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QIrriga: a mobile application for climate-based irrigation management

QIrriga: Aplicativo para manejo de irrigação via clima

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Highlights

QIrriga features an intuitive interface and easy irrigation management.
QIrriga is Compatible with various irrigation system configurations.
QIrriga performs efficient calculation of irrigation time.

Abstract

Overuse of water is evolving into an unsustainable practice, giving rise to various problems. The use of technologies that facilitate the calculation of the actual demand for water resources in irrigated agriculture is of paramount importance for both productive and environmental sustainability. The aim of this study was to develop a computer application for irrigation management based on climate information for sprinkler and localized irrigation systems. QIrriga was developed in the Java programming language using Android Studio, which is an integrated development environment, and can be used to obtain the irrigation time for micro-sprinkler, drip, and conventional sprinkler irrigation systems, as well as the per centimeter value for center pivot irrigation. These values are determined by inputting location, weather, irrigation system, and crop data, thereby facilitating users in achieving efficient and sustainable irrigation management. The application also has a user-friendly interface. To validate the process and use of the app, the results generated by the app were compared with the values calculated using equations from the literature; it was found that both methods yielded consistent values. QIrriga is indicated for irrigation management.

Key words: Irrigated agriculture. Water use efficiency. Irrigation systems.

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Resumo

A utilização incorreta da água, torna-se uma prática insustentável, gerando diversos problemas, que podem ser causados devido ao uso inapropriado do recurso. O uso de tecnologias que possibilitam o cálculo da demanda real dos recursos hídricos na agricultura irrigada é de fundamental importância para a sustentabilidade produtiva e ambiental. O objetivo com este trabalho foi desenvolver um aplicativo computacional para manejo da irrigação com base em informações do clima para os sistemas de irrigação por aspersão e localizada. O QIrriga foi desenvolvido na linguagem de programação Java, através do Android Studio, que é um ambiente de desenvolvimento integrado, e possibilita obter o tempo de irrigação para os sistemas de irrigação por microaspersão, gotejamento, aspersão convencional, e o valor do percentímetro para Pivô central, a partir da inserção de dados de localização, meteorológicos, do sistema de irrigação e da cultura, de modo que o usuário possa fazer o manejo da irrigação de forma mais eficiente e sustentável. O aplicativo também possui uma interface de fácil entendimento para o usuário. Para validar o processo e a utilização do aplicativo, foi comparado os resultados do aplicativo a valores calculados através das equações da literatura, com auxílio de planilha eletrônica e os valores foram iguais. O Qirriga é indicado para manejo da irrigação.

Palavras-chave: Agricultura irrigada. Eficiência de uso da água. Sistemas de irrigação.

Introduction

Irrigation is among the largest uses of water worldwide. In 2019 in Brazil, 49.8% of all water was used for irrigation (Agência Nacional de Águas e Saneamento Básico [ANA], 2023). Crops require water because they lose water through transpiration. Additionally, low irrigation efficiency is related to errors in determining the appropriate amount of water required, use of low-efficiency irrigation methods and systems, and failure of irrigators to perform effective irrigation management.

Over time, irrigation has undergone technological improvements, resulting in the development of precise systems that apply water at the right time and place and in the right quantity. Management techniques involve three fundamental considerations: the methodology of irrigation, the quantity to be irrigated, and the timing of irrigation. These factors are determined using soil data, atmospheric data, plant type and conditions, or combinations of these (V. M. Ferreira, 2011). The use of irrigation coupled with technology promotes sustainability. Using appropriate methods and equipment, it is possible to reduce losses and maximize production gains without increasing the planting area (Dourado et al., 2021).

The use of increasingly accessible technologies has emerged as a viable option for monitoring external environmental variables and aiding in the decision-making process for implementing efficient management practices. In irrigation management, a lack of knowledge or the unavailability of equipment and technologies that facilitate this practice may explain the excessive use of water in irrigated agriculture, particularly in semi-arid regions. The IrrigaGrass application for the Android system was developed by Monteiro (2018) to improve irrigation management for family farming in the production of summer forage crops. Pereira (2020) developed a system that automates localized irrigation management; this system, built using the Arduino platform, enables the determination of reference evapotranspiration (ETo), crop evapotranspiration (ETc), and irrigation time for drip and micro-sprinkler configurations, as well as for monitoring the working pressure during irrigation and turning the system on and off according to the irrigation time. Irriga Café, which was developed by Lopes (2020) in PHP language, was associated with a MySQL database. The application uses the Hargreaves and Samani (1985) method and provides Conilon coffee producers with reliable information on when and how much to irrigate. L. B. Ferreira et al. (2020) developed an application for irrigation management by using artificial neural networks to determine ETo from data on maximum temperature, minimum temperature, and relative humidity.

The applications described above are specific to certain conditions or crops and calculation methods. Therefore, it is imperative to develop broader applications that can effectively enhance their utilization and substantially contribute to the conservation of water resources in irrigated agriculture. This study was conducted to develop a computer application for irrigation management based on climate information for sprinkler and localized irrigation systems.

Material and Methods

The QIrriga application was programmed in the Java programming language and developed in the Android Studio integrated development environment at the Federal Institute of Education, Science and Technology of Bahia, Guanambi Campus in the municipality of Guanambi in the state of Bahia, Brazil.

QIrriga is a climate-based irrigation management application that uses the Penman–Monteith FAO56 model and Hargreaves and Samani to calculate reference evapotranspiration (ETo). Based on location, weather, irrigation system, and crop data, it enables management for various irrigation system configurations. The application is exclusively used on devices with the Android operating system and is compatible with and recommended for use on devices with Android Pie versions higher than 9.0.

The interface of the application is user friendly. Data are entered in a straightforward, simple, and objective manner. There are fields for entering geographical location, meteorological data, choice of irrigation system, and crop data, and the results can be returned and reported to the user. Figure 1 shows the flowchart depicting the programming and calculation routine of QIrriga.

