Appendix A Information needs for the assessment of irrigation system performance

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We have numerous reports from the Nile Basin Initiative and elsewhere regards the *general* status of irrigation development in basin countries, as well as broad policy statements. However, to fully understand how a large scale irrigation system is working, and particularly to assess what contributes to good performance and poor performance, we need information at the project level.

At the national level, the questions are:

1. Is there a national policy on water resources? (If so, please provide copy)
2. Does it cover surface and groundwater?
3. Are priorities specified for water allocation of water among sectors (domestic, agriculture, industry...)?
4. Are objectives specified for large scale irrigation systems (eg food security; increased rural incomes; job creation, etc)
5. Are water rights (absolute volumes, proportions, guaranteed minimum) specified to major users?
6. Are licensing procedures in place for new uses?
7. If water rights are specified, how are they monitored/enforced?
8. What are the categories of irrigation system (individual owner/user; collective small-scale private irrigation, large scale irrigation).
9. In the large-scale irrigation sector, who is responsible* for:
    a. Planning
    b. Design
    c. Construction
    d. Operation and Maintenance**
    e. Regulatory functions

        * Responsibilities may be with central government, state government, project authority, users, private agency, etc.

        **Specifically for large scale-irrigation scheme operation, indicate points at which responsibilities are transferred from agency to farmer-organization to individual farmers, as appropriate.

10. What are the financing arrangements for construction, management, operation and maintenance of irrigation systems?

Additional project-specific questions are set out on the following page. We would appreciate receiving information related to a few selected irrigation schemes, that can be considered to be representative for a given country or agro-ecological zone. We aim at compiling a few good quality and complete datasets for selected schemes (not more than 3 per country).

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Scheme name				
Location				
Describe purpose of project:				
(eg food security; area development, commercial plantation)				
General description				
(irrigation technology, responsibilities of agency and farmers in crop planning and water distribution)				
Average farm size (ha)				

Technical Information:				
Area equipped for irrigation (ha)				
Cropping seasons	(months)			
1				
2				
3				
Main crops PLANNED	Name	Season(s)	% area	Yield (t/ha)
1				
2				
3				
4				
5				
Main crops ACTUAL	Name	Season(s)	% area	Yield (t/ha)
1				
2				
3				
4				
5				

		m3/sec		
Principal water source	Pumped from river			
	Diverted from river			
	Groundwater			
Availability (continuous, seasonal…)				
Seasonal entitlement (000 m3)				
Season 1				
Season 2				
Season 3				
Availability (always, most years…)				
Season 1				
Season 2				
Season 3				
Other sources:				
Type				
Capacity (m3/sec)				

Cropping seasons	(months)			
1				
2				
3				
Main crops	Name	Season(s)	% area	
1				
2				
3				
4				
5				
Rainfall (Monthly)	Mean	Highest 10%	Lowest 10%	
Jan				
Feb				
Mar				
Apr				
May				
Jun				
Jul				
Aug				
Sep				
Oct				
Nov				
Dec				

Cost of Operation & Maintenance				
Currency				
Amount/year				
Sources of funds				
Government				
Water charges				
Responsibilities in operation:				
Agency				
Farmers				
Responsibilities in maintenance:				
Agency				
Farmers				

Appendix B Study Tour to Best Practice Sites of Large Scale Irrigation (LSI) Schemes in Egypt

1. Introduction

The diagnosis of the irrigation peformance in the Nile basin showed that the Governorate General of Kafr-el-Sheik appeared to be the most favourable area. A short study tour was organized to visit some of the irrigated farms in this region. The irrigation activities in the Western Desert appeared also to be extra-ordinary good in terms of using modern technologies that save water, and it was believed interesting to visit these contrasting areas: old land with surface irrigation systems vs. new land with modernized irrigation systems. The program balances technical issues with institutional aspects. This report describes the major findings of the two-day study tour. The detailed program is attached in Appendix 1. The list of course participants is specified in Appendix 3.

Objective of study tour: Exposing irrigation professionals and policy makers from the Nile basin countries to the irrigation conditions and institutions in Egypt; Understanding the reasons behind best practices

The EWUAP project is indebted to Engineer Ibrahim Mohamed Mahmoud and his colleagues who invited the international guests to their ongoing Integrated Irrigation Improvement and Management Project (IIIMP) areas. The service of Dr. Fathy El-Gamal and his colleagues in the facilitation of this study tour and provision of further technical and logistical support is also acknowledged.

2. Monday 15 September 2008

The traditionally irrigated alluvial soils of the Nile Delta were visited during the first day of the study tour. Two mini-busses left early from Cairo to Kafr-El-Sheik. Introduction to the irrigation practices in Egypt and some background information on the IIIMP improvement project was shared by various speakers with the participants of the study tour. The aims of the IIIMP project are:

- increase uniformity of access to irrigation water resources;
- increase agricultural production; and
- reduce operational costs of pumping.

The IIIMP has a few pilot areas, and the Mit Yazeed main canal is one of them. Mit Yazeed is located in the Kafr El Sheik region, and this area was visited for a closer inspection. The inlet of one of the branch canals has been visited. The inlet has now an orifice type of inlet structure that can be remotely controlled (also manually). The excursion continued to the meska and marwa improvements. There is one central lifting point for the meska and the water is put under pressure and brought to individual fields by a burried pipeline. The water is continuously available and it is a true on-demand water supply system: open the tap and irrigate. Due to the growing intensive rice cultivation, there are short periods that the water demand cannot be met. The farmers (who first denied this type of interventions) are happy with the change because:

- less petrol costs by abandoning individual diesel pumps;
- less competition during rotational flow when the branch canal receives water;
- tail end farmers can now irrigate with canal water (before from the drain);
- they can cultivate a larger fraction of rice (they are liberal to sell rice);
- the yields went up by 10 to 15% due to better water quality and reduced crop water stress; and
- it also gives them more flexibility to select the crop since it is feasible to grow 3 crops per year.

The water managers are satisfied because:

- farmer complaints have stopped;
- there is less on-farm water losses because excessive irrigations doesn't occur any longer; and
- the amount of water supply ('gross supply') has been reduced.

Rice is the major crop in Kafr-El-Sheik. The area is very flat, the water table is shallow and the alluvial soils are of excellent quality. Farmers can acquire fertilizers and seed against a relatively low price. The seeds are continuously improved through the breeding programs of the Ministry of Agriculture. The rice season duration is short (90 days after transplantation) and the grain/straw ratio is very favourable. These conditions are fundamental for acquiring 10 ton/ha, an extremely good achievement. The short duration can be hold largely responsible for reducing the total water consumptive use (approximately 600 mm/season).

The LSI analysis also showed an excellent performance in the vicinity of Rasheed (see Appendix 2 with examples of satellite images). This can be largely explained by the presence of orchards and date palm gardens. These permanent crops seem to be suited for constant and good irrigation practices.

3. Tuesday 16 September 2008

During the second day, a trip was organized towards the new land with the main objective to understand modern irrigation systems and impact on irrigation performance. Also a visit was paid to a district water board for getting exposure to institutional changes and arrangements.

Dina farms (www.dinafarms.com)

The farm was established in 1987 with 1500 feddan, and it abstracts groundwater from the Marmarica aquifer. The wells are approximately 200 m deep and the groundwater table can be found at 100 m. Due to the establishment of several new estate farms and absence of groundwater regulations in the new lands along the desert road, over-exploitation of groundwater have been emerging. The commercial farmers - together as a cooperation - will pay the cost of construction of a new pipe line that conveys Nile surface water resources to augment the lack of groundwater resources. The World Bank is providing a loan to the enterprises for facilitation of the capital investment. Dina farm is currently covering 12000 feddan. It employs 2000 workers.

Dina farm has 86 centre pivots. The average size is 60 hectare. The pivots are cultivated with alfalfa and maize for animal feed. Each pivot has its own well. The wells are connected to a network for ensured irrigation water supply.

Dina farm also produces several high value horticultural products. They are sold to the national and international market, hence the timing of the harvesting is of paramount importance. The table below provides some indications on the type of fruits and vegetables grown.

Crop type	Yield
	(ton/ha)
Fruits	Table grapes (30 ton/ha); Strawberries; Oranges (45 to 55 ton/ha) ; Mango (40 ton/ha) ; Apricot ; Lemon; Apple; Bananas; Dates; Olives; Peaches
Vegetables	Onions; potatoes
Field crops	Alfalfa (5 to 6 cuts); maize

The crop water requirements under desert conditions are 1500 mm/yr. This represents the potential evapotranspiration. The centre pivot system is considered to be ideal because irrigation can be provided with much more precision than with surface irrigation methods. Further to water related arguments, it was mentioned that expensive fertilizers and pesticides are not leached out. US-based Siematic pivots were first installed and used (US$ 45,000), and they are nowadays replaced by Egyptian made systems (US$ 35,000). Despite these high costs, it is believed that centre pivots provide a positive renumeration due to reduced pumping costs, reduce water consumption and diminish leaching of fertilizers.

It must be recognized that the sandy desert soils are not suitable for surface irrigation methods, and hence there is not much of an alternative, except the installation of drip systems. The managers remarked that they would also opt for center pivot systems on alluvial soils in the Delta.

Centech farm (www.egyptgreen.com)

Centech farm (600 acres) is part of the El Shorouk farm that sells the EgyptGreen brand name products. The farm aims to achieve a high economic water productivity by intendently optimizing the net profits per unit of water ($\$/m^3$). This is in full line with the approach taken by the LSI study. Cutflowers and ornamental plants are superior for economic returns (upto 12 US$\$/m^3$). Centech has imported irrigation and agronomical technologies from Chili (grapes), South Africa (grapes & mango's) and Morocco. This reveals that taking the best practices from other countries is a wise principle.

Virtually all irrigation on Centech farm occurs with drip systems. Each well has a capacity of 120 m^3 of water/hour and each well serves 50 acres. It is a system of fertigation where fertilizers are applied via the drip system. For safeguarding water supply throughout the farm, the minimal distance between the wells is kept at 50

m. Centech is experimenting with low tech sprinklers for overhead irrigation (20 ha). Irrigation is computed daily on the basis of weather station data and soil moisture measurements. Traditional irrigation in Egypt can be as high as 3200 m^3/feddan/month (26 mm/d) because 50% of the water resourcse will not be available to the crop and all soil in staple crop fields is covered by canopies. The sandy soils with drip systems need only 700 m^3 of water/feddan/month (5.6 mm/d) because:

- the supply is fine-tuned with the demand and losses are minimal; and
- the demand is low because not all soil is covered by canopies

For the above mentioned reasons, actual crop evapotranspiration can be kept low. Most crops are cultivated on high ridges (60 cm tall) for the purpose of salt leaching, easier access to the crop for protection and harvest, and for maintaining strips of bare soil to reduce the consumptive use at plot scale. The wide furrows of 2 meter are kept free from weeds mechanically. Underground fertilizer application and soil structural improvement is realized for reclamation of desert soil. The sandy soils are highly permeable and have a low Cation Exchange Capacity. The experience is that the soil fertility largely improves after 20 years of cultivation. The following crop types are cultivated on Centech farm, among others:

Crop type	
Fruits	Bananas, pear, apricots, pears, olives, citrus
Vegetables	Straberries, tomatoes, asperagus
Ornamental plants	Cutflowers, indoor plants
Nurseries	Citrus, mango, fruits and vegetables

The ornamental plants are cultivated in greenhouses. Some indications on the crop yield can be derived from the table below:

Crop type	Yield
Table grapes (seedless)	15 ton/ha (price is US$ 3.6/kg)
Citrus	58 to 63 ton/ha (price is US$ 0.5/kg)
Bananas (illegal)	63 ton/ha
Olives	15 (pickles) to 25 (processing) ton/ha

District Water boards

It is unique in Egypt to establish district level water boards. The newly established water board in Bustan is one of the first endeavours to combine governmental decision making processes on (i) water allocation and (ii) canal maintenance with the requirement of the commercial farmers. In fact, the water board hosts both small and large holder irrigators in good harmony. The members of the board are freely elected. The board appears to be powerful and decisions between various stakeholder groups are made more transparently. The water board consists of 5 committees:

- irrigation and improvement;
- irrigation;

- drainage;
- environment; and
- pollution

The board meets monthly and more intensively when so required. They believe that the board has contributed to higher crop yields and lower water use. Convincing data to demonstrate this argument were not given. It was however clear that the board members were happy with this new institutional direction.

4. Best irrigation practices in Egypt

On the basis of the several introductions and the discussion with policy makers, researchers, water managers, water boards, water user associations and farmers, it is concluded that various perceptions on the best practices exist. The best practices brought forward by the Egyptians are:

1) Excellent breeding program that have shortened the rice growing period after transplantation to 90 days (e.g. Hakili variety). The maximum harvest index (grain ratio) is 67%. Rice yields of 9 to 10 ton/ha are nowadays normal and potential yield is increasing further;
2) tuned irrigation supply to cropping pattern through the mechanism of planning via agricultural department and irrigation districts;
3) maintenance of constant water level in branch canals by means of continous flow so that on-demand irrigation practices can be applied at mesqa level;
4) intensive extension services through Irrigation Advisory Service, especially at the onset of the project for fostering interaction between farmers and irrigation district managers;
5) proper maintenance of canals;
6) district water boards for merging commerical farmers with public services to detect common interest;
7) surface irrigation on alluvial soils and sprinkler/drip on sandy soils; and
8) cultivation of high value crops and timely access to markets

Overall, it is an integrated or a holistic approach (delivery of water, seed, fertilizer, pesticide, credit, management practices, and extension services) to agricultural productivity improvement that has contributed to existing conditions. In addition to that, it is likely that the natural conditions of soil, groundwater table and climate have a great contribution, that is not sufficiently recognized.

Annex 1.1: Program of the study tour

Saturday / Sunday 13 & 14 September

Arrival of participants from various countries and checking in to the Flamenco Hotel in Cairo (Zamalek Island)

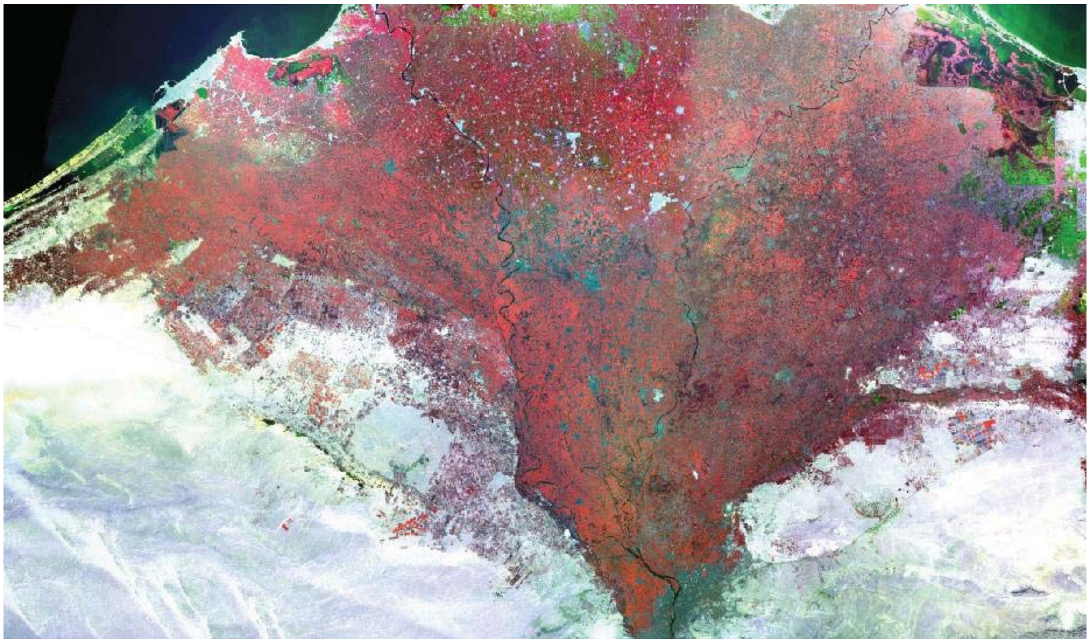
Monday 15 September

6.15 Breakfast at Flamenco Hotel
7.00 Departure by mini-bus
9.15 Arrival at the IIIMP office at Kafr-El-Sheikh – Nile Delta
9.30 Introduction to the irrigation systems in Egypt
Prof. Fathy El-Gamal (National Water Research Centre)
10.00 Institutional issues and irrigation improvement
Eng. Ibrahim Mohamed Mahmoud (Waterboards & IIIMP project)
10.30 Agronomical practices and crop yields
Dr. Hassan Shams (Min. of Agriculture)
11.00 Irrigation performance in the W10 area
Prof. Dr. Wim Bastiaanssen
11.30 Departure to the field
Visiting main and branch canals
Visiting improved mesqa
Discussion with water user association & farmers
Understand best practices
14.30 Departure to Cairo
17.30 Arrival at Flamenco Hotel

Tuesday 16 September

7.15 Breakfast at Flamenco Hotel
8.00 Departure from Cairo
9.30 Arrival at Dina Commercial Estate in the Western Desert (http://www.dinafarms.com/about_who.shtml)
9.45 Introduction to the irrigation management on the farm
Drip irrigation systems, water consumption, groundwater depletion, aquaduct, crop yields, and market prices
10.30 Tour on the farm and departure
11.0 Arrival at CENTECH Farm, Dr. Adel Ghandour
(http://www.egyptgreen.com/)
11.15 Presentation about Irrigation Practices. Production
11.45 Tour on the farm and departure
12.45 Arrival at Bostan District Water Board
13.00 Reception at the District
13.10 Explanation of the objectives and achievements
14.00 Tour through the traditionally irrigated area
15.30 Departure to Cairo
17.00 Arrival at Flamenco Hotel

Annex 1.2: Examples of satellite images of the Nile Delta



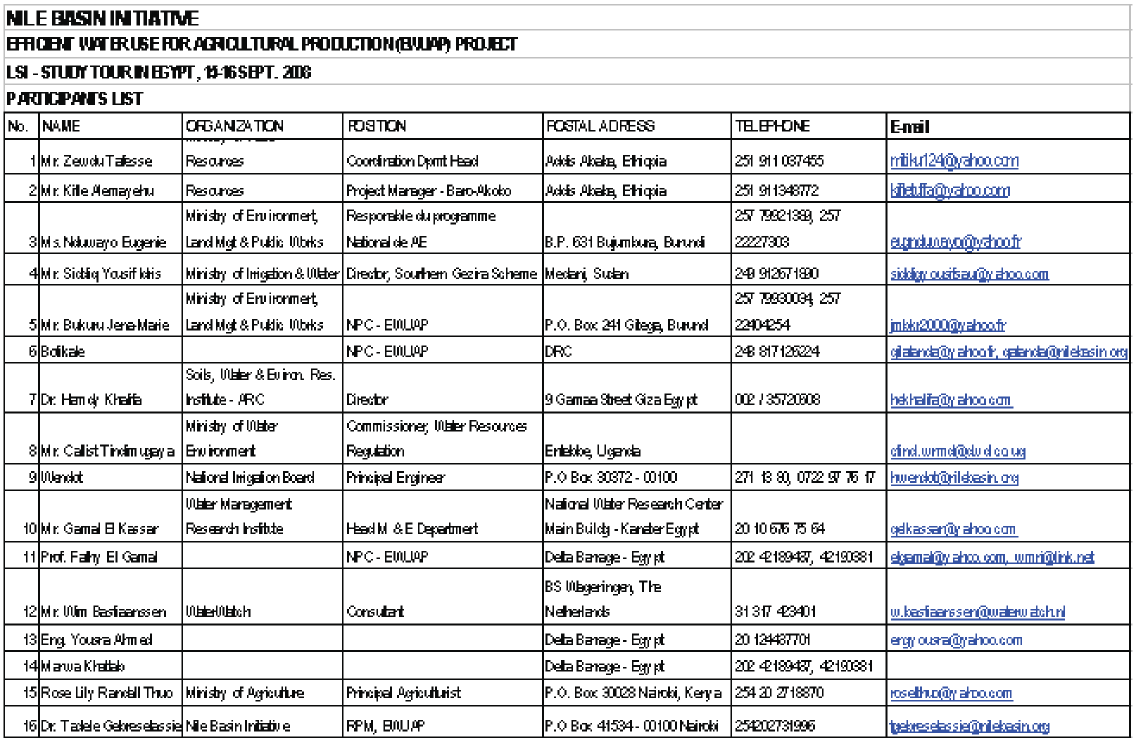
False Colour Composite (FCC) images based on Landsat Thematic Mapper measurements. This FCC images is compiled from different individual Landsat images for the purpose of covering the entire Nile Delta. Red colours express a high near-infrared reflectance, being a characteristic for vigorous crop growth. The more red, the better the agricultural production. The white areas are bright desert sandy soils.

Detailed False Color Composite of a Landsat Thematic Mapper image acquired on 25 June 2008. In this case green represents a high near-infrared reflectance, being a characteristic for vigorous crop growth. The more green, the better the agricultural production. The Western branch of the river Nile (Rosiette Branch) is visible. The purple color represents urban areas (light purple) or sand dunes and beach (bright purple). The black color are wetlands and fishponds. The inset with the yellow boundaries diplayed is the W10 area, being a pilot zone of the IIIMP project. The W10 tertiary irrigation system *has been visited during the study tour. The white lines represent irrigation canals. A detailed picture is portrayed on the next page*

Crop water productivity of rice and cotton fields in the W10 tertiary unit and surrounding area. The background images in green represents the False Colour Image. All black and white pixesl are rice and cotton fields. The pixels with the highest crop water productivity are displayed in white (>1.6 kg/m^3) and in grey are approximately 1.0 kg/m^3. Dark *pixels need to undergo an improvement program. It is interesting to note that the area west of W10 has the best utilization of irrigation water resources. This example demonstrates the capacity to monitor crop water productivity on a field by field basis*

Detailed Landsat Thematic Mapper picture of the Dina farm along the Desert Road. This commercial farm was visited on September 16th. The circular features are center pivot systems present on the farm with sprinkling irrigation. The rectangular structures show orchards with drip systems. The white line from southeast to northwest is the Desert road.

Annex 1.3: List of participants



NILE BASIN INITIATIVE

EFFICIENT WATER USE FOR AGRICULTURAL PRODUCTION (EWUAP) PROJECT

LSI - STUDY TOUR IN EGYPT, 15-16 SEPT. 2008

PARTICIPANTS LIST

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Appendix C Study tour Sudan: Remote Sensing Analysis of Gezira and Kenana, Sudan

Background

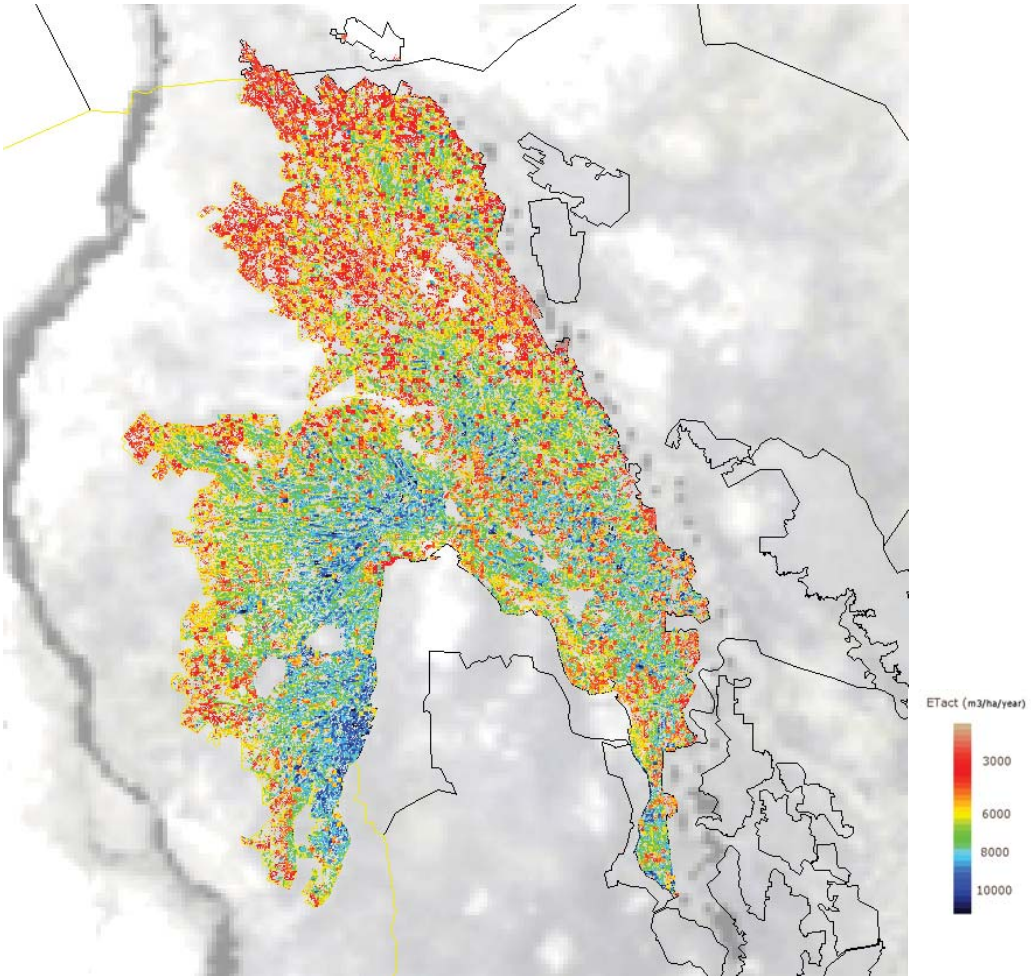
A study tour is organized to the irrigation schemes of Gezira and Kenana as part of the ongoing NBI-EWUAP project on Large Scale Irrigation systems analysis. This memo has been prepared to support the field excursion. It will show the irrigation conditions in these two contrasting areas. These maps could be used when meeting with irrigation managers in the field.

Gezira

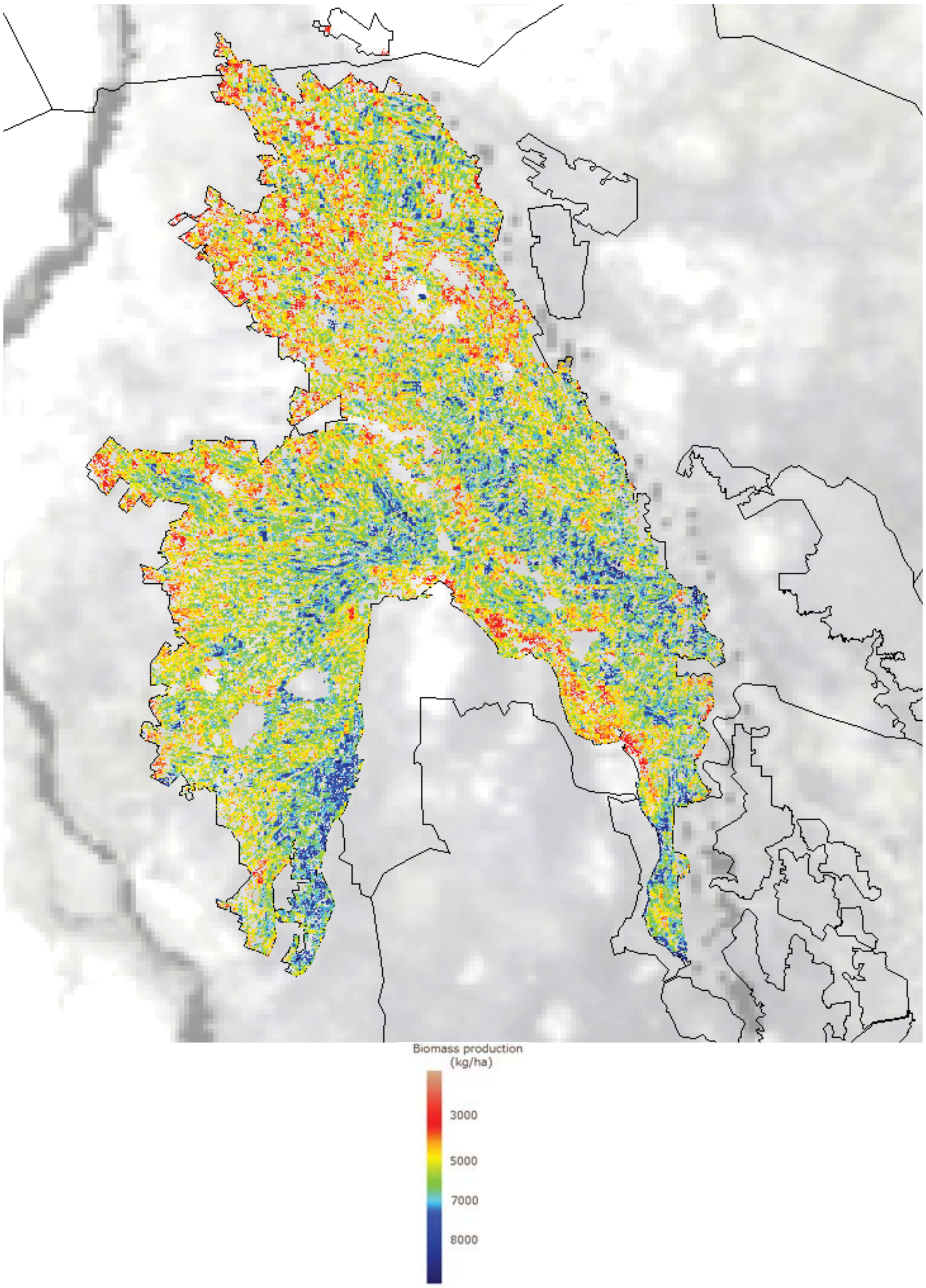
The Gezira Scheme (Arabic: مخطط الجزيرة) is one of the largest irrigation projects in the world. It is centered on the Sudanese state of Al Jazirah, just southeast of the confluence of the Blue and White Nile rivers at the city of Khartoum. The economy of Sudan was historically based on agriculture prior to the beginning of oil exports in the late 1990s. Before independence in 1956, the scheme main objective was to produce cotton raw material to feed textile the textile factories in the United Kingdom. The national government had designated social development as one of the main objectives of the scheme. An appreciable portion of the profit was directed to overwhelming social development projects. The Gezira Scheme started in 1911 with an area of 250 feddans (1=1039 acres) for growing cotton. As cotton proved to be successful the area was increased year after another. At the same time it was decided to construct a dam at Sinnar on the Blue Nile. In 1925 when Sinnar Dam officially inaugurated gravity irrigation started and the area increased to 2.1 million feddans by the end of 1962.

