Agromet 38 (1): 58-67, 2024

PERHIMPI

Agromet

journal.ipb.ac.id/index.php/agromet

ISSN : 0126 - 3633

Correlation between Climate Data and Yields of Some Prominent Food Crops in Manokwari, West Papua, Indonesia

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ARTICLE INFO

Received
25 September 2024

Revised
4 April 2024

Accepted for Publication
6 Juni 2024

Published
28 Juni 2024

doi: 10.29244/j.agromet.38.1.58-67

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ABSTRACT

Environmental factors, particularly climate conditions, play a crucial role in influencing the growth and yield of cultivated crops. Although knowledge on their influence has been revealed in many records, our understanding of their relationship in West Papua is limited due to lack of data. This research leveraged data of monthly climate variables (temperature, rainfall, and radiation intensity) and crop yields from West Papua, Indonesia for period 2011-2020. The Analysis revealed varying trends in the highest average monthly air temperature, humidity, rainfall, and radiation intensity across different months. Despite these fluctuations, there was a general tendency towards increased harvested area and rice, maize, and soybeans production. While the overall impact of climate variables on crop productivity appeared insignificant, certain nuances emerge. Specifically, air humidity demonstrated a notable influence on rice productivity, while air temperature has a stronger effect on maize productivity than other climate variables. However, correlation tests indicated that the relationship between climate variables (air temperature, humidity, rainfall, and radiation intensity) and crop productivity, particularly maize, rice, and soybeans, did not reach statistical significance. This underscores the complexity of the interplay between climate dynamics and agricultural outcomes.

KEYWORDS
agricultural, crop productivity, food sources, weather variability, sustainable yield

INTRODUCTION

Rice, maize, and soybeans stand out as significant food commodities, serving as vital sources of energy, protein, and fat, as highlighted in several studies (Bodie et al., 2019; Hueda, 2017). According to Agriculture Ministry 2021, Indonesian national production trends for rice and maize generally exhibited growth from 2014 to 2018, although soybean production experienced fluctuations, with a notable decrease in 2017 following a peak of 954,997 tons in 2014, it showed significant increases in the subsequent three years. The change in climate is undeniable (Belfer et al., 2017; Burke and Emerick, 2016) and its projected impact on food production is a growing concern (Hasanuzzaman, 2020; Karimi et al., 2018; Kukal and Irmak, 2018). The occurrence of disasters caused by climate change can disrupt national food production and crop productivity (Suciantini et al., 2020). Therefore, preventive measures, such as having information about climate and agriculture in the context of extreme weather, will be highly beneficial for effective farm planning (Setiapermas and Nurlaily, 2021). Lian et al., (2020), reported that climate is a pivotal determinant of production success and crop yields such as small increase in spring temperatures may lead to earlier and faster growth crops. Given the diverse climatic characteristics across regions, the nature of climate variables varies accordingly, by local geographical features. Winarno et al., (2019) further emphasized that factors such as latitude, slope, altitude, and proximity to land and sea, along with ocean currents, collectively shape regional climates. Moreover, the uneven distribution of solar radiation across different locales significantly influences other climatic variables (Med-vigy & Beaulieu, 2012; Muneer et al., 2007; Xu et al., 2017).

Despite some studies on climate change have been conducted partially in Southeast Asia (Marjuki et al., 2016) or other parts of Indonesia in particular aspect such drought (Sabuna et al., 2022) or in particular crop such as rice (Caruso et al., 2016) and more specific in Manokwari Regency (Siburian et al., 2021; Barung et al., 2021) none have specifically addressed how decadal weather data correlate to food crops in Manokwari Regency. West Papua Province boasts vast expanses of land with considerable potential for agricultural development, as indicated by various sources. Within the region, the production of these staples experiences fluctuations. Notably, Manokwari Regency emerges as a significant center for the cultivation of rice, maize, and soybeans, consistently exhibiting the highest levels of harvested area and production compared to other regencies within West Papua Province. Over the past decade, production trends for rice, maize, and soy-beans in Manokwari Regency have been characterized by fluctuation.

