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Tropical climate change and its impact on horticultural plants in Enrekang District, South Sulawesi, Indonesia

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Abstract. *Yassi A, Demmallino EB, Sultani HR. 2023. Tropical climate change and its impact on horticultural plants in Enrekang District, South Sulawesi, Indonesia. Biodiversitas 24: 3073-3079.* Global, regional, and local changes in climate are phenomenologically different and have distinct impacts on the horticultural and agricultural sectors. Therefore, this research aims to examine tropical climate change in South Sulawesi, Indonesia and analyze its impact on horticultural crops. A post-positivistic interpretation framework of the case study tradition was used, while the location was determined by purposive sampling followed by comprehensive data collection. Data were analyzed using integrated techniques, and validity tests were carried out to assess the credibility and reliability. The results indicated a local climate change marked by a difference in the pattern of distribution and intensity of extreme rainfall between 2015 and 2018. This was due to an increase in air temperature, which on average reached ±0.03731°C from the lowest of 22.50°C in 2011 to the highest of 23.12°C in 2020. In other words, it can be stated that the air temperature had increased by ±0.63°C in the last decade. The impact on various types of horticultural crops was marked by a decrease in the production of several kinds of Chinese cabbage, carrots, and green beans in 2015 as well as a very drastic reduction in potato crop production in 2018, while cabbage plants experienced a peak in production in 2018. Some types of horticultural crops such as shallots, cabbage and red chili began to stabilize and even increased their production in the aftermath of climate change during said period.

Keywords: Climate change, crops, ecological adaptation, intensity of rainfall, production of vegetables

INTRODUCTION

Tropical climate change is a global phenomenon that affects various sectors of life including agriculture. Indonesia is flanked by two oceans including the Pacific and the Indian Ocean, as well as two continents namely Asia and Australia, making it part of this change (Khairulbahri 2021). The country also has unique regional and local characteristics. Regionally, Indonesia is surrounded by several large and small islands with the sea as a link, while locally, various large islands including Sumatra, Java, Kalimantan, Sulawesi and Papua have many mountains and valleys, culminating in distinct climate change conditions in each region (Suryadi et al. 2018). In the last three decades, the country has experienced dynamic changes (Clem et al. 2020) including increased temperatures and diversity of current climate patterns (Pachauri et al. 2014). Higher temperatures lead to increased evaporation and evapotranspiration, which led to diminished water availability (Li et al. 2020). Climate change is also manifested by the increased imbalance in water during the dry and rainy seasons (Jerves-Cobo et al. 2020). Therefore, people experience water shortages in the dry season and floods in the rainy season (Yassi et al. 2019). South Sulawesi, Indonesia faces three types of rainfall patterns, namely the west coast or the Moonson type with peak rains in December, January, and February, the east coast or the equatorial style with rain peaks in April, May, June and December, as well as the transitional or local rain type.

In the last ten years, there have been several reports on climate change and its impact on the agricultural sector in various regions, affecting decrease in farmers's income. The previous study by Anik et al. (2021) suggested the need for an adaptation strategy to overcome the impacts of climate change. The level of adaptation capacity of food crop farmers to climate change is classified as moderate and varies among regions causing diverse and low production. Extreme climate change has led to a decrease in agricultural productivity and the need for groundwater conservation practices (Amfo et al. 2021).

Natural events due to climate change, include erratic rainfall patterns, high air temperatures and prolonged dry spells, as well as the early onset of rainy seasons (Mekonnen et al. 2021; Mumenthaler et al. 2021). These three events have posed high risk for crop failure, agricultural sustainability, and pest attacks. The impact of climate change also greatly affects the economy in the form of reduced food production and increased production costs, culminating in elevated food prices (Bhattacharya. 2019). Crop production is greatly affected by rainfall and increasing temperature. Therefore, local farmers must adapt through participatory research, as well as appropriate market strategies to improve food security status. There is also a need for efforts to utilize renewable energy sources in adapting to climate change and reducing CO_2 emissions (Suman 2021).

Previous studies focused more on analyzing the impact of global climate change on the agricultural sector and its adaptation patterns at the local level without considering the differences in the characteristics of tropical climate change at the global, regional and local levels. Therefore, this study focuses on climate change in South Sulawesi and examines its impact on horticultural crops in the horticultural development center.

MATERIALS AND METHODS

Research area

This research was conducted in the last decade from January 2011 to December 2021, during this period, primary and secondary data were collected from the BMKG South Sulawesi, Indonesia and horticultural crop farmers at the research location, namely the horticulture development center in Enrekang District (Figure 1).

Types and source data

Epistemologically, this research used a post-positivistic interpretation framework from the Single Instrument Case Study tradition (Creswell 1998). A five-qualitative research design approach was used comprising narrative, phenomenology, grounded theory, ethnography, and case studies. For each approach, the text included designing qualitative research, introduction and development, data collection, data analysis, the structure of each method, validation and evaluation, as well as conclusions.

