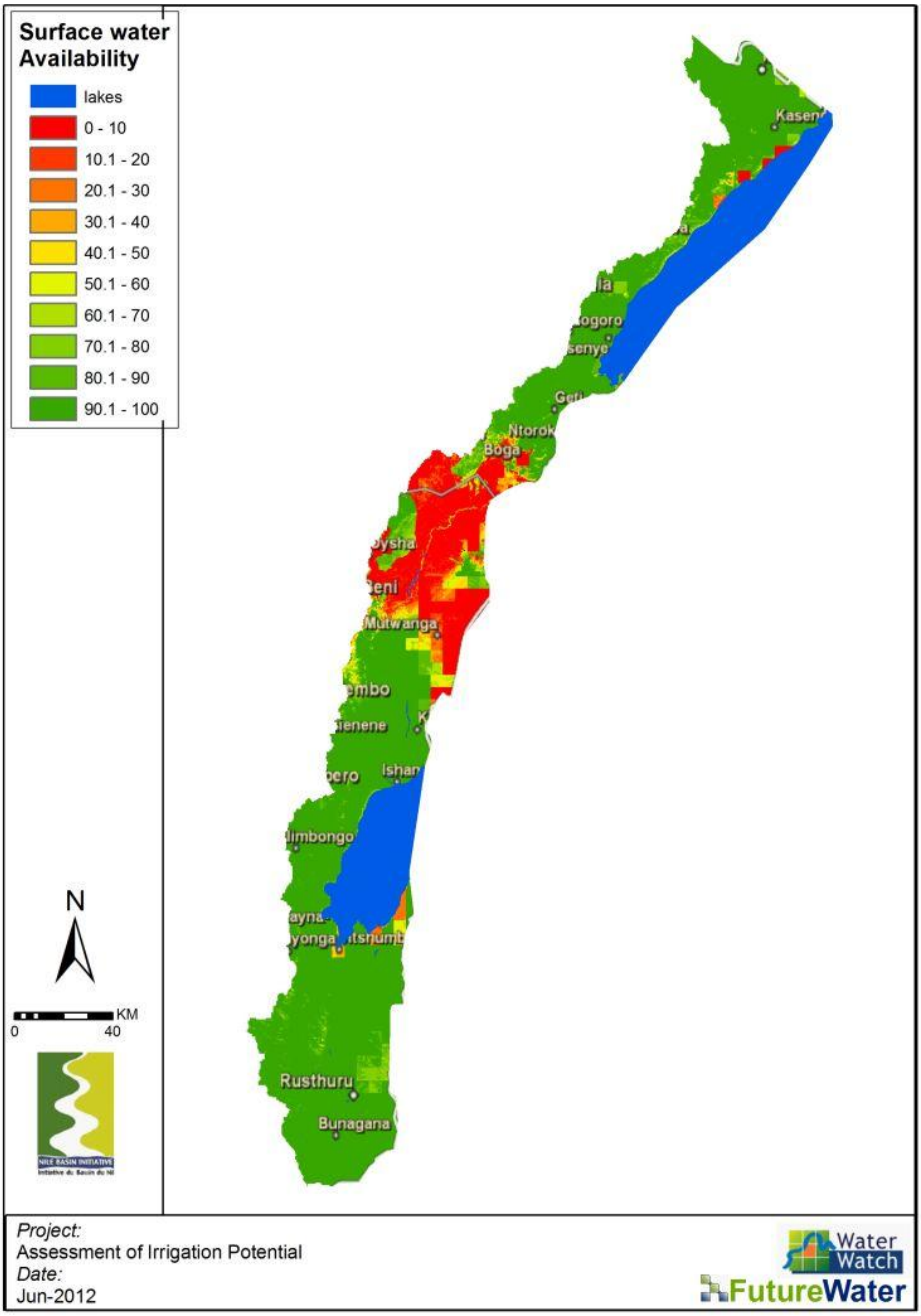
2.2.2.1 NELmod

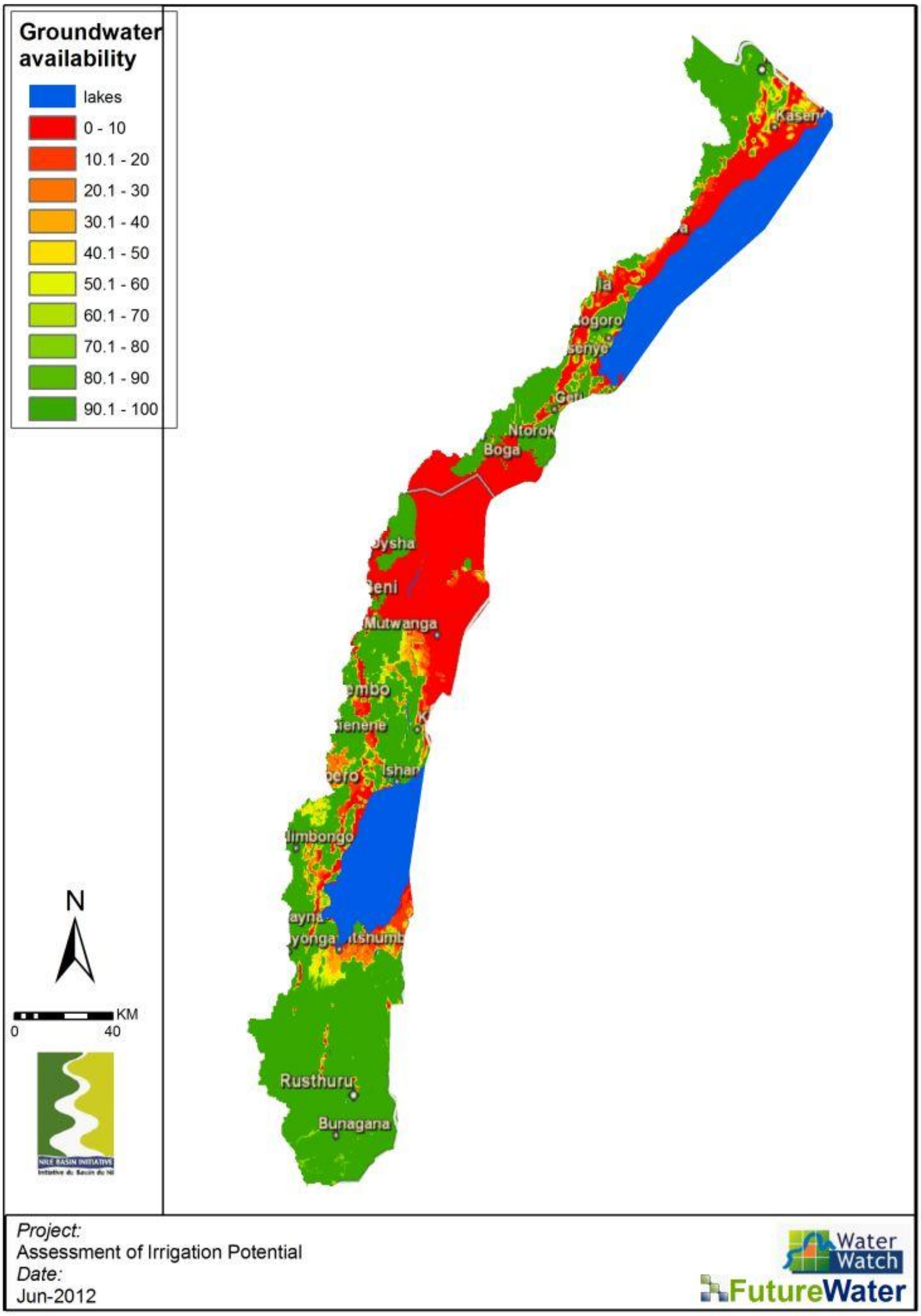
Water for irrigation can originate from three main sources: surface water, groundwater, and reservoirs. Based on the water availability (NELmod results), and irrigation demands (ETLook/SEBAL results) coverage of irrigation water requirements has been made (for details see main report). As explained in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

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



Total water availability
lakes
0 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 90
90.1 - 100
N
KM
0
40
Ntorok
Boga
Mutwanga
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012


Surface water Availability
lakes
0 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 90
90.1 - 100
N
KM
0
40
Kasen
Ntorok
Boga
Mutwanga
Ishan
Rusthuru
Bunagana
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


Groundwater availability
lakes
0 - 10
10.1 - 20
20.1 - 30
30.1 - 40
40.1 - 50
50.1 - 60
60.1 - 70
70.1 - 80
80.1 - 90
90.1 - 100
Boga
Mutwanga
Rusthuru
Bunagana
N
KM
0
40
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

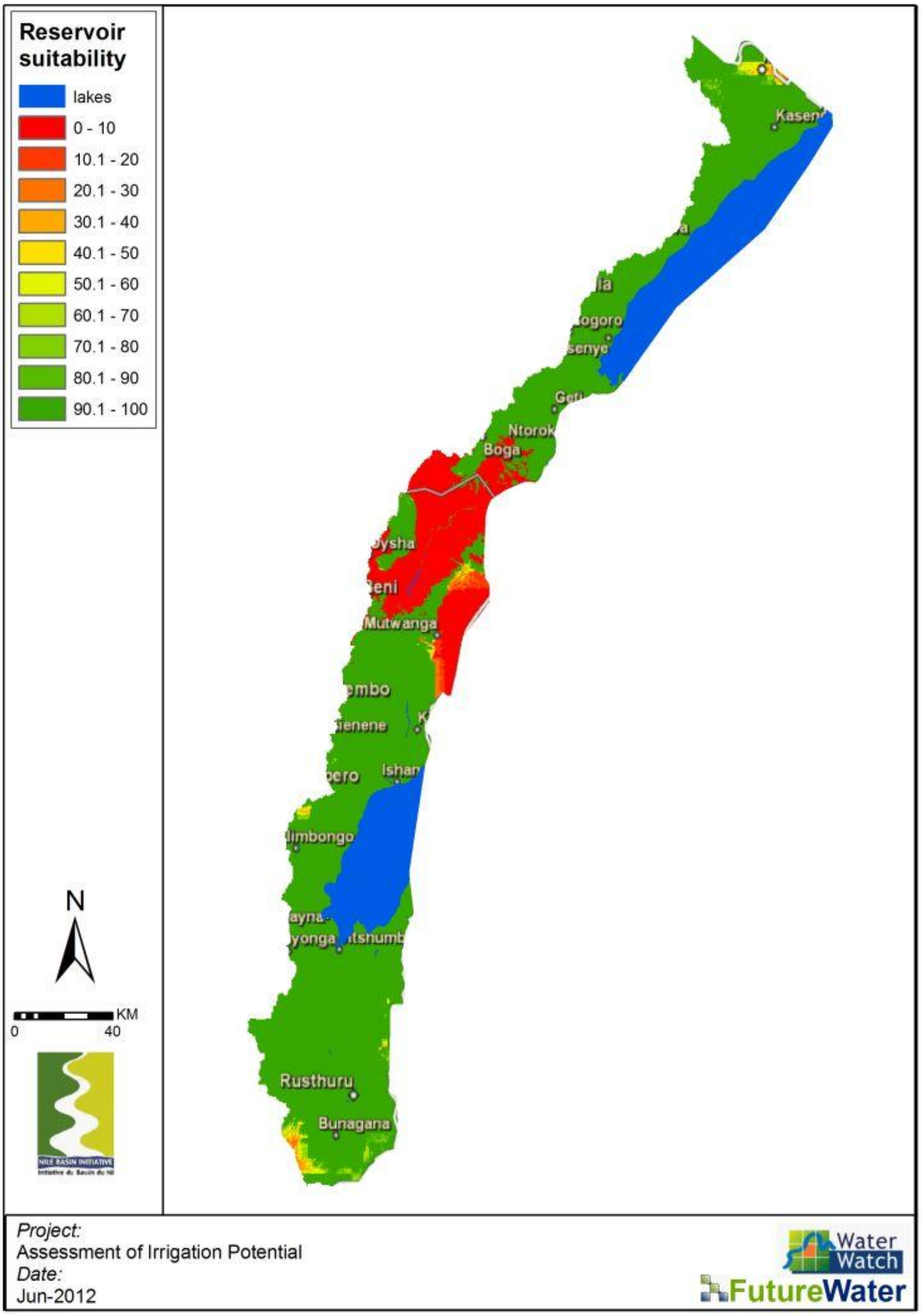


Figure 18. Water availability for irrigation. Total coverage (top), coverage from surface water (second), coverage from ground water (third), and from potential reservoirs (bottom).

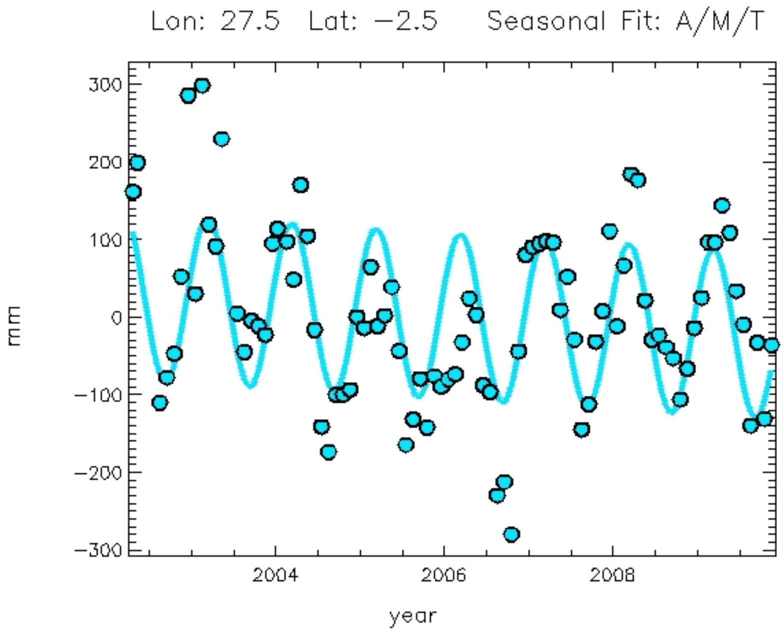


Figure 19: Annual groundwater storage trends for Eastern DRC, based on GRACE satellite observations (Source: UoC, 2011).

2.2.2.2 Groundwater rends

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 based on GRACE can be seen in Figure 19. It is clear that the overall trend is a small reduction in groundwater levels over the last 10 years. Groundwater recharge based on NELmod is presented in Figure 20. Overall groundwater recharge is quite high except for the forest areas around Kikura as most water evaporates.

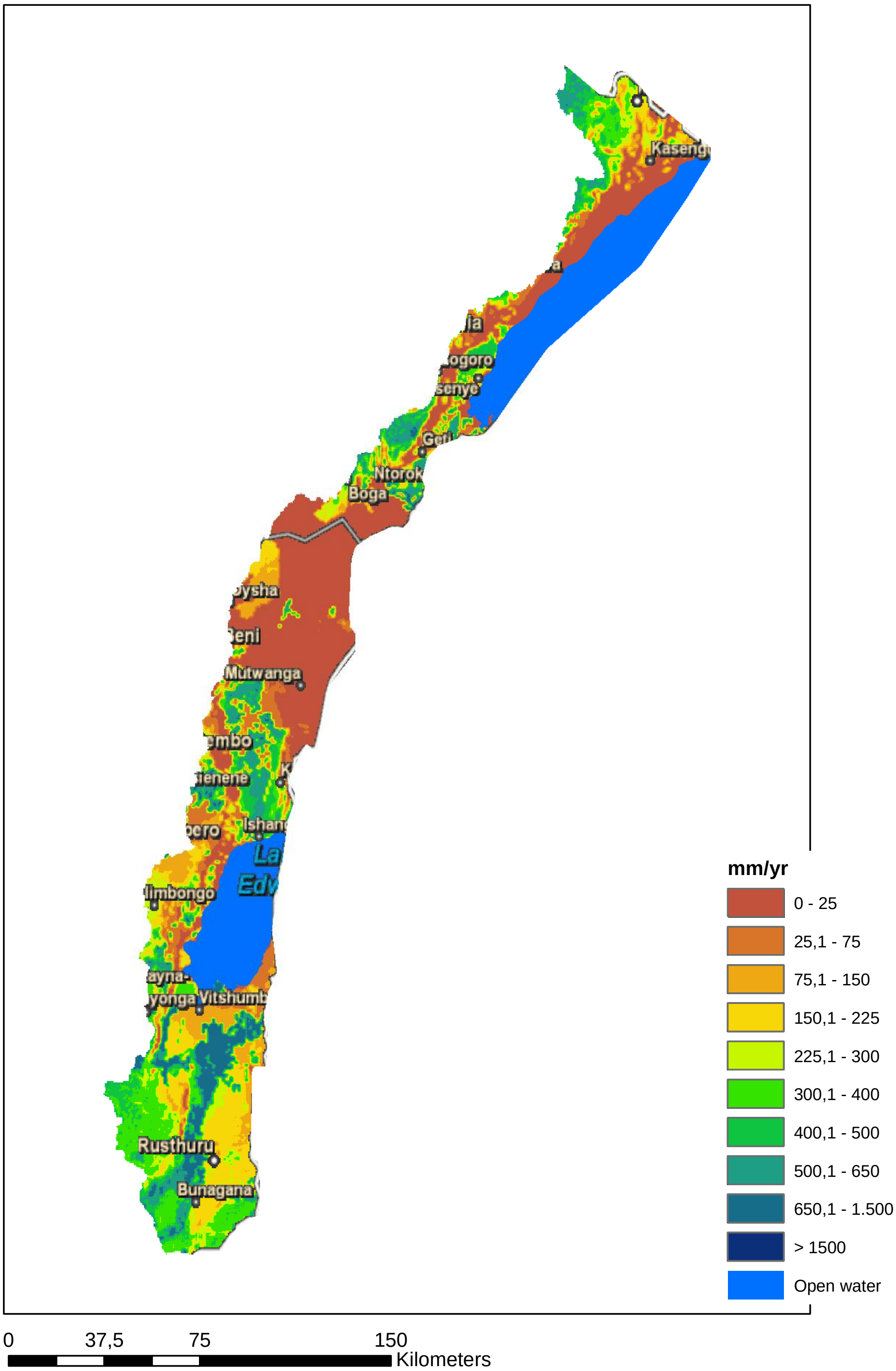
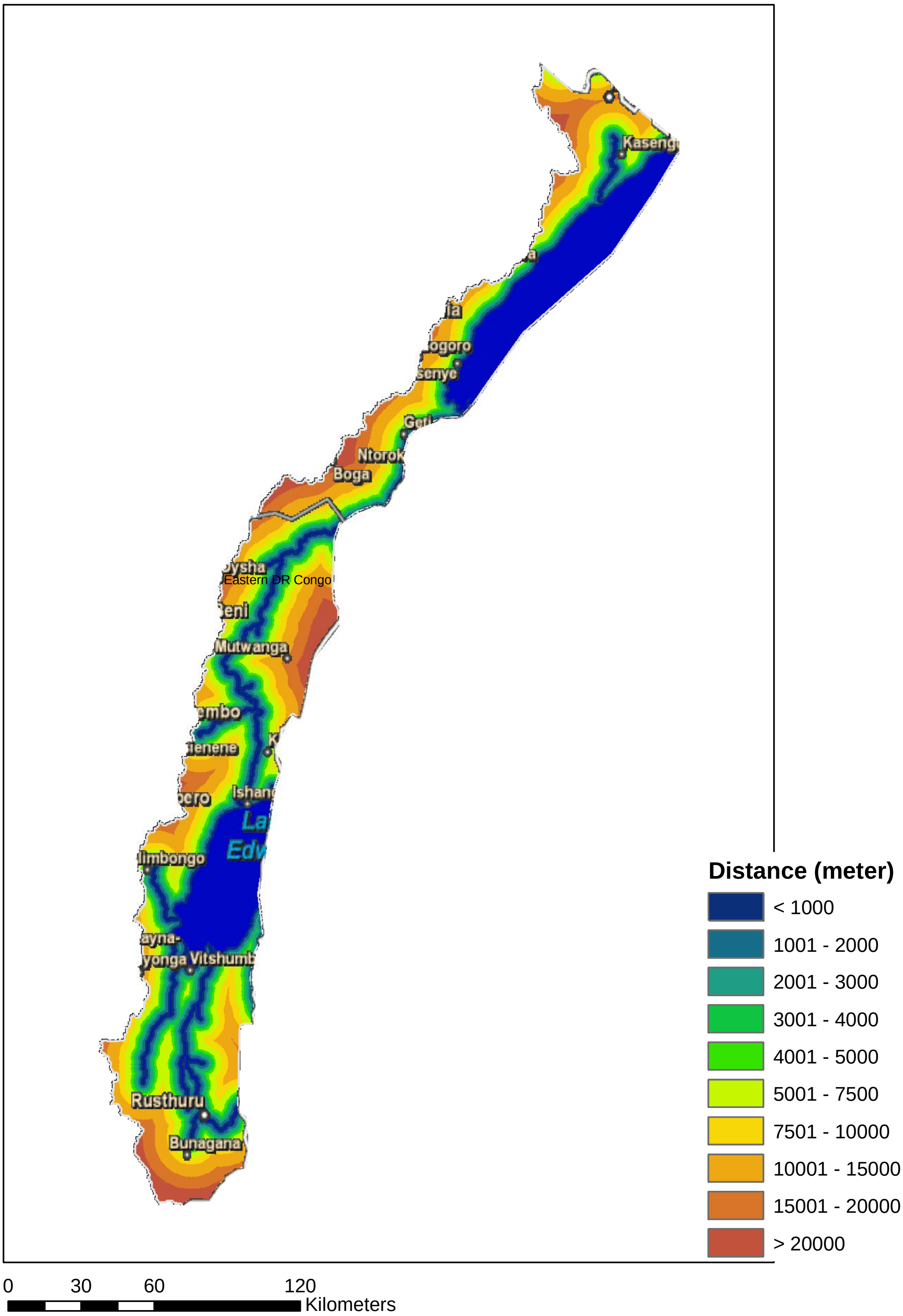
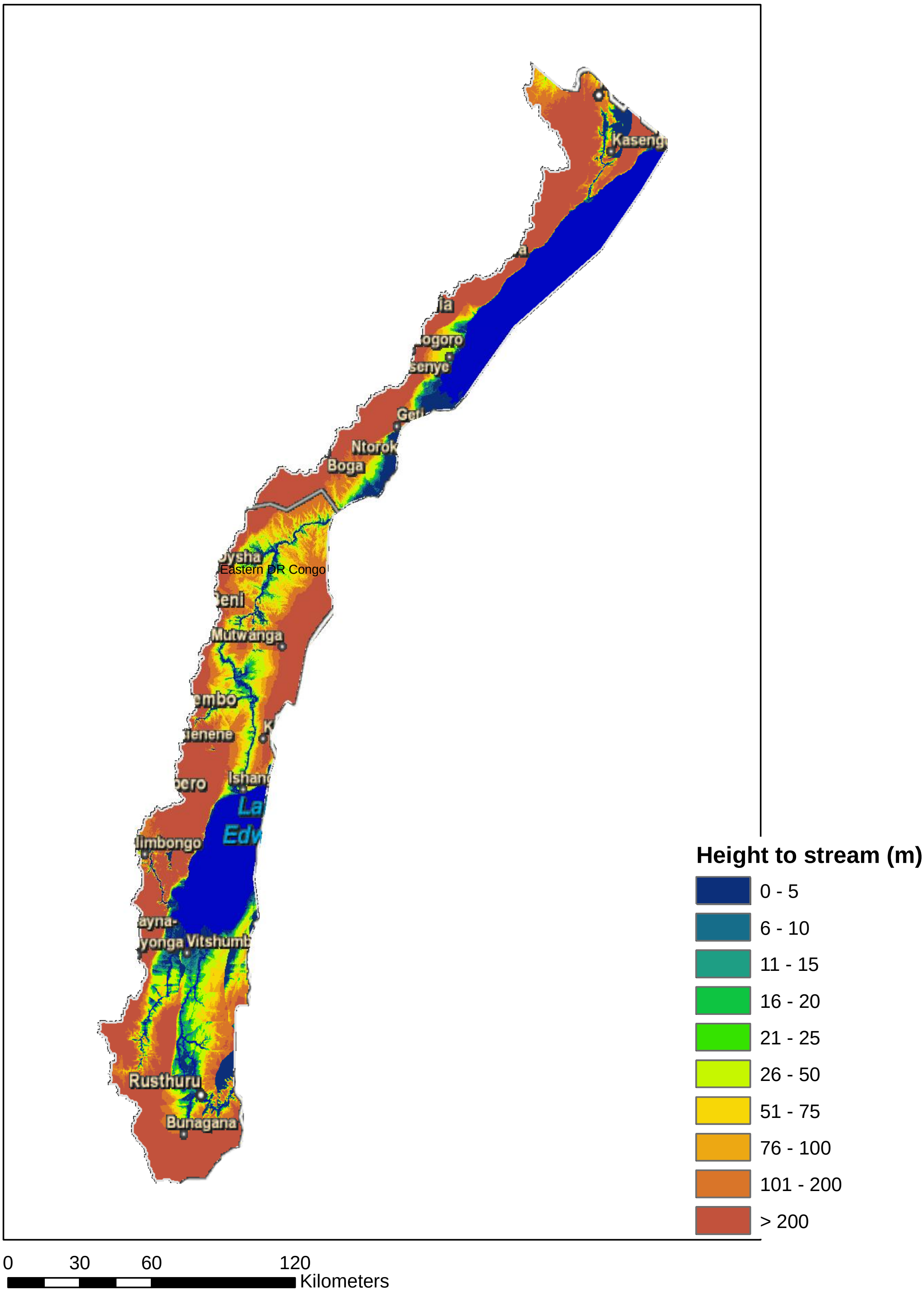


Figure 20: Annual groundwater recharge based on NELmod.

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). Access to a potential water source is quite high in the region.


Kaseng
Geti
Ntorok
Boga
Eastern DR Congo
Mutwanga
Ishang
Rusthuru
Bunagana
Distance (meter)
< 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 7500
7501 - 10000
10001 - 15000
15001 - 20000
> 20000
0 30 60 120
Kilometers


Kaseng
ogoro
senye
Geti
Ntorok
Boga
Eastern DR Congo
Mutwanga
Ishang
Rusthuru
Bunagana
Height to stream (m)
0 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 50
51 - 75
76 - 100
101 - 200
> 200
0
30
60
120
Kilometers

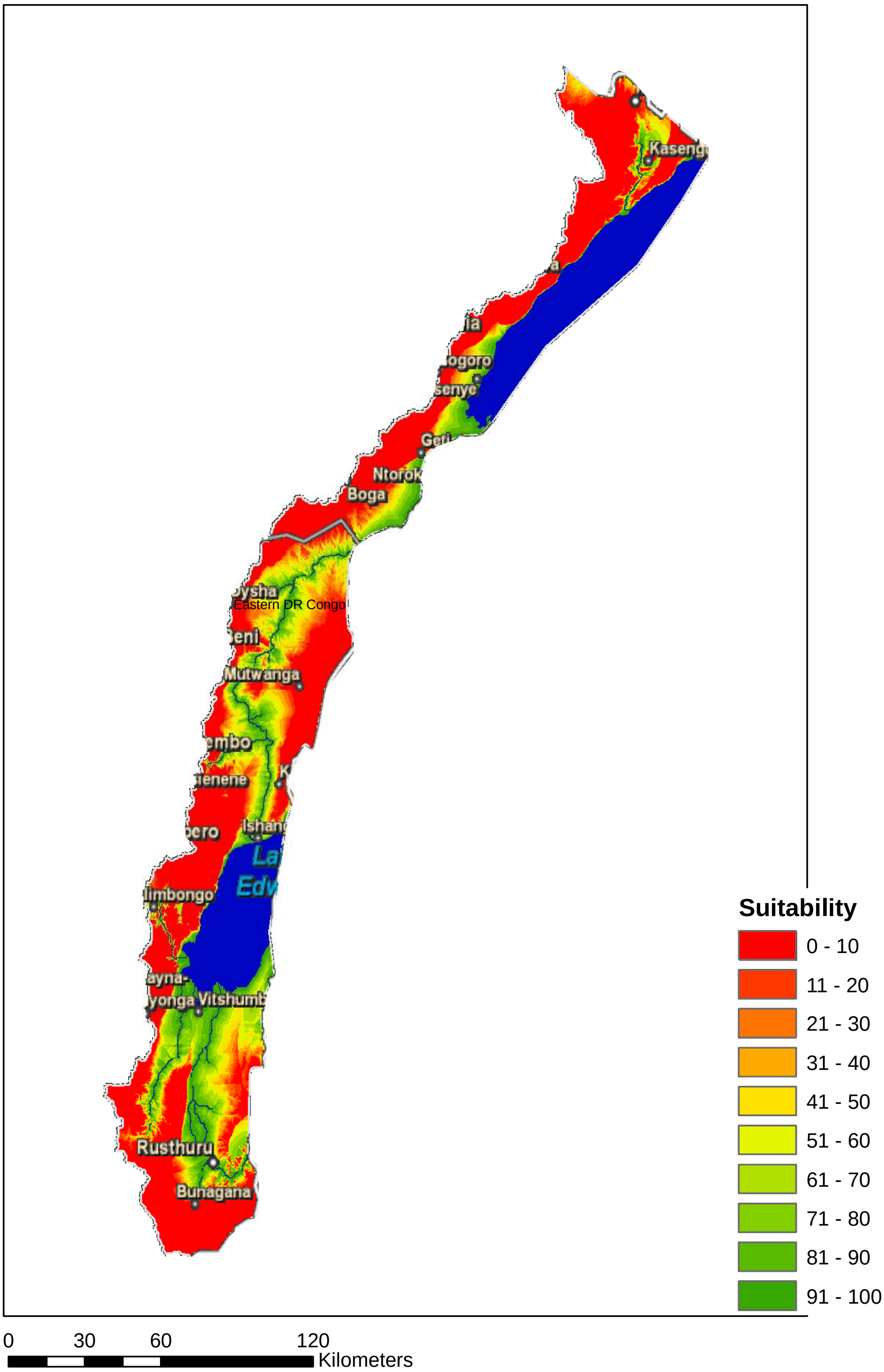


Figure 21: Average distance to a natural stream, lake or reservoir (top), elevation above natural stream, lake or reservoir (middle), and access to water suitability score (bottom).

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.

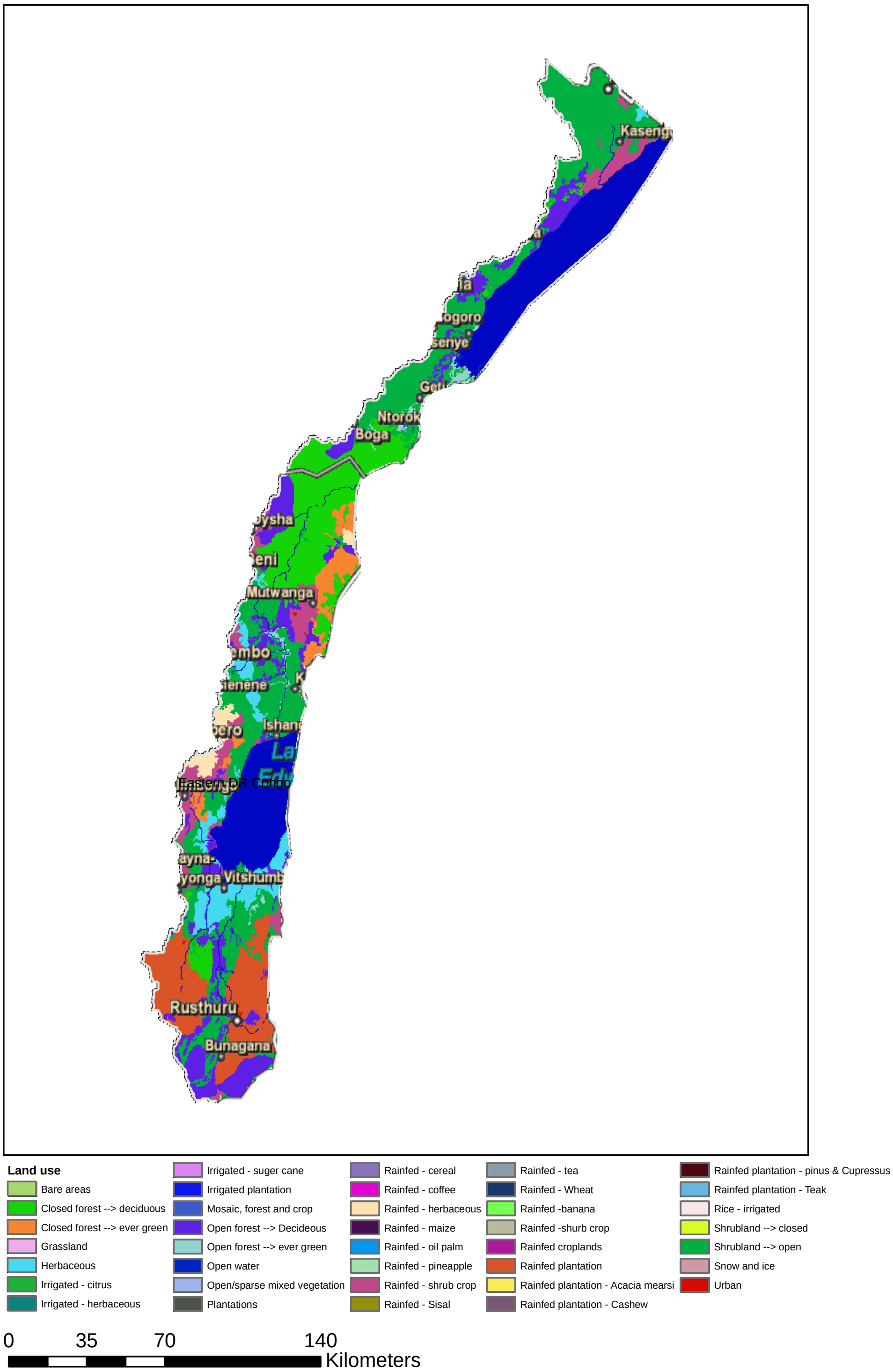
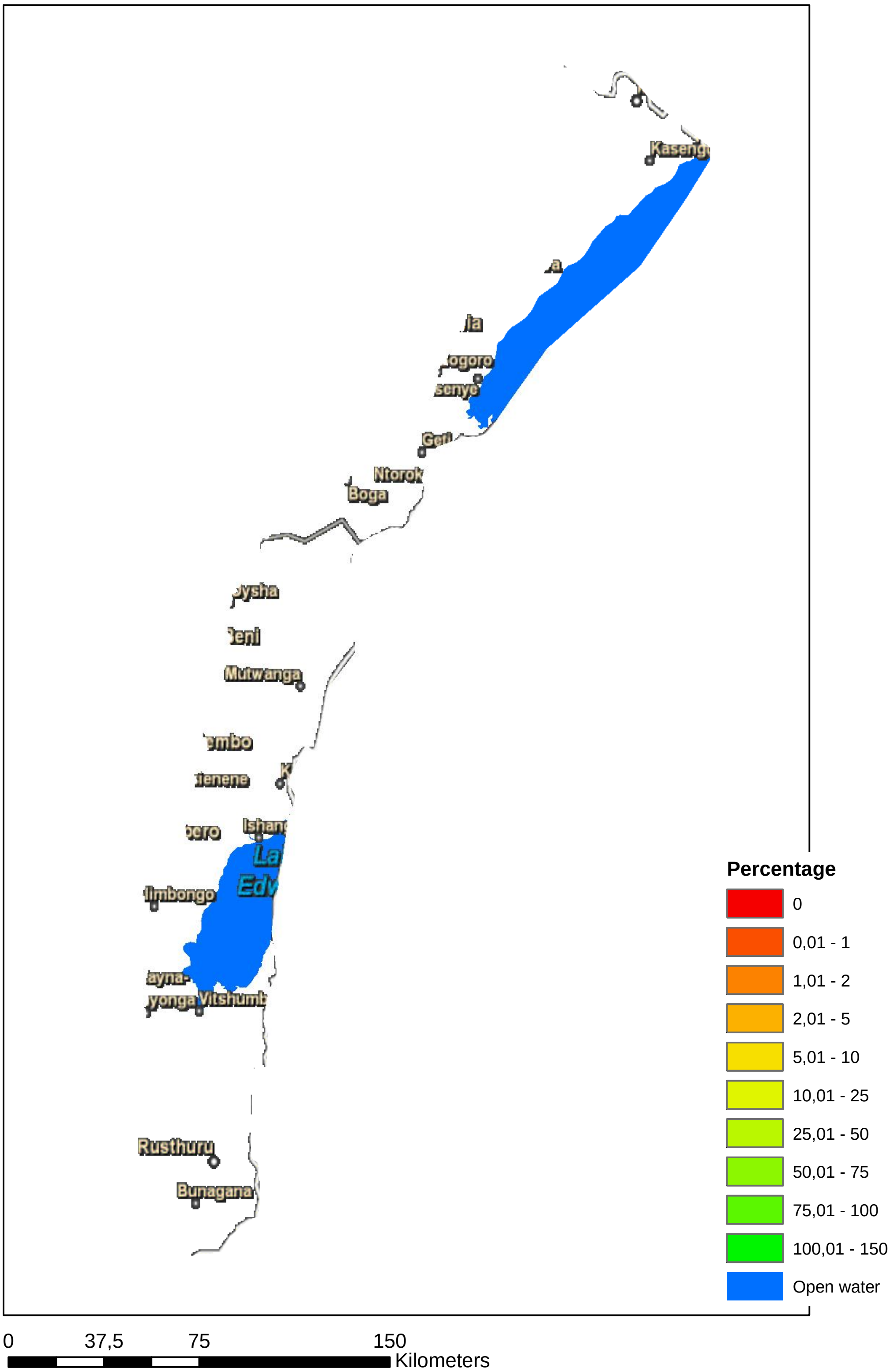


Figure 22: Land use in Eastern DRC, based on AfriCover


Kasenge
ia
Geti
Ntorok
Boga
Mutwanga
Ishang
Edw
Vitshumb
Rusthuru
Bunagana
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
37,5
75
150
Kilometers

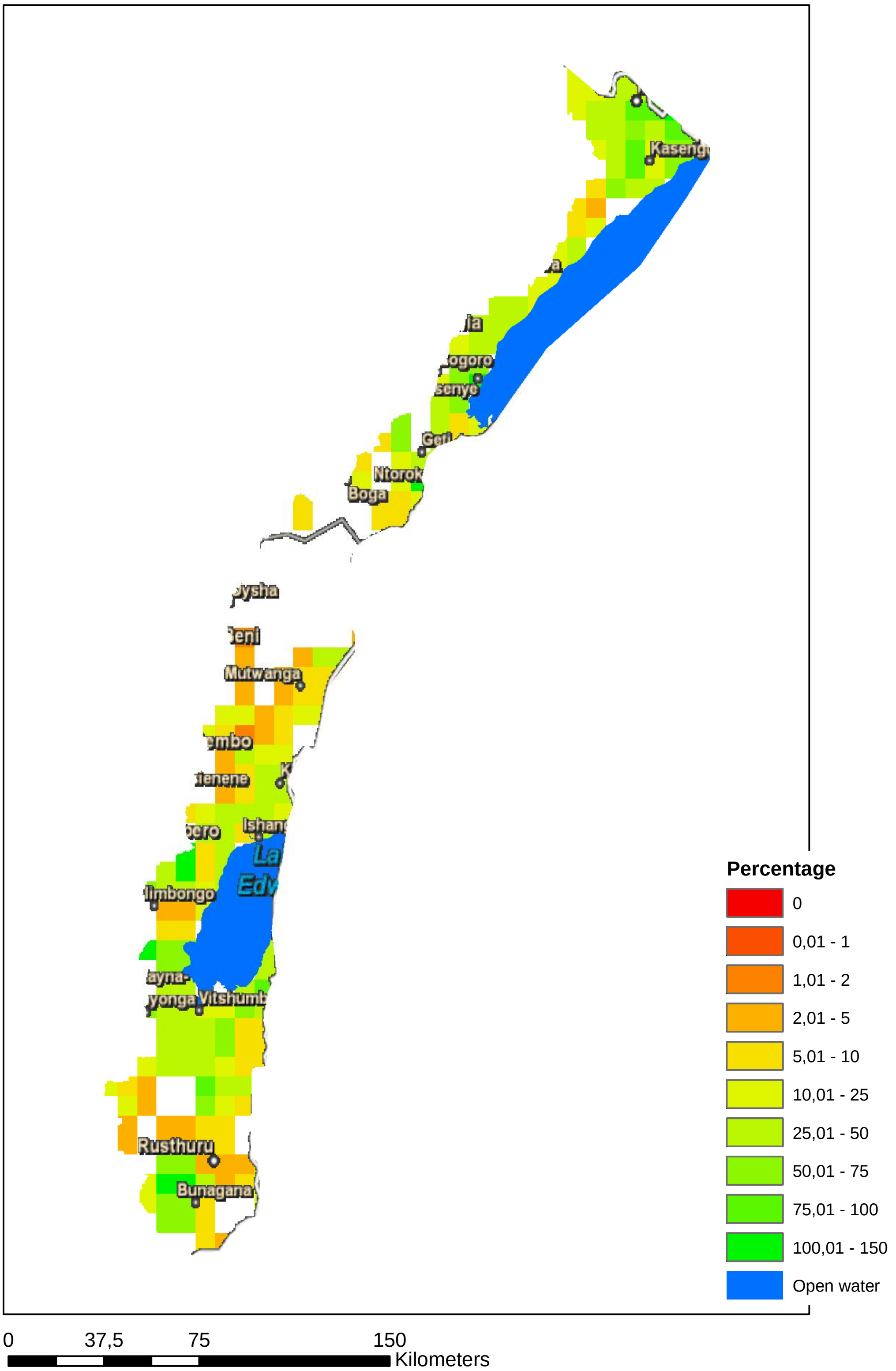
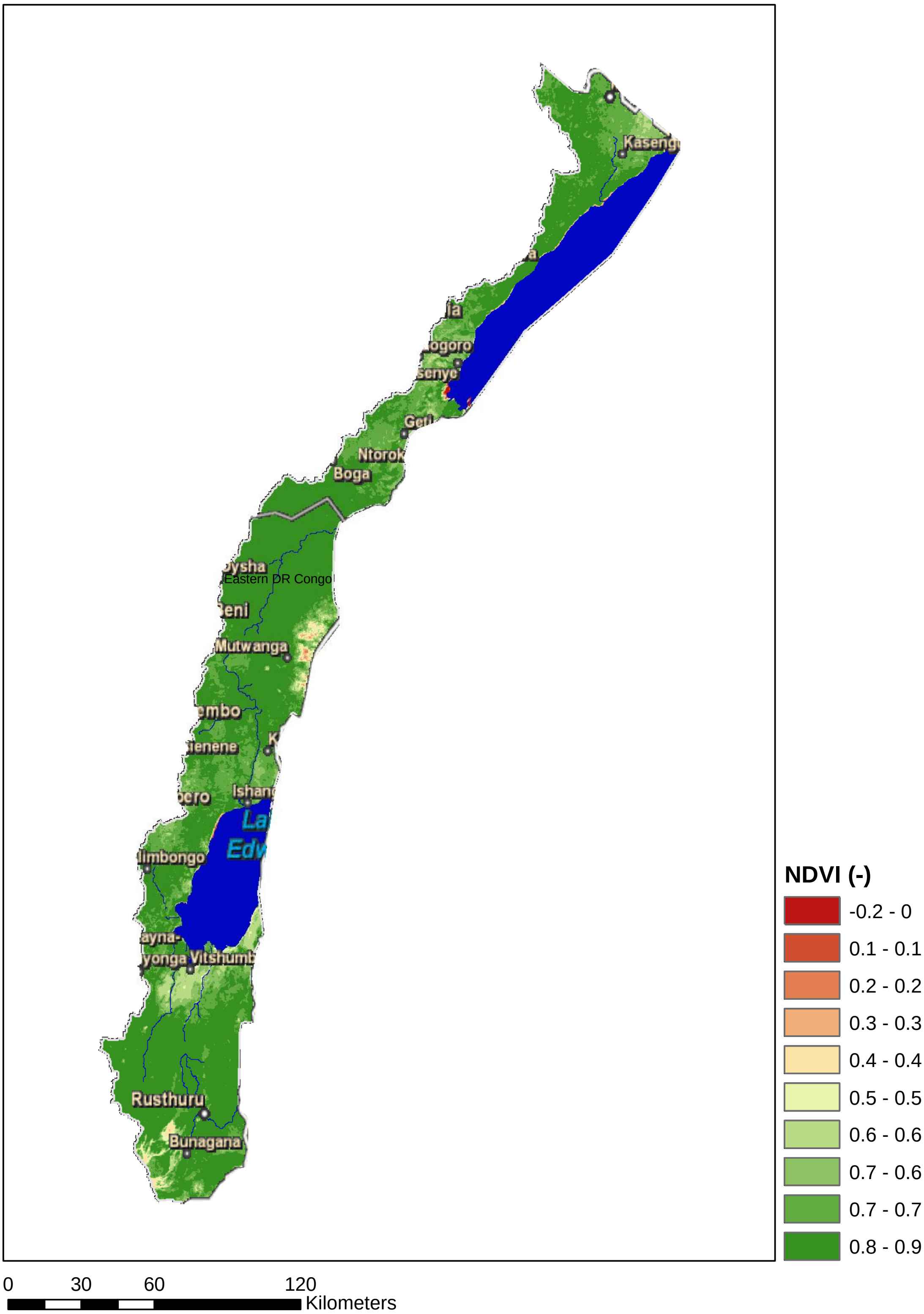


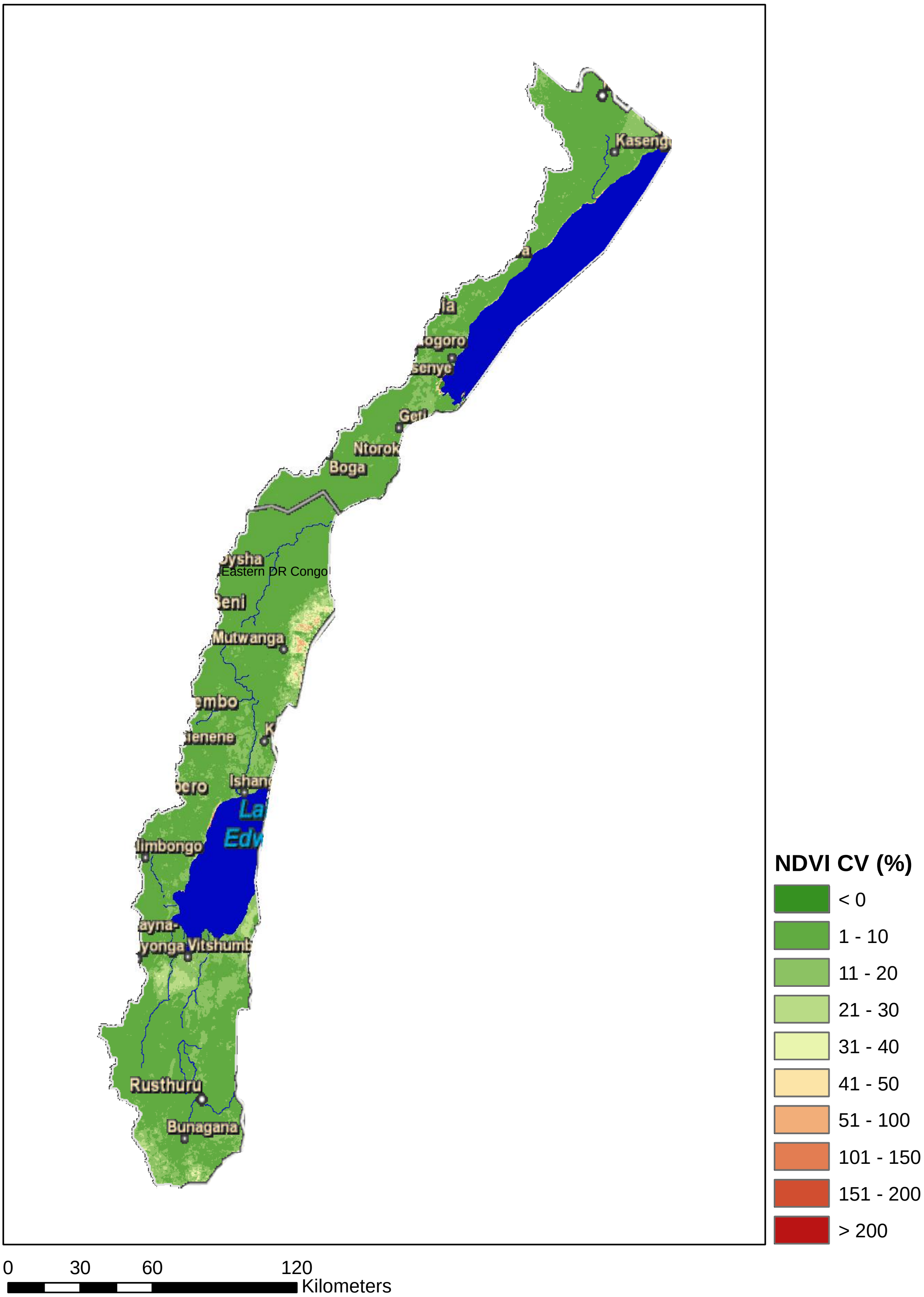
Figure 23. Irrigated (top) and rainfed cropping intensities[1] (bottom) as percentage of cells of about 10 x 10 km (Source: Mirca2000).

