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SUPPORT SYSTEM FOR IRRIGATION SCHEDULINGVIA SMS (SHORT MESSAGE SERVICE)

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1 ABSTRACT

In remote areas, especially in northeastern Brazil, small farmers have difficulty in accessing information and technical assistance on irrigation. The objective of this study was to develop a decision support system for irrigation water management via SMS, called IGmanejo that offers information and irrigation advice on the farmer´s mobile phone. Simulations were performed to evaluate water savings based on current and historical data comparing them with values obtained by a FAO CropWat 8.0 software. The greater water savings, a reduction by 26%, was observed in the cycle that began in the transition season. The proposed software was able to reduce water waste in agriculture and send simple and quality irrigation advice to remote areas using a technology which has already been assimilated into rural areas, that is, the mobile phone.

Keywords: mobile phone, software, semi-arid, technical assistance

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2 RESUMO

Em áreas remotas, especialmente no nordeste brasileiro, os pequenos agricultores têm dificuldades de acesso à informação e à assistência técnica especializada em irrigação. O objetivo deste trabalho foi desenvolver um sistema de suporte à decisão do manejo de irrigação que oferece via SMS informações sobre lâmina e tempo de irrigação para o telefone móvel do agricultor, chamado IGmanejo. Simulações foram realizadas para avaliar a economia de água com base em dados atuais e históricos e comparados com os valores da lâmina obtida pelo software de referência da FAO CropWat 8.0. A maior economia de água se observou no ciclo que teve início no período de transição, ocorrendo uma redução de 26% no consumo de água com IGmanejo em relação ao manejo obtido pelo software CropWat. O software demonstrou a capacidade em reduzir o desperdício de água na agricultura e levar até áreas remotas a

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orientação para um manejo de irrigação de qualidade de forma simplificada e com uma tecnologia já assimilada pelo meio rural, que é o telefone celular.

PALAVRAS-CHAVE: telefone móvel, software; semiárido; assistência técnica.

3 INTRODUCTION

Irrigation is essential to supply the water requirements for plants during periods of low rainfall, and appropriate management can contribute to the rational use of water and power saving. The irrigated area in Brazil covered about 4.45 million hectares in 2006. In this area farmers often make use of an irrigation pump to supply water to irrigated areas. According to the 1995/96 census, the irrigated area has increased by 1.3 million hectares, that is, 42%. The south-east region exceeded the south, having the largest irrigated area in this census. The north-east region ranks third in the listing with 22.12% the mid-west and north together totalled only 14.7% (PAULINO et al., 2011).

There are many software and simulation models for irrigation, such as CropWat software developed by FAO, which can also be used to evaluate farmer’s irrigation practices and to estimate crop performance under both rain-fed and irrigated conditions (SMITH, 1992).

Although a good tool for studying management, it does not reach the small farmers. Other software and models have been developed on the same lines by several researchers. These applications perform irrigation management with good accuracy, but require large amounts of input data and also that the irrigator has a desktop computer with Internet access (MATEOS ET AL., 2002; BAZZANI, 2005; QUEIROZ ET AL., 2008; CASTRO ET AL., 2008; ASAOLU & OGBEMHE, 2009; BERGEZ, ET AL., 2012).

In remote areas, especially in north-eastern Brazil, small farmers have difficulty in accessing information and technical assistance on irrigation, adopting management practices based on experience not modern techniques that define how and when to irrigate.

Short message service (SMS) is increasingly used in irrigation advice, because it sends information in a simplified format, from a technology that is assimilated in rural areas, providing solutions for famers that have difficulty in accessing information via computer software and the Internet. Car et al. (2012), developed a decision support system for irrigation scheduling that sends information daily to the mobile phones of irrigators in Australia, called IrriSatSMS and Antonopoulou et al. (2010) developed mafic-DSS, a system sending information via SMS that assists Greek farmers in choosing crops and monitoring them throughout the production cycle.

4 MATERIAL AND METHODS

The support tool for irrigation advice, proposed in this paper, was titled "IGmanejo". The word "IG" refers to the word water in the indigenous language Tupi-Guarani, "manejo" reflects the functionality of the program for irrigation scheduling in agricultural areas.

The software was developed in the Java SE Platform Standard Edition using IDE (Integrated Development Environment) NetBeans 7.0, Sun Microsystems. The database used was the Postgres SQL database which stores data by farmer, area and schedule. All software used in the system development is free. For sending SMS messages, Java packages, offered by a company SMS Web Service that lets you send SMS text messages for R$ 0.18 each, was used.