The Gezira Scheme distributes water from the Blue Nile through canals and ditches to tenant farms lying between the Blue and White Nile rivers. Farmers cooperate with the Sudanese government and the Gezira Board. This network of canals and ditches is 2,700 miles (4,300 kilometers) long, and the irrigated area covers 8,800 km². The main crops grown in Gezira Scheme are: Cotton, Dura (Sorghum), Wheat, Groundnuts, Vegetables, Fruits, and Fodder.

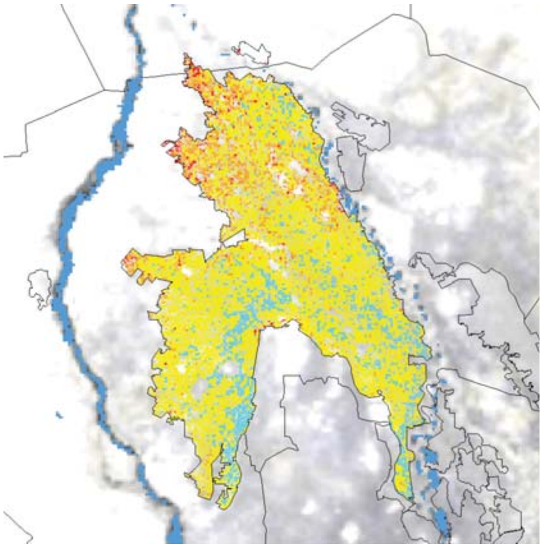
The total water consumption and biomass production have been computed for the year 2007. The results are shown on the next page. The map of actual evapotranspiration shows ET values of 8,000 to 10,000 m^3/ha/yr in the southwestern part of the scheme. This water is conveyed across a long distance. Except for this part, in general it can be observed that the head end of the system, receives more water than the tail end of the system near Khartoum. In general terms it seems that irrigation in the Northern tail end is very extensive. This could be related to limited irrigation water availability, or to the fact that farmers have abandoned their land. Also it is expected that more vegetables are grown in the vicinity of Khartoum.



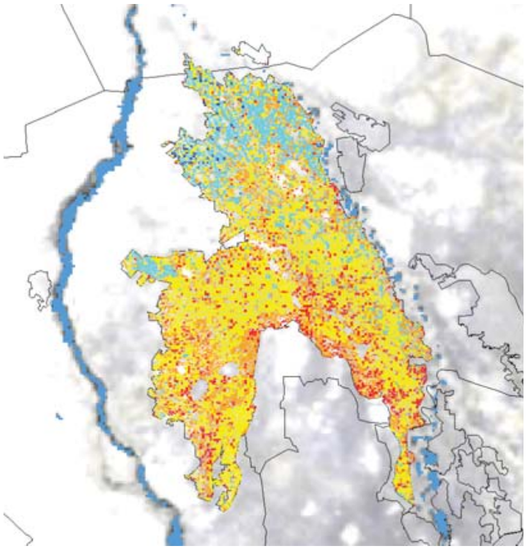
The spatial patterns of biomass production is similar to ET. The largest agricultural production levels are obtained at the southwestern tip of the Gezira scheme. The impression exists that there is a deviating cropping pattern in this part of the LSI system. From a climatic point of view, this could be systems with sugarcane or rice, but this information needs to be confirmed from the field. It could also be related to a double cropping system because 8,000 m^3/ha is basically sufficient for cultivating two seasonal crops.



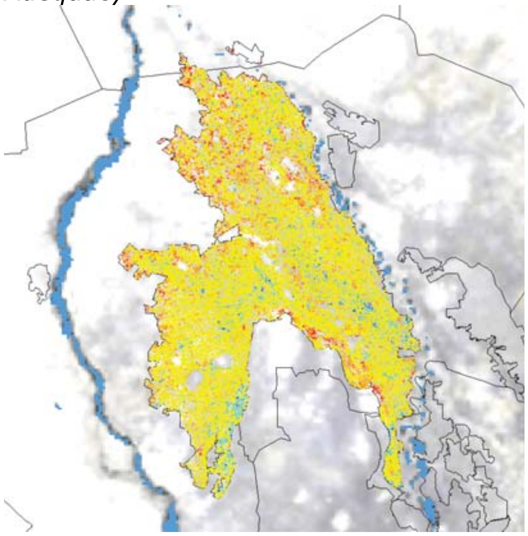
The score for every irrigation indicator has been computed for every 250 m pixel. The values of the score vary between 1 (minimum=brown) to 5 (maximum=blue). The sustainability and reliability of Gezira is high. This implies that there is a very regular pattern of irrigation water supply, and that the longer term trend of these patterns is stable. It implies that the farmers and irrigation department have obtained a stable mutual understanding and expectation. The same cropping patterns and irrigation intensities are irrigated with similar amounts of water, year after year. The adequacy map shows interesting differences in soil water status. The adequacy and crop water consumption maps are by absence of flow measurements good proxies for the real irrigation water distribution in Gezira. Adequacy and crop water consumption are inversely related in terms of score. A good score on adequacy implies that the water has reached the crop. If the crop is consuming lots of water due to frequent irrigations, the score in consumptive use is low. The fact that the beneficial fraction is low implies that the soil evaporation losses are significant. The latter suggests over-irrigation. It is interesting to remark that the highest water productivities are obtained at the tail end near to Khartoum, and the reason is the low crop water consumption. Hence, the huge water amounts evaporated by crop in the southwest are not used productively.



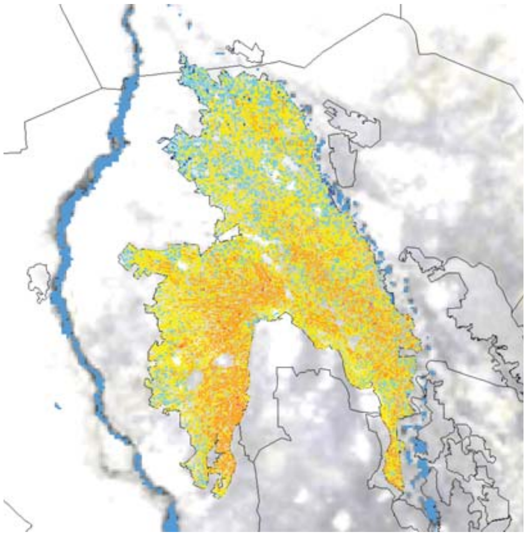
Adequacy



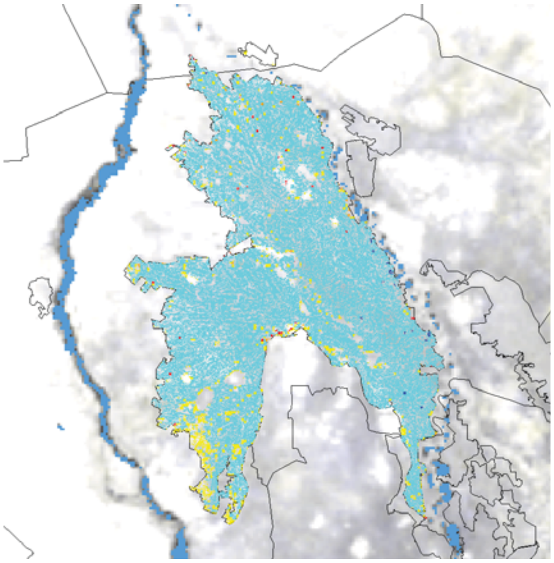
Beneficial fraction



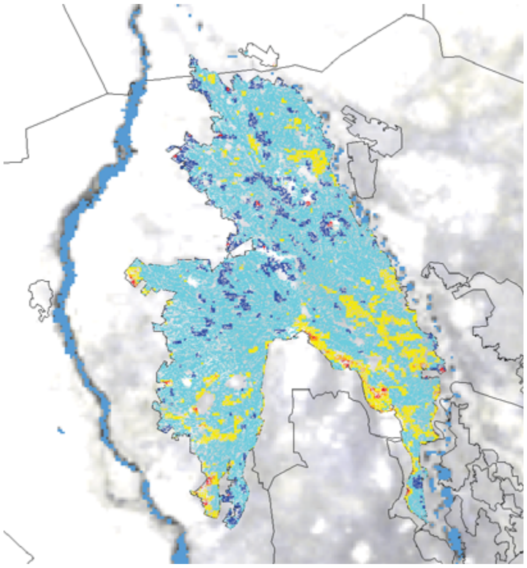
Biomass production



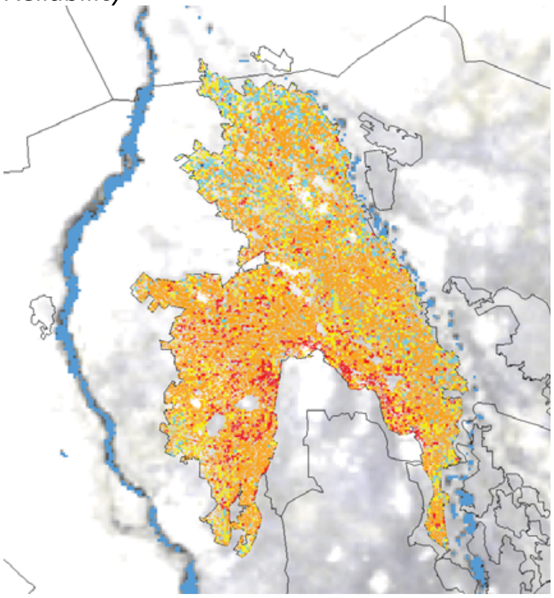
Crop water consumption



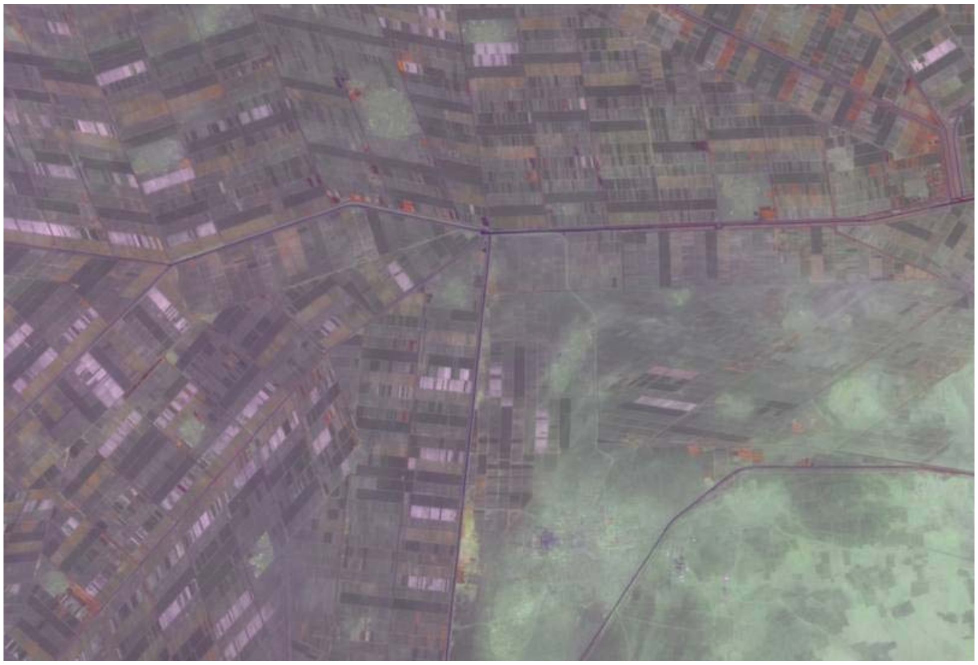
Reliability



Sustainability



Water productivity

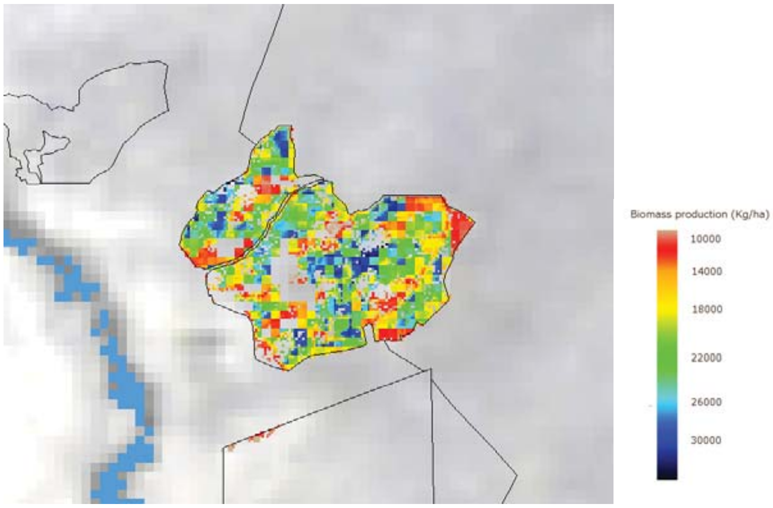


Landsat image of the central part of the Gezira scheme. Fields with a red color are cropped. The dark colored fields are bare. The fields with white color are vegetables with specific mulch treatments

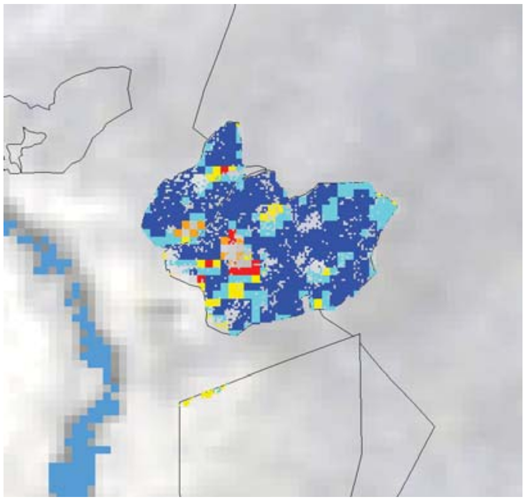
Landsat image of Kenana farm. Red color can be associated with vigorous sugarcane. The grey plots are fallow or recently planted sugarcane shoots

Kenana

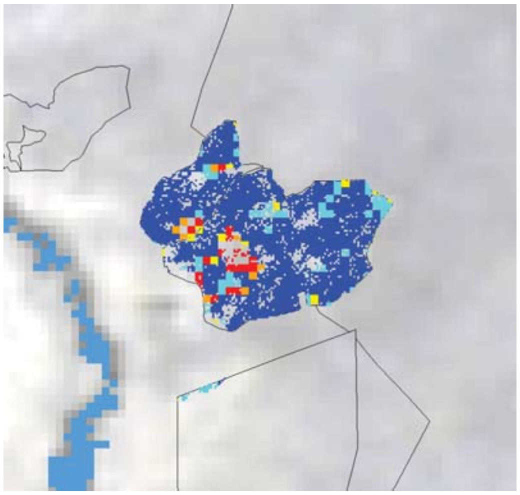
The sugarcane estate of Kenana comprises some 50,000 ha of irrigated land. It is a commercial enterprise and the water is diverted directly from the White Nile. This area has been selected for the sake of comparison against the publicly managed Gezira scheme. The results reveal that the crop water consumption is generally much higher than for Gezira. The average value is approximately 12,000 m^3/ha/yr and certain sections reach even values up to 20,000 m^3/ha/yr. These values are in agreement with the ET values considered to be normal for sugarcane. The resulting biomass production varies from 20,000 to 30,000 kg/ha/yr. This is equivalent to an approximated fresh cane yield of 60 to 100 ton/ha. The picture shows that certain plots have low levels of cane production. These are either areas that are fallow, or planted with young shoots.



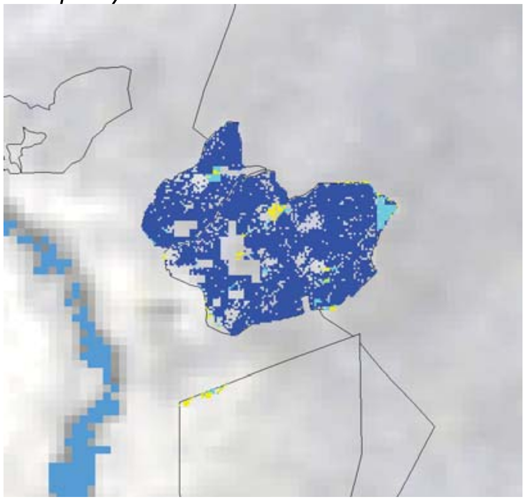
The adequacy and beneficial fraction have both a very good score (blue). This implies that irrigation water is supplied with sufficient quantities and that most water is consumed by beneficial crop transpiration. The non-beneficial evaporation losses are thus very small in Kenana (in contrary to Gezira). For this reason, the beneficial fraction is very high. The biomass production values are the highest of the region, and they have a score of almost 5.0. The crop water consumption is quite high for achieving this significant sugar production. That is also the chief reason for the water productivity being moderate. Most of the pixels have a score of 3.0, which is better than Gezira, but lower than other values attainable under the same climatic conditions. The reliability is good, but could be improved for a commercial mono-cropping sugar estate. The areas with a lower reliability reflect with a lower crop ET and a negligible biomass production. The overall sustainability is satisfactory, although certain fields on the farm are not ideal. This pixel based irrigation performance can help the irrigation management on the Kenana farm.



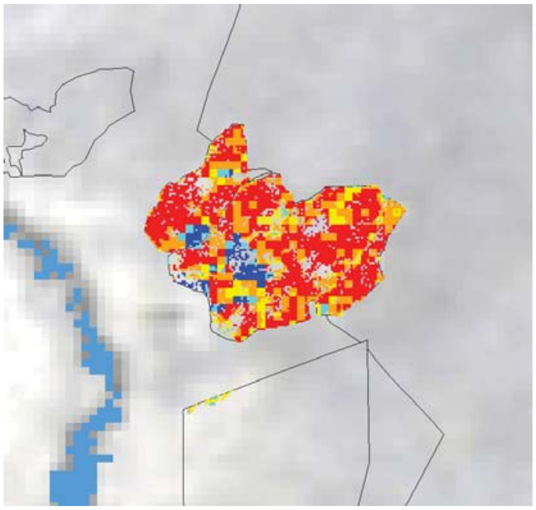
Adequacy



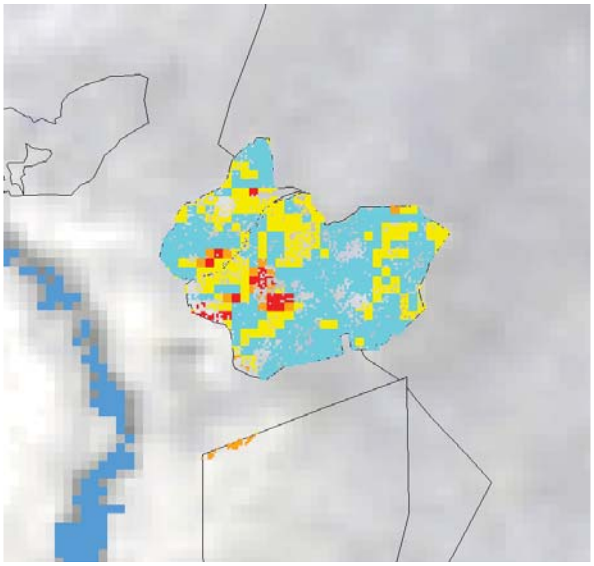
Beneficial fraction



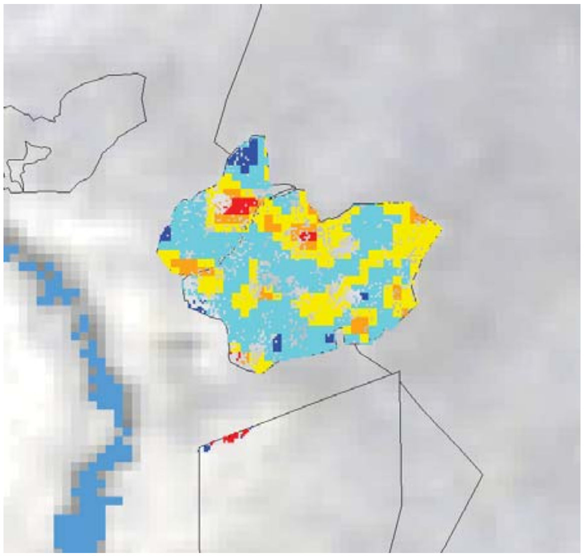
Biomass production



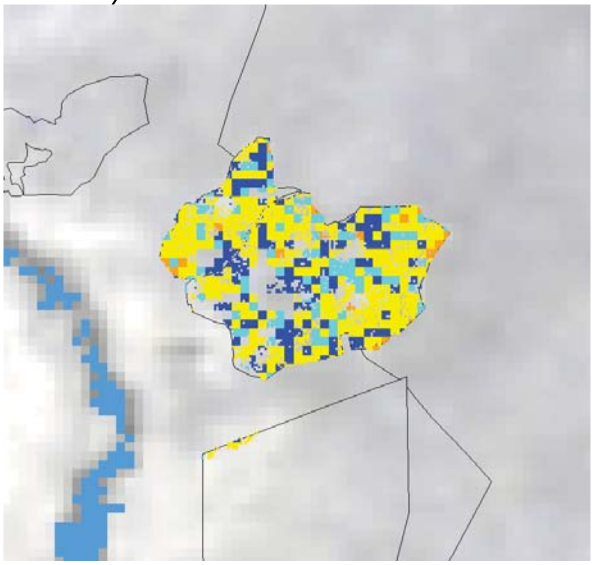
Crop water consumption



Reliability



Sustainability



Water productivity

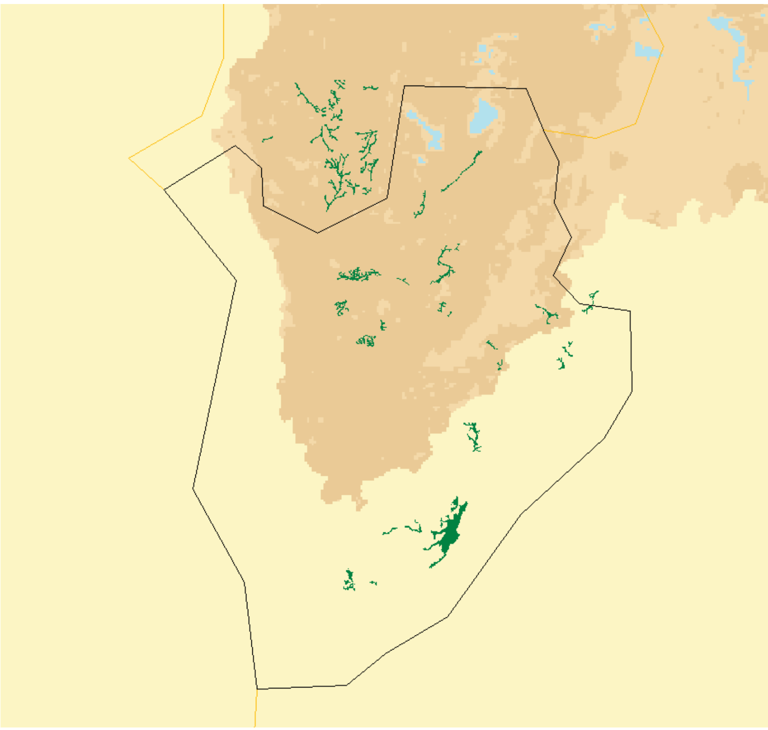
Score

🟥 1
🟧 2
🟨 3
🟦 4
🟦 5

Large Scale Irrigation (LSI)

Nile Basin Country Irrigation Report Series

Burundi



Appendix D

January 2009

Table of contents

Part 1 Overview of irrigated areas
Part 2 Climate
Part 3 Raster and vector-based irrigation performance analysis
Part 4 Recommendations for improvement

Purpose of this report:

This report is one of a series of reports that will describe, and evaluate irrigation schemes in each of the Nile basin countries, and make recommendations for irrigation best practices. This report deals with Burundi and will become an integral component of the final LSI report that will combine results from all countries.

Disclaimer: National and district boundaries in this report are based on data from various internet sources of different years, and do not reflect current political reality. Modern country names and boundaries have not always been added and their omission does not indicate support or non-support of any nation.

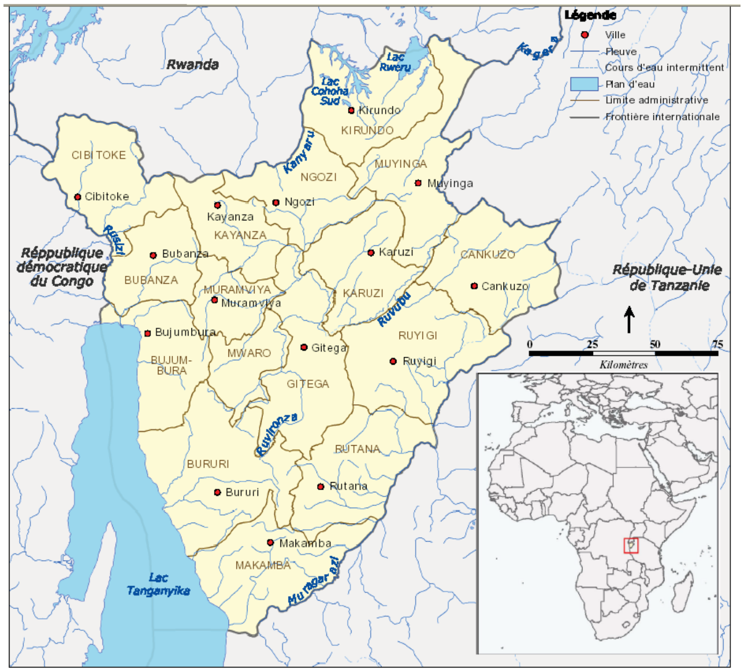
Part 1 Overview of irrigated areas

1.1 Location of the irrigated areas

Burundi is landlocked between Rwanda in the North, DRC Congo in the West, and Tanzania in the East (Figure 1). It covers an area of 27,834 Km^2 and in 2002 the cultivated area was approximately 1,350,000 ha.

Burundi is located in two basins: 13,800 km² of Burundi lies in the Nile Basin (delineated by the blue line in Figure 2); the southern and western part of the country drain into the Congo basin. The irrigated areas in the latter portions of the country are thus not included in the current analysis.

The agricultural sector in Burundi is very important for the national economy, even though the undulated topography and steep slopes are not very favourable for agriculture. The agricultural techniques are therefore still primitive and the irrigated area per household is on average low (about 0.5 ha). In the areas in the vicinity of streams and wetlands, some lands are being irrigated (represented by the red areas on Figure 2) but it represents a very small percentage of the total agricultural area.



FAO - AQUASTAT, 2005

BURUNDI

Déni de responsabilité

Les appellations employées dans cette publication et la présentation des données qui y figurent n´impliquent de la part de l´Organisation des Nations Unies pour l´alimentation et l´agriculture aucune prise de position quant au statut juridique des pays, territoires, villes ou zones, ou de leurs autorités, ni quant au tracé de leurs frontières ou limites.

Figure 1 Burundi and its administrative districts

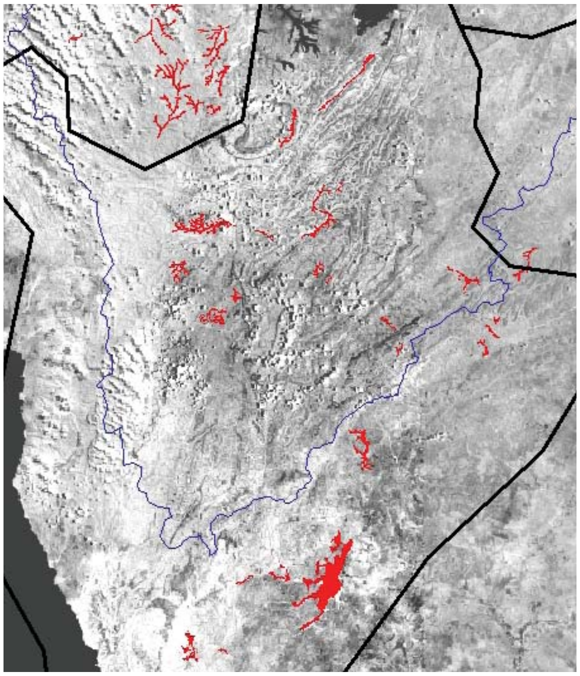


Figure 2 Map showing the distribution of the irrigated areas within the Nile Basin according to the LSI participants of Burundi.

Table 1 shows that an area of 14,625 ha of irrigated land is located in the Nile Basin. It is relatively small compared to the estimated potential irrigable surface of 215,000 ha, according to a survey carried out by the Department of Rural Engineering. The predominant irrigation method is surface irrigation which derives water from rivers by pumping and from small diversion dams. Storage dams are not yet needed as the extent of irrigation is limited and the period of rice cultivation corresponds with the rainy season (December-January to May).

Table 1 Different sources for the irrigation statistics for Burundi

Source	Region covered	Irrigated area (ha)
FAO – GMIA	Entire Burundi	14,400
IWMI – GIAM	Entire Burundi	11,793
Current study	Nile Basin component of Burundi	14,625

According to the FAO AQUASTAT (2005) the main irrigated crop in Burundi is rice, with a total surface of about 4,200 ha, as shown in Figure 3. The rice yield varies between 3 to 3.5 ton/ha (Gitega province). The other main irrigated crops are sugarcane, maize, beans, vegetables and coffee. Other major crops are banana (first in terms of volume production) and cotton. A land use map of Burundi is provided in Annex 2. Figure 4 displays the cropping calendar.

