J. Agromet 18 (2) : 1 – 12, 2004

GLOBAL CLIMATE FORCING FACTORS AND RAINFALL VARIABILITY IN WEST JAVA: CASE STUDY IN BANDUNG DISTRICT

(Faktor Kendali Iklim Global dan Keragaman Curah Hujan di Jawa Barat: Studi Kasus Kabupaten Bandung)

Rizaldi Boer[1,2] and M. Faqih[2]

[1]Laboratory of Climatology, Bogor Agricultural University
[2]Applied Research Centre for Climate and Technology, Indonesia

ABSTRAK

Indonesia sebagai negara tropis dilalui oleh garis equator dan berada di bawah pengaruh lautan India dan Pasifik. Kolam panas di lautan India yang bergerak ke arah Timur dengan siklus 3 sampai 7 tahun, seperti fenomena El-Nino yang terjadi di kawasan lautan Pasifik, berpengaruh terhadap sirkulasi angin zonal (Timur-Barat) di lapisan troposfer dan sirkulasi angin meridional (Utara-Selatan). Oleh karena itu, kedua fenomena global tersebut mungkin memberikan pengaruh nyata terhadap keragaman hujan di Indonesia. Penelitian ini ditujukan untuk (i) mengevaluasi hubungan antara keragaman hujan di Bandung, Jawa Barat dengan suhu muka laut di kawasan lautan Pacific dan India dan (ii) mengevaluasi tingkat keandalan ramalan hujan musiman di Bandung, Jawa Barat dengan menggunakan indek osilasi selatan (SOI) dan dipole lautan India (IOD). Diperoleh bahwa curah hujan musim Ceboran (Mei-Agustus) secara konsisten berhubungan nyata dengan suhu muka laut di kawasan Pasifik, sementara curah hujan musim Wuku (Sepetember-Desember) untuk beberapa stasiun tidak hanya berhubungan nyata dengan suhu muka laut di kawasan Pasifik tetapi juga dengan suhu muka laut di kawasan India. Sementara keragaman curah hujan musim Porekat (January-April) tidak terlihat berhubungan nyata dengan suhu muka laut di kawasan Pasifik maupun India. Analisis lebih jauh menunjukkan bahwa anomali hujan Juli-Oktober berhubungan nyata dengan indeks osilasi Selatan Mei-Juni. Dengan IOD hubungannya hanya nyata untuk beberapa stasiun saja. Temuan yang menarik ialah curah hujan di semua stasiun memperlihatkan hubungan yang sifatnya konsisten positif dengan SOI dan konsisten negatif dengan IOD. Hasil ini mengindikasikan bahwa IOD negatif dapat mengurangi dampak El-Nino terhadap penurunan hujan di Kabupaten Bandung.

Kata kunci: El-Nino, dipole lautan India, keragaman curah hujan.

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). Among the five factors, it was found that most of extreme climate events such as drought occurrences were associated with El-Nino-Southern Oscillation (ENSO) phenomena (Braak, 1919; Berlage, 1927; Nicholls, 1981 and 1983; Hackert and Hastenrath, 1986; Hastenrath, 1987; Malingreau, 1987; Harger, 1995; Yamanaka, 1998). Historical data from 1884 indicated that only 15% of the drought occurrences were not associated with El Niño (Boer and Subbiah, 2004).

Penyerahan naskah : Maret 2004
Diterima untuk diterbitkan : Juni 2004

Recent studies indicated that sea surface temperature anomaly at Indian Ocean also affected rainfall variability in Indonesia significantly (e.g. Faqih, 2002). The phenomenon is called Indian Ocean Dipole or IOD (Saji *et al.*, 1999; Tim Li *et al.*, 2003). A warm pool in the Indian Ocean moves eastward in a cycle of 3 to 7 years like El-Nino phenomenon (Columbia University Record, 1994). The IOD will affect both the zonal (east-west) circulation in the troposphere, and in the meridional (north-south) circulation (Yamagata *et al.*, 2001). This study was aimed (i) to evaluate the relationship between rainfall and Indian/Pacific sea surface temperature on rainfall variability, and (ii) to evaluate the predictability of seasonal rainfall using SOI and IOD at Bandung district, one of crop production center in West Java.

METHODOLOGY

Stations used in this analysis were stations that have monthly rainfall record with length of more than 20 years (Figure 1). The sea surface temperature data and IOD were downloaded from IRI website. The relationship between seasonal rainfall variability and Indian and Pacific sea surface temperature was evaluated using CLIMLAB (Tanco and Berri, 1999). 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 $IOD = (SST_W-SST_E)$ where SST_E and SST_W are eastern and western Indian sea surface temperature. 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 seasons were divided into three following classification used by farmers at Bandung districts. The seasons are wuku (SOND), porekat (JFMA) and ceboran (MJJA). In this area the rainy season normally starts in September/October and ends in March/April. The dry seasons lasts between April/May to August/September.

