



Local Adaptation to Extreme Weather and It's Implication on Sustainable Rice Production in Lampung, Indonesia

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ABSTRACT

Extreme weather incidents refer to high rainfall and strong winds have been speculated to be detrimental on rice production. However, researches on the local adaptation to their impact on rice production are limited especially on tropical region like Indonesia. A study was conducted in Pesawaran, West Lampung, North Lampung, and Bandar Lampung using time series data of 2000-2015 and ground checking during extreme weather and normal seasons and its implication on sustainable management. Data were evaluated using multivariate regressions. Results demonstrated that the impact of extreme weather on the reduction of rice production was weak, 0.92%. Shifting on rice production among swampy, irrigated, and dry lands at which covered area of 13.67%, 42.69% and 43.65%, respectively, minimized the impact of the extreme weather. During limited precipitation, irrigated and swamplands had 2.5-3.0 times cropping intensity. Conversely, during La-Nina with excess precipitation, cropping in irrigated and drylands increased by 20 and 58%, respectively. Moreover, the local government maintained annual production improvement by about 5% through expansion of irrigated land, high yielding varieties and inputs subsidies. Considering that incident of extreme weathers tended to occur more frequently, consequently, planting calendar utilization and rice variety adapted should be implemented.

INTRODUCTION

Rice is an important staple food and its cultivation becomes an important source of local income for many countries (Pandey, Wang, & Bhandari, 2012; Shean, 2012). Indonesia ranks at the third as the main rice producers in the world (www.worldriceproduction.com), and contributes more than 350 trillion rupiah or equal to US\$ 269 billion annually. However, the sustainability of rice production in Indonesia is threatened by the incidence of extreme weather. Climatic factors determine rice production (Dulbari, Santosa, Koesmaryono, &

Sulistyono, 2018).

Extreme weathers like high rainfall and strong winds, may be advantageous to some perennials (Rafati, Hajmohamadi, & Hajmohamadi, 2014); however, they may be disastrous to most annual plants (Gbegbelegbe, Chung, Shiferaw, Msangi, & Tesfaye, 2014; Lesk, Rowhani, & Ramankutty, 2016; Powell & Reinhard, 2016; Subash, Singh, & Priya, 2011; Wassmann et al., 2010). Ray, Ramankutty, Mueller, West, & Foley (2012) predicted that extreme weather decreases the global food crops field by more than 30%. Rice economic losses due

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to extreme weather in Indonesia was approximately 15 trillion rupiah annually. Excess precipitation and strong wind cause water lodging and submerge conditions. Water lodging has reported to have impact on photosynthesis, water and nutrient transports, and other physiological processes within the plants. Rice production and its quality usually low after the impact of the extreme weather (Dulbari, Santosa, Sulistyono, et al., 2018; Salassi et al., 2013). Therefore, assessment of extreme weather incidences and how local farmers response sustainable issues on rice production is urgent to be studied.

Local adaptation to climate change is mainly employed based on technology and policy approaches (Olhoff, 2015). In the context of technology, many plant breeders have developed adaptive rice varieties to address particular issues on climate change such as tolerant to high temperature, drought and flood, lodging, and utilization of Si (Timotiwi & Dewi, 2014). The implementation of such technologies, however, should be supported by sufficient information related to the potential impact of extreme weather on the targeted sites (Powell & Reinhard, 2016). These comprehensive studies on the implementation of local adaptation to climate change in the field are still limited in Indonesia.

The detrimental impact of extreme weather on crop production and its productivity depends on collective and individual farmers (Felkner, Tazhibayeva, & Townsend, 2009), localities (Powell & Reinhard, 2016) and agroecology. In Indonesia, rice fields distribute across from humid bioregion such as in Java and Sumatera to dry bioregion such as in Nusa Tenggara islands. Indonesia has 342 season zones (Ardhitama & Sholihah, 2014); hence, the impact of the extreme weather incidence could vary among the zones.

The extreme weather represented as excess precipitation and strong wind was studied in Lampung Province. Lampung is situated at the proximal Sumatera island that has experienced land-use changes. Hence, extreme weather incident in Lampung is expected to cause a unique impacts on local rice production. The objective of the study was to assess the incidence of extreme weather and its relationship to the dynamics of long-term rice production. Factors affecting the stability of production and its implications for sustainable rice production management especially during the La-Nina incident are analysed and described.

MATERIALS AND METHODS

Characteristic of the Studied Sites

The research was conducted at four districts in Lampung province, i.e. Lampung Utara, Lampung Selatan, Bandar Lampung, and Pesawaran. The locations were furtherly verified through ground checking. Field observations were conducted on October 2015-January 2017. In each district, one village within a subdistrict was selected based on verification as the main rice production. In each village, ten farmers were selected as respondents regarding cultivation techniques and their response to extreme weather issues.