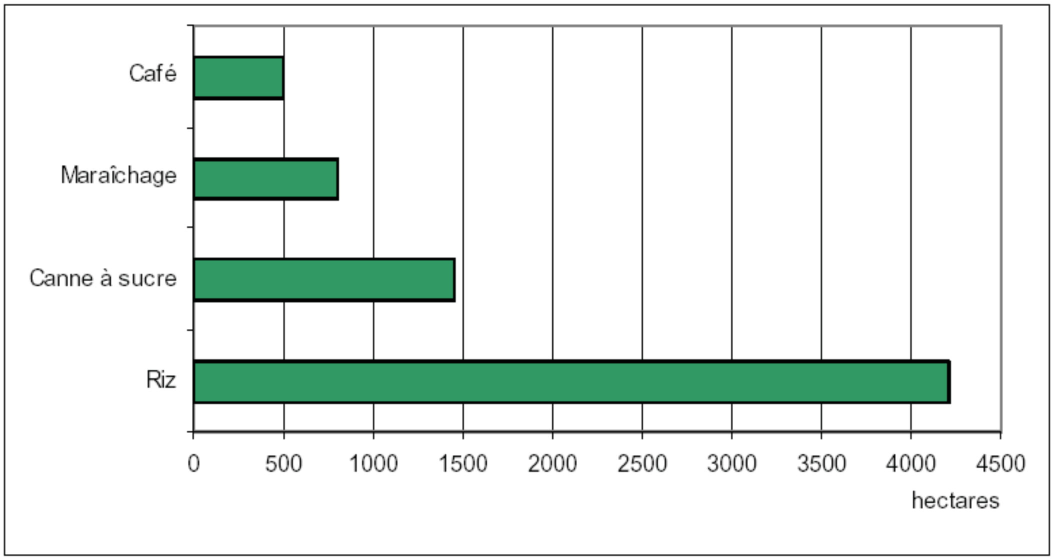
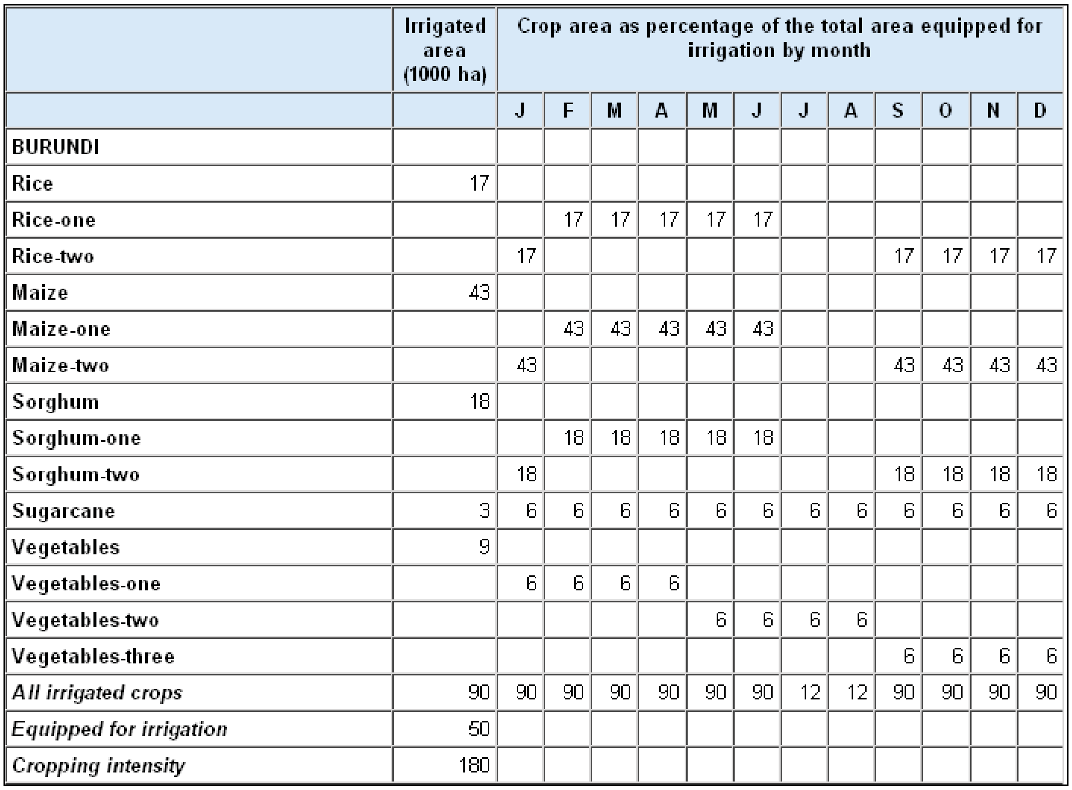


Figure 3 Main irrigated crop in 2000 (source: AQUASTAT 2005)
(café=Coffee; Maraichage=vegetables; Canne a sucre= sugar cane; Riz= Rice)



	Irrigated area (1000 ha)	Crop area as percentage of the total area equipped for irrigation by month											
		J	F	M	A	M	J	J	A	S	O	N	D
BURUNDI													
Rice	17												
Rice-one			17	17	17	17	17						
Rice-two		17								17	17	17	17
Maize	43												
Maize-one			43	43	43	43	43						
Maize-two		43								43	43	43	43
Sorghum	18												
Sorghum-one			18	18	18	18	18						
Sorghum-two		18								18	18	18	18
Sugarcane	3	6	6	6	6	6	6	6	6	6	6	6	6
Vegetables	9												
Vegetables-one		6	6	6	6								
Vegetables-two						6	6	6	6				
Vegetables-three										6	6	6	6
All irrigated crops	90	90	90	90	90	90	90	12	12	90	90	90	90
Equipped for irrigation	50												
Cropping intensity	180												

Table 2: Cropping calendar for Burundi (source: AQUASTAT, 2005)

1.2 Description of LSI

Even though the unit of analysis in this study is the district, information on the irrigation systems within these districts, and the sources of irrigation water is informative (Table 3).

Table 3 Description of a few irrigation districts

Irrigation district	Province	Commune	Surface equiped with irrigation	Irrigation water
NYAMUGARI	KARUSI	BUHIGA	148 ha	Surface Irrigation Diverted from river
KAGOMA	NGOZI	NGOZI	187 ha	Surface Irrigation Diverted from river
NYAKAGEZI	KAYANZA	MUHANGA	123 ha	Surface Irrigation Diverted from river
NYARUBANDA	KAYANZA	MATONGO	187 ha	Surface Irrigation Diverted from river

These four districts have the same characteristic: river water is available throughout the year. There are three main cropping seasons: rice is cultivated in the first season, which starts in November-December. This corresponds with the rainy season. Maize is the main crop cultivated in the second season, which starts in May-June, followed sometimes by a third season in which mainly beans are cultivated.

More detailed information concerning irrigation in Burundi can be found in Annex 4.

Part 2 Climate

2.1 Climatological conditions

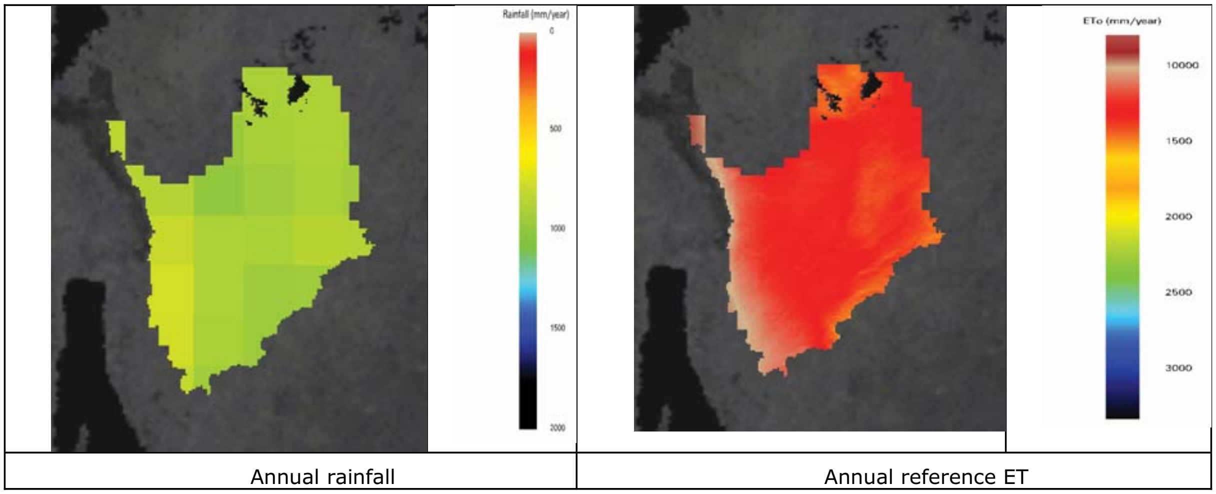
Burundi receives a significant amount of rainfall. The rainfall season is continuous and long, running from September to May. June, July and August are dry, and this is the period that irrigation is typically needed. According to the Ministry of Territorial Development and Environment (2001) and to FAO (AQUASTAT,2005) the water balance for a normal year is as follows:

- Average annual rainfall: 1274 mm
- Average evapotranspiration (ET): 872 mm

Table 4 shows the monthly values for rainfall and reference evapotranspiration (ET_0). The rainfall is based on TRMM satellite data. The ETo is computed with the standardized Penman-Monteith equation specified in FAO56.

Table 4 Monthly values for rainfall and ET_0.

Month	Rainfall (in mm)	ET_0 (in mm)	Aridity (P/ET_0)
January	97	105	0.92
February	106	101	1.05
March	131	108	1.21
April	181	95	1.91
May	91	99	0.92
June	8	107	0.07
July	1	122	0.01
August	17	132	0.13
September	59	125	0.47
October	97	122	0.80
November	146	102	1.43
December	106	99	1.07
TOTAL	1040	1317	



Annual rainfall

Annual reference ET

Figure 4 Spatial variation of rainfall (left) and ET_0 (right) for the part of Burundi that is located in the Nile Basin.

ET_0 exceeds rainfall during seven months and this shows the need of irrigation systems. The monthly water shortage occurs in June to September when the aridity index is lower than 0.5. The highest ET_0 rates occur in the plain area at the east side near Tanzania. Due to the long rainfall season, Burundi is more commonly known as a rainfed agricultural country, rather than an irrigation country.

2.2. Climatic zones

The current study aims to provide information for improved irrigation practices in the Nile Basin and covers various climate zones. This hampers a comparison between countries and among schemes. Rainfall and temperatures specifically need to be analyzed, because they have a large impact on attainable land and water productivities. Unexpected rainfall can for instance reduce the irrigation efficiency, and also induce more variations in soil moisture conditions than in a situation where the crop moisture depends solely on irrigation water supply. To make corrections for these climatic influences on the basis of diagnosis of the irrigation systems, and to define climate dependent target values of irrigation management, four different climate zones have been identified for the Nile Basin. The zones have been made contiguous where possible. Insertion of more zones would result into scattered appearances of the zones.

The irrigation schemes of Burundi are located in climate zone 4 (humid tropics).

Part 3 Raster and vector-based irrigation performance analysis

3.1 Methodology

In this study, the irrigated areas have been identified at a resolution of 250m based on the data send by the LSI representatives of Burundi. The first step was to compute all the indicators per pixel. All the RO and PO indicators have been computed based on the annual accumulated values of biomass production (Bio), Actual Evapotranspiration (ET_{act}), Potential Evapotranspiration (ET_{pot}), Actual Tranpiration (T_{act}), Potential Transpiration (T_{pot}). This was done for the year 2007. These annual accumulated values are the result of a land surface energy balance algorithm that was run for the whole Nile basin based on data from Terra and Aqua satellites. The Modis and AMSR-E sensor data were used.

Sustainability indicators were obtained by investigating the last five year's trends of vegetation index (from the SPOT-Vegetation satellite) and soil moisture (from the AMSR-E satellite). It indicates the slope of the trend line over these past years.

The second step was to allocate a score per pixel. To do so, we studied the distribution of the values for each indicator. From that, four different benchmark values were defined. A score between 1 and 5 has been given to each pixel, 5 being the best category, depending on the value of the indicators compared to the benchmarks (Figure 6).

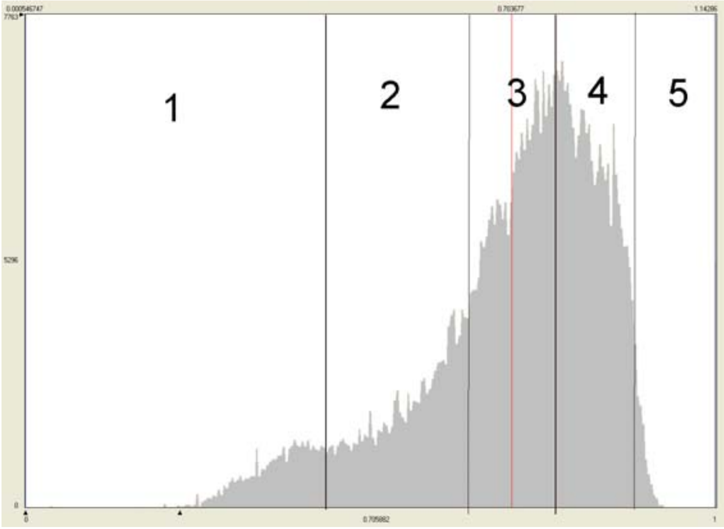


Figure 5 Distribution of the values of one indicator over 5 classes

An average score of 3 for all pixels per climatic zone will indicate good benchmarking.

If the country has irrigation systems included in different climatic zone, different benchmark values are considered to avoid any climatic bias in the allocation of the score. Burundi is located in climatic zone 4.

Table 5 Benchmark values for pixel located in climatic zone 4

	Unit	Score of 1	Score of 2	Score of 3	Score of 4	Score of 5
Bio	Kg/ha/year	<11,000	<17,000 and >11,000	<29,000 and >17,000	<40,000 and >29,000	>40,000
Bwp	Kg/ m3	<1.5	<2.4 and >1.5	<3.3 and >2.4	<3.8 and > 3.3	>3.8
Cwc	M3/ha/year	>13,300	<13,300 and > 10,000	<10,000 and >6,700	<6,700 and >3,400	<3,400
Cwd	M3/ha/year	<180 and >136	>250	<250 and >180	<136 and >80	<80
Bf	-	<0.45	<0.66 and >0.45	<0.82 and >0.66	<0.91 and >0.82	>0.91
Ad	-	<0.62	<0.72 and >0.62	<0.83 and >0.72	<0.92 and >0.83	> 0.92
Un	-	<0.75	<0.85 and >0.75	<0.9 and >0.85	<0.95 and >0.9	>0.95
Rel	-	<0.8	<0.88 and >0.8	<0.92 and >0.88	<0.94 and >0.92	>0.94
Spot	1/year	<-0.1	<-0.02 and >-0.1	<0.1 and >-0.02	<0.3 and >0.1	>0.3
Amsre	1/year	<-0.1	<-0.05 And >-0.1	<0.05 and >-0.05	<0.15 and >0.05	>0.15

Once each indicator gets a score per pixel, district average and country average values can be calculated. The indicators are averaged per type: RO indicators, PO indicators, and sustainability indicators, to simplify understanding of processes and results.

3.2 Results at Country level

As displayed in Figure 7, the average score considering all the indicators together for all the 14,625 ha of irrigated land is 3.6, which is an above average score (the average score being 3). It shows that the irrigation systems in Burundi are sound. This average is translated into scores for each individual indicator. The aspects that Burundi should provide more attention to are those with a relative low score.

The scores of 2.8 for land productivity and 2.9 for water productivities are lower than average but still reasonable.

Concerning the PO indicators, more attention should be given to beneficial fraction. A low beneficial fraction shows a significant amount of non-beneficial ET losses. The lower than expected performance of this last indicator might explain the wide range of the land and biomass water productivity. Because the crop water consumption is quite high and the beneficial fraction low, it leads to relatively low biomass water productivity. On the other hand, there is good performance in terms of reliability, uniformity, and crop water deficit. Because irrigation water supply is continuous in time (as mentioned in 1.3), farmers are not restricted in their application of water; so the crop water deficit is low (it gets a high score). Similarly, they can rely on timely availability of water; so reliability is high.

The sustainability of irrigation practices in Burundi seems to be very good. Compared to the previous years, irrigated land is becoming greener (as the score for the land sustainability is higher than 3), hence the irrigation systems are healthy and continuous. The soils are gradually getting wetter (water sustainability gets the maximum score of 5).

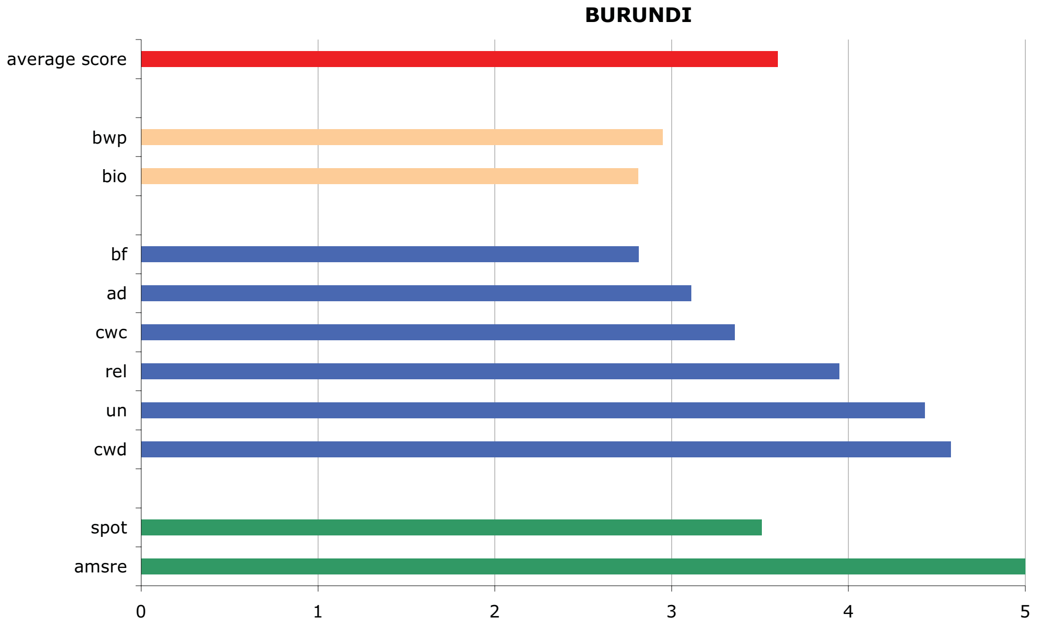


Figure 6 Representation of the average score for each indicator in Burundi.

3.3 Results at district level

3.3.1. Average per district

In Burundi, seven districts[1] have more than 187.5 ha of irrigated land (more than 30 pixels of 6.25 ha). In Figure 8 the average scores for all indicators per district are compared. It can be noticed that all the districts have a good and uniform performance on average, ranking from 3.6 and 3.8, the best district being Buziga and the poorest performing one Bugendana (see Figure 9 for their location). The equal performance per district results in an excellent score for the country level.

---

[1] According to the LSI representatives, there are more than 7 districts with more than 187, 5 ha of irrigated land. There are for example 349, 35 ha in the district of Buhiga (province of Karuzi) and Gitaramuka in the province of Karuzi with 293 ha.

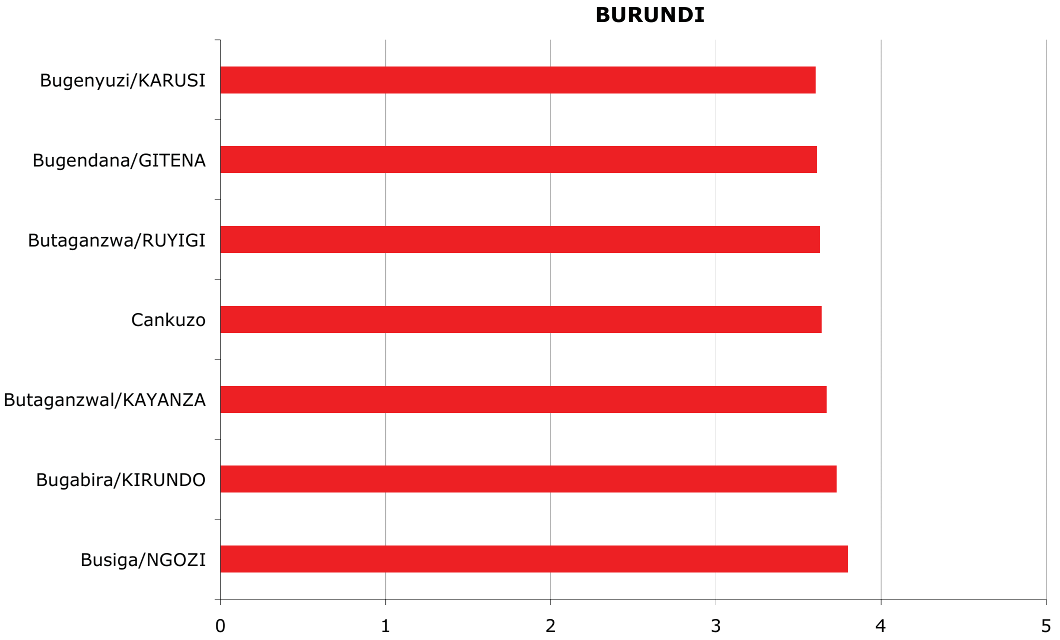


Figure 7 Representation of the total score for Burundi for each district.

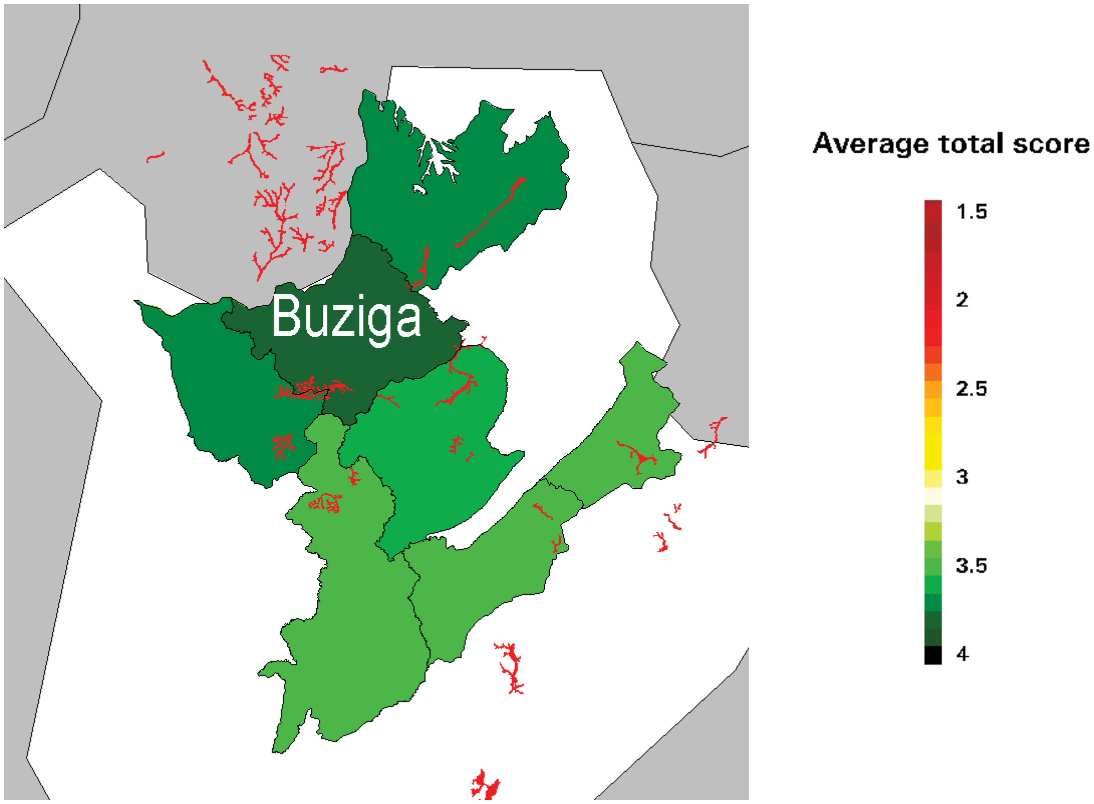


Figure 8 Map showing the total score per irrigated district.

3.3.2. Breaking down the total score into RO indicators, PO and sustainability indicators.

By breaking down the total score into 3 types of indicators (RO, PO, and sustainability), it is possible to better understand the irrigation mechanisms for each district. Figure 10 provides the average score per group of indicators. What is called 'total score' in red is the average of the 10 indicators. Looking at the total average score for all indicators for each district gives an idea of the total performance and enables ranking of the districts. A better understanding of the weak points as well as the strong points of each district will require separate analyses of each indicator group.

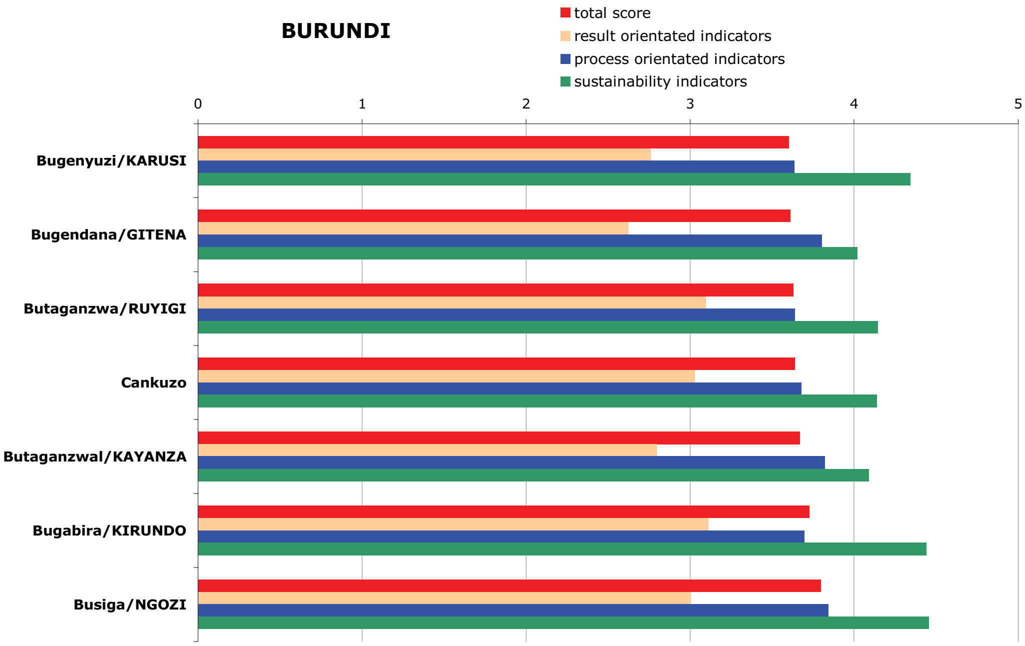


Figure 9 Breaking down the total score per indicator

The first aspect that draws attention is that each of the 7 districts of Burundi presents more or less the same score for each category of indicators, which in turn is linked to the uniform conditions encountered at country level. This could be ascribed to the relative small size of the country and the uniform climate.

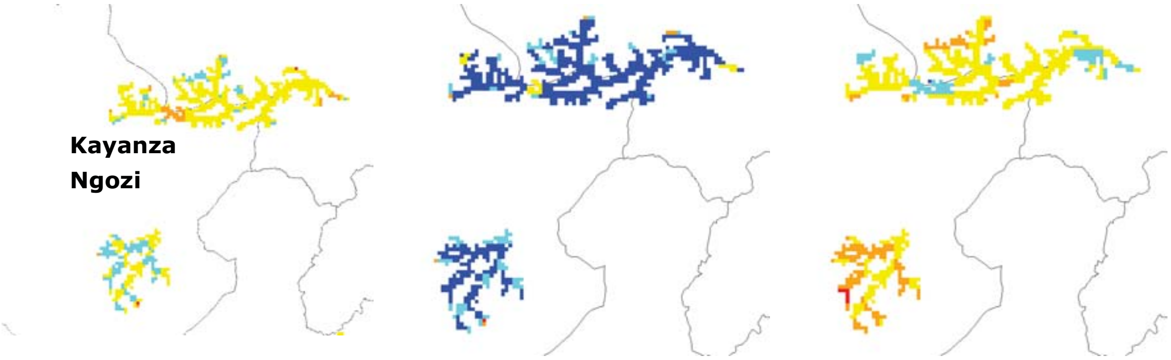
As far as the RO indicators are concerned, the average of the water and land productivity is quite low (between 2.6 and 3.1). Hence, irrigation should become more output orientated.

Concerning the PO indicators, the seven districts of Burundi get a good and homogeneous score, ranking from 3.6 to 3.8. These high scores make it difficult to draw improvement recommendations relating to the functioning of the irrigation systems.

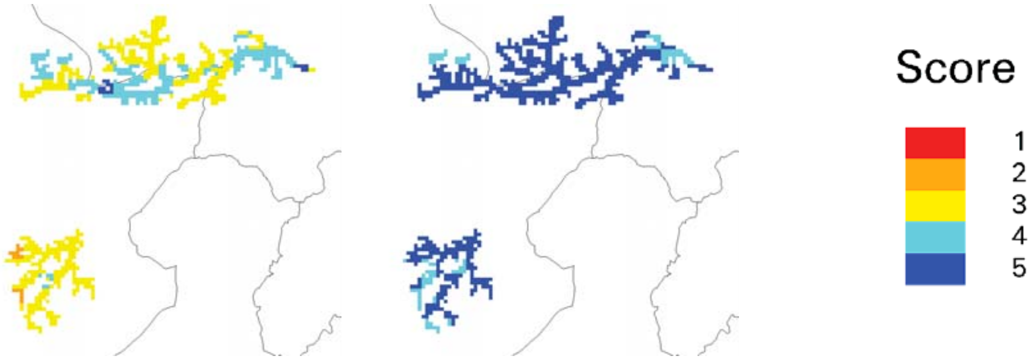
Regarding the land and water sustainability, it is really good. The score for all the districts are comprise between 4 and 4.4.

