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Software application for calculating solar radiation and equivalent evaporation in mobile devices

Bueno Delgado[a,*], Madrid Paredes[b], Molina Martínez[c]

[a] Telecomunication Networks Engineering Group, Universidad Politécnica de Cartagena, Campus Muralla del Mar, Edif. Antigones 30202, Cartagena, Spain
[b] Center of Technologies and Information System, Universidad Politécnica de Cartagena, Campus Muralla del Mar, Edif. I+D +I 30202, Cartagena, Spain
[c] Agromotic and Sea Engineering Group, Universidad Politécnica de Cartagena, Campus Alfonso XIII, ETSIA 30203, Cartagena, Spain

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ABSTRACT

In the agriculture sector, some tasks such as to estimate the water needs of the crops, to validate the data supplied by agricultural weather stations, or to decide the best place for solar water heating systems, photovoltaic panels, etc., involve the use of real data about the extraterrestrial solar radiation or the equivalent radiation and evaporation of the place of interest. These parameters are calculated making use of the geographic position of the place under study. Last generation of mobile phones, the so-called *smartphones*, and other mobile devices, such us tablets, are endowed with the Global Positioning System tool, which permits the geographic position with just a click. A software application that makes use of this tool could be used to calculate those parameters in-situ, improving the way in which the farmers and agricultural technicians work today. This paper presents a powerful software application for mobile devices that calculates, stores, and sends to others, those parameters related with the position and relative distance sun-earth: the extraterrestrial solar radiation, incident radiation on earth, number of hours of sun, equivalent evaporation, etc. This new tool is an improved version of RaGPS, a software application developed in a previous work for mobile devices with Windows Operating System. The application presented in this paper is executed in Android Operating System, compatible with Android 2.3 and latest versions. It has remarkable details like elements in the screen designed to be compatible with tablets and other mobile devices; new methods for detecting and adding coordinates, through Google Maps tool; the height of a coordinate obtained by a web service; graphics included for increasing application usability, options to send the information of interest, not only using text messages, but also via Bluetooth, e-mail, social networks, etc.

1. Introduction

In recent years, the use of the Information and Communication Technologies (ICTs) has increased in the agriculture and food sector (Quinn, 2011). Many examples are found in the scientific literature: wireless sensor networks used to monitor farms, irrigated areas or weather conditions (Wang et al., 2006; Nolz et al., 2013); new hardware and software developments to automate and control agricultural facilities (Voulodimos et al., 2010), etc. The evolution and penetration of mobile devices has also led to the development of many mobile applications for agriculture (Molina-Martínez and Ruiz-Canales, 2009; Jonoski et al., 2012; Fuentes et al., 2012; Wei et al., 2014; Bueno-Delgado et al., 2014). On the one hand, last generation of mobile phones (so-called smartphones) are small computers with a high computing power, and the hardware with which they are endowed is similar to a desktop PC; on the other hand, the number of smartphones in use worldwide has now broken the 1 billion mark (IDC Corp, in press). With this technological scenario it is easy to think of farmers and agriculture technicians working with their mobile devices for addressing many agriculture tasks and executing applications for calculating, with just a couple of clicks, parameters of interest that permit them to take decisions, saving time and money. For example, the approximation of the free water surface evaporation in dams or lakes, the estimation of the water needs of the crops, the validation of the data supplied by agricultural weather stations, or the measurements of the solar radiation for installing solar water heating systems, etc., are tasks that, until recently, were done crudely. First, the technician had to take the coordinates of the place under study. After that, using a desktop PC and taking some bibliographic resources (Allen et al., 1998), the technician had to calculate those parameters needed for taking decisions regarding these tasks: the

* Corresponding author. Tel.: +34 968 326 505; fax: +32 968 325 973.
E-mail address: mvictoria.bueno@upct.es (B. Delgado).

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earth-sun relative distance, the extraterrestrial solar radiation, the incident radiation on earth, the number of hours of sun, the equivalent evaporation, etc. Since one decade ago, new techniques have been proposed for improving the way the above parameters are obtained. For instance, in order to evaluate the equivalent evaporation of a place of interest, many researchers propose the use of satellite-based communications, processing of satellite images, sensor networks and algorithms, etc. (Trezza, 2006; McCabe and Wood, 2006; Allen et al., 2007, Folles et al., 2009; Mateos et al., 2013). Most of the techniques involve the use of sophisticated systems, and are beyond the reach of many farmers and agricultural technicians. Therefore, in this work we have developed a mobile application that permits farmers and technicians to calculate with their smartphone the geographic position, the extraterrestrial solar radiation, and the equivalent radiation and evaporation of a place under study, offering an easy and powerful software tool for the agriculture field.

The application is able to extracts the coordinates by different methods: making use of a Global Positioning System (GPS), because almost all smartphones and tablets in the market are endowed with it, or using Google Maps tool, also considering that nowadays almost all mobile devices have Internet access. Once the coordinates are captured, the parameters of interest are computed and can be loaded in the application data base, or sent by e-mail, SMS, social networks, Bluetooth, etc.

