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

## Final Report
## Appendix Kenya

July 2012

**Client**
Nile Basin Initiative
NELSAP Regional Agricultural Trade and Productivity Project

**Report FutureWater: 114**

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# PREFACE

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

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

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

Tangible outputs of this study area:

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

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

Various people and institutions have contributed to this specific country/focal area report: Hosea Wendot (NLO), Jacqueline Oseko (Field assessor), Raphael Waswa (Field assessor), amongst others. Their contribution is highly appreciated.

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## 1.1 Background[1]

Kenya (Figure 1) covers an area of 582,000 km$^2$ and has wide variations in climate, land forms, geology, soils, and land use. Elevations range from sea level at the Indian Ocean to the top of Mt. Kenya with snow at 5,200 MASL. The Nile basin in Kenya represents only 8.5% of the total area of the country. This area, however, contains over 50% of the national freshwater sources with four major rivers (Nzoia, Yala, Nyando and Sondu Miriu) draining directly into Lake Victoria. The Mara River also drains into this lake, but runs through Tanzania. A detailed map of the country is presented in Figure 1.

Kenya is an agricultural country and depends entirely on agricultural production for subsistence and socio-economic development. About two thirds of the land area in Kenya is in the arid and semi-arid lands. The pressure exerted on the fragile ecosystems that characterize the arid and semi-arid lands lead to severe land degradation. The agricultural sector faces the challenge of producing food for a rapidly growing population. Most of the agricultural activities in Kenya are rainfed and therefore the rainfall amount and distribution are vital components of agricultural production systems. Agricultural activities contribute significantly to the economic growth and GDP of Kenya. Compared to the other sectors of development, agriculture is the main consumer of water. Due to increasing competition for water amongst other sectors, agriculture is therefore expected to produce more crop per given volume of water if agricultural production is to be sustained as a viable economic activity. There is therefore a dire need to improve water use efficiency in irrigated agriculture.


**Figure 1: Map of Kenya (source: CIA Factbook).**

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

### 1.1.1 *Socio-economy*

Agriculture in Kenya contributes directly to 26% of the GDP, and indirectly a further 27% of the GDP through linkages with manufacturing, distribution, and other service-related sectors. The sector produces the bulk of the country's food requirements in years of favorable weather. The agricultural sector accounts for 80% of rural employment with women providing 75% of the labor force. Agriculture contributes 60% of export earnings, 45% of annual Government revenue and produces almost all the raw materials for agro-industries. With this important contribution, development of the sector should have the greatest impact on the livelihood of the people. Kenya is, however, largely arid and semi-arid (83%) with only 17% considered as medium and high potential. Thus this limits the production potential and often leads to chronic deficits in maize, wheat, rice, sugar and edible oils.

### 1.1.2 *Millennium Development Goals, current status*[1]

Kenya had made considerable progress towards the achievement of the Millennium Development Goals (MDGs) but is unlikely to accomplish all eight goals by 2015 largely due to inadequacy of resources. The 2010 MDGs status report indicates that quite a number of targets are not achievable under the current circumstances. Goal 2, achieve universal primary education, goal 3, promote gender equality and empowerment of woman, goal 4, reduce child mortality, goal 6, combat HIV/AIDS, malaria and other diseases and goal 8, develop a global partnership for development are all on the track. However, it is highly unlikel that goal 1, reduce extreme poverty and hunger, goals 5, improver maternal health and goal 7, ensure environmental sustainability will be achieved as progress in these goals has been extremely slow. It is worth noting that the MDGs progress has been uneven from region to region. There is a need to develop a well enabled resource environment and ensure that the government maintains adequate levels of public spending especially in the environment, education and health sectors in order to ensure MDG goals are met. Most importantly, achieving goal 7 on environmental sustainability is critical and more resources ought to be directed towards regaining the forest cover.

A quick overview will be given about the current (2009) status of the MDGs.

**Goal 1: Eradicate Extreme Poverty and Hunger**
Poverty remains a major challenge in the country. The proportion of Kenya's population living below the poverty line increased from 43.3% in 1990 to 52.6% in 1997 and declined afterwards again to 45.9% in 2005/06, the post-election violence and the multiple crises during the years 2008 and 2009 are likely to have increased the poverty levels. The country will need to scale up and sustain measures aimed at wealth creation in order to alleviate poverty. The prevalence of underweighted children under five years has decreased, and it is likely that this goal will be met.

**Goal 2: Achieve universal primary education**
Kenya is likely to achieve full primary school enrolment by 2015, given its 110.0% primary school gross enrolment rate in 2009 up from 107.6% in 2007/08 compared to 73.7% in 2002. The net enrolment rates rose from 77.3% in 2002 to 92.9% over the same period, while the primary school completion rates improved from 62.8% in 2002 to 83.2% in 2009. The enrolment figures for boys and girls in primary school enrolment also point to a near gender parity of 0.958 in 2009. Completion rate improved from 62.8% in 2002 to 79.5% in 2008. The proportion of students who start at grade one of secondary school nearly doubled from 1990 to 2008 towards 83.2%

[1] Section based on MDGs status report for Kenya -2009

**Goal 3: Promote gender equality and empower women**

Gender equality has not yet been achieved. Although the enrollment rates in primary and tertiary education are approaching an equal boy/girl ratio, in secondary education and in employment the improvement is slower. The majority of the woman is engaged in agricultural subsistence and woman participation in waged employment in the non-agricultural sector improved, but remained relatively low at 31.2%. The proportion of woman holding a seat in the parliament improved from 1.5% in 1990 to 9.9% in 2009.

**Goal 4: Reduce child mortality**

All levels of child mortality rates continue to follow a declining trend. The KDHS 2008-9 places the infant mortality rate (IMR) at 52 per 1000 live births for the years 2008-9 down from 77 per 1,000 live births in 2003. The under-five mortality similarly reduced to 74 deaths for every 1000 live births in 2008-9 from 115 deaths for every 1000 live births in 2003. This is a significant improvement, but does not come close to the aimed 2015 target of 21 and 33 respectively.

**Goal 5: Improve maternal health**

Concerning this 5$^{th}$ MDG, it can be said that some progress has been made, but that the goals are unlikely to be met, and some can potentially be met. Maternal mortality per 100,000 living births decreased from 590 in 2000 to 488 in 2009. The target is set on 147/100,000 in 2015. According to the 2006 Kenya Demographic Health Survey (KDHS), 43.8% of all births in Kenya were attended by “skilled” health personnel. The target is set on 90% attendance in 2015.

**Goal 6: Combat HIV/AIDS, malaria and other diseases**

HIV prevalence reduced from 13% in 2000 to about 7.5% in 2008 (Economic Survey, 2009). Antiretroviral (ARV) drugs are free in Government health facilities hence improving the survival rates of people living with HIV. Drugs for prevention of mother-to-child-transmission of HIV are available in almost all Government health facilities and steps are being taken to ensure equity in access. HIV prevalence under young people aged 15-24 increased from 3.6% (2003) to 3.8% in 2007, with woman being 5.2 times as likely to be infected as men. There has been impressive progress on prevention and control of Malaria. According to KDHS 2008-09, 54% of households own at least one Insecticide Treated Net, and 51% of children aged below five years and 53% of pregnant women were reported to have slept under a mosquito net. Targets set for 2015 can potentially be met with additional effort.

**Goal 7: Ensure environmental sustainability**

In Kenya approximately 60% of the population had access to an improved drinking water source in 2009, with a large difference between urban (91%) and rural (53%). The current improvement rate shows that this goal can potentially be met. The percentage of urban population having access to improved sanitation is 95.3% in 2206 and 80.4% for the rural areas. The targeted 96% in 2015 can still be met if additional effort is put in. The percentage of forest in Kenya is low with 1.7%. Deforestation is a problem, and effective conservation and management is just now starting up. The goal for 10% forest cover in 2010 will not be able to reach.

**Goal 8: Develop a global partnership for development**

Despite the nearly tripled official development assistance (ODA) from 2000 to 2009 the development expenditures have increased even more. Kenya imports and exports both increased over the years. Imports however increased more rapidly which results in an expanding trade balance gap.

### 1.1.3 Poverty reduction strategy[1]

The first 5-year Vision 2030 Medium Term Plan (MTP 1) covering 2008 – 2012 was developed taking into account the success achieved under the Economic Recovery Strategy (ERS), 2003-2007. It, therefore, assumed continued strong broad based economic growth and development consistent with Vision 2030 objectives. However, since the implementation of the plan, the macroeconomic setting has changed significantly. This has affected achievement of MTP goals as well as progress in the implementation of policy measures.

The government through relevant agencies has conducted, over the last three years, several consultations with stakeholders such as private sector, civil society, members of parliament and key institutions of Government on ways to fast track the implementation of the Vision 2030 programs, especially the flagship projects. These consultations reviewed progress achieved and challenges experienced in implementing various MTP programs and agreed on broad measures to fast track implementation, including enactment of necessary legislations, availing resources and reporting progress.

Despite Kenya's economy being affected by the multiple adverse domestic (post-election violence and drought) and external (global financial and economic crisis and high international oil and commodity prices) shocks at the initial stages of implementation, significant progress has been achieved in implementing the MTP for 2008-2012.

The four main pillars are: i) Economic pillar ii) Social pillar iii) poverty level and progress on the attainment of the MDGs and iv) Political pillar.

Within the economical pillar progress has been made, but the targeted 10% growth has been constrained by several factors. The six priority sectors identified within the economical pillar are Tourism, Agriculture and Livestock, Wholesale and Retail Trade, Manufacturing, Business Process Outsourcing (BPO) and Financial Services. All these sectors have been performing less than expected over the MTP period.

In the first 3 years of the MTP notable progress has been achieved in the social sectors and development of the nation's human resources. Progress made and challenges in this sector and the progress made in poverty reduction have been described under the MDGs chapter.

Notable progress has been achieved in implementing the programs within the Political Pillar. During the early part of the MTP the following initiatives were to be undertaken under the political pillar: (i) the establishment of a permanent Commission on National Cohesion; (ii) establishment of the Commission on Post-Election Violence; (iii) establishment of an Independent Truth, Justice and Reconciliation Commission (TJRC); and (iv) the establishment of the Public Complaints Standing Committee. All of these have been fully implemented and the recommendations of the various commissions have been implemented.

### 1.1.4 Legal framework

The Water Act 2002 granted the overall responsibility for water management in Kenya to the Ministry of Water Resources Management and Development (MWRMD). The Water Act introduced key reforms to the legal framework for the management of the water sector in Kenya which ware: a) separation of the management of water resources from the provision of water services: b) separation of policy making from day to day administration and regulation; c) decentralization of operational functions to lower level state organs; d) the involvement of the

[1] Section based on first medium term plan update of Kenya vision 2030 – November 2011.

non-government entities and communities in the form of Water Resources Users Associations to manage water resources and provide water supply and sanitation services. The Water Master Plan (1992) provided the basic policy framework for Kenya. The plan was updated in 1998. There is new National Water Masterplan aligned to Vision 2030 being prepared currently by a JICA. The 2nd interim report is completed. The two semi-autonomous bodies that have been established for the organizational functions of water resources management and water services delivery prepared the National Water Resources Management Strategy and the National Water Services Strategies (2005-2007). The overall goal of the NWRMS is to eradicate poverty through the provision of potable water for human consumption and of water for productive use. Specific goals of the strategy are to improve equal access to water resources for all Kenyans; to promote integrated water resources planning and management at catchment basis; and to enhance the availability of water resources of a suitable quality and quantity.

#### *1.1.5 Socio-economic context and institutional setting*

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

- Kenya retains a largely rural population (78%)
- Poverty levels are among the lowest of the studied Nile Basin Countries (42% below national poverty line)
- On main social services: health expenditures (USD 33/ capita), population with access to improved source of drinking water (59%), electric power consumption (157 KWh per capita) and female illiteracy (16.5%) Kenya scores high compared to other countries in the same socio-economic bracket. Only improved sources of drinking water remain some behind.
- Agriculture is the main provider of jobs in Kenya (75%)
- In economic value Kenya is a net exporter of agricultural products (import to export is 0.50). The total value of agricultural exports is high compared to the other countries (USD 2,669 M)
- With respect to food Kenya is a net importer (value of food imports USD 1,174 M)

Agricultural services

- Agricultural road density is low (12.0 km/1000 sq. km arable land) – affecting agricultural marketing
- Fertilizer use is high (33.3 kg/ ha)
- Also the use of mechanical equipment is considerably higher than other countries in the Upper Nile Basin (27.6 tractors per 1000 sq km of arable land)

Irrigation and water use

- Irrigated land is a small fraction of arable land (1.8%)
- Total water abstraction is a small percentage of renewable resources (8.9%)
- Groundwater / Surface water usage ratio is 1 to 4
- Irrigation performance is moderate to high (3.6 on a 0-5 scale) – agricultural water productivity is high (2$^{nd}$ best of the eight Nile Basin Countries) but crop consumption use is relatively low (7$^{th}$ out of eight Nile Basin Countries)

Institutions

- The institutional framework for irrigation and water development is considerable. Main polices for irrigation and water resource development are the 'Draft National Irrigation and Drainage Policy', which envisions an annual irrigated area expansion of 40,000 ha, including smallholder sector irrigation. This irrigation policy is still a draft awaiting ratification by parliament and therefore it is known as the "Draft National Irrigation Policy 2012". The policy has to be considered in the context of Vision 2030, Agricultural Sector Development Strategy 2009-2020 (ASD). Irrigation Act (Cap 347) 1966, although outdated, is till guiding irrigation development.

- The overall mandate for irrigation development is vested in the Ministry of Water and irrigation. The National irrigation Board, by Irrigation Act (CAP 347), coordinates major irrigation and drainage infrastructure at national level, while WRMAs (Water Resource Management Authorities) coordinate irrigation issues on district and local level.
- There is a water licensing system, operated by the WRMAs. Permits for groundwater drilling and withdrawal, as well as proposed constructions for diversion of surface water and withdrawal are issued through the WRMA's. , it also charges fees for irrigation water (volume), it charges for groundwater wells. WRMA charges 50 c/m3 for small users (less than 500 m3/d) and 100 c/m3 for large users (more than 500 m3/d)
- Three types of land tenure exist: Private, Trust, Government land. Private ownership of land has encouraged investment and long-term improvements or development on farms to create a secure market for land
- On indicators of government effectiveness (31.0) and rule of law (-1.07) Kenya scores among the highest of the Nile Basin countries

| **KENYA - INSTITUTIONAL** | |
|---|---|
| Main guiding policies, act and ordinances | • *National Irrigation and Drainage Policy (2009), in which statement 5.4.3 articulates "government will mobilize resources to expand irrigation development by 32,000 ha per year of new irrigation schemes and rehabilitation of 8,000 ha per year of existing ones.*<br>• *Vision 2030, smallholder irrigation should expand 40,000 ha per year (GoK, 2009, pp. 28)*<br>• *Agricultural Sector Development Strategy 2009-2020 (ASD) also mentions improvement of water management and irrigation development (GoK, 2009, pp. 27)*<br>• *Irrigation Act (Cap 347) of 1966, although outdated it still guiding the irrigation sector in the country. A large part of it is devoted to the description of the establishment, mandate, functions and powers of the National irrigation Board (NIB)*<br>• *The Water Act 2002 aims takes over some of regulation provided for in the Irrigation Act 1966*<br>• *Other relevant policies are 9th National Development Plan, Strategy for Revitalizing Agriculture (SRA), Irrigation Sector Training Master Plan-2003, National Water Storage Policy (GoK, 2009, pp. ii)* |
| Institutional mandate irrigation development | • *The overall mandate for irrigation, drainage and water storage is vested with the Ministry of Water and Irrigation, However, a total of 17 Government Ministries currently have some direct or indirect relationship and/or impact on irrigation, drainage and water storage. The Ministries with direct impact on the sector include Ministries responsible for Water, Agriculture, Livestock, Finance, Fisheries and Environment (GoK, 2009, pp. 18)*<br>• *Ministry of Water and Irrigation*<br>    ○ *Dep. Water Resources Management, key functions include Water Rights, Surface and Ground Water Exploration*<br>    ○ *Dep. Irrigation and Drainage, key functions concerns policy formulation (national level), planning and coordination irrigation activities (district level), design and irrigation water management (local level)*<br>    ○ *National Irrigation and Drainage Service (NIDS), mandate for development and implementation of irrigation in government supported projects (to be established still) (GoK, 2009, issue 3.4.3)*<br>    ○ *Water Services Trust Fund in existence and operational to support water related activities but not irrigation (GoK, 2009, issue 3.4.5)*<br>• *National Irrigation Board (NIB), coordinates construction, rehabilitation, operation and maintenance of major irrigation and drainage infrastructure;* |

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|---|---|
| | *focuses on potential expansion of irrigated area; facilitates establishment and capacity building of WUA's (NIB)*<br>• *Water Service Regulating Boards (WSRB),* regulates the water service boards mainly for domestic water supply<br>• *Water Resource Management Authority (WRMAs), their tasks include planning, regulation and management of water resources; introduction of volume related water use charges; issuing water permits; support establishment of WUAs*<br>• *ASCU (Agricultural Sector coordination unit), its mandate is to facilitate and add value to the reform process and to coordinate the efforts of sector ministries and other stakeholders towards implementing the ASDS vision (GoK, 2010, pp. 84)* |
| Water Permit System – Drillers | - *Groundwater: Drilling permits and certificates have to be obtained by the well constructer before drilling at the WRMA.*<br>- *Surface water: Water use for any purpose should be reported (statement 25 in Water Act 2002) and a permit requested at WRMA* |
| Water Permit System – Users | • *Permits are issued though WRMAs, it also charges fees for irrigation water (volume), it charges for groundwater wells. WRMA charges 50 c/m3 for small users and 100 c/m3 for large users*[4] *(Neubert, et al. pp. 31-32 & WRMA, 2006)*<br>• *Permits are issued through Water Appointment Boards in the case of groundwater. (Meghani, M. et al. 2007, pp. 10)* |
| Donors and other institutions involved in irrigation development | • *SIDA (Kameri-mbote, P. 2005), AfDB, IFAD (Eastern Province Horticulture and Traditional Food Crops Project), IMF and FAO (CIA, 2011 and AQUASTAT, 2006), The mini-project (IDB and JICA) (Aquastat, 2006)*<br>• *GTZ (Water Sector Reform Assistance)*<br>• *World Vision Kenya: rehabilitation and development of irrigation schemes in Turkana district (Aquastat, 2006)*<br>• *JICA: Water Resources Management and Development Program Nyando River Basin 2006-2008*<br>• *USAID and World Concern, Water Improvement Program in narok and Lamu District. Including construction of Rainwater Harvesting Systems, Water pans, Wells, Micro (drip) Irrigation.*<br>• *USAID (Kenya Horticultural development Program (KHDP)*<br>• *World Bank, BADEA, Kuwait fund. Funding irrigation projects through NIB*<br>• *There are numerous NGO active in irrigation and agricultural development such as Action Against Hunger (UK), Adventist Development and Relief Agency (ADRA), Africa Harvest Biotech Foundation International* |
| Local organizations | • *Local water user organizations (WUAs) exit throughout the country. E.g. Ngusishi Water Resource User's Association (NWRUA), a local Kenyan* |

[4] Small users are defined as those who abstract less than 500 $m^3$/d, while large users are defines as those who use over 500 $m^3$/d (*Neubert, et al. pp. 32)*

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|---|---|
| | *organization that manages water resources among community members in Mt. Kenya area*<br>• *Key importance of local structures (LLGs) and farmer organization is formulated in statement 8.1.5 and 8.1.6 of the Agricultural Sector Development Strategy (2011)* |
| Private sector | • *Through the formation of the Kenya Private Sector Alliance (KEPSA), private sector players have been organized along sector boards to mirror the public sector arrangements and engage on issues. Key players within the agricultural sector include KENFAP, which represents agricultural producers, and KNFC, which handles the commercial arm of agriculture through the cooperative movement. Other private sector institutions include processors, marketing agencies and farm input dealers that, through their profit-oriented nature, have survived but can neither be regarded as strong nor organized players (GoK, 2010, pp. 86)*<br>• *Especially horticultural organizations (such as flower, vegetable and flower industry), using and developing water sources. There are over 70 export oriented flower companies.* |
| Support to small scale irrigation development (vocational sector, land planning) | • *National Research Institutes are KARI (crops and irrigation-agronomy), KEFRI (Kenya Forestry Research Institute), CETRAD (research on water harvesting), KEWII (former KEWI) (Kenyan Water Irrigation Institute) has mandate for research and training in the water and irrigation sector (GoK, 2009, pp. 40)*<br>• *Agricultural Universities like: Jomo Kenyatta Univeristy of Agriculture and technology; School of Agriculture and Biothnology (Moi University); Baraka Agricultural College nd Bukar Agricultural college*<br>• *No links exist to link research and education capacity with public and private research initiatives and industry (GoK, 2010, pp. 18)* |
| Land tenure | • *Private (6%), Government land (20%), trust land (64%), Other (10%) in 1990 (Kameri-mbote, 2004, pp. 4)*<br>• *The communal land ownership system is based on traditional customary rights, and all individuals born in that community have a right to use but not sell it. Government trust land is land held by ministries, state corporations or other public institutions for public use such as buildings, forests, research and national parks. Privately owned lands are registered; the owner holds the title under a freehold or leasehold system. The owner of such land can use it as collateral to access credit. Private ownership of land has encouraged investment and long-term improvements or development on farms to create a secure market for land (GoK, 2010, pp. 9)* |
| Government Effectiveness (percentile rank 0-100) (Worldbank, 2009) | 31.0 |

| | |
|---|---|
| Rule of Law (-2.5 – 2.5, in which high values represent effective enforcement of law (World Bank, 2009) | -1,07 |

| SOCIO-ECONOMIC | |
|---|---|
| Food exports, FAO (current US$M) (FAO Statistical Yearbook 2010) | 736.58 |
| Food imports, FAO (current US$M) (FAO Statistical Yearbook 2010 | 1,174.30 |
| Imports/exports | 1,59 |
| Health expenditure per capita (World Bank, current US$, 2009) | 33 |
| Improved water source (% of population with access) (World Bank, | 59 |
| Improved water source, rural (% of rural population with access)(WB, | 52 |
| Improved water source, urban (% of urban population with | 83 |
| Poverty (% below national poverty line) (UNSTAT, 2006) | 42 |
| Illiteracy rate –Male (15+) (UNICEF, 2009) | 9.5 |
| Illiteracy rate --Female (15+)(UNICEF, 2009) | 16.5 |
| Primary completion rate, total (% of relevant age group) (UNICEF, | 92.6 |
| Road density (road km/100 sq. km of land area) (IRF, 2004) | 11 |
| Road to arable land density (road km/1000 sq. km arable land)(IRF, | 12.03 |
| Roads, paved (% of total roads)(IRF, 2004) | 14.12 |
| Electric power consumption (kWh per capita) (CIA, 2008) | 157 |
| Country area (km2) (FAOSTAT, 2009) | 580,370 |
| Land area (km2) (FAOSTAT, 2009) | 569,140 |
| Population, Projected/Estimated (FAOSTAT, 2010) | 40,513,000 |
| Urban population (% of total population) (FAOSTAT, 2010) | 22 |
| Rural population (% of total population) (FAOSTAT, 2010) | 78 |
| Population density ($pp/km^2$) (World Bank, 2010) | 71 |
| **AGRICULTURAL** | |
| Agricultural exports (US$M) (FAOSTAT, 2008) | 2,668.76 |
| Agricultural Import (Current US$M) (FAOSTAT, 2008) | 1,343.59 |
| Import/export | 0,50 |
| Value added in agriculture, growth (%) (World Bank, 2010) | 2 |
| Value added, agriculture (% of GDP) (AQUASTAT, 2009) | 22.62 |
| Employment agriculture (% of population) (CIA, 2007) | 75 |
| Agricultual machinery (tractors /100 square km arable) (World bank, | 27.62 |
| Agriculture value added per worker (Constant 2000 US$) (WB, 2009) | 334 |
| Fertilizer consumption (kg per hectare of arable land) (WB, 2008) | 33.3 |
| Cereal cropland (% of land area) (of which irrigated, %) (WB, 2009) | 4 |
| Agricultural area (FAO Resource Stat, 2009) | 27,350,000 |
| Arable land (FAO Resource Stat, 2009) | 5,400,000 |

| IRRIGATED AGRICULTURE | |
|---|---|
| Irrigated land (% of crop land) (Aquastat, 2007) | 1.78 |
| Irrigated land entire country (ha) (Bastiaansen and Perry, 2009; AQUASTAT, 2003 and Ndiritue and Githae, 200X) | 34,000-103,000 |
| Actually irrigated (ha) (AQUASTAT, 2003) | 97,200 |
| Irrigation schemes (IDRC, 1996, pp. 158) | Mwea, Bura and Ahero (a) |
| Irrigation potential (entire country) (FAO, 1997; AQUASTAT, 2007; Ndiritue and Githae, 200X & GoK, 2009) | 180,000-1,300,000 |
| Irrigated Land nile basin (potential) (Bastiaansen and Perry, 2009) | 34,156 (200,000) |
| Irrigation schemes in Nile Basin (Ibid.) | West Kano, Ahero and Bunyala |
| Small schemes (5-1,000ha) (ha) (national level) (Ibid.) | 48,048 |
| Medium schemes (0.5-5,950ha) (ha) (national level) (Ibid.) | 42,7 |
| Large schemes (213-6,200ha) (ha) (national level) (Ibid.) | 12,458 |
| Potential schemes (Nile Basin) | n.a. |
| Water Sources (In order of importance) (Bastiaansen and Perry, 2009) | 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) | 30.7 |
| Overlap | 3 |
| Surface water | 30.2 |
| ground water | 3.5 |
| Dependency ratio | 32.57 |
| **ACTUAL WATER ABSTRACTION RATES** | |
| Groundwater ($10^6$ m3/year) (Ndiritue and Githae, 200X) | 57.21 |
| Surface ($10^6$ $m^3$/year) (Ibid.) | 193 |
| Total water withdrawal (km3/year) (AQUASTAT, 2003) | 2.735 |
| % of renewable water resources (AQUASTAT, 2002) | 8.91 |
| **Water abstraction points** | |
| Deep Motorized borehole | n.a. |
| Motorized borehole | n.a. |
| Manual borehole (Ndiritue and Githae, 200X) | 14,260 |
| Protected shallow wells (Ndiritue and Githae, 200X) | many |
| Windmill borehole | n.a. |
| Springs | n.a. |

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|---|---|
| **IRRIGATION PERFORMANCE (Bastiaansen and Perry, 2009)**[5] | |
| Overall Irrigation performance Large Scale Irrigation (0-5) | 3.6 |
| Result Oriented Performance | 3.55[6] |
| Sustainability Oriented Performance | 3.8[3] |
| Process Oriented Performance | 3.65[3] |
| **Detailed Irrigation Performance Parameters** | |
| Water Productivity (Performance 0-5) (Rank within Nile Basin 1-8) | 3.5 (1) |
| Agricultural water Productivity | 3.6 (2) |
| Crop consumptive use | 2.5 (7) |
| Beneficial Water Use | 3.9 (2) |
| Adequacy | 3.5 (2) |
| Uniformity | 4.0 (6) |
| Reliability | 4.9 (2) |
| Sustainability | 3.0 (8) |
| **AGROPHYSICAL (Bastiaansen and Perry, 2009)** | |
| Irrigated crops (ha) | Maize (4,000), Cotton (3,000), Rice (18,000), Vegetables (26,000), Citrus (5,000), Sugar Cane (2,000), Coffee (18,000) and Bananas (1,000) |
| Cereal yield rainfed (kg/ha) (Nett yield) | 1,374 |
| Biomass production (satellites) (kg/ha) (Nett yield) | 13,989 |
| Cereal yield irrigated (kg/ha) (Nett yield) | 6,063 |
| Yield Increment | 4,689 |
| Net Increment | 1,407 |

[5] *Specific recommendations for improvement of irrigation performance, as mentioned in Bastiaanssen and Perry (2009): No comments, however avoidance of over-use of water, an introduction of an water saving plan and a more uniform water distribution can help further improve irrigation efficiencies*

[6] *Referred to as good in Bastiaansen and Perry (2009), no comments for improvement*

# 2 Countrywide irrigation potential

## 2.1 Terrain and soil

### *2.1.1 Relief, climate, and hydrography*

The average annual rainfall in Kenya ranges from 250 to 2500 mm, while the average potential evaporation ranges from less than 1200 to 2500 mm. The average annual temperature ranges from 10 to 30°C. From the total land area of 582,000 $km^2$, only 16% is considered to be of high potential for agriculture (Mburu, 2008). This high potential area receives over 1000 mm of annual rainfall and accounts for less than 20% of the agricultural land. More than 50% of the country's population lives in this area. The medium potential area receives between 750 and 1000 mm of rainfall per annum. This area occupies 35% of the agricultural land and carries 30% of the total population. The remaining part of Kenya (80%) is classified as arid and semi-arid land with mean annual rainfall of less than 750 mm, carrying 20% of the total population. These numbers show that the country is poorly endowed with potential for rain-fed agriculture. The future growth and development of the agricultural sector will rely on integrated water resources management that encompasses water harvesting and irrigation.

The land potential in Kenya can be based on agro-climatic zones  or agro-ecological zones. Agro-climatic zoning is based on rainfall amount and distribution and temperature. The main agro-climatic zones are based on their probability of meeting the temperature and water requirements of the main leading crops. There are many different rainfall distribution types in Kenya which make it difficult to produce a detailed agro-climatic zone classification to cater for all variations in rainfall and temperature. There are seven main agro-climatic zones in Kenya according to Mburu (2008), based on the average monthly rainfall and potential evapotranspiration.

### *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.

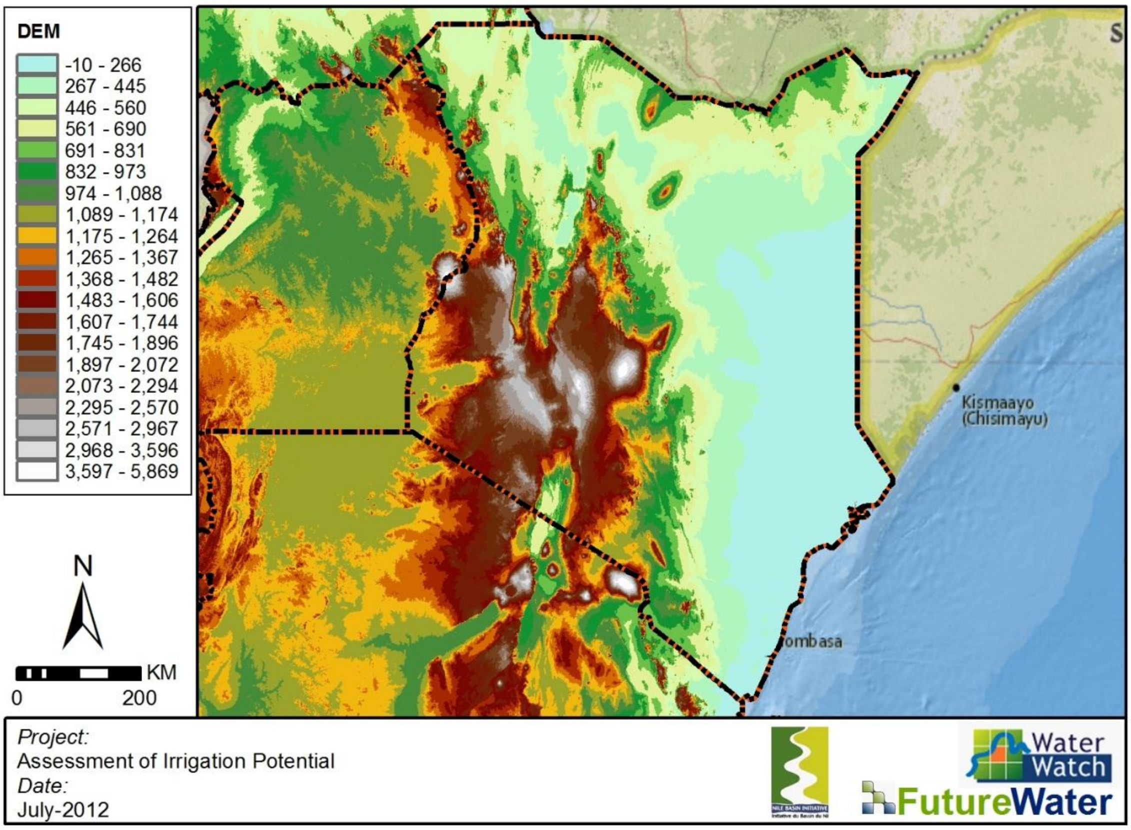
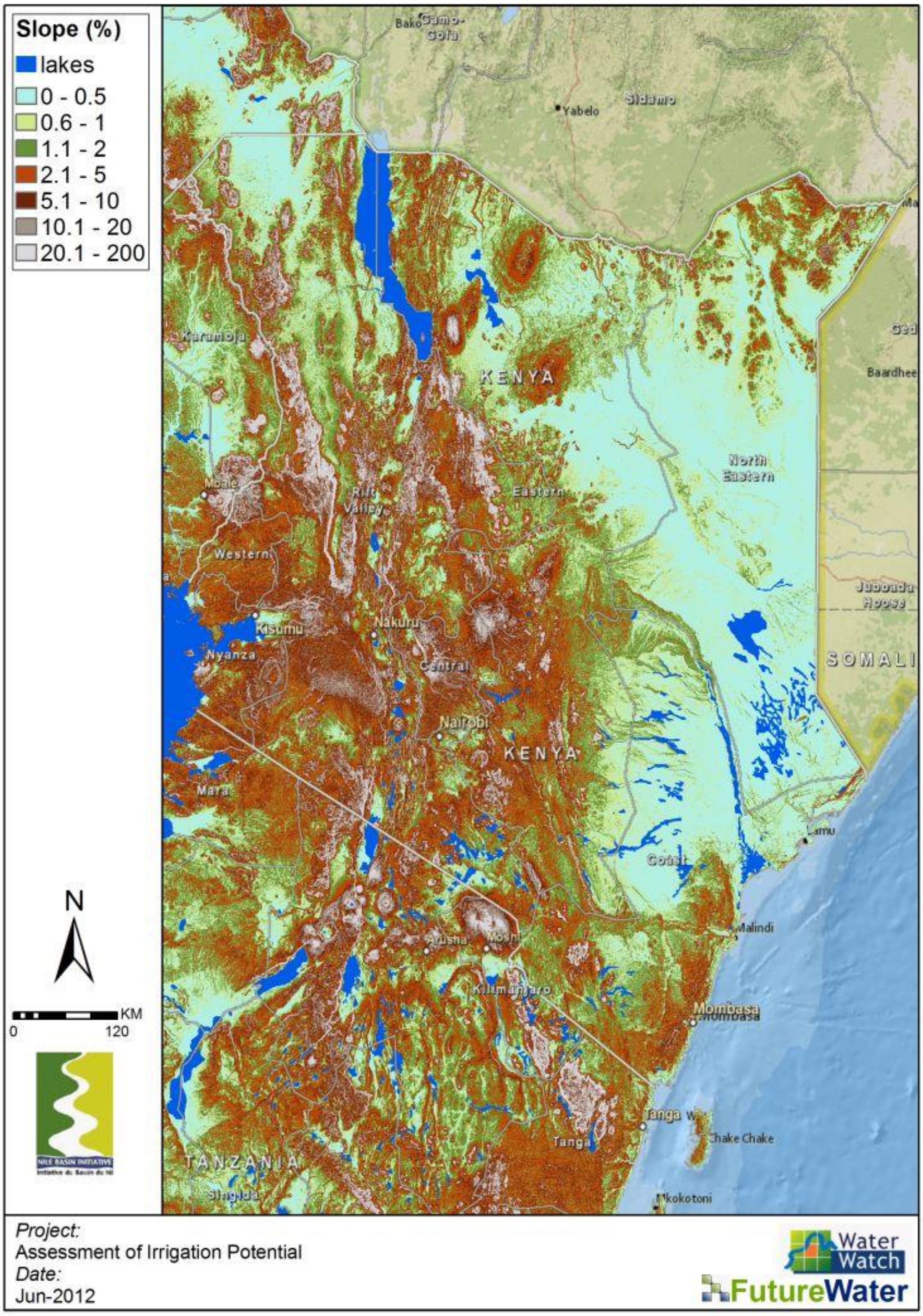



**Figure 2: Digital Elevation Model of Kenya. (Source: ASTER)**

In Figure 2 the DEM for Kenya is shown. The country has flat areas in the east and north and quite some mountains in the rest of the country. Associated slopes can be seen in the next Figure. 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 in the east, although also in between mountains suitable areas exist.


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
120
KENYA
Karamoja
Moale
Western
Rift Valley
Eastern
North Eastern
Kisumu
Nyanza
Nakuru
Central
Nairobi
KENYA
Mara
Coast
Lamu
Malindi
Arusha
Moshi
Kilimanjaro
Mombasa
Tanga
Chake Chake
TANZANIA
Singida
Yabelo
Sidamo
Baardhee
SOMALI
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
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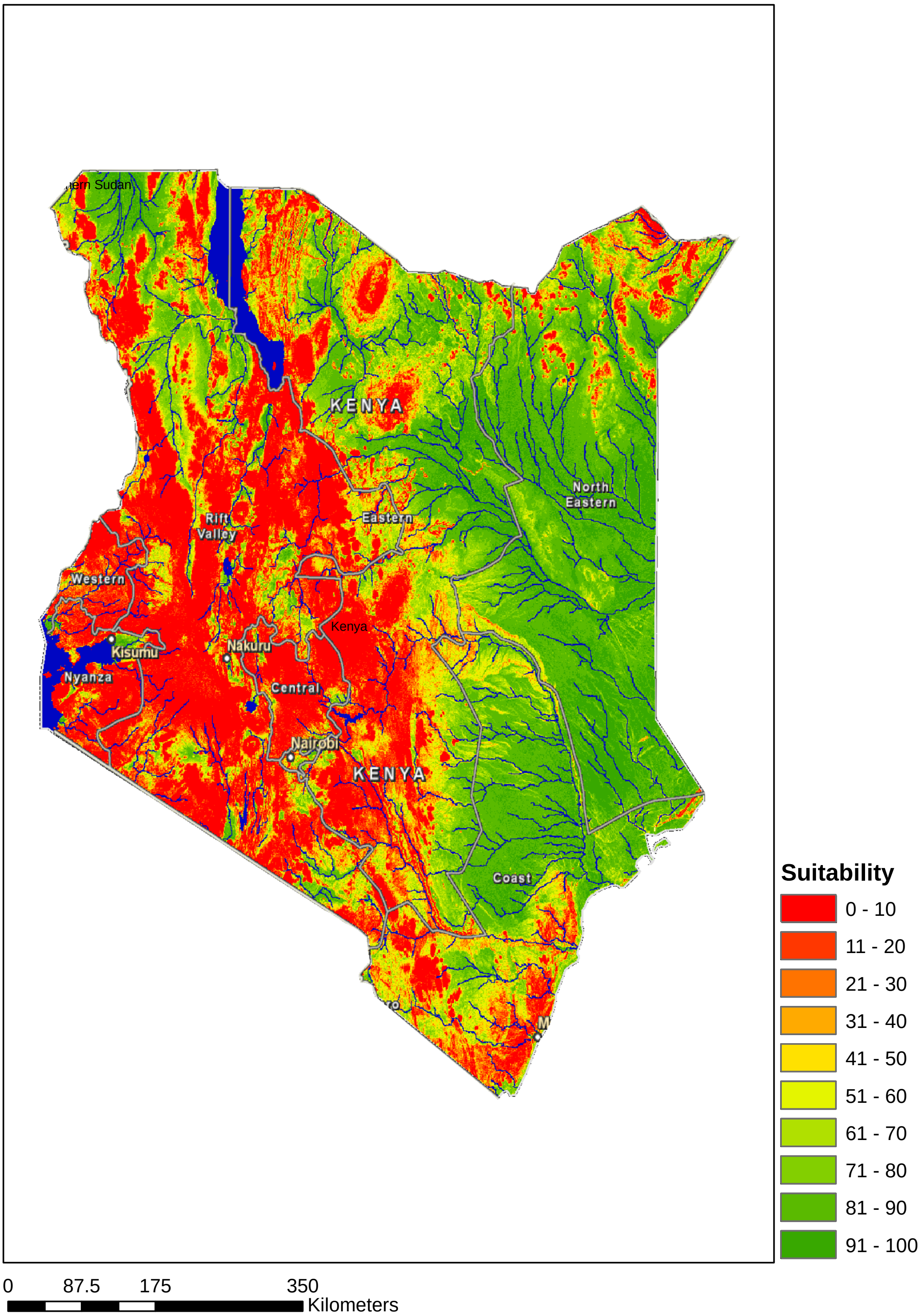
FutureWater


KENYA
North Eastern
Eastern
Rift Valley
Western
Kenya
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
Suitability
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
0
87.5
175
350
Kilometers

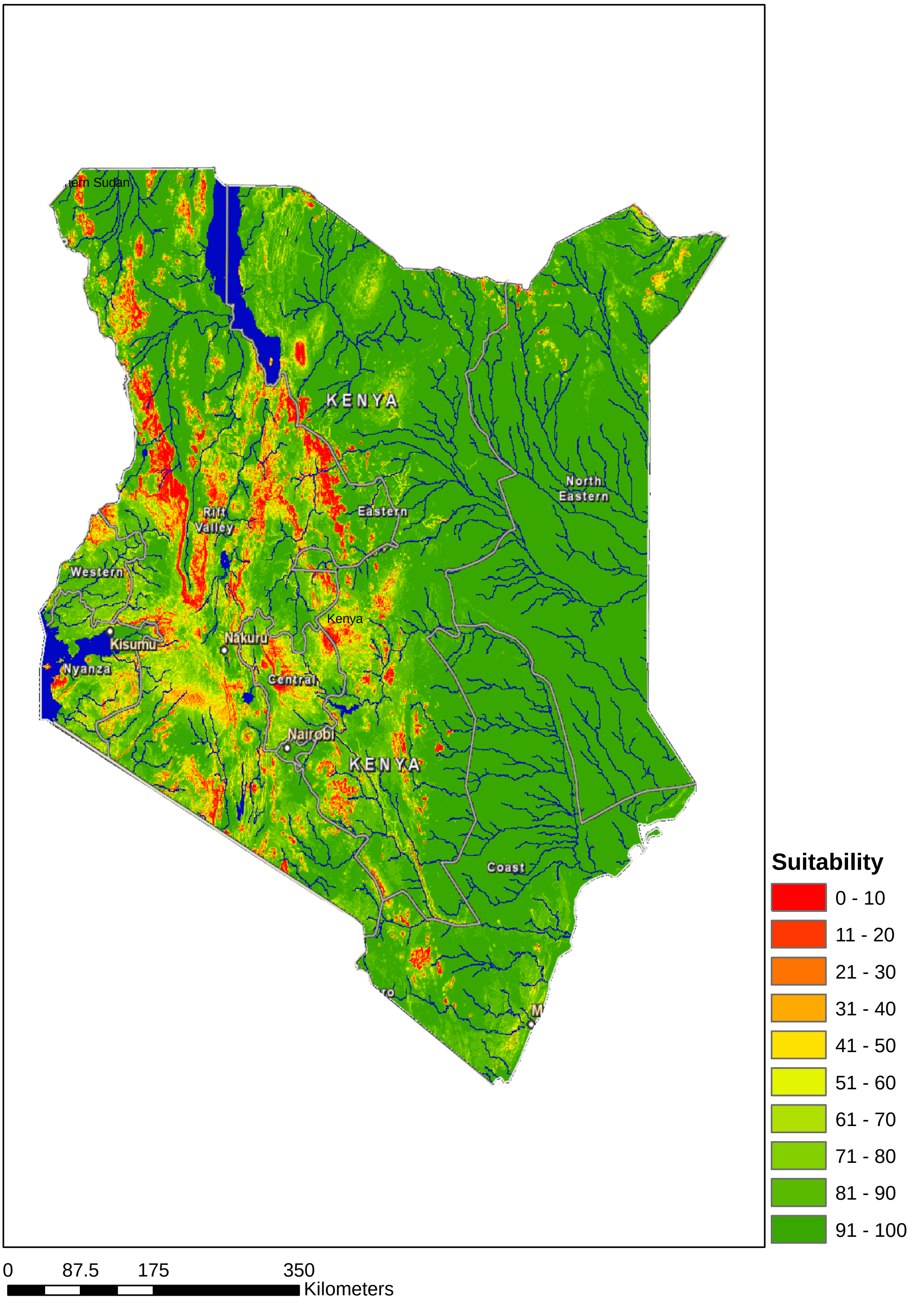
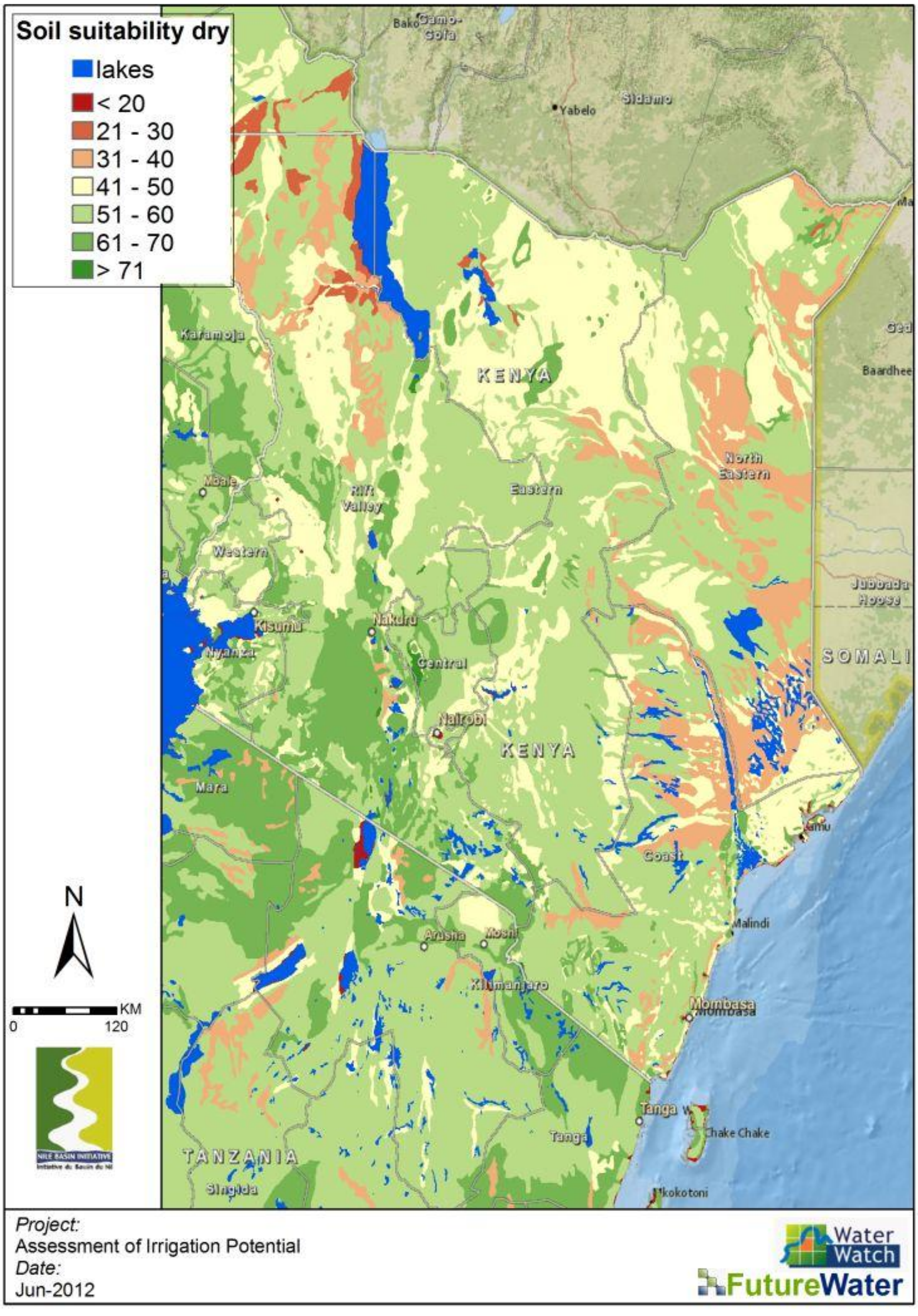



**Figure 3: Terrain slope as percentage (top), surface irrigation (middle), and drip irrigation (bottom).**

### 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 Kenta are by enlarge reasonable suitable to develop irrigation based on soil characteristics. Although in the eastern part of the country soils are relatively poor and production might be somewhat lower.  Salinity problems might occur in the dryer northern regions.


Soil suitability dry
lakes
< 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
> 71
N
KM
0
120
Karamoja
KENYA
Mbale
Rift Valley
Eastern
North Eastern
Western
Kisumu
Nyanza
Nakuru
Central
Nairobi
KENYA
Mara
Coast
Arusha
Moshi
Kilimanjaro
Malindi
Mombasa
Tanga
Tanga
Chake Chake
TANZANIA
Singida
Yabelo
Sidamo
Baardhee
Jubbada Hoose
SOMALI
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

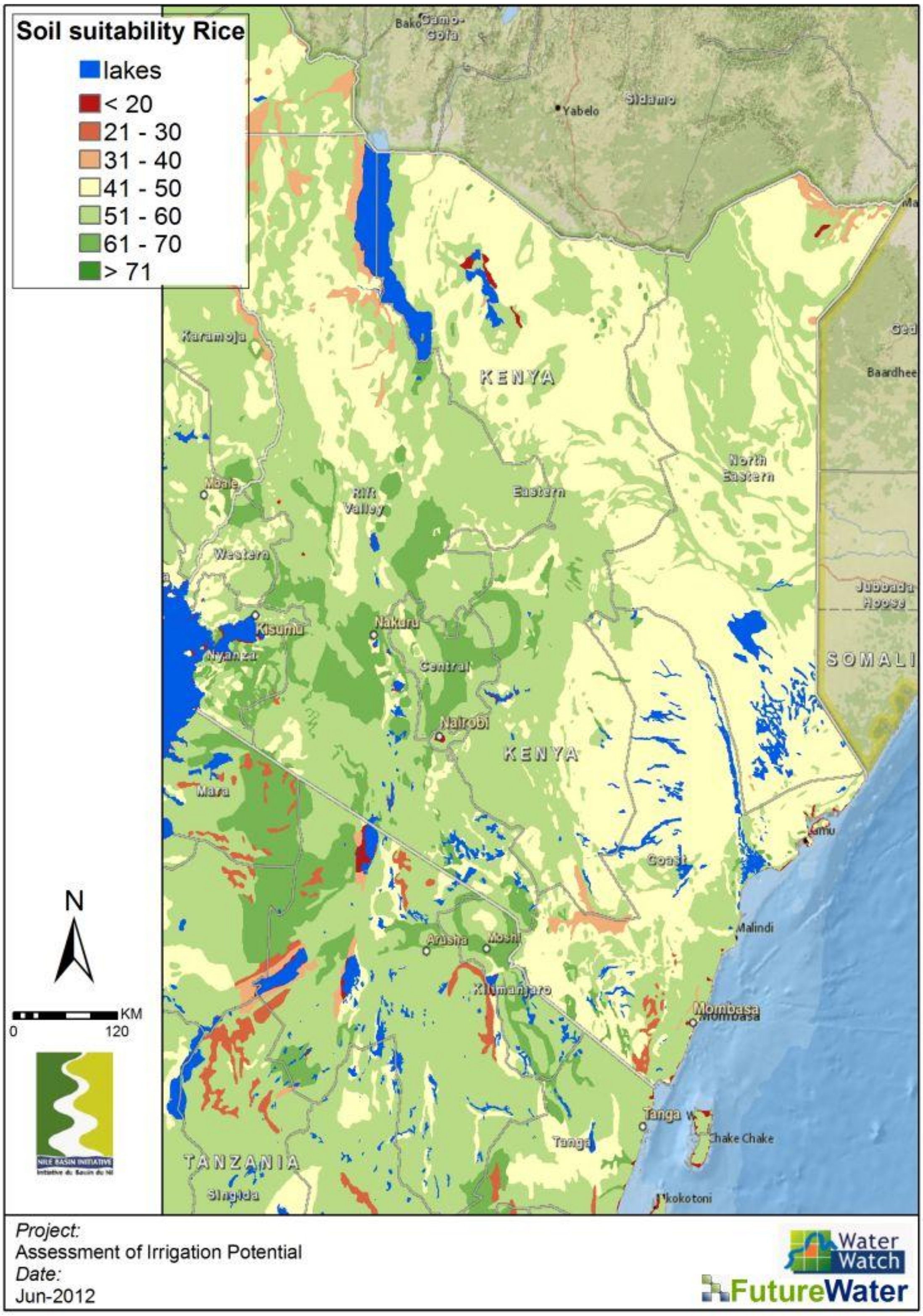



**Figure 4: Soil suitability for dry crops (top) and rice/paddy (bottom) (Source: study analysis)**

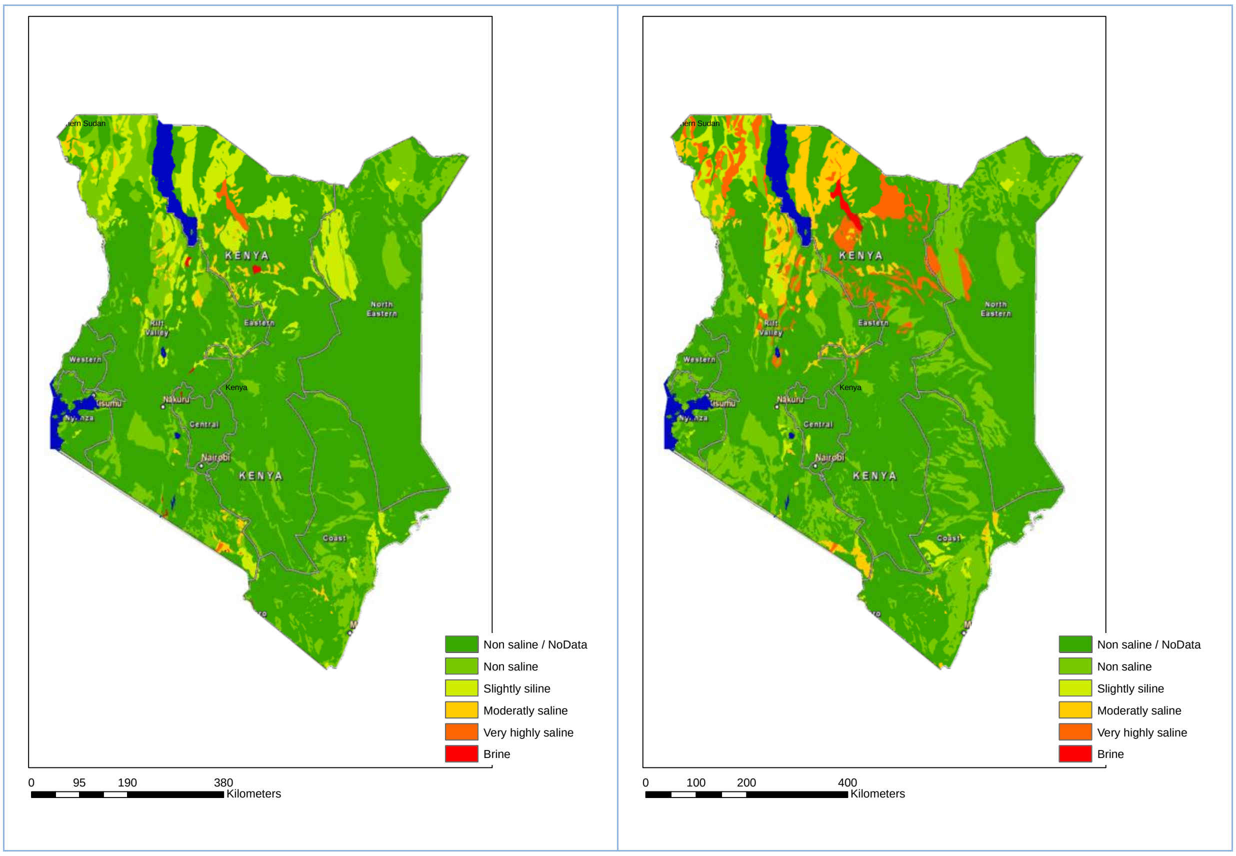


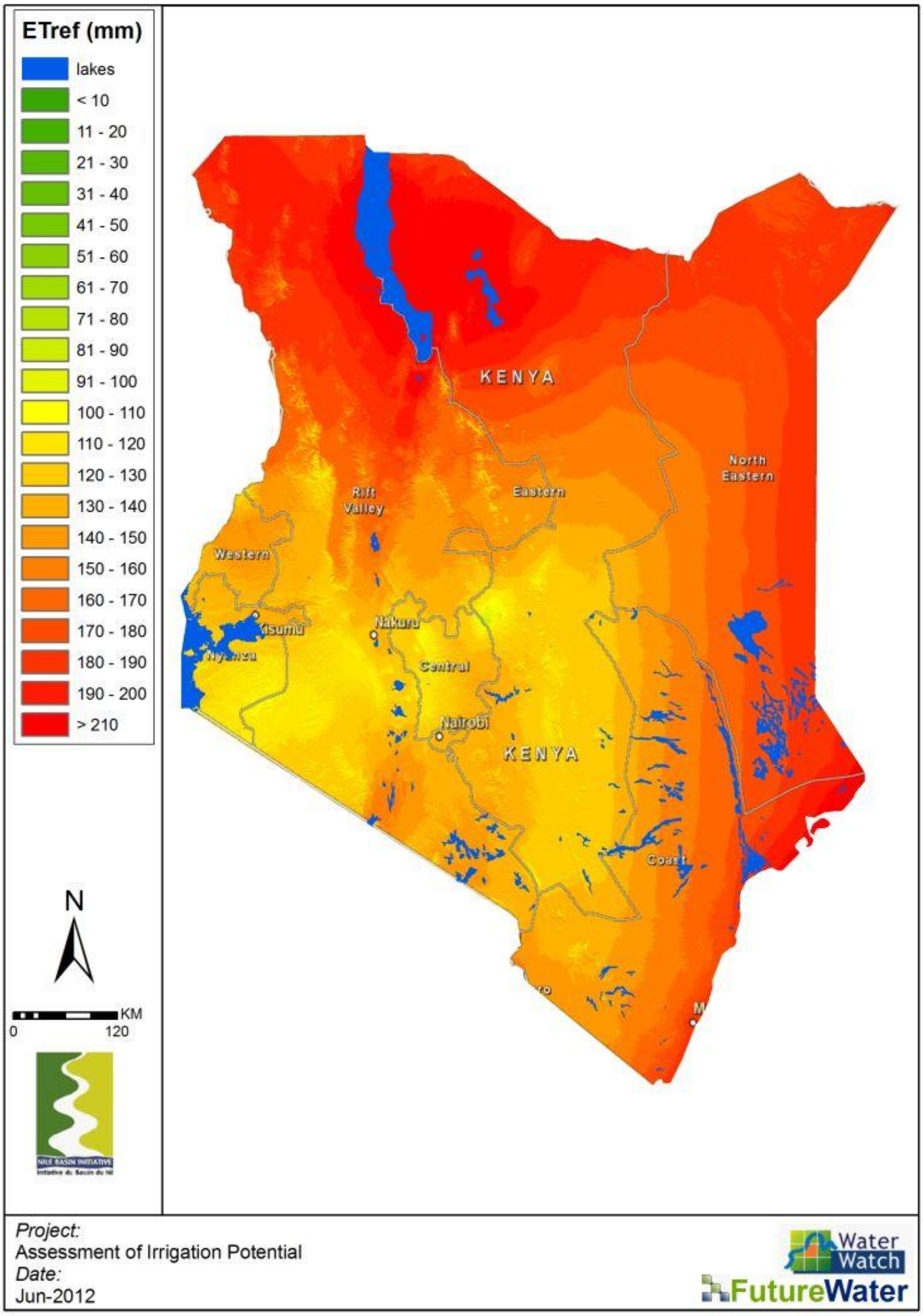

**Figure 5: Salinity, top-soil (left) and sub-soil (right). (Source: study analysis).**

## 2.2 Water

### *2.2.1 Irrigation water requirements*

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

### *January*



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
KENYA
North Eastern
Rift Valley
Eastern
Western
Kisumu
Nakuru
Central
Nairobi
KENYA
Coast
N
KM
0
120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
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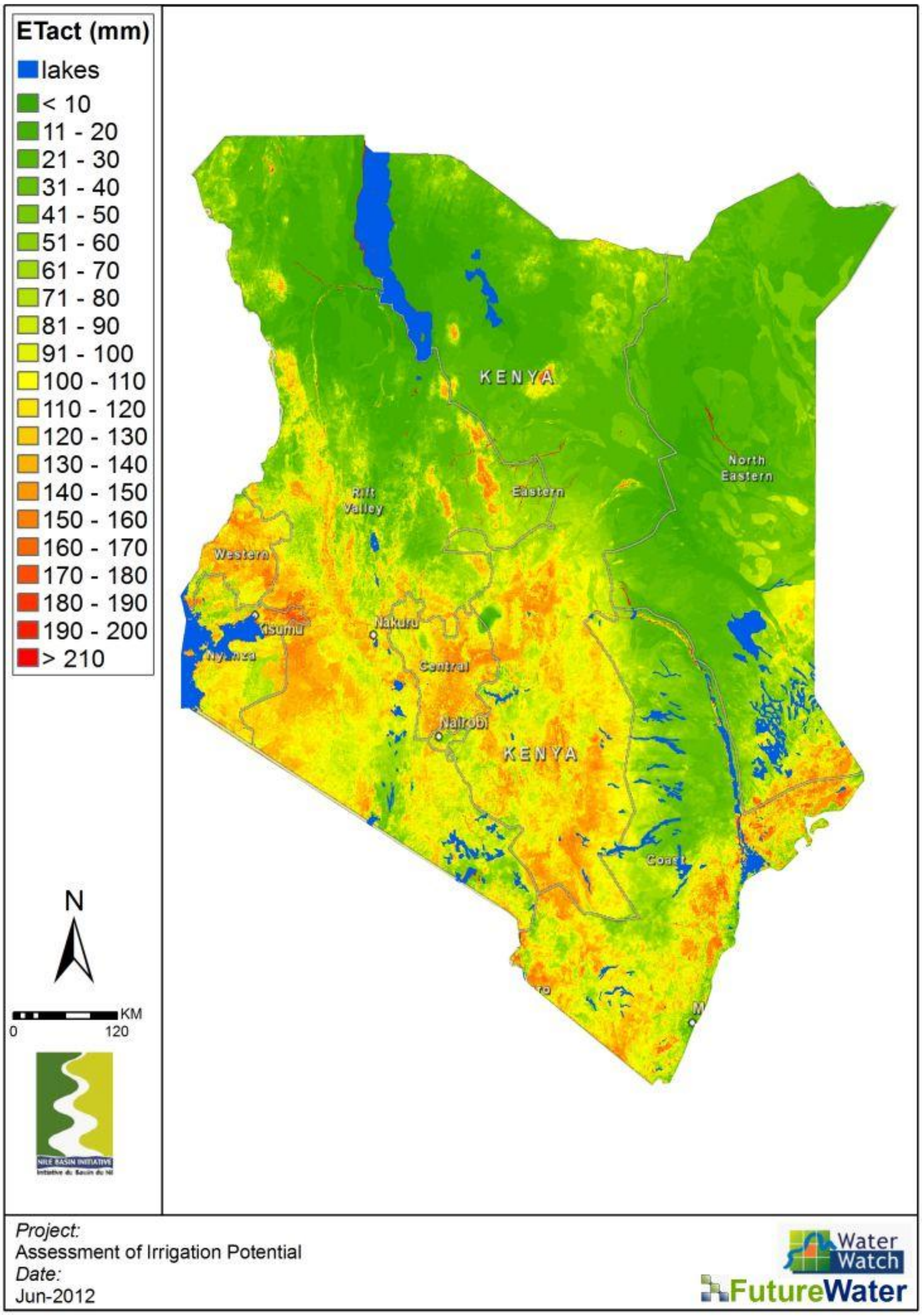
FutureWater


ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
KENYA
North Eastern
Eastern
Rift Valley
Western
Nakuru
Central
Nairobi
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120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

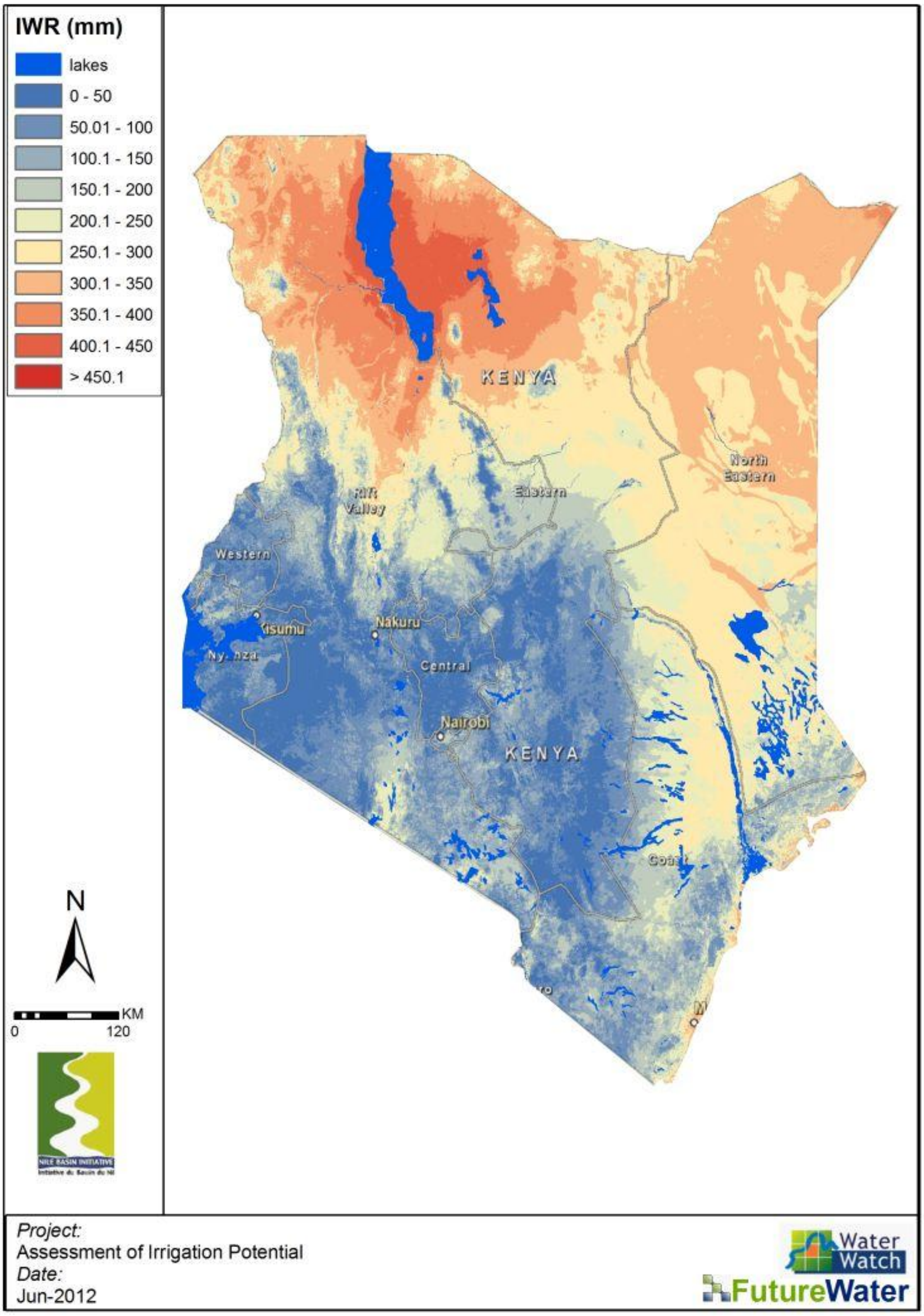
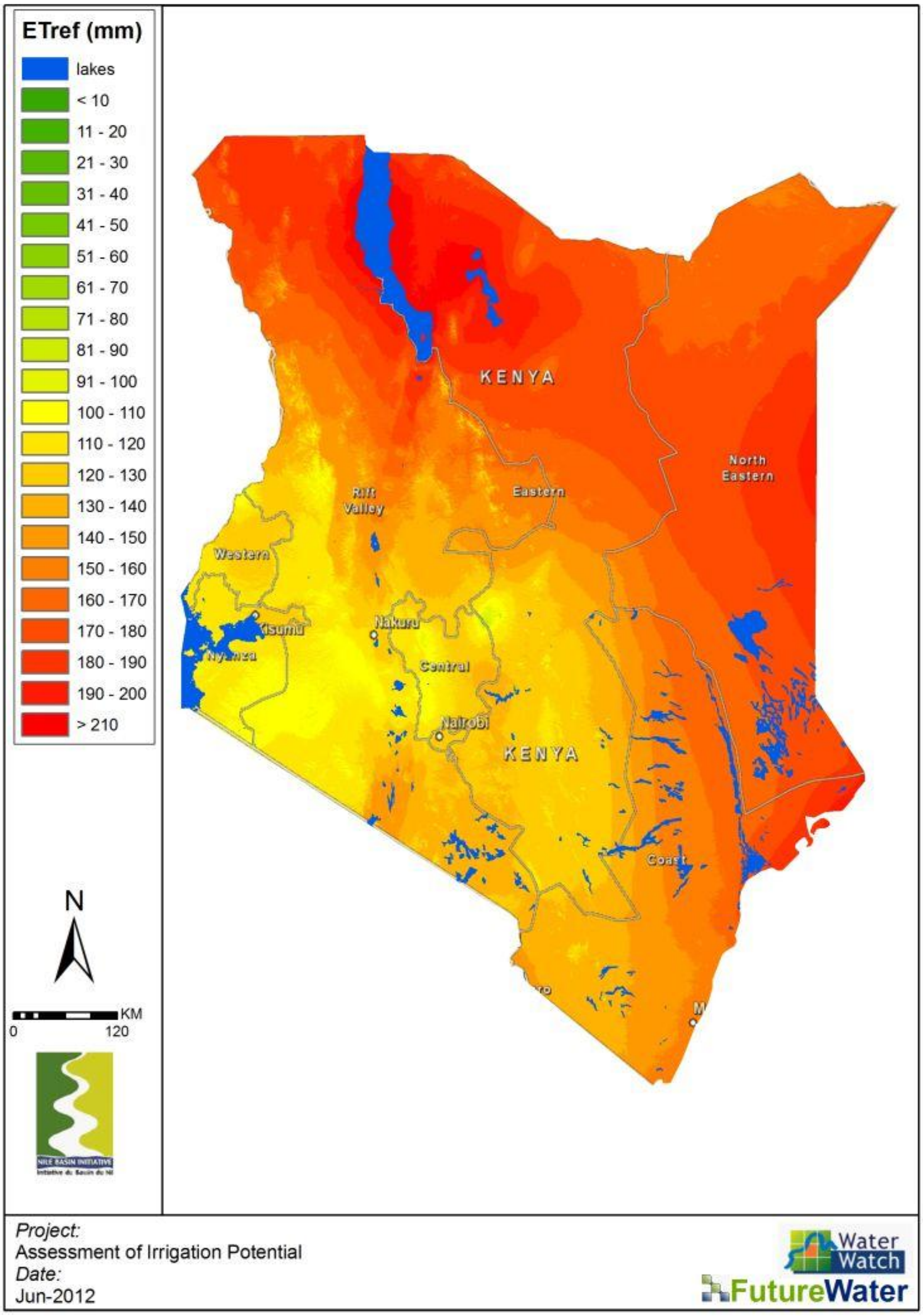



