Advances in Agricultural Technology & Plant Sciences
ISSN: 2640-6586
Academic Strive
Researcher's perception is our reality

Research Article *Volume 4 Issue 2*

Planning of Cropping Patterns in Penajam Paser Utara District

Imang N[1], Sopian A[2], Dianita R[3], Suharlina[4] and Sujalu AP[5]*

[1]Faculty of Agriculture, University of Mulawarman, Indonesia

[2]Faculty of Agriculture, University of Widyagama Mahakam Samarinda, Indonesia

[3]Faculty of Animal Science, University of Jambi, Indonesia

[4]East Kutai Agricultural College School, Indonesia

[5]Faculty of Agriculture, University of 17 Agustus 1945 Samarinda, Indonesia

***Corresponding author:** Akas Pinaringan Sujalu, Faculty of Agriculture, University of 17 Agustus 1945 Samarinda, Indonesia, Tel: +62541743390; Email: akaspinaringansujalu@gmail.com

Received Date: June 23, 2021; **Published Date:** July 02, 2021

Abstract

The water balance analysis reveals the percentages of precipitation made up by surface flow, evapotranspiration, groundwater recharge and the change of soil storage, all of which are considered useful to the further understanding of the hydrological processes. Growing periods can be determined using water balance analysis to decrease harvest risk in certain area. The experiment objective was to determine growing periods of food crop in at Penajam Paser Utara district. Modified method of Thornthwaite and Mather of bookkeeping system of water balance was used based on monthly data. Rainfall and another parameter of climate data were collected from 21 Meteorology stations, then to be analyzed in order to determine land water balance. Monthly land water balance indicated that Penajam Paser Utara area, there were 7 months water surplus (January to June, and December), it was 613 mm/year, while water deficit occurred during 4 months (July to October), it was 22, 4 mm/ year. Optimally, at Penajam Paser Utara area, there was 11 months period for twice rice planting, and once for other food crops.

Keywords: Land Water Balance; Planting Period; Food Crops

Abbreviations: SWB: Soil Water Balance; WCS: Water Content of Soil.

Introduction

Disruption of national food production in the last decade about 65% is caused by natural disasters mainly due to fluctuations in climate elements that are getting sharper. This happens because agro-climate is the most difficult natural resource to be modified and controlled and has very high diversity and dynamics, so extreme fluctuations will occur easily. Although it is a fundamental factor and has a role for plant growth and production, the agro-climate aspect gets an inadequate portion in the process of planning and implementing agricultural activities, especially in the water balance aspect. Agricultural water needs depend on the climatic characteristics of a given region mainly precipitation, solar radiation, temperature, wind speed and relative humidity. In Defining a water balance for agriculture the first step would be to determine the plant water requirements and then in irrigated areas to quantify the water losses due to transport, distribution and application of water. For this purpose, quantitative knowledge of water supply, loss and consumption is needed by performing water balance analysis. It is one of the greatest advances in understanding the response of plants in water-limited environment. Also, it is important to evaluate the difference of hydrologic parameters under different climate condition to find proper water balance such as in watersheds area.

Preparation of the water balance is the basis of the development potential of climate, soil, and plants that are very useful for planning the development of agricultural production. It is intended to provide important information on the net amount of water that can be obtained, the value of the surplus water which can't be accommodated, and when the water balance occur. Therefore, these data can be used as a basis for planning and management of various activities, such as making a water dam (for water storage and distribution), and the possibility of natural water utilization for a variety of other activities [1,2]. Water balance is form the agro meteorological models generally consist of a set of sub models, each simulating one term in the water balance equation: soil available moisture, runoff, drainage and evapotranspiration. They differ in the way each sub model works.

They are usually based on the notion of maximum available moisture, defined as the difference expressed in millimeters between the amount of water stored at field capacity (- 33 Wa) and at wilting point (-1500 Wa) in the zone of the soil occupied by the roots. The maximum available moisture accounts for the fact that only the water stored between wilting point and field capacity is effectively available for plants, since below the wilting point water is too strongly linked with the solid matrix to be extracted by the roots and above the field capacity water is not retained by the solid matrix and is lost by drainage. Since, in the field, the wilting point is often passed beyond in the surface layers and never reached in the deep layers. The water balance concept is very important for areas that have sufficient dry land potential but are not matched by adequate irrigation facilities. Water Balance approach can evaluate the dynamics of soil water and water use quantitatively by plants, monitor the water stress on plants, and evaluate the application of the system of agricultural irrigation in certain climatic conditions as well as calculate the availability of water in the spatial area.