Collecting data method

Primary and secondary data were collected using human instruments through comprehensive data collection technique starting with documentation at the BMKG Office South Sulawesi. This was followed by observation and in-depth interviews with several key informants selected using the snowball method (Marcus et al. 2017) at the horticultural farmer level. This method was used to analyze the adaptation patterns of horticultural farmers to climate change at the Enrekang District horticultural area development center. In general, the snowball sampling method was used in qualitative research where respondents were not recruited directly but through other people (Parker et al. 2019).

Data analysis

The collected data were analyzed holistically, referring to Creswell (1998), Miles and Huberman (1992) with the stages of analysis, namely data collection, categorization, display, and followed by conclusion. The results were then tested in the form of data validity tests, to assess their credibility and reliability.

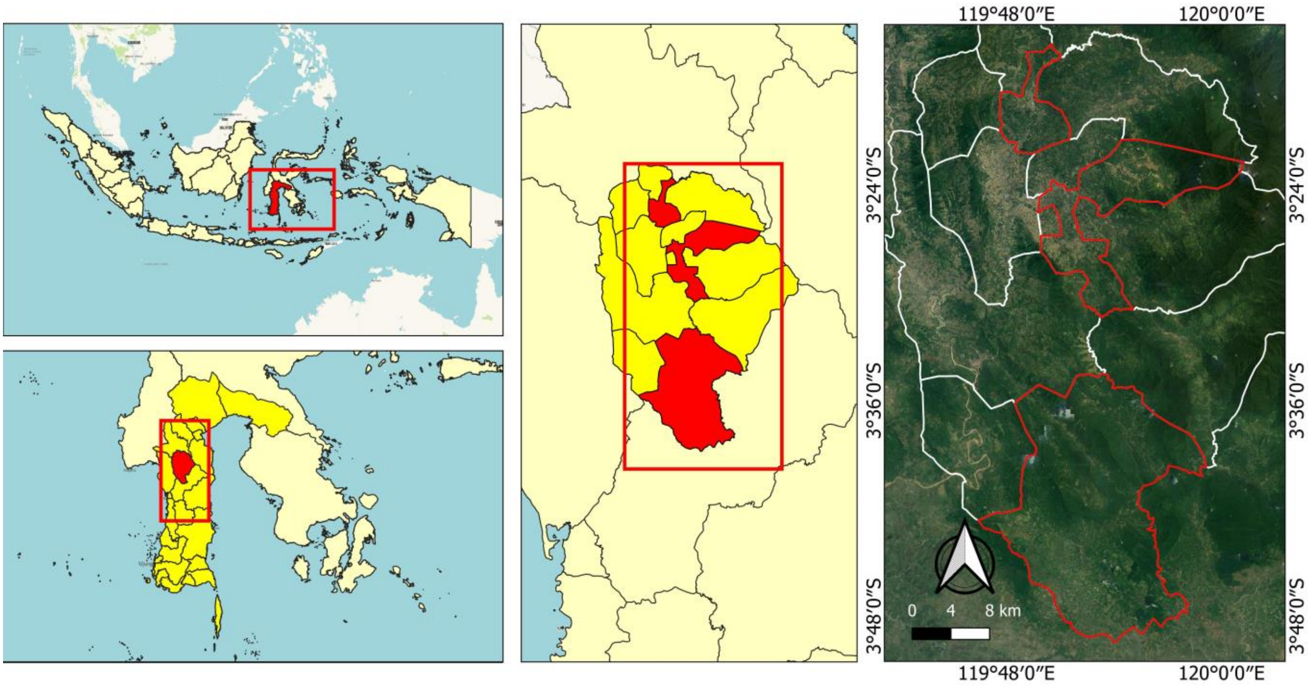

Figure 1. The map of research site in Enrekang District, South Sulawesi, Indonesia

RESULTS AND DISCUSSION

Data on average changes in air temperature in South Sulawesi

Data from the Meteorology, Climatology and Geophysics Agency (BMKG) shows temperature changes in South Sulawesi over the last ten years as described in Table 1.

Data average rainfall in South Sulawesi

The average rainfall data taken from five sample stations around the horticulture development center are shown in Table 2. The observation stations at the research sites were CH Talangriaja, CH Salokaraja, CH Salubarani, CH Mata Allo, and CH Maroangin Stations (Figure 1).

Data of production and horticultural planting area

Table 3 shows plant production and horticultural planting area over the last ten years in Enrekang District. The plant commodities analyzed were shallots, potatoes, cabbage, Chinese cabbage, tomatoes, carrots, green beans and red chili.

Climate change phenomenon

Data in Table 1 shows that on an average, the temperature rises in South Sulawesi over the last decade reached ±0.037°C ranging from the lowest average of 22.50°C in 2011 to the highest of 23.12ºC in 2020. In other words, it can be stated that the temperature had increased by ±0.63°C in the last decade as described in Table 1 and Figure 2. This result is in line with the average increase in global temperature but is still significantly lower due to the influence of the archipelago, as South Sulawesi is one of the largest islands in Indonesia. Furthermore, the country also has several mountains, valleys, forests, lakes, and rivers scattered in its territory.