**Figure 6: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for January (Average 2001-2010). (Source: study analysis).**

### *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
120
KENYA
North Eastern
Rift Valley
Eastern
Western
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Nakuru
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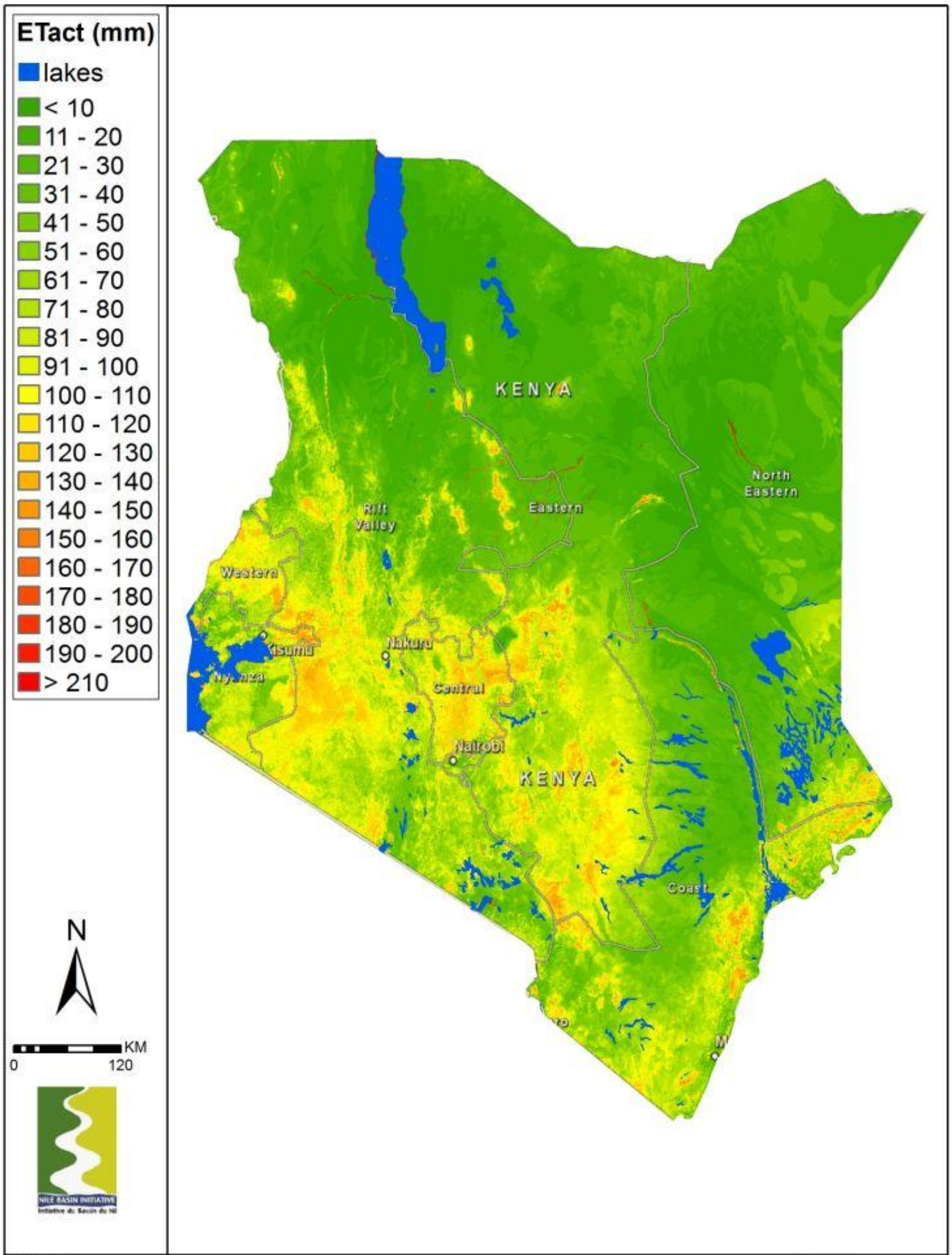


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Assessment of Irrigation Potential
*Date:*
Jun-2012

Water Watch
FutureWater

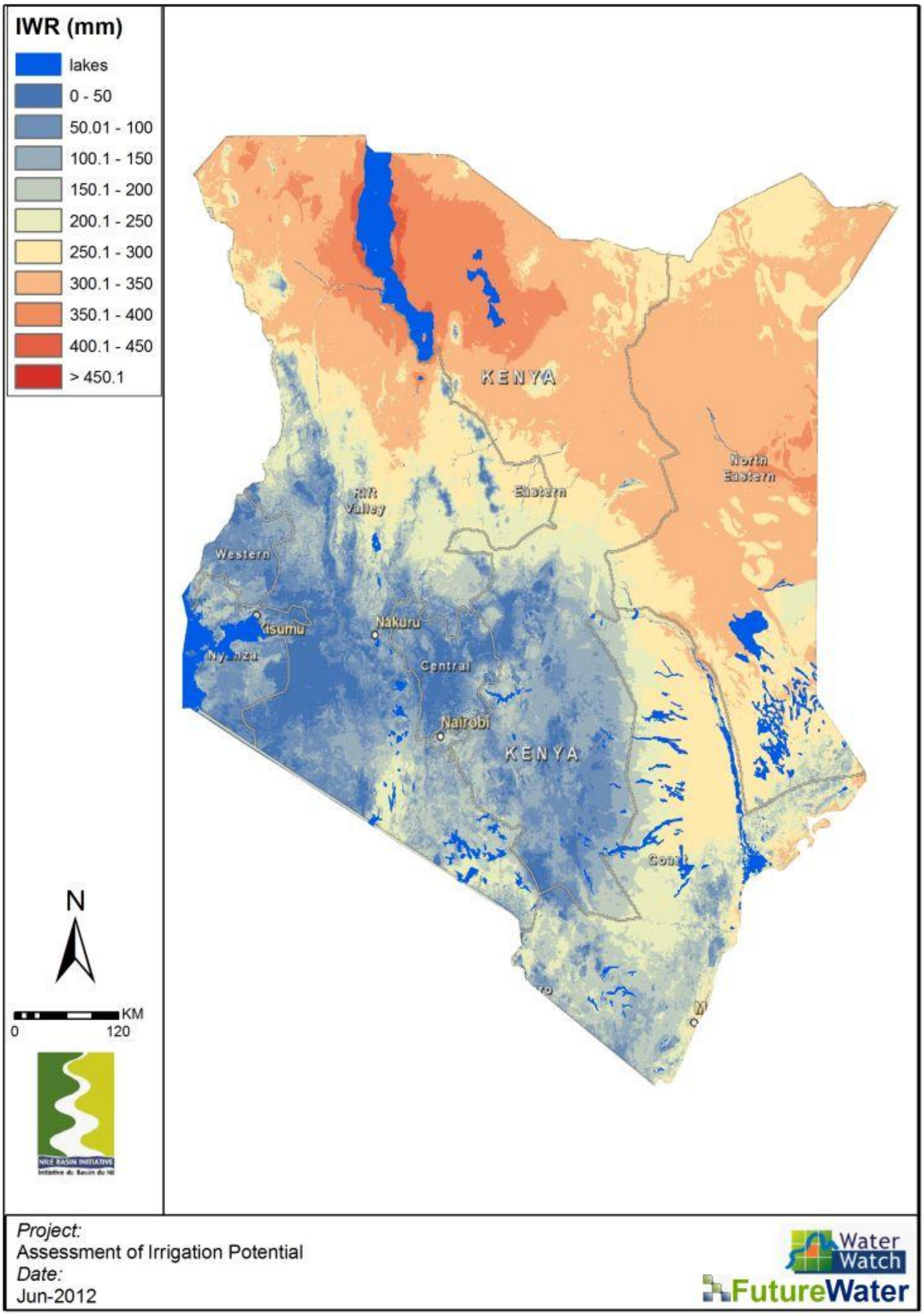
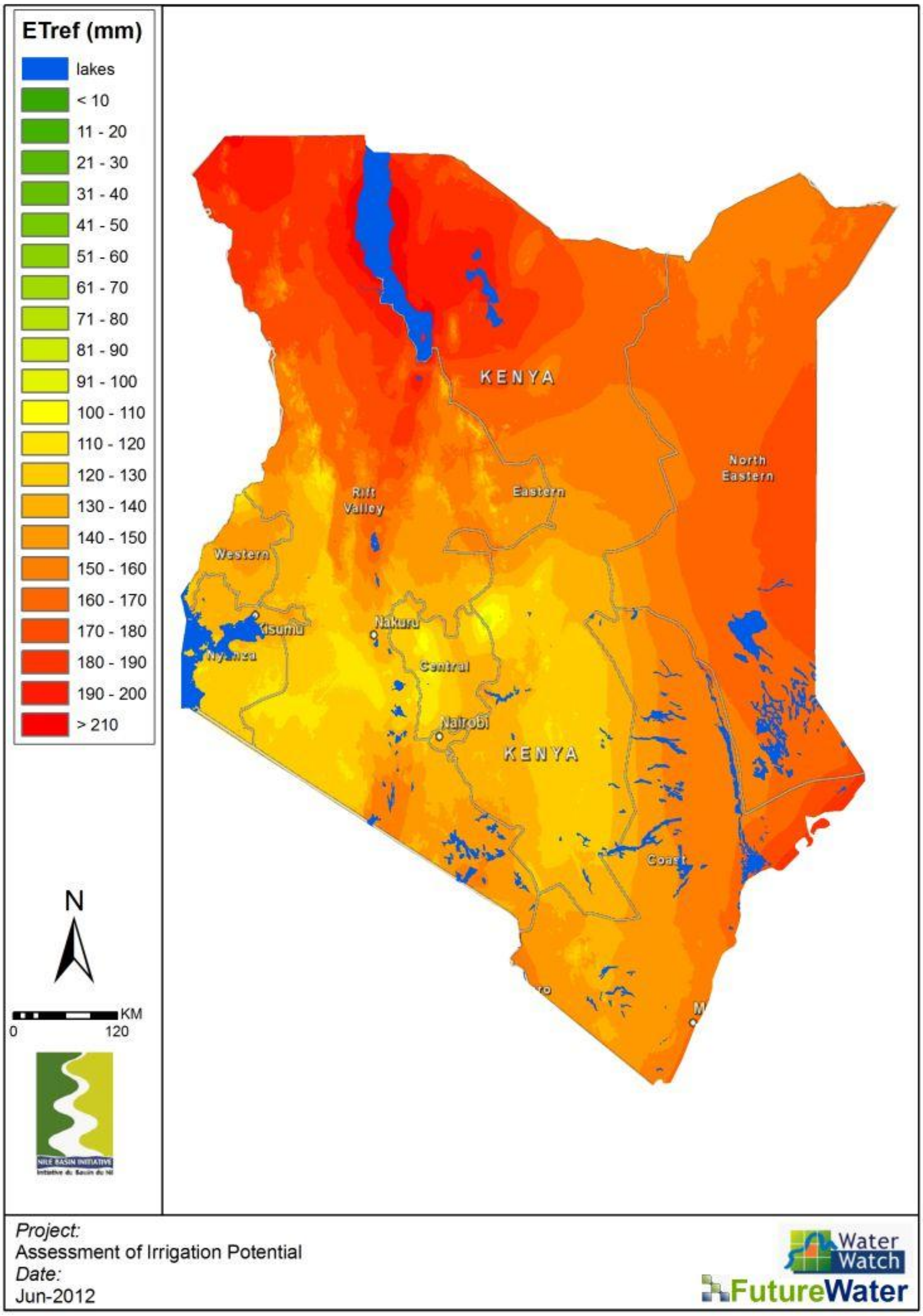



**Figure 7: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for February (Average 2001-2010). (Source: study analysis).**

## *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
KENYA
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Rift Valley
Eastern
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Nakuru
Central
Nairobi
KENYA
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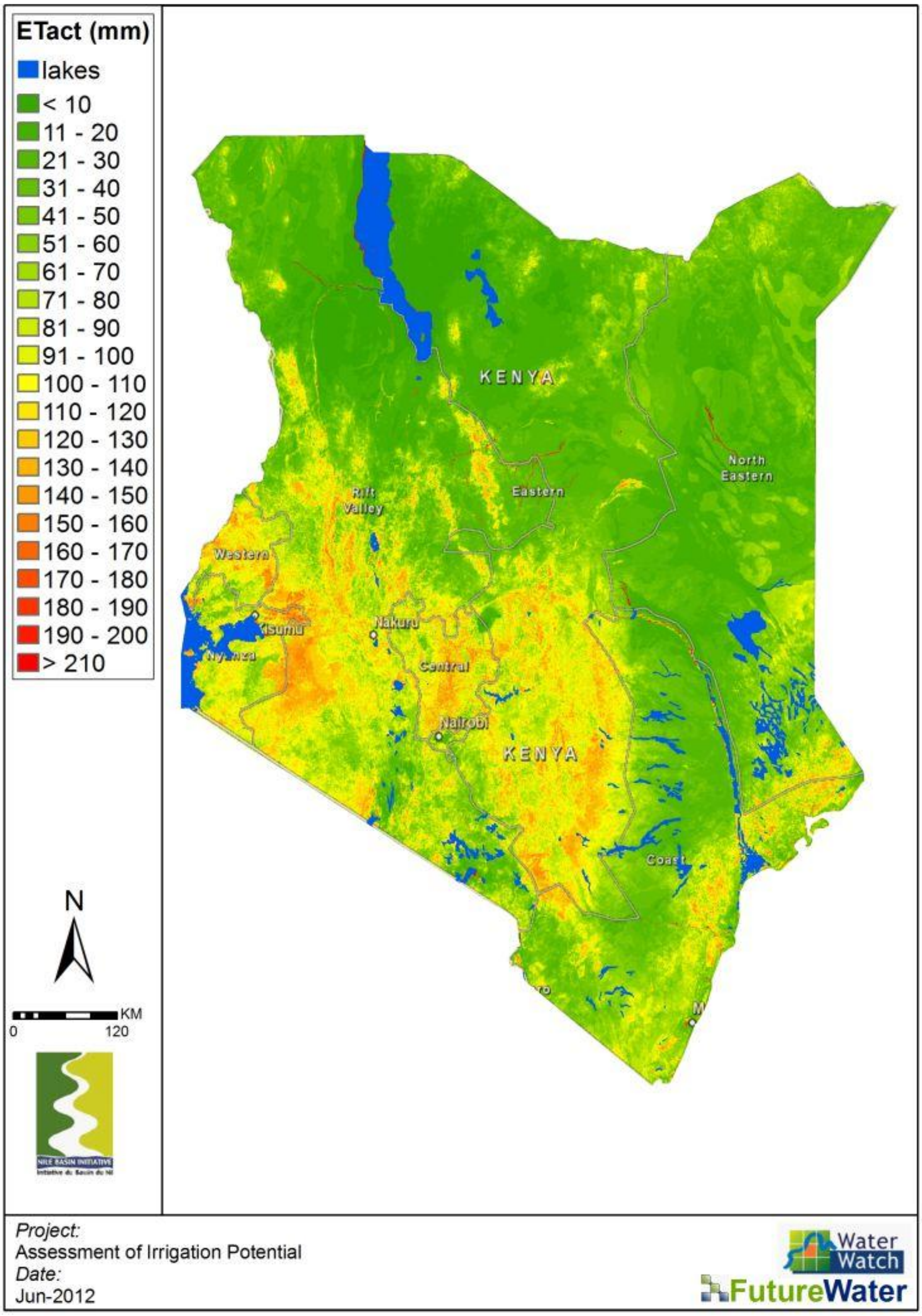
120
NILE BASIN INITIATIVE
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


ETact (mm)
lakes
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11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
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Jun-2012
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FutureWater

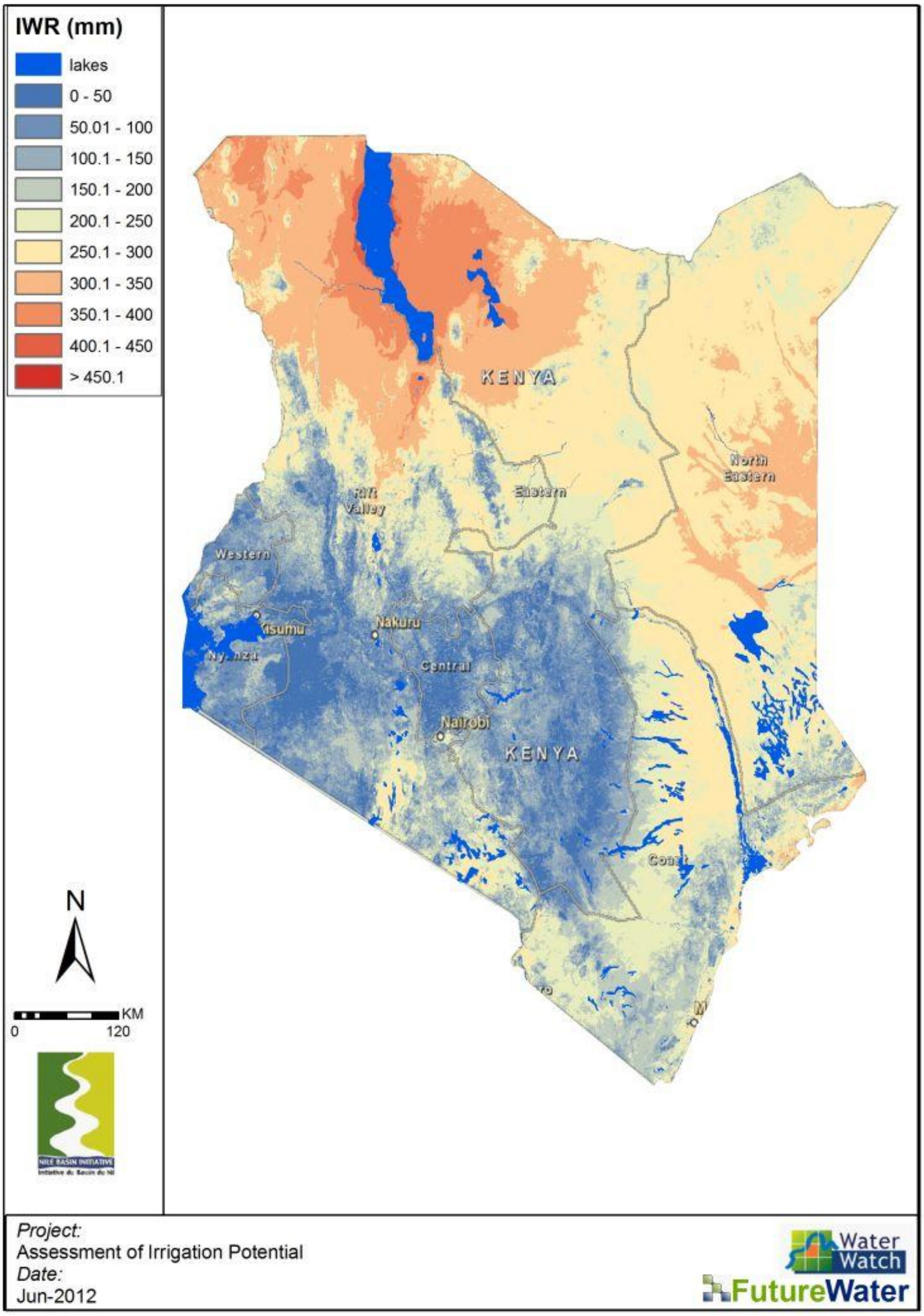
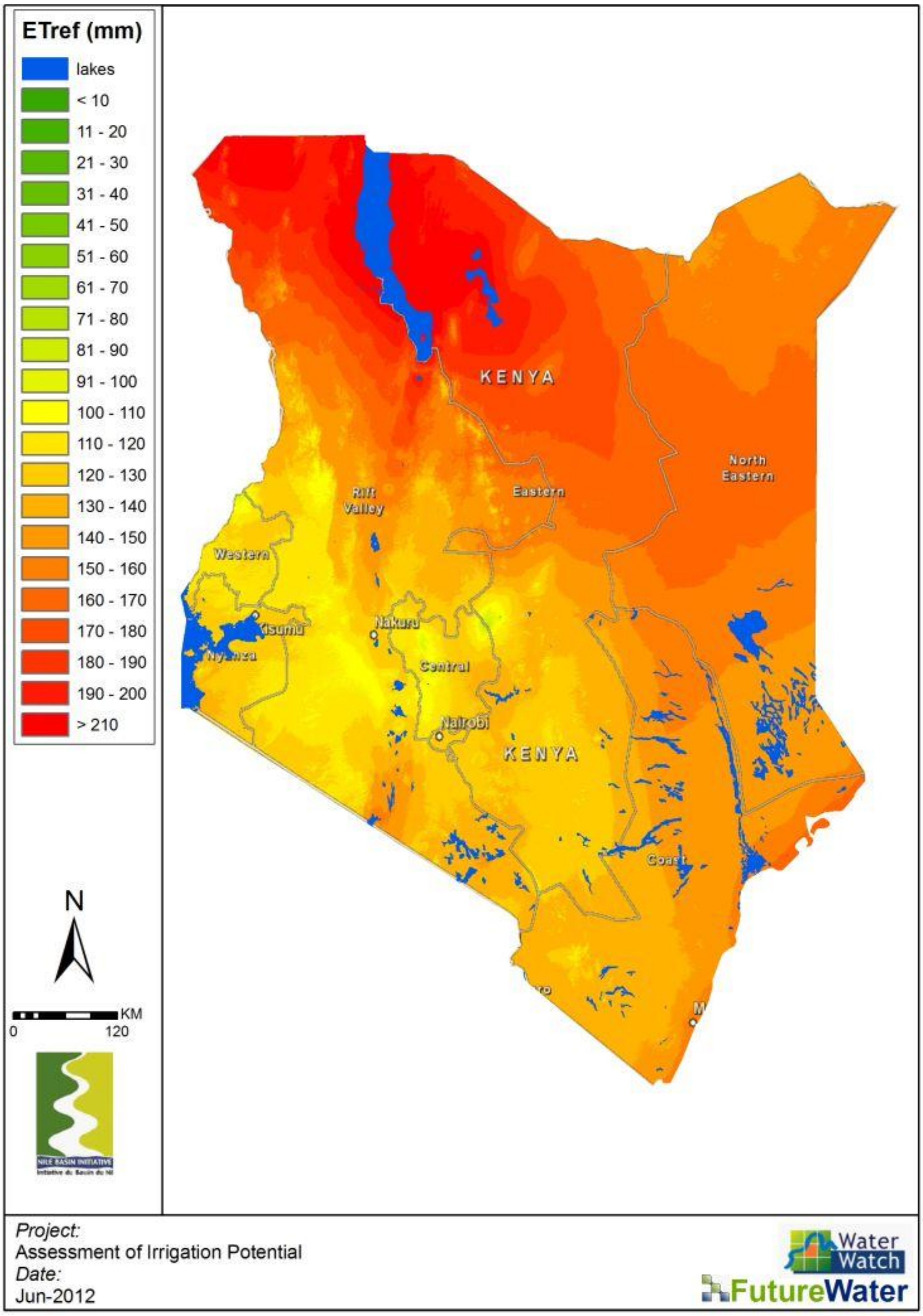



**Figure 8: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for March (Average 2001-2010). (Source: study analysis).**

*April*



ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
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110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
KENYA
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Rift Valley
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Kisumu
Nyanza
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Project:
Assessment of Irrigation Potential
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Jun-2012
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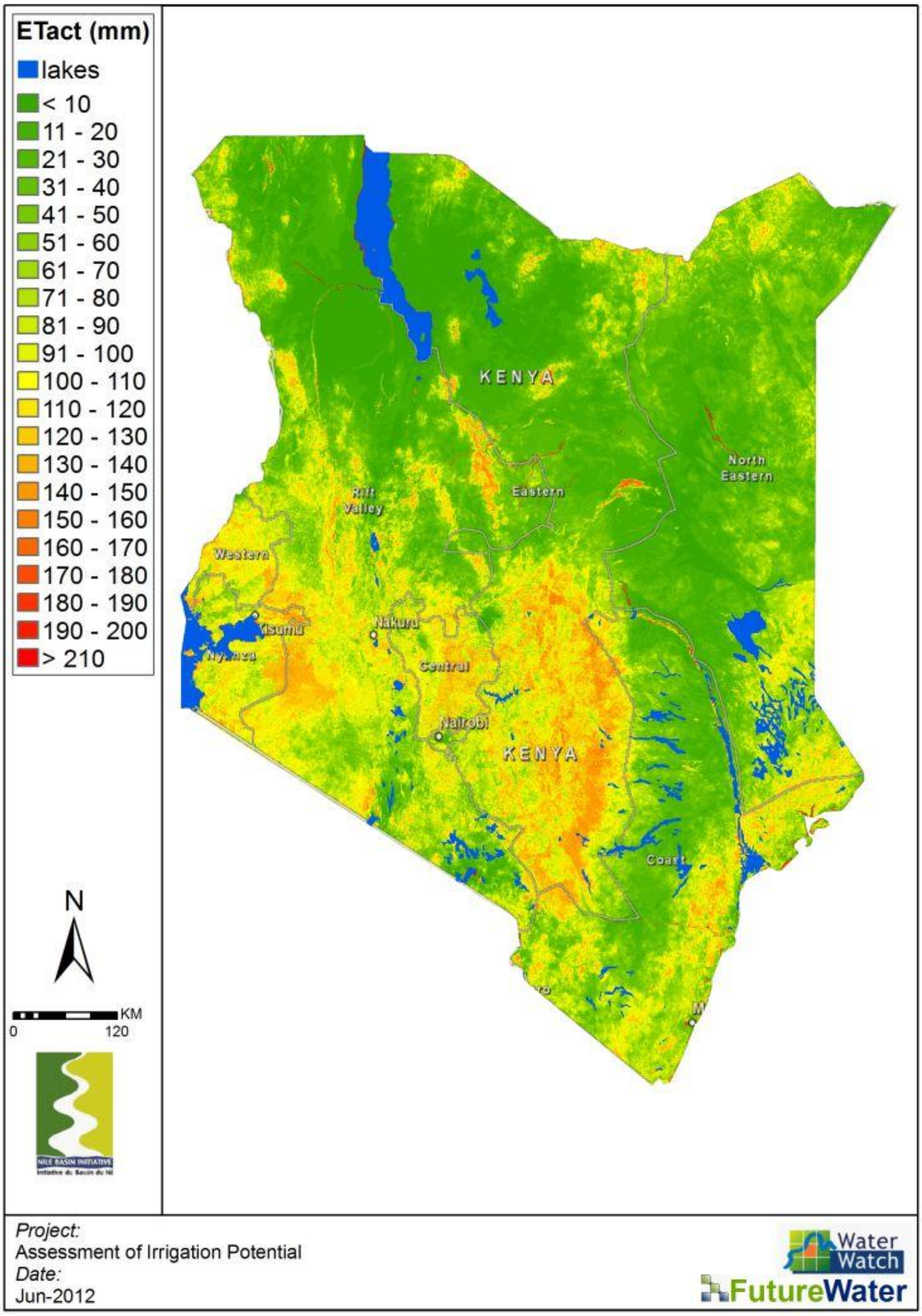
FutureWater


ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
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61 - 70
71 - 80
81 - 90
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100 - 110
110 - 120
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160 - 170
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180 - 190
190 - 200
> 210
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Nyanza
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Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

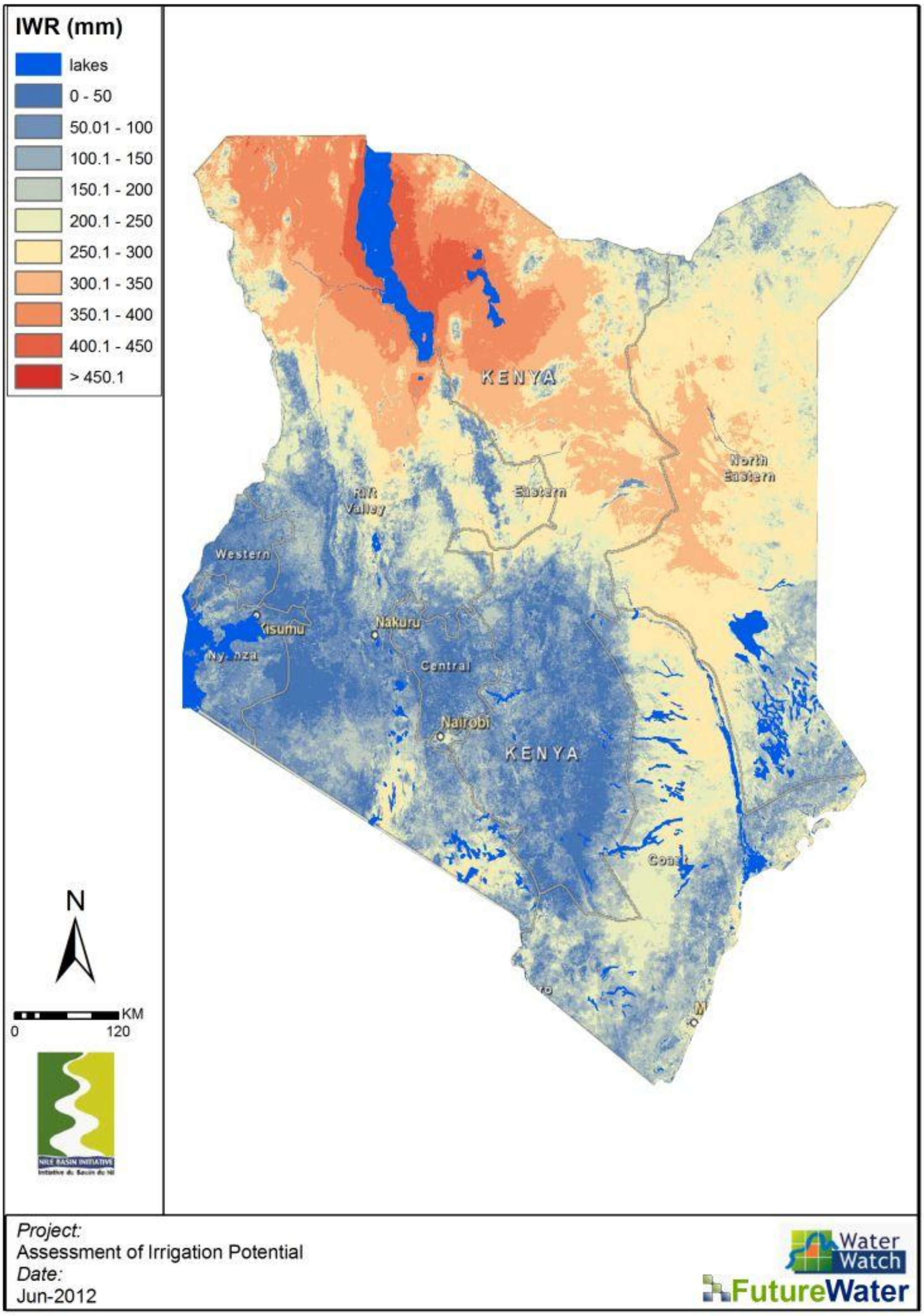
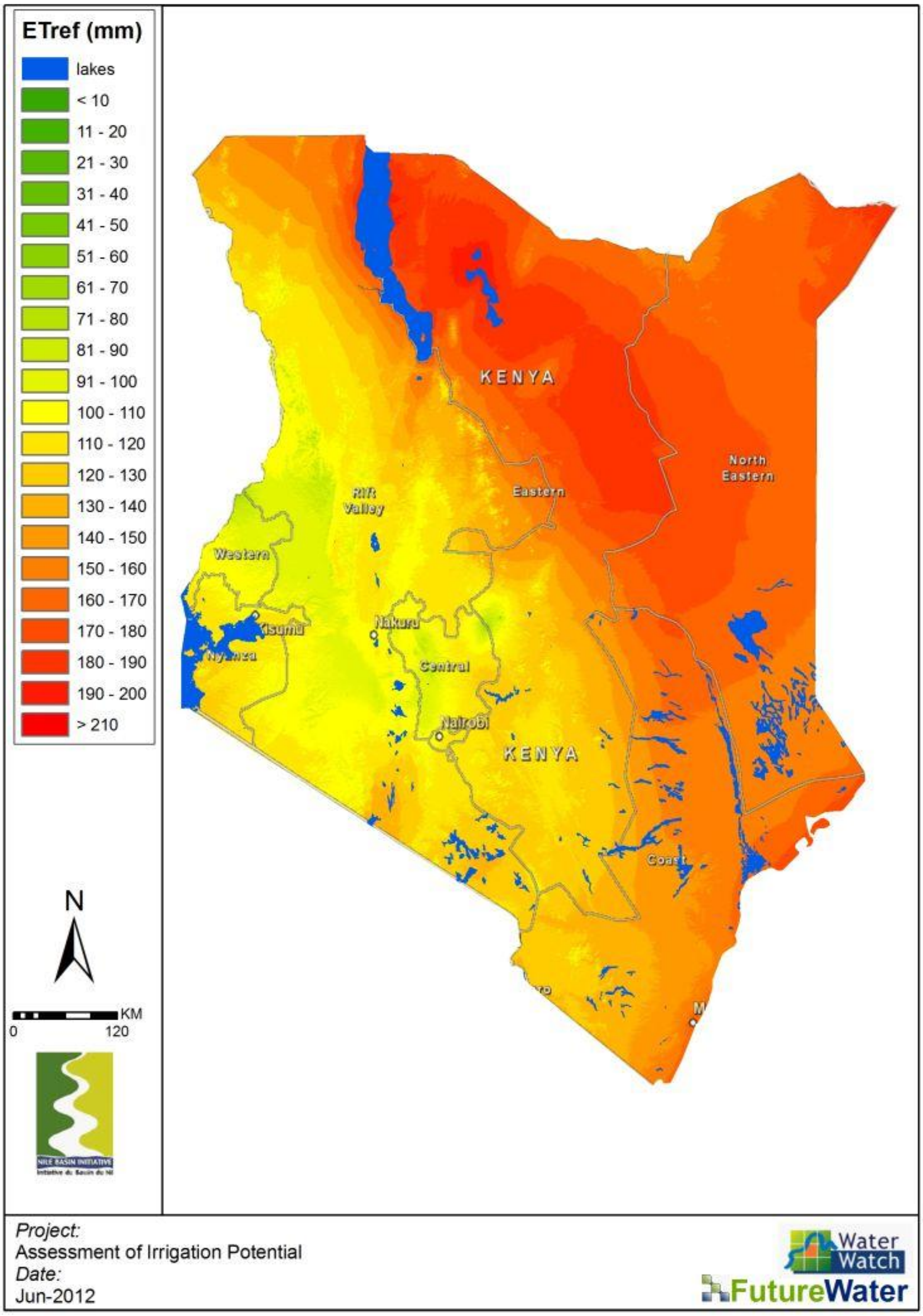



**Figure 9: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). for April (Average 2001-2010). (Source: study analysis).**

*May*


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
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110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
KENYA
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Eastern
Rift Valley
Western
Kisumu
Nakuru
Central
Nairobi
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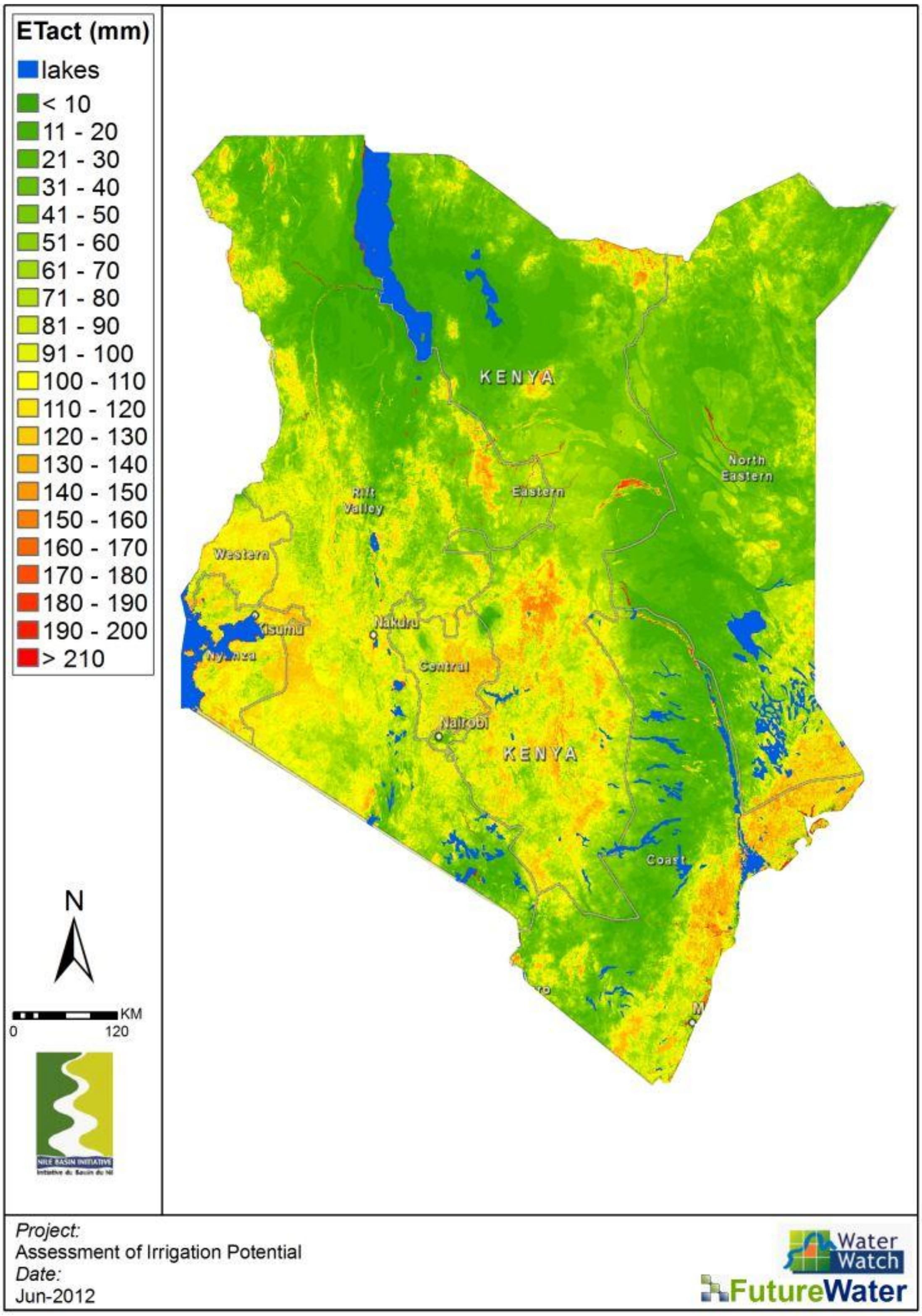
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


ETact (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
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140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
KENYA
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Eastern
Rift Valley
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
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Date:
Jun-2012
Water Watch
FutureWater

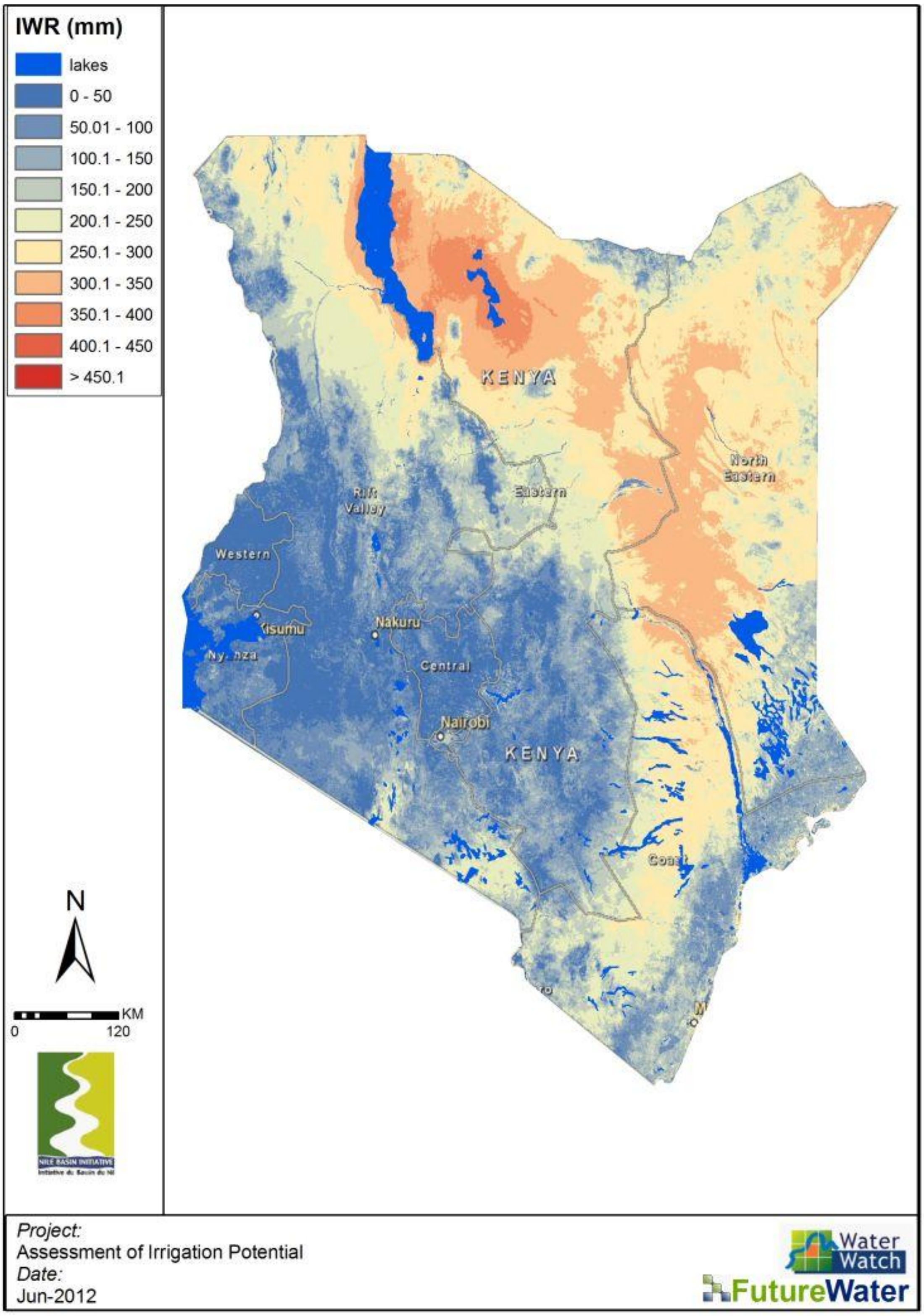
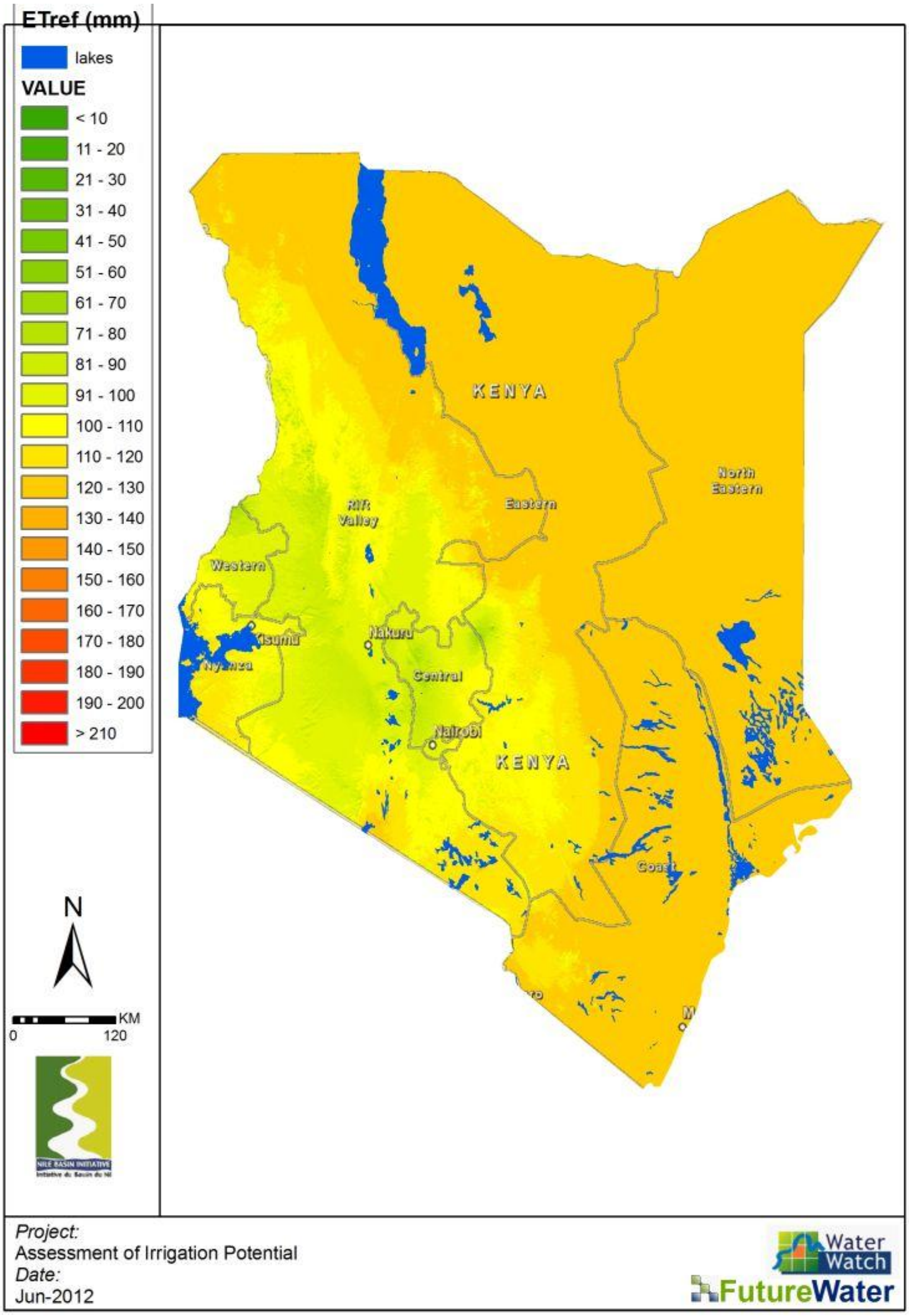



**Figure 10: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for May (Average 2001-2010). (Source: study analysis).**

### *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
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KENYA
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Project:
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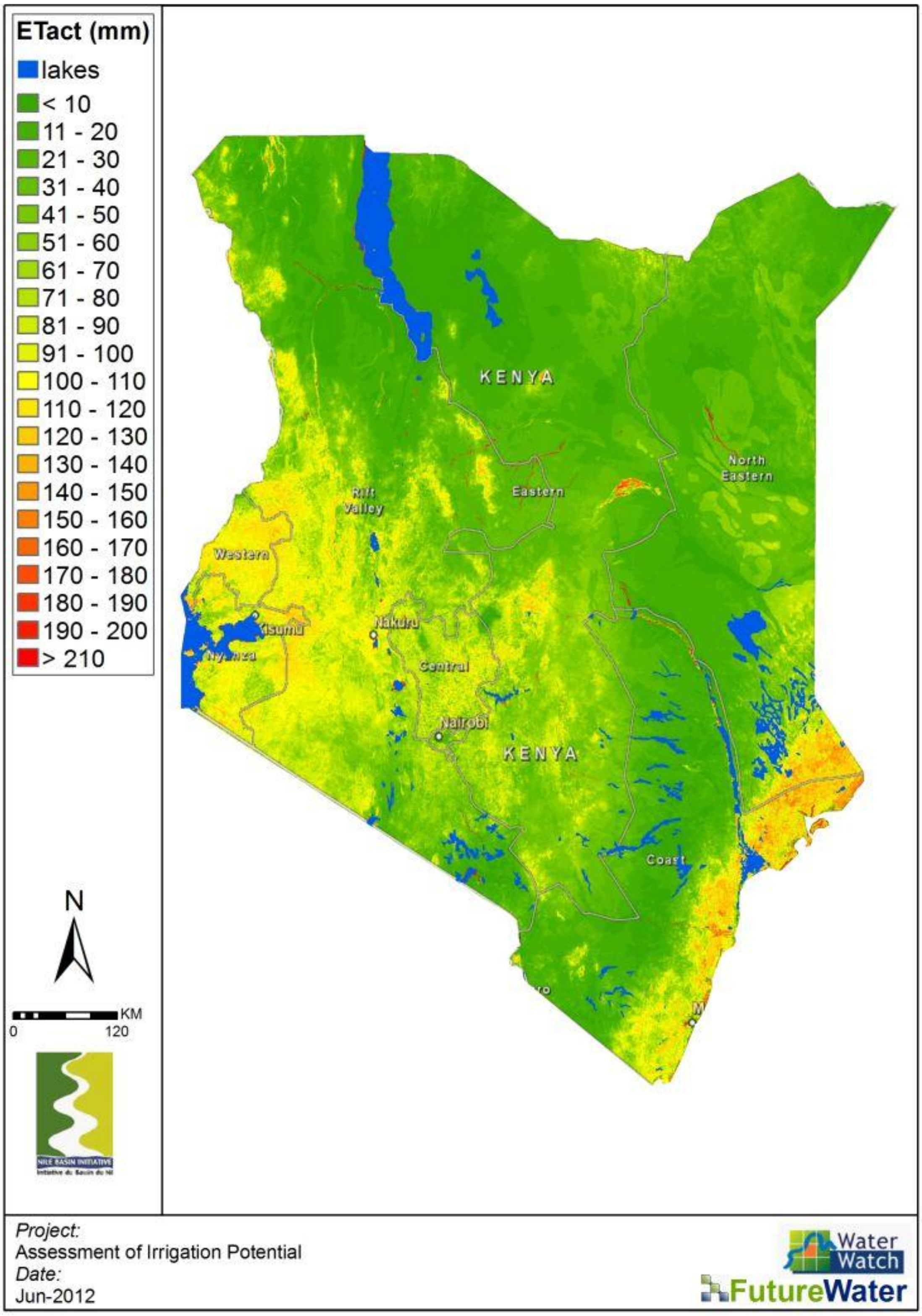
Date:
Jun-2012
Water Watch
FutureWater



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
KENYA
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Rift Valley
Eastern
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Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
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120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

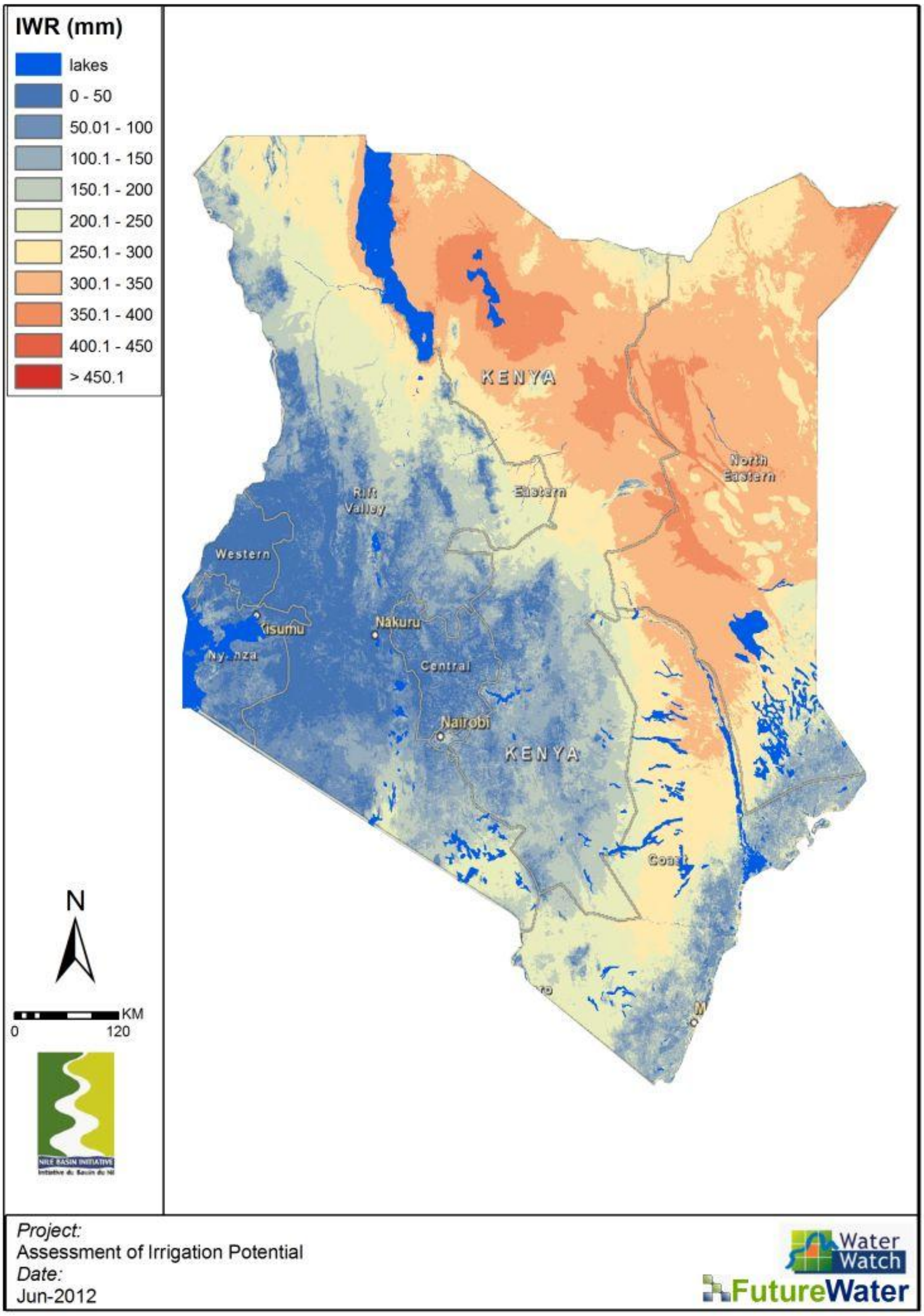
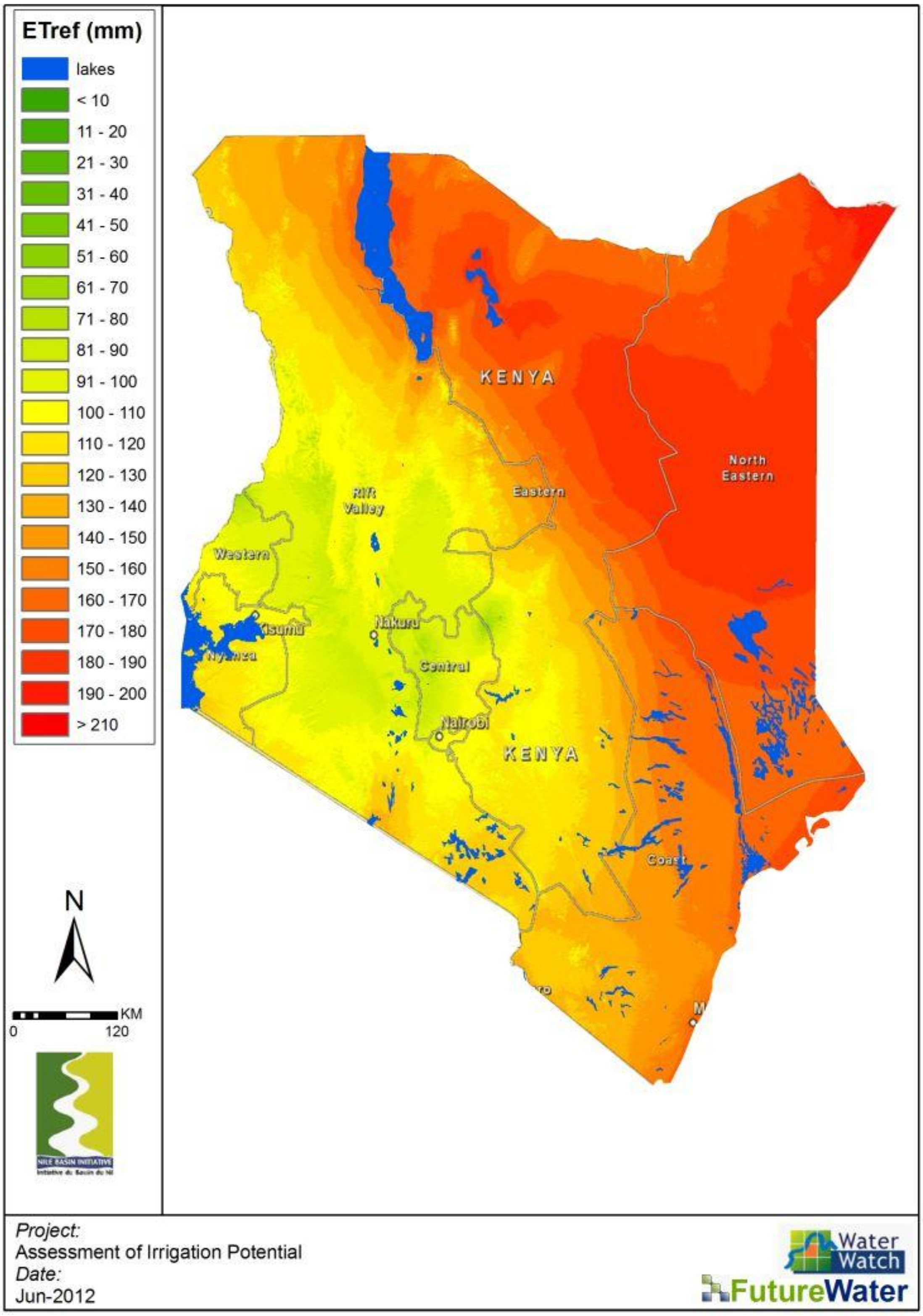



**Figure 11: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom). For June (Average 2001-2010). (Source: study analysis).**

## *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
KENYA
North Eastern
Eastern
Rift Valley
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
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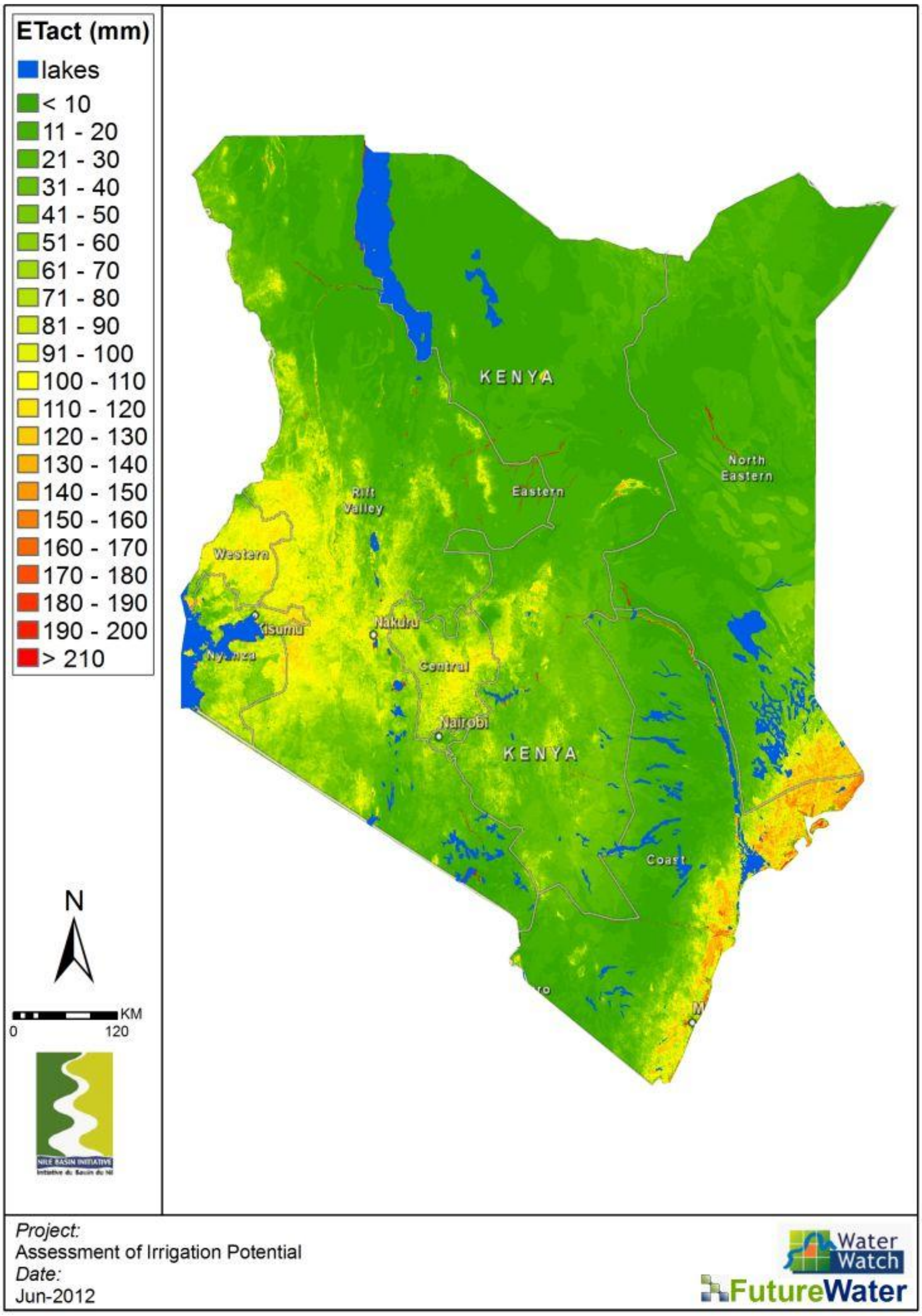
120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


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
KENYA
North Eastern
Rift Valley
Eastern
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
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Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

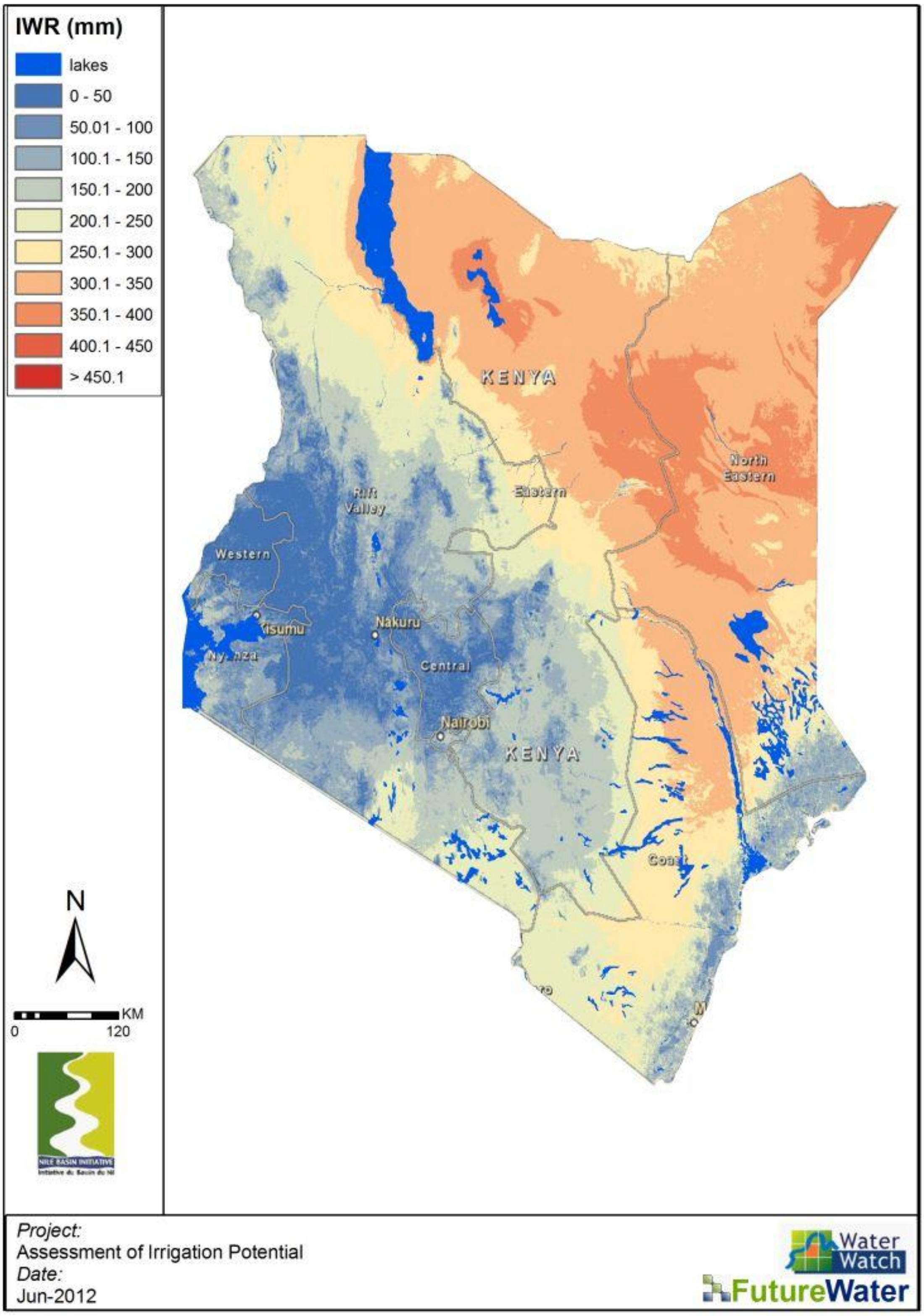
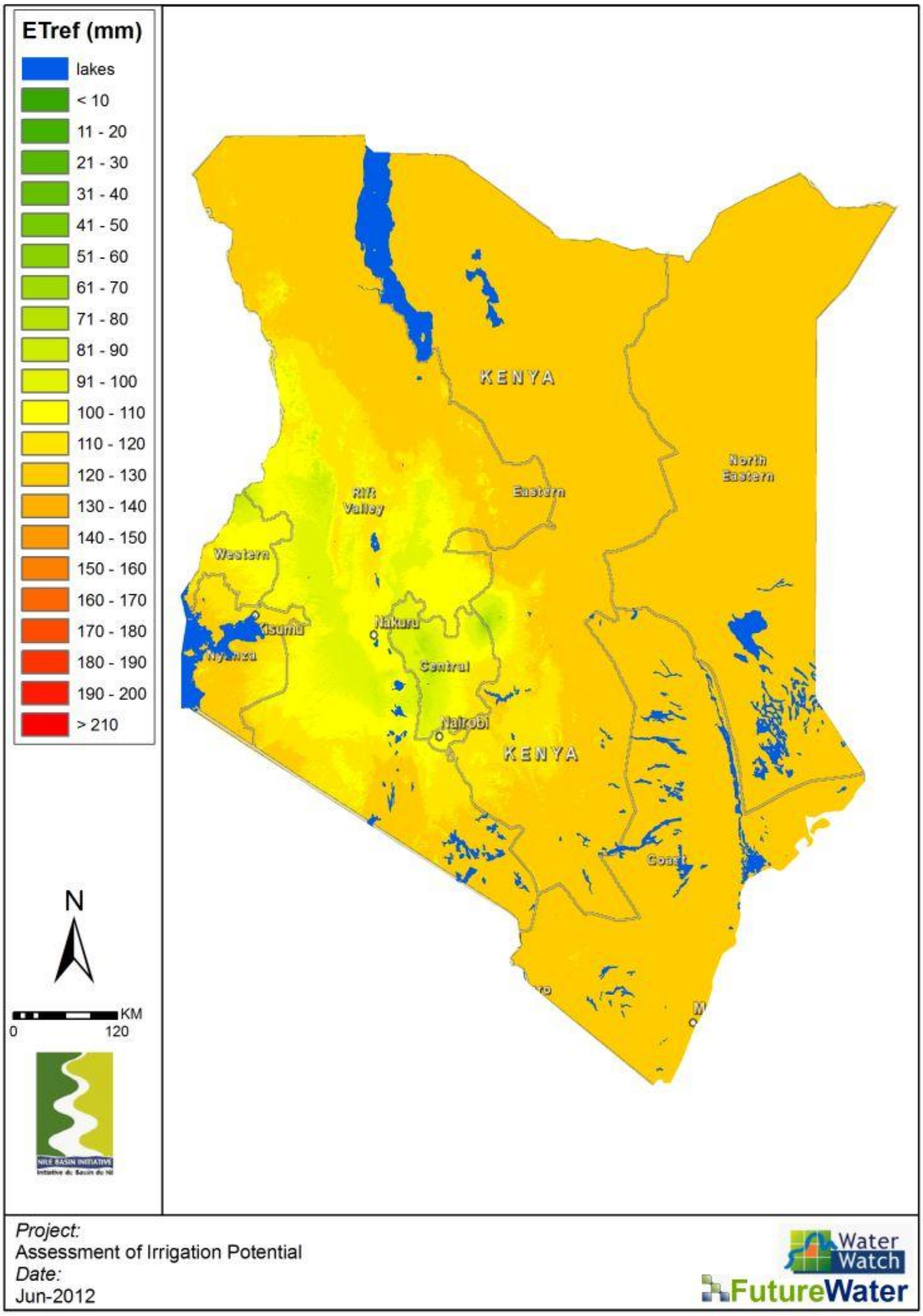
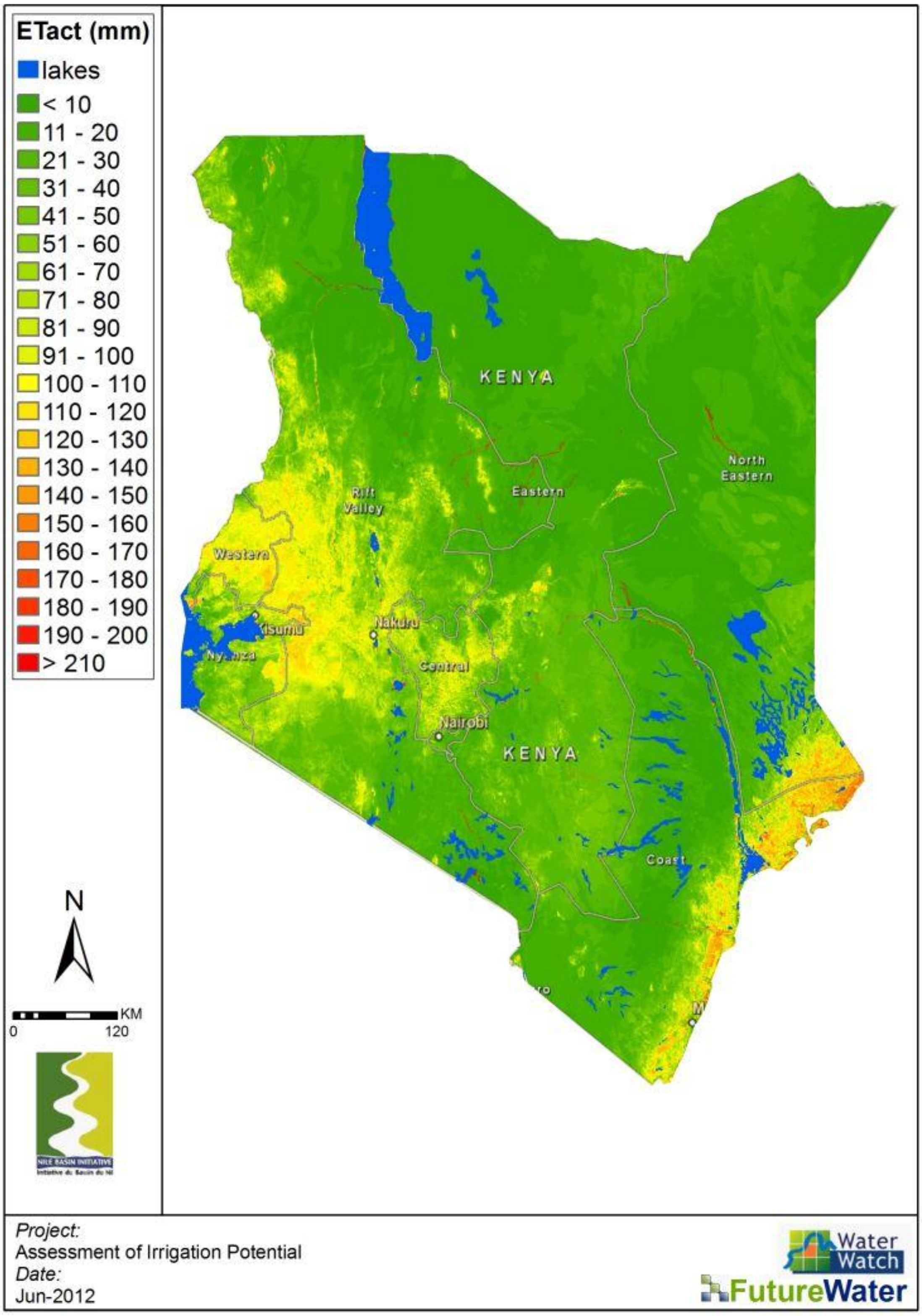