The soil water balance function by climatologically was indispensable for evaluating rainwater availability in a specific area, especially to find out when and how much the surpluses and deficits of water occurs Optimization of water resource management efforts, one of which the analysis of soil water balance (SWB), is urgently needed. SWB approach can evaluate the dynamics of soil water and water use quantitatively by plants, monitor the water stress on plants, and evaluate the application of the system of agricultural irrigation in certain climatic conditions as well as calculate the availability of water in the spatial area. The soil water balance function by climatologically was indispensable for evaluating rainwater availability in a specific area, especially to find out when and how much the surpluses and deficits of water occurs Water balance estimates is important to strengthen, conserve and manage the resources of water availability in an area over a specific period of time and for development within the irrigation system in the cultivation area. Water balance studies in the irrigated area lead to know how much water is available in the crop root zone and how much of water is used by the crops through evapotranspiration processes [3-5].

Method

Research Areas

This study took place in various areas in the Penajam Paser Utara District of East Kalimantan Province, which is geographically located south of the equator with a position between 115° 36'14.5 "- 116° 57'35.03" East Longitude and 00° 45 ' 18.37 "- 02° 27›20.82» South Latitude.

Climate Data Inventory

Rainfall data is obtained from 17 rain observation stations in Penajam Paser Utara District which are spread in 12 Subdistrict areas, and is owned by various agencies (GTZ-TAD, Department of Food Crop Agriculture, BMG Sepinggan Airport - Balikpapan, PT. ITCI Hutani Manunggal - Kenangan, etc. - others), with observations varying from 4 years (in Petung Village - Penajam District) to 39 years (in Kuaro District). Whereas the data of other climate elements (air temperature and relative humidity on a monthly basis) are derived from secondary data based on Puslittanak observations (Anonymous, 1997).

Water Balance

Water balance contains an understanding of the details of the input (input); which can be in the form of rainfall, irrigation water, surface runoff, and subsurface flow; and outputs which can be in the form of evaporation, transpiration, evapotranspiration, surface runoff, infiltration - percolation, and others. For this study the input in the calculation of the water balance is only rainwater because no other supporting data is obtained regarding the amount of surface runoff and underground flow that enters the system. Water balance analysis is expressed in a simple form, using the method developed by Thornthwaite and Mather with the system of "Book Procedure or Note Book" [6,7] in the form of general equations:

$$CH = ETA \pm \Delta\ KAT \pm Li$$

Where:

CH = rainfall

ETA = actual evapotranspiration (≤ ETP)
Δ KAT= changes in groundwater content
Li = Groundwater runoff (surplus or deficit)

Whereas the output in this water balance calculation is only evapotranspiration obtained using the formulation of Thornthwaite in modified for monthly intervals. The ETP estimation equation is as follows:

$$ETPi = 16 * \left(10 * \frac{Ti}{I}\right)$$

$$I = \sum_{i=1}^{12} \left(\frac{Ti}{5}\right)^{1.514}$$

a = 6, 75 x 10-7I3 – 7, 71 x 10-5I2 + 1,792 x 10-3I + 0, 49239

Where:

ETPi = potential evapotranspiration was corrected in the i month
Ti = air temperature in the i month
I = annual heat index
a = correction factor

The maximum available moisture as the difference between the vertical moisture profile at field capacity and the one corresponding to the maximum drying of the soil as observed, for instance, at the end of a dry season. Changes in water content of soil (WCS) is the difference in soil moisture content on a period to prior periods between sequential. For each change in soil water content, it can be calculated with the formula R-ETP and if it is with negative value, there will be a deficit (lack) of water for (ETp =ETa). Conversely, if (R-ETP) is positive, then there will be a surplus/excess of water (R-ETp-DWCS), so that soil water availability decreases water exponentially and expressed by the equation [8-11,2]:

$$KATi = WHC\,(1,000412351 - \frac{1.073807306}{WHC})^{APWLi}$$

Where:

KATi = groundwater content in the i-monthly
WHC = water holding capacity
APWLi = accumulation of potentially lost water in the i-month

