http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Pakistan Journal of Biological Sciences

ISSN 1028-8880
DOI: 10.3923/pjbs.2021.241.251

Research Article
Analysis of Soil Water Balance to Determine Planting Time of Crops on Dryland, Indonesia

[1]Laode Sabaruddin, [2]Nur Arafah, [3]Hasbullah Syaf, [3]Sitti Leomo, [1]Tresjia Corina Rakian and [4]Jumarddin La Fua

[1]Department of Agrotechnology, Faculty of Agriculture, University of Halu Oleo, Kendari, Southeast Sulawesi, Indonesia
[2]Department of Forestry, Faculty of Forestry and Environmental Science, University of Halu Oleo, Kendari, Southeast Sulawesi, Indonesia
[3]Department of Soil Science, Faculty of Agriculture, University of Halu Oleo, Kendari, Southeast Sulawesi, Indonesia
[4]Department of Tadris Biology, Islamic State Institute of Kendari, Southeast Sulawesi, Indonesia

Abstract
Background and Objective: Soil water mainly derived from rainfall is an important limiting factor to increase crop production. Water balance is used to see the availability of soil water for plants at a certain time. This study aims to determine water supplies, water use and potential water loss using plant water balance and designing cropping patterns on dryland in Ranomee to subdistrict. **Materials and Methods:** The analysis of soil water's availability is presented through monthly graphs from January to December in climatological terms. The data used in this analysis are the average amount of monthly rainfall and the average monthly temperature in 2016-2018 from the Meteorological, Climatological and Geophysical Agency in South Konawe Regency representing the study area, Ranomeeto subdistrict and the land area of this district. Ranomeeto Subdistrict of South Konawe has a 7 month growth period, from the 2nd November to the 2nd July. **Results:** Analysis of the contribution of surface water to soil water content in the plant root zone shows that the Ranomeeto subdistrict of Konawe Selatan Regency has seven months-long growth period available from the second decade of November to the second decade of July. **Conclusion:** The planting time in the Ranomeeto subdistrict is in two periods of time, which is in November of decade three to February of decade three (during the rainy season) and May of decade one to July of decade one (during dry season).

Key words: Planting time, water balance, soil water availability, growth period

Citation: Sabaruddin, L., N. Arafah, H. Syaf, S. Leomo, T.C. Rakian and J.L. Fua, 2021. Analysis of soil water balance to determine planting time of crops on dryland, Indonesia. Pak. J. Biol. Sci., 24: 241-251.

Corresponding Author: Laode Sabaruddin, Department of Agrotechnology, Faculty of Agriculture, University of Halu Oleo, Kendari, Southeast Sulawesi, Indonesia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The issues on the soil water use on dry land are varied in each region, both technical and socio-economic aspects, including its management[1]. In general, dry land has low soil fertility, so that the soil layer becomes thin and has low organic material. On the other hand, the availability of water in dryland is the main limiting factor[2]. Water is a major factor for activities in agriculture because all plant metabolic processes need water[3]. Plant development and productivity will be running well if the soil water conditions are in good shape as well[4]. The water availability in the soil greatly affects plant growth directly. In dryland crop cultivation, water is the most determining limiting factor and rain is the main source for plant growth. The variation in rainfall, both in amount, intensity and time may hamper the prediction of planting time or planting pattern management caused by fluctuated water availability[5].

This water fluctuation often occurs in the dryland, so that efficient and effective land planning is needed through soil water balance information[6]. This soil water balance is a water balance for general agricultural land use. This balance sheet is useful in considering the suitability of agricultural land, arranging planting and harvesting schedules as well as regulating irrigation water provision in the right amount and time[7]. Soil water balance is a balance between groundwater stored as a reserve in the soil, derived from irrigation water and rainfall, with potential water loss in the form of drainage, surface runoff, evaporation and transpiration[8]. Furthermore, Imanuddin *et al.*[9] state that in agriculture, water resources play an important role in increasing economic and environmental sustainability through agricultural activities characterized by the fulfillment of evaporation of water into the atmosphere. In encouraging the acceleration of development in Southeast Sulawesi, it is necessary to optimize the production of regional economic resources so that it can provide benefits to increase the community and regional income. One potential economic resource is the agricultural sector. The development of this sector has been largely sought by the majority of the community in the Regency/City in Southeast Sulawesi, including South Konawe Regency. However, production produced from this sector has not reached its peak due to constraints in its operations, including conversion of agricultural land functions, maintenance, price fluctuations, business patterns tend to be subsistence and semi-subsistence, pests and diseases in plants, rainfall and other factors.

To increase the production of the agricultural sector in Southeast Sulawesi, especially in South Konawe Regency, it is necessary to allocate and arrange a certain area for agriculture so that farmers can have long-term business certainty. One important policy is mapping food lands. The mapping of food land currently requires many variables so that the determination of food land is biased. Therefore, a simpler variable is needed. This food availability must be supported by strong soil water balance information to reduce crop failures for food crops. Water balance calculations make it possible to evaluate the dynamics of soil water and water use by plants quantitatively[10] and calculate water availability spatially in a certain area[11]. Water balance is closely related to rainfall, surface temperature and evapotranspiration. In calculating soil water balance, rainfall is always a changing variable[12]. Surface air temperature is the temperature of free air at an altitude of 1.25-2.00 m from ground level[13]. Temperature affects plant growth and productivity, depending on the type of plants in the dry season or rainy season.