3.4 Analysis per pixel for an irrigation system

Considering what happens within one district enables us to see the spatial distribution of the score of each indicator. In other words, it makes it possible to see whether the irrigation system is homogeneously managed. Hereafter, the spatial distribution of the five PO indicators is displayed for the irrigated pixels in the neighboring districts of Butaganzwal/KAYANZA and Buziga/NGOZI, which are the two best districts in terms of performance. The 6th PO indicator uniformity cannot be displayed as it is an indicator at district level. This example demonstrates that at certain places, crop water consumption and beneficial fraction should be managed better (Figure 11).



crop water consumption crop water deficit beneficial fraction



adequacy reliability

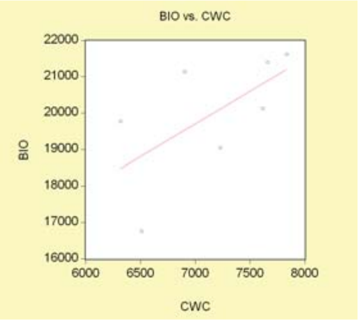
Figure 10 Spatial distribution of each indicator for the districts of Butaganzwal/KAYANZA and Busiga/NGOZI

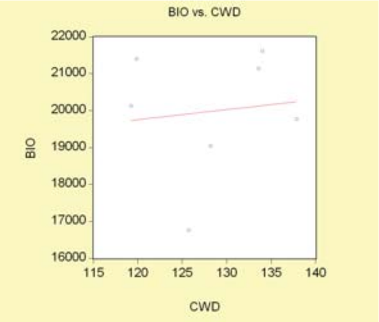
Part 4 Recommendations for improvement

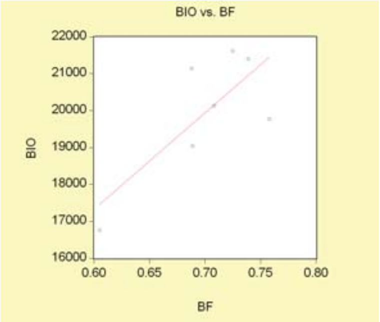
4.1 Explaining the irrigation results

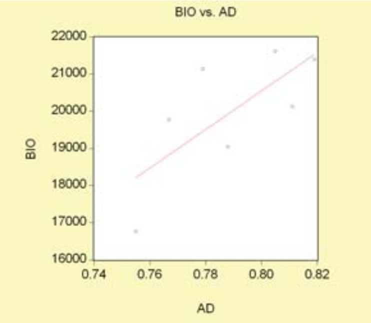
To be able to give proper recommendations, it is important to understand which of the PO indicators influences the RO indicators mostly. A regression analysis was performed with the values for all indicators for the seven districts. It showed that beneficial and crop water consumption are the two main explanatory factors for biomass water productivity and biomass production. An increase in beneficial fraction leads to an increase in biomass production and biomass water productivity. An increase in crop water consumption leads to an increase in biomass production but a decrease in biomass water productivity. No clear relationships could be identified for the other indicators.

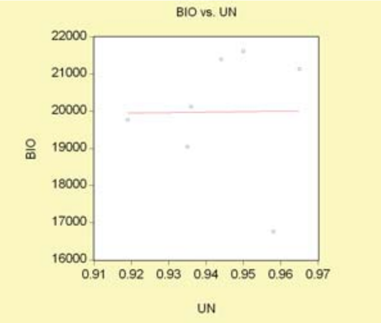
This shows that methods should be investigated to convert non-beneficial evaporation into transpiration. This can be achieved with intercropping and other measures that increase Leaf Area Index.

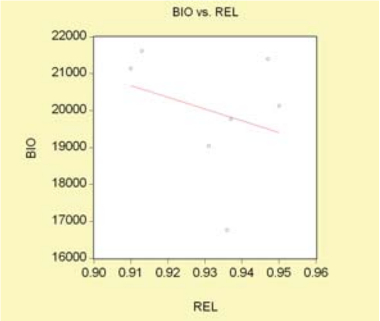


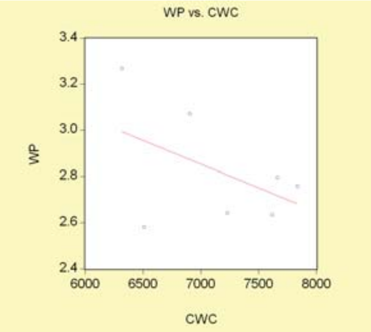


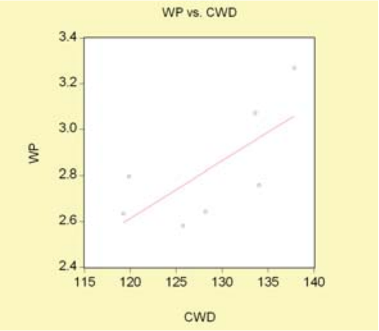


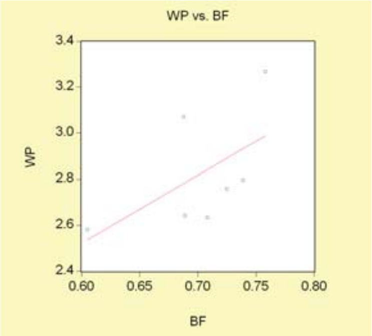












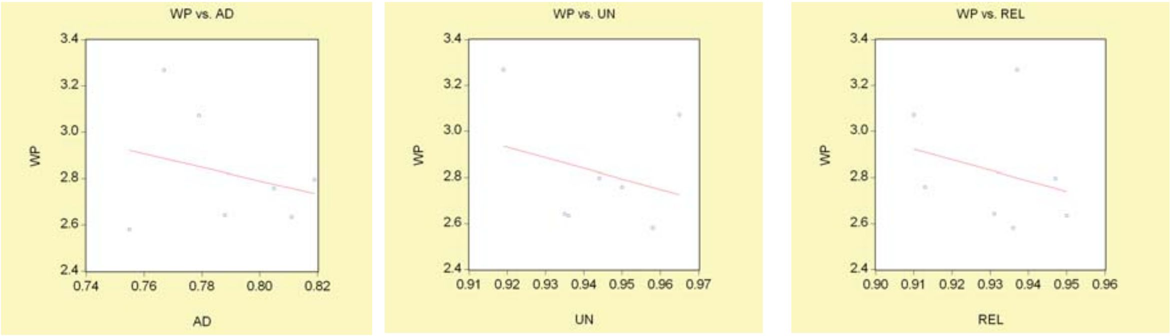


Figure 11 Relationships between RO indicators and PO/Sustainability indicators

4.2 Weak and strong aspects per district

Once the relationships between the indicators are better understood, the next step is to identify the weakest elements per districts. In Table 6, the best and poorest indicators are presented.

It appeared that all irrigation districts function relatively similarly. Beneficial fraction and adequacy are the main problems (it is the worse indicator for almost all districts), as well as the low biomass production and the low beneficial fraction. On the other side of the scale crop water deficit, reliability and uniformity always appear to be the best indicators. These results typically apply to a humid country with high rainfall rates.

Table 6 Best and poorest PO irrigation indicator per district

District	Lowest		2nd lowest		2nd best		Best	
Bugenyuzi/KARUSI	bf	2.79	ad	3.06	rel	4.05	cwd	4.59
Bugendana/GITENA	bf	2.18	ad	3.06	cwd	4.76	un	5.00
Butaganzwa/RUYIGI	bf	2.79	ad	2.95	cwd	4.69	un	5.00
Cankuzo	bf	2.90	ad	2.92	cwd	4.59	un	5.00
Butaganzwal/KAYANZA	bf	2.80	ad	3.15	cwd	4.76	rel	4.86
Bugabira/KIRUNDO	bf	3.17	ad	3.32	cwd	4.04	rel	4.39
Buziga/NGOZI	bf	2.99	cwc	3.16	rel	4.77	cwd	4.77

4.3 Recommendation countrywide

According to the LSI country participants, the purpose of LSI systems in Burundi is to ensure food security, increase rural incomes, and create jobs. However, it has also been mentioned in different reports that food production is relatively unstable and is unable to keep pace with the rise in population (after Rwanda, Burundi is the second biggest country in terms of population density: ranging from 254 persons/km^2 to 400-500 persons/km^2). Ensuring food security should definitely be high on the agenda.

The results of this study are confirming that fact. It has shown than one of the weakest aspects of irrigated agriculture in Burundi is the land productivity. Expanding the irrigated surface could enable higher food production, but it is probably better to in the first place invest on improving the performance of the existing irrigation systems. The idea is to increase land productivity for the existing irrigated areas without increasing crop water consumption, because it is already too high. Thus, special attention should be given to introduce or develop agronomic extension services that could advise on the use of fertilizer or improved seeds stock.

According to LSI country participants there are no water quotas for LSI systems. Specifying water rights (absolute volumes, proportions, guaranteed minimum) to major users could help to decrease water consumption. Also, priorities are not specified for water allocation amongst the sectors (domestic, agriculture, industry, etc.). Implementing an irrigation policy in the future could also help with allocating the water more evenly between the sectors.

Reducing erosion and loss of soil fertility is also one major aspect to focus on according to different reports. The fact that soils are degrading is not coming out of our results as Land sustainability gets a score higher than 3, but it may be because of the short period covered by our report (our analysis only reflects the trend over the past 5 years).

According to LSI country participants, government departments are responsible for planning, design, construction, operation and in some cases maintenance, of LSI schemes, if not delegated to water user associations. The government could also invest in modernizing the irrigation infrastructures. Irrigation systems are outdated and insensitive to climatic variations. Investing in storage of rainfall could also improve the reliability, even though it is already very good. If farmers know that they can rely on the supply of water, they might use it more efficiently and apply irrigation at more appropriated times, which would also help to increase biomass water productivity as well as the beneficial fraction.

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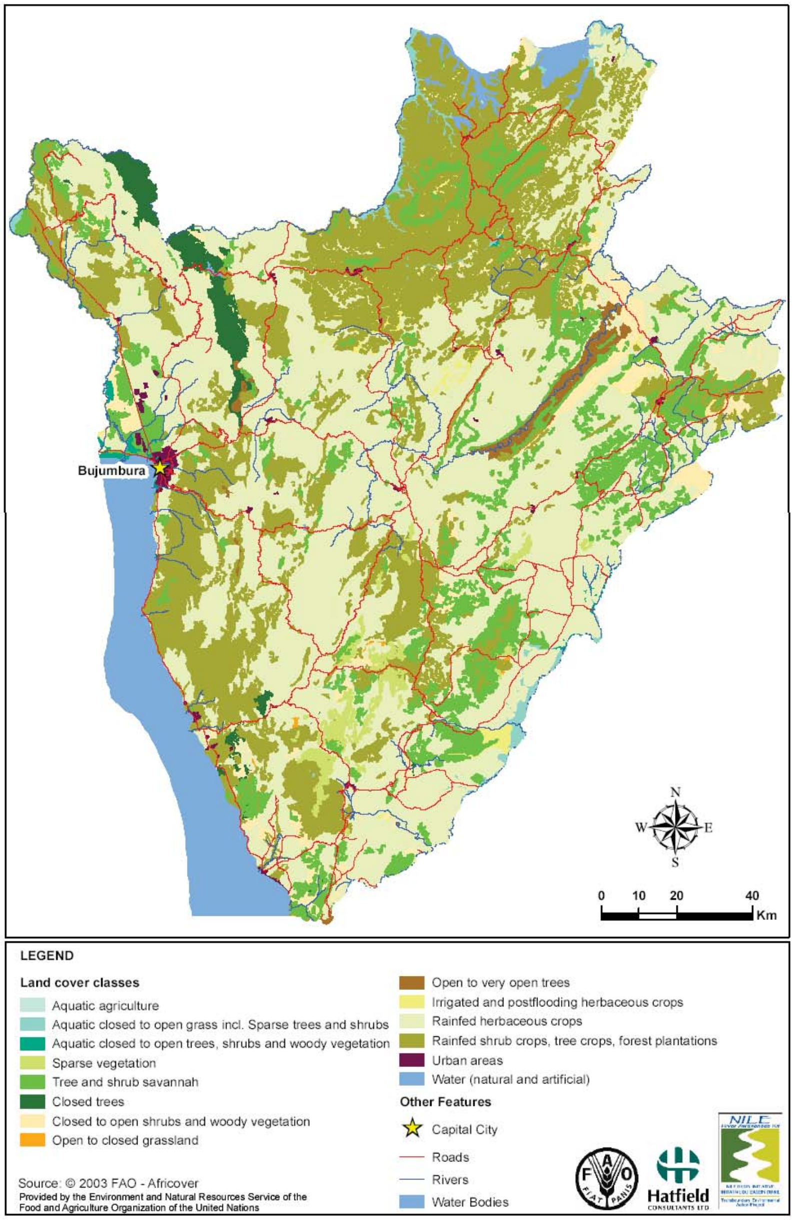
Annex 1 Definition of irrigation performance indicators

Type	Indicator	Acronym	Unit	Formula	Why important ?
RO	Biomass productivity	bio	Kg/ha/year	Bio	Food security; farmer income; farm sustainability
	Biomass water productivity	bwp	Kg/m^3	Bio/ET$_{act}$	High return from total water used by a crop
PO	Crop Water Consumption	cwc	M^3/ha/year	ET$_{act}$	Saving of water resources
	Crop water deficit	cwd	M^3/ha/year	ET$_{pot}$-ET$_{act}$	Indication of water shortage; help to evaluate deficit supply strategies
	Beneficial fraction	bf	-	T$_{act}$/ET$_{pot}$	Indication of proportion of total crop water use going to production of plant (crop) matter
	Adequacy (Crop Water stress)	ad	-	T$_{act}$/T$_{pot}$	Indication of whether irrigation water reaches the roots of the crop
	Uniformity	un	-	1-CV(T$_{act}$/T$_{pot}$)(x,y)	Indication of the spatial homogeneity of the water distribution in a district
	Reliability	rel	-	1-CV(T$_{act}$/T$_{pot}$)(t)	Indication of the ability to deliver water timely, and the flexibility to cope with rainfall variations
Sustainability	Land sustainability	spot	1/year	Slope ndvi spot	Indication of farming sustainability
	Water sustainability	amsre	1/year	Slope soil moisture	Indication of changes of water resources availability

Annex 2 Burundi Land cover (FAO, 2003)

Generalized Land Cover Map of Burundi



Source: © 2003 FAO - Africover
Provided by the Environment and Natural Resources Service of the
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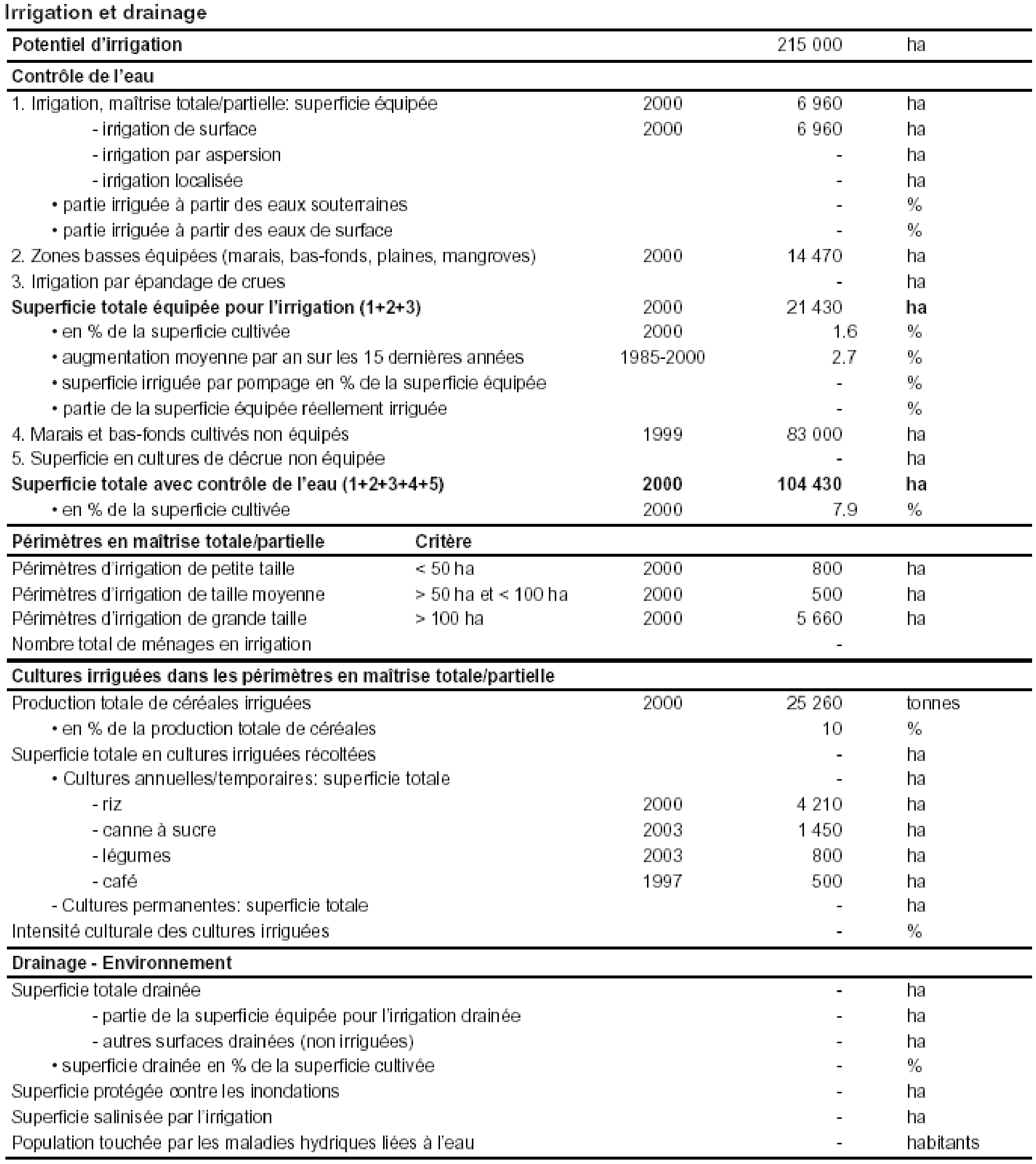
Disclaimer - The boundaries, colors, denominations and any other information does not imply, on the part of the NBI, any judgement or legal status of any territory, or any endorsement or acceptance of such boundaries.

Annex 3 General information on irrigation conditions in Burundi (FAO, 2005)



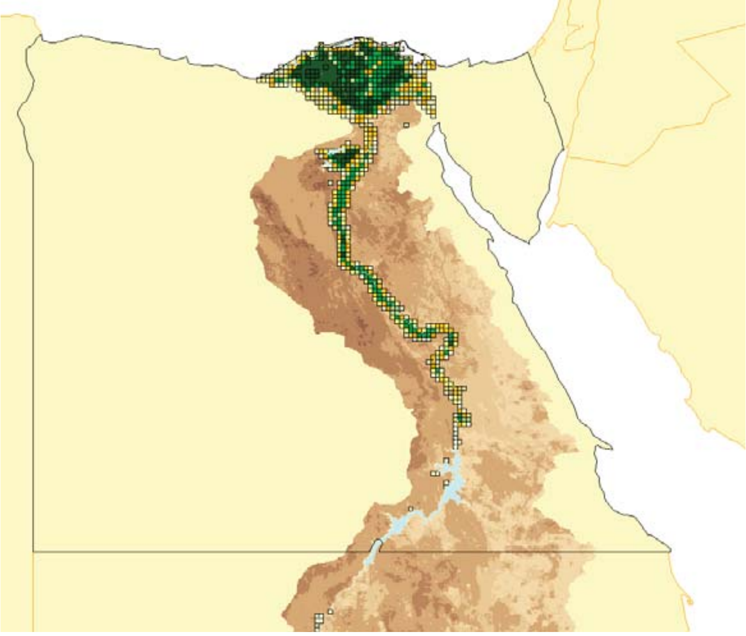
Irrigation et drainage

Potentiel d'irrigation			215 000	ha
Contrôle de l'eau				
1. Irrigation, maîtrise totale/partielle: superficie équipée		2000	6 960	ha
- irrigation de surface		2000	6 960	ha
- irrigation par aspersion			-	ha
- irrigation localisée			-	ha
• partie irriguée à partir des eaux souterraines			-	%
• partie irriguée à partir des eaux de surface			-	%
2. Zones basses équipées (marais, bas-fonds, plaines, mangroves)		2000	14 470	ha
3. Irrigation par épandage de crues			-	ha
Superficie totale équipée pour l'irrigation (1+2+3)		2000	21 430	**ha**
• en % de la superficie cultivée		2000	1.6	%
• augmentation moyenne par an sur les 15 dernières années		1985-2000	2.7	%
• superficie irriguée par pompage en % de la superficie équipée			-	%
• partie de la superficie équipée réellement irriguée			-	%
4. Marais et bas-fonds cultivés non équipés		1999	83 000	ha
5. Superficie en cultures de décrue non équipée			-	ha
Superficie totale avec contrôle de l'eau (1+2+3+4+5)		**2000**	**104 430**	**ha**
• en % de la superficie cultivée		2000	7.9	%
Périmètres en maîtrise totale/partielle	**Critère**			
Périmètres d'irrigation de petite taille	< 50 ha	2000	800	ha
Périmètres d'irrigation de taille moyenne	> 50 ha et < 100 ha	2000	500	ha
Périmètres d'irrigation de grande taille	> 100 ha	2000	5 660	ha
Nombre total de ménages en irrigation			-	
Cultures irriguées dans les périmètres en maîtrise totale/partielle				
Production totale de céréales irriguées		2000	25 260	tonnes
• en % de la production totale de céréales			10	%
Superficie totale en cultures irriguées récoltées			-	ha
• Cultures annuelles/temporaires: superficie totale			-	ha
- riz		2000	4 210	ha
- canne à sucre		2003	1 450	ha
- légumes		2003	800	ha
- café		1997	500	ha
- Cultures permanentes: superficie totale			-	ha
Intensité culturale des cultures irriguées			-	%
Drainage - Environnement				
Superficie totale drainée			-	ha
- partie de la superficie équipée pour l'irrigation drainée			-	ha
- autres surfaces drainées (non irriguées)			-	ha
• superficie drainée en % de la superficie cultivée			-	%
Superficie protégée contre les inondations			-	ha
Superficie salinisée par l'irrigation			-	ha
Population touchée par les maladies hydriques liées à l'eau			-	habitants

Large Scale Irrigation (LSI)

Nile Basin Country Irrigation Report Series

Egypt



Appendix E

January 2009

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Part 1 Overview of irrigated areas
Part 2 Climate
Part 3 Raster and vector-based irrigation performance analysis
Part 4 Recommendations for improvement

Purpose of this report:

This report is one of a series of reports that will describe, and evaluate irrigation schemes in each of the Nile basin countries, and make recommendations for irrigation best practices. This report deals with Egypt and will become an integral component of the final LSI report that will combine results from all countries

Part 1 Overview of irrigated areas

1.1 Location of the irrigated areas

FAO - AQUASTAT, 2005

EGYPT

Disclaimer

Figure 12 Map of Egypt and its districts

Egypt has a history of 6000 years of irrigation. The uncertain and erratic flow of the Nile river, and the need for water supply throughout the entire year has inspired the Egyptians and the British imperial rulers to construct large storage reservoirs in the Nile such as at Aswan. The high Aswan dam was constructed in 1964 and can store 169 BCM water. The presence of huge storage facilities has inspired the development of double and even triple cropping systems. The soils of the delta – and also in the river valley – have rich sediments, and are extremely suitable for irrigation practices. Figure 12 displays the different districts in Lower Egypt that will be used as units of analysis in this study.

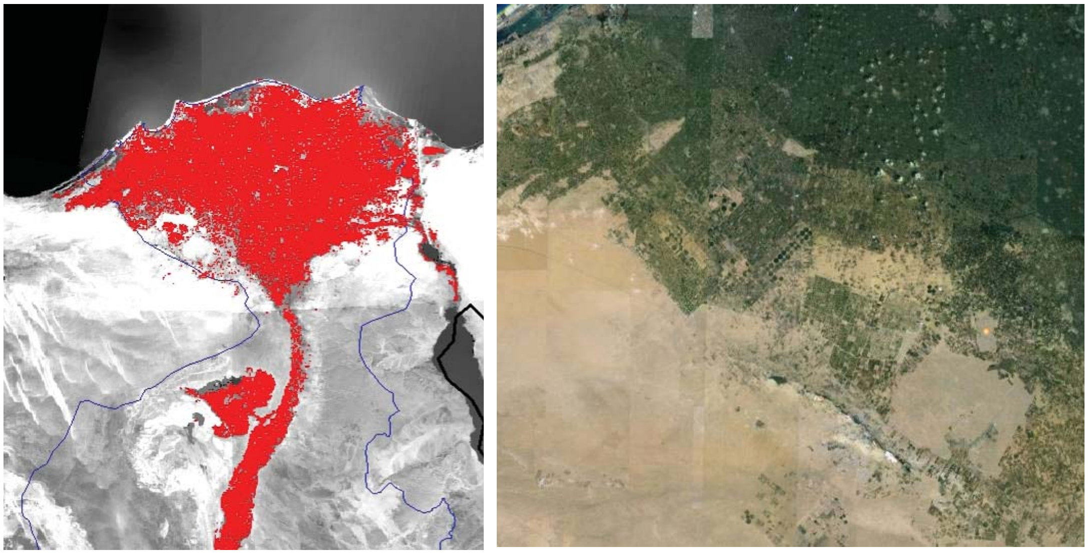


Figure 13 Map showing the distribution of irrigated areas in Lower Egypt according to the FAO-GMIA product, and being refined in the current study. The red dots on the left hand side represent irrigated land

This study estimates the irrigated area to be 3 million ha, of which 85% is in the Nile Valley and Delta. The total irrigated area is 7, 2 million feddan (one feddan is 0.42 ha). Our estimate is larger than the IWMI estimates (2.1 million ha) and smaller than the FAO estimates (3.2 million ha). The irrigated area in Egypt is approximately 60% of all irrigated land present in the Nile Basin.

Table 7 Different sources for the irrigation statistics

Source	Region covered	Irrigated area (ha)
FAO – GMIA	Entire Egypt	3,245,650
IWMI – GIAM	Entire Egypt	2,144,099
Current study	Nile Basin component of Egypt	2,963,581

1.2 Description of LSI

Around 3 million ha is intensively cultivated annually and 85% of this is in the Nile Valley and Delta. The irrigation system in the old land of the Nile Valley is a combined gravity and water lifting system (lift: about 0.5-1.5 m). The irrigation system in the new lands (reclaimed areas) is based on a cascade of pumping stations from the main canals to the fields, with a total lift of up to 50 m. Surface irrigation is banned by law in the new reclaimed areas, which are located at the end of the systems, and are more at risk of water shortage. Farmers have to use sprinkler or drip irrigation, which are more suitable for the mostly sandy soil of those areas.

Egypt's irrigation system extends over 1,200 km, from Aswan to the Mediterranean Sea and includes 2 storage dams at Aswan, and 7 major barrages on the Nile that divert river water into an extensive network of irrigation canals. This includes 13,000 km of main public canals, 19,000 km of secondary public (Branch), and 100,000 km of tertiary private watercourses (mesqas). The mesqa systems are owned, operated and maintained by farmers. They form the main water distribution system to farmer's fields. Complimentary drainage networks cover about 272,000 km with 17,500 km of main drains, 4,500 km of open secondary drains, and 250,000 km of covered secondary & tile drains. While the traditional irrigation systems are all government operated and exists of small land holdings, new settlements in the Western Desert along the Cairo – Alexandria road arose through private investments and full blown commercial agro-business operations. These systems also occur along the Ismailaya Road. These new estates use micro-irrigation technologies on light textured soils, as opposed to surface irrigation methods on heavy textured soils in the Delta and Valley.

In the case of Egypt, the following classification is used to differentiate the irrigation systems according to their scale (according to the LSI participants from Egypt):

- 450 ha is considered a small scale irrigation scheme;
- Between 450 and 4,500 ha, it is considered a medium size irrigation system
- 4,500 ha is considered a large scale irrigation scheme.

Private owners most of the time have irrigation schemes of between 0.2 and 10,000 ha and the private firms have irrigation schemes between 10 and 450 ha.

More detailed information concerning irrigation in Egypt can be found in Annex 2.

1.3 Agricultural conditions

The agriculture year is divided into three separate seasons: winter (October to February), summer (March to June), and Nili (July to September) as displayed in Table 8. Most crops are grown both in the Delta and in the Valley, with the exception of rice (Delta mainly) and sugarcane (Valley). The main winter crops are wheat and fodder or Berseem (Trifolium alexandrinum). Berseem is grown either over 3 months with 2 cuts as feeds and a soil improver (short Berseem) usually preceding cotton, or over 6-7 months either with 4-5 cuts as a fodder crop or grazed by tethered cattle (long Berseem). Minor winter crops are, amongst others, pulses, barley and sugar beet. The main summer crops are maize, rice and cotton, the latter being the most important Egyptian export crop. In 2002, yields were 6.4 ton/ha for wheat, 8.1 ton/ha for maize, 9.4 ton/ha for rice and 2.6 ton/ha for cotton. Figure 14 shows the different crops per hectare according to the FAO-

AQUASTAT. More detailed information concerning irrigation in Egypt can be found in Annex 2.

