Hybrid Mobile Prototype for Evapotranspiration Calculation Using Raspberry Pi

Adriana Karla de Souza Santana
karlasantana22am@gmail.com
Centro Universitário Metropolitano de Manaus – FAMETRO

Elilson Leal de Araújo
elilson.araujjo@gmail.com
Centro Universitário Metropolitano de Manaus – FAMETRO

Waldeck Matheus de Oliveira Lins Belo
waldeckmatheus@gmail.com
Centro Universitário Metropolitano de Manaus – FAMETRO

Bruno Pereira Gonçalves (Advisor)
goncalves.bruno@gmail.com
Centro Universitário Metropolitano de Manaus – FAMETRO

Jean Mark Lobo de Oliveira
jeanlobolive@gmail.com
Centro Universitário Metropolitano de Manaus – FAMETRO

Rilmar Pereira Gomes
rilmargomes@hotmail.com
Centro Universitário Metropolitano de Manaus – FAMETRO

David Barbosa de Alencar
david002870@hotmail.com
Instituto de Tecnologia e educação Galileo da Amazônia ITEGAM - Brasil

Abstract

The hybrid mobile prototype proposes to assist the farmer in obtaining crop evapotranspiration data reducing the effort in calculating them. In warm weather places, it is of the fundamental importance to verify a prototype for the calculation of evapotranspiration, thus favoring sustainable irrigation. To show this important discussion, a study was conducted highlighting the advantages of using the methods for calculating evapotranspiration cited by Hargreaves Samani and the Penman Monteith method. There is the need to use tools that automate the evaporation method, being able to access them on mobile devices *with Android and iOS systems, and also notebook, bringing advantages and relevant contributions to the scientific community and potential users. The benefits of using automated irrigation can serve as basis for more conscious and sustainable decision making.*

Keywords: Evapotranspiration; Prototype; Hybrid; Calculation, Irrigation.

1. Introduction

The damages caused by the few irrigations or its exaggeration are enormous, negatively affecting the farmer and mainly impeding the growth of the crop. The use of water in excess besides to cause the proliferation of fungi that cause diseases in the soil, also raises the water table saturating the soil and preventing the action of nutrients, causing high costs for the farmer, who may need to drain the soil. It can also result in waste of fertilizers, which are run off by water get in the roots reaching the level of river source. All these losses, which are directly linked to farmers, increase production costs, energy and water consumption [1].

The lack of manipulation of the environment to control meteorological indicators in the estimation of crop water calculation has made it difficult to handle irrigation, especially in farmers' families with small farms. Farmers do not have the financial capital to invest in a place equipped with electronic sensors to gather data for measurement and storage of environmental variables. The installation of a professional weather station has a high cost, as well as complex operation of equipment, making it impossible for small producers to acquire [1]. There is a limitation of existing software models to improve the calculation of evapotranspiration and consequently the irrigation. Calculating evapotranspiration to know how much water should be used to irrigate requires manual effort. It occurs because there are two simultaneous water outlets, one from the ground and one from the plant [2].

It is important to verify the need for proper irrigation to avoid damage to the environment and financial losses to the producers. Irrigation is an essential factor for the cultivation of all kinds of agricultural production. An important alternative for controlling a crop's water expenditure is the sustainable irrigation, which allows measuring the amount of water consumed according to the needs of each plant.

The knowledge of daily evapotranspiration rates is very useful for determining water needs in agriculture. Thus, evapotranspiration can be defined as the manner in which water on the earth's surface is transferred to the atmosphere in the form of gaseous particles. The portion of radiation that effectively crosses the clouds and reaches the surface is the main form of energy used in evapotranspiration [3].

It is noted the need of the creation of new software that collaborate for this purpose, reducing the manual effort to perform the calculation of evapotranspiration [2]. The irrigation activity calculation methods proposed by Hargreaves Samani and Penman Monteith are the basis for the creation of hybrid mobile prototypes with simple and user-friendly interface [1].

Given this scenario, we realized the importance of investing in research with alternative means to remedy the issues presented. This work aims to develop a hybrid device prototype with the proposal to assist in reducing the manual effort in the evapotranspiration calculation process, to obtain the water balance coefficient in the crop irrigation handling. Presenting its advantages and disadvantages during the process and how it is distinguished based on the Hargreaves Samani and Penman Monteih methods.

2. Materials and Methods

For the study of case, it was observed the families of small farmers, who have difficulty in proper handling of crop irrigation, however do not have the purchasing power to invest in obtaining equipment with electronic sensors to collect data for measurement and storage of the variables related to the environment [1]. From then on, the environment indicatives were controlled through the electronic sensor with a hybrid mobile device prototype, which has version for notebooks and mobile phones with Android and iOS systems, besides presenting a friendly and simple interface.