**Figure 12: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for July (Average 2001-2010). (Source: study analysis).**

### *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
KENYA
North Eastern
Rift Valley
Eastern
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
N
KM
0
120
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
KENYA
North Eastern
Rift Valley
Eastern
Western
Kisumu
Nakuru
Nyanza
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Nairobi
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Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

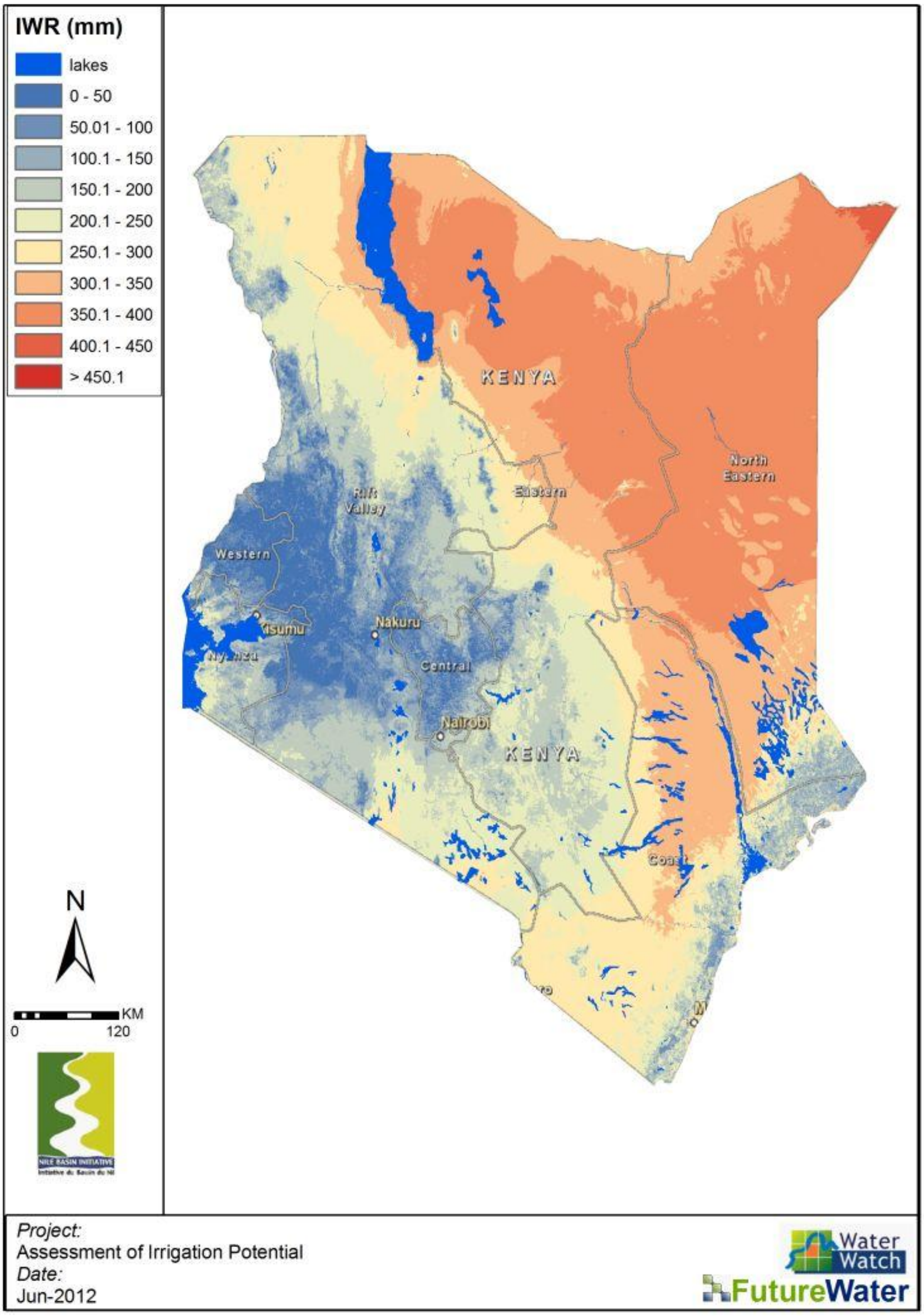
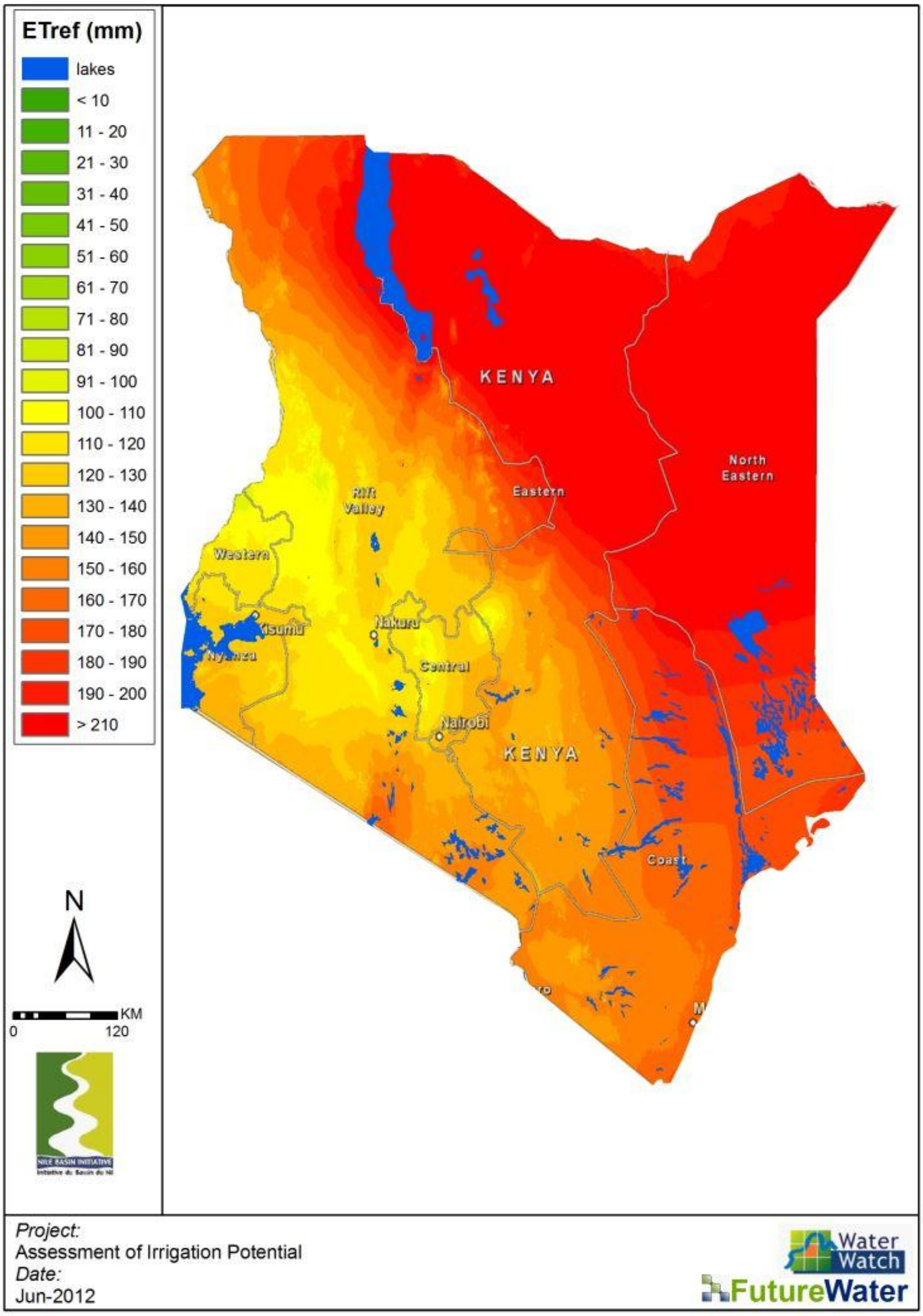



**Figure 13: Reference evapotranspiration (top left), actual evapotranspiration (top right), and irrigation water requirement (bottom) for September (Average 2001 – 2010).**

## *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
KENYA
North Eastern
Eastern
Rift Valley
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
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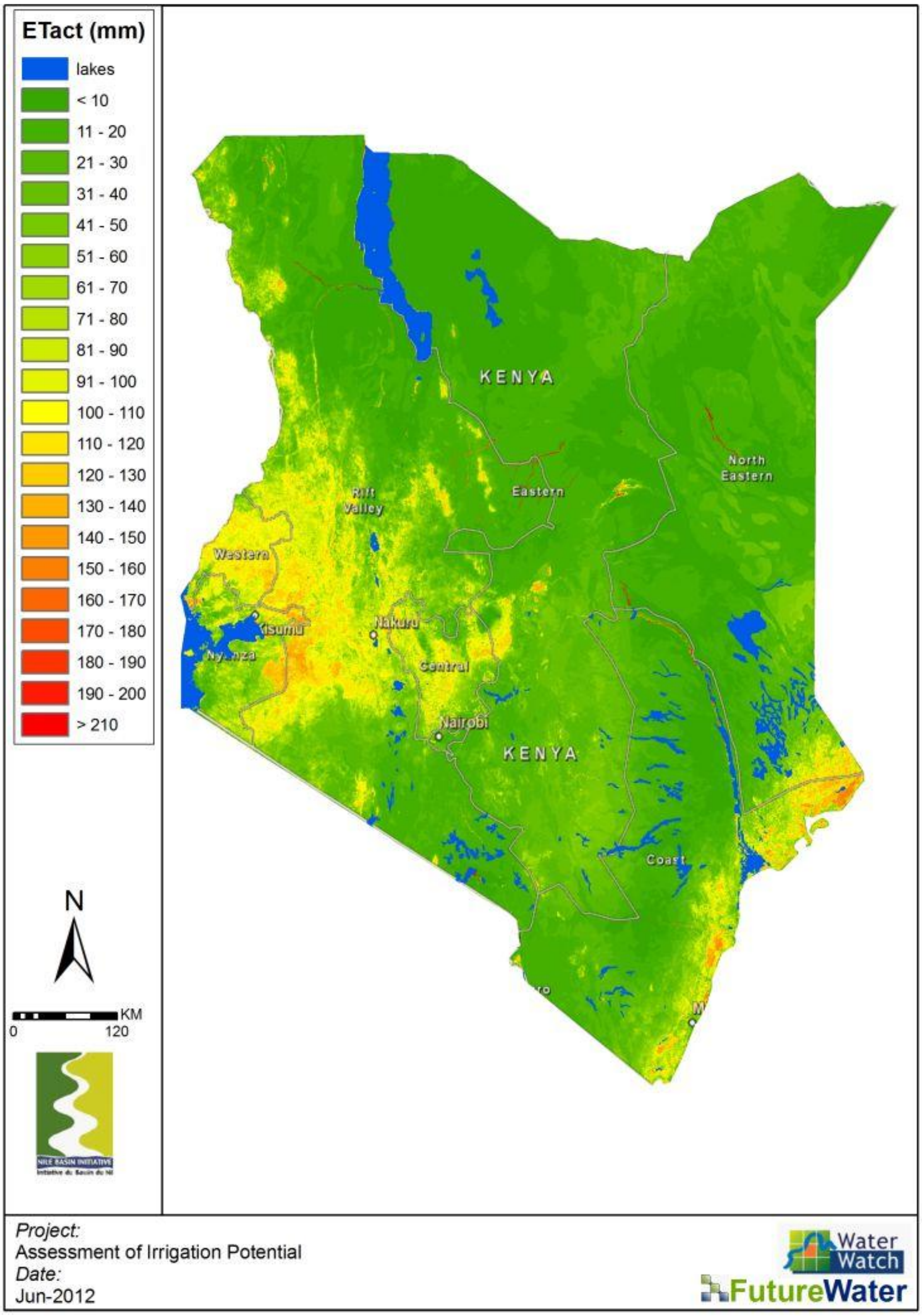
120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


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
KENYA
North Eastern
Eastern
Rift Valley
Western
Kisumu
Nyanza
Nakuru
Central
Nairobi
KENYA
Coast
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120
NILE BASIN INITIATIVE
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

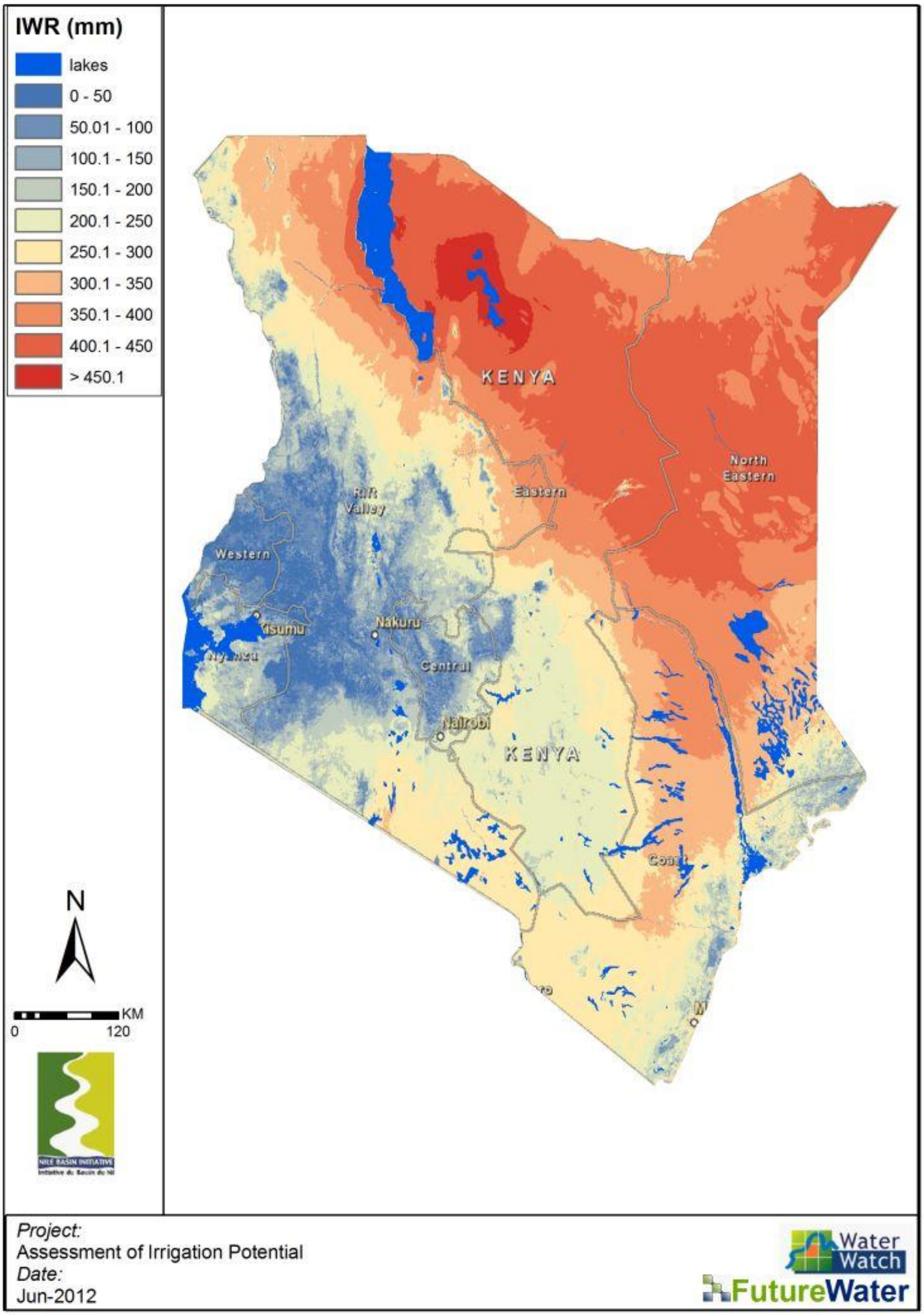
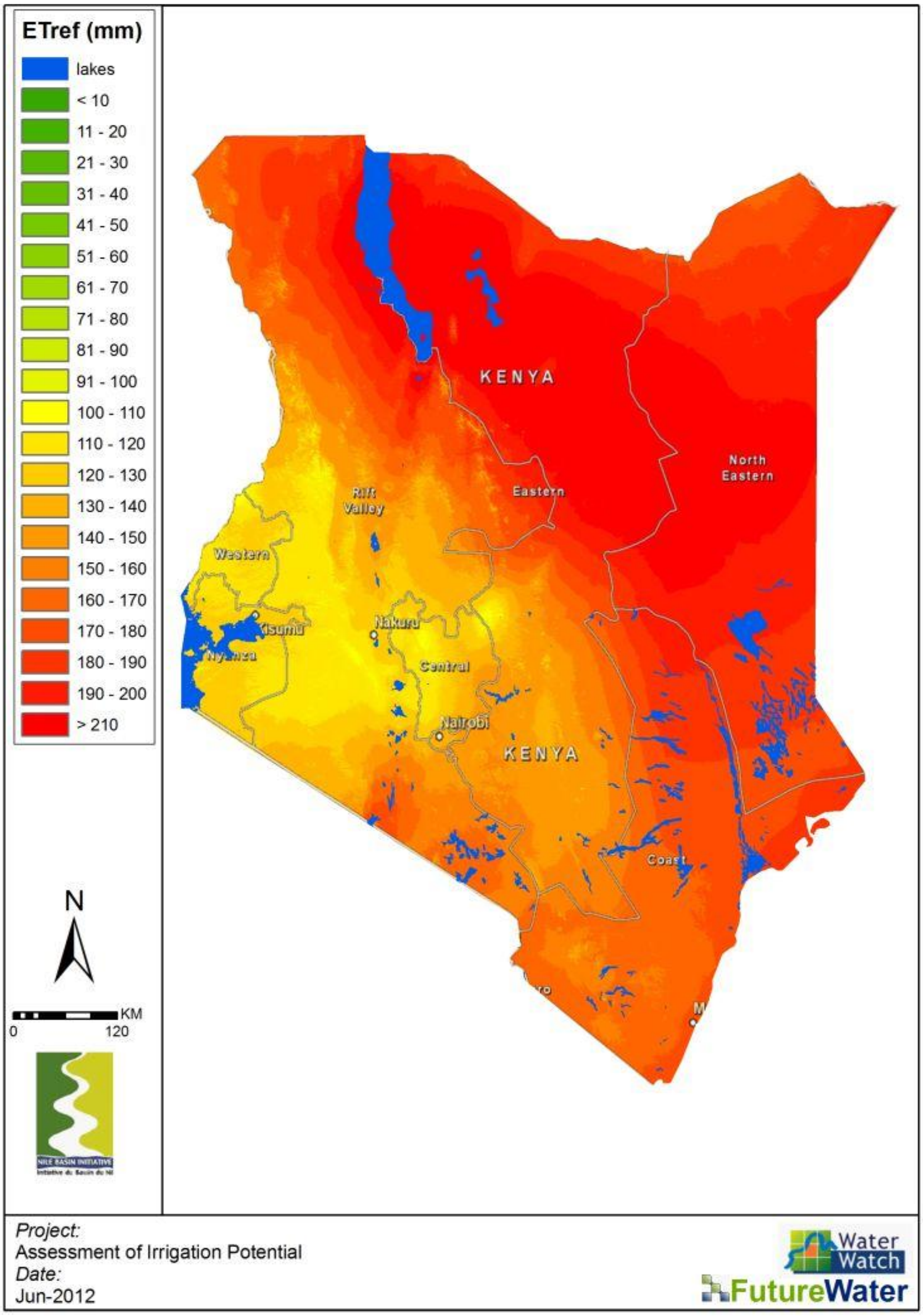



**Figure 14: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for September (Average 2001-2010). (Source: study analysis).**

### *October*



ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
KENYA
North Eastern
Eastern
Rift Valley
Western
Nakuru
Kisumu
Nyanza
Central
Nairobi
KENYA
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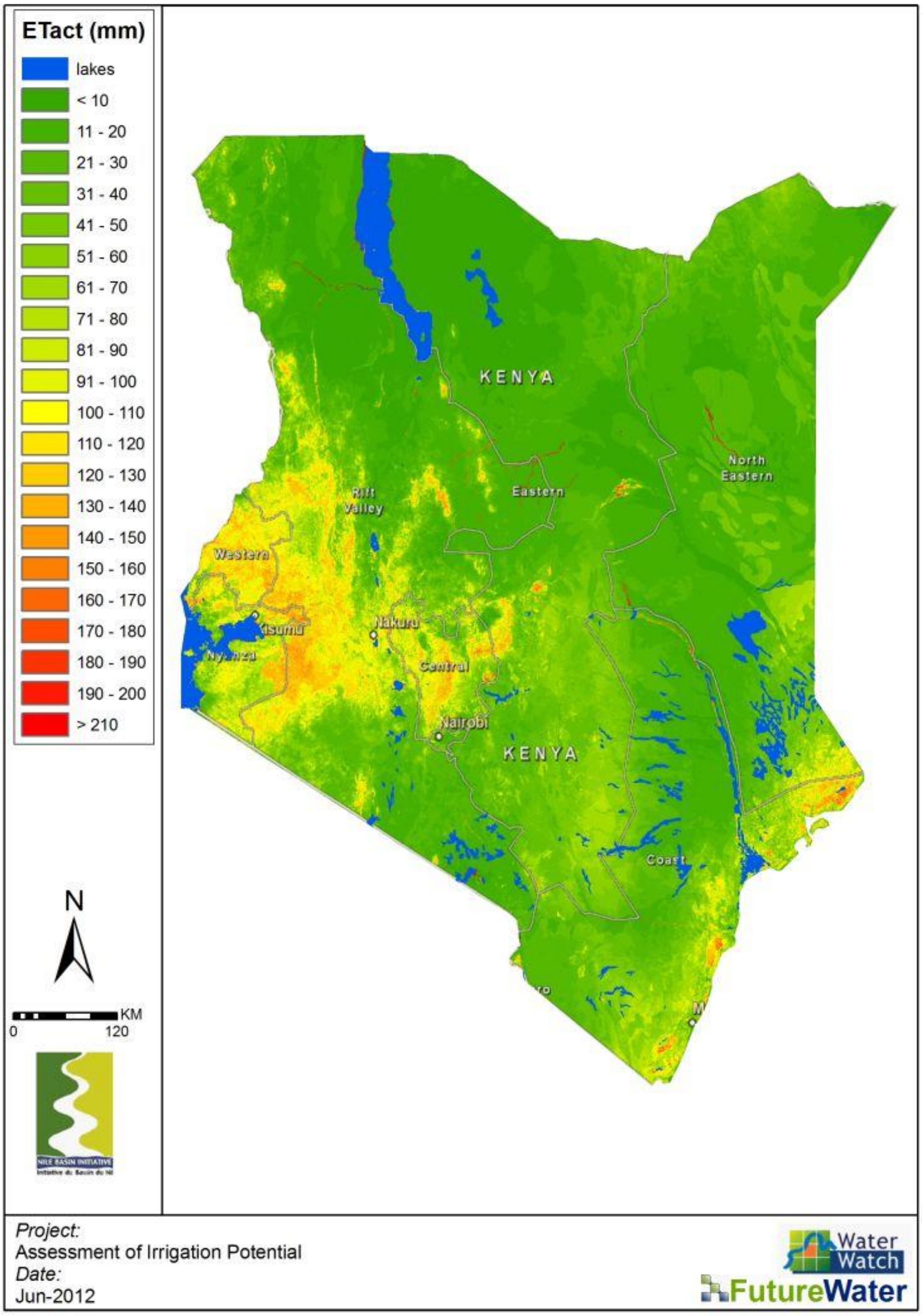
120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


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
KENYA
North Eastern
Rift Valley
Eastern
Western
Nakuru
Kisumu
Nyanza
Central
Nairobi
KENYA
Coast
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KM
0
120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

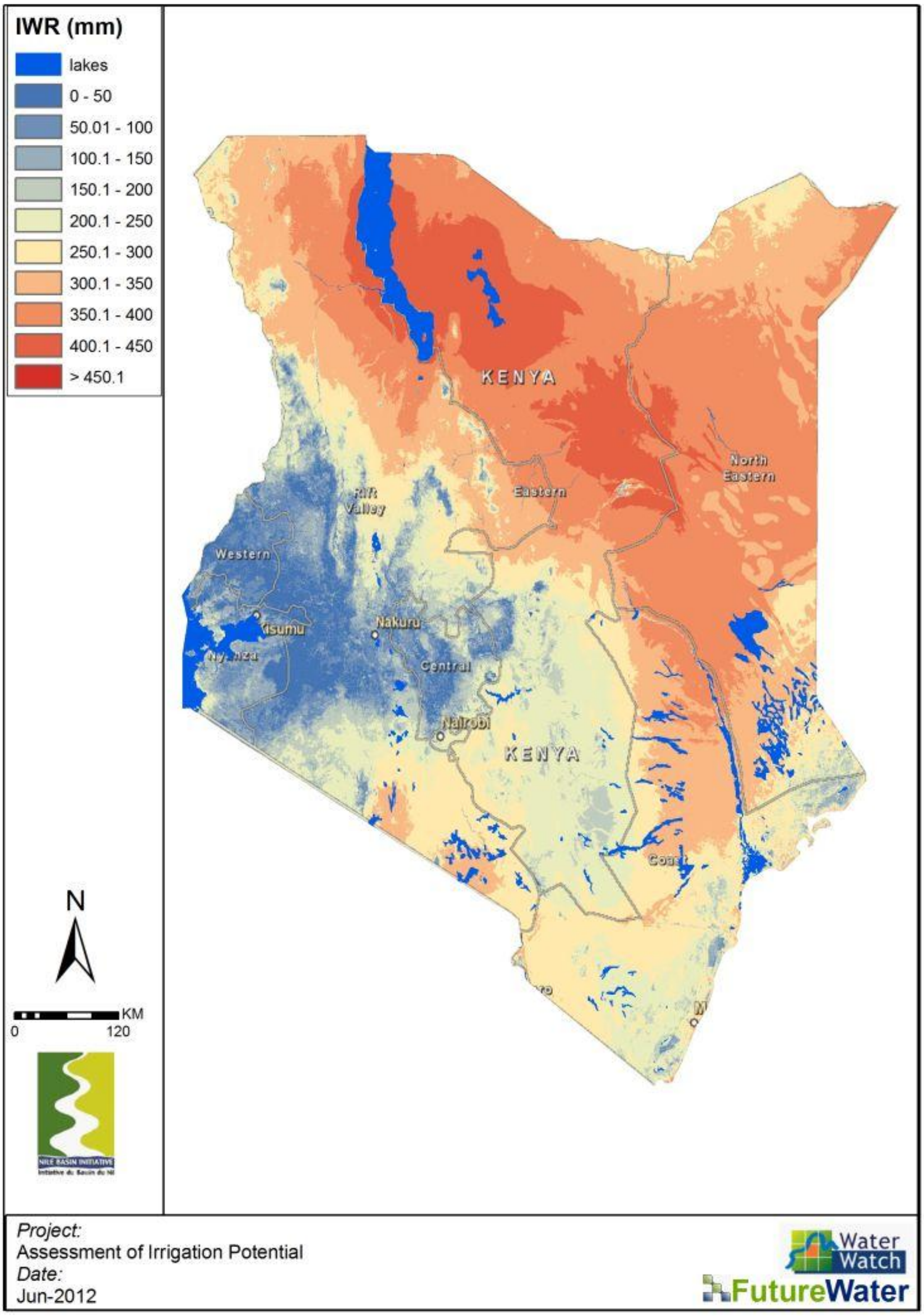
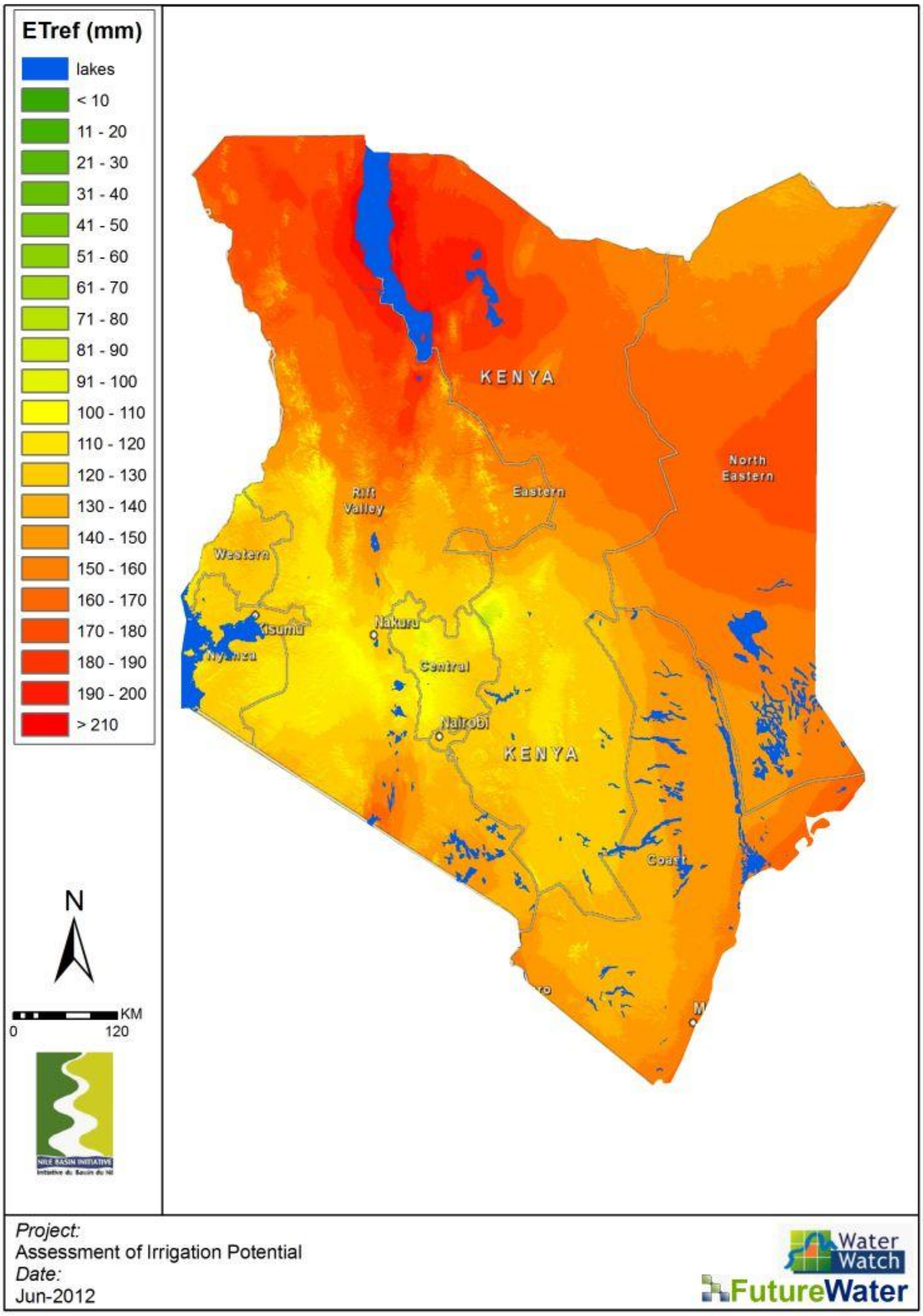
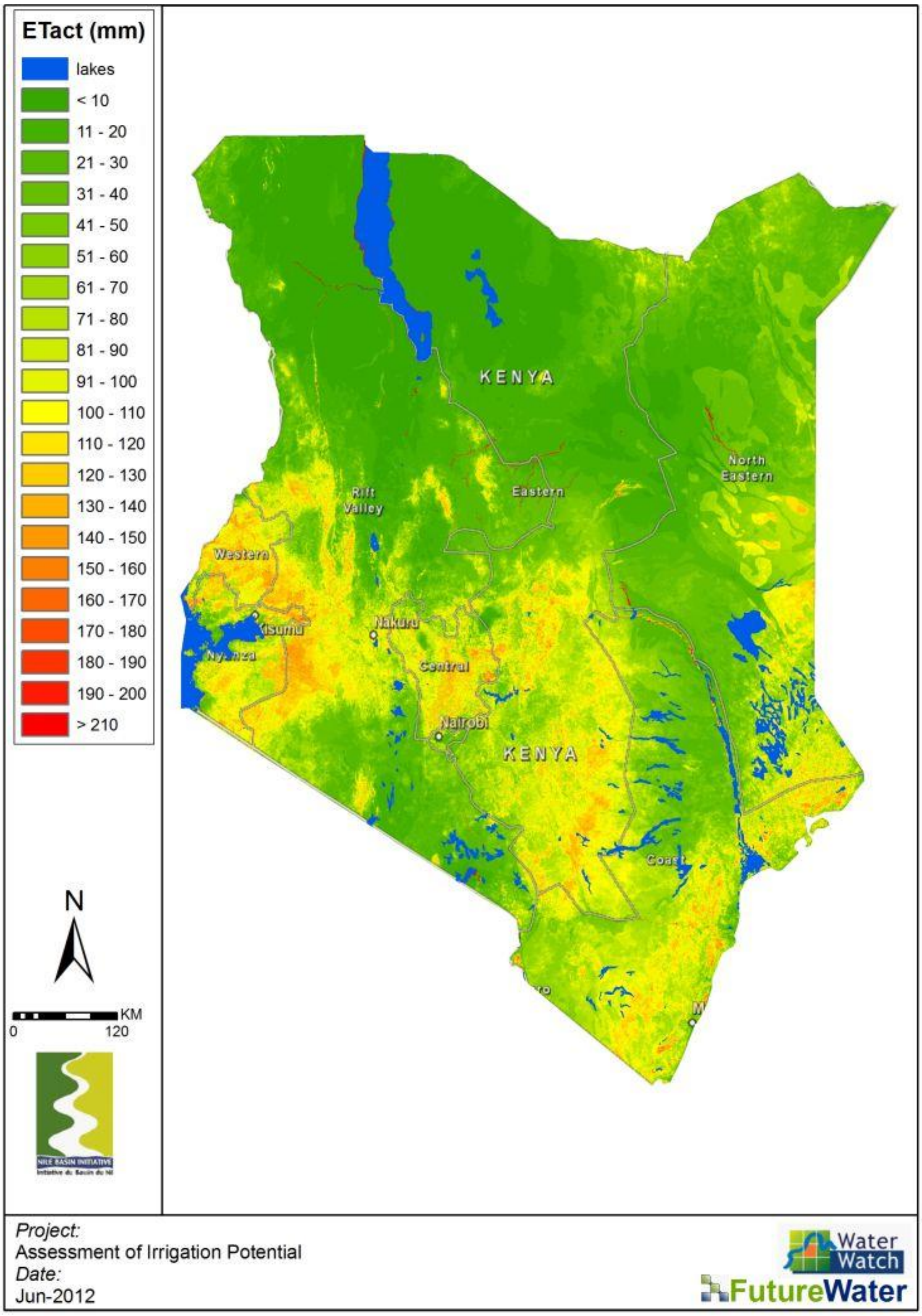



**Figure 15: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for October (Average 2001-2010). (Source: study analysis).**

### *November*



ETref (mm)
lakes
< 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
120
KENYA
North Eastern
Eastern
Rift Valley
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
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
KENYA
North Eastern
Rift Valley
Eastern
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Nakuru
Kisumu
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120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

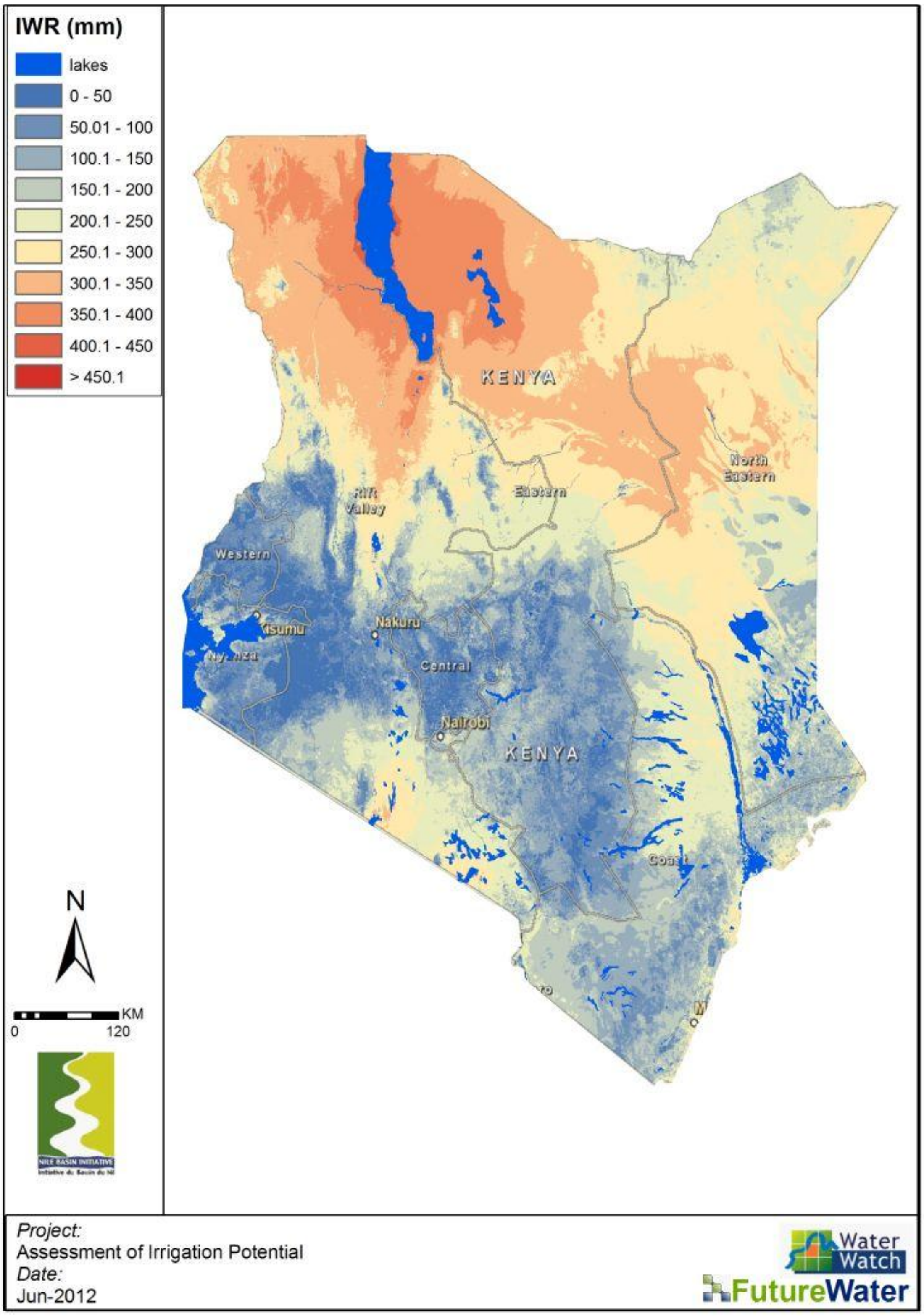
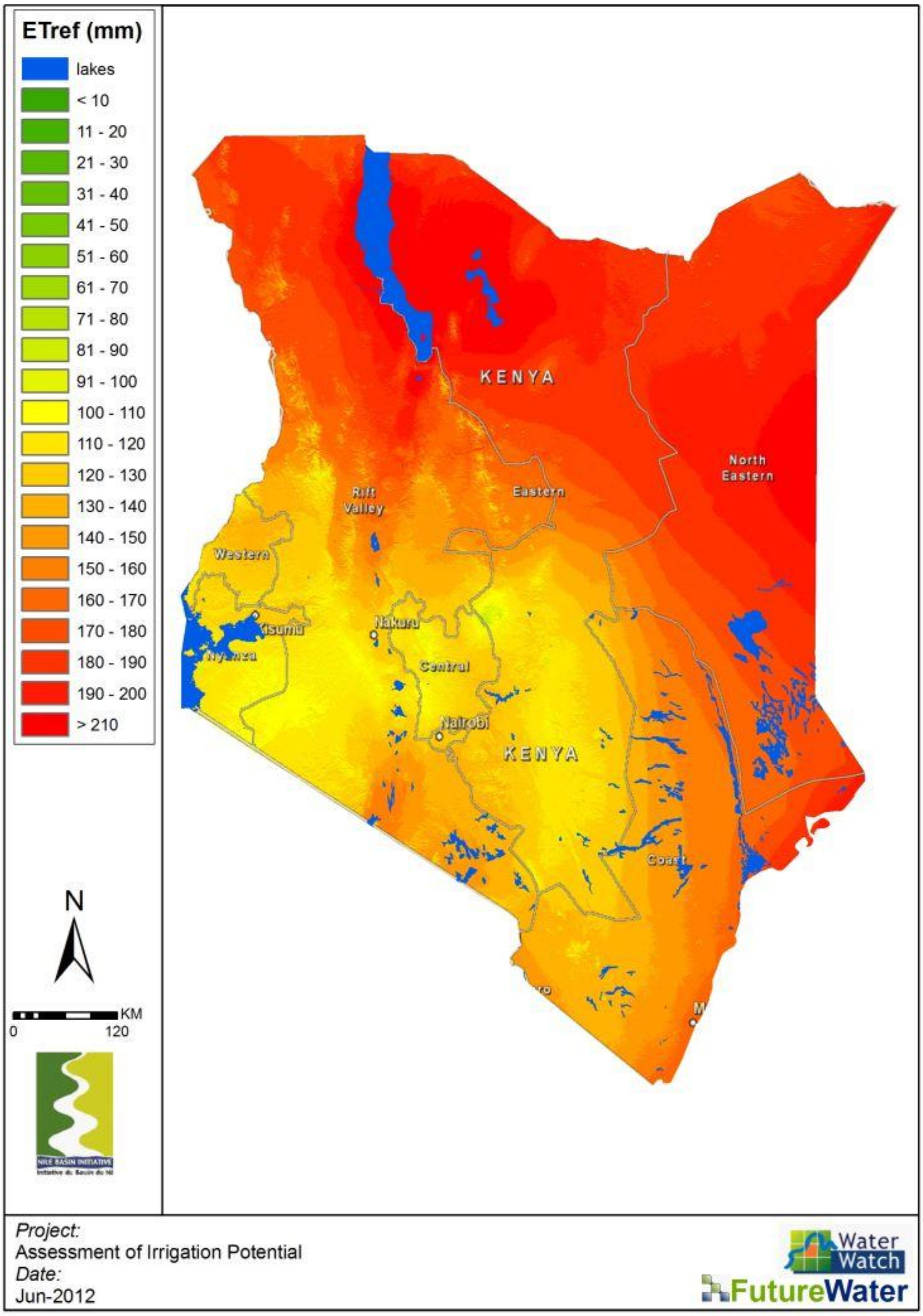
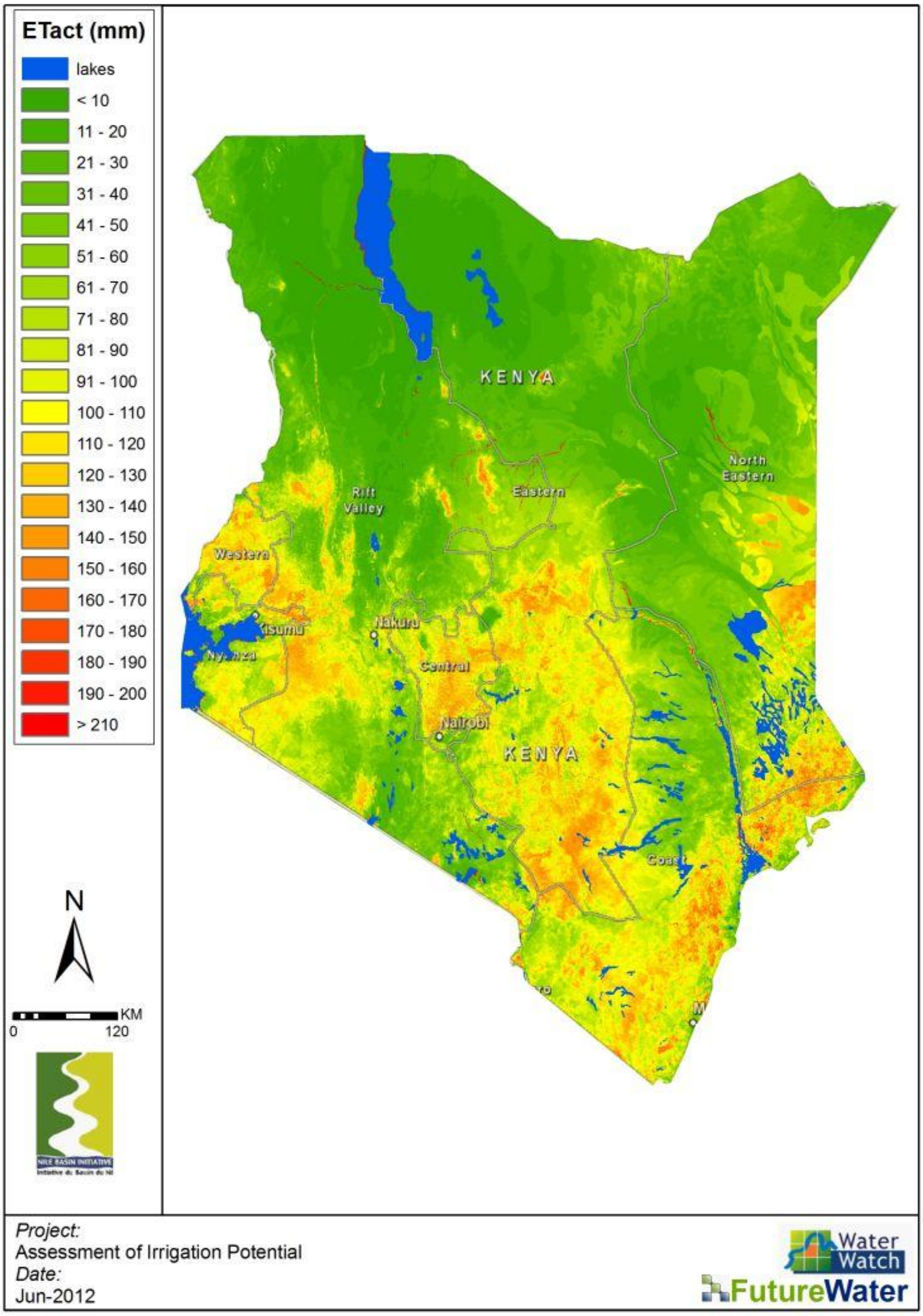



**Figure 16: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for November (Average 2001-2010). (Source: study analysis).**

### *December*


ETref (mm)
lakes
< 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
100 - 110
110 - 120
120 - 130
130 - 140
140 - 150
150 - 160
160 - 170
170 - 180
180 - 190
190 - 200
> 210
KENYA
North Eastern
Rift Valley
Eastern
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
N
KM
0
120
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
KENYA
North Eastern
Rift Valley
Eastern
Western
Nakuru
Central
Nairobi
KENYA
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KM
0
120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

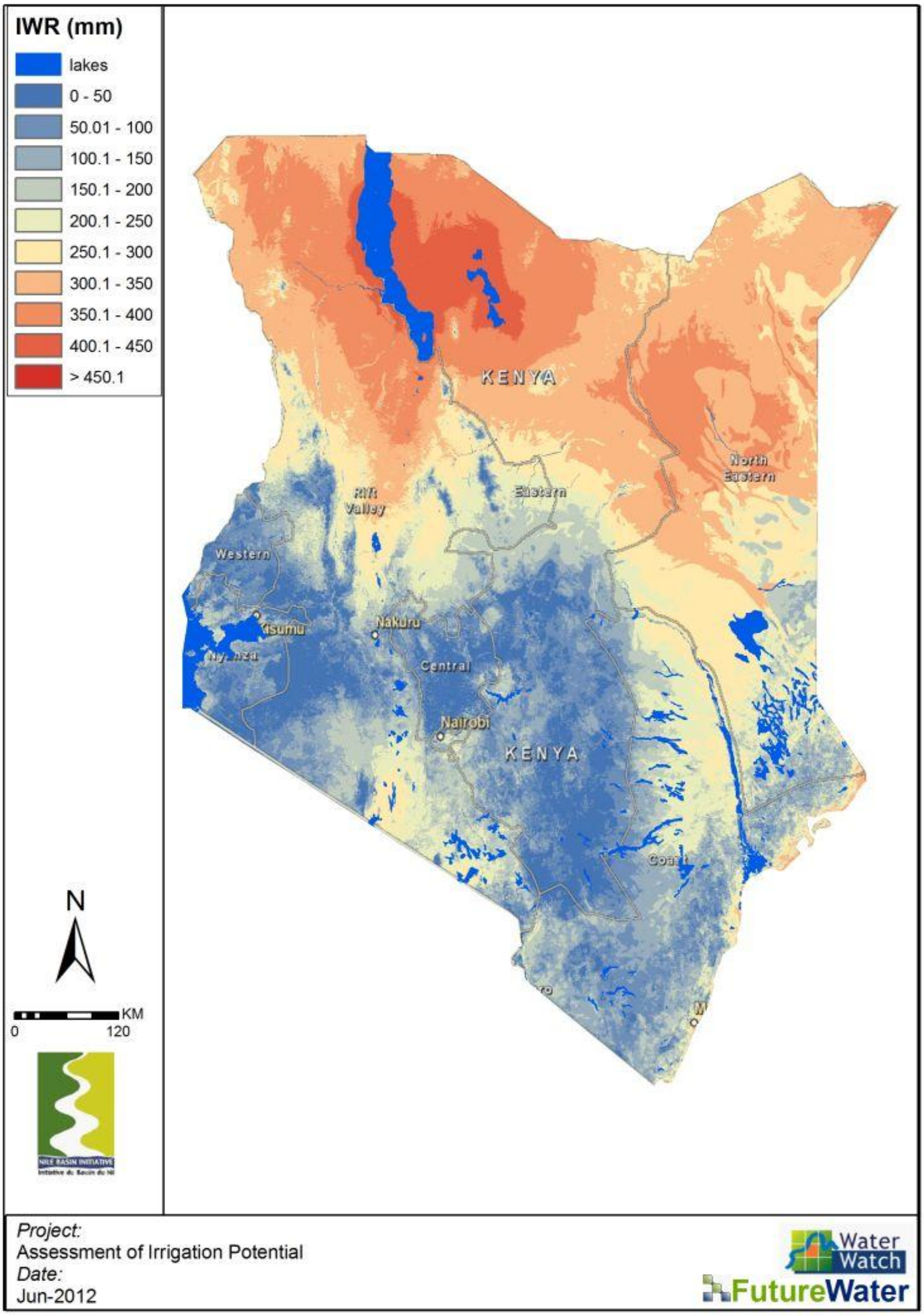
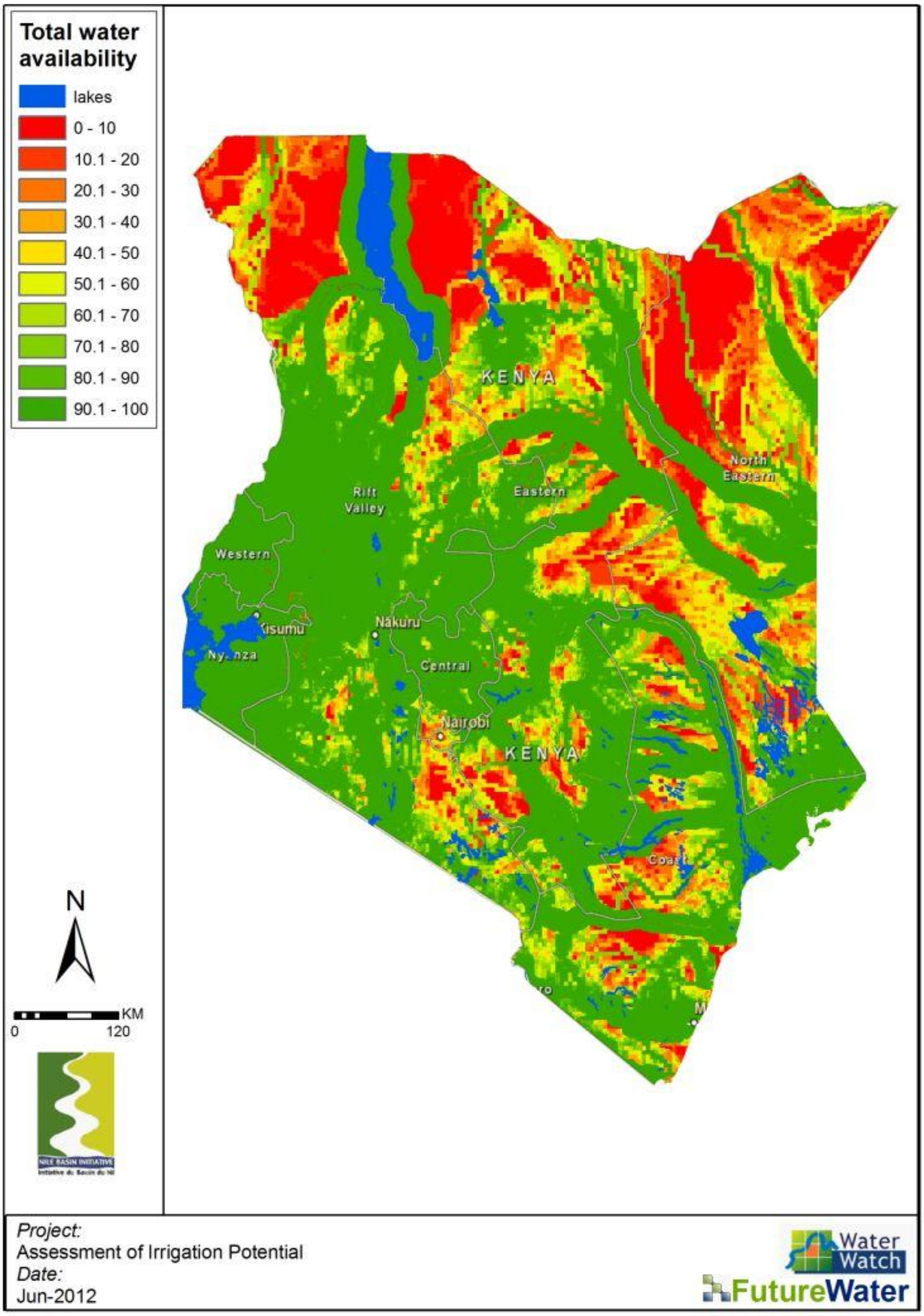


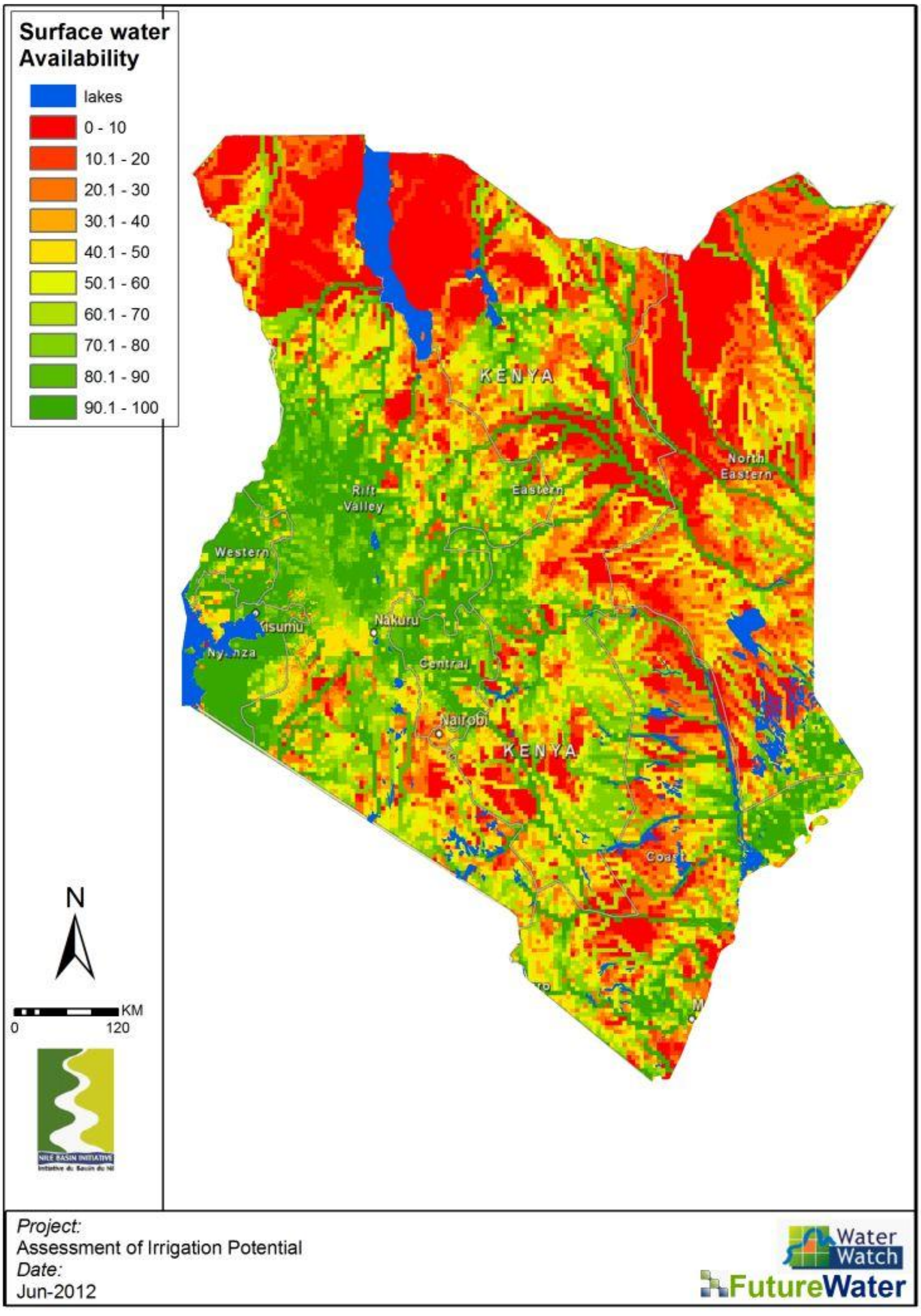

**Figure 17: Reference evapotranspiration (top), actual evapotranspiration (middle), and irrigation water requirement (bottom) for December (Average 2001-2010). (Source: study analysis).**

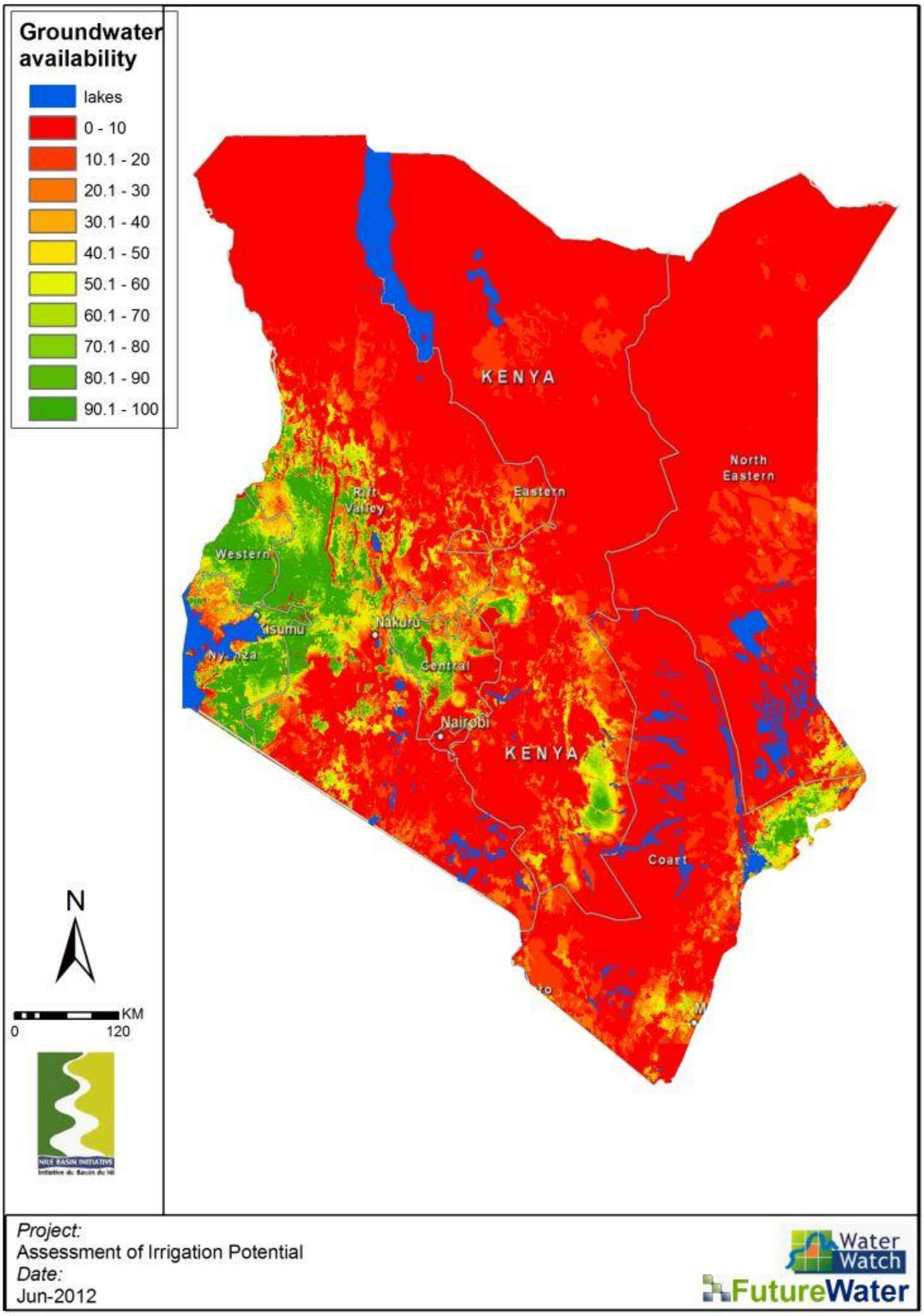
### *2.2.2 Water availability/ model output*

#### 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.


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
KENYA
North Eastern
Eastern
Rift Valley
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
N
KM
0
120
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


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
KENYA
North Eastern
Rift Valley
Eastern
Western
Nakuru
Central
Nairobi
KENYA
N
KM
0
120
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
KENYA
North Eastern
Eastern
Rift Valley
Western
Nakuru
Central
Nairobi
KENYA
Coast
N
KM
0
120
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

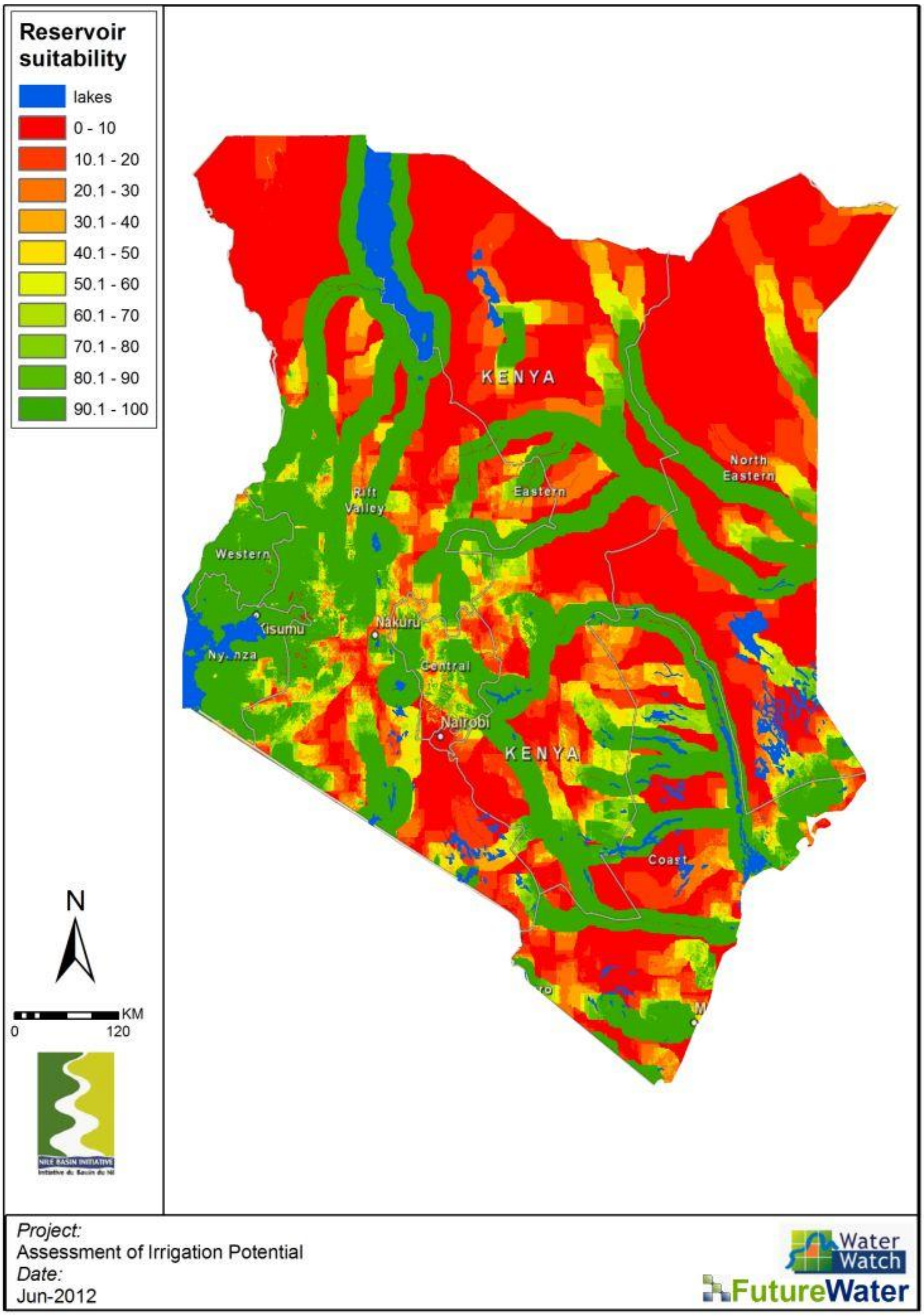



**Figure 18. Water availability for irrigation. Total coverage (top), coverage from surface water (second), coverage from ground water (third), and from potential reservoirs (bottom). (Source: study analysis).**

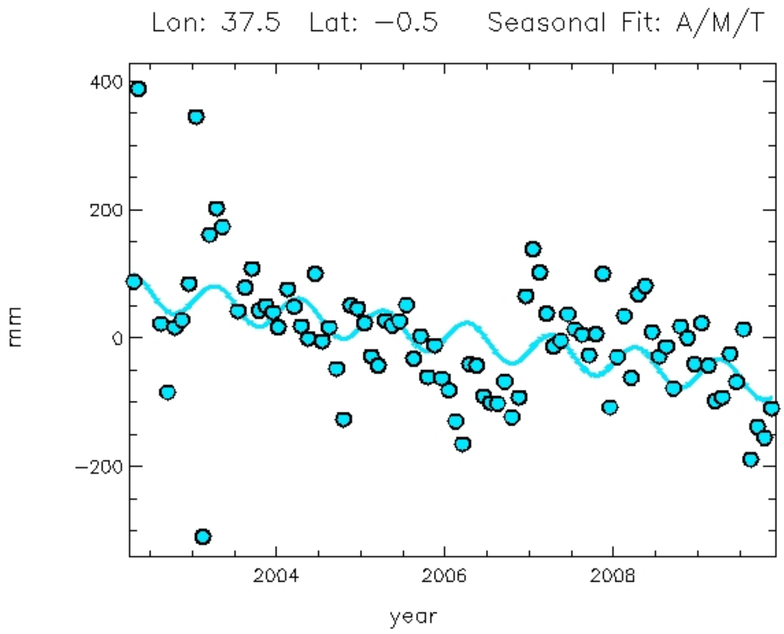



**Figure 19: Annual groundwater storage trends for Kenya, based on GRACE satellite observations (Source: UoC, 2011).**

### 2.2.2.2 Groundwater Trends

Large scale groundwater trends can also be observed from the GRACE satellite. This twin-satellite detects on a monthly base groundwater fluctuations over rather large areas (for details see main report). Long term groundwater trends based on GRACE can be seen in Figure 19. It is clear that the overall trend is an overdraft of groundwater of about 100 mm levels over the last 10 years. Groundwater recharge based on NELmod is presented in Figure 20. Overall groundwater recharge is relatively low in the country, although quite some regions have good recharge rates.

