Impact of El Niño on Rice Planting in The Indonesian Monsoonal Areas *)

by : Bayong Tjasyono HK., Ina Juaeni,
R. Gernowo, Ruminta,
B. Baramantyono **)

Abstract

The phenomenon of El Niño is very closely related to the impact of meteorological drought in the Indonesian maritime continent. This study discuses El Niño events and its relation with seasonal rainfall variations over monsoonal areas such as Bandung (748m, a.s.l) and Jakarta (7m, a.s.l) wich differ in their climatic controls. Bandung area is controlled by orographic effect, while Jakarta by the distribution of land and sea. Episode of El Niño causes drought disaster in western tropical Pacific including the Indonesian maritime continent. The purpose of this research is to estimate the period of rice planting in the two areas Bandung and Jakarta based on the pentad (5 – day) cumulative rainfall calculated from 50th pentad until to the rainfall reach a level of 350 mm. The study concludes that rice planting is very late in the El Niño years.

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**) Department of Meteorology, Faculty of Earth Sciences and Mineral Technology, Institute of Technology Bandung (ITB).

1. <u>Introduction</u>

Indonesia is a part of the earth system as a natural unity between atmosphere, hydrosphere, litosphere and cryosphere (top of Mount Jaya Wijaya, Papua). Base on the decad (10 – day) amount of rainfall, the Indonesian season is categorized into rainy and dry seasons. The rainfall limit of the two season is 50 mm per decad (10 – day).

As a monsoon region, drought and flood damage periodically some places in Indonesia. The intensities of drought increase when dry seasons are related to El Niño events or wind like Föhn effects on the leeward side of mountainous area. The intensities of flood increase when wet seasons are accompanied by phenomena of tropical cyclones or La Niña events.

A main characteristic of the Indonesian region is the mixture of land and sea which makes it a maritime continent. This mixture of sea and land plus the mountainous character of most islands, creates a large variety of local climates in the Indonesian maritime continent[1]. Most of the Indonesian people live directly or indirectly depend on the agriculture and land produces, so that the climate is very important factors in their lives.

Due to geographical and meteorological position more strategic, the Indonesian maritime continent has an important role on the global weather and climate. Its role is more important when the Indonesian throughflow and monsoon current are related to the phenomena of El Niño / La Niña – Southern Oscillation – Monsoon – Dipole Mode[2]. There are ENSO signals in rainfall and temperature throughout the Australian–Indonesian monsoon region. Although there are some discrepancies, drought in the Australian and Indonesian regions are generally associated with ENSO year.

2. Atmospheric Circulation over Indonesia

There are three atmospheric circulations i.e., meridional (Hadley), zonal (Walker), and convection (local) circulation. Over Indonesia, the meridional circulation changes to become monsoon in consequence of it lies in between the two continents (Asia and Australia) and the two oceans (Pacific and Indian oceans). Asian monsoon is more humid than Australian monsoon. Monsoon can be described as a giant sea breeze phenomenon by north–south heat contrast in association with the annual migration of the sun. The main characteristics of the monsoon regions[3] are; the prevailing wind direction shifts by at least 120^0 between midwinter (January) and midsummer (July), the average frequency of prevailing winds in January and

July exceed 40% and the mean resultant winds in at least one of the months exceeds 3 ms^{-1}, see table 1 and table 2.

Table 1. The average wind directions in percent (1988 – 1998) for station Bandung and Jakarta[4].

Wind Direction	**Bandung**		**Jakarta**	
	January	**July**	**January**	**July**
Calm	20	19	0	0
North	0	1	14	27
Northeast	0	0	2	19
East	3	55	1	40
Southeast	0	0	1	6
South	1	2	0	2
Southwest	0	0	5	3
West	76	23	64	2
Northwest	0	0	13	1
Total	**100**	**100**	**100**	**100**

Table 2. Prevailing winds in percent (1988 – 1998) for station Bandung and Jakarta[4].

