The Use of Global Climate Forcing for Rainfall and Yield Prediction in Indonesia: Case Study at Bandung District

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Abstract

Variability of rainfall at Bandung district is significantly correlated with global climate forcing, SOI (Southern Oscillation Index) and IOD (Indian Ocean Dipole), particularly dry season rainfall. The relationship is consistently positive with SOI and consistently negative with IOD. Further analysis suggested that the linear effect of IOD was not significant in all stations, but the interaction effect of the SOI and IOD was significant in some of the stations. The relationship between the anomaly rainfall and the SOI and IOD interaction were positive. This means that if the SOI is negative (indicating El-Nino) and IOD is also negative, the interaction effect will be positive. In other word the IOD negative will counteract the reducing effect of El-Nino on rainfall at Bandung districts. SOI and IOD can also be used to estimate likely yield of soybean, maize and potato. For example, yield of the crop planted in the period of September-December (PT in Julian Day) could also predicted from June-August SOI, and IOD, population density (P in plants per m^2), and nitrogen application (N in t/ha). About 84% of potato yield variability could be explain by the equation. The form of the relationship is as follows: $Ln(Y_{OPT}) = 2.14 + 13.7 N - 2.20(P*N) - 0.000822 (PT*IOD_{JA}) + 0.000890 (PT*SOI_{JA}*IOD_{JA}) - 0.279 (IOD_{JA}*SOI_{JA}) + 0.0000002(PT^2*SOI_{JA})$

Introduction

Indonesia is a tropical country passed by equator line and under influence of Indian and Pacific Oceans. At least five factors, meridional circulation (Hadley), zonal circulation (Walker), monsoon activity, local effect (topography) and tropical cyclone, may affect variability of rainfall in Indonesia. These five factors work simultaneously throughout the year at the same time. However, in a certain condition, a particular factor might become more dominance than the others (Tjasyono, 1997). Many studies have shown that rainfall variability in Indonesia are strongly affected by El-Nino-Southern Oscillation (ENSO) phenomena (Braak, 1919; Yamanaka, 1998). Recent studies indicated that condition in Indian Ocean might also affect rainfall variability in Indonesia (Faqih, 2002). Like Pacific Ocean, Indian Ocean also has phenomenon like El-Nino, called Indian Ocean Dipole or IOD (Saji et al., 1999). A warm pool in the Indian Ocean moves eastward in a cycle of 3 to 7 years. This IOD will affect both the zonal (east-west) circulation in the troposphere, and in the meridional (north-south) circulation (Yamagata et al., 2001).

Variability of yield also depends on rainfall variability, as rainfall is the main source of water for crop growth. Most of agriculture areas at Bandung district are rainfed, except rice growing area they are mostly irrigated. However, area located at end tail irrigated system areas is very prone to drought. In El-Nino years, the second crops were normally suffering from drought due to lack of irrigation water and rainfall during this period (April-September) was normally disappeared or very low. This study examine the use of SOI and IOD for predicting dry season rainfall and crop yields.

Global Climate Forcing and Rainfall Variability

To see which regions have strong or weak correlation with the SOI, the spatial correlation between seasonal rainfalls of the stations with SOI was developed. Equation for predicting seasonal rainfall from SOI and IOD was developed using regression equations. The SOI is defined as: $SOI = (P_{Tahiti}-P_{Darwin})/S_{d(Ptahiti-Pdarwin)} \times 10$ and $IOD=(SST_E-SST_W)$, where SST_E and SST_W are eastern and western Indian sea surface temperature (Saji et al., 1999). The area of the western and eastern covered 50?E - 70?E / 10?S - 10?N, and 90?E-110?E / 10?S-equator respectively.

The result of analysis showed that there was a significant positive correlation between MJJA seasonal rainfall and the SOI as well as between SOND rainfall and the SOI. At some areas, the correlation between MJJA rainfall and the SOI could go up to 0.7, similarly for Wuku seasonal rainfall. For JFMA rainfall the correlations were not statistically significant. Further analysis showed that July-Oct rainfall was significantly correlated with May-June SOI and also with IOD. The interesting finding was that the rainfall in all stations showed a consistently positive correlation with SOI and consistently negative with IOD. The SOI could explain the variation of July-Oct rainfall between 20% and 50%, while IOD mostly less than 10%.