Figure1. Contour and name of stations at Bandung district used in the analysis

RESULT OF ANALYSIS

The result of analysis showed that the ceboran seasonal rainfall (May to August called as wuku season) for most of the stations was consistently related with sea surface temperature of the Pacific Ocean (Figure 2a), while wuku seasonal rainfall (SOND) for some of stations was related not only with sea surface temperature in the Pacific Ocean but also with Indian Ocean (Figure 2b). Whereas, porekat seasonal rainfall has shown no clear relationship with the sea surface temperature. Correlation spatial analysis between rainfall and SOI also indicated that there was a significant positive correlation between ceboran season (MJJA) and the SOI as well as between wuku season (SOND) and the SOI. At Pengalengan, the correlation between ceboran seasonal rainfall and the SOI ranged between 0.4 and 0.7, similarly for wuku seasonal rainfall (Figure 3). For porekat season (JFMA), the correlations were negative. This means that when the anomaly sea surface temperature in the Pacific become more positive, the porekat seasonal rainfall tended to increase. However, these negative correlations were statistically not significant.

As the ENSO is very significantly related with the variability rainfall in Indonesia, particularly in the dry season, the use of SOI for seasonal rainfall prediction is now very common. Bureau of Meteorology and Geophysics (BMG) of Indonesia has adopted RAINMAN (Clewett *et al.*, 2002) which was developed by DPI-Australia, as one of models for seasonal climate prediction. Another similar model which also developed by DPI-Australia is Decadal Climate Variability DCV (Meinke *et al.*, 2001). The models can be used to assess the change of rainfall distribution for a given season based on the condition of SOI phase one, two or more months before the season. In this study, direct relationship between anomaly of dry season rainfall (July-Oct) and May-June SOI as well as May-June IOD was developed. It was found that in most of the stations, the July-Oct anomaly rainfall was significantly correlated with May-June SOI. With the IOD the relationships was significant only for a number of stations (Figure 4). However, 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%.

