Smart Phone Evapotranspiration-Based App for Optimal Irrigation Scheduling for Thai Crops

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Abstract:

Thailand is known as a top producer of many essential agricultural commodities including canary seeds, cassava, mango, mangosteen, guava, and chili pepper. Due to global warming and population growth, droughts are increasing and water is becoming scarce, which have a direct impact on agriculture. Farmers are therefore facing difficulties in supplying their crops with sufficient water due to water scarcity and the increasing irrigation cost. This situation calls for optimal use of irrigation water in agriculture, which is sufficient to avoid crop water stress and at the same time help to sustain water and reduce irrigation expenses.

Methodolgy/approach: With the number of smartphone users in the world exceeding 3.5 billion, this app uses geospatial data and the Water Balance Approach to estimate the optimal irrigation cycle in the current month in Thailand using Java.

Result: This app would result in significant water savings and a less costly irrigation process for both large farms and private gardens in subsistence agriculture.

Conclusion: The proposed smartphone app captures the unique characteristics of the weather and soil conditions of any location in Thailand to determine the optimal average daily amount of water required to prevent crop water stress in the current month.

Keywords: Evapotranspiration; irrigation planning; precision farming; irrigation scheduling; effective rainfall

1. Introduction

In a world facing water shortage and frequent drought events, providing the optimal amount of water sufficient for crop growth, robust irrigation scheduling is needed. There are four irrigation scheduling approaches, which are soil water balance, soil moisture status, plant water status, and models, which are established considering soil water content (Gu, et al., 2020). The most common approach is the soil water balance, which is designed to monitor soil water deficit inside the root zone (Pereira, et al., 2020). The following section presents the reference concepts of the soil water balance approach.

1.1. Crop water requirements

The soil water balance approach determines the crop water requirements (Equation 1). Daily Evapotranspiration (ETc) amounts (i.e. crop water use) are withdrawals from the soil storage. Precipitation or Rainfall (P) and net Irrigation (I) are deposited to this storage. Water requirements for plants depend on water inputs, including rainfall (R) and irrigation (I), and outputs, that is, losses due to runoff (RO) and deep percolation (D). Due to deep percolation, the plant roots can no longer extract water because it is too deep into the ground (Kisekka et al. 2010; Dukes *et al*. 2009), beyond the effective root zone of the crop corresponding to the depth of the surface soil that the plant uses for its physiological purpose. Some of the water is also lost due to the surface Run-Off (RO). The water above field capacity that cannot be retained will drain off and is therefore no longer useful to the plant. Run-Off is higher during or after heavy rainfall or if cultivation occurs on a slope. In contrast, Run-Off is smaller, often negligible, in flat irrigated terrains and agricultural fields. Some of the water is lost due to evapotranspiration, particularly under windy weather conditions and a dry soil, as shown in Figure 1.

Water-based inputs and outputs equation:

$$\Delta S = P - ETc + I - D - RO \qquad \text{Equation 1}$$

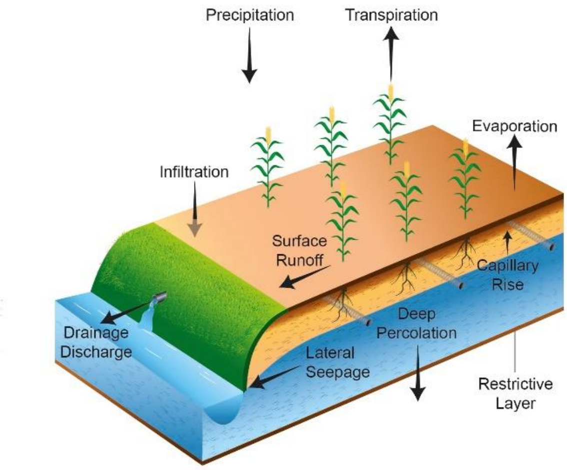
Where,

ΔS = Change in soil water storage (*inches*) / differences between inputs (water gain) and outputs (water loss)
P = Rainfall (*inches*)
ETc = Crop Evapotranspiration (*inches*)
I = Net Irrigation (*inches*)
D = Deep Percolation (*inches*)
RO = Surface Runoff (*inches*)

Once we removed the water lost due to deep percolation and water run-off, which cannot be used by the plant, we obtain the effective rainfall, which will be used by the plant for its growth.

$$Pe = P - D - RO$$

Figure 1. Water Cycle on a Field



Source: Ghane, E. (2018). Agricultural Drainage. *Extension Bulletin E3370*.

Equation (1) becomes Equation (2), if we assume negligible storage. Storage from an annual water balance may be omitted if changes in the volume of water are minor, as in reservoirs, storage in the soil, or underground water reserves such as *aquifers* (Brouwer et al., 2014, Dukes *et al* 2009).

