



Oldeman's Agroclimatic Zone Shifting Analysis and Suitability of Agricultural Land in Bali

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Abstract: Due to climate change, the land suitability for several commodities no longer be the same. Agricultural conditions in Bali province will be expected to face uncertain climate patterns in the future. Therefore, the climate information required by farmers. By knowing the information, they expected able to suit their cultivation planning to the latest climate types information. One of climate information is climate types classification presented as Oldeman's Agroclimatic Zone Map. It resulted by identification of climate types shifting areas. Areas where the wet or dry months become shorter or longer will cause the cultivation period for a commodity to be disrupted, which can reduce crop yields. The research regarding climate types shifting is important to find out which areas experienced in shift and what type of it. The aim of the research is to analyze Oldeman's climate types shifting every decade in the 1991-2020 period to determine the suitability of land to climate for paddy (*Oryza sativa*), corn (*Zea mays*), soybean (*Glycine max.*), chili (*Capsicum annum*) and shallot (*Allium oscolonicum*) in 58 locations to represent all sub-districts in Bali. The results showed that 49 (84.48%) locations experienced shifting.

Keywords: Bali, Climate types, Oldeman, Precipitation, Shifting

As one of climatic factor, precipitation influences the success in harvest. Heavier in its intensity has the potential to destruct agricultural land, while very low precipitation results the plantation unable to produce optimally due to limited water availability. Such precipitation condition for recent years have resulted in changes in the number of wet and dry months so that the climate types in several region changed. Grigorieva et al. (2023) stated because agricultural productivity depends on weather and climate and is highly dependent on climatic stability, climate change poses various challenges to agricultural activities. This change means that the level of land suitability for several agricultural commodities is no longer the same, many efforts required to identify areas experienced climate types shifting so that when planning agricultural activities, the commodities to cultivate expected compatible with the latest climate information in the area. The problem of shifting had an impact on decreasing of harvest. The shifting, either in temporary (tended to be wetter or drier, variable) or permanently (wetter, drier) indicated change in the number of wet and dry months, resulted in new climatic patterns that had an impact on productive plants. Pradana and Sesanti (2018) showed that knowledge about climate in the form of its characteristics and predictions was very important so that farmers could determine suitability for agricultural land.

The World Meteorological Organization /WMO (2018)

stated that normal climatological standards calculated every 10 years for 30 years in the initial period of each decade from years ended with the number one (1981-2010, 1991-2020, etc.), and normal recalculations every 10 years required a large data set that used normal precipitation as a reference. The number of rain stations were far apart due to topographic conditions in some areas of Bali, the precipitation data unable to represent condition in some areas so that the precipitation information produced can be inaccurate. Current remote sensing technology makes it possible to monitor precipitation using satellite imagery in the form of estimation data. One of satellite data with a very high resolution is CHIRPS (Climate Hazards Group InfraRed Precipitation with stations) which developed by the United States Geological Survey and the University of California, Santa Barbara. This research uses CHIRPS monthly precipitation data for the period 1991-2020 in Bali. Research using satellite rainfall estimation data was conducted by Noor et al. (2015) using TRMM to create a map of the Oldeman's Agroclimatic Zone and to analyze agricultural resource management. The results of study showed that based on TRMM satellite data, the Agroclimatic Zone in South Kalimantan divided into five: B1, B2, C1, C2, and D1. Irmawan et al (2024) validated the accuracy rate of monthly precipitation CHIRPS data using the correlation coefficient and RMSE to update Oldeman's agroclimatic zone map.

Determination of land suitability in the research based on monthly precipitation using Oldeman's method. According to Wahyunto et al. (2016), the result of Oldeman's method can be used to determine the class of land suitability. Precipitation factor as one of the limiting factors in plant processing and production as well as plays an important role in determining land suitability such as the number of wet and dry months. An uncertainty in seasonal patterns make it difficult for farmers to plan and harvest their commodities. This shifting has increased the scale of vulnerability in agricultural sector, included in Bali. Government needs to give attention for these shifting. The endorsement for the success of agricultural planning can be implemented in several ways, one of them is by providing Oldeman's Agroclimatic Zone Map. This mapping aimed to support the government and farmers in agricultural planning which areas have a climate that is suitable to cultivate certain crops, the classification of which based on suitability of rainfall characteristics to soil.