However, specific research to understand the correlation between climate variables and the production of food crops in Manokwari Regency is not well understood. By gathering specific data on climate variables such as temperature, humidity, rainfall, and solar radiation, we can address the limited knowledge on this aspect. Hence, this study seeks to analyze a decade's worth of climate data, assess the productivity of the three main food crops, and investigate the relationship between climate factors and crop yields in Manokwari Regency, providing valuable insights into the influence of climate variables on agricultural productivity.

RESEARCH METHODS

Study Area

Geographically, Manokwari regency is located in the Eastern part of the country in the region falls under the tropical zone of indo-gangetic alluvial in Indonesia. It spans from sea level up to approximately 3,000 m, featuring a diverse topography ranging from coastal plains, lowlands to mountainous terrain various studies (Fonataba et al., 2020; Loinenak, 2015; Mahmud et al., 2018). Over 60% of its land area consists of undulating and mountainous landscapes, pre-dominantly situated in the southern and eastern parts of the regency. Seasons are controlled by southeast (May to October) and northwest (December to March) monsoons (ROD, 1975). The rainfall characteristics of eastern Indonesia and the eastern part of central Indonesia are highly correlated with El Niño and La Niña, whereas western Indonesia and the western part of the central Indonesia are correlated with the Indian Ocean via the DMI (Lee, 2015). The monthly rainfall intensity of this region is ranging from 6.6 to 14.3 inch (Lee, 2015). The annual mean temperature is 25.8 °C. This geographical variation contributes to various climate patterns annually, consequently impacting the production of vital commodities such as rice, maize, and soybeans in Manokwari Regency.

Figure 1. Study site of Manokwari Regency.

Method and Data Collection

Method used in conducting the research was descriptive by employing desk study (Yin, 2013). 10-yr data from 2011 to 2020 was gathered from publicly accessible sources online, primarily from the Indonesian Meteorology, Climatology and Geophysics Agency website (https://dataonline.bmkg.go.id/home) for climate data. The data comprised of the daily mean of temperature, relative humidity, rainfall, and radiation. Additionally, data from the Provincial and Regency Statistical Bureau of West Papua Province and Manokwari Regency were utilized to compile monthly and annual datasets, as detailed in Tables A1 and A2. While productivity data was derived from harvested area and production data which were downloaded from Papua Barat Statistics Beureau (Table A3).

Data Analysis

We arranged the collected data in Microsoft Excel, followed by comprehensive statistical analysis. Descrip-tive analysis was conducted on temperature, humidity, rainfall, and radiation data, supplemented by a 10-year moving average for productivity. To address the correlation between climate variables and productivity, Pearson correlation analysis was employed. Additionally, to estimate the productivity of the three prominent crops, we run a double regression test. Both correlation and regression tests were conducted using Minitab 16 to ensure robustness and accuracy in the analysis.

RESULTS AND DISCUSSION

Weather Condition in the Study Area

The annual peak average monthly air temperature typically occurred in February, with the lowest typically observed in March (Figure 2). Conversely, the highest levels of humidity and monthly rainfall were typically recorded in April, whereas the lowest levels were typically seen in October. Notably, the highest monthly rainfall tended to manifest in April, while the lowest occured in August. Furthermore, the highest monthly solar radiation intensity tended to be registered in October, while the lowest was typically observed in December.

The average monthly maximum air temperature, as outlined in Tabel A1, ranged between 31-32 °C throughout the observation period. Notably, the data revealed a discernible upward trend in the average monthly air temperature over the observation period (2011-2020), coinciding with fluctuations in food crop productivity. This rise in average monthly maximum air temperature is anticipated to have a consequential impact on crop yields. Supporting this notion, Olufemi et al., (2020) highlighted that declines in rice production were attributed to corresponding increases in average maximum air temperature.