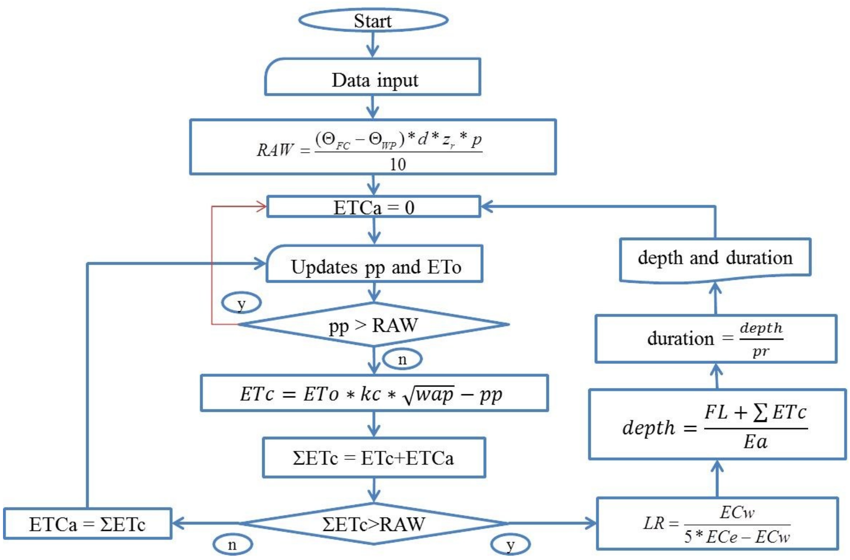
The Administrator of system “IGmanejo” can be a manager responsible for irrigation, the leader of the agricultural community, or some entity responsible for agricultural settlement, this person is responsible for performing the payment SMS and to send the messages for farmers cells phones it is also necessary that the Administrator computer is connected to the Internet.

4.1 System description

IGmanejo software is intended for the engineers and technicians responsible for irrigation scheduling. After registration of their irrigated areas, the farmers will receive, on mobile devices by SMS, information about the areas to be irrigated and the depth and duration of the irrigation. The irrigation scheduling proposed by the software defines depth and irrigation frequency variables, because the system works with daily climate data, calculating the daily hydrological balance.

IGmanejo irrigation scheduling is performed according to the flowchart shown in Figure 1, starting with the data collection of the irrigated area to calculate the readily available soil water in the root zone (RAW) (Equation 1).

Figure 1. Irrigation decision flowchart of IGmanejo software.



Θ_{fc}-field capacity (%) ;
Θ_{wp}-wilting point (%);
D-soil density (g.cm^{-3});
z_r-root depth (m);
p-critical depletion fraction;
kc-crop coefficient;
pwa– per-cent wetted area (decimal);
LR-leaching requirement (mm);
EC_W-salinity of water(dS.m^{-1});
ECe- salinity of soil saturation extract (dS.m^{-1});
pp- rain (mm);
ETo–referencecrop evapotranspiration (mm.day^{-1});
ETc-crop evapotranspiration (mm.day^{-1});
ETCa- accumulated crop evapotranspiration (mm);
EA- Application Efficiency (decimal);
pr-sprinkler precipitation rate (mm.h^{-1}).
RAW-Readily available water (mm).

$$RAW = \frac{(\theta_{FC} - \theta_{WP}) * d * z_r * p}{10} \quad (1)$$

where,
RAW –readily available water, mm;
θ_{FC} – the water content at field capacity, %;
θ_{WP}– the water content at wilting point, %;
d –soil density, g cm^{-3};
z_r – the rooting depth, cm; (according to the crop stage)
p –critical depletion, fraction.

Following the flowchart, the initially calculated evapotranspiration is equal to zero, then the system administrator enters the data for the daily precipitation and evapotranspiration. The system checks whether the precipitation is greater than the RAW: if the statement is true there is no need for irrigation, precipitation is supplied in accordance with the crop water requirement; if the statement is false, the system will calculate the crop evapotranspiration (ETc) as Equation 2.

$$ETc = ETo * kc * \sqrt{wap} - pp \tag{2}$$

where,
ETc – crop evapotranspiration, mm day^{-1};
ETo –reference crop evapotranspiration, mm day^{-1};
kc –crop coefficient, dimensionless;
wap – wetted area percentage, decimal;
pp –precipitation, mm.

The system makes the sum of the current ETc with the accumulated ETc where the algorithm moves to decide the irrigation needs. If the sum of ETc is less than or equal to the RAW there is no need to irrigate, the ETc will be stored and the administrator inserts the rainfall data and the ETo of the next day. If the sum of the ETc is greater than the RAW, irrigation is necessary and the administrator can calculates the leaching requirement if necessary (Rhoades & Merrill, 1976) described in Equation 3, else the administrator must insert "ECw=0", and" ECe = 0", or "LR" below zero that program return depth irrigation without "LR".

$$LR = \frac{ECw}{5 * ECe - ECw} \tag{3}$$

where,
LR – minimum leaching requirement needed to control salts, mm;
ECw – salinity of the applied irrigation water, dS m^{-1};
ECe –average soil salinity tolerated by the crop as measured on a soil saturation extract, dS m^{-1}.

The system calculates the irrigation by the sum of ETc and LR divided for system efficiency (Equation 4), and the irrigation duration is calculated as the division of the irrigation depth and the sprinklerprecipitation rate (Equation 5). Finally, the system sends an SMS containing the information and irrigation advice to the farmer (irrigation duration and depth) and the accumulated ETc is again equal to zero.

$$depth = \frac{LR + \sum ETc}{Ea} \tag{4}$$

W
here,
LR – minimum leaching requirement needed to control salts, mm;
ETc – crop evapotranspiration, mm day^{-1};
Ea–application efficiency (decimal);

$$duration = \frac{depth}{pr} \tag{5}$$

where,

depth– the irrigation depth, mm hours^{-1};
pr –sprinkler precipitation rate, mmh^{-1}.