Growing Season and Planting Pattern

Growing season, also called Frost-free Season, is the period of the year during which growing conditions for indigenous vegetation and cultivated crops are most favorable. It is the period of the year categorize as the rainy or wet season, the length of which varies spatially, temporally, and with crop type. Length of growing season is measured in enumerates the days of the year when average temperature is above the threshold at which crops will germinate and continue to grow (along with native vegetation). The length of growing season in rain fed fields directly related to the amount and distribution of rain and soil properties in water holding [12,13]. The amount of water required of the plants (water consumptive) or water absorbed by plant roots is almost equal to the amount of water lost by evapotranspiration of plants. Determining the length of cropping period (the length of growing season) can be done based on the ratio P/PE (ratio precipitation and potential evapotranspiration), defined as the time interval in a year that have a ratio P/PE > 0.5 plus the time it takes to evapotranspiration as much as 100 mm of ground water is considered available in the soil (FAO, 1978; [14,8]. Whereas the planting period is defined as the period that has groundwater content ≤ 50% available ground water. This refers to the opinion of Buckman and Bradi (1969) in Hidayat, et al. [14] that to get good plant growth, if 50-85% of the water available in the land has been used up, water must be added, otherwise information can be obtained a period of deficit and water surplus.

Results and Discussions

General Conditions of Research Area

In total, the administrative area of Penajam Paser Utara District covers 12 sub-districts with a total of 126 villages, with a total area of around 14,937 km2 or 1,493,700 hectares. The topography of the area varies with a slope between 0% -> 60%, most of the land area has a slope of more than 40% or an area of 511,208 hectares (about 46% of the land area), it is often said that the slope of the land in the entire Penajam Paser Utara District is positively correlated with height, the higher the location of an area, the greater the slope. The height of the place ranges from 0 m above sea level - 1380 above sea level, with 64% of the total land area or an area of 957,255 hectares having an altitude of <100 m above sea level. From the total land area in Penajam Paser Utara District, only 184,751 hectares were recorded which were used optimally to produce staple food (in the form of 26,901 Ha of rice fields, 28,084 Ha of tegal / garden, 82,680 Ha of fields and 47,086 Ha of yards) [15]. The types of soil found in the District of Penajam Paser Utara according to the USDA Taxonomy Soil consist of 6 groups, namely brown podsolic-Andosol, Podsolik-Lithosol, Alluvial- Peat-Organosol, Hydric Organosol, Podsolik, and Lithosol) with the largest distribution (more than 30%) consists of the type of soil association between Podsolik and Lithosol, as contained in Table 1 (Anonymous, 1998a; Anonymous, 1998b).

Altitude Interval (mdpl)	Wide scale(Ha)	Slope (%)	Wide scale(Ha)	Soil Type	Wide scale (Ha)
0 – 7	225.20	0 – 2	289.377	Andosol	33.577
7 – 25	310.039	2 – 8	260.390	Podsolik/Lithosol	76.169
25 – 100	422.026	8 – 15	284.597	Alluvial/Organosol	181.318
100 – 500	369.744	15 – 25	52.769	Organosol Hidrik	53.724
500 – 1000	71.043	25 – 40	400.321	Podsolik	420.837
	278	40 – 60	110.887	Lithosol	625.635
Total	1.398.350	Total	1.398.350	Total	1.391.200

Table 1: Distribution and width of each height class and slope class of the Penajam Paser Utara District land area.
Source: Department of Agriculture, Food Crops (1997)

Climate variables	01	02	03	04	05	06	07	08	09	10	11	12	Year
Air Temperature °C	26,0	26,0	26,5	26,6	25,4	26,2	25,3	25,0	25,4	25,4	25,0	24,7	25,6
RH (%)	88,2	88,4	87,8	88,0	89,6	86,6	88,0	86,0	83,5	88,3	87,5	90,7	87,7
Radiation Intensity(cal/ cm^2)	390	451	447	502	445	480	448	504	454	418	428	368	444,6

Table 2: General condition of climate variables in Penajam Paser Utara District - East Kalimantan in the annual period.