South Konawe Regency is one of the districts in Southeast Sulawesi dominated by dry land covering an area of 42,151 ha with utilization for food agriculture land of around 57%[14], including in Ranomeeto sub district. This sub district is located in the periphery or border between Kendari and South Konawe Regency. This area has a sufficient area for agricultural land. However, it has high crop failure rates. This failure is caused by climatic conditions that do not always support the farmers' cultivation and their knowledge. So that the right planting time strategy is needed for food crops based on the soil water balance. The study is conducted by analyzing the availability of soil water in the form of graphs presented monthly, from January to December on a climatological base. The data used in this analysis are the average monthly rainfall data and the average monthly temperature in 2016-2018 from Ranomeeto Climatology Station, South Konawe Regency, representing the research area and soil data in the Ranomeeto sub district.

MATERIAL AND METHODS

Study area: This research was conducted in the Ranomeeto sub district of South Konawe Regency and the Laboratory of the Soil Department of Agriculture Faculty at Halu Oleo University. The research took place from October-December, 2019.

Materials and equipment: The materials used were fieldwork maps, plastic bags, label paper, rainfall and temperature data of South Konawe and its surroundings and chemicals for laboratory analysis purposes. The tools used in this research are GPS (Global Positioning System), compass, clinometer

(Suunto, Finland), roll meter, hoe, shovel, field knife, machete, ground drill, sample ring, pins, ropes, stationary for writing instruments and equipment for laboratory analysis.

Methodology: This research was conducted using a survey method with an analytical approach. The procedures used in this study include the identification of land-based on climatic information and using free soil survey methods for soil analysis. The soil survey was carried out in several stages, including and the preparation, the field implementation, data and laboratory analysis stage.

Preparation stage: This stage is carried out by reviewing some literatures from various libraries supporting the research problem, collecting data about the research area condition, making a 1:50,000 scale work maps brought to the field. The working map created is based on a thematic map intercropping including land, slope, land use maps, especially food cropland. Furthermore, it is combined with the climatic conditions in the area around South Konawe Regency based on climate data around the observation area over the past 10 years. The area coverage of each station is determined through the Thiessen method (or Polygon Thiessen)[15].

Field implementation stage: This stage determines the sampling point based on a working map covering the climate data obtained during the preparation stage. Making a soil map unit based on the results of soil sampling is then grouped the same properties, features and characteristics to determine the soil map unit. Observation of soil profile was performed on each unit map of the representative land measuring 200×150×150 cm or up to the parent material layer. Profile observations are based on profile description cards from the land survey guide[16]. Taking Soil Sampling in a composite way to assess soil fertility. Composite soil samples are taken at each drilling point with a distance of 20 m. Samples were taken in two ways, namely to take whole and undisturbed soil sample using a ring sampler (ABM, Indonesia) and disturbed soil sample by using one hoe.

Laboratory analysis stage: The variables observed in this study were physical and morphological characteristics of the soil, soil colour, BV, soil texture, soil structure, soil permeability and porosity, soil depth, slope, surface rock conditions, soil drainage conditions and altitude using Global Position System (GPS).

Data analysis: Soil water balance analysis uses a common analysis procedure[15,16]. Water balance is related to the soil's ability to hold water influenced by the soil's physical properties (its texture). The amount of water retained by the soil also depends on the field capacity. The water balance calculation uses an empirical approach. The output produced is the availability of actual soil water, deficits and surpluses. The main inputs used in the calculation of the water balance are rainfall (RF) and air Temperature (T) used to estimate Potential Evapotranspiration (PE). Estimation of potential evapotranspiration will be carried out using the Thornthwaite model[17,18] as follows:

Thornthwaite and Mather model with the following Eq.:

$$PE = 1.6\ (10\ T/I)^{a}\ \ (cm),\ I = \Sigma i$$

$$i = \left[\frac{T}{5}\right]^{1,514}$$

Where:

- T = Mean monthly air temperature in degree C
- i = Monthly heat index
- I = Annual heat index (the sum of twelve monthly heat)
- a = Is a constant that varies from place to place, the following Eq.:

$$a = 6,75\times10^{-7}\ I^{3}\text{-}7,71\times10^{-5}\ I^{2}+0.01792\ I+0.49239$$

Evapotranspiration as an output, will be used to analyze the soil water balance. The soil-related physical characteristics to the water balance are the Soil Water Content (SWC) in field capacity conditions, i.e., at pF 2.42 obtained through the results of soil analysis. The calculation phase begins by subtracting the value of RF as input with PE as the output. In the condition of RF <PE there will be an Accumulation of Potential Water Loss (APWL), then the soil water content is calculated with the following Eq.[17,19-21]:

$$SWC = WHC\times k^{APWL}$$

when, RF>PE, the soil water content is calculated without the Accumulation of Potential Water Loss (APWL) with the following Eq.[17,19-21]:

$$SWC_{i} = SWC_{i-1}+(RF\text{-}PE)$$

So, the soil water content equals the field capacity, which means that the soil water condition reaches the field capacity condition[17,19-21].

$$k = \frac{po+p1}{WHC}$$

Where:

WHC	=	Water holding capacity
SWC	=	Actual soil water content
APWL	=	Accumulate potential water loss
po	=	1.000412351
p1	=	-1.073807306

the changing in actual soil water content is determined by calculating SWC for one-month minus with one previous month as like in the following Eq.[17,19-21]:

$$dSWC = SWCi_{+1}\text{-}SWC_i$$

Actual Evapotranspiration (AE), Deficit (D) and Surplus (S) with the following Eq.[17,19-21]:

$$AE = PE, \text{ if } RF>PE$$

$$AE = RF+[dSWC], \text{ if } RF<PE$$

$$D = PE\text{-}AE$$

$$S = RF\text{-}PE\text{-}dSWC$$

where, [dSWC] is an absolute value or a positive SWC value.

RESULTS

Soil conditions: Soil is a major factor for the growth and production of food crops. Ideal soil conditions are able to have an impact on the success of food crops. This study uses 10 Soil Map Unit (SMU) obtained from the research. The study results of surface soil conditions and physical properties of the soil are presented in Table 1.