Air temperature plays a pivotal role in governing the rate of evaporation within plant tissues. When temperatures soar, the stomata situated on leaves tend to close, thereby diminishing the rate of transpiration and subsequently causing a decrease in the process of photosynthesis. This mechanism serves to safeguard the leaf tissue from desiccation or damage (Kapoor et al., 2020). Consequently, such temperature-induced adjustments can have adverse effects on the production of food crop.

In the realm of food crops, humidity plays a significant role in modulating the process of photosynthesis. The moisture content in the air influences the behavior of stomata on leaves, thereby impacting the rates of transpiration and respiration (Xanthopoulos et al., 2017). Low air humidity levels tend to heighten transpiration rates, leading to increased absorption of water and mineral substances. Conversely, elevated humidity levels result in reduced transpiration rates, consequently impeding nutrient absorption. This limitation in nutrient availability can hinder plant growth. Moreover, air humidity serves as a potential factor contributing to diminished food crop production due to the proliferation of plant-disturbing organisms (Fadila and Aprisal, 2023). Humidity levels can directly or indirectly influence the growth, development, and aggressiveness of pests or diseases, also higher humidity levels often accelerate disease development.

Trend of Harvest Area, Production and Productivity of Main Food Crop

Harvested area, production and productivity of rice, maize and soybeans are illustrated in Figure 4. Productivity is the proportion of production (ton) and harvested area (hectare). The production of food crops is significantly influenced by the intensity of rainfall, as it directly impacts the water reserves within the soil. Adequate soil moisture enhances the decomposition of

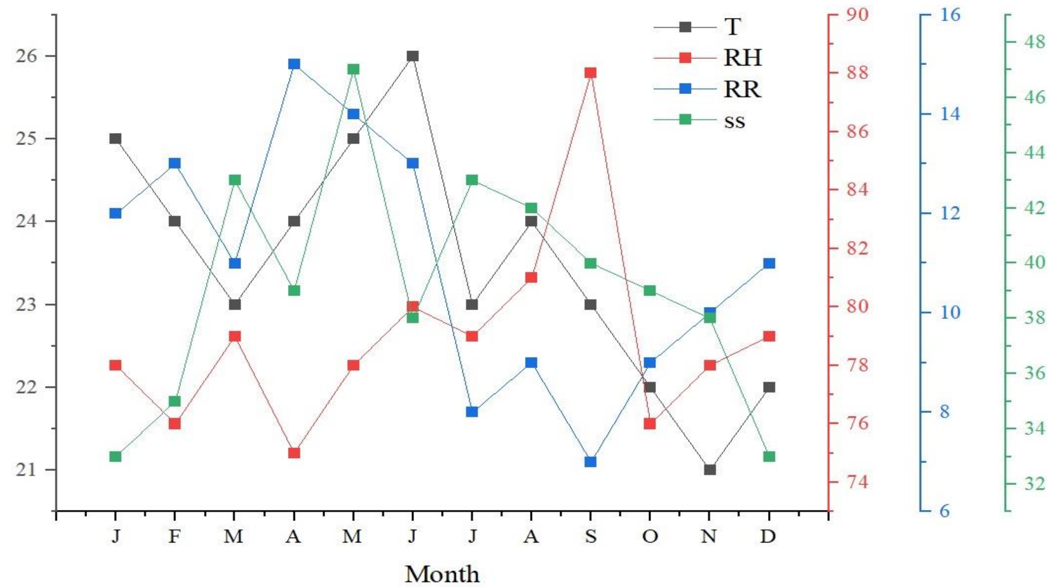


Figure 2. Monthly mean Temperature (°C), Relative Humidity (%), Rainfall (mm), Radiation (%) in the study area.