If there is no record of ETo in the locality, IGmanejo can calculate ETo based on meteorological data. Due to the limited availability of climatic variables for the ETo calculations of the Penman-Monteith method, recommended by the FAO, in this software the method of Hargreaves and Samani (Equation 6) was used.

Researchers assessed the performance of the Hargreaves and Samani method compared with that of Penman-Monteith and obtained a satisfactory result and so it is recommended for irrigation by farmers in the north-east of Brazil (Silva et al., 2010; Sousa et al., 2010).

$$ETo = 0{,}0135 * \mathrm{k} * \mathrm{Ra} * \sqrt{(\mathrm{Tmax} - \mathrm{Tmin})} * (\mathrm{Tavg} + 17{,}8) \qquad (6)$$

where,
ETo – reference crop evapotranspiration, mm day^{-1};
Ra – extra-terrestrial radiation, MJ m^{-2};
Tmax – maximum temperature, °C;
Tmin – minimum temperature, °C;
Tavg – average temperature, °C;
k – coefficient variation according to continental and coastal regions.

4.2 Application requirements

The requirements of the proposed software originated from the specification of functional and non-functional requirements that define the functionality of the software and describe the quality of the system, respectively. Table 1 illustrates the functional and non-functional requirements considered.

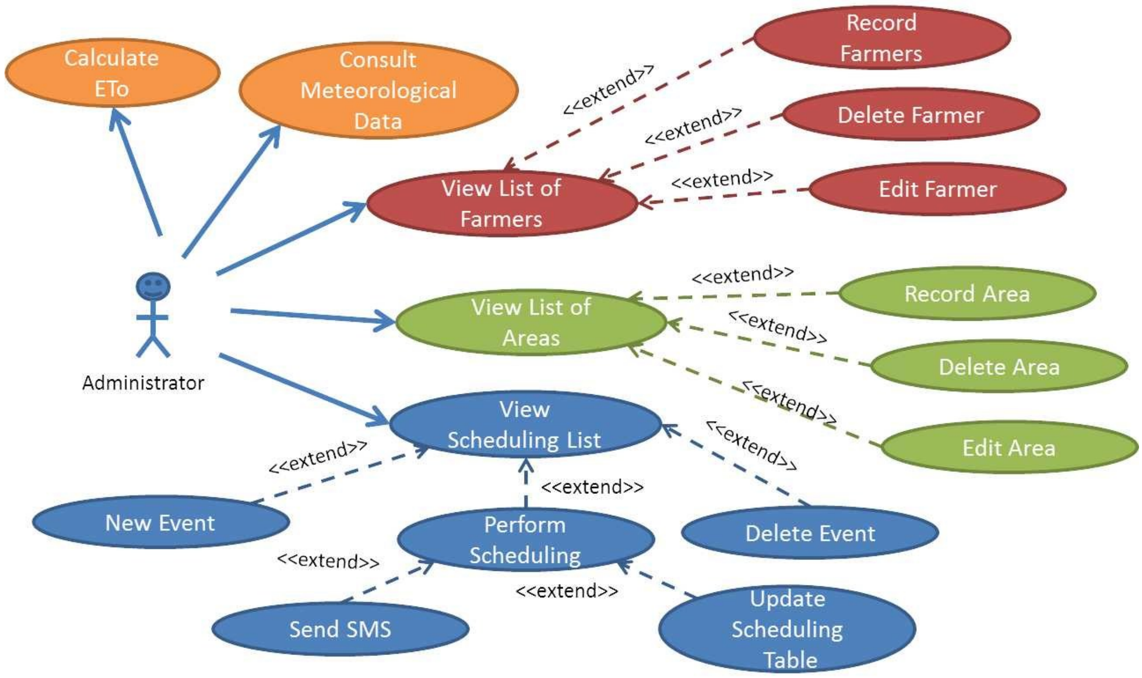
Table 1. IGmanejo software requirements.

Software requirements	
functional requirements	non-functional requirements
RF01–Manage areas and farmers.	RNF01–Platform compatibility
RF02–Consult meteorological data.	RNF02–Usability
RF03– Calculate the reference evapotranspiration.	
RF04–Calculate depth(mm) and irrigation duration (hours).	
RF05–Send SMS.	

4.3 Use case

The use case diagram models the dynamic aspects of the system behaviour and relationships among the objects. The use case diagram, shown in Figure 2, contains a description of the functionality with the respective user. This is represented by an “actor” and labels, connected by solid arrows, which define the functionality of the system from the point of view of the user. The use case is represented by an ellipse and a label of its name, the dotted arrows with the word “<< extend >>”are an indication that other use cases may be added to it. When the use case is called, it checks whether or not its extensions should be executed.