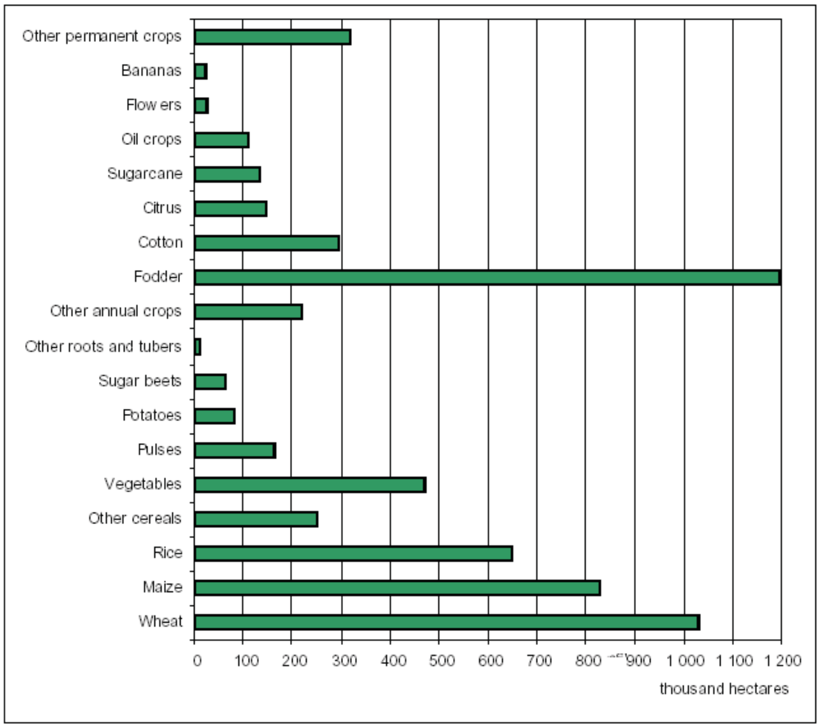


Figure 14 Irrigated crops in Egypt (source: FAO-AQUASTAT, 2005)

Table 8 Cropping seasons (source: FAO-AQUASTAT, 2005)

	Irrigated area (1000 ha)	**Crop area as percentage of the total area equipped for irrigation by month**											
		J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
EGYPT													
Wheat	1021	31	31	31	31	31						31	31
Rice	607						19	19	19	19	19		
Maize	795						24	24	24	24	24		
Barley	58	2	2	2								2	2
Sorghum	158	5	5	5								5	5
Potatoes	85		3	3	3	3	3						
Sugarbeet	41					1	1	1	1	1	1		
Sugarcane	124	4	4	4	4	4	4	4	4	4	4	4	4
Pulses	178				5	5	5	5	5				
Vegetables	421												
Vegetables-one				6	6	6	6						
Vegetables-two								6	6	6	6		
Citrus	132	4	4	4	4	4	4	4	4	4	4	4	4
Fruits	311	10	10	10	10	10	10	10	10	10	10	10	10
Oil crops	20	1	1	1	1	1	1	1	1	1	1	1	1
Groundnut	49					2	2	2	2	2			
Cotton	321	10						10	10	10	10	10	10
Fodder	1098	34	34	34	34							34	34
All irrigated crops	5419	100	93	99	98	67	79	86	86	80	79	100	100
Equipped for irrigation	3246												
Cropping intensity	167												

Part 2 Climate

2.1 Climatological conditions

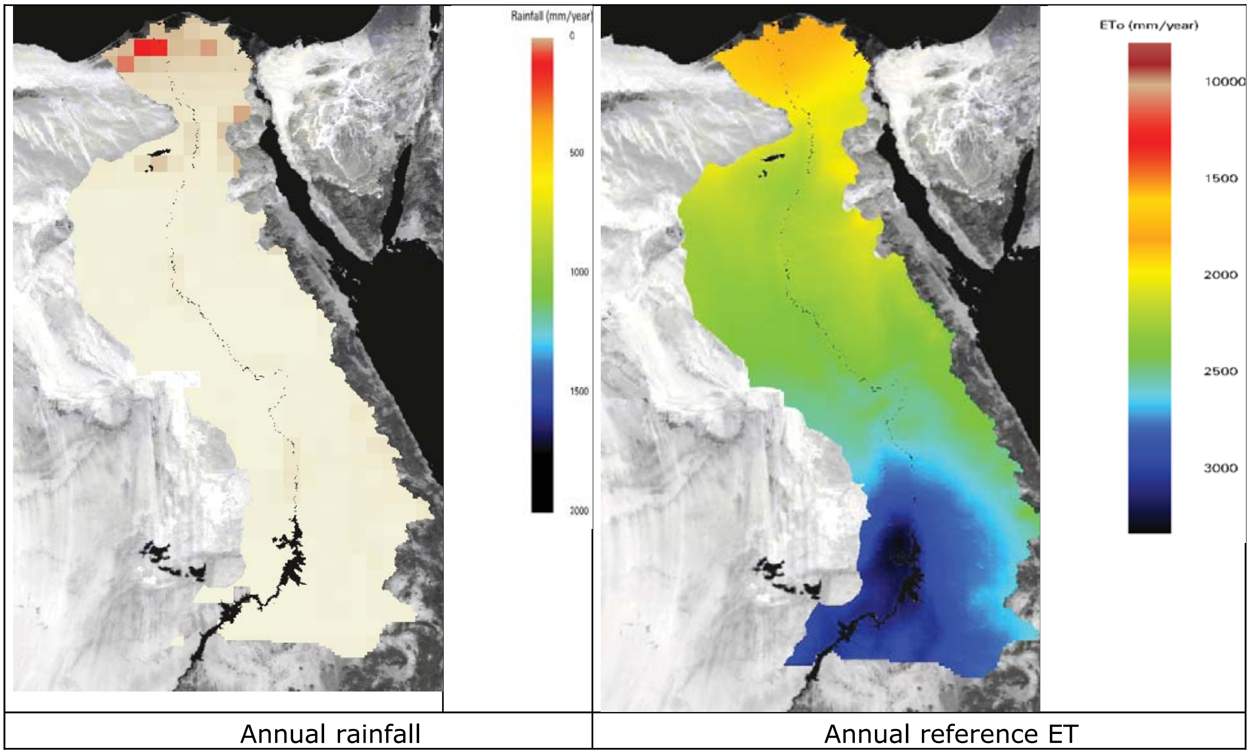
In this study, the reference evapotranspiration (ET_0) is computed with the standardized Penman-Monteith equation specified in FAO56 and the rainfall is based on TRMM satellite data for the year 2007. Table 9 shows the monthly values for rainfall and ET_0.

Egypt is a typical desert country. There is some rainfall along the shore line of the Mediterranean Sea, but a hundred kilometer inland this rainfall reduces to virtually nothing. The average rainfall for Egypt is only approximately 10 mm/yr. Agriculture is thus not feasible without irrigation. The uncertain rainfall factor can be ignored in the planning of water resources. This makes it easier to operate the canals and plan the on-farm irrigation practices.

The temperatures are cool in the winter and hot during the summer. ET_0 varies from 3.5 to 9 mm/d. This is related to the dry and hot desert climate. The winters are mild, and very well suited for various crops. The summer crops must be heat tolerant; hence rice, cotton and sugarcane (grown in Upper-Egypt) are common.

Table 9 Monthly values for rainfall and reference evapotranspiration (ET0).

Month	Rainfall (P)	ET_0	Aridity (P/ET_0)
January	3	80	0.01
February	2	98	0.01
March	1	146	0.01
April	0	190	0
May	0	239	0
June	0	250	0
July	0	232	0
August	0	210	0
September	0	179	0
October	0	152	0
November	1	100	0.01
December	2	81	0.01
TOTAL	9	1957	



Annual rainfall | Annual reference ET

Figure 15 Spatial variation of rainfall (left) and ET0 (right).

2.2 Climatic zones

The current study, aimed at providing information for improved irrigation practices in the Nile basin, covers various climatic zones. Rainfall and temperatures specifically need to be analyzed, because they have a large impact on attainable land and water productivities, as well as on percolation rates and irrigation efficiencies. Unexpected rainfall can for instance reduce the fraction of beneficial transpiration, and also induce more variations in soil moisture conditions than in a situation where the crop moisture depends solely on irrigation water supply. To make corrections for these climatic influences based on the diagnosis of the irrigation systems, and to define climate dependent target values of irrigation management, four different climatic zones have been identified for the Nile Basin. The zones have been made contiguous where possible. Insertion of more zones would result into scattered appearances of the zones.

Part 3 Raster and vector-based irrigation performance analysis

3.1 Methodology

In this study, the irrigated areas have been identified at a resolution of 250m based on (i) the data sent by the LSI representatives of Egypt, (ii) the FAO irrigated areas, and (iii) manual digitization of visually recognizable irrigated system using Google earth and Landsat images.

The first step was to compute all the indicators per pixel. All the RO and PO indicators described have been computed based on the annual accumulated values of biomass production (Bio), Actual Evapotranspiration (ET_{act}), the Potential Evapotranspiration (ET_{pot}), Actual Tranpiration (T_{act}), Potential Transpiration (T_{pot}). This was done for the year 2007. The annually accumulated values are the result of a land surface energy balance algorithm that was run for the whole Nile basin based on data from Terra and Aqua satellites. The Modis and AMSR-E sensor data were used.

The sustainability indicators have been obtained by investigating the last five year's trends in the vegetation index (from the SPOT-Vegetation satellite) and the soil moisture (from the AMSR-E satellite).

The second step was to allocate a score per pixel. To do so, we studied the distribution of the values for each indicator. From that, 4 different benchmark values were defined. A score between 1 and 5 has been given to each pixel; 5 being the best category, depending on the value of the indicators compared to the benchmarks (Figure 16).

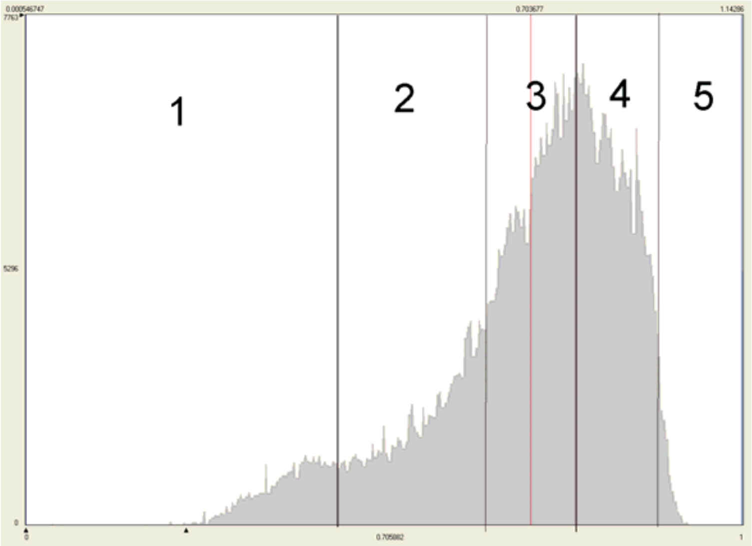


Figure 16 distribution of the values of one indicator in 5 classes

An average score of 3 for all pixels per climatic zone will indicate good benchmarking.

If the country has irrigation systems in different climatic zones, different benchmark values are considered to avoid climatic bias in scoring. In the case of Egypt, irrigation systems are located in climatic zone 1 (Table 10).

Table 10 benchmark values for pixel located in climatic zone 1

	Unit	Score of 1	Score of 2	Score of 3	Score of 4	Score of 5
Bio	Kg/ha/year	<7,000	<16,000 and >7,000	<28,000 and >16,000	<32,000 and 28,000	>32,000
bwp	Kg/ m3	<1.5	<2.3 and >1.5	<2.8 and >2.3	<3.3 and >2.8	>3.3
cwc	M3/ha/year	>12,500	<12,500 and >9,000	<9,000 and >5.700	<5,700 and >1,000	<1,000
cwd	M3/ha/year	<340 and >250	>500	<500 and >340	<250 and >130	<130
bf	-	<0.7	<0.9 and >0.7	<0.94 and >0.9	<0.97 and >0.94	>0.97
ad	-	<0.45	<0.64 and >0.45	<0.74 and >0.64	<0.86 and >0.74	> 0.86
un	-	<0.75	<0.85 and >0.75	<0.9 and >0.85	<0.95 and >0.9	>0.95
rel	-	<0.75	<0.82 and >0.75	<0.88 and >0.82	<0.95 and >0.88	>0.95
spot	1/year	<-0.1	<-0.02 and >-0.1	<0.1 and >-0.02	<0.3 and >0.1	>0.3
amsre	1/year	<-0.1	<-0.05 And >-0.1	<0.05 and >-0.05	<0.15 and >0.05	>0.15

Once each indicator gets a score per pixel, districts average and country average values can be calculated. The indicators are averaged per type: RO indicators, PO indicators, and sustainability indicators, to simplify understanding of processes and results.

3.2 Results at Country level

The average score considering all the indicators together for all the 3 million ha of irrigated land is 3.1. Figure 17 shows the country average for each indicator. The elements with a relative low score are the ones that Egypt should provide more attention to.

Values of 3.0 and 2.9 for land and water productivity respectively, are considered average.

Values of 2.8 and 2.6 respectively for PO indicators, crop water consumption and uniformity are below average. This shows that the access to water resources is not equal everywhere in the Egyptian irrigation systems. This is likely related to the large areas and differences between crop physical systems in upper, middle and lower Egypt. Adequacy and the reliability are slightly above average. Crop water deficit and the beneficial fraction are on the other side of the scale and appear very good at country level.

Sustainability of the land resources does not seem to be fully under control. The irrigated land is constantly green, and there is no clear signal that the system is deteriorating. However, the soil moisture levels show a decline over the last 5 years. This is an interesting issue, because Egypt is expanding its land horizontally, and more irrigation water is now brought from the traditional areas in the valley and delta to the desert. This is occurring already in Sinai and plans exist to convey Nile water resources to the Western Desert to supplement groundwater resources. Although no firm conclusion can be drawn from this finding, decreasing soil moisture values should be treated with caution. The preservation of land wetness definitely needs to get special attention during the monitoring of the irrigation systems.

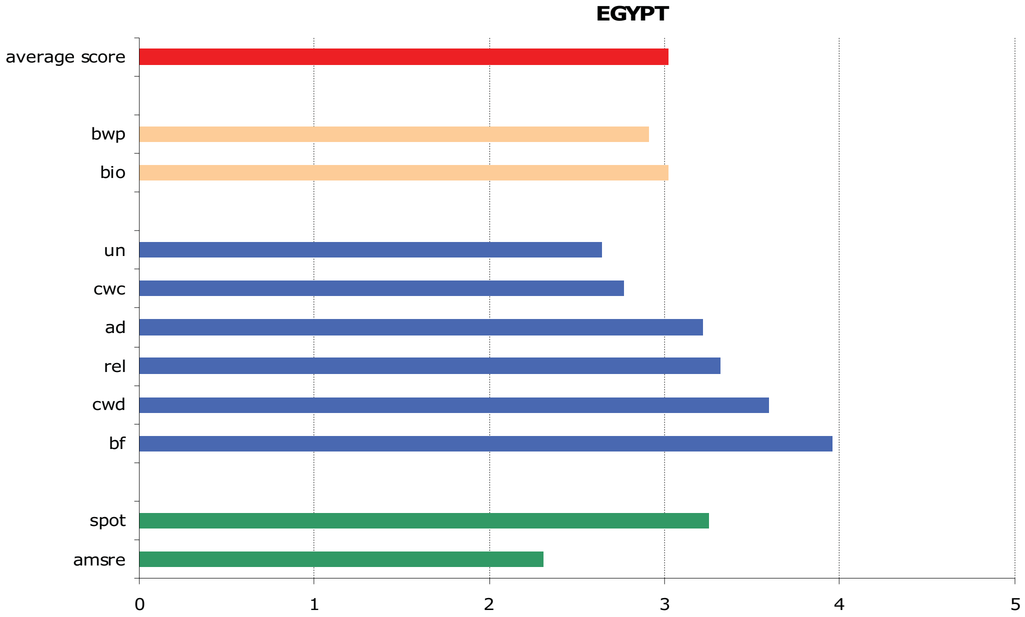


Figure 17 The average score for each indicator in Egypt.

3.3 Results at district level

3.3.1 Average per district

In Figure 18 the average score for all the indicators per district are compared. The western Delta appears to have the best score. Twenty two districts having more than 30 pixels of 6.25 ha have been identified. In terms of total average score, the best irrigation district is Dumyat, with an average of 3.6. The district that has the lowest average is Al Jizah, with an average of 2.5 (see Figure 18 for their locations).

Dumyat is based in the Delta (Lower Egypt) and Al Jizah on the fringes of the Nile valley (Upper Egypt). The soil in Al Jizah is sandy and this could be an explanation for the low performance.

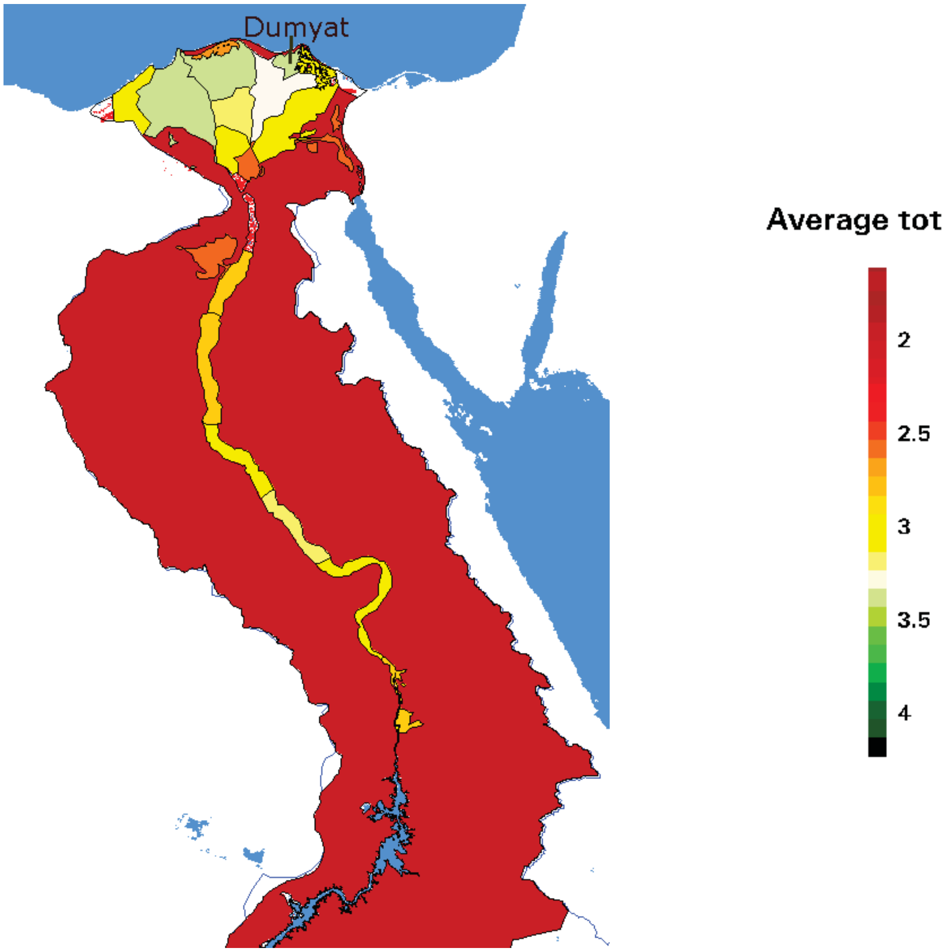


Figure 18 Map of Egypt showing the total score per irrigated district

3.3.2 Breaking down the total score into RO, PO and sustainability indicators

By breaking down the total score into 3 types of indicators (RO, PO and sustainability), it is possible to better understand the irrigation mechanisms for each district. Figure 19 provides the average score per group of indicators. What is called 'total score' in red is the average of the 10 indicators. Looking at the total average score for all indicators for each district gives an idea of the total performance and enables ranking of districts. A better understanding of the weak points as well as the strong points of each district will require separate analyses of each indicator group.

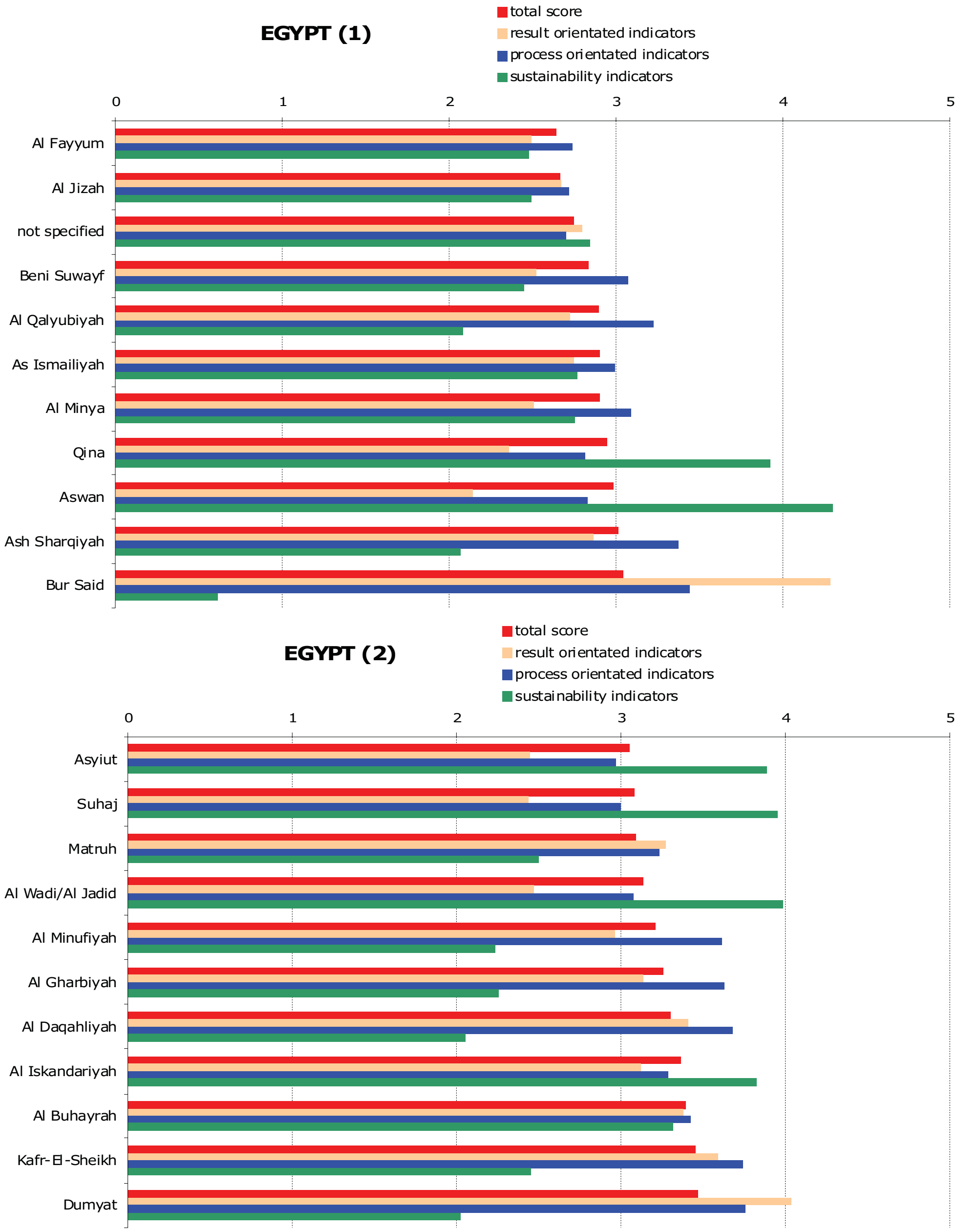


Figure 19 A breakdown of the total score per indicator per district

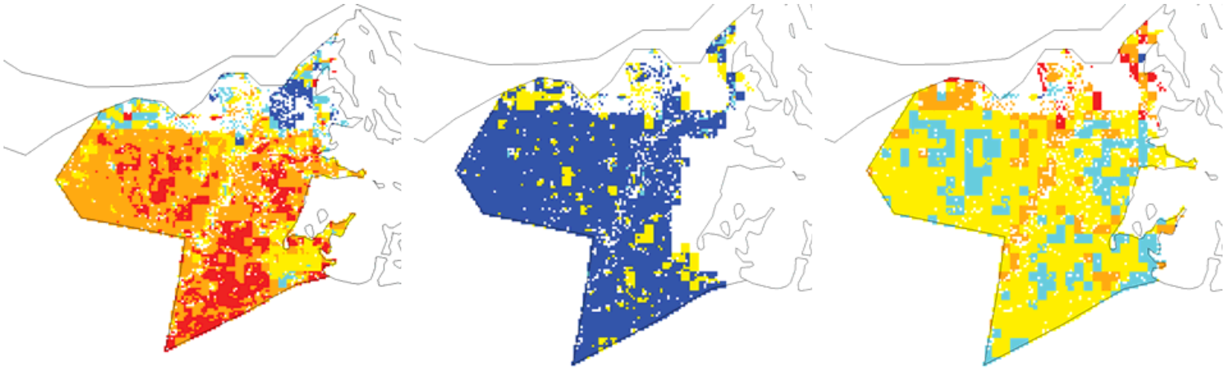
A good total score does not always mean a good performance in terms of results. Similarly, a poor average score does not mean that the district does not have good results.

Considering the total average score for Bur Said, it seems to be an average district. However, by looking at the average of the RO indicators, it appears to be the best performing district, with an average score of 4.3. The low global average that leads to ranking Bur Said amongst the districts with average to poorest irrigation performance is explained by the very low score obtained in terms of sustainability. The managers of Bur Said seem to over-utilize their land and water resources, resulting in unsustainable practices. A good total performance does not mean a sustainable system. This example shows once again the relevance of breaking the irrigation performance down into different types of indicators. It would be valuable to find the main reasons for this un-sustainability.

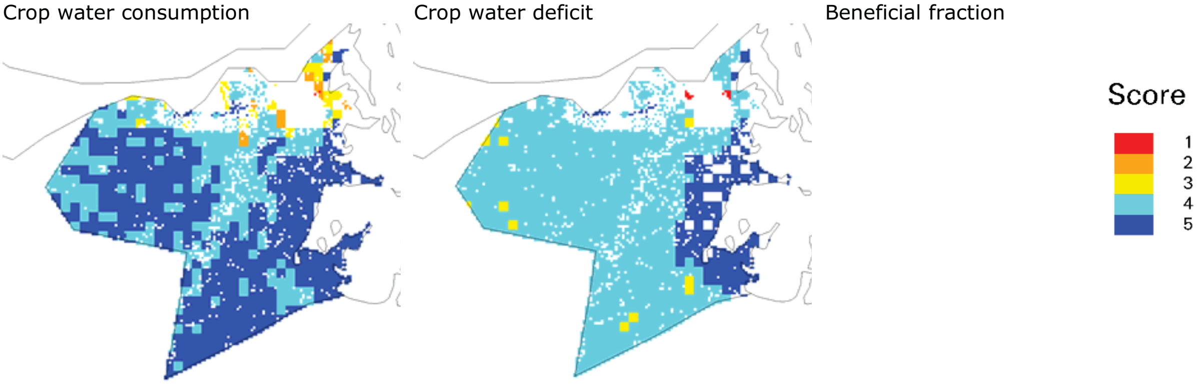
The 22 districts of Egypt have a very variable RO score, ranking from 2.1 to 4. The PO indicators vary too from one district to another, from 2.7 to 3.8. This variation complicates general improvement recommendations at a country scale. In line with the LSI assignment, relevant improvement recommendations should be made district per district by looking at the different scores of every single indicator for each district.

3.4. Analysis per pixel for the best irrigation system

Looking at what happens within one district enables us to see the spatial distribution of the score of each indicator. In other words, it makes it possible to see where which processes need more attention. Hereafter, the spatial distribution of the five PO indicators is displayed for the irrigated pixels in the district of Dumyat, which is the best district in terms of performance. The 6th PO indicator uniformity can not be displayed as it is an indicator at district level. Figure 20 demonstrates that crop water consumption is too high (over 12,500 m^3/ha/year) and that many precious water resources are lost by non-beneficial evaporation. Overall the system is very reliable and adequate.



Crop water consumption Crop water deficit Beneficial fraction



Adequacy reliability

Figure 20 Spatial distribution of each indicator for the district of Dumyat

Part 4 Recommendations for improvement

4.1. Explaining the irrigation results

To be able to give appropriate recommendations, it is important to understand which of the PO indicators influences the RO indicators mostly. A regression analysis was performed with the values for all indicators for the 7 districts. As far as the biomass production is concerned, it appears to be well correlated to adequacy and crop water consumption. The higher the crop water consumption or the adequacy, the more biomass will be produced. While this is good for crop production, it will go at the cost of a high irrigation water usage. It is positively linked to the beneficial fraction and negatively linked to the crop water deficit. No clear relationship between biomass and uniformity, or reliability is apparent.

For a high biomass water productivity, crop water consumption should be low. The highest biomass water productivity occurs when crop water consumption is low and crop water deficit is limited. This is helpful for optimizing either biomass production or biomass water productivity.