Station	**East Component**		**West Component**	
	Jun – Jul – Aug	**Dec – Jan – Feb**	**Jun – Jul – Aug**	**Dec – Jan – Feb**
Bandung	52	4	25	79
Jakarta	63	4	8	82

The intensity of the Walker circulation is controlled by sea surface temperature (SST) variations in the eastern and western Pacific. Changes in SST and thus the heat content of the ocean, are transferred into the atmosphere in the form of atmospheric pressure changes. Ocean and atmosphere are strongly coupled. Such tied ocean and atmospheric events is known as ENSO (El Niño – Southern Oscillation). The principle model of the atmosphere – ocean interaction is the increase of temperature in the equatorial Pacific. Over these temperature anomalies center will occur much evaporation and strong convection. In consequence of the vertical motion, the trade winds in the western temperature anomalies center will be weakened and the trade winds in the eastern this center will be reinforced, see figure 1.

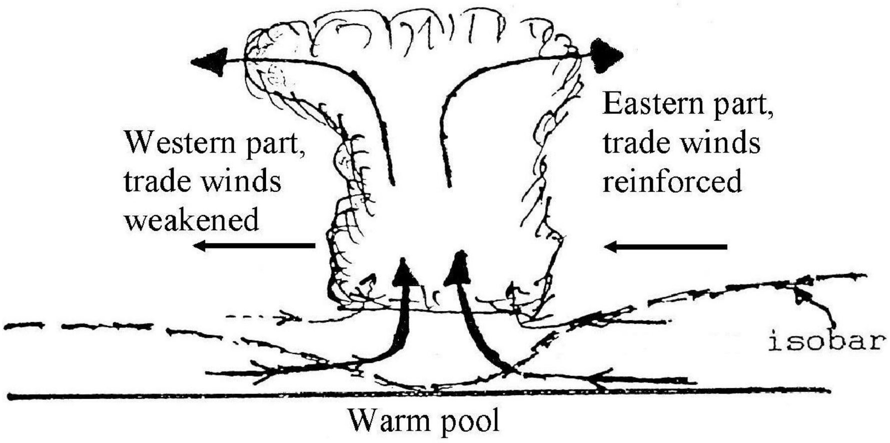

Figure 1. Sketch of the principle circulation in El Niño years.

ENSO is a natural phenomenon emerging from coupled interaction between the atmosphere and the ocean in the tropical Pacific Ocean. El Niño (EN) as the ocean component and Southern Oscillation (SO) as the atmospheric component of ENSO[5]. The impact of ENSO on humanity and society, for instance droughts, floods and other disaster that can severely disrupt agriculture, fisheries, the environment, health, the energy demand, air quality et cetera. During pre–El Niño, sea surface temperature (SST) is greater in the western part than that in the eastern part, while in the El Niño year, it occurs the reverse see figure 2.

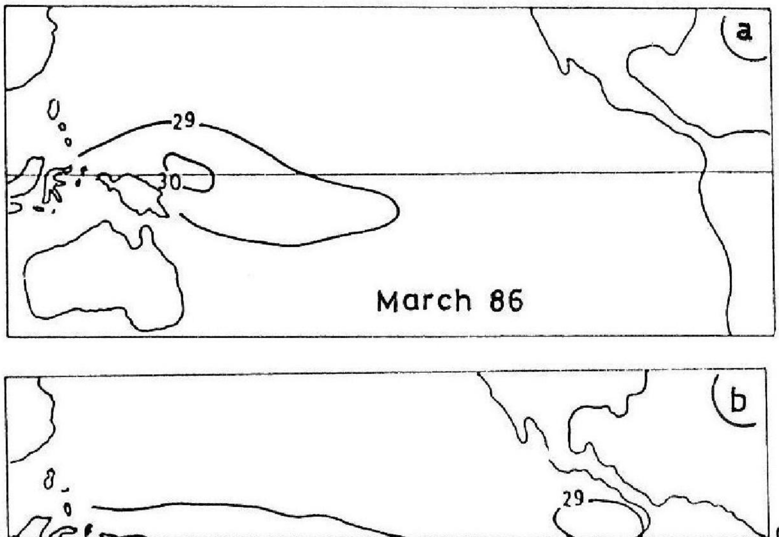

Figure 2. Sea surface temperature in ^{0}C[6]. a). Pre–El Niño, and b). During El Niño 1987.

Figure 2, shows the displacement of warm pool in the Equatorial Pacific Ocean eastward up to the Coast of Peru in the El Niño year. This warm pool motion causes easterly winds or trade winds weakened. As easterly trade winds decrease, warm water in the western Pacific flows eastward. This layer, typically 500 feet deep, flows over cooler, nutrient rich water and bloks its normal upwelling along North and South America. Sea life there can suffer from leak of food[5,7].

