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IDENTIFY CROPPING PATTERNS OF CIHEA IRRIGATION AREA IN CIANJUR REGENCY WEST JAVA USING MODIS IMAGE DATA

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ABSTRACT

To improve the efficiency of irrigation water use and support increased food production, and in an effort to break the life cycle of Plant Disturbing Organism (PDO), it is necessary to adjust cropping patterns. Nowadays, monitoring and data collection on cropping patterns and paddy cultivation calendar can be done by applying remote sensing technology using satellite imagery and aerial imagery, for example, the Moderate Resolution Imaging Spectroradiometer (MODIS) image has a resolution of 250 meters. The purpose of this study was to identify cropping patterns of Cihea Irrigation Area in Cianjur Regency, West Java Province using MODIS imagery data for 2008 - 2018. The results showed in the Cihea Irrigation Area in Cianjur Regency, there are three growing seasons in one cultivation calendar year with a cropping pattern of twice paddy and one secondary crop (*palawija*) or mixed (paddy-*palawija*). The accuracy of the determination of crop types based on the analysis of NDVI data on MODIS imagery in first season (GS 1), second season (GS 2), and GS 3 were 80%, 80%, and 70% respectively.

Keywords: cropping pattern, irrigation area, MODIS, NDVI.

INTRODUCTION

Irrigation area is a unit of land that gets water from an irrigation network. In irrigated areas, irrigation water distribution problems often occur if the amount of available water is smaller than the water needs in the field (especially during the dry season), therefore an efficient water use is very much needed. To improve the efficiency of irrigation water use and support increased food production, and in an effort to break the life cycle of Plant Disturbing Organism (PDO), it is necessary to adjust cropping patterns.

Applying the right cropping pattern is a way to support the realization of food security through precision agriculture. Nowadays, monitoring and data collection on cropping patterns and paddy cultivation calendar making can be done by applying remote sensing technology by detecting the phenology (stages of growth) of paddy for wide area coverage, fast time periods, and accurate results [1]. Remote sensing currently used for monitoring is using satellite imagery and aerial imagery. The obtained image is an image with low to high spatial resolution, for example, the Moderate Resolution Imaging Spectroradiometer (MODIS) image has a resolution of 250 meters [2].

MODIS can benefit by providing measurement in moderate spatial resolution, global, almost daily measurements, optimized for vegetation monitoring. These data are publicly available at no cost and offer the potential to detect and monitor the distribution of inter-global rice farming on a global and regional scale [3]. Multitemporal MODIS data can be used to develop vegetation indices such as NDVI, EVI, and LSWI that are sensitive to vegetation biomass and the water content of vegetation [4].

Vegetation index formulation value commonly used is the Normalized Difference Vegetation Index (NDVI). The values of NDVI range from -1 to 1. Values -1 to 0 indicate the presence of non-vegetation objects, while values from> 0 to 1 indicate vegetation object. The index of values listed in NDVI determines how much influence of the vegetation cover, or not vegetation, as well as the potential distribution characteristics of an area. The higher the NDVI value, the more crop is in the ready-to-harvest phase, conversely the lower the value, the more unproductive the plant (fallow season) [5].

Monitoring of cropping patterns with MODIS has been done by many researchers. Studi [6] discussed the dynamics of changes in paddy land using MODIS imagery in the area of Java Island. The results of these studies can show the estimation of paddycropping patterns from 2001 to 2007 with an accuracy value of 71.11%. Studi [7] conducted a mapping of agricultural land, cropping patterns and distribution of crop types using MODIS NDVI time-series data in Mato Grosso, Brazil. The results of his research show that the proposed approach can effectively map agricultural land, cropping patterns, and crop types. The accuracy is 90%, 73% and 86% respectively.

The Cihea Irrigation Area is located in Cianjur Regency, West Java, with an area of paddy fields administratively reaching 5,484 hectares. The Cihea Irrigation Area in Cianjur Regency receives water from two rivers, i.e., the Cisokan River and the Ciranjang River. The cropping pattern of the Cihea Irrigation Area is determined by the local government based on the Decree of the Cianjur Regent. So far, the determination of cropping patterns in Cihea Irrigation Area is based on the availability of river discharge and rainfall in the local area.

Climate change causes a longer dry season and decreases rainfall, shorter duration of the rainy season and increased rainfall. Changes in rainfall also have an impact on river discharges where peak river discharges are greater than the estimated discharge based on statistics and plan discharges are smaller than the dependable discharge calculation. Climate change causes very complex changes in water resources and the utilization of water resources, especially irrigation.

