Using Satellite Image to Estimate the Effects of El Nino Occurrence on Agriculture in Gunung Kidul, Yogyakarta, Indonesia

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Abstract*—Although many studies has been investigated the effects of El Nino in Indonesia, but little evidence is available for estimation the effects of El Nino using satellite images in the hilly areas. This study is to estimate the effects of El Nino occurrence on agriculture using statistical and satellite images. The study was conducted at Gunung Kidul district, one of district in Yogyakarta Special Province, which is located in hilly region, during 2002 – 2007. In ElNino year shows negative index of Southern Oscillation Index (SOI) and decrease in rainfall and wetland paddy production. Also based on landsat ETM+ in October 12, 2006, mean of NDVI in wetland paddy (-0.1) and rain-fed dry land crops (-0.2) was low vegetation. Comparing with normal year, in landsat ETM+ in October 12, 2004, mean of NDVI in wetland paddy (0.05) and rain-fed dry land crops (0.02), it is indicated vegetation is high. Correlation between mean of NDVI and percentage of planted area in wetland paddy, both of the year, El Nino and normal year was in good correlation, which in El Nino year R^2 = 0.685 and in normal year R^2 = 0.716 and rain-fed dry land crops, only in El Nino year had good correlation with R^2 = 0.431. The result in correlation because cropping pattern in both of land, in wetland paddy with monoculture, the amount of crop only one crop was planted but in rain-fed dry land crops with intercropping, sometimes in rain-fed dry land crops is double counted in each crop. Also, in rain-fed dry land crops is depend on water sufficiency in the land, if enough of water, the correlation is not good because intercropping was done as usual.

***Index Terms*—rainfall, normal year, NDVI, cropping pattern**

I. Introduction

Agricultural condition in Indonesia is influenced by the rainfall distribution pattern. The coherence of local rainfall in Indonesia is influenced by topography and amount of rainfall in each region. [1] had investigated that the varied topography in the area (and the island generally) could be contributing to low coherence of rainfall variation. Since 1980's, climate abnormality occurred in Indonesia and one of the effects from climate abnormality is rainfall, which seriously disturbs the fundamental modes of crop cultivation and damages the production of food and other commodities in the affected areas. Many researchers were investigated about effects of climate abnormality on agriculture in Indonesia. [2] investigated that 93% of droughts in Indonesia occurred during El Nino years, also [3] presented that El Nino have delayed rice harvest in Indonesia and exacerbated food security, and the last was investigated by [4] that El Nino caused decrease mostly located in highland regions and food crops were decreased -10% in each sub district.

Investigation in the effects of El Nino is commonly using statistical data and little evidence to use spatial data, especially satellite images. In recent decades, remotely sensed data have been widely used to provide the vegetation information such as degradation level of forests and intensity of agricultural activities. In remote sensing technology, calculation vegetation change is known as 'The Normalized Difference Vegetation Index (NDVI), which based on ratio between measured reflectivity in the red and near infrared portions of the electromagnetic spectrum. These two spectral bands are chosen because they are most affected by the absorption of chlorophyll in leafy green vegetation and by the density of green vegetation on the surface. Also, in red and near-infrared bands, the contrastbetween vegetation and soil is at a maximum level. It measures, in effect, the amount of green vegetation in an area. It is very interesting, therefore, if we could relate with the El Nino phenomenon, which is very influential on the plants, especially agricultural crops.

The aims of this study are to estimate impact of El Nino in rainfall and crops production, analyze NDVI in El Nino year and Normal year, and finally, estimating correlation between mean of NDVI and percentage of planted area in wetland paddy and rain-fed dry land paddy.

II. Data

A. Sudy Area

Gunung Kidul district is located between 7°46' – 7°09' latitude and 110°21' – 110°50' Longitude (Fig. 1), has hilly topographic condition, half of its region has slope area of more than 15% and only the middle zone is

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relatively plain. This district is dependent from rainfall, not only for agriculture sector, but also for daily life. Annual rainfall in this area is around 1500-2000 mm/year.