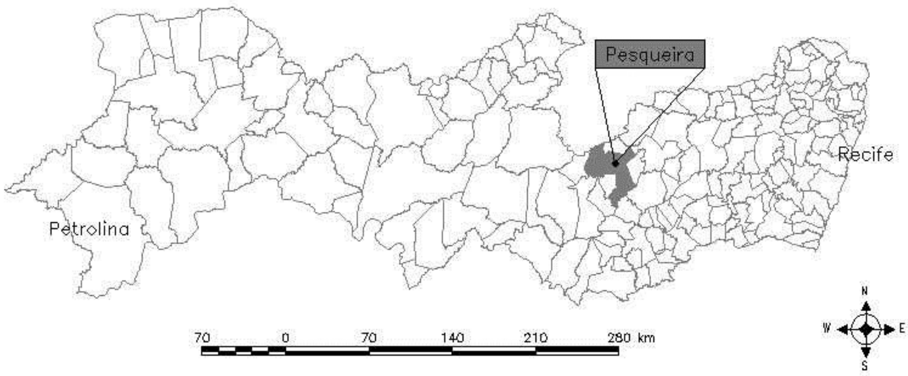
Figure 2.Use case diagram.



4.4 Evaluation system

The system was evaluated in an area of family farms located in Pesqueira (Figure 3) located 230 km from Recife-PE, with geographic coordinates 08º 10' 25" S and 35º 11' 25" W, and altitude of 650 m. The climate is classified as hot semi-arid (Bswh) in the Köeppen classification. The average annual rainfall is 681 mm, maximum 1.208 mm, minimum 193 mm, with average annual potential evapotranspiration of 1.122 mm.

Figure 3. Location of Pesqueira in the state of Pernambuco, north-east Brazil.



In the evaluation of the system, cultivation of cabbage was simulated, an important crop in arid regions (Montenegro & Monteiro, 2000), with crop coefficients (Kc) of 0.78, 0.865, 0.90, 0.80, and root depth (Zc) of 10, 20, 25, 30 cm, according to the stage of development, as recommended by Doorenbos & Pruitt (1977). Soil properties of the study area were extracted from Santos (2010) where soil density, 1,73 g cm^{-3}, the water content at field capacity equals 15,5%, and the water content at wilting point equals 6,1%. The climatological normal for maximum and minimum temperatures, humidity, wind speed and evapotranspiration were obtained from the website of the National Institute of Meteorology (www.inmet.gov.br) comprising a series of 30 years (1961–1990) and data for maximum and minimum temperatures and precipitation of the day's simulated cultivation were purchased from the Agritempo website (www.agritempo.gov.br).

Three types of irrigation scheduling were studied. The first was IGmanejoSMS using the IGmanejo software with a database of temperature and rainfall for the day and place where the cultivation was simulated. The second was IGmanejoHIS, corresponding to the software IGmanejo, using evapotranspiration data from climatological normal data (historical data), and CropWat 8.0, with data for the normal climatological temperature, wind speed, relative humidity and rainfall. CropWat software is widely used by researchers to perform irrigation scheduling in their research (Doria & Madramootoo, 2012; Ashish et al., 2012). The three types of scheduling were subject to the same conditions of soil and culture and were evaluated according to the water consumption during three growing seasons, January (transition from the dry season to the rainy season), May (the rainy season) and September (the dry season) in three different years (2007, 2008 and 2009). The application efficiency of irrigation system was assumed as 80% and sprinkler precipitation rate equals 6,03 mmh^{-1}. The leaching fraction used was 20% following the recommendations by Carvalho et al. (2011). The statistical analysis was performed with the Tukey test for comparison of the means of the application durations obtained by the software IGmanejoand was measured with CropWat through correlation analysis.

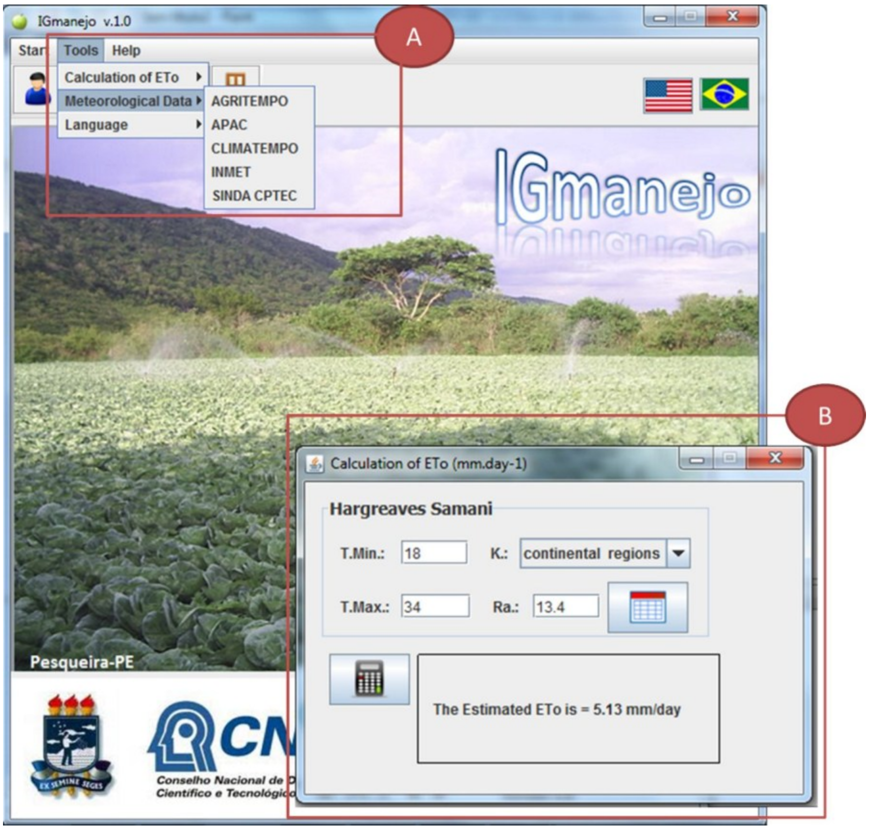
5 RESULTS AND DISCUSSION

The Figure 4 shows the application's home screen with the "Start" menu selected which has the functions "Cadaster" ("Farmer" and "Area") that allows access to the registration areas and farmers, "Scheduling" to access the screen irrigation scheduling and "Exit" to exit the application.