$I = ET_c - P_e$ Equation 2

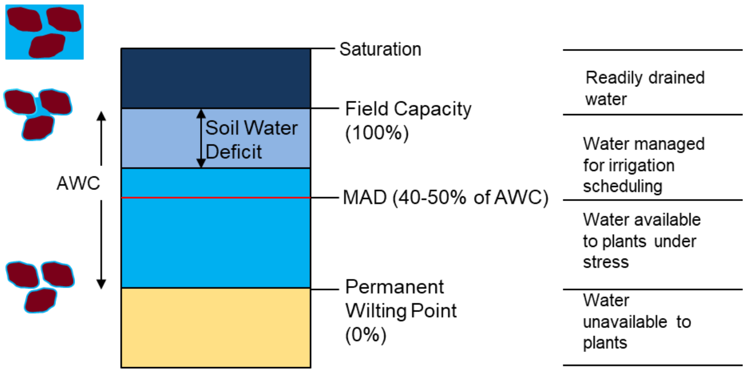
Where,
I = Net Irrigation *(inches)*
ETc = Crop Evapotranspiration *(inches)*
Pe = Effective rainfall *(inches)*

Field Capacity (FC) is the amount of water a well-drained field will retain against after irrigation or rainfall. Failing to provide water, the water volume in the root zone diminishes, as the crop takes up more water. As water absorption increases, the residual water is more firmly retained onto the soil particles, which makes it more difficult for the plant to absorb it. Finally, a point is reached where the crop can no longer extract the remaining water and the plant becomes wilted. Irrigation must occur when the soil water content drops below a minimum level corresponding to the Permanent Wilting Point (PWC), which is the water content at which plants will permanently wilt (Figure 2).

The Available Water Capacity (AWC) (Table 1) is the quantity of water that can be used by the plant to grow. By definition, it is the measure of the quantity of the water, which is accessible to the plant, stored between the Field Capacity (FC) (corresponding to the amount of water remaining in the soil a few days after having been wetted) and the Permanent Wilting Point (PWP), beyond which the plant becomes wilted (Figure 2). AWC depends on the soil type. The soil type and corresponding AWC for any location in Thailand were retrieved from the World Soils Harmonized World Soil Database (available at http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HWSD_Documentation.pdf) and stored in the app. Alternatively, the Kellogg Soil

Survey Laboratory (KSSL) also provides pedon data for soil characterization (National Cooperative Soil Survey; 2020) while the USDA provides soil data, but for the US only (https://sdmdataaccess.nrcs.usda.gov/).

Figure 2. Plant Irrigation Requirement



Source: Vasudha, 2019

Table 1. Soil Water Storage Capacities

Texture Class	AWC (inches/inch)
Clay	0.161
Clay Loam	0.170
Coarse Sand	0.046
Coarse Sandy Soam	0.114
Fine Sand	0.084
Fine Sandy Loam	0.137
Fine Sandy Soam	0.098
Loam	0.183
Loamy Coarse Sand	0.083
Loamy Fine Sand	0.102
Loamy Sand	0.09
Sand	0.055
Sandy Clay	0.158
Sandy Clay Loam	0.163
Sandy Loam	0.12
Silt	0.172
Silt Loam	0.179
Silty Clay	0.160
Silty Clay Loam	0.165
Very Fine Sand	0.123
Very Fine Sandy Loam	0.20

Very Fine Sandy Loam	0.166

Sources: Rhoads & Yonts, 1991; Werner, 1993; Bellingham, 2009.

The maximum Soil Water Deficit (SWD) (Figure 2) is the amount of water stored in the plant's root zone (Nyvall, 2002; Blanco, et al., 2018) that shall not exceed a certain limit to prevent water stress. The water contained in the root zone should remain above this allowable depletion level[1]. A Maximum Allowable Depletion (MAD) factor will determine the Maximum Allowable Depletion or Soil Water Deficit. The MAD factor typically ranges from 30% to 60% of the Available Water Capacity depending on crop type. The MAD for a range of Thai crops is provided in Table 2. We focused on crops for which we were able to retrieve Root Zone Depth, MAD %, and Crop Coefficient (a total of 8 crops). A higher MAD corresponds to a stress-tolerant plant, deep root zones, or lighter soils (Callison, 2012). If data are not available, a 50% MAD is usually an accepted standard and soil moisture should be allowed to deplete up to half of the available water before irrigation is required (Moore, 2009).