MATERIAL AND METHODS

This classification carried out by calculating the average of monthly precipitation data for January during 1991-2000 period. The data from February to December also calculated to get the average of wet, humid and dry month. A month considered as wet (WM) if the precipitation ≥ 200 mm, moist month (MM) if precipitation between 100-200 mm, and dry month (DM) if precipitation ≤ 100 mm. The similar procedure carried out to create climate types during the 2001-2010 and 2011-2020 periods, so that types will be obtained for three periods. The making of Oldeman's Agroclimatic Zone criteria based on division of letters from A to E, and numbers, from 1 to 5. Letter A represented of more than nine wet months consecutively, B for consecutive wet months between 7-9 months, C for consecutive wet months between 5-6 months, D for consecutive wet months between 3-6 months, E for consecutive wet months of <3 months. The Sub Division represented consecutive dry months number in a year (Table 1, 2).

The results of climate types classification every decade during 1991-2020 period would produce climate types shifting in each location. The shifting classified into six types:

- a. Wetter; when during three periods the types tended to increase;
- b. Tended to be wet; when the types of first and second periods had the same but the types in the last period was higher.
- c. Constant; when during three consecutive periods the types did not change.
- d. Tended to be dry; when types in first and second periods

were the same but the types in third period was lower.

- e. Drier; when during three periods the types tended to decrease.

- f. Varied; when the types in second period was higher or lower than the first and third;

In this research, the limiting factor was monthly precipitation. Land suitability classified into four items (Wahyunto et al, 2016):

- a. S1 (very suitable) when the land did not have any significant or real limiting factors for sustainably use, or the limiting factors did not dominant and did not significantly reduce the land productivity.
- b. S2 (quite suitable) when the land has limiting factors, and these factors would affect to its productivity, it required additional input. The barriers usually could be overcoming by farmers themselves.
- c. S3 (marginal) when the land had a dominant limiting factor, and this factor would affect to its productivity, it required more additional input than land classified as S2. The way to overcome the factor needed high capital, farmers needed assistance to cope with.
- d. N (not suitable) when the limiting factors very dominant or difficult to overcome.

Precipitation was one of climatic factors to confine the process of plant to grow and production as well as played important role in determining land suitability such as wet and dry months. Classification of land suitability for agricultural commodities based on consecutive wet and dry months as presented below.

The S1 classification or very suitable for paddy stated if range of consecutive wet months between 6-8 months, corn (3-5 months), soybean (2-4 months), and chili (5-6 months). Another example is suitability for shallot based on consecutive dry months in a year. Suitability for shallot determined as S1 if the number of dry months is between 4-6 months; S2 (>6 months); S3 (between 2 and <4 months); and N if the number of dry months <2 months. Shallot will be more suitable to cultivate during dry season.

RESULTS AND DISCUSSION

Process of grouping monthly precipitation data by Oldeman's method during the 1991-2000, 2001-2010, 2011-2020 periods produced the Oldeman's agroclimatic zone (Table 5).

The shift either temporarily (tended to be wet, tended to be dry, varied) or permanently (became wetter or drier) indicated a change in number of wet and dry months, resulted a new climate patterns that had an impact on productivity. These conditions affected to land suitability and cultivation patterns for several commodities. Regions shifted in varied

types generally referred as climatic variability. Regions where types were constant, basically had the same suitability class as in previous period, but even though during these three periods the types remained the same. Based on above table, Bali province periodically experienced climate types shifting, on which in 1991-2000 shown by following map.