To improve the efficiency of irrigation water use, it is necessary to determine the right cropping pattern. The purpose of this study was to identify cropping patterns of Cihea Irrigation Area in Cianjur Regency, West Java Province using MODIS imagery data for 2008 - 2018.

RESEARCH METHODS

The material used in this research is secondary data, e.g., MODIS MOD13Q1 imagery (1-2 days Temporal, with 250 m resolution, data availability every 16 days, MODIS h28v09 locations from 2008 to 2018 totalling 253 images) and paddy field maps of Cihea Irrigation Area, Cianjur Regency, West Java Province. The types and sources of data used in the study are presented in Table-1. Supporting tools and software used for data processing are quantum GIS and MODIS Reprojection Tools (MRT).

Table-1. Types and sources of data used in research.

No	Data Type	Data Extraction	Data Source
1	MODIS satellite images, h28v09, 253 imagesin 2008-2018	Extracted *hdf* file extension (taking NDVI values) and converted to *tif*	Website USGS
2	land cover RBI map 25k of Cihea irrigation area, Cianjur Regency	The process of clipping the *tif* extension file by *shp* file of paddy field area	Geospatial Information Agency

The research on cropping pattern analysis was carried out in several stages:1) the data collection stage, 2) the pre-processing stage of MODIS imagery, 3) the stage of MODIS imagery analysis, 4) the identifying stage of cropping patterns.

A. Data Collection

MODIS imagery data collected by downloading the MODIS satellite imagery at www.earthexplorer.usgs.gov and land cover RBI map 25k of Cihea Irrigation Area, Cianjur District from the Geospatial Information Agency (BIG) website in the *shp* format to do clipping on the paddy fields area. The MODIS imagery used in this study has a MOD13Q1 code which means it is able to identify vegetation index with temporal data of 1-2 days and spatial resolution of 250 meters. In this study, 16-day intervals were used.

B. Pre-Processing of MODIS Imagery

The MODIS image that has been downloaded then processed in an initial correction process for the NDVI values of the MOD13Q1 Image, with the steps shown in Figure-1.

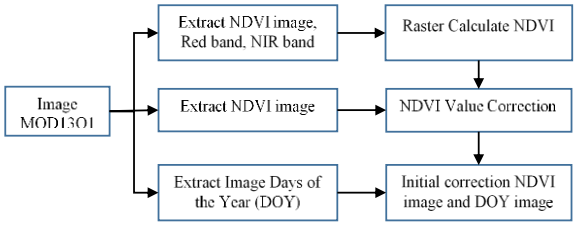

Figure-1. Stages of initial correction MODIS image values.

Processing stages:

a) Extract NDVI image, Red band, NIR band, and Days of the Years image from MOD13Q1 Citra with MODISTools.exe application.
b) Initial correction of NDVI image values by comparing the NDVI value of the Image of the Raster Calculate and the initial NDVI image, resulting in the initial correction NDVI value (the result is the same, only different multiplier factors. Initial NDVI Image Value: (-2000) - 10000 and the NDVI value of the Raster Calculate: (-1) - 1).

NDVI values for each MODIS image obtained are corrected by applying the formula as in equation 1.

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}} \quad (1)$$

Where ρ_{nir} and ρ_{red} are the surface reflectance of the NIR and red canal respectively.

C. MODIS Images Analysis

The MODIS image analysis stage is to identify cropping patterns in Cihea as presented in Figure 2. At this stage, paddy fields in the Cihea irrigation area on the RBI map were clipped. The results of the RBI map clipping are used to determine the MODIS pixels used as data samples. From the clipping process, a paddy field in Cihea irrigation area, Cianjur regency is produced.It can be seen in Figure 3 and Figure-4.

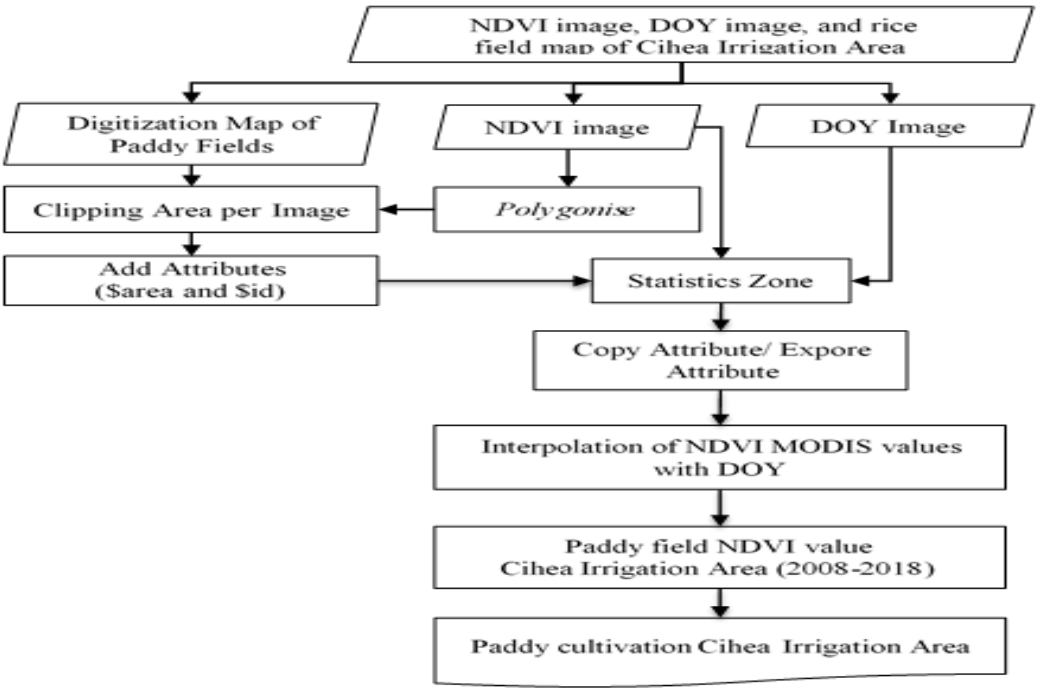

Figure-2. Flow chart of cropping patterns analysis with MODIS imagery.

Digitizing the land is making the area plot shape (Polygonal) following the pixel MODIS shape used for zonal statistics. Digitizing the land serves to limit the area taken by NDVI values on the MODIS raster image. Digitizing paddy fields used are digits paddy field plot that only contains more than 50% -100% in MODIS pixels. Sample sizes with less than 50% of the paddy field plot area were not used. This aims to prevent error values that are too large because the size of the MODIS image's spatial resolution is larger than the size of the paddy field plot.

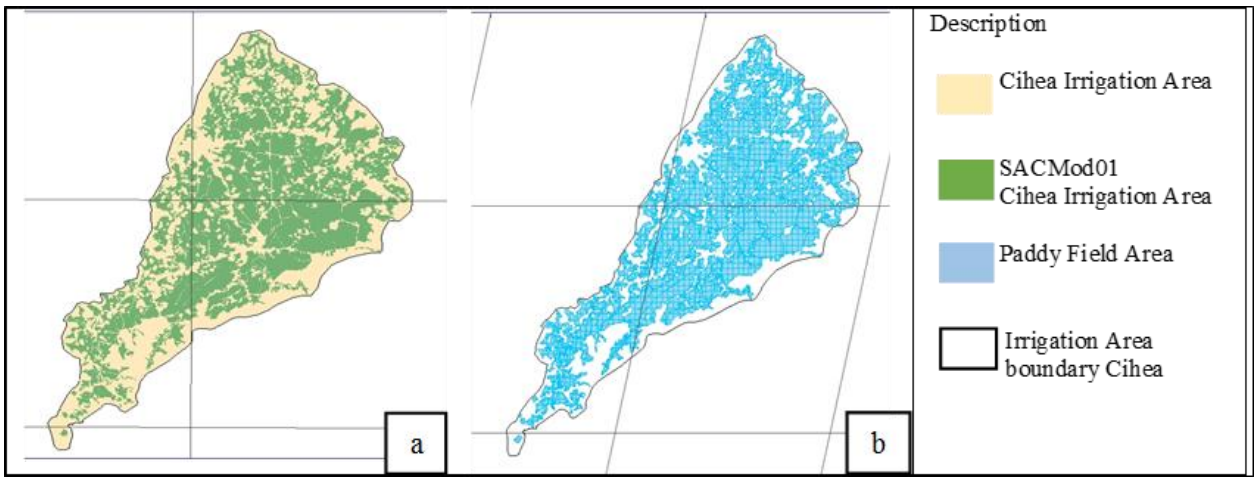

Figure-3. Clipping of paddy fields area in Cihea irrigation area; (a) before, and (b) after.