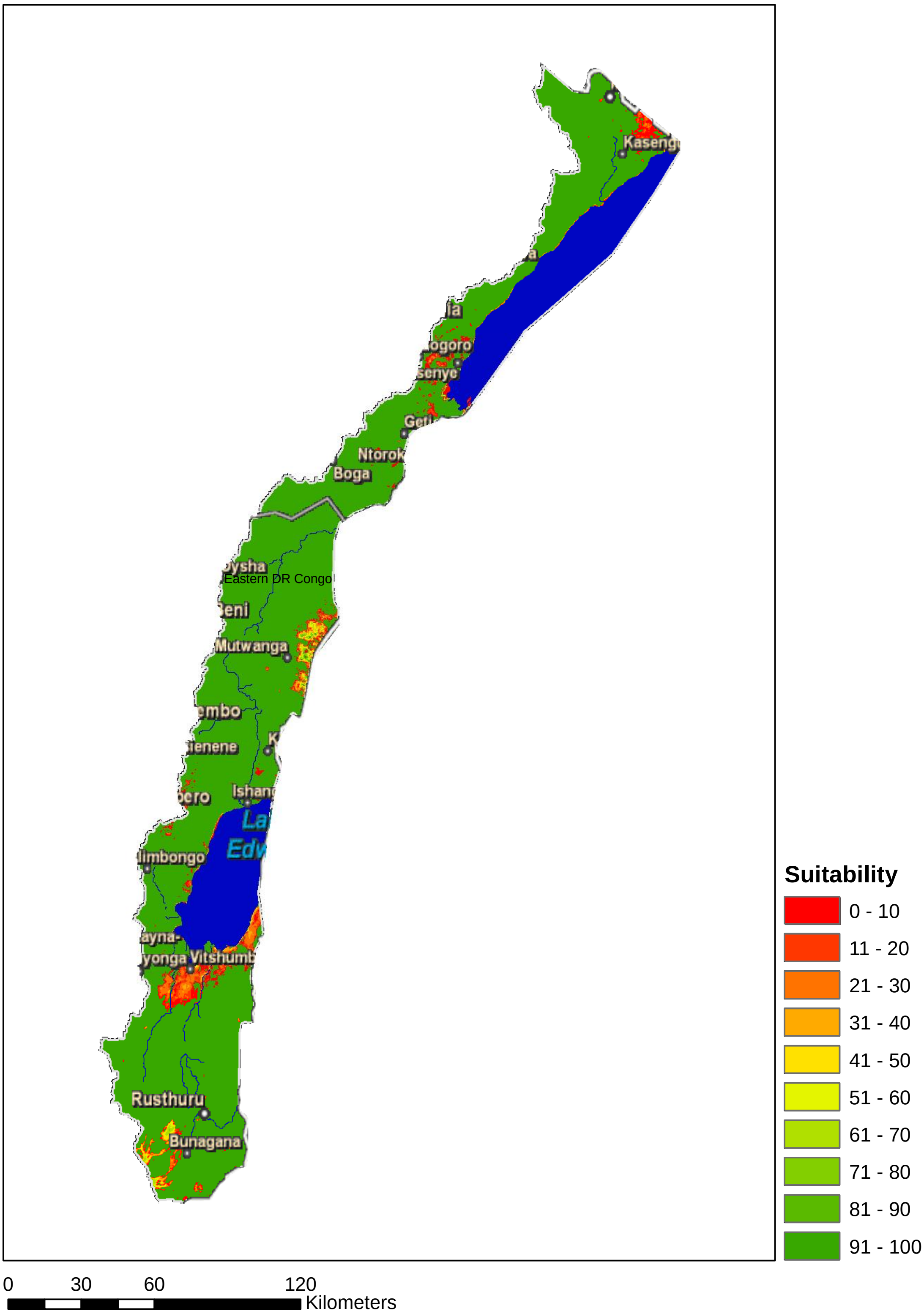
[1] Percentages can be above 100% as multiple cropping season might exist in one year.

2.3.2 *Current land productivity (NDVI)*

Current land productivity is assessed based on satellite information and and is a good proxy of all integrated features like soils, slopes, management, vegetation etc. Current land productivity in the region is high and monthly variation is limited.




Kaseng
Geti
Ntorok
Boga
Eastern DR Congo
Mutwanga
Ishan
Rusthuru
Bunagana
NDVI CV (%)
< 0
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 100
101 - 150
151 - 200
> 200
0
30
60
120
Kilometers


Kaseng
Ntorok
Boga
Eastern DR Congo
Mutwanga
Ishang
Vitshumb
Rusthuru
Bunagana
Suitability
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
0
30
60
120
Kilometers

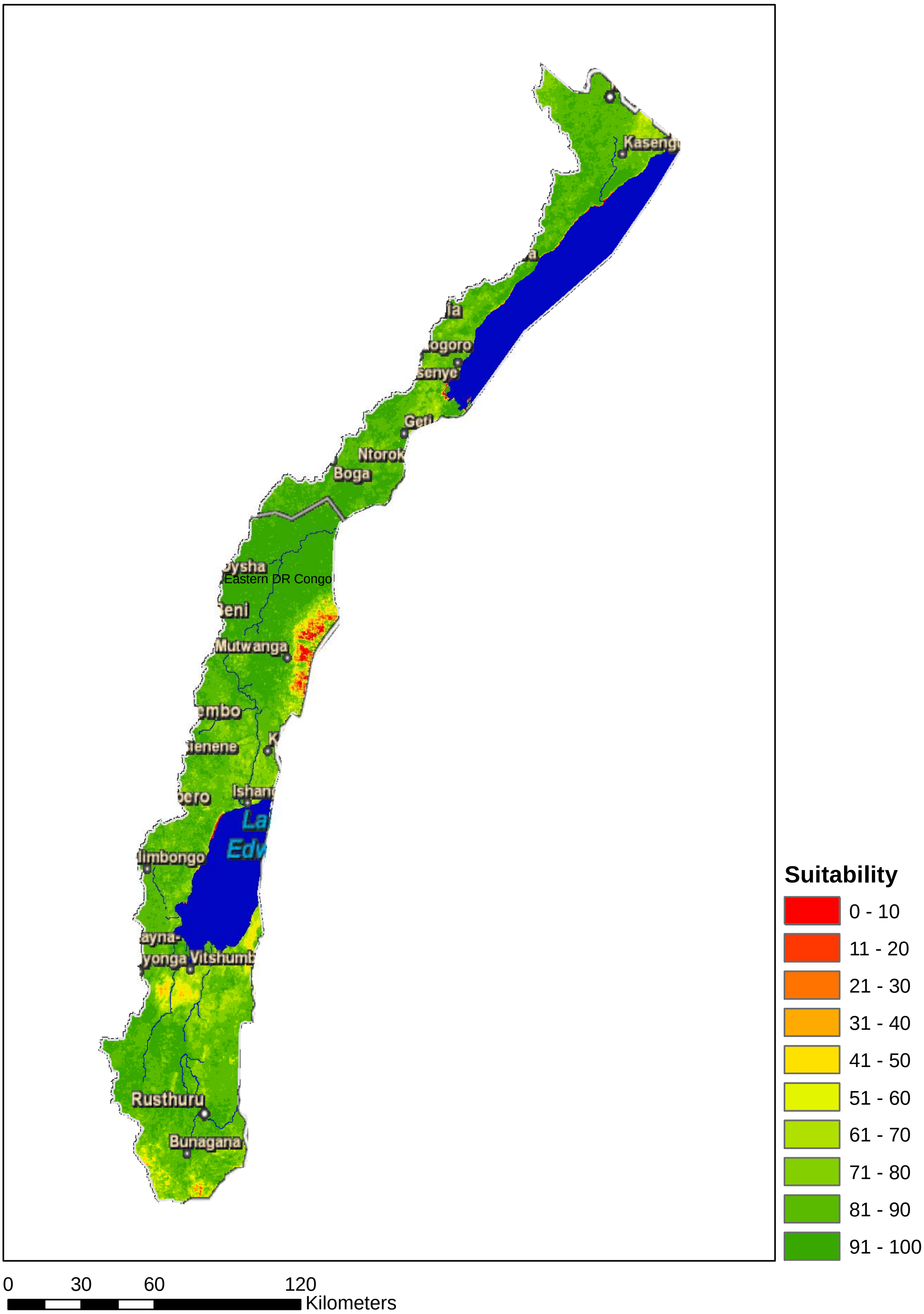


Figure 24: Current land productivity based on NDVI. Average NDVI (top), average monthly coefficient of variation (second), and the land productivity scores based on average NDVI (third) and monthly coefficient of variation (bottom).

2.4 Agriculture

2.4.1 Background

In DRC, food crops and vegetables are currently the bulk of agricultural productions through small farm families grouped in community associations located in rural, urban and sub-urban areas. Yields and crop production are low and the country depends on imports of food products to cover domestic needs. The low development rate of irrigable land resources, whose potential reaches over 7 million hectares, is one of the major factors in the persistence of low levels of agricultural production in the DRC. The lack of mastering the techniques of water harvesting and irrigation during the rainy season declines the yields in agricultural production. Initiatives to improve water retention of rainfall on rainfed upland agriculture are lacking in the DRC.

Currently the percentage of arable land in DRC is 2.9%. Permanent crops occupy an area of 0.5%. The main crops which are grown in DRC are: coffee, sugar, palm oil, rubber, tea, quinine, cassava (tapioca), palm oil, bananas, root crops, corn, fruits, and wood products.

Table 2: Area equipped for irrigation in DR Congo according to FAO-Aquastat, 2012.

DR Congo	ha
1965	N/A
1975	N/A
1985	9,000
1995	11,000
2005	11,000

2.4.2 Potential crop yield assessment

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

The regional and global yields for the five dominant crops in DRC are shown in Figure 26. Harvested area for the 10 dominant crops has increased with almost 20% over the last 30 years. Remarkable is the steep growth in yield of cassava and groundnuts reaching 115% and stabilizing at that level. Maize and paddy show the largest yield gap for DR Congo. Especially the yield of paddy is relatively low compared to some other countries.

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

	1980	1990	2000	2005	2009
Cassava	1.869.600	2.320.050	1.966.850	1.845.510	1.850.000
Maize	743.000	1.234.450	1.481.850	1.483.000	1.500.000
Groundnuts, with shell	481.500	633.334	491.003	473.149	470.000
Rice, paddy	292.900	487.190	447.417	417.854	420.000
Plantains	312.500	430.326	263.116	265.603	270.000
Beans, dry	174.100	232.440	225.508	203.882	210.000
Oil palm fruit	184.400	232.120	200.000	161.605	175.000
Melonseed	61.500	77.000	75.707	91.082	91.436
Bananas	87.100	105.930	83.489	84.017	85.000
Cow peas, dry	76.800	80.000	95.000	124.955	68.334
Total	4.283.400	5.832.840	5.329.940	5.150.657	5.139.770

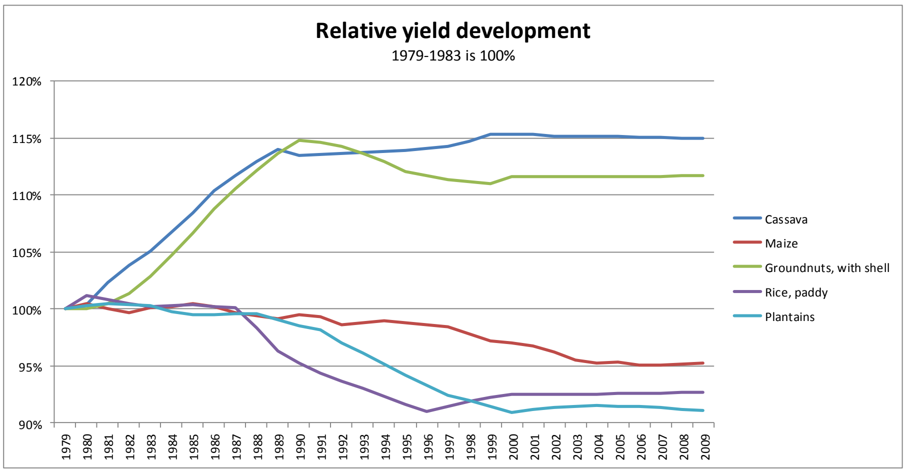


Figure 25. Trend in yields per ha for the five most dominant crops. Average of first five years has been indexed to 100%. (FAOstat, 2010).

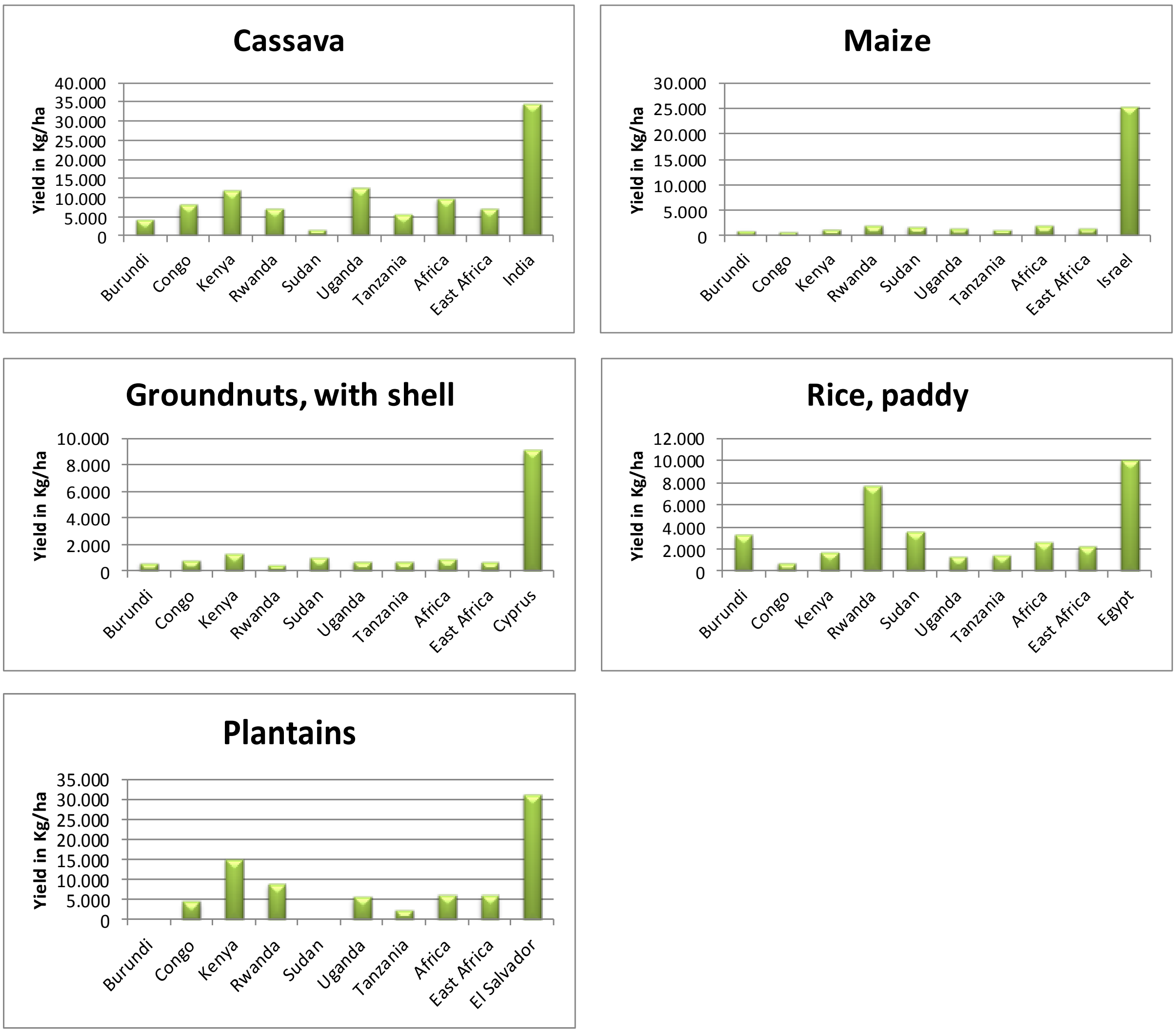
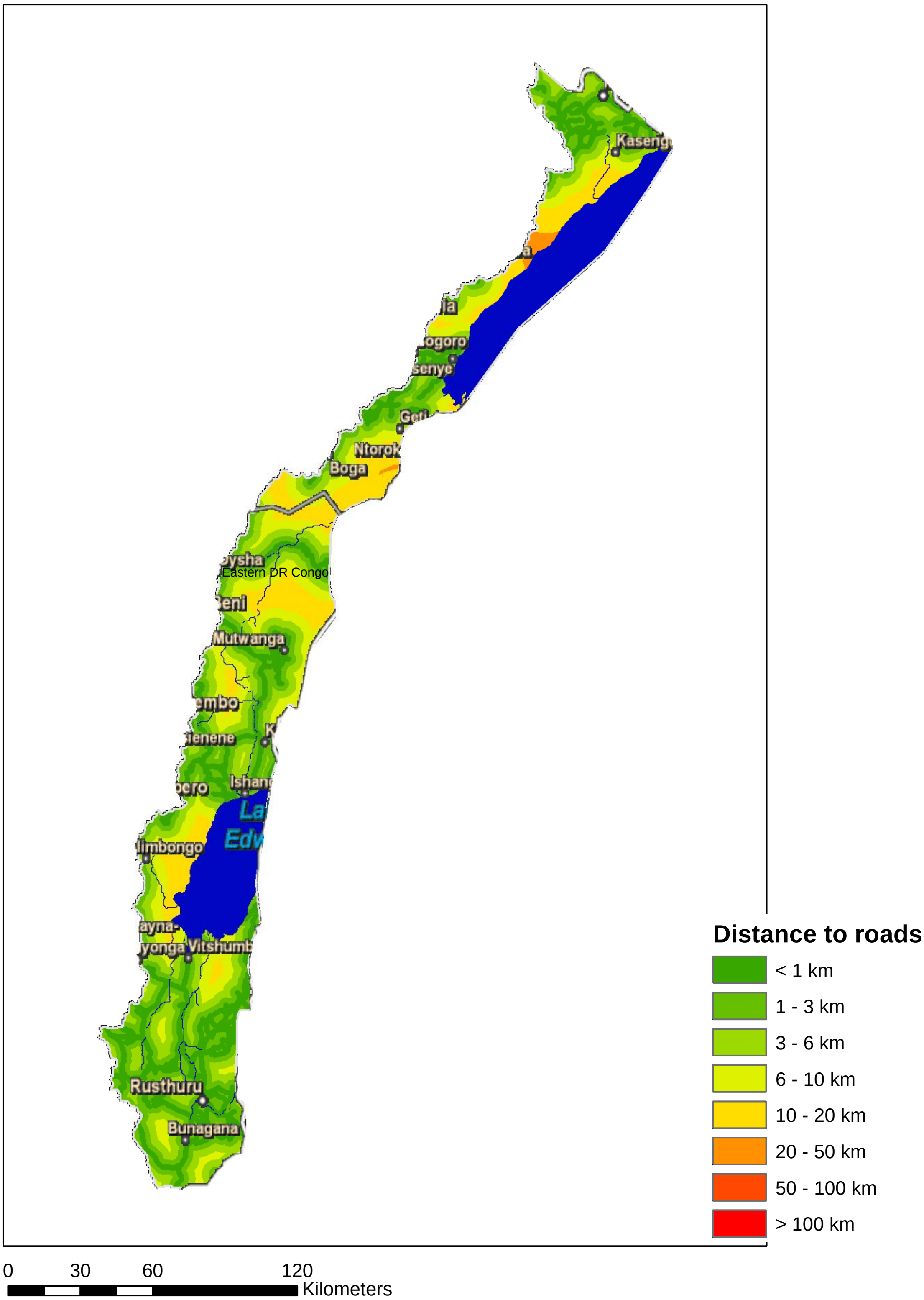


Figure 26. Yield comparison for the five dominant crops in the country. (FAOstat, 2010).

2.5 Infrastructure

2.5.1 Access to transportation

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


Boga
Eastern DR Congo
Mutwanga
Rusthuru
Bunagana
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
30
60
120
Kilometers

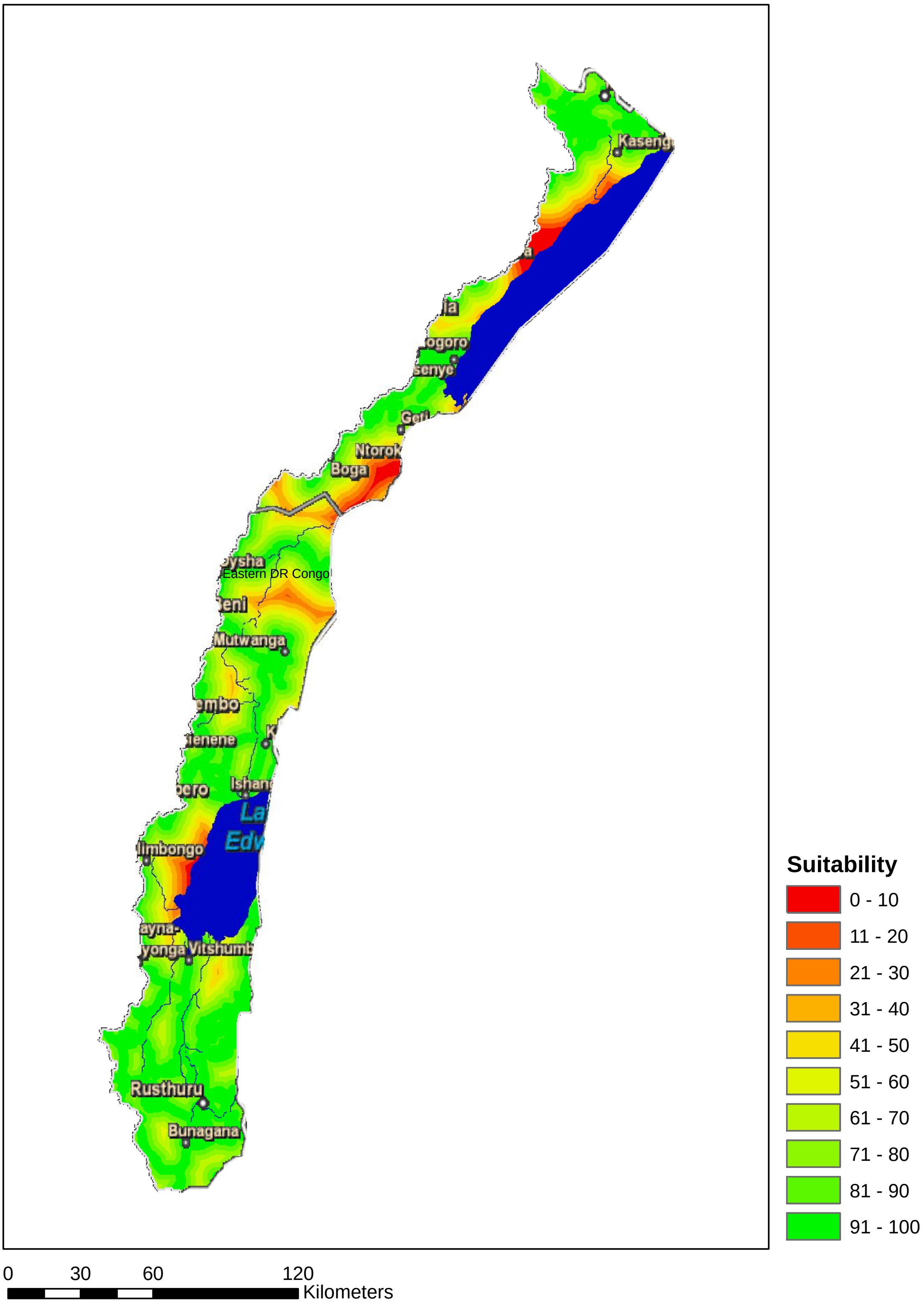
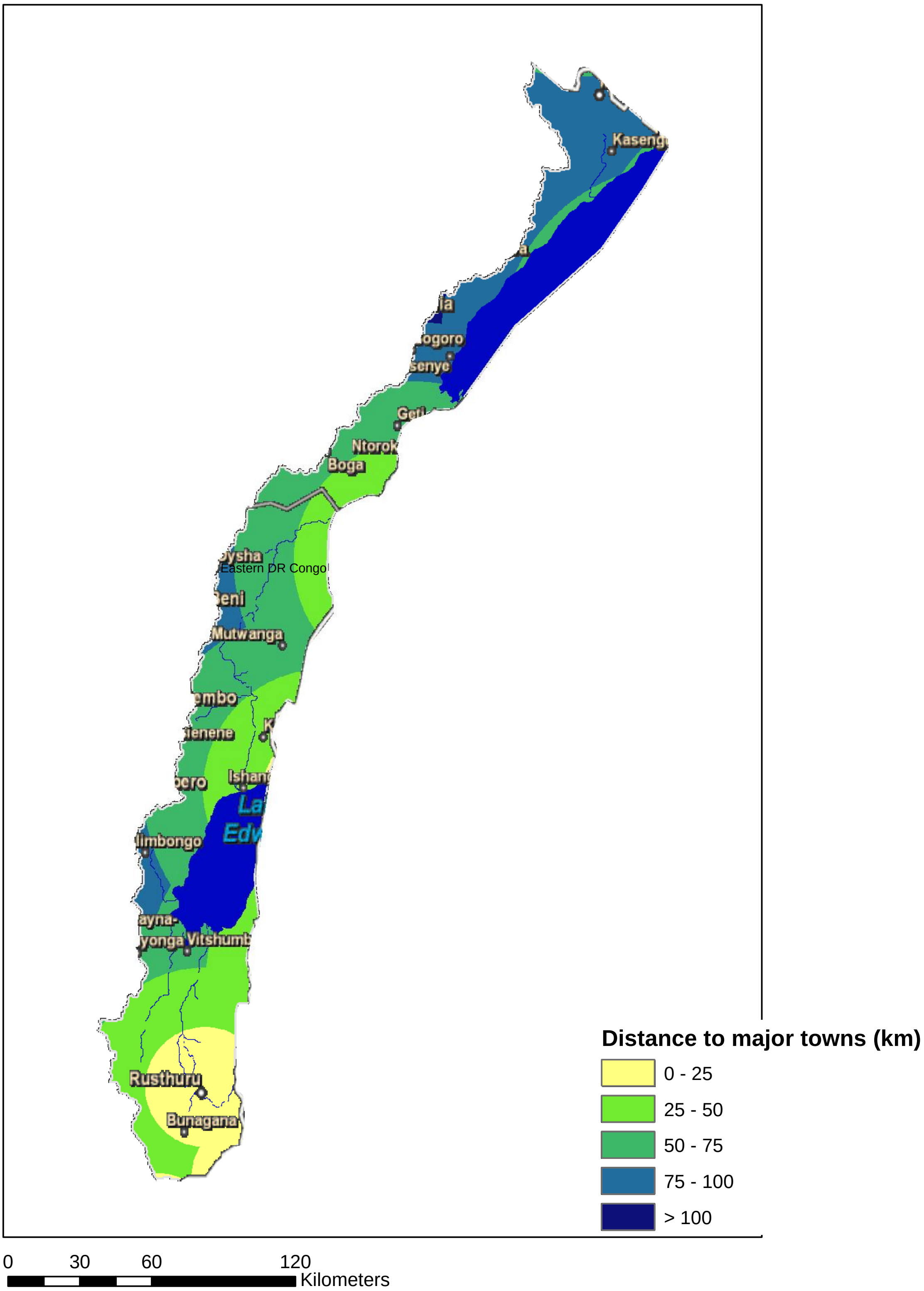
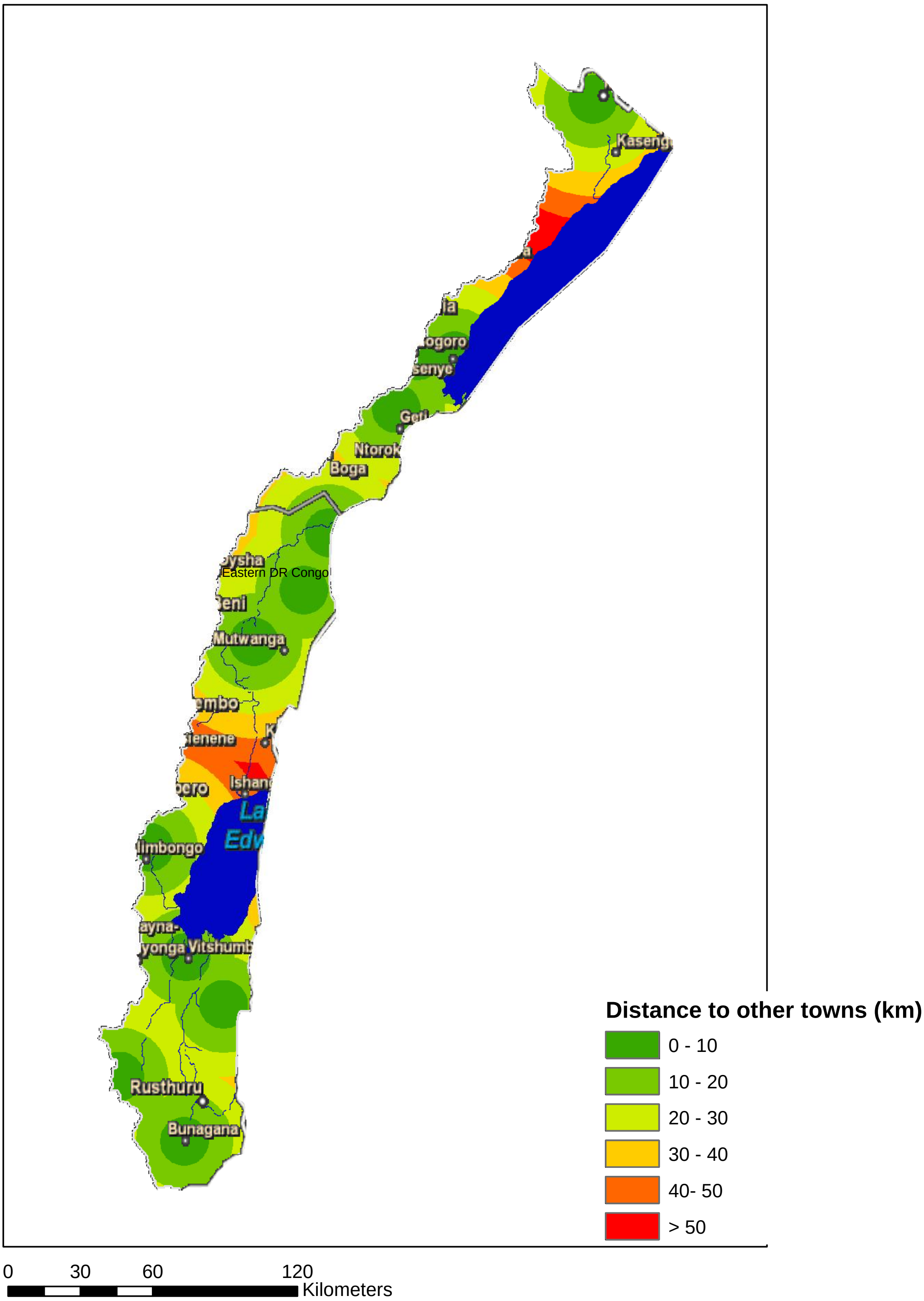


Figure 27: Distance to transportation (top), and suitability (bottom).

2.5.2 *Access to markets*

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




Boga
Eastern DR Congo
Mutwanga
Rusthuru
Bunagana
Distance to other towns (km)
0 - 10
10 - 20
20 - 30
30 - 40
40- 50
> 50
0
30
60
120
Kilometers

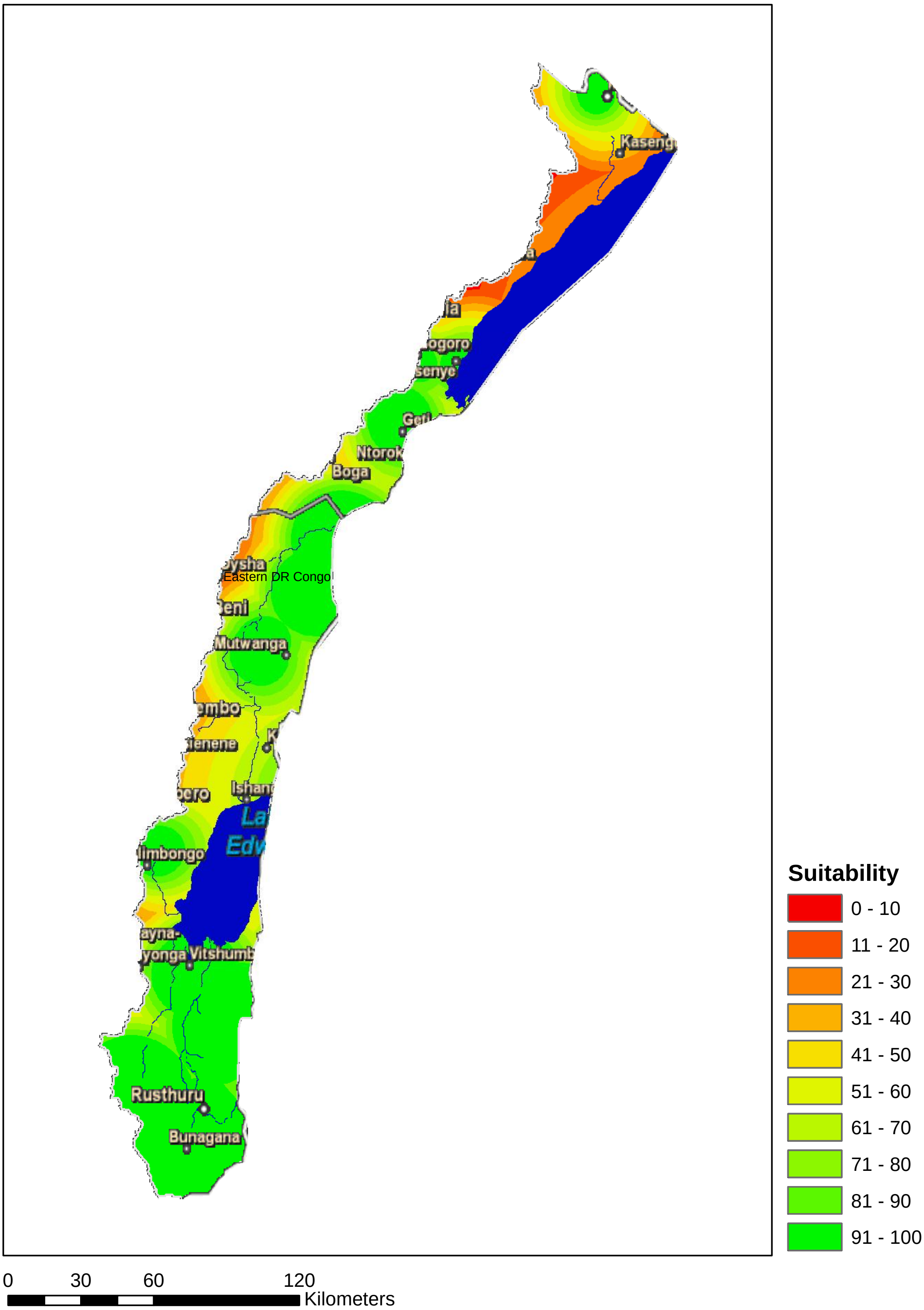


Figure 28: Distance to major towns (top), distance to other towns (middle), and combined suitability index (bottom).

2.6 Population density

Population density should be considered in the context of irrigation. Highly-dens populated areas are not suitable for irrigation. On the contrary, areas where hardly anybody lives might face difficulties in terms of labor and markets. Population density can be observed in the following figure. Overall, population density is relatively low in the region.

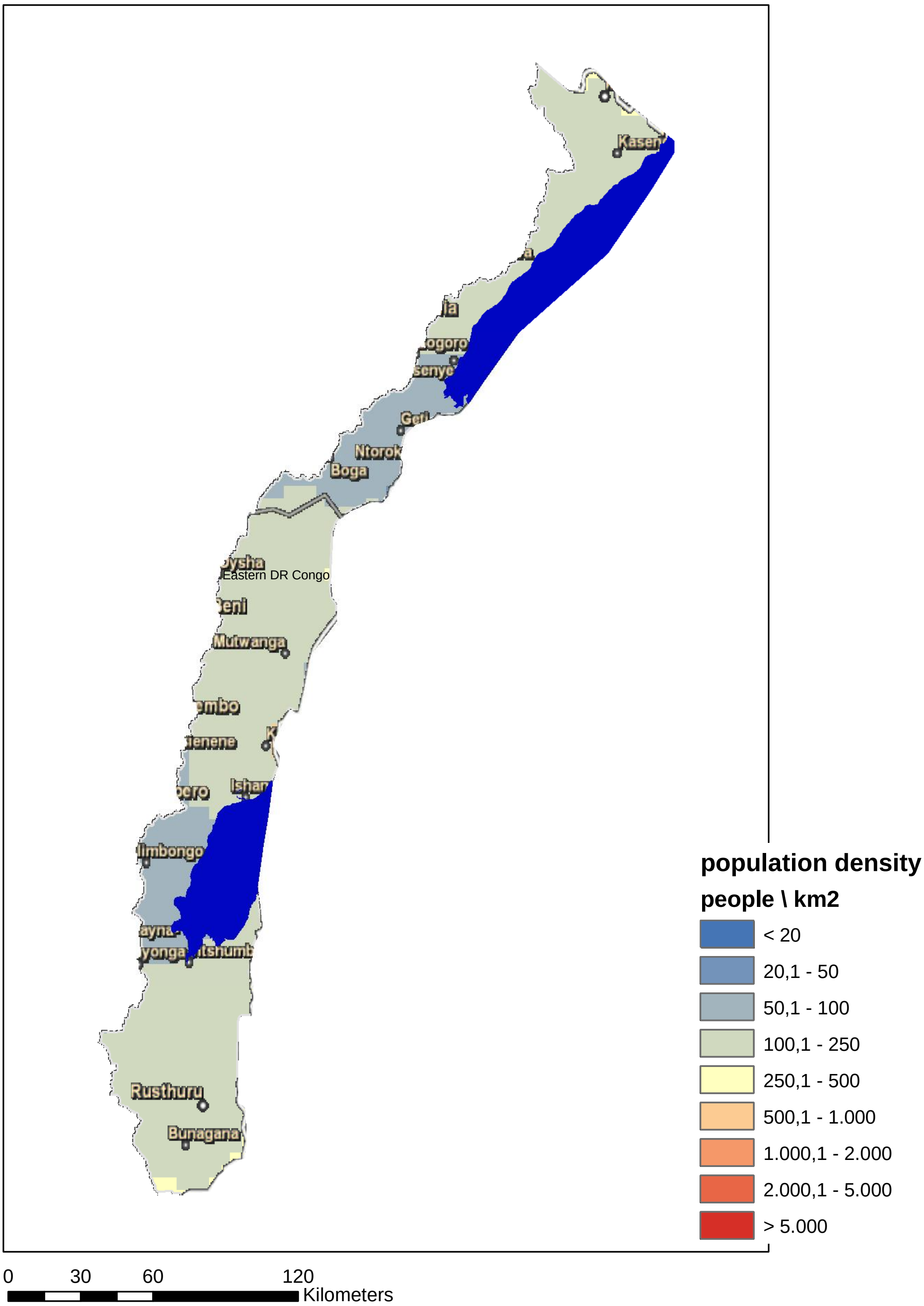


Figure 29: Population density distribution (source: CIESIN).

2.7 Irrigation potential

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

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

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

Based on these maps, the final score indicating suitable for irrigation can be observed in Figure 30 and Table 4. Scores above 60% can be considered as potential suitable for irrigation, while scores above 70% can be considered as very suitable with only minor limitations. The overall suitability for the country is determined at about 124 thousand hectare. In order to assess what limitations are in a certain areas, information from the previous sections can be used.

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

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

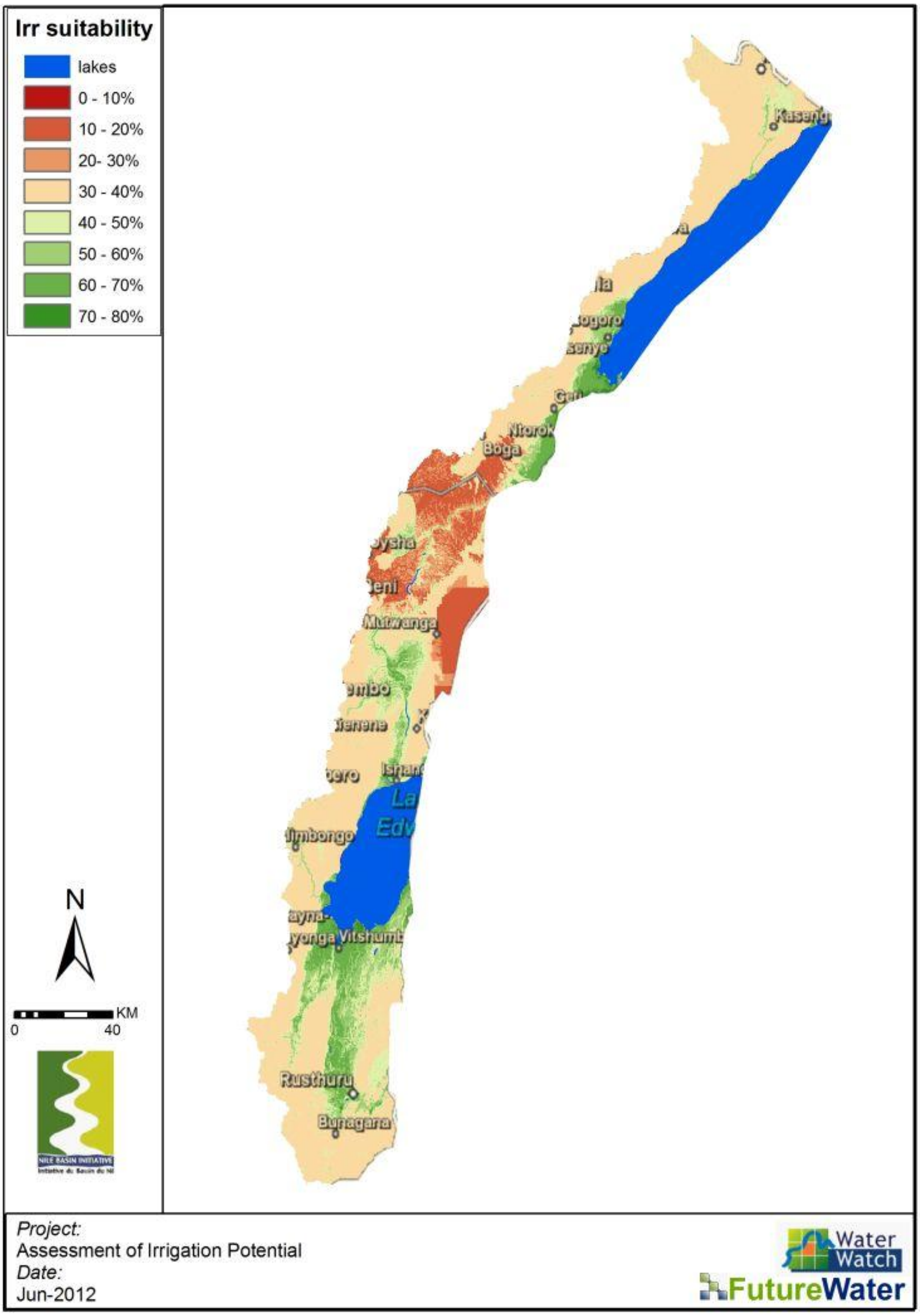


Figure 30: Irrigation suitability score

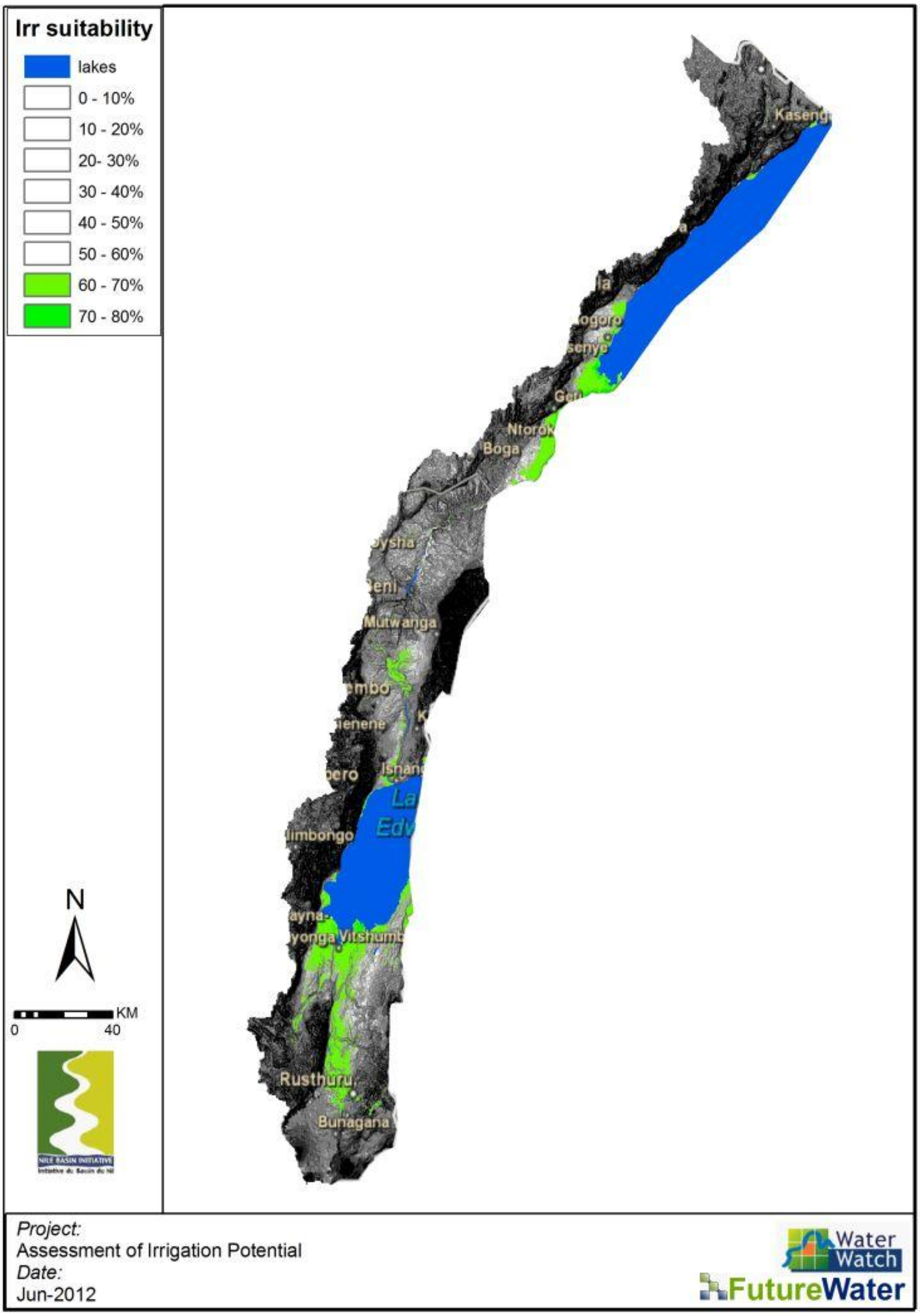


Figure 31. Final map indicating areas suitability for irrigation.

Table 4. Suitability classes.

Suitability	Irrigation potential (ha)
0 - 10%	1,756
10 - 20%	144,938
20 - 30%	69,744
30 - 40%	914,050
40 - 50%	203,800
50 - 60%	145,444
60 - 70%	113,469
70 - 80%	10,956
80 - 90%	0
90 - 100%	0
Total >60%	124,425

2.7.1 Focal areas

Based on the results from the first phase of the irrigation potential study and the local available expert knowledge and political considerations five focal areas have been delineated on which the second phase will focus. In the following chapters these focal areas will be studied on a more detailed level, and the possibilities for irrigation development will be described. In Table 5 the names and areas are given, and in Figure 32 a map is supplied on which the focal areas are shown.