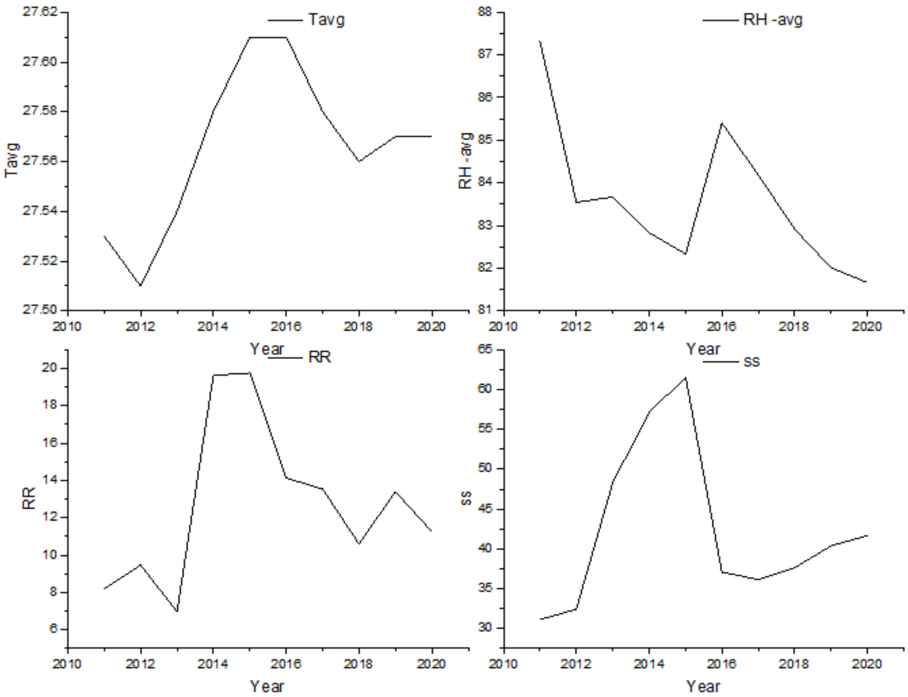


Figure 3. Annual mean of air temperature (upper left), relative humidity (upper right), rainfall (bottom left), radiation (bottom right) in the study area.

organic matter and promotes the formation of soil structure, facilitating deeper root penetration for food plants to access essential nutrients (Seifu and Elias, 2019). Optimal rainfall levels are crucial to support the growth and yield of key crops such as rice, maize, and soybeans, with recommended thresholds of 478.55 mm (Aryal, 2013), 456.9 mm (Udom & Kamalu, 2019), and 409.5 mm, respectively. Over a decade, the average annual rainfall in Manokwari Regency has been recorded at 1,522.7 mm, indicating favorable conditions for the cultivation of food crops.

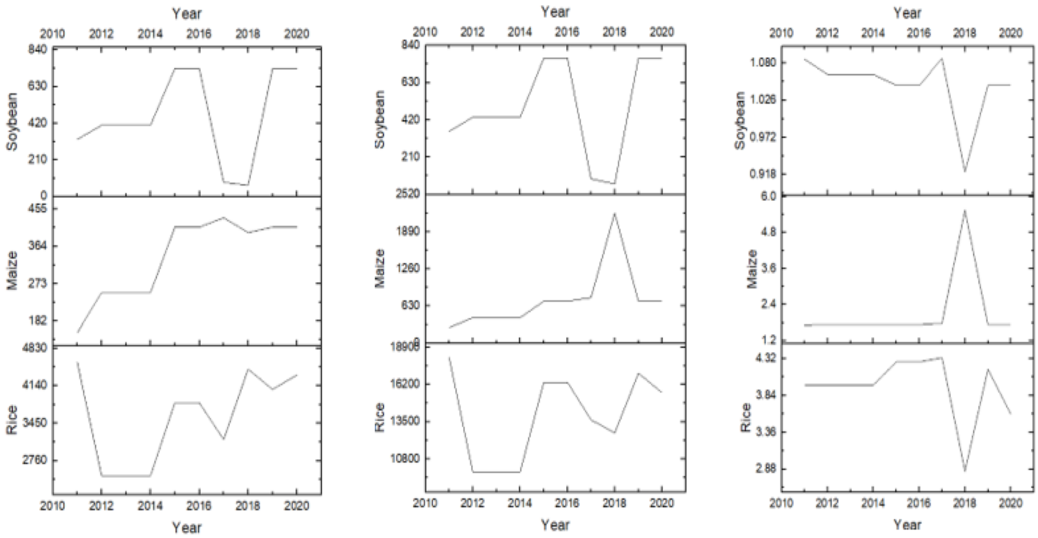
The harvested area and production of rice, maize, and soybean commodities in Manokwari Regency over a decade (2010-2020), illustrated in Figure 4, exhibit a general upward trajectory amidst fluctuating trends. Notably, the highest average productivity for these crops has been observed during the 2018-2020 period. However, it's noteworthy that the harvested area of these three key food sources falls significantly below the national average productivity levels for rice, maize, and soybeans, which are reported to be 2,628,830.77 hectares, etc.