Cropping calendar was obtained from the Indonesian Agency for Agricultural Research and Development Ministry of Agriculture while, rice production and maps were obtained from the Statistical Bureau of Lampung Province. Data of extreme weather incidence were obtained from the National Bureau for Disaster Management, and La-Nina, El-Nino and normal seasons were determined. Extreme weather was considered from precipitation 100 mm/day or more and wind velocity 30 km/h or more. Climatic data for 15 years (2000–2015) were obtained from four weather stations, i.e. Meteorological Station Raden Inten II Branti-Lampung Selatan (5°14'34"S, 105°10'33" E), Geophysical Station Kotabumi-Lampung Utara (4°50'10" S, 104°52'12" E), Maritime Station-Bandar Lampung (5°27'20" S, 105°18'38" E), and Climatology Station Masgar-Pesawaran (5°10'20"S, 105°10'50" E) (Fig. 1).

Model and Data Analysis

Correlation evaluation was conducted between rice production and extreme weather incidences. The rice production model was developed using multiple regression approach consist eight variables, i.e. rice field area (LBS), harvested area (LP), productivity (PDV), fertilizer subsidy (SUBP), agricultural mechanization (MK), pump subsidy (PO), rice milling units (RMU) and irrigation channels (SI).

Multiple regression model was developed by assuming dependent variable of production (yield, Y) was influenced by independent variables (X1, X2,..., Xp) followed the equation:

$$Y = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_p X_{pi} + \epsilon_i \dots\dots\dots 1)$$

Where: Y = rice production, β_0 = constant value of the response variable when the predictor variable met zero, β_{1-p} = constant value, X_{1-pi} = predictor variable and ϵ = error.

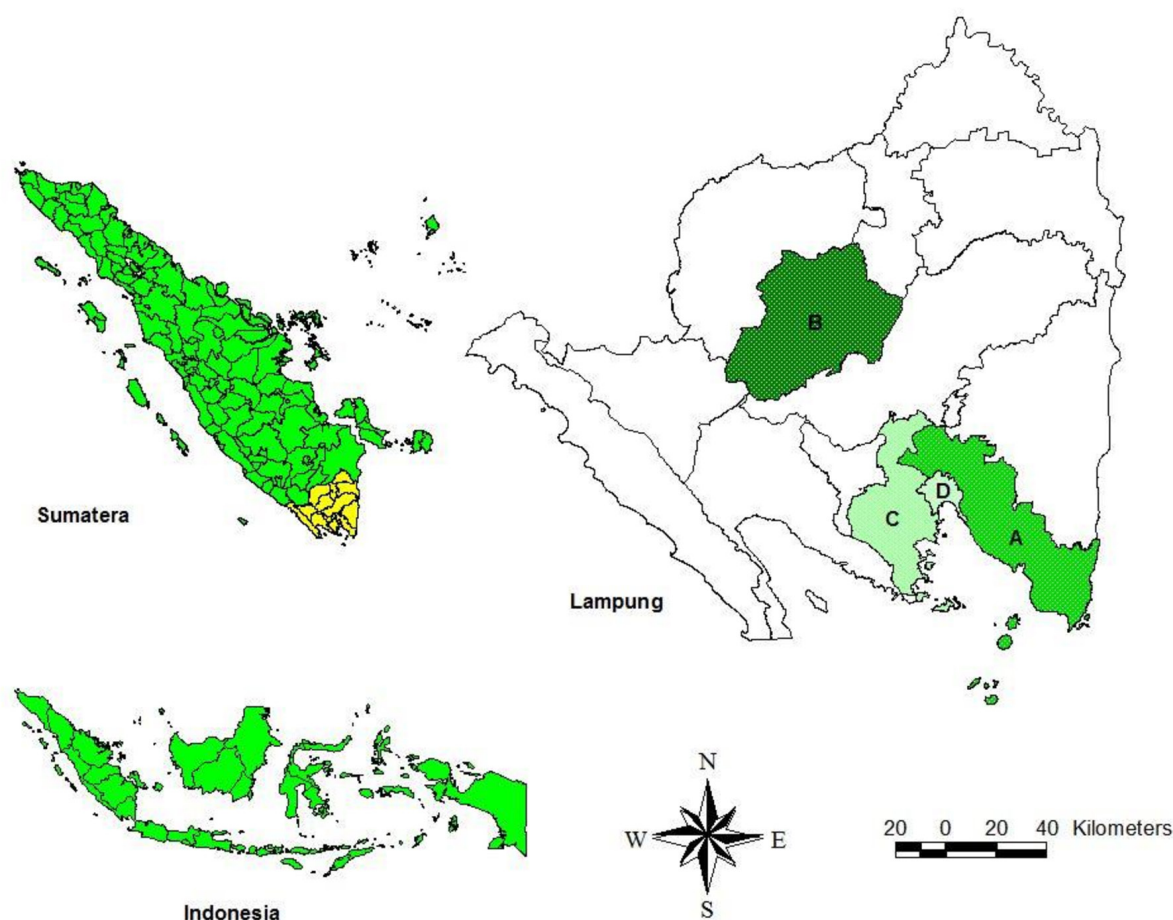


Fig. 1. Site of study in Lampung Province, Indonesia. A: Lampung Selatan District, B: Lampung Utara District, C: Pesawaran District, D: Bandar Lampung City District. Filled dots indicate the location of weather station.

The model of extreme weather correlation was developed based on precipitation (R) and temperature (T) and was associated with rice production (Y). Precipitation data were evaluated based on annual monthly and daily patterns. The trend in extreme weather incident and its impact on rice production were predicted spatially and temporally, by incorporating temperature, air relative humidity, irradiation, and precipitation. The map was drawn using ArcView GIS 3.3 program.