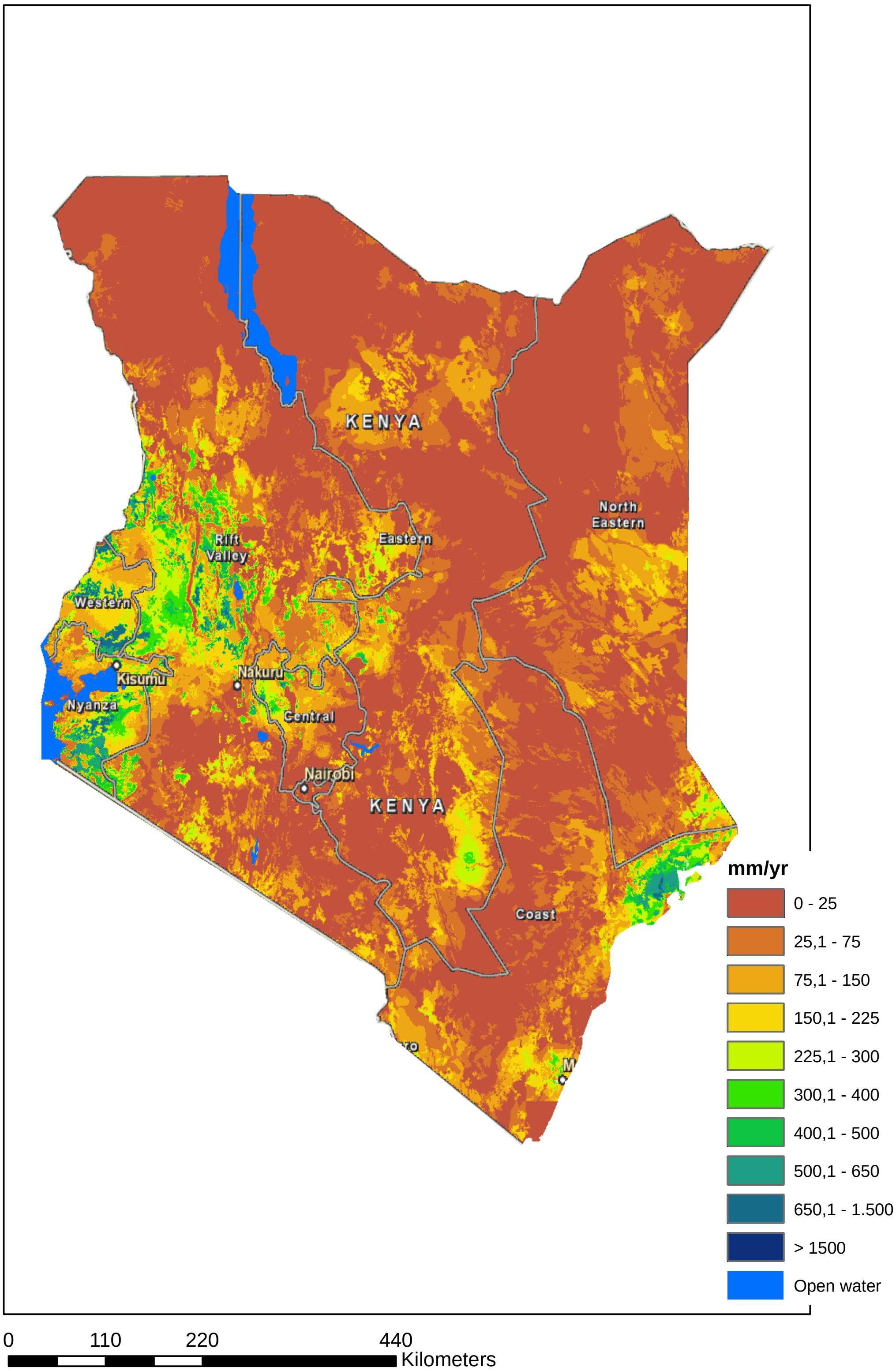
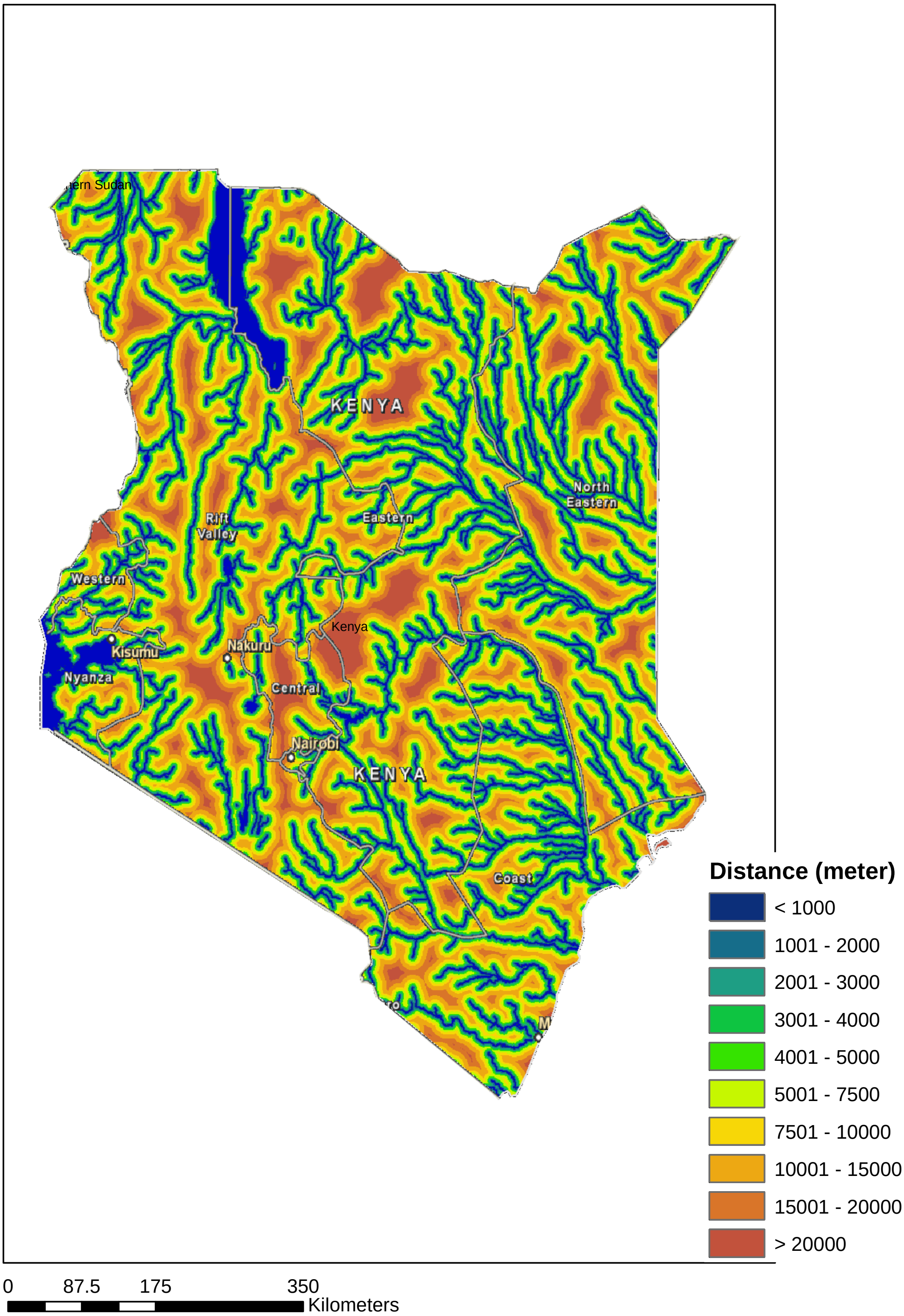
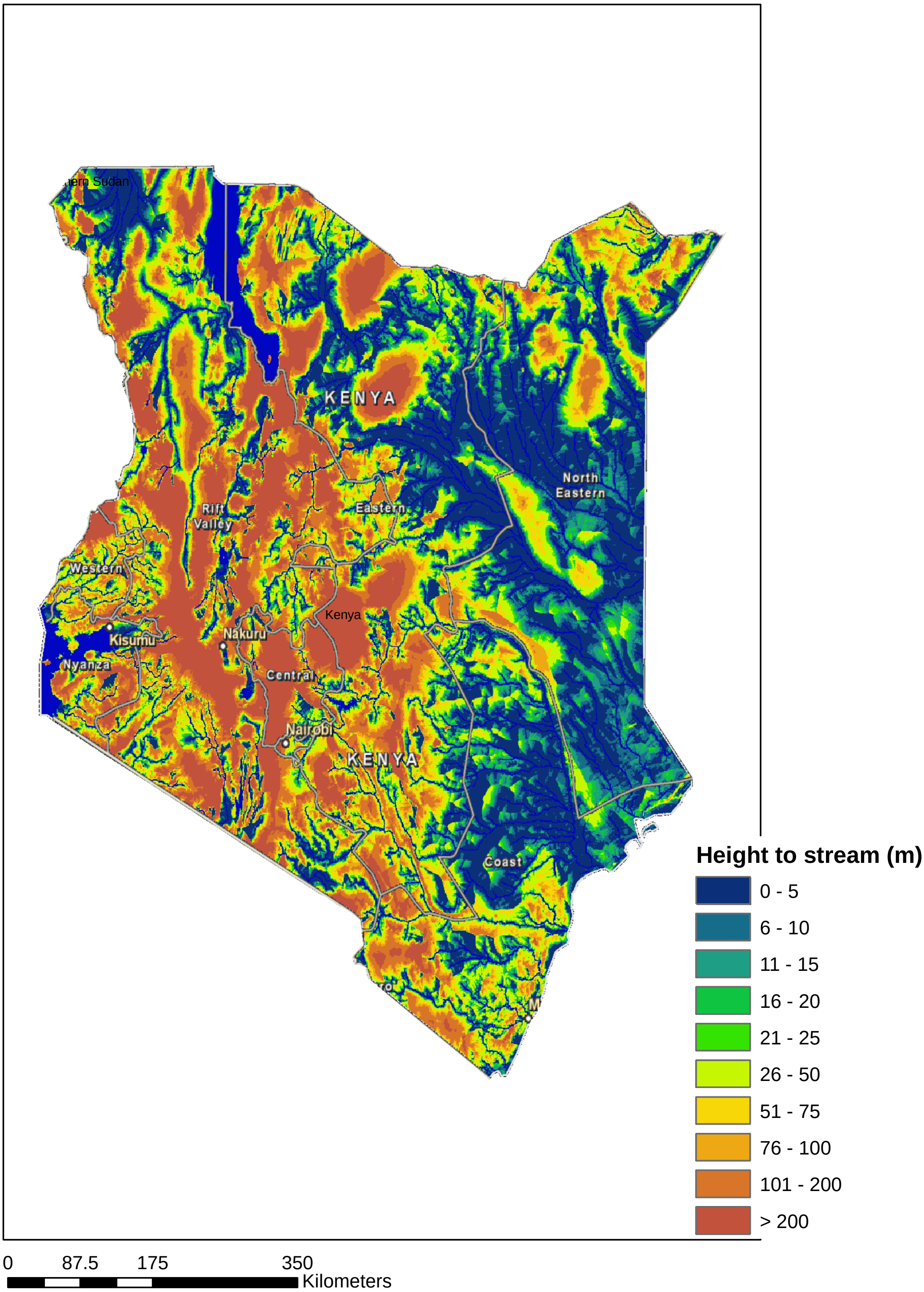



**Figure 20: Annual groundwater recharge based on NELmod.**

### 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.




tern Sudan
KENYA
North Eastern
Rift Valley
Eastern
Western
Kenya
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
Height to stream (m)
0 - 5
6 - 10
11 - 15
16 - 20
21 - 25
26 - 50
51 - 75
76 - 100
101 - 200
> 200
0
87.5
175
350
Kilometers

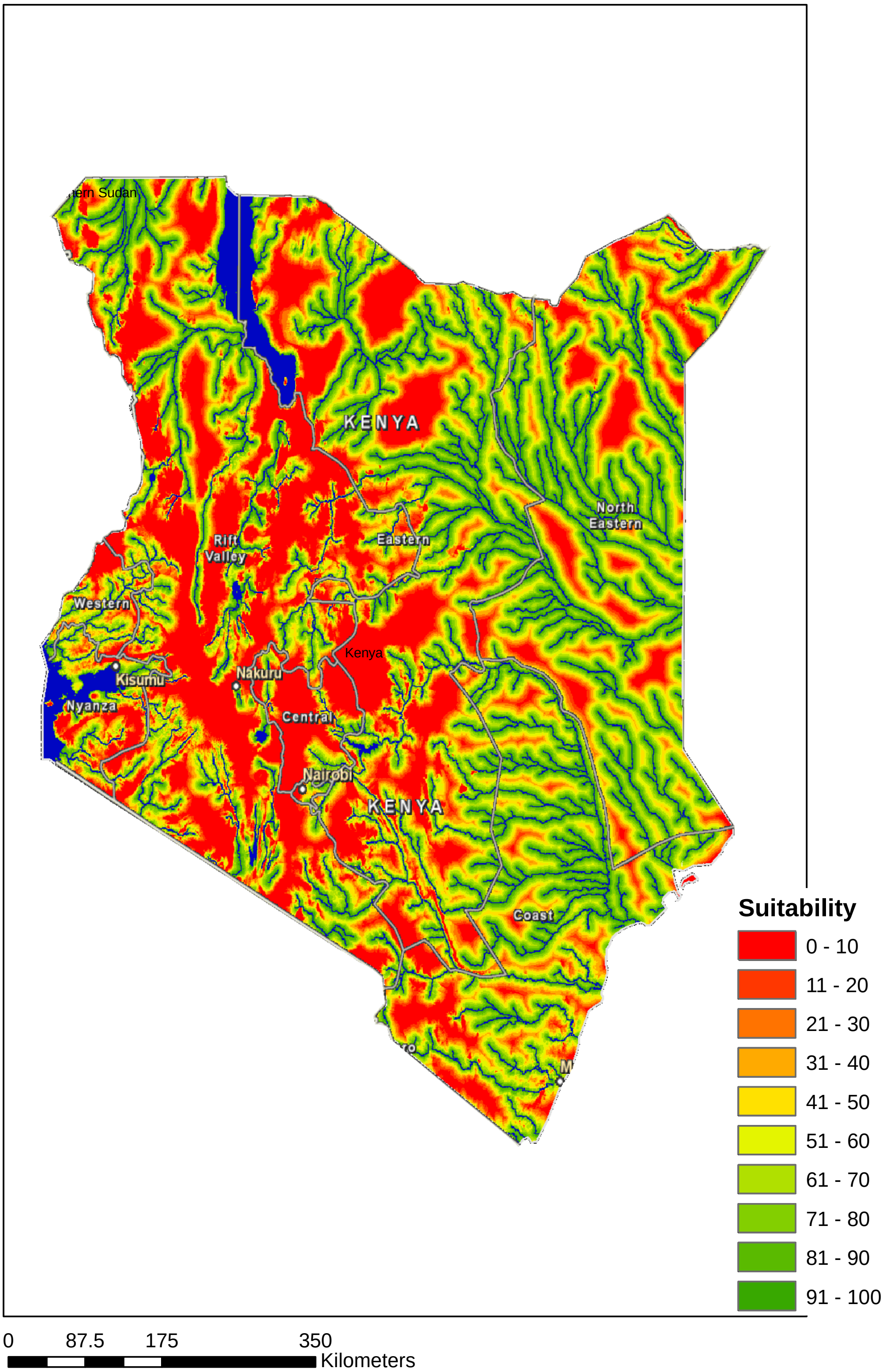



**Figure 21: Average distance to a natural stream, lake or reservoir (top), elevation above natural stream, lake or reservoir (middle), and access to water suitability score (bottom). (Source: study analysis).**

## 2.3 Land use

### 2.3.1 Current land use

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

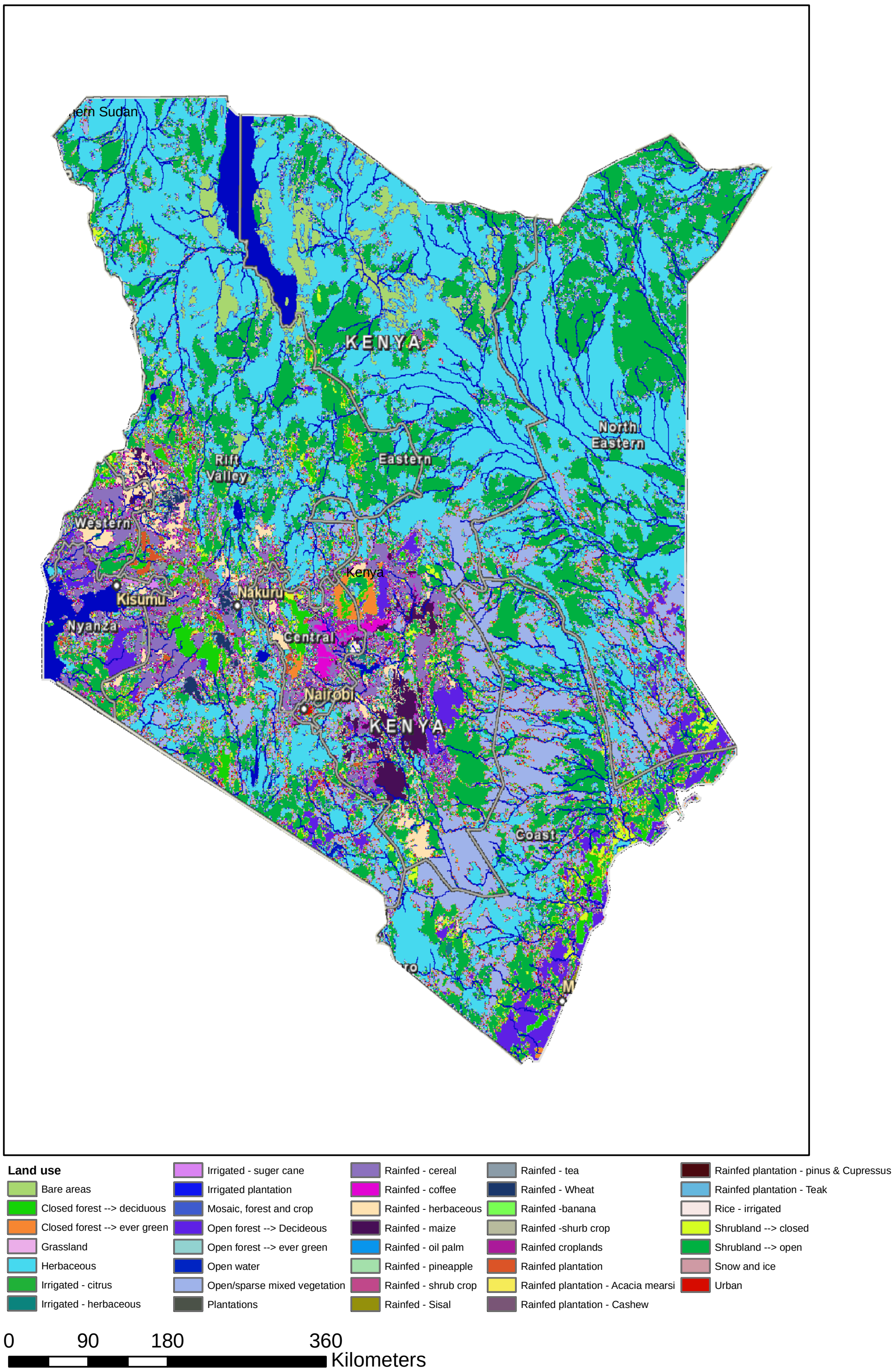
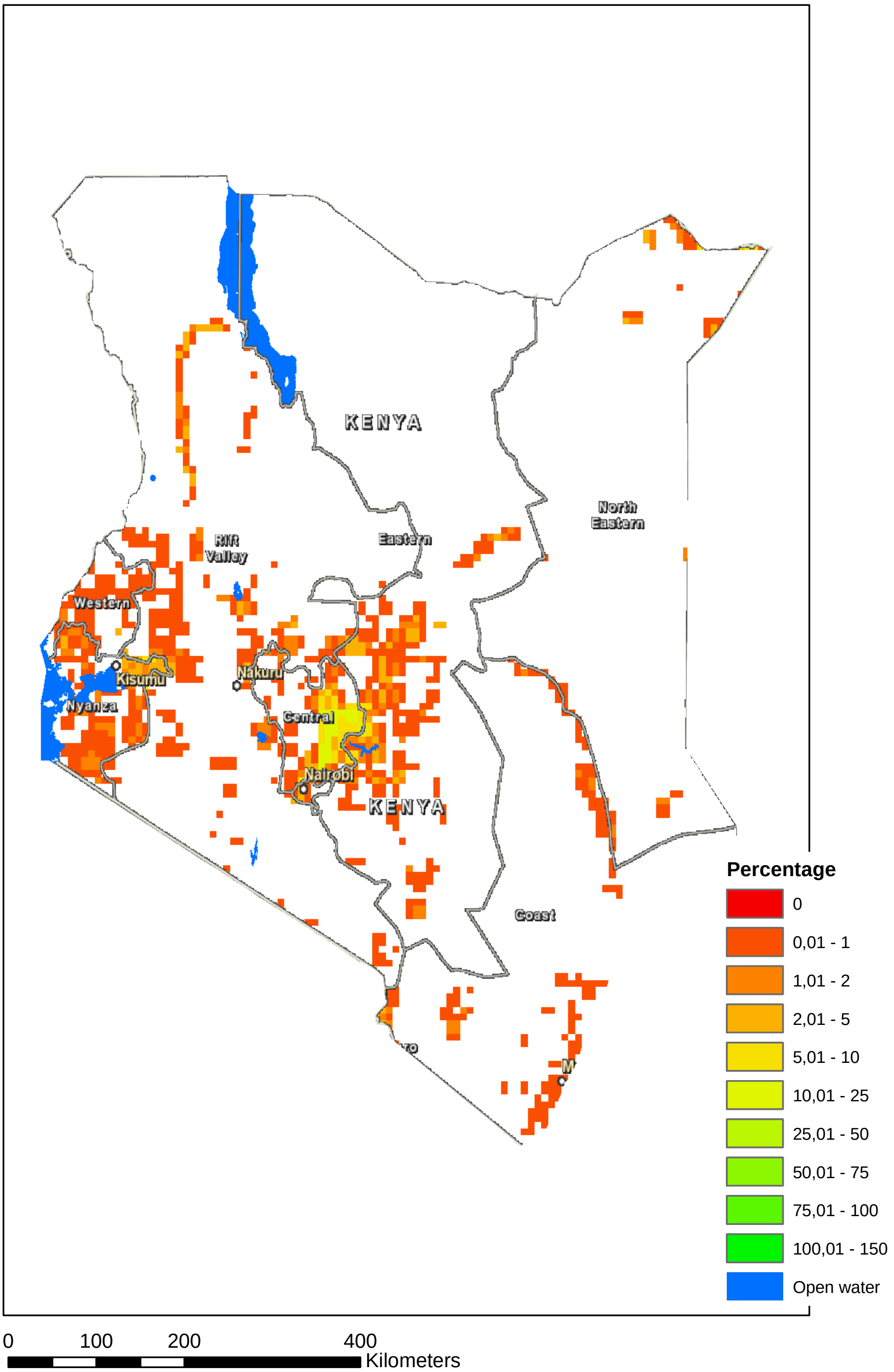



**Figure 22: Land use in Kenya, based on AfriCover.**



KENYA
Rift Valley
Eastern
North Eastern
Western
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
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
100
200
400
Kilometers

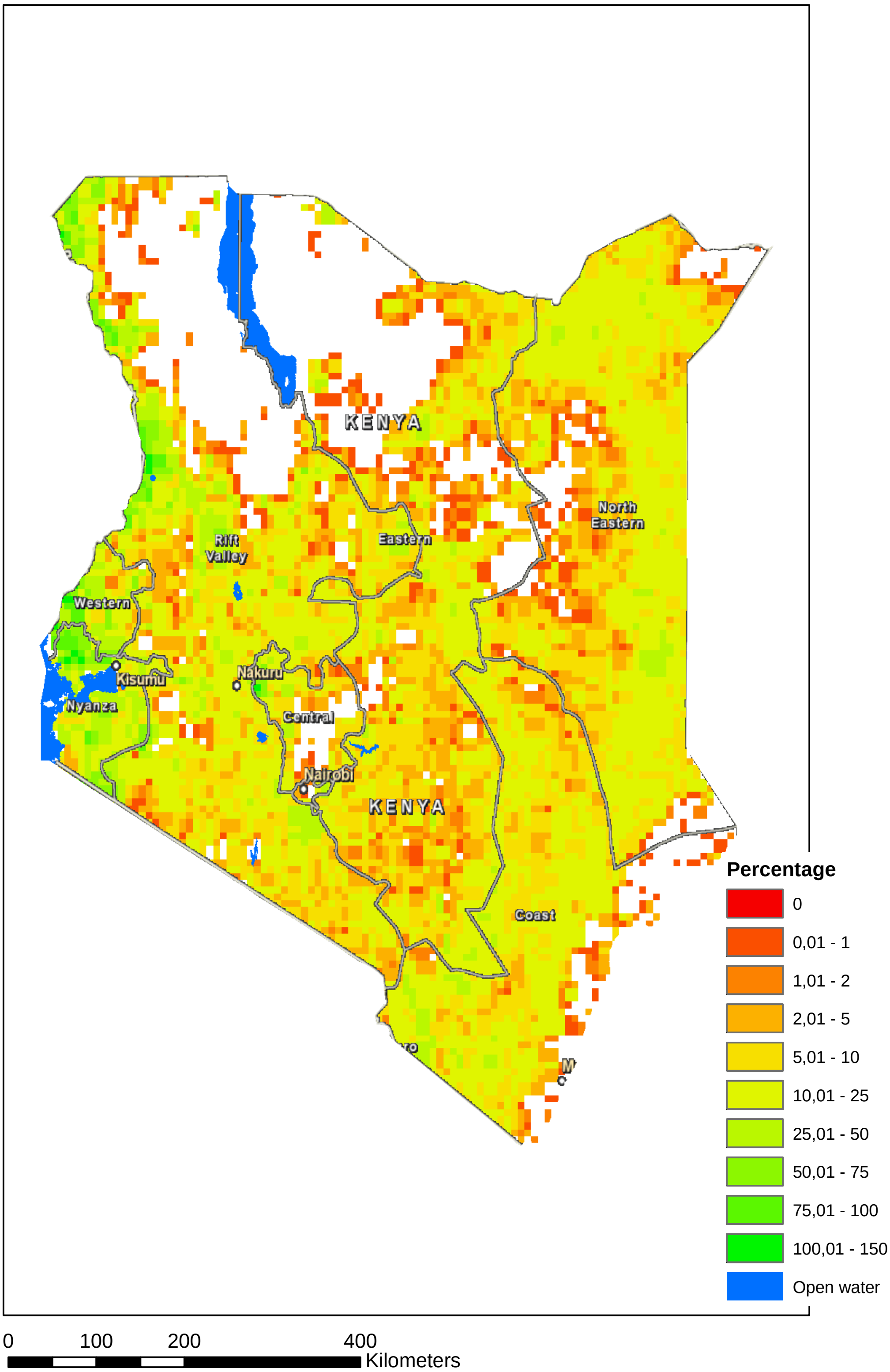
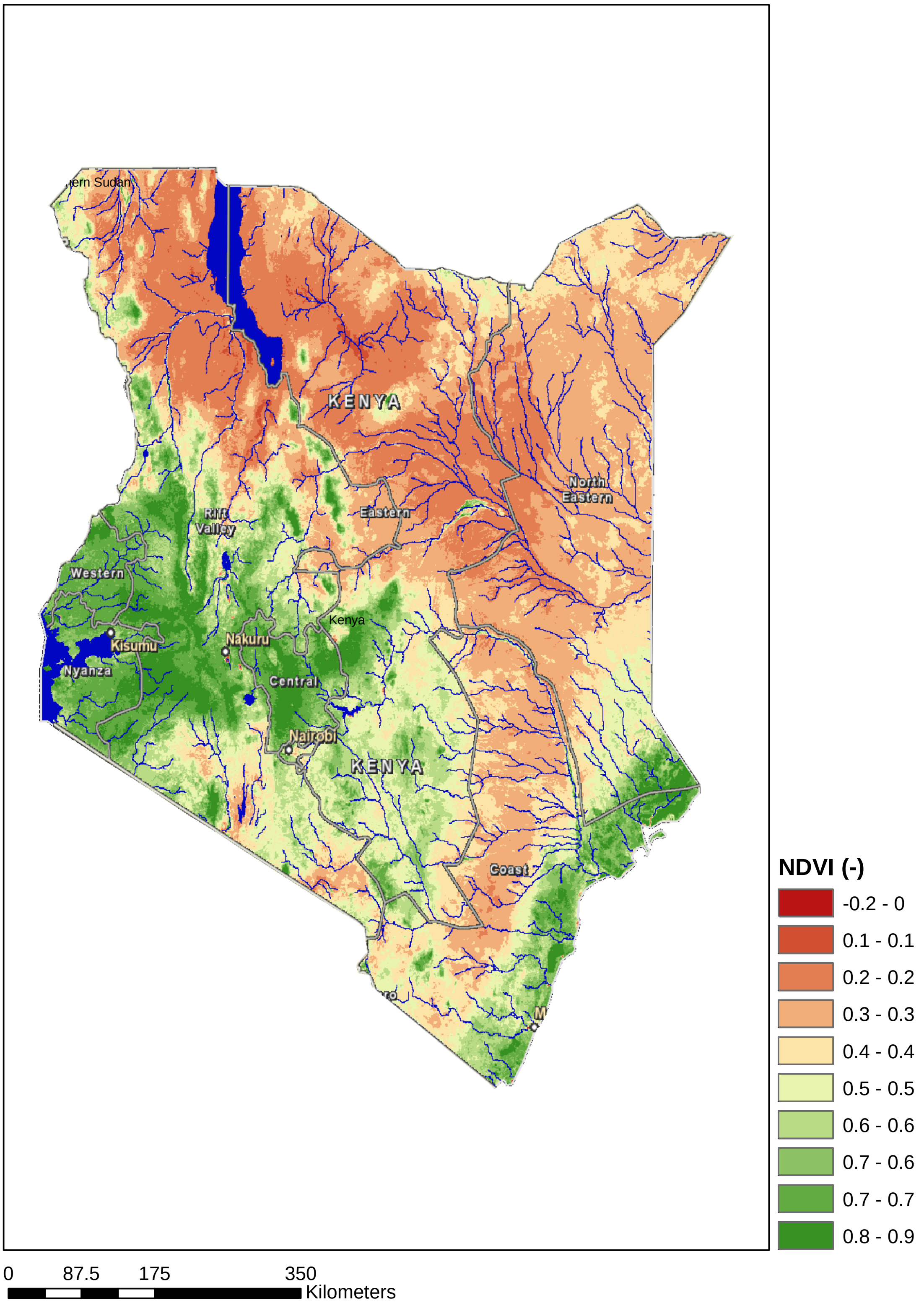


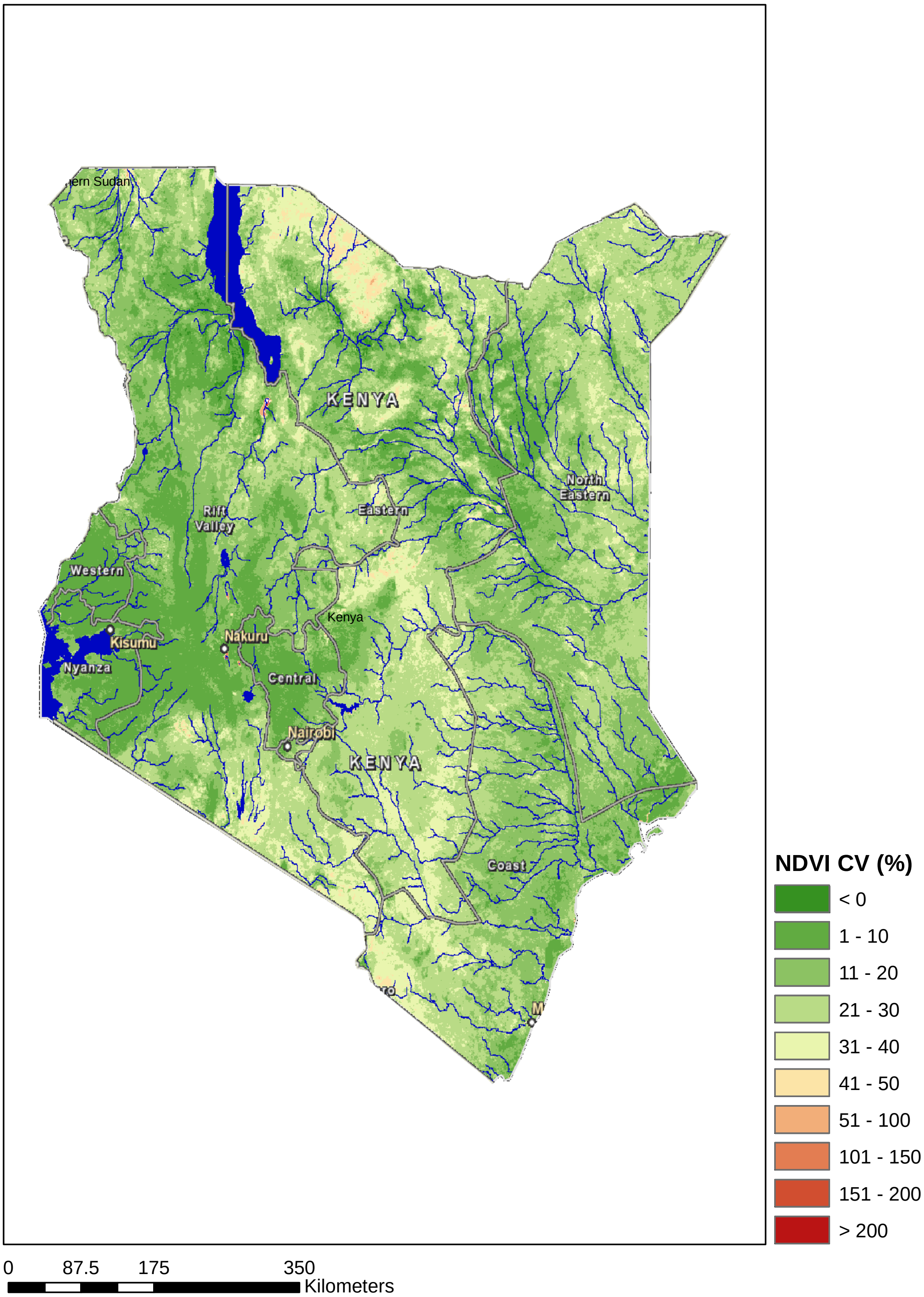

**Figure 23. Irrigated (left) and rainfed cropping intensities[7] (right) as percentage of cells of about 10 x 10 km (Source: Mirca2000).**

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

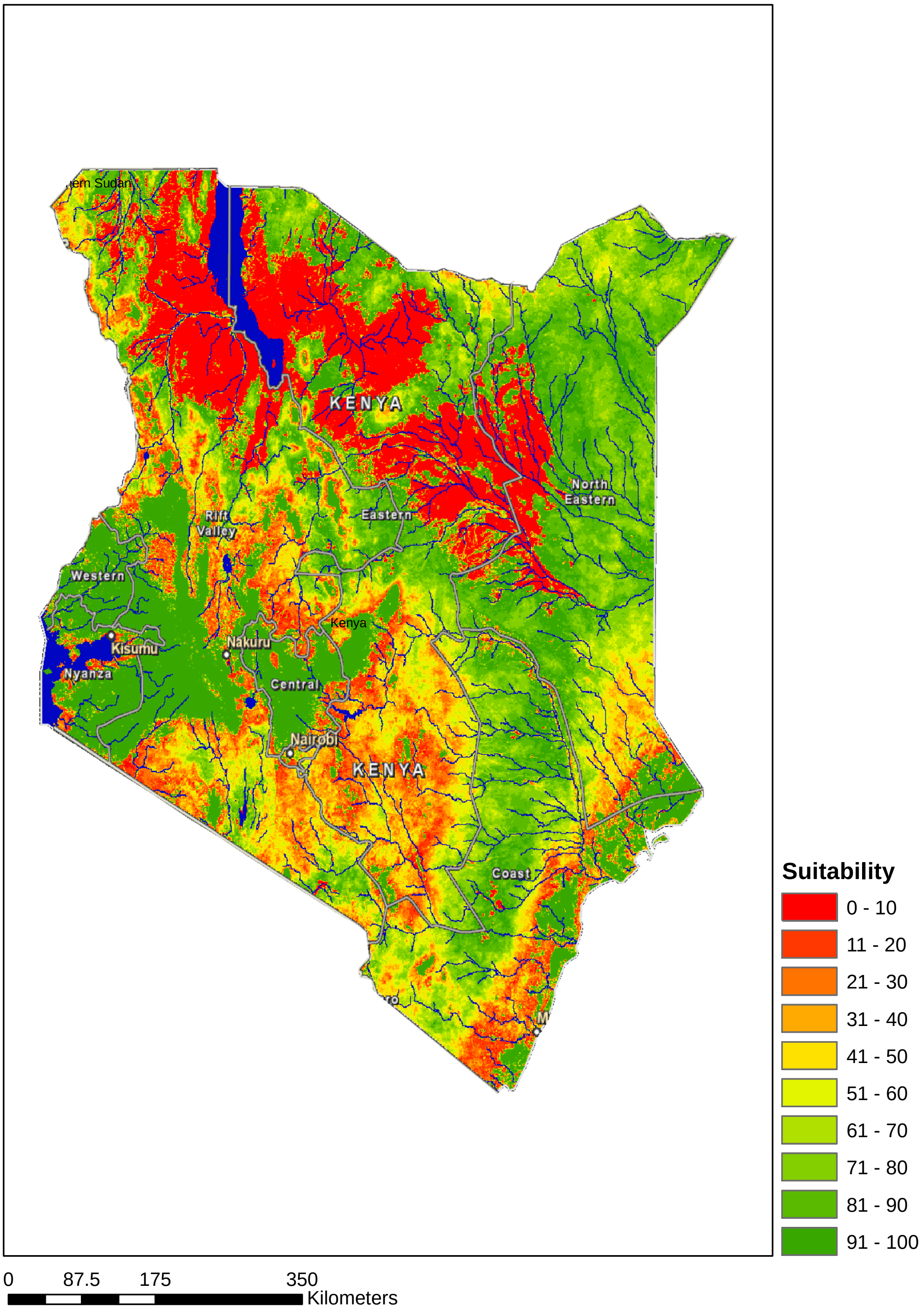
### 2.3.2 *Current land productivity (NDVI)*

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





KENYA
North Eastern
Eastern
Rift Valley
Western
Kisumu
Nyanza
Nakuru
Kenya
Central
Nairobi
KENYA
Coast
0
87.5
175
350
Kilometers
NDVI CV (%)
< 0
1 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 100
101 - 150
151 - 200
> 200


KENYA
Rift Valley
Eastern
North Eastern
Western
Kenya
Kisumu
Nakuru
Nyanza
Central
Nairobi
KENYA
Coast
Suitability
0 - 10
11 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
0
87.5
175
350
Kilometers

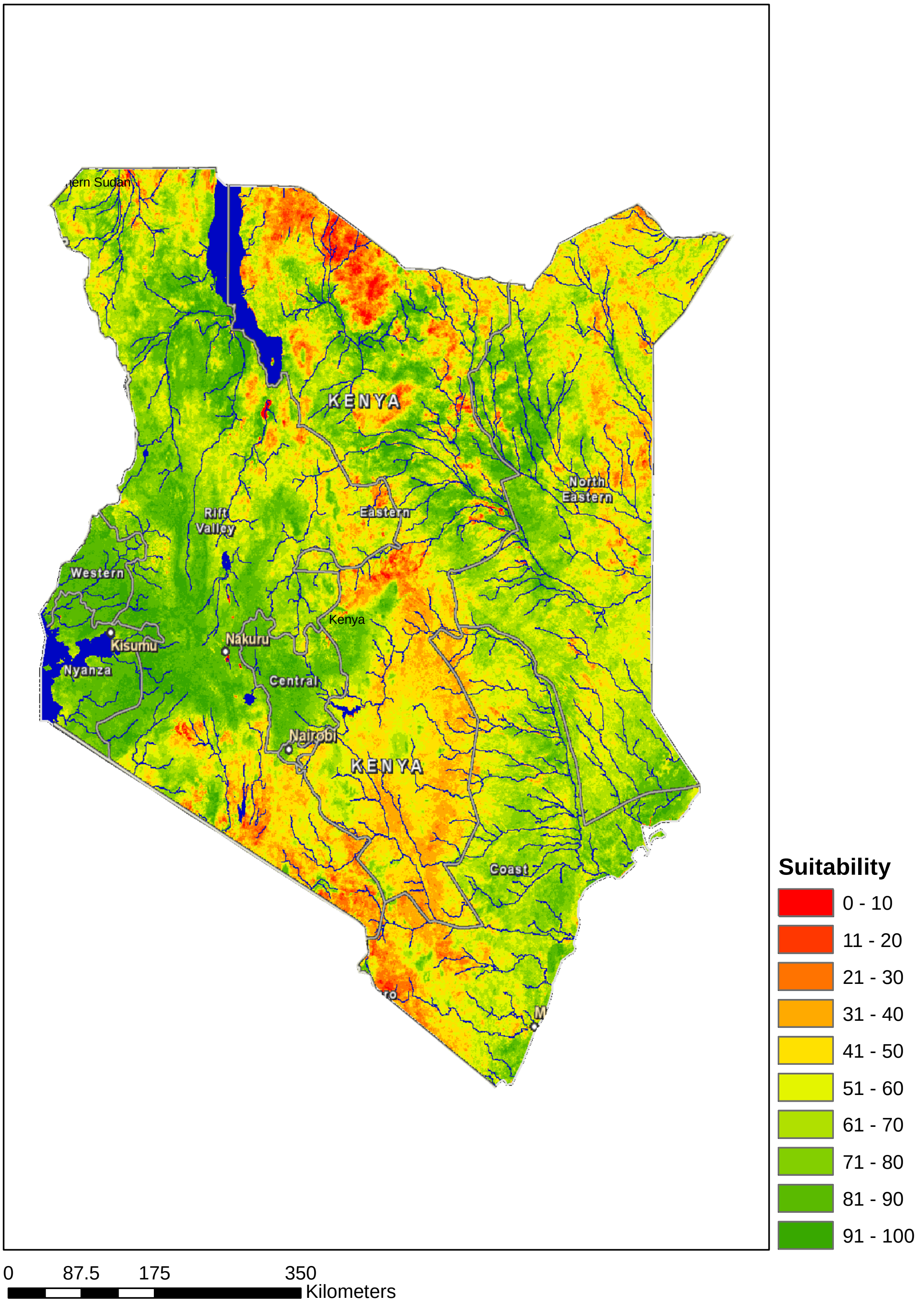



**Figure 24: Current land productivity based on NDVI. Average NDVI (top), average monthly coefficient of variation (second), and the land productivity scores based on average NDVI (third) and monthly coefficient of variation (bottom). (Source: study analysis).**

## 2.4 Agriculture

### *2.4.1 Agriculture, irrigation and main crops*

The humid, sub-humid and semi-humid areas are mainly above 1,500 MASL and are characterized by intensive farming for cash and subsistence. Large farms and estates with tractor mechanization coexist with small holdings using oxen or hand labor. Major crops include tea, coffee, maize, wheat, cut flowers, vegetables, fruits, sugarcane, beans and bananas. High grade dairy cattle are common in these areas but are often stall fed due to shortage of land for grazing. Improved breeds of sheep, pigs and poultry are also found in these high potential areas. The main forest areas, both indigenous and planted, are found above 1,500 MASL but occupy less than 3% of Kenya's land area. The semi-arid areas are characterized by mixed crop and livestock farming whereas the arid and very arid areas are associated with pastoralism and wildlife. Crops grown in the semi-arid areas include maize, sorghum, millet, beans, cow peas, pigeon peas and irrigated vegetables. Cotton and sisal are sometimes grown. The arid and semi-arid lands support 35% of Kenya's cattle, 67% of sheep and goats and all camels. Irrigation is practiced on a relatively small but increasing scale depending on water availability.

The agriculture in Kenya is characterized into smallholdings, medium holdings and large holdings (Table 1). The high and medium potential areas continue to be devoted to intensive crop and milk production systems. Small-scale farming is mainly practiced in the high and medium potential areas and accounts for 75% of the total agricultural output and 70% of the marketed agricultural produce. Small-scale farmers produce over 70% of maize, 65% of coffee, 50% of tea, 65% of sugar-cane, 80% of milk, 70% of beef and related products, and almost 100% of the other food crops (millet, sorghum, pulses, vegetables, roots and tubers) (Isaya, 2007). Smallholdings, defined as agricultural land between 0.2 ha and 10 ha in size, occupy 3.2 million ha (46% of the total agricultural land) and accommodate 3.5 million households (98% of the total farm households). The average size of smallholdings is 0.9 ha.

Kenya's large-scale farming is practiced on farms averaging 50 hectares. The large scale sub sector accounts for 30% of marketed produce and is mainly involved in growing crops such as tea, coffee, horticultural produce, maize and wheat.

**Table 1: Agricultural land sizes in Kenya (Isaya, 2007).**

| | ***Small Holdings*** | | ***Medium Holdings*** | | ***Large Holdings*** | |
|---|---|---|---|---|---|---|
| Land Size (ha) | 0.2 – 2 | 2 – 10 | 10 – 20 | 20 – 60 | 60 – 200 | > 200 |
| No of Holdings (ha) | 2,928,240 | 599,740 | 41,040 | 27,360 | 1,692 | 1,908 |
| % National | 81 | 17 | 1.2 | 0.7 | 0.05 | 0.06 |
| **Total area (ha)** | **3,200,000** | | **1,040,000** | | **2,700,000** | |
| **Ave size (ha)** | **0.9** | | **15** | | **750** | |

**Table 2: Area equipped for irrigation in Kenya according to Aquastat, 2011) Data for 2011 originates from Min. of Water and Irrigation.**

| Kenya | ha |
|---|---|
| 1965 | 14,000 |
| 1975 | 40,000 |
| 1985 | 42,000 |
| 1995 | 70,000 |
| 2005 | 103,000 |
| 2011 | 139,000 |

### *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.

Table 3 shows that the ten dominant crops in Kenya have been expanding in harvested area since 1980 except for sorghum. The harvested area of tea has been more than doubled in these 30 years. Combined with an increase of 80% in yield since 1979, tea is the crop with the lowest yield gap (Figure 25). The yield of coffee has been decreased substantially over the last decades. Also dry beans yields have been declining. Sorghum and maize yields have been more or less stable over the last 30 years.

Comparing the yields of the five most dominant crops with other countries indicates that the yield gap is largest for sorghum. Yields in Kenya reach about half of the yields compared to neighboring countries. Yields of dry beans and coffee have a high potential to increase as well.

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

| | 1980 | 1990 | 2000 | 2005 | 2009 |
|---|---|---|---|---|---|
| Maize | 1.350.000 | 1.380.000 | 1.500.000 | 1.771.120 | 1.884.370 |
| Beans, dry | 420.000 | 501.130 | 770.797 | 1.034.480 | 960.705 |
| Sorghum | 210.000 | 117.960 | 122.493 | 122.368 | 173.172 |
| Coffee, green | 102.400 | 153.100 | 170.000 | 170.000 | 160.000 |
| Tea | 76.541 | 96.981 | 120.390 | 141.300 | 158.400 |
| Potatoes | 40.000 | 87.890 | 108.516 | 120.842 | 153.114 |
| Wheat | 100.000 | 150.695 | 131.834 | 159.477 | 127.410 |
| Cow peas, dry | 0 | 119.413 | 100.300 | 72.654 | 124.302 |
| Pigeon peas | 0 | 152.444 | 171.842 | 180.240 | 118.167 |
| Millet | 80.000 | 96.933 | 93.150 | 92.430 | 104.576 |
| Total | 2.378.941 | 2.856.546 | 3.289.322 | 3.864.911 | 3.964.216 |

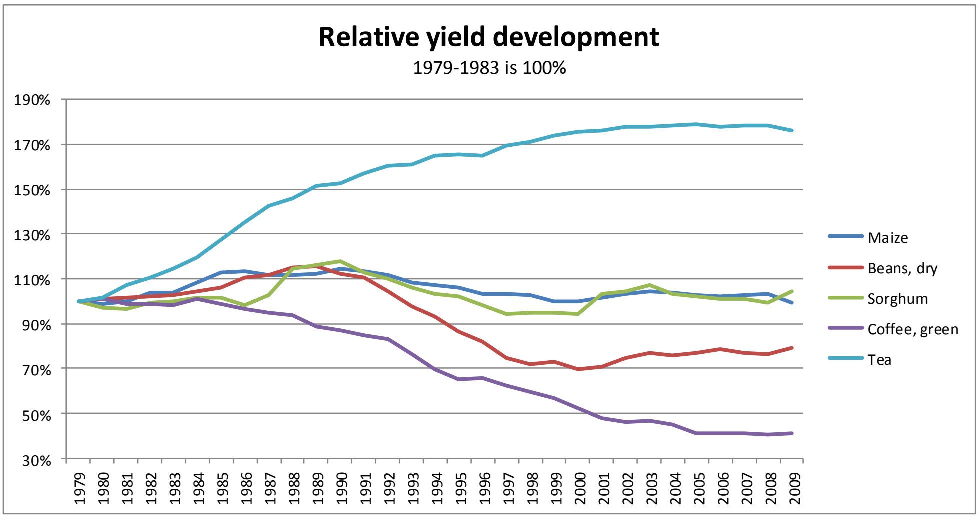



**Figure 25. Trend in yields per ha for the five most dominant crops. Average of first five years has been indexed to 100%. (Source FAOstat, 2010)**

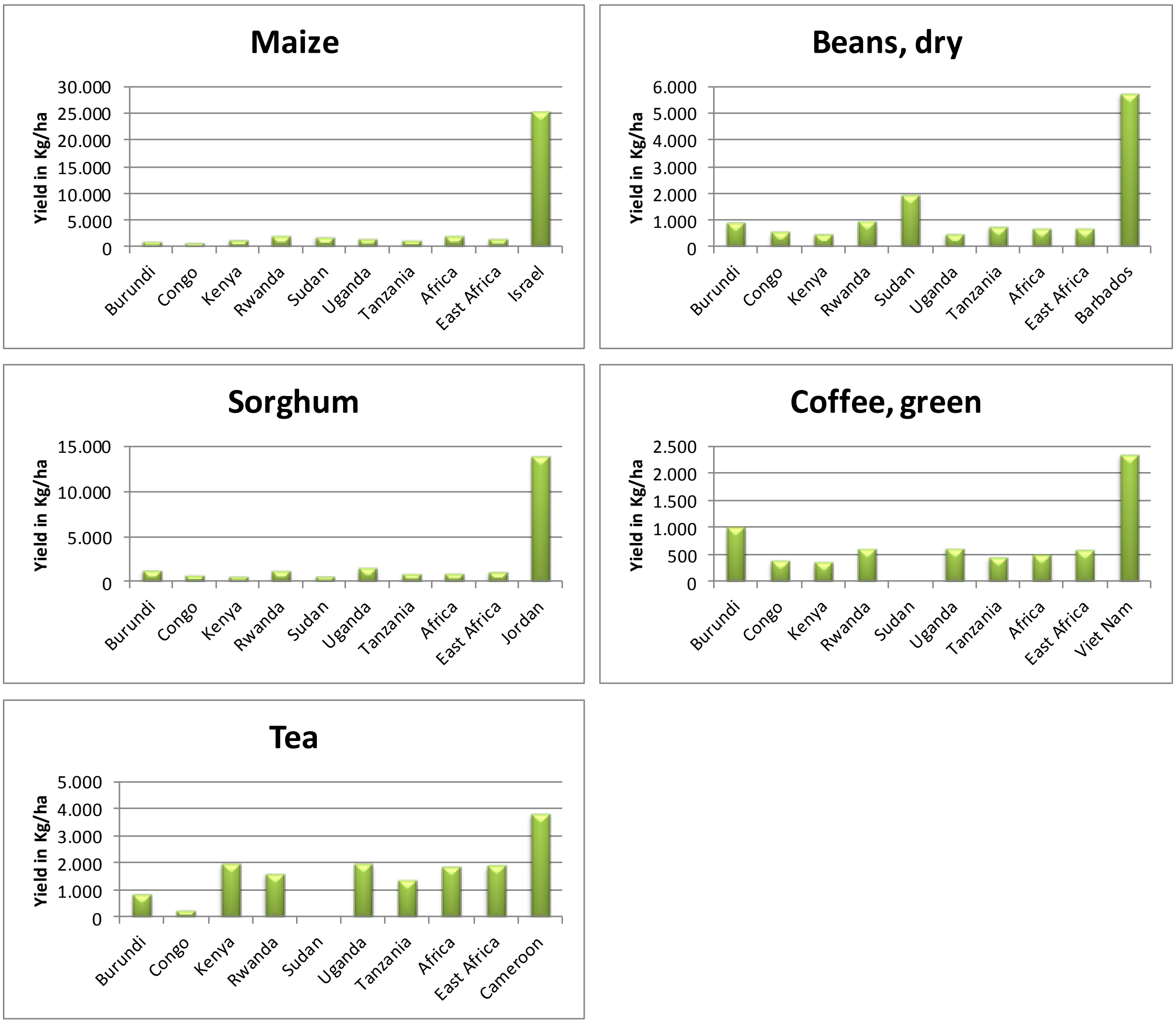
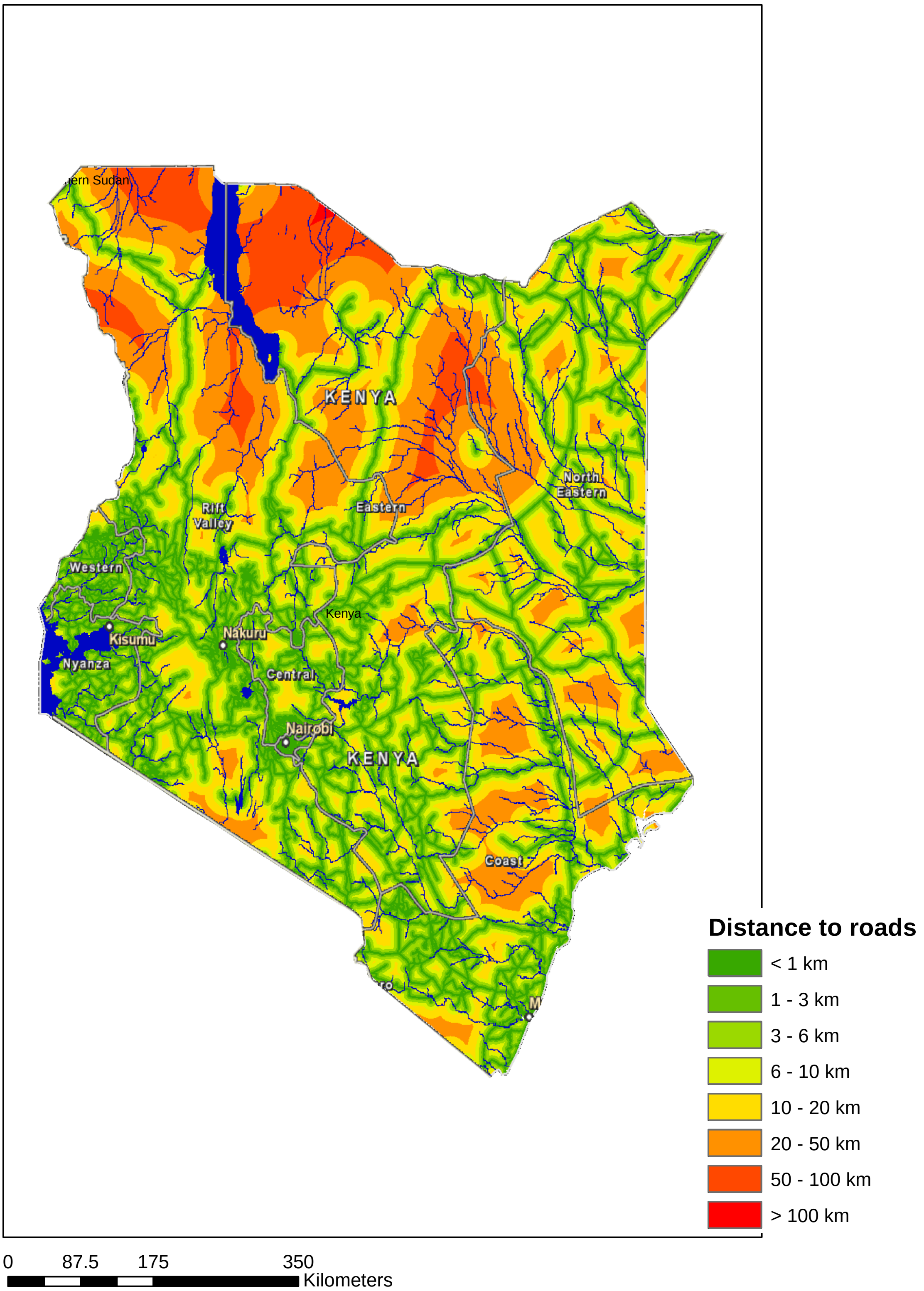



**Figure 26. Yield comparison for the five most dominant crops in the country. (Source FAOstat, 2010)**

## 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). Access to transportation is in the southern and western part of the country quite good. In the northern part and some other regions in the country access to transportation is very low.