The Table 1 shows that drainage at the study site was generally classified as good but was classified as somewhat fair and poor at SMU 171 and SMU 96, respectively. The texture of sandy generally dominates the soil texture at the study site. Sandy loam soil texture was found in SMU 71, 73, 96 and 98. The texture of sandy-slit loam was found at SMU 72 and SMU 203. In addition, a texture of clay was also found at the study site at SMU 171. The effective depth in the highest study area is 120 cm, with the predominant internal criteria identified at the study site. The lowest effective depth was found in SMU 96 with a value of 85 cm and was in the medium range.

The slope at the study site ranges from 0-40%, with the highest slope of 0-8 and 8-15% and very small slopes of 15-40%. In addition, the values at the study site did not include surface rock and rock outcrops. This condition causes the risk of erosion to be classified as very low, to moderate and the risk of flooding is classified as very low, except for SMU 171.

The soil was dominated by acid pH at the study site and one SMU had a slightly acidic pH at SMU 72. The Table 2 shows that the C-organic soil content at the study site ranged from 1.14-3.19 %. The high-criteria C-organic content was found in SMU 98 and the lowest was found in SMU 180, while the medium-criteria C-organic content was found in SMU 134 with an organic C value of 2.78%.

The results of nitrogen content measurements at the study site were the highest in SMU 171 with a value of 0.34% and the lowest of 0.21% in SMU 71, SMU 73 and SMU 96. The phosphate content of the study site varies with low, low and high criteria. The phosphate content range was found to be 5.12-13.85 ppm. The high-criteria phosphate content was found in SMU 72, SMU 97 and SMU 134 with values of 13.85, 12.44 and 12.12 ppm, respectively. While the phosphate content with the criteria is found in SMU 180 with a value of 9.55 ppm and SMU 203 with a value of 10.11 ppm. The K-available values also show variations at study sites with low, medium, high and very high criteria. The results of K-available measurements with very high criteria are found in SMU 134

Table 1: Surface soil conditions and soil physical properties at the research site

SMU	Drainage	Soil texture	Effective soil depth (cm)	Effective soil depth Criteria	Slope (%)	Surface rock outcrop (%)	Rock outcrop (%)	Porosity level	Flood danger
71	Good	Sandy loam	120	Deep	0-8	0	0	Very low	F_0
72	Good	Sandy-silt loam	120	Deep	0-8	0	0	Very low	F_0
73	Good	Sandy loam	120	Deep	0-8	0	0	Very low	F_0
96	Poor	Sandy loam	85	Moderate	8-15	0	0	Low	F_0
98	Good	Sandy loam	100	Deep	8-15	0	0	Moderate	F_0
180	Good	Loam	120	Deep	8-15	0	0	Moderate	F_0
203	Good	Sandy-silt loam	90	Deep	15-40	0	0	Moderate	F_0
97	Good	Loam	120	Deep	8-15	0	0	Low	F_0
134	Good	Silty loam	120	Deep	8-15	0	0	Moderate	F_0
171	Fair	Clay	120	Deep	0-8	0	0	Very low	F_3

SMU: Soil map unit

Table 2: Soil chemical properties at the research site

Land unit	Soil pH		C-Organic		Nitrogen		Phosphate		Kalium		Cation exchangeable		
	Score	C	%	C	%	C	ppm	C	Cmol (+). kg^{-1}	C	Cmol (+). kg^{-1}	C	Al (%)
71	5.01	A	1.27	L	0.21	M	6.13	L	8.22	VL	13.00	L	0.35
72	6.00	SA	1.84	L	0.28	M	13.85	H	36.61	M	46.32	VH	0.00
73	5.01	A	1.27	L	0.21	M	6.13	L	8.22	VL	13.00	L	0.35
96	5.01	A	1.27	L	0.21	M	6.13	L	8.22	VL	13.00	L	0.35
98	5.13	A	3.19	H	0.28	M	5.12	L	41.19	H	18.29	M	0.22
180	5.14	A	1.14	L	0.28	M	9.55	M	22.2	M	16.7	M	0.22
203	4.98	A	1.66	L	0.23	M	10.11	M	28.58	M	17.22	M	0.32
97	5.14	A	1.59	L	0.29	M	12.44	H	12.86	L	18.35	M	0.16
134	6.85	SA	2.78	M	0.27	M	12.12	H	66.24	VH	10.07	L	0.00
171	4.68	A	1.93	L	0.34	M	8.57	M	34.95	M	23.76	M	0.52

A: Acidic, SA: Strongly acidic; L: Low, H: High, VL: Very low, M: Moderate, VH: Very high, C: Criteria

Table 3: Soil water content and soil water availability at the research site

	Water content (%vol)		Soil water availability	
Depth (cm)	$pF_{2.54}$	$pF_{4.20}$	%vol	Mm m^{-1}
1a	28.52	19.42	9.10	91.00
1b	21.91	14.88	7.03	70.30
2a	24.55	14.44	10.11	101.10
2b	21.69	15.17	6.52	65.20
3a	29.73	21.28	8.45	84.50
3b	29.64	16.83	12.81	128.10
4a	33.22	25.10	8.12	81.20
4b	26.64	15.86	10.78	107.80
Mean				
a	29.03	20.06	8.95	89.45
b	24.97	15.69	9.29	92.85
Mean	27.00	17.89	9.11	91.15

$pF_{2.54}$: Water potential energy in the FC: Field capacity, $pF_{4.20}$: Water potential energy in the WP: Wilting point, a: Soil depth of 0-20 cm and b: Soil depth of 20-40 cm

and SMU 98, while K-available measurements with very low criteria are found in SMU 71, SMU 73 and SMU 96. The capacity to exchange cation soils in the study sites is based on medium criteria, whereas the capacity to exchange cation soils with high criteria is found only in SMU 72. The soil Al content in the study location ranges from 0.00-0.52%. The results indicate high Al content in SMU 171 and there are two SMU that do not have the Al content found in SMU 72 and SMU 134.