Table 1. Average temperature change (°C/year) in South Sulawesi, Indonesia in the last decade (2011-2021)

Year	Temperature (°C)			
	Maximum	Minimum	Range	Average
2011	26.45	19.83	6.61	22.50
2012	26.46	19.83	6.62	22.56
2013	26.73	20.17	6.56	22.85
2014	26.97	19.96	7.00	22.82
2015	27.37	19.86	7.50	22.89
2016	27.26	20.74	6.53	23.38
2017	26.70	20.23	6.47	22.85
2018	27.00	20.06	6.94	22.88
2019	27.41	20.10	7.30	23.04
2020	26.97	20.52	6.46	23.12
2021	26.63	20.26	6.36	22.87
Average	26.90	20.14	6.76	22.89
Deviation	1.18	0.83	1.41	0.59

Source: BMKG South Sulawesi 2022

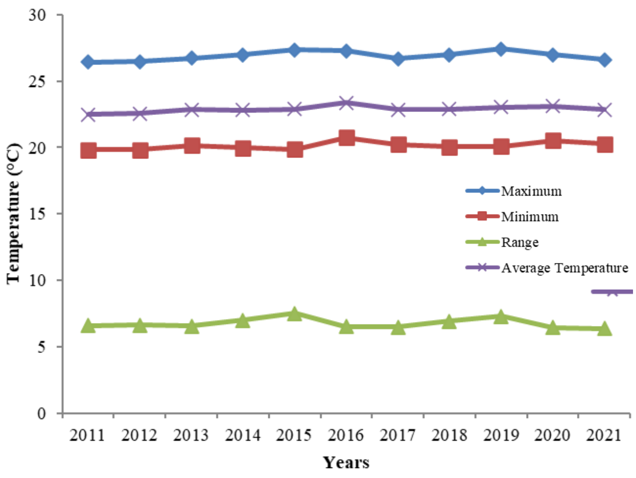

Figure 2. Changes in air temperature (°C/year) in South Sulawesi in the last decade (2011-2021).

Table 2. Average rainfall (mm/month/year) in South Sulawesi, Indonesia in the last decade (five sample stations around horticultural development centers in South Sulawesi)

Month	Year (2011-2021)											Monthly average
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
January	282.49	297.28	352.03	243.06	248.66	270.33	294.86	290.15	256.05	241.23	536.27	301.13
February	219.49	313.69	214.6	175.68	338.35	352.18	231.72	262.86	311.20	279.15	206.28	264.11
March	266.29	504.93	333.35	329.7	231.79	283.56	352.17	301.03	280.46	341.00	352.98	325.21
April	286.64	332.95	384.31	312.17	252.02	427.18	271.34	214.95	339.99	338.59	248.46	309.87
May	292.17	357.57	221.12	282.33	168.06	242.36	416.51	184.35	339.99	383.61	284.30	288.40
June	190.06	169.86	261.08	258.03	177.71	369.91	288.16	243.27	403.71	384.26	172.92	265.31
July	148.33	203.96	287.81	260.39	103.08	119.30	210.93	116.66	91.93	289.30	170.31	182.00
August	56.92	110.48	162.3	148.95	39.62	83.03	184.87	70.43	101.30	204.50	383.90	140.57
September	203.16	96.91	128.93	9.42	20.01	183.45	230.99	119.23	116.07	250.15	315.57	152.17
October	84.48	120.08	51.83	146.63	96.32	264.84	277.07	85.52	278.40	250.53	200.60	168.75
November	157.61	68.47	238.16	128.24	159.86	260.82	254.61	219.61	41.90	246.54	324.28	190.92
December	461.77	290.84	351.66	342.49	351.50	280.30	335.82	376.93	99.13	352.09	401.55	331.28
Annual average	220.78	238.92	248.93	219.76	182.25	261.44	279.09	207.08	221.68	296.75	299.79	

Source: CH Talangriaja Station, CH Salokaraja Station, CH Salubarani Station, CH Mata Allo Station and CH Maroangin Station, South Sulawesi 2022