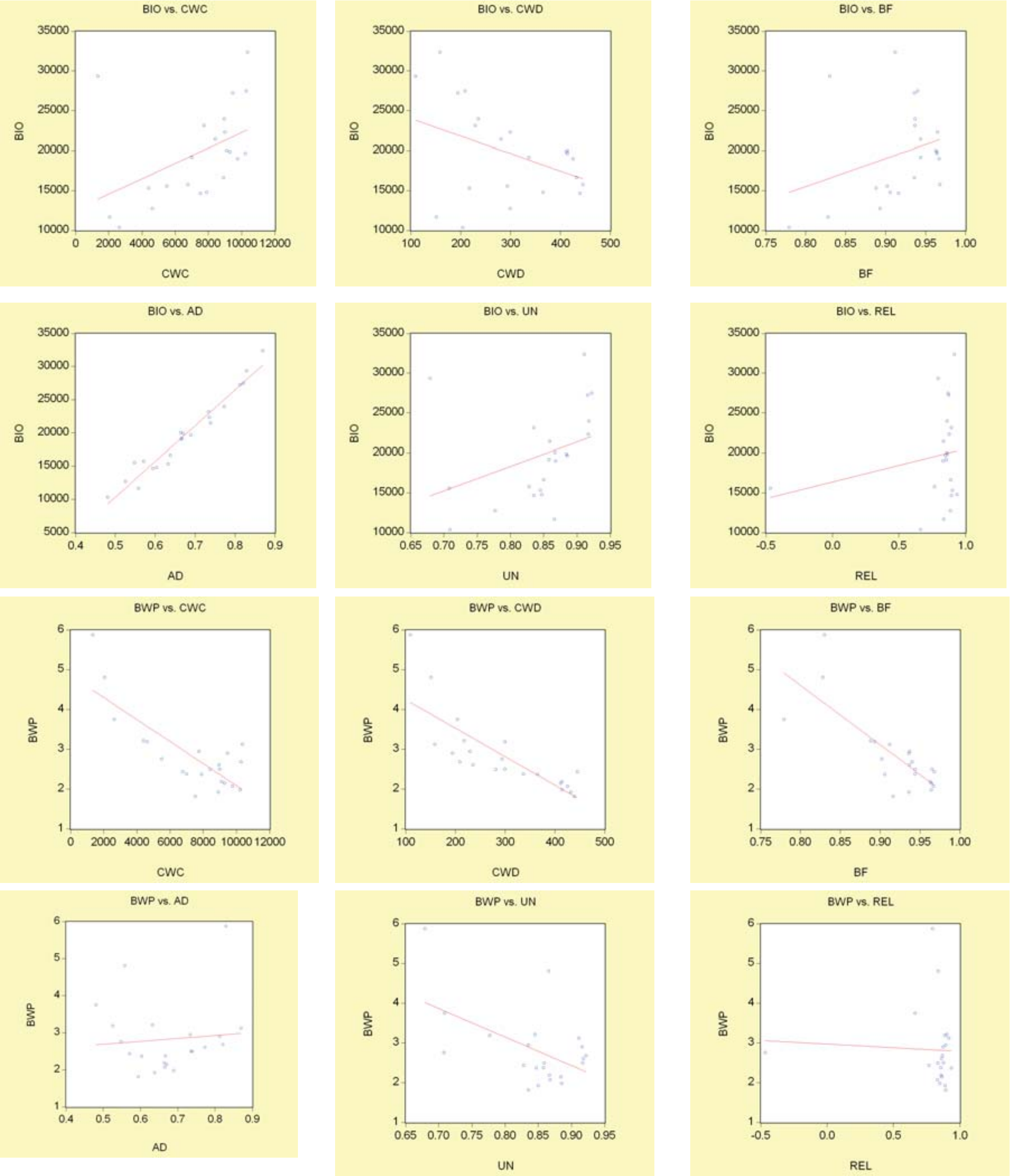


Figure 21 Relationships between RO indicators and PO/Sustainability indicators

4.2. Weak and strong aspects per district

Once the relationship between indicators is better understood, the next step is to identify the weakest elements per districts. In Table 5, the best and poorest indicators are presented.

Table 11 Best and poorest PO irrigation indicators per district

district	lowest score		2nd lowest		2nd best		best	
Al Fayyum	ad	1.69	cwd	1.98	cwc	3.21	bf	4.70
Al Jizah	un	1.00	ad	2.10	cwc	3.82	bf	3.95
not specified	un	1.00	ad	2.17	cwd	3.50	cwc	4.35
Beni Suwayf	cwd	2.17	cwc	2.49	ad	3.97	bf	4.68
Al Qalyubiyah	ad	1.93	cwd	2.78	rel	3.20	bf	4.38
As Ismailiyah	un	2.00	ad	2.06	rel	3.75	cwc	3.81
Al Minya	cwd	2.15	cwc	2.50	rel	3.34	bf	4.66
Qina	un	2.00	cwd	2.10	rel	3.70	bf	3.86
Aswan	un	2.00	cwd	2.03	bf	3.77	rel	3.89
Ash Sharqiyah	cwc	2.70	ad	2.87	cwd	3.89	bf	4.19
Bur Said	un	1.00	ad	2.62	rel	3.93	cwc	4.81
Asyiut	cwd	2.08	cwc	2.46	ad	3.47	bf	4.72
Suhaj	cwd	2.13	cwc	2.23	rel	3.03	bf	4.58
Matruh	bf	2.24	ad	2.83	cwd	3.96	cwc	4.33
Al Wadi/Al Jadid	un	2.00	ad	2.57	bf	3.61	rel	4.34
Al Minufiyah	cwc	2.56	ad	3.03	un	4.00	bf	4.54
Al Gharbiyah	cwc	2.54	rel	3.17	un	4.00	cwd	4.58
Al Daqahliyah	cwc	2.14	rel	3.33	un	4.00	cwd	4.79
Al Iskandariyah	un	2.00	bf	2.99	rel	3.97	cwd	4.32
Al Buhayrah	un	2.00	cwc	2.90	ad	4.16	cwd	4.57
Kafr-El-Sheikh	cwc	2.39	rel	3.42	ad	4.08	cwd	4.89
Dumyat	cwc	2.14	bf	3.03	ad	4.55	cwd	4.73

The elements with low scores indicate the aspects that each district should provide more attention to. Generally, aspects with scores lower than 3 needs to be critically considered. It seems that many districts have a problem with uniformity. The beneficial fraction as well as crop water deficit seem to be the best indicators for many districts. Beneficial fraction can be improved by soil, straw and plastic mulching. Crop water deficit can be regulated by means of shorter irrigation intervals and sufficient supplies. But once again, each district seems to function differently and therefore should be looked at independently.

4.3. Recommendation countrywide

Ancient Egyptians irrigated their land and a rich experience has been built up in agricultural water management. This is reflected in an overall good irrigation system, especially in the areas with alluvial soils at the downstream end of the Nile. Overall, the irrigation performance in upper Egypt is less favourable. The fact that the country is so large will inevitably result in a wide scatter in ranking of irrigation performance.

The most limiting resource for Egyptian agriculture is irrigation water. Management of its water resources has always been the central feature of the country's development strategies. There is indeed insufficient water to meet all demands for competing users and the potential for increasing the amount of available water is limited. Therefore, increasing water productivity should be a priority whereas it seems that all attention is given to production.

Land, next to water, is also a limiting factor. The Delta region contributes to 80% of all arable land in the country and despite the extremely limited land available for agriculture, urbanization is growing. The desert reclamation activities launched in the eighties have been quite successful, albeith the groundwater resources did not appear to be sustainably managed.

The absence of rainfall is an advantage to Egypt, because erratic rain storms can jeopardize and interfere with the irrigation planning. By absence of these events, it is easier to schedule water in the canals. While this works out quite well in the Delta, the performance in the Nile Valley is much less favourable.

The irrigation systems in the downstream end of the Rosetta and Damietta branch are among the best in the world. The national agronomical skills of Egypt and the agricultural policies could be of overriding importance in establishing this success. The short duration varieties are surely debet to that.

The Government of Egypt could focus on the following aspects:

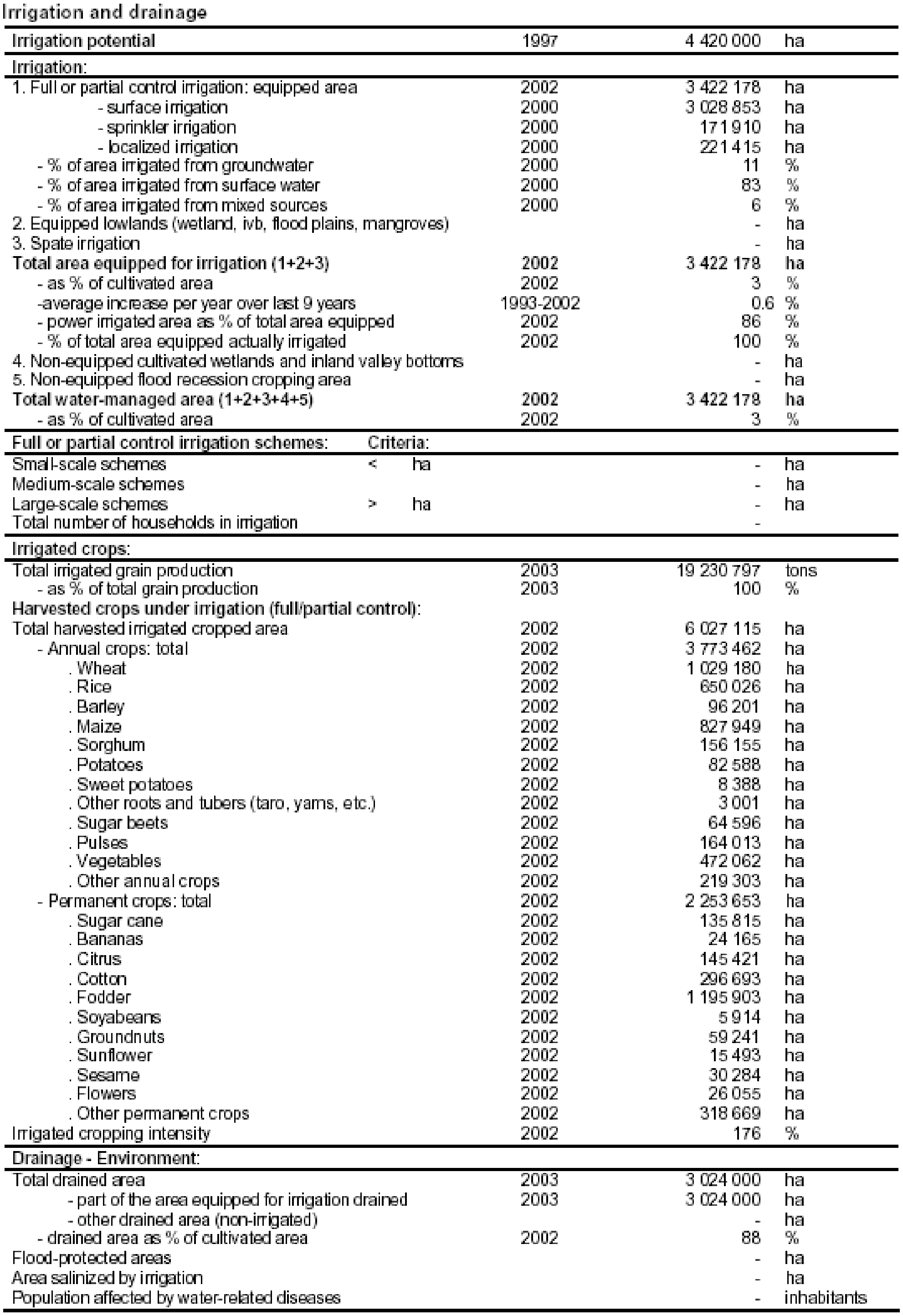
- Provide maximum attention to a proper monitoring technology. There could be undesirable consequences for unlimited horizontal expansion. It is basically a stransfer of water from the old land to the new land
- The minimum drainage flows should be monitored for keeping the leaching fraction of the Nile basin in proper ranges
- Determine the reasons for below-average irrigation performance in certain administrative districts in Egypt.
- There are signals that the institutional capacity in Egypt is not working properly. A critical evaluation should be held by outsiders to detect where in the decision making process aspects can be improved

- Evaluate the operation and maintenance rules for irrigation water management and try to draw lessons that could be used in the arid irrigation systems of Sudan and Ethiopia.
- Continue to invest in extension services and formation of water boards. This could help in making the water distribution more uniform.

Annex 1 Definition of irrigation performance indicators

Type	Indicator	Acronym	Unit	Formula	Why important ?
RO	Biomass productivity	bio	Kg/ha/year	Bio	Food security; farmer income; farm sustainability
	Biomass water productivity	bwp	Kg/m^3	Bio/ET$_{act}$	High return from total water used by a crop
PO	Crop Water Consumption	cwc	M^3/ha/year	ET$_{act}$	Saving of water resources
	Crop water deficit	cwd	M^3/ha/year	ET$_{pot}$-ET$_{act}$	Indication of water shortage; help to evaluate deficit supply strategies
	Beneficial fraction	bf	-	T$_{act}$/ET$_{pot}$	Indication of proportion of total crop water use going to production of plant (crop) matter
	Adequacy (Crop Water stress)	ad	-	T$_{act}$/T$_{pot}$	Indication of whether irrigation water reaches the roots of the crop
	Uniformity	un	-	1-CV(T$_{act}$/T$_{pot}$)(x,y)	Indication of the spatial homogeneity of the water distribution in a district
	Reliability	rel	-	1-CV(T$_{act}$/T$_{pot}$)(t)	Indication of the ability to deliver water timely, and the flexibility to cope with rainfall variations
Sustainability	Land sustainability	spot	1/year	Slope ndvi spot	Indication of farming sustainability
	Water sustainability	amsre	1/year	Slope soil moisture	Indication of changes of water resources availability

Annex 2 General information on irrigation conditions in Egypt (AQUASTAT, 2005)



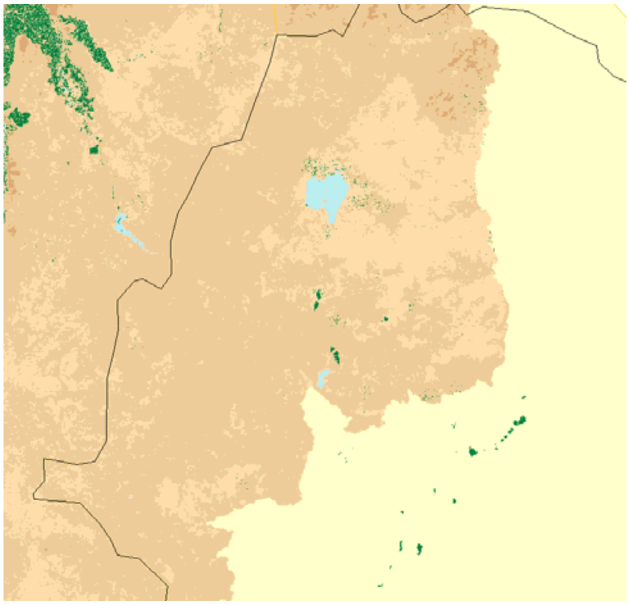
Irrigation and drainage

Irrigation potential		1997	4 420 000	ha
Irrigation:				
1. Full or partial control irrigation: equipped area		2002	3 422 178	ha
- surface irrigation		2000	3 028 853	ha
- sprinkler irrigation		2000	171 910	ha
- localized irrigation		2000	221 415	ha
- % of area irrigated from groundwater		2000	11	%
- % of area irrigated from surface water		2000	83	%
- % of area irrigated from mixed sources		2000	6	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		2002	3 422 178	ha
- as % of cultivated area		2002	3	%
-average increase per year over last 9 years		1993-2002	0.6	%
- power irrigated area as % of total area equipped		2002	86	%
- % of total area equipped actually irrigated		2002	100	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		2002	3 422 178	ha
- as % of cultivated area		2002	3	%
Full or partial control irrigation schemes:	**Criteria:**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes			-	ha
Large-scale schemes	> ha		-	ha
Total number of households in irrigation			-	
Irrigated crops:				
Total irrigated grain production		2003	19 230 797	tons
- as % of total grain production		2003	100	%
Harvested crops under irrigation (full/partial control):				
Total harvested irrigated cropped area		2002	6 027 115	ha
- Annual crops: total		2002	3 773 462	ha
. Wheat		2002	1 029 180	ha
. Rice		2002	650 026	ha
. Barley		2002	96 201	ha
. Maize		2002	827 949	ha
. Sorghum		2002	156 155	ha
. Potatoes		2002	82 588	ha
. Sweet potatoes		2002	8 388	ha
. Other roots and tubers (taro, yams, etc.)		2002	3 001	ha
. Sugar beets		2002	64 596	ha
. Pulses		2002	164 013	ha
. Vegetables		2002	472 062	ha
. Other annual crops		2002	219 303	ha
- Permanent crops: total		2002	2 253 653	ha
. Sugar cane		2002	135 815	ha
. Bananas		2002	24 165	ha
. Citrus		2002	145 421	ha
. Cotton		2002	296 693	ha
. Fodder		2002	1 195 903	ha
. Soyabeans		2002	5 914	ha
. Groundnuts		2002	59 241	ha
. Sunflower		2002	15 493	ha
. Sesame		2002	30 284	ha
. Flowers		2002	26 055	ha
. Other permanent crops		2002	318 669	ha
Irrigated cropping intensity		2002	176	%
Drainage - Environment:				
Total drained area		2003	3 024 000	ha
- part of the area equipped for irrigation drained		2003	3 024 000	ha
- other drained area (non-irrigated)			-	ha
- drained area as % of cultivated area		2002	88	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

Large Scale Irrigation (LSI)

Nile Basin Country Irrigation Report Series

Ethiopia



Appendix F

January 2009

Table of contents
Part 1 Location of irrigated areas
Part 2 Climate
Part 3 Raster and vector-based irrigation performance analysis
Part 4 Recommendations for improvement

Purpose of this report:

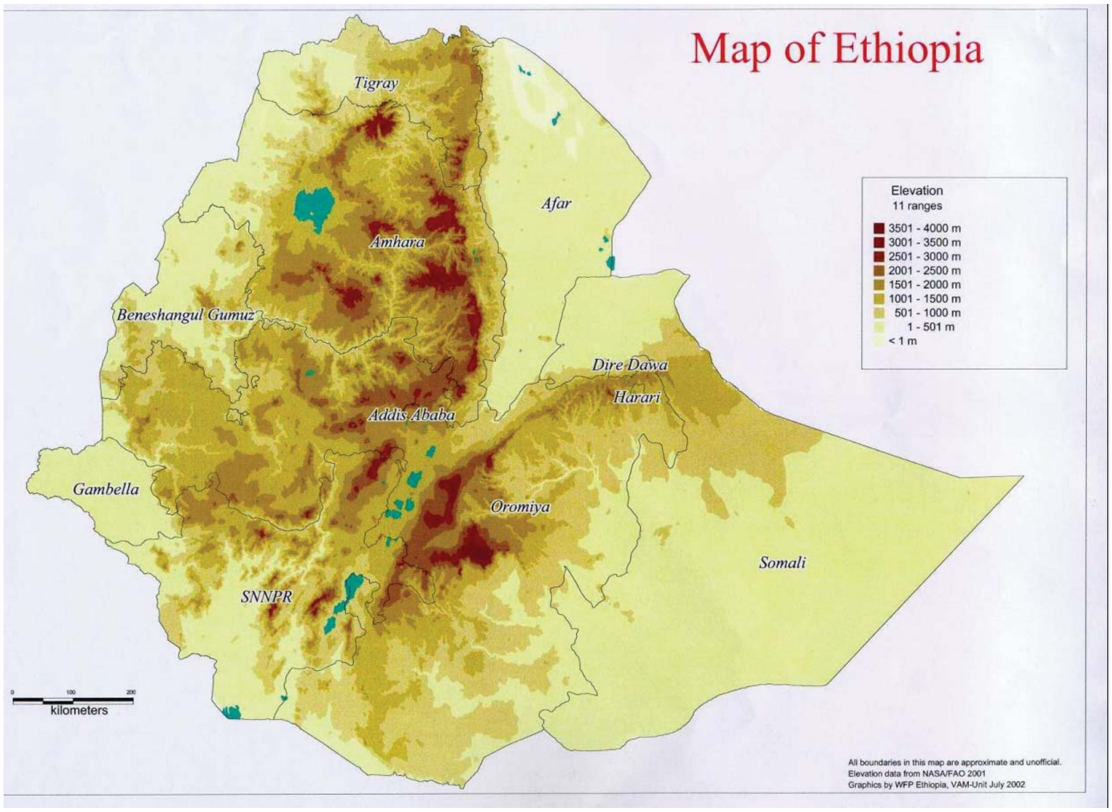
This report is one of a series of reports that will describe, and evaluate irrigation schemes in each of the Nile basin countries, and make recommendations for irrigation best practices. This report deals with Ethiopia and will become an integral component of the final LSI report that will combine results from all countries.

Disclaimer: National and district boundaries in this report are based on data from various internet sources of different years, and do not reflect current political reality. Modern country names and boundaries have not always been added and their omission does not indicate support or non-support of any nation.

Part 1 Location of irrigated areas

1.1 Location of the irrigated areas

Ethiopia is located in the transition zone between the vast irrigation schemes of Egypt and Sudan towards the downstream end of the basin, and the small holder irrigation in the upstream Nile Basin. The Nile Basin in Ethiopia is one of four major drainage systems: (i) Nile basin; (ii) The Rift Valley; (iii) Shebelle–Juba basin (iv) north-east Coast. It represents 32% of the total area of about 1.13 million km^2 and comprises the Abbay, Tekeze and Baro-Akobo rivers. Both the Blue and White Nile drain from Ethiopia (part of the White Nile also drains from Uganda) and together they provide almost 70% of the annual runoff (122 BCMs m^3) of the country. There are several lakes in the country (covering about 7,000 km^2), but only Lake Tana, the source of Abbay River is within the Nile Basin.



All boundaries in this map are approximate and unofficial.
Elevation data from NASA/FAO 2001
Graphics by WFP Ethiopia, VAM-Unit July 2002

Figure 22 Topographical map of Ethiopia

The alluvial soils in the vicinity of streams and rivers and lakes are used for irrigation (see Figure 23). Irrigation in Ethiopia dates back several centuries, if not millennia, while "modern" irrigation was started by the commercial irrigated sugar estate established in the early 1950s.

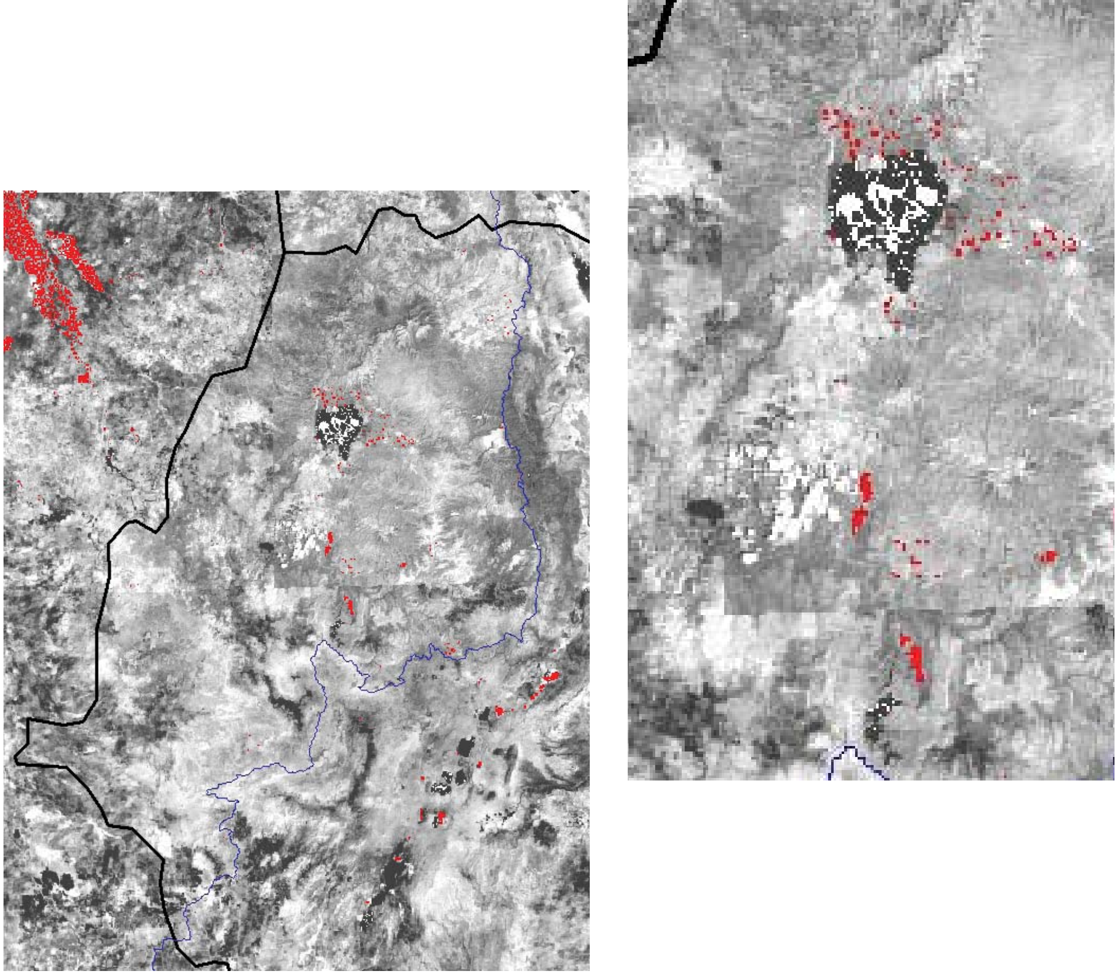


Figure 23 Distribution of the irrigated areas within the Nile Basin according to the FAO-GMIA product, and being refined within the current study. The red dots represent the irrigated areas.

Table 12 shows that 90,769 ha of irrigated land is present in the Nile Basin component of Ethiopia. It also suggests that there is much more irrigation outside the Nile Basin region, which is true. Several irrigation schemes are located in the Awash river basin and the Central Rift Valley. Awulachew et al. (2007) report an amount of 107,265 ha of irrigated land in Ethiopia.

Table 12 Different sources for the irrigation statistics

Source	Region covered	Irrigated area (ha)
FAO – GMIA	Entire Ethiopia	184,239
IWMI – GIAM	Entire Ethiopia	160,785
Current study	Nile Basin component of Ethiopia	90,769

Irrigation potential has been estimated at about 2.7 million ha, considering the availability of water and land resources, technology and finance (AQUASTAT, 2005). According to the LSI representative, the total gross irrigation potential estimate of the country is even higher : 3.7 million ha. The surface water resource potential of the country is indeed impressive, but little has been developed so far. Since recently, Ethiopia has embarked on an irrigation master development plan in the Nile basin ("the Nile irrigation and drainage project"), and it is expected that the irrigated areas will be expanded in the future. The combined Tana-Beles river basin has for instance is foreseen to expand by 240,000 ha.

1.2 Description of LSI

Four categories of irrigation schemes can be distinguished:

(i) Traditional irrigation schemes (1-100 ha) developed by the farmers themselves and covering about 155,014 ha with about 639,031 farmers involved. They are mainly used for the production of vegetables for the local market and experience problems with faulty irrigation systems stemming from lack of technology and knowledge.

(ii) Modern small-scale irrigation schemes: (up to 200 ha) constructed by the government/NGOs with farmer participation. They are generally based on direct river diversions. About 51,198 ha was equipped for irrigation in 2004 involving about 198,393 farmers. The operation and maintenance of the schemes are the responsibility of the water users, supported by the regional authorities/bureaus in charge of irrigation development and management.

(iii) Modern private irrigation: Private investment in irrigation has recently re-emerged with the adoption of a market-based economic policy in the early 1980s. Virtually all irrigated state farms were privately owned farms until nationalization of the private property in the mid 1970s. At the end of 2000, private investors had developed about 5,500 ha of irrigated farms.

(iv) Public irrigation schemes: comprise medium/large-scale irrigation schemes (>200 ha) covering about 97,700 ha. They are constructed, owned and operated by public enterprises along the Awash River and were built in the 1960s–70s as either private farms or joint ventures.

More detailed information concerning irrigation in Ethiopia can be found in Annex 2.

1.3 Agricultural conditions

Agriculture is a very important sector for the Ethiopian national economy as it involves 74% of the active population and represents 57% of the GDP. It is mainly rainfed agriculture and is dominated by subsistence small holder farms. Irrigation accounts for about 5 %. Export crops such as coffee, oilseed and pulses are mostly rainfed but industrial crops such as sugar cane, cotton and fruit are irrigated. Other irrigated crops include vegetables, fruit trees, maize, wheat, potatoes, sweet potatoes and bananas (Figure 24). The cropping seasons are represented in Table 13.