In 2011, maize production stood at 262 tons, steadily climbing to 2,267 tons by 2018 before experiencing a decline to 711 tons in 2020. Similarly, soybean production commenced at 355 tons in 2011, doubling by 2016, but subsequently dropping to 88 tons in 2017 and further to 59 tons in 2018. However, production was resurgent in production in 2019 and 2020, with yields reaching 769 tons. While at a regional level, the production of these three prominent crops is relatively consistent, when compared to national averages, they fall into the low category.

Correlation between temperature and rainfall data on rice, maize and soybean productivity

The correlation test to determine the degree of closeness of the relationship between climate variables and productivity of rice, maize and soybeans is presented in Table 1. The results of the correlation test between climate variables of air temperature, humidity, rainfall and radiation intensity on the productivity of 3 main food crops show the coefficient value $r < 0.50$ and the t-count value is smaller than t-table = 1.812. For example, the results of the correlation test between climate variables, air temperature, humidity, rainfall and radiation intensity on maize productivity show the r coefficient values (-0.032, -0.136, -0.171 and -0.167) and the t-count value (0, 42, -0.66, -0.42, -0.38) is smaller than t-table = 1.812. The same trend is followed by rice and soybeans. This proves that the variables of climate, air temperature, humidity, rainfall, and radiation intensity do not have a significant relationship with the productivity of rice, maize and soybeans.

Rice productivity exhibits a positive correlation with climate variables such as air temperature, humidity, rainfall, and radiation intensity, while soybean productivity shows a positive relationship specifically with air humidity, albeit insignificantly. Conversely, air temperature, rainfall, and radiation intensity display negative correlations with soybean productivity. Maize productivity, on the other hand, demonstrates negative



(a) (b) (c)

Figure 4. Trend of Harvested Area (a), Production (b), and Productivity of the Three Prominent Food Crops.

associations with all four climate variables (Table 1). Despite these observed correlations, the climate variables do not exhibit significant relationships with the productivity of rice, maize, and soybeans in Manokwari. This finding aligns with research conducted by Tiamiyu et al., (2015) which revealed that rainfall variability did not significantly affect national rice yields. Similarly, Faradiba, (2021) also concluded that rainfall had no significant relationship with rice production in West Java, Indonesia.

The data depicting the productivity of rice, maize, and soybeans over the observation period (2011-2020) revealed fluctuations, as illustrated in Figure 4. Despite the absence of a significant correlation between climatic factors and the productivity of these crops in Manokwari, fluctuations were evident during the observation period. These fluctuations in crop productivity are believed to be influenced by non-climatic factors, which should be considered as essential inputs for yield estimation. Such factors may include fertilization practices, seed quality, pest and disease management strategies, and timing of planting Batho et al., (2019) highlighted the importance of integrating various factors such as market access, input utilization, and extension services into multiple regression analysis to provide a comprehensive understanding of maize yield estimation. Similarly, Faradiba, (2021) underscores the necessity of incur-porating factors related to pest and disease incidence during the observation period. Ekanayake et al., (2021) recommend including non-climatic factors in further research studies for a more holistic analysis. Atiah et al., (2022) report that while climatic factors like rainfall and air temperature may not be primary determinants of maize production, non-climatic factors play a sig-nificant role. Optimal planting timing is crucial for mitigating risks and mini-

Table 1. Correlation Test between Climate Variables and Rice, Maize, and Soybean Productivity with t-reference (t-table) 5 % = 1.812.