KENYA
North Eastern
Eastern
Rift Valley
Western
Kisumu
Nakuru
Kenya
Nyanza
Central
Nairobi
KENYA
Coast
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
87.5
175
350
Kilometers

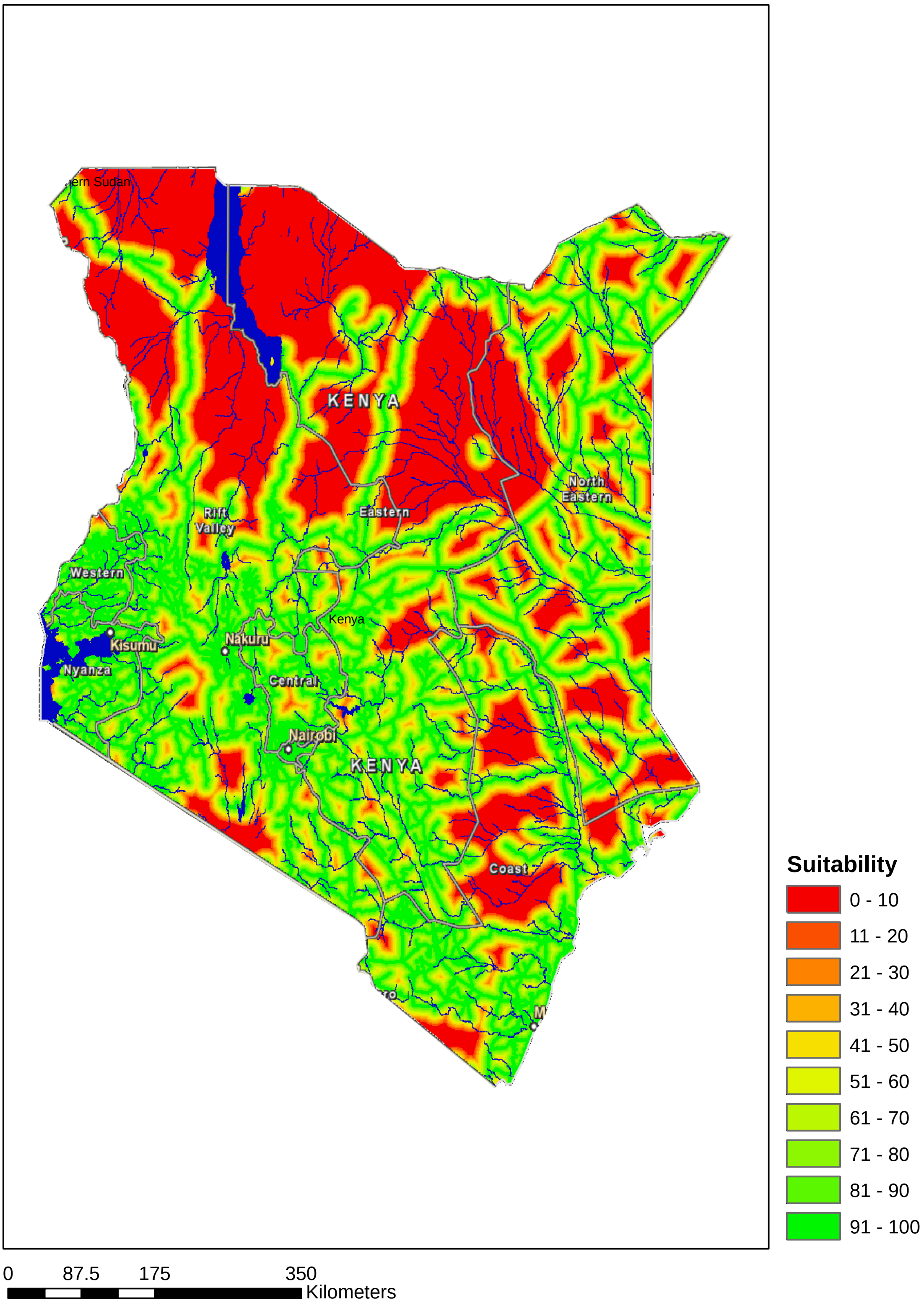
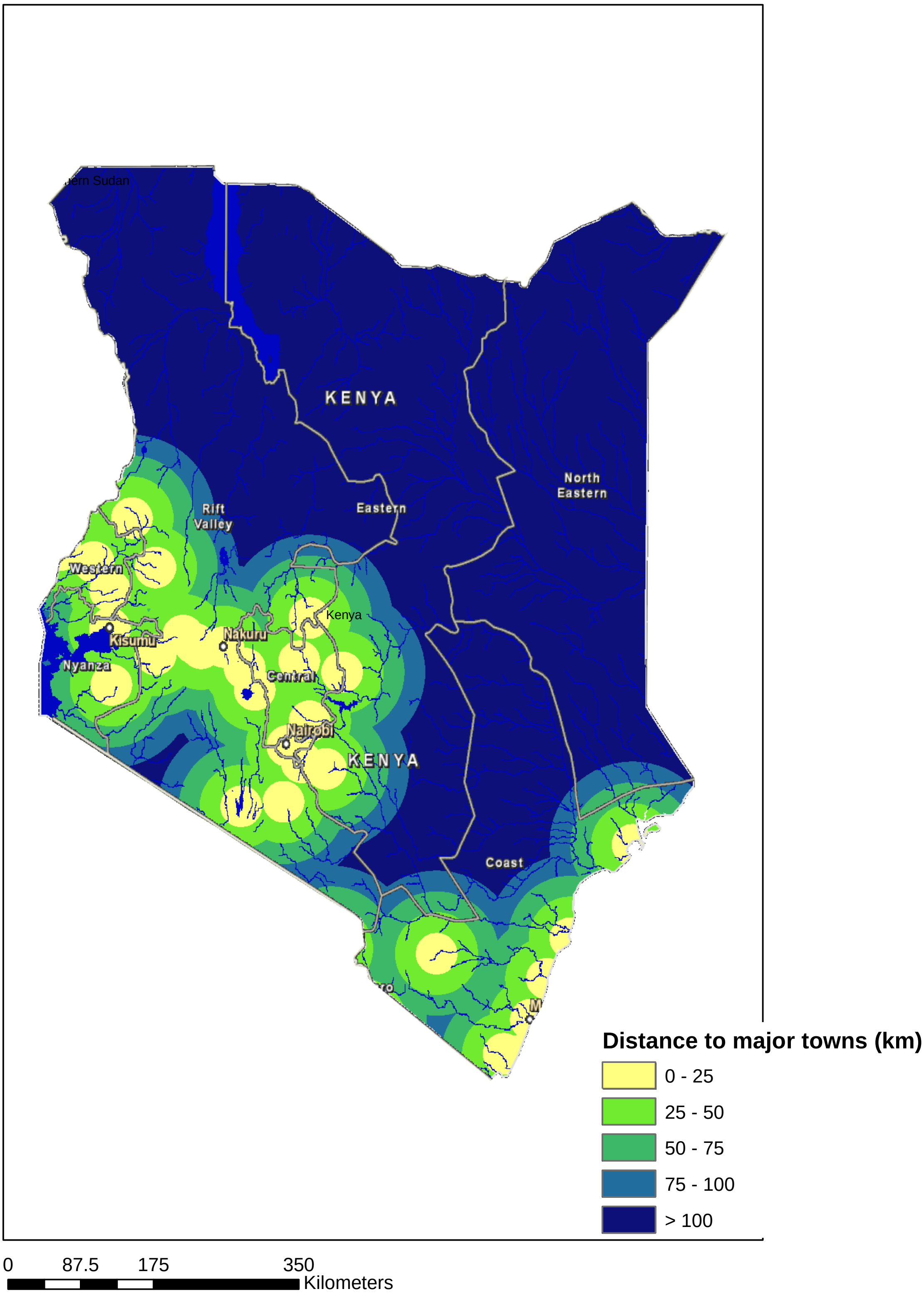
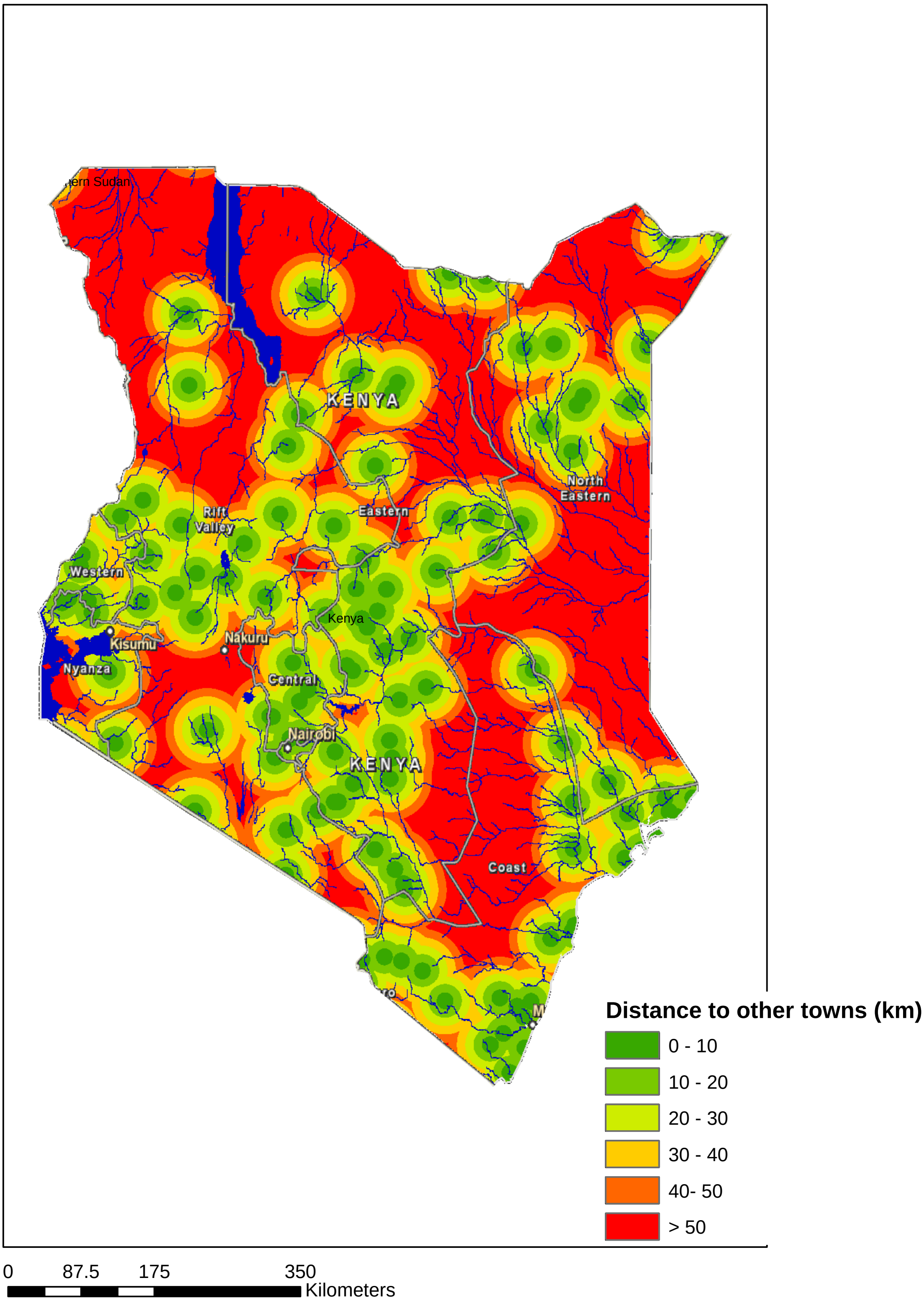



**Figure 27: Distance to transportation (top), and suitability (bottom). (Source: study analysis).**

### 2.5.2 *Access to markets*

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




Rift Valley
Eastern
North Eastern
Western
Kisumu
Nakuru
Kenya
Nyanza
Central
Nairobi
KENYA
Coast
Distance to other towns (km)
0 - 10
10 - 20
20 - 30
30 - 40
40- 50
> 50
0
87.5
175
350
Kilometers

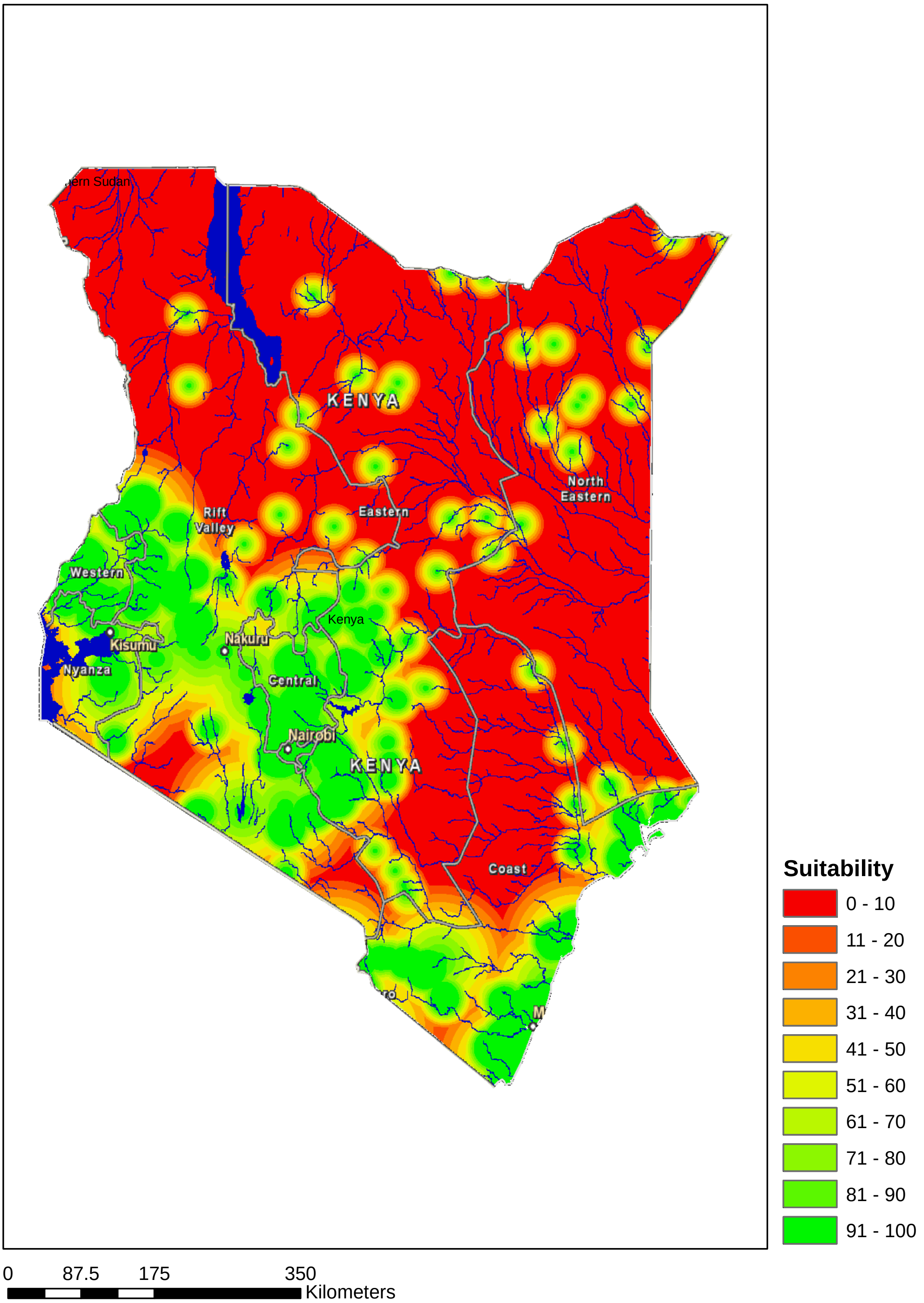



**Figure 28: Distance to major towns (top left), distance to other towns (top right), and combined suitability index (bottom).**

## 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 very low in the country, expect for the Central, Western and Nyanza Provinces.

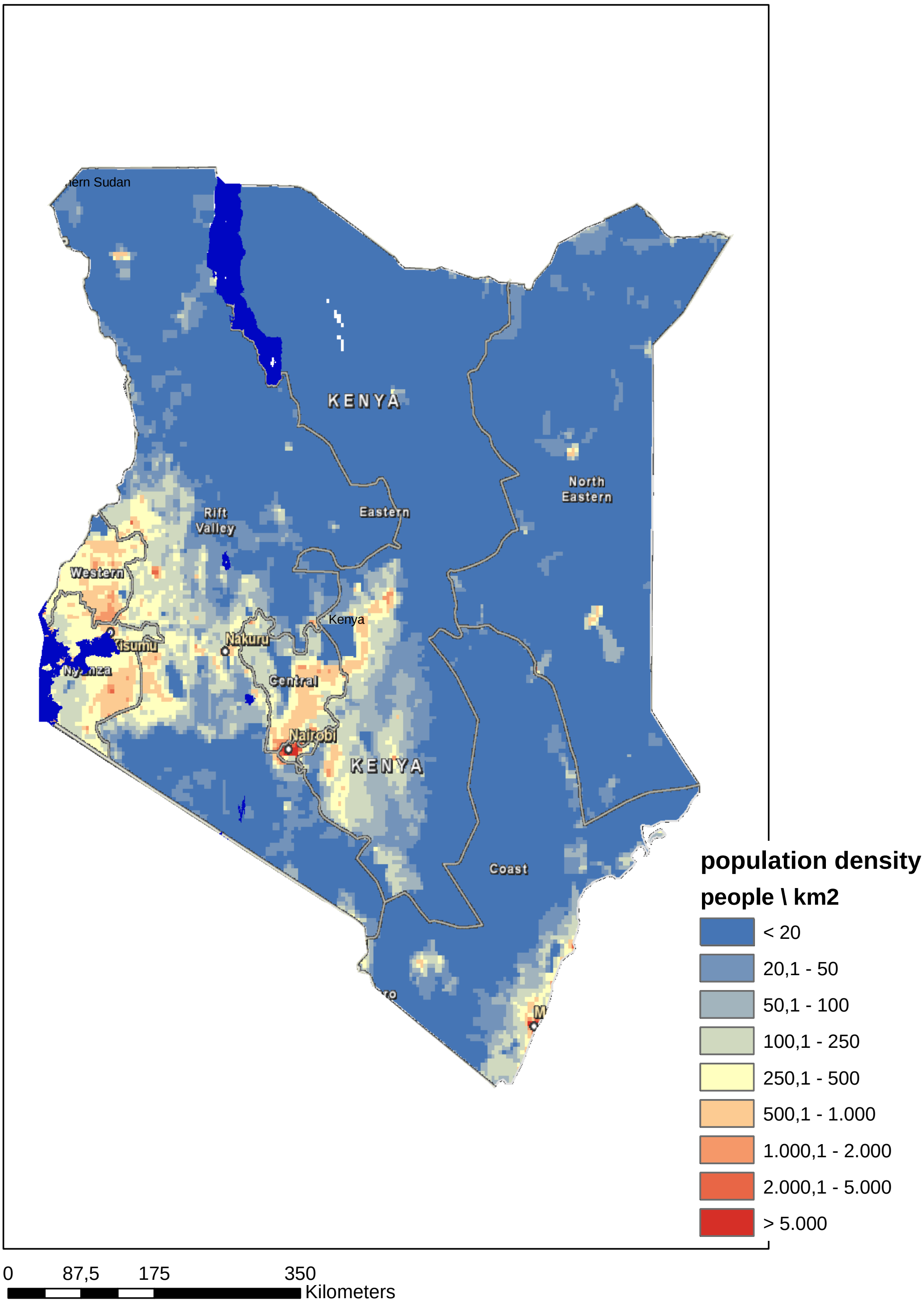



**Figure 29. Population density distribution (source: CIESIN)**

## 2.7 Institutional and legal framework

### *2.7.1 Water treaty agreements*

Kenya made major reforms to its water supply and sanitation (WSS) services sector through the passage of its Water Act 2002. The Act was instrumental in decentralizing Kenya's WSS services and creating the institutional framework that exists today. Through the creation of the Ministry of Water and Irrigation (MWI), the government consolidated the responsibility to develop water resources, policy, and overall sector monitoring functions in MWI, while devolving water service provisions to local water operators. In addition, an independent regulator, the Water Regulatory Services Board (WSRB), was created for the regulation of water and sewerage services, including licensing, quality assurance, and issuance of guidelines for rates, fees, and handling service complaints. The National Irrigation Board is responsible for the development of national irrigation schemes and the promotion of smallholder irrigation. The River Basin Development Authorities are responsible for the planning and use of water and land resources within their jurisdictions.

Seven Water Services Boards (WSBs) are responsible for the efficient and economical provision of water and sewerage services within their area of jurisdiction. The seven WSBs cover the whole country and are responsible for asset development and overall responsibility for services. However, direct provision of water services is undertaken by Water Service Providers (WSPs) to whom the responsibility is delegated by the WSBs. Still, the WSRB can make exceptions. The WSPs can be community groups, non-governmental organizations, or autonomous entities established by local authorities or other persons. As a result, improvements and expansion of WSS services is beginning to gain traction, but sorely needed financing, local capacity building, and an improved system of monitoring and evaluation (M&E) remain as important next steps.

At the international level, the Lake Victoria Tripartite Agreement set the stage for the Lake Victoria Environmental Management Program (LVEMP) and the Nile Basin Initiative provide the basis for cooperation of all riparian countries in the development of the water resources of the Nile Basin. The emphasis is towards the need for equitable sharing of water resources and benefits that accrue from the development of the shared water resources, the sustainability of resources, the need to build trust and cooperation between riparian countries and the need for protection of resources. As a result of these initiatives, there are great opportunities to significantly improve the management of shared water resources. It is essential for Kenya to strengthen its capacity to negotiate and manage international waters in sharing and management issues.

Recent developments include: (i) Water Act 2002 has been reviewed to current Water Act 2012, (ii) National Water Policy 2012, and (iii) Finalized National Irrigation Policy and Bill.

### *2.7.2 Land ownership rights*

The Constitution of Kenya (2010) declares that "land in Kenya shall be held, used and managed in a manner that is equitable, efficient, productive and sustainable, and in accordance with the following principles: i) equitable access to land; ii) security of land rights; iii) sustainable and productive management of land resources; iv) transparent and cost effective administration of land; v) sound conservation and protection of ecologically sensitive areas; vi) elimination of gender discrimination in law, customs and practice related to land and property in land; and vii) encouragement of communities to settle land disputes through recognized local community initiatives consistent with this Constitution” (GOK 2010, Article 60).

The National Land Policy designates all land in Kenya as public, private (freehold or leasehold tenure), or community/trust land, which is held, managed and used by a specific community. Currently, however, the main classifications of land ownership in Kenya are private (freehold), government, and trust land held by councils for the benefit of a community.

Private freehold land makes up about 20% of the country’s land and is held either individually or collectively. Most of the high-value agricultural land has been adjudicated and registered as freehold. Collective freeholds include group ranches established under the Land (Group Representatives) Act in 1968. The Act recognizes customary tenure of pastoralist groups and grants every member of a group an equal, undivided interest in the group ranch. Elected group representatives act as legal trustees of the ranch (GOK 2009b; Mwenda 2006; Aggarwal and Roth 2008).

Approximately 10% of Kenya’s land is under government ownership and includes all un-alienated land, including gazetted forests, protected areas and reserves, rivers, and land occupied by government or quasi-government institutions (Mwenda 2006; Aggarwal and Roth 2008).
Trust land. The balance of land holdings (70%) are trust land. Trust lands derive from the 1915 amendment to the Crown Lands Ordinance of 1902, which converted all native reserve lands to trust lands and (at Independence) vested county councils with the power to hold and alienate land for the benefit of resident communities (Mwenda 2006; Aggarwal and Roth).

## 2.8 Irrigation potential

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

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

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

Based on these maps, the final score indicating suitable for irrigation can be observed in Figure 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 9.6 million hectare. In order to assess what limitations are in a certain areas, information from the previous sections can be used. A first estimate on the impact of developing irrigation in all the focal areas shows that flows in the River Nile will be reduced by less than 1%.

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.

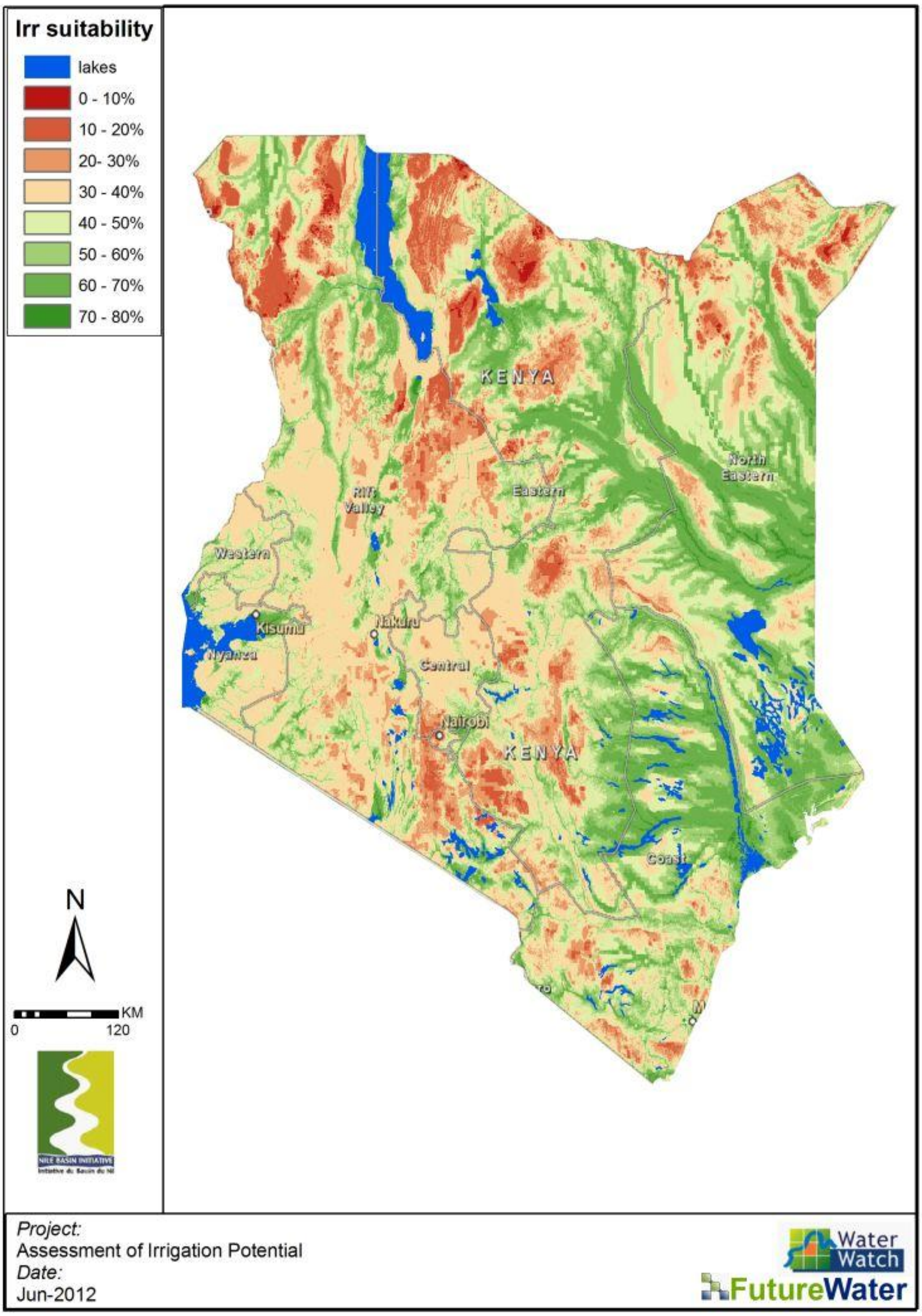



**Figure 30: Irrigation suitability score**

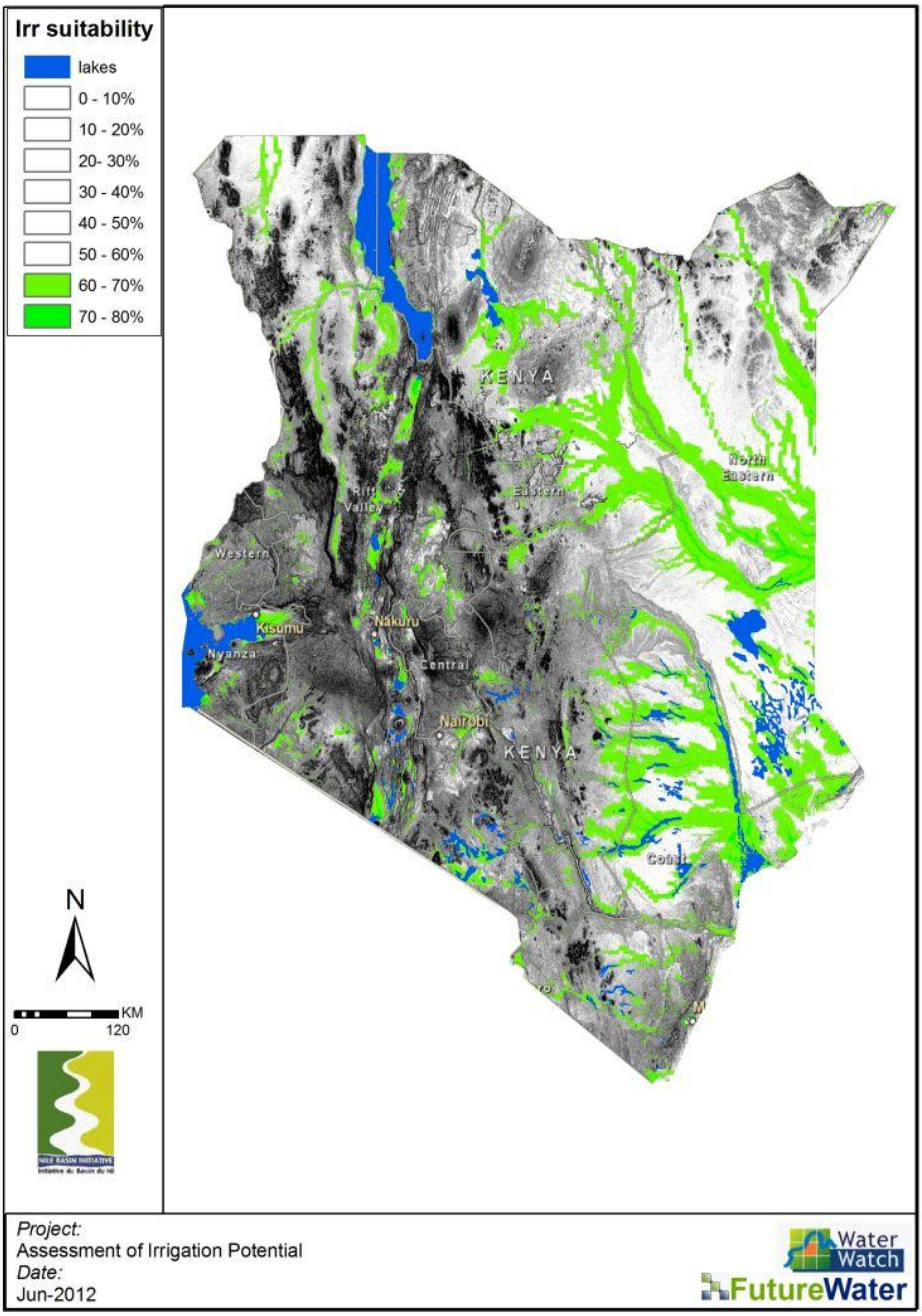



**Figure 31: Final map indicating areas suitable for irrigation. (Source: study analysis).**

**Table 4. Suitability classes.**

| Suitability | Irrigation potential (ha) |
|---|---|
| 0 - 10% | 181,444 |
| 10 - 20% | 2,872,394 |
| 20 - 30% | 5,658,475 |
| 30 - 40% | 15,352,663 |
| 40 - 50% | 12,620,131 |
| 50 - 60% | 10,617,388 |
| 60 - 70% | 9,235,088 |
| 70 - 80% | 448,325 |
| 80 - 90% | 0 |
| 90 - 100% | 0 |
| Total >60% | 9,683,413 |

### *2.8.1 Focal areas*

Based on the results from the first phase of the irrigation potential study and the local available expert knowledge and political considerations five focal areas have been delineated on which the second phase will focus. In this report 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 Kenya**

| | Kuja | Kano Plains | Nzoia river basin | Sio basin |
|---|---|---|---|---|
| Area in ha | 5141 | 7160 | 3599 | 7248 |

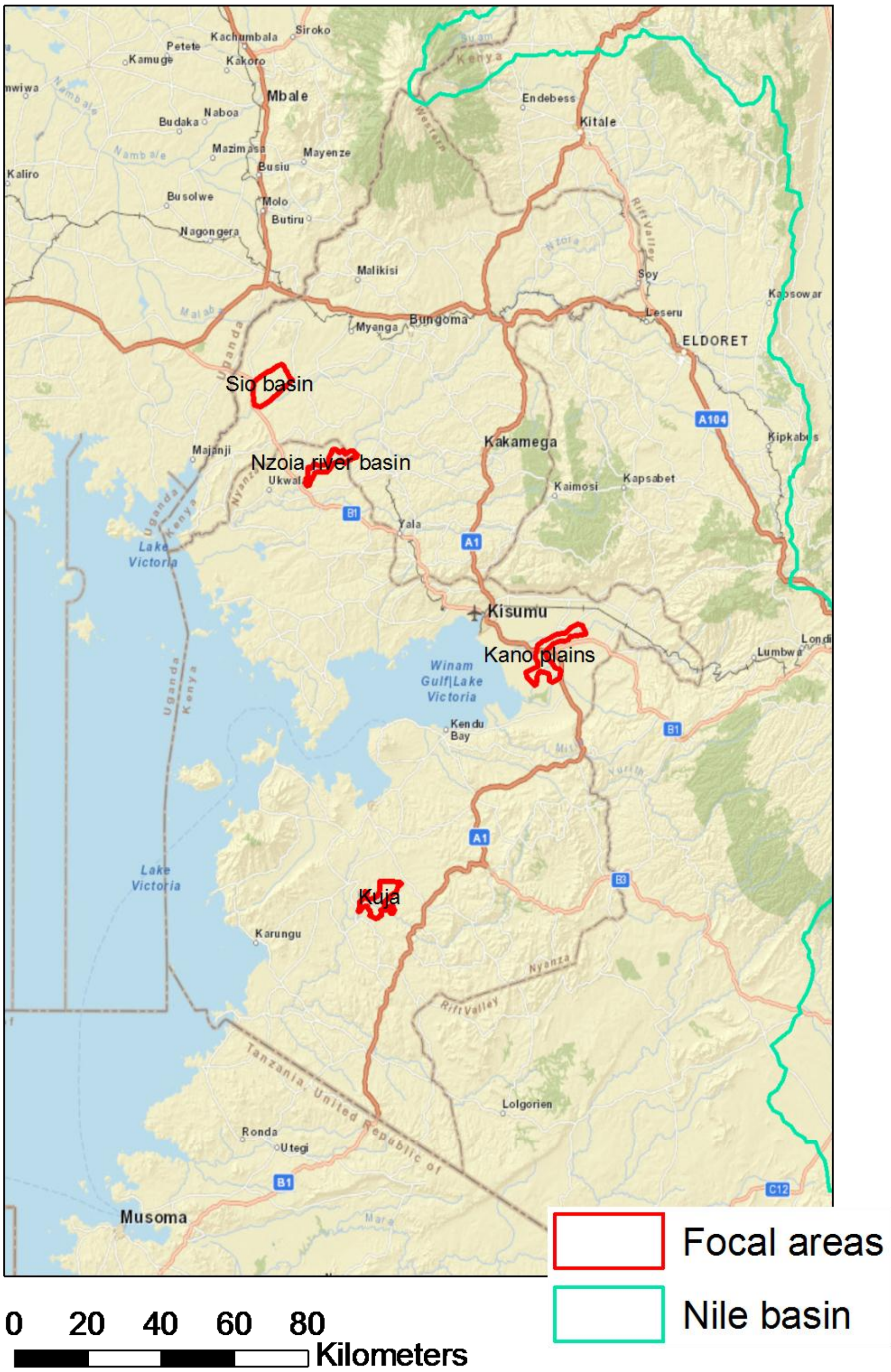



Figure 32: Overview focal areas Kenya

# 3 Kuja focal area

## 3.1 Introduction

This chapter will describe the current state of the Kuja 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 5141 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 Jacqueline Oseko and Hosea Wendot as supervisor in June 2012.

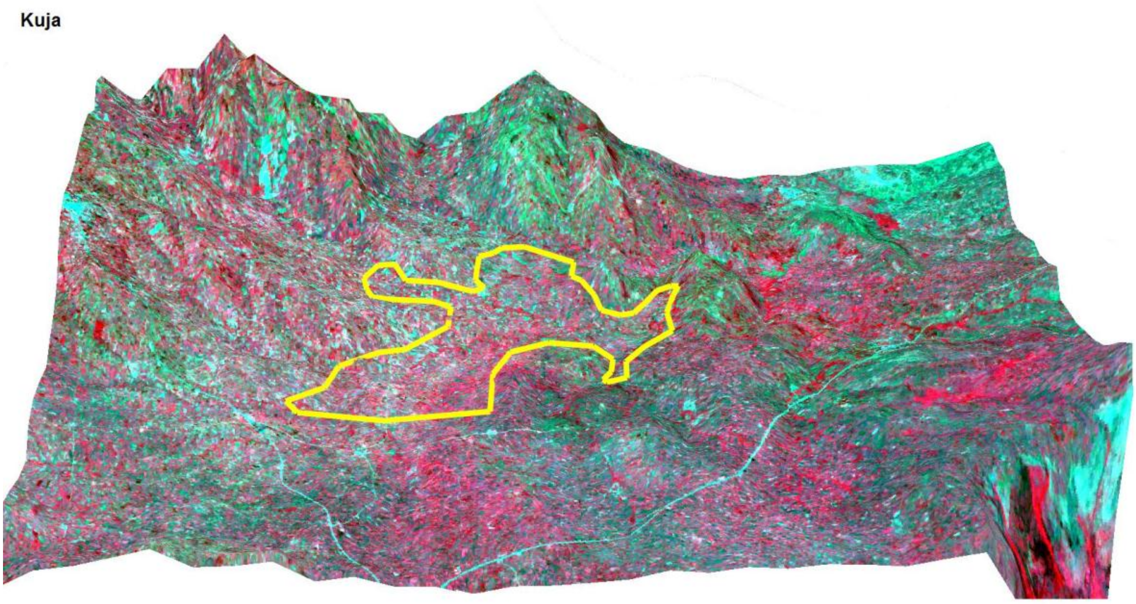



**Figure 33: 3D impression of Kuja focal area, Kenya**

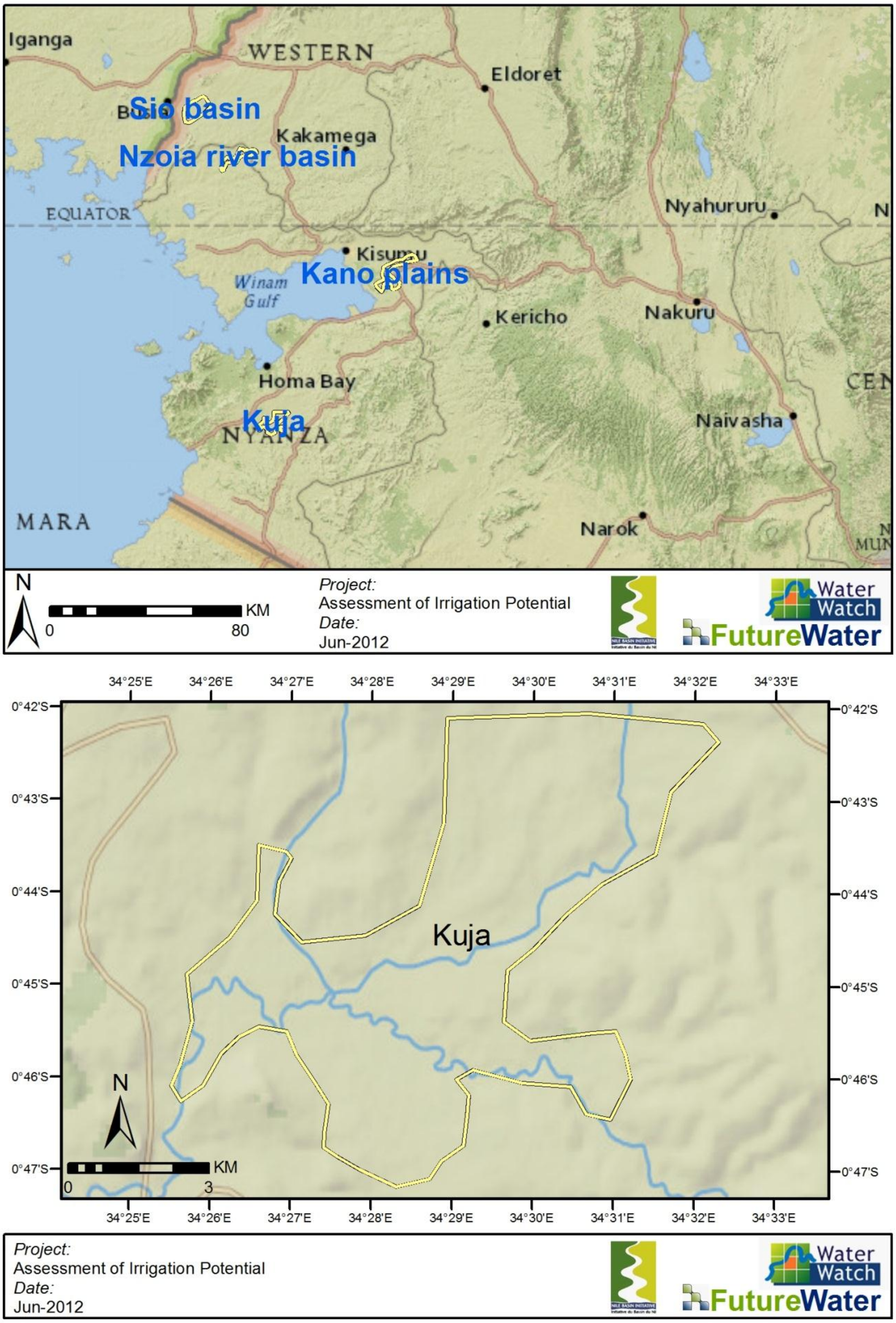



**Figure 34: Kuja focal area, Kenya**

## 3.2 Land suitability assessment

### *3.2.1 Terrain*

Kuja focal area is situated within Nyatike district, within Nyanza province. This area completely in the West of Kenya is highly productive for agriculture. The area is about 30 km from the shores of Lake Victoria at an average elevation of 1300m. The area descends from North West to South East from 1330m towards 1260m above sea level. (Figure 35) The elevation difference of approximately 70m results in very gentle slopes. Slopes range within the area but do not exceed 5% (250m DEM) and are on average around 1-2%. On a 30 meter resolution slopes can reach up to 10% locally. (Figure 36 and Figure 32)

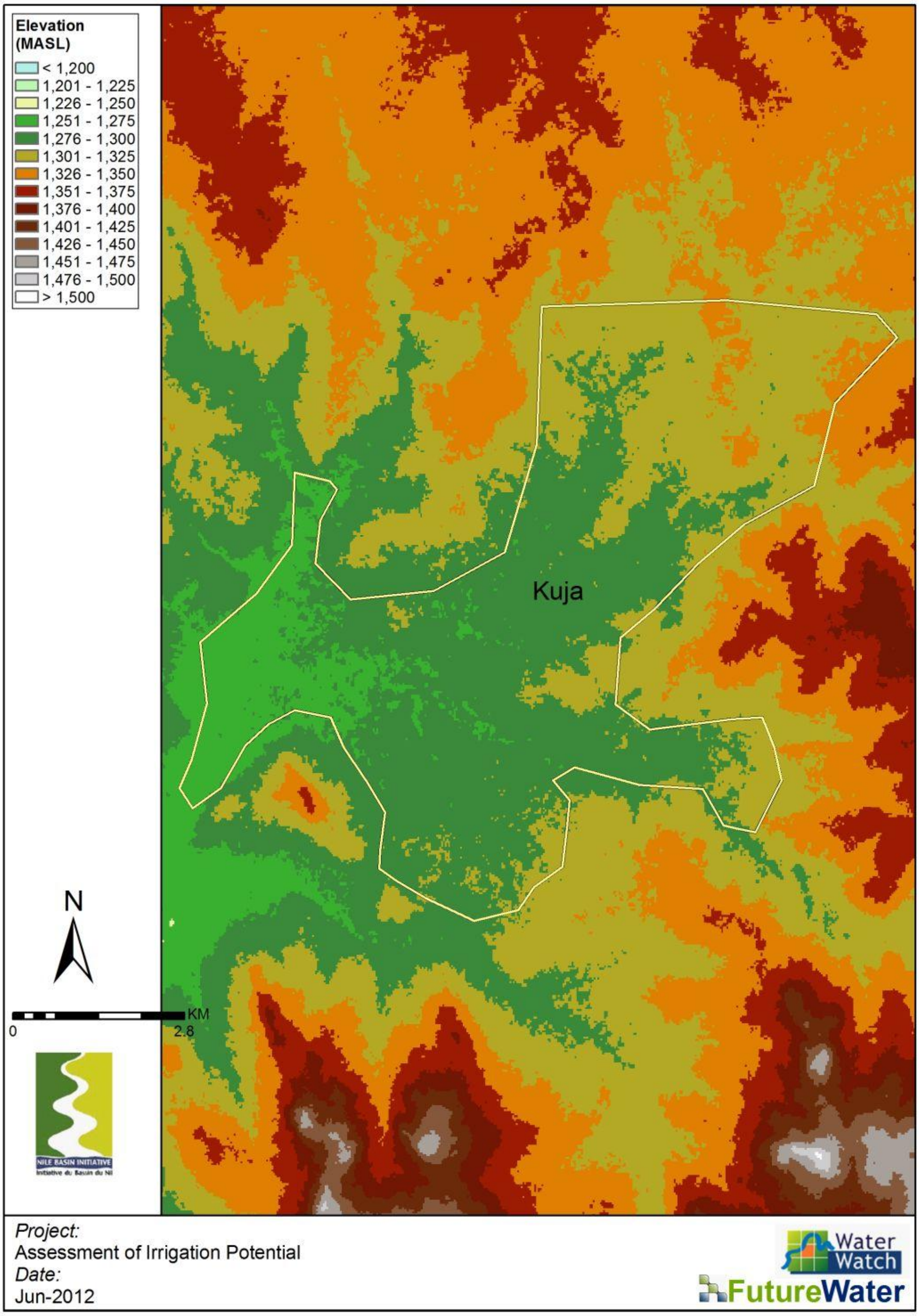



**Figure 35: DEM Kuja focal area. Resolution 1 arc second (+/- 30m)**

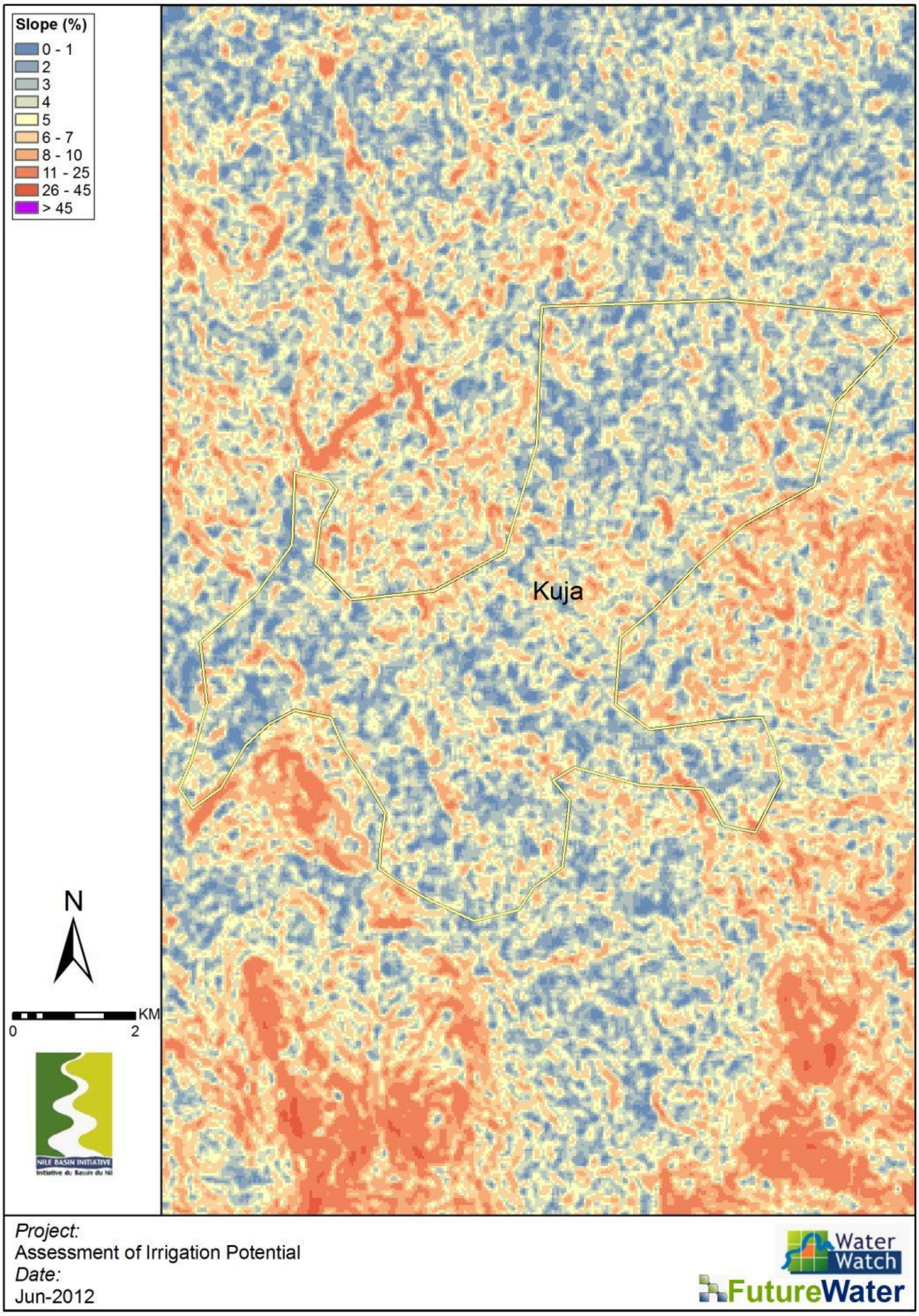



**Figure 36: Slope map Kuja focal area (source: ASTER).**

### 3.2.2 Soil

The soil texture in the focal area is mainly clayey loam. Locally this may vary to loam or clay. According to the field visit the drainage capacity is poor. The soil is formed under alluvial processes, and has typically a finer textured subsoil. The percentage of organic carbon in the top soil is relatively low, ranging from 1- 1.5%. The available water holding capacity is large in most of the area with 125-150 mm/m and may increase locally to over 150 mm/m. The largest part of the focal area can be characterized as a Planosol. Natural Planosol areas support a sparse grass vegetation, often with scattered shrubs and trees that have shallow root systems and can cope with temporary waterlogging. Land use on Planosols is normally less intensive than that on most other soils under the same climate conditions. Vast areas of Planosols are used for extensive grazing. Planosols in the tropics can be planted with single crop of paddy rice produced on bunded fields that are inundated in the rainy season. Efforts to produce dryland crops on the same land during the dry season have met with little success; the soils seem better suited to a second crop of rice with supplemental irrigation. Fertilizers are needed for good yields. Paddy fields should be allowed to dry out at least once a year in order to prevent or minimize microelement deficiencies or toxicity associated with prolonged soil reduction. Some Planosols require application of more than just NPK fertilizers, and their low fertility level may prove difficult to correct. Where temperature permits paddy rice cultivation, this is probably superior to any other kind of land use.

### 3.2.3 Land productivity

The annual average land productivity (NDVI) in the four Kenyan focal areas ranges between 0.59 and 0.66. In Kuja focal area the NDVI is 0.66, which is really high compared to the Kenya average NDVI of 0.36. (Figure 38) Within the focal area the variation in land productivity is quite low. The highest productive grounds can be found on the Northern side where NDVI raises towards 0.8 and on the South eastern part the NDVI is slightly lower with average values around 0.6. The coefficient variation is very low within the whole area, but increases slightly towards the West. Apparently the area is used year through for intensive agriculture, without long breaks in between growing cycles.

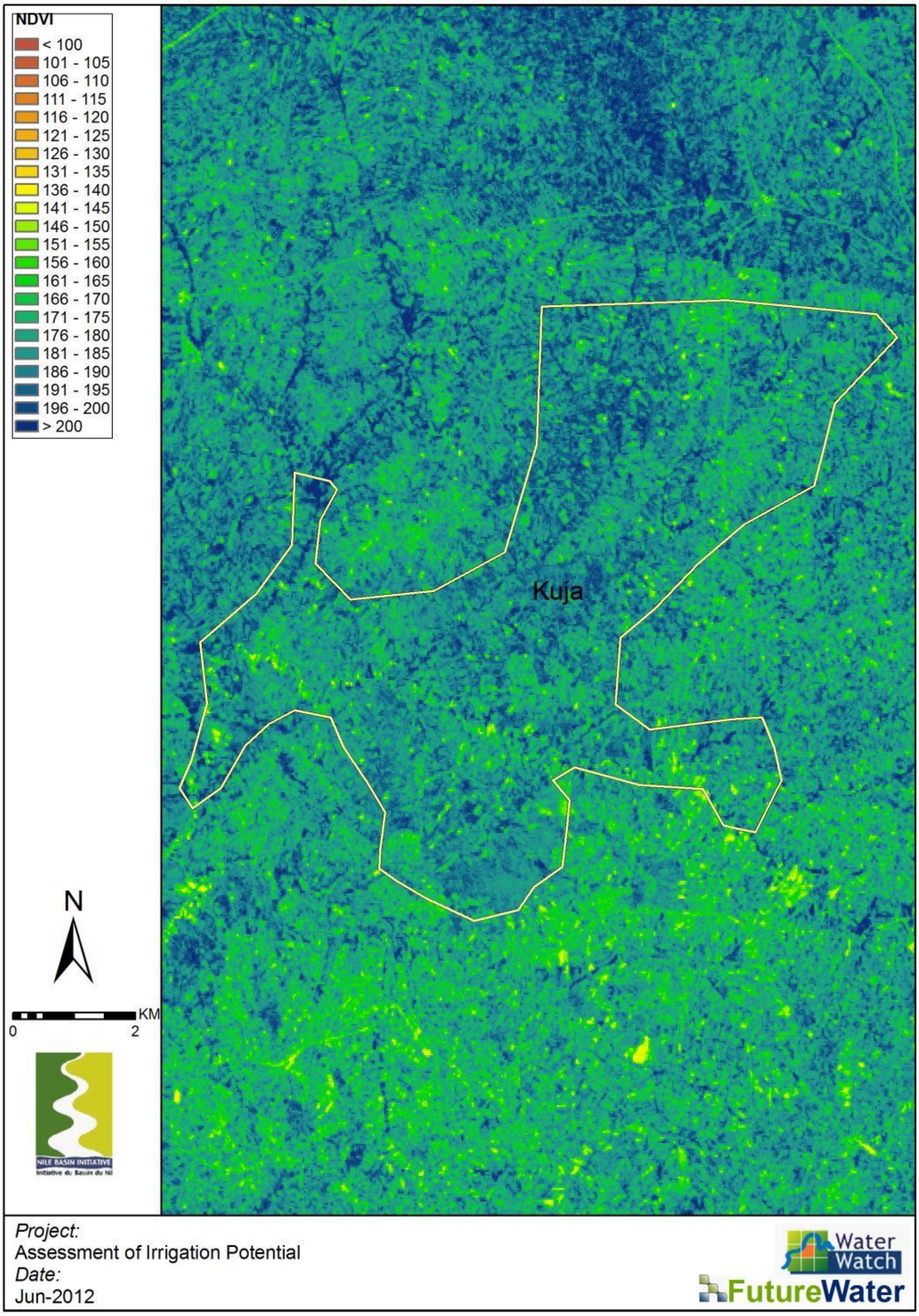



**Figure 37: High resolution NDVI for KUJA focal area**

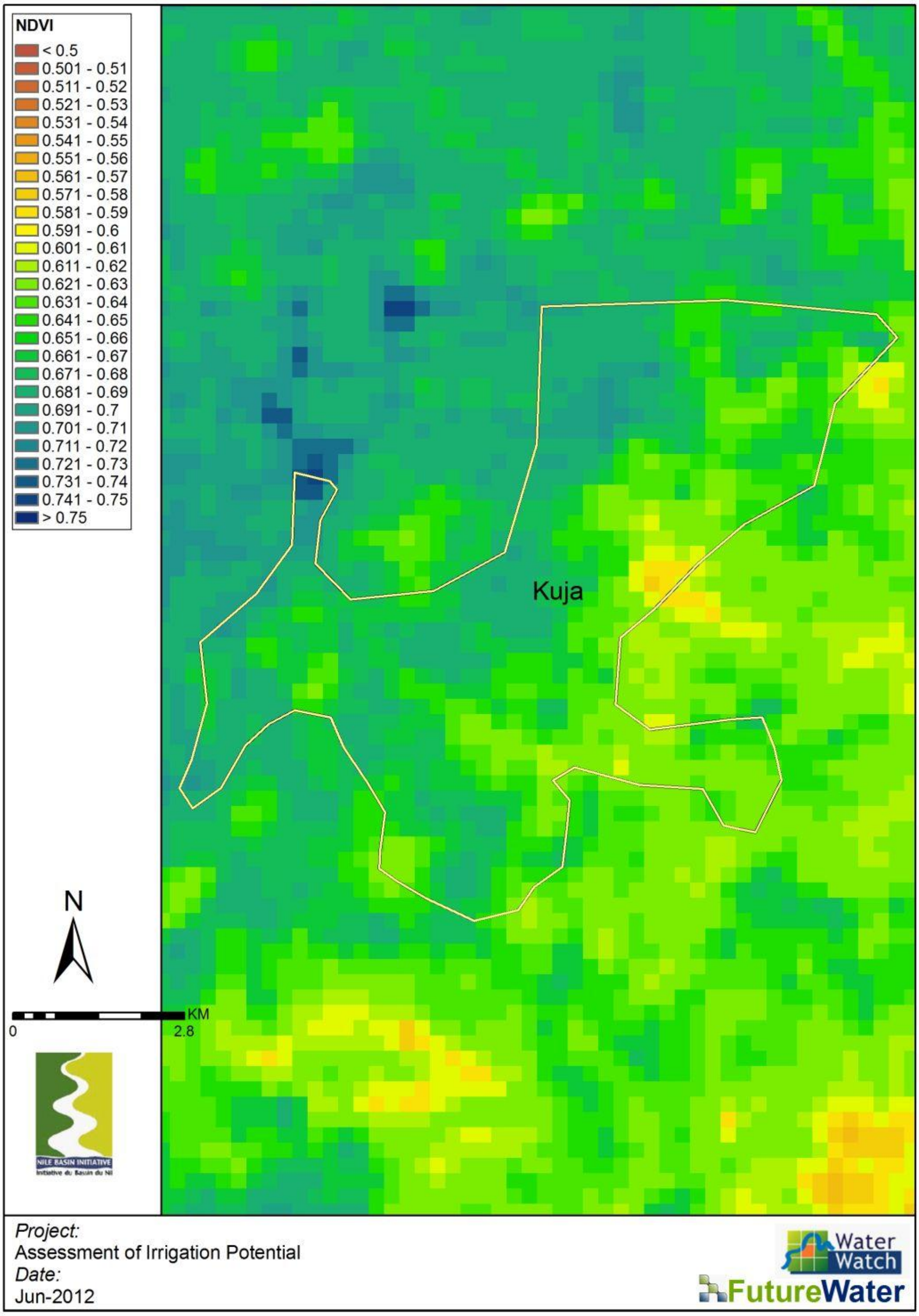



**Figure 38: Yearly average NDVI values for KUJA focal area.**

### 3.2.4 Potential cropping patterns

Field assessments have shown that currently approximately 45% of the land is used for agriculture. Most dominant crops are Sorghum, Maize, and Cassava. Sorghum is grown in two growing cycles per year, first from February until July, and secondly in the other half year. Average yields range from 350-550 kg/ha. Maize follows the same growing cycles as sorghum and has a higher yield with about 700 kg/ha. Cassava is perennial crop which is grown continuously and has yields of approximately 1000 kg/ha. According to Kenya national irrigation policy agriculture is the backbone of Kenya's economy and has a central place in realizing national aspiration and poverty reduction. The make agriculture more independent of the unreliable rainfall patterns Kenya must embrace irrigation and drainage development to remain competitive. Irrigation will also significantly contribute to the meeting of the demands for national food security as well as the sophisticated and emerging export markets for food, fiber, oil crops, animals and fisheries products. Diversification of crops will be enhanced to contribute fully to food security and industrialization. Practically for this focal area this means that paddy rice is a very suitable crop especially seen the soil qualities. Other potential crops suggested during the field assessments are Tomatoes, Capsicums, Cabbage/Kales and Pineapples.

## 3.3 Water resource assessment

### 3.3.1 Climate

Total precipitation in the focal area is 1370 mm per year, while reference evapotranspiration is 1480 mm per year. So there is a clear scope for improvement of crop water requirements by irrigation. Differences between minimum and maximum temperature is quite large and are 17$^{o}$C and 29$^{o}$C respectively.

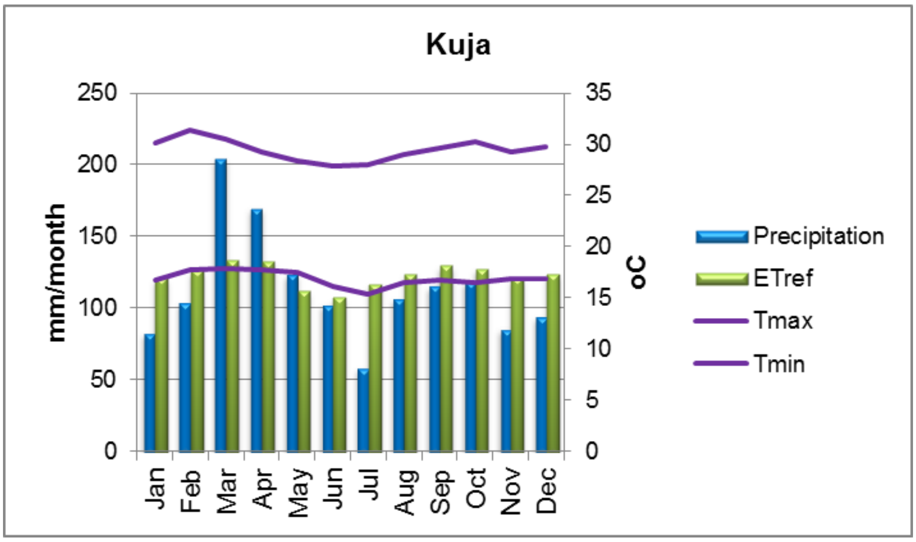



**Figure 39: Average climate conditions for KUJA focal area.**

### *3.3.2 Water balance*

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

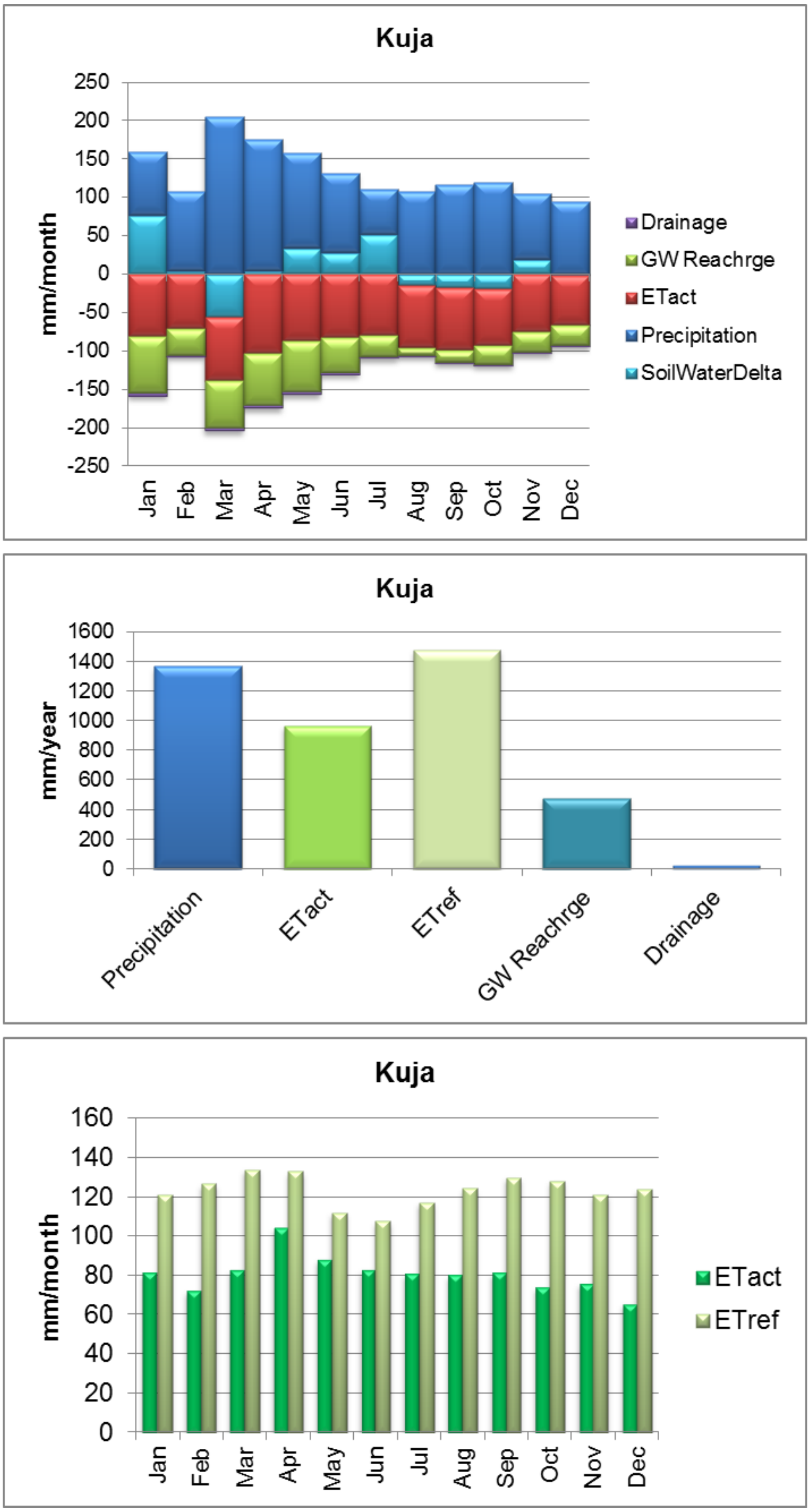
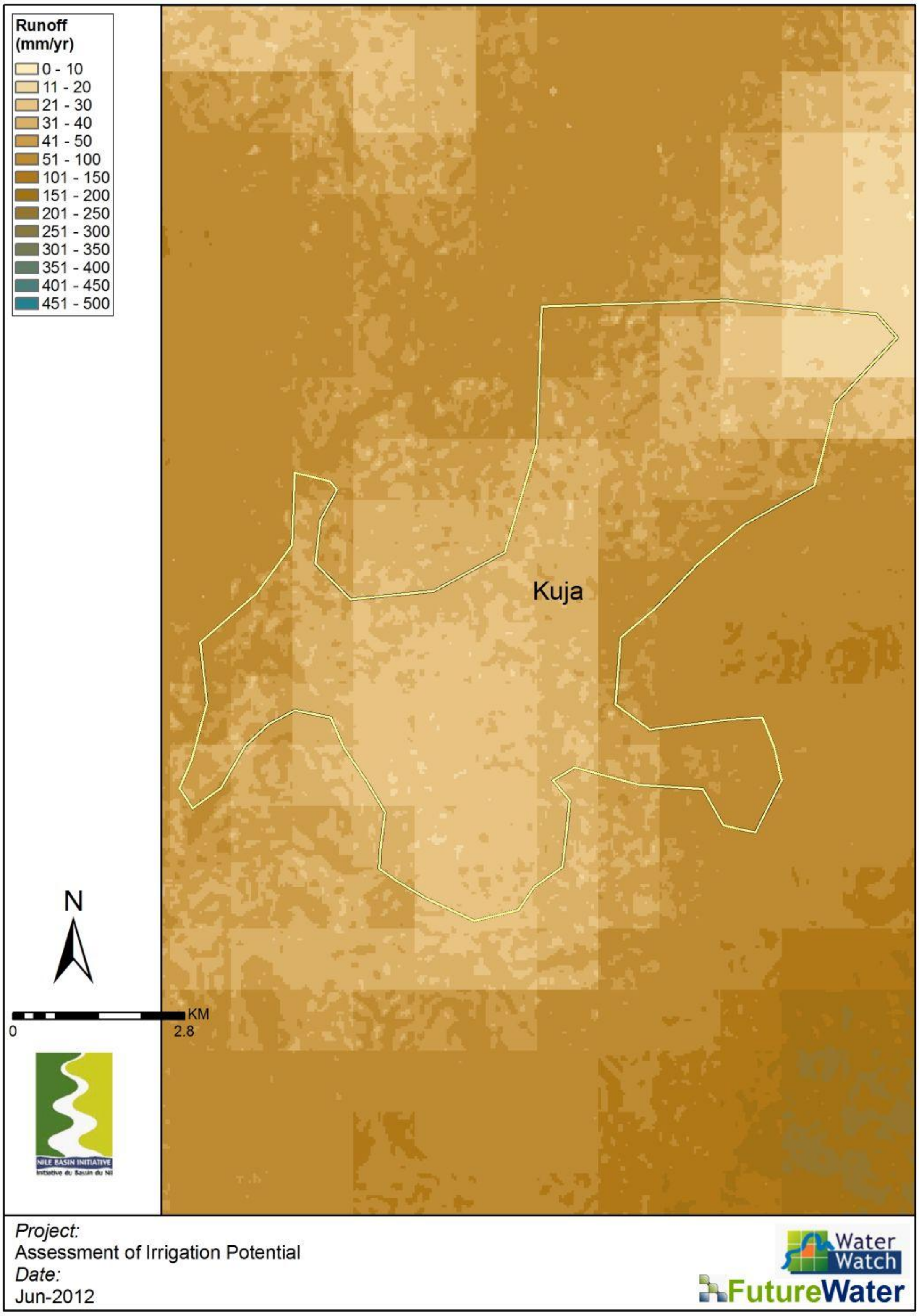
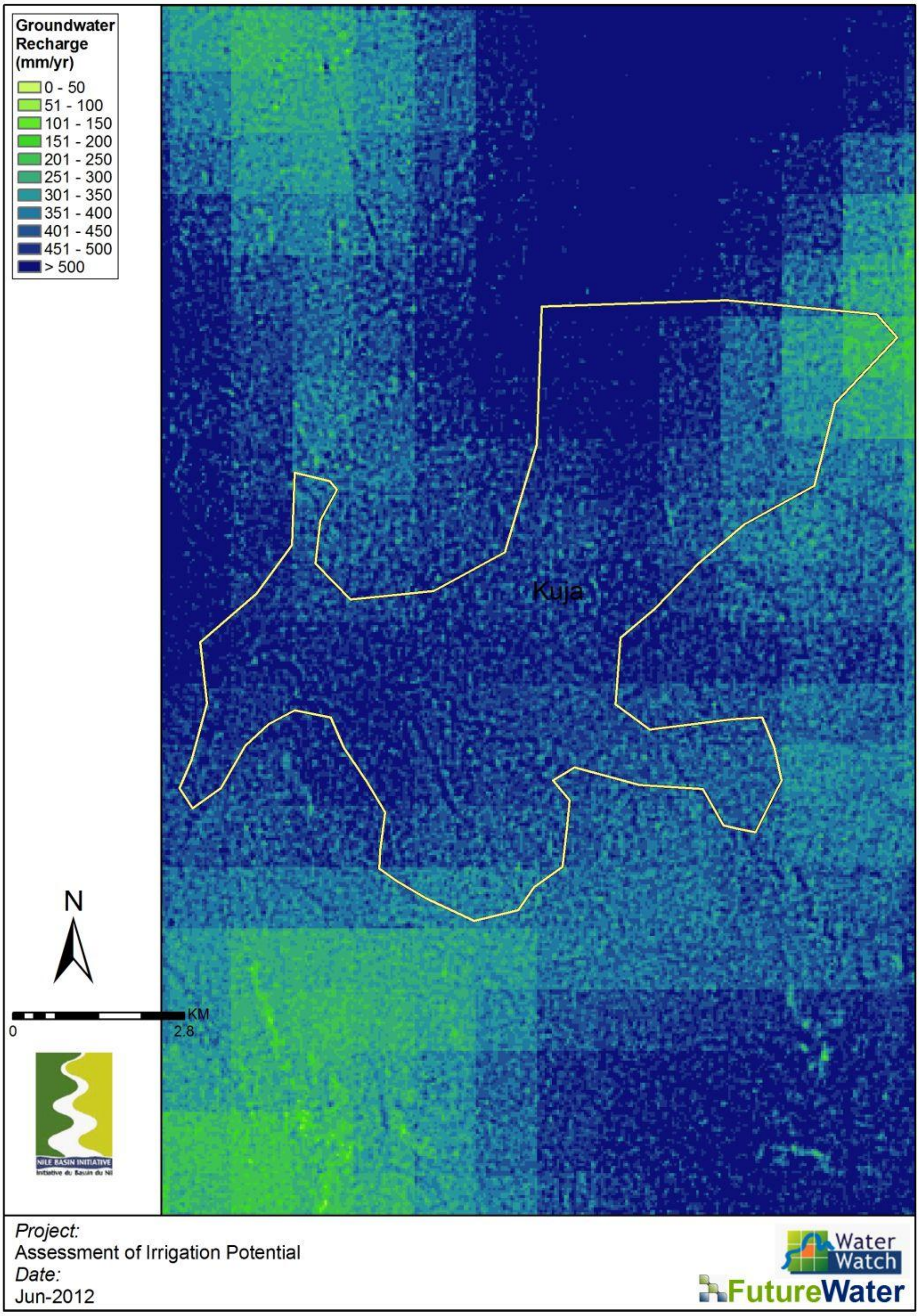



**Figure 40: Water balances for the area based on the high resolution data and modeling approach for KUJA focal area.**


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
Kuja
N
KM
0
2.8
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
Kuja
N
0
2.8
KM
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

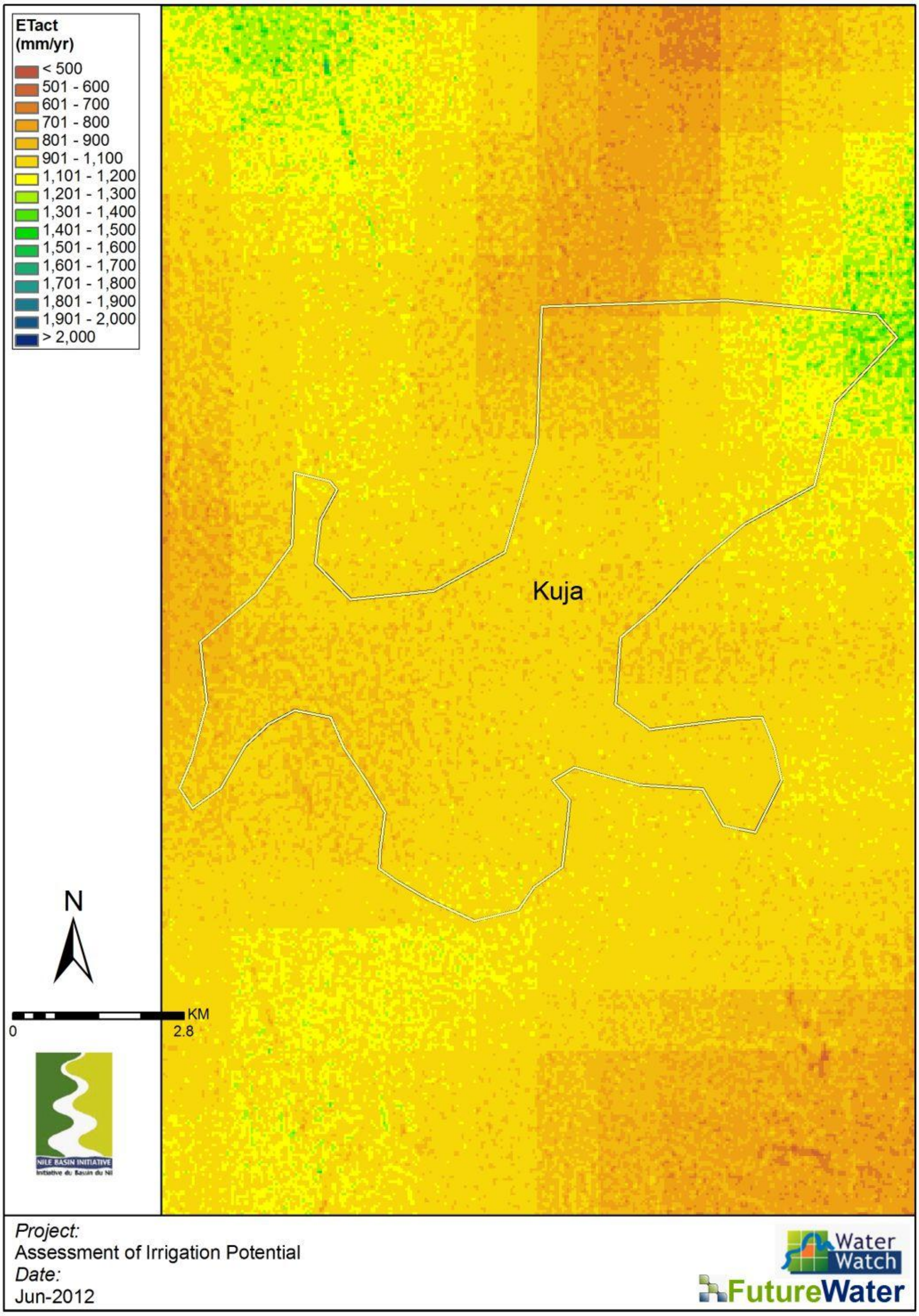



**Figure 41: Water balances for the area based on the high resolution data and modeling approach for KUJA focal area.**

## 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.

All input files and output files for AquaCrop can be found in the database attached to the reports. Note that during this pre-feasibility phase focus with AquaCrop was to obtain crop water requirements. A subsequent feasibility study could focus more on the crop yield validation and calibration components of AquaCrop.