Table 5: Focal areas Eastern DRC[1]

	Bilukwa	Boga	Abia Tungudu	Kitoba Lubango	Rutshuru Mutabo
Area in ha	1259	9361	4358	5664	7291

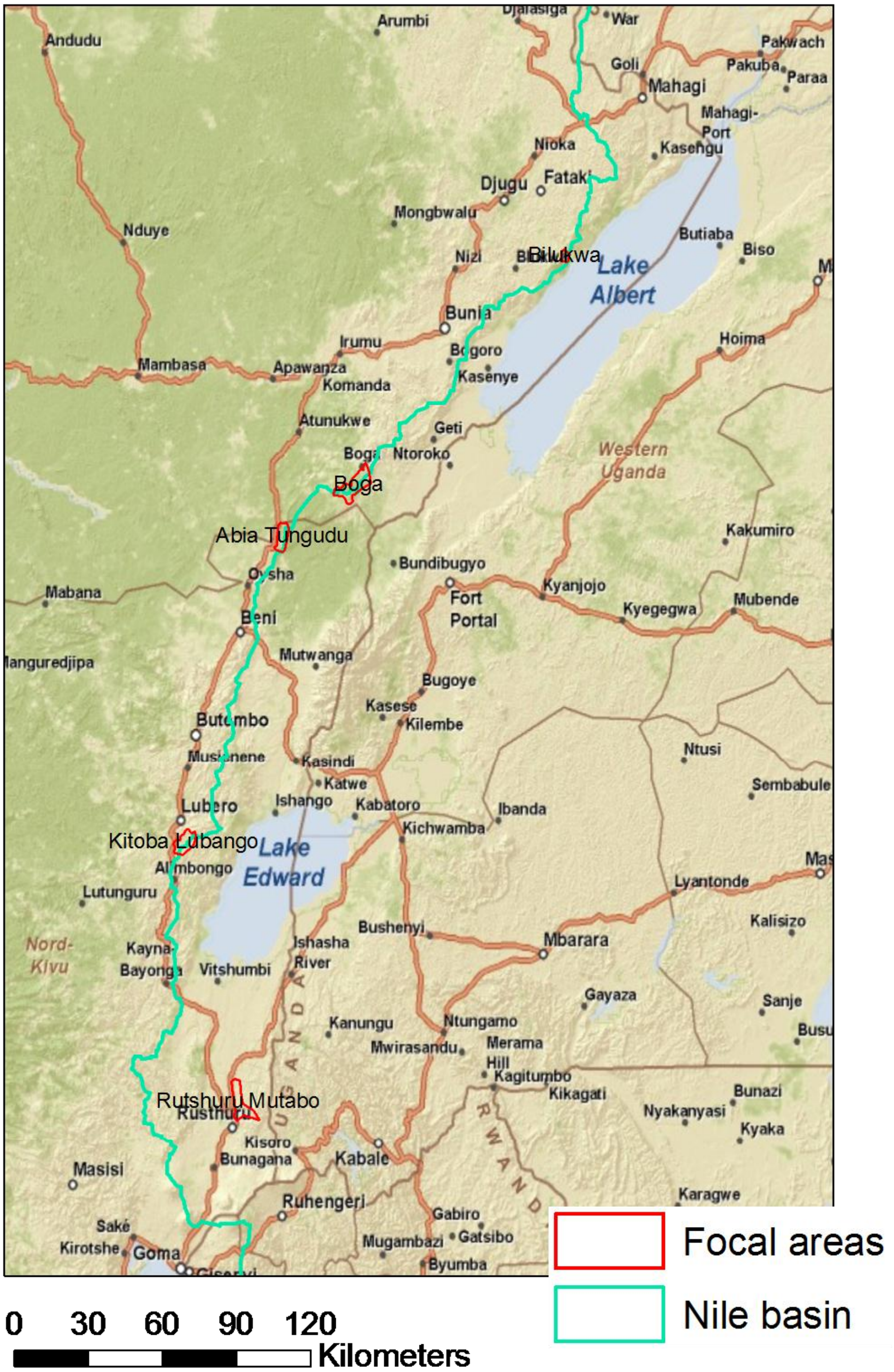


Figure 32: Overview focal areas Eastern DRC

[1] Rutshuru-Mutabo is also referred to as Nsinda-Mutabo.

3 Bilukwa focal area

3.1 Introduction

This chapter will describe the current state of the Bilukwa focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 34 a detailed map of the area is given. Total area is 1260 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 Kasende Taombo Pierrot and supervised by Henri Okitolembo, Bruno Matata, and Isaac Mutela in April and May 2012.

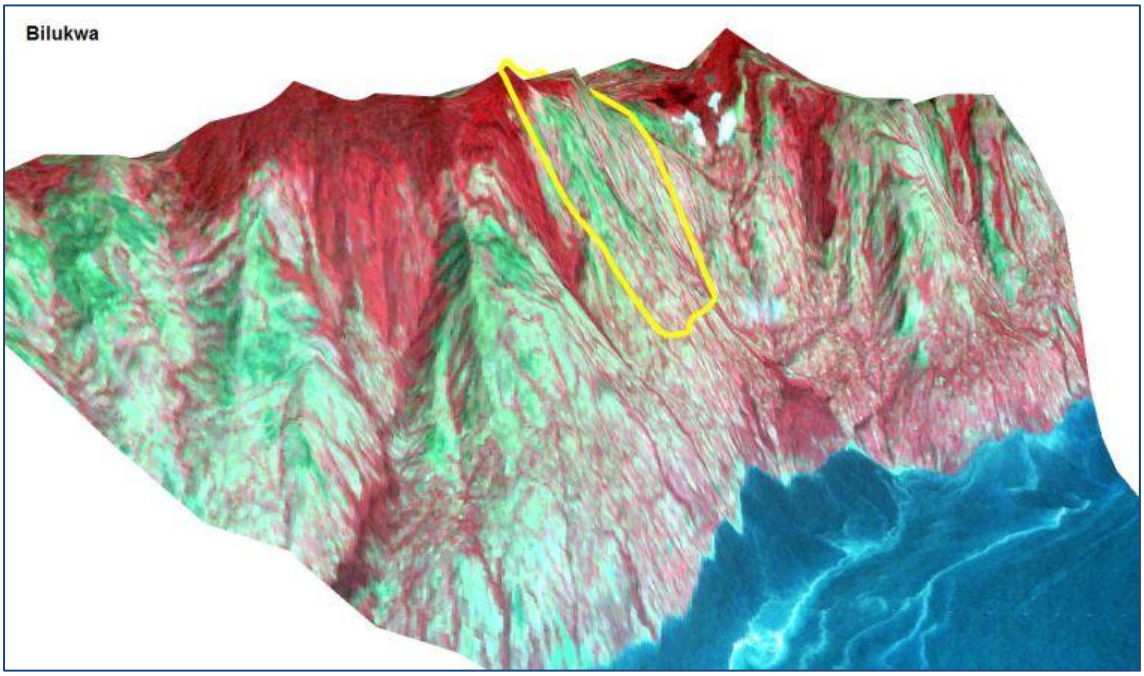
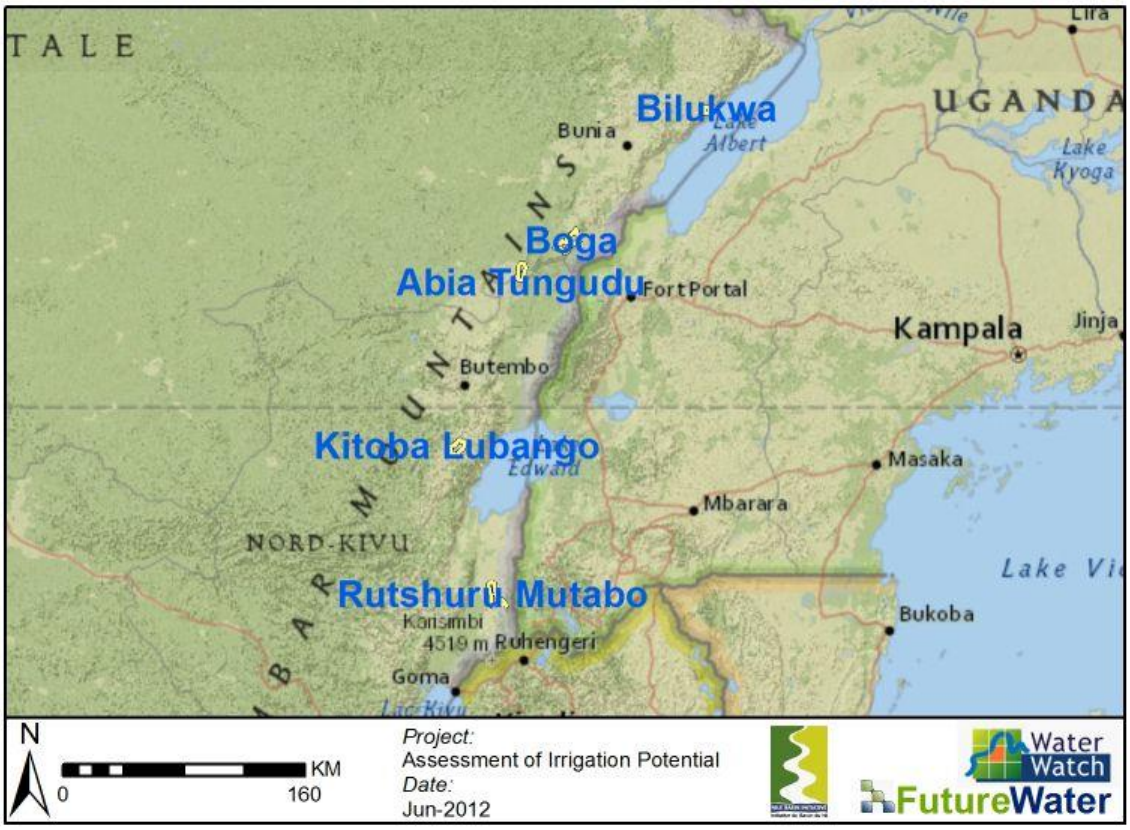


Figure 33: 3D impression of Bilukwa focal area, Eastern DRC



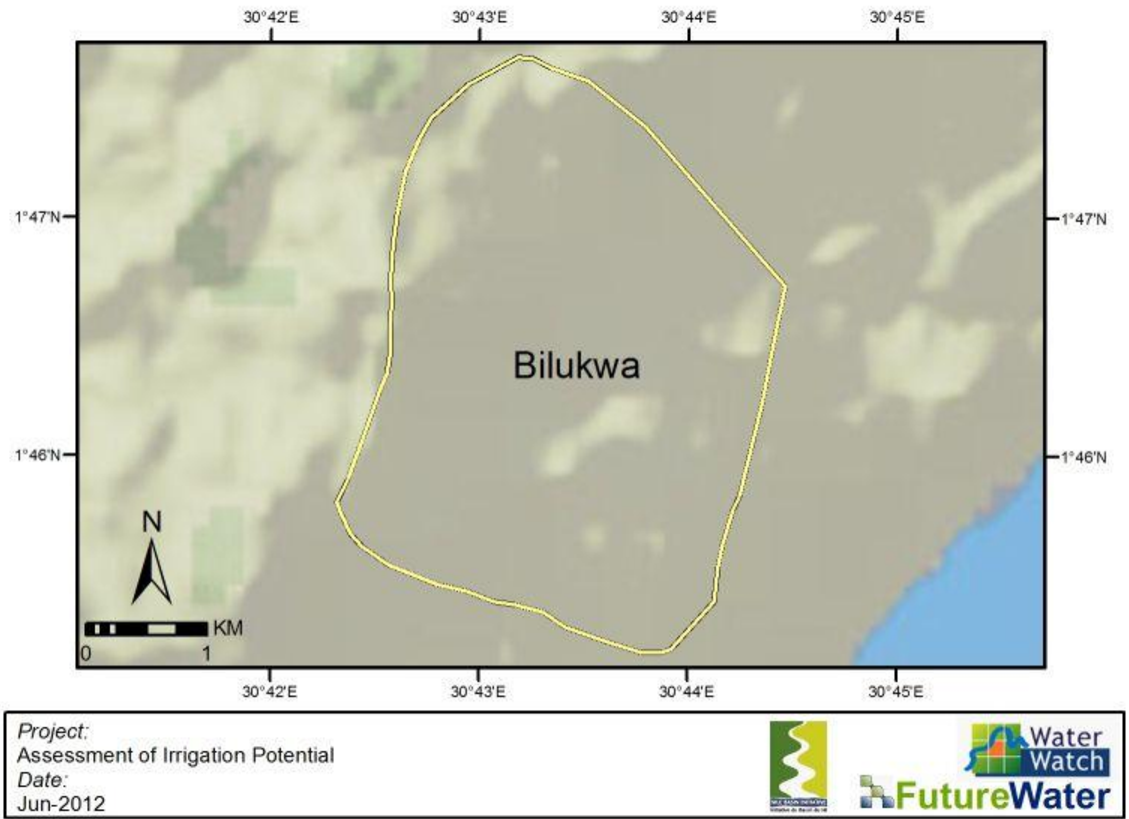


Figure 34: Bilukwa focal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC

3.2 Land suitability assessment

3.2.1 Terrain

Bilukwa is located in the village of Bilukwa in Mahagi territory in the district of Ituri, in Orientale Province, north - east of the Democratic Republic of Congo. Bilukwa is squeezed between the boundary of the Nile basin on the western side, and Lake Albert on the eastern side. Therefore, the focal area descends from the water divide in the west (2200 m) towards the lake (615 m). This is a large elevation difference (Figure 33 + Figure 35). Slopes range largely within the area, but are generally quite steep. Slopes reach to over 50% on some places, and even on the more 'moderate' places they are mostly still around 20% (Figure 36). This makes that the terrain is rather fragmented in topography and agricultural potential. The total area of the focal area is 1259 ha, which is the smallest of all DRC's focal areas.

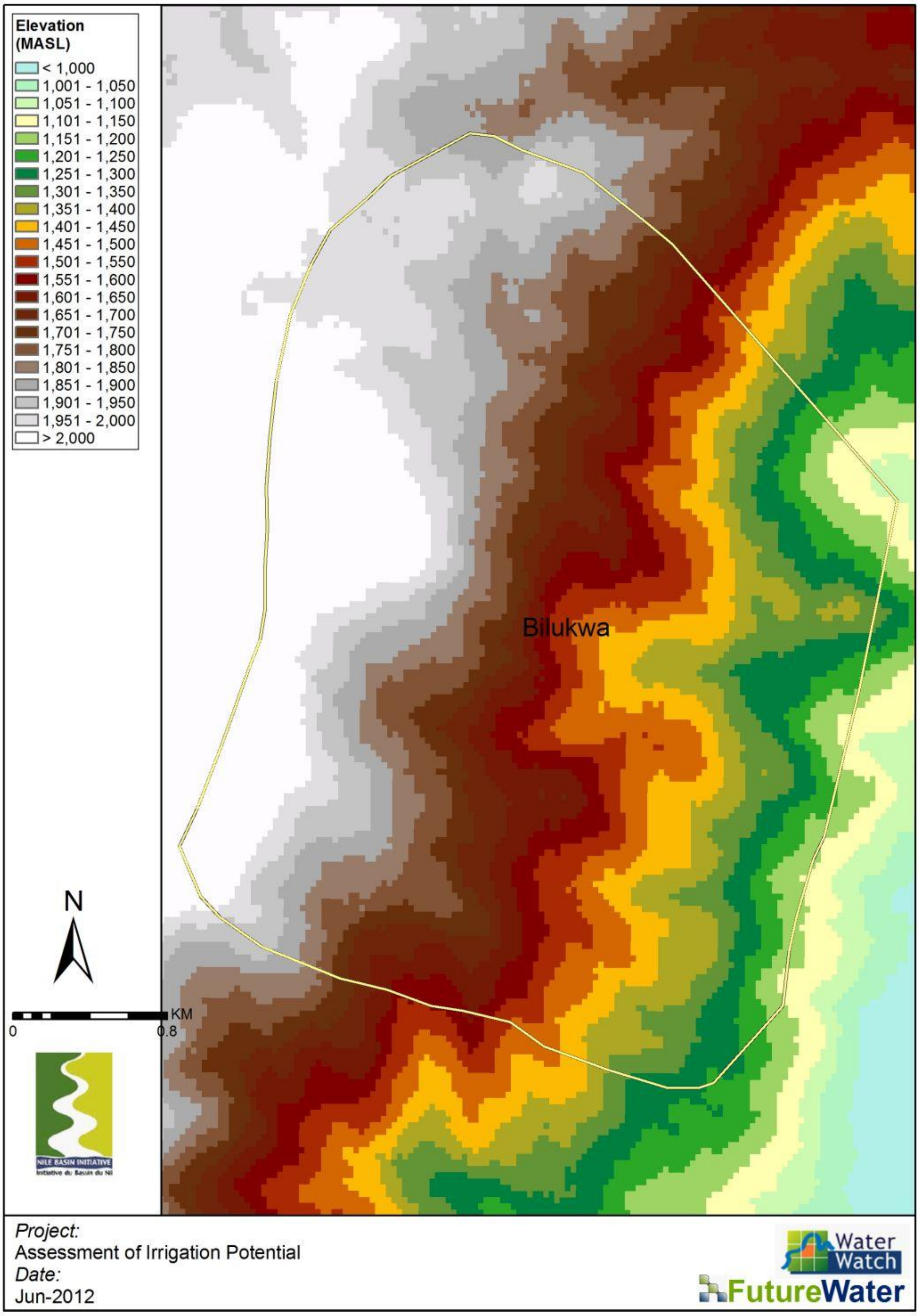


Figure 35: DEM Bilukwa focal area. Resolution 1 arc second (+/- 30m).

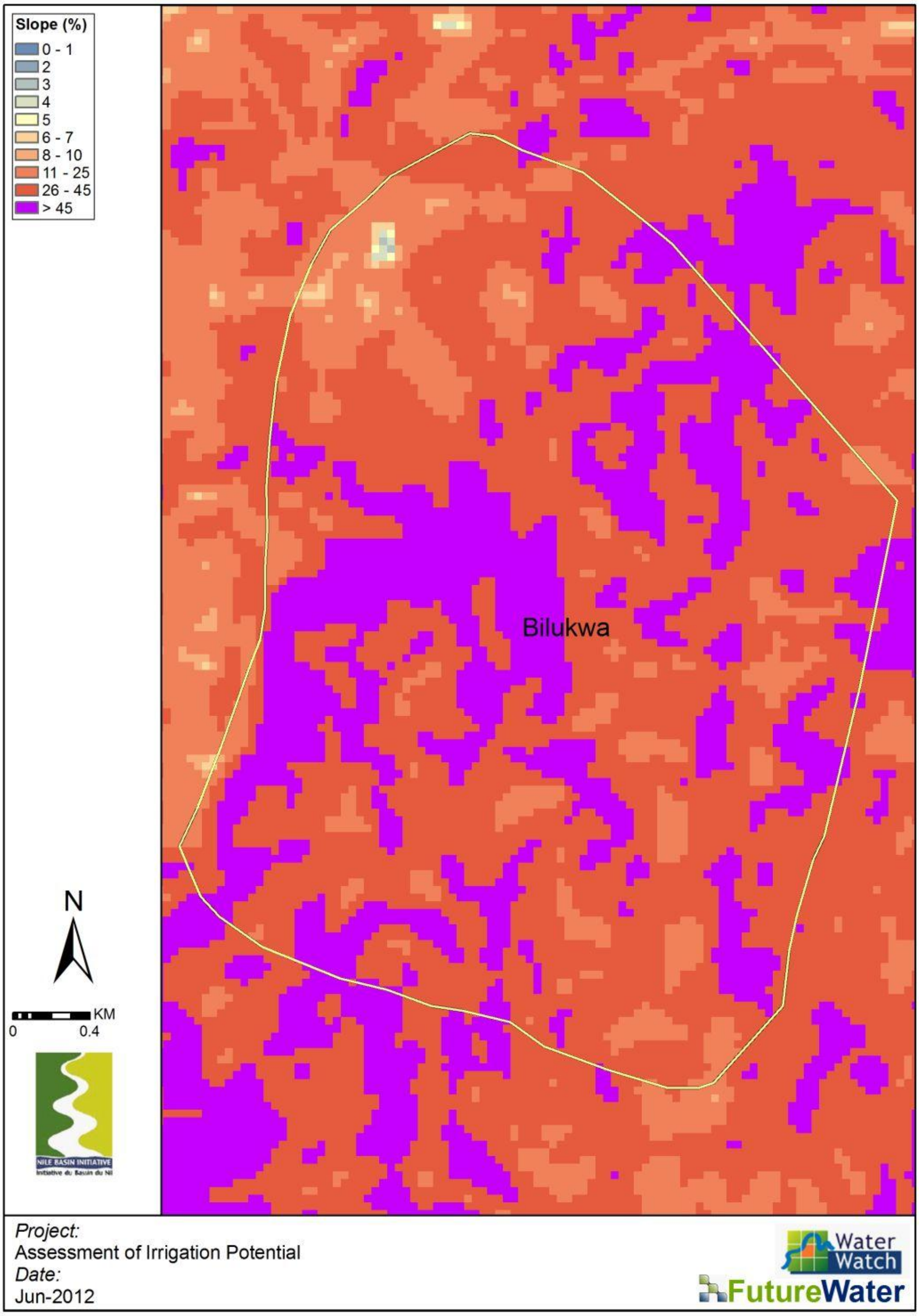


Figure 36: Slope map Bilukwa focal area (source: ASTER).

3.2.2 Soil

The soil in the focal area is loamy. The drainage of the soil is rather poor to well drained, and depends on the exact location. The top soil is relatively poor in organic carbon (1%). The overall water holding capacity is surprisingly well for a Ferralsol, with over 150 mm/m. Ferralsols represent the classical, deeply weathered, red or yellow soils of the humid tropics. These soils have diffuse horizon boundaries, a clay assemblage dominated by low-activity clays (mainly kaolinite), and a high content of sesquioxides. The soil is typically formed during the Pleistocene or before. 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. The chemical fertility of Ferralsols is poor; weatherable minerals are scarce or absent, and cat ion retention by the mineral soil fraction is weak. The bulk of all cycling plant nutrients are contained in the biomass; available plant nutrients in the soil are concentrated in the soil organic matter. If the process of nutrient cycling is interrupted, e.g. upon introduction of low-input sedentary subsistence farming, the root zone will rapidly become depleted of plant nutrients. 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. Fertilizer selection, and the mode and timing of fertilizer application determine to a great extent the success of agriculture on Ferralsols.

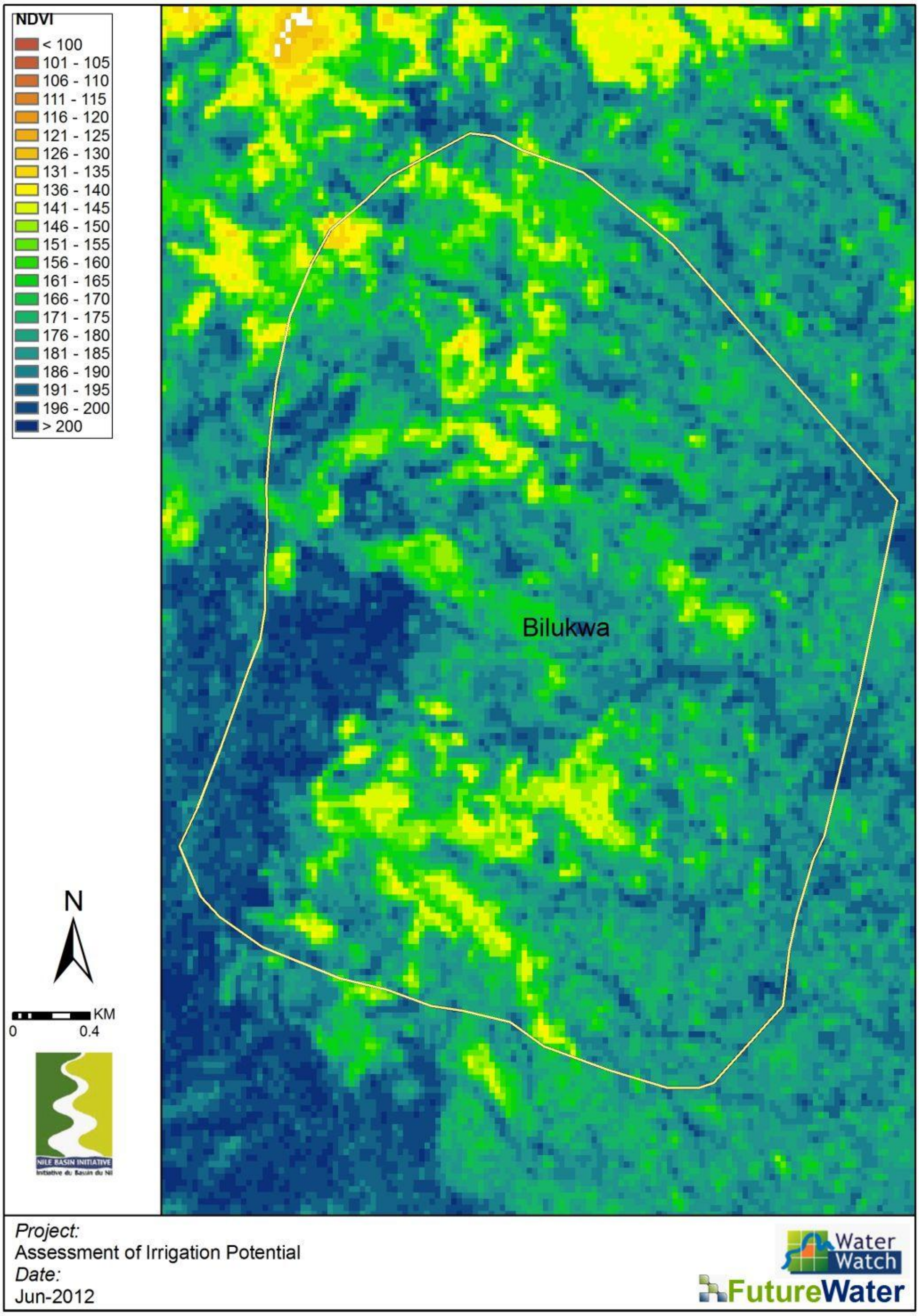


Figure 37: Yearly average NDVI values for BILUKWA focal area.

3.2.3 Land productivity

The land productivity (NDVI) in the five DRC focal areas ranges between 0.66 and 0.83. Compared to the DRC average NDVI of 0.59, all the focal areas have relative high land productivity values. Within the Bilukwa focal area, the land productivity is 0.76, and around the focal area even higher values can be found. Land productivity tends to be higher on the flatter land surrounding Lake Edward. The annual variation in land productivity is in general quite low. The lowest coefficient-of-variation can be found at the lake shores. The very steep areas have a slightly lower NDVI, and a slightly higher variation compared to surrounding areas. The highest variation can be found within the un-deep waters of the lake where the NDVI is very small.

3.2.4 Potential cropping patterns

Current cropping patterns include mainly maize, green beans, bananas and cassava. In total, approximately 10% of the focal area is used for agriculture and mainly in the lower land, which is closer to Lake Albert. Main crops are maize and green beans, which are, according to field visits, both grown on 80% of the agricultural area. This suggests that both crops are grown simultaneously on the same field. Both crops are grown in two growing cycles per year, one starting in August, and one in February. Further are bananas growing on 3% of the agricultural area, and cassava on 5%. Potential future cropping patterns include cabbage, onions and pineapple. These are all crops with a much higher return, which can stimulate the local economy and reduce poverty. Cabbage can be grown year through, and give at least two harvests each year. The same is true for pineapple. Onions can be grown in two growing cycles per year. It is advised to focus on cabbage and pineapple and to keep some bananas and cassava.

3.3 Water resource assessment

3.3.1 Climate

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

The climate of the area can be characterized as relatively warm with constant temperatures during the year ranging from about 17^{o}C to 28^{o}C. Annual average precipitation is 1165 mm and reference evapotranspiration 1382 mm per year.

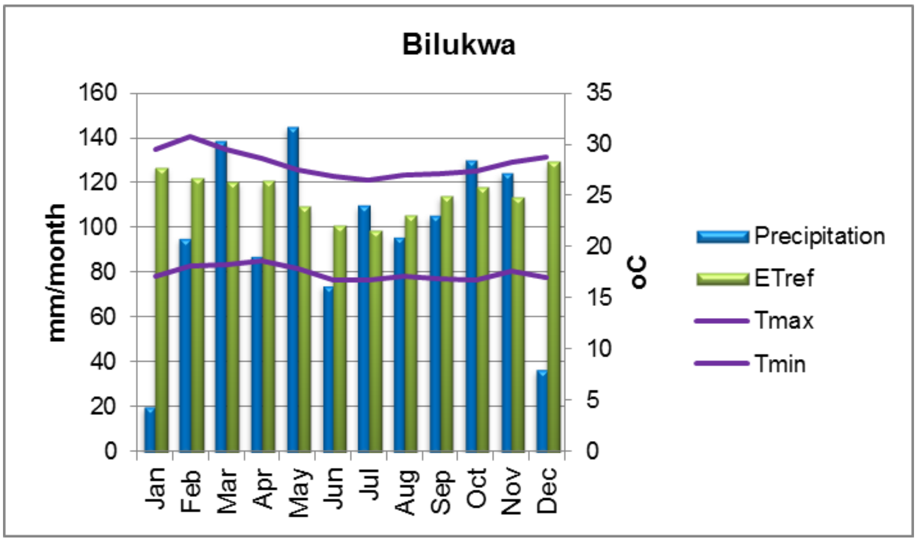


Figure 38: Average climate conditions for the focal area.

3.3.2 Water balance

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

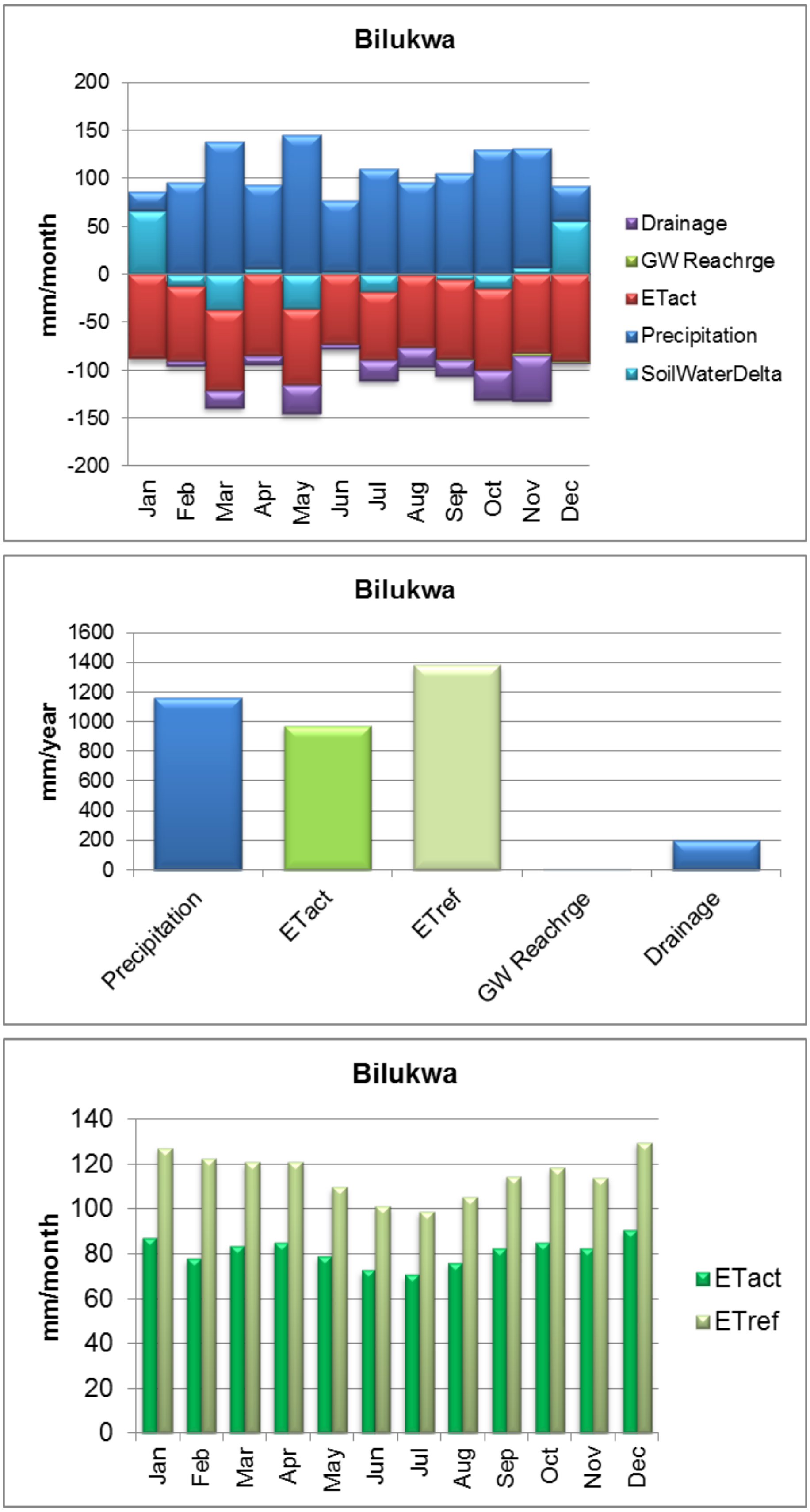
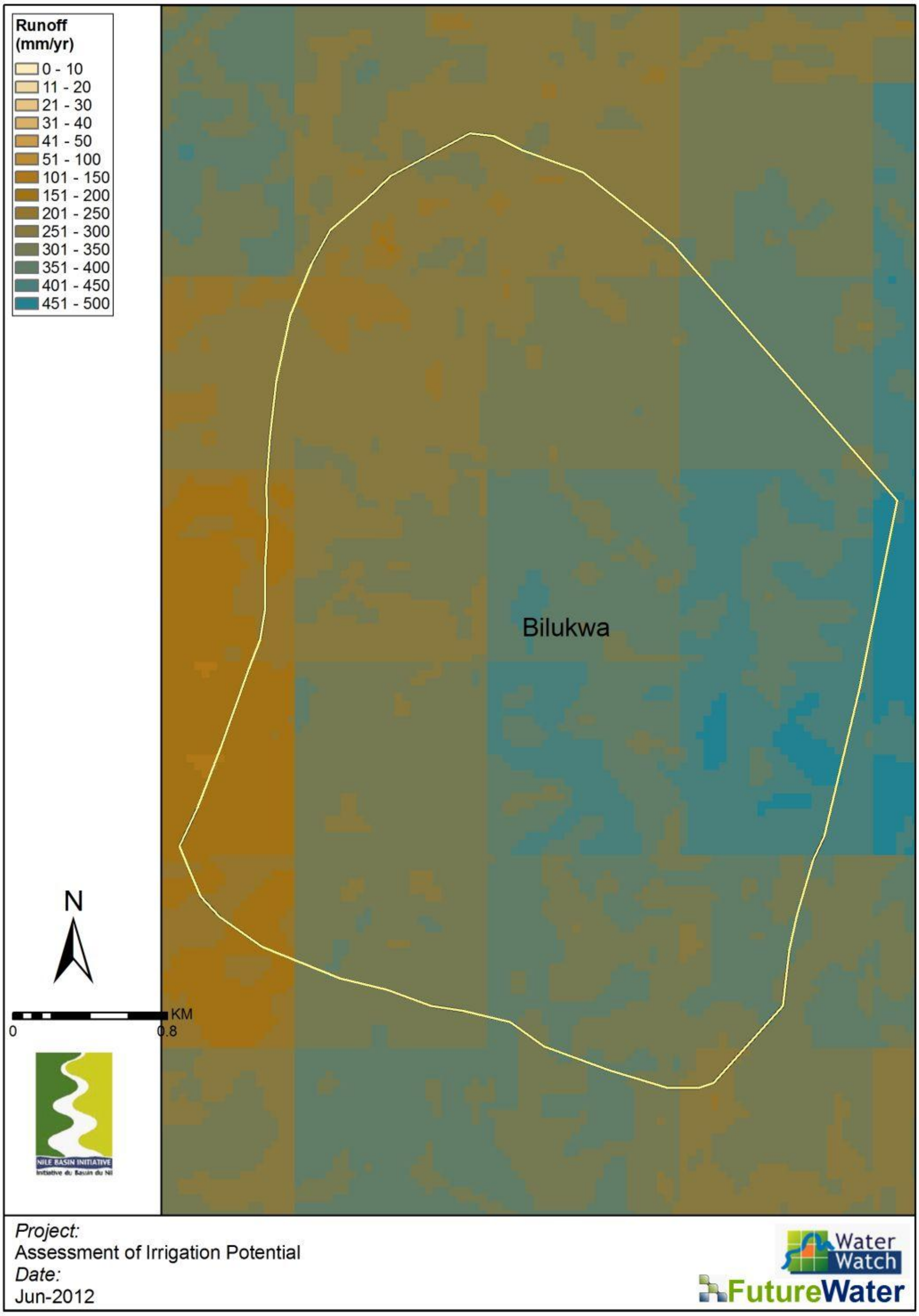
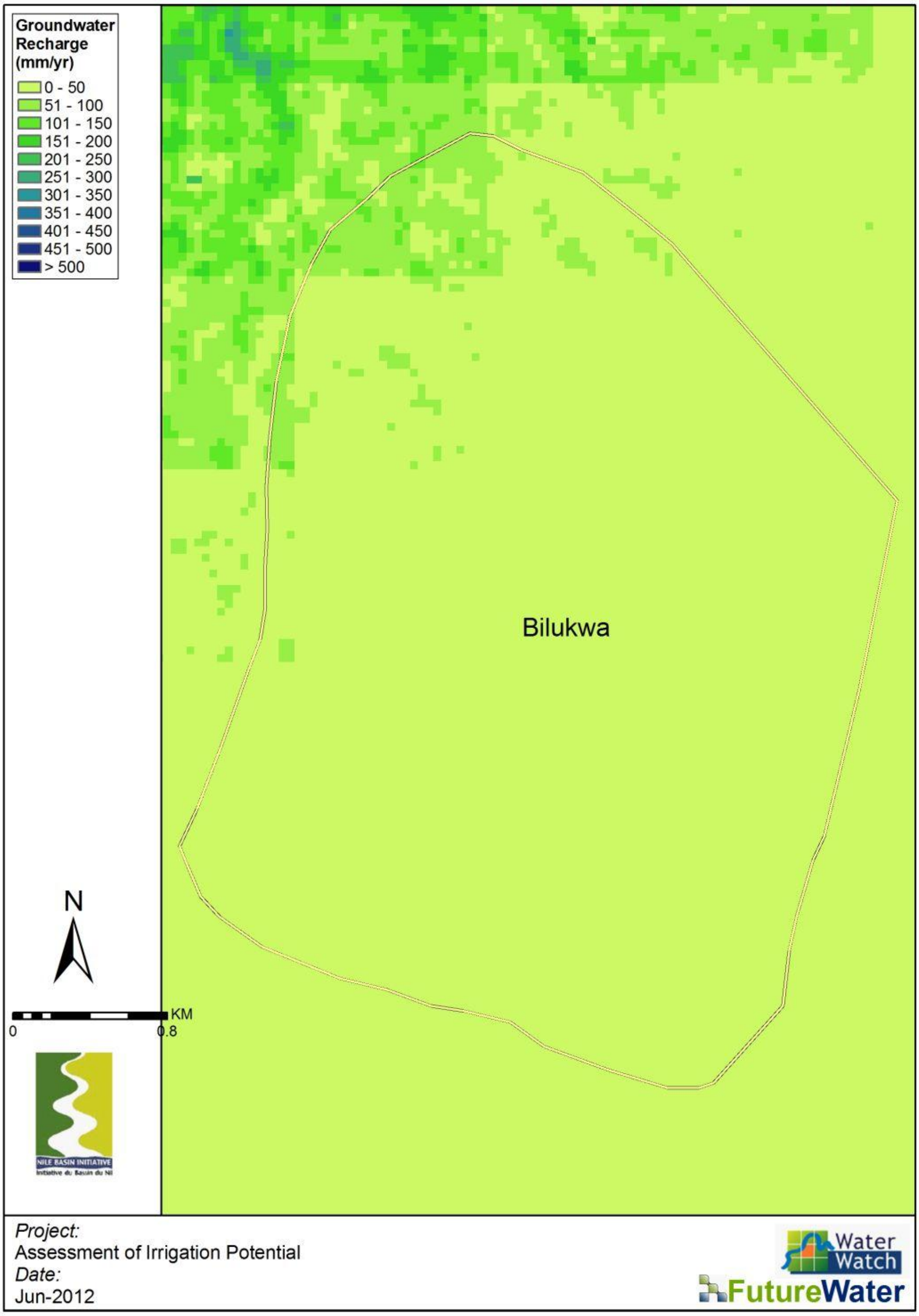


Figure 39: Water balances for the area based on the high resolution data and modeling approach for Bilukwa focal area.


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
0
0.8
KM
Bilukwa
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
> 500
Bilukwa
N
0
0.8
KM
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

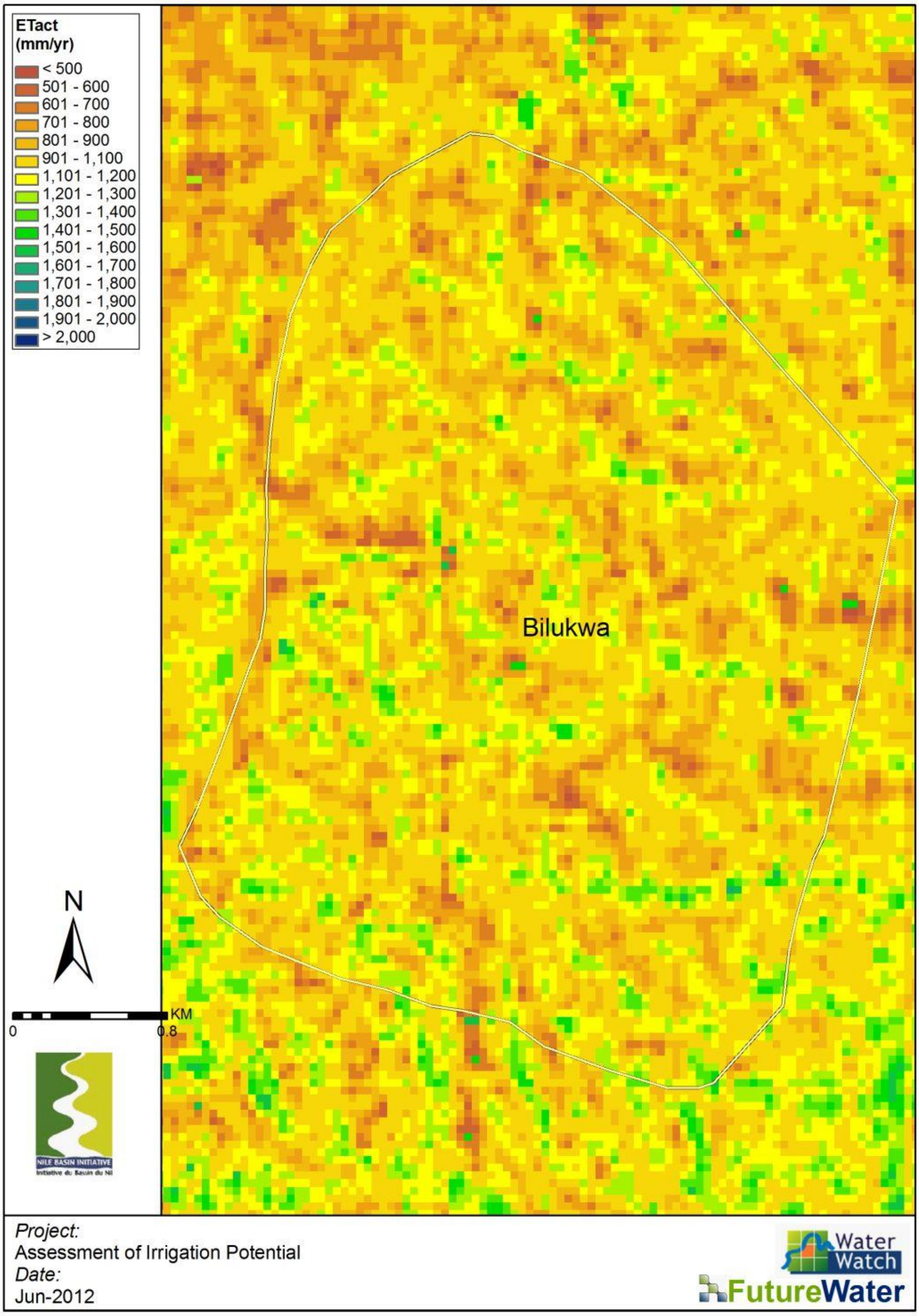


Figure 40: Water balances for the area based on the high resolution data and modeling approach for Bilukwa focal area.

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.

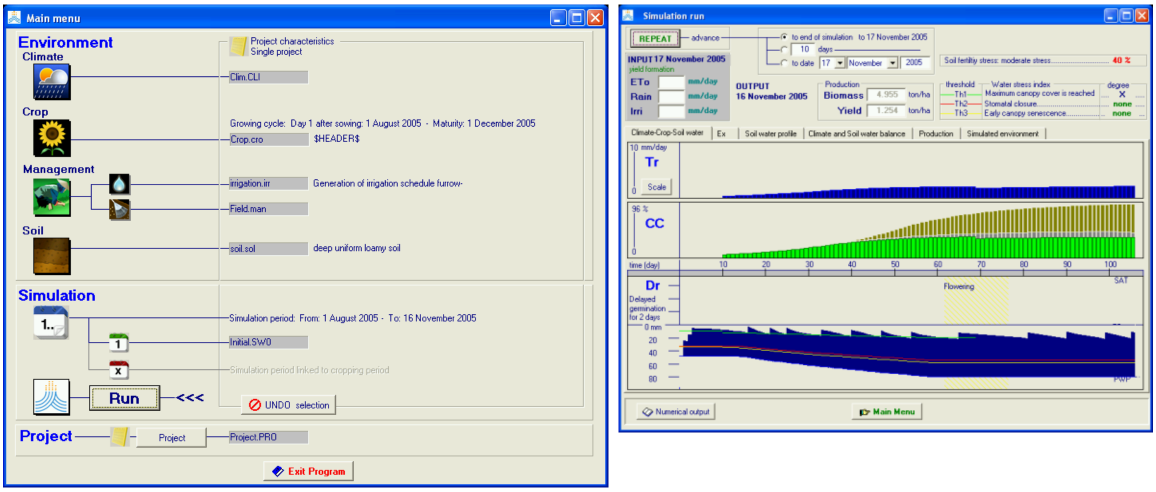


Figure 41: Typical example of AquaCrop input and output screens.

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

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year	===	== (day of year)	==	======== growing season			=======
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Soybeans	1165	1382	167	320	549	140	548	498
Garlic	1165	1382	1	365	1165	240	1378	1045
Pineapples	1165	1382	1	365	1165	330	1378	1045
Onions	1165	1382	1	365	1165	240	1378	1045

3.4.2 Irrigation systems and irrigations efficiencies

Since the focal area is situated directly at the water divide between the Nile and Congo basin, the water catchment is very small with approximately 12 km^2. The area is very hilly, and the steep slopes limit the possibilities for surface irrigation. Slopes for surface irrigation are recommended not to surpass 2%, as increasing flow velocities will reduce water infiltration into the soil, and increase runoff and erosion. On the flatter area towards the lake, surface irrigation will be possible on a small scale. It is advised to have a very close look into the water availability from upstream, which will be very limited due the small catchment, and the possible land which can be irrigated. The use of sprinkler and drip irrigation can decrease water demand due to increased water application efficiencies. These techniques, however, require a much larger financial investment, and demand a higher knowledge base from the farmers whom work with the irrigation system. Since topography and water availability will both push towards small scale irrigation systems, irrigation systems can differ over the area. Wherever possible, it is recommended to use surface irrigation. Although the water application efficiencies are relatively low, the environmental quality of the area will be enhanced, and water is used in a sustainable manner.

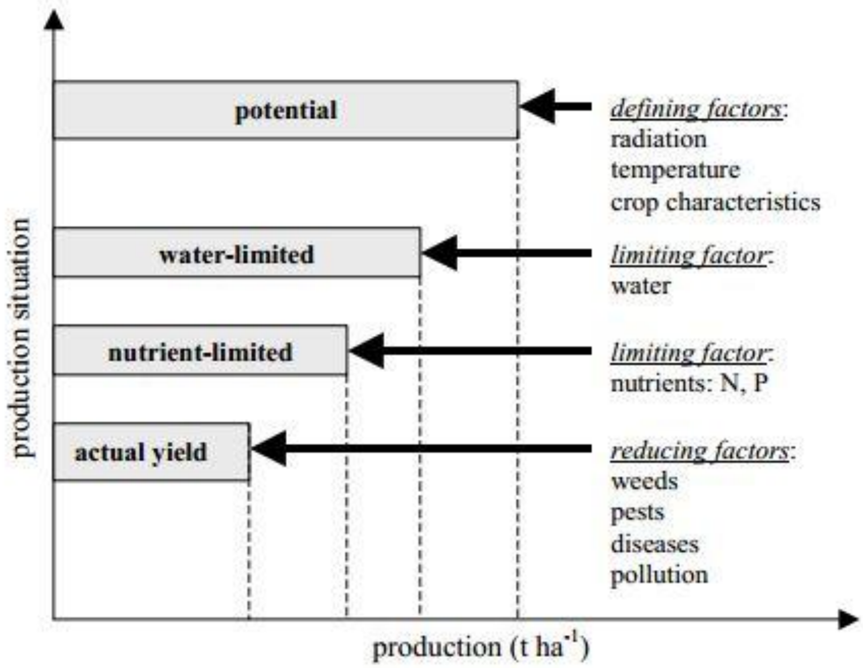
3.4.3 Water source

The initial water source will be surface water. However, due to the small catchment area the surface water is very limited. The annual average precipitation is rather large, with nearly 1200 mm. This creates the possibilities for some small upstream reservoirs, which will store the water for the drier seasons. Especially December and January are dry months, in which the amount of precipitation does not meet the demand for agriculture. Water from Lake Albert can also be used. The lake is just 3 kilometers away, and especially for the lower part this is a nearly inexhaustible water source. The use of groundwater for irrigation is not recommended in this region.