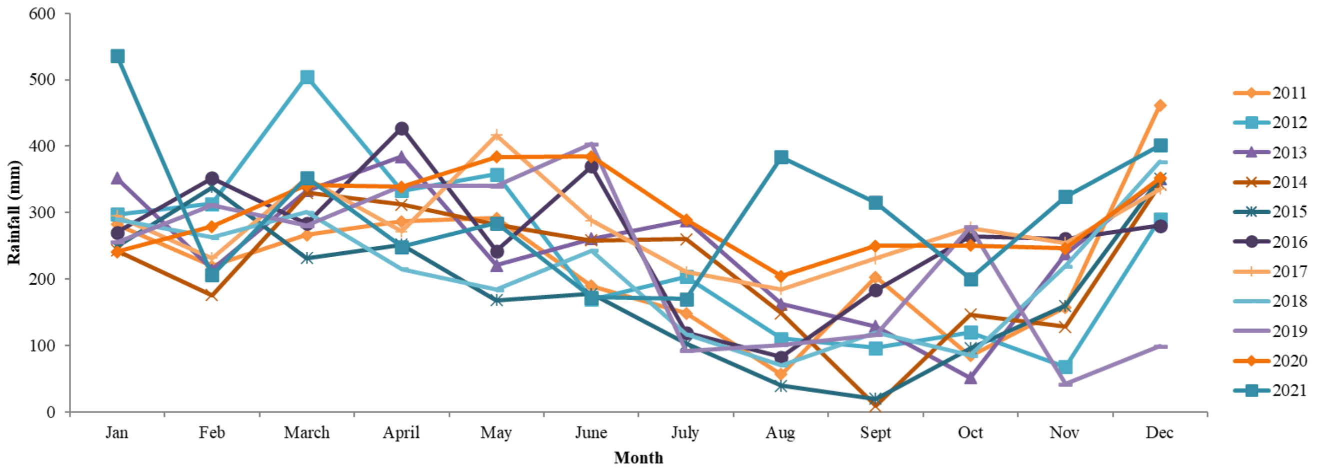

Figure 3. Changes in average rainfall (mm/month/year) at five rainfall stations around the horticultural development area in South Sulawesi, Indonesia

Climate change phenomenon

Data in Table 1 shows that on an average, the temperature rise in South Sulawesi over the last decade reached ±0.037°C ranging from the lowest average of 22.50°C in 2011 to the highest of 23.12ºC in 2020. In other words, it can be stated that the temperature had increased by ±0.63°C in the last decade as described in Table 1 and Figure 2. This result is in line with the average increase in global temperature but is still significantly lower due to the influence of the archipelago, as South Sulawesi is one of the largest islands in Indonesia. Furthermore, the country also has several mountains, valleys, forests, lakes, and rivers scattered in its territory.

Based on data sourced from the South Sulawesi BMKG (2022), in the last decade from 2011-2021, it was found that both maximum, minimum, and average temperatures had continued to increase, although in a fluctuating pattern. This characteristic differs between global, regional, and local climate change, for example, global climate change, as an indication of global warming (Mahony and Cannon 2018), has led to instability of the atmosphere in the lower layers, specifically those close to the earth surface. This is caused by increasing greenhouse gases including CO_2, CH_4, and N_2O which are mainly produced by fossil fuel energy, transportation, and industry. The energy sector plays an important role in the economy of Indonesia but also has negative environmental impacts. Excessive use of fossil fuel energy can pollute the environment because of the pollutants (Najjar et al. 2021). Observations of global temperature since the 19th century showed an increase in average temperature, an indicator of climate change (Mahlstein et al. 2013). This change is indicated by the rise in the average temperature of up to 0.74ºC between 1906-2005. Global temperature is projected to increase continuously to approximately 1.5ºC in this century (Tian et al. 2021).

Abnormal temperatures and extreme weather can change the climate (Howe et al. 2021), affecting agricultural patterns, as stated by Chen et al. (2021) and Akbari et al. (2020). Climate change might alter planting days, crop diversification, as well as reduce water quality, and crop yields. Afzali et al. (2020) added that the number of exports of important agricultural products have deviated due to climate change.

Previous studies provided solutions to the effects of climate change on agriculture, for example, according to Harth (2021), climate change can affect human psychology. One solution to dealing with this problem is increasing awareness in the household and involving women in planning. This effort should be strengthened by other policymakers to minimize utilization conflicts. Meanwhile, Assan et al. (2020), Fachry et al. (2021), and Daris et al. (2022) proposed solutions that involved managing agricultural resources at the community level. Nahar et al. (2020) and Kim et al. (2021) suggested the protection and restoration of tropical peatlands as one possible solution to mitigate the influence of climate change on plant development and diseases.

Changes in air temperature in South Sulawesi

Based on Table 2, there was an impact of the El Nino phenomenon in 2015 which caused a long dry season of about six months, specifically in the eastern sector. Meanwhile, in the western sector, there was a transition of decreased rain intensity impacts from May to November. According to Oldman (1972) there was an increase in the number of wet months in 2016 by up to nine months as shown in Table 2 and the impact of climate change was mainly on rainfall patterns. Based on data sourced from five stations around the horticulture development center in South Sulawesi, in the last decade (2011-2021), there have been two extreme weather changes, namely in 2015 and 2018, which occurred during the dry season from September until October. The average rainfall in these two years fell into the category of wet and dry months (Harahap et al. 2020), but during the rainy seasons, there were quite extreme changes, specifically in 2018, where the number of wet months was between 7-8 with the agricultural climate type B (Figure 3). Meanwhile, in 2015 there were 5 wet months with climate type C as described in Table 2 and Figures 3, 4, 5, and 6. Referring to Oldman (1972), the horticultural development area in Enrekang District in 2011-2021 had an agricultural climate type B.

Previous research found that there are still farmers who need to learn more about climate change beyond its impact on agriculture. Farmers who have adequate knowledge can adapt to changes in the planting time based on water availability, and use generators to add water to rice fields as well as control pests and diseases more intensively (Hasanah et al. 2017). Furthermore, Adiyoga and Basuki (2018) found that farmers perceive three events as consequences of climate change, namely erratic rainfall patterns, an increase in air temperature due to the intensity of the sun and prolonged dry spells, as well as early onset of the rainy season. These three natural events are known to increase the risk of crop failure, agricultural sustainability issues, and high pest attacks. Extreme climate change also impacts food crops by reducing their ability to grow and be harvested, leading to decreased production and productivity, damage to agricultural land resources, increased frequency of area and intensity of drought, as well as high humidity and intensity of plant pest disturbances. The following sections describe the impact of climate change on horticulture planted area (Table 4) and the production of horticultural crops (Table 5) in horticultural development centers, specifically in Enrekang District, South Sulawesi.