General Conditions of Climate Changes in Penajam Paser Utara District

Based on observations from Puslittanak (Anonymous, 1997) as contained in Table 1, it is known that the average annual air temperature in Penajam Paser Utara District is 25.6°C with a range between 24.7°C - 26.6°C. The highest average monthly air temperature occurred in April at 26.6°C and the lowest average monthly air temperature in December amounted to 24.7°C. Humidity between 83.5% to 90.7%. The lowest average monthly air humidity occurred in September of 83.5% and the highest average monthly air humidity occurred in December was 90.7%. The average annual irradiation time is 41.9% with a range between 34.9% to 47.7%. The longest monthly average irradiation took place in July by 47.7% and the lowest average monthly irradiation took place in January by 34.9%. The intensity of the average annual solar radiation of 444.6 cal / cm^2 with a range between 368 cal / cm^2 the intensity of the highest average monthly solar radiation occurred in August of 504 cal / cm^2 and the lowest occurred in December amounted to 368 cal / cm^2.

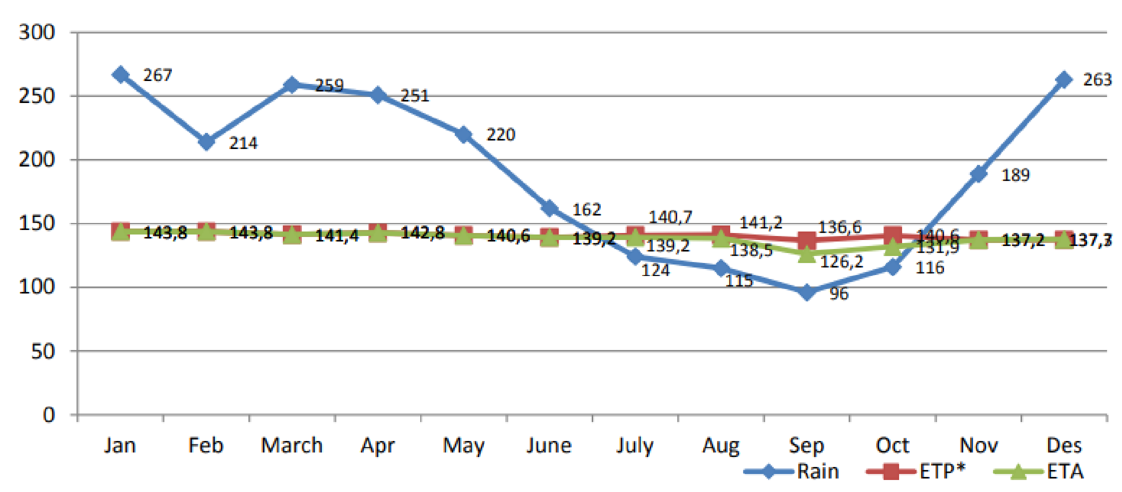

Figure 1: Water Balance on Penajam Paser Utara District.

Rainfall Analysis

The average annual rainfall received by various regions in Penajam Paser Utara District ranges from 1518 mm / year to 2628 mm / year (Table 2) with an average annual rainfall of 2236 mm / year. The number of annual average rainy days is 143.5 rainy days / year with an average monthly rainy day of 11.9 hh / month so that the average monthly rainfall of 190 mm / month [16]. The highest monthly rainfall took place in January of 268 mm / day with the number of rainy days as much as 14.5 hh / month or daily average rainfall of 18.4 mm / day. While the lowest monthly rainfall occurred in September of 96 mm / month with a number of rainy days of 8.3 hh / month or an average rainfall of 11.6 mm / day.

Agro-climate zone

Determination of Agro-climate Zone Type uses criteria from Oldeman (1975) in Sujalu [8] which is indeed very commonly used in climate zoning determination for food crop land in Indonesia. The criteria in this classification are based on the calculation of wet months (BB), ie months with rainfall more than 200 mm / month, dry months (BK), ie months with rainfall less than 100 mm / month, dry months (BK) namely months with rainfall less than 100 mm / month, and criteria for determining the agro-climate zone based on the length of the wet month (BB) and dry month (BK) periods. Based on the data in Table 2, it was found that Kabupaten Penajam Paser Utara has 6 wet months (BB) and 1 dry month (BK) [17]. Thus in general this area belongs to the C1 type agro-climate zone, so based on the elaboration of the agro-climate zone criteria from Oldeman (1975) in Sujalu (1997), the Penajam Paser Utara District generally can be optimally carried out 1-2 times of paddy rice cultivation and once secondary crops in a year