During 1991-2000 period there were seven types, B2 (two locations), B3 (11), C3 (20), D3 (13), D4 (1), E3 (6) and E4 (5). The type that might only be able to cultivate paddy crop once

Table 1. Oldeman's classification of agroclimatic zones

Zone	Climate types	Consecutive wet months	Consecutive dry months
A	A1	10-12	0-1
	A2	10-12	2
B	B1	7-9	0-1
	B2	7-9	2-3
	B3	7-9	4-5
C	C1	5-6	0-1
	C2	5-6	2-3
	C3	5-6	4-6
	C4	5-6	7
D	D1	3-4	0-1
	D2	3-4	2-3
	D3	3-4	4-6
	D4	3-4	7-9
E	E1	0-2	0-1
	E2	0-2	2-3
	E3	0-2	4-6
	E4	0-2	7-9
	E5	0-2	10-12

Source: Alfiandy et al (2021)

a year, depended on availability of irrigation, distributed in outermost, especially in the western and southeastern parts.

In 2001-2010 period there were 11 types, B1 (1), B2 (3), B3 (3), C2 (12), C3 (5), D1 (4), D2 (4), D3 (16), D4 (5), E3 (2) and E4 (3). The period characterized by the addition of four types. Above map shows a shift either in number of wet and dry months or the percentage of types. Dry areas distributed in outside parts and became larger than before.

In 2011-2020 period there were 10 types, B2 (1), C2 (12), C3 (8), D1 (1), D2 (9), D3 (12), D4 (9), E2 (2), E3 (1) and E4 (3). Areas of wet types still distributed in central and southwest parts. The types in the period indicated types shifting happened. In this period, climate types B1 and B3 had unavailable, but there was E2 with 0-2 in consecutive wet months and 2-3 in consecutive dry months.

The differences in number and distribution of Oldeman's types during 3 consecutive periods resulted a trend shifting, there were 2 locations (3.45%) have become wetter, 9 (15.52%) tended to be wet, 9 (15.52%) constant, 18 (31.03%) to be dry, and 5 (8.62%) drier. The classification then updated using monthly precipitation data during the 1991-2020 period resulted in the Oldeman's agroclimatic zone classification presented on Figure 4. Land suitability classification for paddy, corn, soybean, shallot and chili in this study obtained

Table 3. Land suitability classification by climate for paddy, corn, soybean and chili based on consecutive wet months

Class	S1	S2	S3	N
Paddy	6 - 8	4 - <6	2 - <4 or >8 - 10	<2 or >10
Corn	3 - 5	<3 or >5 - 7	>7 - 8	>8
Soybean	2 - 4	>4 - 6	>6 or <2	-
Chili	5 - 6	3 - <5 or >6 - 8	<3 or >8	-

Source: Wahyunto et al 2016

Table 2. Oldeman's classification of agroclimatic zones with explanations

Climate types	Explanations
A1, A2	Suitable to cultivate paddy continuously but production become less because usually the radiation intensity becomes low throughout the year.
B1	Suitable to cultivate paddy continuously through good planning to start cultivating on planting season.
B2, B3	High production during the dry season.
C1	Only able to cultivate paddy twice a year with short-term paddy variety, and when the dry season quite short, it enough to cultivate other secondary crops.
C2, C3, C4	Only able to cultivate paddy once and other secondary crops twice a year
D1	Only able to cultivate paddy once a year, and other secondary crop cultivation must be careful to avoid cultivating on a dry month.
D2, D3, D4	Only able to cultivate paddy once a year and production usually high due to high radiation density. These types have sufficient cultivation time for secondary crops.
E	Only able to cultivate of paddy or other secondary crops once a year, depend on the availability of irrigation water

Source: Alfiandy et al (2021)