RESULTS AND DISCUSSION

Extreme Weather Incident, Precipitation and Climatic Zones

Excess precipitation and strong wind incidents due to La-Nina were recorded in 12 out of 15 districts in Lampung Province (Table 1). Data on precipitation indicated that Lampung province was

affected by El-Nino and La-Nina frequently. During 2000-2015, La Nina hit five times (2000, 2007, 2008, 2010 and 2011), while El-Nino hit six times (2002, 2004, 2006, 2009, 2010 and 2015). Most farmers were not familiar with both terminologies, however, they notified La-Nina as a high rainfall in the dry season (locally known as moist dry season), and El-Nino as an extended dry season for 4 or more months from commonly 2-3 months.

Farmers claimed that the extreme weather caused water lodging and submerge condition on 5-100% rice field. In a farmer group, the group members that were affected by the extreme weather reached 10-27% (3-8 person from 20-40 members). On average, the extreme weather affected a total area of 7,314.18 ha or 1.03% of the total area with yield loss up to 0.92% or equal to 33,594.62 ton.

Tabel 1. Extreme weather incident and simulation of it impact on loss rice production in Lampung Province for 2015

District	CE	ICE	LP (ha)	PROD (ton)	LAT (ha)	KHCE	KH (ton)
Lampung Barat	11	0.13	23,858	112,074.64	316.19	0.087	1,305.60
Tanggamus	5	0.06	52,335	291,708.39	315.27	0.087	1,544.65
Lampung Selatan	26	0.31	96,356	512,843.74	3,018.38	0.087	14,121.12
Lampung Timur	6	0.07	112,750	573,887.78	815.05	0.087	3,646.61
Lampung Tengah	9	0.11	153,127	828,487.24	1,660.41	0.087	7,896.58
Lampung Utara	6	0.07	39,619	188,766.72	268.40	0.087	1,199.46
Way Kanan	6	0.07	37,817	165,693.64	273.38	0.087	1,052.85
Tulang Bawang	1	0.01	50,108	242,874.92	60.37	0.087	257.21
Pesawaran	3	0.04	32,864	177,140.15	118.79	0.087	562.79
Pringsewu	4	0.05	23,631	137,244.83	113.88	0.087	581.39
Mesuji*	-	0.01	40,359	189,461.62	48.63	0.087	200.65
Tulang Bawang Barat*	-	0.01	18,747	90,171.05	22.59	0.087	95.46
Pesisir Barat*	-	0.13	18,341	87,122.62	243.07	0.087	1,014.93
Bandar Lampung	4	0.05	1,678	10,007.86	8.09	0.087	42.39
Metro	2	0.02	5,676	34,409.86	13.68	0.087	72.88
Total (average)	83			3,641,895.05	7,314.18		33,594.62

Remarks: CE = extreme weather events, ICE = extreme weather index, LP = harvested area, PROD = annual production, LAT = wide affected area, KHEC = coefficient of yield loss due to extreme weather, KH = loss results, * = ICE was incorporated in old districts before split as a new district.

Annually, extreme weather hit 1-17 times (average 5.19 times) across the province, and there was a tendency that the number of incidences increased since 2005. Among the districts, Lampung Selatan and Lampung Barat had the highest incidences, i.e. 26 and 10 times, respectively; followed by Lampung Tengah 9 times and Lampung Timur 6 times. In 2010, extreme weather hit 5 times in Lampung Barat. Four times extreme weather incidents in 2010 of Lampung Tengah were interesting because the incident was at a normal season. This indicated that local weather incident was important to cause damage on the rice field.

Spatial distribution of the weather indicated that the Lampung Selatan district was most prone for the incidence of extreme weather compared to the other districts. Rice fields at the heart of Lampung e.g. Lampung Selatan, Lampung Tengah, and Lampung Barat seemed more vulnerable to extreme weather than those districts at peripheral area such as Tulang bawang, Mesuji, and Pesisir Barat. Probably, the presence of Bukit Barisan mountainous chains in the western part of the province provides significant barrier for Pesisir

Barat from extreme weather.

Fig. 2 showed that precipitation fluctuates annually, monthly and daily patterns which was also dynamic over spatial level. Lampung province had low annual precipitation of 1988.84 ± 203.63 mm, with the lowest value was recorded in the Maritime Station (1822.57 mm) and the highest value at the Kotabumi Station (2284.76 mm). However, each region has an incidence of extreme rainfall annually, monthly and daily as well. During 15 years, there were nine years with excess precipitation at the Kotabumi Station, three years at each the Maritime Station and the Masgar Station and two years at the Branti Station. Unexpectedly only in 2010, excess precipitation occurred at all stations.

Monthly precipitation showed U-shape monsoon distribution with one peak at the rainy season within a year in all study sites (Fig. 2B). Wet months with rainfall intensity of 240.9-383.6 mm generally occurred in December-March. Precipitation decreased in April-July, and the lowest precipitation was in August-September. Thereafter, the precipitation gradually increased from October to December.

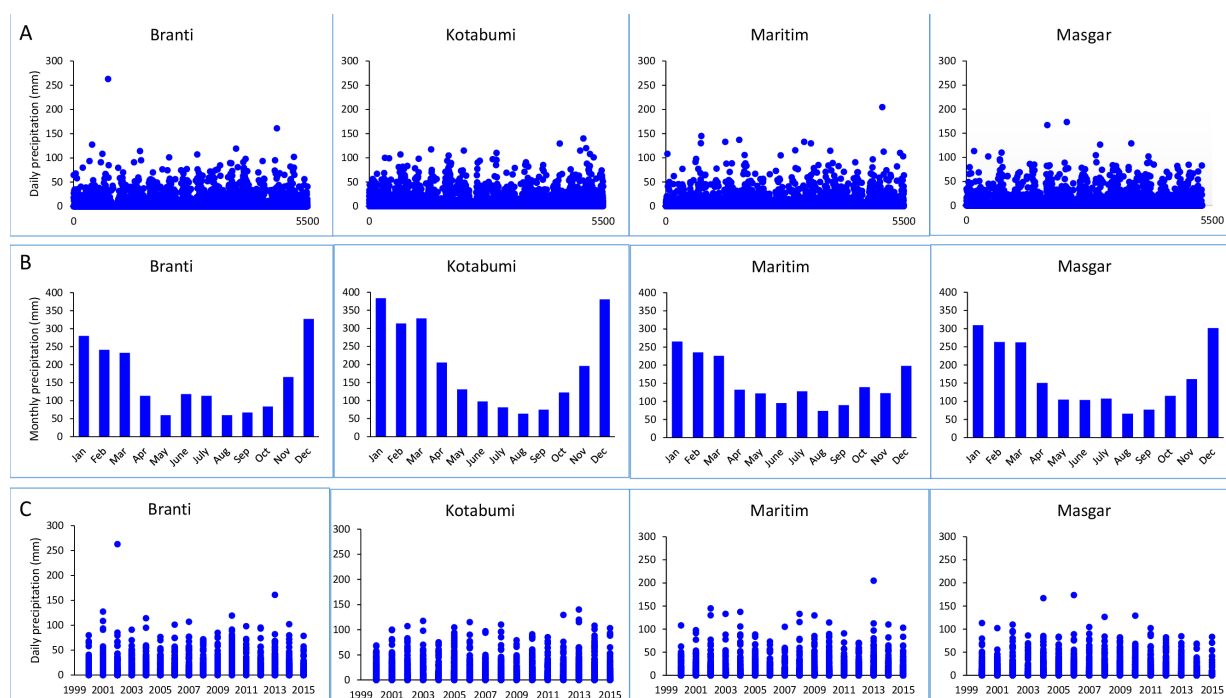


Fig. 2. Precipitation distribution in Lampung in 2000–2015 from each weather station. A: Daily precipitation; B: Average monthly precipitation; C: Annual precipitation.

Several days within a year exhibited excess precipitation across weather stations (Fig. 2C). Pooled analysis of four weather stations showed there was a repetition of extreme rainfall event at every 485 ± 84 days. At Branti Station had 9 days with excess precipitation, i.e. at 436, 676, 809, 1561, 2248, 2909, 3820, 4782, and 5183 days after the first incident; with the highest intensity of daily precipitation was 263 mm on March 19, 2002. Kotabumi Station recorded 12 days with the highest precipitation intensity was 140 mm on October 13, 2013. Maritime Station had 15 days with the highest intensity on September 8, 2013 and Masgar Station had 9 days with the highest intensity on February 25, 2006, with precipitation was at a rate of 204.9 and 173.5 mm, respectively.

Based on to climatic zone, Lampung area was divided into three groups consisting of six climatic zones namely A, B, C, D, E and F. The division considered annual rainfall (CH), the number of wet (BB) and dry months (BK). Group I (CH > 2500 mm) had two zones namely A (BB > 9 months) and B (BB 8-9 months). Group II (CH 1500-2500 mm) consisted of two zones: C (BB > 5 months) and D (BB 3-5 months). Group III (CH < 1500 mm) was divided into two zones, i.e., E (BB < 3 months and BK < 6 months) and F (BK > 6 months).

Characteristics of Rice Production and Determinant Factor on Rice Production

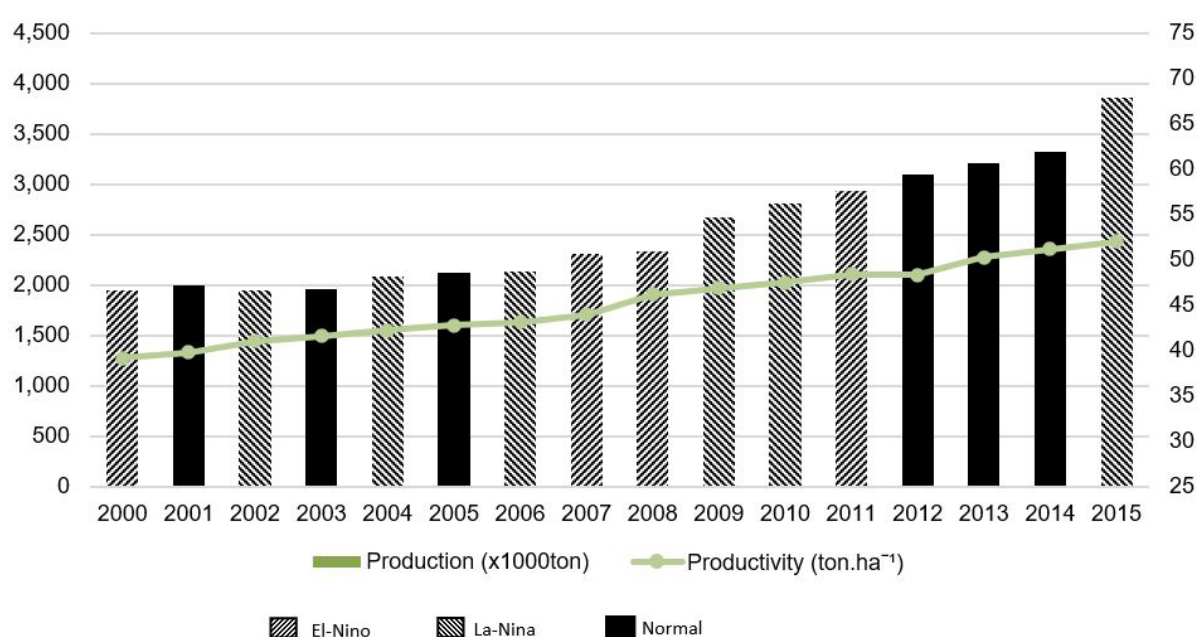
For about 93% of total rice production in Lampung was derived from first (September–December, MH I) and second planting seasons (December–March, MH II). Wet land rice field occupied only 5.57% of total rice plantation, yet contributed for more than 80% rice production (Table 2). There was three rice agroecology types in Lampung, i.e., rainfed, irrigated, and swampland.

In 2015, rice production reached 3.64 million ton that were produced from Lampung Tengah, Lampung Timur, and Lampung Utara at rate of 22.8%, 15.7%, and 14.0%, respectively. The remaining production came from the other 12 districts. High production from these particular districts was due to a large harvested area, i.e. 153,127 ha in Lampung Tengah, 112,750 ha in Lampung Timur and 96,356 ha in district of Lampung Utara. On the other hand, high productivity was obtained in district of Metro City 6.06 t/ha followed by Bandar Lampung 5.96 t/ha and district of Pringsewu 5.80 t/ha. From 2000 to 2015, the annual production increased steadily with an average rate of 5.44% (Table 2; Fig. 3).

Table 2. Total land and land use at each studied district in Lampung Province

District	Total land (km ²)	Wetland (km ²)	Dryland (km ²)	Land used (km ²)	Annual rice production growth rate (%)
Lampung Selatan	700.32	107.34	350.51	242.47	2.28
Lampung Utara	2,725.87	126.27	66.77	2,532.83	3.30
Bandar Lampung	296.00	4.09	5.35	286.56	1.89
Pasawaran	2,243.51	98.02	56.63	2,088.86	8.22
LAMPUNG	34,623.80	1,929.84	1,973.43	30,720.53	5.44

Remarks: Data was obtained from Statistics of Lampung Province (BPS 2016)

**Fig. 3.** Annual production and productivity of rice in Lampung in 2000–2015. Different filled bar indicate El-Nino, La-Nina and normal seasons.**Table 3.** Distribution of rice varieties groups used by farmers at each study site of Lampung Province

District	Planted area (%) ^z			Number of varieties ^y		
	HYV	MYV	LYV	HYV	MYV	LYV
Lampung selatan	90.67	2.40	6.93	25	2	1
Lampung utara	59.74	32.10	8.16	13	3	4
Bandar Lampung	88.05	10.26	1.69	11	1	1
Pesawaran	85.16	8.39	6.45	23	3	4

Remarks: ^z=HYV: high yielding varieties (productivity > 5.0 t/ha), MYV: medium yielding varieties (productivity 4.5–5.0 t/ha), LYV: low yielding varieties (productivity < 4.5 t/ha). ^y=Data was obtained from Agricultural Food Crop and Horticulture Service of Lampung Province (DISTAN TPH, 2015)

Up to 2015, 25 new rice varieties had been introduced to Lampung farmers. The new varieties had 20–25% reduced in height and harvested 10–15 days earlier than old varieties. From 60 rice varieties existed in Lampung, there were 46 varieties classified as high (HYV), 3 medium (MYV) and 11 low yield varieties (LYV). HYV was widely grown in all studied sites (Table 3). In Lampung Selatan, the most popular HYV were Cilayama Muncul, Ciherang, Mekongga, and IR64, and Ciherang and Mekongga varieties were also popular in Lampung Utara, Bandar Lampung and Pasawaran. Farmers selected variety based on yield performance, resistant level to pests and diseases, and early harvesting periods.

In the studied sites, wetland rice was important contributors ranged from 51.61–96.52%, 85.68% on average irrespective of seasons (Table 4). Lampung Utara had a low irrigated field, therefore wetland rice was the lowest percentage among districts. The Pesawaran district was established as independent from Lampung Utara

in 2008, therefore previous data was not available. Table 4 shows there was a variation in wetland and dryland fields according to La-Nina, El-Nino and normal seasons.

Determinant analysis using technological data indicated that rice production in Lampung Province was determined by area for rice field, harvested area, crop productivity, fertilizer subsidy, irrigation channels improvement, and application rate of mechanical tools such as tractor, pump, and rice milling unit ($P < 0.000$; $R^2 = 0.999$). The relationship among production factors as follow:

$$Y(\text{ton}) = -12450 + 0.002\text{LBS} + 5.43\text{LP} + 4097\text{PDV} - 0.845\text{SUBP} - 12.0\text{MK} + 59.0\text{PO} - 29.6\text{RMU} - 0.119\text{I} \dots\dots\dots 2)$$

where: LBS: rice field area, LP: harvested-rice area, PDV: productivity, SUBP: amount fertilizer subsidy, MK: number of tractor subsidy, PO: number of pump, RMU: number of rice milling unit, and I: irrigation rehabilitation subsidy.

Table 4. Percentage of wetland (S) and dryland (L) rice field to total harvest area in four study sites during La-Nina, El-Nino and normal seasons of 2000–2015

Year	District								Season ^z
	Lampung Selatan		Lampung Utara		Pesawaran		Bandar Lampung		
	S	L	S	L	S	L	S	L	
2000	87.50	12.50	53.66	46.34	-	-	82.98	17.02	La Nina
2001	84.95	15.05	51.61	48.39	-	-	86.16	13.84	Normal
2002	85.94	14.06	59.91	40.09	-	-	91.39	8.61	El Nino
2003	86.07	13.93	54.38	45.62	-	-	92.41	7.59	Normal
2004	90.71	9.29	59.58	40.42	-	-	92.66	7.34	El Nino
2005	90.43	9.57	56.40	43.60	-	-	93.06	6.94	Normal
2006	89.97	10.03	59.03	40.97	-	-	90.65	9.35	El Nino
2007	91.24	8.76	61.91	38.09	-	-	92.63	7.37	La Nina
2008	89.01	10.99	66.62	33.38	93.63	6.37	94.90	5.10	La Nina
2009	88.85	11.15	69.90	30.10	94.85	5.15	96.56	3.44	El Nino
2010	90.65	9.35	68.09	31.91	95.68	4.32	96.33	3.67	El Nino
2011	89.28	10.72	70.83	29.17	93.85	6.15	97.53	2.47	La Nina
2012	89.41	10.59	75.03	24.97	94.28	5.72	96.55	3.45	Normal
2013	89.87	10.13	79.89	20.11	93.24	6.76	98.25	1.75	Normal
2014	88.44	11.56	84.33	15.67	97.51	2.49	99.40	0.60	Normal
2015	91.46	8.54	83.32	16.68	93.52	6.48	99.82	0.18	El Nino

Remarks: S = wetland includes irrigated and swampy land, L = dryland; ‘-’ data not available; data was modified from BPS (2016a);^z according to classification by NOAA (2016)

Table 5. Correlation values (below diagonal) and its P values (above diagonal) between annual rice production and climatic factors in Lampung including extreme weather incident in Lampung Province

	Harvested area (ha)	Total production (Y, ton)	Productivity (t/ha)			Temperature (T, °C)			Air relatif humidity (RH, %)	Precipitation (P, mm)	Solar irradiation (I, MJ/m ²)	Extreme weather (EW)
			Min	Average	Max	Min	Average	Max				
Harvested area	-	0.000 ^b	0.051	0.422	0.417	0.422	0.889	0.417	0.680	0.850	0.141	0.559
Y	0.947 ^a	-	0.002	0.277	0.626	0.277	0.779	0.626	0.300	0.773	0.081	0.603
Productivity	0.631	0.846	-	0.188	0.273	0.188	0.386	0.273	0.495	0.981	0.447	0.583
T min	0.277	0.381	0.454	-	0.402	-	0.400	0.402	0.007	0.007	0.032	0.507
T average	-0.050	0.102	0.308	0.300	-	0.300	-	0.031	0.617	0.617	0.674	0.544
T max	0.289	0.177	0.384	-0.290	0.680	-0.290	0.680	-	0.009	0.009	0.323	0.915
RH	0.149	0.365	-0.250	0.448	-0.040	0.448	-0.040	-0.370	-	0.114	0.091	0.610
P	0.069	0.105	0.008	0.787	-0.180	0.787	-0.180	-0.770	0.531	-	0.029	0.546
I	-0.500	-0.580	-0.270	-0.680	0.153	-0.680	0.153	0.349	-0.560	-0.690	-	0.482
EW	0.211	0.188	0.198	-0.240	-0.220	-0.240	-0.220	0.039	-0.180	-0.220	0.252	-

Remarks: ^a value larger than 0.700 or less than -0.700 has significant correlation; ^b P value smaller than 0.05 denotes significant

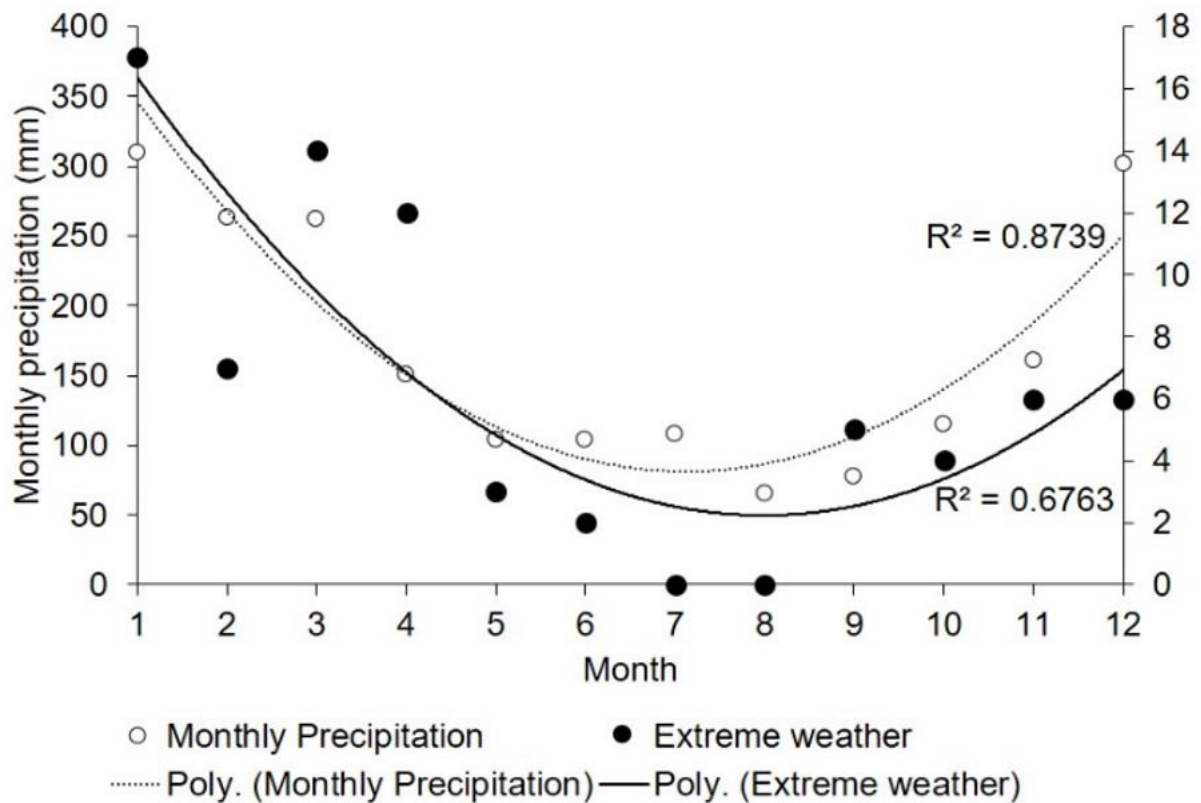


Fig. 4. The relationship between extreme weather incidents and monthly rainfall in Lampung.

The regression model considering technological factors showed that rice production increased by increasing three variables, i.e. total harvested area, plant productivity, and pump subsidy program. Further evaluation using a sensitivity test showed that the harvested area and rice productivity played an important contribution to annual rice production in Lampung Province. On the other hand, the other five variables, i.e. amount of fertilizer subsidies, tractor utilization, construction of rice milling unit and rehabilitation of irrigation channels contributed negatively to the production improvement. These facts indicated that technology improvement solely could not explain the overall annual rice production performance in the study site.

Conversely, correlation test considering climatic factors exhibited a strong relationship between some of the climatic variables with annual rice performance (Table 5). The climatic variables, i.e. temperature and air relative humidity did not significantly correlate with the rice production in Lampung Province. Table 5 shows that annual precipitation levels affected rice production and its productivity. It is understood that saturated-

based rice production in Lampung depends on the availability of water, including precipitation; as stated by Zakaria, Aziz, Hossain, & Farhat Rahman (2014) that precipitation affects water availability. Moreover, minimum and maximum temperatures exhibited mild change, and average temperature tended to increase about 0.5°C within 15 years. However, it needs further evaluation on the effect of raising the temperature on rice production in Lampung.

Weather Dynamic and Land Use Change

The frequency of extreme weather in Lampung tended to increase by years. The incidence could be estimated by the average monthly rainfall ($P=0.006$; $R^2=0.735$). Most extreme weather occurred in January-March at which is inline with high precipitation intensity in the region (Fig. 4). The frequency tended to decrease in April-September and increased again in October-December. Although the cause of extreme weather in Lampung needs further evaluation, some situations that might contribute to the incidence. First, the position of Lampung is unique because it situated at a transitional climate zone between

Java and Sumatera regions and under the hardy-cell tropical monsoon. Secondly, massive land-use change in Sumatera and Java from tropical forest into managed palm and tree plantations, and from agriculture land to the industry in the last decades could be seen in a wider perspective. Java is a fast-growing area with industrialization and the conversion of agricultural to non-agricultural lands on the repected island was estimated 70–100 ha annually. On the other side, land conversion in Sumatera is massive and more than one million hectare lands had been changed into plantations within the last two decades (Miettinen et al., 2012). These landscape changes could affect the macro hydrology of the particular area.

Finally, the expansion area of irrigated rice fields followed by the construction of irrigation channels could affect microclimate due to increasing saturated air humidity. A total length of irrigation channels increased steadily 0.47% annually; the area had increased from 182,114 ha in 2009 to 185,569 ha in 2013. On the other hand, Lampung is generally known as a dry area therefore, there was additional water vapor released to the air about 0.13 million m³ after the expansion of the rice field. At Lampung Barat, there is the mountainous Bukit Barisan lays along the west coast of Sumatera. This topography in combination with orographic might produced an additional feature on the escalation of extreme weather in Lampung.

Local Adaptation To Extreme Weather and Future Challenge

Fifteen years of precipitation data showed only in 2010 extreme weather hit all studied sites. Interestingly, extreme weather did not exist in several years even at La-Nina season. Although the detrimental impact of the extreme weather on the level of farmers was apparent, e.g. 0.92% annually, however, the correlation test between the incidence of extreme weather and aggregate rice production in Lampung was weak. This fact was contrary to the general hypothesis by many authors (Hansen, Mason, Sun, & Tall, 2011; Iizumi et al., 2014; Lee et al., 2013; Zhang et al., 2014) where extreme weather reduces rice production.

It seemed that local government policy and technology adoption by farmers had supported local adaptation to extreme weather in the present study. Local authorities eager farmers to maintain steady rice field expansion and gain a higher production

level through scheme self-sufficiency rice program (known as *swasembada beras*). Although the direct impact of the developments of irrigation channels, providing tractors, and subsidized seeds and fertilizers, and cover rice insurance fees were negligible to rice production, however, the cooperation between government and local farmers was able to minimize the negative impact of climatic fluctuation.

Secondly, the availability of diverse rice varieties including local varieties (Table 3) that have adapted with local agroecology could be a great contribution to stable production. Besides that, farmers had applied appropriate planting calendars provided by extension officers in the field. Farmers considered monthly rainfall to start planting rice. For example, farmers in Bandar Lampung, Kotabumi, and Pesawaran started planting rice seedling in both irrigated and rainfed fields for the first planting season (*Musim Hujan I*, MH I) in the third week of September to the first week of October, while farmers in Lampung Selatan started to plant at the second or third week of October. Therefore, less farmers severed crop failure due to miss-calendars was reported. The application of planting calendar and proper rice variety became important in Lampung because rice cultivation mostly depended on monsoon rainfall. This practice is common in rice production as stated by Asada & Matsumoto (2009).

Third, different rice agroecology might facilitate production buffer under uncertain extreme weather. The planting area during the La-Nina, El-Nino and normal seasons were slightly different. Using 2001 as basis data, there was a tendency that the proportion of dryland rice fields increased during La Nina by about 1.55% from normal seasons from 13.89 % to 15.43%. Conversely, the wetland field increased by 0.26% during the El Nino season. In Lampung Utara and Pasarawan districts, cropping expansion to dryland during La Nina reached 2% and 4%, respectively. It is probably that during La Nina, excess precipitation facilitated adequate moist soil in the dryland. On the other hand, during the El Nino season, swampy and *Rawa pasang surut* became suitable for rice cultivation after the introduction of specific varieties such as Impara group and water management technology. These three reasons could be as an explanation of how rice increment production by 5.44% per year able to minimize the negative impact of extreme weather at a value of 0.92% (Table 1 and Table 2).

The present study demonstrated that local adaptation of extreme weather incidence involved complex aspects in the field. In such a case, the availability of weather stations is important to improve the accuracy of the study. For example, in 2014 there were 11 extreme weather incidents in Lampung between January-April as reported. On 2 January 2014, there was extreme weather in district of Pesawahan, while at all weather stations close to particular district recorded normal rainfalls, i.e., 0, 11.4, 21.5 and 42.0 mm at the Maritime, Masgar, Branti and Kotabumi stations, respectively. In this case, a correlation test between precipitation data and rice production might underestimate.

In a tropical country with many islands like Indonesia, extreme weather could exist at the local level like in the present study. Therefore, local efforts including broader weather station coverage, agroecology management, and local technology on rice production become important. Water management likely becomes a critical action for areas like Lampung Selatan.

Lampung Province can be a model of the region that is success to minimize the negative impact of extreme weather as indicated by steady rice production of annual growth a rate of 5.44%. This success was supported by the ability to increase the area of rice fields by 0.69% per year by utilizing the swampland area by 61,782 ha in 2015. In the future, it is interesting to compare local adaptation strategies among rice production centers that have been at leveling-off for the intensification and limited land for rice expansion to develop better local adaptation.

CONCLUSION

The objective of the study was to assess the incidence of extreme weather and its relationship to the dynamics of long-term rice production. Factors affecting the stability of production and its implications for sustainable rice production management especially during the La-Nina incident are discussed in this article. Evident of extreme weather incident in Lampung could be minimized through diversification of rice cultivation to different agroecology and improving rice productivity. Excess precipitation is considered beneficial to increase the water availability in rainfed area and irrigated fields but the disadvantages to a swampy rice field. The success of local adaptation to extreme weather impact was mainly supported by the proper

application of the cropping calendar. Continuous government aids on input subsidies and improving cropping intensity became a longterm incentive for a farmer to expand rice production field. In this case, the rice field expansion became a key success for local adaptation. Since the extreme weather incident was a most likely local issue, therefore, improving weather monitor facilities is important for a better forecast. Finally, the adoption of adaptive rice varieties and cropping calendar by local communities should be encouraged to response to climate change incidences.

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