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To cite this article: P Sarjana *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **724** 012076

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Effects of climate change on the vulnerability of cocoa production in Medewi, Bali Indonesia

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Abstract. A survey of the effects of climate change on the vulnerability of cocoa production has been conducted in Medewi Village, Jembrana Regency, Bali Island. Unfortunately, the international standard requirements have not been met. The survey started during the La-Nina phenomenon from April to October 2015 in wet conditions. This study aims to determine the impact of climate change on cocoa production and farmers' perspectives on the level of vulnerability and their responses. The research methodology used a simple randomized sample survey in which 20 percent of a sample of cocoa farmers were interviewed. The results showed a decrease in cocoa production during the La-Nina period, respectively 10 - 90%, 10 -70% in Baler Setra, Delod Bale Agung, and Pangkung Selepe hamlets. Another problem is that 52% of trees died and the remaining 48% were dormant. Efforts to minimize dead trees were carried out by cutting down vegetative branches, irrigating, and watering, namely 75% of each farmer in 3 areas Baler Setra, Delod Bale Agung 11%, and Pangkung Selepe Hamlet 9%. Overall, it can be concluded that La-Nina affects the growth and the development of cocoa plantation vegetatively rather than generatively. Therefore, cocoa produces more leaves and branches rather than fruit or seeds.

1. Introduction

Climate change making it difficult to establish new cocoa farms, impacting soil health and fertility, rapid depletion of forest vegetation. Reduced rainfall and increased temperatures, leading to a prolonged period of drought, lead to a reduction in soil moisture during the dry season and a decrease in soil fertility [1]. It has been widely reported that climate change also plays a major role in changing the development of pests and pathogens of cocoa and changes their interactions [2]. Also, it was reported by Mpako and Ngome [3] that some years bring sufficient rainfall but most people fail to maximize the opportunity due to confusion of rainfall patterns. Enete and Amusa [4] reported that climate change is one of the most serious environmental threats facing mankind worldwide. This affects agriculture in several ways, including their direct impact on food production caused by natural climate cycles and human activities which have adversely affected agricultural production in Africa [5]. Climate change is projected to have serious environmental, economic, and social impacts, particularly on rural farmers whose livelihoods depend heavily on rainfall. The magnitude of this impact depends largely on awareness and the degree of adaptation in response to climate change [1]



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Medewi village is one good example farming area in Jembrana Regency, Bali Province. Medewi has been known as a cocoa plantation area for a long time. However, cocoa farmers in this area have problems during post-harvest when the production is abundant and prices fall, causing farmers to lose a lot of money. So, postharvest technology and cocoa processing technology need to be provided. The effects of climate change also affect production. During the short rainy season, the air temperature is relatively high, and this low humidity condition greatly affects cocoa production in the Medewi area. Cocoa farming training as a whole including post-harvest needs to be provided to cocoa plantation farmers in this area.

It is greatly necessary to identify and process climate change data for cocoa production in Medewi Village. This is because research on vulnerability and development of cocoa production capacity in the face of climate change in the Medewi, Jembrana Regency needs to be done. It is suggested to identify the main causes of the decline in the number of cocoa farmers in Medewi and process the data on climate change for cocoa production while assessing the vulnerability of cocoa production to climate change. In addition, farmers are also invited to handle pre and post-harvest cocoa, especially during extreme climates such as summer or prolonged rainy season, due to climate change as one of the main factors affecting cocoa production.

2. Research methods

This research was conducted in Medewi Village, Mendoyo District, Jembrana Regency, Bali Province. The research location is at coordinates 8.398999 °S 114.817390 ° E Longitude. Conducted from May to October 2016, the survey was carried out in Medewi Village in 3 areas namely Baler Setra, Delod Bale Agung, and Pangkung Selepa Hamlet, which consist of 2 farmer groups such as *Subak* Merta Masa and *Subak* Taman Sari. *Subak* is a traditional irrigation organization system, representation of agriculture in Bali Island.

The methodology used was a simple randomized sample survey in which 20 percent of a sample of cocoa farmers were interviewed. The survey was conducted by preparing a special questionnaire in advance to determine the vulnerability of cocoa production to climate change [5]. The survey was conducted with the following details: 1) to determine the causes of the decline in the number of cocoa farmers in Medewi Village. 2) identify and process the climate change data of cocoa production in Medewi Village and measure the temperature, humidity, and rainfall; 3) Test the vulnerability of cocoa production facing climate change.