Table 4. Climate shifting in Bali province

Location	Sub District	1991-2000	2001-2010	2011-2020	Trend
Kampung Anyar	Buleleng	D4	E4	E4	Tended to be dry
Sinabun	Sawan	D3	D4	E4	Drier
Depeha	Kubutambahan	D3	D4	D4	Tended to be dry
Pejarakan	Gerokgak	E4	E4	E4	Constant
Sembiran	Tejakula	D3	D4	D4	Tended to be dry
Banjarasem	Seririt	E4	E4	D3	Tended to be wet
Wanagiri	Sukasada	C3	C3	C3	Constant
Melaya	Melaya	E3	D3	E3	Varied
Berangbang	Negara	C3	D3	D3	Tended to be dry
Munduk	Banjar	C3	C3	C3	Constant
Candikuning	Baturiti	B3	C3	C3	Tended to be dry
Kintamani	Kintamani	D3	D3	D4	Tended to be dry
Pohsanten	Mendoyo	C3	D3	C3	Varied
Sepang	Busungbiu	B3	B3	C3	Tended to be dry
Pelaga	Petang	C3	C3	C3	Constant
Tulamben	Kubu	D3	D3	D4	Tended to be dry
Batungsel	Pupuan	B3	C2	B2	Varied
Pupuan	Tegallalang	C3	C3	C3	Constant
Pengotan	Bangli	B3	C2	D2	Drier
Besakih	Rendang	B3	C2	D2	Drier
Buanagiri	Bebandem	C3	D2	D2	Tended to be dry
Mangesta	Penebel	B2	B2	C2	Tended to be dry
Tua	Marga	B3	B3	C2	Tended to be dry
Buahan	Payangan	B3	B3	C2	Tended to be dry
Manukaya	Susut	B3	C2	C2	Tended to be dry
Yangapi	Tembuku	B3	C2	C2	Tended to be dry
Ababi	Abang	D3	D3	D3	Constant
Seraya Timur	Karangasem	E4	E3	D4	Wetter
Gumbrih	Pekutatan	C3	C2	D2	Varied
Mundeh	Selemadeg Barat	C3	C2	C2	Tended to be wet
Petiga	Marga	B3	B2	C2	Varied
Tegalalang	Tampaksiring	C3	B2	C2	Varied
Duda	Selat	B3	B1	D2	Varied
Berembeng	Selemadeg	C3	C2	C2	Tended to be wet
Meliling	Kerambitan	C3	C2	C3	Varied
Selanbawak	Marga	C3	C2	C2	Tended to be wet
Taman	Abiansemal	B2	C2	C2	Tended to be dry
Aan	Banjarangkan	C3	D1	D2	Drier
Kerthabuana	Sidemen	D3	D1	D1	Tended to be wet
Manggis	Manggis	E4	E3	D3	Wetter
Tegalmengkeb	Selemadeg Timur	C3	D3	D3	Tended to be dry
Delod Peken	Tabanan	C3	C2	C2	Tended to be wet
Sedang	Abiansemal	D3	D2	D3	Varied
Mas	Ubud	D3	D2	D3	Varied
Gianyar	Gianyar	E3	D1	D2	Varied
Tusan	Klungkung	E3	D1	E2	Varied
Gunaksa	Dawan	E3	D2	E2	Varied
Buwit	Kediri	C3	D3	D2	Varied
Sempidi	Mengwi	D3	D3	D3	Constant
Peguyangan Kangin	Denpasar Utara	D3	D3	D3	Constant
Sukawati	Sukawati	E3	D3	D3	Tended to be wet
Parerenan	Kuta Utara	C3	D3	D2	Varied
Kerobokan Kaja	Denpasar Barat	D3	D3	D3	Constant
Sumerta Kaja	Denpasar Timur	E3	D3	D3	Tended to be wet
Seminyak	Kuta	C3	D3	D4	Drier
Sidakarya	Denpasar Selatan	D3	D3	D4	Tended to be dry
Toyapakeh	Nusa Penida	E4	D4	D4	Tended to be wet
Jimbaran	Kuta Selatan	C3	D4	D4	Tended to be dry

through analysis of dry and wet months.