Table 2. Root Zone Depth, MAD %

Crop	Depth in *ft*	(*inches*)	MAD (%)
Rice (Direct Sowing)	1.5	(18)	0.2
Rice (Transplanting)	1.5	(18)	0.2
Maize	4	(48)	0.52
Soy Beans	2.77	(33.24)	0.5
Peanut	2.5	(30)	0.5
Mungbean	1.6	(19.2)	0.65
Cassava	2	(24)	0.5
Sugarcane	4	(48)	0.65

1.2 Evapotranspiration (ET)

Evapotranspiration (*ET*) is the rate at which soil and plants release water into the atmosphere. *ET* is the sum of all water losses through the processes of soil evaporation and plant transpiration when water vapor moves out of leaf stomata (i.e. tiny pores on plant leaf surface) after being extracted by plant roots. Reference *ET* or *ETo* is the evapotranspiration from a well-watered, disease free, short, evenly cut grass of 8 to 15 cm tall, shading the ground or for alfalfa. The choice of alfalfa over grass depends on the weather conditions. In humid and semi-humid areas, grass is more likely to be used as reference *ET* while in arid or semi-arid areas, alfalfa is preferred. Most of the evapotranspiration, which varies with temperature, wind, humidity, and sunshine hours, occurs after a rainfall or an irrigation event. Agricultural research institutions often have their own Agro-meteorology observatories that record weather parameters to compute evapotranspiration locally because field equipment that measures evapotranspiration directly from the field are expensive for local farmers. *ET* estimates use complex equations that

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[1] https://extension.colostate.edu/topic-areas/agriculture/crop-water-use-and-growth-stages-4-715/

are constantly being refined. Some of these methods require relative humidity, solar radiation, number of rainy days and sunshine hours or cloud coverage, wind and air temperature while others need only mean monthly air temperature (Doorenbos and Pruitt, 1977).

1.2.1 Evapotranspiration Data Sourcing:

In this study, we have obtained local monthly potential evapotranspiration (ET_0) for Thai provinces from the Royal Irrigation Department (RID) (Table 3) and stored these data into the app. The app retrieves ET_0 for any location selected by the user on a map of Thailand. The RID computed monthly potential evapotranspiration using long-term average climatological data from 74 climatological stations (30-year period) and 29 agro climatological stations (25-year period) (Gheewala et, 2014). The monthly climatic data of 1981–2010 including Minimum Temperature, Maximum Temperature, Humidity (%), Wind (km/day), Sun hours, and Radiation (MJ/m^2/day) reported by the Meteorological Department of Thailand were used by the RID to compute ET_0 by the Penman method. However, ET_0 was unavailable for the following provinces: Amnat charoen, Ang Thong, Bueng Kan, Nakhon Nayok, Nong bua Lam Phu, Nonthaburi, Phangnga, Phra Nakhon Si Ayutthaya, Samut Sakhon, Samut songkhram, Sing Buri, Uthai Thani, Yasothon. Therefore, our app doesn’t work in these provinces.

Table 3. Monthly Reference Evapotranspiration (ET0) (in inches per day)

Province	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mae Hong Son	0.113	0.146	0.183	0.204	0.174	0.128	0.113	0.119	0.122	0.126	0.117	0.109
Chiang Rai	0.111	0.136	0.170	0.193	0.167	0.155	0.137	0.131	0.141	0.134	0.124	0.104
Phayao	0.111	0.139	0.175	0.193	0.173	0.145	0.141	0.133	0.134	0.127	0.115	0.102
Chiang Mai	0.124	0.159	0.199	0.212	0.168	0.154	0.131	0.132	0.131	0.136	0.128	0.114
Lampang	0.124	0.151	0.188	0.196	0.165	0.155	0.142	0.137	0.135	0.136	0.131	0.118
Lamphun	0.116	0.149	0.186	0.215	0.180	0.149	0.145	0.137	0.137	0.132	0.120	0.108
Phrae	0.117	0.146	0.176	0.193	0.180	0.147	0.141	0.135	0.138	0.134	0.125	0.106
Nan	0.116	0.142	0.178	0.187	0.168	0.152	0.138	0.125	0.141	0.143	0.126	0.109
Uttaradit	0.128	0.153	0.188	0.193	0.174	0.141	0.138	0.134	0.139	0.141	0.137	0.118
Tak	0.134	0.157	0.193	0.214	0.172	0.134	0.127	0.123	0.119	0.128	0.129	0.119
Phitsanulok	0.129	0.158	0.196	0.209	0.185	0.149	0.144	0.138	0.129	0.140	0.135	0.126
Phetchabun	0.128	0.157	0.182	0.189	0.161	0.144	0.141	0.122	0.126	0.142	0.141	0.128
Kamphaeng Phet	0.128	0.154	0.171	0.197	0.175	0.154	0.138	0.134	0.140	0.137	0.131	0.122
Sukhothai	0.126	0.148	0.180	0.210	0.165	0.163	0.147	0.142	0.141	0.140	0.137	0.123
Phichit	0.129	0.153	0.171	0.181	0.159	0.157	0.138	0.134	0.126	0.137	0.141	0.128
Nong Khai	0.122	0.149	0.182	0.182	0.159	0.140	0.138	0.134	0.138	0.143	0.130	0.120