Rainfall in South Sulawesi

Figures 4, 5 and 6 show the distribution of average rainfall patterns at Mata Allo, Maroangin and Salu Barani Stations. The average rainfall intensity during climate change in 2011-2021 was higher than in 2002-2010. The average rainy season occurred from April-June, and the dry season on average, occurred between July and September. Hence, the cropping pattern, specifically those related to the planting schedule, should be based on harvest time in months with rainfall below 60 mm per month.

Rainfall varies every year, can change quickly and have different rainfall events even though they are in almost the same place (Giarno et al. 2018). Areas with high rainfall can affect the physicochemical properties of the soil (Ahmad et al. 2018), causing a lot of waste to be carried away (Massiseng et al. 2022) and also, if land use is not adjusted to the capacity of the land will cause landslides and affect the availability water for plants (Saida et al. 2016). High rainfall intensity can be the leading cause of flooding (Ramadhan et al. 2023). Climate change suggests that rainfall can trigger an increase in waterlogging areas or potentially become areas affected by affected-flood area (Hettiarachchi et al. 2018); therefore, the production of horticultural crops need attention to rainfall to reduce the impact that will be caused.

Impact on horticultural plants

Based on data from BPS Enrekang District and South Sulawesi, as well as the results of interviews with several informants in the field, it can be concluded that at the two extreme points of climate change in 2015 and 2018, a phenomenon of decreased horticultural crop production occurred. During the first extreme point (2015), an El Nino event caused extremely dry weather leading to decreased production of cabbage plants and several other horticultural crops including Chinese cabbage, tomatoes, carrots, green beans, and red chili (Table 5). This phenomenon was caused by rainfall patterns which began to change in 2014, causing a reduction in production (Figure 3). During the second extreme point in 2018, a very drastic decline in production was also found, including a decrease in potato crop production which only reached 1.83 100kg/ha compared to 75.86 100kg/ha for the previous year (Table 5).

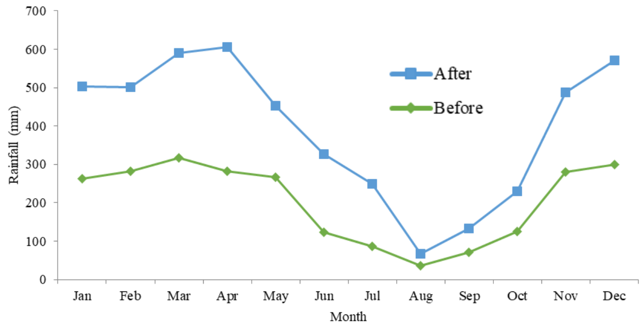

Figure 4. Distribution of average rain patterns (mm/year) that occurred before climate change (2002-2010) and after climate change (2011-2021) at Mata Allo Station, Baraka Sub-district, Enrekang District, around the Horticulture Development Area in South Sulawesi, Indonesia

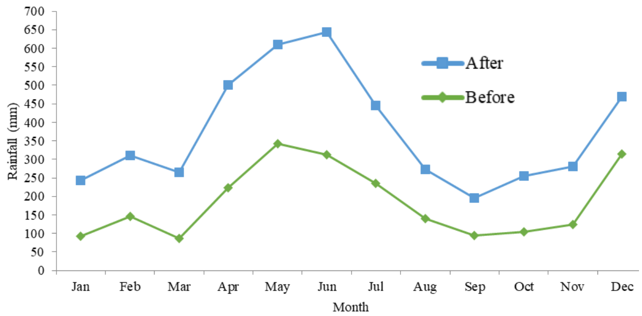

Figure 5. Distribution of average rainfall patterns (mm/year) that occurred before climate change (2003-2010) and after climate change (2011-2021) at Maroangin Station, Maiwa Sub-district, Enrekang District, around the Horticulture Development Area in South Sulawesi, Indonesia

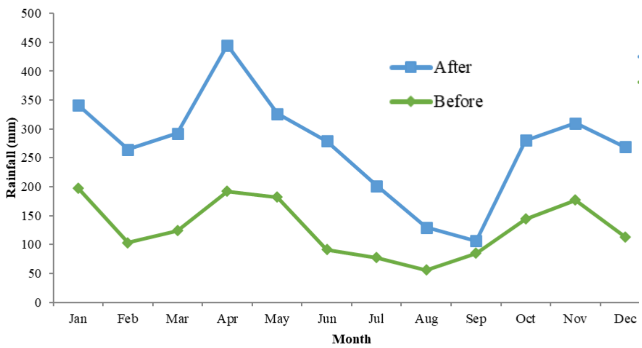

Figure 6. Distribution of average rainfall patterns (mm/year) that occurred before climate change (2003-2010) and after climate change (2011-2021) at Salu Barani Station, Alla Sub-district, Enrekang District, around the Horticulture Development Area in South Sulawesi, Indonesia

