International Water Management Institute

Using Remote Sensing in Support of Solutions to Reduce Agricultural Water Productivity Gaps

Technical Report:
Implementation of on-farm water management solutions to increase water productivity in Egypt

ICT- Phone Application “IRWI-اروي” for Water Management in Agriculture

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Acknowledgements

This research was carried out under the project "Using Remote Sensing in support of solutions to reduce agricultural water productivity gaps" (specifically Component 4, Capacity development for increasing water productivity) (GCP/INT/229/NET) led by the Food and Agricultural Organization of the United Nations (FAO), and financed by the Government of The Netherlands. The research was implemented under a collaborative partnership between the International Water Management Institute (IWMI) and the Soils, Water and Environment Research Institute (SWERI), and MSA University-start-up.

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1. Executive summary

In Egypt, WaPOR capacity building activities at field level have focused on increasing water productivity and yields in three governorates (Kafer-ElShiekh, Dakahlia, Beheira) with a focus on five key crops (rice, cotton, soybean, maize and potatoes) through improved timing of water application in irrigation schemes, using ICT (phone application) and crop health evolution and predicted yield. This project was implemented through a co-design and co-create approach with both farmers and public institutions to design and develop the "IRWI App". IRWI- IRrigation Water Information Application is applicable at the farm level, and is in the process of field trials with small holder farmers; to date it has received positive feedback and uptake by farmers in three governorates (Kafer-ElShiekh, Dakahlia, Beheira) in Egypt. The App, provides farmers with information customized to their plots, weather conditions and crop types by integrating location specific data with the WaPOR database, and translates the technical data into easily understandable irrigation schedules and crop health.

2. Introduction

Given the scarcity of land and water resources, global strategies to increase food production should focus efforts on increasing production per unit resources, i.e. the combined increase of production per unit land surface (yield expressed in kg/ha1) and the increase of production per unit water used (water productivity expressed in kg/m^3). Improving land and water productivity is a complex task which requires: (i) monitoring of current levels of productivity in various crop production systems; (ii) assessment of observed productivity relative to potential; (iii) identification and analysis of the underlying causes of the productivity gaps; and (iv) evaluation of options and identification of viable solutions to close the productivity gaps in the local context.

To support these processes, the WaPOR project (http://www.fao.org/in-action/remote-sensing-for-water-productivity/en/) is applying and analyzing high resolution satellite images in conjunction with specific algorithms to determine spatial and temporal variability of agricultural water and land productivity. Through the project activities, a validated remote sensing based methodological framework has been created to assess and monitor land and, more specifically, water productivity. The provision of near real time information through an open access data portal enables a range of service-providers to assist farmers attain more reliable yields and to improve their livelihoods; irrigation operators will have access to new information to assess the performance of systems and to identify where to focus investments to modernize the irrigation schemes; and government agencies will be able to use the information to monitor and promote the efficient use of natural resources.

The International Water Management Institute (IWMI) is implementing Component 4 of the project to meet the objective of improving the capacity of the direct beneficiaries to improve water productivity in both rain-fed and irrigated systems in a sustainable manner, through the WaPOR database (https://wapor.apps.fao.org) and the development of locally relevant interventions. The direct beneficiaries include: (i) national institutions involved with ICT services for water and agriculture as well as NGOs and the private sector; (ii) water user associations and extension services, irrigation authorities; and (iii) the farmers themselves. The capacity development program has been targeted at individual sites, and these pilot activities will generate lessons, good practices and learning materials that will enable replication and out-scaling in other areas and countries.

The implementation of the Component 4 activities is guided by three key objectives:

- *Objective 1: Identify relevant stakeholders and undertake stakeholder needs assessment*
- *Objective 2: Identify current activities for ICT and other solutions in agricultural water management and undertake capacity building with identified partners*
- *Objective 3: Develop, design, pilot, and evaluate potential solutions to increase water productivity sustainably*

This Technical Report addresses Objective 3, in Egypt, where the International Water Management Institute IWMI-MENA has carried out the activities with the cooperation of the Soil, Water and Environment Research Institute (SWERI) and October University for Modern Sciences and Arts (MSA).