Loei	0.128	0.158	0.188	0.193	0.170	0.157	0.148	0.137	0.146	0.139	0.131	0.119
Udon Thani	0.131	0.160	0.191	0.205	0.180	0.161	0.146	0.140	0.142	0.147	0.146	0.127
Sakon Nakhon	0.130	0.154	0.184	0.197	0.172	0.163	0.146	0.141	0.154	0.151	0.138	0.125
Nakhon Phanom	0.135	0.156	0.173	0.186	0.162	0.152	0.143	0.131	0.144	0.141	0.142	0.126
Khon Kaen	0.135	0.157	0.189	0.192	0.176	0.161	0.153	0.139	0.140	0.145	0.144	0.134
Mukdahan	0.144	0.165	0.197	0.203	0.162	0.143	0.140	0.135	0.141	0.150	0.156	0.139
Maha Sarakham	0.141	0.165	0.185	0.206	0.182	0.166	0.151	0.143	0.143	0.148	0.151	0.141
Kalasin	0.163	0.193	0.213	0.215	0.189	0.170	0.166	0.144	0.146	0.160	0.169	0.161
Chaiyaphum	0.142	0.165	0.197	0.202	0.176	0.163	0.148	0.142	0.142	0.149	0.153	0.138
Roi Et	0.148	0.169	0.189	0.198	0.174	0.168	0.159	0.148	0.142	0.146	0.153	0.146
Ubon Ratchathani	0.150	0.162	0.180	0.180	0.159	0.150	0.146	0.130	0.131	0.139	0.155	0.150
Si Sa Ket	0.134	0.154	0.180	0.187	0.174	0.174	0.165	0.146	0.152	0.143	0.149	0.136
Nakhon Ratchasima	0.152	0.169	0.185	0.186	0.164	0.166	0.157	0.152	0.132	0.138	0.151	0.149
Surin	0.142	0.165	0.183	0.189	0.165	0.159	0.147	0.139	0.141	0.144	0.150	0.143
Buri Ram	0.154	0.177	0.198	0.206	0.180	0.170	0.159	0.142	0.143	0.150	0.158	0.149
Nakhon Sawan	0.151	0.181	0.215	0.217	0.178	0.160	0.154	0.142	0.136	0.140	0.145	0.141
Chai Nat	0.130	0.145	0.171	0.180	0.170	0.168	0.151	0.137	0.135	0.128	0.130	0.126
Ayutthaya	0.156	0.165	0.180	0.180	0.158	0.161	0.147	0.145	0.132	0.136	0.154	0.155
Pathum Thani	0.139	0.152	0.175	0.183	0.159	0.163	0.143	0.141	0.128	0.114	0.151	0.139
Ratchaburi	0.159	0.181	0.207	0.203	0.157	0.156	0.141	0.143	0.135	0.133	0.152	0.158
Suphan Buri	0.136	0.162	0.189	0.194	0.163	0.156	0.146	0.135	0.132	0.138	0.139	0.136
Lop Buri	0.154	0.181	0.202	0.199	0.164	0.148	0.144	0.130	0.128	0.144	0.152	0.153
Kanchanaburi	0.139	0.166	0.187	0.206	0.157	0.139	0.127	0.126	0.119	0.128	0.134	0.135
Bangkok	0.160	0.178	0.201	0.200	0.178	0.175	0.171	0.162	0.148	0.145	0.167	0.161
Samut Prakan	0.045	0.080	0.128	0.148	0.147	0.156	0.147	0.132	0.102	0.070	0.057	0.039
Phetchaburi	0.141	0.167	0.192	0.193	0.166	0.147	0.144	0.125	0.133	0.121	0.133	0.137
Prachuap Khiri Khan	0.151	0.170	0.183	0.190	0.165	0.157	0.146	0.139	0.137	0.135	0.144	0.153
Nakhon Pathom	0.146	0.171	0.203	0.202	0.158	0.157	0.143	0.124	0.135	0.145	0.154	0.144
Chachoengsao	0.152	0.151	0.165	0.170	0.152	0.139	0.136	0.136	0.128	0.131	0.137	0.138
Prachinburi	0.150	0.160	0.170	0.183	0.157	0.138	0.135	0.124	0.128	0.141	0.158	0.158
Sa Kaeo	0.155	0.174	0.190	0.189	0.159	0.156	0.146	0.138	0.130	0.139	0.148	0.146
Chon Buri	0.165	0.175	0.189	0.197	0.173	0.168	0.166	0.158	0.144	0.139	0.166	0.173

