ASSESSMENT CLIMATE-BASED AGRICULTURAL WATER BALANCE IN EAST KALIMANTAN PROVINCE, INDONESIA

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Abstract. East Kalimantan's climate is influenced by the monsoon winds and because of its geographical position on the equator, it is affected by the equatorial climate. The aim of this research is to develop a soil water balance model to calculate the amount of stored water. In dry land crop cultivation, water is the main resource and the most important limiting factor in plant growth. This study conducted a Thornthwaite-Mather water balance analysis using 20 years of climate data (2000-2020) to understand the water potential of East Kalimantan province. The assessment consists of a calculation that accounts for all significant inputs and outputs of water to and from the surface water; method used in this research is a quantitative descriptive method. Analysis of the water balance is based on rainfall, air temperature and evaporation, with a monthly period. Studies have shown that the differences in the monthly water balance in East Kalimantan is 223 mm year-1 of water surplus in 9 months, and the driest in 3 months, August tends to be the driest of the year and exhausting the total deficit values arrived 72 mm year-1. However, annual precipitation is greater than annual evapotranspiration.
Keywords: *water balance, rainfall, evapotranspiration, cropping*

Introduction

In tropical humid climates rainfall amounts are enough to satisfy dry-land agricultural production; however, these dry land agricultural schemes are very sensitive to climatic change and the productivity is linked to precipitation patterns. Soil properties in the tropics become very important in their function as a buffer system for the development of food security systems, especially regarding the presence of water, with the irregularity of rainfall. In dry land 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 (Reichardt et al., 2020; Azmeri et al., 2019; Pathak et al., 2015). This water fluctuation often occurs in the dry land, so that efficient and effective land planning is needed through soil water balance information. This soil water balance is a water balance for general agricultural land use (Maihemuti et al., 2021). 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. 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 (Pereira et al., 2020).

Actual water use in annual water balances is changing over time as cropping patterns and cropping intensities shift and change, sometimes in response to available water resources. This water fluctuation often occurs in the dry land, so that efficient and effective land planning is needed through soil water balance information. Agriculture accounts for about 70% of the freshwater withdrawals in the world (FAO, 2013), while consumptive use of water in agriculture (water that is evaporated on irrigated fields) accounts for about 90% of all of the water that is evaporated as a result of human intervention (Vale et al., 2024; FAO, 2013). So important is the availability of water for procurement planning and improvement of agricultural support facilities that the success of a farm management is also determined by how far the availability of water can be distributed by physical facilities (Azmeri et al., 2021; Rusli et al., 2021; Koivusalo et al., 2017). For this reason, research was conducted to analysis land water balance based on normal rainfall in East Kalimantan Province. Each component of the water balance and at a certain time or period desired according to its needs. This water balance has an accumulative nature, while the unit of each component of water balance is the height or range of water (mm or cm) and the unit of time is daily, weekly, decade, monthly and yearly (Lei et al., 2021; Mammoliti et al., 2021; Chen et al., 2020). 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.

Materials and Methods

Research location

The Province of East Kalimantan with the capital city of Samarinda before the division of the region has an area of East Kalimantan province possesses an area of 16,732,065.18 hectare, with land area of 12,734,691.75 hectare (*Figure 1*). Located between 113°44'E and 119°00'E, and between 2°33'N and 2°25'S. The land area of East Kalimantan Province has an undulating topography with a slope that is from steep to highest, with land elevations ranging from 0-1,000 m above sea level. East Kalimantan tropical climate and has two seasons, dry and rainy seasons. The dry season usually occurs in May to October, while the rainy season in November to April. This situation continued every year interspersed with transitional season in certain months. Moreover, because of its location on the equator, the climate in East Kalimantan are also affected by wind monsoon, monsoon wind is November–April west and east monsoon winds from May to October. In recent years, the situation in East Kalimantan season is sometimes erratic. In the months that it is supposed to rain, there is no rain at all, or vice versa in the months that should be dry it rains for a much longer time In general, East Kalimantan hot climates with temperatures ranged from 21.6 °C in October to 35.6 °C in September. Aside from being a tropical area with extensive forests, the average humidity between 83 and 87% of East Kalimantan. The lowest air humidity observed by the meteorological stations happens in a few months with RH 82%, while the highest occurred in February with RH 91%.

