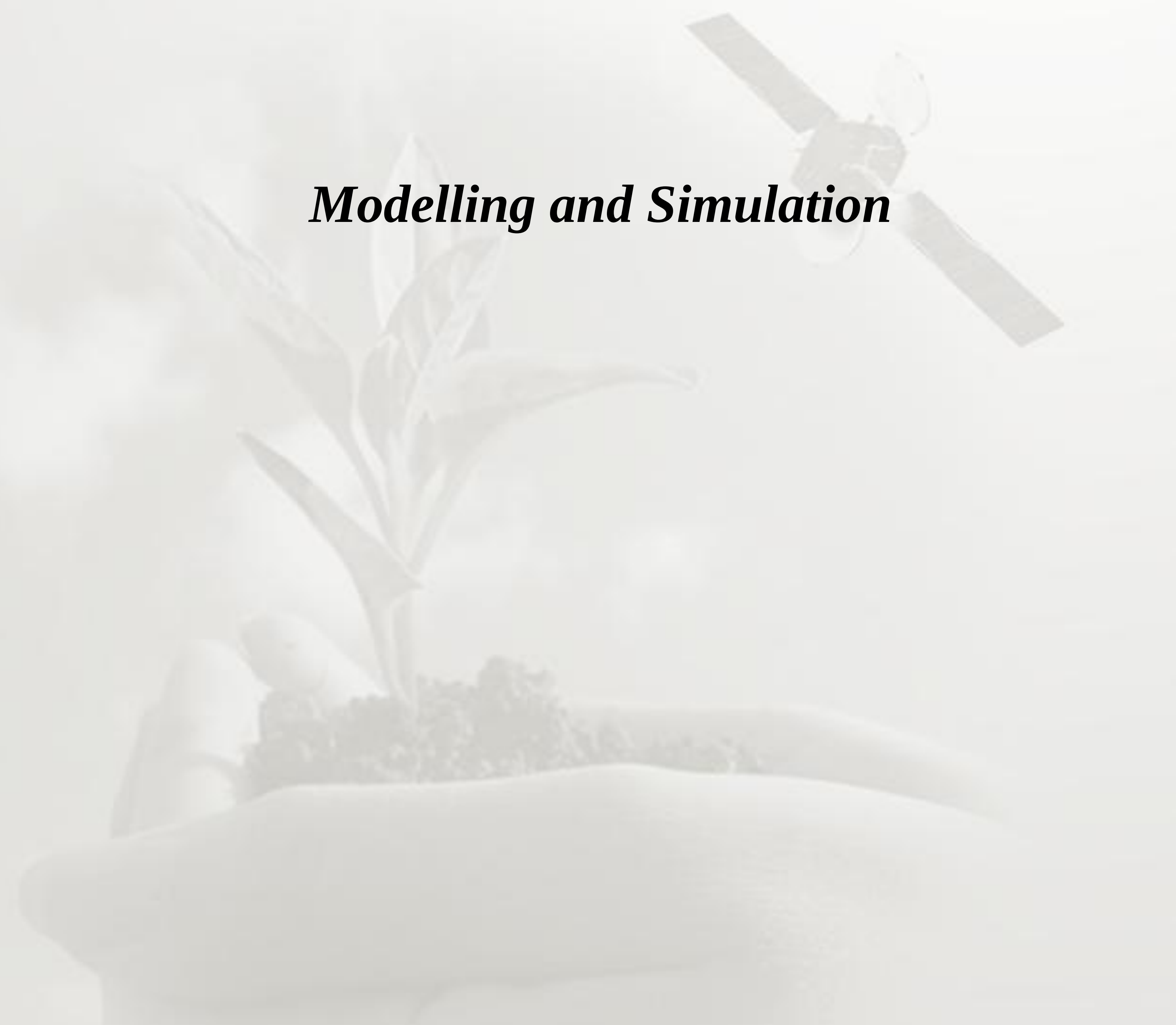
Modelling and Simulation



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].