3. Project Objective

The overall objective is to develop a mobile application based on the Water Productivity through Open access of Remotely sensed derived data portal (WaPOR. https://wapor.apps.fao.org) to support farmer's daily decisions on farm related to water management and productivity. WaPOR uses satellite information to compute and map key variables related to water and agriculture, such as evapotranspiration, biomass production and water productivity. The provision of near real time information through such open access data portal can enable a range of service-providers to assist farmers attain more reliable yields and to improve their livelihoods. For this purpose, the **IR**rigation **W**ater **I**nformation (IRWI) Application has been co-designed and co-developed to provide daily information to farmers, extension services and any person related to and/or interested in the agriculture sector. This information includes:

- 'when' and 'how much' water to apply for 5 major selected crops

- Agro-meteorological information incl. Max and Min temperature, humidity, rainfall prediction, ...etc.
- Energy costs for each time the farm is irrigated
- Crop status like: growth stage and net productivity
- Tables for previous irrigations and daily statistics records
- Archiving information of the past seasons

4. Geographic background

The project geographical focus is Egypt. Farmers in Egypt are the target audience of the IRWI application, which is intended to support their decision making through the provision of information on irrigation water requirements. Agriculture plays a major role in the Egyptian economy even though it is considered to be a semi-arid country, characterized with very little rainfall. Egypt depends mainly on irrigation for its agriculture using the waters of the river Nile,

shows how the irrigated areas are concentrated around the Nile and in its Delta. With increasing population Egypt faces several challenges regarding food security and water shortages to irrigate its crops. Egypt's agriculture sector is dominated by small farms using traditional practices that do not meet international standards. This is especially true when it comes to water productivity and efficient water use on small farms. However, the Egyptian government has developed several strategies and measures to improve water productivity and water use efficiency especially in the Nile Delta where farmers own small plots of land. The IRWI application fits right in the mission of the country to develop its agricultural sector and improve its productivity through advanced technologies that provide farmers with the technical inputs they need. The App focuses on three governorates; Kafr Elshiegh, Eldakhlia and Elbihera. Five crops were selected by the local experts for this trial representing the key crops in these governorates; these crops are soybean, rice, cotton, maize and potato.