The highest suitability class for paddy was S2 (24 locations) with 41.38% in percentage, corn (S1) in 30 locations (51.72%), soybean (S1) in 29 locations (50.00%), shallot (S1) in 39 locations (67.24%), and chili (S2) in 28 locations (48.28%). Plants cultivated in suitable climate and

land conditions able to produce optimally, conversely plants in unsuitable climate and land conditions had an impact on decreasing production (Nganji and Simanjuntak 2020). Plants cultivated on land that very suitable to climatic conditions expected to produce higher levels of productivity than those cultivated on land that is quite suitable or

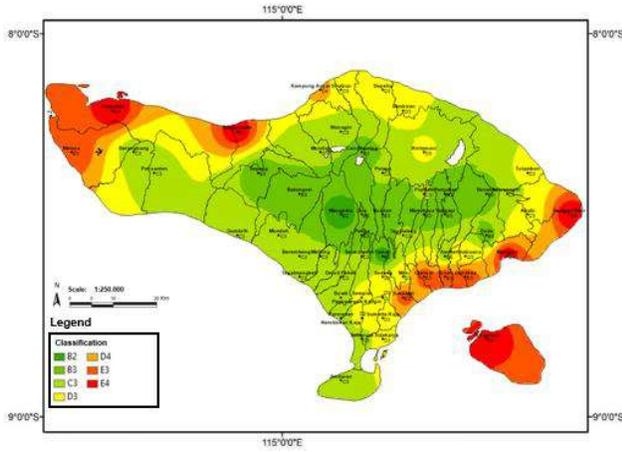


Fig.1. Agroclimatic Zone during 1991-2000

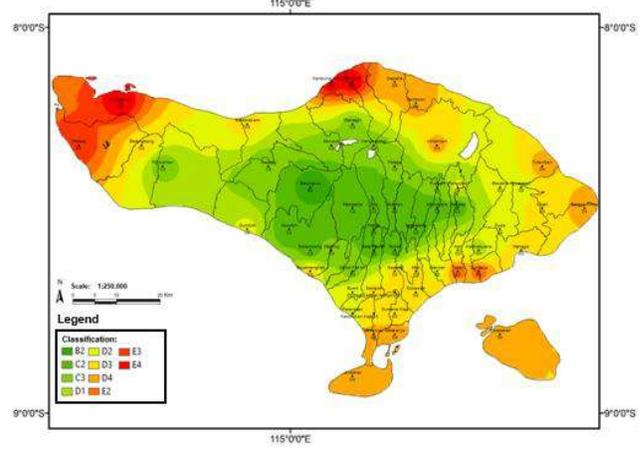


Fig. 3. Agroclimatic Zone during 2011-2020

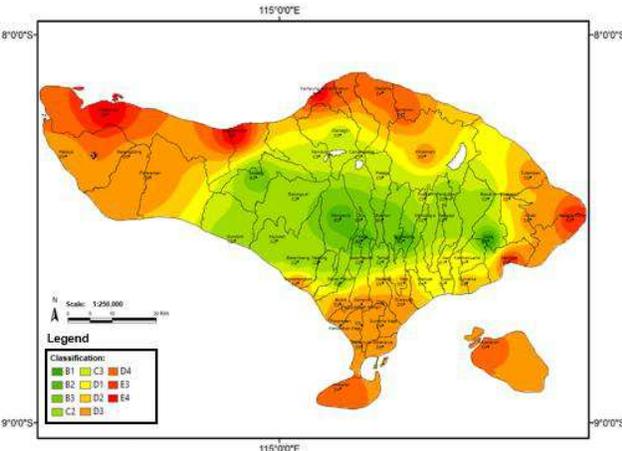


Fig. 2. Agroclimatic Zone during 2001-2010

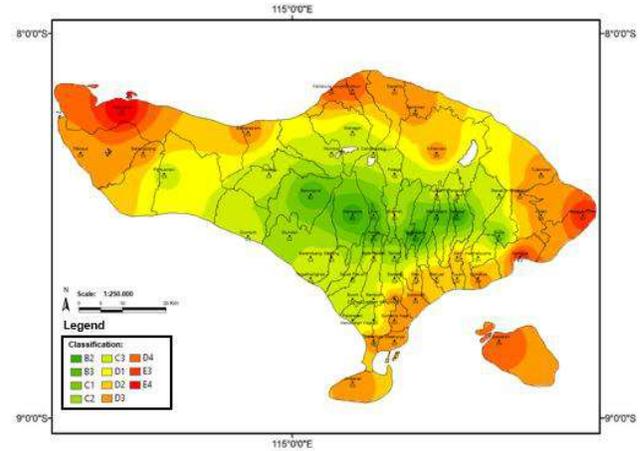


Fig. 4. Agroclimatic Zone during 1991-2020

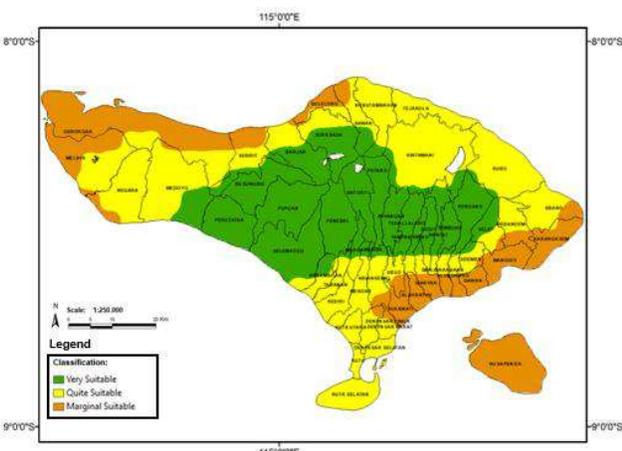


Fig. 5. Suitability for paddy

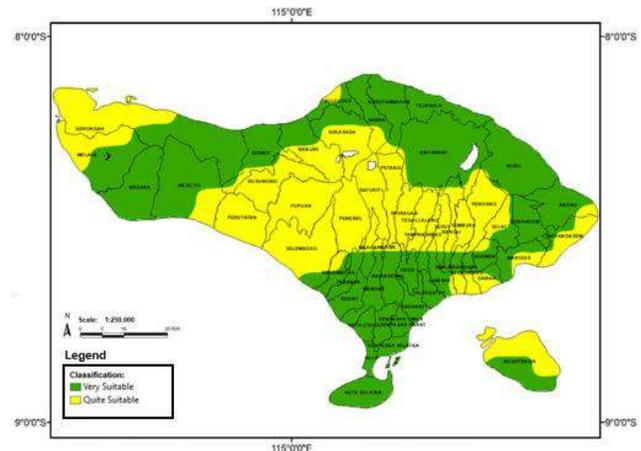


Fig. 6. Suitability for corn

Table 5. Recapitulation of agroclimatic land suitability for paddy, corn, soybean, shallot and chili