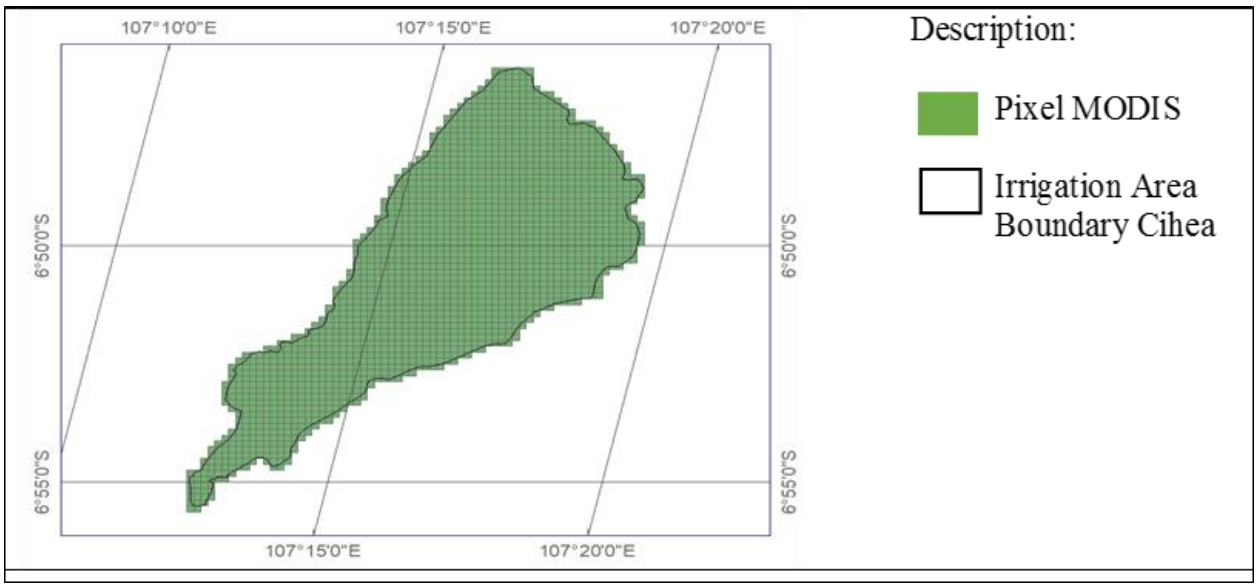

Figure-4. Digitization of paddy fields area in Cihea irrigation area in MODIS pixels.

D. Verification of the Cropping Pattern Determination Method in Cihea Irrigation Area

Cropping patterns generated from MODIS satellite imagery data were verified with historical cropping patterns in Cihea irrigation area, Cianjur regency. Therefore, the accuracy of the method of cropping patterns analysis with MODIS imagery can be known. The verification of cropping patterns is conducted by comparing cropping patterns obtained through research based on analysis of NDVI values 2008-2018 with realization cropping data in Cihea irrigation area, Cianjur Regency in 2008-2018 based on productivity reports and water-sharing balance of the Cihea Irrigation Area by the PSDAP Office of Cianjur Regency.

RESULTS AND DISCUSSIONS

Cihea Irrigation Area is the oldest technical irrigation in Indonesia, which was built by the Dutch government from 1879 to 1904 and began functioning in 1914. Geographically and administratively, Cihea Irrigation Area is a plain area located in two sub-districts, i.e., Bojongpincung and Ciranjang in Cianjur regency, West Java with an area of paddy fields of 5,484 ha. The irrigation area consists of 3,292 ha of paddy fields which irrigated from the Ciruru / Cisokan weir with water sources from the Cisokan River, and 2,192 ha of paddy fields irrigated from Ciranjang Weir with water sources from the Ciranjang River, with a total water withdrawal capacity of 7,000 liter/second.

Water Distribution in Cihea is divided into three groups and serves 28 Villages from 3 districts, i.e., Group I at BojongPicung sub-district covering 1,863 ha, Group II at Haurwangi sub-district covering 1,852 ha and Group III at Ciranjang sub-district covering 1,769 ha. The cropping pattern and plan of Cihea irrigation areas are determined by the decision of the Regent of Cianjur, where the beginning of the cultivation season starts during the rainy season. The Cihea irrigation area cultivation season is planned three times in one calendar year, taking into account the period of the rainy season, the dry season, and the drying time of the irrigation area.

The standard size of the Cihea Irrigation Area administratively is 5,484 hectares, but the spatial paddy field area based on Geospatial Information Agency (BIG) data is 5,134 ha. An area difference occurred between the tabular data of paddy fields and the spatial analysis of the existing 350 hectares of paddy fields. The difference in data is related to the conversion of paddy fields to non-paddy fields. For the analysis of cropping patterns, the area of paddy field analyzed was 4,355 ha, i.e., paddy fields with more than 50% pixels of MODIS. Sample sizes with less than 50% of the plot area were not used. This aims to prevent error values that are too large because the size of the MODIS image's spatial resolution is larger than the size of the paddy field. The cropping patterns of Cihea irrigation area from 2008-2018 were analyzed annually in the cropping calendar. Example the results of the analysis of the patterns of each period are shown in Figure-5 to Figure-7.

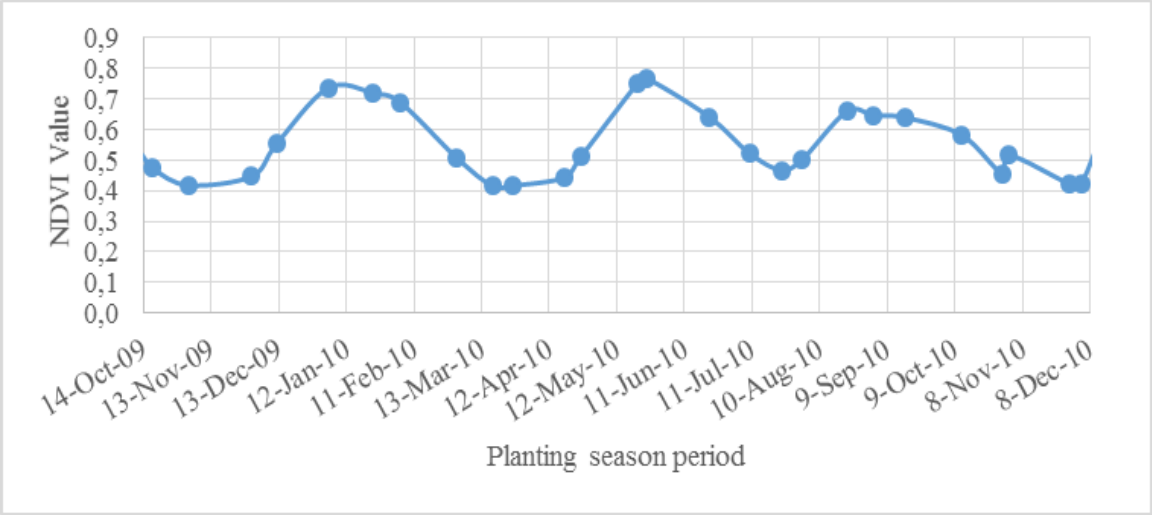

Figure-5. Cropping patterns in Cihea irrigation area for the period 2008-2009.

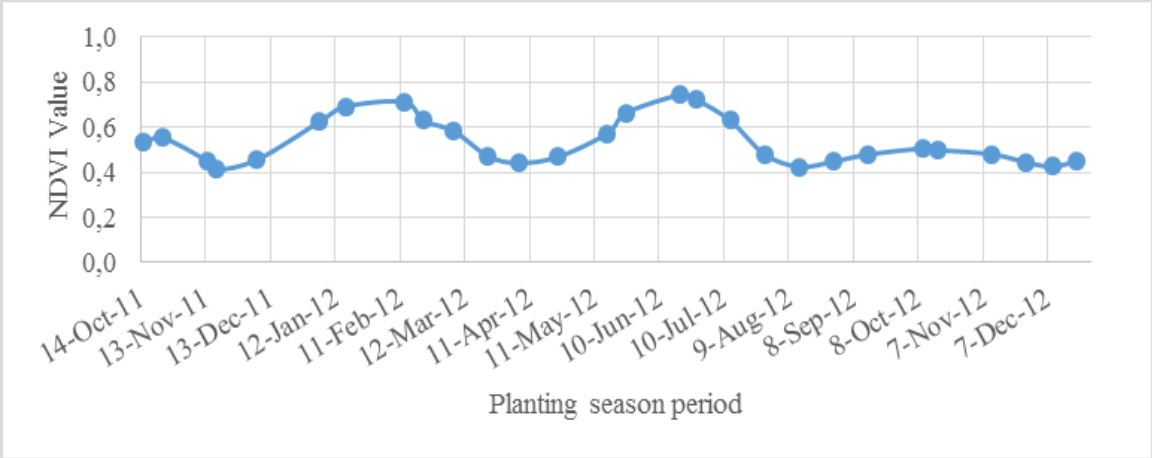

Figure-6. Cropping patterns in Cihea irrigation area for the period 2011-2012.