Rayong	0.144	0.157	0.170	0.179	0.161	0.156	0.148	0.147	0.135	0.135	0.146	0.145
Chanthaburi	0.151	0.146	0.159	0.169	0.135	0.122	0.122	0.112	0.116	0.131	0.150	0.154
Trat	0.150	0.151	0.164	0.169	0.153	0.132	0.131	0.113	0.127	0.132	0.145	0.151
Chumphon	0.134	0.152	0.171	0.170	0.150	0.151	0.141	0.145	0.139	0.133	0.128	0.132
Ranong	0.151	0.166	0.169	0.168	0.148	0.131	0.129	0.130	0.126	0.130	0.134	0.139
Surat Tani	0.139	0.162	0.172	0.170	0.150	0.143	0.140	0.143	0.138	0.126	0.122	0.126
Nakhon Si Thammarat	0.131	0.148	0.161	0.163	0.145	0.144	0.139	0.143	0.139	0.125	0.118	0.116
Phatthalung	0.144	0.161	0.163	0.165	0.147	0.145	0.138	0.143	0.139	0.130	0.130	0.129
Phuket	0.165	0.177	0.178	0.168	0.149	0.148	0.148	0.151	0.138	0.132	0.131	0.147
Krabi	0.161	0.186	0.174	0.166	0.147	0.141	0.139	0.143	0.141	0.121	0.129	0.138
Trang	0.166	0.191	0.184	0.169	0.146	0.142	0.128	0.132	0.128	0.123	0.129	0.143
Songkhla	0.147	0.166	0.171	0.167	0.146	0.144	0.145	0.148	0.141	0.131	0.118	0.124
Satun	0.174	0.181	0.173	0.165	0.143	0.139	0.139	0.144	0.129	0.124	0.131	0.150
Pattani	0.132	0.156	0.154	0.156	0.137	0.133	0.135	0.139	0.137	0.128	0.116	0.112
Yala	0.139	0.165	0.167	0.170	0.148	0.144	0.144	0.150	0.148	0.141	0.116	0.122
Narathiwat	0.131	0.150	0.160	0.165	0.148	0.143	0.142	0.146	0.134	0.128	0.116	0.115

Source: Water, 2014, (6)

1.2.2 Crop Evapotranspiration:

As the plant canopy cover increases in size over the soil surface, evaporation from the wet soil surface gradually decreases while plant transpiration increases. The crop development stage is based on observations of crops in the field. Therefore, reference Evapotranspiration needs to be adjusted using a crop coefficient (*Kc*). The value of Kc depends on the crop type, planting date, and development stage. When the plant reaches full cover, ETc will be at the maximum. The *ETc* value is estimated by multiplying *ETo* by *Kc* retrieved from Table 4.

Table 4. Crop Coefficients (K_c) for selected Thai Crops

Source: Royal Irrigation Department (RID), 2011; Kwanyuen, B et al, 2010

1.2.3 Crop coefficient

The proposed app focuses on Thai crops such as cassava, sugarcane, pineapple, maize that were prioritized by the government for Thailand's main geographic areas or provinces (Table 5) and for which crop coefficients were available (Table 4). In the app, the user selects the crop type from the list (Screenshot 1), which includes Cassava, Maize, Mungbean, Peanut, Rice

(Direct Sowing and Planting), Sugarcane and Soy Beans. The user then selects the number of weeks after the initial plantation (Screenshot 2). The app would then retrieve the corresponding crop coefficient factor.

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Rice (Direct Sowing)	0.8	1.05	1.25	1.4	1.5	1.55	1.6	1.63	1.68	1.6	1.5	1.36	1.08	0.65
Rice (Transplanting)	1.03	1.07	1.12	1.29	1.38	1.45	1.5	1.48	1.42	1.34	1.23	0.94	0.86	–
Maize	0.63	0.72	0.86	1.13	1.35	1.52	1.61	1.63	1.58	1.5	1.38	1.15	0.9	0.67
Soybean	0.64	0.69	0.81	1.01	1.23	1.32	1.35	1.34	1.27	1.09	0.85	0.74	0.74	0.72
Peanut	0.6	0.72	0.85	0.94	1.17	1.24	1.28	1.36	1.04	0.99	0.91	0.77	0.6	0.5
Mungbean	0.58	0.87	1.18	1.4	1.28	1.19	0.66	0.44	0.34	–	–	–	–	–
Cassava	0.28	0.29	0.32	0.34	0.50	0.72	0.99	1.13	1.01	0.79	0.58	0.42	–	–
Sugarcane	0.65	0.86	1.13	1.35	1.56	1.29	1.20	0.93	0.63	0.52	–	–	–	–

Table 5. Recommended Crops for each Thai Provinces

Crop	North	North-East	Center	East	South	Total
Cassava	14	20	9	6	-	59
Sugarcane	11	20	11	6	-	48
Pineapple	5	3	4	3	1	16
Maize	17	12	8	6	-	43