Figure 4. Initial screen of the application with the "Start" menu activated

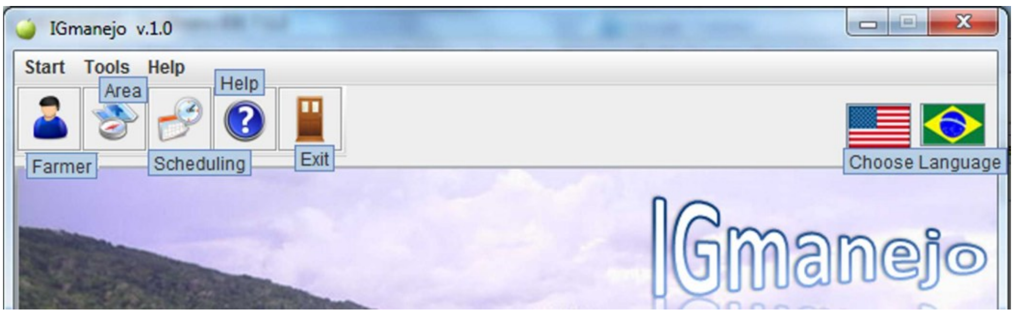
The Figure 5 shows tools that have been entered in the software to assist in the acquisition of meteorological data, the calculation of ETo and to choose the language. In the "Tools" menu, by selecting the item "Calculation of ETo" and "Hargreaves & Samani" (Figure 5A), access is given to an evapotranspiration calculator (Figure 5B), which visualizes the fields of maximum and minimum temperature, radiation, a combo box of the K coefficient that varies in coastal and continental regions, the button "Table" which provides tabulated values of radiation and the "Calculate" button to perform the ETo calculation. The submenu "Meteorological Data" has hyperlinks to institutions with climatological databases in Brazil.

Figure 5. Tools for calculation and querying meteorological variables (A); ETo calculator (B).



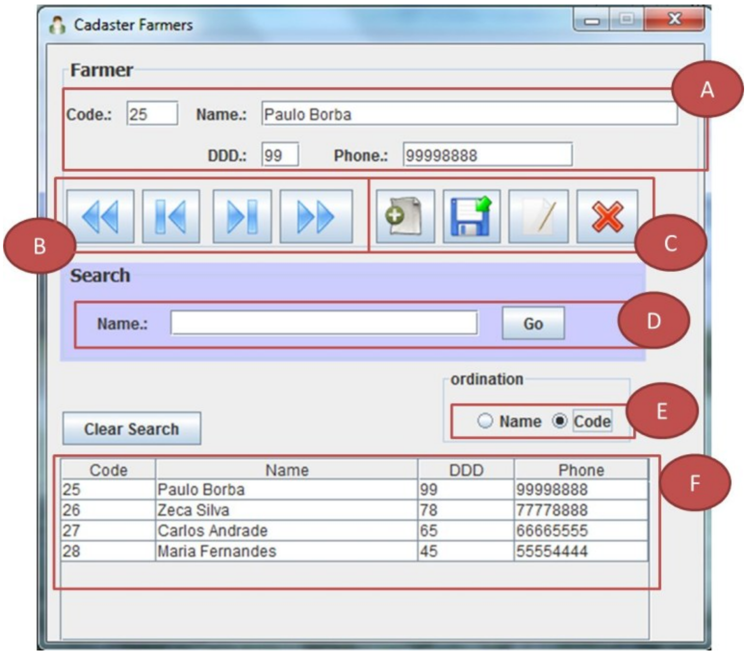
The quick access buttons for the main functions of the application are shown in Figure 6, where the administrator can select "Farmer" to access the list of farmers, "Area" to access the list of areas, "Scheduling" to access the scheduling screen, "Help" to access the software manual, "Exit" to close the program and flags to change the language, English or Portuguese.

Figure 6. Main screen with quick access buttons identified.



The screen for farmers can be seen in Figure 7. Figure 7identified by the letter "A" shows the fields to add a new farmer and delete or edit existing farmers. Figure 7identified by the letter "B" shows the navigation buttons "go to the first farmer", "previous farmer", "next" farmer, "go to the last farmer". In Figure 7 identified by the letter "C", the functions "new farmer", "save", "save changes" and "delete" are available. To perform the search for a registered farmer, enter the name or part of it in the offered field, and then press the "Go" button (Figure 7 identified by the letter "D"). The button group to choose the ordering of the table, either alphabetically or by registration code, can be seen in Figure 7 identified by the letter "E" and a complete list of all farmers registered is shown in Figure 7 identified by the letter "F".