2.1 Prototype Javac

For this prototype Javac was used as compiler and a Raspberry Pi board, being this small and portable; We also used the baster version that acts as a file server with the following settings: a Quad Core 1.2, 64 bit, 1 gig ram, with Wi-Fi and Bluetooth connection; It has Ethernet Rj 45, 40 pin, for each pin an input/ output that can be used for a sensor, camera support and Etier balena software for writing to the memory card. The environment used for application development was the Windows 10 operating system, drive and write validation on the SSD itself. Raspbian is an operating system that functions as a Debian-based computer for Raspberry Pi [4].

Figure 1: Raspberry Pi board.
Source: Authors, (2019).

2.2 Prototype Raspberry

For the Raspberry Pi board, a thermal paste has been added to help reduce high processor temperatures. It is the constituent part that is between the heat sink and the processor, increasing the junction between these components, so that more efficient cooling can occurs [5].

Figure 2: Gloves, thermal paste, cotton swabs, heat sink and Raspberry Pi board.
Source: Authors, (2019).

2.3 Control the Environment

To control the environment data was used the humidity and air temperature sensor - DHT22, which makes measurements through 4 digital pins, having 5v supply voltage. It can measure air temperature between -40 and 125ºC. Later, with a friendlier image, this information is projected into an interface, so that the user can read it [6].

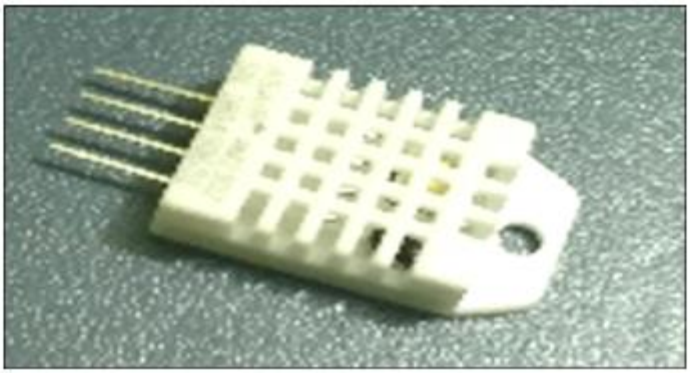


Figure 3: Humidity and air temperature sensor - DHT22.
Source: Authors, (2019).

2.4 Data Presented

Data were presented using a 7-inch Raspberry screen, Touch Pi2 LCD display with 1920x1080 resolution, HDMI, VGA support and AV video input. The screen can also be used as a computer monitor [7].

Figure 4: Presentation of the interface through the display.
Source: Authors, (2019).

Secondly, we applied the bibliographic researches that were performed through digital scientific articles, books and e-books to understand about proper irrigation. With the evapotranspiration calculation methods, it is able to reduce the complexity of obtaining the value of the water level that leaves and returns to the ground [1]. The main studies about development of mobile hybrid devices were analyzed, and a prototype hybrid mobile device was developed to control the indicators, which can be accessed through Android and iOS phones or notebooks. Finally, it displays the evapotranspiration calculation process based on the

Hargreaves Samani and Penman Monteith methods. Then, the results of the observations and the case study discussion were presented.

3. Theoretical Reference

Raspberry Pi is used to explore an alternative wireless communication platform, such as a server by connecting to the smartphone as a client on the same network. The work explored the following scenario: client-server communication using Wi-Fi. The Router is used to create a connection through the remote, wireless network file sharing environment between devices [4].

The prototype hybrid mobile device receives the variables of the main factors that control the evapotranspiration process, highlighting solar radiation, altitude, air temperature, wind speed, relative humidity, atmospheric pressure and rain precipitation [8]. The device is then able to store measurement data in software called MySQL workbench database. The choice of the software used in the development of the work was motivated by the excellent storage performance, its easy usability and because of the free distribution of the software [1].