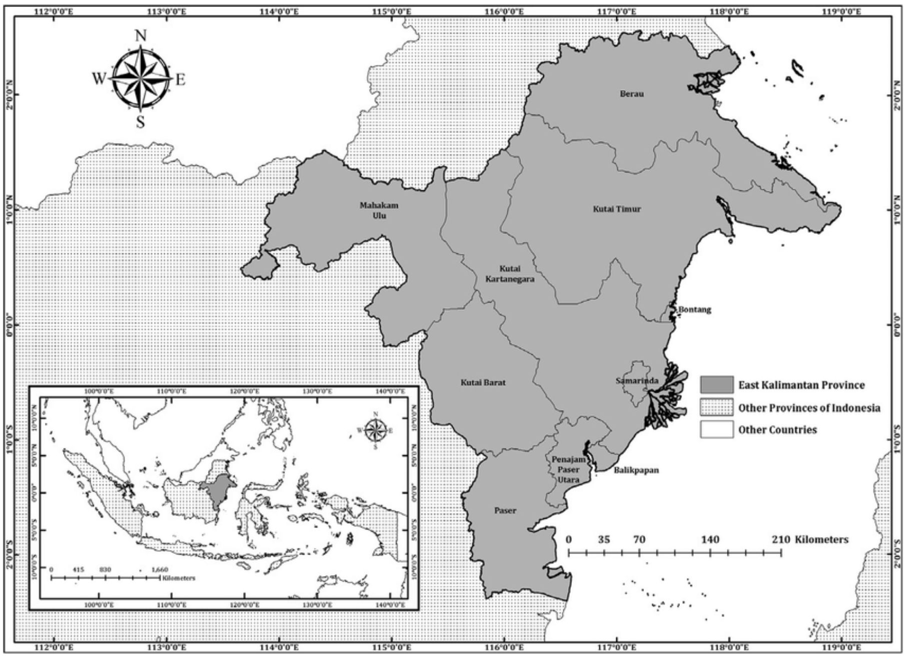

Figure 1. *The East Kalimantan Province study area is located on Borneo.*

In this study using historical data on rainfall The research object observed was the condition and extent of forest cover along with the condition of climate elements "in situ" from 2000 to 2020 from 76 Meteorological Stations in East Kalimantan Province, data was obtained from Agriculture and Horticulture Department, Meteorology Climatology and Geophysics Agency (BMKG) as the main source of weather data. The method used in this research is a quantitative descriptive method with comparative analysis techniques of exploration of the area data and the characteristics of the climate elements that are owned.

The analysis of land water balance

Water balance analysis is expressed in the form of integral equations by simplifying some equations, so that the water balance of an agricultural project area can be expressed in the form of equations (Rusli et al., 2021; Chen et al., 2020; Koivusalo et al., 2017).

$$P = ETA \pm \Delta\ SWC \pm Ro \qquad \text{Eq. (1)}$$

Where, P is rainfall (mm), ETA is the Actual Evapotranspiration, Δ SWC is the soil water content, and Ro is the run off. Precipitation provides part of the water crops' need to satisfy their transpiration requirements. The soil stores part of the precipitation water, which is later evaporated or transpired by plants. Thornthwaite-Mather water balance equation uses the soil moisture capacity to estimate water budgets (Lei et al., 2021; Mammoliti et al., 2021; Nugroho et al., 2019). The parameters needed for using this method include: (1) difference between precipitation and potential evapotranspiration (P-PE); (2) accumulated potential water loss (APWL); and (3) available water capacity (AWC). Lues during periods when P-PE is negative. This running represents the total amount of: (1) actual evapotranspiration (AE); (2) deficit and surplus of the water budget; and (3) runoff estimation. Accumulated Potential Water Loss (APWL) is a condition in which the number of potential evapotranspiration is greater than the amount of rainfall, which indicates a dry month. The equation for Accumulated Potential Water Loss (APWL) is as follows: APWL=P-PE, sum of the daily P-PE values during periods when P-PE is negative. This running sum represents the total amount of unsatisfied potential evapotranspiration to wich the soil has been subyected (Lei et al., 2021; Mammoliti et al., 2021; Nugroho et al., 2019).

Results and Discussion

Climate status in East Kalimantan

In this study, climatological data (including irradiation duration, irradiation intensity, monthly average air temperature and monthly average air humidity) obtained from 76 weather observing stations were collected (*Table 1*).

Table 1. *Monthly average climate element data for East Kalimantan Province.*

Climate parameter	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Rainfall (mm/month)	166	178	166	184	165	145	126	118	107	155	130	205
Rain days (days)	12	11	12	14	12	11	9	10	9	11	11	12
Temperature (°C)	26.8	26.7	26.6	26.4	26.4	26.3	26.2	26.0	26.0	25.8	25.7	26.2

Land water balance

Monthly water balance analysis of the above-mentioned results shows that these areas have surpluses during the eight Monthly water balance analysis of the above-mentioned results shows that these areas have surpluses during the eight months that occur in the month periods from January to June, and November-December. In addition to experiencing a monthly water surplus, the eastern Kalimantan Province also experienced a monthly cumulative water deficit in the 4-month period from July to October. APWL values are utilised for actual evapotranspiration (ETA) and the absence of rainwater supply causes the deficit (*Figure 2*). The effect of this water deficit depends on the water-holding capacity of the soil, which differs for each soil type influenced by clay content (texture), organic matter and topography. That period was the dry season characterised by a water deficit in the East Kalimantan province, and the dry season occurred evenly across the region in June, and the impact of the drought amplified until it reached its peak in August to September. The lack of rainfall during July to August was followed by relatively high air temperatures leading to a water deficit in the active root zone causing a disruption of the soil water balance. Despite this, agricultural lands in the eastern Kalimantan province theoretically do not yet require additional irrigation water as the water status in the soil is still >50% Available Soil Water Content (Lei et al., 2021; Mammoliti et al., 2021).