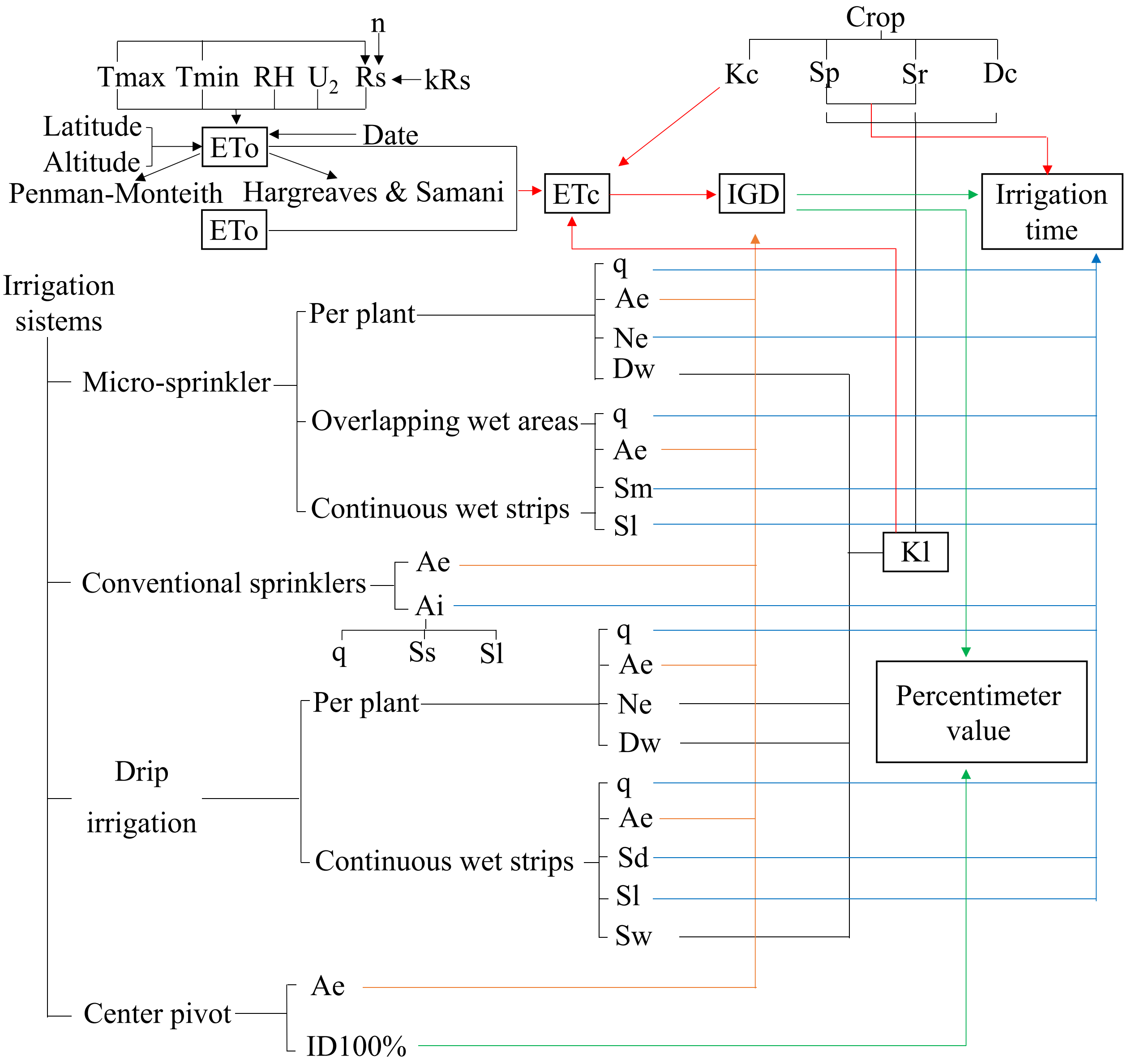

Figure 1. Flowchart depicting the programming and calculation routine of QIrriga.
Tmax: maximum temperature, Tmin: minimum temperature, RH: air humidity relative, U2: wind speed, Rs: net solar radiation, n: actual duration of daylight, kRs: constant that depends on the location, Kc: crop coefficient, Sp: spacing between plants, Sr: spacing between rows, Dc: diameter of the canopy, IGD: irrigation gross depth, q: flow rate, Ae: application efficiency, Ne: number of emitters per plants, Dw: diameter of the wet bulb, Sm: spacing between mivro-sprinklers, Sl: spacing between laterals, Sd: spacing between drippers, Sw: shaded and wet strips, Ai: application intensity, Ss: spacing between sprinklers, ID100%: pivot irrigation depth at 100% of the rotation speed, Kl: location coefficient, ETo: reference evapotranspiration and ETc: crop evapotranspiration.

In QIrriga, ETo is determined using two methods, the Penman–Monteith model (FAO Standard) (Allen et al., 1998) and Hargreaves and Samani (1985) method, which are the most reliable, applied and recognized methods in the literature.

The Penman–Monteith equation for determining ETo is a standard method that is parameterized by the FAO and is recommended for all soil and climate conditions. It is necessary to use complete weather stations to obtain climate data on air temperature (maximum and minimum), relative humidity, solar radiation, wind speed, and rainfall. The calculation sequence for obtaining daily ETo (Equation 1) using the Penman–Monteith FAO (Allen et al., 1998), is shown below.

$$\mathrm{ETo} = \frac{0{,}408 \times \mathit{\Delta} \times (\mathrm{Rn} - G) + \gamma \times \left[\frac{900}{T+273}\right] \times U_2 \times (e_s - e_a)}{\mathit{\Delta} + \gamma \times (1 + 0{,}34 \times U_2)}, \qquad (1)$$

where ETo is the reference evapotranspiration (mm day^{-1}), Δ is the slope of the vapor pressure curve (kPa °*C*$^{-1}$), Rn is net radiation at the crop surface (MJ m^{-2} day^{-1}), G is the soil heat flux density (MJ m^{-2} day^{-1}), γ is the psychometric constant (kPa °*C*$^{-1}$), T is the average air temperature (°C), U2 is the average air speed at a height of 2 m (m s^{-1}), e_s is the average saturation vapor pressure (kPa), and e_a is the current vapor pressure (kPa). According to Allen et al. (1998), for irrigation events with a frequency of less than 10 days, the density of heat flow in the soil can be disregarded; therefore, G is not considered in ETo calculations.

The slope of the vapor pressure curve is calculated using Equation 2.

$$\mathit{\Delta} = \frac{4098 \times \left[0{,}6108 \times \exp\left(\frac{17.27 \times T}{T+237.3}\right)\right]}{(T+237.3)^2} \qquad (2)$$

The wind speed at a height of 2 m (U2) is obtained as a function of the speed at a height of z (m) using Equation 3. In QIrriga, the wind speed must be entered with a correction for 2 m height, i.e., U2.

$$\mathrm{U_2} = \mathrm{Uz}\frac{4{,}87}{\ln(67.8\mathrm{z} - 5.42)}. \qquad (3)$$

The psychometric constant is determined using Equation 4.

$$\gamma = 0.665 \times 10^{-3}\mathrm{P}, \qquad (4)$$

where P is the atmospheric pressure determined using Equation 5.

$$\mathrm{P} = 101.3\left(\frac{293 - 0.0065\mathrm{z}}{293}\right)^{5.26}, \qquad (5)$$

where z is the elevation above sea level (m).