Table 3. Production of horticultural plants (100kg/year) in Enrekang District, South Sulawesi, Indonesia

Commodity	Production (100kg/year)										
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Shallots	344699	330178	392950	441880	583574	851736	1116123	735811	800173	1028726	1509113
Potatoes	13125	11338	770	2564	250	2784	3869	2376	3006	2883	896
Cabbage	401390	426820	498930	363705	265195	353819	451224	405543	288300	363606	356406
Chinese cabbage	36530	31810	30080	25428	19210	27016	16868	29255	25643	22598	14629
Tomatoes	122445	139338	161180	108120	159025	295654	472850	453893	332996	372568	308842
Carrots	44170	33810	37040	39874	35100	66410	60464	54667	40013	58431	28339
Green beans	37882	34515	35950	24340	19080	48347	41245	62429	35696	29256	36367
Red chili	39768	189572	50910	13770	26969	75405	65973	61899	55563	53199	54926

Source: BPS Enrekang District, South Sulawesi 2022

Table 4. Horticulture planted area (Ha/year) in the last ten years in Enrekang District, South Sulawesi, Indonesia

Commodity	Planted area (ha/year)										
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Shallots	3342	3203	3744	4151	5356	7820	10245	6610	7605	9565	13887
Potatoes	131	110	61	26	39	27	51	1298	45	39	10
Cabbage	1085	1143	1282	962	825	1131	1297	34	1215	1023	1338
Chinese cabbage	139	151	174	152	113	168	148	185	151	148	108
Tomatoes	1097	1271	1348	966	826	1112	1398	1468	1058	1314	1510
Carrots	291	198	215	239	193	280	367	330	242	386	239
Green beans	283	295	270	405	168	179	190	276	186	163	237
Red chili	812	856	856	527	471	585	700	629	527	498	514

Source: BPS Enrekang District, South Sulawesi 2022

Table 5. Production of horticultural plants (100kg/ha) in Enrekang District, South Sulawesi, Indonesia

Commodity	Production (100kg/ha)										
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Shallots	103.14	103.08	104.95	106.45	108.96	108.92	108.94	111.32	105.22	107.55	108.67
Potatoes	100.19	103.07	12.62	98.61	250.00	71.38	75.86	1.83	66.80	73.92	89.60
Cabbage	369.94	373.42	389.18	378.07	321.45	312.84	347.90	11927.74	237.28	355.43	266.37
Chinese cabbage	262.80	210.66	172.87	167.29	170.00	160.81	113.97	158.13	169.82	152.69	135.45
Tomatoes	111.61	109.62	119.57	111.92	192.52	265.88	338.23	309.19	314.74	283.54	204.53
Carrots	151.79	170.75	172.28	166.84	181.86	237.18	164.75	165.66	165.34	151.38	118.57
Green beans	133.86	117.00	133.15	60.10	113.57	270.09	217.08	226.19	191.91	179.48	153.45
Red chili	48.97	221.46	59.47	26.13	57.26	128.90	94.25	98.41	105.43	106.82	106.86

Source: BPS Enrekang District, South Sulawesi 2022

The leading cause of the decline was the lack of rainfall or drought from July to November in the dry season. In addition, a decrease in production was attributed to pest attacks which multiplied and acted as virus carriers. During this season, the rainfall volume fell into the dry month category (Harahap et al. 2020) as shown in Tables 3, 4 and 5. Shallot plants generally remained stable due to the ability of farmers to provide water through pumping from nearby sources (river basin). However, in 2019, the plant experienced a decrease in the production of about 6 tonnes/ha due to pest attacks that multiplied in 2018 and acted as carriers of viruses (disease vectors). Farmers in Enrekang District also use pesticides in very varied quantities and types, for example, they often mix different types of pesticides with 63 types identified, of which nine are unregistered and 54 are registered. These pesticides are often used in doses exceeding the recommended amounts, making the cost of maintaining horticulture, specifically shallots, very high.

The results show that farmers can still recover their agricultural production even after extreme point events or changes in rainfall patterns except for the shallot plant as shown in Figures 2 and 4. Cabbage was found to reach its production peak during the second extreme weather change in 2018. This suggests that horticultural farmers can adapt ecologically during drastic weather changes and recover their agricultural systems in socio-cultural, economic, and technological or agronomic forms.

In conclusion, climate change in South Sulawesi is characterized by extreme changes in rainfall volume that occurred in 2015 and 2018 due to increased air temperature. The change in temperature on average reached ±0.037°C per year ranging from the lowest of 22.50°C in 2011 to the highest of 23.12°C in 2020. In other words, it can be stated that the air temperature had increased by around ±0.63°C in the last decade. At the two extreme points of changes in rainfall patterns, phenomena of decreased horticultural crop production were found due to the lack of rainfall or drought and the breeding of certain types of pests, which lasted from July to November. Therefore, various kinds of horticultural crops can remain stable in production even after climate change.