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

Yields in DRC are generally below the average of the seven research countries. The agricultural area expanded over the years from 4,283,400 ha in 1980, towards 5,139,770 ha in 2009. This is an increase of 20%, while the population nearly tripled in the same time. The average yield per hectare, however, has hardly increased. Yields from cassava and groundnut are among the few crops that show a positive yield development. Other crops have remained stable or even decreased in yield per hectare over the years. In Figure 42, the yield gap is shown relatively to the highest obtainable yield in the world, the world's average, and to Africa's average. Yields in Bilukwa focal area are nearly 30% above the DRC average. The potential crops, cassava and cabbage, are both crops from which DRC keeps good records. Due to the farmers' experience with these crops, it is expected that the yields of these two crops can easily double under irrigation. Pineapple is a good cash crop, but yields are relatively low. Due to this large yield gap, it is expected that the pineapple yield can increase four fold to 20% of the world maximum yield. Onions will increase in yield, and may double compared to current yields. With an expected focus on cassava, pineapple and cabbage, the yield increase of onions may not contribute much in the total yield increase.

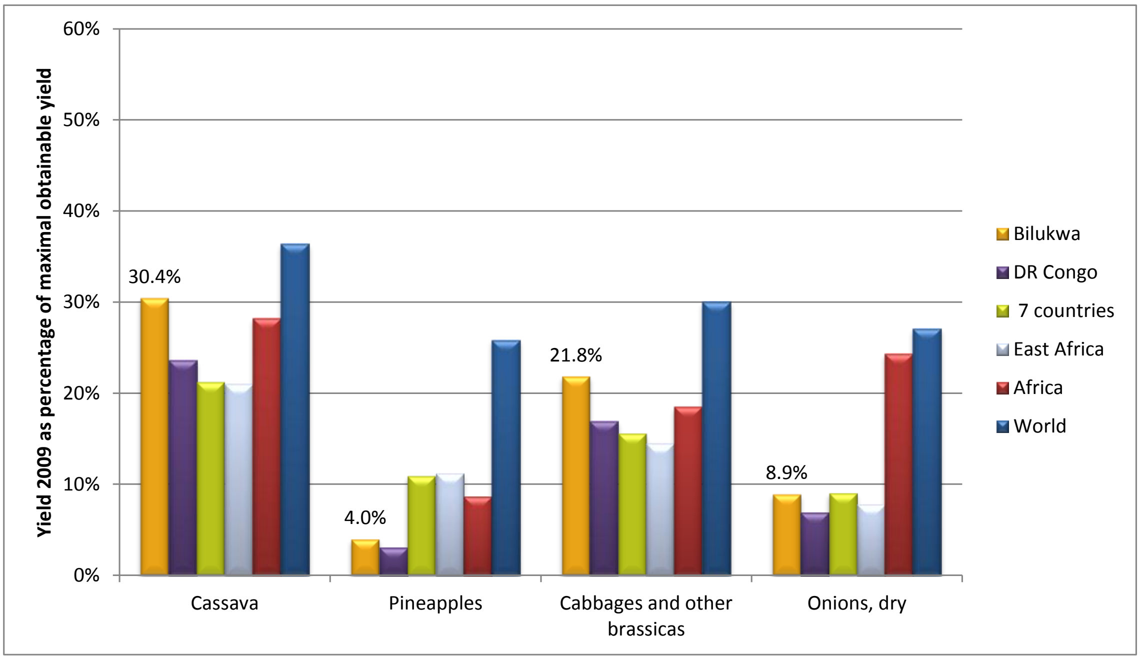


Figure 42: Yield gap Bilukwa (source: FAOSTAT, 2012).

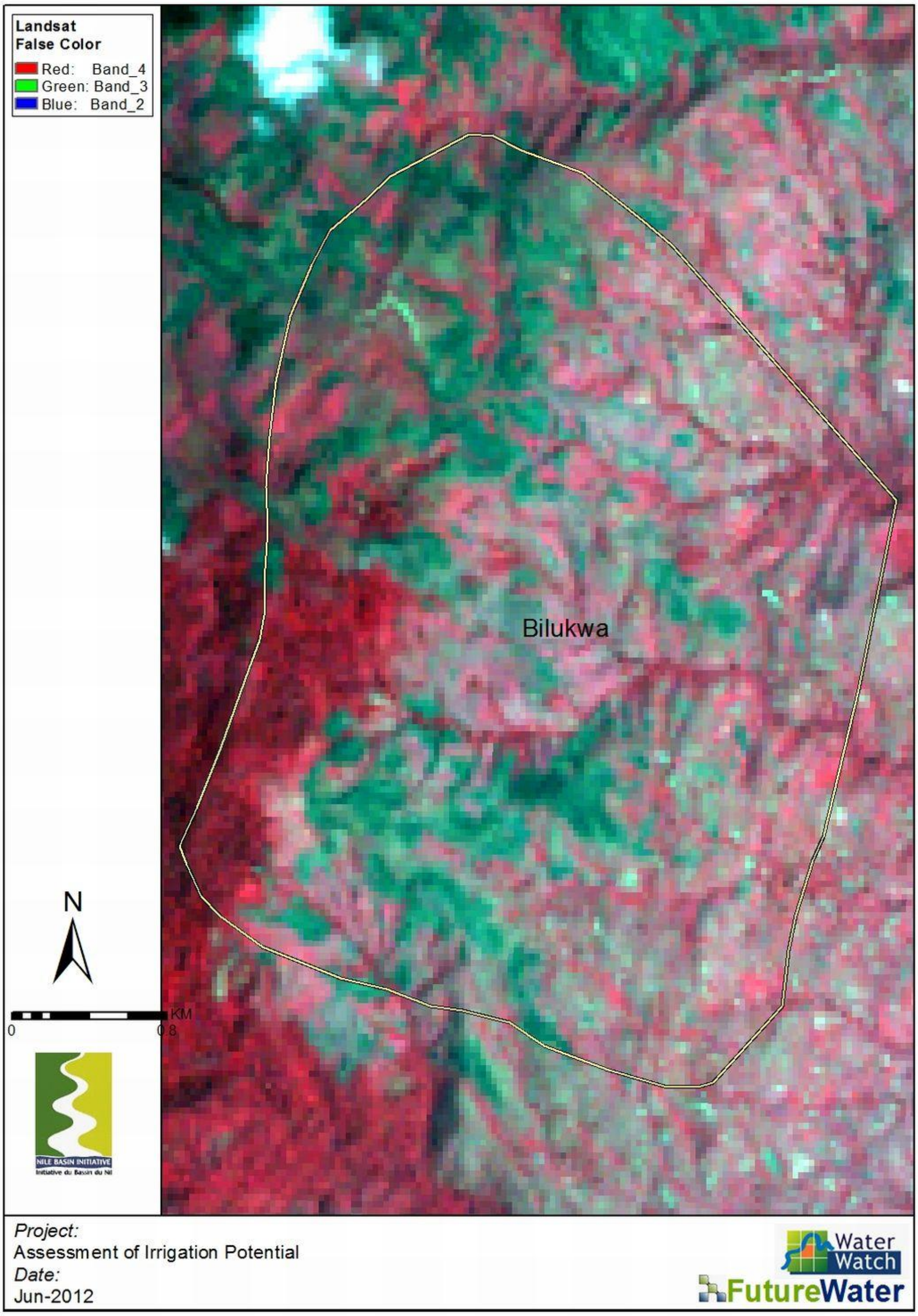


Figure 43: Landsat False Color Composite indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC

3.6 Environmental and socio-economic considerations

3.6.1 Population displacements

The population density in the focal area is very low. People live very scattered over the area, and there are few small settlements. Most people live in the lower part of the focal area or near the lake. If an irrigation system is developed, it is not expected that any population displacement is needed. Especially since the population density and topography do not allow for large scale irrigation development. With the design of any irrigation scheme, it is advised to limit any population displacement. The irrigation scheme can be developed around the existing houses. The exact numbers of effected houses can only be known after designing the scheme, which is beyond the scope of this pre-feasibility study.

3.6.2 Social

The population density within the focal area is low with less than one person per km^2. Within the Ituri district, the population density is the highest of the Orientale province with 65 people/km^2 (2003 population estimate). This is well above the DRC average of 30 people/km^2. The ratio of male to female is slightly in favor of the females with 0.96. According to the field visits, the tribe inhabiting the region is the Hema. Other tribes may include Lendu, Nyali and Mambisa. The equality between man and woman is poor. Women hardly take any reading position in official institutions. On lower levels they may take up to 10% of the seats, but on higher levels it is man only. The enrollment rate on primary and secondary school shows that roughly 35% of the children are girls. The majority of the population in Orientale province is extremely poor. Main diet consists for 70-80% of a staple food of starch or grain, such as cassava, plantains, rice, sweet potatoes, potatoes or maize. The staple food is accompanied by beans, vegetables and sometimes fish, game or meat. Infrastructure in the area is quite poor, which makes it difficult to develop the area. Small roads reach towards the focal area, but the first main road is 30 km away. Main towns and markets are even further at 50 km, or Bunia at 100 km.

3.6.3 Upstream downstream consideration

The upper part of the focal area is covered with natural forest vegetation. Further down the vegetation becomes sparse, and more and more areas are being used for agriculture. The sparse vegetated soils in combination with the large amount of precipitation during the year are factors that stimulate erosion in the area. Currently, there are very few anti-erosion measures. Whenever developing irrigation, it is advised to incorporate anti-erosion measures within the focal area, and also upstream of the irrigated land. This keeps the fertile top soil in place, and will store the water. The soil fertility is rather poor, and therefore the use of fertilizers is recommended in order to use the irrigation system in a durable and sustainable way. The mode and timing of fertilizer appliance determines to a large extent the success of farming on these soils. Besides, good fertilizer application minimizes leaching of nutrients and ensures downstream water quality.

3.6.4 Protected areas

Within the focal area no protected areas are reported.

3.6.5 Institutional and legal framework

Information on the water treaty agreements and the land ownership rights can be found in chapter 1.1.5.

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. Of the total area of 1259 ha as selected by the country representatives, only about 100 ha might be potentially suitable to bring under irrigation.

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 the financial benefits are somewhat limited.

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):
    - Soybeans: 10,000 kg/ha, 0.44 $/kg
    - Garlic: 2,500 kg/ha, 0.30 $/kg
    - Pineapples: 15,000 kg/ha, 0.22 $/kg
    - Onions: 3,000 kg/ha, 0.25 $/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.

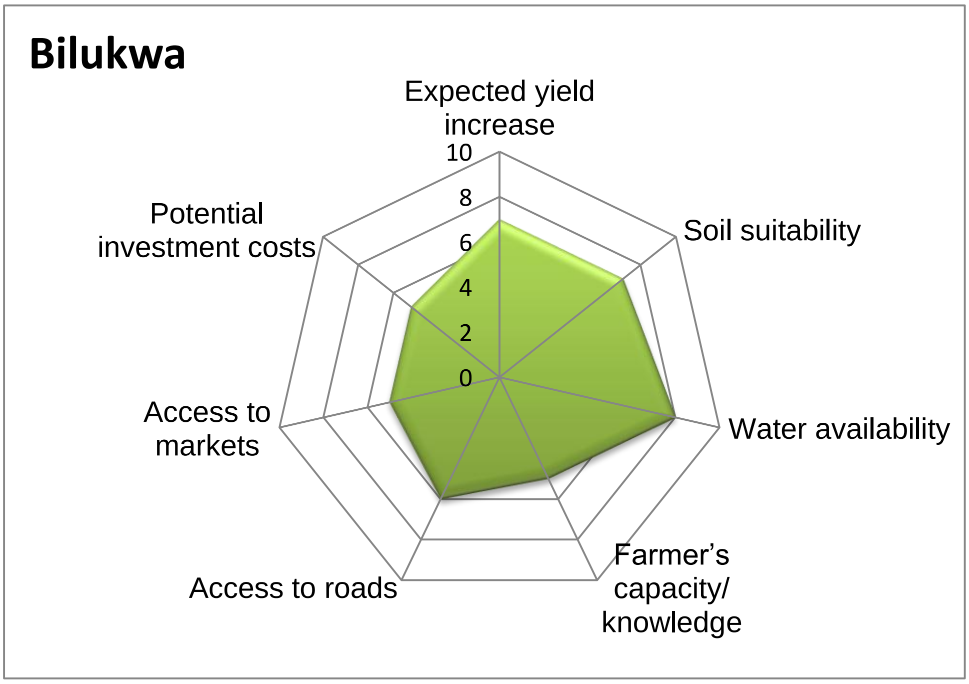


Figure 44: Filled radar plot indicating expert knowledge score to develop irrigation in the Bilukwa focal area (1 = negative, 10 = positive)

Table 7: Benefit-cost analysis for Bilukwa area.

Characteristics	
Irrigated land (ha)	100
Farmers	100
Investment Costs	
Irrigation infrastructure (US$/ha)	6,000
Social infrastructure (US$/farmer)	750
Accessibility infrastructure (million US$)	3.0
Operational Costs	
O&M irrigation (US$/ha/yr)	60
Extension service (US$/farmer)	15
O&M roads (US$/yr)	60,000
Summary	
Initial investments (million US$)	3.7
O&M costs (million US$/yr)	0.068
Net benefits per year (million US$/yr)	0.138
IRR (Internal Rate of Return)	-5.3%

4 Boga focal area

4.1 Introduction

This chapter will describe the current state of the Boga focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 46 a detailed map of the area is given. Total area is 9360 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 Alitum Ukelo and supervised by Henri Okitolembo, Bruno Matata, and Isaac Mutela in April and May 2012.

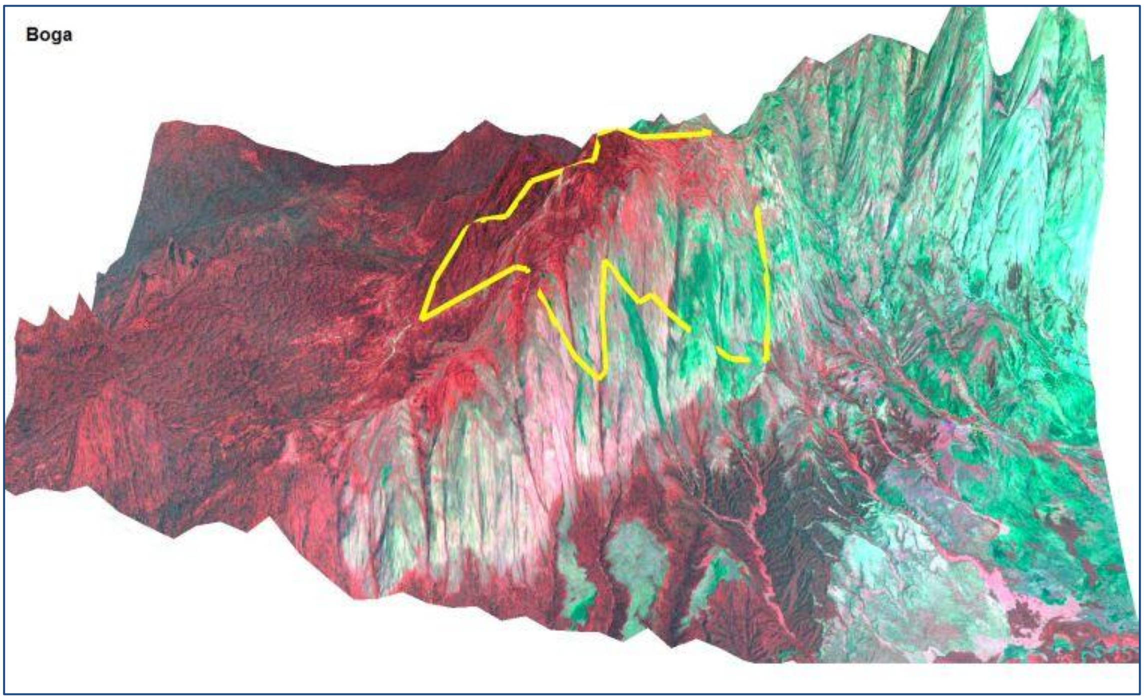
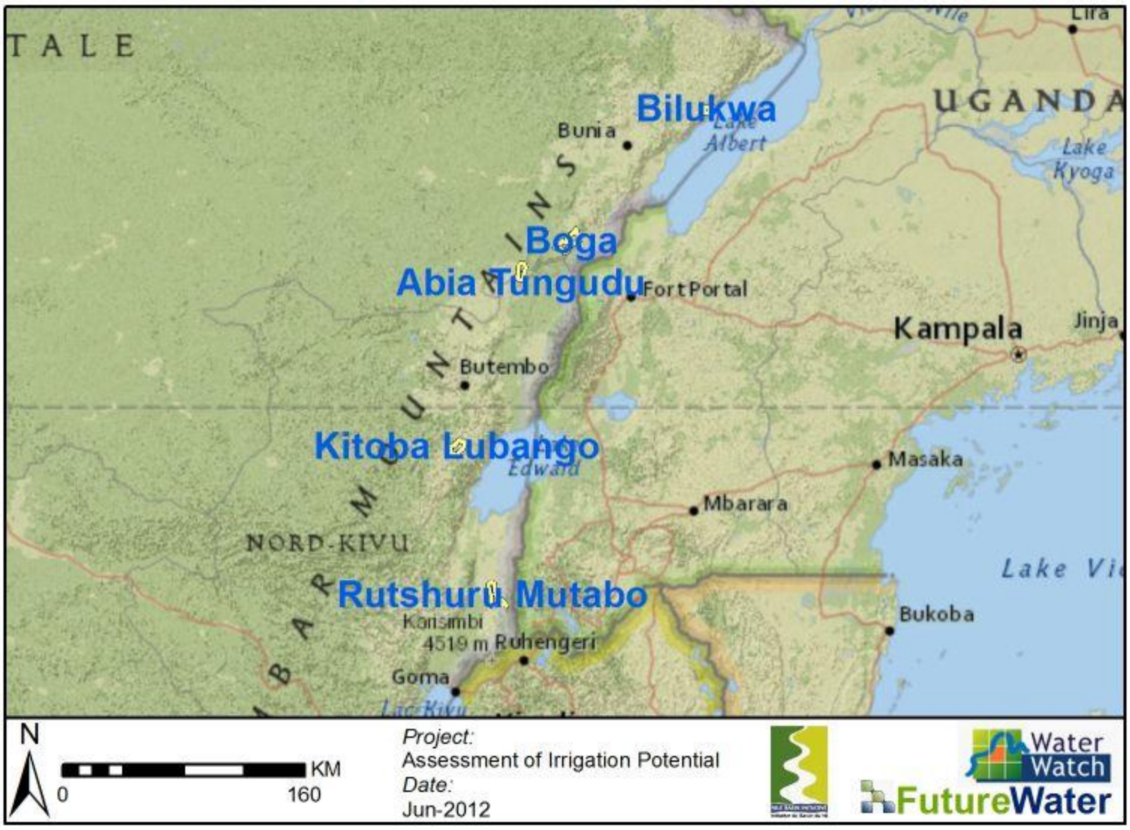


Figure 45: 3D impression of Boga focal area, Eastern DRC.



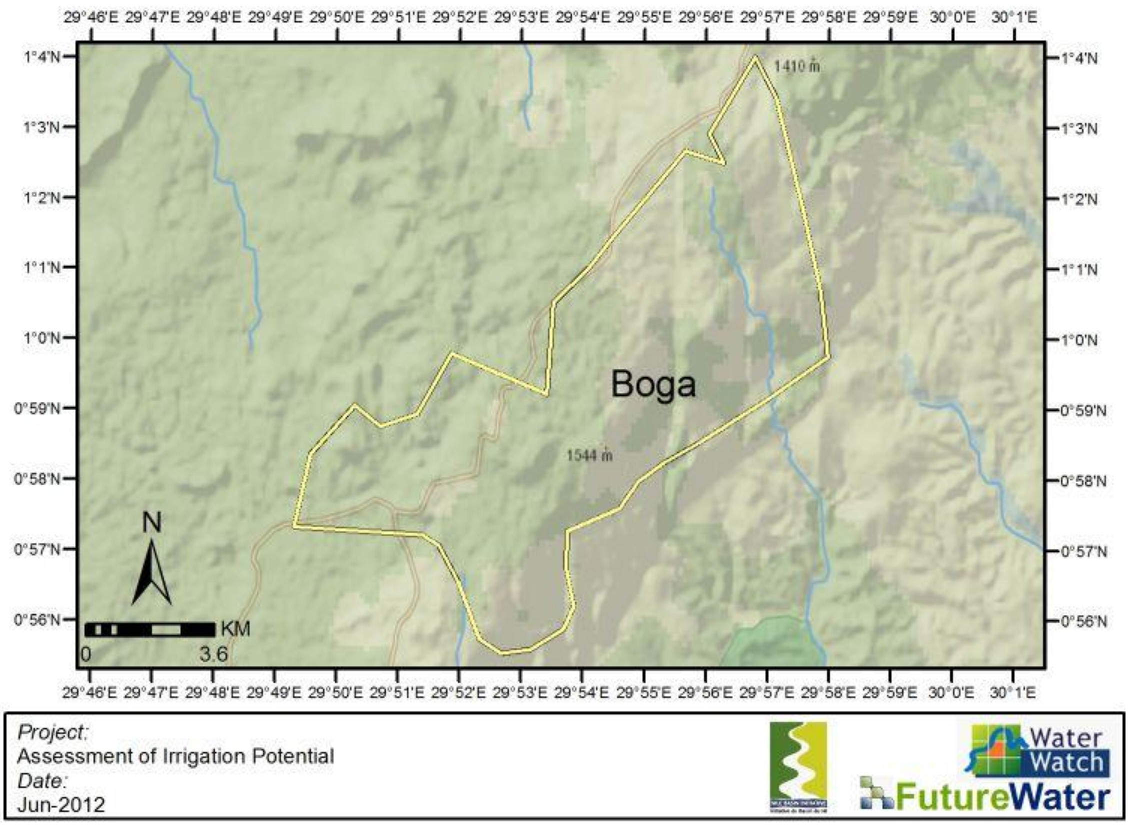


Figure 46: Boga focal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC

4.2 Land suitability assessment

4.2.1 Terrain

Boga Focal area (9,361 ha) is located in the village of Boga in Irumu in the district of Ituri, in Orientale Province, north - east of Democratic Republic of Congo.. The western boundary of the focal area is formed by the water divide from the Nile basin and the Congo basin. Most of the area is currently covered with forest. The area is located at an average elevation of 1300 m, which ranges from 1550 m in the center towards 950 m in the North East (Figure 47). Slopes in the area are steepest at the eastern side, where there is a transition between the low land and the mountainous highland on which the focal area is situated. Slopes in the East go up to 30%, and slopes on the highland are mainly limited to 5% or less (Figure 48).

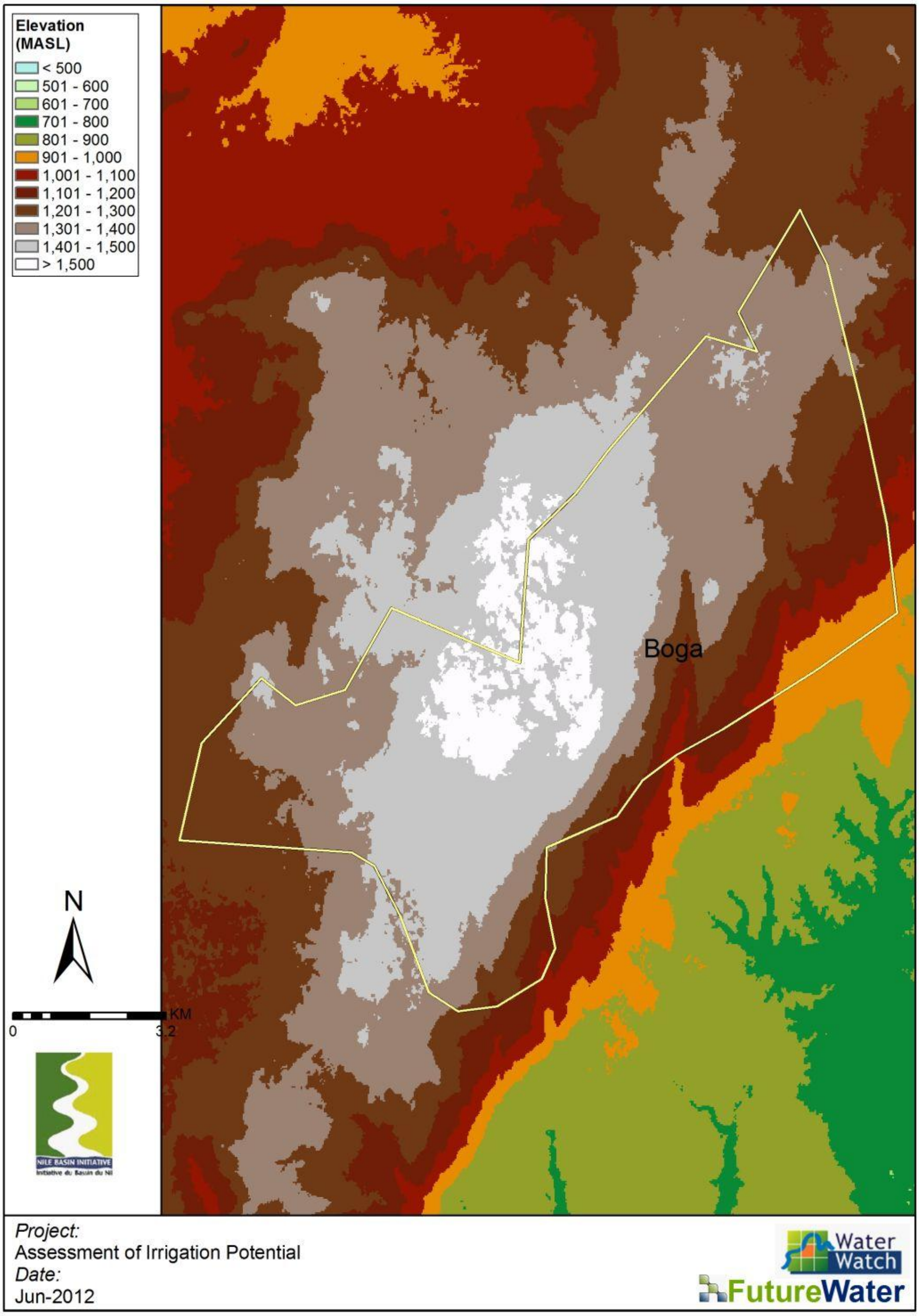


Figure 47: DEM Boga focal area. Resolution 1 arc second (+/- 30m).

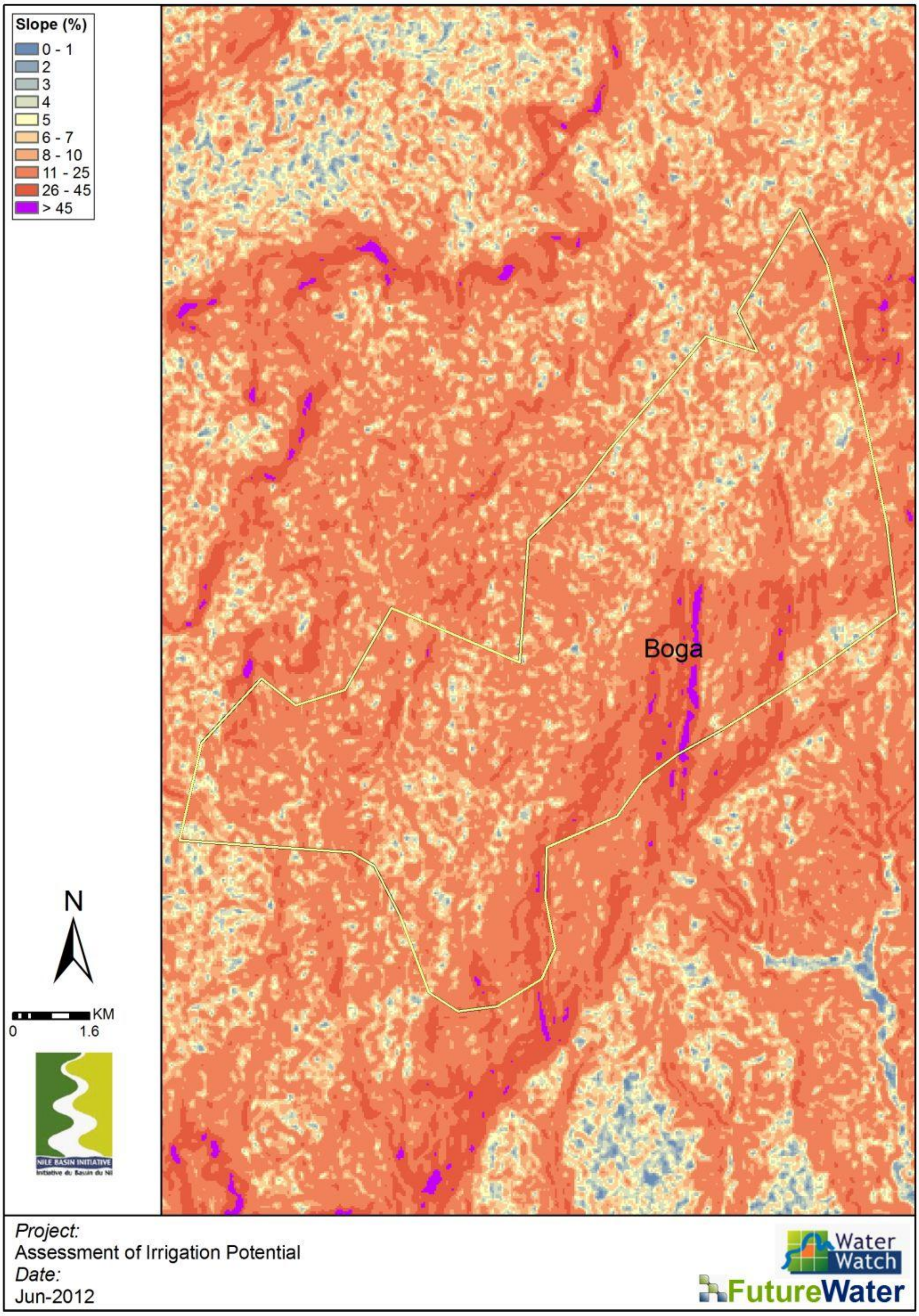


Figure 48: Slope map Boga focal area (source: ASTER).

4.2.2 Soil

The soil in Boga focal area is silty loam, and drainage is slightly poor. The soil has an average pH, and contains approximately 2.5% organic carbon in the top soil. The water holding capacity is large with over 150 mm/m. The soil is not uniform within the focal area. Most common are the Lixisols, and secondly the Ferralsols. Lixisols are found in seasonally dry tropical and subtropical regions on Pleistocene and older surfaces. Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration), leading to an argic subsoil horizon. Preservation of the surface soil with its all-important organic matter is of utmost importance. Degraded surface soils have low aggregate stability, and are prone to slaking and/or erosion where exposed to the direct impact of raindrops. Tillage of wet soil, or use of excessively heavy machinery, compacts the soil and causes serious structure deterioration. Tillage and erosion control measures, such as terracing, contour ploughing, mulching, and use of cover crops, help to conserve the soil. The low absolute level of plant nutrients and the low cat ion retention by Lixisols, makes recurrent inputs of fertilizers and/or lime a precondition for continuous cultivation. Chemically and/or physically deteriorated Lixisols regenerate very slowly, if not reclaimed actively. Perennial crops are to be preferred to annual crops, particularly on sloping land. Cultivation of tuber crops (cassava and sweet potato) or groundnut increases the danger of soil deterioration and erosion. Rotation of annual crops with improved pasture has been recommended, in order to maintain or improve the content of soil organic matter. Ferralsols represent the classical, deeply weathered, red or yellow soils of the humid tropics. They are less susceptible to erosion than most other intensely weathered tropical soils. Although the Ferrasols have good physical properties, the chemical fertility is poor. Maintaining soil fertility by maturing, mulching, and/or adequate fallow periods, or agroforestry practices, and prevention of surface soil erosion, are important management requirements.

4.2.3 Land productivity

The land productivity (NDVI) in the five DRC focal areas ranges between 0.66 and 0.83. Compared to the DRC average NDVI of 0.59, all the focal areas have relative high land productivity values. Within Boga focal area the average land productivity is 0.80 (Figure 49). There is a quite large variation. Lower values can be found at the steep transition from the lower land to the higher land. The highest land productivity values can be found on the higher lands with values around 0.85. The coefficient-of-variation is low within the whole area. Lowest variations can be found in the same areas as high NDVIs can be found.

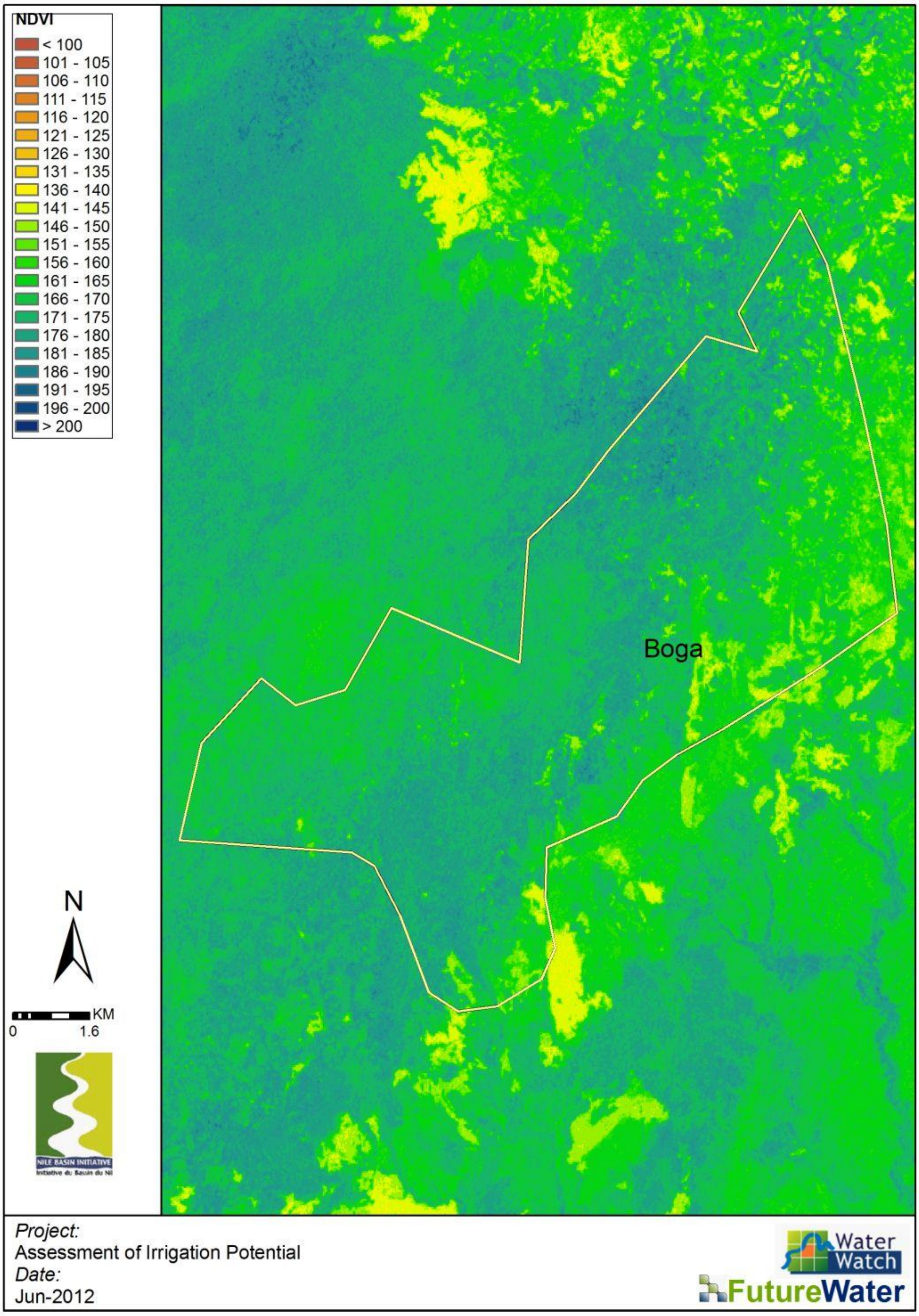


Figure 49: High resolution NDVI for BOGA focal area

4.2.4 Potential cropping patterns

Within the focal area a maximum of 10% of the land is used for agricultural purposes. The South of the focal area is mainly covered with forest, while in the North more land is prepared for agriculture. The current grown crops, observed during the field visit, are cassava, beans, rice and maize. Cassava is the most dominant crop with 40% of the agricultural area, followed by beans (20%), rice (12%), and maize (8-10%). Cassava is grown in one growing cycle per year. However, the leaves can be harvested continuously. Beans are grown in three growing cycles per year, and rice is also grown in three growing cycles per year according to field surveys. Maize is grown in two growing cycles per year. All crops are already grown year round, which means that no yield increase can be achieved by adding cropping cycles. The yield increase should come from more intensive farming or the change to high value crops. Future potential crops include sorghum, eggplant and cabbage. It is expected that sorghum can be grown on a large scale, but that irrigation will not or hardly be needed due to the high amount of precipitation over the year (+/- 1350 mm). The other crops do need some irrigation. With irrigation, eggplant and cabbage can be grown twice or even three times a year. Coffee can possibly be grown on the steeper areas in the East of the focal area.

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 constant temperatures during the year ranging from about 18^{o}C to 29^{o}C. Annual average precipitation is 1355 mm and reference evapotranspiration 1314 mm per year.

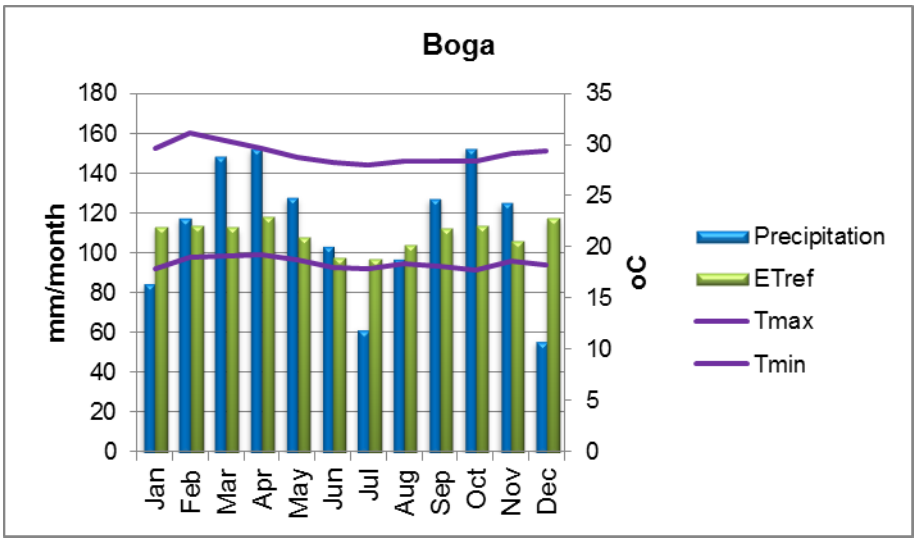


Figure 50: Average climate conditions for the focal area.

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.

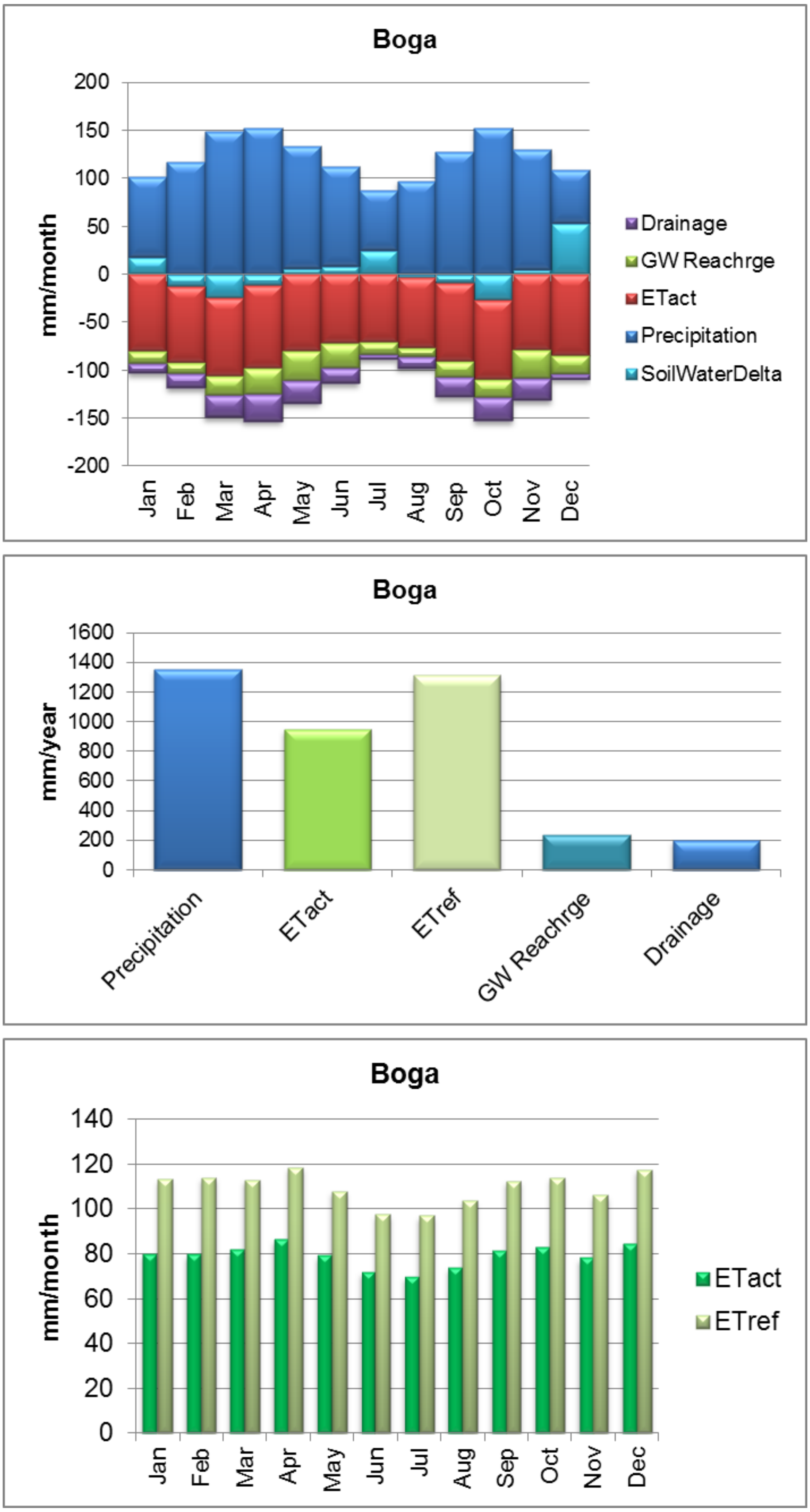
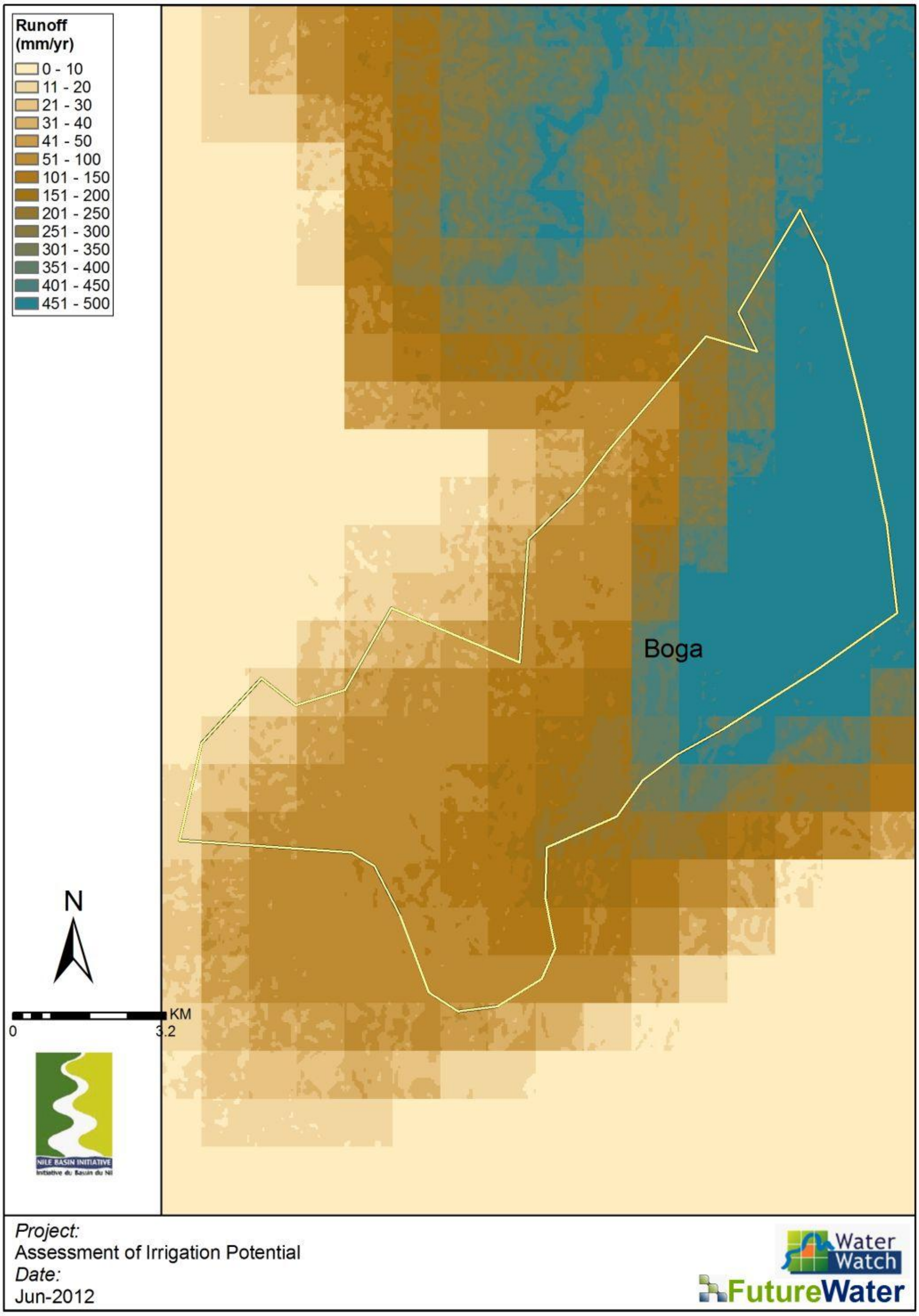
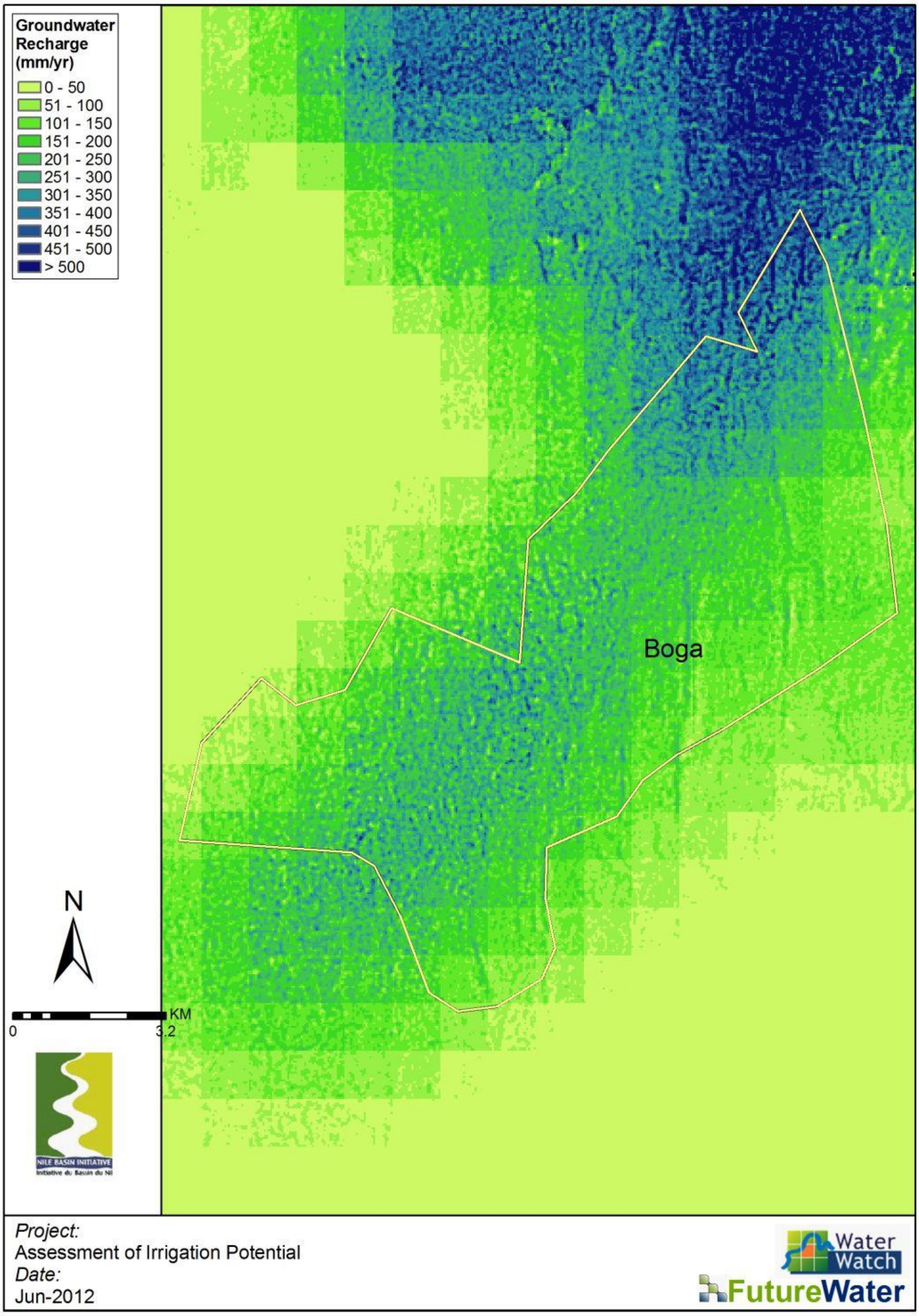


Figure 51: Water balances for the area based on the high resolution data and modeling approach for BOGA focal area.