Yamagata et al. (2001) and Kumar *et al.* (1999) found that the effect of IOD would counteract the effect of El-Nino when they occur together. The IOD affects not only the zonal (east-west) circulation in the troposphere, but also affects the meridional (north-south) circulation. In the case of India, they found that a positive IOD produced a positive rainfall anomaly along the monsoon trough prevailing across Northern India, and over the Bay of Bengal. This study suggests that for Indonesian case the negative rainfall anomalies are expected when the IOD is positive. From regression analysis, it was suggested that the linear effect of IOD was not significant in all stations, but the interaction effect of the SOI and IOD was significant in some of the stations (Table 1). The relationship between the anomaly rainfall and the SOI and IOD interaction were positive. This means that if the SOI is negative (indicating El-Nino) and IOD is also negative, the interaction effect will be positive. In other word the IOD negative will counteract the reducing effect of El-Nino on rainfall at Bandung districts. This finding is in line with Yamagata et al. (2001) finding that IOD has opposite effect of ENSO. Further analysis is required to see the spatial pattern of the interaction impact for Indonesia as this finding may have considerably impact on the improvement of short-term prediction of seasonal rainfall in Indonesia.

Table 3.1. Coefficients of regression equation that relate July-Oct Rainfall Anomaly with May-June SOI/IOD at nine rainfall stations at Bandung district

Stations	Period of record	Intercept	SOI	SOI*IOD	R^2 (%)
Darangdan	‘61-‘90	39.75	15.10**	33.67*	37.9
Purwakarta	’61-‘90	34.68	18.22***	24.98**	56.4
Cikao-Bandung	’61-‘90	28.44	11.85**	23.77*	35.9
Margahayu	’61-‘90	18.58	11.08**	11.50^{ns}	21.6
Bandung	’61-‘90	25.98	9.92**	18.29*	40.7
Husein Sastranegara	’61-‘90	17.62	6.82*	16.94*	33.4
Bojong Picung	’61-‘88	-4.92	20.62**	-4.64^{ns}	42.3
Pakar Dago	’61-‘88	0.10	9.37*	7.54^{ns}	29.2

Montaya	'61-'87	-3.25	20.72**	-7.37^{ns}	35.3

Note: *, **, and *** significant at 10%, 5% and 1% level respectively and *ns* not significant

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Stone *et al.* (1996) categorized the SOI into five phases. The SOI phases were determined based on SOI values in the current and immediately preceding month. The five SOI phases are: 'consistently negative denoted as 1', 'consistently positive denoted as 2', rapid fall denoted as 3', 'rapid rise denoted as 4' and 'consistently near zero denoted as 5'. SOI phase 1 and 3 may indicate dry month (El-Nino events), while phases 2 and 4 may indicate wet month (La-Nina events), and phase 5 indicates normal month. As the SOI phase in a given month may affect the likely rainfall in the following months, this information is used to define likely crop productivity in the coming season under given crop management. The result of analysis suggested that planting soybean after April is still possible if the value of SOI phase in April was 2, 4, or 5 (Figure 1), similarly for Maize. There is a 50% chance of getting soybean yield of more than 750 kg/ha or maize yield of more than 2000 kg/ha for May planting.

Further analysis at potato growing areas also showed that yield of the crop planted in the period of September-December (PT in Julian Day) could also predicted from June-August SOI, and IOD, population density (P in plants per m^2), and nitrogen application (N in t/ha). About 84% of potato yield variability could be explain by the equation. The form of the relationship is as follows:

$Ln(Y_{OPT}) = 2.14 + 13.7\ N - 2.20(P*N) -0.000822\ (PT*IOD_{JA}) +0.000890\ (PT*SOI_{JA}*IOD_{JA})$

$- 0.279\ (IOD_{JA}*SOI_{JA}) + 0.0000002(PT^2*SOI_{JA})$

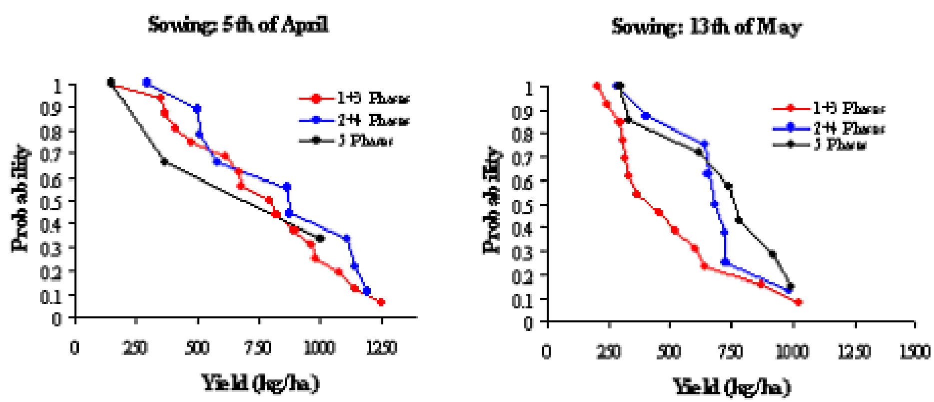

Figure 1. Probability of soybean yield at different sowing times based on previous month SOI phase

By applying the above equation using SOI_{JA} and IOD_{JA} data of 1876-2000, the likely potato yields under different combination SOI, IOD and planting time, can be assessed. For this analysis population and nitrogen application were set to be 3 plants/m^2 and 130 kg/ha respectively. The result of analysis is presented in Figure 2.