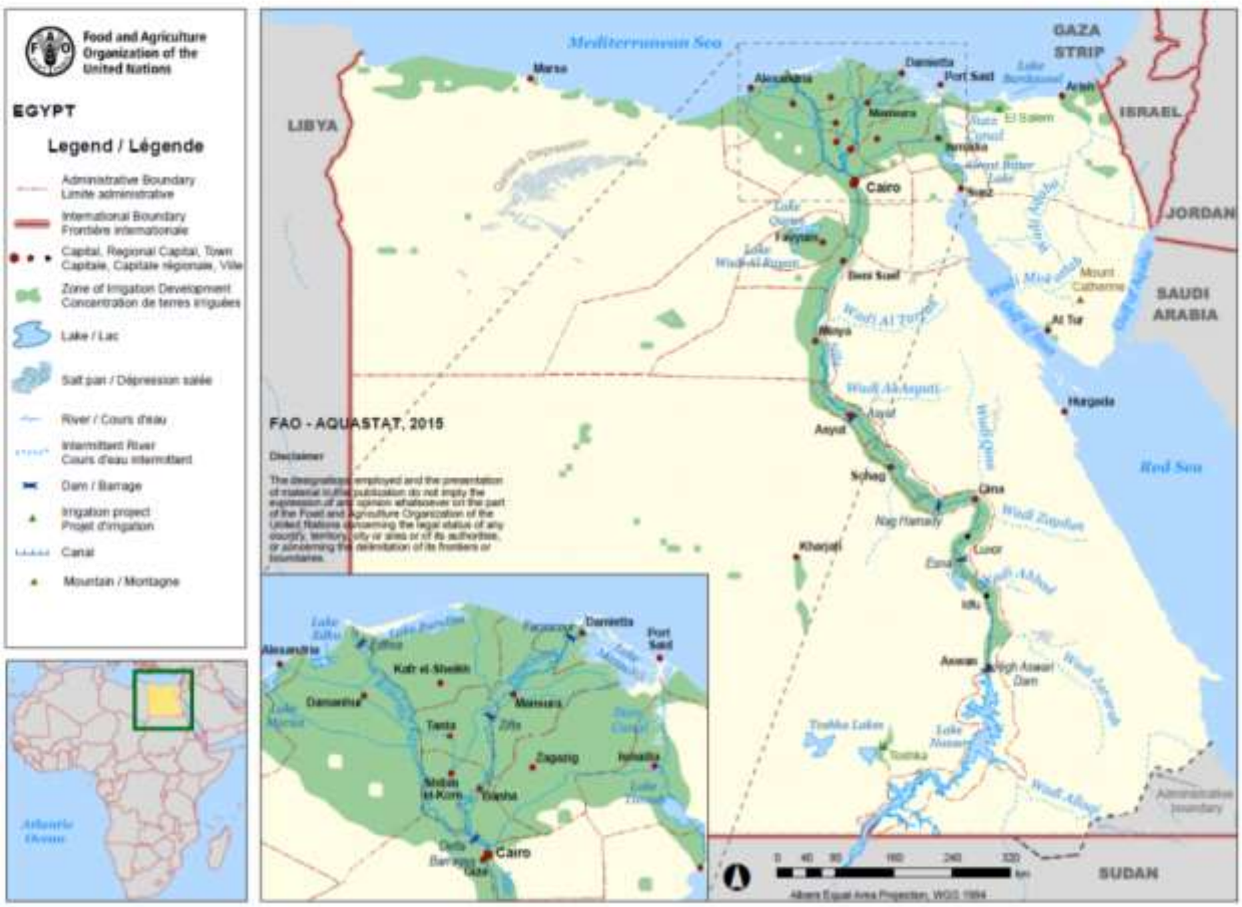

Figure 1: Map of Egypt (Source: FAO AQUASTAT)

5. Methodology

The main step of the methodology is the spatial estimations of actual evapotranspiration (ETa). ETa estimation is based on the use of satellite images from the WaPOR portal where satellite information is used to compute and map key variables related to water and agriculture, such as evapotranspiration, biomass production and water productivity, every ten days since 2009. The provision of near real time information through the open access data portal enables a range of service-providers to assist farmers to attain more reliable yields and to improve their livelihoods; irrigation operators will have access to new information to assess the performance of systems and to identify where to focus investments to modernize the irrigation schemes; and government agencies will be able to use the information to monitor and promote the efficient use of natural resources. Moreover, it enables estimation of key variables over large spatial domains with temporal variations.

5.1. Crop water requirement

Crop water requirement is a key part of crop characteristics, management, and environmental demands. The accurate assessment of it is crucial for correct water management. It is defined as the depth of water (mm) needed to meet the water consumed through evapotranspiration (ETc) by a disease-free crop. Both crop water requirement and evapotranspiration concepts can be applied to either rain-fed or irrigated crops.

$$ETc = Kc \times ETo$$

where;
Etc. crop evapotranspiration [mm/day],
Kc crop coefficient [dimensionless],
ETo reference crop evapotranspiration [mm/day]. (FAO 56)
The Eta of WaPOR has not validated locally in the governorates that targeted in this project, and it is reported to be underestimated in some areas, and it shows less quality in the desert areas like Fayoum in Egypt. The 250m and 100m pixels are less suitable for detecting AETI of vegetables and fruit crops. However, 30 m pixels will add a lot of value and continue local validation with local monitoring.

5.1.1. ETo mapping using WaPOR

WaPOR is the portal to monitor Water Productivity through Open access of Remotely sensed derived data. It provides access to continued observations over Africa and the Near East since 2009 with different spatial resolutions, 250m (Level I), 100m resolution (Level II) for some selected countries and river basins, as well as data for selected areas at 30 meter resolution (Level III). It is accessible through the following link:
https://wapor.apps.fao.org/home/WAPOR_2/1.
It should be noted that ETo maps, at daily basis (mm/day) are calculated on the basis of low-resolution meteorological data and can be extracted through the WaPOR portal at approximately 20 km resolution. As the ETo data are not available for lower resolutions or at national/basin scales, these layers are assumed the same value for lower scale..

5.1.2. Kc crop coefficient database

The crop coefficient (Kc value), characterizes the crop type and the development of the crop. There may be several Kc values for a single crop depending on the crop's stage of development.

Crop growth periods can be divided into four distinct growth stages; initial, crop development, mid-season and late season (Figure 2). The length of each of these stages depends on the crop variety, climate, latitude, elevation and planting date. Local observations are best for determining the growth stage of the crop and which Kc values to use corresponding to each stage. The Soil, Water and Environment Research Institute (SWERI) provides the local Kc for the selected five crops namely; rice, cotton, maize, potato and soya beans. These crops are the main summer crops in the Nile delta region. The detailed data for the five crops are presented in Annex 1.