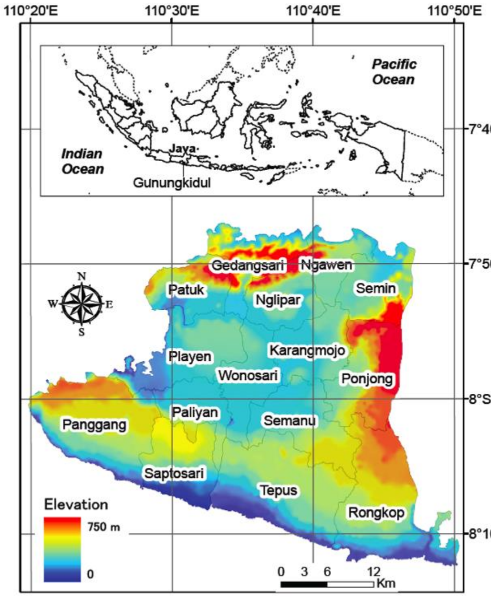


Figure 1. Location of Gunungkidul district [5]

B. Data

Historical secondary data from various publications and official reports from local government institutions was the main data used for impact analysis of El Nino on rainfall and planted area in Gunung Kidul district. The main sources for the basic data are; [6] for planted area, production and rainfall data, [7] for rainfall, temperature, humidity, sunshine and wind speed data, [8], and [9] for Southern Oscillation Index (SOI), this data was guide to decide El Nino year.

As spatial data, especially land use map of Gunung Kidul district with a scale of 1:25.000 was used. This spatial data was used to analysis of vegetation change in GunungKidul district based on El Nino year. The main source for spatial data is taken from [10], and landsat 7 ETM (Enhanced Thematic Mapper) taken from [11] on October 12, 2004 and 2006. These multispectral images have original a pixel-size of 30 x 30 meters.

III. Methods

A. Impacts of El Nino in Rainfall and Crops Production

In this research, estimations of expected production for each year were conducted based on 3-year moving averages. A period of 3-years was used to avoid gaps between the years and the other years, including reliability issues and errors associated with the data. Therefore, losses due to El Nino events of a given year can be expressed as the following equation:

$$\text{Loss} = (Pt - Pm)/Pm \times 100 \quad (1)$$

where:

Loss = losses expressed as a percentage
Pm = 3-year moving average of crops production
Pt = crops production in year t

Estimations of losses due to El Nino were conducted using annual and monthly data from 1994-2007, which covered six food crops; wetland paddy, dry land paddy, corn, soybean, cassava and peanut. Based on monthly data from 1994-2007 was especially useful in estimating food area losses by season (wet and dry season) in the district of Gunung Kidul. In this study, two methods were used as follows: annual and sub round (4 months). In rainfall analysis three methods were used; annual, season and sub round (4 months). In annual method, rainfall is accumulative from 15 sub districts in Gunung Kidul district. Further, season methods is accumulative during six months from 15 sub districts, while sub round is accumulative during 4 months in a year. One year is divided into 3 sub round, sub round I (January-April), sub round II (May-August) and sub round III (September-December).

B. Analysis of Normalized Difference Vegetation Index (NDVI) Based on El Nino Year and Normal Year

Based on Southern Oscillation Index (SOI) and analysis on deviation rainfall between actual data and 3-years moving average, El Nino in 2006 and normal year in 2004 were determined. To analyze of NDVI in GunungKidul district, software ArcGIS 9 was used, as well as, landuse map of Gunung Kidul district from National Coordinating Agency for Survey and Mapping (Bakosurtanal). Analysis of effect El Nino was divided into 2; (1) NDVI in El Nino year and normal year comparison, and (2) Correlation between mean of NDVI in El Nino and normal year with percentage of planted wetland paddy and rain-fed dry land paddy area.