Source: Ministry of Agriculture and Cooperatives (MOAC)*: Nilsalab & Gheewala, 2017*

1.3.Effective Precipitation:

To estimate the correct volume of irrigation required to satisfy the crop water needs, the value of effective precipitation (*Pe*) is needed. While there are many definitions of effective precipitation, the most common is the portion of the rainfall that enters the root zone and contributes to the evapotranspiration requirements of a crop. The portion of rainfall not lost from the farm, either as surface runoff or as deep percolation, seepage, or evaporation, and can be used for crop development, directly or indirectly, is considered effective (Peace Corps, 1990). Effective precipitation is often calculated as a fraction of the rainfall and depends on factors such as the amount of water, the initial soil moisture, rainfall duration, intensity, and frequency in addition to soil and crop type (USDA - SCS 1970).

The uneven distribution of precipitation reduces its effectiveness. Higher volumes of precipitation and a more intense rainfall, as exemplified by short and extreme downpours, usually decrease the amount of effective water and increase the water run-off. In contrast, regular rainfall is more beneficial to plant growth.

The computation of effective rainfall for different crops and locations will require different equations. *Pe* is always equal to or larger than zero, but never negative, therefore it should be nullified if computation generates a negative *Pe*. This lead to three scenarios, each having a different Net Irrigation Requirements (IR).

a) Net Irrigation Requirements is zero

This is the case of sufficient rainfall that supplies enough water for the crop to grow. The monthly net Irrigation Requirement (IR) is negative (Pe >ETc), and therefore irrigation is not required. This is likely to occur in Thailand during the monsoon season.

b) Net Irrigation Requirement (IR) equals to ETc

Negative rainfall is set to zero and crop water needs (crop consumptive use) would need to be met by irrigation.

c) Net Irrigation Requirement (IR) equals to ‘ETc – P_e’

In this case, irrigation is needed to supplement rainfall when effective rainfall is not sufficient to cover the crop needs.

Less rainfall is required for Thai Grassy land because moisture is absorbed and held by the grass while bare dry grounds do not have that ability to retain water. In the computation of effective precipitation, it is common to deduct small amounts of up to 4 or 5 mm (corresponding to ineffective rain), sometimes more, for instance when ground cover is incomplete and climatic conditions (dry soils, strong winds) cause evaporation from the soil surface to be higher. With a dry soil surface with no vegetation cover, rainfall of up to 8 mm/day may be entirely lost due to evaporation (Mavi & Tupper, 2004[2]). Frequent light rains intercepted by a plant canopy with full ground cover are close to 100 percent effective (FAO, 1977). The three major characteristics of effective rainfall are air temperature, duration, and intensity of the rainfall.

To compute effective rainfall (*Pe*) in the app, monthly rainfall values are retrieved for the selected location via Advance Programming Interface (API) from the following ESRI website: (https://www.arcgis.com/home/webmap/viewer.html?layers=e15bf6e4b74b4559a9a3e9ea902a7a57). The retrieved value is then multiplied by a percentage that depends on the month as shown in Table 6.

Table 6. Effective Precipitation as a % of Rainfall

Period	% taken as effective	Remarks
April - September	75	Wet season
October	65	High rainfall intensity
November	80	Dry season
December - March	90	Dry and cool season

Source: Allen et al, 1998

2. Irrigation Requirement

The app calculates the net Irrigation water requirement (I) using Equation 3 shown below.

$$I = ET_c - P_e \quad \text{Equation 3}$$

ETc is given by multiplying ETo by Kc (Table 4)
Pe is the effective rainfall in the current month

Net Irrigation water requirement (I) is the amount of water necessary for crop growth. The app user needs to select the location (Screenshot 3), enters the sprinkler precipitation rate and efficiency (E), and average daily precipitation/rainfall (Screenshot 4) to determine the Gross Irrigation water requirement (GI) (Equation 4), which is the quantity of water to be applied, considering unavoidable water losses due to improper design, maintenance, construction of the irrigation system, as well as evaporation.

$$GI = \frac{I}{E} = \frac{ET_c - P_e}{E} = \frac{ET_0 K_c - P_e}{E} \quad \text{Equation 4}$$

where E is the efficiency of the irrigation system in %.