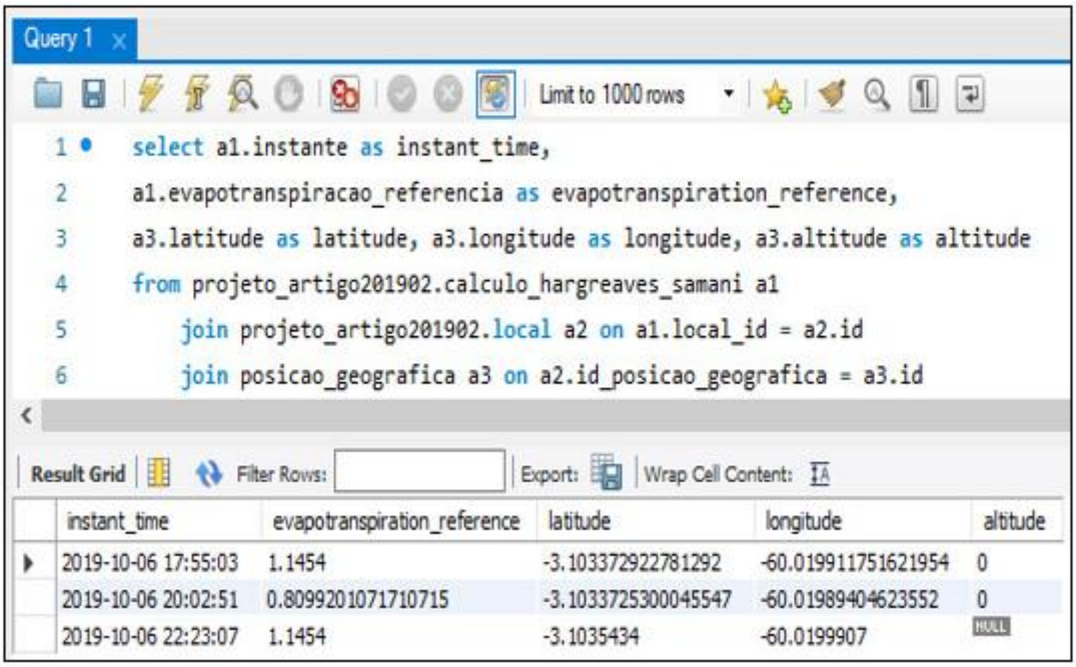


Figure 5: MySQL workbench database.
Source: Authors, (2019).

Regarding the functional qualities of the software, they are accessible to common users so that they can query the data, including filtering previous periods for data calculation [3].

These values are provided by the sensors or through data collected by INMET (National Institute of Meteorology of Brazil). After displaying the collected data, the device calculates these variables using the Hargreaves Samani and Penman Monteith methods and in turn displays the calculated value, which results in the evapotranspirated water level. From this result, the farmer will know the appropriate amount that he should irrigate the crop. To increase user convenience, the hybrid device prototype can be accessed from a computer or from a smartphone.

Hybrid devices have several advantages over pure native devices, especially in support. The platform reduces complexity, code size, development time, maintenance expense and requires less knowledge about API, as well as easier development and increased market share [9].

Figure 6: Preparing the machine to run the build for iOS.
Source: Authors, (2019).

The Ionic framework is for mobile application development in Html5, focused on hybrid development. Angular is a JavaScript framework, and it will be used by the Ionic framework. Angular 2 is a webpage script language developed by Google that has a code interpreted by the web browser. The Ionic framework was chosen for hybrid applications due to its free distribution, and because it is based on the Angular 2 framework. Apps that are developed with Ionic framework behave like native Apps, and they have support of various platforms as Android and iOS [9]. For the services layer, Java EE (Enterprise Edition) and Python language were used to communicate with the sensors. To develop the user's screen the Angular 2 was used. RESTful defines the quality of the architecture that makes applications communicate. Being obtained by the principles/ rules/ constraints that when observed allow the creation of a project with well-defined interfaces [10].