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
Boga
N
0
3.2
KM
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
> 500
Boga
N
KM
0
3.2
Project:
Assessment of Irrigation Potential
Date:
Jun-2012

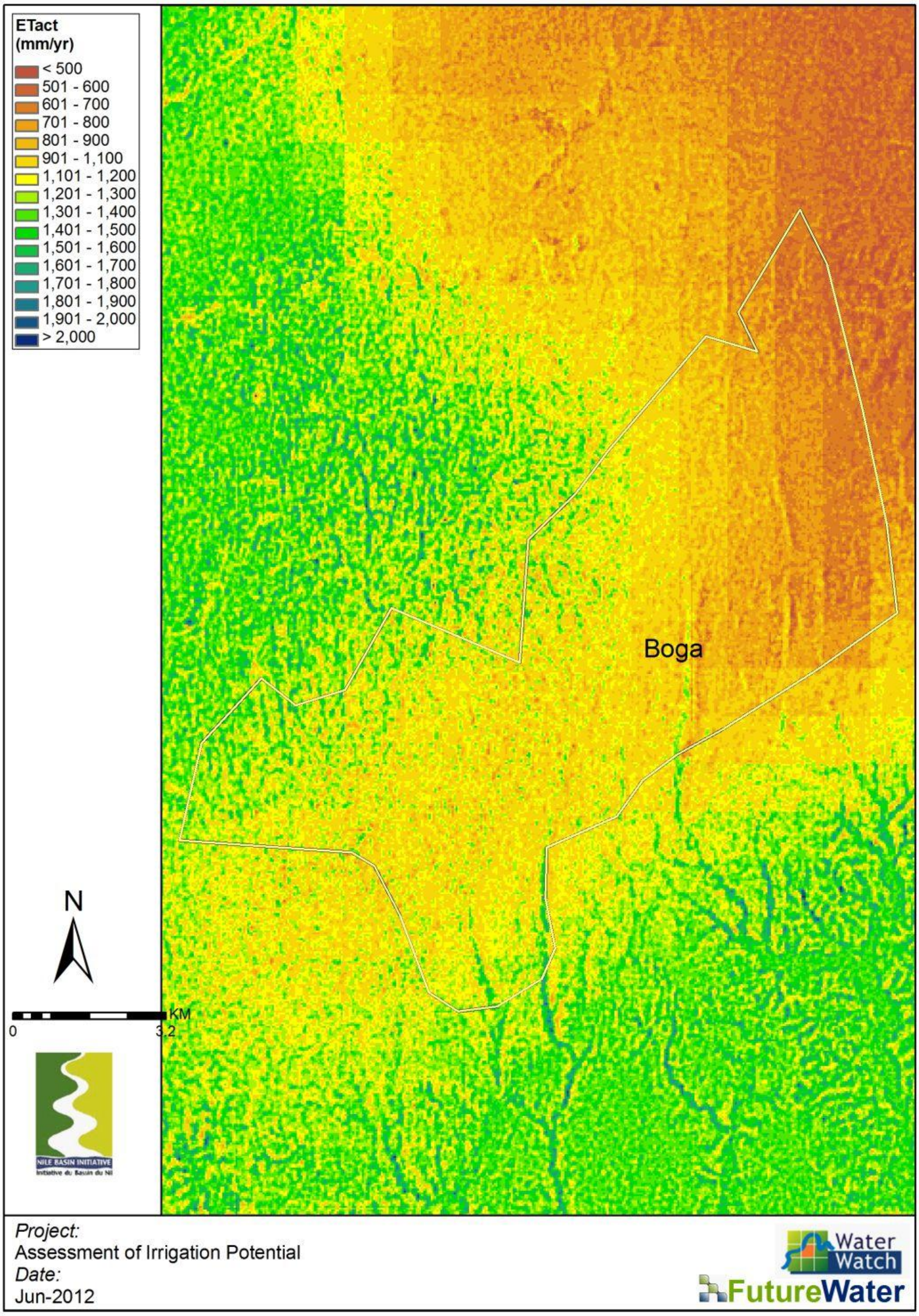


Figure 52: Water balances for the area based on the high resolution data and modeling approach for BOGA focal area.

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.

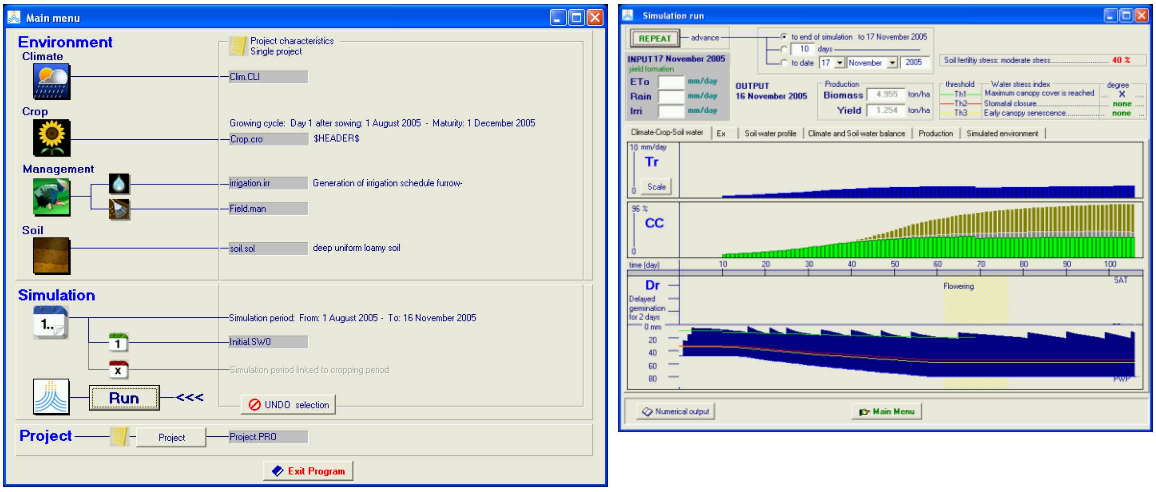


Figure 53: Typical example of AquaCrop input and output screens.

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

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year ===		== (day of year) ==		======== growing season =======			
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Sorghum	1355	1314	136	289	534	180	526	473
Aubergine	1355	1314	1	365	1355	130	1311	1033
Cabbage	1355	1314	1	365	1355	130	1311	1033
Coffee	1355	1314	198	304	410	150	383	353

4.4.2 Irrigation systems and irrigations efficiencies

Since the focal area is situated directly at the water divide between the Nile and Congo basin, the water catchment is quite small with approximately 93 km^2. The area is very hilly on the east side, where the steep slopes limit the possibilities for surface irrigation. Slopes for surface irrigation are recommended not to surpass 2%, as increasing flow velocities will reduce water infiltration in the soil, and increase runoff and erosion. On the flatter highland in the northwestern part, surface irrigation will be possible on small scales. It is advised to have a very close look into the water availability from upstream, which will be very limited due the small catchment, and the possible land which can be irrigated. The use of sprinkler and drip irrigation can decrease water demand due to increased water application efficiencies. These techniques, however, do require a much larger financial investment, and demand a higher knowledge base from the farmers who work with the irrigation system. Since topography and water availability will both push towards small scale irrigation systems, irrigation systems can differ over the area. Wherever possible, it is recommended to use surface irrigation. Although the water application efficiencies are relatively low, the environmental quality of the area will be enhanced, and water is used in a sustainable way.

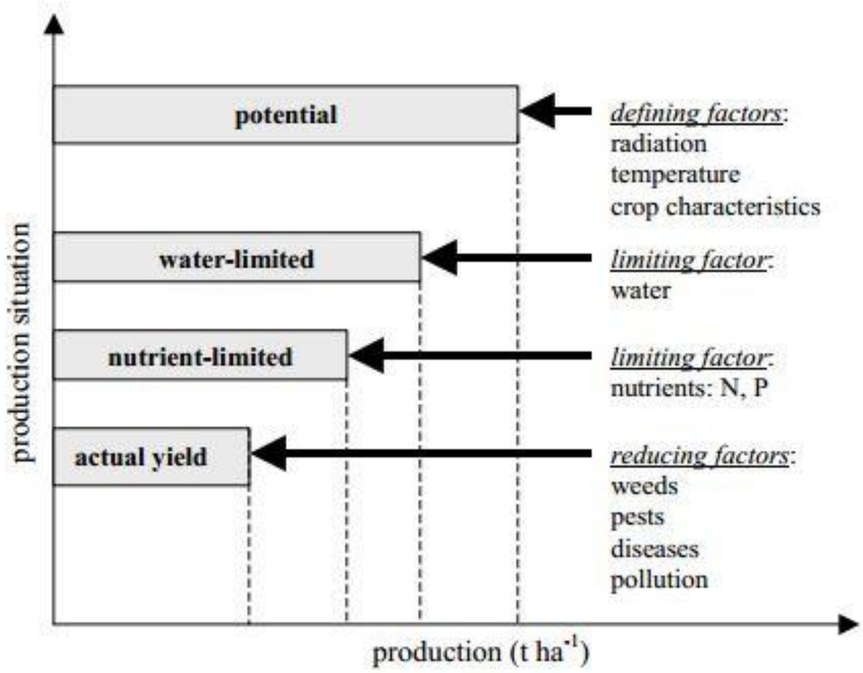
4.4.3 Water source

The initial water source will be surface water. However, due to the small catchment area the surface water is very limited. The annual average precipitation is rather large with nearly 1400 mm. This creates the possibilities for some small upstream reservoirs, which will store the water for the drier seasons. Especially the months July, December and January are dry months, in which the amount of precipitation does not meet the demand for agriculture. The average flow of the three 'major' streams with their source within the focal area range from 0.3 m^3 to 0.9 $m^{3.}$ The use of groundwater for irrigation in this area is a good possibility. Model outputs show that within most of the area, groundwater can be an irrigation source. Field visits have shown that the groundwater table ranges between 20 and 40 minus surface level.

4.5 Potential crop yield assessment

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

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



4.5.1 Yield gap analysis potential dominant crops

Yields in DRC are generally below the average of the seven research countries. The agricultural area expanded over the years from 4,283,400 ha in 1980, towards 5,139,770 ha in 2009. This is an increase of 20%, while the population nearly tripled in the same time. The average yield per hectare, however, has hardly increased. Yields from cassava and groundnut are among the few crops that show a positive yield development. Other crops have remained stable or even decreased in yield per hectare over the years. In Figure 54, the yield gap is shown relatively to the highest obtainable yield in the world, the world’s average, and to Africa’s average. Yields in Boga focal area are over 30% above DRC average. The four selected crops are a good combination of staple crops and cash crops. Sorghum can be grown on a large scale, and yields under irrigation are expected to double. Yields of coffee in the area are already above African average, but under irrigation this may increase towards 40% of the world’s maximum yield. The yield gap for cabbage in the focal area is relatively small, as yields are already high. Yields of cabbage will increase under irrigation, but not largely. Eggplant will be a good crop for the focal area, which can reach towards African average, which is at 5% of the world’s highest obtainable yield. When irrigation is developed, rice will be another high potential crop, which will deliver high yields.

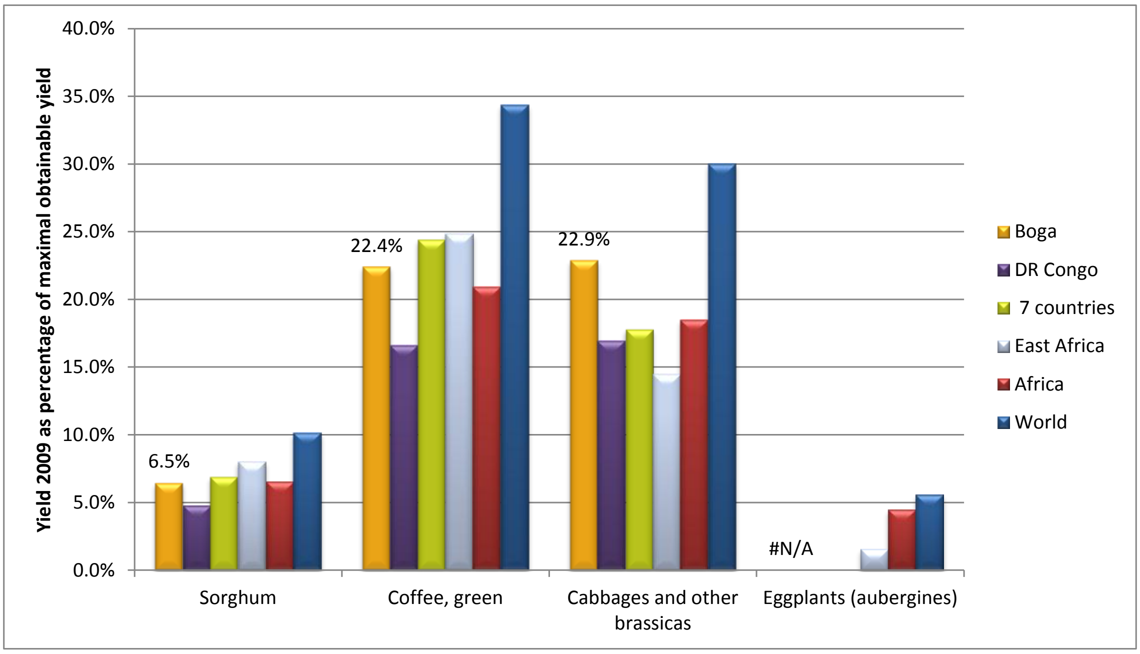


Figure 54: Yield gap Boga (source: FAOSTAT, 2012).

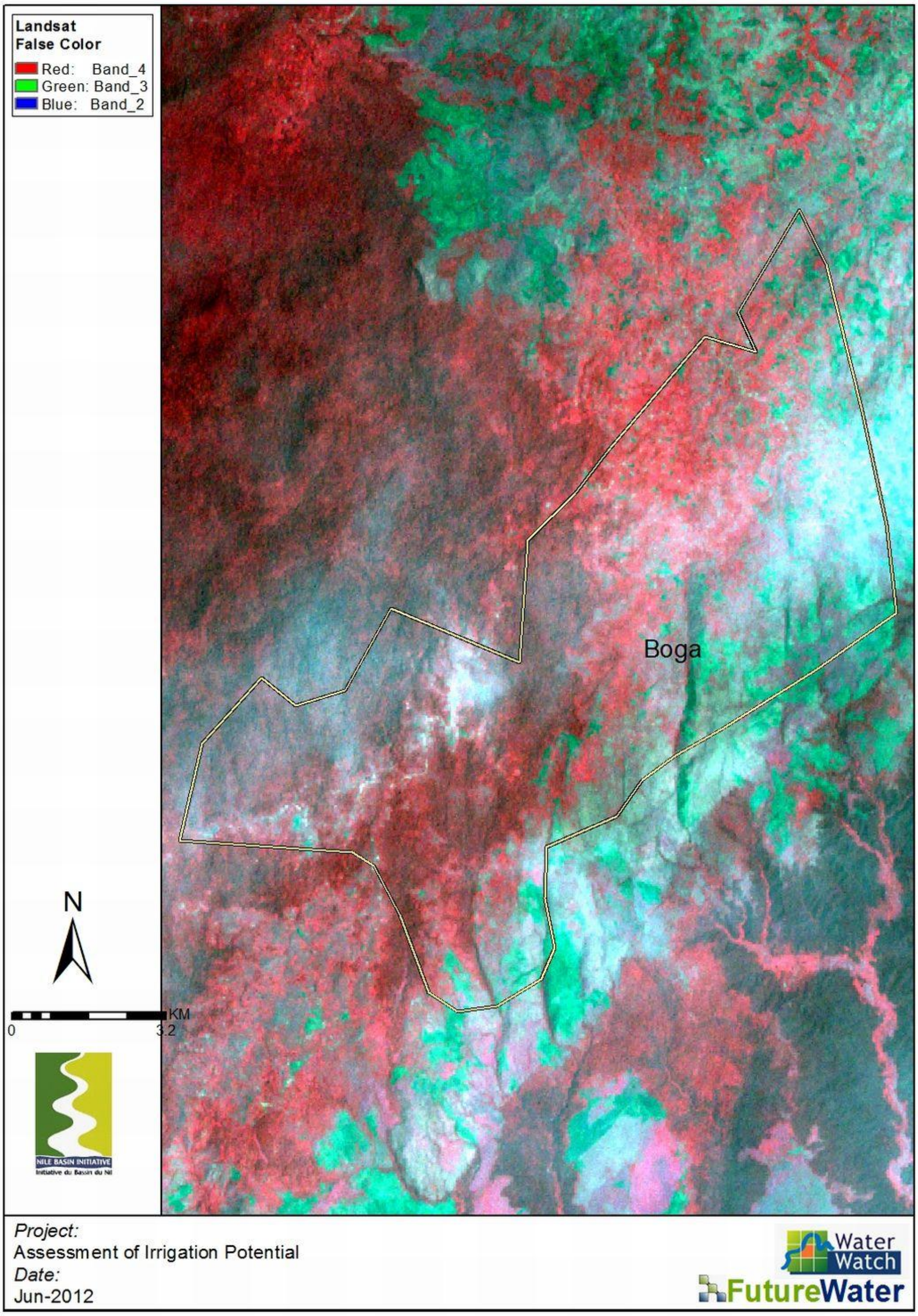


Figure 55: Landsat False Color Composite indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC

4.6 Environmental and socio-economic considerations

4.6.1 Population displacements

The population density is above DRC average, but is still rather sparse. People live in Boga village, and further mainly in linear structures along the roads. The land is fragmented by the houses, and some displacements may be needed; especially if large scale irrigation is planned. However, with the design of any irrigation scheme, it is advised to limit any population displacement. The irrigation scheme can probably be developed around the existing houses. 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 within the focal area is relatively large with 37 persons per km^2. Within the Ituri district, the population density is highest of the Orientale province with 65 people per km^2 (2003 population estimate). This is well above the DRC average of 30 people km^2. The ratio male to female is slightly in favor of the female with 0.96. According to field visits, the tribes inhabiting the region are the Hema and Boga. The equality between man and woman is poor. Women hardly take any reading position in official institutions. On lower levels they may take up to 10% of the seats, but on higher level it is man only. The enrollment rate on primary and secondary school shows that approximately 35% of the children are girls. The majority of the population in Orientale province is extremely poor. Main diet consists for 70-80% of a staple food of starch or grain, such as cassava, plantains, rice, sweet potatoes, potatoes or maize. The staple food is accompanied by beans, vegetables and sometimes fish, game or meat. Infrastructure in the area is quite poor, which makes it difficult to develop the area. Although some small roads cross the focal area, the main roads are rather far away on 50 km distance. Main markets at Owicha, Bunia or Beni are even further. The farmers do have average irrigation experience, and also have some knowledge about farmers’ cooperations.

4.6.3 Upstream downstream consideration

The southwestern part of the focal area is mainly covered with forest. The northern part is much used for agriculture and is further scrubland. Plots are often burned to prepare them for agriculture. This practice is possible if the land had enough time to recover afterwards. If the land cannot recover for about 20 years, then the land will gradually degrade. Whenever irrigation is developed, the land should be used in a durable and sustainable way so that the irrigation system can contribute to significant yield increase over a long period. The steep slopes on the eastern part of the focal area are very susceptible for erosion. It is advised to keep them covered with natural forest vegetation to prevent erosion, or if the land is very much needed for agricultural land, to take precautions against erosion and plant preferable perennial crops. The soil fertility is poor to average, and therefore the use of fertilizer is recommended to use the irrigation system in a durable and sustainable way. The mode and timing of fertilizer appliance determines to a large extent the success of farming on these soils. Besides, good fertilizer application minimizes leaching of nutrients and ensures downstream water quality.

4.6.4 Protected areas

Within the focal area no protected areas are reported.

4.6.5 Institutional and legal framework

Information on the water treaty agreements and the land ownership rights can be found in chapter 1.1.5.

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. Total area as selected by the country representatives is 9360 ha of which about 1000 ha is actually suitable for irrigation.

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 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):
    - Sorghum: 900 kg/ha, 0.65 $/kg
    - Aubergine: 15,000 kg/ha, 0.25 $/kg
    - Cabbage: 20,000 kg/ha, 0.07 $/kg
    - Coffee: 500 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, 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 is a great deal for the area that will foster an increase yields.

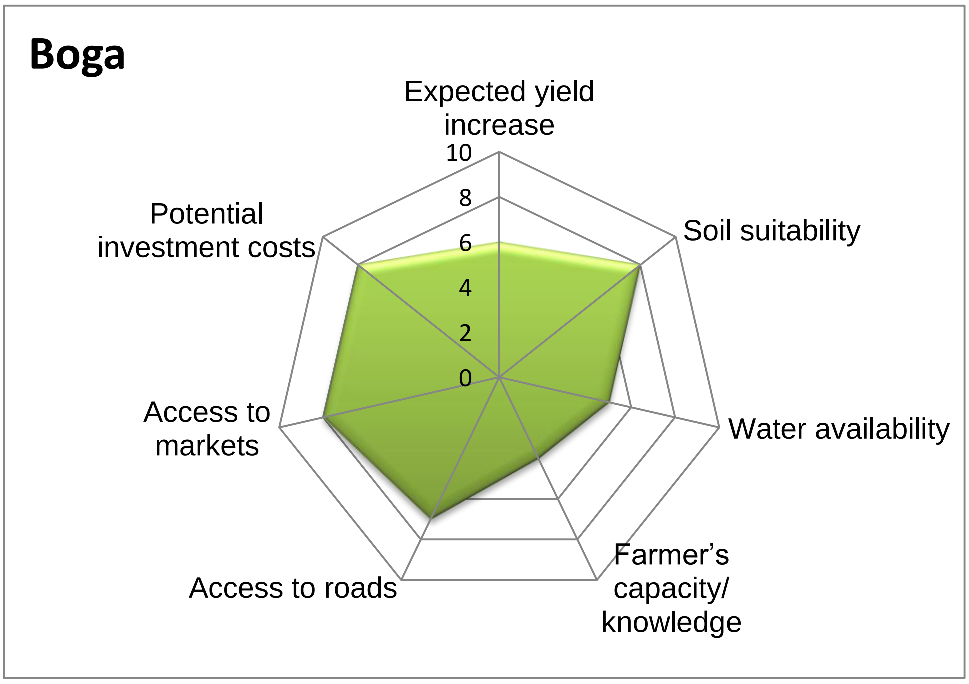


Figure 56: Filled radar plot indicating expert knowledge score to develop irrigation in the Boga focal area (1 = negative, 10 = positive)

Table 9: Benefit-cost analysis for Boga area.

Characteristics	
Irrigated land (ha)	1,000
Farmers	2,000
Investment Costs	
Irrigation infrastructure (US$/ha)	7,000
Social infrastructure (US$/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$)	10.0
O&M costs (million US$/yr)	0.120
Net benefits per year (million US$/yr)	1.194
IRR (Internal Rate of Return)	11.1%

5 Abia-Tungudu focal area

5.1 Introduction

This chapter will describe the current state of the Abia- Tungudu 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 58 a detailed map of the area is given. Total area is 4360 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 Mwana Katya Pitchou and supervised by Henri Okitolembo, Bruno Matata, and Isaac Mutela in April and May 2012.

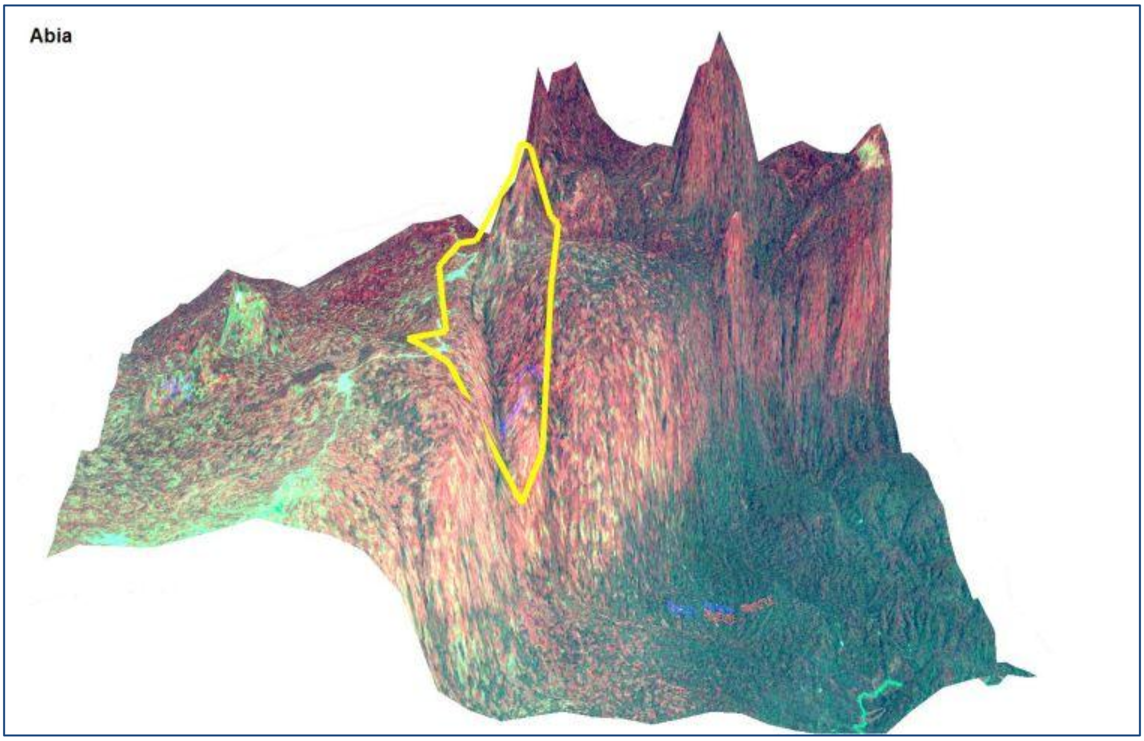


Figure 57: 3D impression of Abia- Tungudu focal area, Eastern DRC

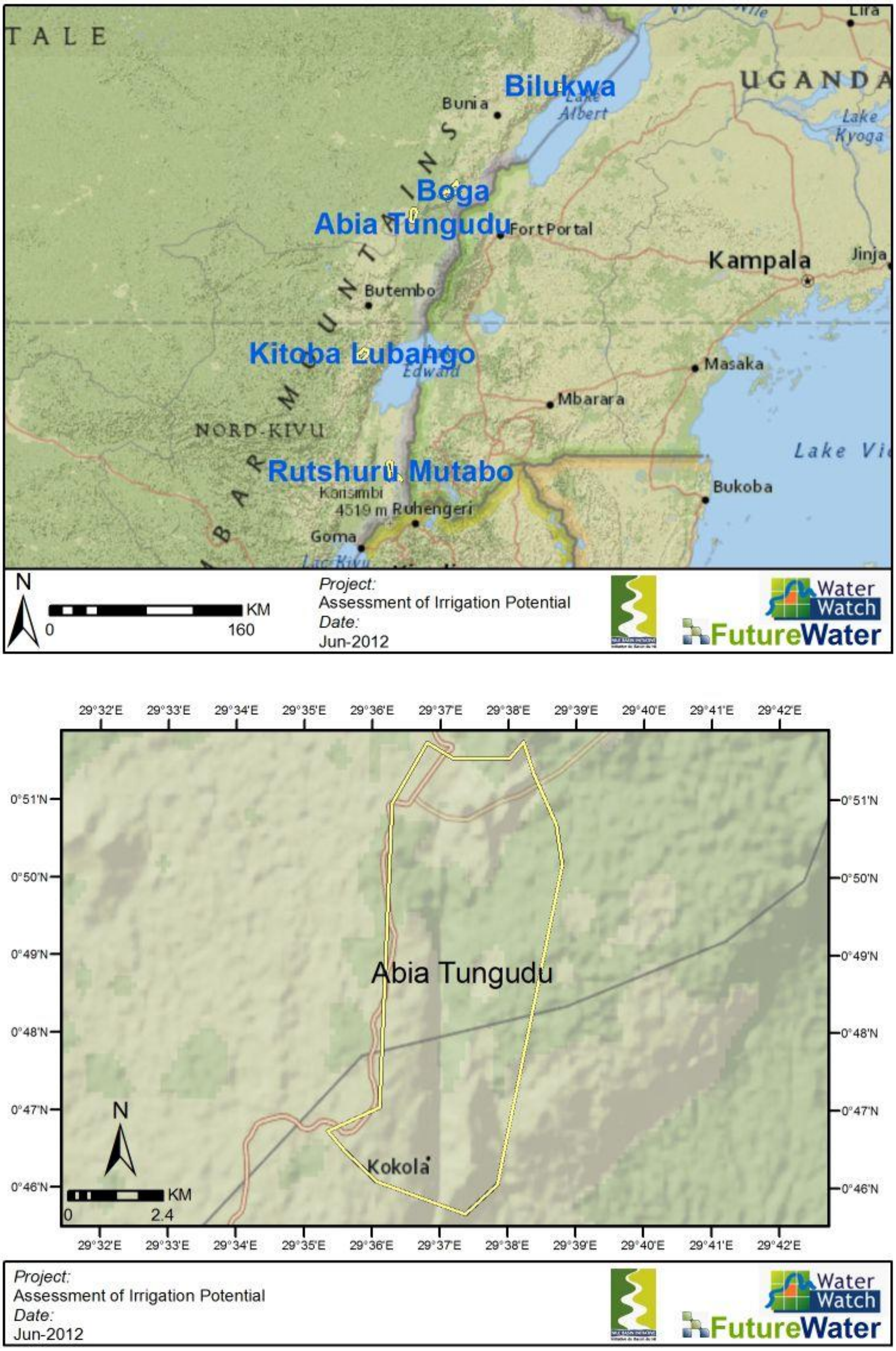


Figure 58: Abia- Tungudu focal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC

5.2 Land suitability assessment

5.2.1 Terrain

Abia- Tungudu is among four focal areas in DRC that are located at the most western edge of the Nile basin. The focal area stretches from the village of Abia towards the village of Tungudu, and is situated in the territory of Beni, in the district of of Goma, in the province of North-Kivu in eastern Democratic Republic of Congo. The focal area covers a total area of 4358 ha, and stretches from the water divide between the Nile and Congo basin at the western and northern side towards the lower land south of the focal area. The area covers a stream valley and two hills on the side draining on the stream. Elevation differs from 1250 m in the far northeastern tip towards 930 down the valley in the South (Figure 59). Slopes in the area can be steep; especially directly bordering the stream valley in the middle of the focal area the slopes are steep (25%). This is one line of steep slopes that goes through the area from North to South. On the higher lands slopes are moderate, and at most places under 5%.

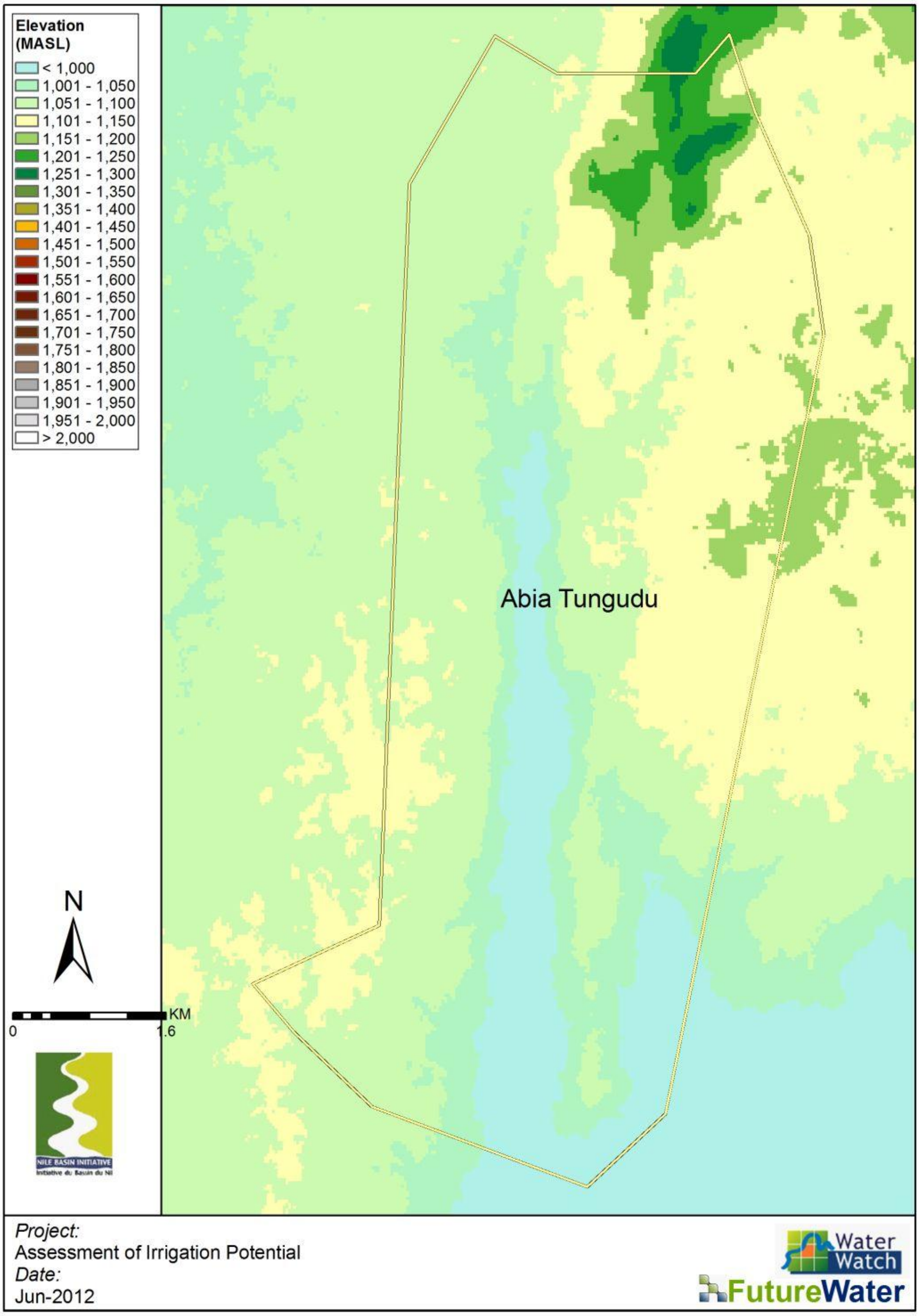


Figure 59: DEM Abia- Tungudu focal area. Resolution 1 arc second (+/- 30m).

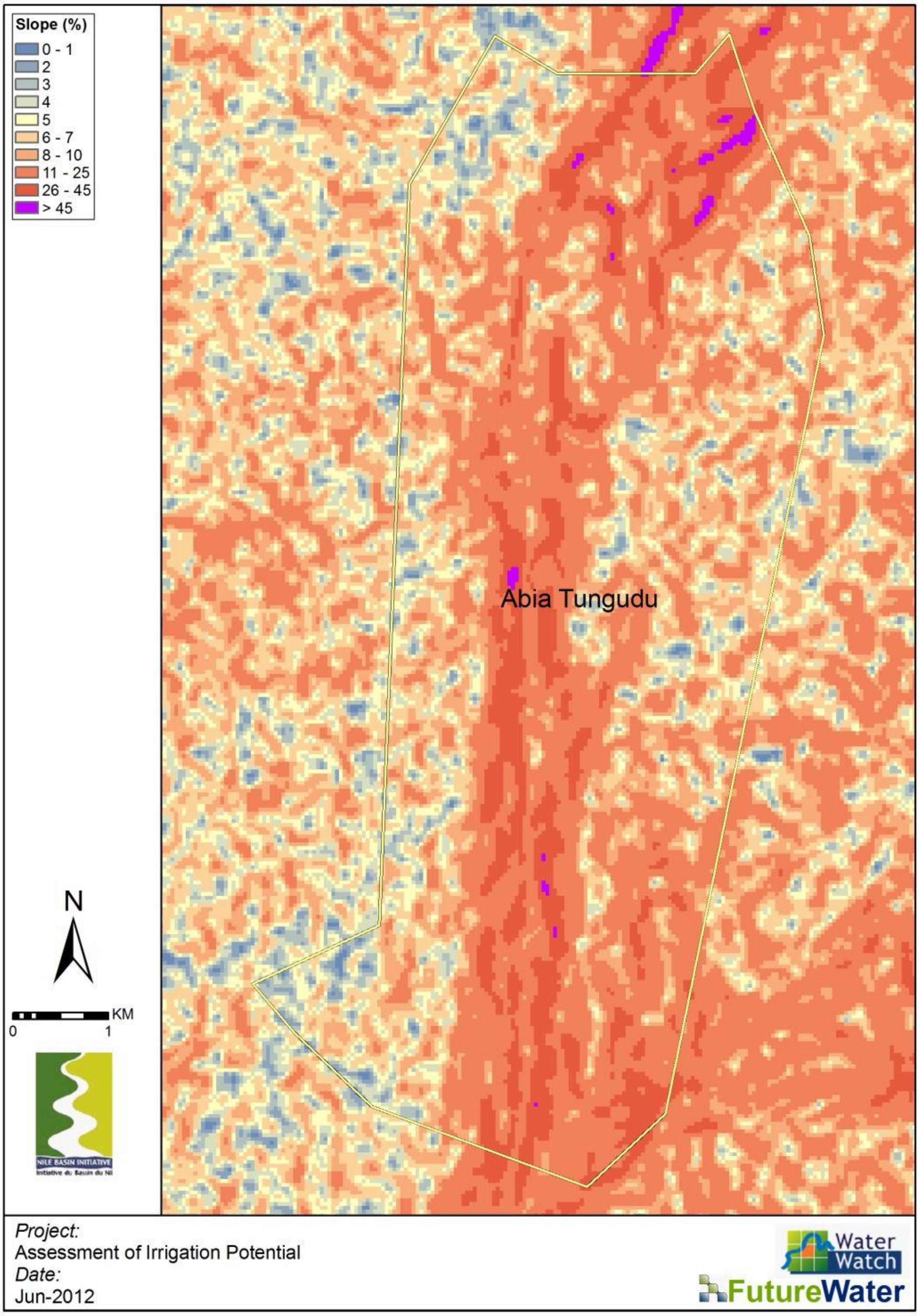


Figure 60: Slope map Abia- Tungudu focal area (source: ASTER).

5.2.2 Soil

The soil in Abia- Tungudu focal area is silty loam, and drainage is slightly poor. The soil has an average pH, and contains about 2.5% organic carbon in the top soil. The water holding capacity is large with over 150 mm/m. The soil is not uniform within the focal area; most common are the Lixisols, and secondly the Ferralsols. Lixisols are found in seasonally dry tropical and subtropical regions on Pleistocene and older surfaces. Lixisols comprise soils that have a higher clay content in the subsoil than in the topsoil, as a result of pedogenetic processes (especially clay migration) leading to an argic subsoil horizon. Preservation of the surface soil with its all-important organic matter is of utmost importance. Degraded surface soils have low aggregate stability and are prone to slaking and/or erosion, where exposed to the direct impact of raindrops. Tillage of wet soil, or use of excessively heavy machinery, compacts the soil and causes serious structure deterioration. Tillage and erosion control measures, such as terracing, contour ploughing, mulching, and use of cover crops, help to conserve the soil. The low absolute level of plant nutrients and the low cat ion retention by Lixisols, makes recurrent inputs of fertilizers and/or lime a precondition for continuous cultivation. Chemically and/or physically deteriorated Lixisols regenerate very slowly where not reclaimed actively. Perennial crops are to be preferred to annual crops, particularly on sloping land. Cultivation of tuber crops (cassava and sweet potato) or groundnut increases the danger of soil deterioration and erosion. Rotation of annual crops with improved pasture has been recommended, in order to maintain or improve the content of soil organic matter. Ferralsols represent the classical, deeply weathered, red or yellow soils of the humid tropics. They are less susceptible to erosion than most other intensely weathered tropical soils. Although the Ferrasols have good physical properties, the chemical fertility is poor. Maintaining soil fertility by maturing, mulching and/or adequate 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 DRC focal areas ranges between 0.66 and 0.83. Compared to the DRC average NDVI of 0.59, all focal areas have relative high land productivity values. Within the Abia- Tungudu focal area, the average land productivity value is 0.83, which is the highest of all focal areas within the study (Figure 61). The red places at the western side of the focal area are villages, in which the NDVI is slightly lower with values around 0.6. The coefficient-of-variation is very low within the whole area. Around the village in the North West the variation increases, which can be a sign of seasonal agriculture around the village.

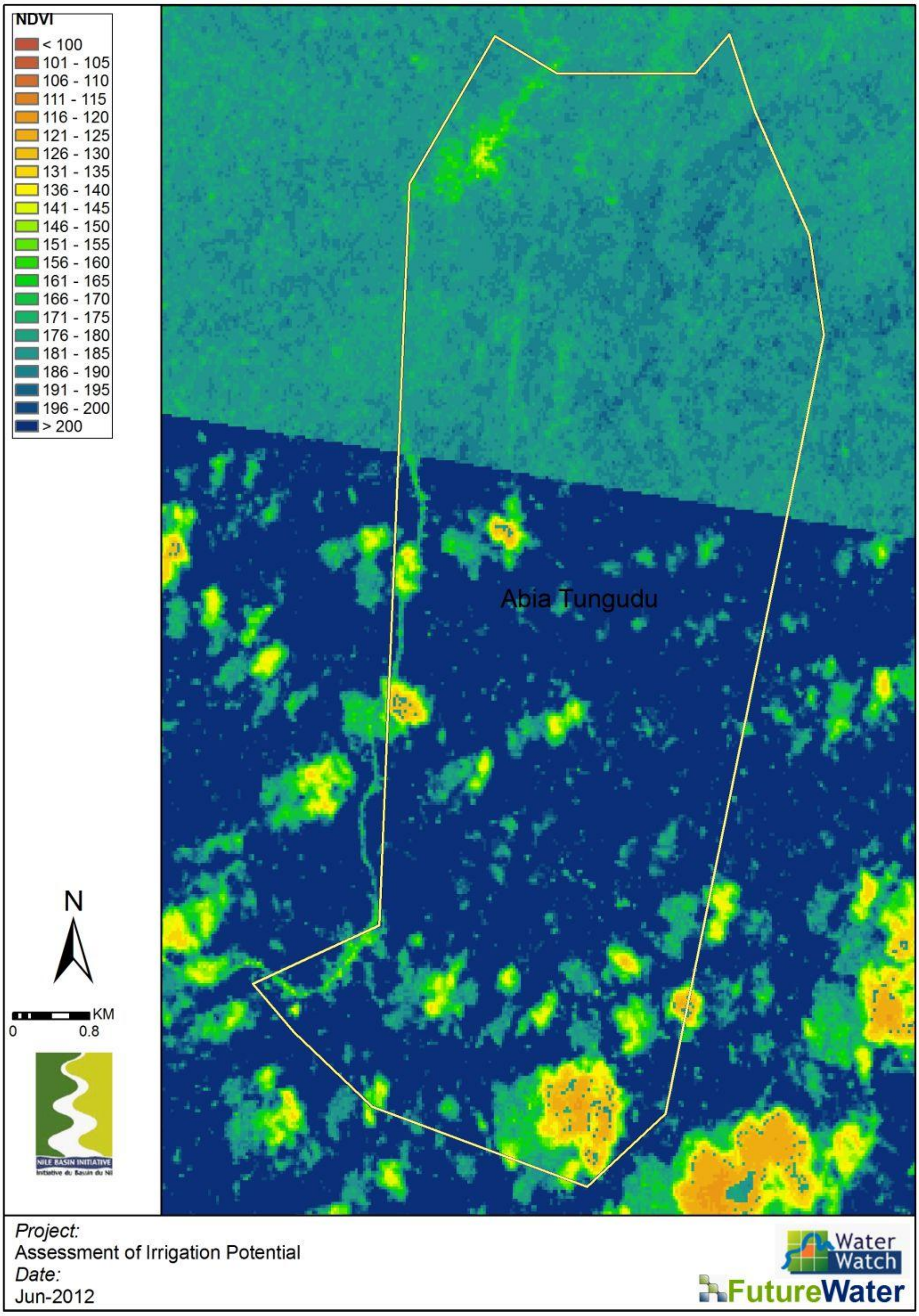


Figure 61: High Resolution NDVI for Abia-Tungudu focal area

5.2.4 Potential cropping patterns

Currently, about 10-20% of the area is used for agriculture. Agricultural practice varies over the area, but main crops that are currently grown are oil palms, cassava, rice, beans, and banana plantains. Beans and rice are harvested two and sometimes three times a year. Cassava is grown year round in one growing cycle. Bananas and palm oil trees are perennial crops. The potential future crops under irrigation are crops with a high economic return. In that way the region can develop, and poverty reduced. For this reason, potential crops include cacao, aloë vera and sorghum. These are, apart from Sorgum, all perennial crops with a high market value. Sorghum is not expected to need irrigation, so it can be grown on large scale on areas where the soil water holding capacity is large. The other crops can be irrigated to increase yields.

5.3 Water resource assessment

5.3.1 Climate

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

The climate of the area can be characterized as warm with constant temperatures during the year ranging from about 18^{o}C to 29^{o}C. Annual average precipitation is 1254 mm and reference evapotranspiration 1340 mm per year.

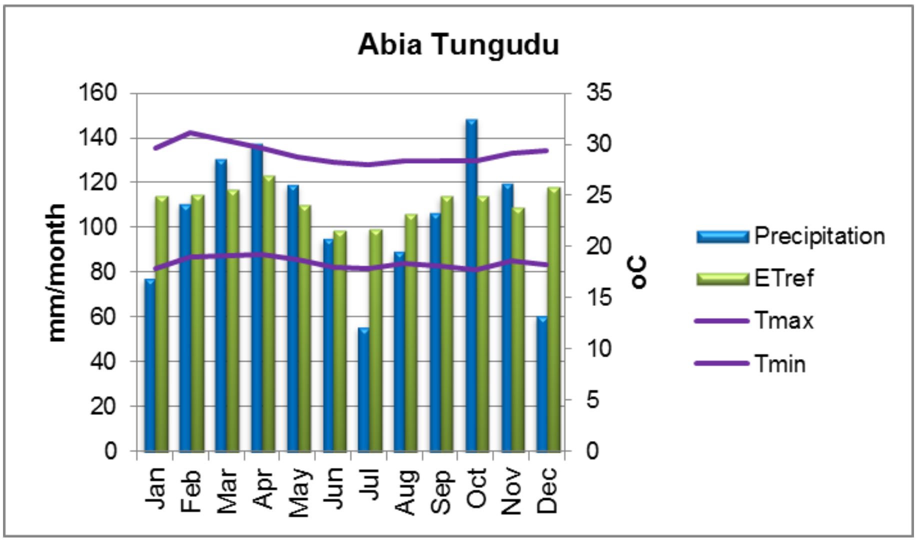


Figure 62: Average climate conditions for Abia-Tungudu focal area.

5.3.2 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.