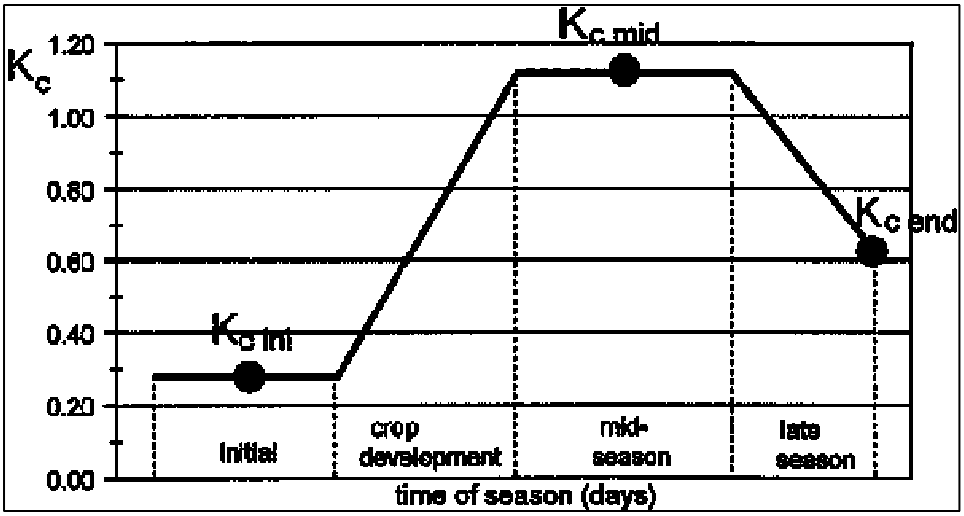

Figure 2: Crop Coefficient (Kc) and Crop Development Stages (source: FAO 56 report)

5.2. Mapping precipitation (Pe)

Effective Precipitation (Pe) is the amount of precipitation that is actually added and stored in the soil, and it is important in irrigation scheduling decisions. Not all precipitation that falls on the soil surface can be used by the crop. Some of the precipitation percolates below the root zone of the plants. This means that only a portion of the precipitation is stored in the root zone and used by the crop. It is assumed that 70% of the precipitation is considered to be effective based on expert opinions

$$Pe = 0.7 * P$$

where;
Pe the effective precipitation [mm/day],
P the precipitation on the study area [mm/day]
Daily data of rain were acquired from the WaPOR portal. Net irrigation requirements (NIR)

The net irrigation requirement is the quantity of water necessary for crop growth. It depends on the cropping pattern and the climate. NIR of different crops is estimated from potential crop evapotranspiration (ETc) by this equation

$$NIR = ETc - Pe$$

where;
ETc. crop evapotranspiration [mm/day],
Pe the effective precipitation [mm/day],

5.3. daily water needs (IRR)

The daily water needs are calculated as follows:

$$IRR = \frac{NIR}{Ieff} \times A \times L$$

where;
NIR net irrigation requirement [mm/day],
Ieff the irrigation efficiency [%],
A planting area [m^2],
L leaching factor [%],

When the irrigation day comes, the total water needs are calculated as follows

$$\text{Total IRR} = \sum_{k=Last\ irrigation\ date}^{k=Today} \text{IRR}_k$$

5.4. Calculating the hours of irrigation

Working hours = Total IRR / Q

where;
Q the discharge of the water pump [m^3/sec],

5.5. The gas price required for irrigating

Total liters used = gas usage × working hours
Energy cost per Irrigation = total liters * price per liter

5.6. Estimated Fresh Crop Yield

The freshly crop yield/ health estimation was based on data derived from the remote sensing open access database of FAO-WAPOR. More specifically, map layers of the Net Primary Production (NPP), at decadal timeframe were used (10 days). The NPP layers is charaterising the conversion of carbon dioxide into green biomass driven by photosynthesis.
By using the NPP layer at the national scale (10 days) from WAPOR and the values of the harvest index_HI (%) and dry matter_DM (%) Villalobos and Fereres (2017) and local experts opionion , for the five summer crops (table 1); the accumulated crop estimated fresh yield per feddan from the planting day is calculated:

$$Crop\,Yield = \sum_{Planting\ day}^{t} NPPv * HIc * DMc$$

Where :

- NPPc (value): is the net primpary productivity value for each pixel
- HIc : is the harvest index percentage per crop(c)
- DMc: is the dry matter percentage per crop (c)
- T : is the day/time of calculation

Table 1 Recommended Values of HI and DM

Crop		**Harvest index (%)**	**Dry matter (%)**
Wheat	Grain	40-50	87.5
	Staw	40-50	90.5
Potato	Tuber	50-80	23.5
Maize	Grain	40-55	86
Rice	Grain	17-56	70
Soybean		24-52	36

6. Design of the phone Application

The application is a responsive website hosted at (www.irwicrop.com) that can be accessed from any mobile phone with any screen size. This application provides farmers with the information needed to decide when they should irrigate their land, the amount of irrigation water to use, and the associated energy consumption. It also helps the farmer archive the historical data from previously planted crops and seasons. These data can be used to see the difference in productivity between seasons and help the farmer to make smarter choices for management of the land. The application has been co-designed with local experts and farmers to take early inputs into the design. Two workshops were conducted with the experts to discuss and design the best way to present the technical information to the farmers and extension service. Another two workshops were conducted with farmers to design the app to increase its uptake and to determine what data they wish to enter into the app.