C. Correlation between Mean of NDVI and Percentage of Planted Area from Actual Statistical Data

In this study, correlation between mean of NDVI and planted area from actual statistic was measured in each sub district in Gunung Kidul district based on satellite image. Percentage of planted area is planted area in sub round 3 (September-December) in each sub district on the basis of statistical data were taken from Agricultural Service of Foods and Horticulture, Gunung Kidul district. In this research, planted area was determined into wetland paddy (sawah) and rain-fed dry land paddy (sawah tadah hujan).

Landuse map of wetland paddy and rain-fed dry land paddy of Gunung Kidul district (polygon) was employed to analyze mean of NDVI in both of landuse. Administration map (polygon) also used to analyze mean of NDVI in each sub district. Further, extension spatial analyst in ArcGIS software was used to obtain mean of NDVI in each sub district. NDVI based on landuse map was overlaid with administration map (polygon) and zonal statistic in extension spatial analyst was performed to determine mean of NDVI in each sub district. Percentage of planted area was obtained from planted area in each sub district in sub round 3 (September-December) in El Nino year (2006) and normal year (2004) then divided by total area in landuse map in El Nino (2004) and normal year (2002).

IV. Result

A. *Impacts of El Nino in Rainfall and Crops Production*

1) *Rainfall*

The analysis of El Nino impacts on rainfall was carried out by comparing annual , seasonal and sub round (4 months) rainfall from 1994-2007. In annual rainfall analysis, in actual rainfall data of Gunung Kidul district, it shows rainfall in 1997 and 2002 were decreased by comparing with the other year from 1994-2007 (Fig. 2). In the both of year, annual rainfall is below 2000 mm. In case of an El Nino, rainfall in Gunung Kidul tends to decrease compared with the average. Based on monthly average of rainfall from 1994-2007 in each sub district in Gunung Kidul, it reveals that the highest deviation is occurred in 1997, compared from the previous year, from -8 percent to -42 percent. In addition, rainfall was decreased from -7 percent in the previous year to -2 percent in 2002. This fact was one indicator to determine El Nino year in Gunung Kidul district. In seasonal rainfall analysis, in wet season analysis, the case in El Nino year was occurred in 1997-1998, 2001-2002 and 2006-2007. In 1997-1998, from October 1997 until March 1998, deviation of rainfall was decreased 14 percent compared with the previous wet season. The decreasing of 15 % in deviation of rainfall was also measured in 2001-2002. The higher deviation, 28 percent decrease of rainfall was observed in 2006-2007. In sub round rainfall, sub round 3 from September-December was used as an indicator to analyze, since the start of both rainy season and planting season are October. The highest decrease was found in 1997 with 65.7 percent.

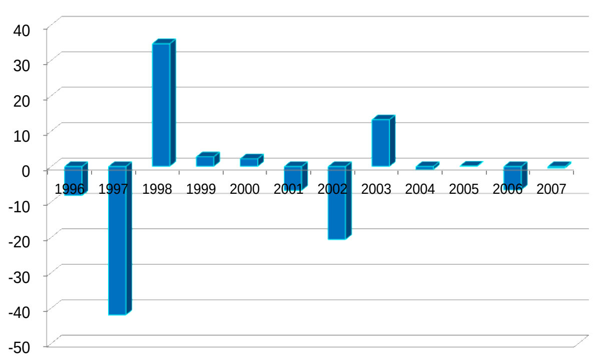


Figure 2. Deviation of annual accumulative rainfall from 1996 to 2007

2) *Crops production*

Annual analysis in wetland paddy was shown that effects of El Nino in wetland paddy were occurred in 1997 and 2002 (Fig. 3). This finding was 'strange'as on the basis of rainfall decrease, in 2006 was affected by El Nino year, on the other hand, by comparing with the previous year, wet land paddy production was decreased in 2007. Wetland paddy in Gunung Kidul mainly was produced in irrigated north area. In sub round analysis, it is reveals that El Nino in 2006 affected in wetland paddy in 2007 as production was decreased 1.5 percent. Compared with actual production data in sub round III, production of wetland paddy in 2007 was increased from the previous year. It is indicated that rainfall was delayed from the normal season. Peak of rainfall season also moved as it influenced harvesting season moving to sub round II (May-Augustus).