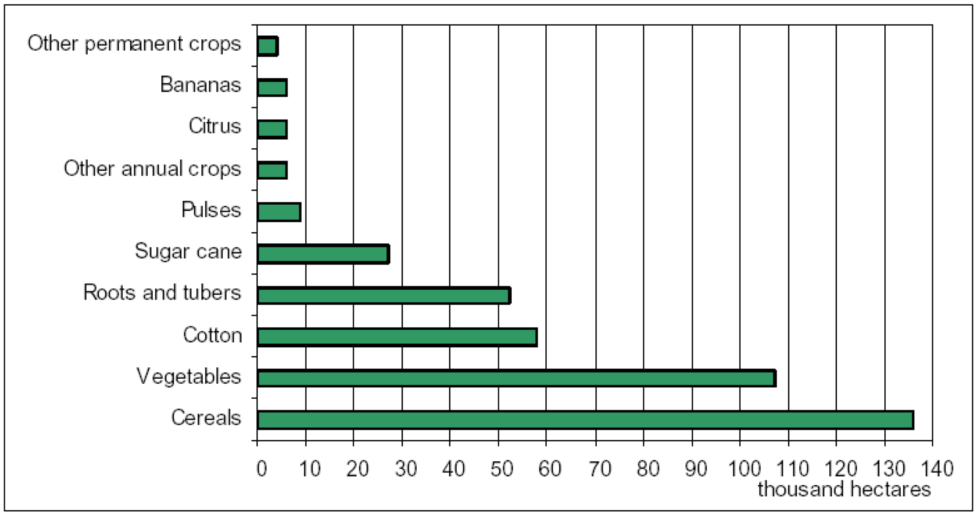


Figure 24 Irrigated crops in Ethiopia (FAO, AQUASTAT, 2005)

Table 13 Cropping calendar in Ethiopia (FAO, AQUASTAT, 2005)

	Irrigated area (1000 ha)	**Crop area as percentage of the total area equipped for irrigation by month**											
		J	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
ETHIOPIA													
Maize	23						14	14	14	14	14		
Sorghum	20						12	12	12	12	12		
Sugarcane	17	11	11	11	11	11	11	11	11	11	11	11	11
Pulses	2	1	1	1								1	1
Vegetables	70	43	43	43								43	43
Bananas	1	1	1	1	1	1	1	1	1	1	1	1	1
Citrus	3	2	2	2	2	2	2	2	2	2	2	2	2
Soybean	4	2	2	2								2	2
Tobacco	4	2	2	2								2	2
Cotton	43				27	27	27	27	27	27	27		
All irrigated crops	187	63	63	63	40	40	66	66	66	66	66	63	63
Equipped for irrigation	161												
Cropping intensity	116												

Part 2 Climate

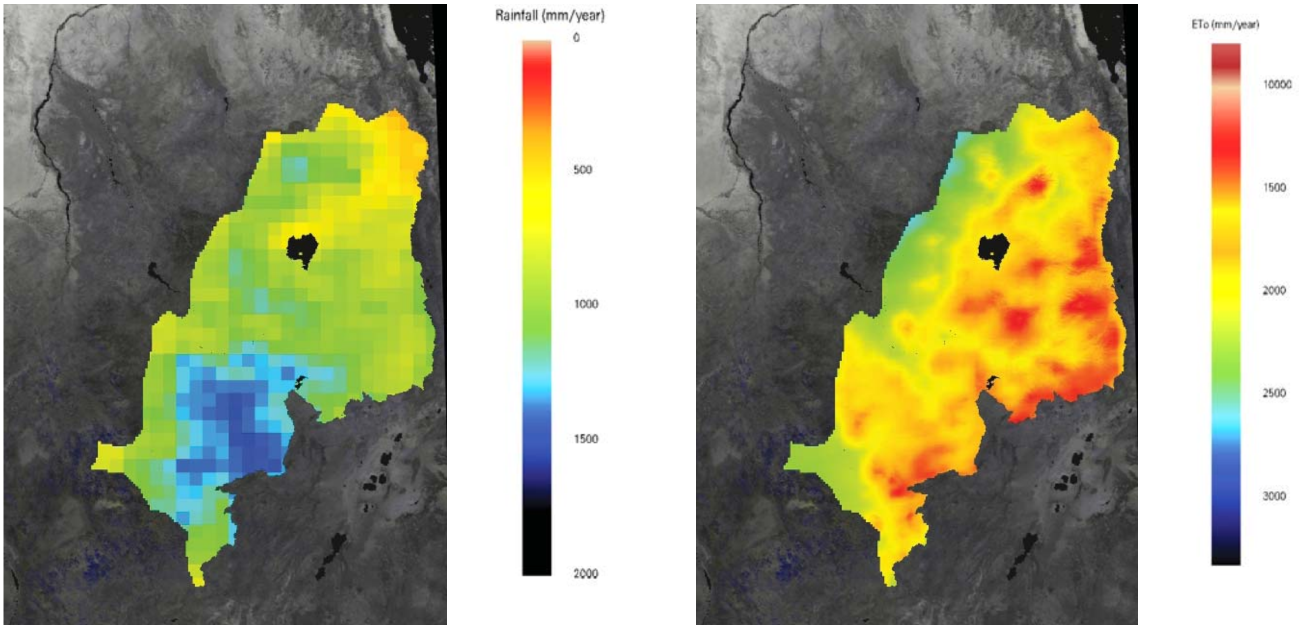
2.1 Climatological conditions

Ethiopia has a tropical monsoon climate with wide topographic-induced variations. Three climatic zones are identified: a cool zone consisting of the central parts of the western and eastern section of the high plateaus, a temperate zone between 1,500 m and 2,400 m above sea level, and the hot lowlands below 1,500 m. Mean annual temperature varies from less than 7−12ºC in the cool zone to over 25 ºC in the hot lowlands. Mean annual potential evapotranspiration varies between 1,700−2,600 mm in arid and semi-arid areas and 1,600−2,100 mm in dry sub-humid areas. Average annual rainfall is 848 mm, varying from about 2,000 mm over some parts of south-west Ethiopia to less than 100 mm over the Afar Lowlands in the north-east.

In this study, the reference evapotranspiration (ET_0) is computed with the standardized Penman-Monteith equation specified in FAO56 and the rainfall is based on TRMM satellite data for the year 2007. Table 14 shows that the winter months November to March have hardly any rainfall. ET_0 exceeds rainfall during ten months. Therefore irrigation systems are needed for maintenance of soil moisture of cropland. Only the monsoon rains in July and August induce an aridity index that exceeds 1.0. As Figure 25 shows, the highest rainfall occurs in the south-western part of Ethiopia due to the south-west monsoon that hits the highlands upstream of Gambella plain i.e. orographically induced rainfall. The highest reference ET occurs near the border of Sudan in the lower part of the Beles basin.

Table 14 Monthly values for rainfall and ET0 for the year 2007.

Month	Rainfall (P)	ET_0	Aridity (P/ET_0)
January	0	162	0
February	0	166	0
March	8	196	0.04
April	23	190	0.12
May	74	177	0.42
June	137	152	0.90
July	324	121	2.68
August	298	117	2.55
September	118	131	0.90
October	45	141	0.32
November	11	138	0.08
December	2	146	0.01
TOTAL	1040	1837	



Annual rainfall

Annual reference ET

Figure 25 Spatial variation of rainfall and ET0.

2.2 Climatic zones

The current study, aimed at providing information for improved irrigation practices in the Nile basin, covers various climate zones. Rainfall and temperatures specifically need to be analyzed, because they have a large impact on attainable land and water productivities, as well as the irrigation efficiencies. Unexpected rainfall can for instance reduce the irrigation efficiency, and also induce more variations in soil moisture conditions than in a situation where the crop moisture depends solely on irrigation water supply. To make corrections for these climatic influences based on the diagnosis of the irrigation systems, and to define climate dependent target values of irrigation management, four different climate zones have been identified for the Nile Basin. The zones have been made contiguous where possible. Insertion of more zones would result into scattered appearances of the zones.

The irrigation schemes across Ethiopia are included in three climatic zones: semi-arid climate (zone 2), arid climate (zone 3) and the humid climate (zone 4) (see Figure 26). Very few areas are located in climate zone 3.

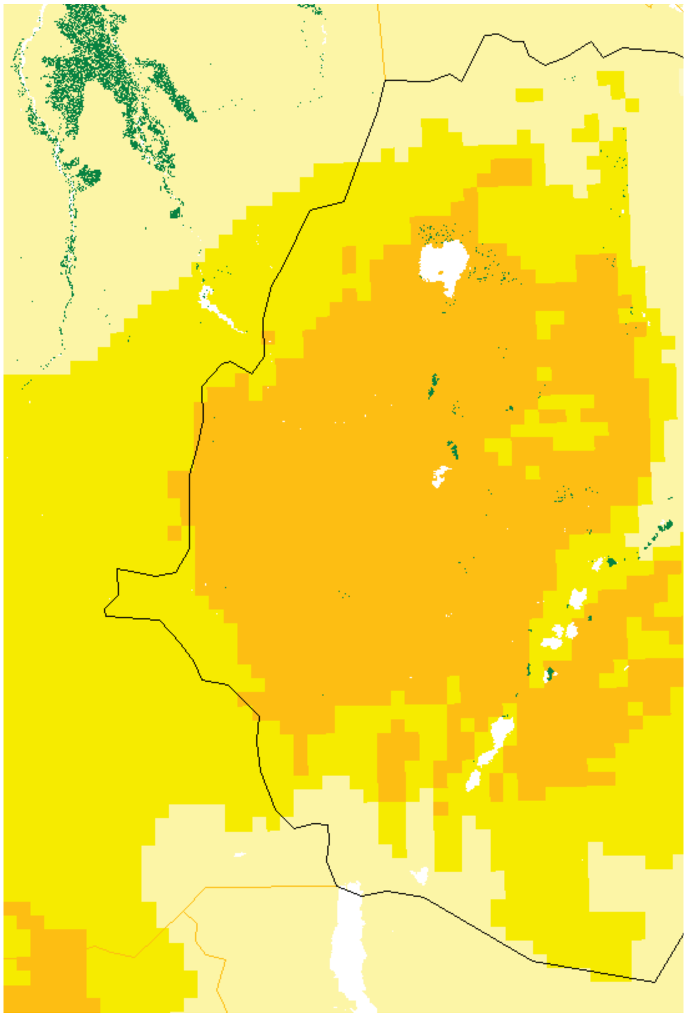


Figure 26 Climate zones distinguished for the mapping of best irrigation practices. The irrigated areas of Ethiopia are located in all the three climate zones identified (light yellow: arid; yellow: semi-arid; orange: humid tropics)

Part 3 Raster and vector-based irrigation performance analysis

3.1 Methodology

In this study, the irrigated areas have been identified at a resolution of 250m based on (i) the data send by the LSI representatives of Ethiopia, (ii) the FAO irrigated areas, and (iii) manual digitization of visually recognizable irrigated system using Google earth and Landsat images.

The first step was to compute all the indicators per pixel. All the RO and PO indicators have been computed based on the annual accumulated values of biomass production (Bio), Actual Evapotranspiration (ET_{act}), Potential Evapotranspiration (ET_{pot}), Actual Tranpiration (T_{act}), Potential Transpiration (T_{pot}). This was done for the year 2007. The annually accumulated values are the result of a land surface energy balance algorithm that was run for the whole Nile basin based on data from Terra and Aqua satellites. The Modis and AMSR-E sensor data were used.

The sustainability indicators have been obtained by investigating the last five year's trends in the vegetation index (from the SPOT-Vegetation satellite) and the soil moisture (from the AMSR-E satellite).

The second step was to allocate a score per pixel. To do so, we studied the distribution of the values for each indicator. From that, 4 different benchmark values were defined. A score between 1 and 5 has been given to each pixel; 5 being the best category, depending on the value of the indicators compared to the benchmarks (Figure 27).

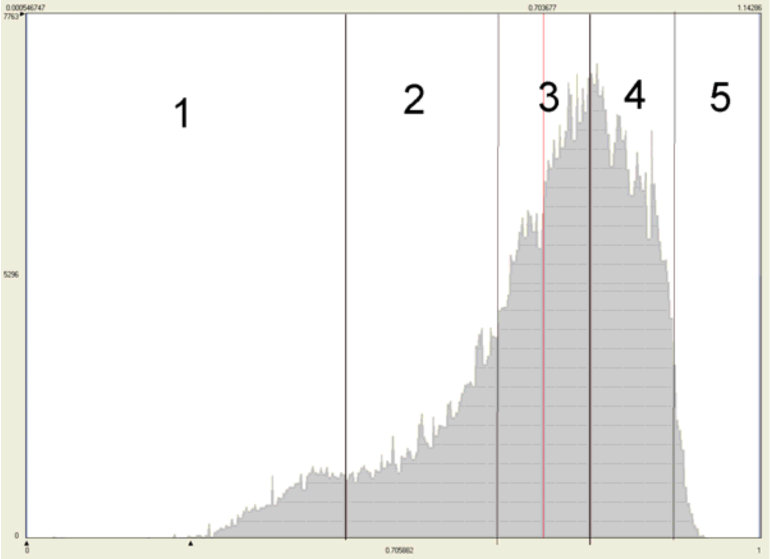


Figure 27 Distribution of the values of one indicator in 5 classes

An average score of 3 for all pixels per climatic zone will indicate good benchmarking.

If the country has irrigation systems included in different climatic zones, different benchmark values are considered to avoid any climatic bias in the allocation of the score (Table 15, Table 16, Table 17). Ethiopia, it is located in climatic zone 2, 3 and 4. The benchmark values for each climatic zone will be displayed in the tables below. The benchmarks for Tigray are based on what is physically feasible in the semi-arid zone, which is more comparable to the climate of Sudan, than to the humid tropics of Gambella plain.

Table 15 benchmark values for pixel located in climatic zone 2

	Unit	Score of 1	Score of 2	Score of 3	Score of 4	Score of 5
bio	Kg/ha/year	<3,300	<4,400 and >3.300	<7,800 and >4,400	<10,000 and >7,800	>10,000
bwp	Kg/ m3	<0.7	<1 and >0.7	<1.5 and >1	<2.3 and >1.5	>2.3
cwc	M3/ha/year	>11,600	<11,600 and >7,600	<7,600 and >4,400	<4,400 and >2,000	<2,000
cwd	M3/ha/year	<390 and >280	>500	<500 and >390	<280 and >168	<168
bf	-	<0.47	<0.62 and >0.47	<0.75 and >0.62	<0.86 and >0.75	>0.86
ad	-	<0.40	<0.47 and >0.4	<0.58 and >0.47	<0.7 and >0.58	> 0.7
un	-	<0.75	<0.85 and >0.75	<0.9 and >0.85	<0.95 and >0.9	>0.95
rel	-	<0.56	<0.72 and >0.56	<0.80 and >0.72	<0.90 and >0.8	>0.90
spot	1/year	<-0.1	<-0.02 and >-0.1	<0.1 and >-0.02	<0.3 and >0.1	>0.3
amsre	1/year	<-0.1	<-0.05 And >-0.1	<0.05 and >-0.05	<0.15 and >0.05	>0.15

Table 16 benchmark values for pixel located in climatic zone 3

	Unit	Score of 1	Score of 2	Score of 3	Score of 4	Score of 5

bio	Kg/ha/year	<7,000	<10,500 and >7,000	<13,500 and >10,500	<15,000 and >13,500	>15,000
bwp	Kg/ m3	<1.3	<2.2 and >1.3	<2.5 and >2.2	<3 and >2.5	>3
cwc	M3/ha/year	>10,200	<10,200 and >7,000	<7,000 and >5,300	<5,300 and >4,000	<4,000
cwd	M3/ha/year	<110	<175 and >110	<310 and >220	>310	<220 and >175
bf	-	<0.5	<0.7 and >0.5	<0.83 and >0.7	<0.88 and >0.83	>0.88
ad	-	<0.56	<0.63 and >0.56	<0.70 and >0.63	<0.78 and >0.70	> 0.78
un	-	<0.75	<0.85 and >0.75	<0.9 and >0.85	<0.95 and >0.9	>0.95
rel	-	<0.74	<0.8 and >0.74	<0.86 and >0.8	<0.92 and >0.86	>0.92
spot	1/year	<-0.1	<-0.02 and >-0.1	<0.1 and >-0.02	<0.3 and >0.1	>0.3
amsre	1/year	<-0.1	<-0.05 And >-0.1	<0.05 and >-0.05	<0.15 and >0.05	>0.15

Table 17 benchmark values for pixel located in climatic zone 4

	Unit	Score of 1	Score of 2	Score of 3	Score of 4	Score of 5
bio	Kg/ha/year	<11,000	<17,000 and >11,000	<29,000 and >17,000	<40,000 and >29,000	>40,000
bwp	Kg/ m3	<1.5	<2.4 and >1.5	<3.3 and >2.4	<3.8 and > 3.3	>3.8
cwc	M3/ha/year	>13,300	<13,300 and > 10,000	<10,000 and >6,700	<6,700 and >3,400	<3,400
cwd	M3/ha/year	<180 and >136	>250	<250 and >180	<136 and >80	<80
bf	-	<0.45	<0.66	<0.82	<0.91	>0.91

			and >0.45	and >0.66	and >0.82	
ad	-	<0.62	<0.72 and >0.62	<0.83 and >0.72	<0.92 and >0.83	> 0.92
un	-	<0.75	<0.85 and >0.75	<0.9 and >0.85	<0.95 and >0.9	>0.95
rel	-	<0.8	<0.88 and >0.8	<0.92 and >0.88	<0.94 and >0.92	>0.94
spot	1/year	<-0.1	<-0.02 and >-0.1	<0.1 and >-0.02	<0.3 and >0.1	>0.3
amsre	1/year	<-0.1	<-0.05 And >-0.1	<0.05 and >-0.05	<0.15 and >0.05	>0.15

Once each indicator gets a score per pixel, districts average and country average values can be calculated. The indicators are averaged per type: RO indicators, PO indicators, and sustainability indicators, to simplify understanding of processes and results.

3.2 Results at country level

The average score considering all the indicators together for all the irrigated land is 2.9, which is a relatively poor score. Figure 28 shows the country average for each indicator. The elements with a relative low score are the ones that Ethiopia should provide more attention to.

The score of 3.1 for biomass water productivity is about average. The score of 2.4 for land productivity tends to indicate poor practices.

Concerning the PO indicators, there is very good performance in terms of uniformity, and average performance in terms of crop water deficit and crop water consumption and reliability. The weakest aspect of Ethiopian irrigation seems to be adequacy and, to a lesser extent, the beneficial fraction.

The land sustainability of irrigation practices seems to be under control. From the last years, the irrigated land have remained relatively constant in terms of soil moisture and greenness (as the score for the land and water sustainability is around 3), hence the irrigation systems are quite healthy and continuous. The soils are being relatively well maintained. Hence, the irrigation system in Ethiopia is relatively sound but special attention should be given to avoid water sustainability to get worse.

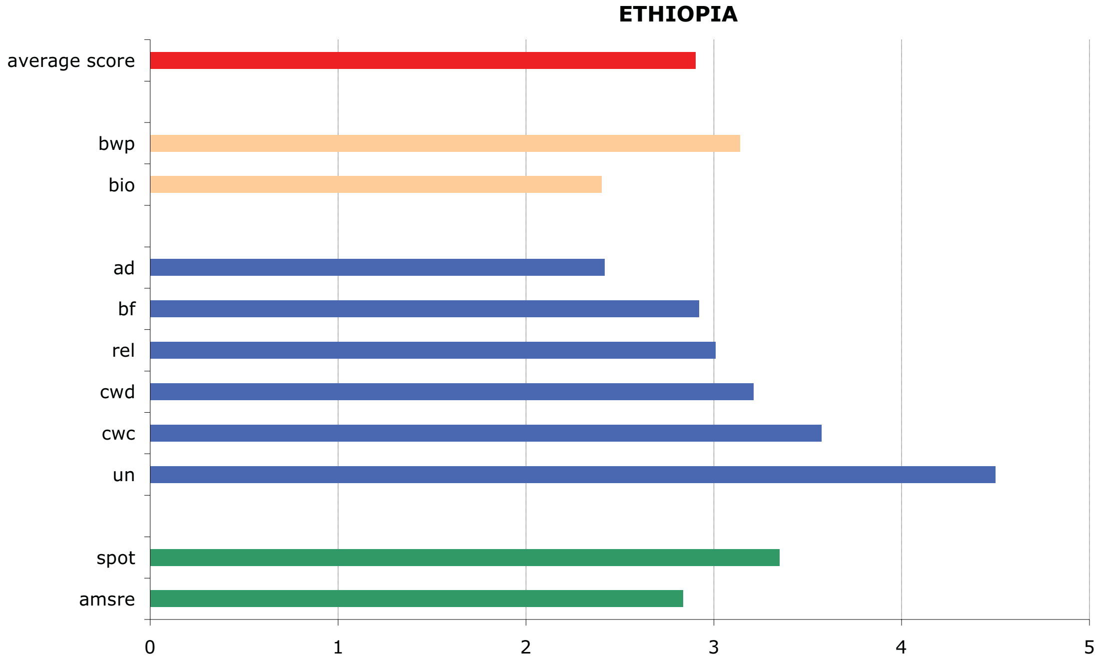


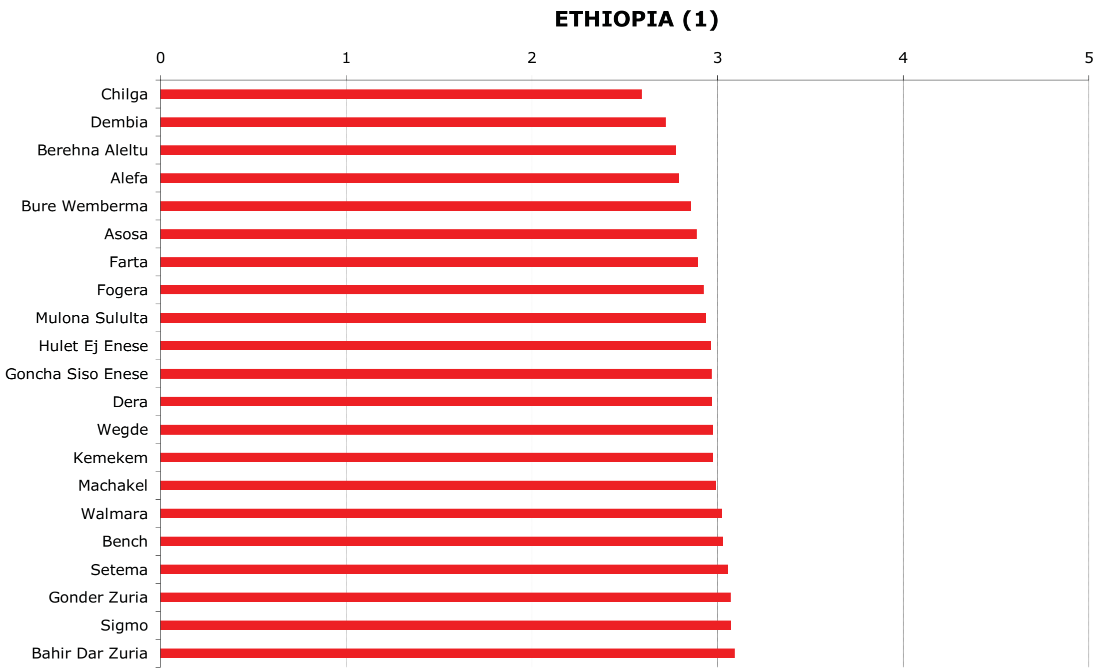
Figure 28 Representation of the average score for each indicator in Ethiopia.

3.3 Results at district level

3.3.1 Average per district

In Figure 29 the average score for all the indicators per district are compared. In Ethiopia, 42 districts with more than 30 pixels of 6.25 ha have been identified.

In terms of total average score, the best irrigation district is Adwa, with an average of 3.9. The district that has the lowest average is Chilga, with an average of 2.6 (see Figure 30 for their locations). Hence, there is a significant variability in the irrigation practices in Ethiopia. This shows that local solutions and management practices can make a difference.



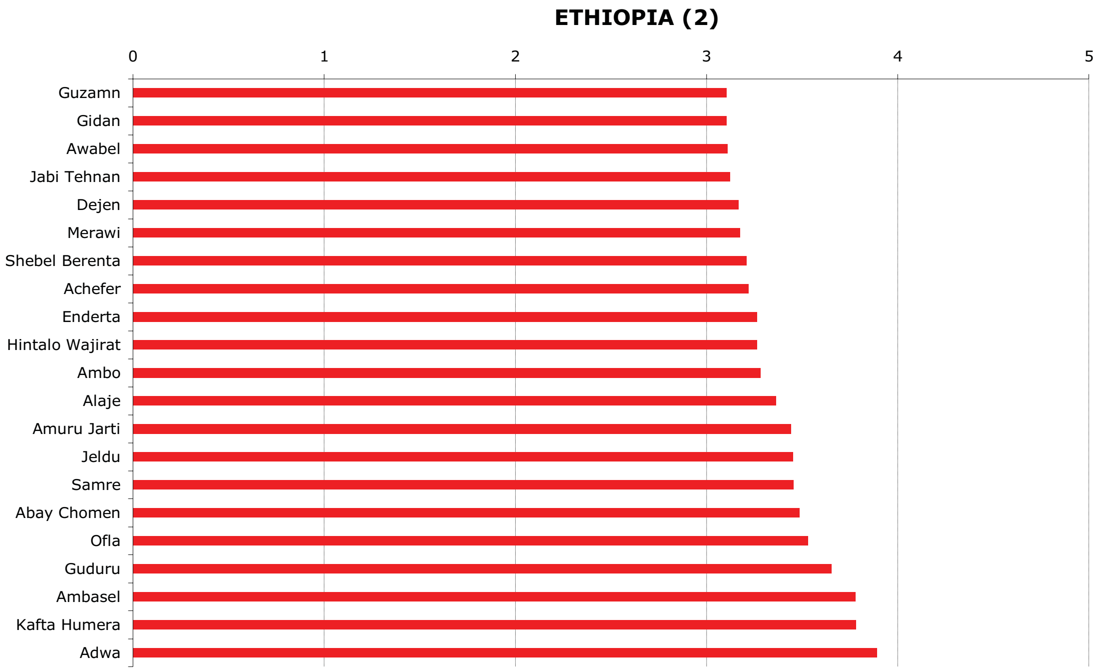


Figure 29 Representation for the average total score for Ethiopia for each district.

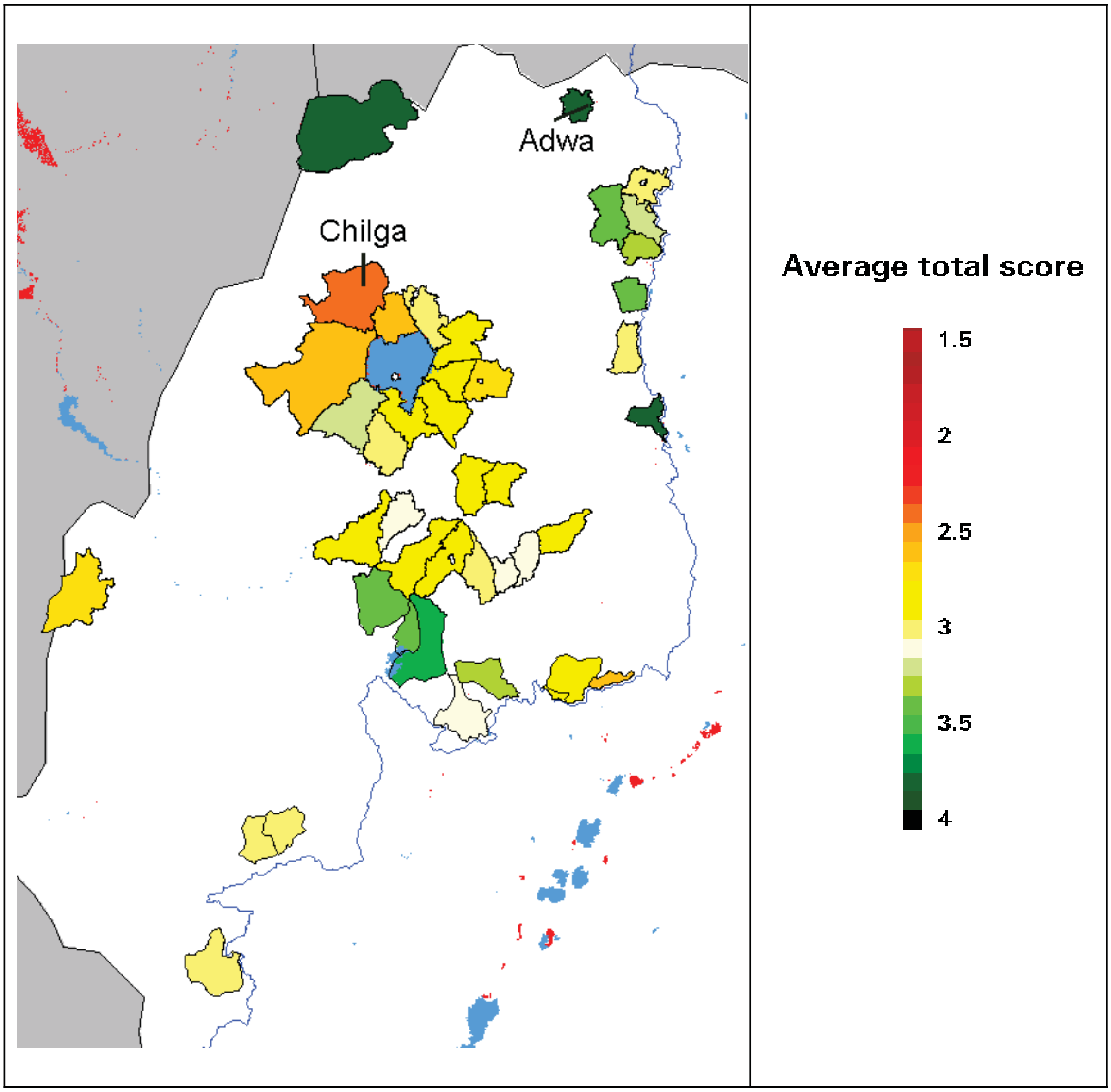
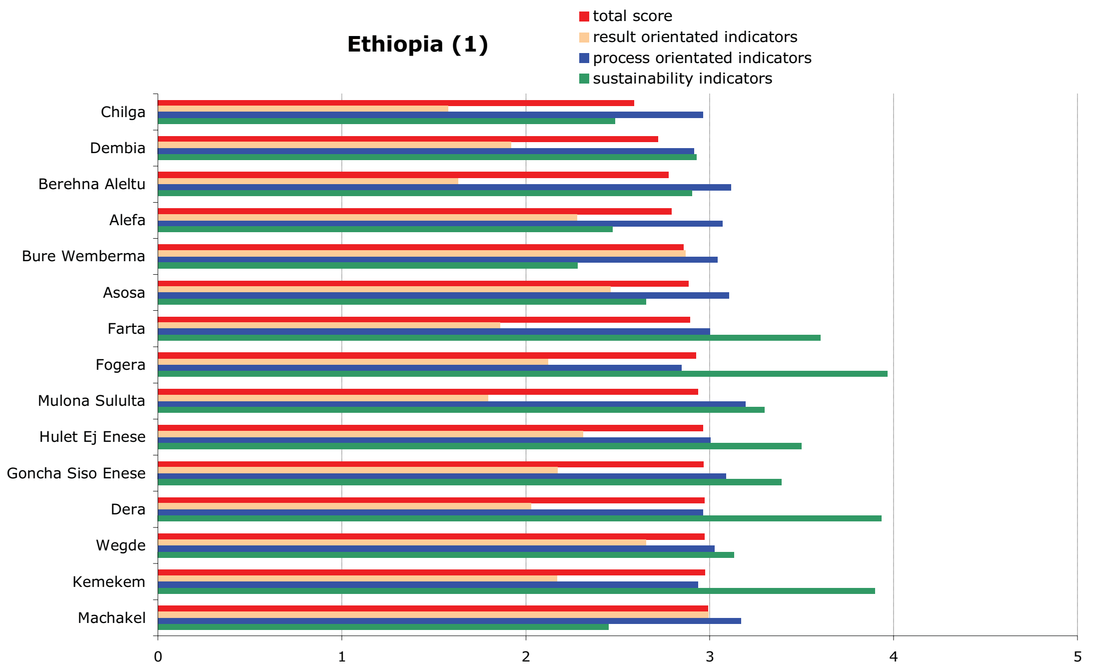
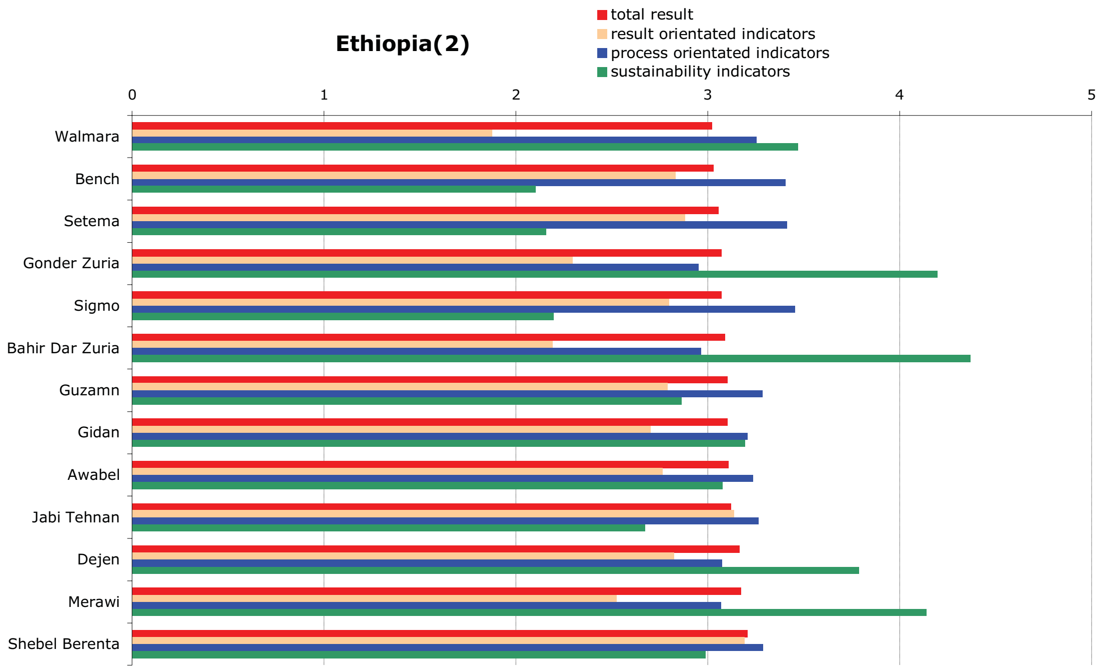


Figure 30 Map showing the total score per irrigated district.