Figure 7. Screen cadaster farmers. Data visualization for editing (A), navigation buttons (B), action buttons (C), the search field (D), table sorting (E), table of registered farmers (F).



The screen areas (Figure 8) include area research tools (Figure 8 identified by the letter "A"), navigation buttons "Go to the first area", "previous area", "next area" and "last area" (Figure 8 identified by the letter "B") and data visualization of the selected area (Figure 8 identified by the letter "C"). The buttons to add "New Area", "Save", "Edit" and "Delete", and the button group to select table sorting (alphabetically or by registration code) and a complete list of all areas registered are shown in Figures 8identified by the letter "D", "E" and "F", respectively.

Figure 8.Screen cadaster areas. Research areas (A), navigation buttons (B), visualization of technical data (C), action buttons (D), table sorting (E), table of areas registered (F).

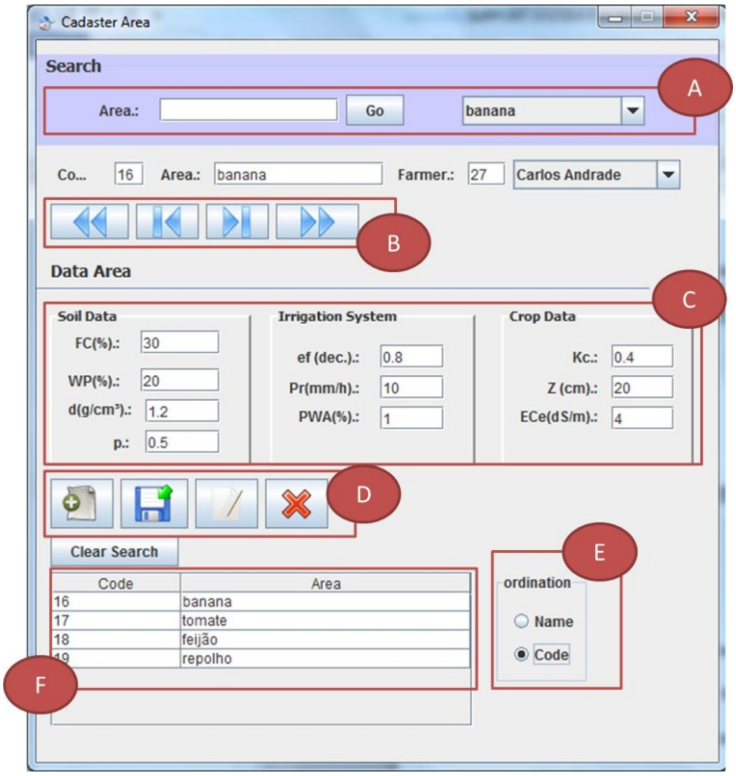


Figure 9 shows the scheduling screen, which contains the combo box to search for areas registered (Figure 9 identified by the letter “A”), the summary data area (Figure 9 identified by the letter “B”), the fields for updating data scheduling (Figure 9 identified by the letter “C”) and the results of the verification of the need for irrigation (Figure 9 identified by the letter “D”). To “Check”, “Clear”, “add to database” and “send SMS” the buttons shown in Figure 9 identified by the letter “E” appear, records are managed in Figure 9 identified by the letter “F” and a table with the last scheduling records selected is displayed in the area in Figure 9 identified by the letter “G”.

Figure 9. Screen irrigation scheduling. Research areas (A), general data of the selected area (B), update data scheduling (C), irrigation scheduling (D), action buttons (E), navigation buttons (F), scheduling records (G).