The average saturated vapor pressure is calculated as a function of the saturated vapor pressure of the maximum and minimum air temperature (eo(T)), according to Equation 6:

$$\mathrm{e_s} = \frac{\mathrm{e^\circ}_{(\mathrm{Tmax})} + \mathrm{e^\circ}_{(\mathrm{Tmin})}}{2}, \qquad (6)$$

$$\text{in which } \mathrm{e^\circ}_{(\mathrm{T})} = 0.6108\exp\left[\frac{17.27 \times \mathrm{T}}{\mathrm{T} + 237.3}\right]. \qquad (7)$$

The current vapor pressure (e_a) is obtained from the average relative humidity of the atmospheric air, defined as the average between the maximum and minimum relative humidity (Equation 8):

$$\mathrm{e_a} = \frac{\mathrm{UR}}{100}\left[\frac{\mathrm{e^\circ}_{(\mathrm{Tmax})} + \mathrm{e^\circ}_{(\mathrm{Tmin})}}{2}\right]. \qquad (8)$$

The surface radiation balance (Rn) is estimated using Equation (9) based on the difference between the incoming and outgoing shortwave and longwave radiation, Rns and Rnl, respectively.

$$\mathrm{Rn} = \mathrm{Rns} - \mathrm{Rnl} \tag{9}$$

Net solar radiation, Rns, is the fraction of solar radiation Rs that is not reflected by the surface and is obtained from Equation 10.

$$\mathrm{Rns} = (1 - \sigma) \times \mathrm{Rs} \tag{10}$$

where α is the albedo (0.23) and Rs is calculated using Equation 11.

$$\mathrm{Rs} = \left(\mathrm{a_s} + \mathrm{b_s}\frac{\mathrm{n}}{\mathrm{N}}\right)\mathrm{Ra} \tag{11}$$

where as + bs is the fraction of extraterrestrial radiation that reaches Earth on clear days. Values of 0.25 and 0.50 are assumed for as and bs, respectively, n is the actual duration of daylight (h), and N is the maximum possible duration of daylight (h) calculated using Equation 12.

$$\mathrm{N} = \left(\frac{24}{\pi}\right)\omega_{\mathrm{s}}, \tag{12}$$

where ω_s is the hourly sunset angle (rad) obtained using Equation 17.

For weather stations that do not provide insolation or radiation data, which are considered as incomplete data, solar radiation can optionally be calculated using Equation 13. Thus, there is the option in QIrriga to indicate/choose the solar radiation (Rs) option or enter the actual duration of sunlight for the day; if neither is available, Rs can be calculated using Equation 13.

$$\mathrm{Rs} = \mathrm{kRs} \times \sqrt{(\mathrm{Tmax} - \mathrm{Tmin})} \times \mathrm{Ra} \tag{13}$$

where kRs is a constant that depends on the location, using 0.16 for regions far from the coast and 0.19 for coastal regions, maximum temperature (Tmax), minimum temperature (Tmin) and Ra, extraterrestrial radiation, or radiation at Earth's upper atmosphere, determined using Equation 14.

$$\mathrm{Ra} = \frac{24(60)}{\pi} \times \mathrm{Gsc} \times \mathrm{dr} \times [\omega_{\mathrm{s}} \times \sin(\phi) \times \sin(\delta)$$
$$+ \cos(\phi) \times \cos(\delta) \times \sin(\omega_{\mathrm{s}})], \tag{14}$$

where Gsc is the solar constant (0.082 MJ m^{-2} h^{-1}), dr is the inverse of the relative earth-sun distance, calculated using Equation 15, and δ is the solar declination (rad) (Equation 16). In Equation 17, ϕ is the latitude (rad) for the southern hemisphere (the value must be negative) and ω_s is the hour angle of sunset (rad).

$$\mathrm{dr} = 1 + 0.033\cos\left(\frac{2\pi}{365}\mathrm{J}\right) \tag{15}$$

$$\delta = 0.409\sin\left(\frac{2\pi}{365} \times \mathrm{J} - 1.39\right) \tag{16}$$

$$\omega_{\mathrm{s}} = \arccos[-\tan(\phi) \times \tan(\delta)] \tag{17}$$

Net Rnl is determined using Equation 18.

$$\mathrm{Rnl} = \sigma\left[\frac{\mathrm{T_{max\,K}}4 + \mathrm{T_{min\,K}}4}{2}\right]\left(0.34 - 0.14\sqrt{\mathrm{e_a}}\right)$$
$$\left(1.35\frac{\mathrm{Rs}}{\mathrm{Rso}} - 0.35\right), \tag{18}$$

where σ is the Stefan-Boltzmann constant (4.903 × 10^{-9} MJ K^{-4} m^{-2} day^{-1}), TmaxK is the absolute maximum temperature during the 24-h period (K = °C + 273.16), $\mathrm{T_{minK}}$ is the absolute minimum temperature during the 24 h (K = °C + 273.16), and Rso is the clear sky radiation (MJ m^{-2} day^{-1}), calculated using Equation 19.

$$\mathrm{Rso} = 0.75 \times \mathrm{Ra}, \tag{19}$$

The method developed by Hargreaves and Samani (1985) (Equation 20) considers the maximum, minimum, and average air temperature, as well as the solar radiation received at the Earth's upper atmosphere.

$$\mathrm{ETo} = (\mathrm{Tmed} + 17.8)\ 9.38 \times 10^{-4} \times \mathrm{Ra} \times (\mathrm{Tmax} - \mathrm{Tmin})^{0.5}, \qquad (20)$$

where Tmed is the average temperature of the day (°C) and Ra is the radiation at the Earth's upper atmosphere (MJ m^{-2} day^{-1}), calculated using Equation 14.

Once the ETo value has been defined, ETc is calculated using Equation 21.

$$\mathrm{ETc} = \mathrm{ETo} \times \mathrm{Kc} \times \mathrm{Kl}, \qquad (21)$$

where Kc is the crop coefficient and Kl is the location coefficient, which represents the area that contributes to ETo in localized irrigation. For conventional sprinklers, center pivot systems, and micro-sprinkler irrigation systems with overlapping wet areas, the location coefficient is unitary. For other systems and configurations, Kl calculations are performed using the methods reported by Keller (1978) (equation 22) or Fereres (1981) (Equations 23–25), as described by Bernardo et al. (2019).

The Keller (1978) method is used for more dense crops and the Fereres (1981) method is used for less dense crops. To differentiate use of the model in the application, a plant area greater than 10 m was considered for less dense crops and less than or equal to 10 for more dense crops.

$$\mathrm{Kl} = 0.01 \times \mathrm{P} + 0.15 \times (1 - 0.01 \times \mathrm{P}) \qquad (22)$$

$$\mathrm{Kl} = 1 \qquad (23)$$

$$\mathrm{Kl} = 0.0109 \times \mathrm{P} + 0.30 \qquad (24)$$

$$\mathrm{Kl} = 0.0194 \times \mathrm{P} + 0.10 \qquad (25)$$

For the Fereres (1981) method, Equation 23 is used when P is greater than or equal to 65%; if P is greater than 20% and less than 65%, Equation 24 is used. When P is less than or equal to 20%, Equation 25 is used. In both cases, P corresponds to the percentage of the shaded area (PS) or percentage of the wet area (PM), with the higher value being adopted. To calculate P, Equations 26 and 27 are used, as described by Cotrim et al. (2019).

$$\mathrm{PS} = \frac{78 \times \mathrm{Dc}^2}{\mathrm{Ep} \times \mathrm{Ef}} \qquad (26)$$

$$\mathrm{PM} = \frac{78 \times \mathrm{n} \times \mathrm{Dm}^2}{\mathrm{Ep} \times \mathrm{Ef}}, \qquad (27)$$

where, Dc is the diameter of the canopy (m), Dm is the diameter of the wet bulb (m) of the emitter, n is the number of emitters, Ef is the spacing between rows (m), and Ep is the spacing between plants (m).