Soil water content: Groundwater content or groundwater availability varies in the study location area as in other regions. The variation is determined by the rainfall conditions that fall in the region and the physical characteristics, particularly the soil texture. The concentration of groundwater in Field Capacity (FC) and Wilting Point (WP) in the study area based on the potential pressure of pure water (free energy potential, pF) is presented in Table 3. Data shows in Table 3 that at depth 0-20 cm, the groundwater content in field capacity varies from 24.55-33.32% volume with an average of 29.03% vol and at the wilting point of 14.44-25.10% volume with an average of 20.06% volume.

Likewise, at a depth of 20-40 cm, the field water content varies from 21.69-29.64% volume with an average of 24.97% volume. The water content in field capacity shows that the maximum capacity of the soil holding water (water holding capacity) in the study area is 27.00% vol or 270.00 mm m^{-1}. The depth of its roots largely determines the ability of plants to use groundwater. If the depth of the annual crop roots in the dry land is as deep as 25 cm, the maximum quantity of water plants can be absorbed 270.00 mm/mx 0.25 m = 67.5 mm. Therefore, to increase the effectiveness of groundwater utilization to meet the needs of plants on dry land, it is necessary to arrange the right planting time, especially food crops.

Soil water balance: Water balance is a balance between water supplies due to rainfall and evapotranspiration when water is used. The difference between the two values shows the short length of the growing period available to plants, especially on dry soil. Data on average daily rainfall and air temperature values in the study area are shown in Fig. 1.

The Fig. 1 shows that the average annual rainfall in the research activity area is 2,649.5 mm, with an average rainwater range of 78.0-441.6 mm. The highest average rainfall was 441.6 mm in May and 411.5 mm in June, while the lowest average rainfall was 79.9, 78 and 93 mm in August, September and October. Rainfall directly affects fluctuations in surface runoff and indirectly affects the availability of groundwater. The temperature or temperature of the air is needed to determine evapotranspiration as a component of the water output in the water balance. The average temperature measurements in the study area (Fig. 1) showed that the temperature range is between 25.4-28.1°C. The highest temperature was reported to occur in September at 28.1°C and the lowest was reported in July is 25.4°C. Empirically, data on air temperature can estimate the potential evapotranspiration value used to estimate the water reserves

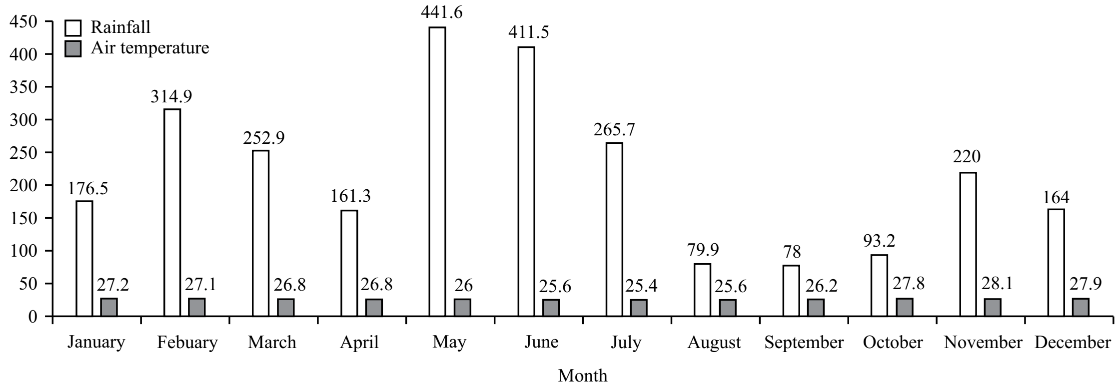

Fig. 1: Average daily rainfall (mm) and daily air temperature in the study area in 2016-2018 observation period
Source: Meteorological, Climatological, and Geophysical Agency of Ranomeeto (2019), Coordinate: 04° 03' 21" S; 122° 26' 57" E

Table 4: Results of a potential evapotranspiration analysis (10^{th} decade daily) in the study area based on the Thornthwaite model

Periods (decade)	Air temperature (°C)	Monthly heat index (I)	Potential evapotranspiration (mm)
January-01	27.0	12.8	45.8
January-02	26.8	12.7	45.0
January-03	27.7	13.4	51.1
February-01	27.4	13.1	48.5
February-02	27.2	13.0	47.3
February-03	26.7	12.6	44.4
March-01	26.8	12.7	44.9
March-02	26.9	12.7	45.3
March-03	26.8	12.7	45.0
April-01	26.7	12.7	44.5
April-02	26.9	12.7	45.2
April-03	26.8	12.7	45.0
May-01	26.4	12.4	42.5
May-02	25.4	11.7	36.9
May-03	26.1	12.2	40.6
June-01	25.9	12.1	39.4
June-02	25.9	12.1	39.5
June-03	25.1	11.5	35.2
July-01	25.2	11.6	35.5
July-02	25.4	11.7	36.8
July-03	25.6	11.8	37.6
August-1	25.8	12.0	38.9
August-2	25.2	11.6	35.9
August-3	25.7	12.0	38.6
September-01	26.0	12.1	40.0
September-02	26.3	12.3	41.6
September-03	26.4	12.4	42.2
October-01	27.4	13.1	48.5
October-02	28.0	13.6	52.9
October-03	28.2	13.7	54.1
November-01	28.6	14.0	57.4
November-02	28.2	13.7	54.3
November-03	27.5	13.2	49.4
December-01	27.8	13.4	51.4
December-02	27.9	13.5	52.3
December-03	28.0	13.6	52.7
Annual	26.7	151.8	1.606.2

Source: Meteorological, climatological, geophysical agency of Ranomeeto (2016-2018)

in the soil. Calculation of the groundwater balance is very important because it can explain the flow of water from the rain that falls and reaches the surface of the ground, which is then infiltrated into the ground and becomes part of the groundwater. Groundwater balance analysis performed using the Thornthwaite model is shown in Table 4.