3.3.2 Breaking down the total score into RO, PO and sustainability indicators

By breaking down the total score into 3 types of indicators (RO, PO, and sustainability), it is possible to better understand the irrigation mechanisms for each district. Figure 31 provides the average score per group of indicators. Considering the total score or the average for all indicators for each district gives an idea of the total performance. A better understanding of the weak points as well as the strong points of each district will require separate analyses of each indicator group.


Ethiopia (1)
total score
result orientated indicators
process orientated indicators
sustainability indicators
Chilga
Dembia
Berehna Aleltu
Alefa
Bure Wemberma
Asosa
Farta
Fogera
Mulona Sululta
Hulet Ej Enese
Goncha Siso Enese
Dera
Wegde
Kemekem
Machakel
0
1
2
3
4
5


Ethiopia(2)
total result
result orientated indicators
process orientated indicators
sustainability indicators
0
1
2
3
4
5
Walmara
Bench
Setema
Gonder Zuria
Sigmo
Bahir Dar Zuria
Guzamn
Gidan
Awabel
Jabi Tehnan
Dejen
Merawi
Shebel Berenta

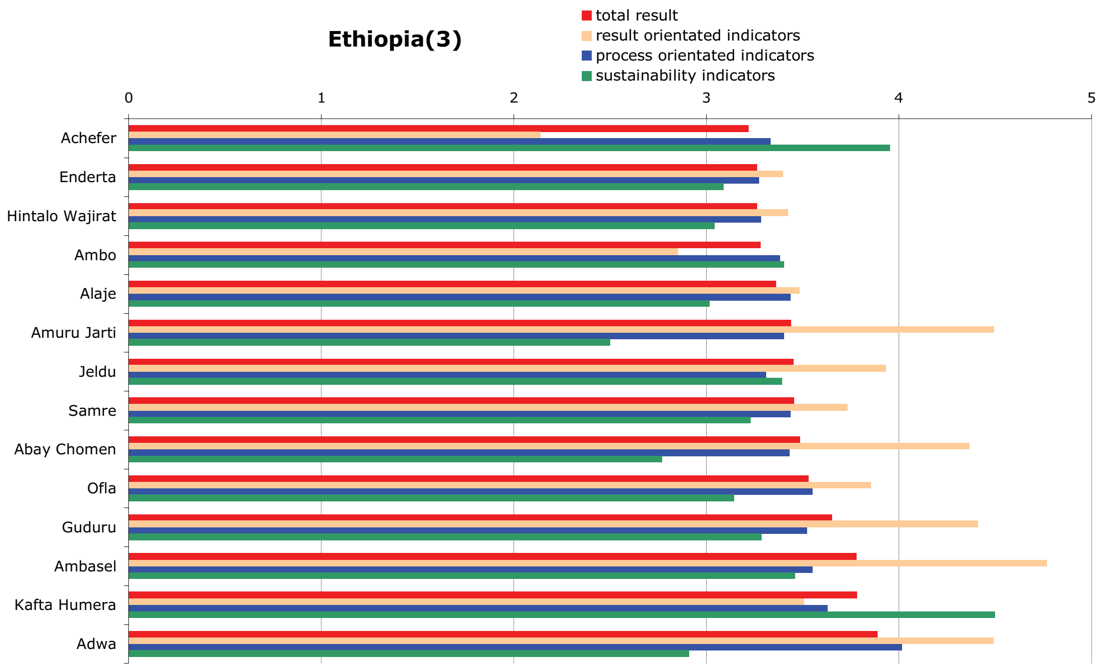


Figure 31 Breaking down the total score per indicator

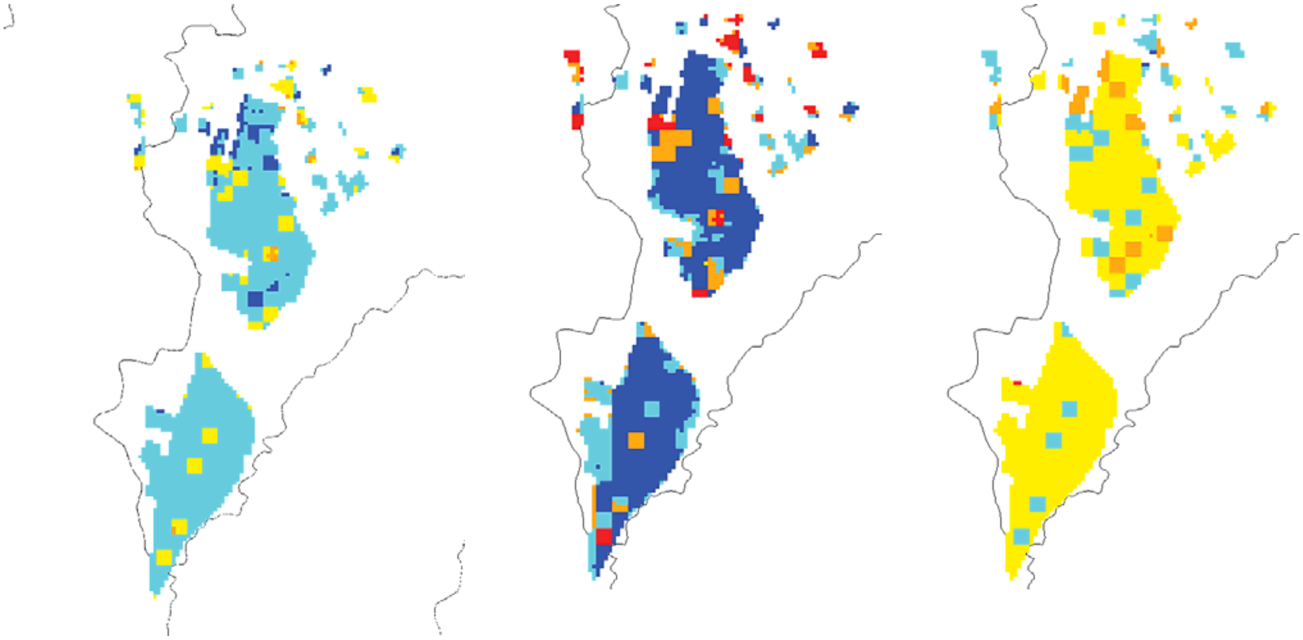
A good total score does not always mean a good performance for the three categories of indicators: RO, PO and sustainability. Indeed, if one looks at the average score for the RO indicators, Bahir Dar Zuria is fourth best in terms of total score whilst it has a low score in terms of land and biomass water productivity. This is due to the fact that its score for land and water sustainability is really good. Hence, a favourable total performance does not mean a sustainable system. In fact, considering the score for the sustainability indicators, there is no obvious difference between the good performing and the bad performing districts. This shows once again the relevance of breaking the irrigation performance down into different types of indicators.

The upper third best performing districts have a good to very good score in terms of RO indicators. On the contrary, the other districts have a better score in terms of the PO indicators average score than in terms of RO indicators. It means that even though the management of the irrigation systems seems quite good, other factors are limiting the land and water productivity. These factors might be linked to agricultural practices such as crop types or application of fertilizers. Relevant improvement recommendations should be made district per district by looking at the different scores of every single indicator.

3.4 Analysis per pixel for an irrigation system

Looking at what happens within one district enables us to see the spatial distribution of the score of each indicator. In other words, it makes it possible to see whether the irrigation system is homogeneously managed. Hereafter, the spatial distribution of the five PO indicators are displayed for the irrigated pixel in the district of Jabi

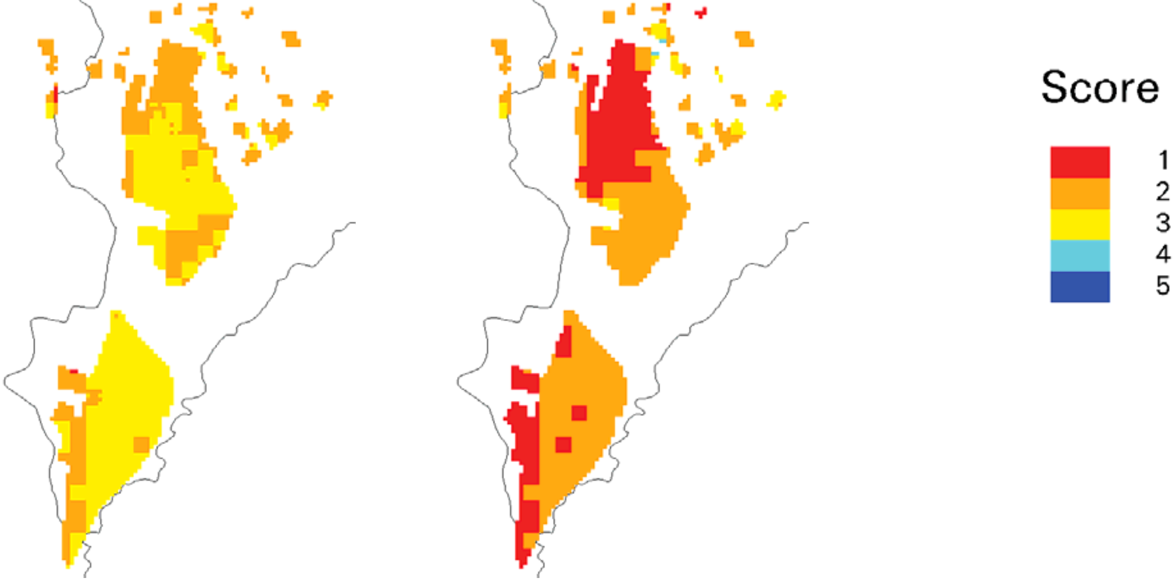
Tehnan, which is an average district in terms of performance. The 6th PO indicator uniformity can not be displayed as it is an indicator at district level. This example demonstrates that reliability and adequacy need to be managed better (Figure 32).



crop water consumption

crop water deficit

beneficial fraction



adequacy

reliability

Figure 32 Spatial distribution of each indicator for the districts of Jabi Tehnan

Part 4 Recommendations for improvement

4.1 Explaining the irrigation results

To be able to give proper recommendations, it is important to understand which of the PO indicators and the sustainability indicators influence the RO indicators mostly. A regression analysis was performed with the values for all indicators of the 42 districts. It showed that crop water consumption, reliability, and adequacy are the three main explanatory factors for biomass production. Hence the timely delivery of adequate irrigation amounts should get more attention in Ethiopia.

Besides, an increase in beneficial fraction leads to an increase in biomass production and biomass water productivity. An increase in crop water consumption leads to an increase in biomass production but a decrease in biomass water productivity. It seems that the lower the crop water consumption and the higher the beneficial fraction, the better the biomass water productivity. But none of the relationships depicted is clear. It is thus better to focus on increasing biomass production rather than biomass water productivity.

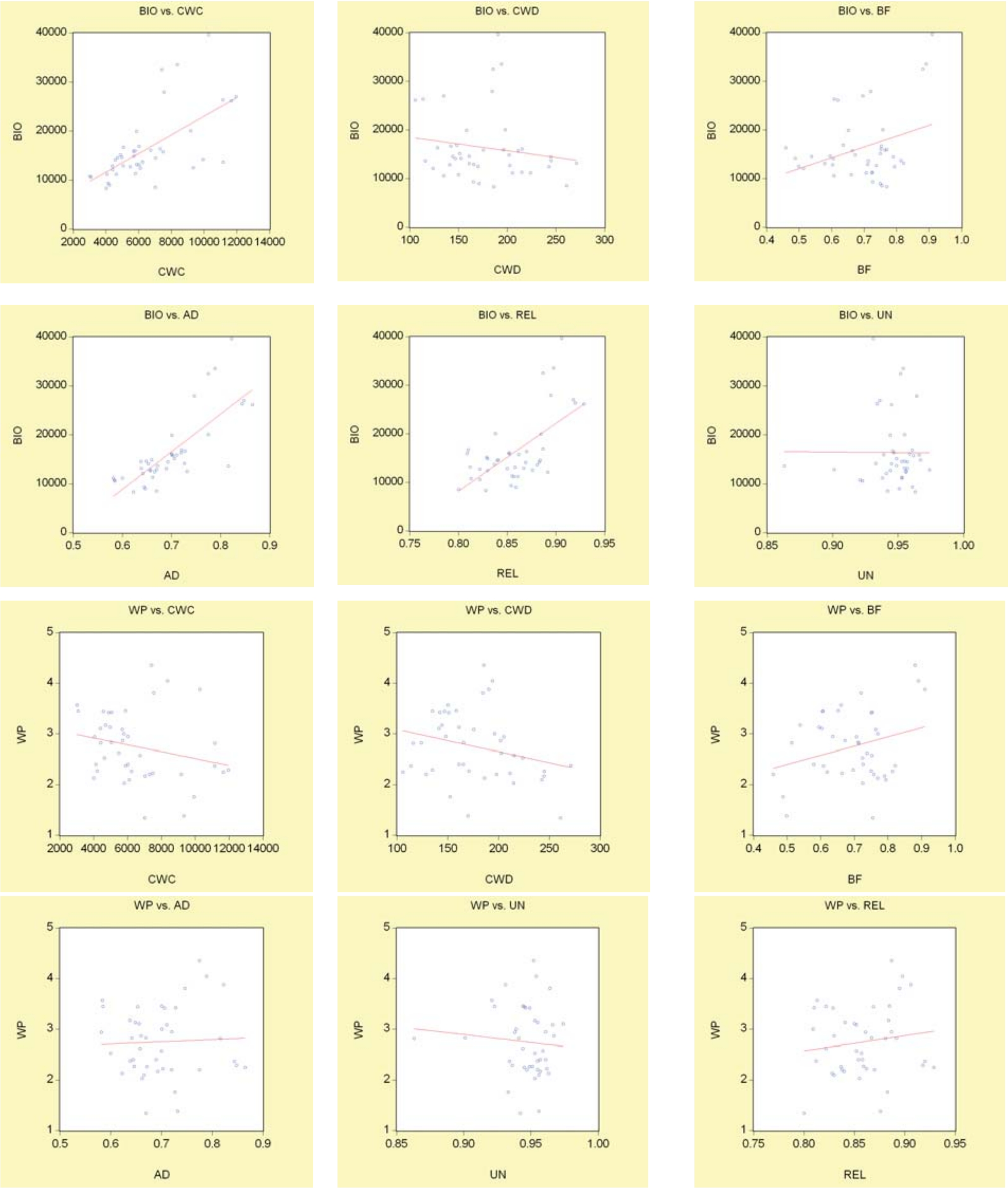


Figure 33 Relationships between RO indicators and PO indicators

4.2 Weak and strong aspects per district

In Table 18, the best and poorest indicators are presented. This helps to identify which elements of irrigation performance need improvement.

Adequacy, beneficial fraction, and reliability seem to be the main problem factors for the majority of the districts. On the other side of the scale, crop water deficit and uniformity are often mentioned as being the best indicators.

Table 18 best and poorest PO irrigation indicator per district

district	lowest score		2nd lowest		2nd best		best	
Chilga	ad	1.55	bf	1.67	cwd	3.42	un	5.00
Dembia	bf	1.65	rel	2.63	cwd	3.77	un	4.00
Berehna Aleltu	ad	1.79	rel	2.03	cwc	4.13	un	5.00
Alefa	bf	1.49	ad	2.30	un	4.00	cwd	4.16
Bure Wemberma	rel	1.74	ad	2.57	cwc	3.77	un	4.00
Asosa	ad	1.93	rel	2.01	bf	3.01	un	5.00
Farta	rel	2.10	cwd	2.30	cwc	3.84	un	5.00
Fogera	cwd	1.80	ad	1.88	cwc	3.70	un	4.00
Mulona Sululta	ad	2.02	rel	2.10	cwc	4.19	un	5.00
Hulet Ej Enese	rel	2.13	ad	2.31	cwc	3.17	un	5.00
Goncha Siso Enese	ad	1.77	rel	2.09	cwc	3.56	un	5.00
Dera	cwd	1.85	rel	1.92	cwc	3.78	un	5.00
Wegde	ad	1.96	rel	1.96	cwc	3.62	un	5.00
Kemekem	rel	1.64	cwd	1.68	cwc	3.85	un	5.00
Machakel	rel	1.85	ad	1.87	cwc	3.98	un	4.00
Walmara	rel	2.01	ad	2.05	cwc	4.20	un	5.00
Bench	ad	2.00	cwc	2.20	un	4.00	cwd	4.26
Setema	ad	1.87	cwc	2.28	un	4.00	cwd	4.59
Gonder Zuria	rel	1.83	ad	2.32	un	4.00	cwc	4.06
Sigmo	ad	1.94	cwc	2.07	un	4.00	cwd	4.27
Bahir Dar Zuria	cwd	1.92	rel	2.03	cwc	3.36	un	5.00
Guzamn	rel	2.03	ad	2.30	cwc	3.81	un	5.00
Gidan	bf	1.73	ad	2.92	cwd	4.08	cwc	4.22
Awabel	ad	1.81	rel	2.00	cwc	4.08	un	5.00
Jabi Tehnan	rel	1.70	ad	2.16	un	4.00	cwd	4.29
Dejen	ad	2.22	bf	2.30	un	4.00	cwc	4.09
Merawi	rel	2.10	ad	2.22	cwc	3.44	un	5.00
Shebel Berenta	bf	2.22	rel	2.40	cwd	4.06	un	5.00
Achefer	rel	2.78	bf	2.87	ad	3.69	cwd	4.71
Enderta	bf	2.47	rel	3.11	un	4.00	cwc	4.65
Hintalo Wajirat	bf	2.16	rel	3.38	un	4.00	cwc	4.73
Ambo	bf	2.47	rel	2.72	cwd	3.94	un	5.00
Alaje	ad	2.54	bf	2.87	cwc	3.68	un	4.00
Amuru Jarti	cwc	2.34	cwd	2.86	ad	4.00	bf	4.53
Jeldu	ad	2.77	rel	2.83	cwc	3.40	un	5.00
Samre	ad	2.82	bf	2.89	un	4.00	cwc	4.06
Abay Chomen	cwd	2.39	cwc	2.97	bf	4.13	un	5.00
Ofla	bf	1.71	ad	3.45	cwc	4.10	un	5.00

Guduru	rel	2.82	cwd	2.83	bf	4.12	un	5.00
Ambasel	bf	2.19	ad	3.31	un	4.00	cwd	4.58
Kafta Humera	cwc	2.68	bf	3.53	cwd	3.81	un	4.00
Adwa	cwc	3.41	bf	3.44	cwd	4.43	un	5.00

4.3 Recommendation countrywide

With a growing population, food security is becoming a major concern in Ethiopia even though it has a high agricultural potential (the total arable land is estimated to be 55 million ha according to FAO). However, improvements in rainfed agriculture will fail to make up the deficits and keep pace with the increasing demand resulting from population growth. Since 1991, a combination of the positive effects of policy initiatives and good rains allowed the country to achieve food self-sufficiency and food exports in 1996/97. But bad weather – a combination of rainfall deficits during the growing season and excess rainfall during the ripening and harvest season – has reversed that situation in 1997/98, demonstrating the dependence of agriculture on climatic factors. Even in good years Ethiopia cannot meet its large food deficit through rainfed production. Improving the productivity of irrigated land should be on the agenda. The fact that on average, the performance of the LSI is quite low offers the greatest possibilities for improved productivity and for meeting the demand for food within the country.

The weakest aspect is more on the agronomical side than on the irrigation side.
As the population is growing fast, food deficit is getting bigger and bigger.
If the country is to address its serious problems of poverty and food deficits due to the fast growing population, it is important to increase the productivity of existing irrigation systems. Biomass production can be increased if sufficient irrigation water (adequacy) is applied at the right time (reliability). To do so, investments should be made to improve agronomical research and extension services: more qualified and equipped staff able to advice on application of fertilizers.

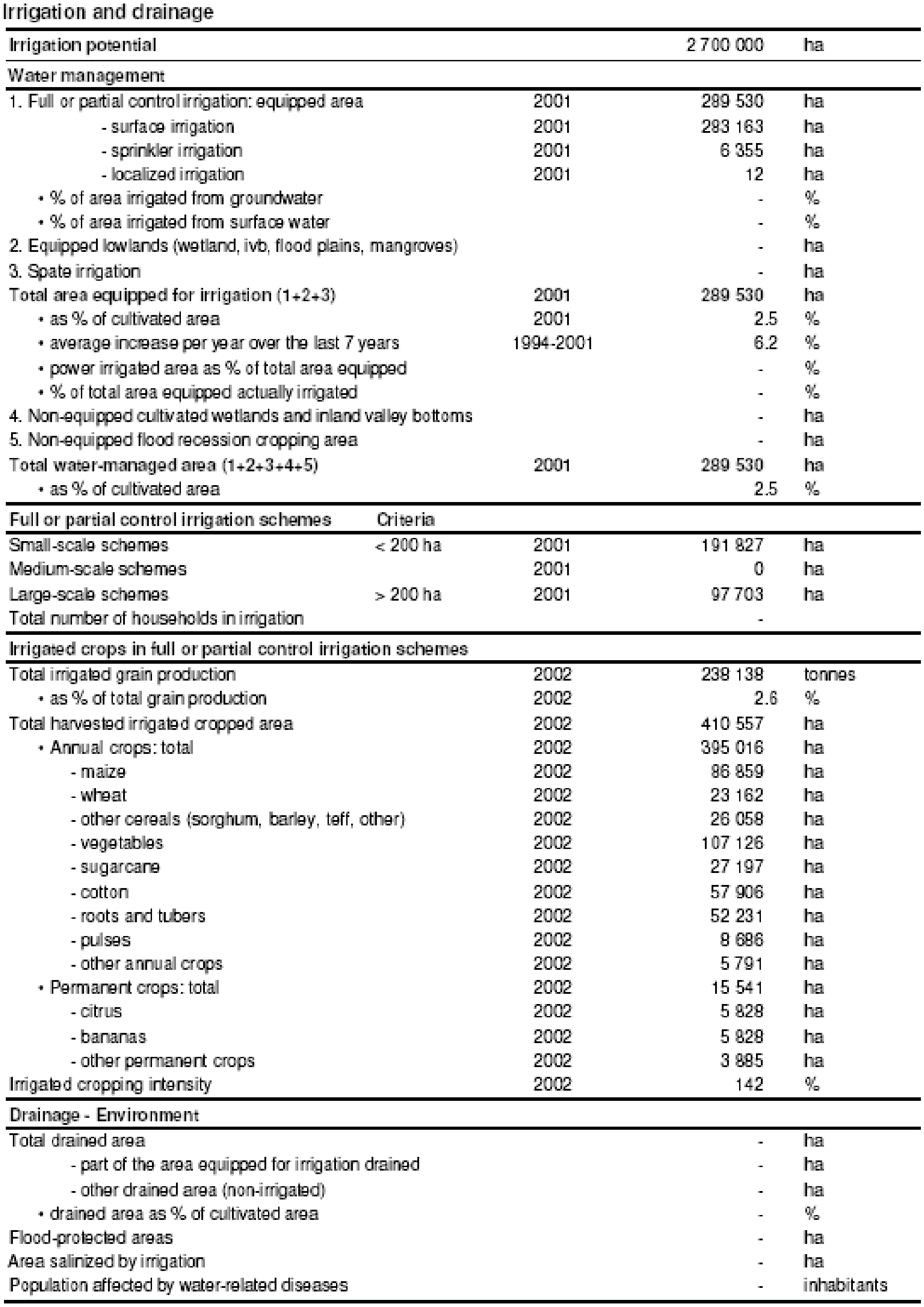
According to an IWMI study, the limitation in the availability of water in semi arid areas (like Ethiopia) is not caused by low rainfall but lack of capacity for sustainable management and use of the available water. Neither the farmers nor the extension services are attempting to generate/implement practices that can retain the temporary excess rain water for use during dry spells. The agronomical research has an important role to play to find crop varieties and practices that could tolerate the temporary water logging problems and the sporadic dry spells.

The institutional context does not seem to favour the cooperative management of the irrigation systems, such measures because of its lack of organization, different institution involved, and its instability (in the irrigation sector).

Annex 1 Definition of irrigation performance indicators

Type	Indicator	Acronym	Unit	Formula	Why important ?
RO	Biomass productivity	bio	Kg/ha/year	Bio	Food security; farmer income; farm sustainability
	Biomass water productivity	bwp	Kg/m3	Bio/ETact	High return from total water used by a crop
PO	Crop Water Consumption	cwc	M3/ha/year	ETact	Saving of water resources
	Crop water deficit	cwd	M3/ha/year	ETpot-ETact	Indication of water shortage; help to evaluate deficit supply strategies
	Beneficial fraction	bf	-	Tact/ETpot	Indication of proportion of total crop water use going to production of plant (crop) matter
	Adequacy (Crop Water stress)	ad	-	Tact/Tpot	Indication of whether irrigation water reaches the roots of the crop
	Uniformity	un	-	1-CV(Tact/Tpot)(x,y)	Indication of the spatial homogeneity of the water distribution in a district
	Reliability	rel	-	1-CV(Tact/Tpot)(t)	Indication of the ability to deliver water timely, and the flexibility to cope with rainfall variations
					Indication of changes of water resources availability
Sustainability	Land sustainability	spot	1/year	Slope ndvi spot	Indication of farming sustainability
	Water sustainability	amsre	1/year	Slope soil moisture	Indication of changes of water resources availability

Annex 2 General information on irrigation conditions in Ethiopia (Aquastat, 2005)



Irrigation and drainage

Irrigation potential			2 700 000	ha
Water management				
1. Full or partial control irrigation: equipped area		2001	289 530	ha
- surface irrigation		2001	283 163	ha
- sprinkler irrigation		2001	6 355	ha
- localized irrigation		2001	12	ha
• % of area irrigated from groundwater			-	%
• % of area irrigated from surface water			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		2001	289 530	ha
• as % of cultivated area		2001	2.5	%
• average increase per year over the last 7 years		1994-2001	6.2	%
• power irrigated area as % of total area equipped			-	%
• % of total area equipped actually irrigated			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		2001	289 530	ha
• as % of cultivated area			2.5	%
Full or partial control irrigation schemes	Criteria			
Small-scale schemes	< 200 ha	2001	191 827	ha
Medium-scale schemes		2001	0	ha
Large-scale schemes	> 200 ha	2001	97 703	ha
Total number of households in irrigation			-	
Irrigated crops in full or partial control irrigation schemes				
Total irrigated grain production		2002	238 138	tonnes
• as % of total grain production		2002	2.6	%
Total harvested irrigated cropped area		2002	410 557	ha
• Annual crops: total		2002	395 016	ha
- maize		2002	86 859	ha
- wheat		2002	23 162	ha
- other cereals (sorghum, barley, teff, other)		2002	26 058	ha
- vegetables		2002	107 126	ha
- sugarcane		2002	27 197	ha
- cotton		2002	57 906	ha
- roots and tubers		2002	52 231	ha
- pulses		2002	8 686	ha
- other annual crops		2002	5 791	ha
• Permanent crops: total		2002	15 541	ha
- citrus		2002	5 828	ha
- bananas		2002	5 828	ha
- other permanent crops		2002	3 885	ha
Irrigated cropping intensity		2002	142	%
Drainage - Environment				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants