AFITA 2010
International Conference
The Quality Information for Competitive Agricultural Based Production System and Commerce

IPB International Convention Center (IICC), Baranangsiang, Bogor - Indonesia
October 4 - 7, 2010

Organized by:
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Published by:

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Assessment of Agricultural Production in Dry Season in Nganjuk District, East Java, Indonesia

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Abstract—Grain production in dry season is important for regional sustainable development; however water shortage in dry season is problem in Nganjuk district. Therefore, groundwater is conjunctively used for irrigation with surface irrigation in the dry season. Objective of this paper is spatial assessment of agricultural production using GIS. GIS and remote sensing were used to analysis land use and irrigation wells density. Land use analysis was conducted to identify cultivated area in second dry season. Surface irrigation analysis conducted to get actual surface water supply in second dry season. The irrigation well density and utilization of groundwater for irrigation in second dry season was analyzed. The result shows land use was stable condition from 1999 until 2009 in second dry season. Agricultural production in Mrican-Kiri block was supported by water supply from surface irrigation. Agricultural production in other blocks was supported by conjunctive use of groundwater with surface irrigation, where Kuncir-Bodor block was enough water supply; Widas block was enough water supply but potentially water shortage was occur; and Ketandan-Tretes block was occurring of water shortage.

Keywords: GIS, agricultural production, land use, irrigation well density

I. INTRODUCTION

Grain production in dry season is still important for regional sustainable development in Indonesia. Java is the main production area for grain in Indonesia, where 53 percent of paddy and 55 percent of corn from each total production are produced [5]. In the long term from environmental perspective, agriculture in Java must be conserved for sustainable food security in Indonesia. For that purpose, improvements in land use and water management are needed.

The Nganjuk District lies in a climatic regime characterized by the annual progress of rainy and dry seasons, and receives roughly 80% of precipitation within the 5 to 6 months of the rainy season (December-May). Nganjuk area has flat area in central and eastern of Nganjuk with altitude ranging from 35 to 100 m above sea level. Mountains area is located at southern and northern area.

The Brantas river basin has been one of the most productive and advanced granaries in Indonesia [10].

Nearly 84,000 ha within 387,100 ha on Brantas River basin is irrigated by the Brantas River while the rest is served from its tributaries [8]. There has been a dramatic transformation from low intensity agriculture to high intensity agriculture within the basin nowadays. Cropping intensity increased from around 0.8 in 1960 to 2.2 crops per year by 2000, while the area cultivated increased from 247,000 ha to the current 387,100 ha due to improvements in rice variety, increased agricultural inputs, and reliable water supply in the dry season [1].

Nganjuk District lies in Brantas basin at Widas sub-basin. In Nganjuk area, there are 3 planting season, wet season (WS, November-February), first dry season (DS1, March-June), and second dry season (DS2, July-October). Paddy
fields are cultivated in WS and DS1. Sugar cane cultivated in WS, DS1, and DS2. Secondary crops (corn, soybean, red onion, chilies, melons and vegetables) are cultivated in DS1 and DS2.

There are three main sub-basins in Nganjuk area, Widas, Kuncir, and Bodor sub-basins. Kedungsoke River is for Kuncir and Bodor, sub-basins, Widas River is for Widas sub-basin and those rivers were merged into Brantas River. In Nganjuk area, there are two main surface irrigation systems, Widas block and Mrican-Kiri block. The Widas block has irrigation command area in north western area of Nganjuk (around 8,832 ha). The Mrican-Kiri block has irrigation command area in south eastern area of Nganjuk (around 12,570 ha). In Widas block a reservoir is constructed in west of Nganjuk, and in Mrican-Kiri block, irrigation water is uptake from Brantas River (Mrican barrage). The surface irrigation system in Nganjuk area can supply irrigation water in DS1, however, it is not enough to supply water in DS2. Therefore, groundwater is used for conjunctive irrigation with surface irrigation in the DS2.

An objectives of this paper is spatial assessment of agricultural production in second dry season. Especially, land use and irrigation wells density was analyzed by GIS to get spatial distribution.

II. METHODS

A. Land Use Analysis

The classification was concern to the irrigated area which was cultivated in DS2. NDVI analysis was conducted for LANDSAT series data from 1972 to 2009 in DS2.

B. Irrigation Wells Density Analysis

Irrigation well density (IWD) was generated from number of wells at agricultural field areas in each village. Criteria of IWD based on the radius influent of well in the research area. Radius influent of well in these research areas are varied at 118-348 m [6].

C. Irrigation Data

Irrigation intake was obtained from surface irrigation data in 2009. Average irrigation intake data was collected from four blocks in Nganjuk District. Water supply in DS2 (September 2009) was analyzed to confirm conjunctive use of groundwater.

D. Overlay Analysis

Overlay analysis was used to get the actual utilization of irrigation well in DS2. Irrigation well density (IWD) map was overlay with land use map to get the actual utilization of irrigation well or pumps to support agricultural production in DS2.