For continuous wet conditions, PS and PM are obtained using Equations 28 and 29, respectively, according to Santos and Silva (2020).

$$\mathrm{PS} = \frac{\mathrm{Lfs}}{\mathrm{Ef}} \times 100 \qquad (28)$$

$$\mathrm{PM} = \frac{\mathrm{Lfm}}{\mathrm{Ef}} \times 100, \qquad (29)$$

where Lfs and Lfm are the widths of the shaded and wet strips, respectively.

To determine Kc, the application will have the option of entering the value manually. Therefore, the irrigator must know or research the Kc values for each crop or stage of plant development, considering the water requirements of each plant species.

The irrigation time in hours and minutes for micro-sprinkler conditions per plant is obtained from Equation 30, whereas for overlapping wet areas and continuous wet strips, the irrigation time is obtained from Equation 31, according to Santos and Brito (2016).

$$\mathrm{Ti} = \frac{\mathrm{LB} \times \mathrm{Ep} \times \mathrm{Ef}}{\mathrm{n} \times \mathrm{q}} \tag{30}$$

$$\mathrm{Ti} = \frac{\mathrm{LB} \times \mathrm{Em} \times \mathrm{El}}{\mathrm{q}}, \tag{31}$$

where LB is the irrigation gross depth (mm) obtained from equation 32 (Bernardo et al., 2019), Ep is the spacing between plants (m), Ef is the spacing between rows (m), n is the number of emitters per plant and q is the emitter flow rate (L h^{-1}), Em is the spacing between micro-sprinkler (m) and El is is the spacing between laterals.

$$\mathrm{LB} = \frac{\mathrm{ETc}}{\mathrm{Ea}}, \tag{32}$$

where Ea is the application efficiency (decimal).

For conventional sprinklers, the irrigation time is calculated using Equation 33, according to Bernardo et al. (2019).

$$\mathrm{Ti} = \frac{\mathrm{LB}}{\mathrm{IA}}, \tag{33}$$

where IA (mm h^{-1}) is the application intensity; this value is entered or calculated using Equation 34.

$$\mathrm{IA} = \frac{\mathrm{q}}{\mathrm{Eas} \times \mathrm{El}}, \tag{34}$$

where q is the flow rate (L h-1), Eas is the spacing between sprinklers (m), and El is the spacing between laterals (m).

For drip irrigation, Equation 35 is used for the dripper per plant condition, and Equation 36 is used for the drip irrigation condition in a continuous wetted strip, according to Santos and Brito (2016).

$$\mathrm{Ti} = \frac{\mathrm{ETc} \times \mathrm{Ef} \times \mathrm{Ep} \times \mathrm{Kl}}{\mathrm{n} \times \mathrm{q} \times \mathrm{Ea}} \tag{35}$$

$$\mathrm{Ti} = \frac{\mathrm{LB} \times \mathrm{Eg} \times \mathrm{El}}{\mathrm{q}}, \tag{36}$$

where Eg is the spacing between drippers.

For the center pivot condition, the percentimeter value (%) (Mantovani et al., 2009) is obtained from Equation 37.

$$\% = \frac{\mathrm{LAM}_{100} \times 100}{\mathrm{LB}}, \tag{37}$$

where LAM100 is the irrigation depth applied by the center pivot at 100% speed.

When the irrigation gross depth is less than the LAM100, the application indicates DO NOT IRRIGATE, so the irrigator must add the ETo of the previous day with the current one or integrate the ETo on the corresponding days and enter this value in the application.

As a validation process, a study was conducted to compare the values obtained from the application with those obtained from a spreadsheet, using real-world examples found in irrigators' routine.

Results and Discussions

Figure 2a shows the homepage of the application, which displays the options for performing irrigation management calculations (NEW CALCULATION), checking saved calculations, user information, and information about the application. The user information option provides a PDF file with information and illustrations regarding the settings of the irrigation system, thereby assisting irrigators in selecting the most suitable management approach.

Dados de Localização

Insira os dados abaixo:

Latitude (°)
-14.2103418

Altitude (m)
535

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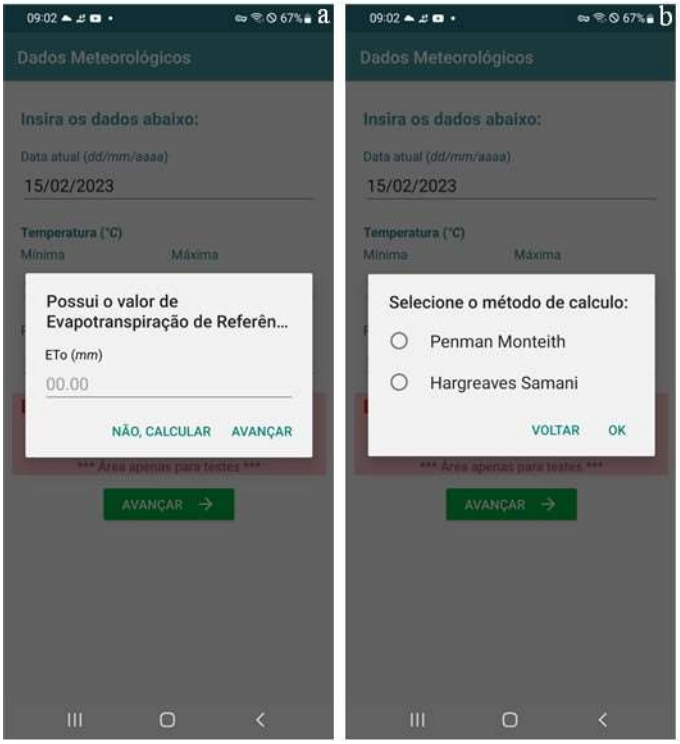
Figure 2. QIrriga home screen (a) and tab for entering QIrriga location data (b).

In the new calculation option, the geographic location data, latitude in degrees, and altitude in meters must be entered. However, the application provides an option to search for the location using the phone's GPS on the second tab, as shown in Figure 2b. The latitude for the region in the southern hemisphere is negative, whereas this value is positive in the northern hemisphere. Brazil is located almost entirely in the southern hemisphere, with only part of the northern region of Brazil in the northern hemisphere.

After entering the location data, there is the option to save the information for future calculations; clicking on next directs to the next tab for meteorological data (Figure 3). On this tab, there is an option to enter the reference evapotranspiration (ETo) value (Figure 3a); if this value is not available, the 'Calculate' option can be used to choose the ETo calculation method, either Penman–Monteith or Hargreaves and Samani (Figure 3b).