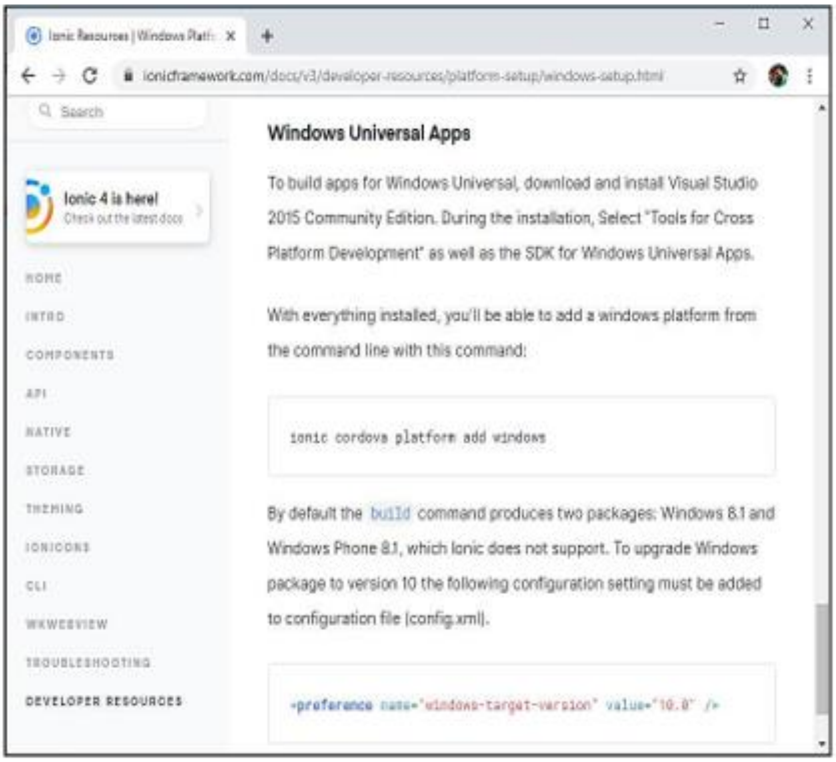


Figure 7: Build Windows documentation, Ionic Framework.
Source: Authors, (2019).

Microservices are small service modules that act independently. Even working together, each module is like a separate entity that can be run isolated of a service platform. There is an alternative to manipulating different internal technologies of each service and this is an advantage when using the microservices architecture. Communicating via Application Programming Interface (API) and Hypertext Markup Language (HTML) resources, the hypertext markup language is the most basic part of the web, which performs its function by defining the structure and basic content of the web page, thus allowing to properly choosing the tool for each type of work [10]. The Java framework called Spring Boot 2 is widely used and well-known due to its ease in setting up and delivering application content to the public. The purpose of the framework is to quickly get the project up and running, simply by informing the software of the preference modules [10].

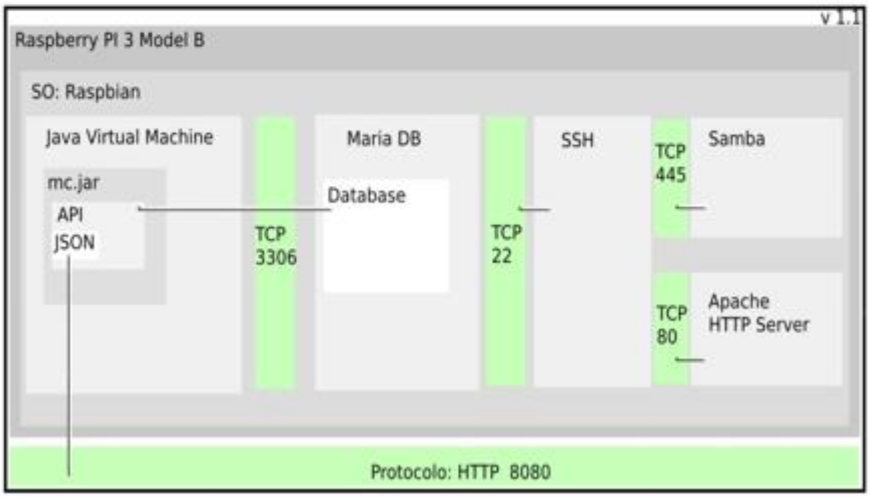
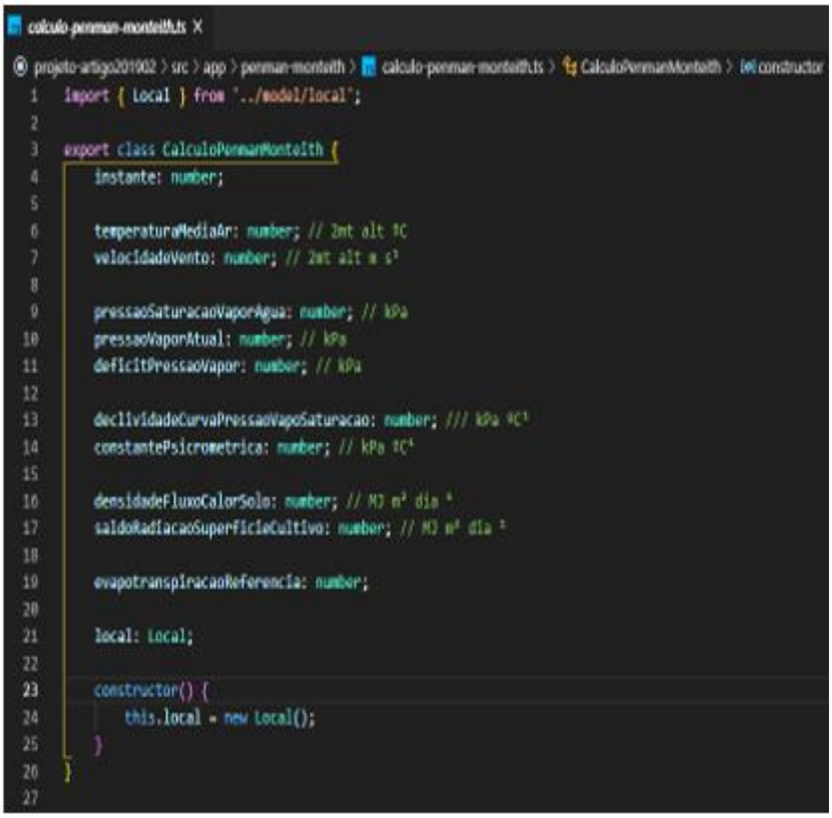