6.1. Application background

This application is a technical tool for the farmer that helps monitoring the water requirements and notifies him/her whenever irrigation is needed. This tool calculates the estimated required water amount to irrigate and crop health using different sources of data:

a. Data entered by the farmer. :
    - Area of the crop
    - Type of soil
    - Crop type
    - Irrigation methods
    - Water pump discharge rate
    - Planting date
    - Last irrigation date
    - Soil Salinity (if exist)
    - Last irrigation date
    - Location of farm
    - Gas price
    - Water pump discharge specification

b. Static data:
    - Local single crop coefficient (Kc) at each crop growth stage for each crop type
    - Irrigation interval for each local crop type

c. Data pulled from WaPOR FAO API.:
    - Daily evapotranspiration
    - Daily precipitation
    - Decadal net primary production

d. OpenWeather API
    - Wind speed
    - Temperature (Minimum & Maximum)
    - Humidity
    - Weather State

6.2. Overview and workflow

Once a user enters the application, they follow three steps. First, the user enters the information for their farm including the farm name, location, size, gas price and gas usage, and water discharge rate. The user then adds a crop type to the farm profile and enters relevant data including planting date, last irrigation date, and irrigation type. Lastly, the user can then monitor the crops through the application to determine when the next irrigation is due, how many hours to irrigate, and what the energy costs will be.