3. Relationship of Indonesian Drought and El Niño Event

Drought is difficult to define precisely, this case can generally be regarded as the condition where there is lack of sufficient water to meet requirement[8]. Drought originates from a deficiency of rainfall over an extended period of time for instance a month, a season or more. Meteorological drought is defined on the basis of the degree of dryness and the duration of the dry period. When drought begins, the agricultural sector is generally the first to be affected because of its heavy dependence on stored soil water. The main factor causing drought in Indonesia is high pressure cell. When high cell exists, then surface wind becomes divergence and upper air subsides to the surface. Upper air is less humid and consequently it is difficult in the cloud droplets and rain drops development.

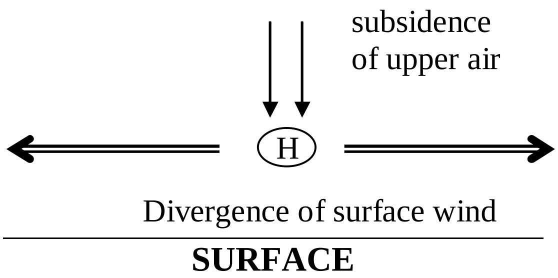

Figure 3. Sketch of subsidence and divergence of air mass caused by high pressure cell H.

Interannual variations in temperature, and rainfall over the Indonesian maritime continent are strongly affected by El Niño. Figures 4 and 5 show absolute temperatures (K), and rainfall (mm/day) in August during the pre–El Niño, El Niño and post–El Niño events respectively. The Indonesian drought periods are highly correlated with the El Niño phenomena, see table 3. It can be seen that in the El Niño year, the temperature over the Indonesian maritime continent is cooler with less rainfall. On the other hand, the area with rainfall less than 60 mm/month is larger during the El Niño year than during pre and post–El Niño. When the air over Indonesia is cooler, its density and its pressure is higher. In such a manner upper air subside and surface wind becomes divergence to the Equatorial Pacific ocean from Indonesia. Subsidence of upper air obstruct cloud and rain development, hence Indonesia suffers severe drought disaster with a higher risk of forest fire in the El Niño events.

Table 3. Percentage of dry season region (%) and the characteristic of rainfall[10].

Year	Below normal	Normal	Above normal	Natural Phenomena	Meteorological Disaster
1961	94	6	0	El Niño	Drought
1962	33	39	28	-	-
1963	92	8	0	El Niño	Drought
1964	12	20	68	-	-
1965	96	4	0	El Niño	Drought
1966	65	26	9	-	Drought
1967	96	4	0	El Niño	Drought
1968	0	8	92	-	-
1969	91	9	0	El Niño	Drought
1970	31	41	28	-	-
1971	34	33	33	-	-
1972	98	2	0	El Niño	Drought
1973	2	11	87	-	-
1974	7	22	71	-	-
1975	9	17	74	-	-
1976	72	28	0	El Niño	Drought
1977	78	20	2	El Niño	Drought
1978	3	12	85	-	-
1979	46	26	28	-	-
1980	67	17	16	-	Drought
1981	15	28	57	-	-
1982	100	0	0	El Niño	Drought
1983	52	19	29	El Niño	Drought
1984	15	18	67	-	-
1985	24	44	62	-	-
1986	28	26	46	-	-
1987	91	9	0	El Niño	Drought
1988	57	30	13	El Niño	Drought
1989	10	52	38	-	-
1990	12	60	28	-	-
1991	98	2	0	El Niño	Drought
1992	16	40	44	-	-
1993	60	37	3	El Niño	Drought
1994	99	1	0	El Niño	Drought
1995	26	59	15	-	-
1996	26	50	24	-	-
1997	94	5	1	El Niño	Drought
1998	44	41	15	-	-
1999	67	25	28	-	Drought
2000	30	60	10	-	-