3. Results

3.1. Topography of cocoa plantation land at Medewi Village

Data on the topography of the garden land, the cocoa plantation business and the reasons why working on cocoa plantations as presented in Table 1.

Tabel 1. Land situation, length of the plantation, and reasons for cocoa gardening in Medewi Village.

Subaks	Banjar	Respondent	Soil contours			Cocoa growing year		Reasons for cocoa plantation		
			Flat	A bit steep	Very steep	1971–1990	1991–2010	High cocoa prices	Cocoa resistant to dry conditions	Other support (government, NGOs, friends, etc.)
Merta Masa	Baler Setra	26	5	21	-	-	26	16	8	2
	Delod Bale Agung	12	1	11	-	1	11	5	4	3
	Pangkung Selepa	6	5		1	1	5	1	3	2

Nearly 100% of the land is in a rather steep area. Only one farmer works in Pangkung Selepa Hamlet which is very steep. Table 1 showed that the local farmers are quite familiar with this less productive land for plantations since flat areas are reserved for rice fields. Most of the farmers have been farming cocoa from 1991 until 2020 (approximately 29 years ago), namely 25 out of 26 farmers, 11 out of 12 farmers, and 5 out of 6 farmers in Baler Setra, Delod Bale Agung, and Pangkung Selepa Hamlet, respectively. The reason why farmers decided to plant cocoa crops is that the price of cocoa beans is quite high compared to other commodities. Also, the cocoa plant is very resistant to a dry environment. In addition, the farmers argued that they were invited by friends and influenced by local NGOs. Data on the number of trees, the origin of seedlings, and the situation for planting cocoa are presented in Table 2.

3.2. Number of trees, the origin of seedlings, and the situation of cocoa plants

Data on the varieties and resistance of cocoa plants to climate are presented in Table 3. Table 3 showed that the cocoa varieties cultivated by farmers in Medewi Village are local varieties. Apart from being productive, local varieties are also resistant to dry climates. Besides, cocoa plants can adapt to the climate in Medewi Village. So, the local varieties of cocoa are more valued by the farmers as the main reason for using them.

Table 2. Number of trees, the origin of seedlings, and the situation of cocoa plants.

Subaks	Banjar (Hamlet)	Respondent	Numbers of tree		Origin of cocoa seedlings			Bear fruit (2016)		Old bear fruit (year)			
			20–260	261–500	Government's	Own production	Others	Yes	Not yet	0–1	1–2	2–3	>3
Merta Masa	Baler Setra	26	23	3	3	21	2	26	-	-	2	9	15
	Delod Bale Agung	12	12	-	3	7	2	12	-	-	3	4	5
Taman Sari	Pangkung Selepa	6	5	-	3	1	2	6	-	-	-	5	1

Table 3. Varieties and resistance to the climate of cocoa plants.

Subaks	Banjar	Respondent	Cocoa varieties		Cocoa varieties more productive					The driest climate-resistant of cocoa varieties		The most vulnerable cocoa varieties in dry climate		
			Loc	Sul 1	Loc	Sul 1	JBR 2	M45	Un	Loc	Un	Loc	Sul 1	Un
Merta Masa	Baler Setra	26	26	-	4	4	1	7	9	15	11	4	1	21
	Delod Bale Agung	12	11	1	4	1	-	5	5	8	4	4	1	7
Taman Sari	Pangkung Selepa	6	6	-	3	-	1	-	2	2	4	1	-	5

Note. Loc: local, Sul 1: Sulawesi 1 and Un: unknown.

3.3. Productivity and production quality

Data on cocoa production and marketing is presented in Table 4. Table 4 showed that the wet cocoa beans become the dominant product produced by cocoa farmers in Medewi Village which can be seen from all respondents' responses. Some farmers process more cocoa pods into dry cocoa beans without fermentation. Almost 100% of cocoa farmers sell their products to brokers which represents another problem for the farmers.

Table 4. Cocoa production and marketing.

Subaks	Banjar (Hamlet)	Respondent	Wet cocoa beans sales last year					Sales of dried cocoa beans without fermentation last year					Sales of fermented dried cocoa beans last year			
			Amount (kg/year)		Marketing			Amount (kg/year)		Marketing			Amount (kg/year)		Marketing	
			A	B	Coop.	Brokers	SS	C	D	Coop.	Brokers	SS	20–50	Coop.	Brokers	SS
Merta Masa	Baler Setra	26	18	8	1	25	-	9	1	-	10	-	-	-	-	-
	Delod Bale Agung	12	10	2	-	12	-	6	1	-	7	-	2	-	2	-
Taman Sari	Pangkung Selepa	6	5	1	-	6	-	1	-	-	1	-	1	-	1	-

Note. A: 20–350, B: 351–700, C: 20–300, D: 301–600, Coop.: Cooperative and SS: sales station.

3.4. Comparison of normal weather cocoa bean production with cocoa bean production in 2016

Data on the comparison of normal weather cocoa bean production with cocoa bean production in 2016 are presented in Table 5. Table 5 showed that cocoa production appears to be in decline. This can be seen from the scale of wet seeds in 2015 which ranged from 50 to 1000 kg which did not reach the same achievement as in 2016 which ranged from 60 kg to 600 kg. This is likely due to uncertain weather, long droughts, and long rainy seasons.

Table 5. Comparison of normal weather cocoa bean production with cocoa beans production 2016.

Subaks	Banjar (Hamlet)	Respondents	Normal weather cocoa bean production (kg/year)					Cocoa bean production in 2016 (kg/year)			
			Wet bean		Dry bean without fermentation		Fermented dry bean	Wet bean		Dry bean without fermentation	Fermented dry bean
			50–500	501–1000	30–300	301–600	50	50–300	301–600	240	
Merta	Baler Setra	26	19	5	1	1	-	20	6	-	-
Masa	Delod Bale Agung	12	10	1	-	1	-	10	1	1	-
Taman Sari	Pangkung Selepa	6	6	-	-	-	-	4	2	-	-

3.5. Problems and solutions after a failed harvest

Based on Table 6, the problem in the cocoa plant was 77% caused by pests and diseases while 23% was caused by the weather. The problem caused 86% of failed harvest, while the probability of harvest success was only 14%. The solutions or efforts made by cocoa farmers in Medewi village were 63% cleaned the cocoa trees area, 29% of farmers re-cultivate cocoa trees, 5% of farmers just let it, and 3% for other reasons. Most of the failed harvests were due to diseases and pests which required further handling of diseases and pests to reduce or thwart crop failure.

Table 6. Problems and solutions or efforts made after a failed harvest.

Subaks	Banjar (Hamlet)	Respondent	Cocoa problems							Efforts after failed harvest			
			Obstacles			Failed harvest		Failed harvest (year)					
			Pests and diseases	Climate	Others	Yes	No	2000–2008	2009–2016	Cleaned	Fert.	Left	Others
Merta Masa	Baler Setra	26	20	6	-	23	3	3	20	16	5	1	1
	Delod Bale Agung	12	9	3	-	9	3	-	6	5	3	1	-
Taman Sari	Pangkung Selepa	6	5	1	-	6	-	-	6	3	3	-	-

Note. Fert.: fertilized.

3.6. The effect of the long dry season on cocoa productivity and survival of cocoa plants

The effect of the long dry season on cocoa productivity and survival of cocoa plants is presented in Table 7. Based on Table 7, there was a decrease of cocoa productivity of 50% which is 48%; the decrease in productivity was at least 4.5% in 10%, and the productivity increased only 4.5%. The long drought led to the death of cocoa trees by 2-25 cocoa trees by 63%, cocoa tree deaths 26 - 50 by 7%, while surviving cocoa trees by 30%.

Table 7. The effect of the long dry season on cocoa productivity and the survival of cocoa crops.

Subaks	Banjar (Hamlet)	Respondent	Cocoa productivity							Death of the cocoa plant		
			Decrease					Increase	Unknown	Yes		No
			10%	30%	50%	70%	90%			2 - 25	26 - 50	
Merta Masa	Baler Setra	26	-	5	14	4	3	-	-	15	3	8
	Delod Bale Agung	12	1	3	5	2	-	1	-	10	-	2
Taman Sari	Pangkung Selepa	6	1	-	2	2	-	1	-	3	-	3

3.7. The effect of the long rainy season on cocoa productivity and the survival of cocoa plants

The effect of the long rainy season on cocoa productivity and the survival of cocoa plants is presented in Table 8. While the long rainy season causes the death of cocoa trees by 52%, only 48% were able to survive.

Table 8. Effect of the long rainy season on cocoa productivity and cocoa plant survival

Subaks	Banjar (Hamlet)	Respondent	Cocoa productivity							Death of the cocoa plant	
			Decrease					Increase	Unknown	Yes 3 - 20	No
			10%	30%	50%	70%	90%				
Merta Masa	Baler Setra	26	4	5	1	0	5	1	1	13	13
	Delod Bale Agung	12	2	2	6	2	-	-	-	7	5
Taman Sari	Pangkung Selepa	6	-	-	2	3	-	1	-	3	3

3.8. Action to handle climate change

Measures to handle climate change and the source of information from such actions is presented in Table 9. Based on Table 9, farmers' have a strategy to handle climate change was 75% pruning cocoa trees, 11% irrigation, 9% watering, and others around 5%. The most action information was obtained from the counselor by 55%, from *Subak* by 32%, from others by 11%, and the least information from the cooperative by 2%.

Table 9. Measures to handle climate change and sources of information.

Subaks	Banjar (Hamlet)	Respondent	Irrigation	Watering	Pruning	Others	Sources of information			
							Cooperative	Counselors	<i>Subak</i>	Others
Merta Masa	Baler Setra	26	4	2	18	2	1	13	9	3
	Delod Bale Agung	12	-	1	11	-	-	8	4	-
Taman Sari	Pangkung Selepa	6	1	1	4	-	-	3	1	2

4. Discussion

In Indonesia, cocoa production provides the main source of income for millions of smallholder farmers and their families [6]. Farmers in Medewi Village decided to plant cacao crops because the

price of cocoa beans is quite high when compared to other commodities. The cacao varieties cultivated by farmers in Medewi Village are local varieties. This variety is more productive and also resistant to dry climates. According to Nyasse *et al.* [7], a good source of resistance to black pods was identified in several local clones. Therefore, they have been selected as parent clones of the varieties proposed for the creation of regional varieties trials in African producing countries. In the opinion of farmers, local varieties from the West African Amelonado population are more resistant to *Phytophthora* pod rot than Amazon cacao, although the latter is relatively higher-yielding [8].

Most farmers process cocoa pods into dry cocoa beans without fermentation. This is because the price of fermented cocoa beans is the same as unfermented cocoa beans. Veronice [9] reported that the application of this technology is difficult to develop because of the similarity in prices among farmers who use the technology to non-fermented cocoa beans. The classic problem above is in stark contrast to the positive attitude of farmers who tend to (accept) this technology so that farmers accept the uncertainty of steps taken by related parties. Almost all cocoa farmers in the village sell their products to brokers which is another problem for farmers.

Climate gradient has a significant effect on cocoa production; productivity tends to decrease due to long dry season causing insufficient water supply, or vice versa; the prolonged rainy season is prone to pests and diseases [10]. To the reduction of long solar radiation in the dry season is necessary such as canopy, especially in the growth phase there is a kind of shady tree used in cocoa agroforestry systems [10]. Climate change in agricultural systems often impacts the vegetative and generative phases of cocoa trees. That despite the change of climate is a very big challenge but the social and environmental problems still exist [11].

5. Conclusion

Based on the survey data, it can be concluded that the decline in cocoa production during the La-Nina period was 10-90%, 10-70%, and 50-70% in Baler Setra, Delod Bale Agung, and Pangkung Slepé hamlets, respectively. Farmers' efforts to minimize dead trees were carried out by cutting down vegetative twigs, irrigating and watering. Overall, it can be concluded that La-Nina affects the growth and development of cocoa plants vegetatively rather than reproductively. Therefore, cocoa produces more leaves and branches compared to beans.

Acknowledgments

The authors would like to express their gratefulness toward the Directorate General of Higher Education (DGHE) Republic of Indonesia and the Institute of Research and Community Service, Udayana University, Indonesia (Udayana Research Grant) for their financial support and facility.

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