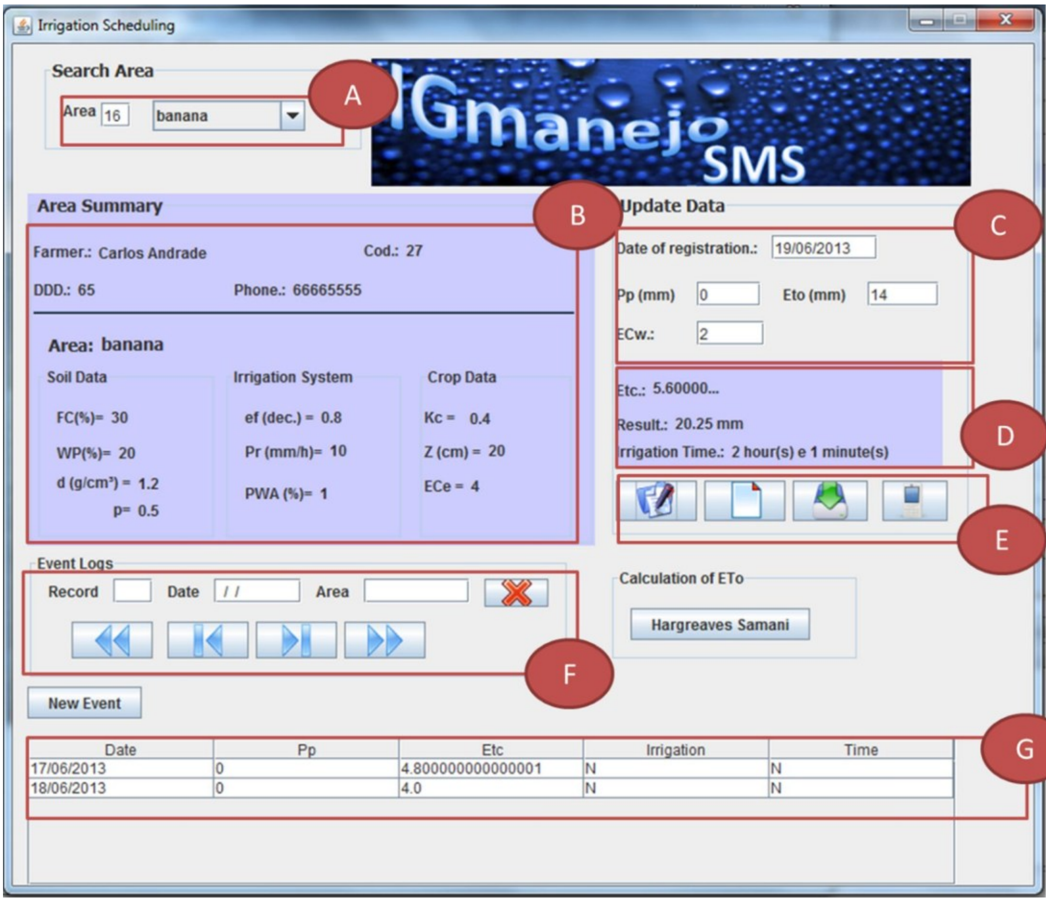


Figure 10 shows the format of the SMS as it arrives on the farmer's mobile displaying the values for the irrigation depth and duration.

Figure 10.SMS model on mobile.

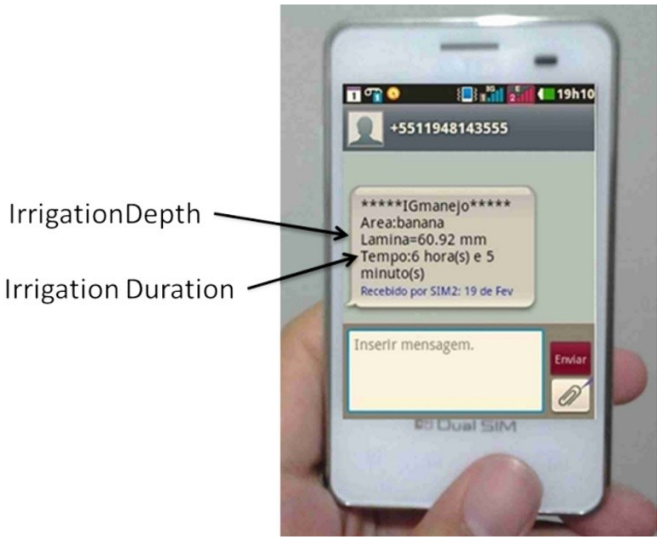


Table 2 shows the values of the irrigation depth plus the leaching fraction in the three seasons. The greatest difference in irrigation depth was observed in the cycle that began in the period of transition where the reduction was 26% in water consumption with IGmanejoSMS compared the CropWat software, because the IGmanejoSMS used data updated daily while CropWatt work with historical data. However, the IGmanejoSMS used updated data to perform irrigation scheduling, while CropWat uses historical data. The results for water economy reflect the importance of using updated data in the management of irrigated areas. In this table, we can see that there is no significant difference in Tukey test between the three scheduling systems when the cultivation is started in the rainy season. It is believed that the high coefficient of variation of the data favoured this scenario.

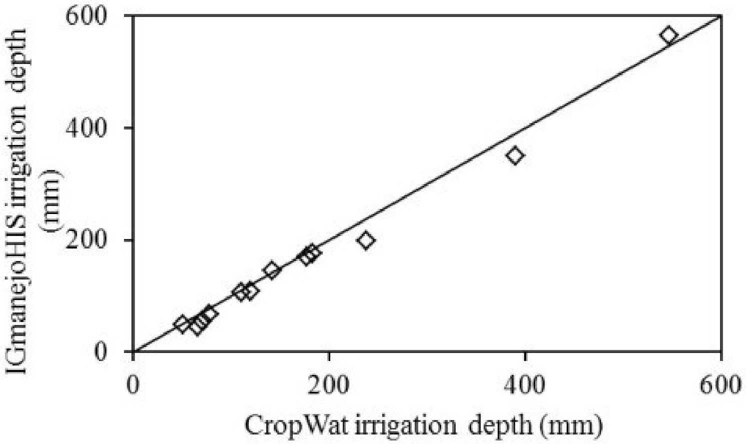
Singels & Smith (2006) used irrigation management by SMS in an area planted with sugarcane in Pongola, South Africa and obtained reductions (33%) in applied irrigation and irrigation costs compared to the standard practice of a fixed schedule.

Table 2. Values for different irrigation scheduling studied

ScheduleTypes	Transition Period (dry / wet)	Rainy season	Dry season
	irrigation depth (mm)		
IGmanejoSMS	569 b	348 a	757 c
IGmanejoHIS	722 a	368 a	933 b
CropWat	767 a	453 a	956 a
CV (%)	14	29	10

The validation of IGmanejoHIS with CropWat software was satisfactory, reaching a coefficient of determination (R^2) of 0.9881 when comparing the total water applied during different stages of crop development calculated for each computer program (Figure 11).