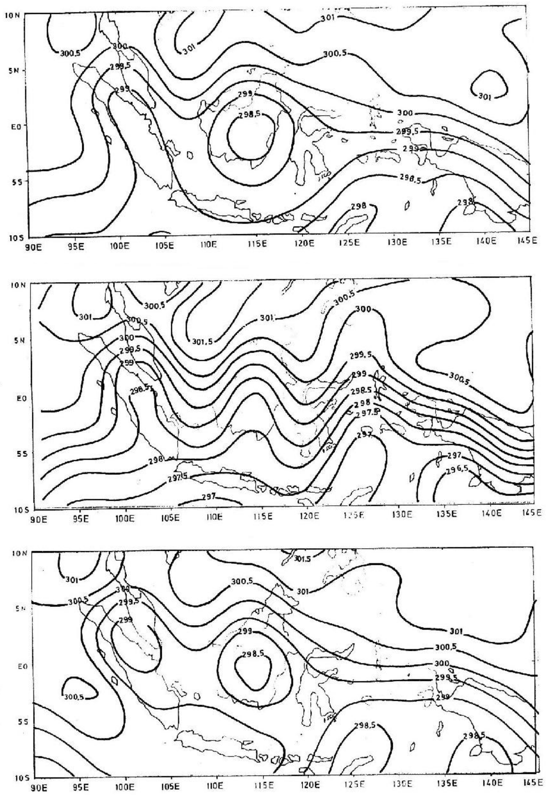

Figure 4. Absolute temperature over the Indonesian maritime continent in August. Above : Pre–El Niño 1996, middle : El Niño year 1997, and bottom : post–El Niño 1998.

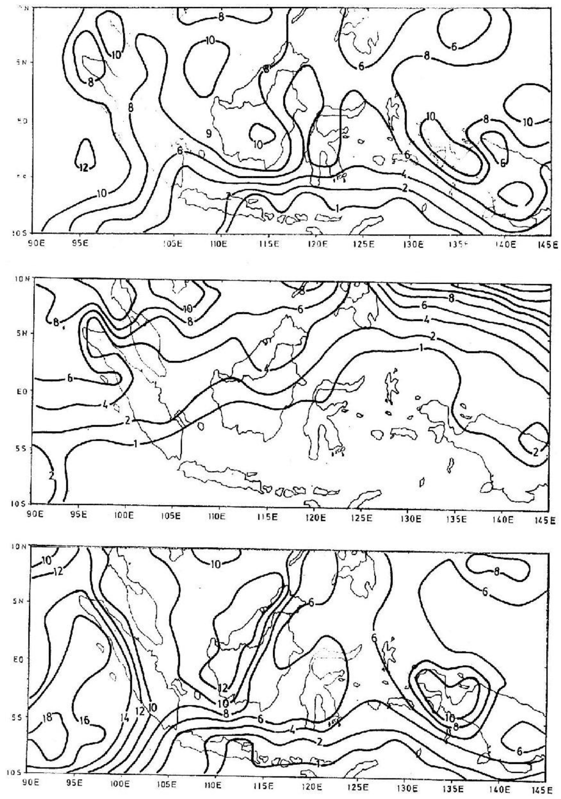

Figure 5. Isohyet (mm/day) over the Indonesian maritime continent in August. Above : Pre–El Niño 1996, middle : El Niño year 1997, and bottom : post–El Niño 1998.

The natural phenomenon of El Niño is very closely related to the meteorological drought in the Indonesian maritime continent. The occurrence of meteorological drought can be indicated as follows :

> when in the dry season the percentage of Indonesian region is greater than 50% with cumulative number of rainfall less than that in the normal period and this condition is followed by the begining of earlier dry season and the retreat of dry season from its normal period[9].

There are 108 regions of season forecasting spreaded in the whole Indonesian region. In table 3, percentage of season region is divided in 3 categories i.e :

(i). above normal, when the amount of rainfall in one season is greater than its normal value.

(ii). normal, when the amount of rainfall in one season is close to its normal value.

(iii). below normal, when the amount of rainfall in one season less than its normal value.

The Indonesian maritime continent has an important role in the El Niño event. The occurence of El Niño is strongly related to the climate elements over the Indonesian region. More than 80% of the Indonesian drought is dominated by El Niño especially El Niño event. Severe drought can be occured when south east monsoon is strengthened by El Niño event.

4. The Impact of El Niño on Agriculture

Long dry season or drought in the monsoonal areas are frequently related to the El Niño events. Table 4 indicates the number of decad (10 – day) having rainfall less than 50 mm for Bandung and Jakarta areas. It can be seen that during El Niño events, the number of decad having rainfall amount less than 50 mm is greater in comparison to during non El Niño years. The influence of El Niño on dry season in monsoonal areas is significant, that is a longer dry season.

Table 4. The number of decad having rainfall amount less than 50 mm.