Table 5: Length of plant growth periods based on the calculation of water balance based on the Thornthwaite method at the study area's

Periods (decade)	Rainfall (mm)	Potential evapotranspiration (mm)	Soil water content (mm m^{-1})	Water deficit (mm)	Water surplus (mm)
January-01	63.0	45.8	270.0	0.0	17.2
January-02	53.6	45.0	270.0	0.0	8.6
January-03	59.9	51.1	270.0	0.0	8.8
February-01	40.3	48.5	262.2	0.4	0.0
February-02	95.7	47.3	270.0	0.0	56.2
February-03	183.3	44.4	270.0	0.0	138.9
March-01	52.2	44.9	270.0	0.0	7.3
March-02	56.3	45.3	270.0	0.0	11.0
March-03	144.4	45.0	270.0	0.0	99.4
April-01	65.8	44.5	270.0	0.0	21.3
April-02	44.0	45.2	268.8	0.0	0.0
April-03	51.5	45.0	270.0	0.0	7.7
May-01	97.9	42.5	270.0	0.0	55.4
May-02	183.6	36.9	270.0	0.0	146.7
May-03	160.0	40.6	270.0	0.0	119.4
June-01	88.2	39.4	270.0	0.0	48.8
June-02	113.8	39.5	270.0	0.0	74.3
June-03	209.5	35.2	270.0	0.0	174.3
July-01	131.6	35.5	270.0	0.0	96.1
July-02	88.4	36.8	270.0	0.0	51.6
July-03	45.7	37.6	270.0	0.0	8.1
August-1	25.8	38.9	257.7	0.8	0.0
August-2	48.1	35.9	269.9	0.0	24.4
August-3	6.1	38.6	240.5	3.1	0.0
September-01	18.2	40.0	222.5	3.8	0.0
September-02	24.2	41.6	209.1	4.0	0.0
September-03	35.6	42.2	204.2	1.7	0.0
October-01	23.2	48.5	186.6	7.7	0.0
October-02	16.0	52.9	163.6	13.9	0.0
October-03	54.0	54.1	163.5	0.0	0.0
November-01	45.9	57.4	157.0	4.9	0.0
November-02	86.4	54.3	189.1	0.0	86.4
November-03	87.7	49.4	227.4	0.0	87.7
December-01	66.1	51.4	242.1	0.0	66.1
December-02	74.9	52.3	264.7	0.0	74.9
December-03	23.1	52.7	243.0	7.9	0.0

Evaporation is a process of evaporation through changes in the form of water or liquid into gas and diffusion into the atmosphere, while the transpiration of water is lost from the body of the plant to the atmosphere. This total evaporation and transpiration of the atmosphere are called evapotranspiration. Results of evapotranspiration measurements using the Thornthwaite method show that the potential evapotranspiration value in the study area is 1.606.2 mm per year with a range of 35.2-57.4 mm. The highest possible evapotranspiration was found at 57.4 mm in the first decade of November and the lowest was found at 35.2 mm in the third decade of June.

Based on Table 4, the highest possible evapotranspiration rate occurs in October, November and December. The lowest possible evapotranspiration occurs in June, July and August. The high potential for evapotranspiration in October, November and December is due to daily heat indexes and air temperatures that show higher values than other months, both of which play a role in converting a quantity of water into water vapor.

Planting time: Calculation of the beginning of the planting time using the Thornthwaite method shall be carried out to determine the amount of water in each month in one year, in which case the water has a surplus or a deficit of water and to determine the monthly runoff, to determine the loss of water through the surface runoff. Calculations using the Thornthwaite method take into account precipitation, evapotranspiration, monthly heat index and Water Holding Capacity (WHC). The preliminary analysis of planting time based on the review of the soil water balance and the length of the food crop growth period in the study area are presented in Table 5.

From Table 5 above, it can be seen that the rainfall (RF) and the potential evapotranspiration (PE) are visible periods of deficit, surplus and replenishment. The District of Ranomeeto has a deficit period of 4 months, namely July, decades three to November decade one. There is a deficit month if the rainfall (RF) is smaller than the Potential Evapotranspiration (PE). While the surplus has eight months, namely November two decades to July the second decade. A period of surplus occurs when rainfall (RF) exceeds the Potential for Evapotranspiration (PE). The filling period occurred in November of the second decade, in this month, the replenishment of water occurred after the period of water deficit. Two factors predominantly determine the availability of water in the soil, the first, precipitation through the mechanism of infiltration and percolation as a source of filling in the system. The second is evapotranspiration as emptying, which causes loss of water from the system. If the emptying of water is greater than filling the water, there will be a decrease in groundwater availability.

The Ranomeeto District, a research area, is a dry land area where all agricultural activities use rainwater springs, making water availability very important for planting time. The Table 5 shows that the Ranomeeto District has a potential water deficit for four months from July decade three to November decade one. These conditions led to the depletion of groundwater from a potential condition of 270.0-157.4 mm m^{-1} in November decade one. The recharging of groundwater, then occurs in precipitation that is higher than evapotranspiration so that the groundwater condition returns to normal in the following month. The results of the water balance data analysis of Ranomeeto climatology station in South Konawe Regency show that the District of Ranomeeto has two planting periods of crops, the first period can be started in November decade three to February decade three (in the Rainy Season) and the second period starts in May decade one until July decade two (during the Dry Season).