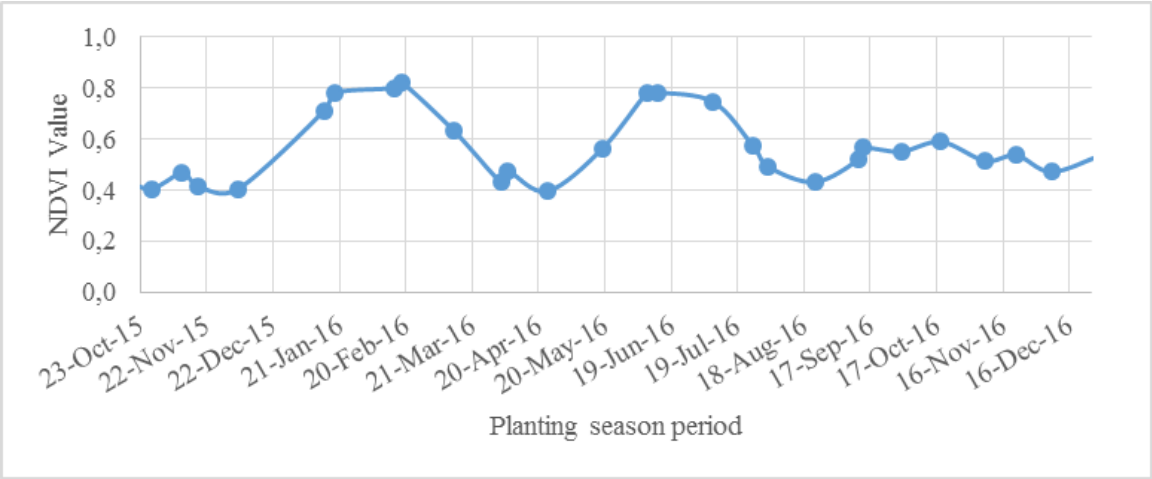

Figure-7. Cropping patterns in Cihea irrigation area for the period 2015-2016.

Based on Figure-5 to Figure-7, it can be seen that in Cihea irrigation area, there are three growing seasons (GS) in one cropping calendar year. The determination of crop species in one growing season is based on NDVI values and the number of 16-day composite data dates. The peak value of NDVI of paddy> 0.7, palawija (secondary crops) <0.6, while mixed crops 0.6-0.7. The peak value of NDVI of paddy in this study is similar with the results of [8], where the peak NDVI value of paddy was 0.736, which was in the vegetative phase when the

paddy was 4-6 weeks old. The number of 16-day composite data dates for paddy is 7 or 8 times, assuming the cultivation period for lowland paddy ranges from 105-120 days. Whereas for crops (soybeans) around 6 or 7 times, assuming the soybean cultivation period ranges from 100-110 days. Graph interpretation of NDVI values on cropping patterns in Cihea is presented in Table-2.

Table-2. Cropping patterns in Cihea irrigation area in 2008-2018 based on NDVI values.

Year	NDVI Peak Value			Cropping Pattern		
	GS 1	GS 1	GS 1	GS 1	GS 1	GS 1
2008-2009	**0.7325**	**0.7649**	**0.5641**	**paddy**	**paddy**	**palawija**
2009-2010	0.7371	0.7686	0.6594	paddy	paddy	mixed
2010-2011	0.7887	0.6979	0.5548	paddy	mixed	palawija
2011-2012	0.7127	0.7448	0.5063	paddy	paddy	palawija
2012-2013	0.7383	0.7753	0.6104	paddy	paddy	mixed
2013-2014	0.6591	0.7260	0.5315	mixed	paddy	palawija
2014-2015	0.7415	0.7265	0.4670	paddy	paddy	palawija
2015-2016	0.8239	0.7834	0.5898	paddy	paddy	palawija
2016-2017	0.5804	0.6023	0.6649	palawija	mixed	mixed
2017-2018	0.7371	0.7439	0.5438	paddy	paddy	palawija

Based on NDVI values and the number of 16-day composite data dates, there are three groups of cultivation in Cihea irrigation area, i.e., paddy, palawija (secondary crops), and mixed (paddy-palawija). On the graph of the cropping calendar season, 70% of the cropping patterns in Cihea analyzed were twice the paddy cultivation season and once the cultivation season of palawija or mixed crops (paddy and palawija). The beginning of the cultivation season based on the results of NDVI analysis in Cihea irrigation area is presented in Table-3.