Year	Area	
	Bandung	Jakarta
1982	16	17
1983	8	6
1984	10	10
1985	3	7
1986	4	8
1987	15	16
1988	13	15

Note : 1982 and 1987 are El Niño years.

The amount of rainfall in the transition period between the driest months and rainy season is certaintly of considerable importance to agriculture. The most important effect of the rainfall in this period is that they contribute to the gradual moistening of the soil after it has more or less completely dried out during the dry season. It is preferred to take the 1st of September or the 50th pentad as the beginning of the transition period in all areas of West Java.

It is proposed that cumulative rainfall amount at a level of 350 mm would be a suitable criterion to indicate the end of the transition period. The 350 mm criterion, mainly on account of its association with rice culture, for when this amount of rainfall after the 50th pentad, the soil is generally sufficiently moistened to allow the farmers to prepare the seed beds for the rainy season rice crop[11].

The nature of rainfall in this season is expressed in the duration of the transition period, that is the length of time which it takes the rainfall after the 50th pentad to reach a level of 350 mm. The duration of this period in a certain year may be conveniently expressed by its deviation from the mean of eleven years (1988 – 1998).

Figures 6 and 7 show cumulative rainfall from the 50th to the 73rd pentad for Bandung and Jakarta respectively. It is evident that El Niño events cause long transition periods in comparison with the mean of a number of years, such as in the El Niño 1997. Accordingly, El Niño events lengthen dry season or shorten rainy season, it means that rice planting will be very late. The cumulative number of rainfall 350 mm wil be reached very late. Consequently rice plantation will be very late.

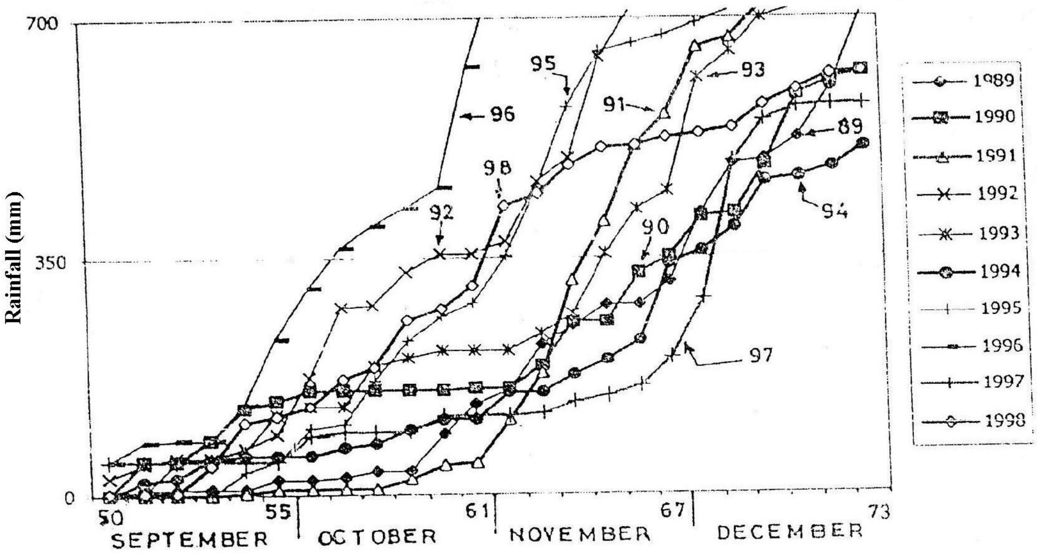

Figure 6. Cumulative rainfall from the 50th pentad (September 3rd) to 73rd pentad (December 31st) in Bandung area.