Figure 8: Platforms that communicate via HTTP.
Source: Authors, (2019).

4. Results

The set of web technologies, such as HTML5, CSS and JavaScript, added to the native mobile application platform results in hybrid application theory. Hybrid apps are configured to work just like other native apps on digital app distribution platforms (Play Store, Apple Store, and Windows Phone Store). The installation and configuration of the NodeJS software was performed and also the installation of the Ionic CLI and Cordova packages through the Node Package Manager (NPM) which consisted of the process of designing. For the Process of Building stage, the project was created through the Ionic CLI interface, based on the "side menu" template included in the Ionic documentation. CSS was implemented to customize the visual structure of the application and the necessary markings were added through the HTML language [11].
The Model View Controller (MVC) was used, which was consisted on the separation of the domain classes (model), and on the separation of the use of components and markup languages, and the controllers that join the model with the visualization layer [12].




```
import { Local } from '../model/local';

export class CalculoPenmanMonteith {
    instante: number;

    temperaturaMediaAr: number; // 2mt alt ºC
    velocidadeVento: number; // 2mt alt m s¹

    pressaoSaturacaoVaporAgua: number; // kPa
    pressaoVaporAtual: number; // kPa
    deficitPressaoVapor: number; // kPa

    declividadeCurvaPressaoVapoSaturacao: number; /// kPa ºC¹
    constantePsicrometrica: number; // kPa ºC¹

    densidadeFluxoCalorSolo: number; // MJ m² dia ¹
    saldoRadiacaoSuperficieCultivo: number; // MJ m² dia ¹

    evapotranspiracaoReferencia: number;

    local: Local;

    constructor() {
        this.local = new Local();
    }
}
```

Figure 9: Prototype version for Android.
Source: Authors, (2019).

For the testing and debugging process was built the application for the Android platform, and was digitally signed the file with the extension "apk". For the execution and publishing process, the application was installed on a smartphone with the operating system Android 9.0 [13].
The prototype is a system that collects environmental data through sensors and devices in real time. The

prototype performs evapotranspiration calculations using Hargreaves and Samani and Penman Monteith methods. It is noteworthy that for the exposed work the function is aimed at helping small farmers to help evapotranspiration calculation, seeking to reduce the effort to obtain the value of the evapotranspiration process. The formula developed by Hargreaves Samani needs only solar radiation and the average, maximum and minimum temperatures to generate the result, according to equation 1 [1].

(Eq. 1)

$$ET0 = 0.023(0.408)\,(T\,mcan + 17.8)\,(T\max - T\min)0.5\,R\alpha.$$

In Hargreaves Samani's method (Figure 10) the user does not need enter weather station results [1]. The prototype performs the calculations using the value that comes from the DHT22 air temperature sensor to estimate the temperature value of equation 1.