Table-3. Beginning of season of the Cihea irrigation area in 2008-2018 based on NDVI scores.

Year	Beginning of season		
	GS 1	GS 1	GS 1
2008-2009	**November I**	**March II**	**July I**
2009-2010	November I	March II	July II
2010-2011	November I	April I	July I
2011-2012	November I	March II	July I
2012-2013	November I	March II	August I
2013-2014	December I	February II	June II
2014-2015	November I	March II	June II
2015-2016	November I	March II	June II
2016-2017	November I	February II	August I
2017-2018	November II	March II	August I

In Table-3, it can be seen based on the results of the analysis of the NDVI value of initial cultivation per period of the non-permanent cropping calendar. The beginning of cultivation season GS 1 (paddy) was dominated in November I, GS 2 (paddy) was dominated in March II, while the initial cultivation of GS 3 (palawija) was more varied on June II, July 1, and August I. In this period, the value NDVI in paddy fields decreases and then rises again after paddy is cultivated.

The Cihea Irrigation Area is included in the irrigation area of the Ciranjang service branch which is managed directly by the Central Government. In the global cropping plan of Cihea irrigation area based on the Decree of the Regent of Cianjur, it always stipulates three growing seasons in one year cropping calendar with the beginning of the cultivation season in the rainy season, and with the general cropping pattern being paddy, paddy

and palawija. Data on cropping patterns for realization in Cihea are presented in Table-4.

Table-4. Realization data of cropping patterns in Cihea irrigation area, Cianjur Regency.

Year	Cropping pattern			Beginning of season		
	GS 1	GS 2	GS 3	GS 1	GS 1	GS 1
2008-2009	paddy	paddy	palawija	November I	March II	July I
2009-2010	paddy	paddy	mixed	November I	March II	July I
2010-2011	paddy	paddy	mixed	November I	March II	July I
2011-2012	paddy	paddy	palawija	November I	March II	July I
2012-2013	paddy	paddy	palawija	November I	March II	June II
2013-2014	paddy	paddy	palawija	November I	February II	June II
2014-2015	paddy	paddy	palawija	November I	March II	June II
2015-2016	paddy	paddy	palawija	November I	March II	June II
2016-2017	paddy	paddy	mixed	November I	March I	August I
2017-2018	paddy	paddy	Mixed	November I	March II	August I

In the cropping plan, the cropping pattern in Cihea is paddy-paddy-palawija. However, based on the data from Table-4, from 2008-2018 in GS 1 and GS 2 of Cihea irrigation area, the types of the crop were always paddy, but in GS 3 the crops were palawija and mixed, so that the accuracy of the determination of crop types based on the analysis of NDVI data on MODIS imagery on GS 1 was 80%, GS 2 was 80%, and GS 3 was 70%. While the accuracy of initial cultivation determination based on NDVI values in GS 1, GS 2, and GS 3 is 80%.

Cropping pattern is one of the factors that determine the need for irrigation water. The cropping pattern will give an idea of the type of crop and the cultivation area that will be cultivated within one cropping calendar year. The realization of cropping patterns will not necessarily be the same as the plan. So, monitoring the cropping patterns in a fast time is needed to avoid mistakes in allocating irrigation water. In the application of real-time irrigation, data are needed in a fast time. MODIS is able to present data in a spatial and temporal form for wide-area coverage and fast period of time because MODIS takes measurements every day.

CONCLUSIONS

In the Cihea Irrigation Area in Cianjur Regency, there are three growing seasons in one cultivation calendar year with a cropping pattern of twice paddy and one secondary crop (*palawija*) or mixed (paddy-*palawija*). The accuracy of the determination of crop types based on the analysis of NDVI data on MODIS imagery in first season (GS1), second season (GS 2), and GS 3 were 80%, 80%, and 70% respectively.

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