2.1 Irrigation Runtime (IR)

The irrigation run time (IR) measured in minutes per irrigation cycle/event depends on the sprinkler Precipitation Rate (PR). The user provides the PR (Screenshot 4). IR corresponds to the volume of water applied over a given area in a given time. The PR (flow rate per wetted area in inches per hour) will determine IR in Equation 5 (Kisekka *et al.* 2010, 2016 and Broner, 1989).

$$IR = \frac{MAD \times TAW}{PR} \quad \text{Equation 5}$$

Where,
MAD is the Maximum Allowable Depletion (MAD) (Table 2)Total Available Water (TAW) is the amount of water that can be extracted by the crop from its root zone. The magnitude of TAW depends on the soil Available Water-holding Capacity (AWC) and the crop rooting depth and is determined by multiplying AWC by the crop rooting depth (D_{rz}) as shown in Equation 6 Below (Rai et al, 2017; Andales, 2011). Root Zone Depth of annual field crops on deep well-drained soil ranges from 0.30 to 2.0 m. The soil depth from which the crop extracts most of the water needed to meet its needs is known as the effective root zone depth. The water available beyond the root zone depth cannot be extracted by the crop, and therefore cannot be used for its growth. The depth of the root zone of selected Thai crops (Table 2) is recorded in the app, so the user does not have to input it.

$$TAW = AWC \times D_{rz} \quad \text{Equation 6}$$

Where,
AWC is the Available Water Capacity of the root zone (in inches/inch) as shown in Table 1.
D_{rz} is the root zone depth in *inch* in, as shown in Table 2

2.2 Irrigation Frequency

The Irrigation Frequency *(IF)* (*i.e*., number of days between irrigation events) is calculated as following Kisekka *et al*. (2010) as shown in Equation 7 below.

$$IF = \frac{MAD \times TAW}{GI} \qquad \text{Equation 7}$$

Knowing IR and IF, the app can compute the average daily irrigation run time (average minutes of irrigation per day in the current month) by dividing IR by the number of days between irrigation events (Screenshot 5).

Conclusion

Drought, water scarcity, and the increasing irrigation cost require optimal use of the water available for irrigation. Since the majority of the world population uses smartphones, a smartphone app that helps farmers with optimal irrigation scheduling can be useful given the complexity of its calculations for farmers. South and Southeast Asia regions are susceptible to long intense drought events and irrigation water shortages. In the region, and although agriculture is a not major human activity in it, Thailand is known as one of the top producers of many essential agricultural commodities. This article presents a smartphone app for optimal irrigation scheduling for Thai farmers. The app can be modified for use in countries where critical data such as average monthly evapotranspiration is accessible. Examples of these counties include Iran, Poland, Namibia, Spain, and Chile. Countries such as Egypt that provides average monthly ETo under current and future scenarios (the 2050s and 2100s) can also help identify future changes in irrigation requirements (Abdrabbo et al, 2013). The authors plan to create a similar app for these countries in the future to help optimize the use of irrigation water to help sustain water resources.

References

Abdrabbo, M. A. A., Farag, A. A., Elmorsy, A. T., & Abou-Hadid, A. F. Mango Irrigation Requirements under Egyptian Climate Change Conditions. Egypt. J. Agric. Res., 91 (3), 2013

Allen, R. G., L. S. Pereira, D. Raes, and M. Smith. 1998.*Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements*. United Nations FAO, Irrigation and Drainage Paper 56. Rome, Italy: FAO.

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). FAO Irrigation and drainage paper No. 56. *Rome: Food and Agriculture Organization of the United Nations*, *56*(97), e156.

Andales, A.A., J.L. Chávez, and T.L. Bauder. (2011). Irrigation Scheduling: The Water Balance Approach. Fact Sheet No. 4.707. Colorado State University Extension, Fort Collins, CO.

Bellingham, B.K. (2009) Method for Irrigation Scheduling Based on Soil Moisture Data Acquisition. In Proceedings of the 2009 Irrigation District Conference, Salt Lake City, UT, USA, pp. 1– 17, p. 383.
Blanco, V., R. Domingo, A. Pérez-Pastor, P. Blaya-Ros, R. Torres-Sánchez 2018. Soil and plant water indicators for deficit irrigation management of field-grown sweet cherry trees. Agricultural Water Management, Volume , pp. 83-94

Broner, I. (1989). Irrigation scheduling: the water-balance approach. Colorado State University Cooperative Extension. Fort Collins, Colo. 4 p.

Brouwer, C., Prins, K., & Heibloem, M. (2014). Irrigation Water Management: Irrigation Scheduling. Training Manual No. 4, FAO, Rome, Italy. Chapter 3

Callison, D. (2012). Management Allowed Depletion Irrigation Scheduling. Rain Bird

Doorenbos, J. and Pruitt, W.O. “Guidelines for Predicting Crop Water Requirements.” Irrigation and Drainage Paper 24, FAO, Rome, 1977
Dukes, M. D., Shedd, M. L., & Davis, S. L. (2009). Smart irrigation controllers: operation of evapotranspiration-based controllers. *EDIS AE, 446*. Available at http://edis.ifas.ufl.edu/LyraEDISServlet?command=getImageDetail&image_soid=FIGURE 1&document_soid=AE446&document_version=99065
Food and Agriculture Organization of the United Nations (FAO) 2020. Land & Water. http://www.fao.org/land-water/water/drought/en/. Accessed in July 2020. Gheewala, S. H., Silalertruksa, T., Nilsalab, P., Mungkung, R., Perret, S. R., & Chaiyawannakarn, N. (2014). Water footprint and impact of water consumption for food, feed, fuel crops production in Thailand. *Water*, *6*(6), 1698-1718.