The application developed in this work is an enhanced version of a previous one, described by the authors in (Molina-Martinez et al., 2011). It was implemented for mobile devices running Windows Mobile Operating System (OS). There are several improvements in the new application over the existing one, but the most remarkable is the OS. This new software has been developed in Android OS which is freely available, stable, with free libraries and development environments to design all kinds of applications. Another reason to choose Android as the OS is the degree of market penetration. In 2013, the Android Operating System dominated new smartphones sold worldwide and is forecasted to remain so till 2017 (IDC Corp, in press). Furthermore, the application is compatible with version 2.3 and higher, including the latest available 4.4. The remaining improvements implemented are highlighted throughout the work.

The paper is organized as follows: in Section 2 the formulation used to obtain the data of interest is analyzed. Section 3 describes the software application and Section 4 its validation. Finally, Section 5 summarizes the conclusions.

2. Parameters formulation

The theoretical base of the formulas used in this application is described in this section. Note that, for example, if the water needs of the crops must be estimated, it is necessary to consider, among others, the determination of the free water surface evaporation and the extraterrestrial radiation values. Hence, in the next subsections we analyze the solar, the clear-sky solar, and the extraterrestrial solar radiation as well as the equivalent evaporation, following the guidelines for computing crop water requirements described by FAO (Allen et al., 1998). These guidelines have been widely applied by the researcher community in agriculture.

2.1. Extraterrestrial solar radiation

The extraterrestrial solar radiation determines the solar radiation received at the top of the Earth's atmosphere on a horizontal surface. For each day of the year, it can be determined by the following formula:

$$R_a = \frac{24 \cdot 60}{\pi} G_{sc} d_r [\omega_s \sin(\phi) \sin(d_s) + \sin(\omega_s) \cos(\phi) \cos(d_s)] \quad (1)$$

where, R_a is measured in $MJ\,m^{-2}\,day^{-1}$. φ is the latitude, measured in radians (rad), being positive for the northern Hemisphere and negative for the southern Hemisphere. $G_{sc} = 0.0820$ $MJ\,m^{-2}\,min^{-1}$ is the solar constant. d_r is the Earth–Sun inverse relative distance (rad), which is given by:

$$d_r = 1 + 0.333 \cos\left(\frac{2\pi}{365} J\right) \quad (2)$$

where J the so-called Julian day, the day-of-year number, between 1 (January 1st) and 365 or 366. (December 31st).

R_a also depends on ω_s, which is the sunset hour angle (rad) and d_s which is the solar declination (rad), both calculated as follows:

$$\omega_s = \mathrm{ar}\cos[-\tan(\phi)\tan(d_s)] \quad (3)$$

$$d_s = 0.409 \sin\left(\frac{2\pi}{365} J - 1.39\right) \quad (4)$$

For hourly or shorter periods, extraterrestrial solar radiation is denoted as R_{ah} and is calculated with a formulation similar to the day-to-day period:

$$R_{ah} = \frac{12 \cdot 60}{\pi} G_{sc} d_r [(\omega_2 - \omega_1) \sin(\phi) \sin(d_s) + (\sin(\omega_2) - \sin(\omega_1)) \cos(\phi) \cos(d_s)] \quad (5)$$

where R_{ah} is measured in $MJ\,m^{-2}\,h^{-1}$. ω_1 and ω_2 are the solar time angles (rad) at the beginning and the end of the period respectively. They are calculated as follows:

$$\omega_1 = \omega - \frac{\pi t_1}{24} \quad (6)$$

$$\omega_2 = \omega + \frac{\pi t_1}{24} \quad (7)$$

where, t_1 the calculation period, is measured in hours. That is, 1 for hourly period, 0.5 for a 30 min period, etc. ω is the solar time angle at midpoint of hourly period (rad), which is given by:

$$\omega = \frac{\pi}{12} [t + 0.06667(L_z - L_m) + S_c - 12] \quad (8)$$

where, t is the standard clock time (hour) at the midpoint of the period. That is, for a period between 17:00 and 18:00, $t = 17.5$. L_z is the longitude of the center of the local time (degrees west of Greenwich), L_m is the longitude of the measurement site (degrees west of Greenwich), and S_c is used to describe the seasonal correction for solar time, by means of the following equation:

$$S_c = 0.1645 \sin(2b) - 0.1255 \cos(b) - 0.025 \sin(b) \quad (9)$$

where, b is given by:

$$b = \frac{2\pi(J - 81)}{364} \quad (10)$$

Note that R_{ah} and R_a is 0 if $\omega < -ar\cos[-\tan(\varphi) \times \tan(d_s)]$ or $\omega > ar\cos[-\tan(\varphi) \times \tan(d_s)]$ because the sun is below the horizon.

2.2. Solar radiation

Solar radiation (R_s) can be calculated day-to-day through the following formula:

$$R_s = R_a \left(a_s + b_s \frac{n}{N}\right) \quad (11)$$