Annual and sub round analysis in rain-fed dry land paddy was shown that production of dry land paddy was stable; effect of El Nino was not significant.

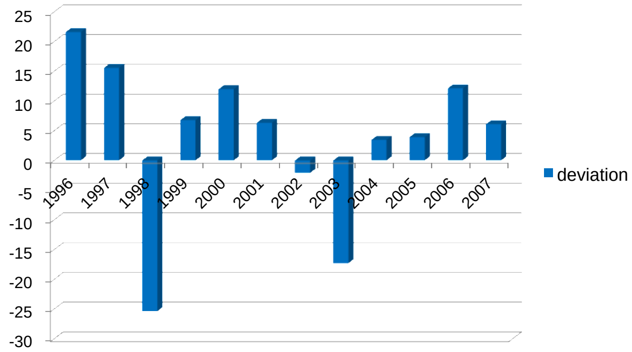
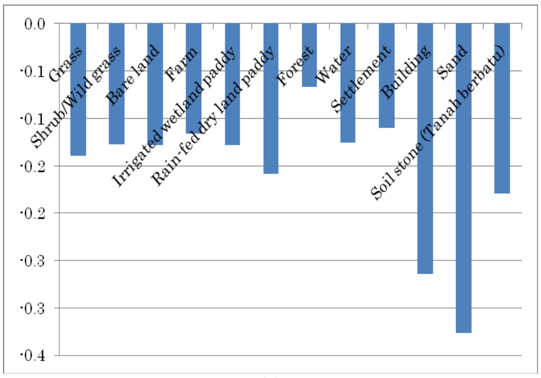


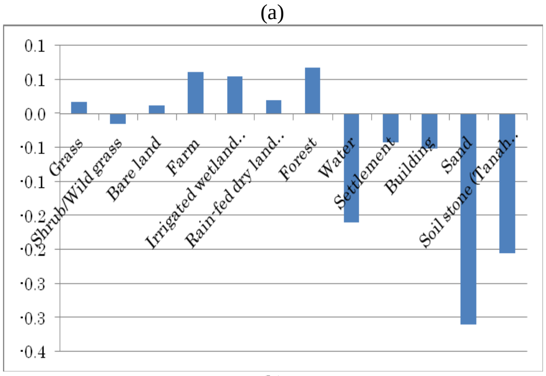
Figure 3. Deviation of crops production from 1996 to 2007

B. *Analysis of Normalized Difference Vegetation Index (NDVI) Based on El Nino Year and Normal year*

NDVI in El Nino year shows that that all vegetation in landuse was under zero or negative in October 2006 (Fig. 4). It was indicated that no agricultural activities in that month. This finding was proved as severe drought was occurred in October. Consequently, planting season was not started, based on calendar crop in Indonesia in October, which first month of rainy season, also the starting of planting season. This phenomenon was also confirmed by rainfall and crop water requirement in Gunung Kidul district.



(a)



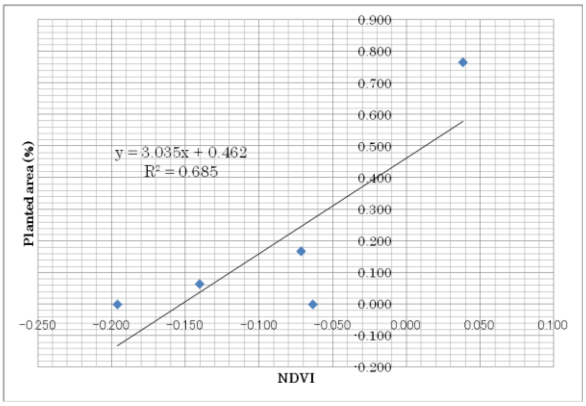
(b)

Figure 4. Observation using sttelite images in October 12, 2006 (a) and October 12, 2004 (b)