Once the ETo calculation model has been chosen, the user proceeds to the tab on which the date and values of the meteorological variables can be entered (Figure 4).



Insira os dados abaixo:

Data atual (dd/mm/aaaa)
15/02/2023

Temperatura (°C)
Mínima
Máxima

Possui o valor de Evapotranspiração de Referên...

ETo (mm)
00.00

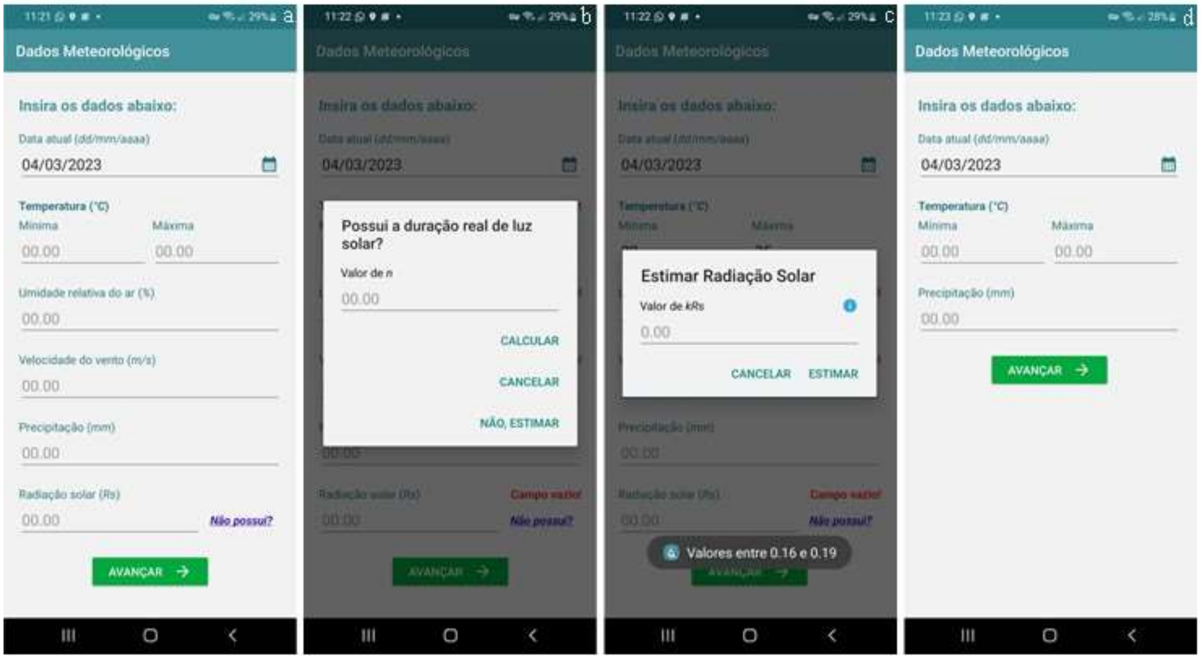
Selecione o método de calculo:

○ Penman Monteith

○ Hargreaves Samani

*** Área apenas para testes ***

Figure 3. Tab for entering the reference evapotranspiration (ETo) value (a) and choosing the ETo determination method (b).



Insira os dados abaixo:

Data atual (dd/mm/aaaa)
04/03/2023

Temperatura (°C)
Mínima 00.00
Máxima 00.00

Umidade relativa do ar (%)
00.00

Velocidade do vento (m/s)
00.00

Precipitação (mm)
00.00

Radiação solar (Rs)
00.00
Não possui?

Campo vazio!

Possui a duração real de luz solar?

Valor de *n*
00.00

Estimar Radiação Solar

Valor de *k*Rs
0.00

Valores entre 0.16 e 0.19

Figure 4. Tab for entering data on climate elements (a), actual sunshine duration (b), and the kRs constant (c) for the Penman–Monteith method and for entering information for the Hargreaves-Samani method (d).

QIrriga always provides the current date, but the user can enter any date. Depending on the method, the user must include the following meteorological data: maximum and minimum air temperatures (°C), relative humidity (%), wind speed (m s^{-1}), rainfall (mm), and solar radiation (MJ m^{-2} day^{-1}) (Figure 4a). If solar radiation data are unavailable, the actual sunshine duration of the day can be entered (Figure 4b). If neither of these data points are known, the application estimates solar radiation using the Hargreaves method (Allen et al., 1998); however, the value of the kRs constant, which varies from 0.16 to 0.19 (Figure 4c) must be entered. The value is 0.16 for inland locations and 0.19 for coastal regions. When using the Hargreaves and Samani method (Figure 4d), users are only required to input the minimum and maximum temperatures, along with the corresponding rainfall when it occurs.

After inputting the climate information, the next step is to select the irrigation system (Figure 5a). The following systems are available: micro-sprinkler, which can be per plant, overlapping wet area, and continuous wet strip (Figure 5b); conventional sprinkler; drip in the configuration of drip per plant and continuous wet strip (Figure 5c); and center pivot. These systems are provided because they are the main systems used in semi-arid regions, where precision in irrigation management is prioritized.