Commodity	Variable	Productivity	t-counted
Rice	T	0.290^{ns}	-0.02
	RH	0.227^{ns}	1.01
	RR	0.352^{ns}	0.63
	ss	0.189^{ns}	0.19
Maize	T	-0.032^{ns}	0.42
	RH	-0.136^{ns}	-0.66
	RR	-0.171^{ns}	-0.42
	ss	-0.167^{ns}	-0.38
Soybean	T	-0.370^{ns}	-1.45
	RH	0.466^{ns}	1.60
	RR	-0.127^{ns}	0.80
	ss	-0.106^{ns}	0.49

Note: ns denotes for not statistically significant

Table 2. Regression Analysis of Three Prominent Food Crop Productivity.

Commodity	Variable	R-square	a	b
Rice	T	27.82	-2	-0.17
	RH			0.116
	RR			0.0456
	ss			0.0048
Maize	T	13.26	-260	10.3
	RH			-0.229
	RR			-0.091
	ss			-0.0289
Soybean	T	47.02	33.9	-1.257
	RH			0.0196
	RR			0.00616
	ss			0.00131

Note: a = constanta, b= coefficient of regression, T = air temperature, RH = relative humidity, RR= rain fall, ss = solar radiation, R-square = coefficient of determination

-mizing yield fluctuations, as emphasized by Casali et al., (2022), who argue for strategic crop scheduling to alleviate temperature stress during critical planting stages. Moreover, Zanon et al., (2016) suggested the importance of setting appro-priate planting times for rainfed soybean cultivation to mitigate disease risks effectively.

Estimation of Three Prominent Food Crops Productivity

As double regression test was subjected on climate data towards productivity of rice, maize and soybean, the model of productivity estimation of each commodity as follows:

Rice:

$$\mathrm{Y} = -2 - 0.17\mathrm{T} + 0.116\mathrm{RH} + 0.0456\mathrm{RR} + 0.0048\mathrm{ss} \quad (1)$$

Maize:

$$\mathrm{Y} = -260 + 10.3\mathrm{T} - 0.229\mathrm{RH} - 0.091\mathrm{RR} - 0.0289\mathrm{ss} \quad (2)$$

Soybean:

$$\mathrm{Y} = 33.9 - 1.257\mathrm{T} + 0.0196\mathrm{RH} + 0.00616\mathrm{RR} + 0.0013\mathrm{ss} \quad (3)$$

The multiple regression equation results for climate variables including air temperature, humidity, rainfall, and radiation intensity on the productivity of rice, maize, and soybeans in Manokwari are detailed in Table 2. Analysis indicates that an upward trend in climate factors such as air temperature, humidity, rainfall, and radiation intensity correlate with increased soybean productivity, exhibiting a coefficient of determination of 47%. Conversely, elevated air temperature is associated with decreased productivity of rice and maize, with coefficients of determination of 27.8% and 13.2%, respectively.

The relationship between climate variables and the productivity of rice, maize, and soybeans in Manokwari Regency appears to lack a clear linear trend, as indicated by the relatively weak coefficients of determination. This finding is consistent with research by Schlenker and Roberts, (2008), identified a nonlinear relationship between temperature increases and yields of maize, soybeans, and cotton in America. Similarly, Schauberger et al., (2017) observed a consistent negative response of US crops to high temperatures, both in observations and crop models. Ranasinghe et al., (2022) observed no significant linear correlation between rainfall amounts and rice yield in Sri Lanka. Moreover, Beding et al., (2021) found that climatic factors such as rainfall, air temperature, and humidity exhibited weak or no relationship with rice production in Merauke, Papua, Indonesia.