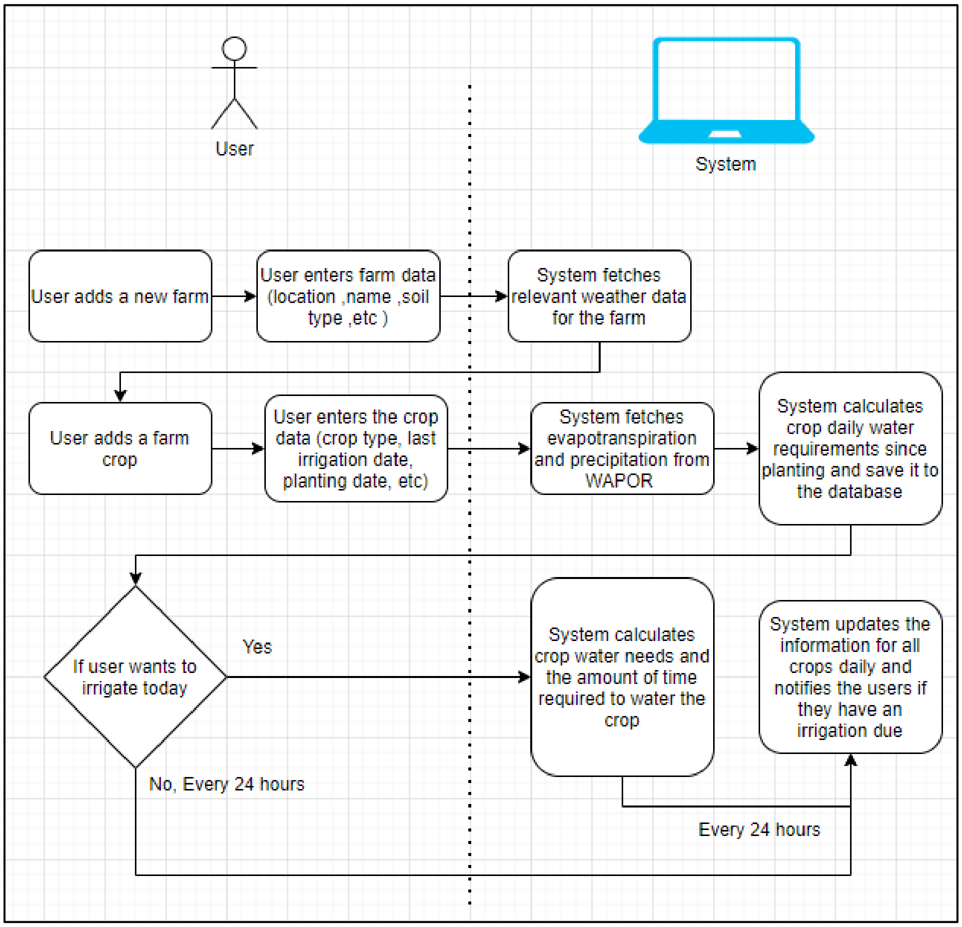

Figure 3: Flow Chart of IRWI App

Once a user registers a new crop, the system sends a request to WaPOR to retrieve the evapotranspiration, precipitation, and net primary production values from planting date till today. The system uses the predefined crop values (defined in the application) to calculate water requirements for this crop, irrigation time, and gas cost for irrigating the land. The system updates the crop data daily based on the data from WaPOR. **Error! Reference source not found.** shows t he workflow of the app and the interaction between the app and the user.

6.3. Technical specifications

The App website has been designed using

- ASP.Net MVC-5
- bootstrap 4.0
- MS SQL Database (the full database schema is shown in Annex 2)

The website is built in a responsive manner so that it can fit and display seamlessly on any screen size. This allows users to access the website from any device. The application is hosted entirely on the server.
There are 2 applications available on the play store and Apple app store that enable both android and Apple users to access the website and use the app to get mobile notifications about their upcoming scheduled irrigations.

6.4. Mobile Application

Android

The mobile application has been developed using Java; this provides a web view for the irwicrop.com website and notifies users whenever an irrigation event is due. The application is available on the play store.

Apple

A mobile application has been developed using Swift; this provides a web view for the irwicrop.com website and notifies users whenever an irrigation event is due. The application is available on the app store.

6.5. Main application outputs

a. Water requirements

The main goal of the app is to provide the water requirements for each crop selected; information

is provided for how long the crop should be irrigated, what is the price of each irrigation, how much energy is required and its cost; this is shown in **Error! Reference source not found.**.

Figure 4: Outputs for users of IRWI app

b. Weather information

The system provides information including temperature, humidity, and wind speed according to the location of the user's farm, this is shown in **Error! Reference source not found.**

Figure 5: Weather information widget in IRWI app

c. Calculated/estimated records

The calculated records show the farmer the recommended (ideal) irrigation practices for the crop (irrespective of whether they are followed or not). For example, the timing for each irrigation since planting and the water requirement for each irrigation. The layout of the table providing information on the ideal irrigation records can be seen in Figure 6.

Figure 6: Layout of Ideal Irrigation records table in IRWI app

d. Actual irrigation records

These are the actual times the farmer entered showing when he irrigated. Each record contains information about the irrigation like date, water requirements, gas usage price, and operating hours. The layout of the table providing information on the actual irrigation records can be seen in Figure 7.

Figure 7: Layout of actual Irrigation records table in IRWI app

e. Harvested crops records

Once the crop has been harvested, it is achieved automatically and the user can view all the records for the achieved crop in the "previous seasons" tab. The layout of the table providing information on the ideal irrigation records can be seen in Figure 8.

Figure 8: Layout of previous crops records table in IRWI app

6.6. Type of Users of IRWI app

There are 3 types of users:

a. Full Admin

The full admin can monitor all farms and crops added by normal users. Full admin has the authority to edit the static data. The system basically started using 5 crop types but the full admin can add more or remove any crop type. The admin can edit the Kc values for each crop type, and view the users' suggestions. In addition to the privileges of normal users.

b. Monitoring Admin

The full admin can monitor all farms and crops added by normal users. He can also view the users' suggestions. In addition to the privileges of normal users.

c. Users (Farmers)

Can create farms and add crops to them. Moreover, they can see the outputs of the analysis like water requirements and the tables of their crop data. They can also provide suggestions

7. Training events and testing the application

7.1. IRWI App Testing and validation

The Soil, Water and Environment Research Institute (SWERI) led the testing and training events with the farmers; in addition feedback was collected in the three governorates through direct visits and one to one discussions and training. In each governorate, 15 farmers were targeted to this introduction and capacity building and App testing before release. The feedbacks and uptake was very encouraging, with over 10 farmers at each governorate very engaged and following up with the team from SWERI. The feedback collected during the testing phase contributed to the development and release of the App.

In addition, on July 25th and 27th IWMI-MENA in collaboration with the Soil, Water and Environment Research Institute (SWERI) and the October University for Modern Sciences and Arts (MSA), held two workshops on "The use of IRWI Phone Application in Agriculture and Water Management in Egypt" in Dakahlia and Kafr EL-Sheikh governorates respectively to collect wider feedback from many farmers (around 30 farmers in each governorate).