DISCUSSION

Observations of soil conditions in the study area show that the soil texture is generally dominated by the texture of sandy loam and sandy loam. The texture of dusty loam and sandy loam has the characteristics of having a large surface area, being able to hold water or to bind large amounts of water[18]. As a result, the texture of dusty clay and sandy clay has a low level of flood hazard as it is easy to pass water into the soil. This is consistent with the view of An *et al.*[22] that soil with a large percentage of sand in its texture will easily pass through the soil. This is related to the effect of the texture on the proportion of colloidal material, the pore space and the adsorption surface area. The more refined the texture will be, the greater the water storage capacity, the higher the level and availability of groundwater. The Soil Map Unit (SMU) at the study site also has a clay texture found in SMU 171 . The movement of water in the texture of the clay is thought to be inhibited because the texture of clay in wet soils floats in such a way that it closes the pores and inhibits the movement of water into the soil[23]. Inhibited movement of water into the soil may pose a high risk of flooding as identified in SMU 171. According to Arkhangelskaya and Lukyashchenko[24], soil texture determines the water system, ease of processing and soil structure. In addition, Yao *et al.*[25] argued that heavy-textured soils are difficult to process and difficult to see. Because the smaller the particle size, the larger the surface area. The surface area of the fraction of clay is greater than the fraction of dust, while the fraction of dust is greater than the fraction of sand[26,27]. The results of the measurement of the effective depth of the observation area have criteria in that this means that there is enough water for plant growth. Whereas in SMU 96, there are moderate criteria. This shows that the availability of water and root growth in the soil is very limited and therefore affects the absorption of water. According to Leenaars *et al.*[28] soil with a moderate or shallow depth will reduce water availability and root growth.

Measurement of the soil's chemical properties at the study site shows different criteria because the soil's chemical content is always transforming the soil biota from one form to another, thereby altering the soil's chemical composition. The results of measurements of soil chemical properties at the study site showed that soil pH ranged from 6.68-6.85 which was dominated by acid criteria, C-organic soil ranged from 1.27-3.19% which was dominated by low criteria, N-a total of 0.21-0.34% with moderate criteria, P-available 5.12-13.85% with high criteria, K available 8.22-66.24 cmol (+). kg^{-1}, which is dominated by very low criteria, cation exchange capacity of 13-46.31 with moderate criteria and Al ranges from 0.00-0.35%. Soil organic matter with ideal criteria may hold more water in soil with low organic matter content[29]. In addition, Rabot *et al.*[30] reported that organic matter has an influence on the physical properties of the soil, including the ability to keep water increasing, the color of the soil brown to black, stimulates and stabilizes aggregate granulation and reduces plasticity, cohesion and other bad properties of clay. Overall, the content of soil organic matter in the study area is generally dominated by low and medium criteria so that this soil still needs a high supply of organic material.

In addition to the supply of organic material for plant growth, water availability is also a key factor in farming activities because every plant needs an adequate supply of water to support its growth[31]. The soil water content in Field Capacity (FC) and Wilting Point (WP) of the study area based on the potential pure water pressure is 26.99 percent/volume. At the wilting point, 17.88 percent/volume with groundwater content is 182.2 mm per meter of soil depth, which is optimal for plant growth. Optimum water availability will support plant production capacities. Another factor that indirectly affects groundwater availability is water pressure, particularly the potential for matrix. Toth *et al.*[32] indicated that soil water content is affected by soil physical properties (soil texture), organic matter content and matrix potential. In soil conditions not covered by vegetation, soil erosion will transport the soil rich in organic material so that the ability to store water is different. If the topsoil has been lifted, the lower fertility subsoil, which acts as a layer for plant cultivation, decreases its ability to bind water. According to Zhang *et al.*[33] efforts to improve soil fertility and the ability to bind water are made through fertilization to increase soil organic matter and improve pore space drainage. With the tendency to increase the amount of pore drainage better soil aeration, faster water distribution and easier root penetration.

Calculation of the soil water balance at the location of the study is based on rainfall (precipitation) and evapotranspiration data. Thornthwaite is a method used to estimate and calculate potential evapotranspiration[34]. The potential evapotranspiration value (EP) in the study area for one year is 1,606.2 mm or 60.62% of the amount of precipitation falling, while the monthly average is 44, 11 mm. Based on the alleged potential evapotranspiration (EP) performed, the amount of precipitation received is high, which is 60.62%. This shows that the potential for water loss in the Ranomeeto District, South Konawe District study area is high. However, the study area is a tropical wetland with year-round rainfall, (Table 5). It shows that there is a potential for drought. Drought potential occurs when monthly rainfall is lower than the current EP value, i.e., from August-November. These conditions may be concluded that the study area has the potential to cause drought in the region. However as long as the annual rainfall value is higher than the EP value, yearly meteorological drought can be avoided. According to Rajib *et al.*[35] evapotranspiration is an important component in affecting the hydrological balance of the region, since its importance is a major part of the water flow. The amount of evapotranspiration value of a landscape is significant to know, in particular its relationship to the time of planting on agricultural land. Knowledge of planting time is therefore needed for farmers to minimize the impact of crop failure by recognizing the potential for the drought to increase crops' productivity.

The determination of planting time in the Ranomeeto district is based on an analysis of the groundwater balance sheet. Water balance is a model of the quantitative relationship between the amount of water above and within the soil and the amount of rainfall that falls over a period of time[36]. According to Pravalie *et al.*[37] the water balance is the balance between rainfall (RF) and the rate of potential evapotranspiration (EP). If rainfall exceeds the potential evapotranspiration (RF>EP), there is an increase in groundwater so that sufficient water is available, even the land has excess water or Surplus (S) and vice versa, if the rainfall is smaller than the potential evapotranspiration (RF<EP), the soil water content or Deficit (D) will decrease[38]. Based on the results of the analysis of the water balance, it can be seen that the area of the district of Ranomeeto has a food crop planting period of two periods, namely the first period from November three decades to February three decades (in the rainy season) and the second period from May one decade to July the second decade (in the dry season). Besides, the Ranomeeto district has had a water deficit for 11 decades and a surplus of water for only two decades, namely May two decades and three decades in June or early May and late June. Using the information on the water balance, which is a period of surpluses and deficits to determine planting time, can help to increase growth and crop production, increasing agricultural production will increase farmers' incomes.