III. RESULTS AND DISCUSSIONS

A. Land Use

Vegetation NDVI typically ranges from 0.1 up to 0.7 [9], with higher index values associated with greater density and greenness of the plant canopy. Based on NDVI values, cultivated area in DS2 was increasing around 12% from 26.8% in 1972 to 38.8% in 1982. In the last decade, cultivated area was increasing around 30-40%, varied 71.0-86.3% area was cultivated. Widas, Ketandan-Tretes, and Kuncir-Bodor blocks were increased more than 10, 6, and 5 times, respectively. Mrican-Kiri block was increased around 1.6 times (Table 1 and Figure 2).

<p>| Table I. NDVI Value of Landsat in Irrigated Area in DS2 |</p>
<table>
<thead>
<tr>
<th>No</th>
<th>Year</th>
<th>NDVI &gt; 0.1 (% of area)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Widas</td>
</tr>
<tr>
<td>1</td>
<td>Sep 27, 1972</td>
<td>1.6</td>
</tr>
<tr>
<td>2</td>
<td>Sep 11, 1982</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>Sep 7, 1999</td>
<td>12.6</td>
</tr>
<tr>
<td>4</td>
<td>Sep 9, 2000</td>
<td>17.3</td>
</tr>
<tr>
<td>5</td>
<td>Sep 28, 2001</td>
<td>13.9</td>
</tr>
<tr>
<td>6</td>
<td>Oct 1, 2002</td>
<td>11.2</td>
</tr>
<tr>
<td>7</td>
<td>Aug 1, 2003</td>
<td>21.6</td>
</tr>
<tr>
<td>8</td>
<td>Sep 4, 2004</td>
<td>17.4</td>
</tr>
<tr>
<td>9</td>
<td>Aug 22, 2005</td>
<td>23.7</td>
</tr>
<tr>
<td>10</td>
<td>Sep 10, 2006</td>
<td>17.0</td>
</tr>
<tr>
<td>11</td>
<td>Aug 28, 2007</td>
<td>20.0</td>
</tr>
<tr>
<td>12</td>
<td>Sep 15, 2008</td>
<td>12.1</td>
</tr>
<tr>
<td>13</td>
<td>Sep 18, 2009</td>
<td>17.2</td>
</tr>
</tbody>
</table>

1.6 times (Table 1 and Figure 2).

| Table II. Percentage of Cultivated Area per Season |
| Irrigation Block | Widas | Ketandan-Tretes | Kuncir-Bodor | Mrican-Kiri |
| Paddy           | WS    | DS1             | DS2          |             |
|                | 90    | 38              | 6            |             |
| Sugar Cane      | WS    | DS1             | DS2          |             |
|                | 3     | 3               | 3            | 5           |
| Secondary Crop  | WS    | DS1             | DS2          |             |
|                | 6     | 58              | 64           |             |

Source: RTTG 2006/2007, Nganjuk Irrigation service
Cultivated area was stable in WS and DS1 in whole irrigation blocks. 100% of irrigation blocks area was cultivated in WS and DS1 (Table 2). Paddy was predominant in WS (86-95% cultivated area). Paddy and secondary crop was predominant DS1, 38-69% and 28-58% cultivated area was paddy and secondary crop, respectively.

Land use was stable condition of land use change from 1999 until nowadays. Secondary crop was cultivated in almost cultivated area in DS2 (63-95% cultivated area). Paddy was cultivated 1-6% cultivated area in Widas and Kuncir-Bodor blocks. Sugar cane was cultivated 3-14% cultivated area in all irrigation blocks (Table 2).

Cropping intensity actual based on Central Bureau of Statistics of Nganjuk District 2007 and cropping intensity based on Global Annual Planting Plan (RTTG) 2006/2007 almost same is around 2.83 crops per year. Based on LANDSAT data 1999-2009, cropping intensity in DS2 is around 0.71-0.85 crop per season.

Agricultural production has same meaning with cropping intensity. The agricultural production was dramatically increased during 20 years. In 1991, average cropping intensity was 2.31 crops per years [3], and in the last 10 years was increased and stable at 2.8 crops per years.

Rice production was 414 metric ton per year with productivity around 5.8 ton per hectare and harvested area was 71,893 hectare. Corn production was 204 metric ton per year with productivity around 5.8 ton per hectare and harvested area was 35,144 hectare. Soybean production was 17 metric ton per year with productivity around 1.7 ton per hectare and harvested area was 10,091 hectare[4].

Nganjuk is one of central of vegetable crops, especially red onion. The production of that plant in 2008 was 86 metric ton. Total harvested area of red onions commodity in Nganjuk was around 6,000 ha per year or 25% of total East Java or 6% of total Indonesia (Table 3). Total harvested area of onions was 5% of total harvested area of Nganjuk District per year (113,192 ha). The percentage is not so high, but mostly onions commodity was cultivated at DS1 or DS2.