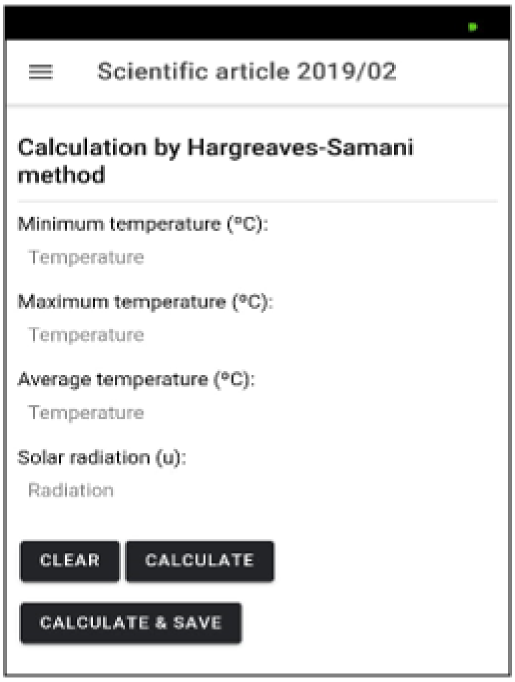
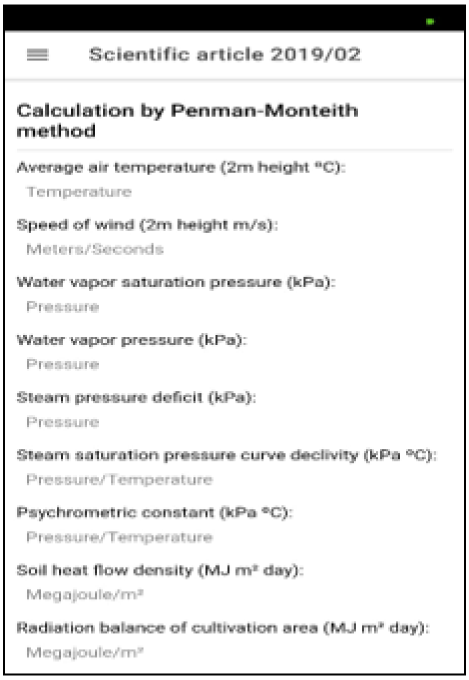


Figure 10: Presentation of the calculation by Hargreaves Samani method.
Source: Authors, (2019).

If the user prefers to verify the evapotranspiration result by the Penman Monteith method (Figure 11), it is necessary to enter the information in the hybrid mobile device to calculate, according to the data collected by the local Meteorological Station [13].

(Eq. 2)

$$ET() = \frac{0{,}408\Delta(Rn - G) + \gamma\frac{900}{T + 273}u2(\in s - \in \alpha)}{\Delta + \gamma(1 + 0{,}34u2)}$$



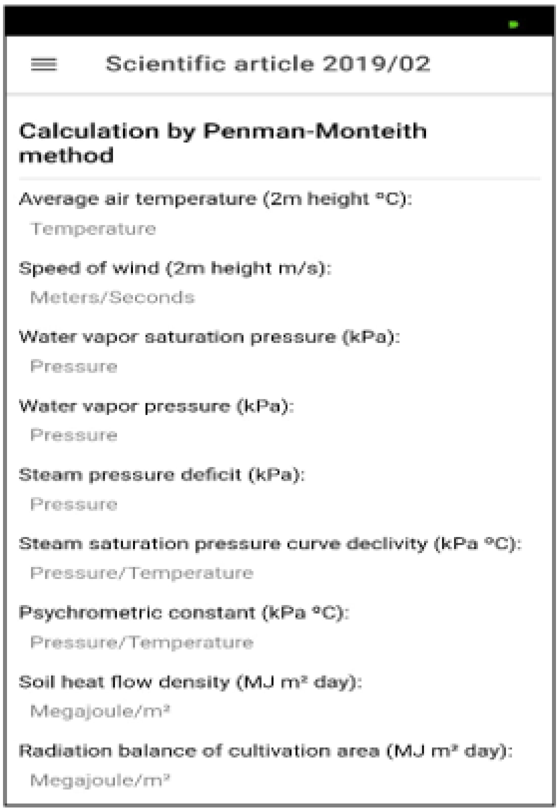


Figure 11: Presentation of the calculation by the Penman Monteith method.
Source: Authors, (2019).