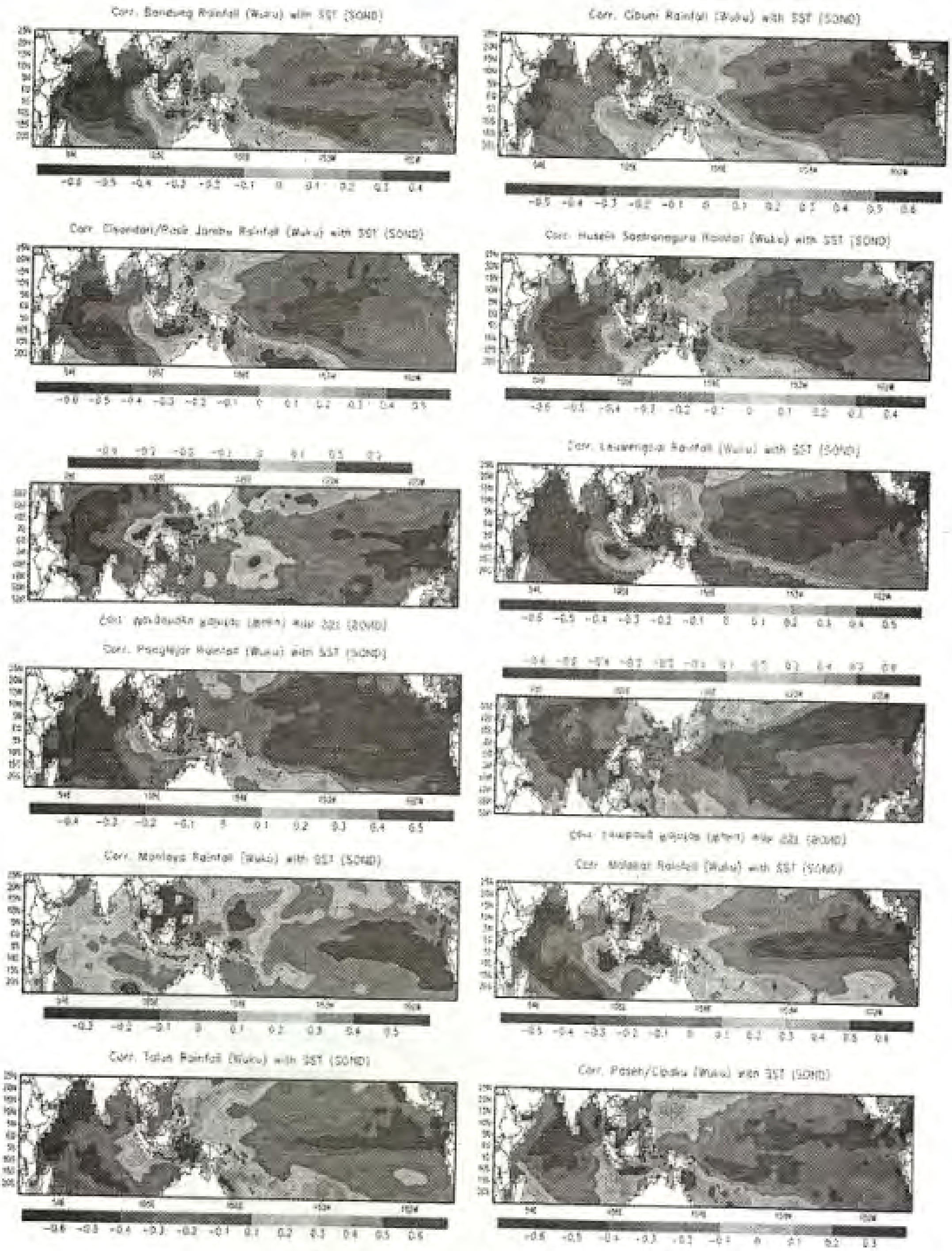

Figure 2a. Correlation between Wuku seasonal rainfall and sea surface temperature.