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

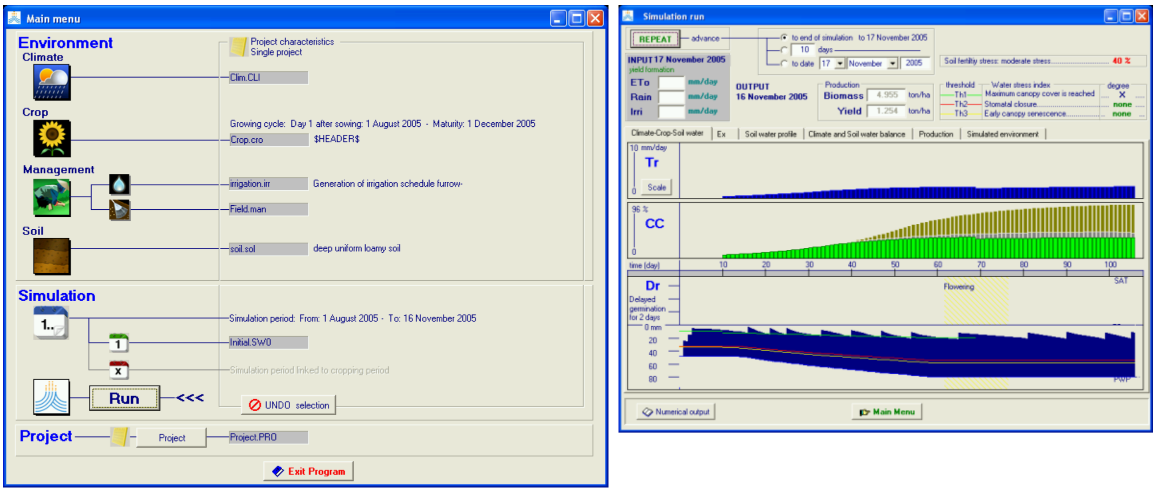



**Figure 42: Typical example of AquaCrop input and output screens.**

**Table 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 | Harvests | Rain | Irrigation | ETref | ETact |
|---|---|---|---|---|---|---|---|---|
| | === year | === | == (day of year) == | | ======== growing season | ======= | | |
| | (mm) | (mm) | | | (mm) | (mm) | (mm) | (mm) |
| Tomatoes | 1368 | 1479 | 1 | 365 | 1369 | 160 | 1474 | 1088 |
| Capsicums | 1368 | 1479 | 1 | 365 | 1369 | 160 | 1474 | 1088 |
| Kales | 1368 | 1479 | 1 | 365 | 1369 | 160 | 1474 | 1088 |
| Pineapples | 1368 | 1479 | 1 | 365 | 1369 | 250 | 1474 | 1087 |
| Rice | 1368 | 1479 | 121 | 304 | 625 | 220 | 723 | 644 |
| Cassava | 1368 | 1479 | 151 | 30 | 766 | 240 | 978 | 730 |

### 3.4.2 Irrigation systems and irrigations efficiencies

Three rivers are flowing through the area. One coming from the North East, with an yearly average flow of $8m^3/s$, Kuja river coning from the East, with yearly average flow of $12\ m^s/s$ and one smaller one from the North with an average flow if $1.5\ m^3/s$. The abundance of streams has developed this area already as a strong agriculture orientated area. The average water availability will be enough to irrigate over 20,000 ha. This means that whole of the focal area can be covered when other factors allow to. In the best situation the water can be diverted from the river upstream so that the fields can be irrigated under gravity. In that case either furrow or border irrigation is recommended. These two techniques no not require high investments as they are relatively cheap compared to pressurized irrigation systems such as sprinkler or drip irrigation. On top of that the farmers can get used to flood irrigation much easier as pressurized irrigation which enhances a sustainable irrigation system, which can be managed by the farmers. Efficiencies of flood irrigation are relatively low. After conveyance and application efficiency correction about 40% of the water is used effectively. For pressurized systems this is much higher, and can reach up to 70-80%.

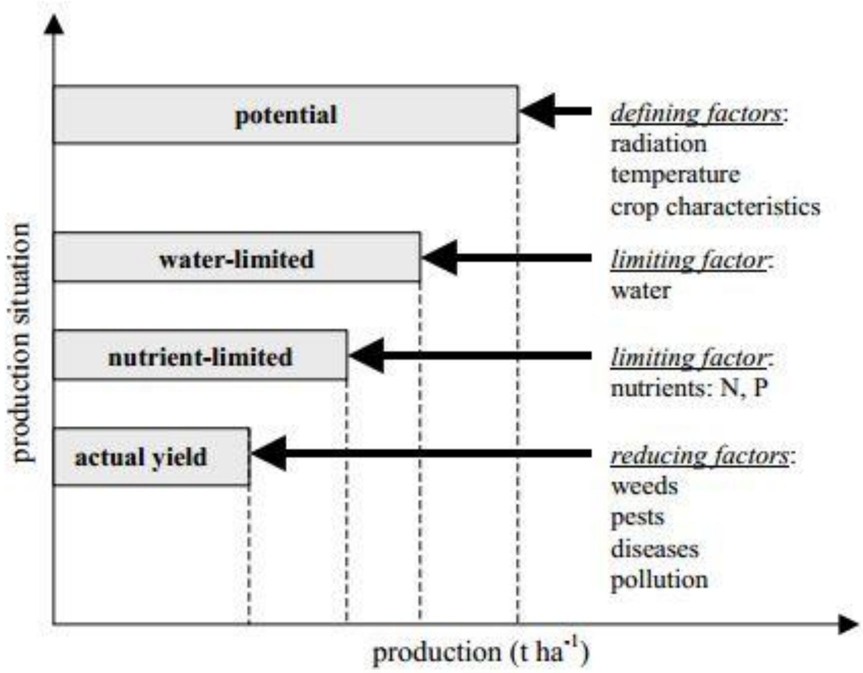
### 3.4.3 Water source

The water source will be Kuja River and the stream coming from the North. The Kuja river drains a large area of 1200 $km^2$, and has a yearly average flow of $12m^3/s$. The streams from the North drain an area of approximately 400 $km^2$. On average this water will be more than sufficient to irrigate the whole area. The only constraint will be the large seasonal variety of the river flow. Therefore stream control structures will be required, in combination with storage capacity.

## 3.5 Potential crop yield assessment

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

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximal 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*

Average Kenyan yields are the lowest of all research countries. Within the focal areas however the conditions are favorable and yields high, even compared to surrounding countries. For this focal area is chosen to focus on high value crops, which give good return. This can be seen in Figure 43. These potential crops will al give an excellent yield under irrigation, and will be very rewarding. It is expected that the gains with these potential crops can double or triple per hectare.

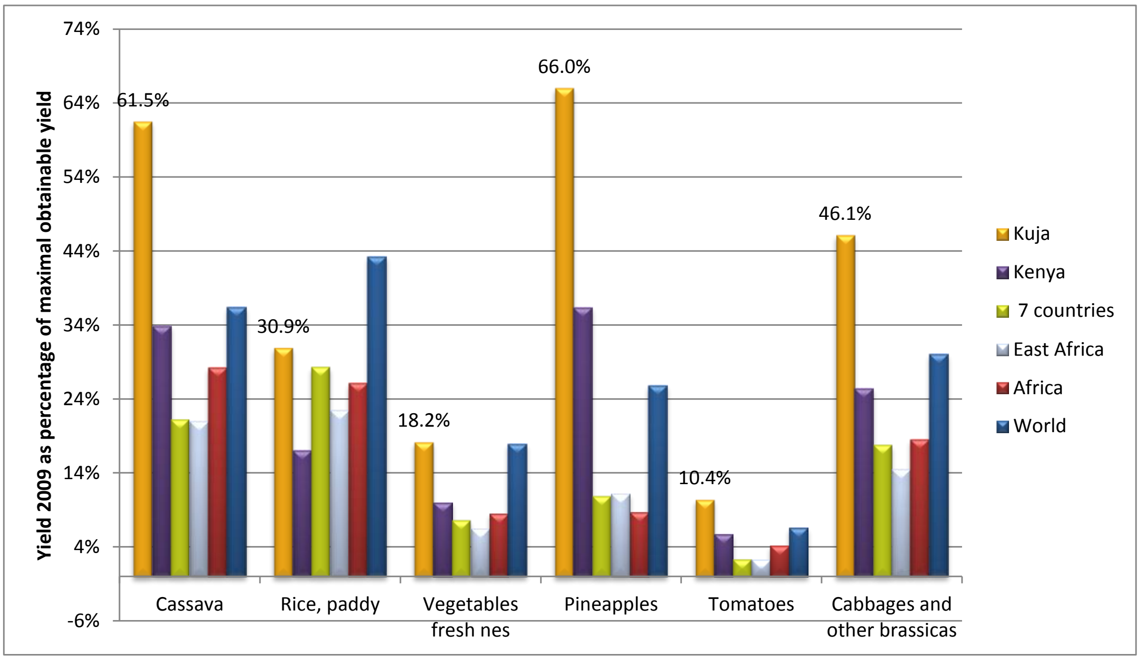



**Figure 43: Yield gap Kuja (source: FAOSTAT, 2012).**

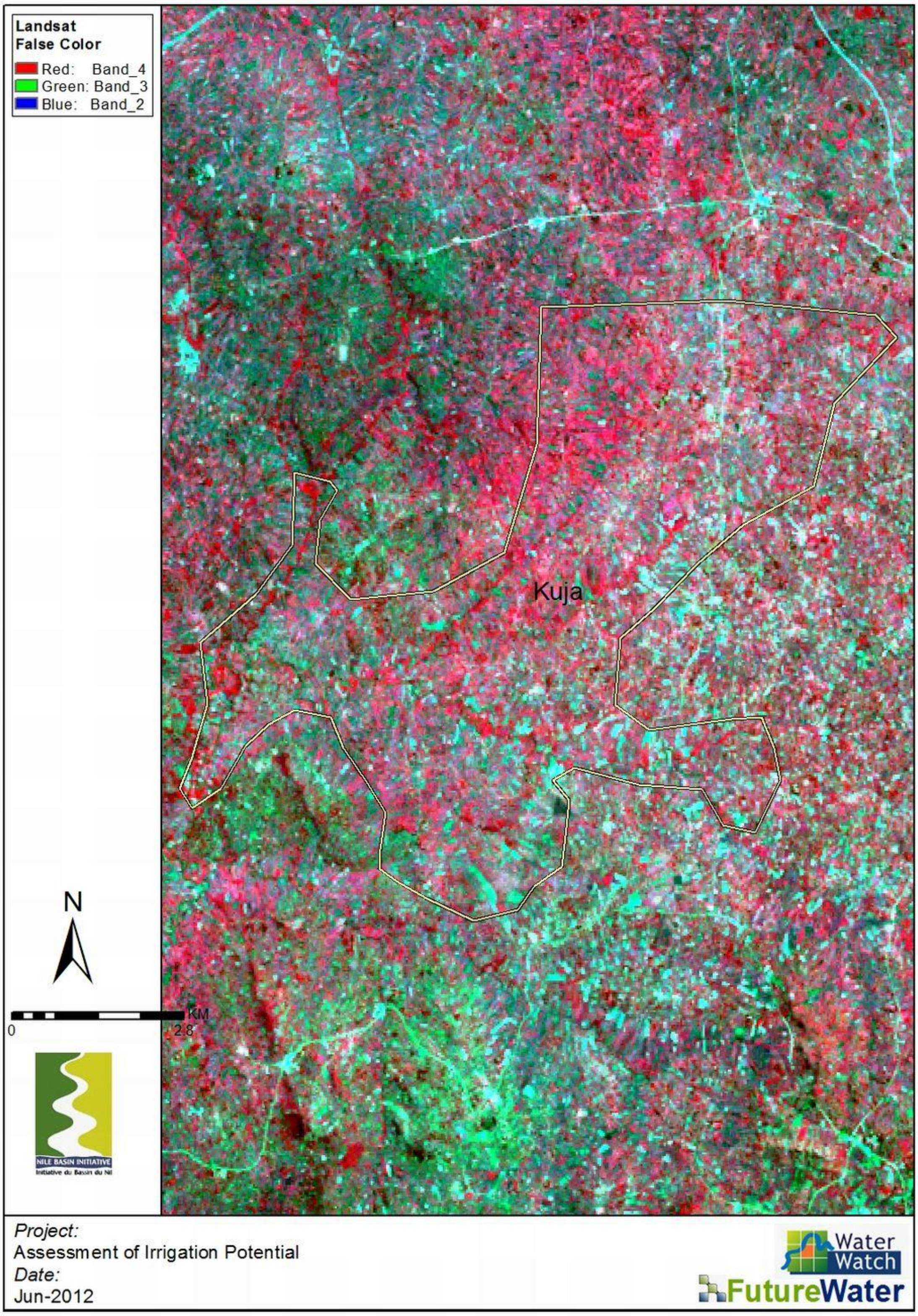



**Figure 44: Landsat False Color Composite indicating current productivity of the area for KUJA focal area.**

## 3.6 Environmental and socio-economic considerations

### *3.6.1 Population displacements*

The area is quite densely populated, but there are no settlements within the area. All people live extremely scattered around the area. This makes is rather difficult to design a large scale irrigation system. With the design of any irrigation scheme, it is advised to limit any population displacement and to develop the irrigation scheme as much as possible 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. Whenever population displacement is thought to be necessary, this should be discussed and decided together with inhabitants, local government and other stakeholders.

### *3.6.2 Social*

Within Kenya 85% of the land area is classified as Arid and Semi-Arid Lands (ASAL) and the remaining 15% sustain more than 75% of the population. Therefore the population density in Nyanza and Western province are the highest of Kenya, with respectively 350 and 406 people per km2. This is very high compared to Kenyan average of 56 inhabitants/$km^2$. Within the focal area the population density is estimated to be slightly lower with 211 inhabitants/$km^2$. The rapidly increasing population is largely the cause for degradation of the catchment and degradation of this focal area. Deforestation, river bank cultivation and compromising water quality are some examples of the raising pressure on the water and land resources, which weaken the adaptation possibilities of the ecosystem. Most people in the area belong to the Luo tribe. Infrastructure in the area is not developed well. Tarmac roads are passing by the focal area, but within the focal area all roads are weathered dirt roads. For irrigation development the infrastructure should be strengthened to make it easier to bring construction material and agricultural inputs, and to reach the nearby markets with the products. Nearby markets include Migori, Kisii, or further away the larger towns Kisumu, Musoma or Nakuru. The farmer's knowledge about irrigation and agricultural cooperatives is low. When developing an irrigation scheme extra attention should be paid to this social part. Unemployment rate in this area is very high, irrigation development can create more agro-related jobs and as such reduce unemployment and poverty. In Nyanza and Western province the percentage of woman as head of a household is highest in Kenya with 38%. The net enrollment rate for primary schools in Nyanza province is 98.7% which is the second highest of Kenya, and well above the Kenyan average of 92.9%. Literacy rate is the highest of Kenya with 90.45% of the population. The gender parity index for the enrollment ratio on secondary schools shows a negative trend for Nyanza province, decreasing from 0.737 in 2002 to 0.694 in 2009. HIV prevalence in Nyanza province is the highest in Kenya with 13.9% of the population being infected.

### *3.6.3 Upstream downstream consideration*

Since the upstream catchment (1600 $km^2$) and discharge are not enormously large, the water availability for irrigation should be considered well. Upstream and downstream of the focal area, people should still have enough water available to practice agriculture, and have water for living. Population pressure stimulates the use of resources in an unsustainable way. This may lead to land and environmental degradation. To enhance the environmental aspects upstream-, within- and downstream of the focal area, it is advised to search for measures which retain the precipitation water firstly, and try to store it upstream. This will enhance the upstream ecosystem, and groundwater levels. On a larger scale the groundwater is recharged, which can become available downstream, and evaporation enhances the water cycle and the precipitation in the area. The use of fertilizer is recommended, but it is needed to use fertilizer in a responsible and well considered way. Otherwise the water quality downstream may be compromised.

#### *3.6.4 Protected areas*

Within the focal area no protected areas are reported.

## 3.7 Benefit-cost Analysis

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

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

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Tomatoes: 20,000 kg/ha, 0.85 $/kg
    - Capsicums: 14,000 kg/ha, 0.90 $/kg
    - Kales: 13,000 kg/ha, 0.07 $/kg
    - Pineapples: 90,000 kg/ha, 0.22 $/kg
    - Rice: 6,750 kg/ha, 1.55 $/kg
    - Cassava: 7,000 kg/ha, 0.28 $/kg

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

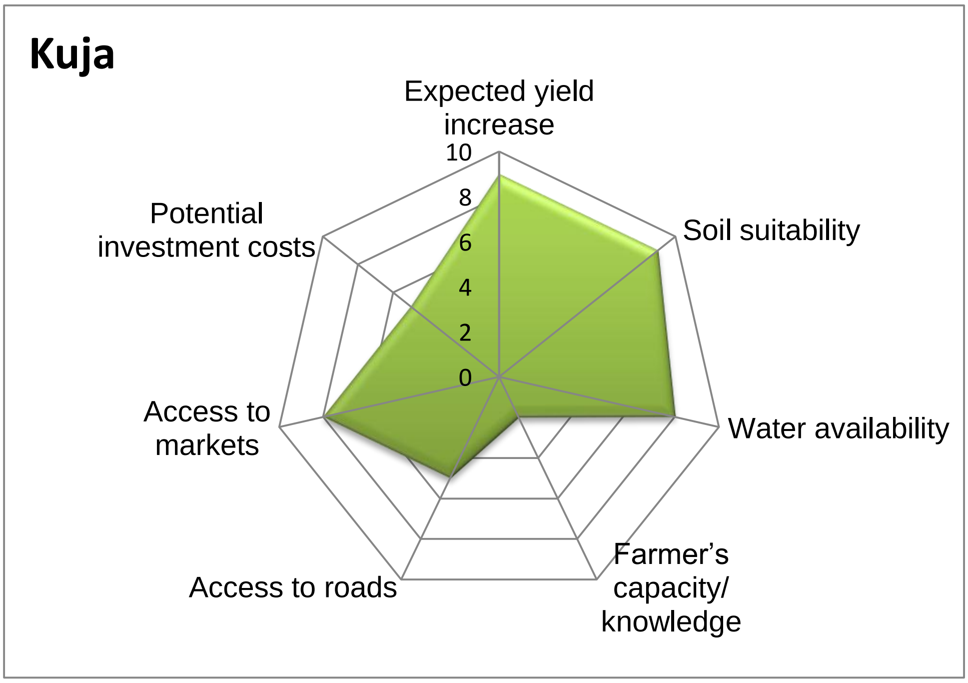



**Figure 45: Filled radar plot indicating expert knowledge score to develop irrigation in the Kuja focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).**

**Table 7: Benefit-cost analysis for Kuja area.**

| | |
|---|---|
| **Characteristics** | |
| Irrigated land (ha) | 3,500 |
| Farmers | 4,375 |
| **Investment Costs** | |
| Irrigation infrastructure (US$/ha) | 4,000 |
| Social infrastructure (US$/farmer) | 750 |
| Accessibility infrastructure (million US$) | 4.0 |
| **Operational Costs** | |
| O&M irrigation (US$/ha/yr) | 60 |
| Extension service (US$/farmer) | 15 |
| O&M roads (US$/yr) | 80,000 |
| **Summary** | |
| Initial investments (million US$) | 21.3 |
| O&M costs (million US$/yr) | 0.356 |
| Net benefits per year (million US$/yr) | 21.951 |
| IRR (Internal Rate of Return) | >100% |

# 4 Kano plains focal area

## 4.1 Introduction

This chapter will describe the current state of the Kano plains focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations and institutional frameworks. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 47 a detailed map of the area is given. Total area is 5141 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 Jacqueline Oseko and Hosea Wendot as supervisor in June 2012

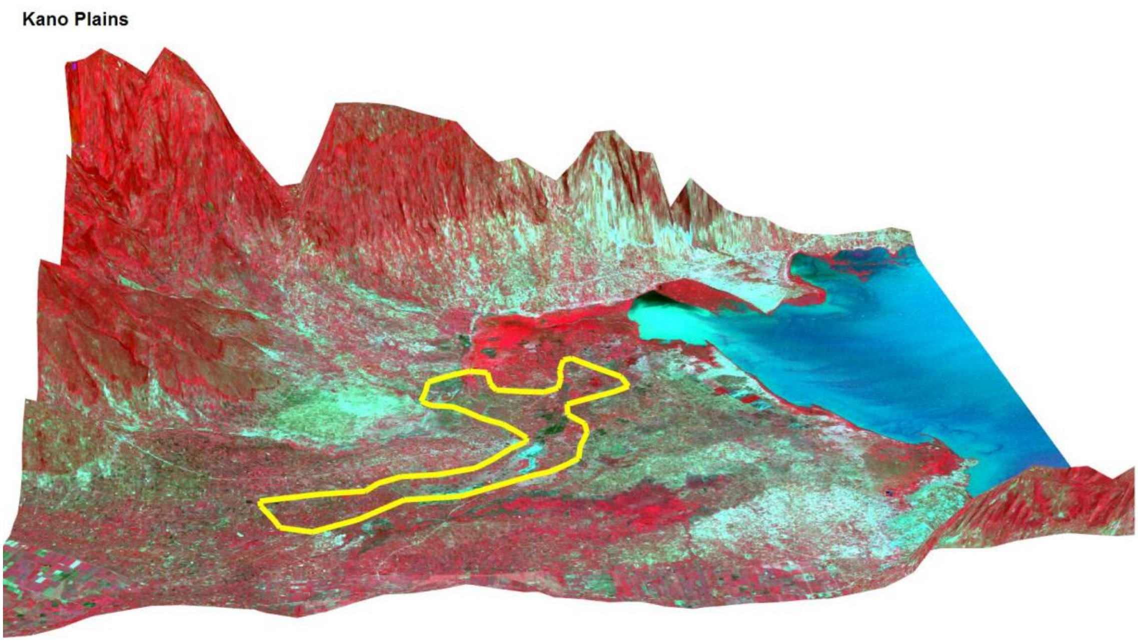



**Figure 46: 3D impression of Kano plains focal area, Kenya**

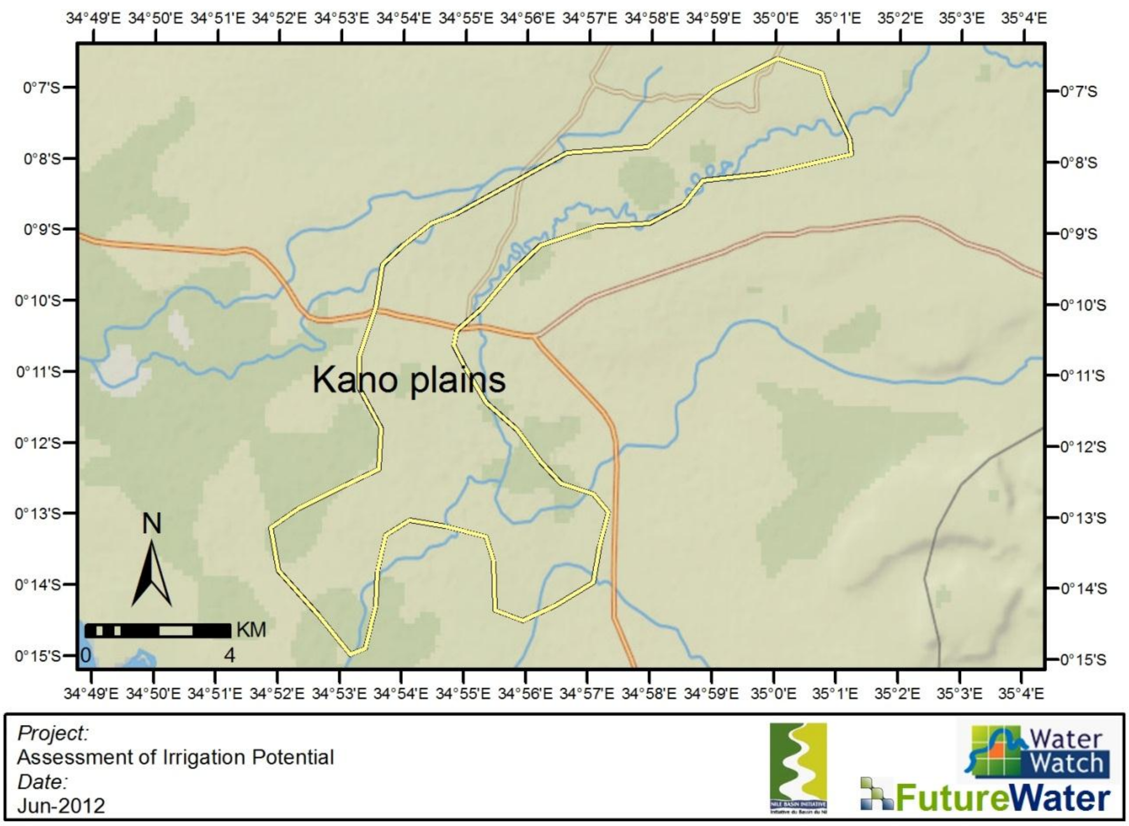




**Figure 47: Kano plains focal area, Kenya**

## 4.2 Land suitability assessment

### *4.2.1 Terrain*

Kano plains focal area is situated in western Kenya within Nyanza province and Nyando District. Slopes are very gentle, and the area descends slightly from East to West. Elevation in the east is 1180m which descends approximately 40 meters towards 1140 meter in the South West. (Figure 48 and Figure 45) Slopes reach up to 10% very locally, but on average they stay under 2%. (Figure 49) The area is very uniform in topography which makes it very suitable for large scale irrigation if water is available abundantly.

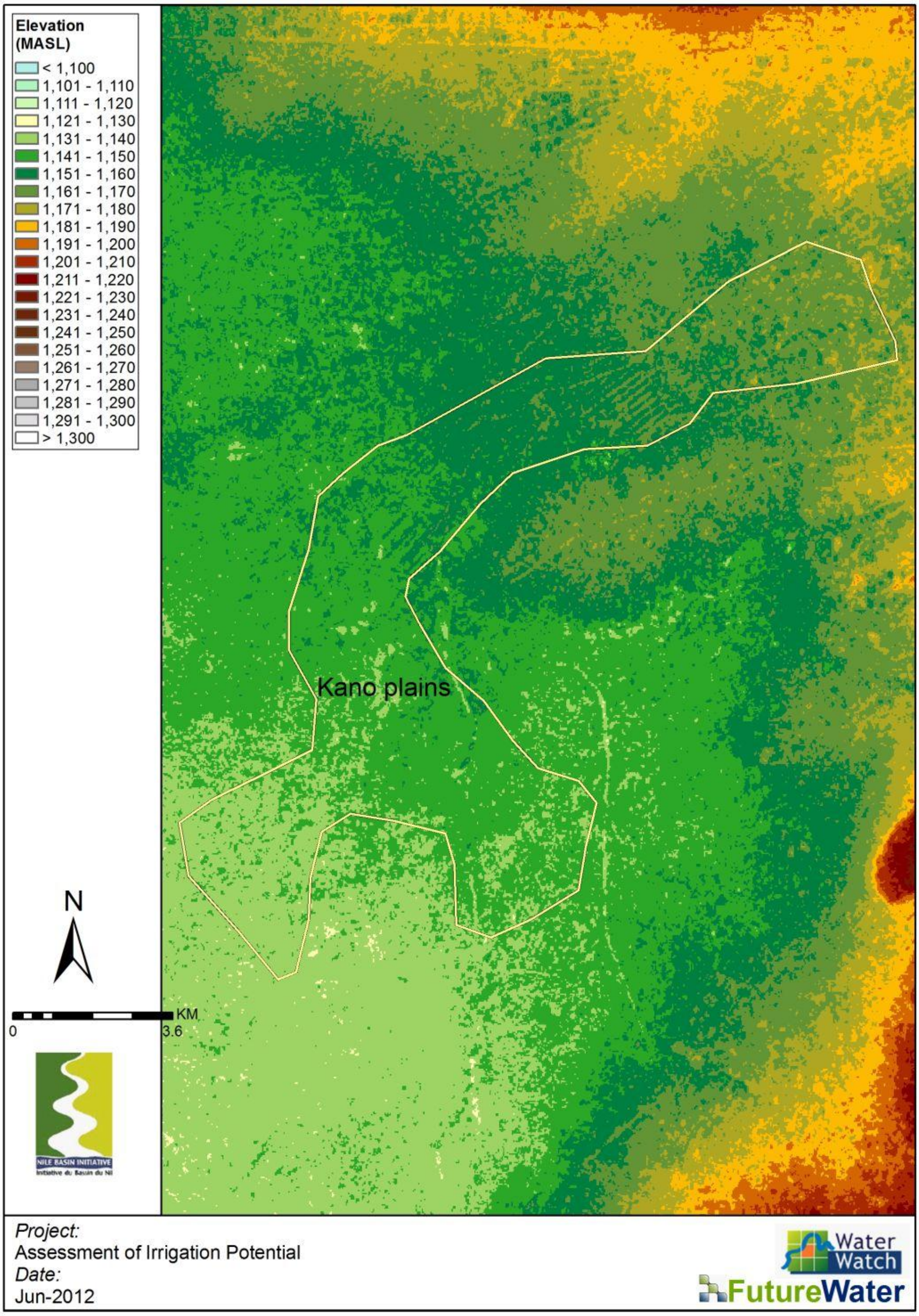



**Figure 48: DEM Kano plains focal area. Resolution 1 arc second (+/- 30m)**

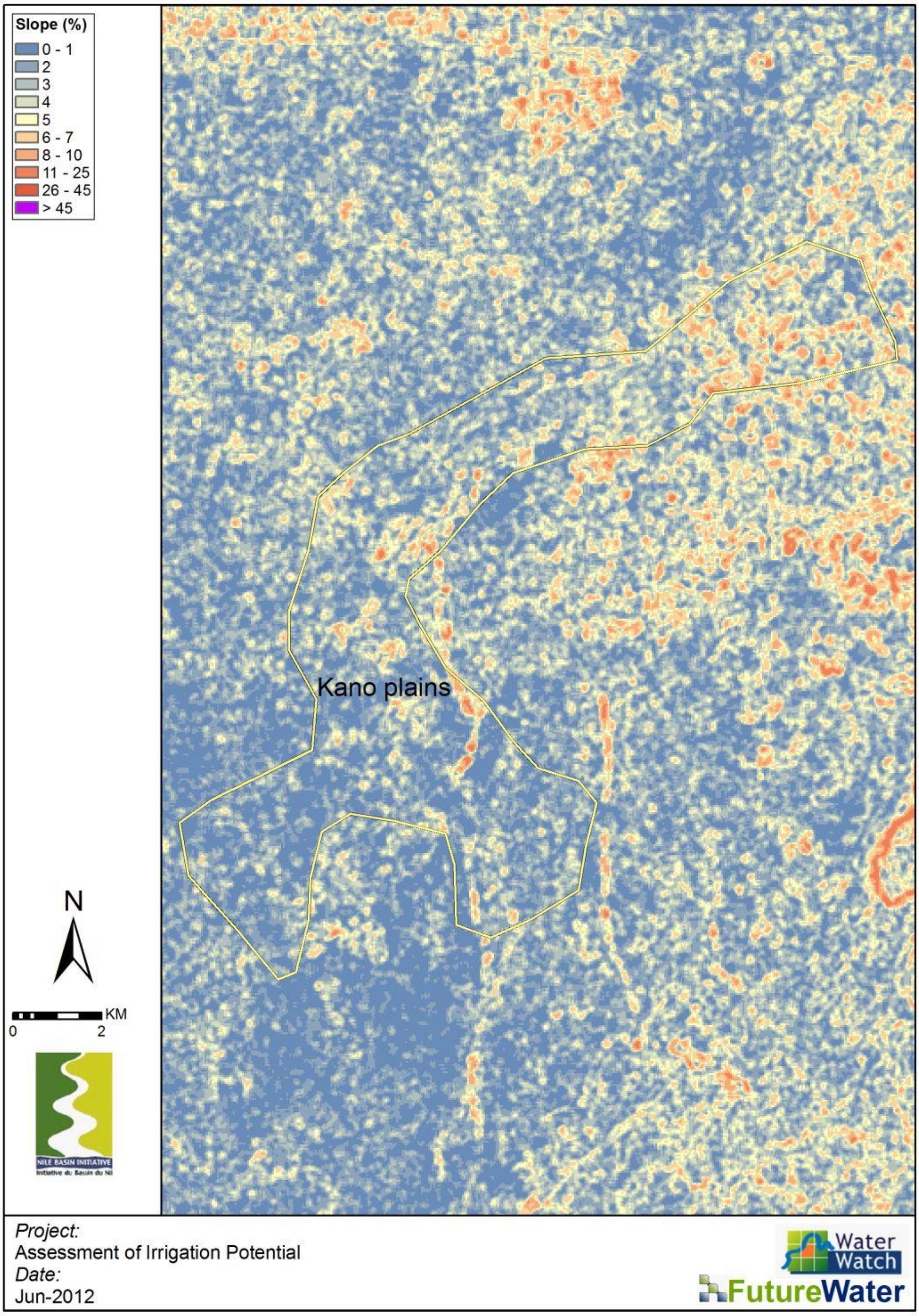



**Figure 49: Slope map Kano plains focal area (source: ASTER).**

### *4.2.2 Soil*

The soil texture within the focal area ranges but is mainly clayey loam. The percentage of organic carbon in the top soil is relatively low with around 0.5%. Drainage capacity is somewhat poor to poor. The soil is deep, and has an available water holding capacity of 125-150 mm/m. This soil is typically formed under alluvial processes, and can be mainly characterized as a Fluvisol, in combination with Cambisols and Vertisols. Paddy rice cultivation is widespread on tropical Fluvisols with satisfactory irrigation and drainage. Paddy land should be dry for at least a few weeks every year in order to prevent the redox potential of the soil from becoming so low that nutritional problems (Fe or H2S) arise. A dry period also stimulates microbial activity and promotes mineralization of organic matter. Many dryland crops are grown on Fluvisols as well, normally with some form of water control. 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. Vertisols contain a high proportion of swelling clays and form deep wide cracks from the surface downward when they dry out, which happens in most years. The agricultural uses of Vertisols range from very extensive (grazing, collection of fuelwood, and charcoal burning) through smallholder post-rainy season crop production (millet, sorghum, cotton and chickpeas) to small-scale (rice) and large-scale irrigated agriculture (cotton, wheat, barley, sorghum, chickpeas, flax, noug and sugar cane). Cotton is known to perform well on Vertisols, allegedly because cotton has a vertical root system that is not damaged severely by cracking of the soil. Tree crops are generally less successful because tree roots find it difficult to establish themselves in the subsoil and are damaged as the soil shrinks and swells.

### *4.2.3 Land productivity*

The annual average land productivity (NDVI) in the four Kenyan focal areas ranges between 0.59 and 0.66. In Kano plains focal area the NDVI is 0.59, which is high compared to the Kenya average NDVI of 0.36. (**Error! Reference source not found.**) Land productivity is extraordinary high on places where irrigation takes already place around the river, and besides the land productivity is rather uniform over the area. The coefficient variation in the area is mainly low, except for some irrigation schemes, and the most western tip of the focal area. This suggest that the land is not used year round for agricultural purposes.

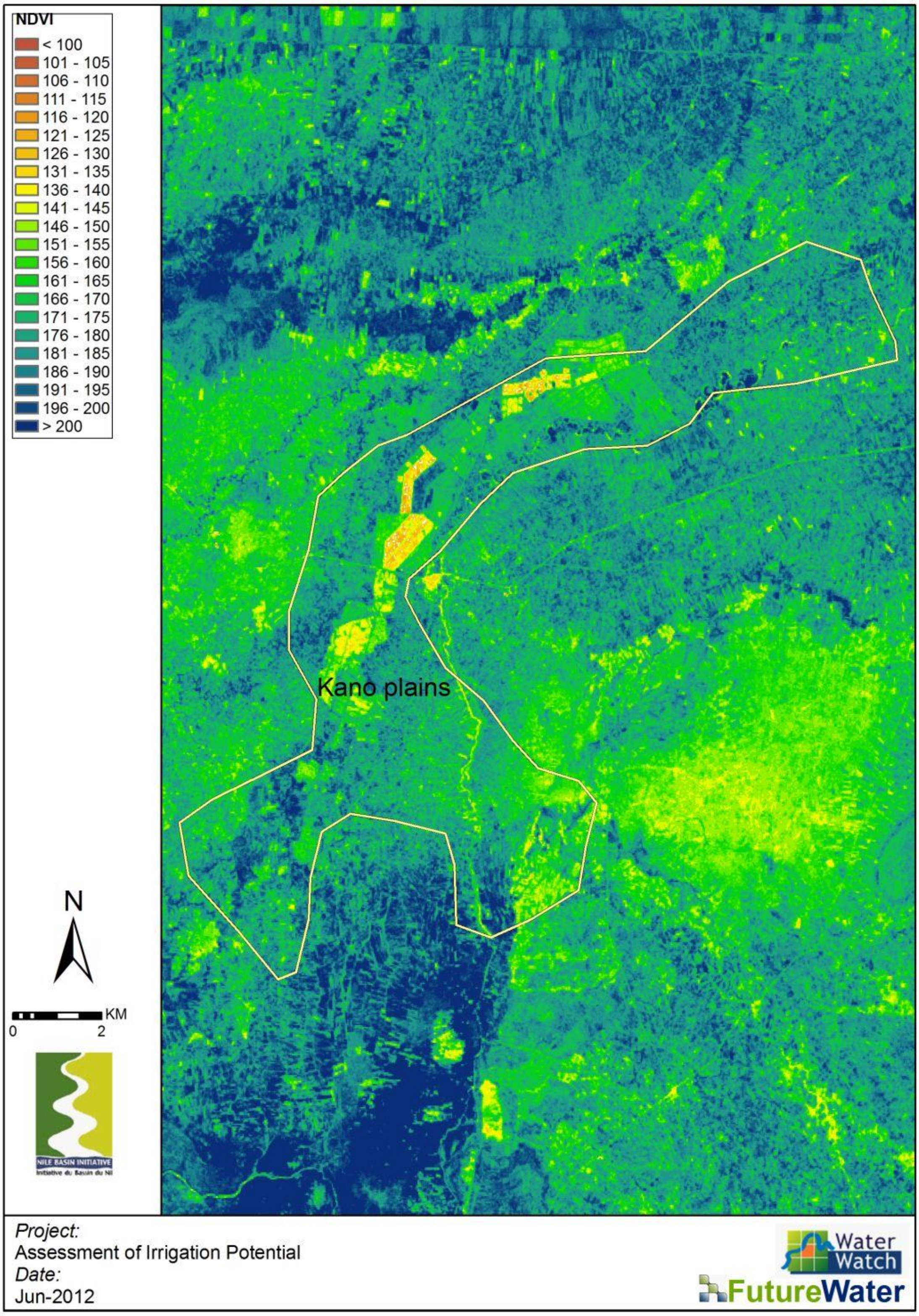



**Figure 50: High resolution NDVI for KANO Plains focal area**

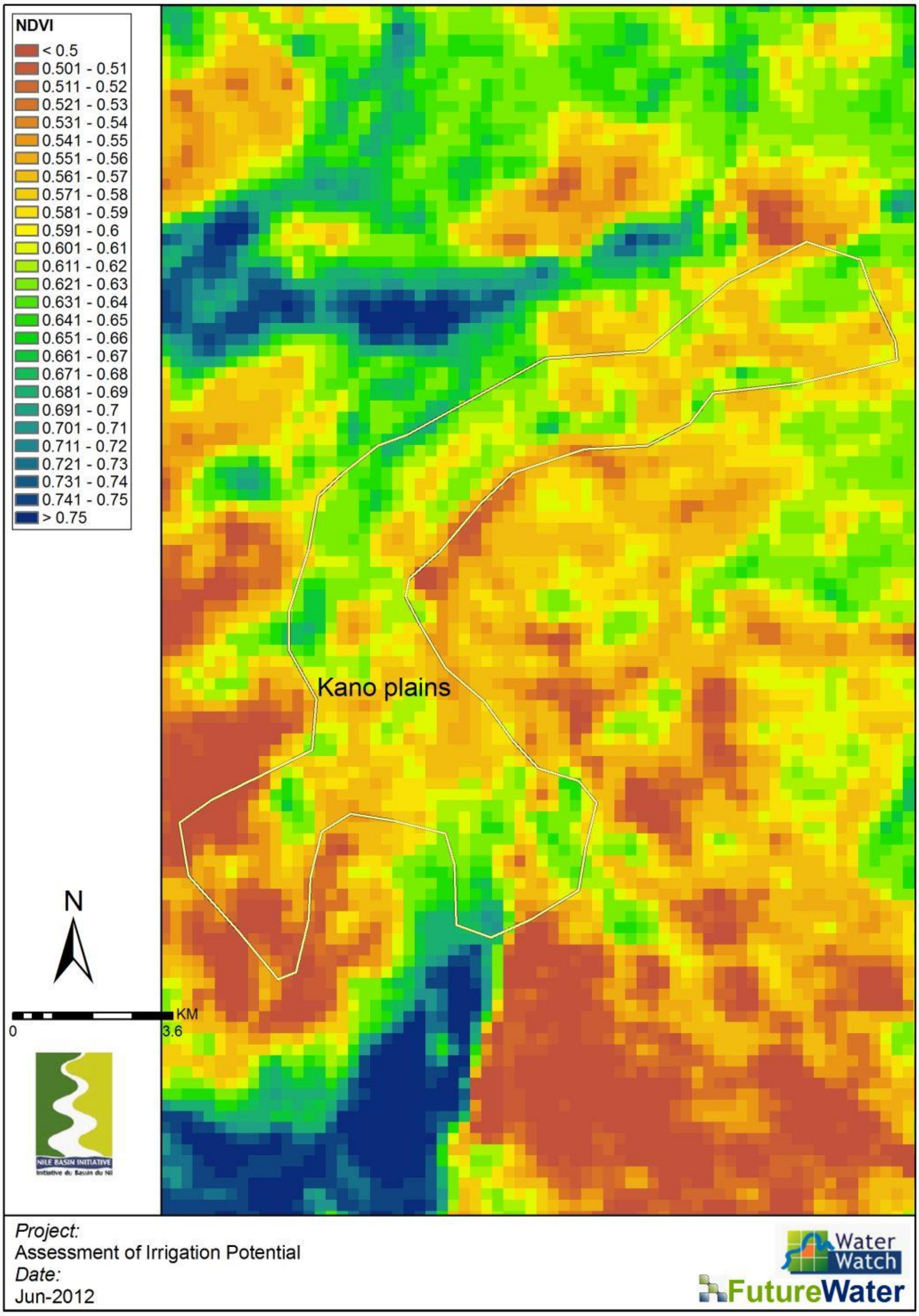



**Figure 51: Yearly average NDVI values for KANO Plains focal area.**

### 4.2.4 Potential cropping patterns

Field assessments have shown that currently approximately 80% of the land is used for agriculture. Most dominant crops are Maize, Sorghum, Paddy/rice and Sugarcane. Sorghum is grown in one growing cycle per year from March-April until July-August. Average yields range from 900-1100 kg/ha. Maize grows in two cycles firstly from March-April until July-August and secondly in the other half year. Yield are approximately 1350 kg/ha. Paddy/rice is growing I 1 growing cycle per year in the same period. Yields are around 45 bags or 4000 kg/ha. Sugarcane is a perennial crop which grows year round, and yields vary from 60-80 tons/ha. According to Kenya national irrigation policy agriculture is the backbone of Kenya's economy and has a central place in realizing national aspiration and poverty reduction. The make agriculture more independent of the unreliable rainfall patterns Kenya must embrace irrigation and drainage development to remain competitive. Irrigation will also significantly contribute to the meeting of the demands for national food security as well as the sophisticated and emerging export markets for food, fibre, oil crops, animals and fisheries products. Diversification of crops will be enhanced to contribute fully to food security and industrialization. Practically for this focal area this means that paddy rice is a very suitable crop. Other potential crops suggested during the field assessments are Onions, Tomatoes, Capsicums and Cabbage/Kales.

## 4.3 Water resource assessment

### 4.3.1 Climate

Total precipitation in the focal area is 1570 mm per year, while reference evapotranspiration is 1500 mm per year. So on a annual base precipitation is sufficient, but between October and February there is a clear scope for improvement of crop water requirements by irrigation. Differences between minimum and maximum temperature is quite large and are 18$^{o}$C and 30$^{o}$C respectively.

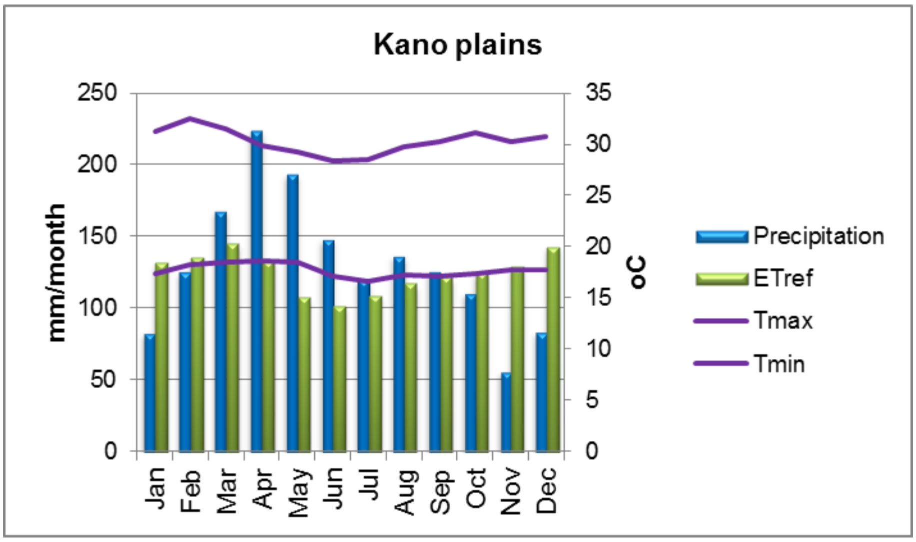



**Figure 52: Average climate conditions for KANO Plains focal area.**

### 4.3.2 Water balance

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

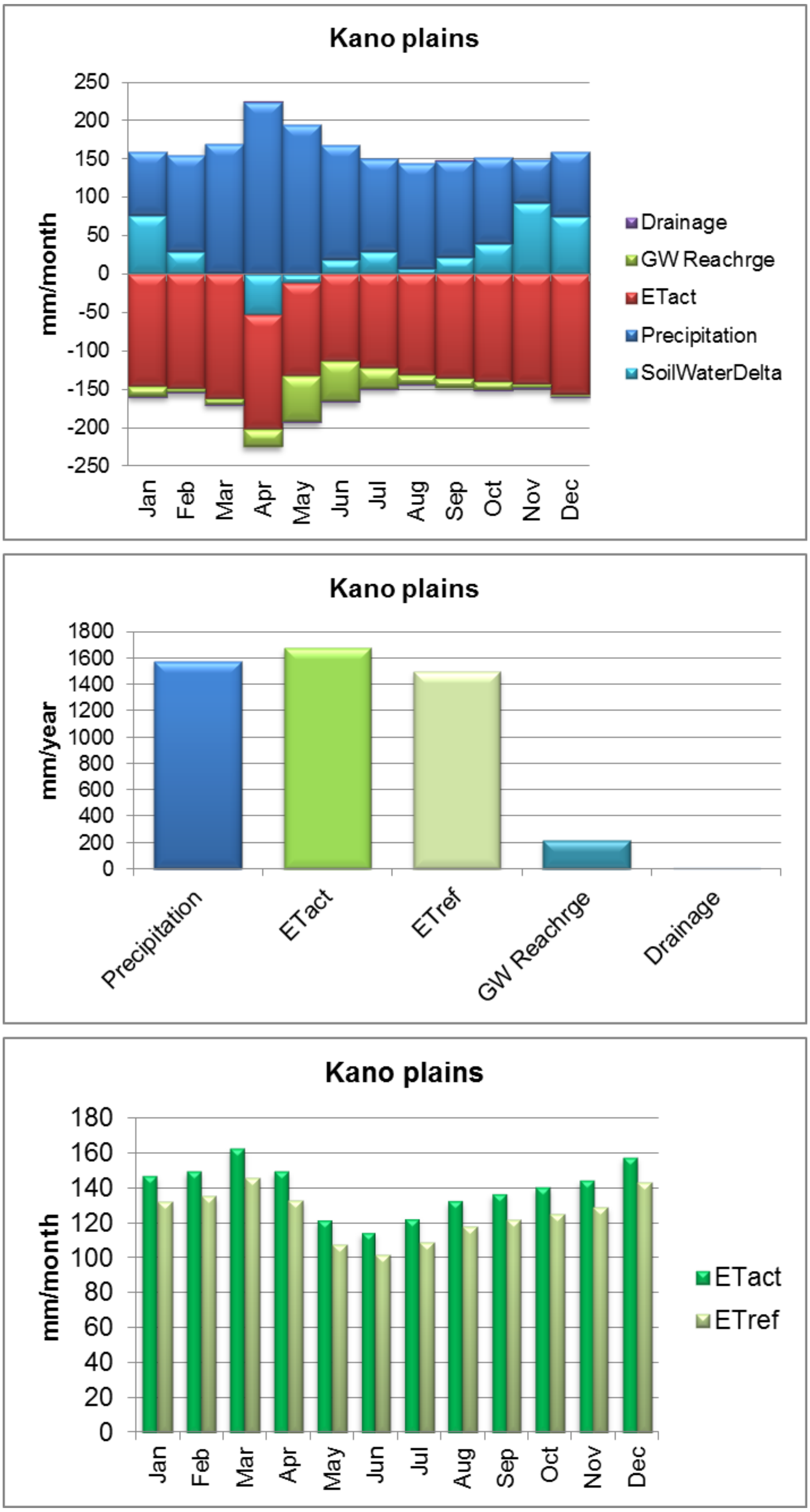
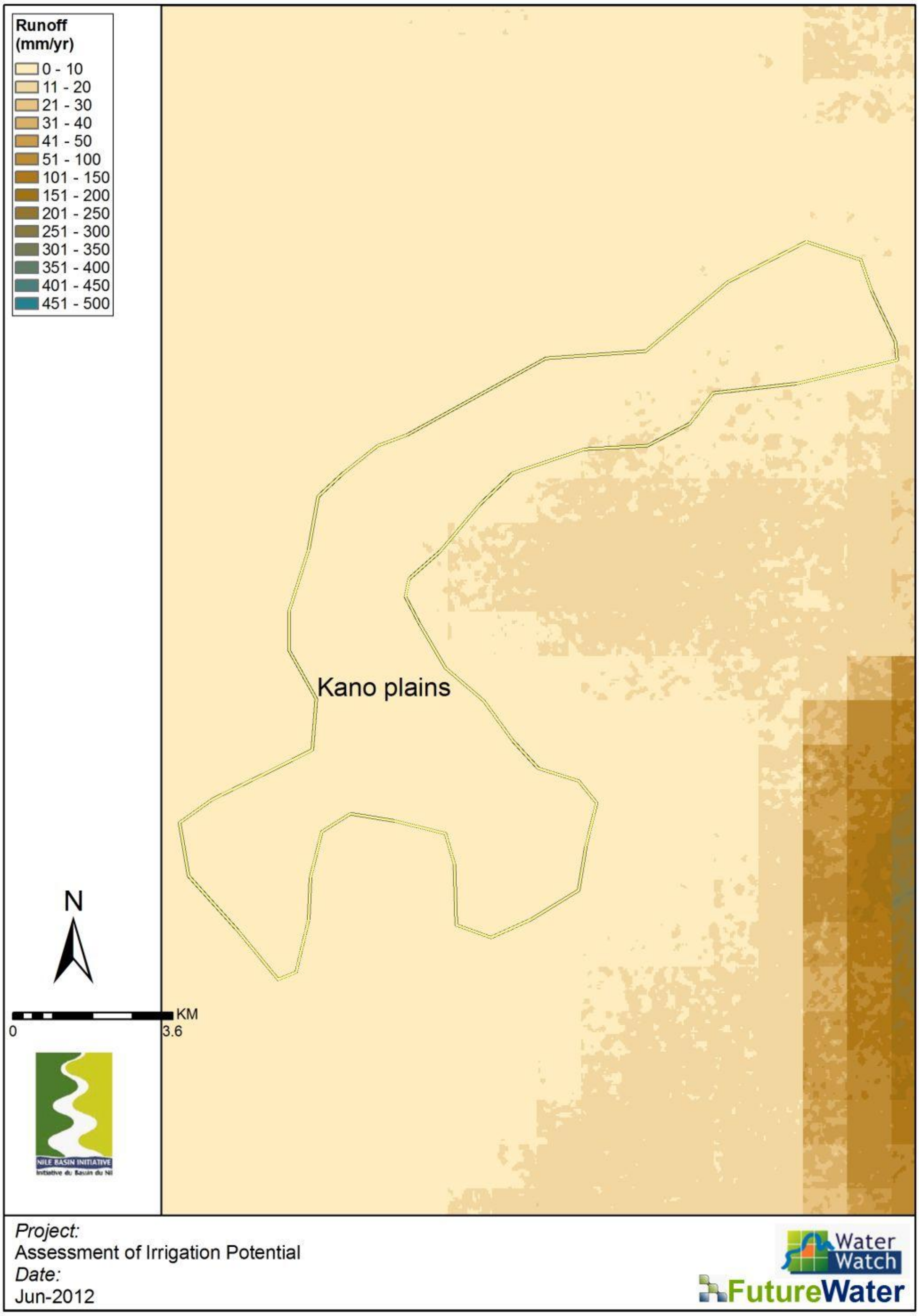
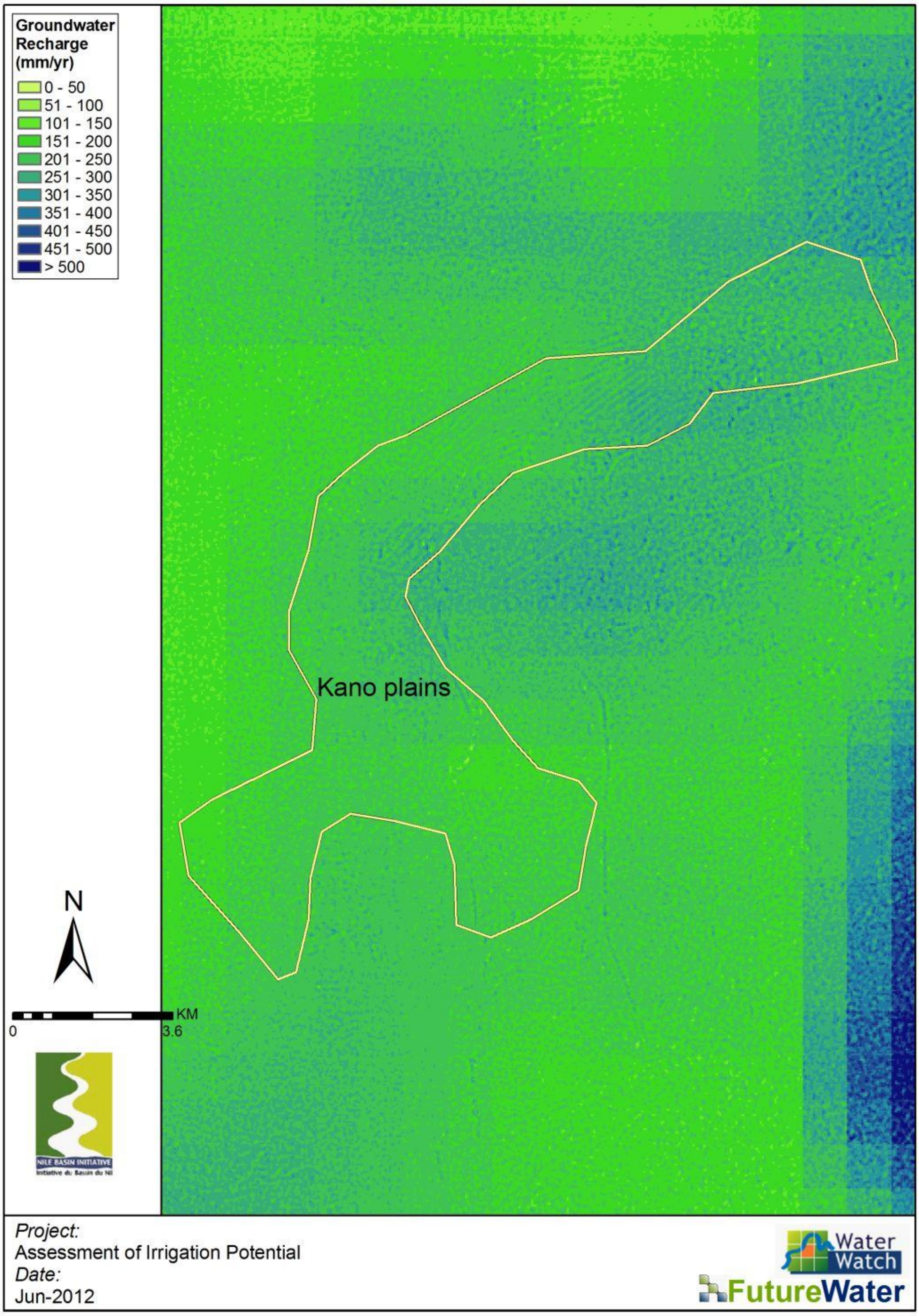



**Figure 53: Water balances for the area based on the high resolution data and modeling approach for KANO Plains focal area.**


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
Kano plains
N
KM
0
3.6
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
Kano plains
N
KM
0
3.6
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater

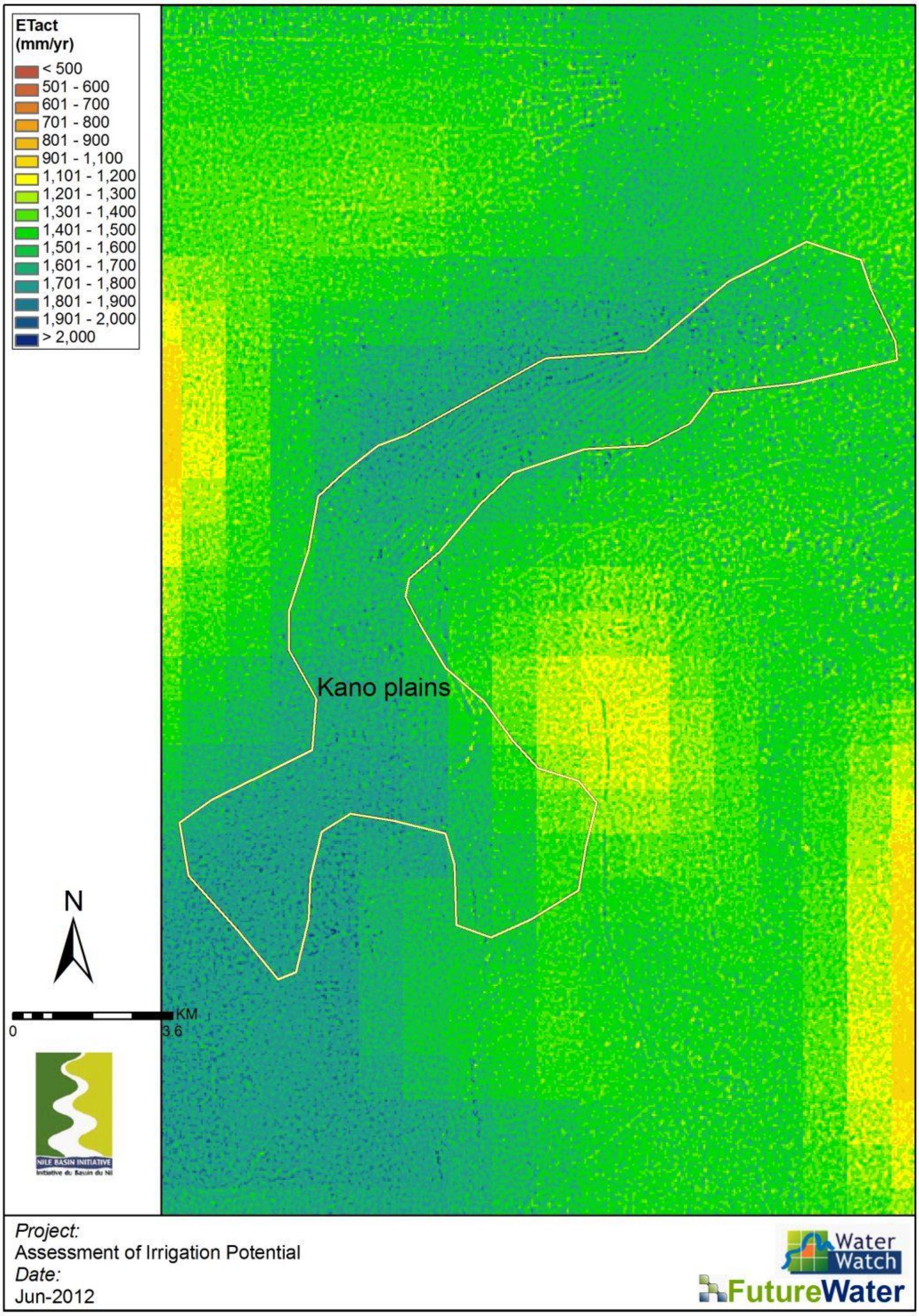



**Figure 54: Water balances for the area based on the high resolution data and modeling approach for KANO Plains focal area.**

## 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.

All input files and output files for AquaCrop can be found in the database attached to the reports. Note that during this pre-feasibility phase focus with AquaCrop was to obtain crop water requirements. A subsequent feasibility study could focus more on the crop yield validation and calibration components of AquaCrop.

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

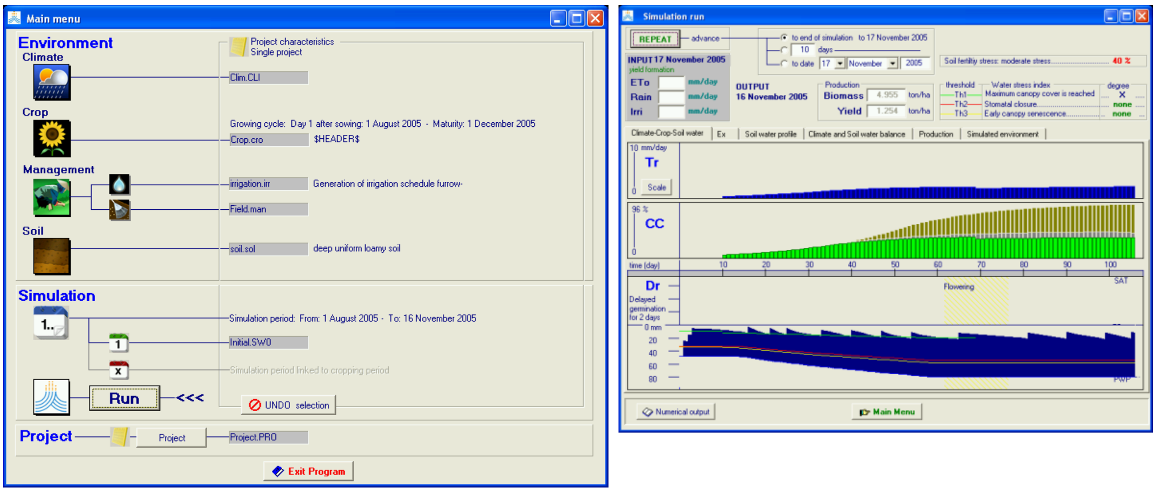



**Figure 55: Typical example of AquaCrop input and output screens.**

**Table 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 | Harvests | Rain | Irrigation | ETref | ETact |
|---|---|---|---|---|---|---|---|---|
| | === year | === | == (day of year) == | | ======== growing season ======= | | | |
| | (mm) | (mm) | | | (mm) | (mm) | (mm) | (mm) |
| Rice | 1578 | 1501 | 121 | 304 | 832 | 90 | 687 | 606 |
| Onions | 1578 | 1501 | 1 | 365 | 1578 | 160 | 1497 | 1112 |
| Tomatoes | 1578 | 1501 | 1 | 365 | 1578 | 160 | 1497 | 1112 |
| Kales | 1578 | 1501 | 1 | 365 | 1578 | 160 | 1497 | 1112 |
| Capsicums | 1578 | 1501 | 1 | 365 | 1578 | 160 | 1497 | 1112 |

#### *4.4.2 Irrigation systems and irrigations efficiencies*

The Nyando River is flowing through the focal area. This river drains a very large area of approximately 2900 $km^2$. Kano River has a yearly average flow of 36 $m^3/s$ in the upper part of the focal area, and 49 $m^3/s$ in the low part of the focal area, due to the tributaries draining on the Nyando River within the focal area. In the best situation the water can be diverted from the river upstream so that the fields can be irrigated under gravity. In that case either furrow or border irrigation is recommended. These two techniques no not require high investments as they are relatively cheap compared to pressurized irrigation systems such as sprinkler or drip irrigation. On top of that the farmers can get used to flood irrigation much easier as pressurized irrigation which enhances a sustainable irrigation system, which can be managed by the farmers. Within Kano plains focal area farmers already have some irrigation knowledge and skills as some irrigation schemes have already been developed. Efficiencies of flood irrigation are relatively low. After conveyance and application efficiency correction about 40% of the water is used effectively. For pressurized systems this is much higher, and can reach up to 70-80%.

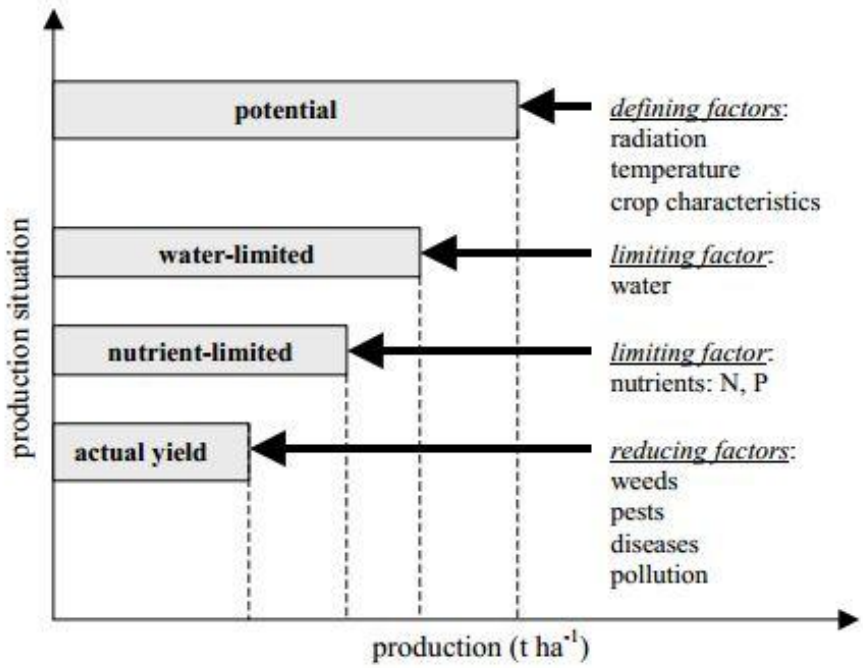
#### *4.4.3 Water source*

The source of the water will be the Nyando River. The Yearly average flow in the river will be more than enough to irrigate the whole focal area, and more, up to 40,000 ha.  The only constraint will be the large seasonal variety of the river flow. Therefore stream control structures will be required, in combination with storage capacity. These structures can also be used as an intake point for irrigation water diversion. In most of the focal area groundwater is also a potential irrigation water source, but this will be more costly than surface water.

## 4.5 Potential crop yield assessment

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

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximal 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

Average Kenyan yields are the lowest of all research countries. Within the focal areas however the conditions are favorable and yields high, even compared to surrounding countries. For this focal area is chosen to focus on high value crops, which give good return. This can be seen in Figure 56. These potential crops will al give an excellent yield under irrigation, and will be very rewarding. It is expected that the gains with these potential crops can double or triple per hectare.