Date	Time	Temperature (°C)			Humidity			Dew (°C)			Pressure (hPa)			Wind (m/s)			Radiation	Rain
	UTC	Inst.	Max.	Min.	Inst.	Max.	Min.	Inst.	Max.	Min.	Inst.	Max.	Min.	V.	direction	Squall	(KJ/m²)	(mm)
20/10/2019	00	26.6	27.5	26.6	74	74	68	21.5	21.7	21.1	1004.1	1004.1	1003.2	0.5	353	1.4	0.000	0.0
20/10/2019	01	25.8	26.7	25.8	83	83	73	22.7	22.7	21.4	1004.7	1004.7	1003.9	0.6	2	2.0	0.000	0.0
20/10/2019	02	25.6	26.0	25.6	81	84	78	22.0	22.9	21.7	1005.8	1005.9	1004.7	0.5	312	2.6	0.000	0.0
20/10/2019	03	25.4	25.7	25.3	80	82	80	21.7	22.2	21.7	1006.0	1006.2	1005.8	0.5	355	2.3	0.000	0.0
20/10/2019	04	25.2	25.4	25.2	80	82	79	21.5	22.0	21.5	1005.6	1006.0	1005.6	0.5	351	1.3	0.000	0.0
20/10/2019	05	24.8	25.2	24.8	90	90	80	23.1	23.1	21.5	1004.9	1005.6	1004.9	0.5	6	1.7	0.000	0.0
20/10/2019	06	24.6	24.9	24.5	83	91	82	21.5	23.2	21.5	1004.1	1004.9	1004.1	0.6	330	2.4	0.000	0.0
20/10/2019	07	24.7	24.8	24.4	83	85	83	21.6	21.8	21.5	1004.1	1004.2	1004.0	0.4	285	1.6	0.000	0.0
20/10/2019	08	24.7	24.8	24.4	81	84	80	21.2	21.7	21.1	1004.2	1004.2	1004.0	0.9	281	2.1	0.000	0.0
20/10/2019	09	24.4	24.9	24.4		100	81		24.3	21.2	1004.7	1004.7	1004.2	0.8	277	1.9	0.000	0.0
20/10/2019	10	25.2	25.2	24.5							1005.1	1005.1	1004.7	1.7	229	4.0	13.84	0.0
20/10/2019	11	26.3	26.4	25.2	84			23.3			1005.7	1005.7	1005.1	0.9	259	3.5	375.4	0.0
20/10/2019	12	27.0	27.1	26.3	81	85	79	23.6	23.9	23.1	1006.4	1006.4	1005.7	1.0	185	3.0	925.2	0.0
20/10/2019	13	28.3	29.2	27.0	73	81	69	22.9	23.9	22.8	1007.2	1007.2	1006.4	1.7	227	3.2	1811.	0.0
20/10/2019	14	29.8	30.3	28.3	68	75	66	23.2	24.2	22.9	1007.1	1007.3	1007.1	1.8	290	4.5	2284.	0.0
20/10/2019	15	29.3	30.4	29.3	69	70	64	22.9	23.9	22.6	1006.2	1007.1	1006.2	2.4	254	4.9	1815.	0.0
20/10/2019	16	30.6	31.1	29.3	63	70	63	22.8	24.1	22.6	1004.7	1006.2	1004.7	1.9	242	5.9	1706.	0.0

Figure 12: Automatic query station data of the city of Manaus, AM, Brazil.
Source: [14].

5. Discussions

It is important for farmers to obtain knowledge about the necessity of adequate irrigation, and thus improve crop yields by benefiting from new technologies. There are several devices on the market that calculate evapotranspiration through sensors, but not with the same proposal of the developed prototype. According to this work, the proposal is to show the viability of the hybrid mobile device prototype, which can work on with Android and iOS smartphones, and also notebooks.

Therefore, considering the results, it can be described that the use of Hargreaves Samani method presented greater viability due to the simplicity of the information, which in this case uses temperature sensors to measure the data that will be used in the calculator. The result of calculating evapotranspiration in this method is simpler, faster and easier to achieve. To use the Penman Monteith method, the user would need a high financial cost to have a weather station or obtain the information through the National Institute of Meteorology [14].

6. Conclusion

According to the work presented, there was a need to develop a hybrid mobile device prototype, with benefits from which it is viable to use a mobile device to assist in the calculation of evapotranspiration. It is possible to control the process data and offer convenience and practicality to the user in decision making through its indicators. In the market, there are already tools with this type of functionality and display of indicators, but the prototype presented stands out for having a hybrid mobile application, which can be accessed from smartphones with Android or iOS systems, also by notebooks. From the comparative mentioned, it was observed that this work contributes positively to the scientific community and to the possible users of the prototype, aiming at reducing the effort for those who need to calculate evapotranspiration data, thus favoring the farming management.

7. References

[1] G. R. Correia, H. R. O. Rocha, S. D. Rissino. Automação de sistema de irrigação com monitoramento via aplicativo web. Engenharia na Agricultura, Viçosa - MG, v. 24 no. 4, JULY/ AUGUST, 2016. Available in: https://periodicos.ufv.br/reveng/article/view/609/0.

[2] D. P. Melo. Aplicativo web para cálculo de balanço hídrico no manejo da irrigação. Revista Brasileira de Agricultura Irrigada v. 11, nº 2, pp. 1302 - 1309. ISSN 1982-7679 (On-line). DOI: 10.7127/rbai. v11n200610, 2017. Fortaleza, CE, INOVAGRI. Available in:http://www.inovagri.org.br.