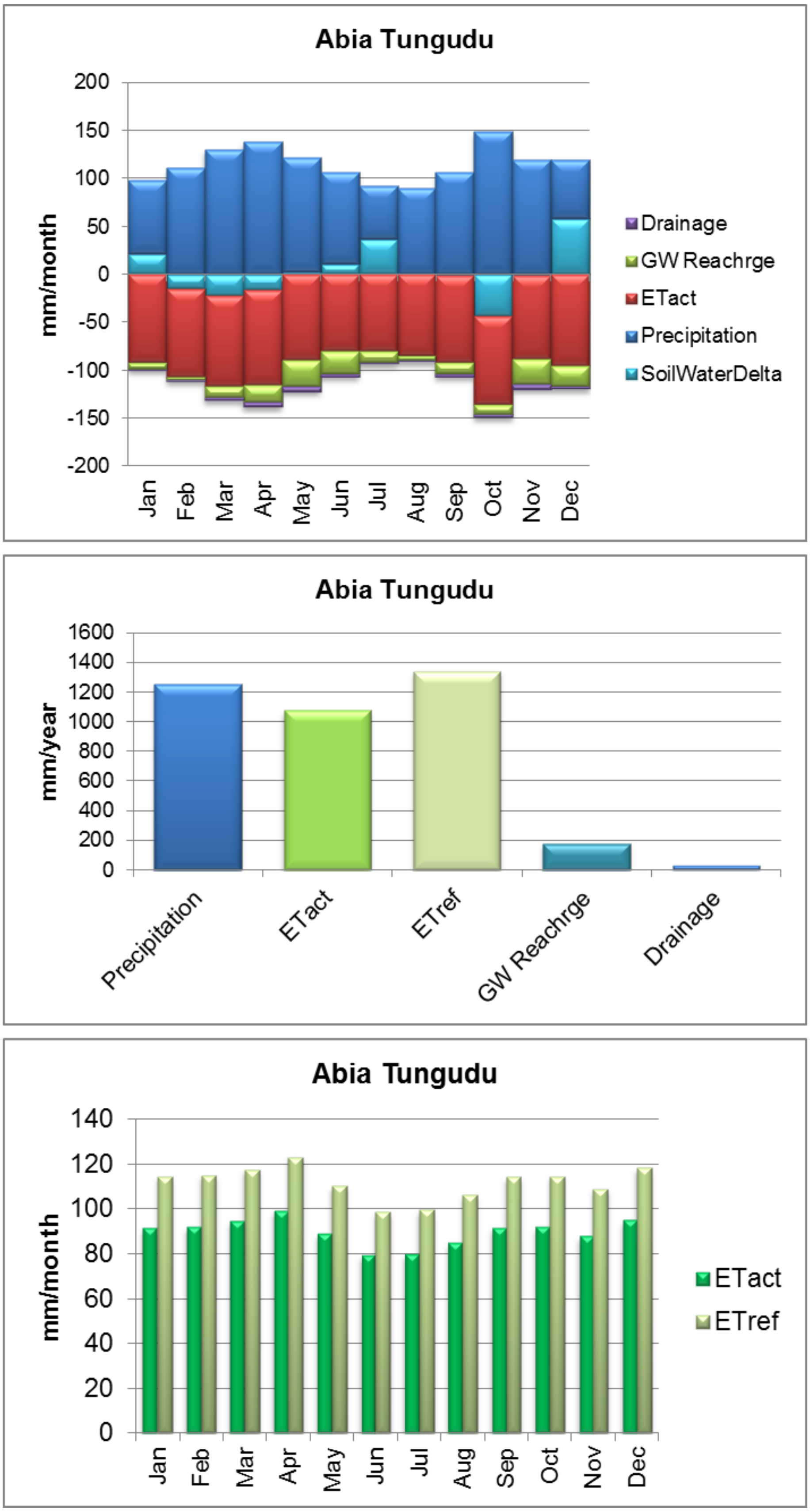
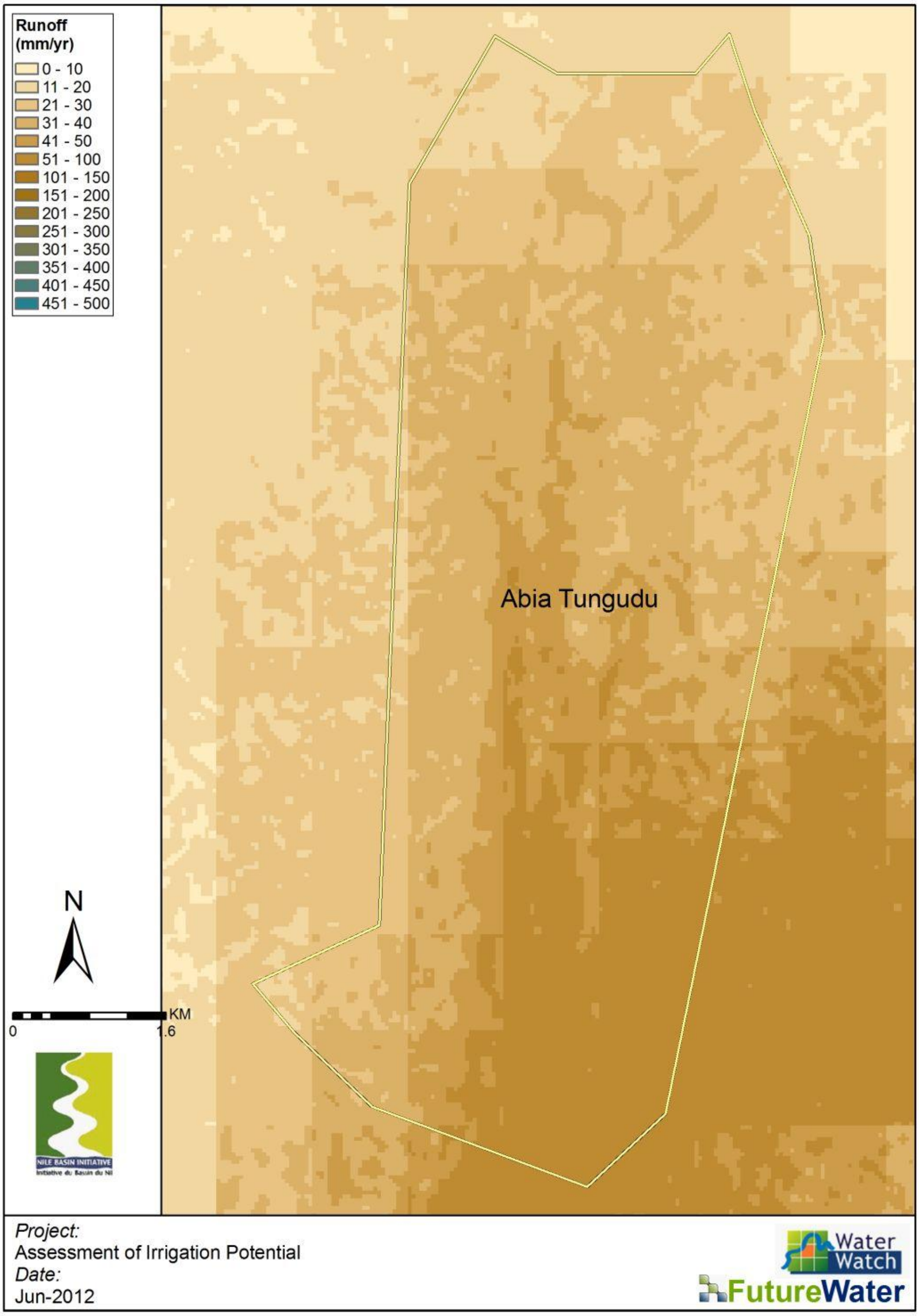
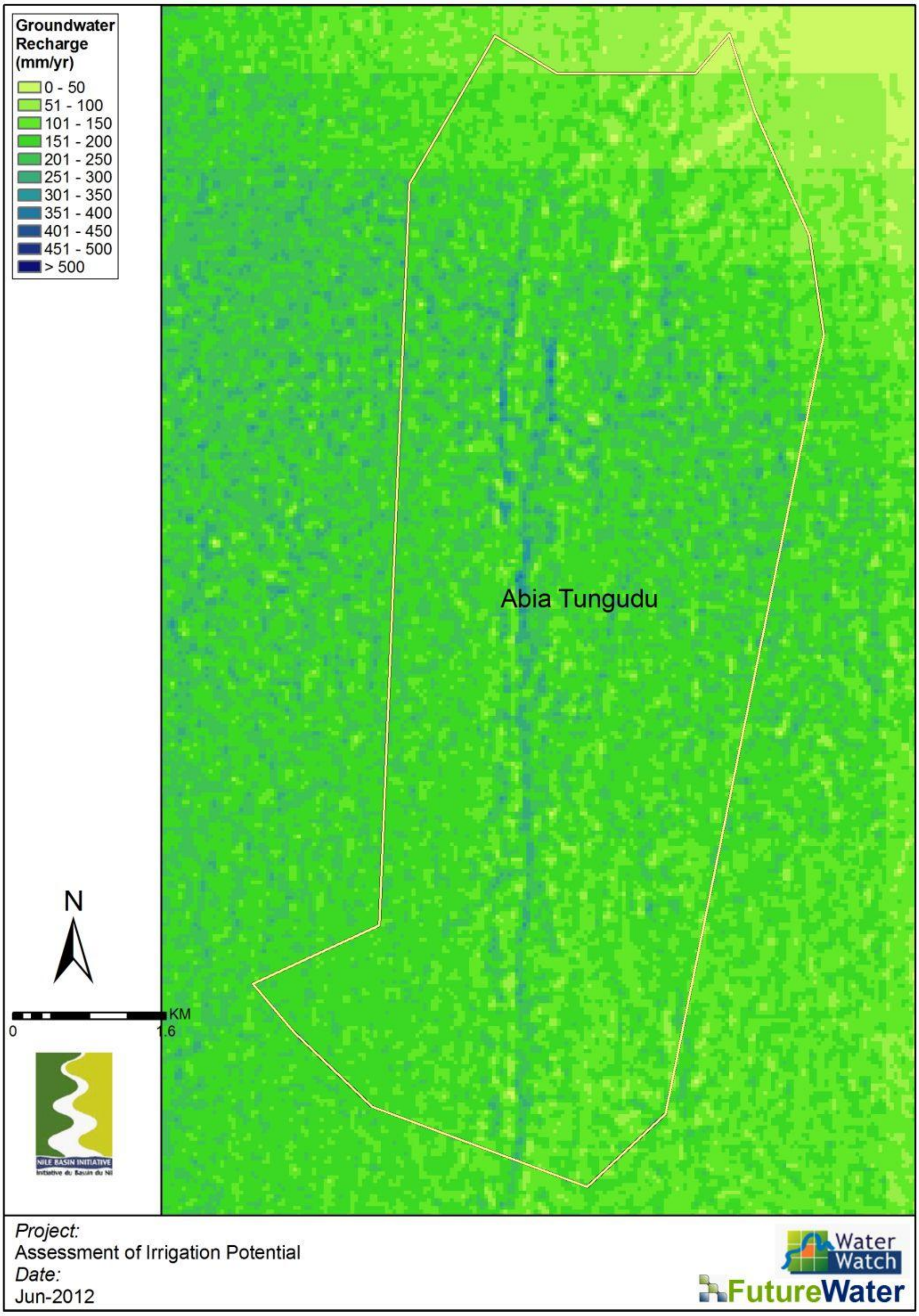


Figure 63: Water balances for the area based on the high resolution data and modeling approach for Abia-Tungudu focal area.


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
Abia Tungudu
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
Abia Tungudu
N
KM
0
1.6
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

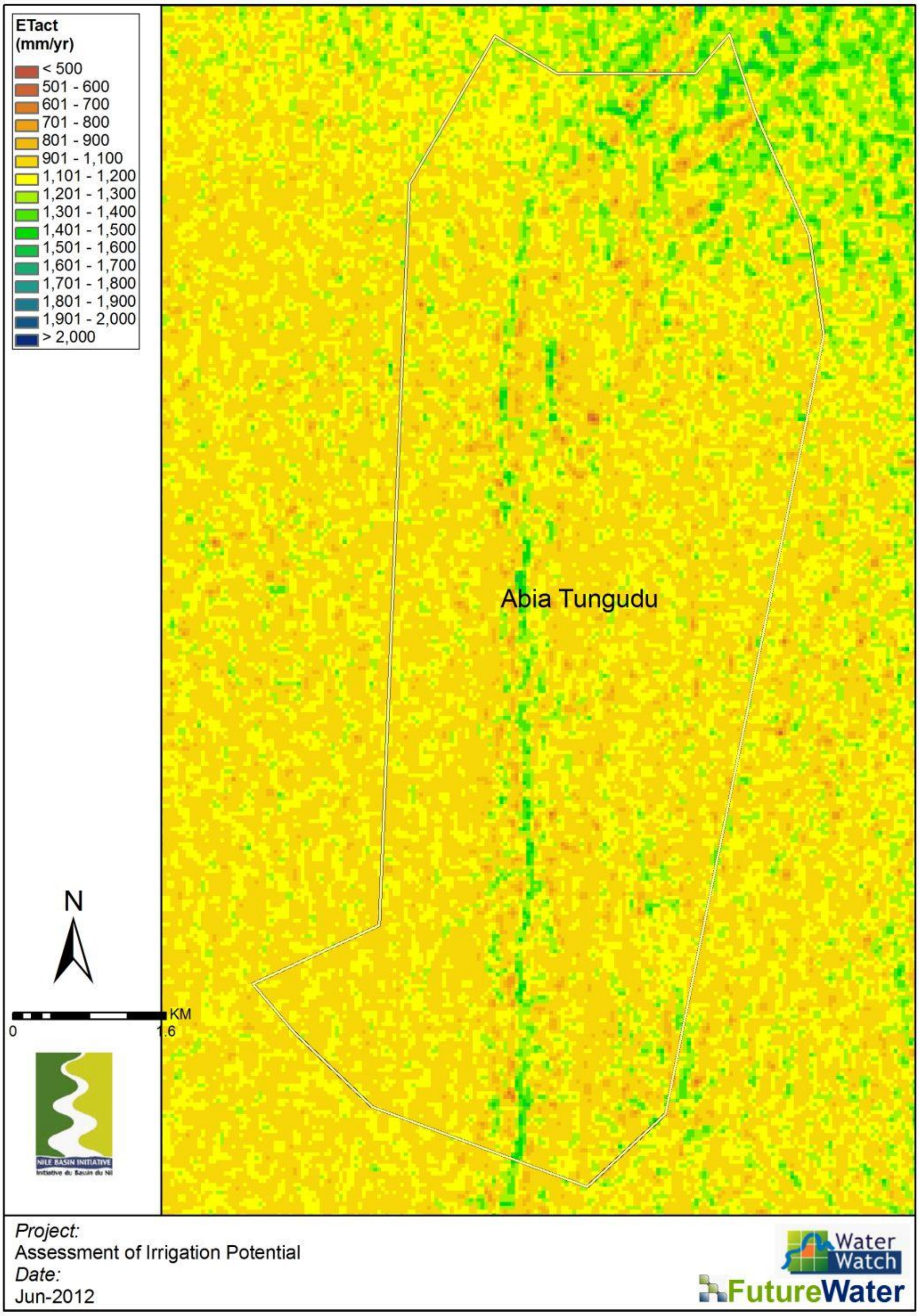


Figure 64: Water balances for the area based on the high resolution data and modeling approach for Abia-Tungudu focal area.

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.

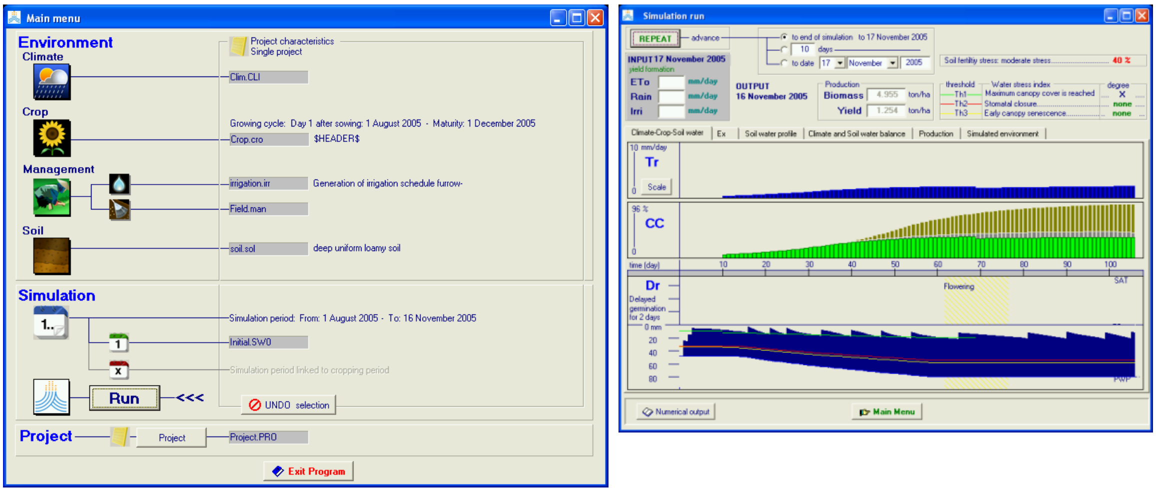


Figure 65: Typical example of AquaCrop input and output screens.

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

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year ===		== (day of year) ==		======== growing season =======			
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Sorghum	1254	1340	136	289	485	210	535	482
Aloe vera	1254	1340	1	365	1254	140	1336	1029
Vanilla	1254	1340	1	365	1254	140	1336	1029
Coffee	1254	1340	198	304	375	180	390	359

5.4.2 Irrigation systems and irrigations efficiencies

Since the focal area is situated directly at the water divide between the Nile and Congo basin, the catchment is quite small with approximately 44 km^2. The area is very hilly in the middle of the focal area, and the steep slopes limit the possibilities for surface irrigation. Slopes for surface irrigation are recommended not to surpass 2%, as increasing flow velocities will reduce water infiltration in the soil, and increase runoff and erosion. On the flatter highlands east and west of the stream, surface irrigation will be possible on small scales. It is advised to have a very close look into the water availability from upstream, which will be very limited due the small catchment, and the possible land that can be irrigated. The use of sprinkler and drip irrigation can decrease water demand due to increased water application efficiencies. These techniques, however, do require a much larger financial investment, and demand a higher knowledge base from the farmers who work with the irrigation system. Since topography and water availability will both push towards small scale irrigation systems, irrigation systems can differ over the area. Wherever possible, it is recommended to use surface irrigation. Although the water application efficiencies are relatively low, the environmental quality of the area will be enhanced, and water is used in a sustainable way. A detailed economic analysis should show how the cost of pumping the water relates to the water efficiencies. If water conveyance costs are high, due to the large elevation difference, which should be overcome, than the use of drip or sprinkler irrigation will be beneficial. This is beyond the scope of this pre-feasibility study and should be carried out under a detailed further study.

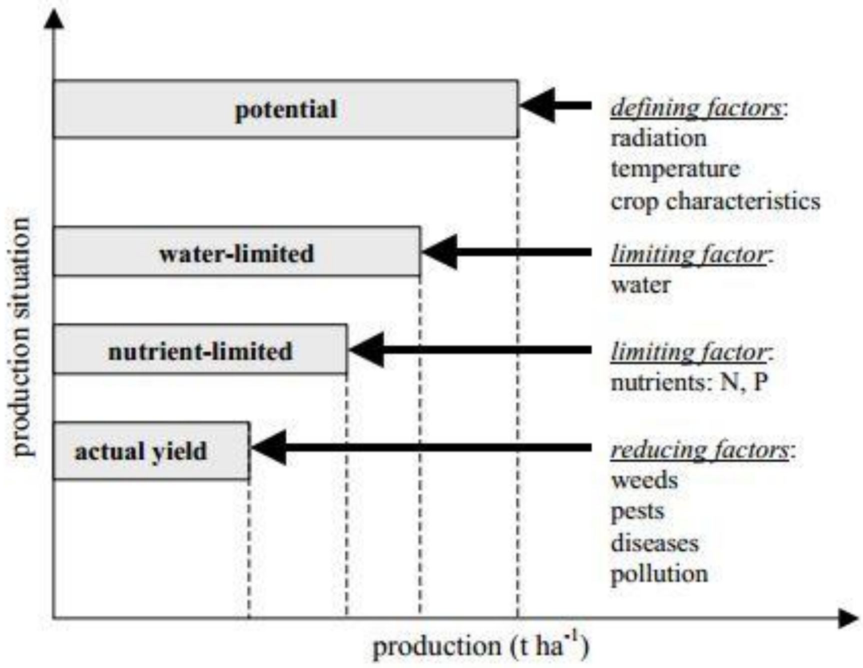
5.4.3 Water source

The initial water source will be surface water. However, due to the small catchment area the surface water is very limited. The annual average precipitation is rather large with nearly 1300 mm. This creates the possibilities for some small upstream reservoirs, which will store the water for the drier seasons. Especially the months July, December and January are dry months in which the amount of precipitation does not meet the demand for agriculture. The average flow of the stream that flows from North to South is 0.37 m^3/s. The use of groundwater for irrigation in this area is a good possibility. Model outputs show that within most of the area groundwater can be an irrigation source.

5.5 Potential crop yield assessment

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

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



5.5.1 Yield gap analysis potential dominant crops

Yields in DRC are generally below the average of the seven research countries. The agricultural area expanded over the years from 4,283,400 ha in 1980, towards 5,139,770 ha in 2009. This is an increase of 20%, while the population nearly tripled in the same time. The average yield per hectare, however, has hardly increased. Yields from cassava and groundnut are among the few crops that show a positive yield development. Other crops have remained stable or even decreased in yield per hectare over the years. In Figure 66, the yield gap is shown relatively to the highest obtainable yield in the world, the world's average, and to Africa's average. Yields in the Abia- Tungudu focal area are approximately 40% above DRC average. The need for agricultural intensification is large, and therefore a mixture between staple crops and cash crops is required to meet the food demand and to develop the region, and reduce poverty. The staple crop sorghum is currently grown at 6.8% of the maximum obtainable in the world. Since sorghum is a rather drought resistant crop, the yields do not increase enormously under irrigation. It is expected that yields will increase towards 10%, or slightly above of the world's maximum obtainable yields.

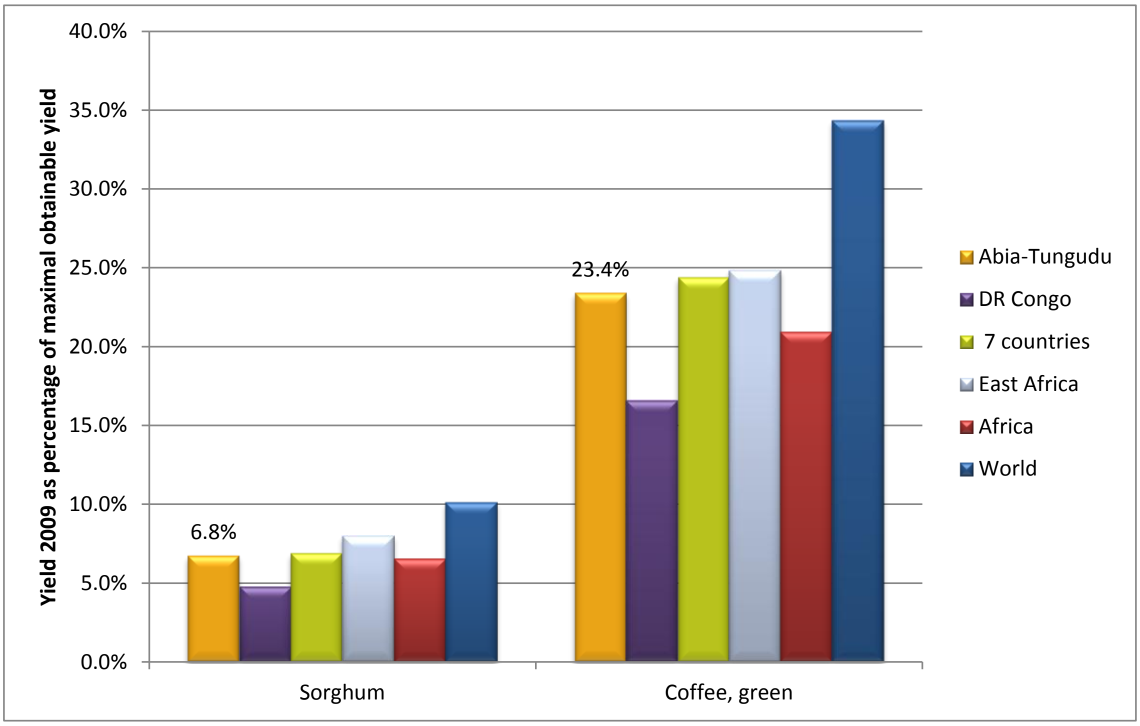


Figure 66: Yield gap Abia- Tungudu (source: FAOSTAT, 2012).

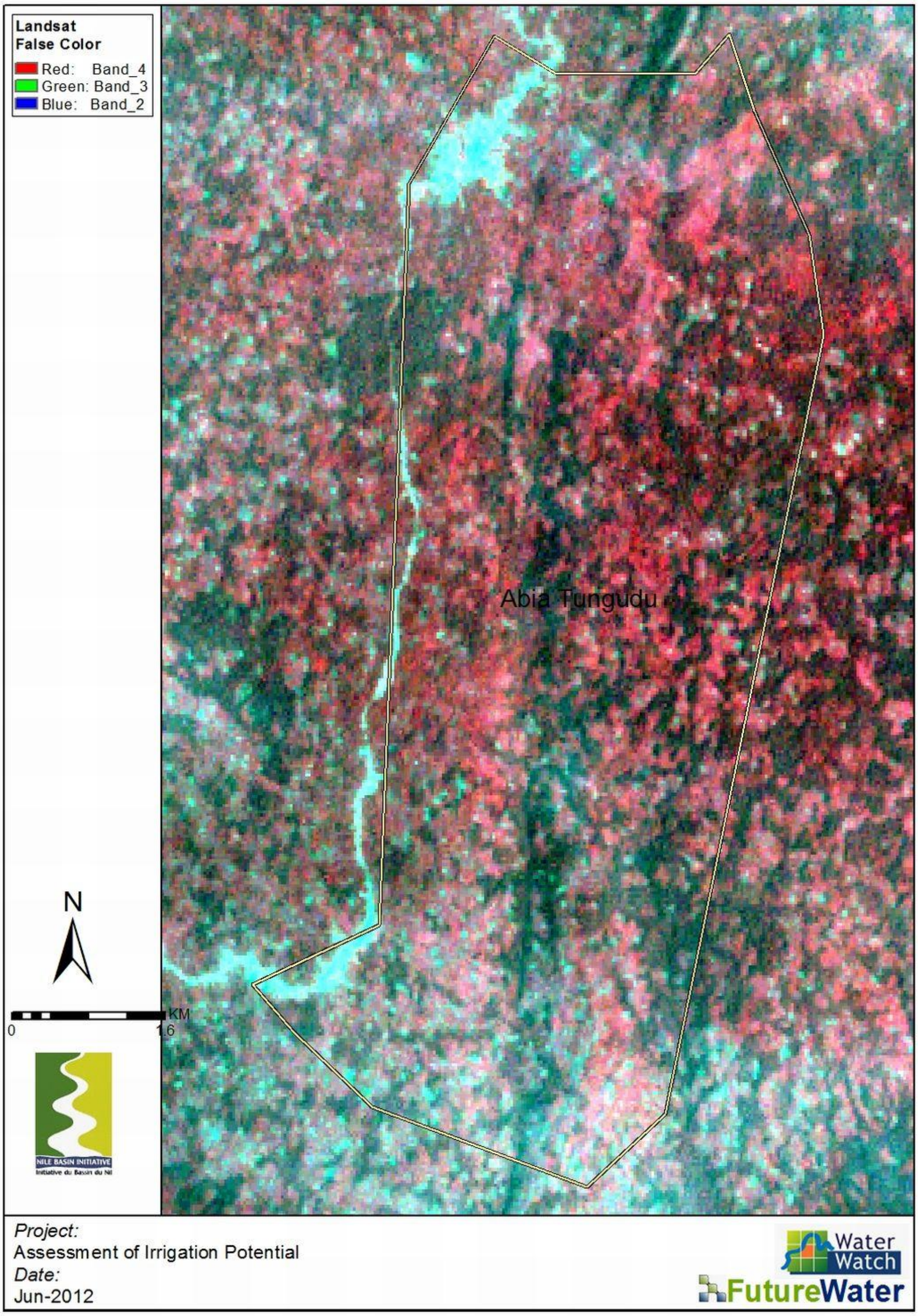


Figure 67: Landsat False Color Composite indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC

5.6 Environmental and socio-economic considerations

5.6.1 Population displacements

Population density within the focal area itself is very low. Most people live along the road that borders the focal area on the western side. The village of Eringite, Katola and further South the town of Owicha are the main settlements. If an irrigation system is developed, it is not expected that any population displacement is needed, as villages will be avoided and the rural area is very sparsely populated. With the design of any irrigation scheme, it is advised to limit any population displacement. The irrigation scheme can be developed around the existing houses. The exact numbers of effected houses can only be known after designing the scheme, which is beyond the scope of this pre-feasibility study.

5.6.2 Social

The population density within the focal area is small, except for the villages, where the density increases. Within the Ituri district, the population density is the highest of the Orientale province with 65 people per km^2 (2003 population estimate). This is well above the DRC average of 30 people/km^2. The ratio male to female is slightly in favor of the female with 0.96. According to the field visits, the tribes that inhabit the region are the Hema and Boga. The equality between man and woman is poor. Women hardly take any reading position in official institutions. On lower levels they may take up to 10% of the seats, but on higher level it is man only. The enrollment rate on primary and secondary school shows that about 35% of the children are girls. The majority of the population in Orientale province is extremely poor. Main diet consists for 70-80% of a staple food of starch or grain, such as cassava, plantains, rice, sweet potatoes, potatoes or maize. The staple food is accompanied by beans, vegetables and sometimes fish, game or meat. Infrastructure in this area is quite good; one main road passes the focal area on the western side. The infrastructure within the rural area, however, is much worse. This makes it more difficult to develop the area. Main markets are at Owicha, Bunia or Beni, which are all good reachable. The farmers do have low to average irrigation experience, and have some knowledge about farmers' cooperations.

5.6.3 Upstream downstream consideration

Within the focal area the land is used for extensive agriculture. This minimizes the upstream – downstream problems. However, when developing irrigation it is very important that the land will not be degraded. Degraded surface soils have a low aggregate stability, and are prone to slaking and/or erosion where exposed to the direct impact of raindrops. The large amount of precipitation can flush away the fertile top soil. Soils flushed away can cause serious problems downstream if peak flows increase, and floods or landslides take place more often. The low absolute level of plant nutrients make recurrent inputs of fertilizers and/or lime a precondition for continuous cultivation. Chemically and/or physically deteriorated soils regenerate very slowly where not reclaimed actively. Perennial crops are to be preferred to annual crops, particularly on sloping land. The mode and timing of fertilizer appliance determines to a large extent the success of farming on these soils. Besides this, good fertilizer application minimizes leaching of nutrients and ensures downstream water quality.

5.6.4 Protected areas

Within the focal area no protected areas are reported.

5.6.5 Institutional and legal framework

Information on the water treaty agreements and the land ownership rights can be found in chapter 1.1.5.

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. Total focal area is 4358 ha of which about 500 ha is suitable to develop irrigation.

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 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):
    - Sorghum: 900 kg/ha, 0.65 $/kg
    - Aloe vera: 1,000 kg/ha, 2.00 $/kg
    - Vanilla: 1,000 kg/ha, 2.00 $/kg
    - Coffee: 550 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, accessibility to roads, to markets and the expected yield increase. This in-turn affects access to market as farmers cannot transport their yield easily and more importantly may not fetch golden prices.

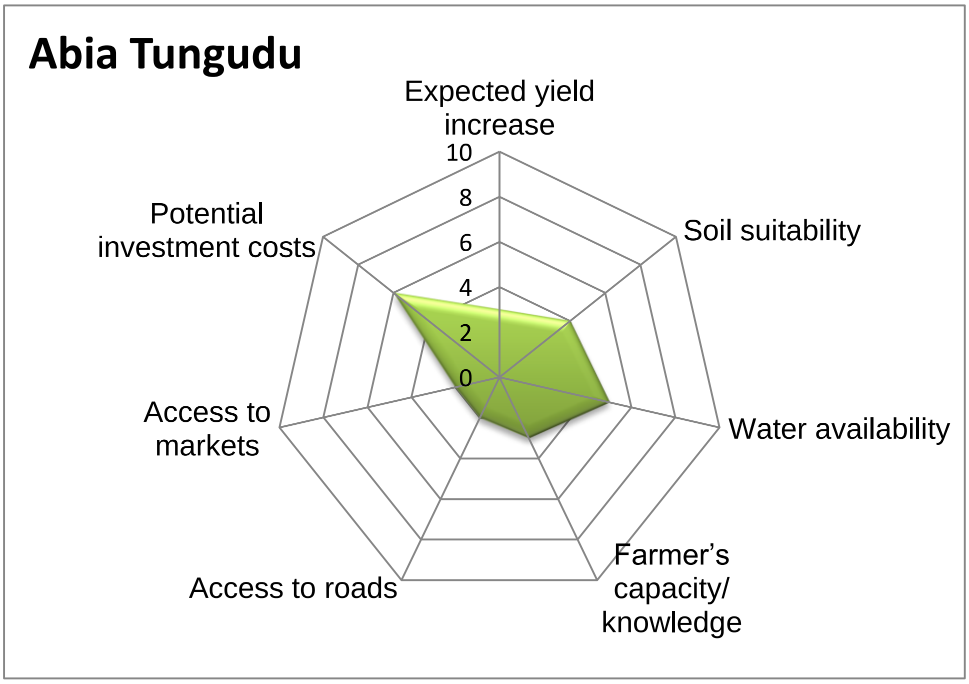


Figure 68: Filled radar plot indicating expert knowledge score to develop irrigation in the Abia- Tungudu focal area (1 = negative, 10 = positive)

Table 11: Benefit-cost analysis for Abia- Tungudu area.

Characteristics	
Irrigated land (ha)	500
Farmers	500
Investment Costs	
Irrigation infrastructure (US$/ha)	8,000
Social infrastructure (US$/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$)	5.3
O&M costs (million US$/yr)	0.055
Net benefits per year (million US$/yr)	0.527
IRR (Internal Rate of Return)	8.5%

6 Kitoba-Lubango focal area

6.1 Introduction

This chapter will describe the current state of the Kitoba-Lubango 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 70 a detailed map of the area is given. Total area is 5660 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 Kambale Sukayamolo Christian and supervised by Henri Okitolembo, Bruno Matata, and Isaac Mutela in April and May 2012.

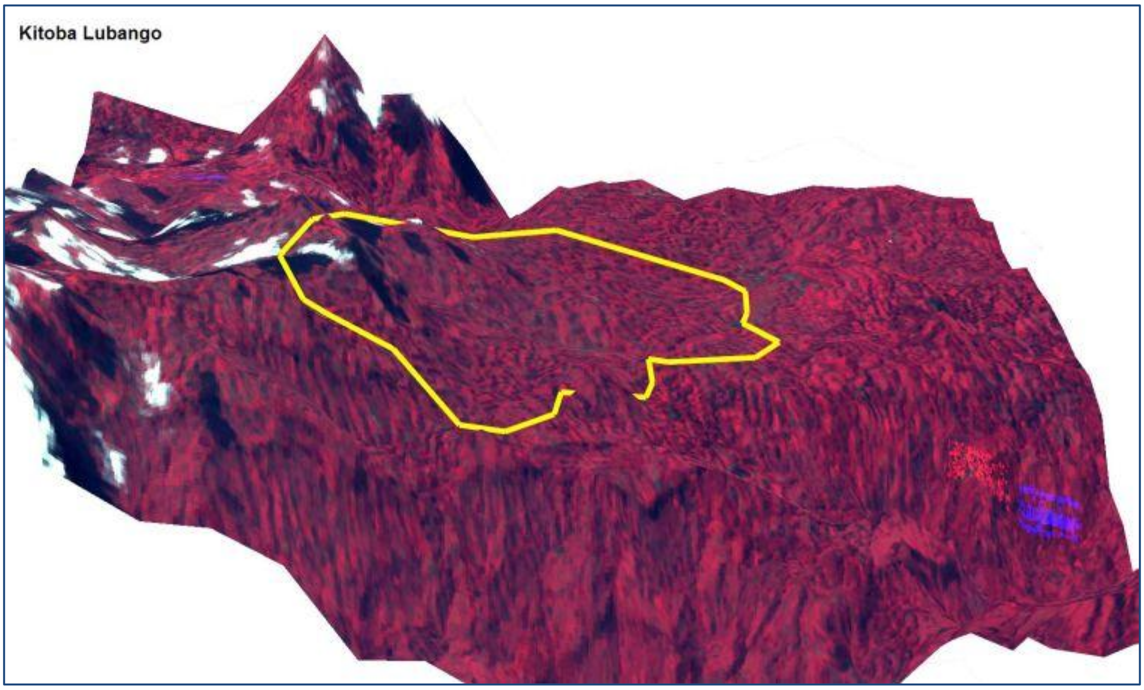
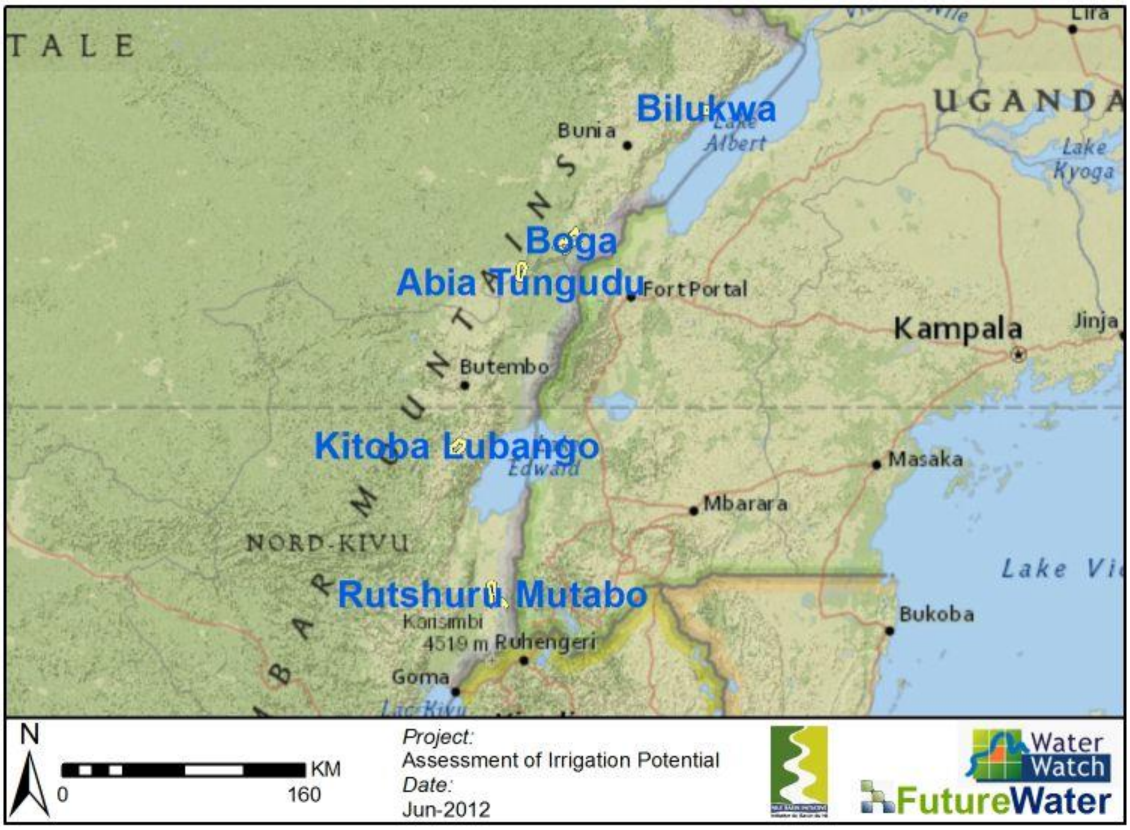


Figure 69: 3D impression of the Kitoba-Lubango focal area, Eastern DRC



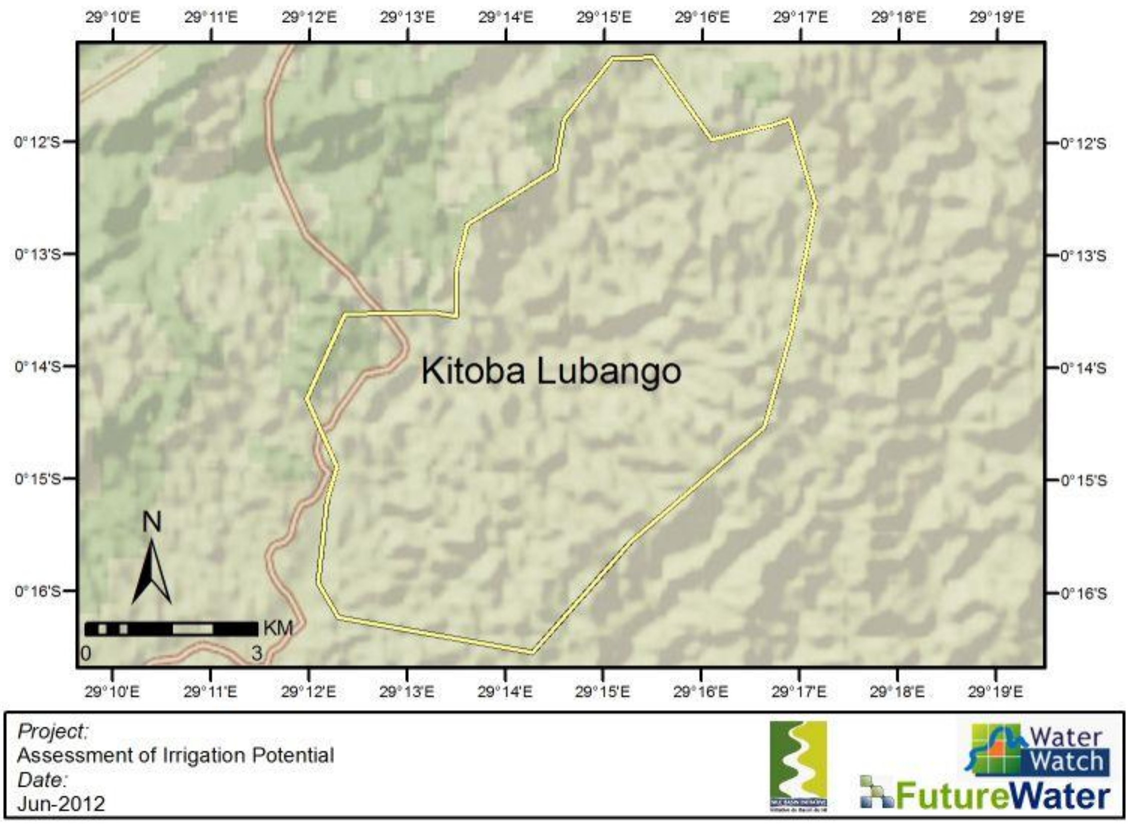


Figure 70: Kitoba-Lubango focal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC

6.2 Land suitability assessment

6.2.1 Terrain

The Kitoba-Lubango focal area (5664 ha) is situated in is located between the villages of Kitoba and Lubango, in the territory of Lubero, in the district of Goma, in the province of North Kivu, in eastern DR Congo. The western and northern borders are formed by the Nile basin boundary. The area is located on high elevation, and descends from North East (2500 m) to South West (2150 m) (Figure 71). The focal area can be seen as a small catchment area, of which all the water drains towards the South West. Slopes differ very much on a 30 m scale, with many slopes reaching over 30% (Figure 72). This figure shows that steep slopes can be found all over the area. On a 250 m scale, however, it becomes clear that most severe slopes can be found in the North eastern region, and that slopes decrease towards 0-10% in the whole southwestern region.

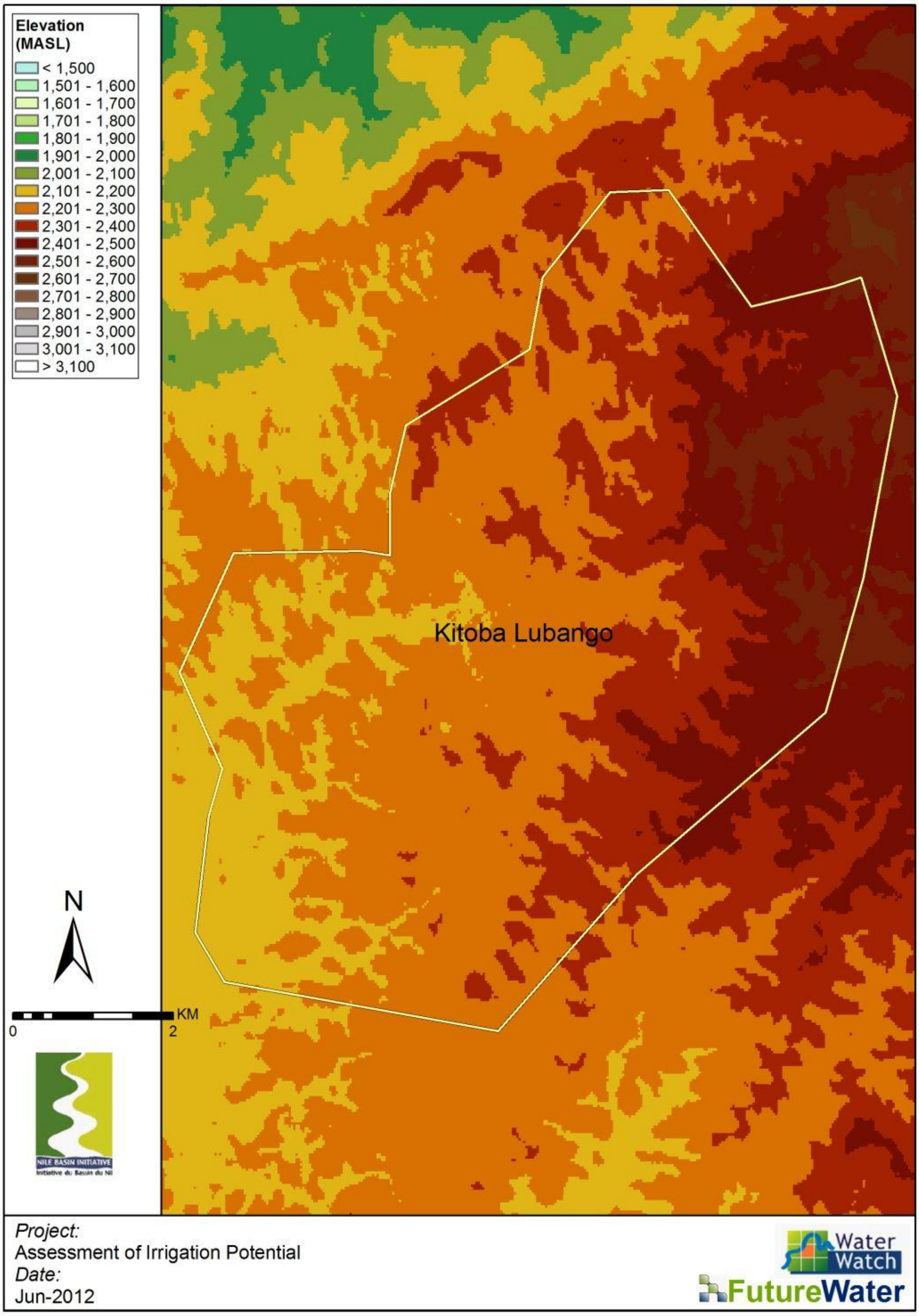


Figure 71: DEM Kitoba-Lubango focal area. Resolution 1 arc second (+/- 30m).

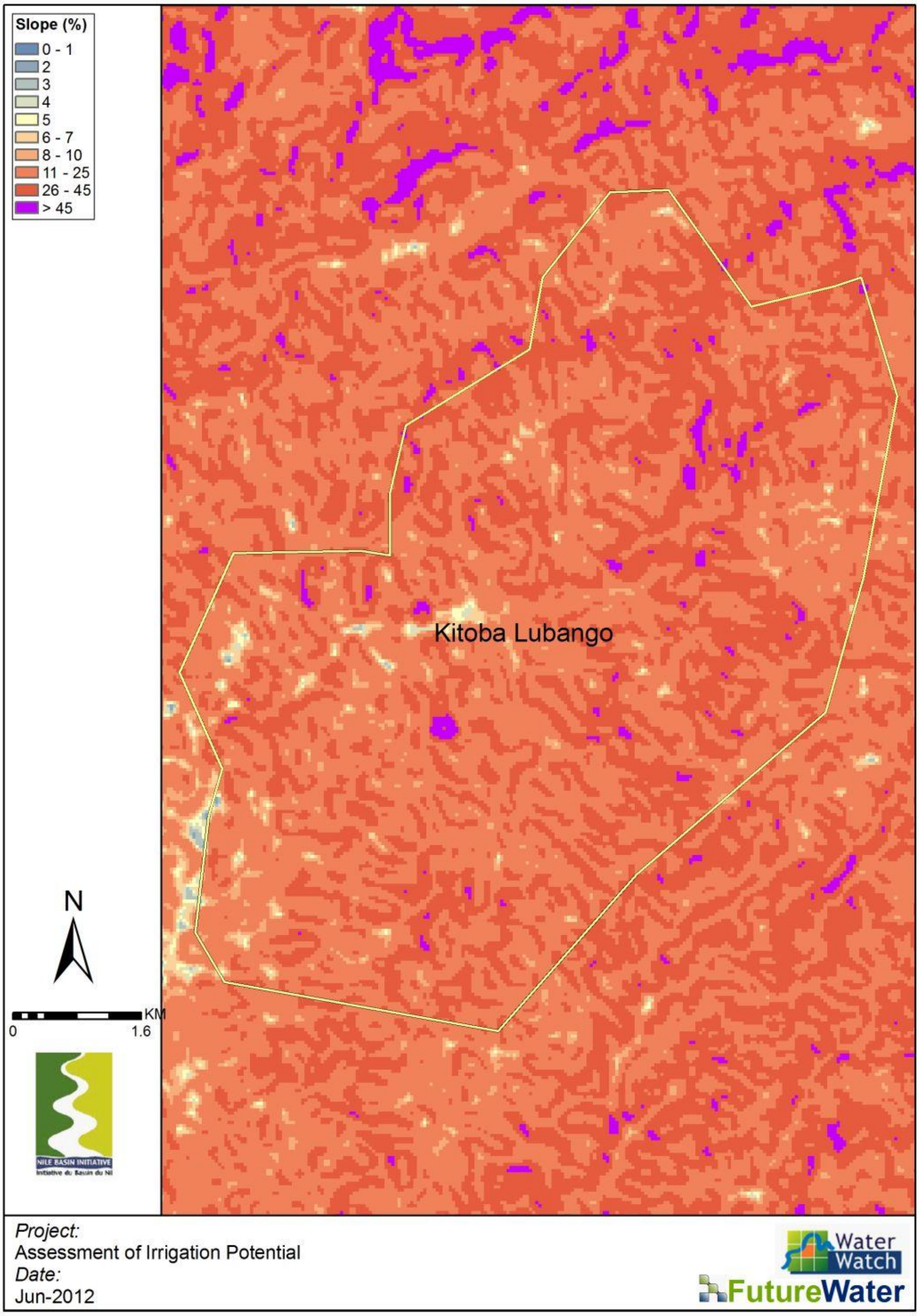


Figure 72: Slope map Kitoba-Lubango focal area (source: ASTER).