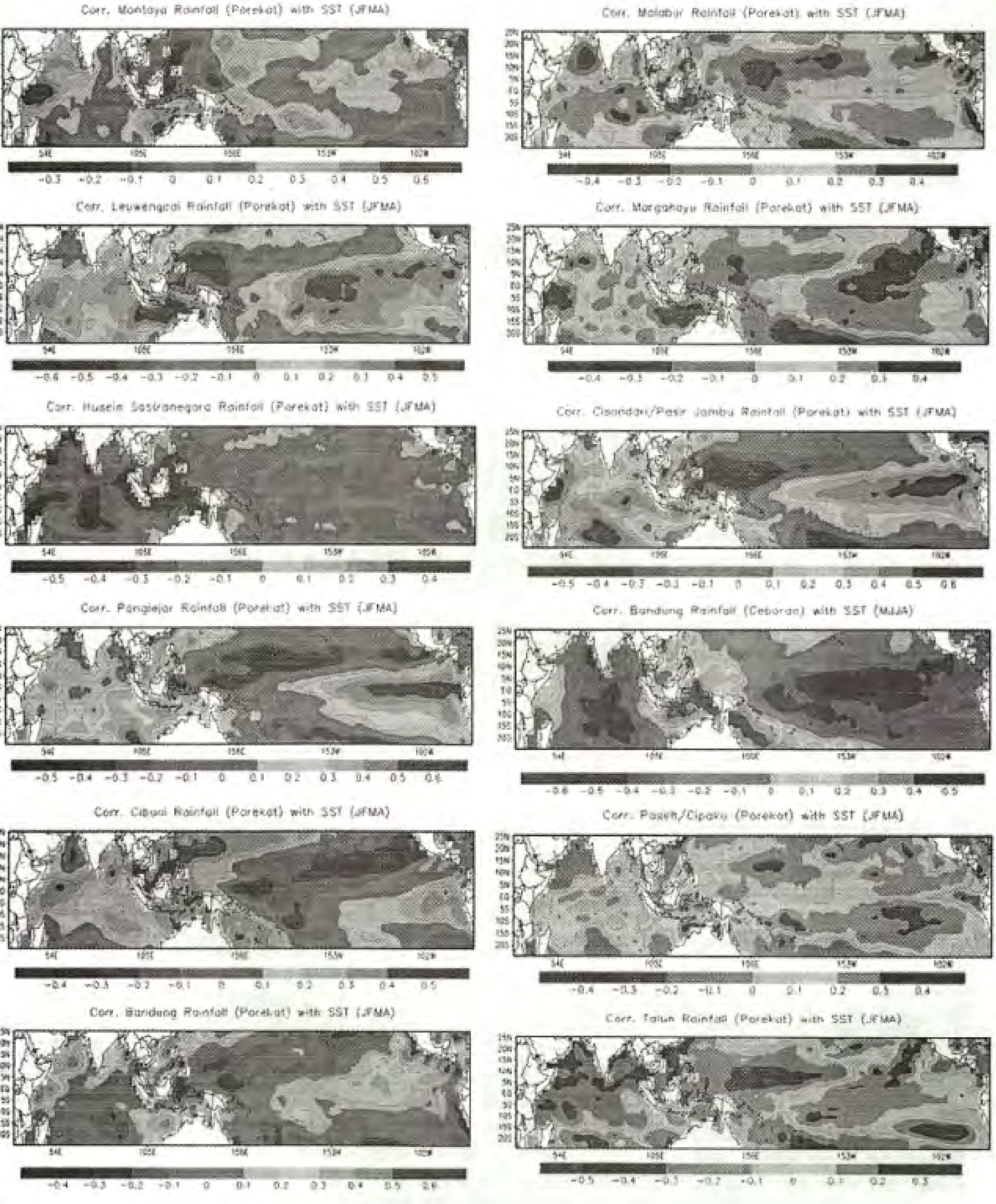

Figure 2b. Correlation between porekat seasonal rainfall and sea surface temperature.

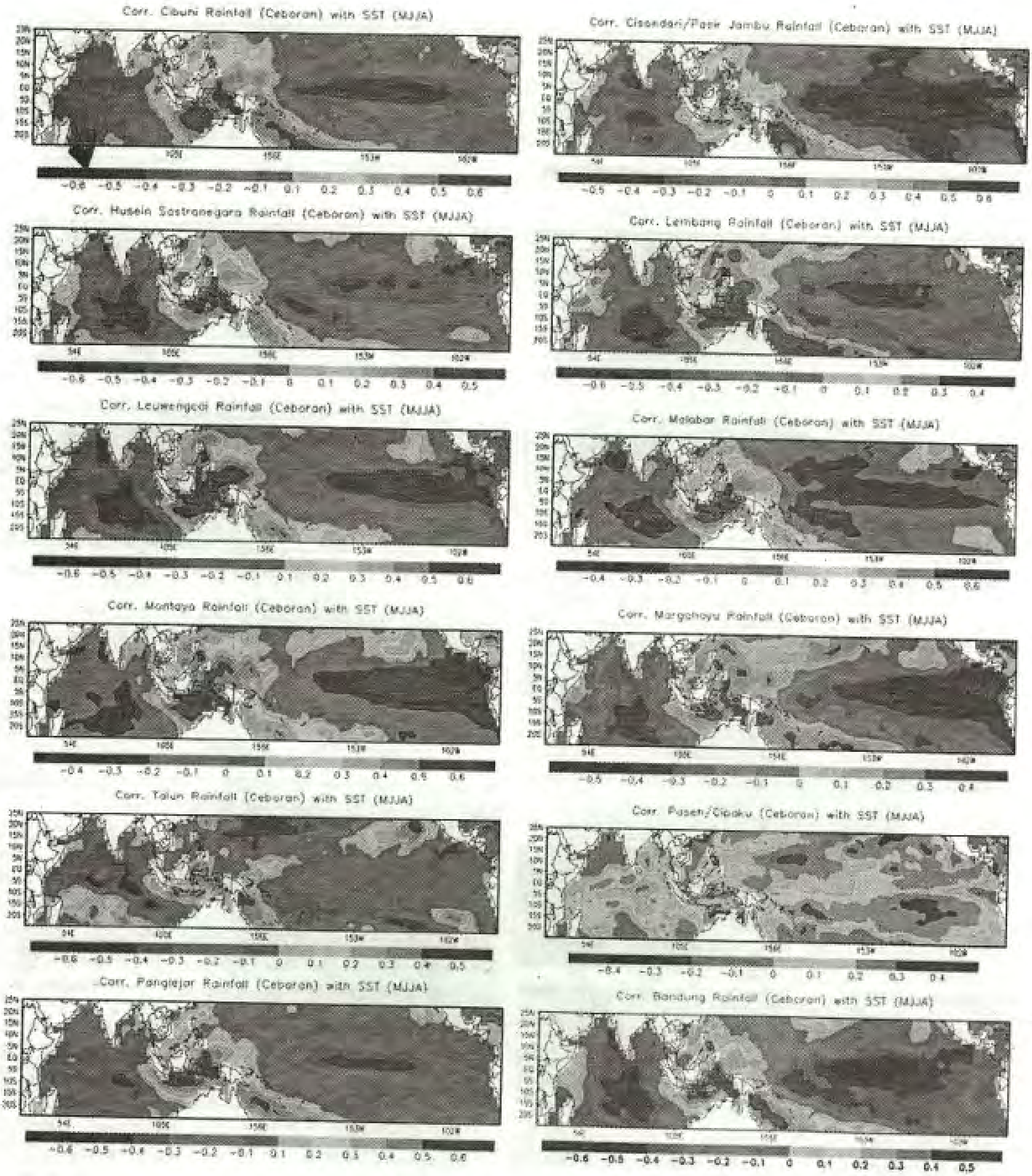

Figure 2c. Correlation between Ceboran seasonal rainfall and sea surface temperature.