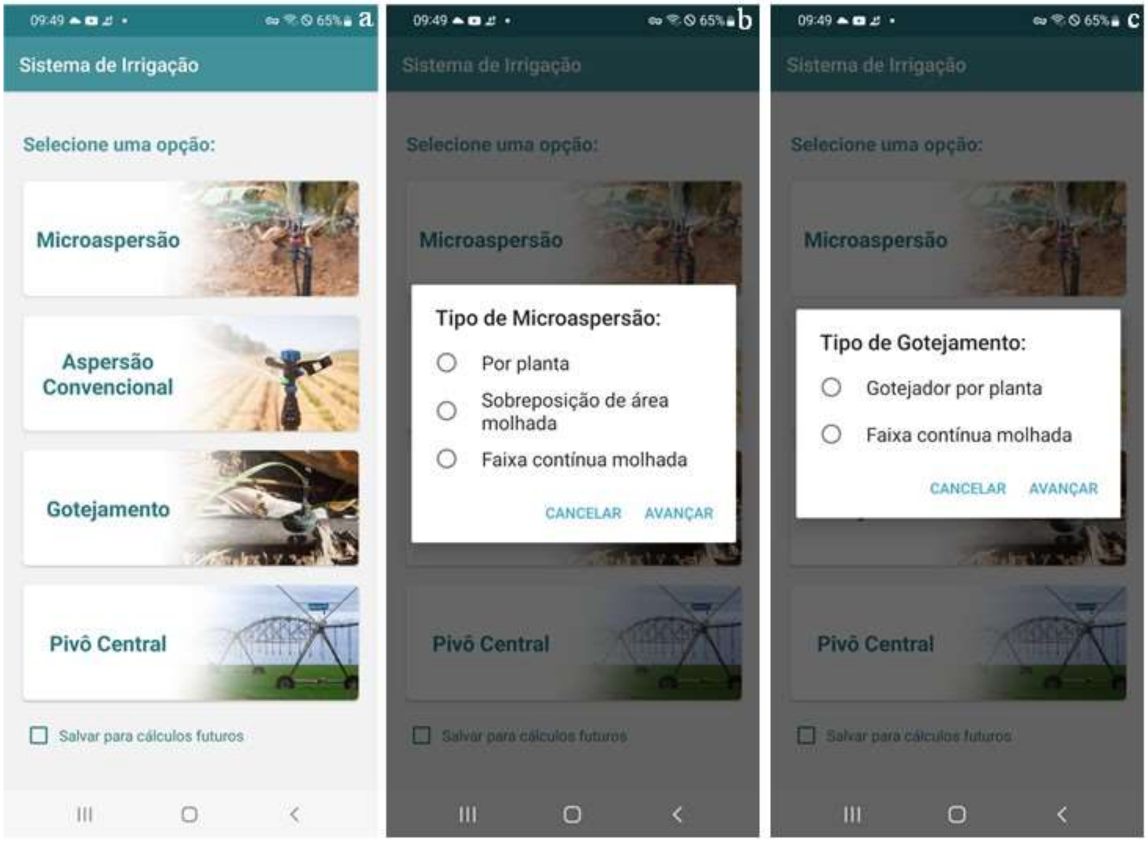
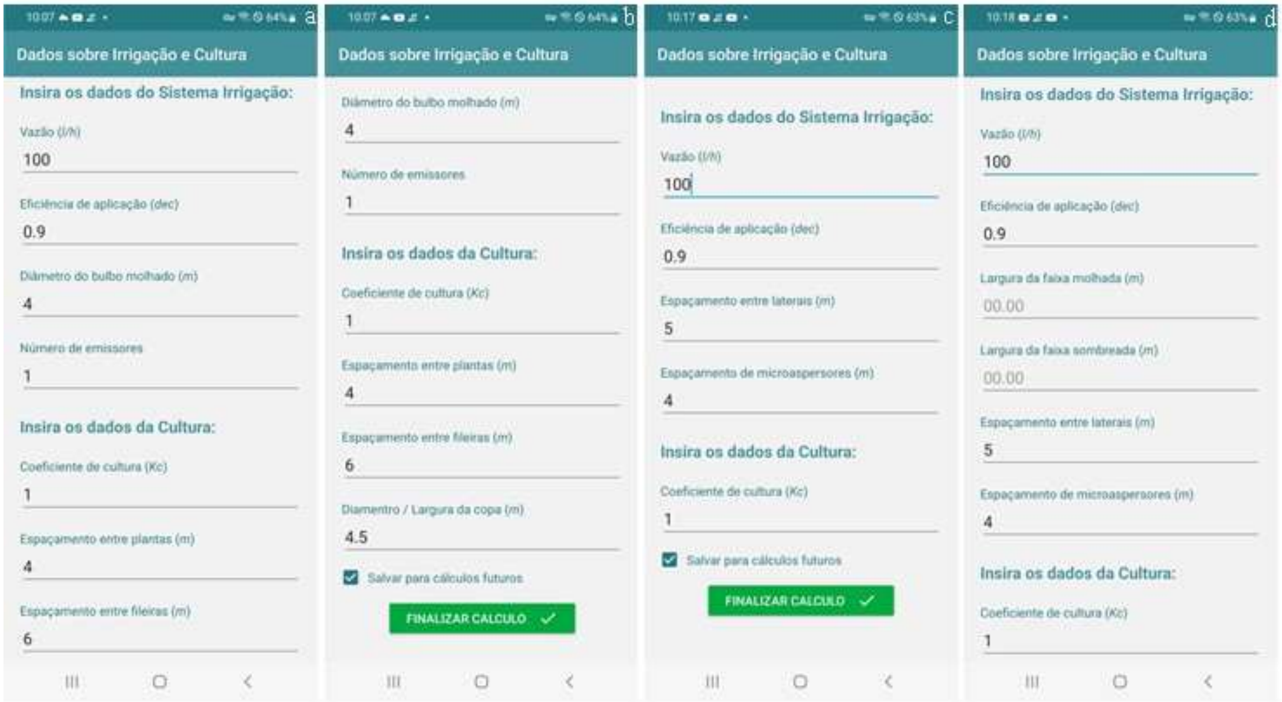


Figure 5. Tab for choosing irrigation systems (a), micro-sprinkler system configurations (b), and drip system configurations (c).

Once the irrigation system and/or configuration is selected, the next step involves inputting the pertinent information related to the selected irrigation system, including the flow rate, application efficiency, emitter spacing, lateral spacing, wet bulb diameter or wetted strip width, application intensity, and number of emitters per plant. This information may vary depending on the system chosen.

For application efficiency, the application does not perform the calculation; for greater precision, this value should be obtained according to Bernardo et al. (2019) and Mantovani et al. (2009). In the same tab, crop data are entered, such as plant spacing, row spacing, canopy diameter or width of the shaded strip, and Kc. Depending on the crop, the irrigator must look up the Kc for the specific crop to be irrigated in the region and for the stage of development.

For micro-sprinklers, when selecting micro-sprinklers per plant (Figures 6a, 6b), the data required are the flow rate, application efficiency, wet bulb diameter, number of emitters per plant, Kc, plant spacing, plant row spacing, and crown diameter or width. Micro-sprinkler and drip irrigation systems offer high application efficiency.



a

Insira os dados do Sistema Irrigação:
Vazão (l/h): 100
Eficiência de aplicação (dec): 0.9
Diâmetro do bulbo molhado (m): 4
Número de emissores: 1

Insira os dados da Cultura:
Coeficiente de cultura (Kc): 1
Espaçamento entre plantas (m): 4
Espaçamento entre fileiras (m): 6

b

Diâmetro do bulbo molhado (m): 4
Número de emissores: 1

Insira os dados da Cultura:
Coeficiente de cultura (Kc): 1
Espaçamento entre plantas (m): 4
Espaçamento entre fileiras (m): 6
Diamentro / Largura da copa (m): 4.5
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c

Insira os dados do Sistema Irrigação:
Vazão (l/h): 100
Eficiência de aplicação (dec): 0.9
Espaçamento entre laterais (m): 5
Espaçamento de microaspersores (m): 4

Insira os dados da Cultura:
Coeficiente de cultura (Kc): 1
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d

Insira os dados do Sistema Irrigação:
Vazão (l/h): 100
Eficiência de aplicação (dec): 0.9
Largura da faixa molhada (m): 00.00
Largura da faixa sombreada (m): 00.00
Espaçamento entre laterais (m): 5
Espaçamento de microaspersores (m): 4