Climate Change	1	2	3	4	5	6	7	8	9	10	11	12	Tahunan
Rainfall (mm)	267	214	259	251	220	162	124	115	96	115	189	263	2275
Air Temperature °C	26,0	26,0	26,5	26,6	25,4	26,2	25,3	25,0	25,4	25,4	25,0	24,7	25,6
Hot Index	12,13	12,13	12,49	12,56	11,71	12,28	11,64	11,4	11,71	11,71	11,244	11,23	1500,7
Basic ETP (mm)	138,3	138,3	137,34	141,4	135,2	37,8	135,3	135,3	135,8	135,2	135,8	132,4	1685,6
Actual ETP (mm)	143,8	143,8	141,4	142,8	140,6	139,2	140,7	141,2	136,6	140,6	137,2	137,3	1685,6
Corrected CH-ETP	123,2	70,2	117,6	108,2	79,4	22,8	-16,7	-26,2	-40,6	-24,6	51,8	125,3	
APWL	-	-	-	-	-	-	-16,7	-43,9	-84,5	109,1	-	-	
ETA (mm)	143,8	143,8	141,1	142,8	140,6	139,2	139,2	138,5	126,2	131,9	137,2	137,7	1662,3
Surplus (mm)	123,2	70,2	117,6	108,2	79,4	22,8	-	-	-	-	51,8	125,3	698,5
Deficit (mm)	-	-	-	-	-	-	0,5	2,7	10,4	8,7	-	-	22,4

Table 3: Water Balance on Penajam Paser Utara District.
Keterangan: ETP = evapotranspiration
ETA = actual evapotranspiration
APWL = accumulation potential water loss

Climate Change	01	02	03	04	05	06	07	08	09	10	11	12	Year
Surplus (mm)	123, 2	70,2	117, 6	108, 2	79,4	22,8	0	0	0	0	0	91,7	613,1
Deficit (mm)	0	0	0	0	0	0	0,5	2,7	10,4	8,7	0	0	21,8

Table 4: The water surplus and deficit period in Penajam Paser Utara District.

General Water Balance Analysis

The major requirements of water balance studies are:

- Rapid and accurate assessment of changes in the soil water profile.
- Measurements of field capacity and permanent wilting point of the root zone.
- Assessment of infiltration capacity, and runoff rate and amount.
- Data on deep drainage and soil moisture characteristic for different depths.

The preparation of water balance is the basis of developing climate, soil and plant potential which is very useful for the development planning of agricultural production [18,19]. The water balance function for hydrological disaster mitigation by climatologically was indispensable for evaluating land water availability in a specific area, especially to find out when and how much the surpluses and deficits of water occurs. And intended to provide important information about the amount of net water that can be obtained, the value of surplus water that cannot be accommodated and the actuary period.

Calculation of the General Water Balance is carried out using the "Book Procedure" method with 7 components; namely rainfall, standard daily evapotranspiration (ETP) and corrected ETP, air temperature, heat index, day-long correction factor, water deficit and surplus Table 3. For more details the condition of the monthly land water balance in the District of Penajam Paser Utara can be seen in Figure 1. Determination of the type of rain is done by using the methods of Schmidt and Fergusson (1951) in Sosrodarsono and Takeda (1976) and Handoko (1998), this method is a refinement of the previously existing Mohr (1933) classification system. In principle, the level of wetness or dryness of an area is shown by the ratio between the numbers of dry months (BK), ie months with rainfall less than 60 mm / month with the number of wet months (BB), ie months with rainfall more than 100 mm / month, with Q notation. Penajam Paser Utara District has 11 wet months (BB) and 1 humid month (i.e. a month with rainfall between 60-100 mm / month) that occurs in September and does not have dry month (BK) so that it includes a type of rain A with a value of Q = 9.9%. Based on the calculation of the Monthly Land Water Balance as contained in Table 3, it can be seen that Penajam Paser Utara District has 7 months of water surplus, which means the rainfall is greater than the potential corrected evapotranspiration (CH> ETP corrected) and has 4 months water deficit which means CH <ETP is corrected, which as a whole can be seen in Table 4. From Table 4, when viewed from the aspect of water requirements for plants, the rainfall in the dry land depicted in the Land Water Balance in addition to providing benefits also shows the obstacles that are difficult to overcome manually. With the occurrence of a surplus of water for 7 consecutive months it causes a variety of disruptions to plants, especially the high intensity of insect pests and diseases and also decay in cultivation plants that produce tubers. In addition, the condition also illustrates that the areas of development of food crop cultivation are in dire need of adequate irrigation facilities, so that the management of farming is not disrupted due to excess water.