CONCLUSION

The results indicate that soil is highly dependent on water supply from rainfall. This condition shows that the availability of water on the soil is strongly influenced by rainfall, which makes water management's purpose carried out water retention and maximizes the utilization of rainfall. Analysis of the contribution of surface water to soil water content in the plant root zone shows that the Ranomeeto subdistrict of Konawe Selatan Regency has a seven-month-long growth period available from the second decade of November to the second decade of July. When planting food crops in Ranomeeto, it can be done in two periods, namely in the third decade of November to the third decade of February (in the Rainy Season) and the first May to the second June.

SIGNIFICANCE STATEMENT

This study discovers the planting time of food crops in the Ranomeeto District Area based on average monthly temperature and rainfall data for the years 20016-2018 from the Ranomeeto Climatology Station, Konawe Selatan Regency and was available in two periods, namely the first period in November decade three-February decade three (Rainy season) and the second period in May the first decade-July second decade (dry season). This research can be useful in determining planting time for farmers to minimize the impact of crop failure in order to increase crop productivity. This study will help the researcher to uncover the critical areas of periods of surplus and groundwater deficit so as to know the potential for drought in an area where many researchers have not explored much about the use of climatological data to help determine the ideal planting time to increase plant growth and production. Thus, a new theory on the determination of the surplus period and the water deficit based on the analysis of the land water balance is acceptable in order to determine the availability of groundwater which is used as the basis for the determination of planting time may be arrived at.

ACKNOWLEDGMENTS

The authors would like to thank the Rector of Halu Oleo University for supporting this research by DIPA funds of the University of Halu Oleo in 2019 with a contract number: 16011e/ UN29.LPPM/2019, dated October 1, 2019. Besides, the authors would like to thank the students of the Agrotechnology Department of Agriculture, Faculty of Halu Oleo University involved in this research.

REFERENCES

1. Jian, S., C. Zhao, S. Fang and K. Yu, 2015. Effects of different vegetation restoration on soil water storage and water balance in the Chinese Loess Plateau. Agric. For. Meteorol., 206: 85-96.
2. Ullah, H., R. Santiago-Arenas, Z. Ferdous, A. Attia and A. Datta, 2019. Improving water use efficiency, nitrogen use efficiency and radiation use efficiency in field crops under drought stress: A review. Adv. Agron., 156: 109-157.
3. Wang, J., B. Fu, N. Lu, L. Zhang, 2017. Seasonal variation in water uptake patterns of three plant species based on stable isotopes in the semi-arid Loess Plateau. Sci. Total Environ., 609: 27-37.
4. Sujalu, A., I. Hardwinarto and S. Boer, 2014. Analysis of water balance to determine cropping patterns for food crops in watershed Karangmumus-the province of east Kalimantan. Agrolife Sci. J., 3: 68-74.
5. Sujalu, A.P., M. Hidayanto, Y. Fiana and A.Y.P. Asih, 2019. Analysis of water balance to determine cropping patterns of food crop in sub-watershed tenggarong, kutai kartanegara regency. Bulg. J. Agric. Sci., 25: 214-220.
6. Wright, A., S.A. Schnitzer and P.B. Reich, 2015. Daily environmental conditions determine the competition-facilitation balance for plant water status. J. Ecol., 103: 648-656.
7. Dwiratna, S., N. Bafdal, C. Asdak and N. Carsono, 2018. Study of runoff farming system to improve dryland cropping index in Indonesia. Int. J. Adv. Sci. Eng. Inf. Technol., 8: 390-396.
8. Azmeri, A., A. Yulianur, U. Zahrati and I. Faudli, 2019. Effects of irrigation performance on water balance: Krueng baro irrigation scheme (Aceh-Indonesia) as a case study. J. Water Land Dev., 42: 12-20.
9. Imanudin, M.S., E. Armanto, R.H. Susanto and S.M. Bernas, 2010. Water table fluctuation in tidal lowland for developing agricultural water management strategies. J. Trop. Soils, 15: 277-282.
10. Rahman, A.S., M.S. Ahmed, M.A. Hasnat, M. Kamruzzaman, M.A. Khalek, Q.H. Mazumder and C.S. Jahan, 2018. Modeling the changes in water balance components of the highly irrigated western part of Bangladesh. Hydrol. Earth Syst. Sci., 22: 4213-4228.
11. Ren, X., D. Sun and Q. Wang, 2016. Modeling the effects of plant density on maize productivity and water balance in the Loess Plateau of China. Agr. Water Manage., 171: 40-48.
12. Hatfield, J.L. and C. Dold, 2019. Water-use efficiency: Advances and challenges in a changing climate. Front. Plant Sci., Vol. 10. 10.3389/fpls.2019.00103.
13. Wu, H., Y. Zhong, W. Xu, W. Shi, X. Shi and T. Liu, 2020. Experimental investigation of ground and air temperature fields of a cold-region road tunnel in NW China. Adv. Civ. Eng., 2020: 1-13.
14. Sulfiar, A.E.T., B.A. Atmoko, B. Guntoro and I.G.S. Budisatria, 2020. Study of pasture productivity for semi-intensive cattle system during dry season in the south Konawe regency, southeast Sulawesi. Buletin Peternak, 44: 85-91.
15. Fiedler, F.R., 2003. Simple, practical method for determining station weights using Thiessen polygons and isohyetal maps. J. Hydrol. Eng., 8: 219-221.
16. Kopec, R.J., 1963. An alternative method for the construction of Thiessen polygons. Prof. Geogr., 15: 24-26.
17. McKenney, M.S. and N.J. Rosenberg, 1993. Sensitivity of some potential evapotranspiration estimation methods to climate change. Agric. For. Meteorol., 64: 81-110.
18. Aparecido, L.E.D.O., G.D.S. Rolim, J. Richetti, P.S.D. Souza and J.A. Johann, 2016. Thornthwaite and Camargo climate classifications for climatic zoning in the State of Paraná, Brazil. Ciênc. Agrotec., 40: 405-417.
19. Ritchie, J.T., 1998. Soil water balance and plant water stress. Klulrer Academic Publishers, Springer Netherlands, ISBN: 978-94-017-3624-4 14.