The impact of climate variables on rice, maize, and soybean productivity is not statistically significant. However, air humidity demonstrates a relatively stronger influence on rice productivity, while air temperature appears to exert a more pronounced climate variables. This observation is supported by the coefficients of air humidity (0.116) for rice productivity and air temperature (10.3) for maize productivity, which surpass those of other climate variables. Adaptation strategies are necessary needed to cope with climatic changes based on crops characteristics Mahmudah et al., (2021) to minimise the adverse impacts of climate change effect on maize productivity compared to other.

CONCLUSIONS

All in all, monthly weather data, encompassing air temperature, humidity, rainfall, and solar radiation intensity, exhibit notable month-to-month variability. Concurrently, the harvested area and production of rice, maize, and soybean commodities demonstrate a general inclination towards growth, albeit amidst fluctuating trends. However, the influence of climate variables on crop productivity appears to be non-significant. Notably, air humidity's effect on rice productivity and air temperature's impact on maize productivity tend to overshadow that of other climate variables, as evidenced by their higher coefficients. Interestingly, correlation coefficients (r) representing the relationship between climate variables (air temperature, humidity, rainfall, and radiation intensity) and maize productivity fall below critical values obtained from the t-table. This consistent trend is observed across rice and soybeans as well.

ACKNOWLEDGEMENT

We thank the technical support from our colleagues of Department at Agriculture, Papua University. We also thank the anonymous reviewers for their valuable and constructive comments.

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ANNEX

Table A1. Monthly Decadal Data Mean of Temperature (T), Humidity (RH), Rainfall (RR) and Radiation (ss).

Month	Tn	Tx	Tavg	RH -avg	RR	ss
JAN	24.49	31.75	27.29	83.97	13.57	37.29
FEB	24.57	31.60	27.12	83.01	16.49	42.37
MAR	24.36	31.28	27.10	84.61	18.11	38.04
APR	24.48	31.49	27.24	85.48	21.82	40.85
MAY	24.68	31.78	27.66	84.59	12.23	46.73
JUN	24.50	31.39	27.28	84.56	11.19	39.04
JUL	24.16	31.25	27.25	83.59	9.76	43.44
AGT	24.26	31.36	27.32	82.36	7.50	45.17
SEP	24.49	31.72	27.60	82.21	8.33	49.19
OCT	24.37	32.06	27.88	81.45	7.82	53.31
NOV	24.54	32.00	27.71	83.01	9.66	40.39
DEC	24.62	31.93	27.54	84.22	15.79	32.25

Source: https://dataonline.bmkg.go.id/home. Data were processed from primary source

Table A2. Annual Decadal Data Mean of Temperature (T), Humidity (RH), Rainfall (RR) and Radiation (ss).

Year	Tn	Tx	Tavg	RH -avg	RR	ss
2011	24.45	31.69	27.53	87.32	8.19	31.13
2012	24.42	31.67	27.51	83.54	9.47	32.41
2013	24.41	31.71	27.54	83.67	6.97	48.33
2014	24.45	31.77	27.58	82.83	19.62	57.14
2015	24.47	31.82	27.61	82.33	19.75	61.50
2016	24.47	31.83	27.61	85.40	14.13	37.09
2017	24.48	31.80	27.58	84.18	13.53	36.13
2018	24.47	31.78	27.56	82.91	10.59	37.62
2019	24.45	31.76	27.57	82.01	13.39	40.37
2020	24.45	31.76	27.57	81.66	11.26	41.68

Source: https://dataonline.bmkg.go.id/home

Table A3. Harvested Area and Production of Three Prominent Crops in Manokwari Regency during 2011-2020.

Year	Harvested Area (Ha)			Production (Tonnes)		
	Rice	Maize	Soybean	Rice	Maize	Soybean
2011	4573	153	327	18175	262	355
2012	2481	251	409	9862	435	435
2013	2481	251	409	9862	435	435
2014	2481	251	409	9862	435	435
2015	3828	411	734	16364	711	769
2016	3828	411	734	16364	711	769
2017	3149.1	433.9	81	13638	774	88
2018	4446	398	64	12683	2207	59
2019	4073.1	411	734	17022.5	711	769
2020	4339.69	411	734	15601.2	711	769

Source: https://www.bps.go.id/id