Climate Change	01	02	03	04	05	06	07	08	09	10	11	12
Rainfall (mm)	235	210	244	233	211	151	116	111	99	127	177	263
ETP* (mm)	144	144	141	143	141	139	141	141	137	141	137	138
P/PE	1,6	1,5	1,7	1,6	1,5	1,1	0,8	0,8	0,7	0,9	1,3	1,9

Table 5: Ratio between rainfall (P) and corrected evapotranspiration (PE) on monthly cumulative data in Penajam Paser Utara District.
Notes: ETP* = Corrected potential evapotranspiration

Furthermore, using the approach of Oldeman (1975) in Sujalu [8-10] which, among others, considers aspects of crop water requirements (water crop requirements) with the basic principle "it can be calculated crop water needs for plants in the field by considering the monthly growing period" in the wet season and dry season, during the age of the plants 3 and 4.5 months Table 5. Then it can be estimated plant water needs for each commodity on average by 100 mm / month. Furthermore, when using consideration of determining the Land Suitability Class Criteria for the Semi-Detailed and Detailed Level of Puslittanak (Anonymous, 1997) for soybean commodities, then all sub-districts in Penajam Paser Utara District are included in the Land Suitability Criteria S2 or quite appropriate, so optimally it can be cultivated to a maximum of 2 times the planting season of lowland rice with one growing season for soybeans or secondary crops in general.

Planting Period and Planting Pattern

Climate affects four components of food security such as food supply, food access, the use of foodstuffs, and resilience of the food production system. Climate an impact on changes in distribution patterns, intensity, and periods of the rainy season so that the start of the rainy season and the dry season becomes late. As a result, there is a shift in the season from its normal average conditions, which can have severe implications for rice crops and other food crops. The impact of these phenomena is also very pronounced on changes in cropping patterns in both irrigated and rainfed lowlands. At present, most of the rice planting area uses the rice-paddy cropping pattern, wherein the second planting season is highly dependent on the availability of irrigation water. The drought in the second planting season will change the cropping pattern from rice to non-rice to decrease of rice production, which will disrupt the sustainability of the national rice stock. Analysis of the planting period and cropping pattern is actually a supporter and also a complement of the Water Balance analysis. By determining the length of the growing season (Growth period) and the beginning of the planting season using the Effective Rainy Period approach given by FAO (1978) and Reddy (1983) in Pramudia and Estiningtyas (1996), which is 14 weeks moving averages of P / PE ≥ 0.75, and the beginning of this period is the weeks that have a P / PE value of ± 0.5. Planting preparation (including tillage) can begin when the average 14-Week P / PE value nilai 0.5 with the P / PE value must be ≥ 0.25. For this reason, an analysis of crop periods with the aforementioned limitations is carried out with the monthly cumulative data approach as can be seen in Table 6. Based on the results of this analysis it can be seen that there are 11 months that have a P / PE value> 0.75, and only 1 month has a P / PE value <0.75 (in September), this can be interpreted that the District of Penajam Paser Utara optimally has 11 months of growing season (growth) for rice and secondary crops.

Parameter/Months	Jan	Feb	Marc	April	May	June	July	Aug	Sept	Oct	Nov	Dec
P/PE	1,6	1,5	1,7	1,6	1,5	1,1	0,8	0,8	0,7	0,9	1,3	1,9
Evaporation Status	ETP	ETP	ETP	ETP	ETP	ETP	ETA	ETA	ETA	ETA	ETP	ETP
Cropping Pattern			Rice			Second Crop					Rice	

Table 6: Cropping Pattern in Penajam Paser Utara District.
Notes: ETP* = Corrected potential evapotranspiration

When referring to the availability of agro-climate resources (air temperature, solar radiation, and rainfall) owned by Penajam Paser Utara District as a potential that is used to anticipate the level of crop production in plant growth zones, the "expected yield" for soybean management in dry land the conditions of low and high management levels range from 0.1 to 1.0 ton hectare-1 (Riyanto, 1992). Thus the cropping patterns that can be carried out in the District of Penajam Paser Utara optimally, and by using the assumption that pest attacks can be controlled are as follows. Paddy rice planting can be done in the period November - February (planting season I) and the period March - June (planting season 2) this can be recommended by using the results of water balance analysis which shows the condition of the surplus and at the same time the monthly average rainfall is always above 200 mm / month, and at the same time the results of the analysis of rainfall and potential evapotranspiration periods which show a value always greater than 0.75 (P / PE> 0.75), while planting crops palawija (especially soy) can be done on period July- September.