### B. Irrigation Well Density Analysis

The number of well were varied from 0 to 606 wells per village and total number of well in Nganjuk is 15,475 wells. The IWD was varied 0-3 wells/ha. High exploitation (IWD >0.5 well/ha) has conducted in 79 villages. These villages are mostly located at Kuncir-Bodor block (Figure 3). Medium exploitation (0.05 < IWD ≤ 0.5 well/ha) has conducted in 120 villages and mostly located at Widas and Mrican-Kiri blocks. Low exploitation (IWD < 0.05 well/ha) has conducted in 47 villages.

The number of well in Kuncir-Bodor block was highest

![Figure 2. NDVI of irrigation block area in DS2 in 1972, 1982, and 2009](image)

### Table III. Production of Onion (in Metric Hectare and Metric Ton)

<table>
<thead>
<tr>
<th>Location</th>
<th>2001 Total area</th>
<th>2001 Production</th>
<th>2002 Total area</th>
<th>2002 Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>82.2</td>
<td>861.2</td>
<td>88.4</td>
<td>772.1</td>
</tr>
<tr>
<td>Java</td>
<td>62.5</td>
<td>665.0</td>
<td>67.2</td>
<td>596.3</td>
</tr>
<tr>
<td>East Java*</td>
<td>24.6</td>
<td>na</td>
<td>22.8</td>
<td>na</td>
</tr>
<tr>
<td>Nganjuk*</td>
<td>5.8</td>
<td>na</td>
<td>6.1</td>
<td>na</td>
</tr>
</tbody>
</table>

Source: BPS and Province Agricultural Service, East Java

![Figure 3. Map of distribution of irrigation well density (IWD)](image)
C. Surface Irrigation

Based on data 2009, Mrican-Kiri, Widas, Kuncir-Bodor, and Ketandan-Tretes blocks was supply surface irrigation water around 7,390, 842, 300, and 0 l/s, respectively. Based on LANDSAT 2009, cultivated area in Mrican-Kiri, Widas, Kuncir-Bodor, and Ketandan-Tretes blocks was supplied irrigation water around 4.7, 1.1, 0.3, and 0 mm/d, respectively (Table 5).

Mrican-Kiri block was supply enough surface water in DS2. Widas block was supply little bit surface water and not enough for normally plant growth. Kuncir-Bodor was supply very small surface water and Ketandan-Tretes was not supply surface water in DS2.

D. Groundwater Utilization to Increase Agricultural Production

The Widas River is one of the three major tributaries of the Brantas River and the large flatland lying between the Widas and the Brantas functioned as a retarding basin for years. Central and eastern of Nganjuk is located at the lowland of Solo Zone. The lowland in Solo Zone in Nganjuk area is alluvial plain formed by Widas River and Brantas River. Based on hydrogeology map [7], these area has good aquifer with medium and high productivity and has high specific capacity (>172.8 m$^3$/d).

Water uses from groundwater until today not considered in the water resource planning. However almost farmer uses groundwater if the surface water (irrigation water) was insufficient in DS1 and DS2, that is groundwater is used for conjunctive irrigation with surface irrigation in the DS1 and DS2. The extraction of groundwater was using pumps. The irrigation well density (IWD) in Table 4 shows Kuncir-Bodor block had highest density (0.76 well/ha) and Ketandan-Tretes block had lowest density (0.08 well/ha). The IWD where related with water pumps was estimated by agricultural area and number of irrigation wells. However, IWD in Mrican-Kiri block was not related, because surface water was enough for a year. Irrigation wells in Mrican-Kiri block is only used in occasional condition such as water allocation not well doing.

Based on overlay of IWD and land use in dry season, six class of farm area was classified (Figure 4). Cultivated and IWD >0.05 well/ha has 63% of farm area field. 86% of Mrican-Kiri block and 88% of Kuncir-Bodor block was cultivated with IWD >0.05 well/ha. These blocks have highest agricultural production. If refer to Table 5, Mrican-Kiri block was enough surface water, so the IWD was not related with agricultural production in this block. However, IWD in Kuncir-Bodor block was related with agricultural production because need more water supply from groundwater in DS2. Agricultural productivity in both blocks was almost same in WS, DS1, and DS2.

Water shortage was potentially occur in cultivated area with low IWD, especially in Ketandan-Tretes block caused no water supply in this area in DS2. 25% of Widas block was uncultivated and has IWD >0.05 well/ha. This area was already harvested in August and red onion was predominant. Agricultural productivity in DS2 in these blocks was lower than another blocks caused of water shortage.

IV. CONCLUSIONS

Land use and well density analysis is needed to get spatial evident in wide area to know actual cultivated area in DS2 within irrigation wells. Agricultural production in Mrican-Kiri block was supported by water supply from surface irrigation. Agricultural production in other blocks was supported by conjunctive use of groundwater with surface irrigation, where Kuncir-Bodor block was enough water supply; Widas block was enough water supply but potentially water shortage was occur; and Ketandan-Tretes block was occurring of water shortage.

REFERENCES