REFERENCES

Adiyoga W, Basuki RS. 2018. Perceptions of vegetable farmers on the impact of climate change in South Sulawesi. Jurnal Hortikultura 28 (1): 133-146. [ndonesian]

Afzali R, GharehBeygi M, Yazdanpanah DQ. 2020. Climate Changes and food policies: Economic pathology. Clim Risk Manag 30: 100249. DOI: 10.1016/j.crm.2020.100249.

Ahmad A, Lopulisa C, Imran AM, Baja S. 2018. Soil physicochemical properties to evaluate soil degradation under different land use types in a high rainfall tropical. IOP Conf Ser:Earth Env Sci 157: 012005. DOI: 10.1088/1755-1315/157/1/012005.

Akbari M, Alamdarlo HN, Mosavi SH. 2020. The effects of climate change and groundwater salinity on farmers' income risk. Ecol Indic 110: 105893. DOI: 10.1016/j.ecolind.2019.105893.

Amfo B, Ali EB, Atinga D. 2021. Climate change, soil water conservation, and productivity: Evidence from cocoa farmers in Ghana. Agric Syst 191: 103172. DOI: 10.1016/j.agsy.2021.103172.

Anik AR, Rahman S, Sarker JR, Al Hasan M. 2021. Farmers' adaptation strategies to combat climate change in drought prone areas in Bangladesh. Intl J Disaster Risk Reduct 65: 102562. DOI: 10.1016/j.ijdrr.2021.102562.

Assan E, Suvedi M, Olabisi LS, Bansah KJ. 2020. Climate change perceptions and challenges to adaptation among smallholder farmers in semi-arid Ghana: A gender analysis. J Arid Environ 182: 104247. DOI: 10.1016/j.jaridenv.2020.104247.

Bhattacharya A. 2019. Global Climate Change and Its Impact on Agriculture. In: Bhattacharya A (eds). Changing Climate and Resource Use Efficiency in Plants. Academic Press, London. DOI: 10.1016/b978-0-12-816209-5.00001-5.

Chen H, Bai X, Li Y, Li Q, Wu L, Chen F,. 2021. Soil drying weakens the positive effect of climate factors on global gross primary production. Ecol Indic 129: 107953. DOI: 10.1016/j.ecolind.2021.107953.

Clem KR, Fogt RL, Turner J, Lintner BR, Marshall GJ, Miller JR, Renwick JA. 2020. Record warming at the South Pole during the past three decades. Nat Clim Change 10: 762-770. DOI: 10.1038/s41558-020-0815-z.

Creswell JW. 1998. Qualitative Inquiry and Research Design. Choosing Among Five Traditions. SAGE Publication, Inc, London.

Daris L, Massiseng ANA, Fachry ME, Jaya J, Zaenab S. 2022. The impact of fishermen's conflict on the sustainability of crab (*Portunus pelagicus*) resources in the coastal areas of Maros District, South Sulawesi, Indonesia. Biodiversitas 23 (10): 5278-5289. DOI: 10.13057/biodiv/d231037.

Fachry ME, Massiseng ANA, Bahar A, Tuwo A. 2021. Stakeholder roles in the Baluno Mangrove Learning Center Ecotourism. AACL Bioflux 14 (4) : 2525-2536.

Giarno D, Didiharyono, Fisu AA, Mattingaragau A. 2018. Influence rainy and dry season to daily rainfall interpolation in complex terrain of Sulawesi. IOP Conf Ser Earth and Env Sci 469: 012003. DOI 10.1088/1755-1315/469/1/012003

Harahap S, Imleda IZM, Suryanto, Indah EK, Fitri I. 2020. Mapping climate classification of oldeman in agricultural resources management in South Tapanuli District. IOP Conf Ser Mater Sci Eng 1156: 012002. DOI: 10.1088/1757-899X/1156/1/012002.

Harth NS. 2021. Affect, (group-based) emotions, and climate change action. Curr Opin Psychol 42: 140-144. DOI: 10.1016/j.copsyc.2021.07.018.

Hasanah U, Lesmana D, Imang. 2017. Knowledge and adaptation of lowland rice farmers to climate change in Gerirejo, Lempake Village, North Samarinda District. Jurnal Ekonomi Pertanian dan Pembangunan 14 (2): 64-77. [Indonesian]

Hettiarachchi S, Wasko C, Sharma A. 2018. Increase in flood risk resulting from climate change in a developed urban watershed – the role of storm temporal patterns, Hydrol. Earth Syst Sci 22 (3): 2041-2056. DOI: 10.5194/hess-22-2041-2018.

Howe PD. 2021. Extreme weather experience and climate change opinion. Curr Opin Behav Sci 42: 127-131. DOI: 10.1016/j.cobeha.2021.05.005.

Jerves-Cobo R, Forio MAE, Lock K, van Butsel J, Pauta G, Cisneros F, Goethals PLM. 2020. Biological water quality in tropical rivers during dry and rainy seasons: A model-based analysis. Ecol Indic 108: 105769. DOI: 10.1016/j.ecolind.2019.105769.

Khairulbahri M. 2021. Analyzing the impacts of climate change on rice supply in West Nusa Tenggara, Indonesia. Heliyon 7 (2): e08515. DOI: 10.1016/j.heliyon.2021.e08515.