6.2.2 Soil

Soil texture in the area is silty loam to loam. Drainage is somewhat poor to moderately well drained. The percentage of organic carbon in the top soil is large with approximately 4%. The soil has a large water holding capacity of over 150 mm/m. The soil is acid with a pH of 4-5.5. Soils in the area consist for 70% of Acrisols. Acrisols are soils that have a higher clay content in the subsoil than in the topsoil as a result of pedogenetic processes (especially clay migration), leading to an argic subsoil horizon. Preservation of the surface soil with its all-important organic matter, and preventing erosion, are preconditions for farming on Acrisols. Mechanical clearing of natural forest, by extraction of root balls and filling the holes with surrounding surface soil, produces land that is largely sterile, where Al concentrations of the former subsoil reach toxic levels. Adapted cropping systems with complete fertilization and careful management are required if sedentary farming is to be practiced on Acrisols. Agroforestry is recommended as a soil-protecting alternative to shifting cultivation, in order to achieve higher yields without requiring expensive inputs. Low-input farming on Acrisols is not very rewarding. Undemanding, acidity tolerant cash crops, such as pineapple, cashew, tea and rubber can be grown with some success. Increasing areas of Acrisols are planted with oil-palm (e.g. in Malaysia and on Sumatra). Large areas of Acrisols are under forest, ranging from high, dense rain forest to open woodland. Most of the tree roots are concentrated in the humus surface horizon, with only a few tap-roots extending down into the subsoil. Acrisols are suitable for production of rain fed and irrigated crops only after liming and full fertilization. Rotation of annual crops with improved pasture maintains the organic matter content.

6.2.3 Land productivity

The land productivity (NDVI) in the five DRC focal areas ranges between 0.66 and 0.83. Compared to the DRC average NDVI of 0.59, all focal areas have relative high land productivity values. Within the Kitoba-Lubango focal area, the annual average land productivity value is 0.66, which is the lowest of all DRC focal area values, but still well above the country average (Figure 73). The coefficient-of-variation in the focal area is very low. Regarding the relatively large percentage of agricultural land within the focal area, this suggests that the agricultural land is used year through in several growing cycles.

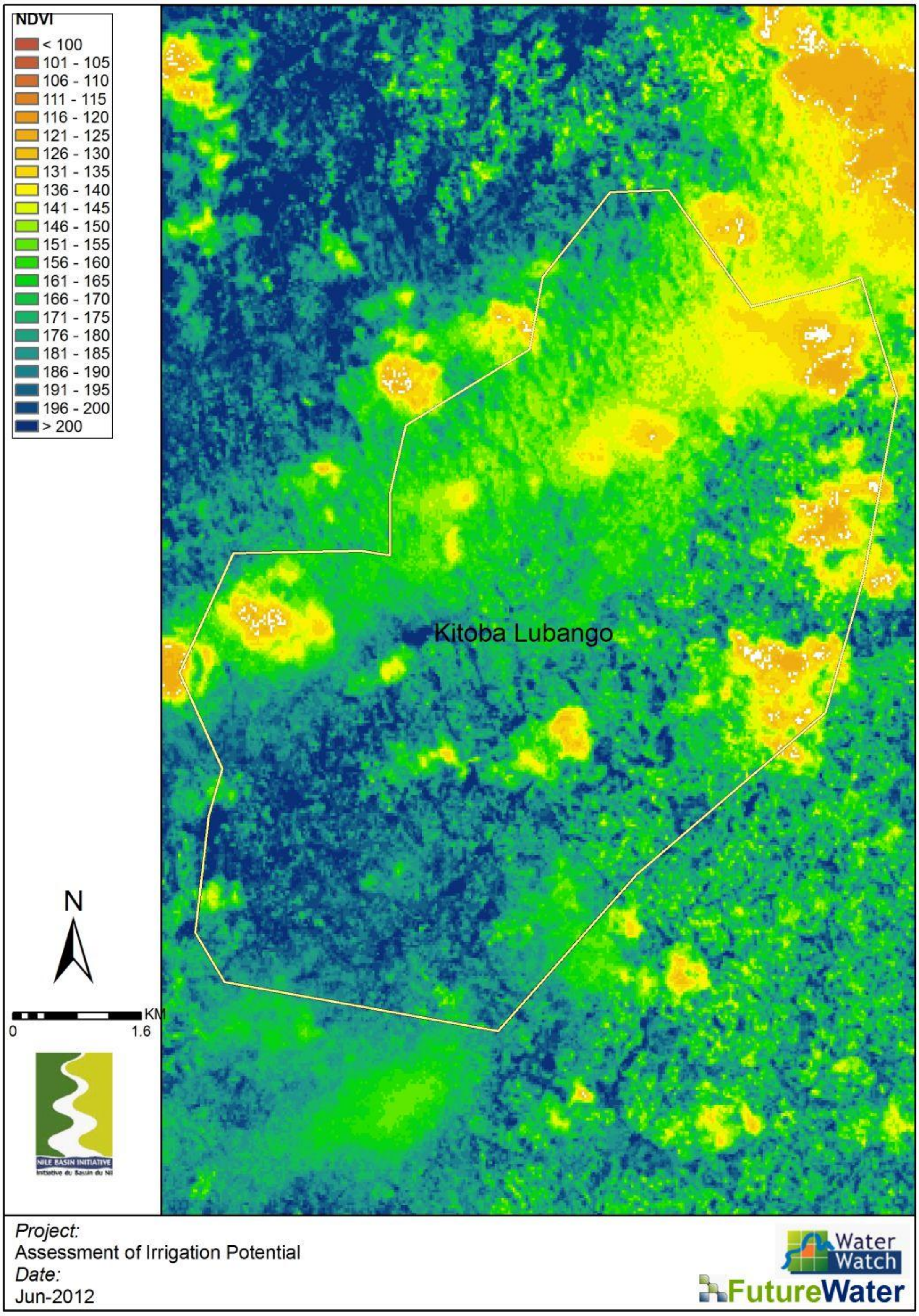


Figure 73: High resolution NDVI for Kitoba-Lubango focal area

6.2.4 Potential cropping patterns

Within this focal area, the area used for agriculture is relatively large (70-80%). Main crops include banana, maize, beans, cassava, rice, soybeans, potatoes, and vegetables. Maize and beans are the most dominant crops, and are probably grown simultaneously on the same area. Both are grown in two growing cycles per year. Future crops that can be grown under irrigation include rice, maize, bananas and vegetables. It is recommended to focus on crops that have a high potential, and a high economic return. This is preferably, since the irrigation system will be more profitable, and the return on investment period will be shorter. Therefore, rice, bananas and vegetables are very suitable. The return on maize, however, is generally low. Rice can be grown in two or even three growing cycles per year, vegetables in most cases too. Banana is a perennial crop with a yield that can be increased under irrigation. It is advised to keep the diversity in crops to meet the local food demand. Whenever the local food demand is reached, a focus can be developed towards a crop with a strong link to a processing industry.

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 moderate with constant temperatures during the year ranging from about 13°C to 23°C. Annual average precipitation is 1468 mm and reference evapotranspiration 1350 mm per year.

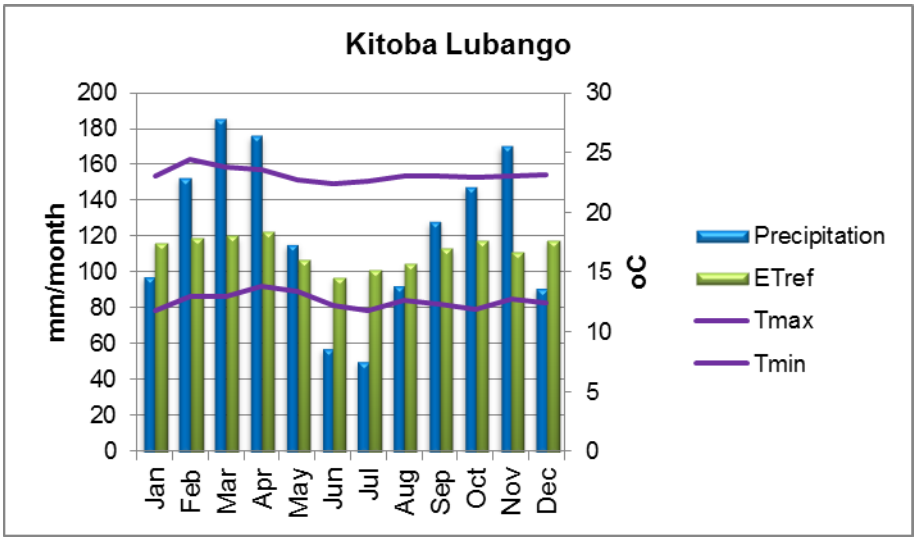


Figure 74: Average climate conditions for Kitoba-Lubango focal area.

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.

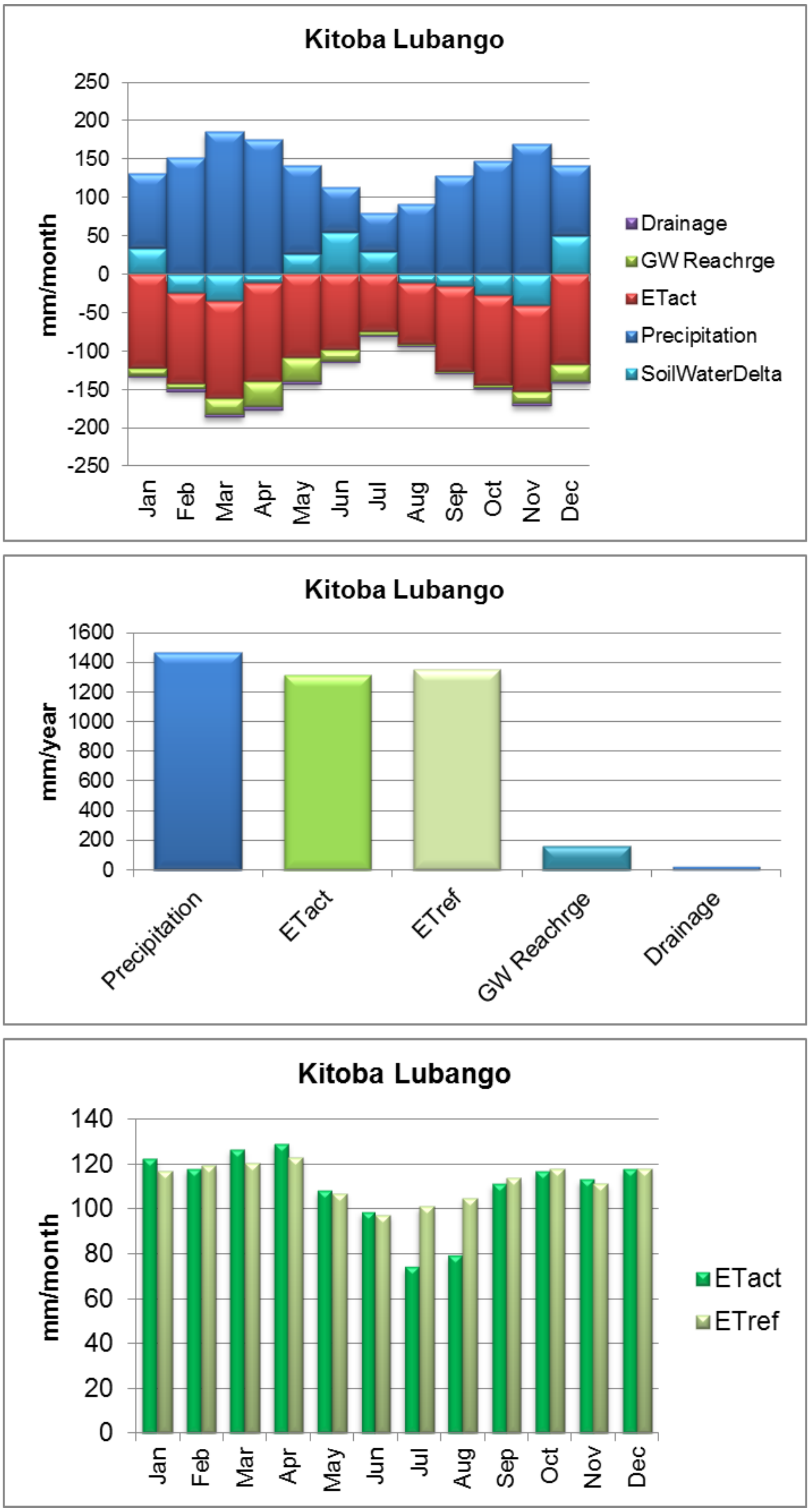
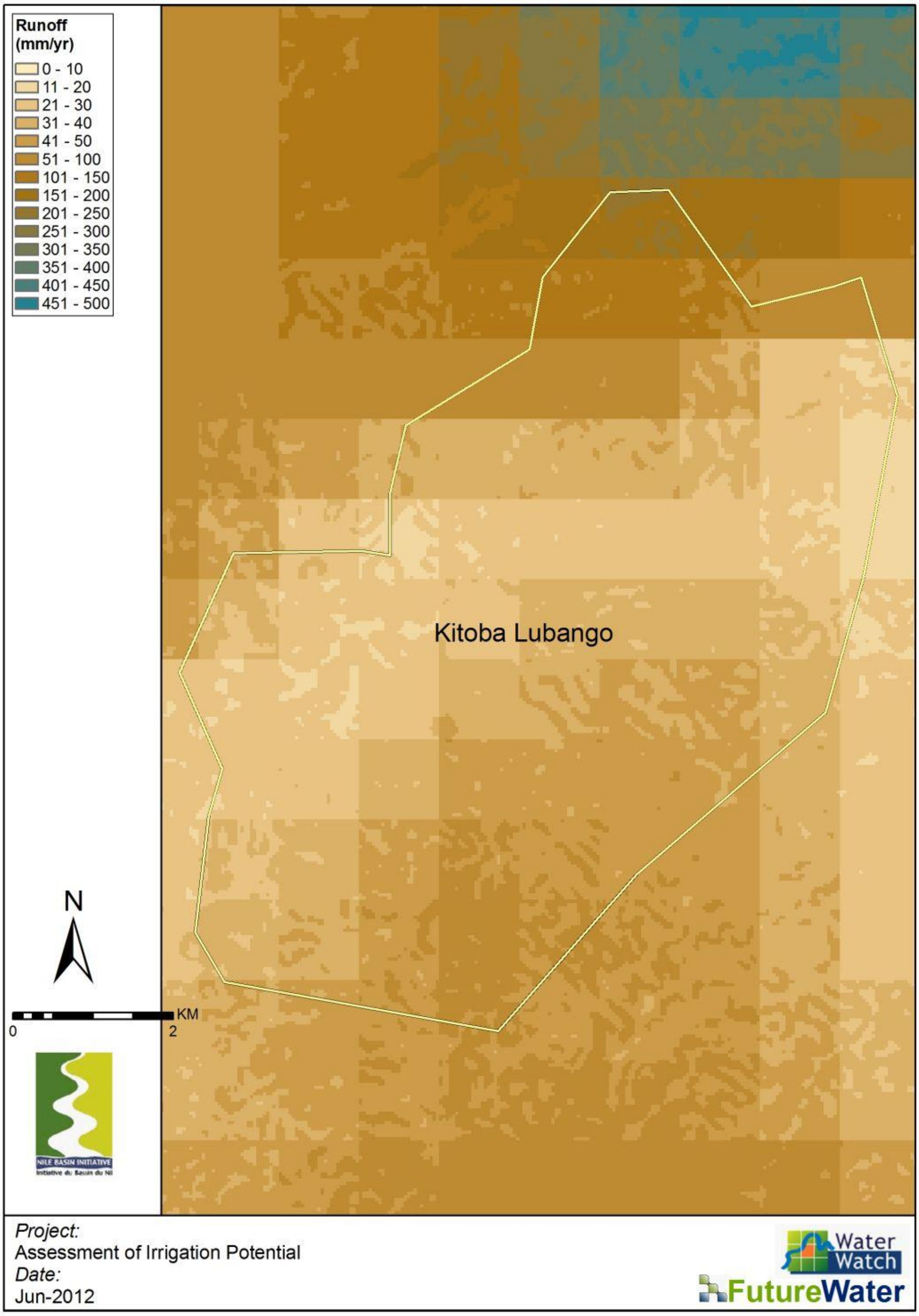
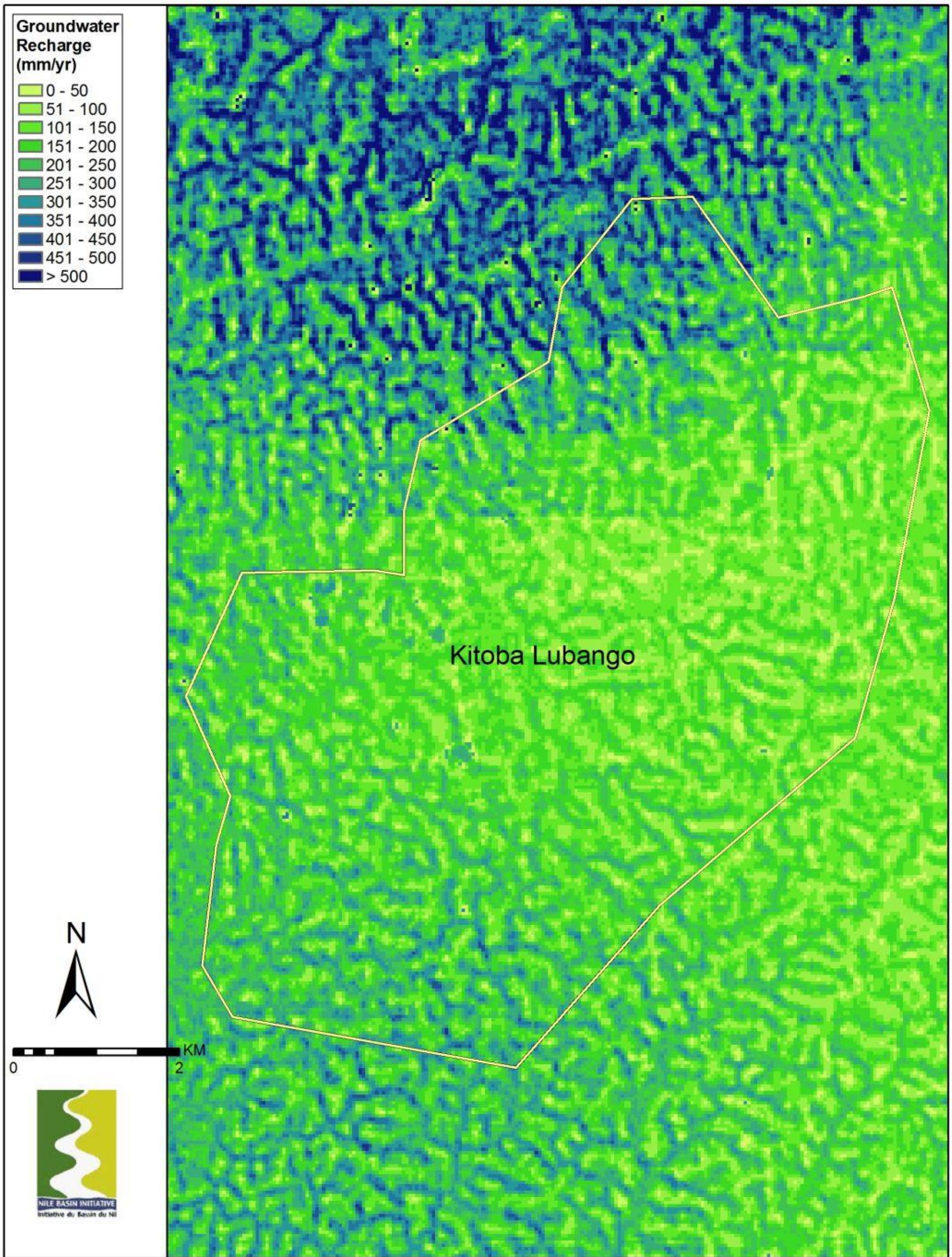


Figure 75: Water balances for the area based on the high resolution data and modeling approach for Kitoba-Lubango focal area.


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
Kitoba Lubango
N
0
2
KM
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater



Project:
Assessment of Irrigation Potential
Date:
Jun-2012

WaterWatch
FutureWater

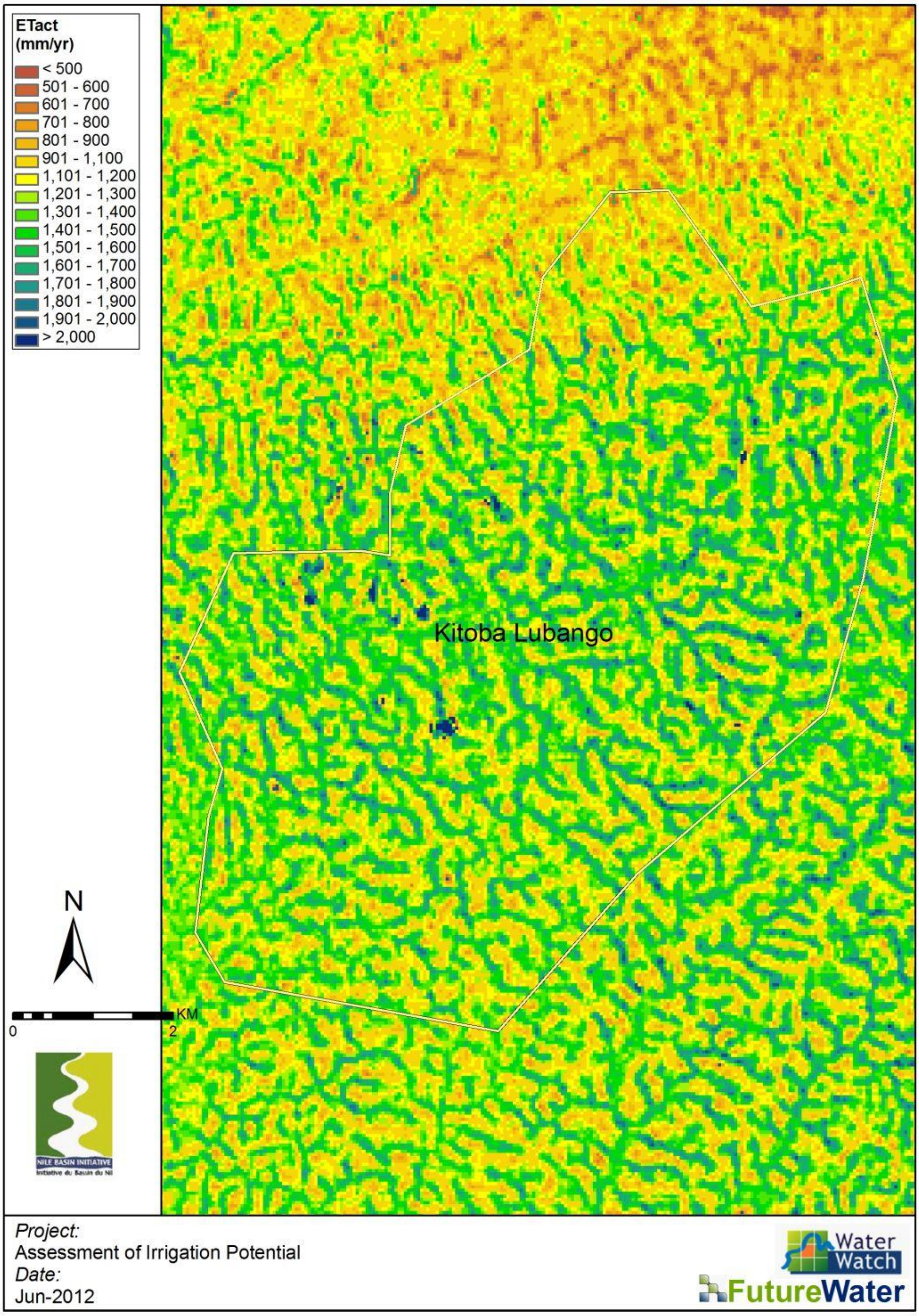


Figure 76: Water balances for the area based on the high resolution data and modeling approach for Kitoba-Lubango focal area.

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.

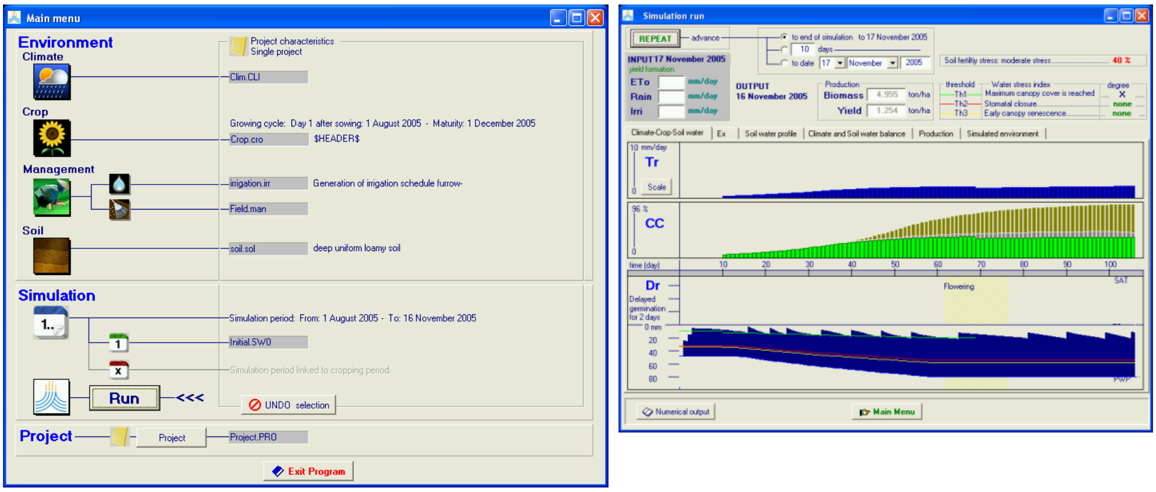


Figure 77: Typical example of AquaCrop input and output screens.

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

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year	===	== (day of year) ==		======== growing season =======			
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Rice	1468	1350	1	136	685	140	533	489
Maize	1468	1350	228	351	553	130	462	429
Bananas	1468	1350	1	365	1468	170	1346	1033
Vegetables	1468	1350	1	365	1468	120	1346	1034

6.4.2 Irrigation systems and irrigations efficiencies

Since the focal area is situated directly at the water divide between the Nile and Congo basin, the catchment is quite small with approximately 57 km^2. The area is hilly in the eastern part of the focal area and descends westwards. The steeper slopes limit the possibilities for surface irrigation. Slopes for surface irrigation are recommended not to surpass 2%, as increasing flow velocities will reduce water infiltration into the soil, and increase runoff and erosion. On the flatter lands towards the South West of the focal area, surface irrigation will be possible on smaller scales. It is advised to have a very close look into the water availability from upstream, which will be very limited due the small catchment, and the possible land that can be irrigated. The use of sprinkler and drip irrigation can decrease water demand due to increased water application efficiencies. These techniques, however, do require a much larger financial investment, and demand a higher knowledge base from the farmers who work with the irrigation system. Since topography and water availability will both push towards small scale irrigation systems, irrigation systems can differ over the area. Wherever possible, it is recommended to use surface irrigation. Although the water application efficiencies are relatively low, the environmental quality of the area will be enhanced, and water is used in an environmental sustainable way. If water is the limiting factor for irrigation, the use of high efficiency irrigation systems becomes more profitable. A detailed economic analysis is beyond the scope of this pre-feasibility study and should be carried out under a detailed further study.

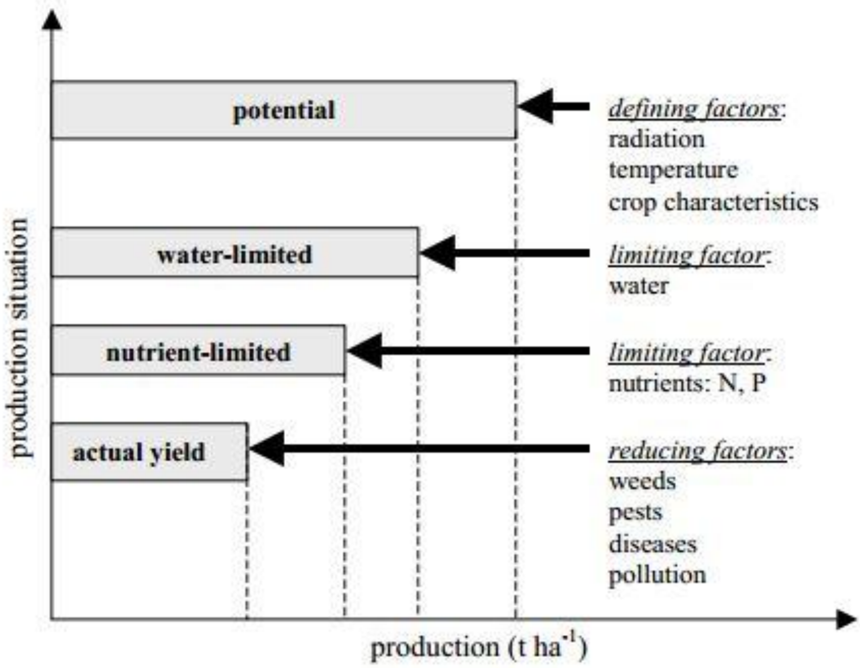
6.4.3 Water source

The initial water source will be surface water. However, due to the small catchment area the surface water is very limited. The annual average precipitation is rather large with nearly 1500 mm. This creates the possibilities for some small upstream reservoirs, which will store the water for the drier seasons. Especially the months June, July, and to a lesser extend December and January, are dry months in which the amount of precipitation does not meet the demand for agriculture. The average annual flow of the major stream, with its source within the focal area, is 0.55 m^3/s. This is a very small discharge, which can be enough to irrigate an approximate area of 50-60 ha. The use of groundwater for irrigation in this area is a possibility. Model outputs show that in the southwestern part groundwater can be an irrigation source, and that groundwater will be les suitable towards the North East.

6.5 Potential crop yield assessment

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

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



6.5.1 Yield gap analysis potential dominant crops

Yields in DRC are generally below the average of the seven research countries. The agricultural area expanded over the years from 4,283,400 ha in 1980, towards 5,139,770 ha in 2009. This is an increase of 20%, while the population nearly tripled in the same time. The average yield per hectare, however, has hardly increased. Yields from cassava and groundnut are among the few crops that show a positive yield development. Other crops have remained stable or even decreased in yield per hectare over the years. In Figure 78, the yield gap is shown relatively to the highest obtainable yield in the world, the world's average, and to Africa's average. Yields in the Kitoba-Lubango focal area are approximately 10% above DRC's average. With the selected potential future crops the yield gap is large. With irrigation a large part of the yield gap can be closed, and yields are expected to increase dramatically under irrigation. Bananas grown on an irrigated plantation can reach towards 10.000 kg/ha, which would be an increase towards 15-20% of the world's maximum obtainable. Maize under irrigation is expected to triple in yield towards 10%, which is about the East African average. Rice production is preferred above maize, as yields and benefits are higher. Yields can triple towards 30% of the world's maximum yield. Vegetables are already performing quite well, and yields will increase, but will maximum be doubled.

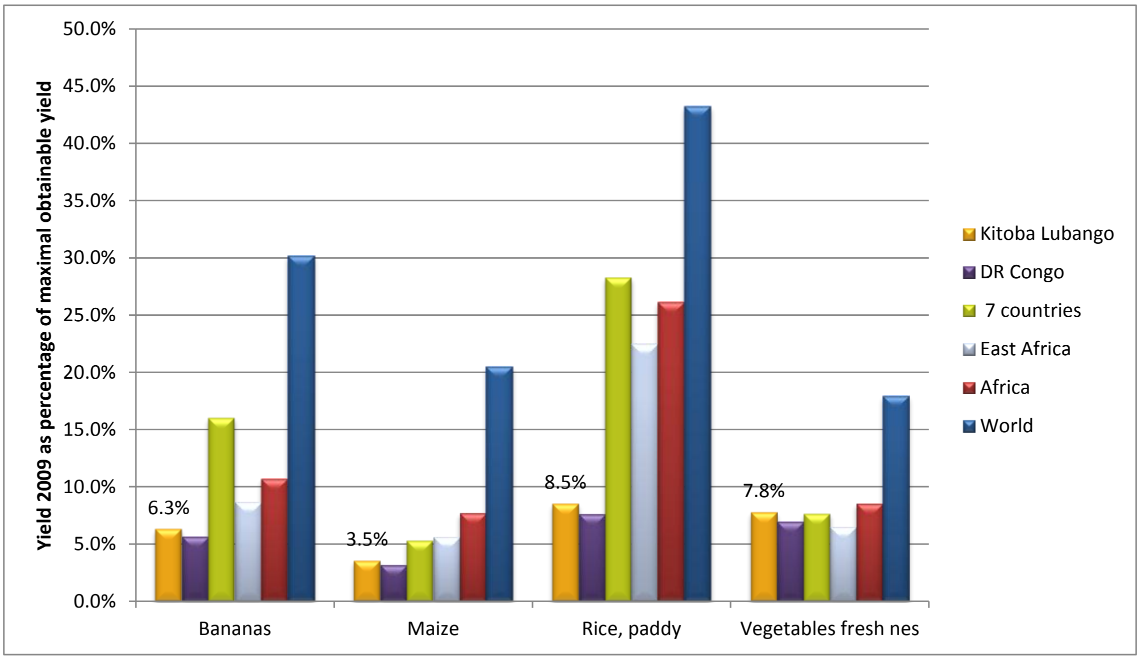


Figure 78: Yield gap Kitoba-Lubango (source: FAOSTAT, 2012).

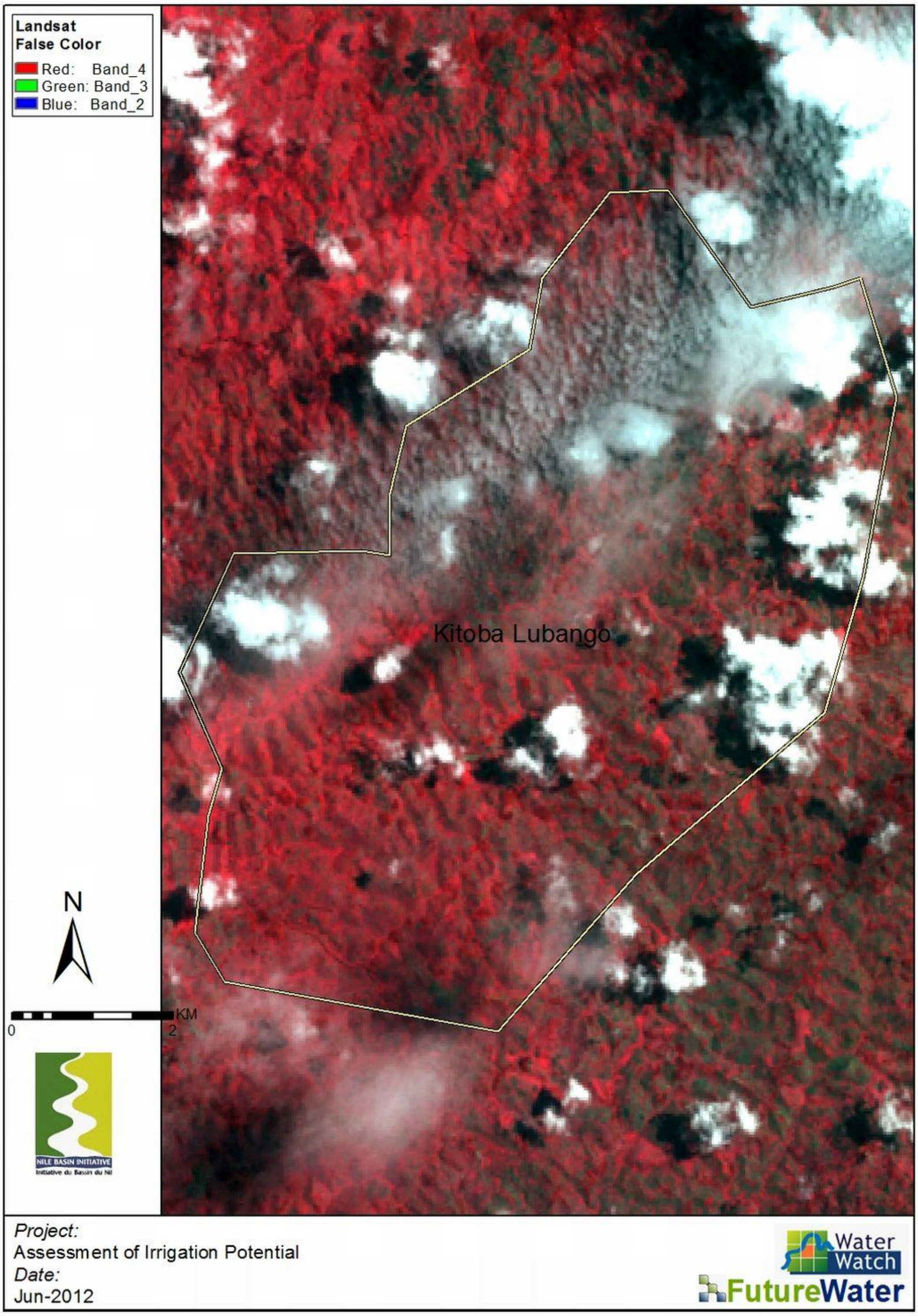


Figure 79: Landsat False Color Composite indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC

6.6 Environmental and socio-economic considerations

6.6.1 Population displacements

People in the focal area mainly live in villages. Main villages are Kitoba, Bikara and a few others. Apart from the villages people tend to stick together. This limits the amount of solemn houses, which is positive for irrigation development. If an irrigation system is developed, it is not expected that many population displacement are needed. It is advised to limit any population displacement also in the rural areas. The irrigation scheme probably can be developed around the existing houses. 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 within the focal area is small with 43 persons per km^2. Within the North Kivu province the population density is estimated to be 97 people/km^2. It is estimated that 40% of the people live in an urban environment, and that 60% lives in a rural environment. Within the territory of Lubero the ratio female to male is 1.11. The population in North Kivu is extremely young with over 50% of the population being under the age of 20 years. This also influences the amount of people being active as labor force. These are the people between 18 and 55 years old. In total this age group covers 37.1% of the total population. The main tribe that inhabits the area is the Nande. Malnutrition is a serious problem, and 45.4% of the population suffers from malnutrition, against 38.2% in DRC. The enrolment rate in primary school is 53%, of which most are boys. Adult literacy is 52.2%, which is slightly under DRC's average. The percentage of people that have access to save drinking water increased over the last years, but with 17% against 45.7% in the whole of DRC, this is still very low. The area is good reachable by road, as one main road passes the focal area and one crosses trough. Main markets nearby include Lubero, Kipese, Butembo and other towns. North Kivu has eight airports, which are mainly owned by individuals. One of these airports is at Lubero. The farmers do have average irrigation experience, and also have some knowledge about farmers' cooperations.

6.6.3 Upstream downstream consideration

Most of the area is used for agriculture, despite the presence of steep slopes. This results in quite some erosion over the area, but especially in the North East where slopes are steepest. Preservation of the surface soil, with its all-important organic matter, and preventing erosion, are pre-conditions for farming on this soil type. Flushed away soils can cause serious problems downstream when peak flows increase, and flooding or landslides take place more often. Currently, there are very few anti-erosion measures. Whenever developing irrigation, it is advised to incorporate anti-erosion measures within the focal area, and also upstream of the irrigated land. The soil is suitable for production of rain fed and irrigated crops only after liming and full fertilization. Rotation of annual crops with improved pasture maintains the organic matter content. The mode and timing of fertilizer appliance determines to a large extent the success of farming on these soils. Besides, good fertilizer application minimizes the leaching of nutrients and ensures downstream water quality.

6.6.4 Protected areas

Within the focal area no protected areas are reported.

6.6.5 *Institutional and legal framework*

Information on the water treaty agreements and the land ownership rights can be found in chapter 1.1.5.

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. The total area as selected by the country is 5660 ha, of which about 3000 ha has the potential to be developed for irrigation

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: 2,000 kg/ha, 1.33 $/kg
    - Maize: 1,500 kg/ha, 0.39 $/kg
    - Bananas: 8,000 kg/ha, 0.22 $/kg
    - Vegetables: 20,000 kg/ha, 0.25 $/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.

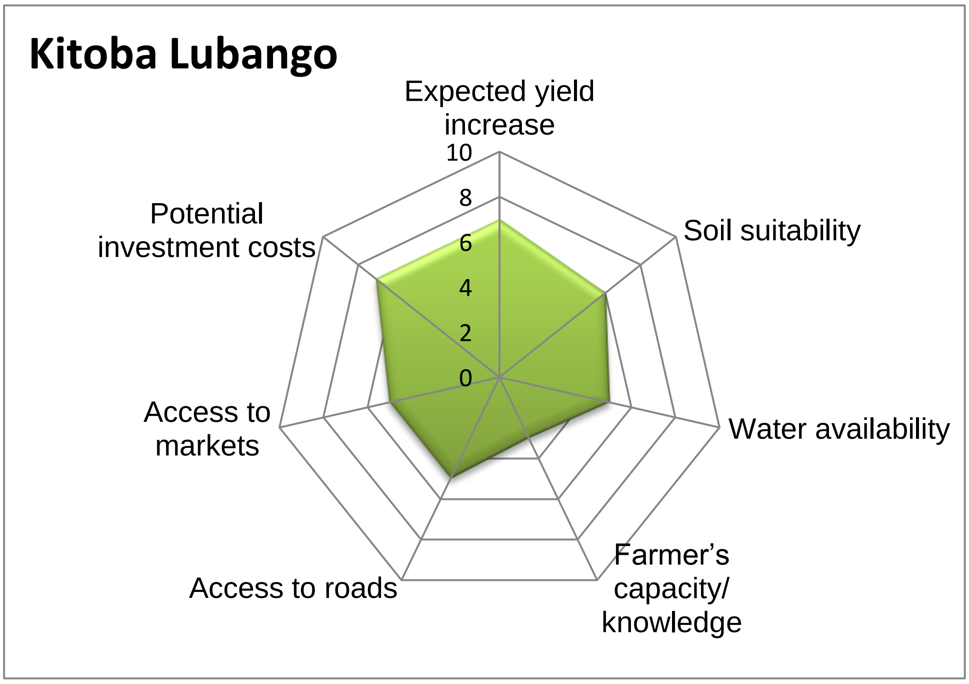


Figure 80: Filled radar plot indicating expert knowledge score to develop irrigation in the Kitoba-Lubango focal area (1 = negative, 10 = positive)

Table 13: Benefit-cost analysis for Kitoba-Lubango area.

Characteristics	
Irrigated land (ha)	3,000
Farmers	4,286
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$)	21.1
O&M costs (million US$/yr)	0.243
Net benefits per year (million US$/yr)	4.502
IRR (Internal Rate of Return)	25.1%

7 Nsinda-Mutabo focal area

7.1 Introduction

This chapter will describe the current state of the Nsinda-Mutabo focal area (also referred to as Rutshuru-Mutabo) 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 82 a detailed map of the area is given. Total area is 7290 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 Baruka Grace and supervised by Henri Okitolembo, Bruno Matata, and Isaac Mutela in April and May 2012.

Figure 81: 3D impression of the Nsida-Mutabo focal area, Eastern DRC.

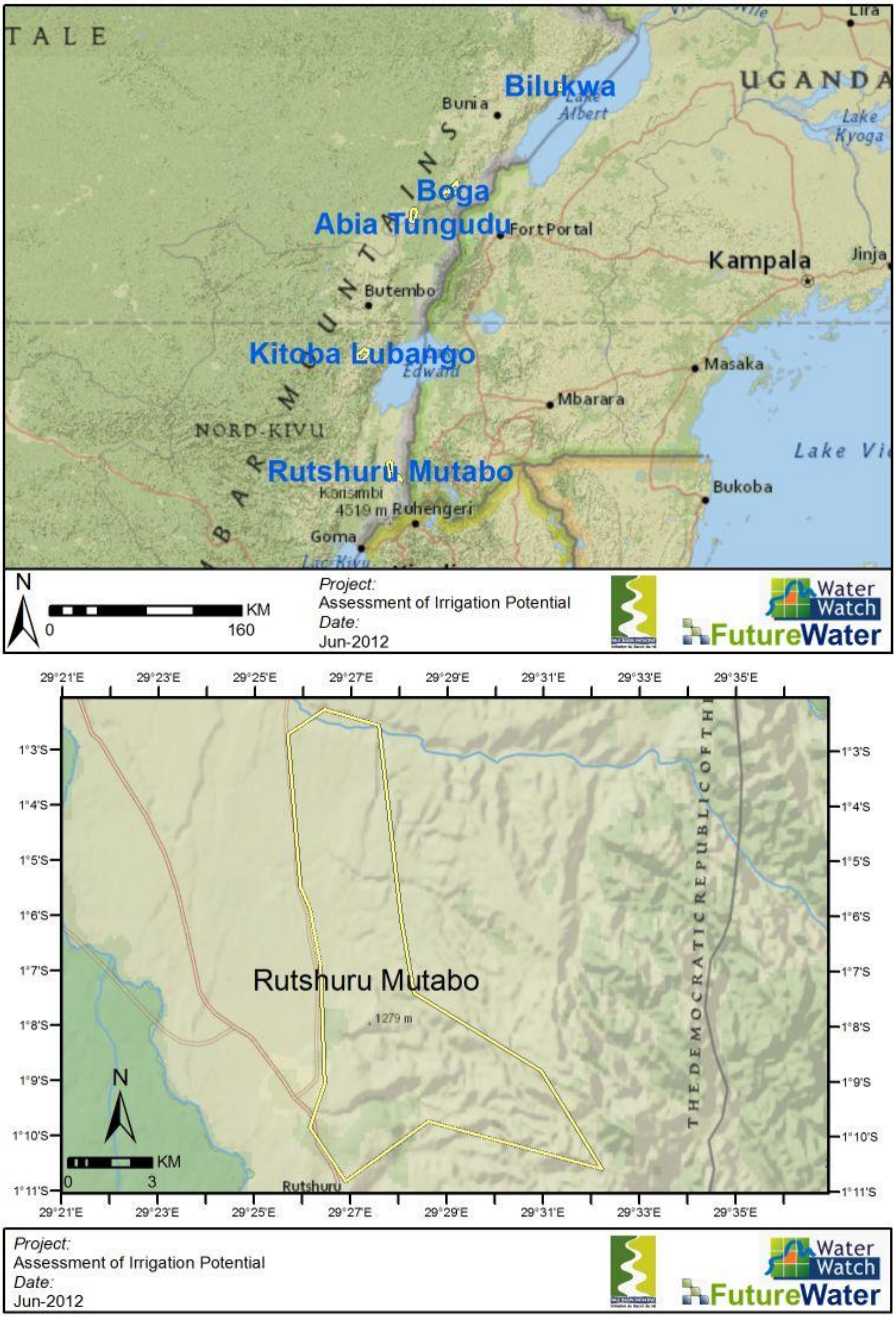


Figure 82: Nsida-Mutabo Mutabo focal area, Eastern DRC. Shapes contributed by: LABO-DIAF/DRC

7.2 Land suitability assessment

7.2.1 Terrain

The Nsida-Mutabo focal area is located between the village of Nsinda and the village of Mutabo in the territory of Ruthuru, in the district of Goma, in the province of North Kivu, in eastern DR Congo. This is the only focal area in DRC, which is not located directly at the border of the Nile basin. This focal area covers a total area of 7291 ha, of which most is situated in the depression between lake Edward and lake Kivu. The most Eastern tip of the focal area reaches into the mountain that borders Uganda, which reaches an elevation of 1700 m within the focal area. From there the area descends gradually westwards to 1200 m, and descends further towards 1030 m in the northern tip (Figure 83). The slopes within the area are steepest in the South East, with an average around 15%. Slopes are gentler in the South West, with an average around 10%, and slopes in the northern tip hardly reach over 5% (Figure 84). Slopes are steepest along the streams, which cross the area from East to West.