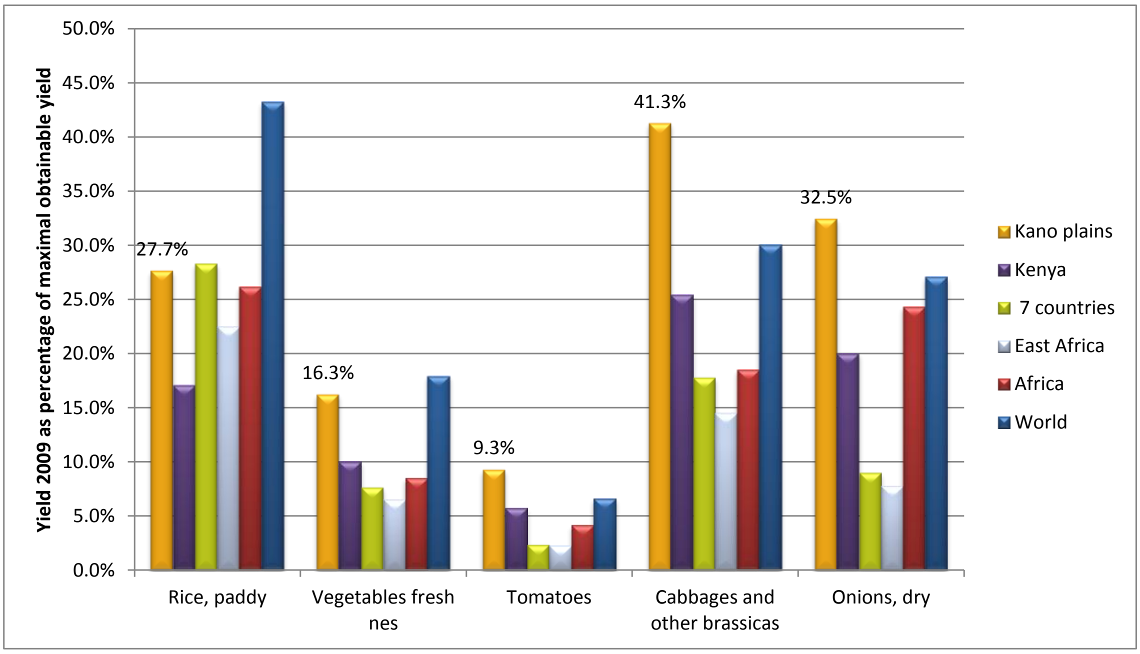



**Figure 56: Yield gap Kano plains (source: FAOSTAT, 2012).**

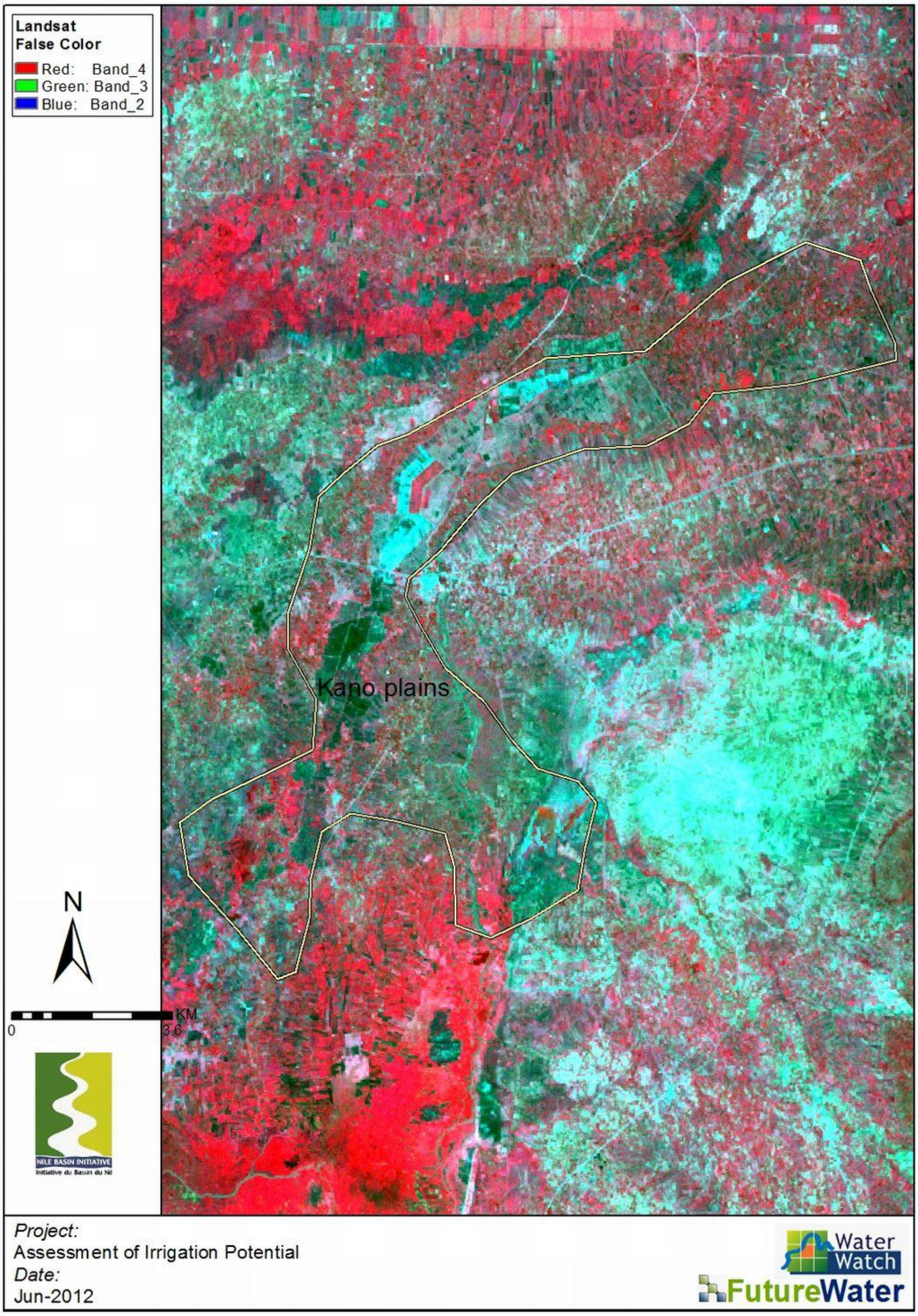



**Figure 57: Landsat False Color Composite indicating current productivity of the area for KANO Plains focal area.**

## 4.6 Environmental and socio-economic considerations

### *4.6.1 Population displacements*

The area is densely populated, but there are few settlements within the area. All people live scattered around the area. However some highly productive agricultural grounds have not been inhabitant so far, and are used for agriculture. This makes is rather difficult to design a large scale irrigation system. With the design of an irrigation scheme, it is advised to limit any population displacement and to develop the irrigation scheme as much as possible 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. Whenever population displacement is thought to be necessary, this should be discussed and decided together with inhabitants, local government and other stakeholders.

### *4.6.2 Social*

Within Kenya 85% of the land area is classified as Arid and Semi-Arid Lands (ASAL) and the remaining 15% sustain more than 75% of the population. Therefore the population density in Nyanza and Western province are the highest of Kenya, with respectively 350 and 406 people per km2. This is very high compared to Kenyan average of 56 inhabitants/km$^2$. Within the focal area the population density is estimated to be slightly lower with 285 inhabitants/km$^2$. The rapidly increasing population is largely the cause for degradation of the catchment and degradation of the focal area. Deforestation, river bank cultivation and compromising water quality are some examples of the raising pressure on the water and land resources, which weaken the adaptation possibilities of the ecosystem. The majority (+/- 80%) of the people in the area belong to the Luo tribe and other tribes include Kisii, Luhya and Kalenjins. Infrastructure in the area is developed relatively well. Tarmac roads are passing through the focal area such as the Nairobi Kisumu highway and the Kisii Kisumu road. However within the focal area all other roads are weathered dirt roads. For irrigation development the infrastructure should be strengthened to make it easier to bring construction material and agricultural inputs, and to reach the nearby markets with the products. Nearby markets include Ahero, Kisumu or further away the larger towns Eldoret, Nairobi or Nakuru. The farmers have average knowledge about irrigation and agricultural cooperatives. When developing an irrigation scheme attention should be paid to this social part. Unemployment rate in this area is very high, irrigation development can create more agro-related jobs and as such reduce unemployment and poverty. In Nyanza and Western province the percentage of woman as head of a household is highest in Kenya with 38%. The net enrollment rate for primary schools in Nyanza province is 98.7% which is the second highest of Kenya, and well above the Kenyan average of 92.9%. Literacy rate is the highest of Kenya with 90.45% of the population. The gender parity index for the enrollment ratio on secondary schools shows a negative trend for Nyanza province, decreasing from 0.737 in 2002 to 0.694 in 2009. HIV prevalence in Nyanza province is the highest in Kenya with 13.9% of the population being infected.

### *4.6.3 Upstream downstream consideration*

The upstream catchment (2900 km$^2$) is quite large, and the yearly average flow large with around 40m$^3$/s. Since Kano plains focal area is situated very close to lake Victoria most issues are related to the upstream area. Erosion is taking place within and upstream of the focal area. Population pressure stimulates the use of resources in an unsustainable way. This may lead to land and environmental degradation. To enhance the environmental aspects upstream-, within- and downstream of the focal area, it is advised to search for measures which retain the precipitation water firstly, and try to store it upstream. This will enhance the upstream ecosystem, and groundwater levels. On a larger scale the groundwater is recharged, which can become available downstream, and evaporation enhances the water cycle and the precipitation in the area. The use of fertilizer is recommended, but it is needed to use fertilizer in a responsible and well considered way. Otherwise the water quality downstream may be compromised.

#### *4.6.4 Protected areas*

Within the focal area no protected areas are reported.

## 4.7 Benefit-cost Analysis

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

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

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Rice: 6,750 kg/ha, 1.55 $/kg
    - Onions: 18,000 kg/ha, 0.25 $/kg
    - Tomatoes: 20,000 kg/ha, 0.85 $/kg
    - Kales: 14,000 kg/ha, 0.07 $/kg
    - Capsicums: 13,000 kg/ha, 0.90 $/kg

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

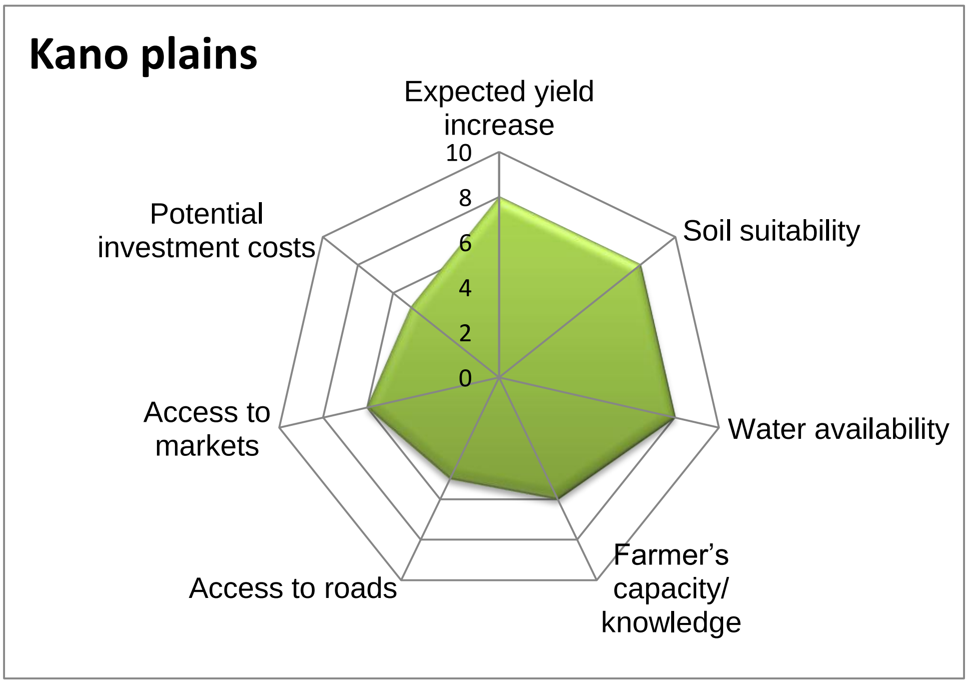



**Figure 58: Filled radar plot indicating expert knowledge score to develop irrigation in the Kano plains focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).**

**Table 9: Benefit-cost analysis for Kano plains area.**

| | |
|---|---|
| **Characteristics** | |
| Irrigated land (ha) | 4,000 |
| Farmers | 5,714 |
| **Investment Costs** | |
| Irrigation infrastructure (US$/ha) | 5,000 |
| Social infrastructure (US$/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$) | 24.9 |
| O&M costs (million US$/yr) | 0.337 |
| Net benefits per year (million US$/yr) | 21.421 |
| IRR (Internal Rate of Return) | 100.0% |

# 5 Nzoia river basin focal area

## 5.1 Introduction

This chapter will describe the current state of the Nzoia river basin focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations and institutional frameworks. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 60 a detailed map of the area is given. Total area is 5141 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 Raphael Waswa and Hosea Wendot as supervisor in March 2012

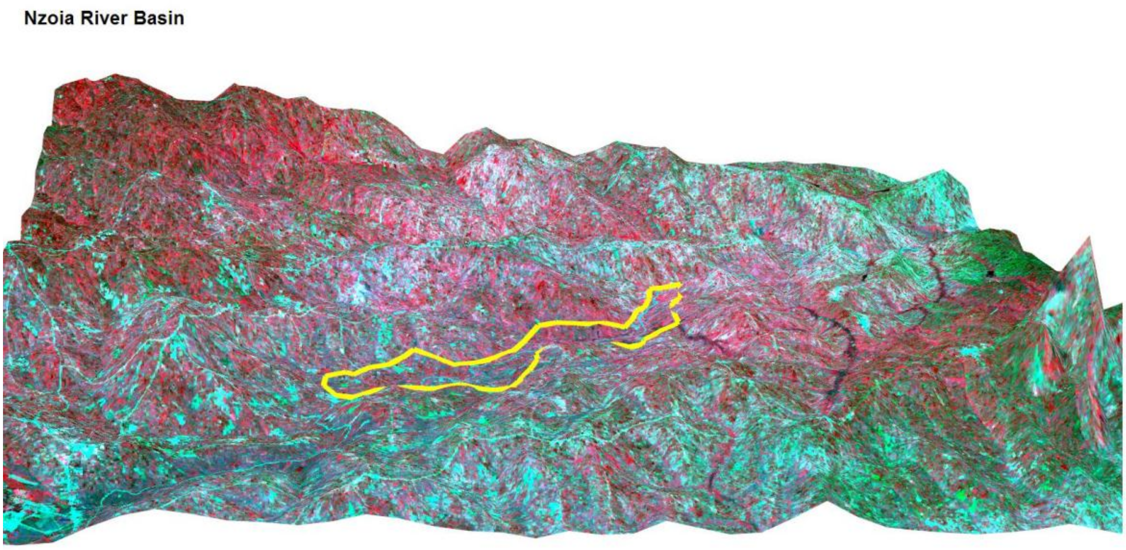



**Figure 59: 3D impression of Nzoia river basin focal area, Kenya**

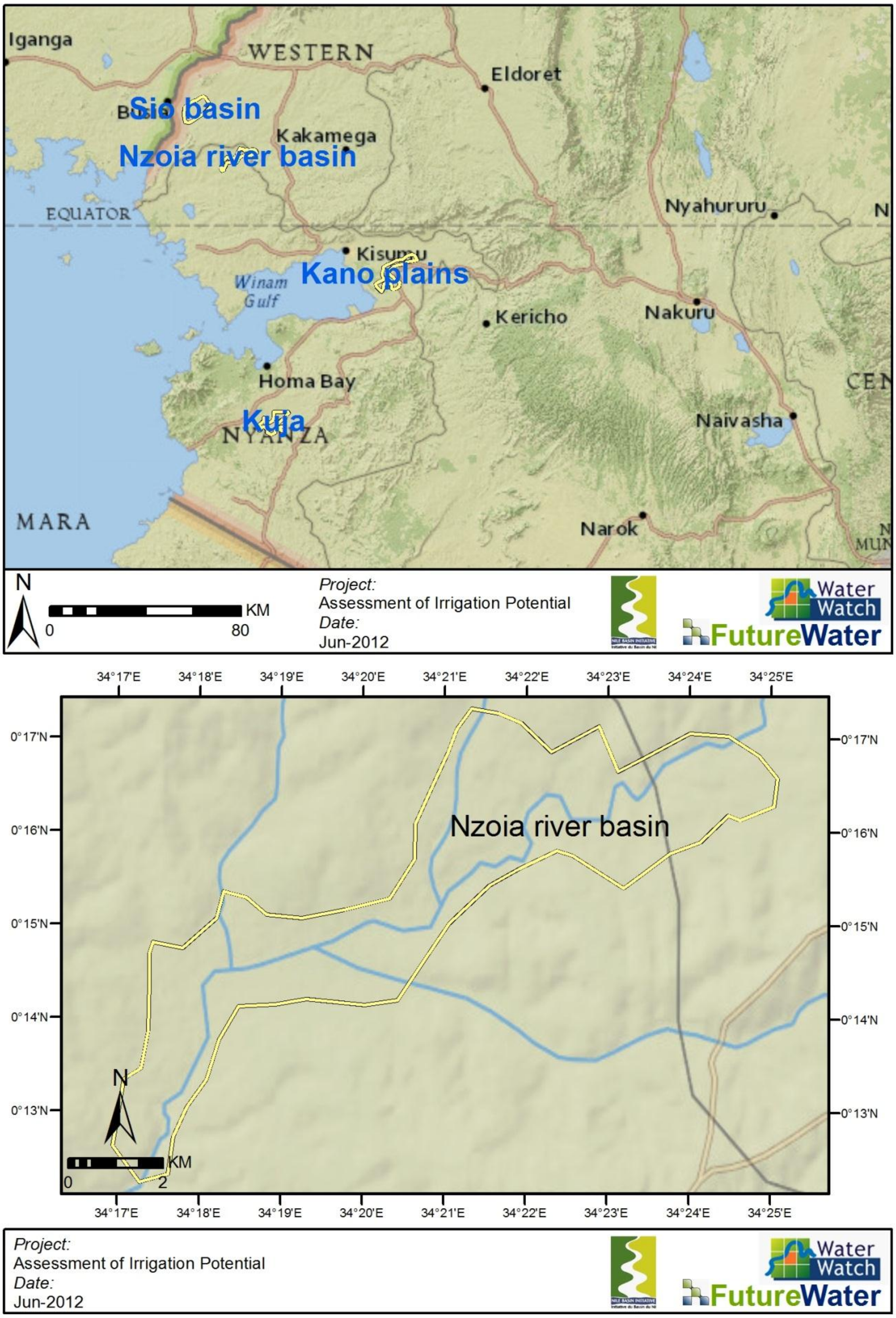



**Figure 60: Nzoia focal area, Kenya**

## 5.2 Land suitability assessment

### *5.2.1 Terrain*

Nzoia river basin focal area is located in the western part of Kenya, on the border of the Western and Nyanza province. The focal area spreads out within a valley, which covers the stream valley from Nzoia River. The area descends from East to West from 1240m above sea level to 1200m downstream. In the upper part of the focal area the river valley is quite small which makes that the area next to the river ascends for about 20 meters. (Figure 61 and Figure 58) Downstream the focal area is more flat. Slopes are very limited, and reach up to 10% locally, but stay well below 3% on a 250 meter resolution. (Figure 62)

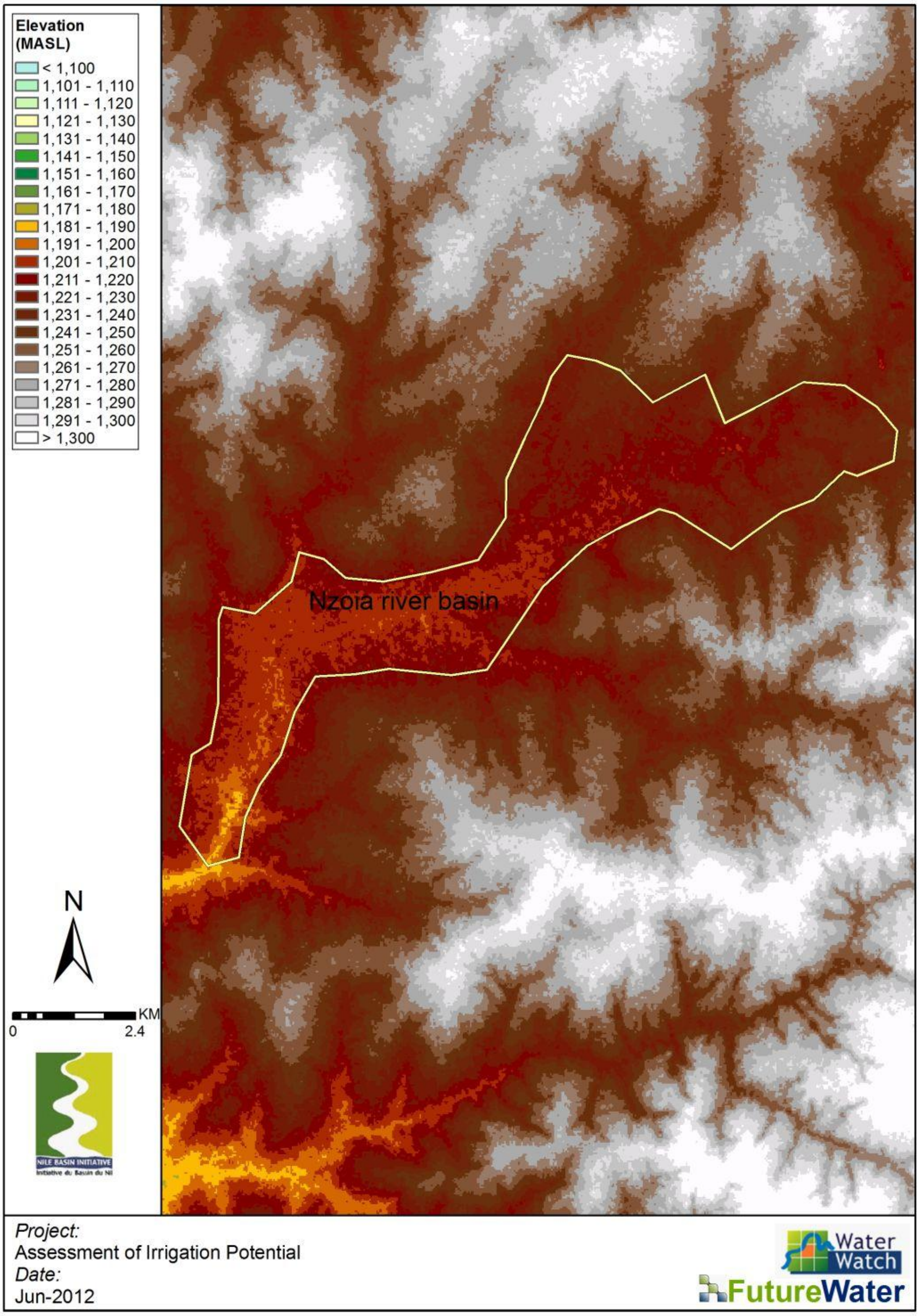



**Figure 61: DEM Nzoia river basin focal area. Resolution 1 arc second (+/- 30m)**

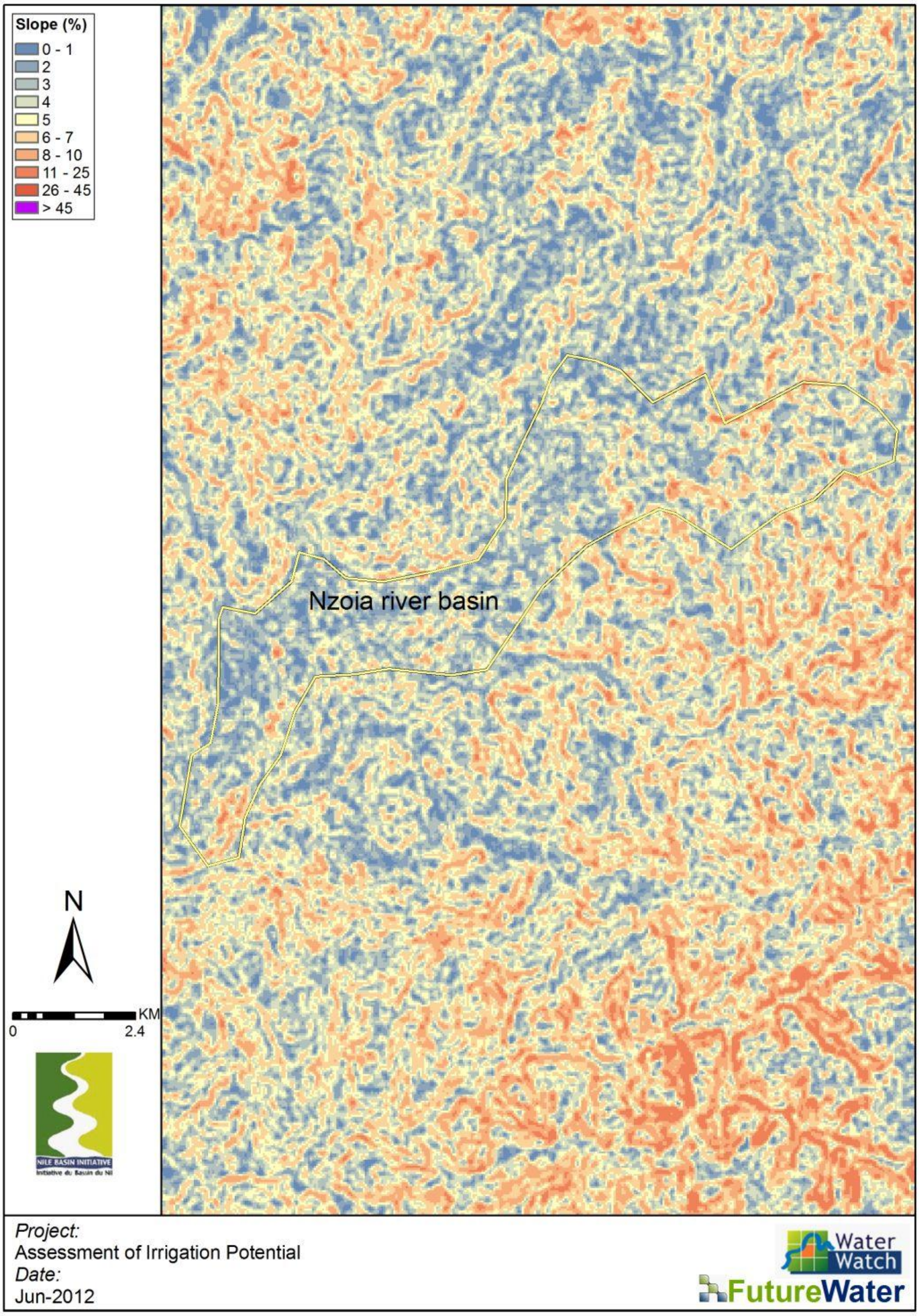



**Figure 62: Slope map Nzoia river basin focal area (source: ASTER).**

### 5.2.2 Soil

The soil texture in the focal area is loamy. The soil is deep, and is typically located in a depression in which products of rock weathering are deposited, or other sediments that have the characteristics of swelling clays. De drainage capacity is moderately. Whenever the soil is wet the swelling of the clay can easily cause water logging, and in dry season deep cracks in the soils cause excessive drainage. Vertisols have considerable agricultural potential, but adapted management is a precondition for sustained production. The comparatively good chemical fertility and their occurrence on extensive level plains where reclamation and mechanical cultivation can be envisaged are assets of Vertisols. Their physical soil characteristics and, notably, their difficult water management cause problems. The agricultural uses of Vertisols range from very extensive (grazing, collection of fuel wood, and charcoal burning) through smallholder post-rainy season crop production (millet, sorghum, cotton and chickpeas) to small-scale (rice) and large-scale irrigated agriculture (cotton, wheat, barley, sorghum, chickpeas, flax, and sugar cane). Cotton is known to perform well on Vertisols, allegedly because cotton has a vertical root system that is not damaged severely by cracking of the soil. Tree crops are generally less successful because tree roots find it difficult to establish themselves in the subsoil and are damaged as the soil shrinks and swells. Management practices for crop production should be directed primarily at water control in combination with conservation or improvement of soil fertility. A small part on the eastern tip of the focal area is characterized as an Acrisols. These soils have higher clay content in the sub soil as in the top sol, which limits the drainage capacity. Preservation of the surface soil with its all-important organic matter and preventing erosion are preconditions for farming on Acrisols. Adapted cropping systems with complete fertilization and careful management are required if sedentary farming is to be practised on Acrisols. Acrisols are suitable for production of rainfed and irrigated crops only after liming and full fertilization. Rotation of annual crops with improved pasture maintains the organic matter content.

### 5.2.3 Land productivity

The annual average land productivity (NDVI) in the four Kenyan focal areas ranges between 0.59 and 0.66. In Nzoia river basin focal area the NDVI is 0.66, which is really high compared to the Kenya average NDVI of 0.36. (Figure 64) The land productivity is lowest directly bordering the Nzoia river, and is further uniform over the area. The coefficient variation is very low all over the area.  This suggests a year round agricultural land use with little time between each growing period.

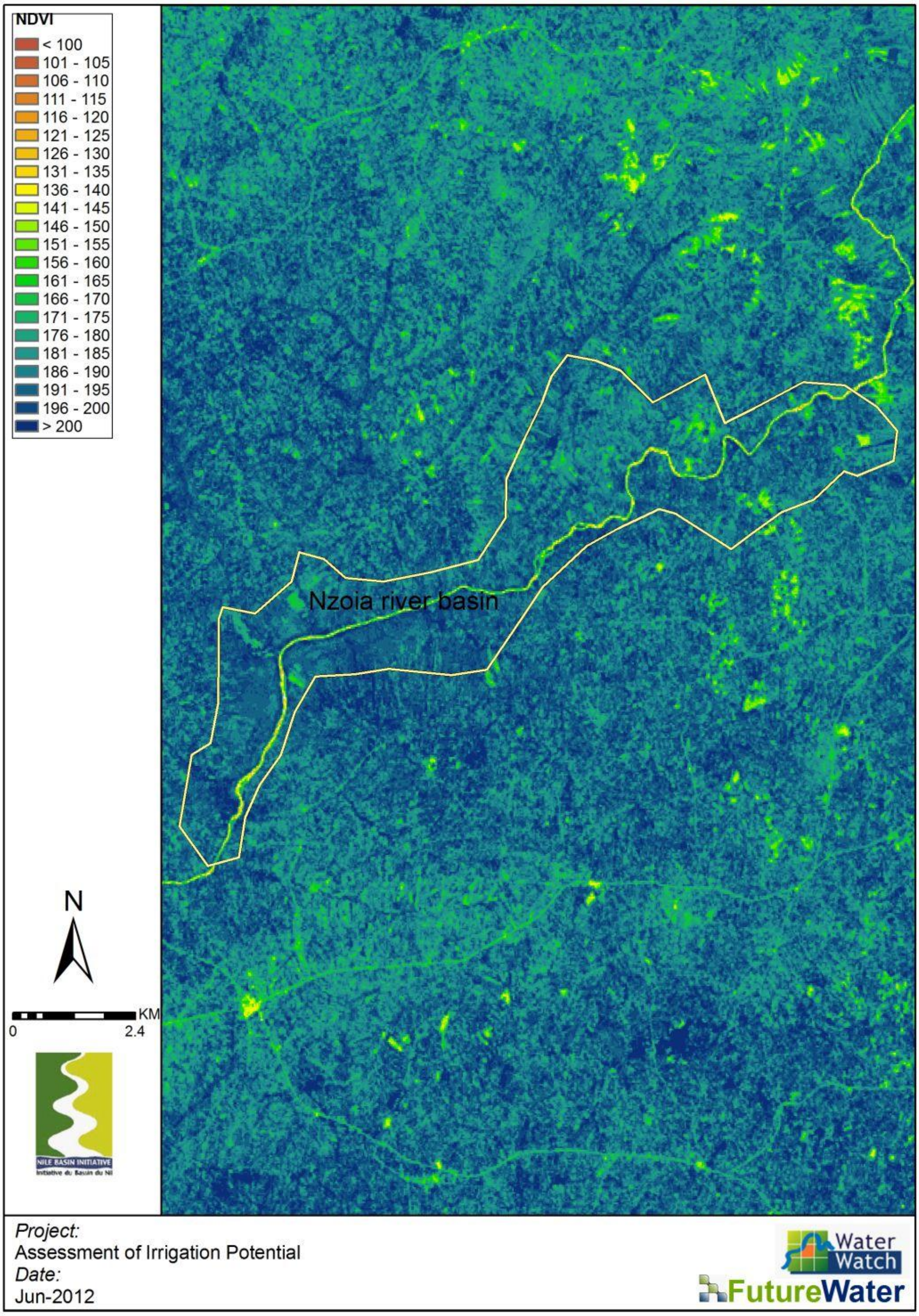



**Figure 63: High resolution NDVI for NZOIA river basin focal area**

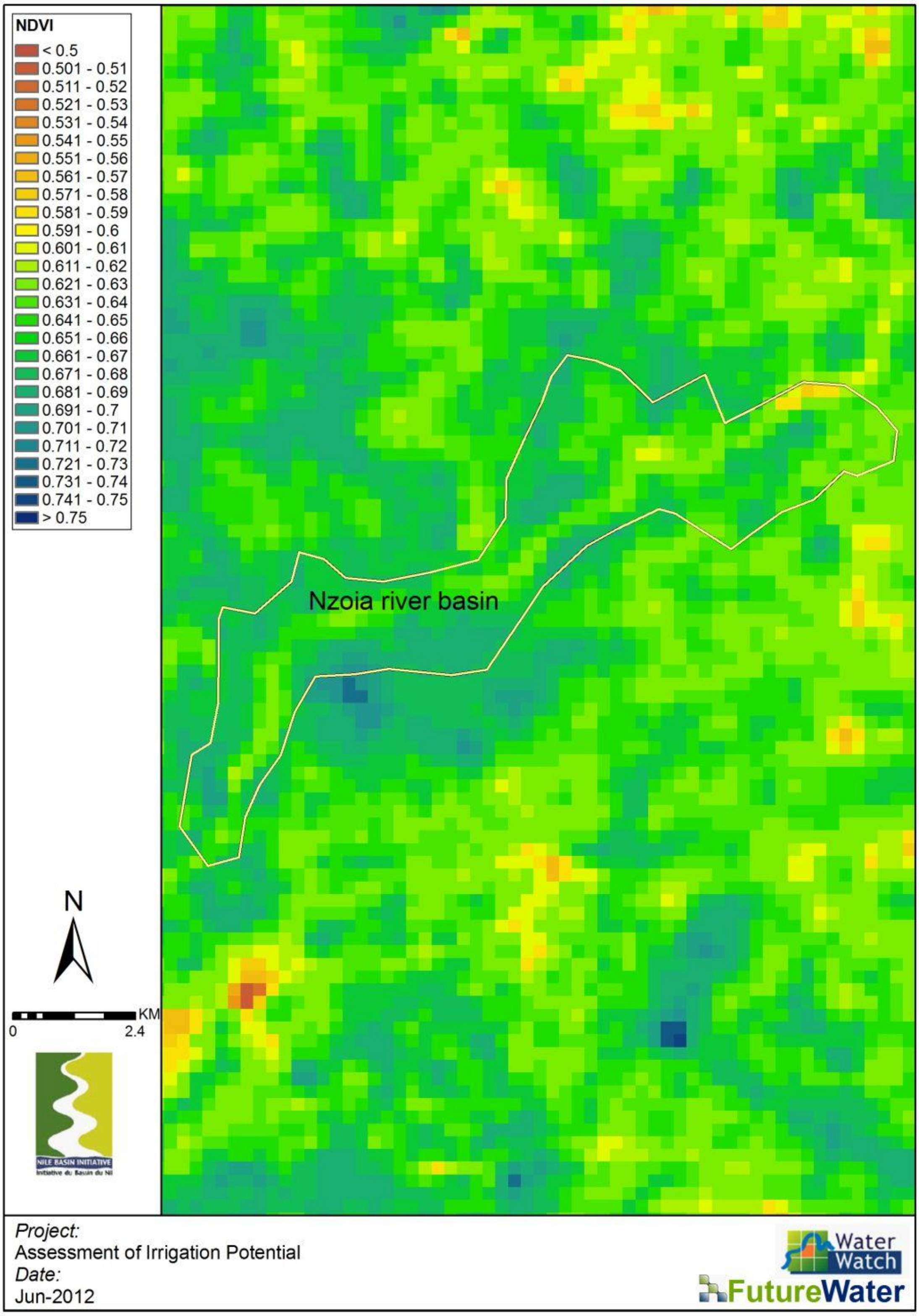



**Figure 64: Yearly average NDVI values for NZOIA river basin focal area.**

### 5.2.4 Potential cropping patterns

Field assessments have shown that currently approximately 75% of the land is used for agriculture. Most dominant crops are Maize, Beans, Cassava and Sorghum. Maize, Beans and Sorghum are all grown in two growing cycles per year. Starting in March and August and running for 5 months for Maize and Sorghum and 3 months for beans. Yields for Maize are around 1550 kg/ha for Beans 1350 kg/ha and for Sorghum 1400 kg/ha. Cassava is grown in one growing cycle per year, and has an average yield of 15 tons/ha. According to Kenya national irrigation policy agriculture is the backbone of Kenya's economy and has a central place in realizing national aspiration and poverty reduction. The make agriculture more independent of the unreliable rainfall patterns Kenya must embrace irrigation and drainage development to remain competitive. Irrigation will also significantly contribute to the meeting of the demands for national food security as well as the sophisticated and emerging export markets for food, fibre, oil crops,  animals and fisheries products. Diversification of crops will be enhanced to contribute fully to food security and industrialization. Practically for this focal area this means that Tomatoes, Kales, Onions and pineapples are suggested.

## 5.3 Water resource assessment

### 5.3.1 Climate

Total precipitation in the focal area is 1410 mm per year, while reference evapotranspiration is 1464 mm per year. So there is a clear scope for improvement of crop water requirements by irrigation. Differences between minimum and maximum temperature is quite large and are 18$^{o}$C and 31$^{o}$C respectively.

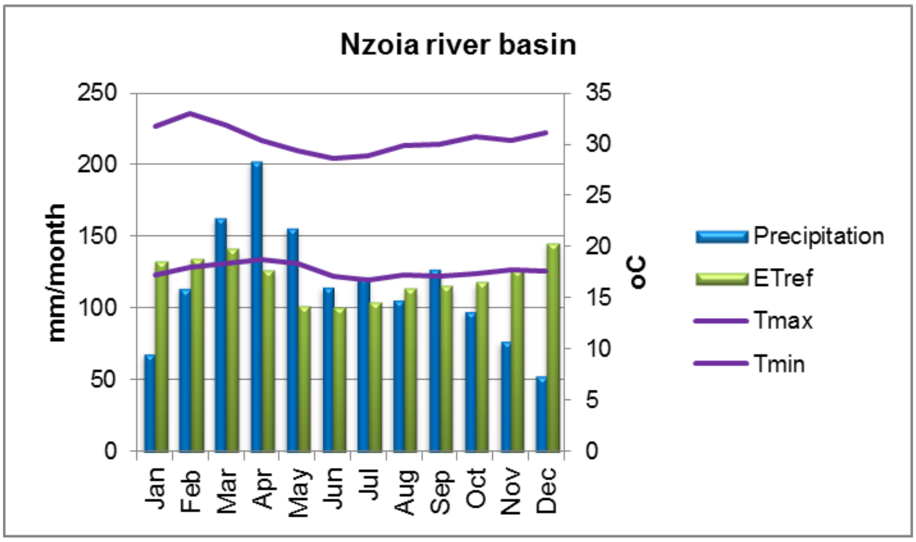
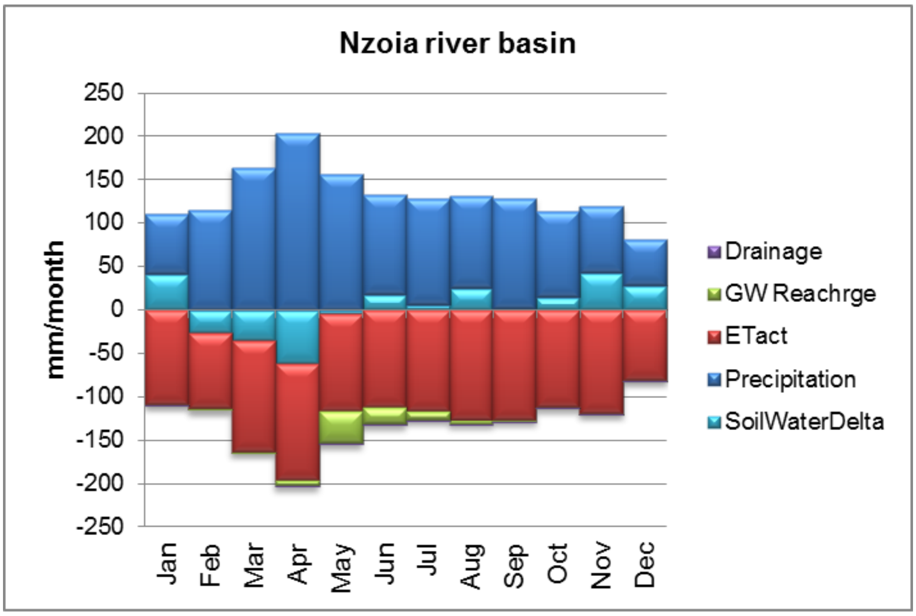
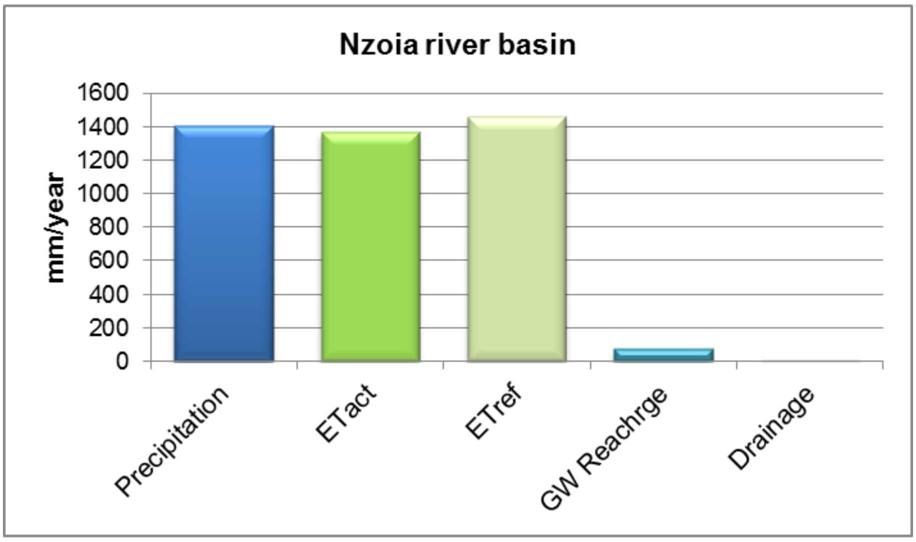



**Figure 65: Average climate conditions for NZOIA river basin focal area.**

### 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.



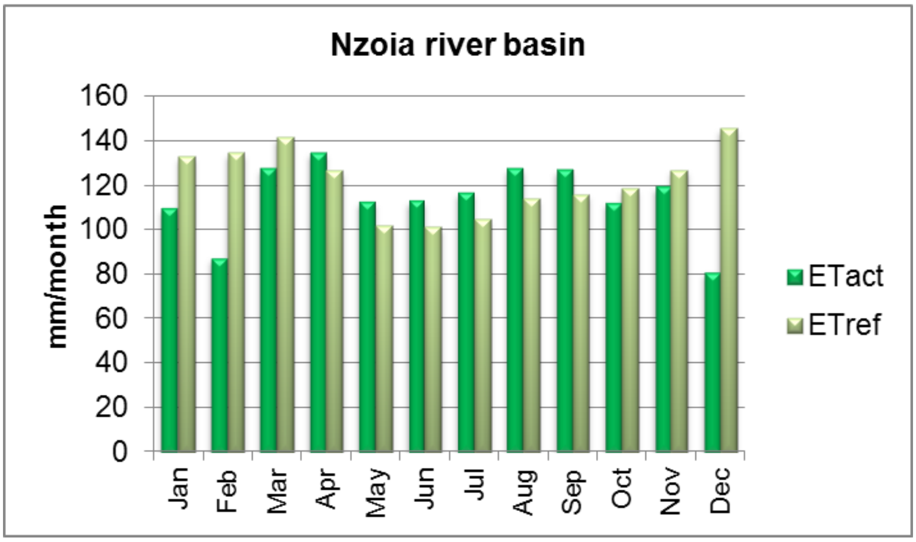
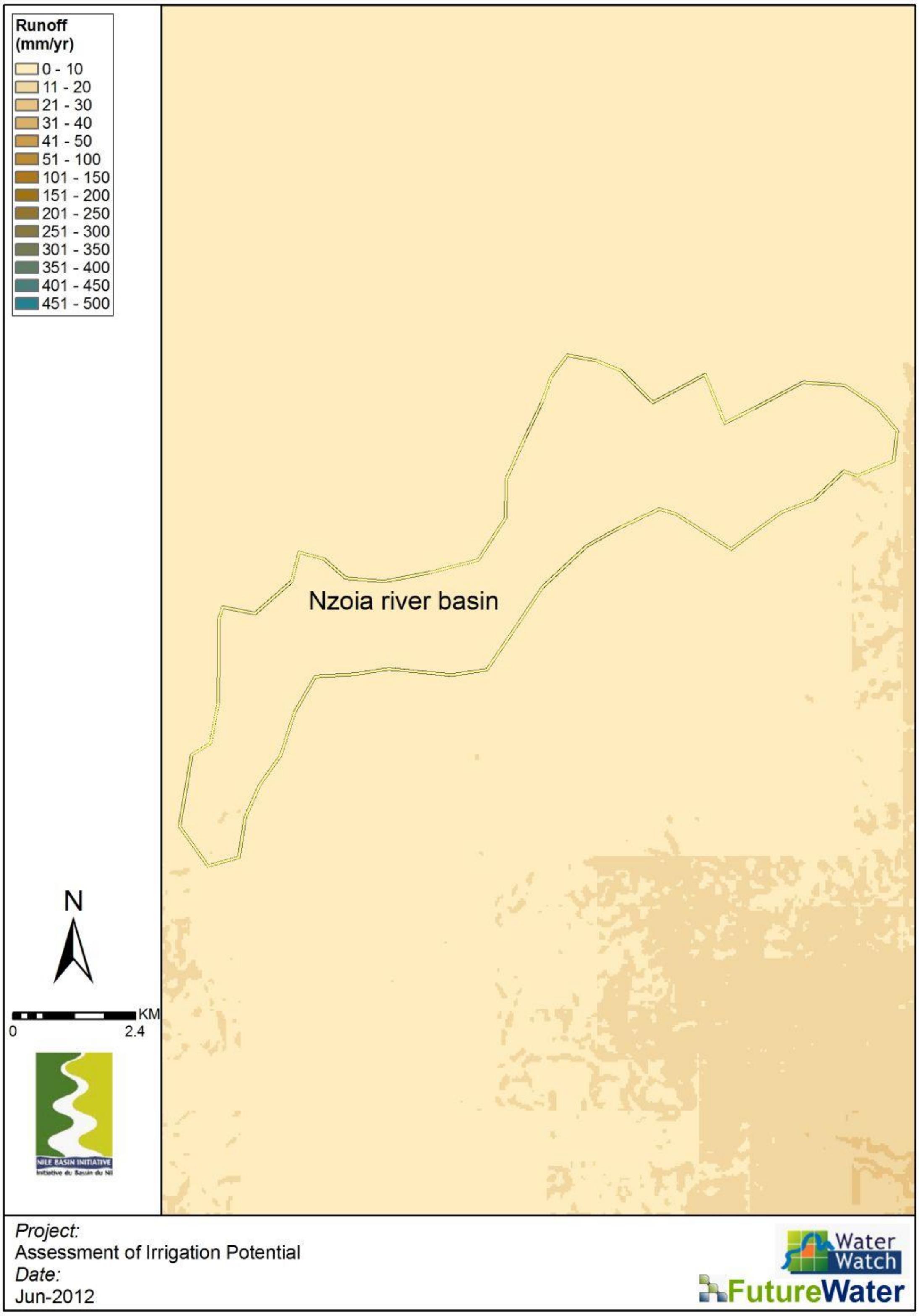
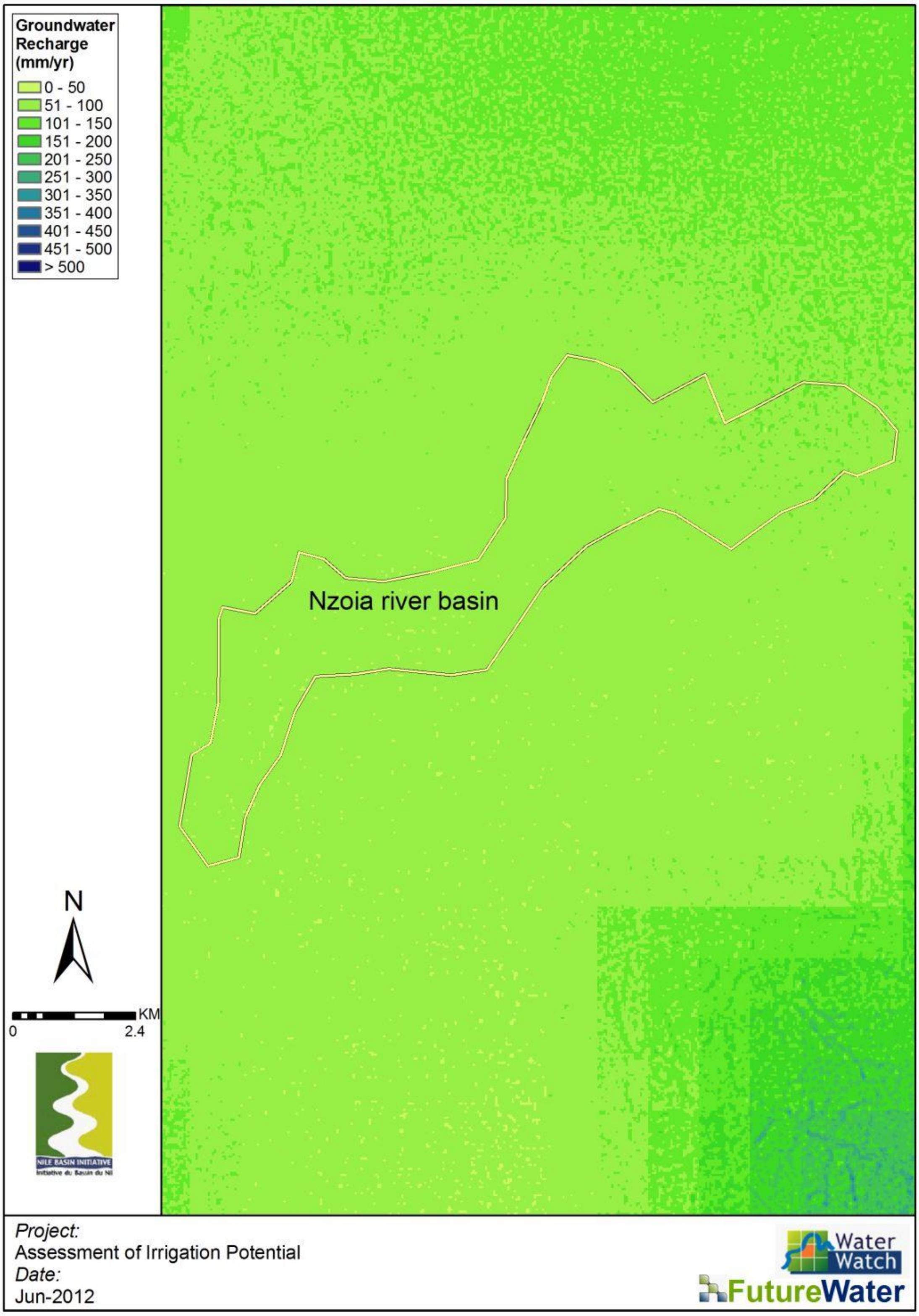




**Figure 66: Water balances for the area based on the high resolution data and modeling approach for NZOIA river basin focal area.**


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
Nzoia river basin
N
KM
0
2.4
NILE BASIN INITIATIVE
Initiative du Bassin du Nil
Project:
Assessment of Irrigation Potential
Date:
Jun-2012
Water Watch
FutureWater


Groundwater Recharge (mm/yr)
0 - 50
51 - 100
101 - 150
151 - 200
201 - 250
251 - 300
301 - 350
351 - 400
401 - 450
451 - 500
> 500
Nzoia river basin
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NILE BASIN INITIATIVE
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Project:
Assessment of Irrigation Potential
Date:
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FutureWater

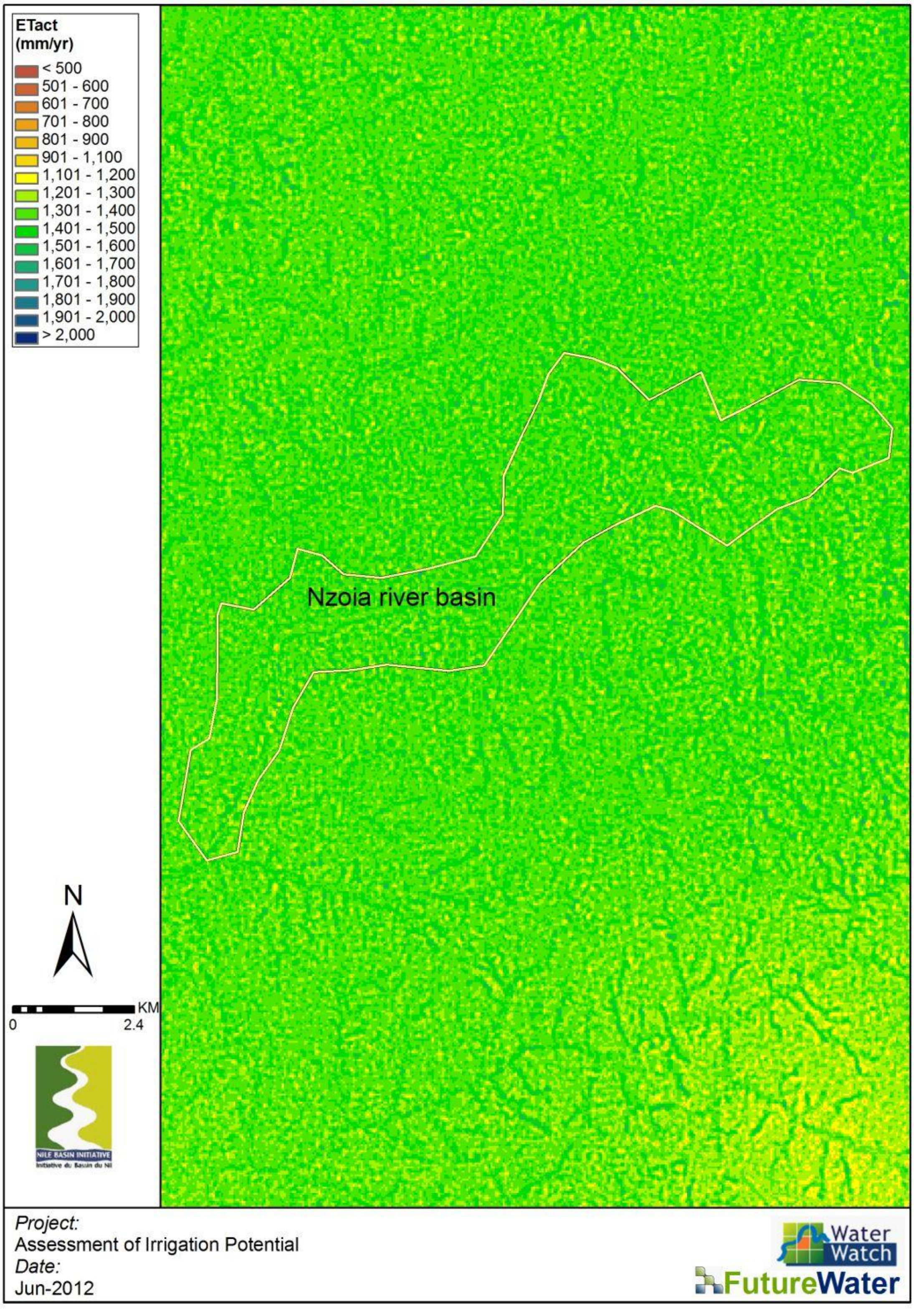



**Figure 67: Water balances for the area based on the high resolution data and modeling approach for NZOIA river basin focal area.**

## 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.

All input files and output files for AquaCrop can be found in the database attached to the reports. Note that during this pre-feasibility phase focus with AquaCrop was to obtain crop water requirements. A subsequent feasibility study could focus more on the crop yield validation and calibration components of AquaCrop.

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

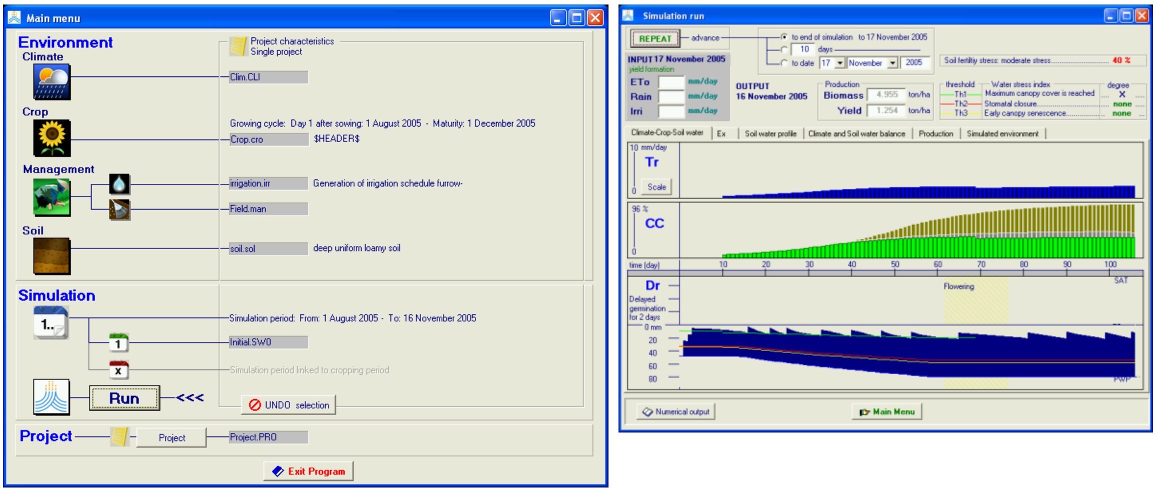



**Figure 68: Typical example of AquaCrop input and output screens.**

**Table 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 | Harvests | Rain | Irrigation | ETref | ETact |
|---|---|---|---|---|---|---|---|---|
| | === year | === | == (day of year) == | | ======== growing season | ======= | | |
| | (mm) | (mm) | | | (mm) | (mm) | (mm) | (mm) |
| Tomatoes | 1406 | 1464 | 1 | 365 | 1406 | 180 | 1460 | 1060 |
| Kales | 1406 | 1464 | 1 | 365 | 1406 | 180 | 1460 | 1060 |
| Onions | 1406 | 1464 | 1 | 365 | 1406 | 180 | 1460 | 1060 |
| Pineapples | 1406 | 1464 | 1 | 365 | 1406 | 280 | 1460 | 1059 |

### 5.4.2 *Irrigation systems and irrigations efficiencies*

Nzoia River flows through the focal area. This river originates from mount Elgon, and drains a very large area of approximately 12500 $km^2$. Within the focal area four minor streams are draining on Nzoia river. These streams all have small discharges below 0.5 $m^3/s$. The abundance of water has developed this area already as a strong agriculture orientated area. The average water availability will be enough to irrigate 200,000 ha. This means that whole of the focal area can be covered when other factors allow to. In the best situation the water can be diverted from the river upstream so that the fields can be irrigated under gravity. In that case either furrow or border irrigation is recommended. These two techniques no not require high investments as they are relatively cheap compared to pressurized irrigation systems such as sprinkler or drip irrigation. On top of that the farmers can get used to flood irrigation much easier as pressurized irrigation which enhances a sustainable irrigation system, which can be managed by the farmers. Efficiencies of flood irrigation are relatively low. After conveyance and application efficiency correction about 40% of the water is used effectively. For pressurized systems this is much higher, and can reach up to 70-80%.

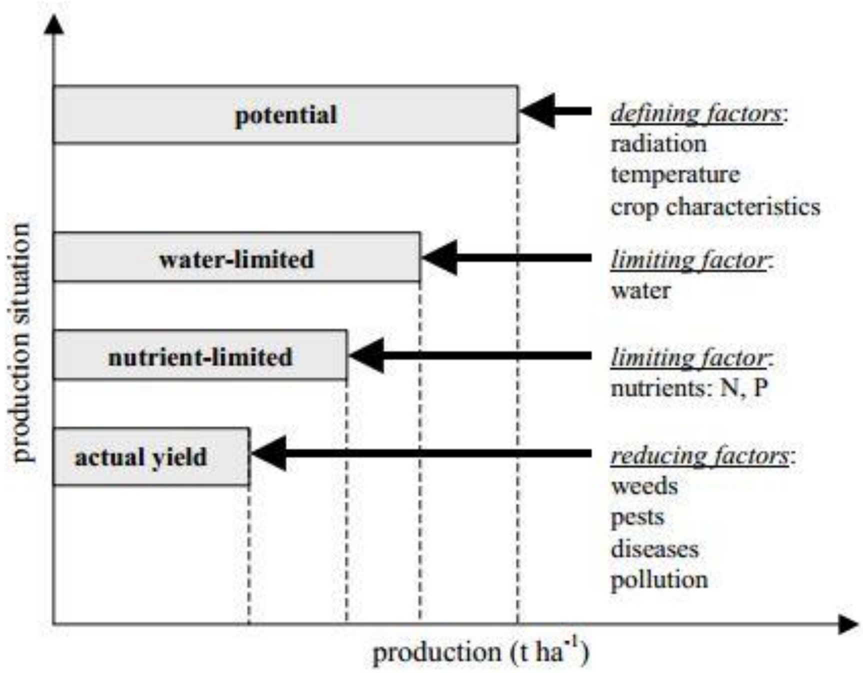
### 5.4.3 *Water source*

The irrigation water source will be Nzoia River. The river has an annual average flow of 190 $m^3/s$, which is more than sufficient to irrigate the full focal area. It is estimated that for the irrigation of the full focal area a discharge of roughly $5m^3/s$ is needed. The only constraint will be the large seasonal variety of the river flow, which may cause floods. Therefore stream control structures will be required, in combination with storage capacity. These structures can also be used as an intake point for irrigation water diversion. Groundwater is not a very suitable source within the focal area.

## 5.5 Potential crop yield assessment

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

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximal 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

Average Kenyan yields are the lowest of all research countries. Within the focal areas however the conditions are favorable and yields high, even compared to surrounding countries. For this focal area is chosen to focus on high value crops, which give good return. This can be seen in Figure 69. These potential crops will al give an excellent yield under irrigation, and will be very rewarding. It is expected that the gains with these potential crops can double or triple per hectare.

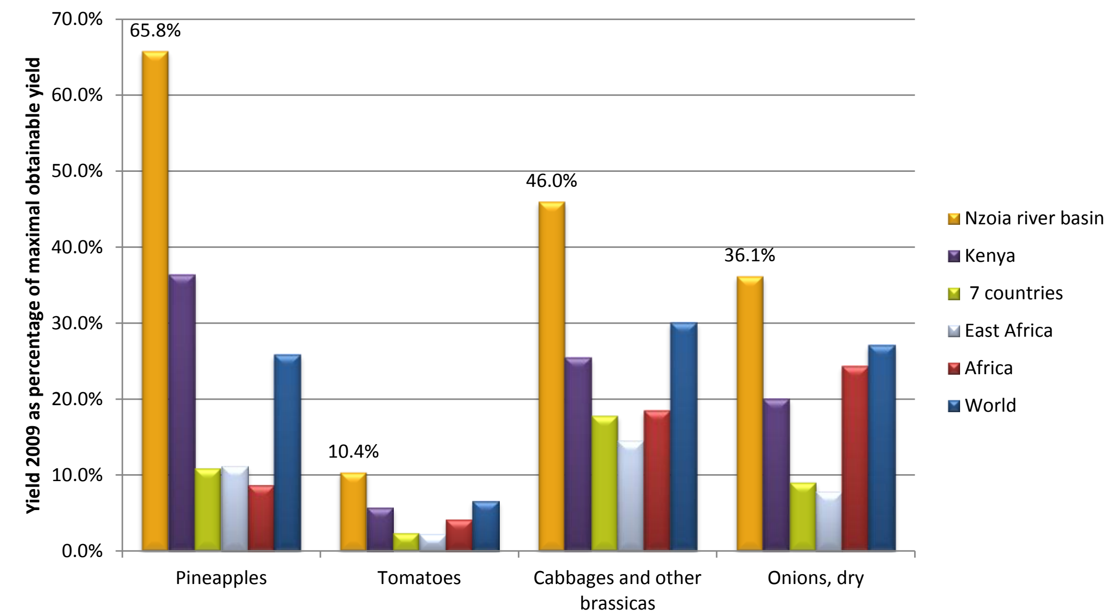



**Figure 69: Yield gap Nzoia river basin (source: FAOSTAT, 2012).**

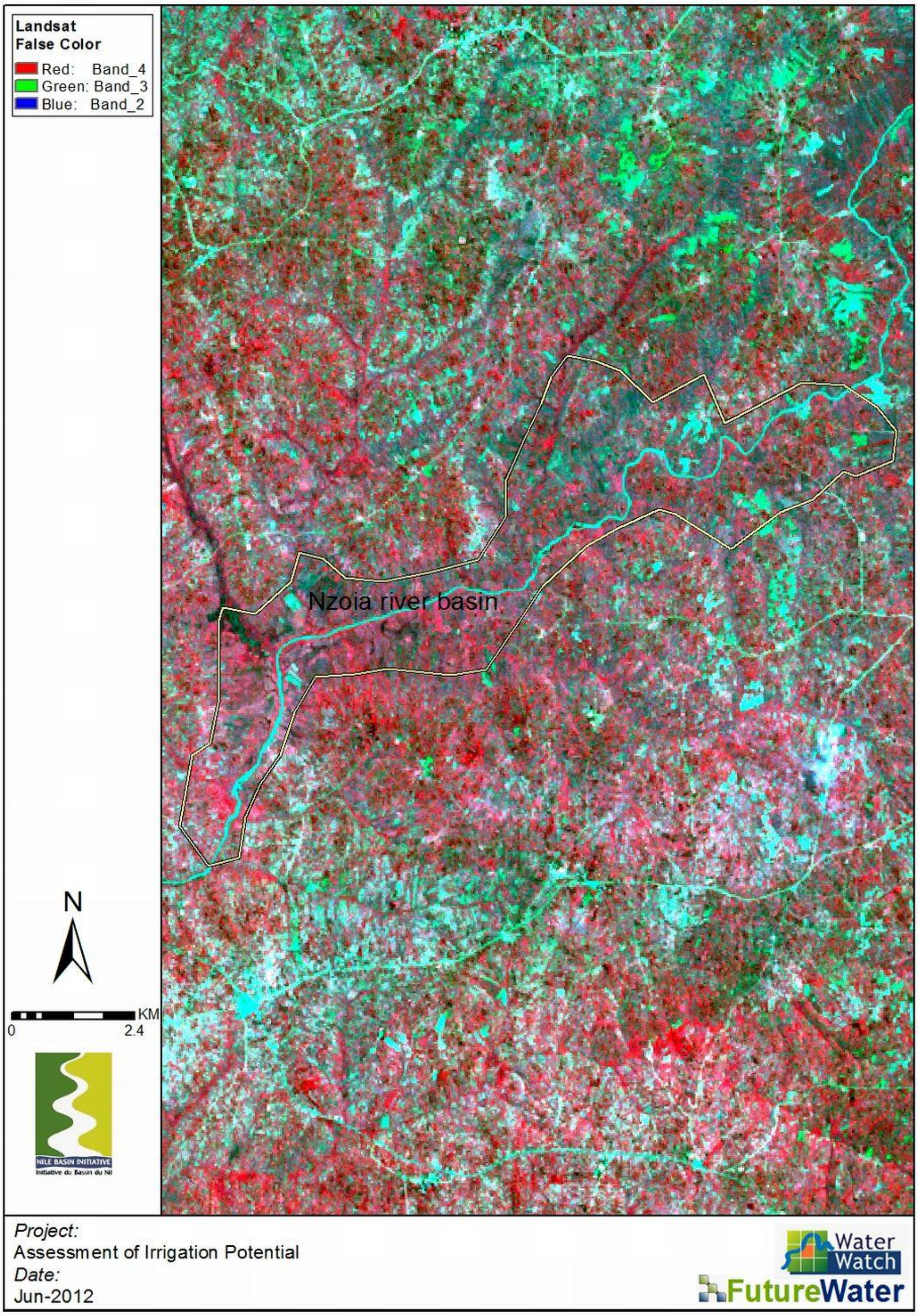



**Figure 70: Landsat True Color (top) and False Color Composite (bottom) indicating current productivity of the area for NZOIA river basin focal area.**

## 5.6 Environmental and socio-economic considerations

### *5.6.1 Population displacements*

The area is very densely populated, but there are no settlements within the area. All people live scattered around the area. However the areas in the stream valleys and near the Nzoia River have hardly been inhabitant so far, and are used for agriculture. This makes is rather difficult to design a large scale irrigation system. With the design of an irrigation scheme, it is advised to limit any population displacement and to develop the irrigation scheme as much as possible 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. Whenever population displacement is thought to be necessary, this should be discussed and decided together with inhabitants, local government and other stakeholders.