20. Allocca, V., P. De Vita, F. Manna and J.R. Nimmo, 2015. Groundwater recharge assessment at local and episodic scale in a soil mantled perched karst aquifer in southern Italy. J. Hydrol., 529: 843-853.
21. Sujalu, A.P. and Ismail, 2015. Water Balance Analysis for the Determination of Available Growing Season at Sub-watershed, Loa Janan, East Kalimantan. In: Food Security and Food Safety for the Twenty-first Century, Hongladarom, S., (Ed.)., Springer, Singapore, ISBN: 978-981-287-417-7 pp: 131-140.
22. An, N., C.S. Tang, S.K. Xu, X.P. Gong, B. Shi and H.I. Inyang, 2018. Effects of soil characteristics on moisture evaporation. Eng. Geol., 239: 126-135.
23. Armenise, E., R.W. Simmons, S. Ahn, A. Garbout, S.H. Doerr, S.J. Mooney and K. Ritz, 2018. Soil seal development under simulated rainfall: Structural, physical and hydrological dynamics. J. Hydrol., 556: 211-219.
24. Arkhangelskaya, T. and K. Lukyashchenko, 2018. Estimating soil thermal diffusivity at different water contents from easily available data on soil texture, bulk density and organic carbon content. Biosyst. Eng., 168: 83-95.
25. Yao, Y., J. Liu, Z. Wang, X. Wei, H. Zhu, W. Fu and M. Shao, 2020. Responses of soil aggregate stability, erodibility and nutrient enrichment to simulated extreme heavy rainfall. Sci. Total Environ., Vol. 709. 10.1016/j.scitotenv.2019.136150.
26. Ben-Israel, M., Y. Enzel, R. Amit and Y. Erel, 2015. Provenance of the various grain-size fractions in the Negev loess and potential changes in major dust sources to the Eastern Mediterranean. Quat. res., 83: 105-115.
27. Shahabinejad, N., M. Mahmoodabadi, A. Jalalian and E. Chavoshi, 2019. The fractionation of soil aggregates associated with primary particles influencing wind erosion rates in arid to semiarid environments. Geoderma, Vol. 356. 10.1016/j.geoderma.2019.113936.
28. Leenaars, J.G., L. Claessens, G.B. Heuvelink, T. Hengl, M.R. González, L.G. Van Bussel and K.G. Cassman, 2018. Mapping rootable depth and root zone plant-available water holding capacity of the soil of sub-Saharan Africa. Geoderma, 324: 18-36.
29. Sarker, J.R., B.P. Singh, W.J. Dougherty, Y. Fang, W. Badgery, F.C. Hoyle and A.L. Cowie, 2018. Impact of agricultural management practices on the nutrient supply potential of soil organic matter under long-term farming systems. Soil Tillage Res., 175: 71-81.
30. Rabot, E., M. Wiesmeier, S. Schluter and H.J. Vogel, 2018. Soil structure as an indicator of soil functions: A review. Geoderma, 314: 122-137.
31. Komin, W. and G. Sedana, 2019. Sustainable agricultural tehcnologies on rice farming: Case of subaks' in bali province, Indonesia. J. Sus. Dev. Sci., 1: 18-26.
32. Tóth, B., A. Makó and G. Toth, 2014. Role of soil properties in water retention characteristics of main Hungarian soil types. J. Cent. Eur. Agr., 15: 137-153.
33. Zhang, L., J. Hu, Y. Li and N.S. Pradhan, 2018. Public-private partnership in enhancing farmers' adaptation to drought: Insights from the Lujiang Flatland in the Nu River (Upper Salween) valley, China. Land Use Policy, 71: 138-145.
34. Ogunbode, T.O. and I.P. Ifabiyi, 2019. Temporal water balance analysis in different climatic scenarios in Oyo State, Nigeria. Sustainabil. Agric. Food Environ. Res., 7: 163-177.
35. Rajib, A., G.R. Evenson, H.E. Golden and C.R. Lane, 2018. Hydrologic model predictability improves with spatially explicit calibration using remotely sensed evapotranspiration and biophysical parameters. J. Hydrol., 567: 668-683.
36. Chandrasekhar, P., J. Kreiselmeier, A. Schwen, T. Weninger, S. Julich, K.H. Feger and K. Schwärzel, 2018. Why we should include soil structural dynamics of agricultural soils in hydrological models. Water, Vol. 10. 10.3390/w10121862.
37. Pravalie, R., A. Piticar, B. Ro ca, L. Sfîcă, G. Bandoc, A. Tiscovschi and C. Patriche, 2019. Spatio-temporal changes of the climatic water balance in Romania as a response to precipitation and reference evapotranspiration trends during 1961–2013. Catena, 172: 295-312.
38. Tirivarombo, S., D. Osupile and P. Eliasson, 2018. Drought monitoring and analysis: standardised precipitation evapotranspiration index (SPEI) and standardised precipitation index (SPI). Phy. Chem. Earth, Parts A/B/C, 106: 1-10.