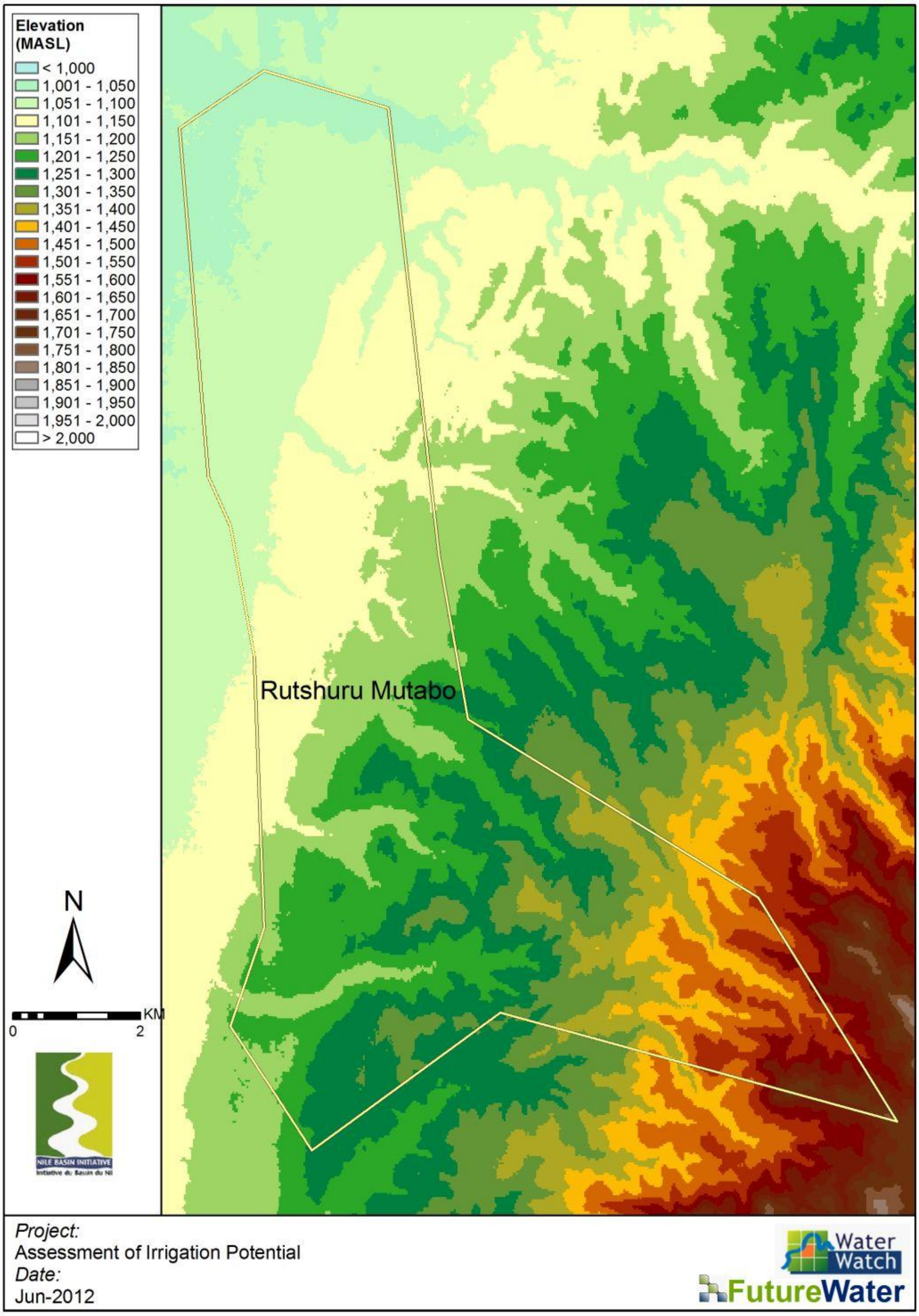


Figure 83: DEM Nsida-Mutabofocal area. Resolution 1 arc second (+/- 30m).

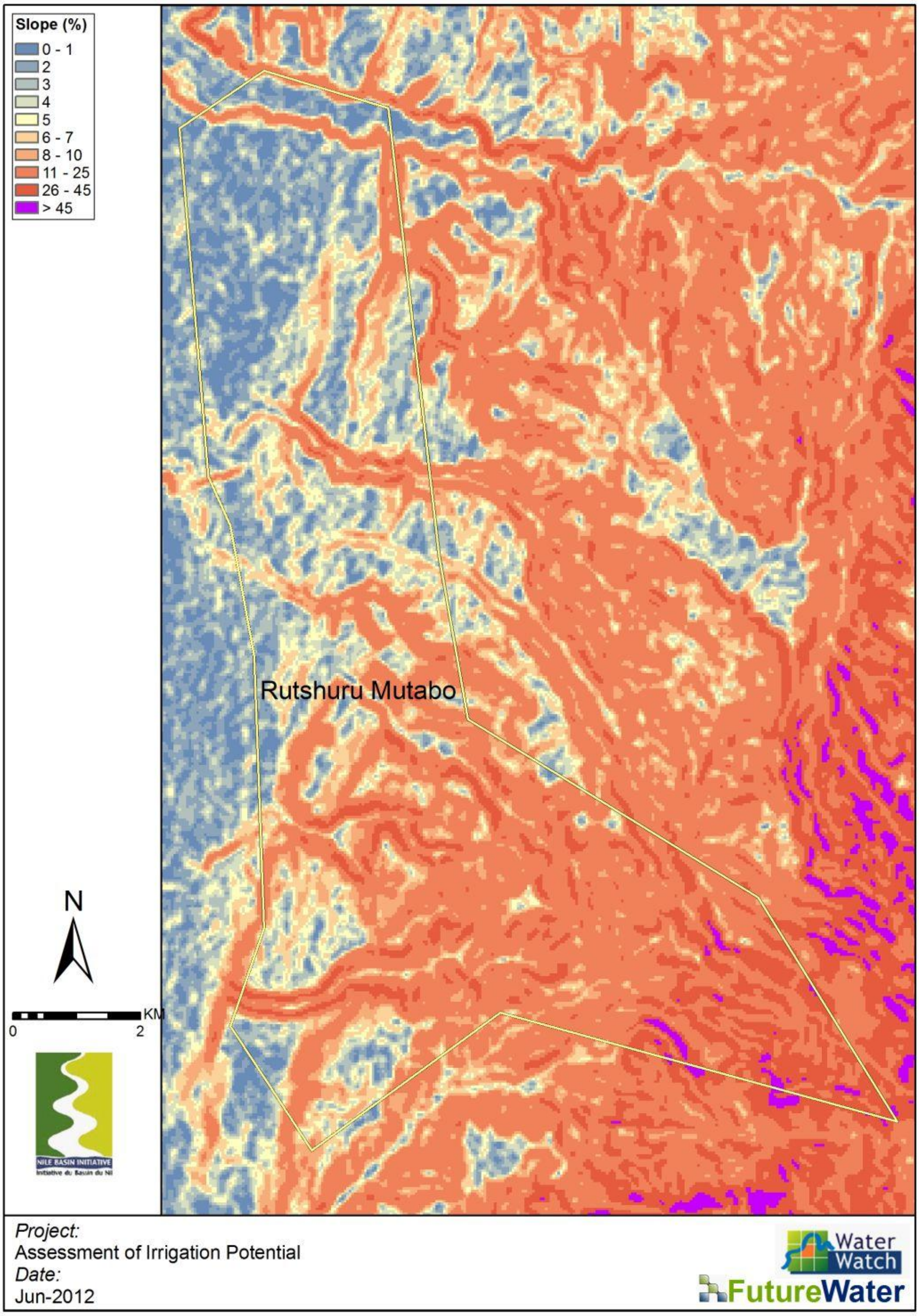


Figure 84: Slope map Nsinda-Mutabo focal area (source: ASTER).

7.2.2 Soil

The soil texture in the focal area is clayey loam in the eastern tip, and sandy clay loam in the western and northern part of the area. Drainage capacity in the whole area is somewhat poor. The soil on the eastern tip of the area is slightly richer in organic carbon (2%). The western side has organic carbon levels of 1-1.5%. The water holding capacity in the whole area is large with over 150 mm/m. The Mountainous eastern part of the area has a predominantly Cambisol, and the western and northern part have a uniform Phaeozem soil. Cambisols generally make good agricultural land and are used intensively. Cambisols in the humid tropics are typically poor in nutrients, but are still richer than associated Acrisols or Ferralsols, and they have a greater CEC. Cambisols with groundwater influence in alluvial plains are highly productive paddy soils. Phaeozems accommodate soils of relatively wet grassland and forest regions. Consequently, they have dark humus rich surface horizons that, in comparison with Chernozems and Kastanozems, are less rich in bases. Phaeozems may or may not have secondary carbonates, but have a high base saturation in the upper meter of the soil. Phaeozems are porous, fertile soils and make excellent farmland. Wind and water erosion are serious hazards. Vast areas of Phaeozems are used for cattle rearing and fattening on improved pastures.

7.2.3 Land productivity

The land productivity (NDVI) in the five DRC focal areas ranges between 0.66 and 0.83. Compared to the DRC average NDVI of 0.59, all focal areas have relative high land productivity values. Within the Nsinda-Mutabo focal area the average land productivity is 0.77, which is well above the DRC average value (Figure 85). Land productivity is highest in some places in the North and East of the focal area; in the North due to plantation of perennial crops, and in the steeper eastern part due to a less intensive agricultural use. The red places in the West of the focal areas are the build-up areas and surrounding lands. The coefficient-of-variation in the area is low, but highest in the western part of the area along the road and the build-up area.

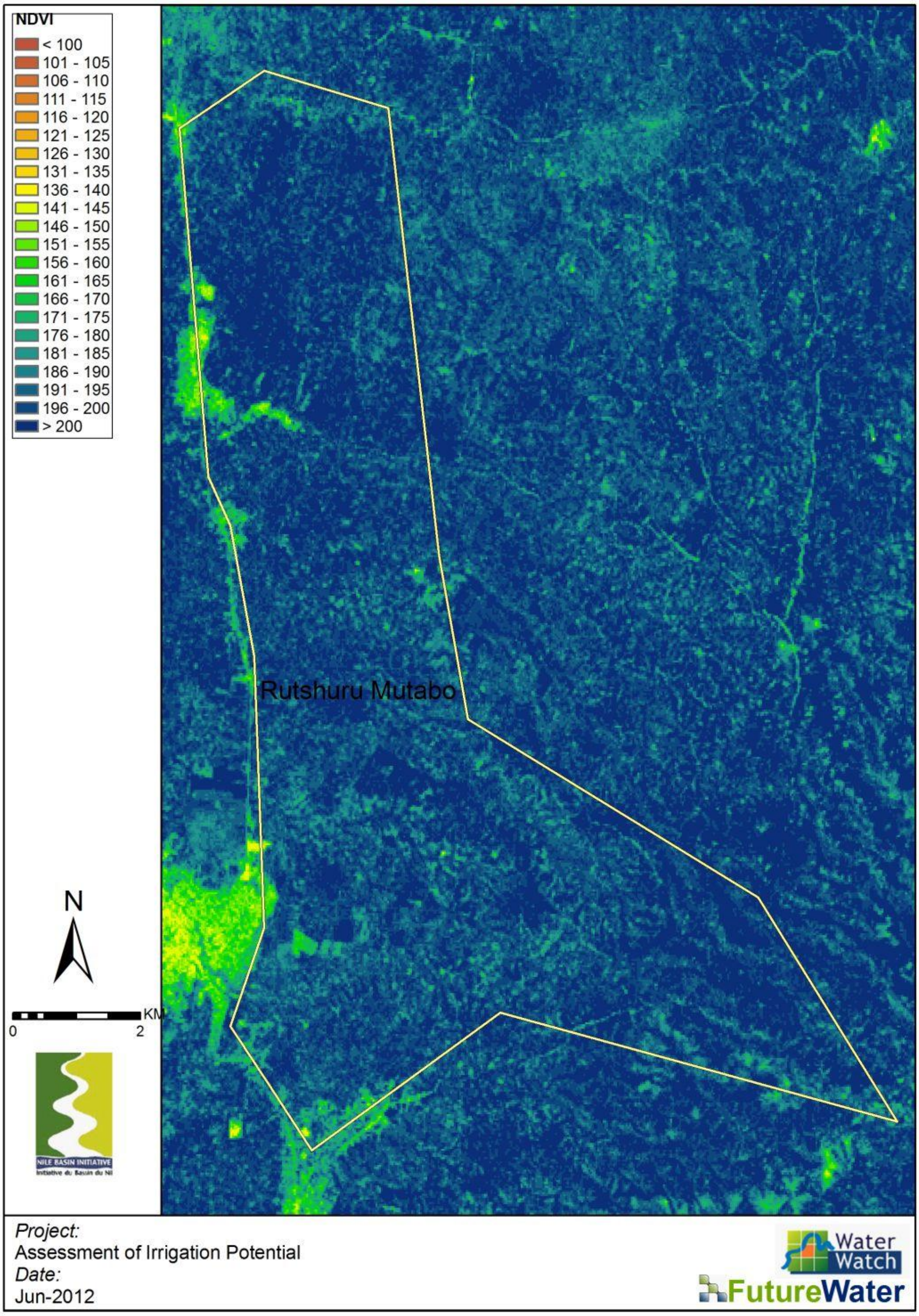


Figure 85: High resolution NDVI for Nsinda-Mutabo

7.2.4 Potential cropping patterns

Agriculture in the focal area plays an important role, and approximately 60-70% of the area is prepared and used for agriculture. The most dominant crops are maize, beans, rice, soybeans, cassava, sugarcane, potatoes and bananas. Beans are by far grown on the largest part of the area, followed by rice. Soybeans and rice are both grown on about 5% of the total area. Currently, rice is the only crop which is already irrigated. All above mentioned crops are grown in two growing cycles per year, except for the perennial crops, and sugarcane, which is growing once a year. This large variety in crops and the experience with rice irrigation is promising for future irrigation development. It is recommended to focus on high value crops, in addition to some staple crops to meet the local food demand. Potential crops for irrigation are rice, vegetables, sugarcane and soybeans. These crops can grow in two or even three growing cycles per year, except for sugarcane, which can grow in one cycle per year. The combination of crops is very strong, as rice and vegetables can feed the region, and sugarcane has a strong link to agro-industry, which creates jobs, added value on crops, and could reduce poverty.

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 moderate with constant temperatures during the year ranging from about 14°C to 25°C. Annual average precipitation is 1502 mm and reference evapotranspiration 1496 mm per year.

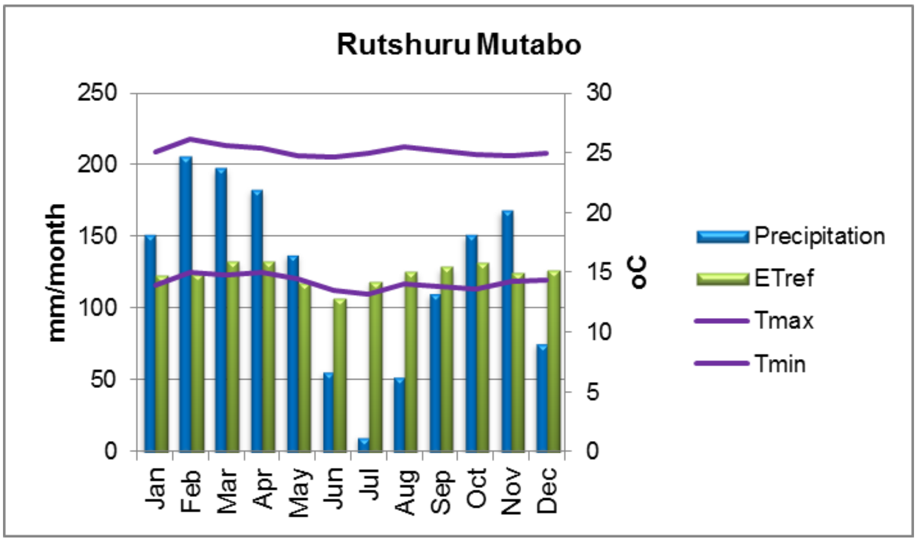


Figure 86: Average climate conditions for the focal area.

7.3.2 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.

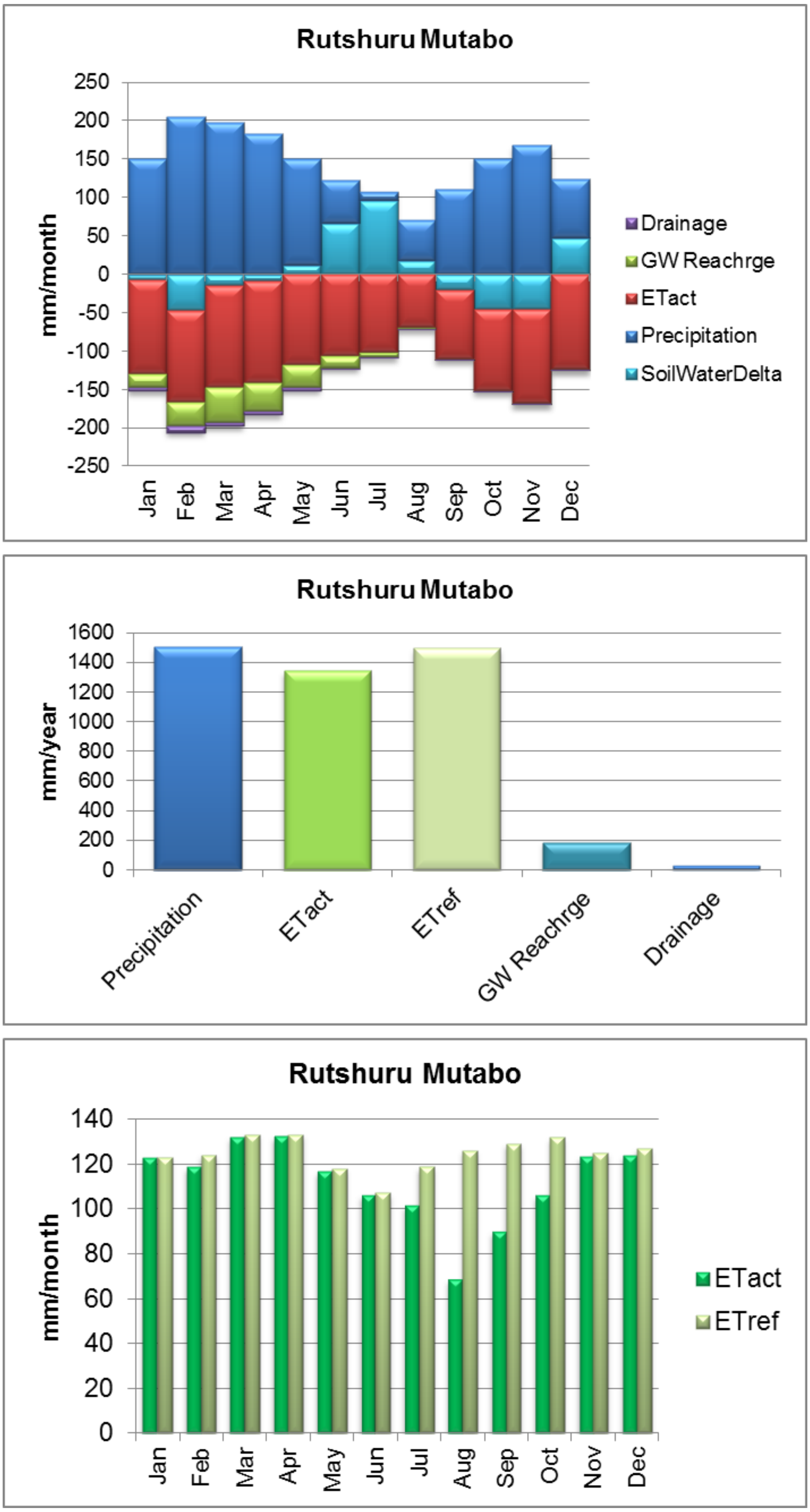
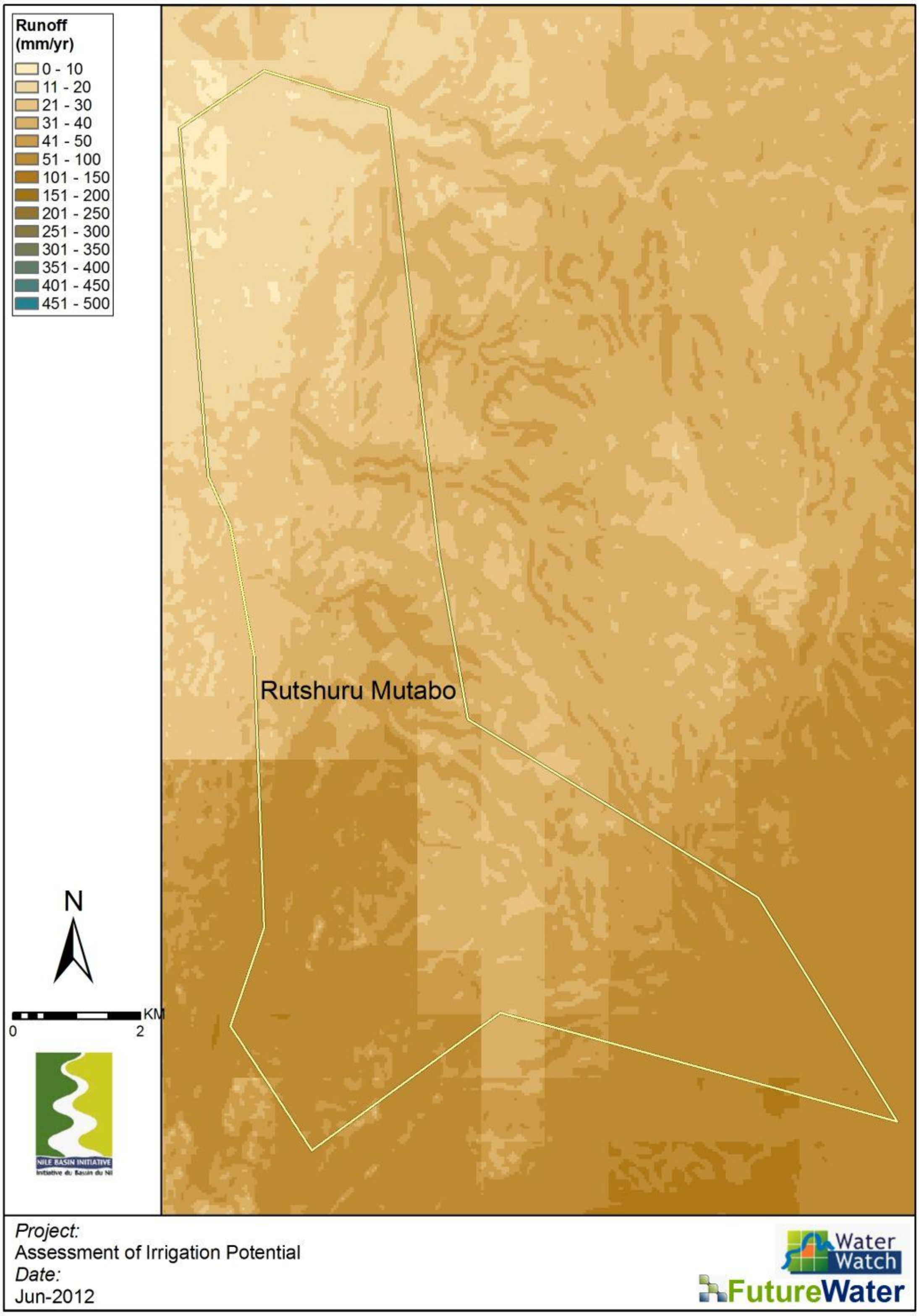
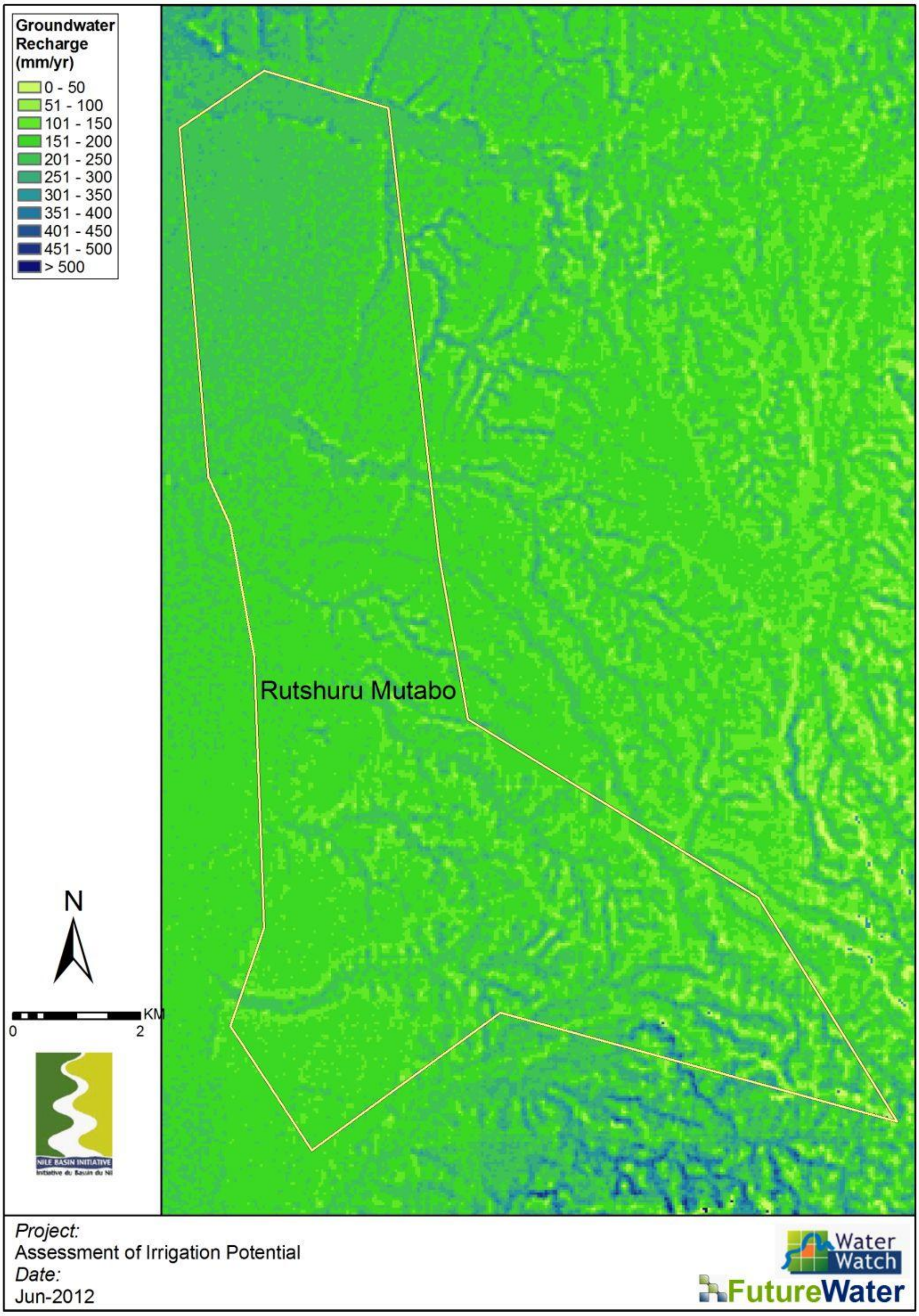


Figure 87: Water balances for the area based on the high resolution data and modeling approach for Nsinda-Mutabo.


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
Rutshuru Mutabo
N
KM
0
2
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
Rutshuru Mutabo
N
KM
0
2
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

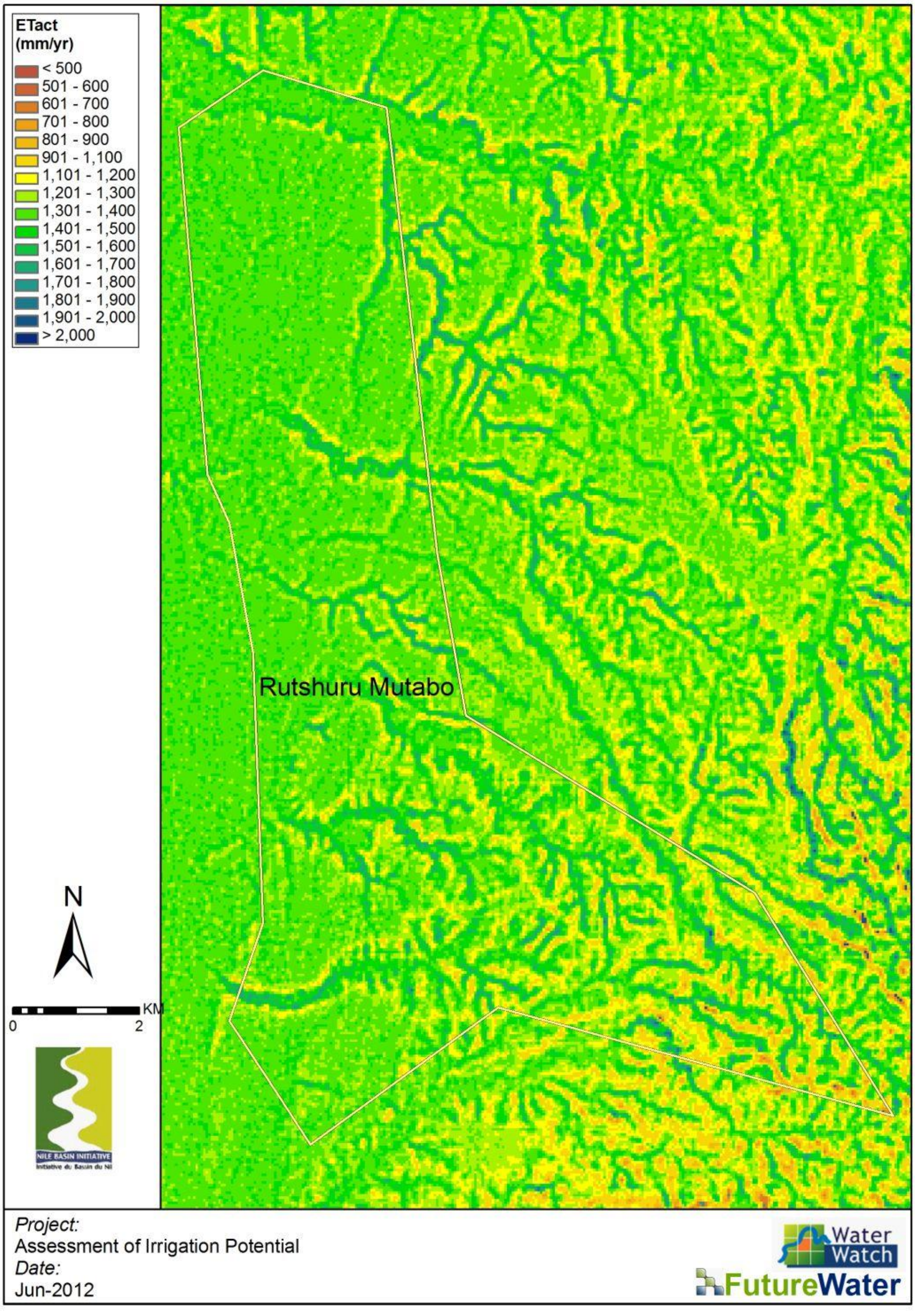


Figure 88: Water balances for the area based on the high resolution data and modeling approach for Nsinda-Mutabo focal area .

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.

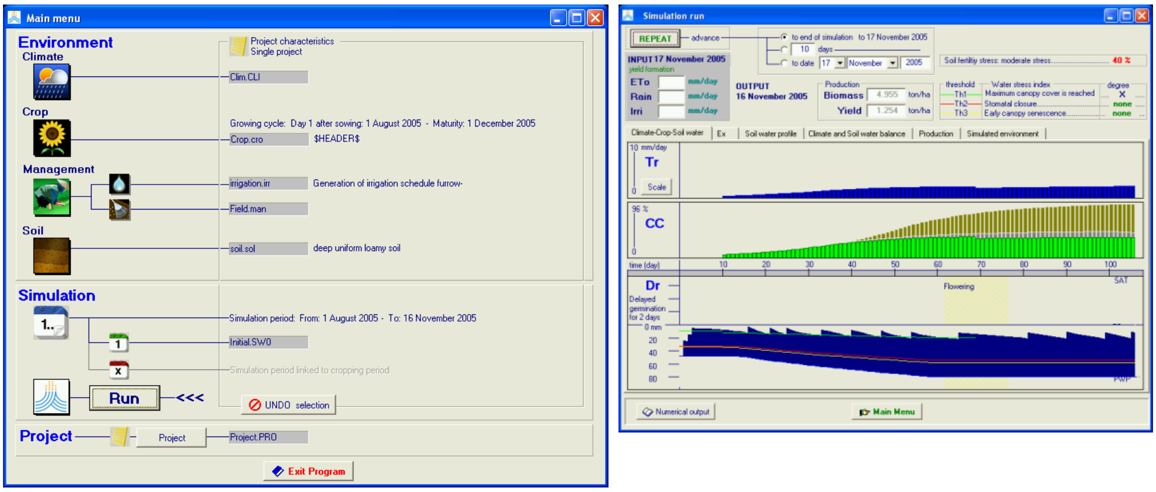


Figure 89: Typical example of AquaCrop input and output screens.

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

Crop	Rain	ETref	Planting	Harvets	Rain	Irrigation	ETref	ETact
	=== year ===		== (day of year) ==		======== growing season =======			
	(mm)	(mm)			(mm)	(mm)	(mm)	(mm)
Rice	1502	1496	1	136	824	100	572	526
Vegetables	1502	1496	1	365	1502	100	1492	930
Sugar cane	1502	1496	1	365	1502	130	1492	929

7.4.2 Irrigation systems and irrigations efficiencies

This is the only focal area in DRC which is not at the border of the Nile basin. Although the catchment is larger, the focal area is still rather small. The river in the very North of the area is largest, and drains an approximate area of 180 km^2. The river that crosses from East to West in the middle drains approximately 60 km^2, and there are some minor streams in the South of the focal area.

The area is quite hilly in the East of the focal area, and the steep slopes limit the possibilities for surface irrigation. Slopes for surface irrigation are recommended not to surpass 2%, as increasing flow velocities will reduce water infiltration in the soil, and increase runoff and erosion. On the flatter lands in the western part of the focal area, surface irrigation will be possible. It is advised to have a very close look into the water availability from upstream, which will still be limited due the small upstream catchment, and the possible land which can be irrigated. The use of sprinkler and drip irrigation can decrease water demand due to increased water application efficiencies. These techniques, however, require a much larger financial investment, and demand a higher knowledge base from the farmers who work with the irrigation system. The farmers already have some knowledge of rice irrigation. The efficiency of surface irrigation is quite low, with averages of 40-60% effective water use. If water availability is the restricting part for further irrigation development, it is advised to make a detailed cost benefit analysis. This will show whether is it profitable to start drip or sprinkler irrigation. This is beyond the scope of this pre-feasibility study and should be carried out under a detailed further study.

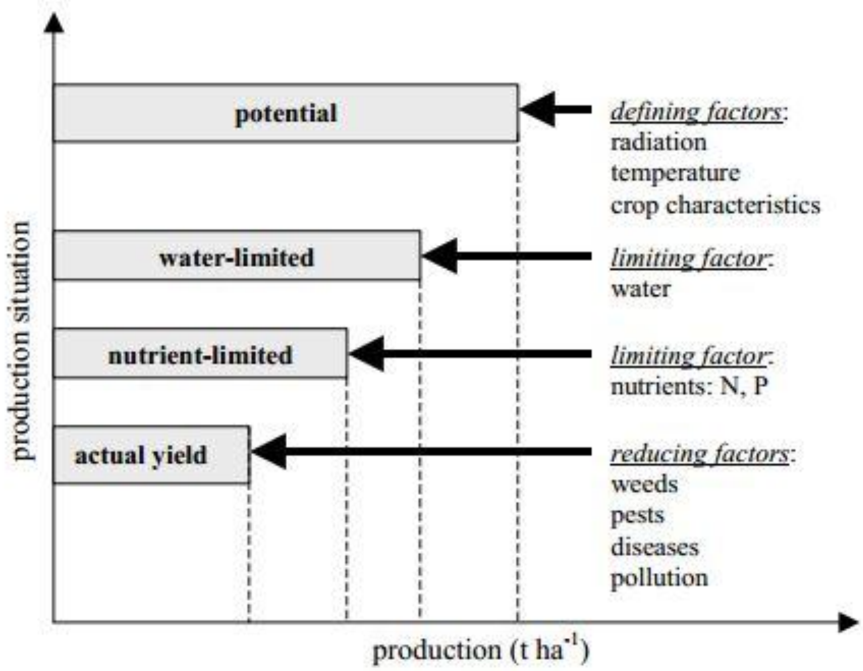

7.4.3 Water source

The initial water source will be surface water. However, due to the small catchment area the surface water is limited. The annual average precipitation is rather large with 1500 mm. This creates the possibilities for some small upstream reservoirs, which will store the water for the drier seasons. Especially the months June, July, August, and to a lesser extend December, are dry months in which the amount of precipitation does not meet the demand for agriculture. The annual average flow of the stream in the North of the focal area is 1.90 m^3/s. The stream in the middle of the focal area has an average flow of 0.8 m^3/s. In total, these average discharges will be enough to irrigate an approximate area of 2500-3000 ha. The use of groundwater for irrigation in this area is a good possibility. Model outputs show that within most of the area groundwater can be an irrigation source.

7.5 Potential crop yield assessment

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

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



7.5.1 Yield gap analysis potential dominant crops

Yields in DRC are generally below the average of the seven research countries. The agricultural area expanded over the years from 4,283,400 ha in 1980, towards 5,139,770 ha in 2009. This is an increase of 20%, while the population nearly tripled in the same time. The average yield per hectare, however, has hardly increased. Yields from cassava and groundnut are among the few crops that show a positive yield development. Other crops have remained stable or even decreased in yield per hectare over the years. In Figure 90, the yield gap is shown relatively to the highest obtainable yield in the world, the world's average, and to Africa's average. Yields in the focal area are nearly 30% above DRC's average. In the area a good combination of crops is selected for irrigation. Staple crops will enhance food security and cash crops will push development and reduce poverty. The yield gap for rice is large, and is expected to triple towards 30% of the highest obtainable yield. Sugarcane is already performing well, and with an abundant water supply the yields are expected to reach towards 70%. Vegetables like sugarcane have a quite low yield gap, and yields may double under irrigation. Soybeans can increase also towards 1250 kg/ha. Unless that significant increase, soybean yields stay low at 5% of the maximum obtainable.

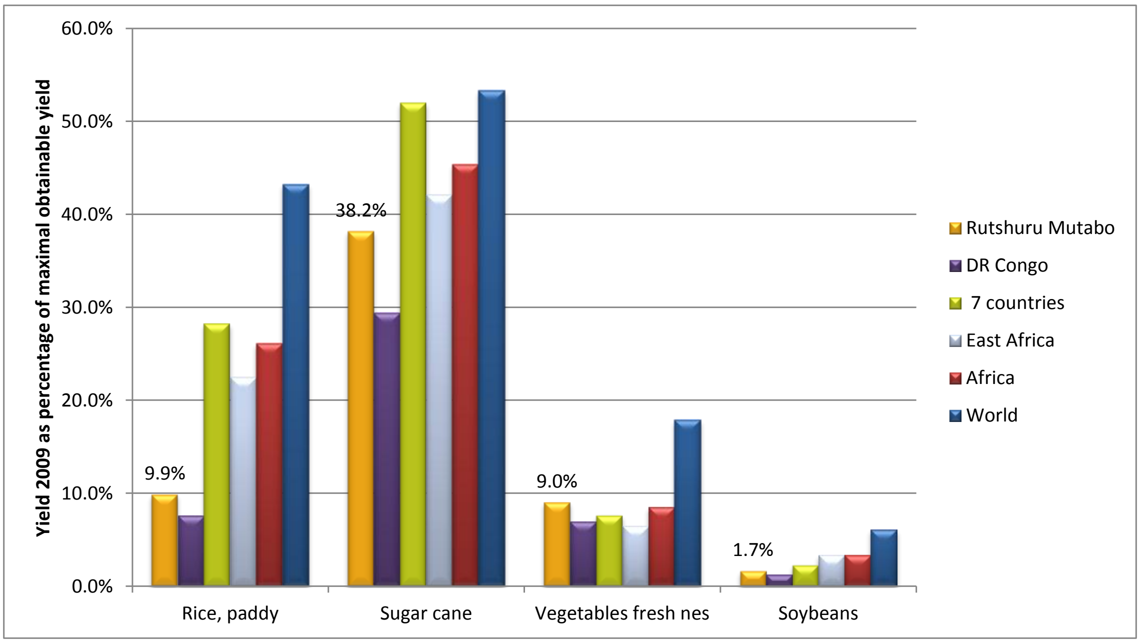


Figure 90: Yield gap Nsida-Mutabo(source: FAOSTAT, 2012).

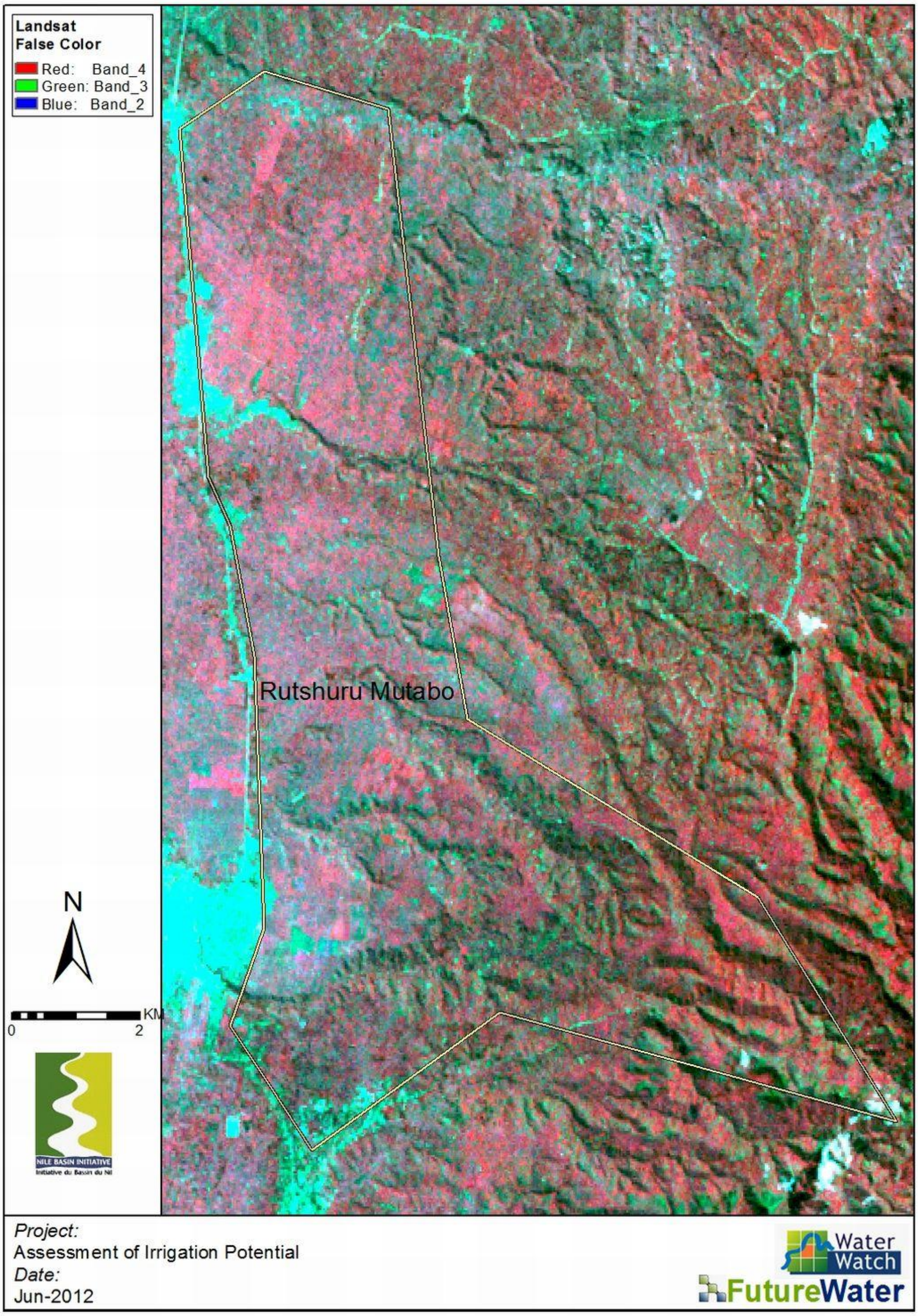


Figure 91: Landsat False Color Composite indicating current productivity of the area. Shapes contributed by: LABO-DIAF/DRC

7.6 Environmental and socio-economic considerations

7.6.1 Population displacements

People in the area mainly live in the main villages Rutshuru, Kagera, and other small villages along the roads. Population in the agricultural area is very scarce. Therefore, if an irrigation system is developed, it is not expected that any population displacement is needed. It is advised to limit any population displacement. The irrigation scheme can probably be developed around the existing houses. 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 within the focal area is rather large with 112 persons per km^2. Within the North Kivu province the population density is estimated to be 97 people/km^2. It is estimated that 40% of the people live in an urban environment, and that 60% lives in a rural environment. Within the territory of Rutshuru, the ratio female to male is nearly equal with 1.03. The population in North Kivu is extremely young with over 50% of the population being under the age of 20 years. This also influences the amount of people being active as labor force. These are the people between 18 and 55 years old. In total, this age group covers 37.1% of the total population. The main tribes that inhabit the area are the Nande, Hutu, Hunde, Twa (pygmée), Tutsi, Bingi, Banyabinza and Nyanga. Malnutrition is a serious problem, and 45.4% of the population suffers from malnutrition, against 38.2% in DRC. The enrolment rate in primary school is 53%, of which most are boys. Adult literacy is 52.2%, which is slightly under DRC's average. The percentage of people that have access to save drinking water increased over the last years, but with 17% against 45.7% in the whole of DRC, this is still very low. The area is good reachable by road, as one main road passes the focal area, and one crosses trough. Main markets nearby include Rutshuru, Kagara and Goma at 75. North Kivu has eight airports, which are mainly owned by individuals. The largest of these airports is at Goma. The farmers do have average irrigation experience, and also have some knowledge about farmers' cooperations.

7.6.3 Upstream downstream consideration

Most of the area is used for agriculture, despite the presence of steep slopes in the East. This results in quite some erosion in this area especially. Preservation of the surface soil with its all-important organic matter, and preventing erosion are preconditions for farming. Flushed away soils can cause serious problems downstream when peak flows increase, and flooding or landslides take place more often. Currently, there are very few anti-erosion measures. Whenever developing irrigation, it is advised to incorporate anti-erosion measures within the focal area, and also upstream of the irrigated land. The soils in this focal area are relatively fertile and could make high productive paddy lands. However, for a sustainable and durable use of the land the use of fertilizer is recommended. The mode and timing of fertilizer appliance determines to a large extent the success of farming on these soils. Besides, good fertilizer application minimizes leaching of nutrients and ensures downstream water quality.

7.6.4 Protected areas

Within the focal area no protected areas are reported.

7.6.5 Institutional and legal framework

Information on the water treaty agreements and the land ownership rights can be found in chapter 1.1.5.

7.7 Benefit-cost Analysis

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

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

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Rice: 4,000 kg/ha, 0.40 $/kg
    - Vegetables: 20,000 kg/ha, 0.25 $/kg
    - Sugar cane: 160,000 kg/ha, 0.05 $/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.

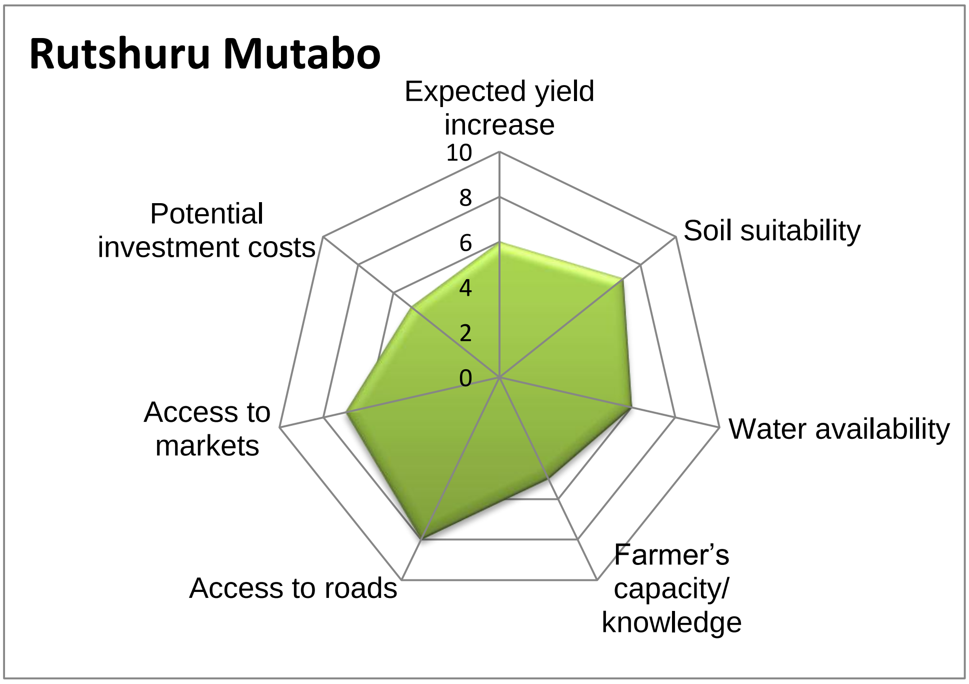


Figure 92: Filled radar plot indicating expert knowledge score to develop irrigation in the Nsida-Mutabofocal area (1 = negative, 10 = positive)

Table 15: Benefit-cost analysis for Nsinda -Mutaboarea.

Characteristics	
Irrigated land (ha)	7,291
Farmers	9,114
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$)	49.3
O&M costs (million US$/yr)	0.549
Net benefits per year (million US$/yr)	21.280
IRR (Internal Rate of Return)	72.6%