Grid/ Location	Sub district	Climate types	Land suitability				
			Paddy	Corn	Soybean	Shallot	Chili
Kampung Anyar	Buleleng	D4	S3	S2	S1	S2	S3
Sinabun	Sawan	D4	S3	S1	S1	S2	S2
Depeha	Kubutambahan	D3	S2	S1	S1	S2	S2
Pejarakan	Gerokgak	E4	S3	S2	S1	S2	S3
Sembiran	Tejakula	D3	S2	S1	S1	S2	S2
Banjarasem	Seririt	D3	S3	S1	S1	S2	S2
Wanagiri	Sukasada	C3	S1	S2	S2	S1	S1
Melaya	Melaya	D3	S3	S2	S1	S1	S3
Berangbang	Negara	D3	S2	S1	S1	S1	S2
Munduk	Banjar	C3	S1	S2	S2	S1	S1
Candikuning	Baturiti	C3	S1	S2	S2	S1	S1
Kintamani	Kintamani	D3	S2	S1	S1	S1	S2
Pohsanten	Mendoyo	C3	S2	S1	S2	S1	S1
Sepang	Busungbiu	C3	S1	S2	S2	S1	S1
Pelaga	Petang	C3	S1	S2	S2	S1	S1
Tulamben	Kubu	D3	S2	S1	S1	S1	S2
Batungsel	Pupuan	B3	S1	S2	S3	S1	S2
Pupuan	Tegalalang	C3	S1	S2	S2	S1	S1
Pengotan	Kintamani	C3	S1	S2	S2	S1	S1
Besakih	Rendang	C3	S1	S2	S2	S1	S1
Buanagiri	Bebandem	D3	S2	S1	S1	S1	S2
Mangesta	Penebel	B2	S1	S2	S3	S3	S2
Tua	Marga	B3	S1	S2	S3	S1	S2
Buahan	Petang	C3	S1	S2	S2	S1	S1
Manukaya	Susut	B3	S1	S2	S3	S1	S2
Yangapi	Tembuku	B2	S1	S2	S3	S3	S2
Ababi	Abang	D3	S2	S1	S1	S1	S2
Seraya Timur	Karangasem	E3	S3	S2	S1	S2	S3
Gumbrih	Pekutatan	C3	S1	S2	S2	S1	S1
Mundeh	Selemadeg Barat	C2	S1	S2	S2	S3	S1
Petiga	Marga	B3	S1	S2	S3	S1	S2
Tegalalang	Tampaksiring	B2	S1	S2	S3	S3	S2
Duda	Selat	C1	S2	S1	S2	N	S1
Berembeng	Selemadeg	C3	S1	S2	S2	S1	S1
Meliling	Kerambitan	C3	S1	S2	S2	S1	S1
Selanbawak	Marga	C3	S2	S1	S2	S1	S1
Taman	Abiansemal	C2	S2	S1	S2	S3	S1
Aan	Banjarangkan	D2	S2	S1	S1	S3	S2
Kerthabuana	Sidemen	D1	S2	S1	S1	N	S2
Manggis	Manggis	E3	S3	S2	S1	S1	S3
Tegalmengkeb	Selemadeg Timur	C3	S2	S1	S2	S1	S1
Delod Peken	Tabanan	C3	S2	S1	S2	S1	S1
Sedang	Abiansemal	C3	S2	S1	S1	S1	S2
Mas	Ubud	D2	S3	S1	S1	S3	S2
Gianyar	Gianyar	D2	S3	S1	S1	S3	S2
Tusan	Klungkung	D2	S3	S2	S1	S3	S3
Gunaksa	Dawan	D3	S3	S2	S1	S1	S3
Buwit	Kediri	C3	S2	S1	S2	S1	S1
Sempidi	Mengwi	C3	S2	S1	S2	S1	S1
Peguyangan Kangin	Denpasar Utara	D3	S3	S1	S1	S1	S2
Sukawati	Sukawati	D3	S3	S1	S1	S1	S2
Parerenan	Kuta Utara	C3	S2	S1	S2	S1	S1
Kerobokan Kaja	Denpasar Barat	C3	S2	S1	S1	S1	S2
Sumerta Kaja	Denpasar Timur	D3	S2	S1	S1	S1	S2
Seminyak	Kuta Utara	D3	S2	S1	S1	S1	S2
Sidakarya	Denpasar Selatan	D3	S2	S1	S1	S1	S2
Toyapakeh	Nusa Penida	D4	S3	S2	S1	S2	S3
Jimbaran	Kuta Selatan	D3	S2	S1	S1	S1	S2

marginally suitable. The next stage is to create land suitability class map for these commodities.

The suitability class for paddy ranged between very suitable to marginally suitable. Land with very suitable classes located in the central part has higher precipitation