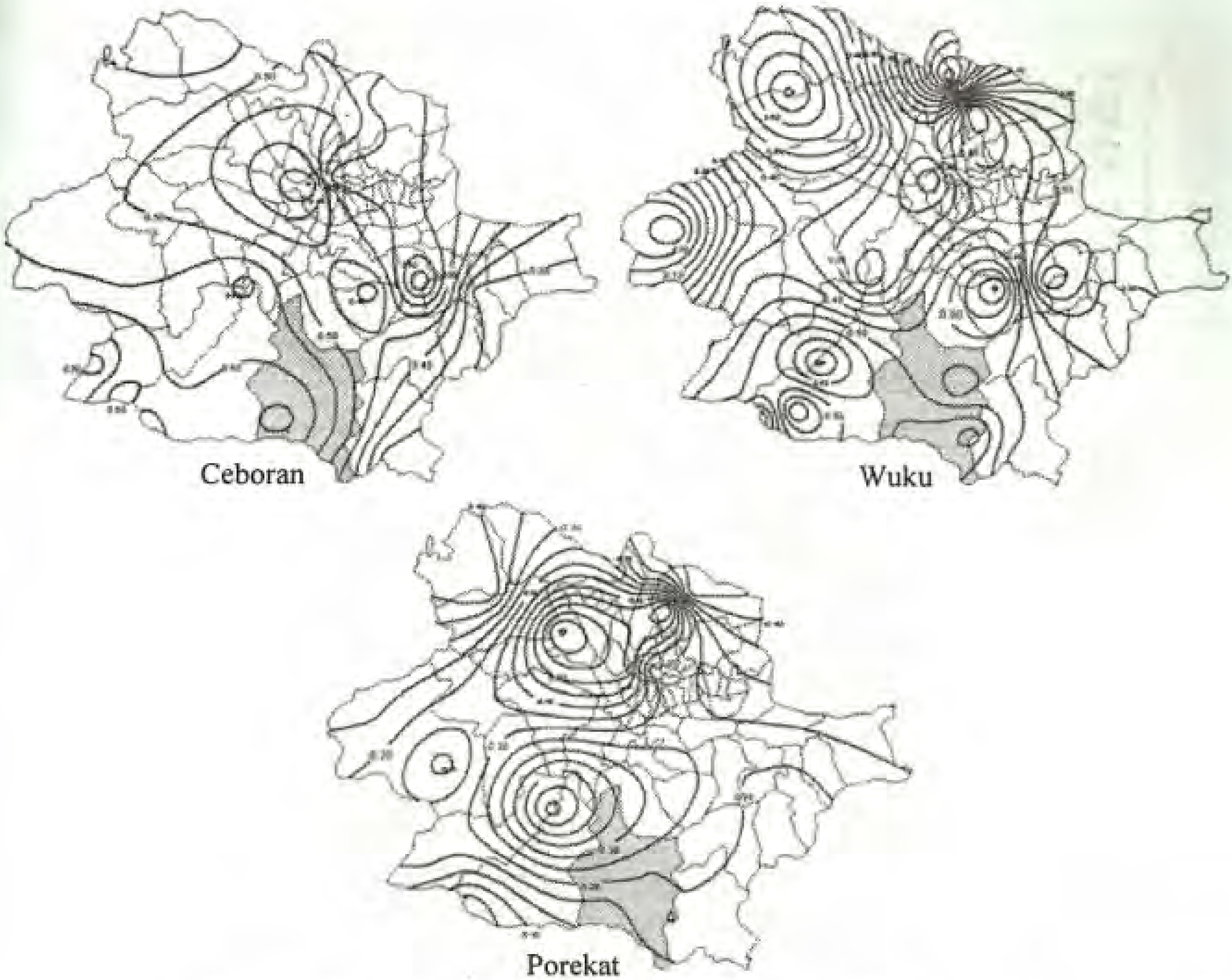

Figure 3. Spatial correlations between seasonal rainfall and the SOI.