[3] A. P. Martins, R. Rosa. Estimativa de evapotranspiração real a partir de imagens do sensor modis/aqua e do algoritmo sebal na bacia do rio paranaíba - brasil. Caderno de Geografia, v.29, n.57, 2019. ISBN 2318-2962. DOI 10.5752/p.2318-2962.2019v29n57p351. Available in: http://periodicos.pucminas.br/index.php/geografia/article/view/19210

[4] C. W. Zhao, J. Jegatheesan, F. C. Loon. International journal of computer networks and applications. Quest International University Perak International Journal of Computer Networks and Applications. v. 2, Issue 1, January – February, 2015. ISBN 2395-0455. Available in: http://oaji.net/articles/2015/1858-1428151269.pdf

[5] L. M. Santos. A inserção da termoeletricidade no ensino médio: uma alternativa metodológica a partir do ensino de geradores elétricos. Universidade estadual da paraíba pró-reitoria de pós-graduação e pesquisa mestrado nacional profissional em ensino de física. Polo Campina Grande Lenildo Morais Dos Santos. Campina Grande – PB, 2019. Available in: http://tede.bc.uepb.edu.br/jspui/bitstream/tede/3516/2/PDF%20-%20Lenildo%20Morais%20dos%20Santos.pdf

[6] W. U. Leite. Destilação solar para fins de dessalinização: aplicação de materiais alternativos e tecnológicos para a produção mais eficiente de água potável. Universidade Federal do Rio Grande do Norte Centro de Tecnologia. Departamento de Engenharia Química Programa de Pós-Graduação em Engenharia Química. Natal/RN, February 2019. Available in: https://repositorio.ufrn.br/jspui/bitstream/123456789/27131/1/Destila%c3%a7%c3%a3osolarfins_Leite_2019.pdf

[7] S. R Vilayatkar. IoT Based Weather Monitoring System using Raspberry Pi. International Research Journal of Engineering and Technology (IRJET). V. 06, Issue: 01/Jan 2019. ISSN: 2395-0056, p-ISSN: 2395-0072. Available in: https://www.irjet.net/archives/V6/i1/IRJET-V6I1220.pdf

[8] L. P. Alencar, G. C. Sediyama, E. C. Mantovani. Estimation of reference evapotranspiration (eto) under fao, Standards with missing climatic data in minas gerais, brazil. Journal of the Brazilian Association of Agricultural Engineering. ISSN: 1809-4430 (on- line). Available in: Doi: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v35n1p39-50/2015

[9] E. P. A. Silva, E. C. S. Sotto. A utilização do ionic framework no desenvolvimento de aplicações híbridas em arquitetura orietanda a serviço. Faculdade de Tecnologia de Taquaritinga (FATEC) – SP – Brasil. Revista Interface Tecnológica, v. 15, no. 1, pp. 97-108, 30 jun. 2018. DOI: 10.31510/infa. v15i1.333. Available in: https://revista.fatectq.edu.br/index.php/interfacetecnologica/article/view/333.

[10] L. M. Malipense, J. D. Zuchi. A study on the concept and the application of microservice architecture. DOI: 10.31510/infa. v15i1.324. Faculdade de Tecnologia de Taquaritinga (FATEC) – SP – Brasil. Revista Interface Tecnológica, v. 15, no. 1, pp. 122-134, 30 jun. 2018. ISSN 1807-3980. Available in: https://revista.fatectq.edu.br/index.php/interfacetecnologica/article/view/324.

[11] B. D. Dunka, A. E. Edim, D. O. Oyeyinka. Hybrid mobile application based on ionic framework technologies. International Journal of Recent Advances in Multidisciplinary Research, 2017. ISSN: 2350-0743. Available in: https://www.researchgate.net/publication/322397904_HYBRID_MOBILE_APPLICATION_BASED_ON_IONIC_FRAMEWORK_TECHNOLOGIES

[12] I. S. Moura. Desenvolvimento de aplicativos híbridos baseado em arquitetura orientada a serviços. Fortaleza – Ceará, 2016. Universidade Estadual do Ceará Centro de Ciências e Tecnologia. Available in: https://www.researchgate.net/publication/320273298_Desenvolvimento_de_Aplicativos_Hibridos_baseado_em_Arquitetura_Orientada_a_Servicos.

[13] L. Silva. Application Development for Mobile Devices: Types and Application Example on the iOS platform. II Workshop de Iniciação Científica em Sistemas de Informação, Goiânia – GO, 26 a 29/05/2015. Available in: http://www.lbd.dcc.ufmg.br/colecoes/wicsi/2015/004.pdf

[14] Consulta dados da estação automática: Manaus AM. Available in: http://www.inmet.gov.br/sonabra/pg_dspDadosCodigo_sim.php? EwMQ