### *5.6.2 Social*

Within Kenya 85% of the land area is classified as Arid and Semi-Arid Lands (ASAL) and the remaining 15% sustain more than 75% of the population. Therefore the population density in Nyanza and Western province are the highest of Kenya, with respectively 350 and 406 people per km2. This is very high compared to Kenyan average of 56 inhabitants/$km^2$. Within the focal area the population density is estimated to be slightly lower with 348 inhabitants/$km^2$. The rapidly increasing population is largely the cause for degradation of the catchment and degradation of the focal area. Deforestation, river bank cultivation and compromising water quality are some examples of the raising pressure on the water and land resources, which weaken the adaptation possibilities of the ecosystem. The majority (+/- 90%) of the people in the area belong to the Luo tribe and the remaining 10% belong to the Luhya tribe. Infrastructure in the area is not developed really well. A tarmac road from Kisumu to Busia is passing by the focal area, however within the focal area all roads are weathered dirt roads. For irrigation development the infrastructure should be strengthened to make it easier to bring construction material and agricultural inputs, and to reach the nearby markets with the products. Nearby markets include Siaya, or further away the larger towns Busia, or Kisumu. The farmer's have low knowledge about irrigation and agricultural cooperatives. When developing an irrigation scheme extra attention should be paid to this social part. Unemployment rate in this area is high, irrigation development can create more agro-related jobs and as such reduce unemployment and poverty. In Nyanza and Western province the percentage of woman as head of a household is highest in Kenya with 38%. The net enrollment rate for primary schools in Nyanza province is 98.7% which is the second highest of Kenya, and well above the Kenyan average of 92.9%. Literacy rate is the highest of Kenya with 90.45% of the population. The gender parity index for the enrollment ratio on secondary schools shows a negative trend for Nyanza province, decreasing from 0.737 in 2002 to 0.694 in 2009. HIV prevalence in Nyanza province is the highest in Kenya with 13.9% of the population being infected.

### *5.6.3 Upstream downstream consideration*

The upstream catchment (12500 $km^2$) is very large, and the yearly average flow large with around 190$m^3$/s. Since Nzoia focal area is situated close to lake Victoria most issues are related to the upstream area. Erosion is taking place within and upstream of the focal area. Upstream erosion, deforestation or accelerated precipitation drainage can cause severe flood risk downstream. Population pressure stimulates the use of resources in an unsustainable way.

This may lead to land and environmental degradation. To enhance the environmental aspects upstream-, within- and downstream of the focal area, it is advised to search for measures which retain the precipitation water firstly, and try to store it upstream. This will enhance the upstream ecosystem, and groundwater levels. On a larger scale the groundwater is recharged, which can become available downstream, and evaporation enhances the water cycle and the precipitation in the area. The use of fertilizer is recommended, but it is needed to use fertilizer in a responsible and well considered way. Otherwise the water quality downstream may be compromised. When growing cotton, which is an important crop in the region, the use of chemicals should be minimized.

### *5.6.4 Protected areas*

Within the focal area no protected areas are reported.

## 5.7 Benefit-cost Analysis

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

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

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Tomatoes: 26,500 kg/ha, 0.85 $/kg
    - Kales: 11,420 kg/ha, 0.07 $/kg
    - Onions: 16,500 kg/ha, 0.25 $/kg
    - Pineapples: 16,430 kg/ha, 0.22 $/kg

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

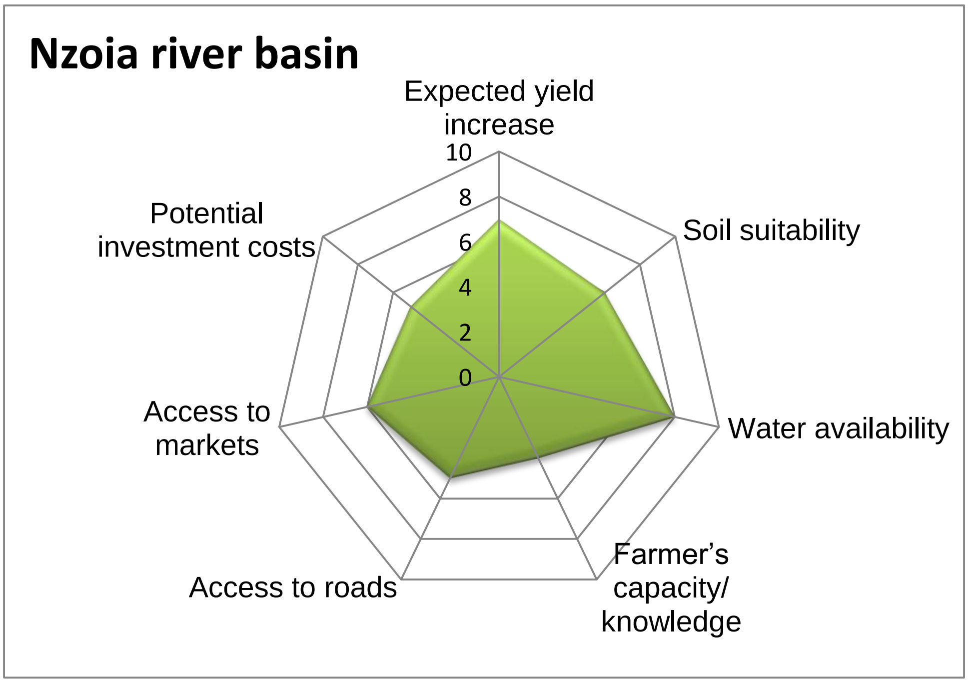



**Figure 71: Filled radar plot indicating expert knowledge score to develop irrigation in the Nzoia basin focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).**

**Table 11: Benefit-cost analysis for Nzoia river basin area.**

| | |
|---|---|
| **Characteristics** | |
| Irrigated land (ha) | 2,500 |
| Farmers | 5,000 |
| **Investment Costs** | |
| Irrigation infrastructure (US$/ha) | 4,000 |
| Social infrastructure (US$/farmer) | 750 |
| Accessibility infrastructure (million US$) | 4.0 |
| **Operational Costs** | |
| O&M irrigation (US$/ha/yr) | 60 |
| Extension service (US$/farmer) | 15 |
| O&M roads (US$/yr) | 80,000 |
| **Summary** | |
| Initial investments (million US$) | 17.8 |
| O&M costs (million US$/yr) | 0.305 |
| Net benefits per year (million US$/yr) | 11.649 |
| IRR (Internal Rate of Return) | 100.0% |

# 6 Sio basin focal area

## 6.1 Introduction

This chapter will describe the current state of the Sio basin focal area, concerning land and water resources, and will discuss the potential to develop irrigation in the area. This irrigation potential will be based on the land and water resources, the irrigation requirements, the potential crop yields and will also involve the socio-economic considerations and institutional frameworks. Based on these aspects the potential for irrigation will be described, and cost for irrigation development calculated. In Figure 73 a detailed map of the area is given. Total area is 5141 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 Raphael Waswa and Hosea Wendot as supervisor in March 2012

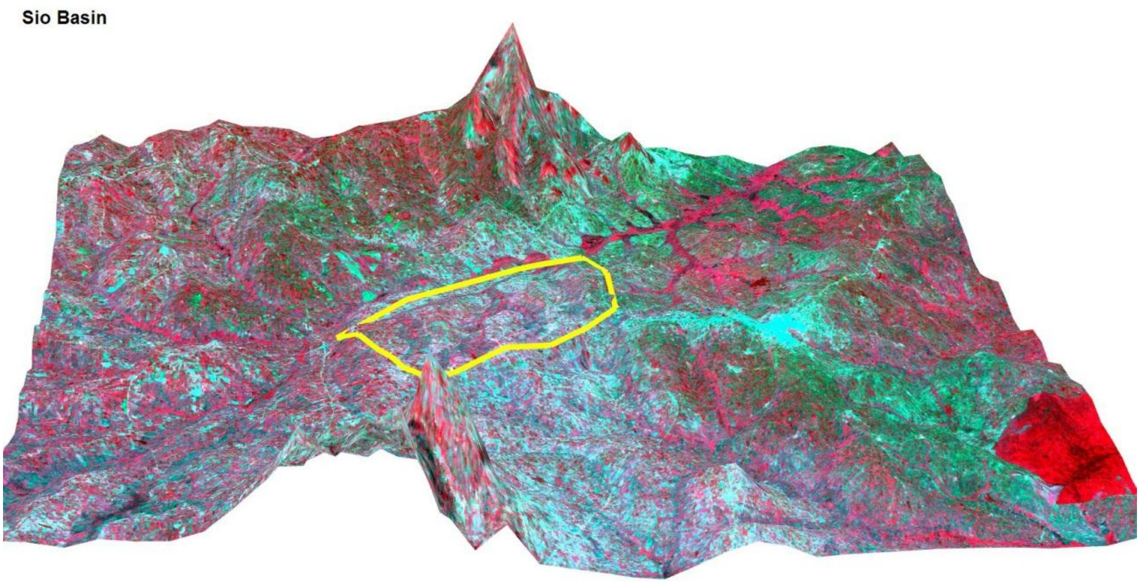



**Figure 72: 3D impression of Sio basin focal area, Kenya**

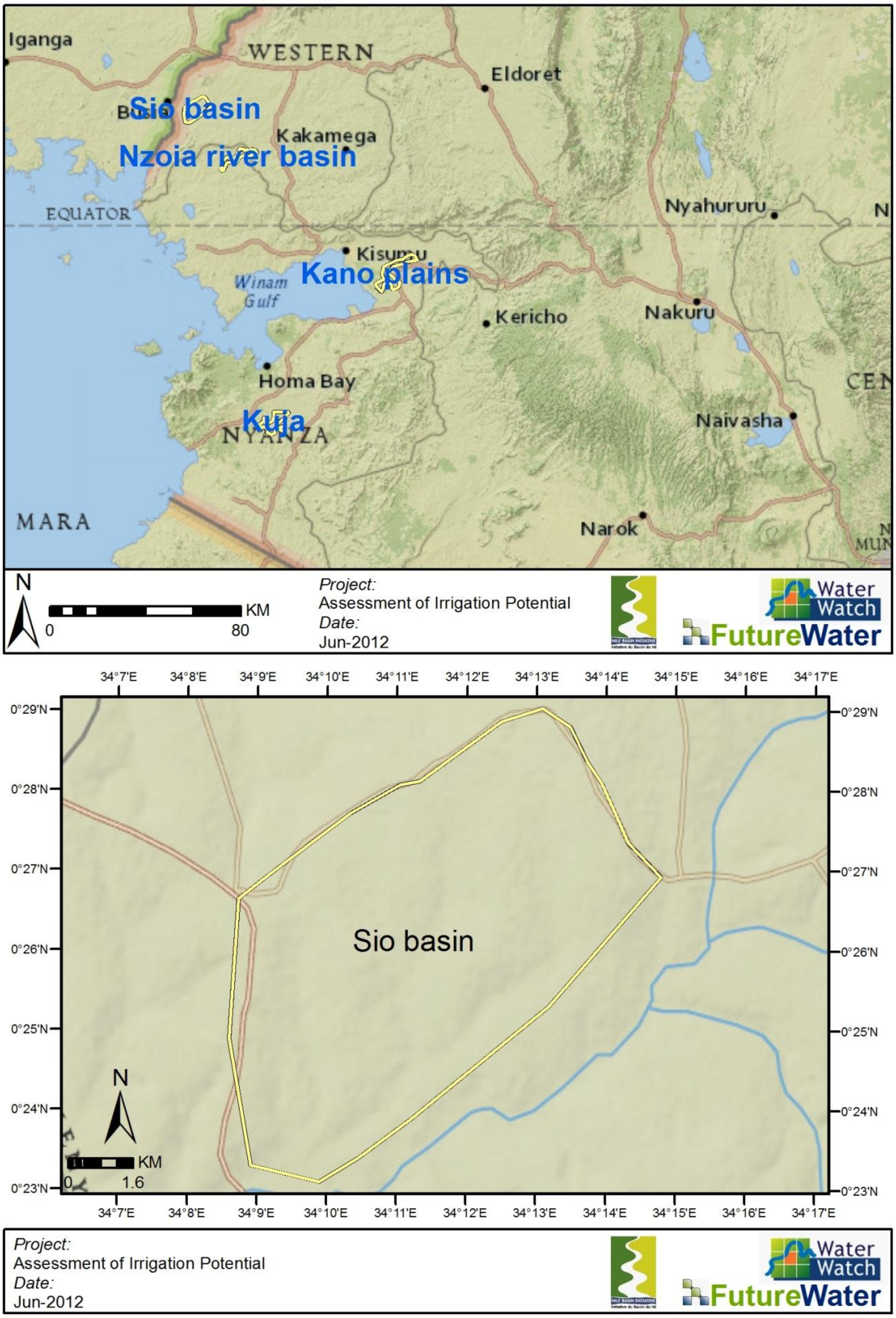



**Figure 73: Sio basin focal area, Kenya**

## 6.2 Land suitability assessment

### *6.2.1 Terrain*

Sio basin Focal area is located in the West of Kenya, near the border to Uganda, and about 20km North of Lake Victoria. The focal area is located within the Western province and Busia district. The Sio River is passing by the focal area on the South eastern side. The focal area itself is located on the foothills covering several valleys draining into the Sio River. Elevation differs from 1240m in the North East towards 1160m above sea level down in the valley in the South of the focal area. (Figure 71 and Figure 74) Slopes are limited, and can reach up to 10% locally but stay well below the 5% on average. (Figure 75) If enough water is available from upstream the area would be very suitable for gravity irrigation.

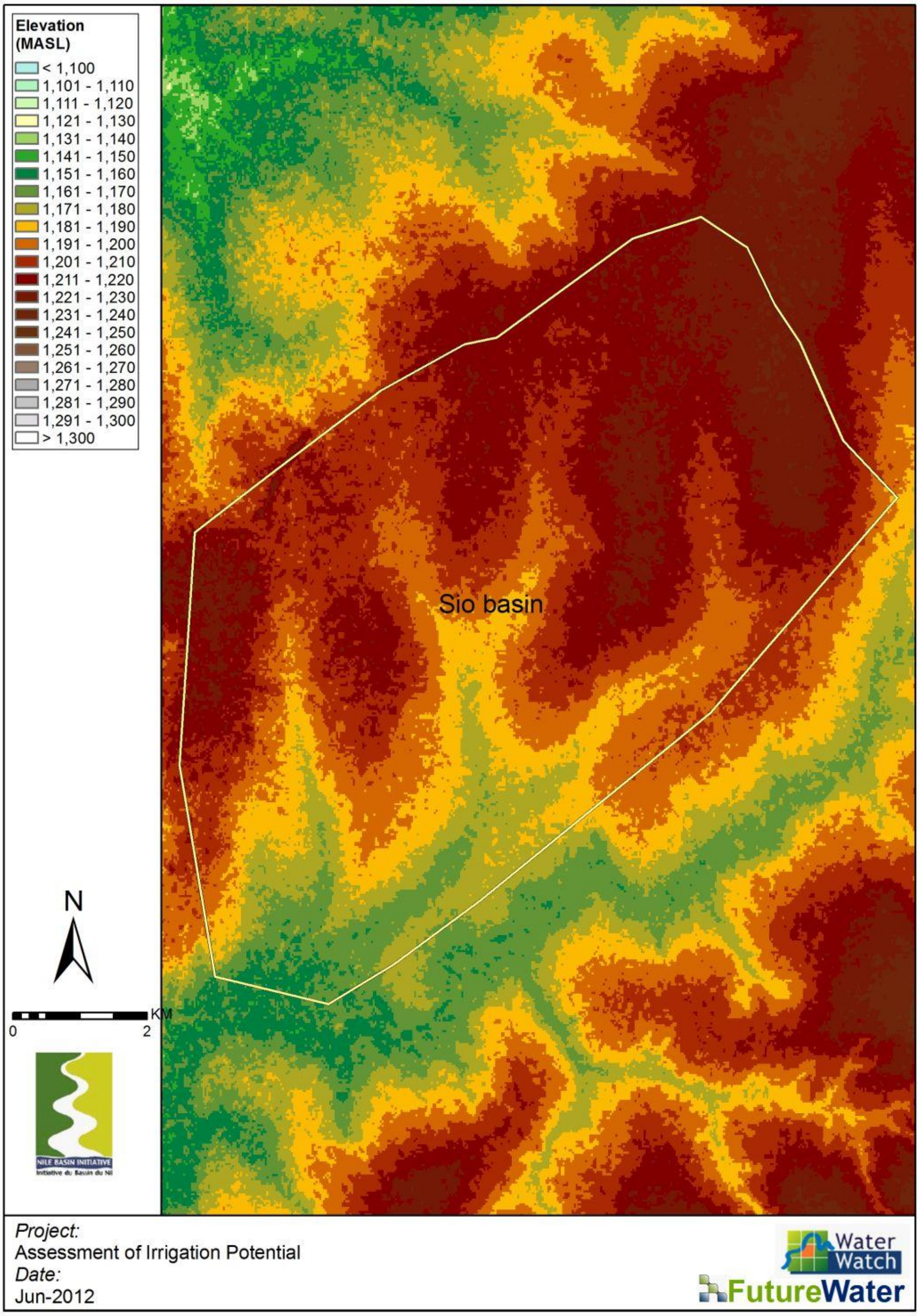



**Figure 74: DEM Sio basin focal area. Resolution 1 arc second (+/- 30m)**

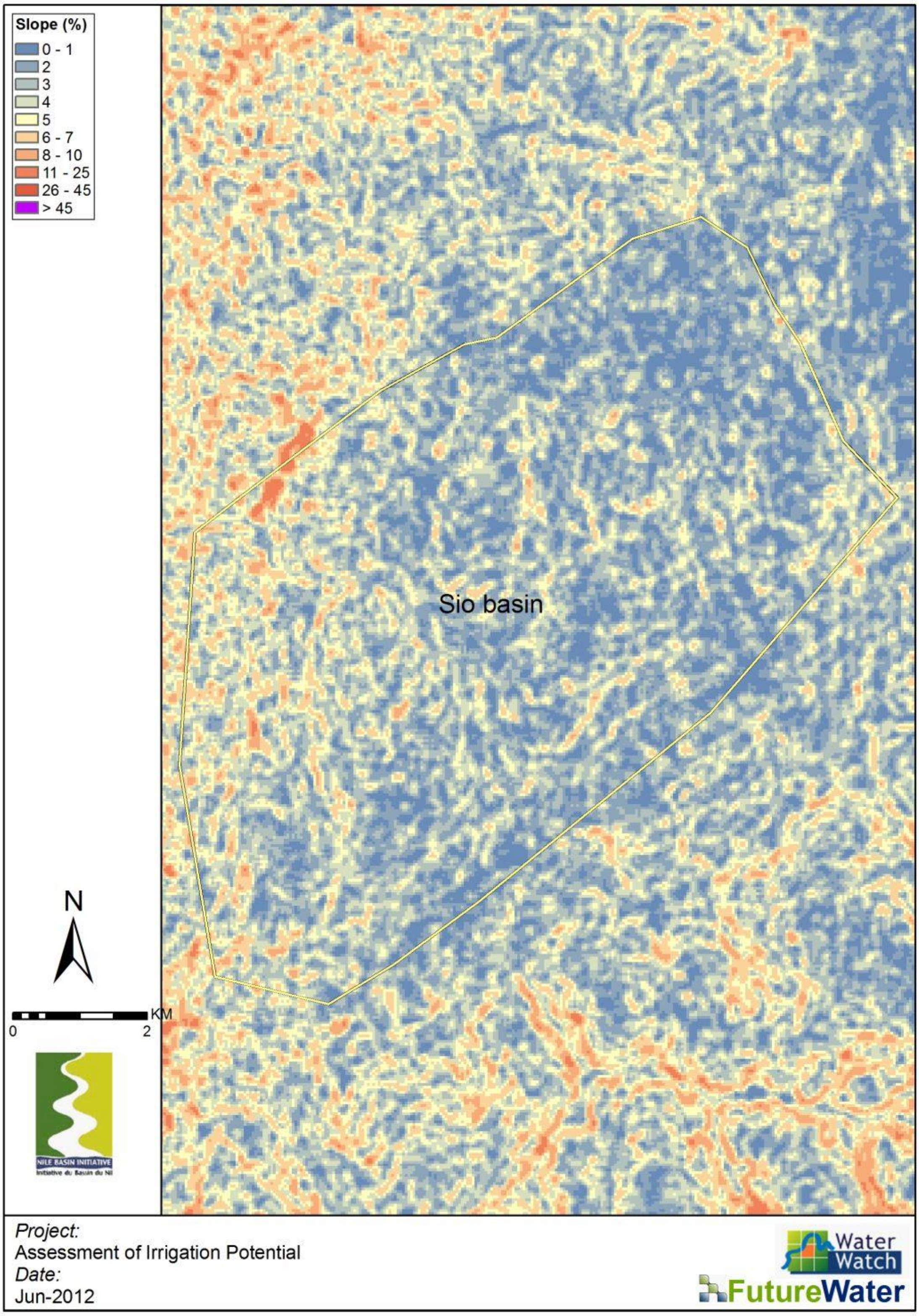



**Figure 75: Slope map Sio basin focal area (source: ASTER).**

### *6.2.2 Soil*

Soils in the area are rather diverse and can differ from place to place. It can be said that the Sio river valley and the small stream valley within the focal area share most characteristics, and that the North western part which is hillier is more uniform. Soil texture in the area ranges from loamy to clayey loam. Drainage capacity is somewhat poor in the North, and moderately well in the southern part of the focal area. The percentage of organic carbon in the topsoil is nearly twice as high in the river valley with 1.5%. The available water holding capacity is large in the whole area with 150 mm/m. Management of the Gleysols which are most common in the southern part of the focal area should focus on drainage to make the soil useful. Adequately drained Gleysols can be used for arable cropping, dairy farming and horticulture. Soil structure will be destroyed for a long time if soils are cultivated when too wet. Therefore, Gleysols in depression areas with unsatisfactory possibilities to lower the groundwater table are best kept under a permanent grass cover or swamp forest. Liming of drained Gleysols that are high in organic matter and/or of low pH value creates a better habitat for micro- and meso-organisms and enhances the rate of decomposition of soil organic matter (and the supply of plant nutrients). Gleysols can be well used for wetland rice cultivation where the climate is appropriate. The soil in the North of the area can be predominantly characterized as an Acrisols although the soil here is very diverse. Acrisols have higher clay content in the sub soil as in the top sol, which limits the drainage capacity. Preservation of the surface soil with its all-important organic matter and preventing erosion are preconditions for farming on Acrisols. Adapted cropping systems with complete fertilization and careful management are required if sedentary farming is to be practiced on Acrisols. 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 annual average land productivity (NDVI) in the four Kenyan focal areas ranges between 0.59 and 0.66. In Sio basin focal area the NDVI is 0.64, which is high compared to the Kenya average NDVI of 0.36. (Figure 77) Land productivity is highest within the river valley in the South and the stream valleys in the focal area. These areas are most intensively used for agriculture. The variation in NDVI is very low all over the area. This suggest a year round cultivation.

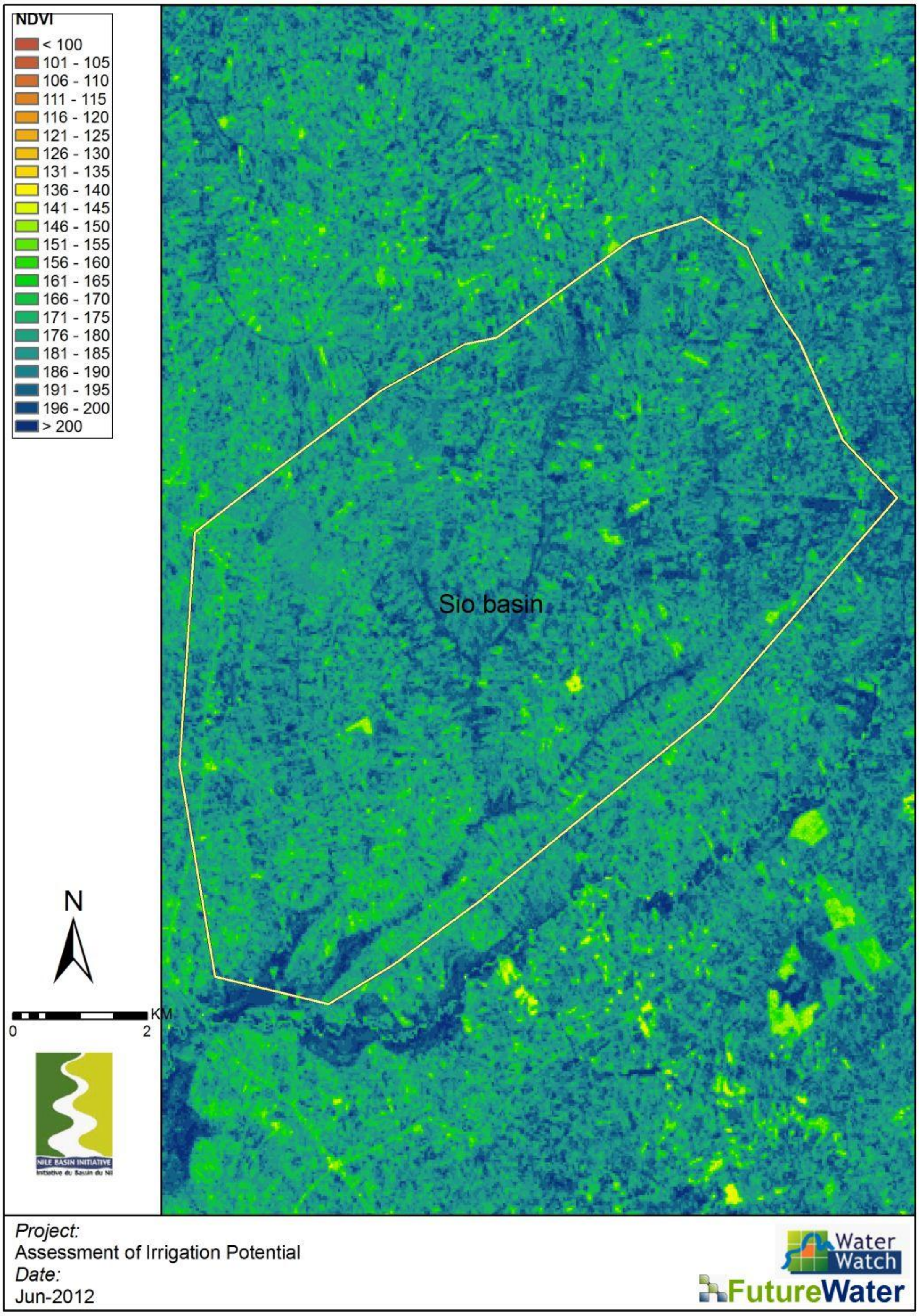



**Figure 76: High resolution NDVI for SIO Basin focal area**

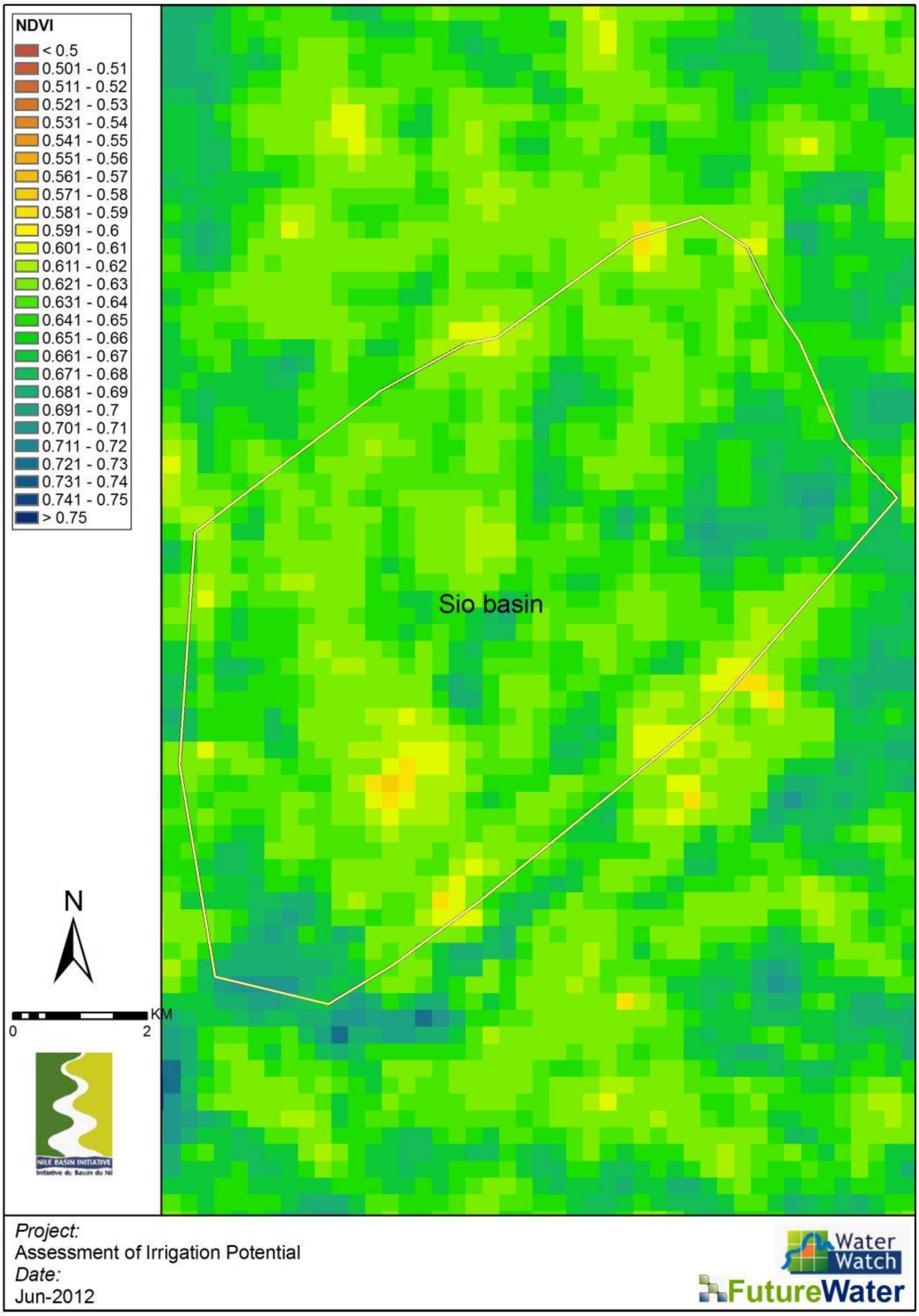



**Figure 77: Yearly average NDVI values for SIO Basin focal area.**

### 6.2.4 Potential cropping patterns

Field assessments have shown that currently approximately 80% of the land is used for agriculture. Most dominant crops are Maize, Cassava, Beans and Sorghum. Maize, Beans and Sorghum are all grown in two growing cycles per year. Starting in March and August and running for 5 months for Maize and Sorghum and 3 months for beans. Yields for Maize are around 1600 kg/ha for Beans and Sorghum 1400 kg/ha. Cassava is grown in one growing cycle per year, and has an average yield of 16 tons/ha. According to Kenya national irrigation policy agriculture is the backbone of Kenya's economy and has a central place in realizing national aspiration and poverty reduction. The make agriculture more independent of the unreliable rainfall patterns Kenya must embrace irrigation and drainage development to remain competitive. Irrigation will also significantly contribute to the meeting of the demands for national food security as well as the sophisticated and emerging export markets for food, fibre, oil crops, animals and fisheries products. Diversification of crops will be enhanced to contribute fully to food security and industrialization. Practically for this focal area this means that Tomatoes, Kales, Onions and Watermelon are suggested. In the valleys where soils are more humid Paddy/rice will be a suitable crop to enhance food security. Under irrigation most of these crops can be grown in two and maybe three growing cycles per year.

## 6.3 Water resource assessment

### 6.3.1 Climate

Total precipitation in the focal area is 1435 mm per year, while reference evapotranspiration is at the same level of 14300 mm per year. However, during November to February there is a clear scope for improvement of crop water requirements by irrigation. Differences between minimum and maximum temperature is quite large and are 18°C and 31°C respectively.

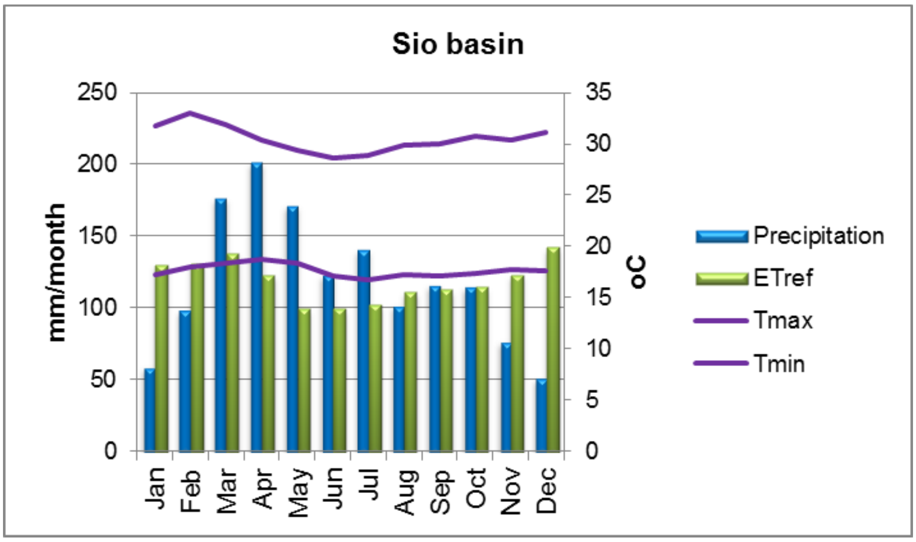



**Figure 78: Average climate conditions for SIO Basin focal area.**

### *6.3.2 Water balance*

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

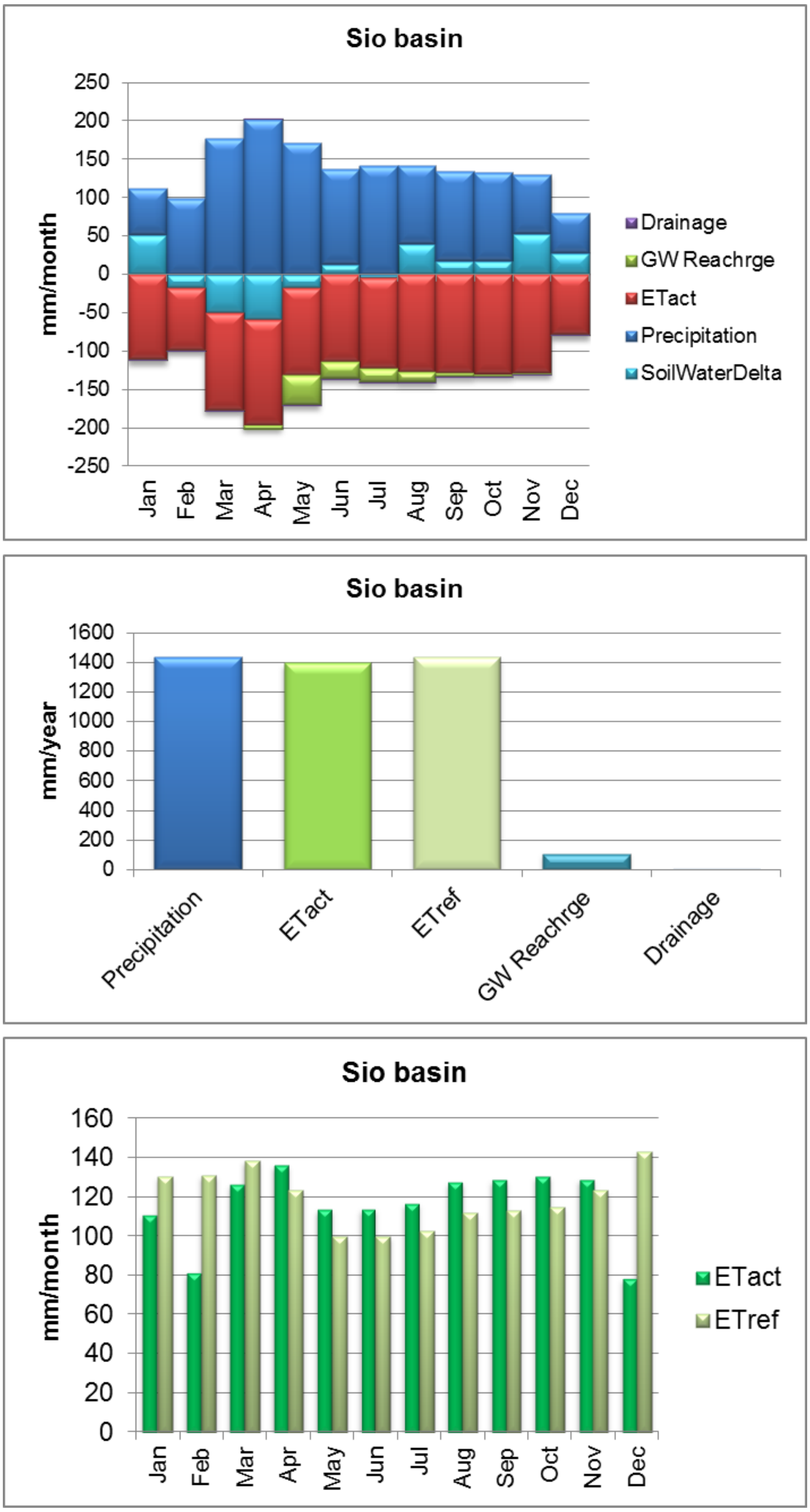
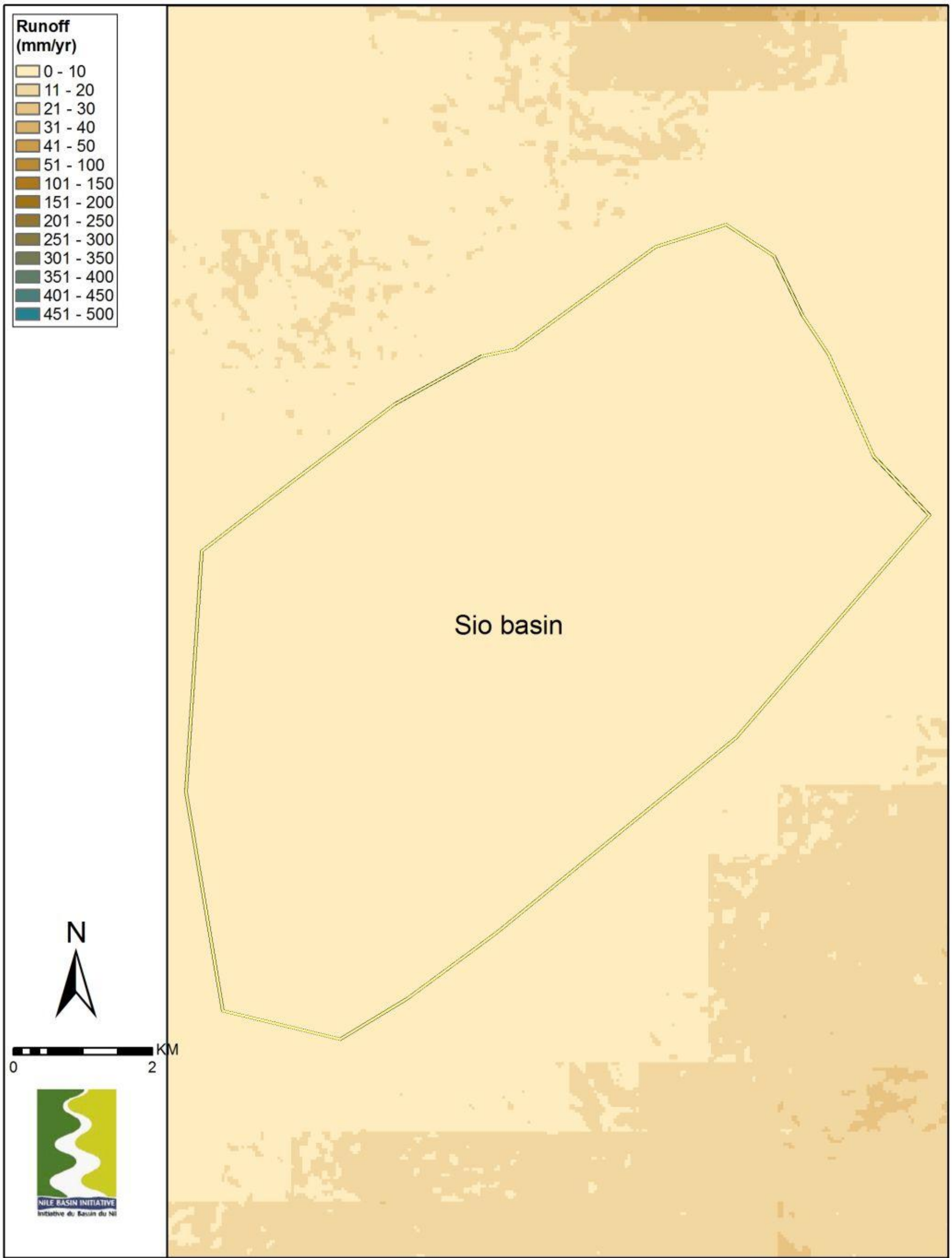
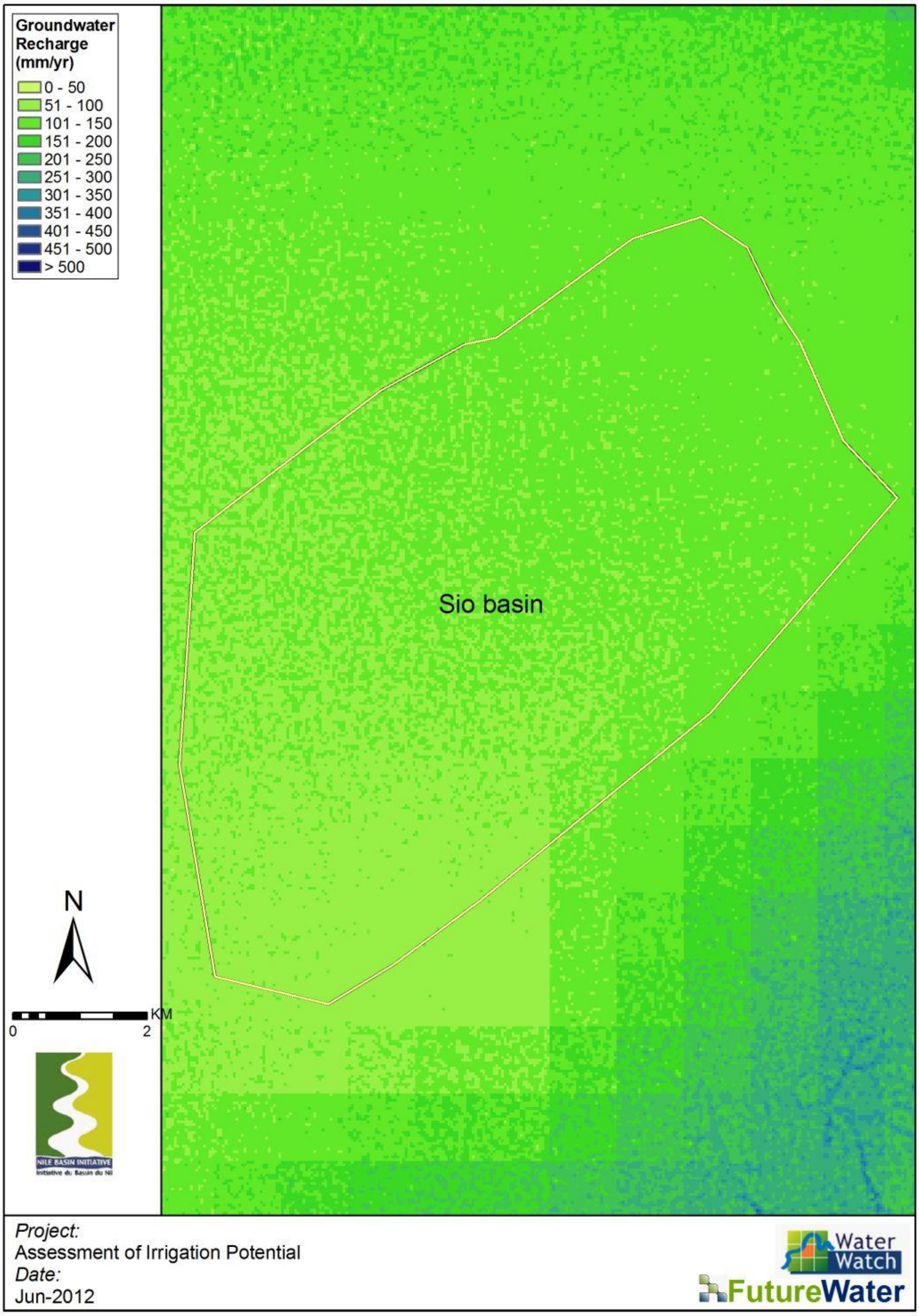



**Figure 79: Water balances for the area based on the high resolution data and modeling approach for SIO Basin focal area.**




*Project:*
Assessment of Irrigation Potential
*Date:*
Jun-2012

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

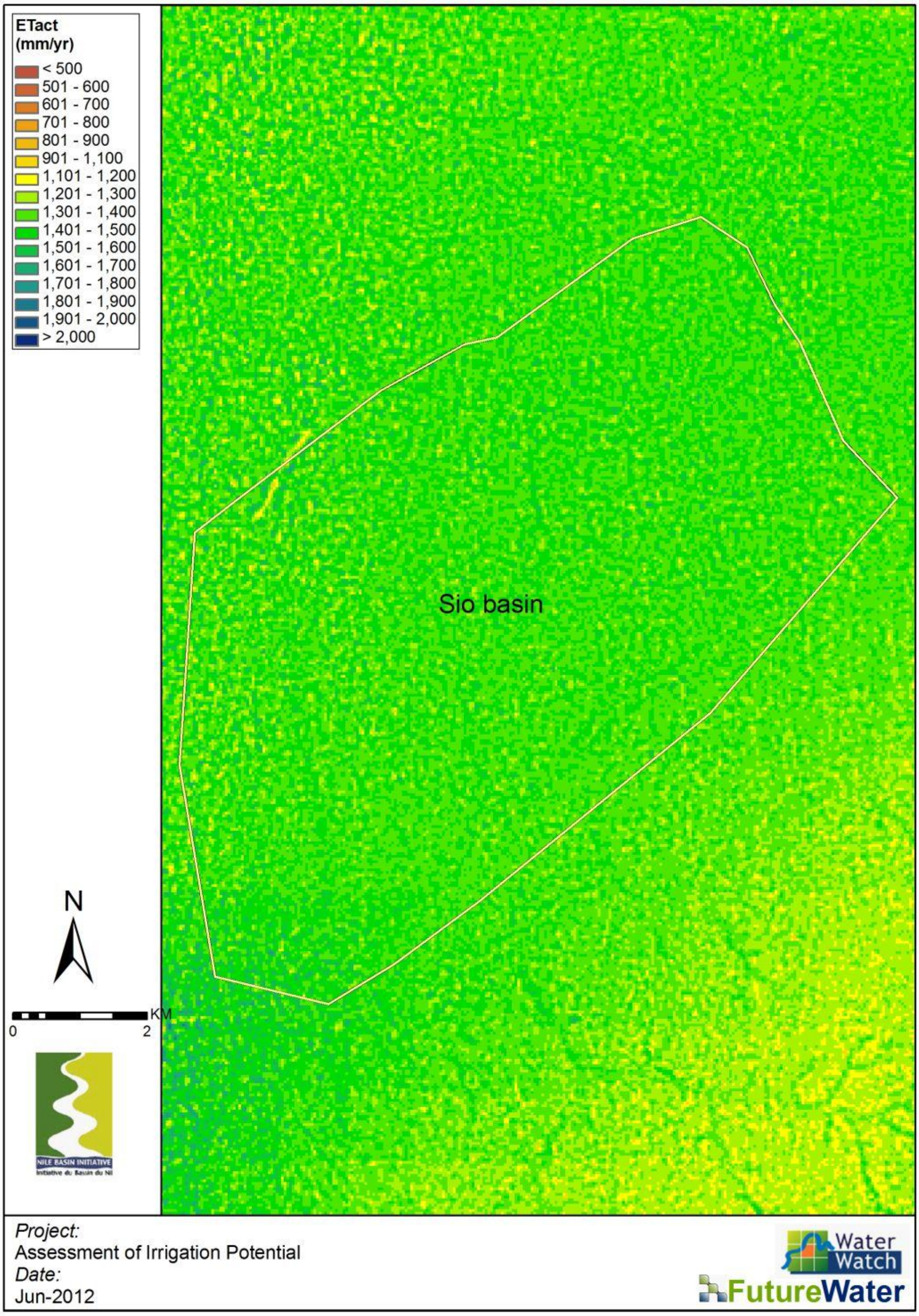



**Figure 80: Water balances for the area based on the high resolution data and modeling approach for SIO Basin focal area.**

## 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.

All input files and output files for AquaCrop can be found in the database attached to the reports. Note that during this pre-feasibility phase focus with AquaCrop was to obtain crop water requirements. A subsequent feasibility study could focus more on the crop yield validation and calibration components of AquaCrop.

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

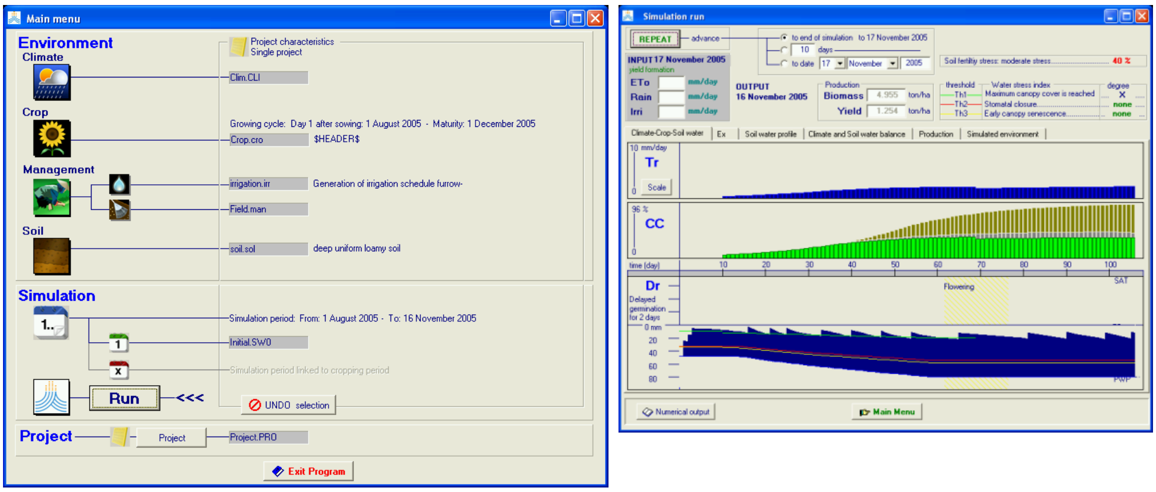



**Figure 81: Typical example of AquaCrop input and output screens.**

**Table 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 | Harvests | Rain | Irrigation | ETref | ETact |
|---|---|---|---|---|---|---|---|---|
| | === year | === | == (day of year) == | | ======== growing season | | ======= | |
| | (mm) | (mm) | | | (mm) | (mm) | (mm) | (mm) |
| Tomatoes | 1434 | 1431 | 1 | 365 | 1434 | 190 | 1426 | 1055 |
| Kales | 1434 | 1431 | 1 | 365 | 1434 | 190 | 1426 | 1055 |
| Onions | 1434 | 1431 | 1 | 365 | 1434 | 190 | 1426 | 1055 |
| Water melon | 1434 | 1431 | 1 | 365 | 1434 | 190 | 1426 | 1055 |

### *6.4.2 Irrigation systems and irrigations efficiencies*

Water availability in Sio basin focal area is slightly more complicated as the other Kenyan focal areas. Sio River passes by the focal area in the South eastern side. Sio River drains an area of roughly 900 $km^2$ upstream of the focal area. Three minor stream find there source within the focal area, but since there catchment is very small these stream will not generate sufficient discharge to irrigate the full focal area. In the best situation the water can be diverted from the river upstream so that the fields can be irrigated under gravity. In that case either furrow or border irrigation is recommended. These two techniques no not require high investments as they are relatively cheap compared to pressurized irrigation systems such as sprinkler or drip irrigation. On top of that the farmers can get used to flood irrigation much easier as pressurized irrigation which enhances a sustainable irrigation system, which can be managed by the farmers. However, water from the Sio River will be needed to irrigate the area. Therefore the water should be pumped up for maximum 30-40 meters. Since this pumping makes the conveyance costs much higher it is good to consider pressurized irrigation as efficiencies are much higher. Efficiencies of flood irrigation are relatively low. After conveyance and application efficiency correction about 40% of the water is used effectively. For pressurized systems this is much higher, and can reach up to 70-80%. A detailed costs analysis is beyond the scope of this pre-feasibility study, and should be carried out in a next stage.

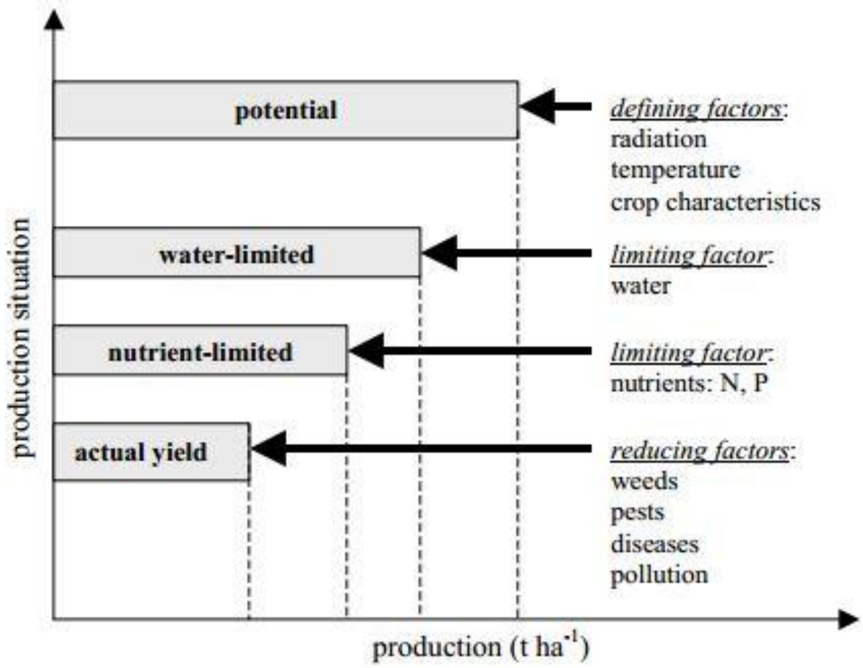
### *6.4.3 Water source*

The irrigation water source will be partly the streams originating within the focal area, but mainly Sio River. The river has an annual average flow of 12 $m^3/s$, which will be sufficient to irrigate the full focal area. The only constraint will be the large seasonal variety of the river flow. Therefore stream control structures will be required, in combination with storage capacity. These structures can also be used as an intake point for irrigation water diversion. Groundwater is not a very suitable source within the focal area.

## 6.5 Potential crop yield assessment

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

The gap between the actual yield and the potential yield can be caused by several processes. Factors which may cause that the maximal 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

Average Kenyan yields are the lowest of all research countries. Within the focal areas however the conditions are favorable and yields high, even compared to surrounding countries. For this focal area is chosen to focus on high value crops, which give good return. This can be seen in Figure 82. These potential crops will al give an excellent yield under irrigation, and will be very rewarding. It is expected that the gains with these potential crops can double or triple per hectare.

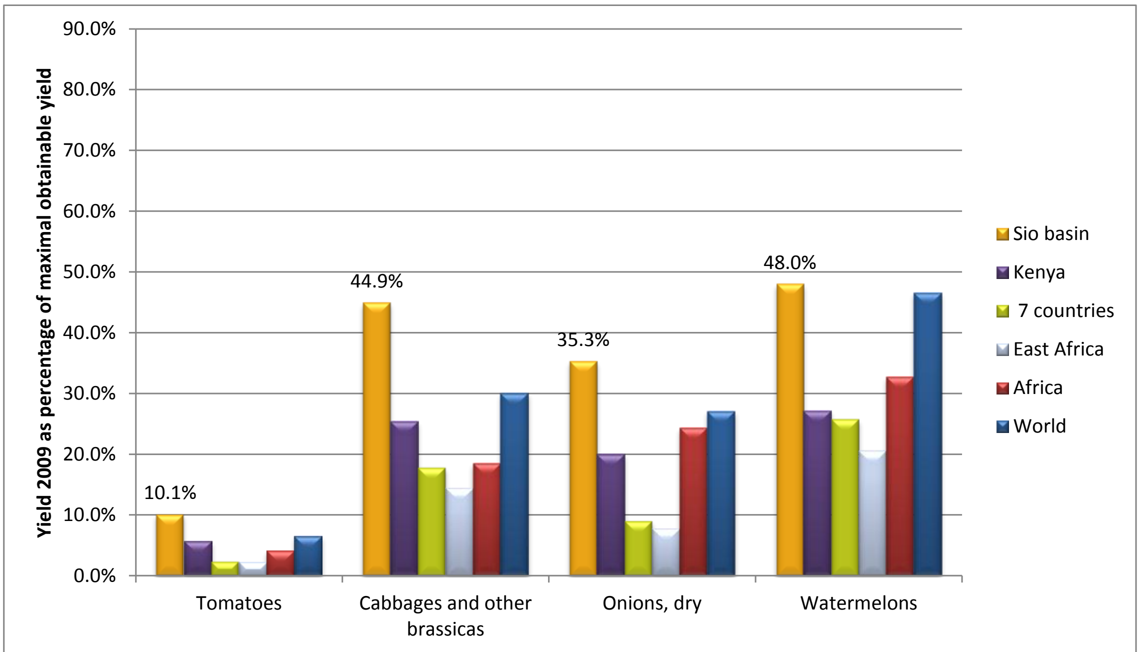



**Figure 82: Yield gap Sio basin (source: FAOSTAT, 2012 year???).**

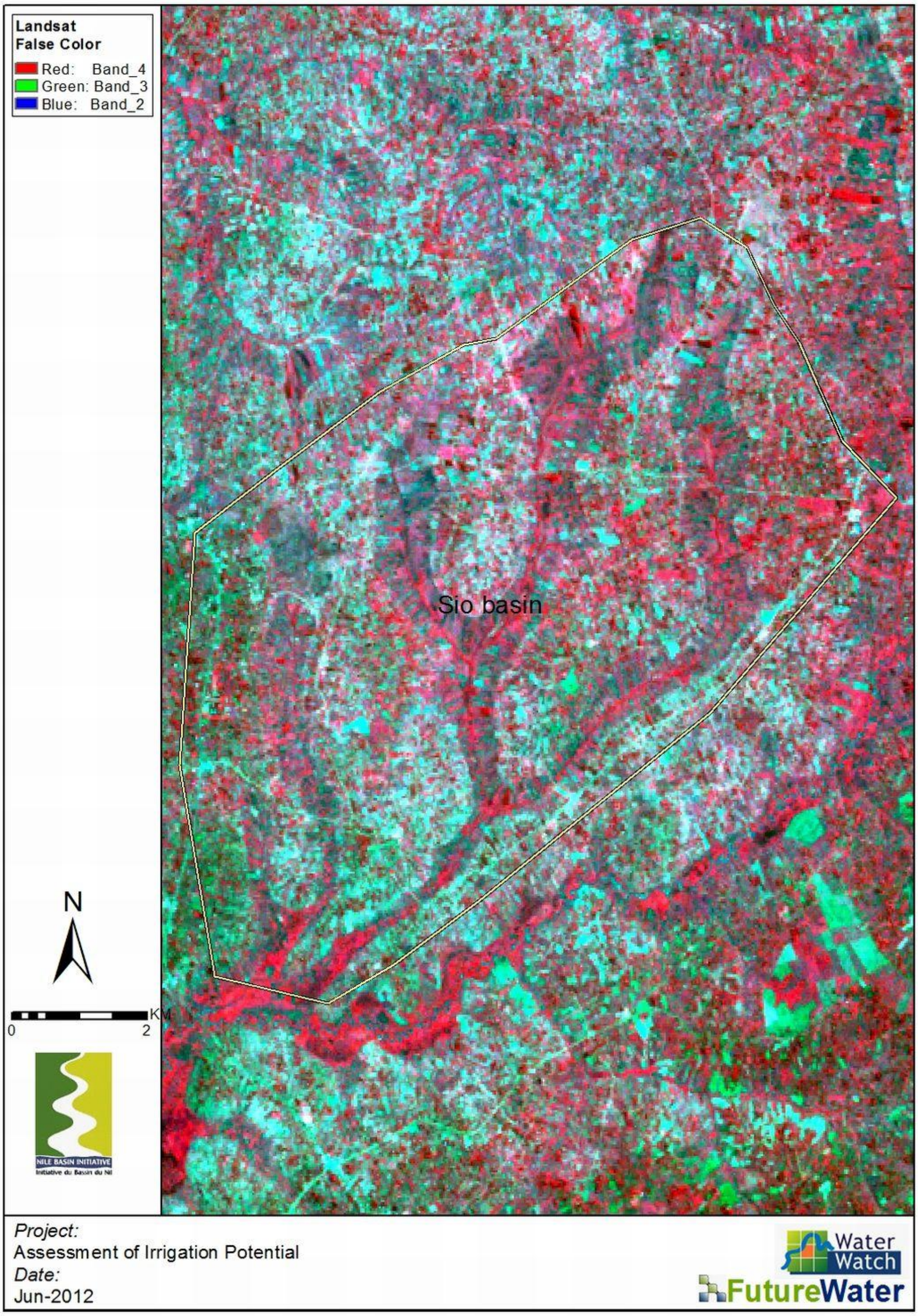



**Figure 83: Landsat True Color (top) and False Color Composite (bottom) indicating current productivity of the area for SIO Basin focal area.**

## 6.6 Environmental and socio-economic considerations

### *6.6.1 Population displacements*

The area is very densely populated, but there are no settlements within the area. All people live scattered around the area on the slightly higher places. However the areas in the stream valleys and near the Sio River have hardly been inhabitant so far, and are used for agriculture. This makes is rather difficult to design a large scale irrigation system. With the design of an irrigation scheme, it is advised to limit any population displacement and to develop the irrigation scheme as much as possible 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. Whenever population displacement is thought to be necessary, this should be discussed and decided together with inhabitants, local government and other stakeholders.

### *6.6.2 Social*

Within Kenya 85% of the land area is classified as Arid and Semi-Arid Lands (ASAL) and the remaining 15% sustain more than 75% of the population. Therefore the population density in Nyanza and Western province are the highest of Kenya, with respectively 350 and 406 people per km2. This is very high compared to Kenyan average of 56 inhabitants/$km^2$. Within the focal area the population density is estimated to be slightly lower with 360 inhabitants/$km^2$. The rapidly increasing population is largely the cause for degradation of the catchment and degradation of the focal area. Deforestation, river bank cultivation and compromising water quality are some examples of the raising pressure on the water and land resources, which weaken the adaptation possibilities of the ecosystem. The majority of the people in the area belong to the Luhya tribe. Infrastructure in the area is developed quite well. A tarmac road from Kisumu to Busia is passing by the focal area and one other tarmac road surrounds the focal area. However within the focal area all roads are weathered dirt roads. For irrigation development the infrastructure should be strengthened to make it easier to bring construction material and agricultural inputs, and to reach the nearby markets with the products. Nearby markets include Busia, Namble, Bumala, Bungoma, Mumias, Kisumu or towns in neighbouring Uganda. The farmer's have low knowledge about irrigation and agricultural cooperatives. When developing an irrigation scheme extra attention should be paid to this social part. Unemployment rate in this area is high; irrigation development can create more agro-related jobs and as such reduce unemployment and poverty. In Nyanza and Western province the percentage of woman as head of a household is highest in Kenya with 38%. The net enrollment rate for primary schools in Western province is 99.5% which is the highest of Kenya, and well above the Kenyan average of 92.9%. Literacy rate is slightly above Kenyan average with 82.9% of the population. The gender parity index for the enrollment ratio on secondary schools shows a negative trend for Western province, decreasing from 0.989 in 2002 to 0.858 in 2009. HIV prevalence in Western province is 6.6% of the population.

### *6.6.3 Upstream downstream consideration*

Since the upstream catchment (900 $km^2$) and discharge are not enormously large, the water availability for irrigation should be considered well. Upstream and downstream of the focal area, people should still have enough water available to practice agriculture, and have water for living. This is especially for the small streams originating within the focal area. Erosion is taking place within and upstream of the focal area. Upstream erosion, deforestation or accelerated precipitation drainage can cause severe flood risk downstream. Population pressure stimulates the use of resources in an unsustainable way. This may lead to land and environmental degradation. To enhance the environmental aspects upstream-, within- and downstream of the focal area, it is advised to search for measures which retain the precipitation water firstly, and try to store it upstream. This will enhance the upstream ecosystem, and groundwater levels. On a larger scale the groundwater is recharged, which can become available downstream, and evaporation enhances the water cycle and the precipitation in the area. The use of fertilizer is recommended, but it is needed to use fertilizer in a responsible and well considered way. Otherwise the water quality downstream may be compromised. When growing cotton, which is an important crop in the region, the use of chemicals should be minimized.

#### *6.6.4 Protected areas*

Within the focal area no protected areas are reported.

## 6.7 Benefit-cost Analysis

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

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

Main assumptions for the benefit-costs analysis include:

- Irrigated land based on GIS and local experts for boundaries
- Number of farmers based on average land tenure area
- Irrigation infrastructure based on irrigation type and source
- Social infrastructure based on local expert judgment on farmers' trainings need
- Accessibility infrastructure based on generalized road conditions
- Internal Rate of Return based on 25 years
- Crop revenues based on local crop potentials and local market prices (crop, kg/ha, $/kg):
    - Tomatoes: 27,000 kg/ha, 0.85 $/kg
    - Kales: 12,000 kg/ha, 0.07 $/kg
    - Onions: 17,000 kg/ha, 0.25 $/kg
    - Water melon: 6,000 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, to markets and the initial investment cost. This in-turn affects access to market as farmers cannot transport their yield easily and more importantly may not fetch golden prices. However, soil suitability and water availability is a great deal for the area that will foster an increase yields.

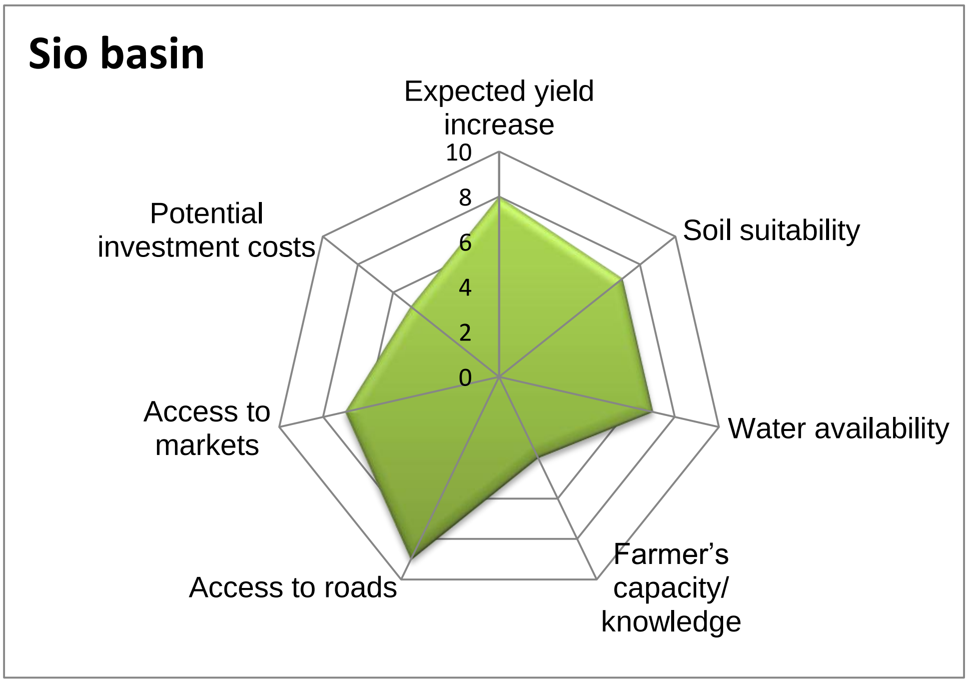



**Figure 84: Filled radar plot indicating expert knowledge score to develop irrigation in the Sio basin focal area (1 = negative, 10 = positive). (Source: local experts and study analysis).**

**Table 13: Benefit-cost analysis for Sio basin area.**

| | |
|---|---|
| **Characteristics** | |
| Irrigated land (ha) | 3,500 |
| Farmers | 3,182 |
| **Investment Costs** | |
| Irrigation infrastructure (US$/ha) | 6,000 |
| Social infrastructure (US$/farmer) | 500 |
| Accessibility infrastructure (million US$) | 2.0 |
| **Operational Costs** | |
| O&M irrigation (US$/ha/yr) | 60 |
| Extension service (US$/farmer) | 10 |
| O&M roads (US$/yr) | 40,000 |
| **Summary** | |
| Initial investments (million US$) | 24.6 |
| O&M costs (million US$/yr) | 0.282 |
| Net benefits per year (million US$/yr) | 15.509 |
| IRR (Internal Rate of Return) | 100.0% |