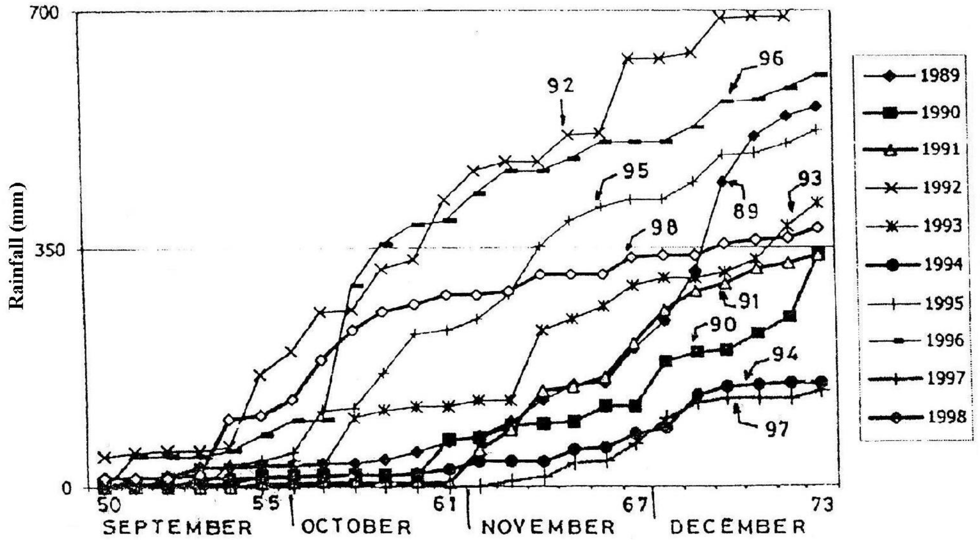

Figure 7. Cumulative rainfall from the 50th pentad (September 3rd) to 73rd pentad (December 31st) in Jakarta area.

Figure 8, displays the strong link between maize production and interannual precipitation fluctuations in Zimbabwe for the period 1970 to 1993. ENSO years (1972/73, 1982/83, 1986/87, 1991/92) are associated with strongly decrease in rainfall and maize production[12].

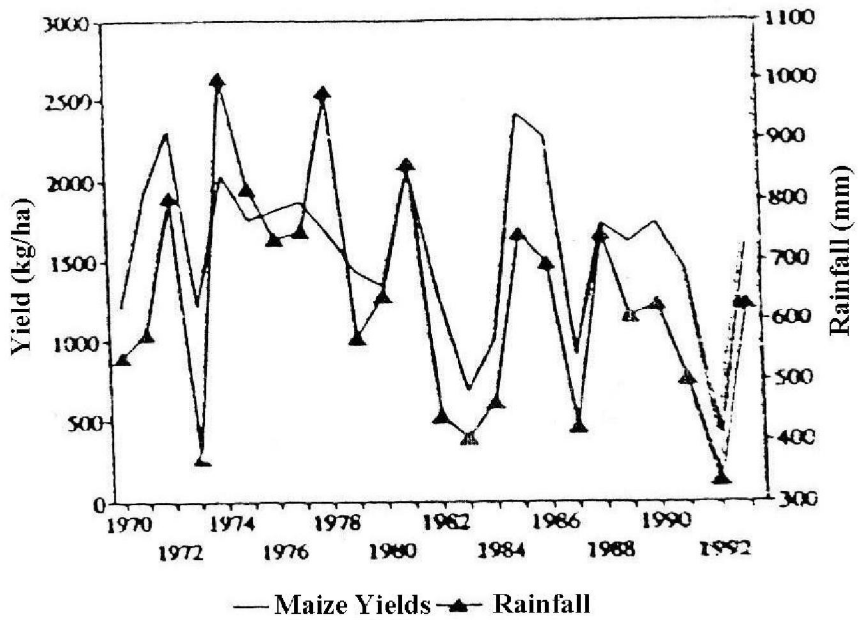

Figure 8. Relationship between yearly anomalous rainfall (mm) over Zimbabwe and the production of maize (kg/ha) for the period 1970 – 1993.

Conclusions

The driest period in Java covers the months of June, July and August, the so called east monsoon. It is characterized by the frequent occurrence of easterly winds. Wet or rainy season (December, January and February) is related to west monsoon or werterly winds.

The Indonesian maritime continent has an important role in the El Niño event. The occurence of El Niño is strongly related to the climate elements over Indonesia. El Niño event is indicated by cooler temperature, higher pressure and rainfall deficiency in comparison with pre and post El Niño events.

More than 80% of the Indonesian drought is affected by El Niño. In the El Niño year, the number of rainfall in some parts of the Indonesian maritime continent is less than that in the normal conditions. El Niño events certainly influence drought, but drought in Indonesia uncertainly will be caused by El Niño.

Cumulative rainfall come from the 50th pentad (September 3rd) to the 73rd pentad (December 31st) indicates that El Niño events cause long dry season or short rainy season. The number of rainfall 350 mm will be very late, so that rice planting will be very late in El Niño year.

Acknowledgements

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