Gu, Z, Z. Qi, R. Burghate, S. Yuan 2020. Irrigation Scheduling Approaches and Applications: A Review. Journal of Irrigation and Drainage Engineering, 146 (6): 04020007

Kisekka, I., Migliaccio, K. W., Dukes, M. D., Schaffer, B., & Crane, J. H. (2010). *Evapotranspiration-based Irrigation Scheduling for Agriculture. AE457*. Agricultural and Biological Engineering Department, Florida Cooperative Extension Service, IFAS, UF. Available at http://edis. ifas. ufl. edu/ae457, 6.
Kwanyuen, B.; Numkhang, P.; PhuthongSook, W.; Tonwiboonsak, S. The Study of Cassava’s Crop Coefficient (K_c). The 11th Thai Society of Agricultural Engineering International Conference, Bangkok, Thailand, 5–6 May 2010.
Mavi, H. S., & Tupper, G. J. (2004). *Agrometeorology: principles and applications of climate studies in agriculture*. CRC Press.
Meza, F. J. (2004, January). ENSO effects on reference evapotranspiration (ETo) at the Maipo river basin, Chile. In *18th Conference on Hydrology*.

Moore SE. *Quantifying Effective Rain in Landscape Irrigation Water Management*. 20 October 2009. Irrisoft, Inc. PO Box 6266. North Logan, Utah 84321

National Cooperative Soil Survey; 2020. National Cooperative Soil Survey Characterization Database; http://ncsslabdatamart.sc.egov.usda.gov/Accessed Monday, May 25, 2020

Nyvall, J. (2002). Soil water storage capacity and available soil moisture. *Abbotsford, BC*.

Peace Corps (1990). Irrigation Reference Manual. *Information Collection & Exchange Washington DC.*
Pereira, L., P. Paredes, N. Jovanovic 2020. Soil water balance models for determining crop water and irrigation requirements and irrigation scheduling focusing on the FAO56 method and the dual Kc approach**.** Agricultural Water Management, Volume 241: 106357

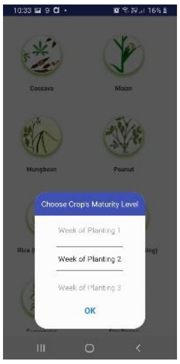
Rhoads FM. Yonts CD. 1991. Irrigation scheduling for corn–why and how. In *National Corn Handbook. NHC, 20.*

RID Royal Irrigation Department (RID). *Reference Crop Evapotranspiration by Penmen Monteith*, 2nd ed.; Office of Hydrology and Water Management, Royal Irrigation Department: Bangkok, Thailand, 2011.
RID Royal Irrigation Department (RID). *Crop Coefficient of 40 Varieties*; Office of Hydrology and Water Management, Royal Irrigation Department: Bangkok, Thailand, 2011.
USDA - SCS (1970). Irrigation water requirements. *Technical Release no 21*. USDA Soil Conservation Service, Washington, DC.
Vasudha S. Soil-water basics for irrigation scheduling Newsletter January 2019 Available at https://blog-crop-news.extension.umn.edu/2019/01/soil-water-basics-for-irrigation.html

Werner H. (1993) Checkbook Irrigation Scheduling. Irrigation Management Manual for South Dakota, *Cooperative Extension Service*, South Dakota State University. US Department of Agriculture

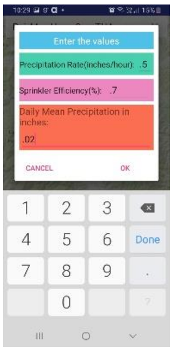
Screenshot 1

Screenshot 2



Screenshot 3

Screenshot 4



Precipitation Rate(inches/hour): .5
Sprinkler Efficiency(%): .7
Daily Mean Precipitation in inches: .02

Screenshot 5

Lat long is:19.2959,98.3618
Eto: 0.146
Kc : 0.29
Sprinkler Efficiency : .7
Sprinkler Precipitation Rate : .5
Soil Texture: Sandy clay loam
ETc for Cassava : 0.042
Average Daily Rainfall Pt :0.02
Unadjusted effective precipitation : 0.018000000000000002
Effective Precipitation Pe : 0.018000000000000002
Gross Irrigation Requirement (GI) :0.034
Net Irrigation Requirement (I) : 0.024339999999999994
Irrigation Runtime (IR) :234.72min
Irrigation Frequency (IF) : Every 56.253 days
Recommended Irrigation Cycle: Irrigate 4.17 minutes per day

Version no:1.3