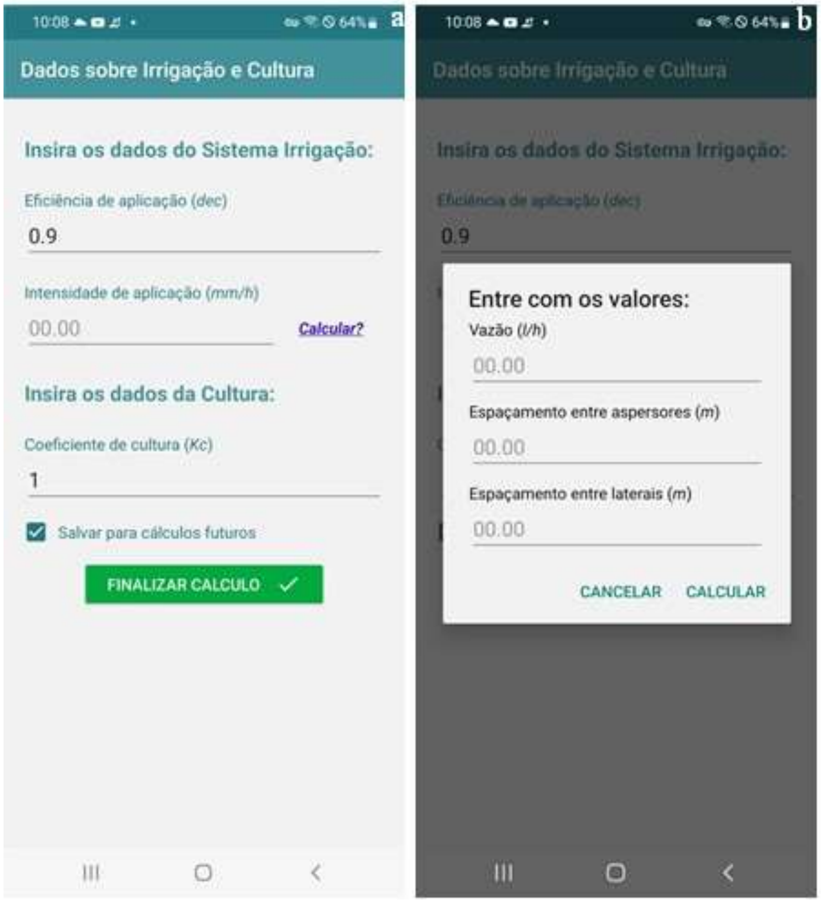
Insira os dados da Cultura:
Coeficiente de cultura (Kc): 1

Figure 6. Insertion of irrigation system and crop data for the micro-sprinkler per plant condition (a and b). Micro-sprinkler with overlapping wetted area (c) and micro-sprinkler with continuous wetted strip (c).

For micro-sprinkling with an overlapping wetted area (Figure 6c), the data required are the flow rate, application efficiency, lateral spacing, micro-sprinkler spacing, and Kc. For micro-sprinkling in a continuous wetted strip (Figure 6d), the data required are the flow rate, application efficiency, wetted strip width, shaded strip width, lateral spacing, micro-sprinkler spacing, and Kc.

For the conventional sprinkler system, it is necessary to enter the application efficiency, application intensity, and Kc (Figure 7a). When the application intensity is not available, it is necessary to calculate this value (Figure 7b) based on the flow rate and spacing between sprinklers. In addition to annual crops, conventional sprinkling is used for most crops.

For drip irrigation, when selecting drip per plant (Figures 8a and 8b), the data required are the flow rate, application efficiency, wet bulb diameter, number of emitters per plant, Kc, plant spacing, plant row spacing and canopy diameter or width. For dripping in a continuous wetted strip (Figure 8c), the data required are the flow rate, application efficiency, wetted strip width, shaded strip width, lateral spacing, dripper spacing, and Kc.



Dados sobre Irrigação e Cultura

Insira os dados do Sistema Irrigação:

Eficiência de aplicação (dec)
0.9

Intensidade de aplicação (mm/h)
00.00

Insira os dados da Cultura:

Coeficiente de cultura (Kc)
1

☑ Salvar para cálculos futuros

Entre com os valores:

Vazão (l/h)
00.00

Espaçamento entre aspersores (m)
00.00

Espaçamento entre laterais (m)
00.00

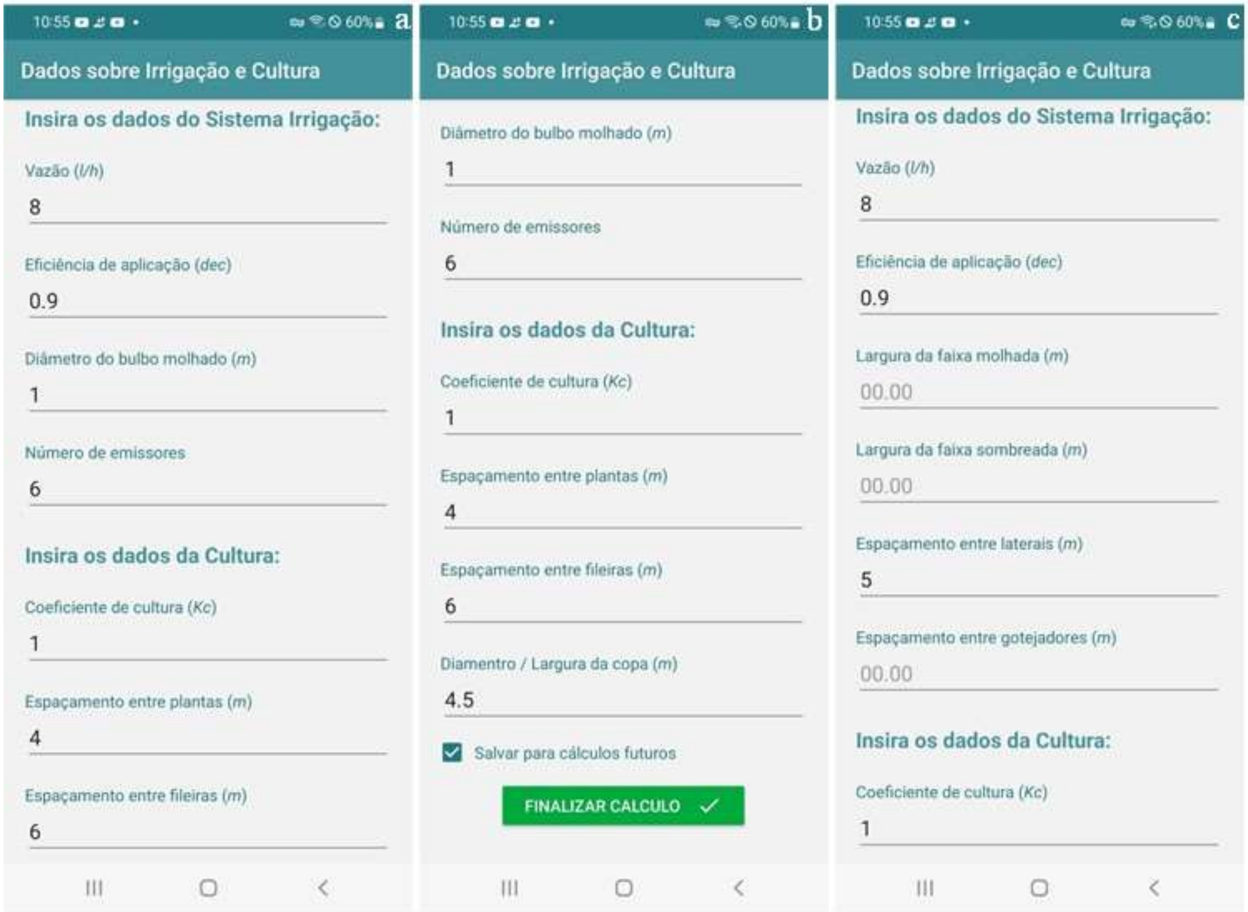
Figure 7. Entering data from the conventional sprinkler irrigation system and crop (a) and data for calculating the application intensity (b).