Participants were smallholder farmers from the two governorates. The aim of the workshops was to provide training to the end-users, the farmers, in how to install the application, how to use it, and to get feedback on its features. Additionally, the farmers shared their expectations regarding further developments of the App and mentioned several services they wished to be provided to them through it in the future.

The workshops achieved the following outcomes:

- Draw the participants' attention to the importance of using ICT in agriculture
- Introduced farmers to the use of the IRWI APP
- Peer to peer well trained farmers who can use the App introduced the App and transfer their knowledge to other farmers
- Understanding the challenges in developing and implementing the ICT in agriculture and water management

7.2. Feedback from Farmers

In the current version of the App the farmers requested:

- Including the pump power in their familiar measurement unit (expressed in HP) as not all know the flow rate.
- Including the type of water source (from freshwater canals or mixed agricultural drainage water).

Farmers also expressed their interest in new services they would like to be added to the App in the next phase:

- Providing assistance with information on pest control and prediction of plant diseases
- Full extension services

Finally, the farmers positively reviewed the workshops, interacted and discussed their own experiences with using the IRWI App. The App act like a farmer' e-notebook that the farmers were enthusiastic about it.

Figure 9: Participants during the Workshop held in Dakahlia

Figure 10: Participants during the Workshop held in Kafr ELshiekh

8. Conclusion

The work presented here introduces the first phase of development of a phone based application based on the data provided through the WaPOR portal; the application provides farmers with technical information regarding irrigation times, frequency, crop productivity, with the aim of supporting daily decision making related to irrigation practices and crop management. The application has great potential to be developed further and reach higher levels of precision as well as to provide additional services to farmers. This has been considered in its design and thus the application has been developed to be flexible for further additions. These potential future developments are summarized in the points below based on the feedback received from farmers and extension users:

- Increase the number of crops including their varieties to meet the need for many farmers rather than using the average of the crop;
- Including market prices that are updated regularly to facilitate products marketing and access to market information;

- Provide live assistance/chat with experts on the crop health, by sharing pictures through the App and receiving feedback on the appropriate taken action;
- Provide alerts regarding heat waves for farmers, suggesting when to irrigate and how much;
- Alert farmers before expected frost, and suggesting practices to reduce the risk;
- Alert farmers of any pest outbreak based on field observation, mentioning the area of the outbreak, the specific crop, and any recommended measures for pest control;
- Crop forecasting price and feasibility studies for different crops to assist farmers with crop selection for the following season and also predict their revenues during the harvest e.g. market price.

Finally, through this pilot study it is concluded that the Egyptian farmers are ready and eagerly waiting to using ICT to help them to increase their productivity and irrigation efficiency.

9. Annex 1: Initial Crop Data

Below are the initial data for each of the five crops included in the app: Soybean, Maize, Cotton, Rice and Potatoes presented in tables 1,2,3,4 and 5 respectively.

Soybean:

Table 1: Initial crop data for Soybean

stage	Initial البداية	Mid النمو الخضري	Late التزهير	Ripe النضج	Stop irrigation
KC	0.5	1	1.15	0.5	20
No of days	20	30	40	25	
Irrigation interval	12				
Season days	Total number of days 115				

Maize:

Table 2:Initial crop data for Maize

stage	Initial البداية	Mid النمو الخضري	Late التزهير	Ripe النضج	Stop irrigation
KC	0.6	1.2	1.5	0.6	20
No of days	20	30	40	30	
Irrigation interval	15				
Season days	Total number of days 120				

Cotton:

Table 3: Initial crop data for Cotton

stage	Initial البداية	Mid النمو الخضري	Late التزهير	Ripe النضج	Stop irrigation
KC	0.5	1.1	1.2	0.7	20

No of days	30	40	50	30	
Irrigation interval	15				
Season days	Total number of days 150				

Rice:

Table 4: Initial crop data for Rice

stage	Initial البداية	Mid النمو الخضري	Late التزهير	Ripe النضج	Stop irrigation
KC	0.9	1.05	1.2	0.75	15
No of days	30	30	40	30	
Irrigation interval	6				
Season days	Total number of days 130				

Potatoes:

Table 5: Initial crop data for Potatoes

stage	Initial البداية	Mid النمو الخضري	Late التزهير	Ripe النضج	Stop irrigation
KC	0.6	0.75	1.15	0.4	10
No of days	20	30	40	20	
Irrigation interval	12				
Season days	Total number of days 110				