Figure 4 shows that in general the July-Oct rainfall anomaly became negative when the SOI was less than –5. The rate of the decrease was between 100 and 230 mm per 10 units decrease in SOI depending on the stations. This suggests that in these region the rainfall condition in July-Oct can be predicted reasonably well using May-June SOI.

The decrease in July-Oct rainfall as the SOI increase may have an implication that the onset of rainy season in this area is also delay. Many studies found that the onset of rainy season could be postponed up to two month during El-Nino years (e.g. USDA, 1984; ADPC, 2000). If the development of ENSO occurs early in the year the onset of dry season could be advanced as much as two months (ADPC, 2000).

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, he 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 (Figure 4).

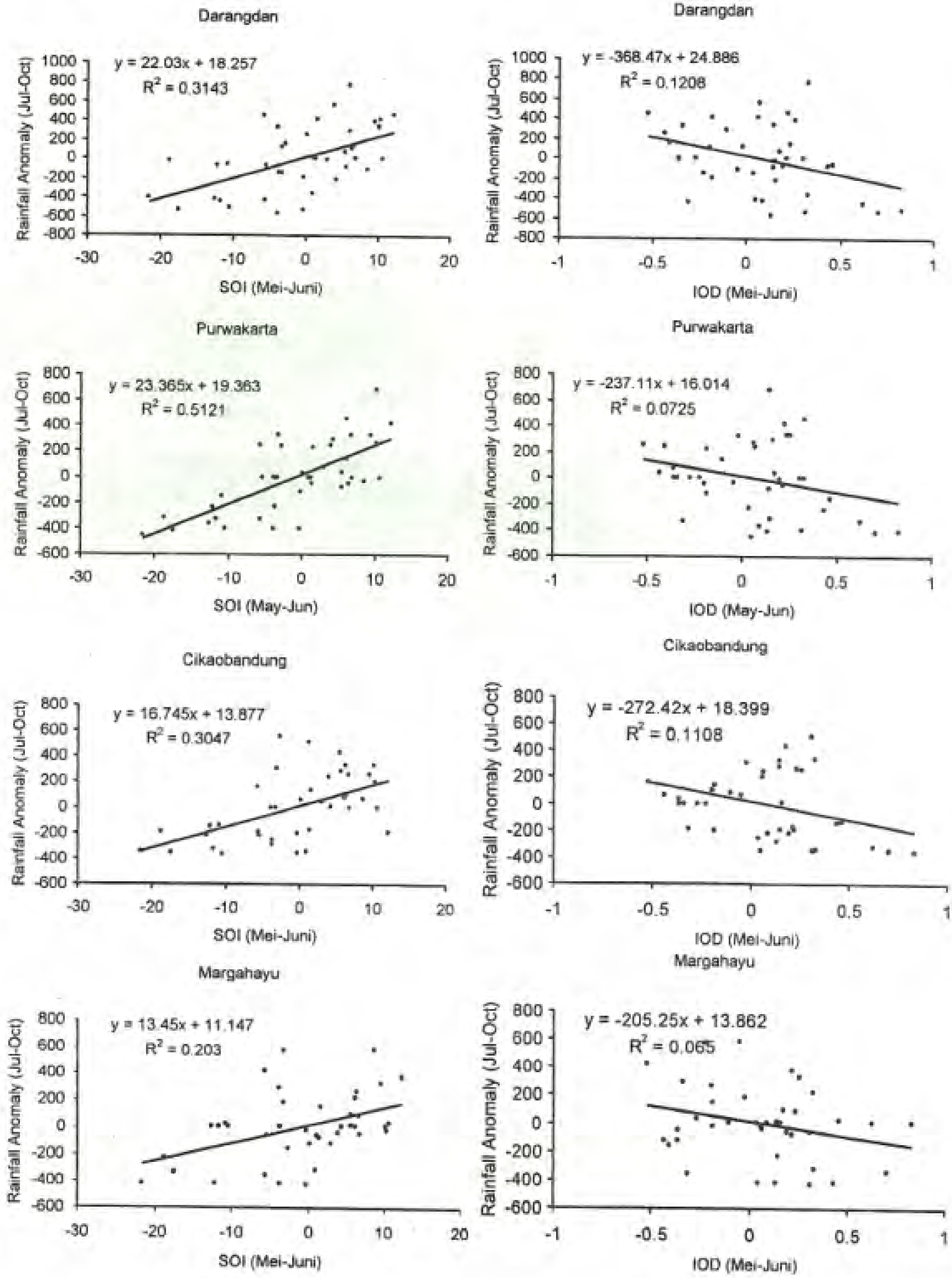

Figure 4. Relationship between May-June SOI/IOD and July-Oct rainfall anomaly.