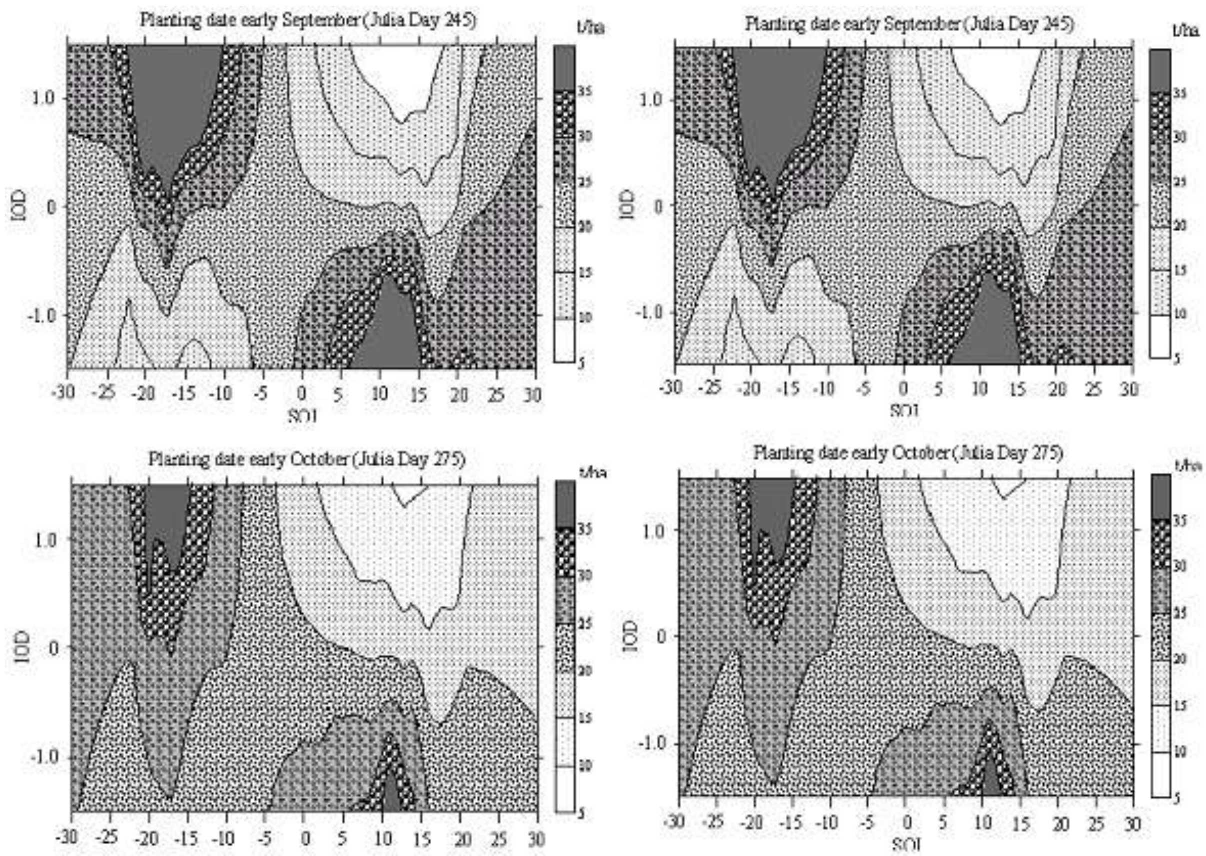

Figure 2. Estimated potato yields planted at four different planting dates under different combination of IOD_{JA} and SOI_{JA}. Nitrogen application was 130 kg/ha and population was 30,000 plants/ha.

Figure 2 showed that if SOI_{JA} were less than –5 (indicating El-Nino), and IOD_{JA} were also negative, planting early September would not give good yield. The yield would be less than 20 t/ha. Under this condition, the planting time should be postponed by 1-2 months. Under SOI strong negative, planting early September could give good yield if IOD were strongly positive. Whereas, if SOI_{JA} were strongly positive (indicating La-Nina), planting early September was recommended, except if IOD were strongly positive. In general, planting later in the season (early November-Early December) is recommended when SOI is strongly negative irrespective of IOD condition, while planting early in the season (early September) is recommended when SOI is strongly positive (greater than 20) irrespective of IOD condition. Thus farmers who want to start planting potato early in the season (September and October) should consider the July-August SOI and IOD.

Conclusion

Rainfall and yield variability of soybean, maize, and potato at Bandung District were significantly related with SOI and IOD. These global climate-forcing factors could be used to estimate likely crop yield and optimum planting time.

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