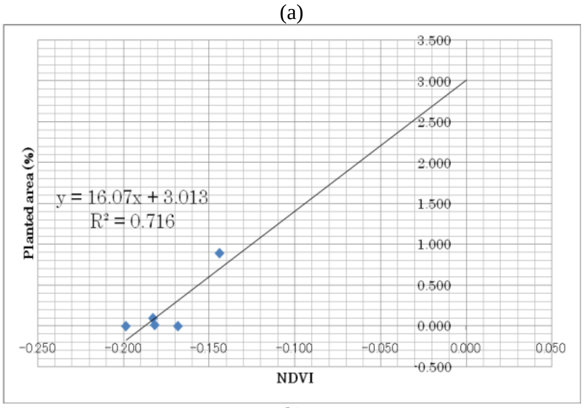
NDVI normal year results a different tendency as many agricultural activities was done in October 12. It was showed from the value of NDVI in many landuse, especially in irrigated wetland paddy and rain-fed dry land paddy. For paddy crop, NDVI can be measured after paddy is reaching 3-4 week. This is due before 3-4 week, paddy field seems puddle [12].

C. Correlation between Mean of NDVI and Percentage of Planted Area from Actual Statistical Data

Percentage of planted area was obtained from statistical data planted area in sub round 3 (September-December) is divided total area. In rain-fed dry land paddy, dry land paddy and palawija crops (maize/corn, soybean, cassava and peanut) were combined. The reasons were in NDVI, it was difficult to differentiate paddy and palawija crops; and in rain-fed dry land paddy, cropping system is intercropping system, which the meaning is the agricultural practice of cultivating two or more crops in the same area at the same time.



(a)



(b)

Figure 5. Correlation between mean of NDVI and statistical data of planted areas; (a) October 12, 2006, and (b) October 12, 2004

Correlation between mean of NDVI in each sub district and percentage of planted area in wetland paddy field in both of year had strong correlation (Fig. 5). Correlation between mean of NDVI and percentage of planted area in wet land paddy field, both of the year, El Nino and normal year was in good correlation, which in El Nino year R^2 = 0.685 and in normal year R^2 = 0.716 and rain-fed dry land crops field, only in El Nino year had good correlation with R^2 = 0.431. About this correlation, it due to cropping pattern in both of land, in wet land paddy field with monoculture, the amount of crop only one crop was planted but in rain-fed dry land crops with intercropping, sometimes in rain-fed dry land crops is double counted in each crop. Also, in rain-fed dry land crops is depend on water sufficiency in the land, if enough of water, the correlation is not good because intercropping was done as usual.

V. Conclusion

In this study, El Nino was occurred in 1997, 2002 and 2006. It was indicated by negative index of Southern Oscillation Index (SOI) during six months in 1997, 2002 and 2006. The other indicator in effects of El Nino was the decrease in rainfall and crops production. Compared with deviation of rainfall in 2002 and 2006, the highest deviation of rainfall was -42% measured in 1997. In upland region, which mostly dependent in rainfall, decrease of rainfall will influence crops production. In wetland paddy, decrease of production was -25% and -17% occurred in 1998 and 2003, respectively. In both years, the decrease of production was due El Nino effect in the previous year, 1997 and 2002. In Normal Difference Vegetation Index (NDVI) analysis, mean of NDVI in Gunung Kidul district was negative or under zero in El Nino year (2006). It was indicated that planting season in Gunung Kidul district was started in October 2004. Correlation between mean of NDVI and percentage of planted area in wetland paddy field, both of the year, El Nino and normal year was in good correlation, which in El Nino year R^2 = 0.685 and in normal year R^2 = 0.716 and rain-fed dry land crops field, only in El Nino year had good correlation with R^2 = 0.431. About this correlation, cropping pattern in wetland paddy field with monoculture, the amount of crop only one crop was planted but in rain-fed dry land crops field with multiple cropping, sometimes in rain-fed dry land crops field is double counted in each crop.

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