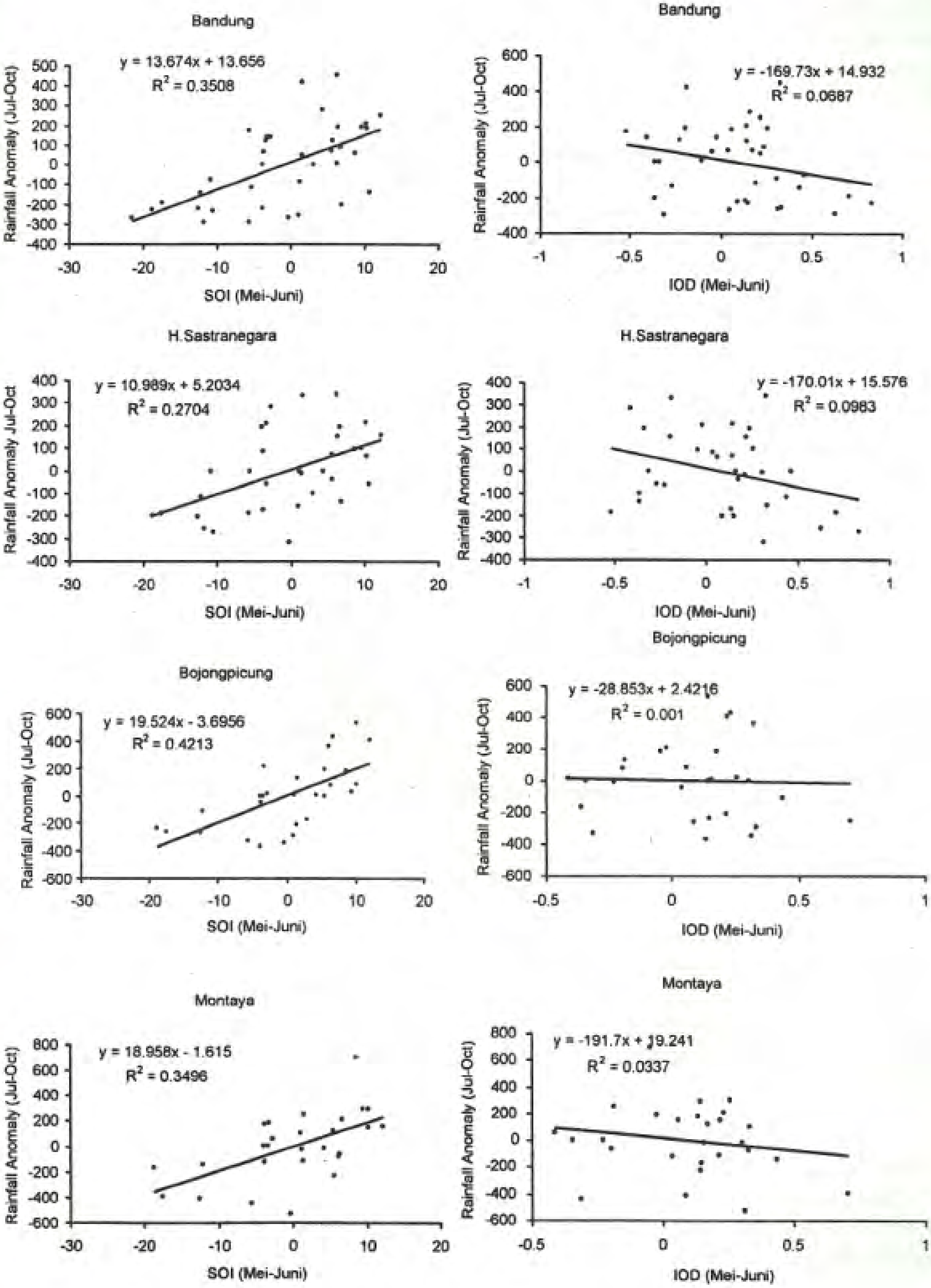

Figure 4. (*Continued*).

In order to see the interaction effect between SOI and IOD on Bandung rainfall, simple linear regressions that use (SOI*IOD) as another independent variable was developed. The results of analysis showed 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 (sea surface temperature in the region of 90°E - 110°E/ 10°S –equator, near Indonesia is lower than that of 50°E - 70°E/10°S - 10°N), 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 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.