Kim IS, Cho H, Sohn KS, Kim K, Kim S. 2021. A study on the severe crazing phenomenon of the PMMA canopy under prolonged exposure to tropical climates. Eng Fail Anal 129: 105719. DOI: 10.1016/j.engfailanal.2021.105719

Li X, Shi W, Broughton K, Smith R, Sharwood R, Payton P,2020. Impacts of growth temperature, water deficit and heatwaves on carbon assimilation and growth of cotton plants (*Gossypium hirsutum* L.). Environ Exp Bot 179: 104204. DOI: 10.1016/j.envexpbot.2020.104204.

Mahlstein I, Daniel JS, Solomon S. 2013. The pace of shifts in climate regions increases with global temperature. Nat Clim Chang 3 (8): 739-743. DOI: 10.1038/nclimate1876.

Mahony CR, Cannon AJ. 2018. Wetter summers can intensify departures from natural variability in a warming climate. Nat Commun 9 (1): 783. DOI: 10.1038/s41467-018-03132-z.

Marcus B, Weigelt O, Hergert J, Gurt J, Gelléri P. 2017. The use of snowball sampling for multi-source organizational research: Some cause for concern. Pers Psychol 70 (3): 635-673. DOI: 10.1111/peps.12169.

Massiseng ANA, Tuwo A, Fachry ME, Bahar A. 2022. Characteristics of plastic waste and perceptions of coastal communities in the MLC Baluno mangrove ecotourism area, West Sulawesi, Indonesia. Biodiversitas 23 (12): 6262-6274. DOI: 10.13057/biodiv/d231222.

Mekonnen A, Tessema A, Ganewo Z, Haile A. 2021. Climate change impacts on household food security and farmers adaptation strategies. J Agric Food Res 6: 100197. DOI: 10.1016/j.jafr.2021.100197.

Miles MB, Huberman AM. 1992. Qualitative Data Analysis. Indonesia University Press, Jakarta.

Mumenthaler C, Renaud O, Gava R, Brosch T. 2021. The impact of local temperature volatility on attention to climate change: Evidence from Spanish tweets. Glob Environ Chang 69: 102286. DOI: 10.1016/j.gloenvcha.2021.102286.

Nahar MS, Naher N, Alam MJ, Hussain MJ, Yasmin L, Mian MY, Rosa C. 2020. Survey, morphology and white mold disease of country bean (*Lablab purpureus* L.) caused by *Sclerotinia sclerotiorum* (Lib.) de Bary in-relation to soil physico-chemical properties and weather conditions in Bangladesh. Crop Prot 135: 104825. DOI: 10.1016/j.cropro.2019.05.019.

Najjar E, Al-Hindi M, Massoud M, Saad W. 2021. Life Cycle Assessment of a seawater reverse osmosis plant powered by a hybrid energy system (fossil fuel and waste to energy). Energy Rep 7 (5): 448-465. DOI: 10.1016/j.egyr.2021.07.106.

Oldman M.1972. Ergonomics in agricultural equipment design: National Institute of Agricultural Engineering. J Sound Vib 22 (4): 500-501, DOI: 10.1016/0022-460X(72)90459-2.

Pachauri RK, Allen MR, Barros VR, Broome J, Cramer W, Christ R. 2014. Climate Change. Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC DOI: 10013/epic.45156.

Parker C, Scott S, Geddes A. 2019. Snowball sampling. Sage research methods foundations. Sage Publications, London.

Ramadhan C, Dina R, Nurjani E. 2023. Spatial and temporal based deforestation proclivity analysis on flood events with applying watershed scale (case study: Lasolo watershed in Southeast Sulawesi, Central Sulawesi, and South Sulawesi, Indonesia). Intl J Disaster Risk Reduct 93: 103745. DOI: 10.1016/j.ijdrr.2023.103745.

Saida, Abdullah, Novita E, Ilsan M. 2016. Sustainability analysis of potato farming system at sloping land in Gowa Regency, South Sulawesi. Agric Agric Sci Proc 9: 4-12. DOI: 10.1016/j.aaspro.2016.02.107.

Suman A. 2021. Role of renewable energy technologies in climate change adaptation and mitigation: A brief review from Nepal. Renew Sustain Energy Rev 151: 111524. DOI: 10.1016/j.rser.2021.111524.

Suryadi Y, Sugianto DN, Hadiyanto. 2018. Climate Change in Indonesia (Case Study: Medan, Palembang, Semarang). E3S Web Conf 31: 09017. DOI: 10.1051/e3sconf/20183109017.

Tian C, Yue X, Zhou H, Lei Y, Ma Y, Cao Y. 2021. Projections of changes in ecosystem productivity under 1.5°C and 2°C global warming. Glob Planet Chang 205: 103588. DOI: 10.1016/j.gloplacha.2021.103588.

Yassi A, Kaimuddin, Bahrun AH, Sahur A. 2019. Study of climate determination analysis based on pallontara/papananrang and rainfall opportunities in Sidrap District. IOP Conf Ser Earth Environ Sci 279: 012052. DOI: 10.1088/1755-1315/279/1/012052.