Figure 11. Comparison between the irrigation depth obtained by IGmanejoHIS and CropWat software at different phenological stages.

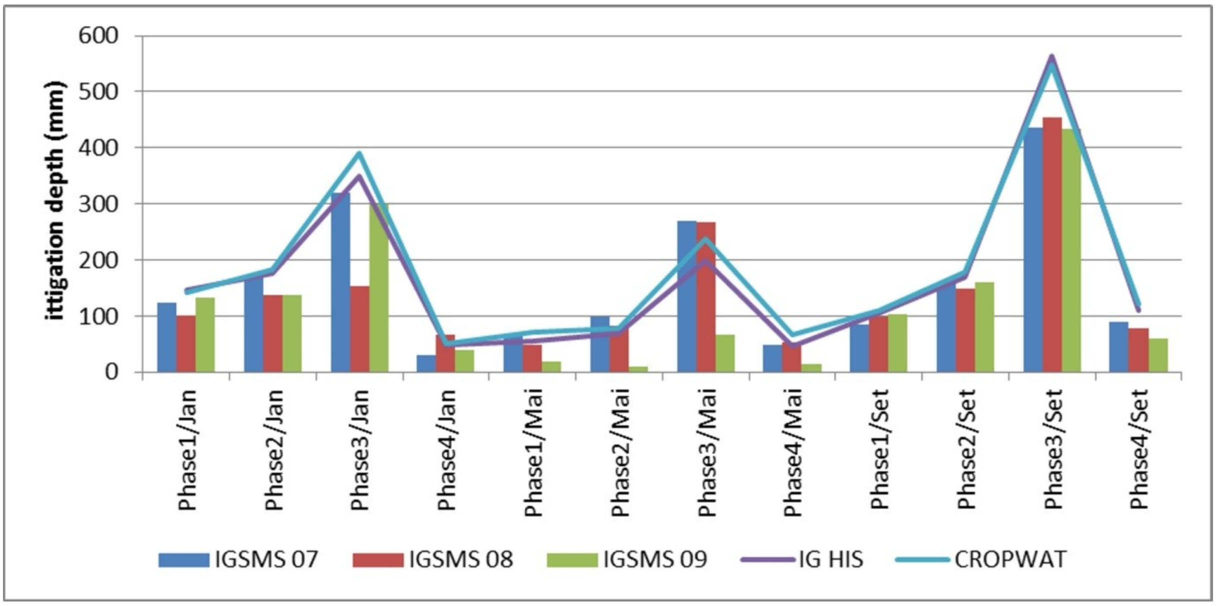


Unlike the irrigation depth obtained through historical series, the irrigation calculated with daily data for temperature and rainfall are more appropriate because they respect the rainfall seasonality and climate anomalies, like El Niño and La Niña, affecting the rainy season in Brazil.

The Figure 12 reflects the importance of using daily data for irrigation scheduling, and annually and monthly seasonality of the crops' water requirements. The crops started in May 2007 and 2008 in three phases culture, demanded more water than that required by the historical series. However, in the same period in 2009, the opposite occurred; the water required by the crop was lower than that estimated by the historical series. Csótó (2010) emphasizes that each farm is different, and has its own characteristics of climate, soil type and management, and its own and updated information of these elements can play a more effective role in terms of exploration.

IGmanejo software can work with daily information of the irrigated area, generating irrigation scheduling that reflects the real situation in the field, including the variations of the seasons and the daily crop's water requirement.

Figure 12.Irrigation obtained by IGmanejo and CropWat software in different seasons and in different years for IGSMS 07, 08, 09 representing the years 2007, 2008 and 2009 respectively.



Although the model used in the evaluation of the proposed software has been based on historical data (30 years) and that for three recent years, for just a culture, research has shown that such simulations are very close to real data measured in the field. According to Liburne et al. (1998), such tools can assist governments in monitoring the use of water for irrigation, especially in irrigated areas. The results of this paper show that its application can be extrapolated to other areas and cultures. In addition, IGmanejo can be used to indicate which culture, area, season or area to be irrigated is more suitable through simulations, based on recent historical data and current data. The most common problem among irrigators reported by Hess (1996) and Singels and Smith (2006), is that the farmer has limitations on when to irrigate, whether equipment or labour is available, whether he chooses to irrigate a contiguous sequence of lots and not necessarily by technical recommendation. As the target beneficiaries of the proposed software are initially small farmers, they will probably have restrictions imposed by the availability of equipment, water and labour. IGmanejo systematizes field information and assists daily irrigators in their decisions to irrigate with high accuracy in comparison with traditional software (CropWat) that is known worldwide. Moreover, it presents the advantage of integrating an existing technology in rural areas and guiding the farmer aiming to save water and electricity.

6 CONCLUSIONS

The developed software is able to reduce the water waste in agriculture and is available in remote areas on mobile phones. It recommends irrigation scheduling for agricultural communities in a simplified form.

IGmanejo systematizes the information field and assists daily irrigators in their decisions as to when to irrigate the crops and how much to irrigate.

The language, accessibility as a result of being able to use the simplest models of phone, no maintenance costs and the lack of requirement for an Internet connection are important points that contribute to the farmer's acceptance.

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