For the center pivot system (Figure 9a), it is necessary to insert the application efficiency, pivot irrigation depth at 100% of the rotation speed, and Kc.

The last tab shows the results (Figure 9b), which include the ETo, Kc, location coefficient, crop evapotranspiration, irrigation gross depth, and irrigation time and/or value in the per centimeter in the case of the center pivot. There are options to save or share the calculations and return to the home page.

As a validation process, a study was conducted to compare the values obtained from the application with those obtained from a spreadsheet, using real-world examples found in irrigators' routine. In all comparisons, the values obtained using the application and spreadsheet were the same. Thus, the QIrriga application is advantageous, as all irrigators have a cell phone and can perform the entire operation on their own property.

The QIrriga application has been registered with the National Institute of Intellectual Property under Process no: BR512023001089-8 and published in the Google Play Store with free access.



a

Dados sobre Irrigação e Cultura

Insira os dados do Sistema Irrigação:

Vazão (l/h)
8

Eficiência de aplicação (dec)
0.9

Diâmetro do bulbo molhado (m)
1

Número de emissores
6

Insira os dados da Cultura:

Coeficiente de cultura (Kc)
1

Espaçamento entre plantas (m)
4

Espaçamento entre fileiras (m)
6

b

Dados sobre Irrigação e Cultura

Diâmetro do bulbo molhado (m)
1

Número de emissores
6

Insira os dados da Cultura:

Coeficiente de cultura (Kc)
1

Espaçamento entre plantas (m)
4

Espaçamento entre fileiras (m)
6

Diamentro / Largura da copa (m)
4.5

☑ Salvar para cálculos futuros

c

Dados sobre Irrigação e Cultura

Insira os dados do Sistema Irrigação:

Vazão (l/h)
8

Eficiência de aplicação (dec)
0.9

Largura da faixa molhada (m)
00.00

Largura da faixa sombreada (m)
00.00

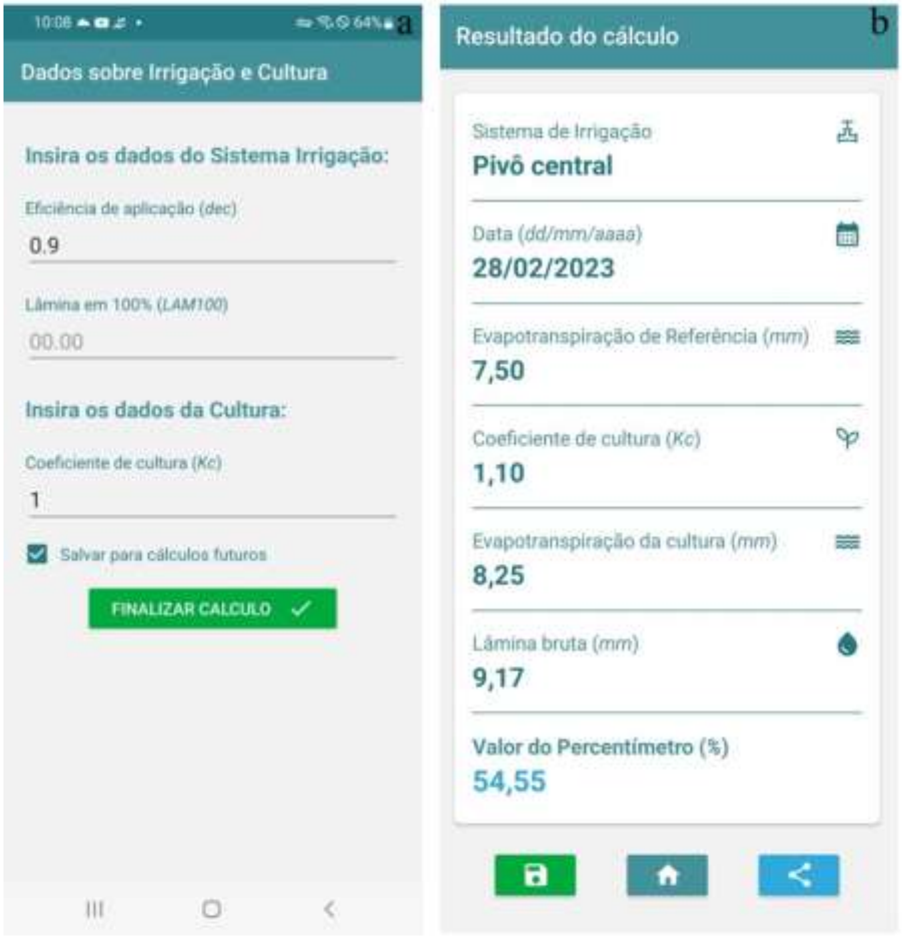
Espaçamento entre laterais (m)
5

Espaçamento entre gotejadores (m)
00.00

Insira os dados da Cultura:

Coeficiente de cultura (Kc)
1

Figure 8. Insertion of irrigation system and crop data for the dripper per plant condition (a and b) and drip with continuous wetted strip (c).



Dados sobre Irrigação e Cultura

Insira os dados do Sistema Irrigação:

Eficiência de aplicação (dec): 0.9

Lâmina em 100% (LAM100): 00.00

Insira os dados da Cultura:

Coeficiente de cultura (Kc): 1

☑ Salvar para cálculos futuros

Resultado do cálculo

Sistema de Irrigação: Pivô central

Data (dd/mm/aaaa): 28/02/2023

Evapotranspiração de Referência (mm): 7,50

Coeficiente de cultura (Kc): 1,10

Evapotranspiração da cultura (mm): 8,25

Lâmina bruta (mm): 9,17

Valor do Percentímetro (%): 54,55

Figure 9. Data entry tab for the center pivot condition (a) and results tab for the center pivot irrigation system (b).

Conclusions

The application developed in this study is designed for the management of evaluated irrigation systems. Its intuitive interface is tailored to meet the needs of irrigators, providing a simplified irrigation process compared to other manual methods for calculating irrigation times.

QIrriga accurately determines the reference and crop evapotranspiration, location coefficient, irrigation gross depth, irrigation time for different configurations of localized irrigation, conventional sprinkling, and per centimeter value in the center pivot.

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