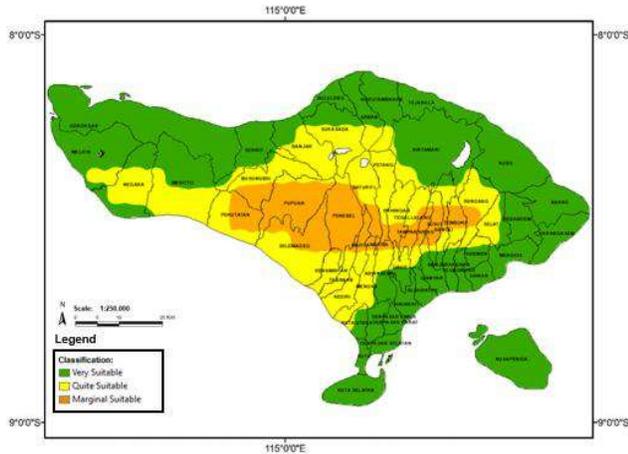


Fig. 7. Suitability for soybean

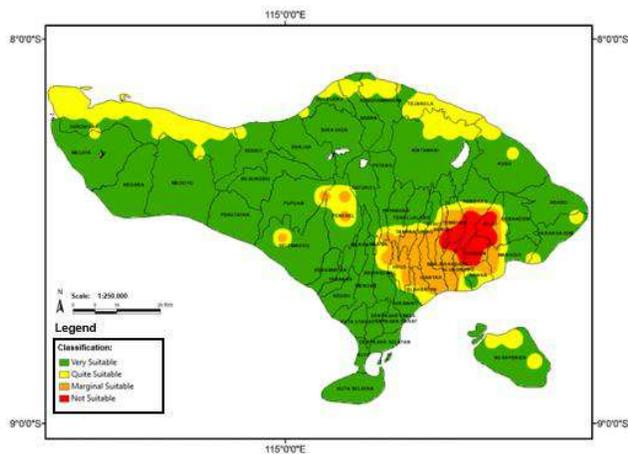


Fig. 8. Suitability for shallot

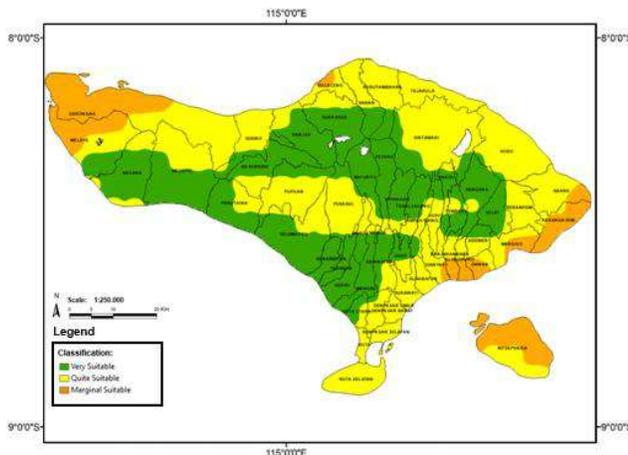


Fig. 9. Suitability for chili

because it is influenced by orographic rain. Meanwhile in western and southeast parts considered as areas of less in wet months. Land suitability classification for corn commodities is very suitable or have a number of wet months in a row between 3-5 months per year covering the outermost land except the western, central and eastern tip and the southern Nusa Penida.

Soybean can be well cultivated in areas of D1 – D4 in types, and at 0-500 meters of altitude above mean sea level. Areas with suitability class S1 distributed in outermost area except the southwest and central parts. By knowing this map, farmers will be able to plan the way to increase soybean production again in areas of S1 and S2 suitability classes.

Suitability for shallot ranges from very suitable to not suitable. Some areas that are not suitable for shallot cultivation because the number of dry months less than two months and have Oldeman's climate types other than C1 – C4. Suitability for chili ranges from very suitable to marginally suitable. It is hoped that these maps will help farmers in Bali to determine the precious time to start cultivating. Bali has experienced a decline in chili production over the last three years (2022-2024). By knowing above suitability map, it will help farmers to increase production of chili production again.

CONCLUSION

Central part of Bali considered as areas with more wet months, while the outermost parts except the southwest tend to have fewer wet months. This condition causes agricultural commodities that depend on wet months to be more suitable if cultivated there, taking into account the suitability of crops for height. The climate types shifting during 1991-2020 period showed that 49 (84.48%) locations experienced shifting, while 9 (15.52%) other locations did not experience shifting or remained the same. Research using longer data such as 30-year data able to provide a more complete picture of shift patterns than shorter data such as 10-year data. The author suggests climate types of 1991-2020 period to be used in agricultural planning.

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