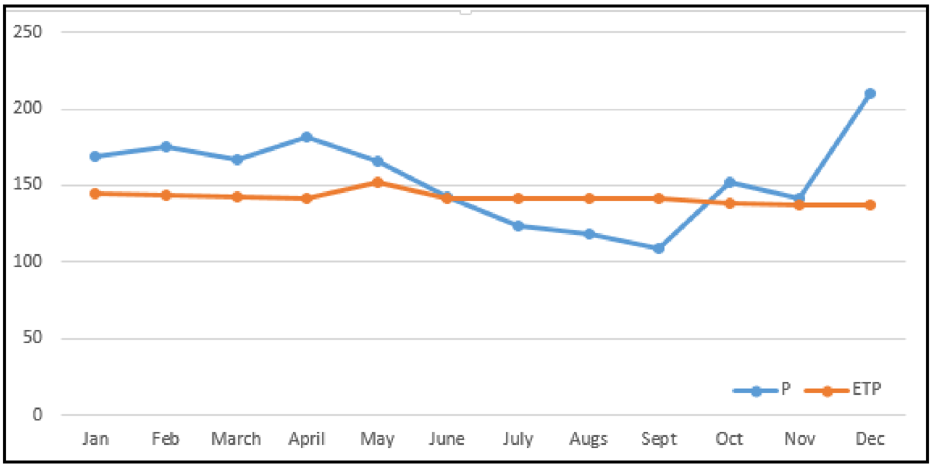

Figure 2. *Water Balance East Kalimantan Province.*

The results of the analysis of monthly land water balance of the East Kalimantan Province region were subjected to evapotranspiration potential (ETP) analysis which was calculated based on monthly average air temperature data. It is known that this area has a surplus for 9 months which occurs in the period January-June and in October-December the total water surplus reaches 223 mm/year. In addition to having a water surplus, the area normally experiences a monthly cumulative water deficit due to rainfall received being lower than the corrected evapotranspiration rate (CH<corrected ETP). Based on the data analysis in the *Table 2*, the water deficit occurred in the July-September period which totaled 72 mm/year. Thus, resulting in potential groundwater is depletion. Under such conditions of circulating water availability and depletion, water needs for farming areas must be added through physical means of irrigation networks (Yang, 2007).

Table 2*. Monthly water balancer East Kalimantan Province.*

Climate parameter	Months											
	1	2	3	4	5	6	7	8	9	10	11	12
Precipitation (mm)	169	175	167	182	166	143	124	118	109	152	141	210
Evapotr.Pot/ETP (mm)	145	144	143	142	142	142	141	141	141	138	137	137
Deficit (mm)	0	0	0	0	0	0	- 17	- 23	- 32	0	0	0
Surplus (mm)	24	31	24	40	24	1	0	0	0	14	4	73

When viewed from the aspect of water requirements for the development of physical facilities, the rainfall on dry land as illustrated in the Monthly Land Water Balance (Cumulative) in addition to providing a variety of advantages, including very possible to develop the fisheries sector, especially inland fisheries (freshwater ponds) but also shows the existence of constraints that are difficult to overcome manually (Vale et al., 2024; Rusli et al., 2021; Koivusalo et al., 2017). The water surplus experienced during the 9 months can cause a high intensity of disturbance to the construction of physical facilities, especially disturbance from high levels of erosion and heavy water discharge that must be removed from the farming area, because surplus water that cannot be released smoothly will cause various things that are detrimental to farming (Turunen et al., 2013). Among them are the high chances of the emergence of disturbances in scattering due to decay, especially in land management for the purpose of tubers (Lei et al., 2021).

Some important information that can be taken for technical purposes operations in the field is that in months where there is a consecutive water surplus, it is necessary to make a drainage/disposal channels to drain excess water, especially if excess water, especially if soil conditions do not conditions are not favorable for rapid infiltration (Rusli et al., 2021). As for the deficit period (April, September and October) are still possible to do business crop cultivation because groundwater conditions are still favorable for the business and remain in an available state. In September and October it is recommended to be careful in planting activities especially planting short-rooted crops. It is possible to carry out planting activities planting activities then during these months must be supplied with water. Watering (irrigation) measures are still needed so that plants can grow and develop properly according to their genetic potential. In addition, considering the topographical conditions of the region, it is possible to build several dams or reservoirs in East Kalimantan Province, which have various functions. With the main function being to accommodate the considerable water surplus in the region, as well as a water reserve during water deficit months that can be utilised for various purposes including drinking water. This is very possible if the irrigation channels that function to dispose of excess water are not well organised and maintained.

Conclusion

Based on the results of the Land Water Balance analysis and the overall description in the discussion as previously presented, it can be concluded that the province of East Kalimantan experiences rainfall every month, even in dry years. Rainfall in a normal climatic year ranges from 107 mm/month - 205 mm/month with 9-12 rainy days. The region has a water surplus experiencing 9 months of groundwater surplus and 3 months of groundwater deficit resulting in Accumulation Potential water loss although the groundwater status is still above field capacity.

Acknowledgement

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Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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