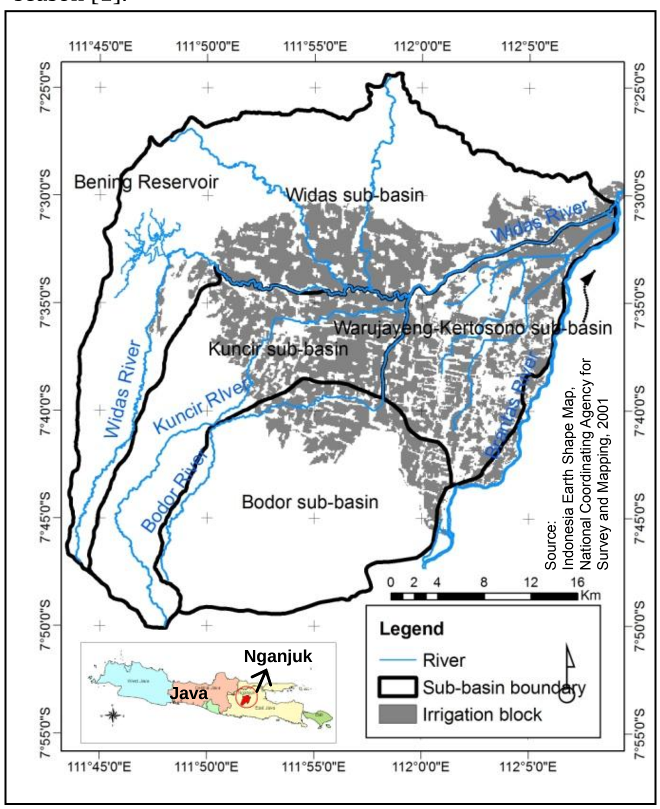

Figure 1. Widas Basin

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. Kedungsoko 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 conjunction 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 DISSCUSSIONS

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).

TABLE I. NDVI VALUE OF LANDSAT IN IRRIGATED AREA IN DS2

No	**Year**	**NDVI > 0.1 (% of area)**				
		Widas	**Mrican Kiri**	**Kuncir-Bodor**	**Ketandan-Tretes**	**Total**
1	Sep 27, 1972	1.6	20.2	4.1	0.8	26.8
2	Sep 11, 1982	1.2	26.5	9.7	1.4	38.8
3	Sep 7, 1999	12.6	34.9	23.9	5.1	76.5
4	Sep 9, 2000	17.3	36.2	24.4	7.8	85.7
5	Sep 28, 2001	13.9	34.6	23.0	6.4	77.8
6	Oct 1, 2002	11.2	34.8	21.6	3.4	71.0
7	Aug 1, 2003	21.6	27.5	17.5	7.9	74.5
8	Sep 4, 2004	17.4	31.9	25.2	6.7	81.2
9	Aug 22, 2005	23.7	31.7	22.9	7.9	86.3
10	Sep 10, 2006	17.0	33.1	24.9	7.1	82.1
11	Aug 28, 2007	20.0	33.1	24.3	7.6	84.9
12	Sep 15, 2008	12.1	34.2	23.1	7.0	76.4
13	Sep 18,2009	17.2	33.6	25.0	9.0	84.8

TABLE II. PERCENTAGE OF CULTIVATED AREA PER SEASON

Irrigation Block		Widas	Ketandan-Tretes	Kuncir-Bodor	Mrican-Kiri
Paddy	WS	90	86	95	95
	DS1	38	44	69	64
	DS2	6	0	1	0
Sugar Cane	WS	3	14	3	5
	DS1	3	14	3	5
	DS2	3	14	3	5
Secondary Crop	WS	6	0	3	0
	DS1	58	42	28	30
	DS2	64	63	74	95

Source: RTTG 2006/2007, Nganjuk Irrigation service

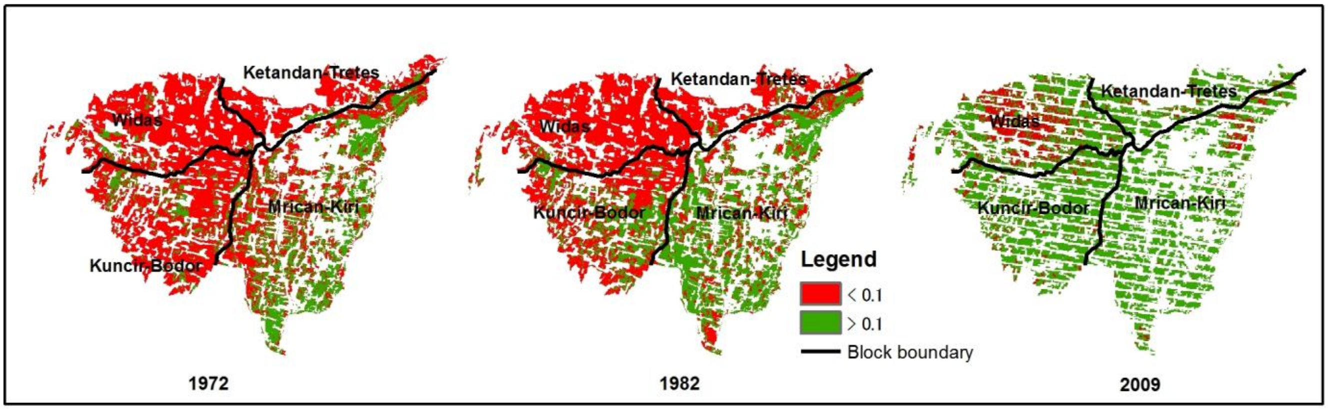

Figure 2. NDVI of irrigation block area in DS2 in 1972, 1982, and 2009

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 nowdays. 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.