10. Annex 2: Application Database schema

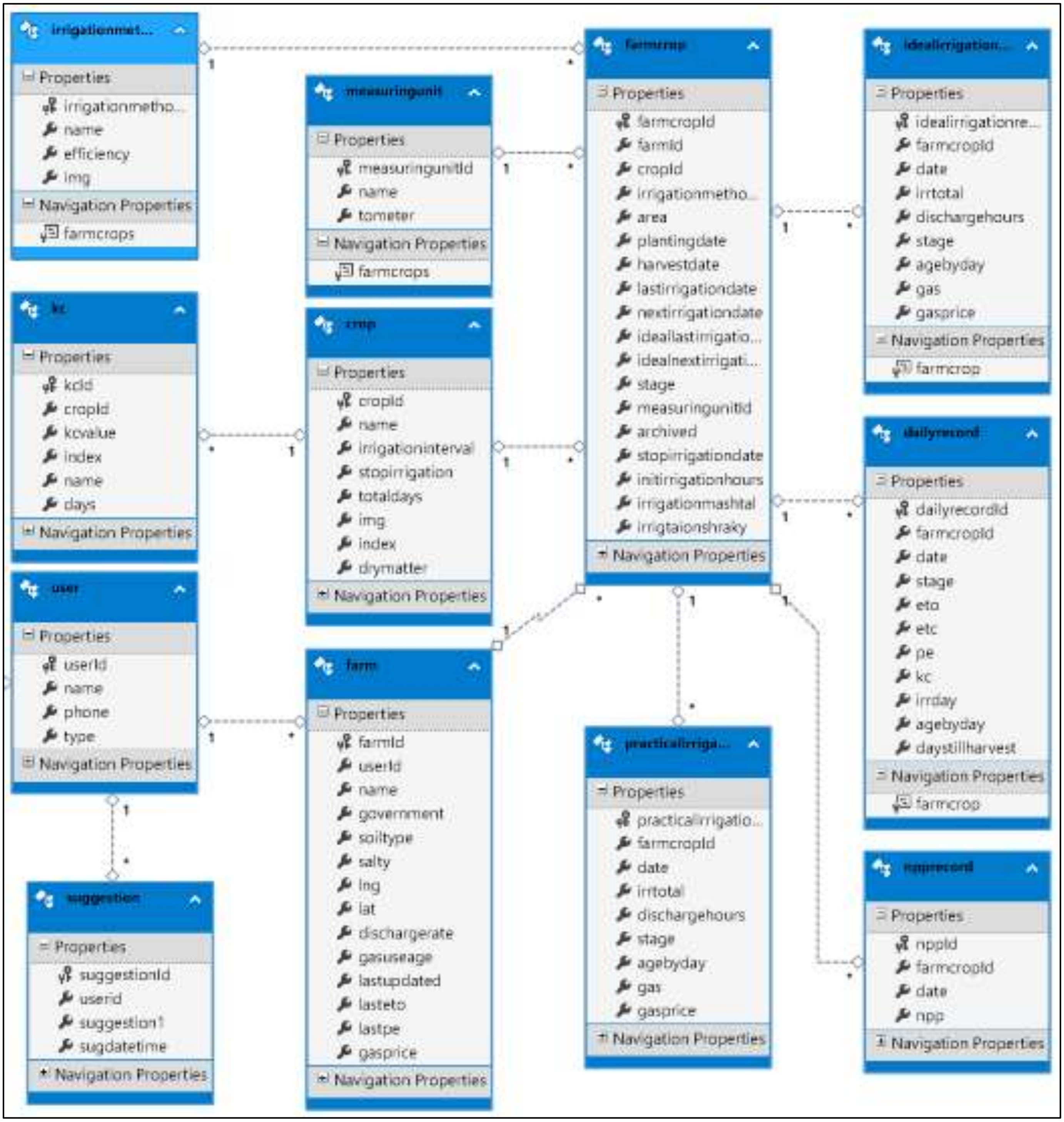

Figure 1: Database Schema for IRWI app

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The International Water Management Institute (IWMI) is a non-profit, scientific research organization focusing on the sustainable use of water and land resources in developing countries. IWMI works in partnership with governments, civil society and the private sector to develop scalable agricultural water management solutions that have a real impact on poverty reduction, food security and ecosystem health. Headquartered in Colombo, Sri Lanka, with regional offices across Asia and Africa, IWMI is a CGIAR Research Center and leads the CGIAR Research Program on Water, Land and Ecosystems (WLE).

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