Conclusion

Water Balance Monthly land in Penajam Paser Utara District shows a 7 month surplus (January, February, March, April, May, June, and December) of 613.1 mm / year, while the water deficit occurred for 4 months (July, August, September and October) as much as 22.4 mm / year. This District has an optimal growth period of 11 months with an estimated feasible 2 times planting paddy rice, and once a cropping season.

References

1. Mardawilis M, Sudira P, Sunarminto BH, Shiddieq D (2011) Water balance analysis for the development of food crops in different climatic conditions Agritech 31(2): 21-28.

2. Rao MS, Bhaskara NM (2015) Andhra Pradesh water balance and cropping pattern of the Garladinne Mandal, Anatapuramu District, Andhra Pradesh, India. Transactions of Institute of Indian Geographers 37(1): 1-16.

3. Ghandhari A, Moghaddam SMRA (2011) Water balance principles: A review of studies on five watersheds in Iran. Journal of Environmental Science and Technology 4(5): 465-479.

4. Bhagat V (2014) Agriculture water balance of micro-watershed using GIS techniques. Journal of Earth Science Research 2(1): 1-12.

5. Bhatt R (2017) Soil water balance computation – the instrumental part. Annals of Agricultural and Crop Science 2(1): 1-6.

6. Calvo JC (2009) An evaluation of Thornthawaite's water balance technique in predicting stream runoff Costa Rica. Hytdrological Journal 31(1): 51-60.

7. Steenhuis TS, Molen WHVD (1986) The Thornthwaite-Mather procedure as a simple engineering method to predict recharge. Journal Hydrology 84(3-4): 221-229.

8. Sujalu AP (2011) Water Balanced Analysis to Available Growing Season at River Pinang District, East Kalimantan. In: Proceeding of International Conference on Sustainable Agriculture and Food Security. Faculty of Agriculture. Padjadjaran University.

9. Sujalu A, Hardwinarto I, Boer S (2014) Analysis of water balance to determine cropping patterns for food crops in watershed Karangmumus-the province of east Kalimantan. Agrolife Scientific Journal 3(2): 68-74.

10. Sujalu AP, Hidayanto M, Fiana Y, Asih AYP (2019) Analysis Of Water Balance To Determine Cropping Patterns Of Food Crop In Sub-Watershed Tenggarong, Kutai Kartanegara District. Bulgarian Journal of Agricultural Science 25(1): 214-220.

11. Karim MR, Ishikawa M, Ikeda M (2012) Modeling of seasonal water balance for crop production in Bangladesh with implications for future projection. Italian Journal of Agronomy 7(21): 146-153.

12. Coughlan KJ, Huda AKS (2018) Use of weather and climate information for agricultural planning and decision making. Journal of Agro meteorology 2: 249-260.

13. Odekunle TO (2014) Rainfall and the length of the growing season in Nigeria. International Journal of Climatology: A Journal of the Royal Meteorological Society 24(4): 467-479.

14. Hidayat T, Koesmaryono Y, Pramudia A (2006) Analysis of water balance for determine growing periods potency of food crops in Banten Province. Journal Floratek 20(1): 44-51.

15. Anna AN, Priyono KD, Suharjo, Priyana Y (2016) Using Water Balance to Analize Water Available for Communities (A Case Study in Some Areas of Bengawan Solo Watershed) Forum Geografi 30(2): 166-172.

16. Anonim (2019) Penajam Paser Utara in Figures. Statistic Bureau Penajam Paser Utara District.

17. Fulazzaky MA, Heryansyah A, Solaiman MH (2017) A water balance approach for assessing the potential source of water in Dohuk Dam for agricultural, domestic and tourism purposes. Water Policy 19(12): 322-340.

18. Hoogeveen J, Faurès JM, Peiser L, Burke J, Giesen VD, et al. (2015) A global water balance model to assess water use in irrigated agriculture. Hydrol Earth Syst Sci Discuss 19(9): 3829-3844.

19. Nugroho BDA, Nuraini L (2016) Cropping Pattern Scenario based on Global Climate Indices and Rainfall in Banyumas District, Central Java, Indonesia. Agricultureand Agricultural Science Procedia 9: 54-63.