TABLE III. PRODUCTION OF ONION (IN METRIC HECTARE AND METRIC TON)

Location	2001		2002	
	Total area	Total Production	Total area	Total Production
Indonesia	82.2	861.2	88.4	772.1
Java	62.5	665.0	67.2	596.3
East Java*	24.6	na	22.8	na
Nganjuk*	5.8	na	6.1	na

Source: BPS and Province Agricultural Service, East Java

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

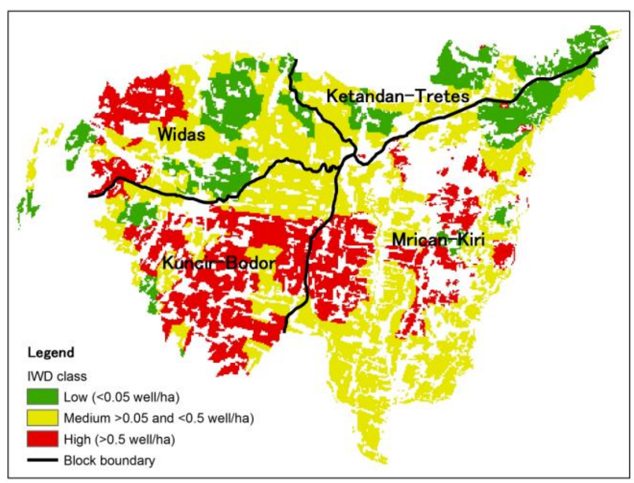

Figure 3. Map of distribution of irrigation well density (IWD)

(7,677 wells) and in Ketandan-Tretes block was lowest (346 wells) with average IWD 0.76 and 0.08 well/ha, respectively. The IWD has correlation with groundwater exploit, however, depend on the surface water supply in DS2.

TABLE IV. NUMBER OF WELL AND IWD PER IRRIGATION BLOCK

Irrigation Block	Area (ha)	Number of well (wells)	Range & (average) of IWD (well/ha)
Widas	9,889	2,005	0 – 1.05 (0.20)
Mrican-Kiri	14,608	5,447	0 – 2.83 (0.37)
Kuncir-Bodor	10,151	7,677	0 – 2.99 (0.76)
Ketandan-Tretes	4,131	346	0 – 3.36 (0.08)

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.

TABLE V. SURFACE WATER SUPPLY IN SEPTEMBER 2009 PER IRRIGATION BLOCK

Irrigation block	Uncultivated area (ha)	Cultivated area (ha)	Surface irrigation supply	
			l/s	mm
Mrican-Kiri	959	13,635	7,390	4.7
Widas	3,523	6,348	842	1.1
Kuncir-Bodor	815	9,351	300	0.3
Ketandan-Tretes	413	3,486	0	0.0

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^2/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 field area. 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.

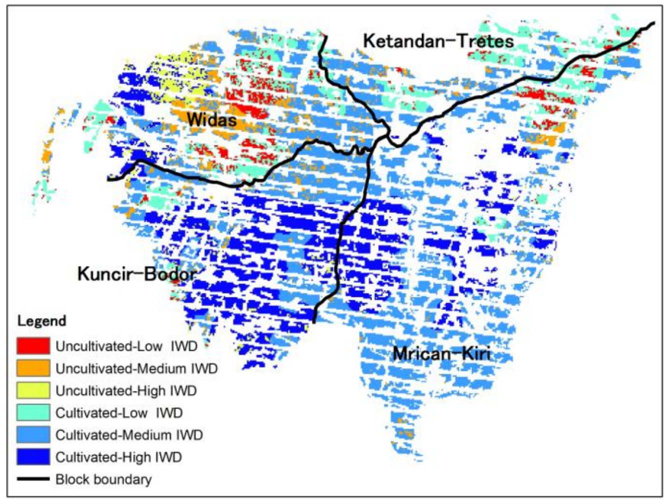

Figure 4. Overlay map of land use and irrigation well density (IWD)

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.

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