DISCUSSIONS

Seasonal rainfall variability of Bandung district, particularly July-October rainfall, is significantly related with Pacific and Indian sea surface temperature. This seasonal rainfall is consistently positive correlated with SOI and consistently negative correlated with IOD. The negative IOD will counteract the reducing effect of El-Nino on rainfall at Bandung districts and July-October rainfall can be predicted from May-June SOI and May-June IOD.

ACKNOWLEDGEMENT

The authors wish to acknowledge Packard Foundation and START who provides financial support for the studies. The authors also acknowledge Mugni and Ismail Wahab for their assistant during the study.

REFERENCES

ADPC, 2000. ENSO impact and potential forecast applications in Indonesia. Extreme Climate Events Program. Asian Disaster Preparedness Center, Bangkok, Thailand. 90p.

Berlage, H.P. 1927. East monsoon forecasting in Java. Verhandelingen No. 20. Jakarta, Koninklijk Magnetisch en Meterologisch Observatorium te Batavia.

Boer, R. and A.R. Subbiah, 2004. Agriculture drought in Indonesia. Chapter 26. In *Agricultural Drought: Global Monitoring and Prediction. Oxford University Press. In Press.*

Braak, C. 1919. Atmospheric variations of short and long duration in the Malay archipelago and neighbouring regions, and the possibility to forecast them. Verhandelingen No. 5. Jakarta, Koninklijk Magnetisch en Meterologisch Observatorium te Batavia.

Clewett, J.F., O.S. Hwang, D.T. Owens, D.A. George, and I.J. Partridge. 2002. RAINMAN International. ACIAR and Department of Primary Industry, Australia – SOFTWARE.Columbia University Record, 1994

Faqih, A. 2002. Analisis pola spasial dan temporal anomali suhu permukaan laut di samudera pasifik, hindia dan atlantik serta kaitannya dengan anomali curah hujan bulanan. Skripsi, Institut Pertanian Bogor.

Hackert, E. and S. Hastenrath. 1986 Mechanisms of Java rainfall anomalies. J Clim. Appl. Meteorol. 26:133-141.

Harger, J.R.E. 1995. ENSO variation and drought occurrence in Indonesia and the Phillipines. Atmospheric Environment 29:1943-1955.

Hastenrath, S. 1987 Predictability of Java monsoon anomalies: a case study. J. Clim. Appl. Meteor. 26:133-141.

Kumar, K.K., Rajagopalan, B., and Cane M.A. 1999. On the weakening relationship between the Indian Monsoon and ENSO. Science 284: 2156-2159.

Malingreau, J.P. 1987. The 1982-83 drought in Indonesia: Assessment and monitoring. P: 11-18. *In* M. Blantz, R. Katz and M. Krenz. Climate crisis: The societal impacts associated with the 1982-83 worldwide climate anomalies. UNEP.

Meinke, H., Power, S., Allan, R. and deVoil, P. 2001. Can decadal climate variability be predicted? Final Report to Land and Water Australia. Agriculture Production System Research Unit (APSRU), Bureau of Meteorology (BoM), and Quensland Government Department of Primary Industry, Australia - PROJECT REPORT

Nicholls, N. 1981. Air-sea interaction and the possibility of long-range weather prediction in the Indonesian archipelago. Mon. Weather Rev. 109:2435-2443.

Nicholls, N. 1983. The Southern Oscillation and Indonesian sea surface temperatures. Mon. Weather Rev. 112:424-432.

Saji NH, Goswani BN, Vinayachandran PN, Yamagata T. 1999. A dipole mode in the tropical Indian ocean. *Nature Magazine* 401:360-363.

Tim Li, Bin Wang, C.P. Chang, and Y. Zhang, 2003. A Theory for the Indian Ocean Dipole–Zonal Mode. Journal of the Atmospheric Sciences: Vol. 60, No. 17, pp. 2119–2135

Tanco, R. and G. Berri, 1999. CLIMLAB 2000 version 1.1. International Research Institute for Climate Prediction, New York.

Tjasyono, B. 1997. Mekanisme fisis para, selama, dan pasca El Niño. Paper disajikan pada Workshop Kelompok Peneliti Dinamika Atmosfer, 13-14 Maret 1997.

USDA. 1984. World indices of agriculture and food production, 1974-1983. Statistical Bulletin 710. Economic Research Service, U.S. Department of Agriculture, Washington DC.

Yamagata, T., Karumuri, A and Zhaoyong, G. 2001. Indian Ocean Dipole Phenomenon's Impact on Correlation between Indian Monsoon and El Niño/Southern Oscillation. NASDA and JAMSTEC. http://www.jamstec.go.jp.

Yamanaka, M (ed.) 1998. Climatology of Indonesia Maritime Continent. Kyoto University Press.