Spot-5 multispectral image for 60-75 days of rice mapping

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Abstract. The objective of this study is to investigate the potential application of Spot-5 multispectral satellite data in monitoring rice cultivation areas in IADA (Integrated Agriculture Development Area) located at Kerian District, Perak Malaysia. Information of the rice cultivation areas is a global economic and environmental significance. Multi-spectral images acquired at high spatial resolution are an important tool, especially in agricultural applications. This paper addresses the relationship between normalize difference vegetation index (NDVI) and ancillary data acquired from Farmers Organization Authority (PPK) for 217 farmer’s field in IADA Kerian. The results indicated that NDVI range 0.62 - 0.75 has a strong positive relationship with the ground survey area estimation with ($r = 0.85; p <0.01$) ($r^2 = 0.722$). The $r^2$ value of 0.722 indicated a statistically significant linear relationship between the rice area estimate using NDVI range 0.62 - 0.75 and on the ground surveyed data for 217 farmers’ fields. The equation of unstandardized distribution can be described as $\hat{Y}=0.0197+0.852x$. The equation for standardized regression formula for this distribution is $\hat{Y}=0.850x$. Thus, the results indicate that 60-75 days of rice area can be estimated from the following equation $\hat{Y}=0.0197+0.852x$, where $\hat{Y}$ is the predicted rice area and $x$ is area calculated using NDVI range 0.62-0.75 in IADA Kerian Perak Malaysia. The results appear promising and rice mapping operations using SPOT-5 multispectral image data can be foreseen.

1. Introduction
Rice (Oryza Sativa L.) attains second place among cereal crop, both for acreage and production in the world. Rice forms the economic, cultural and nutritional basis for many countries, making this crop’s successful annual production of key significance to the world community. Recent projections made by the International Rice Research Institute (1998) show that demand for rice will increase by about 1.8% per year until 2025 [1]. Malaysia has experienced, in recent years, achieving self-sufficiency in rice production at about 65% -70% of the local consumption. Since Malaysia does not have the comparative advantage in rice production, it implements a wide range of market interventions to achieve the intended level of rice production [2]. In Malaysia, Granary areas refer to major irrigation scheme which is the area is greater than 4,000 hectares and recognized by the Government in the National Agricultural Policy as the main paddy producing areas. There are 8 Granary areas in Malaysia, namely MADA, KADA, IADA Kerian, IADA Barat Laut Selangor, IADA Pulau Pinang, IADA Seberang Perak, IADA Ketara and IADA Kemasin Semerak [17].

The main season is the period when the paddy is grown without depending wholly on any irrigation system. For administrative purpose, the main season is defined as the commencement date of paddy.
planting between 1st August to 28/29 February of the following year. Off season is the dry period and paddy planting normally depends upon the irrigation system. For administrative purposes, Off season is defined as the commencement date of paddy planting between 1st March to 31st July of the year. The definition of paddy planting is sowing for direct seeding system and transplanting for nursery system. The definition of a paddy parcel is a piece of land, which is usually used for planting Paddy meanwhile planted paddy area is a portion or might be full of the paddy parcel. The planted rice area in Malaysia was reduced by 9.34% from 680,650 ha in 1990 decrease to 617,028 ha in 2011 [16].

Remote sensing has long been recognized as a useful tool for acquiring rice information. Leaf pigments, particularly chlorophyll, absorb mainly the blue and red portions of the incoming solar energy spectrum, which can result in very low canopy reflectance in the visible region. Increase reflectance in the near infrared (NIR) region is related to increased crop biomass and leaf area Index (LAI) [3]. Thus, changes in canopy reflectance spectrum in the visible and near infrared regions should be associated with crop yield and area estimation [4]. Normalized difference vegetation index (NDVI), can reflect the growth of crops, and it has difference between difference crops in different phenology period [5]. The objective of this study is to investigate the potential application of Spot-5 multispectral satellite data in monitoring rice cultivation areas in IADA (Integrated Agriculture Development Area) located at Kerian District, Perak Malaysia.

2. Previous studies

In the recent years, many methods have been developed and applied in rice mapping. Some studies have used optical remote sensing data, such as the NOAA Advanced Very High Resolution Radiometer (AVHRR), Landsat Thematic Mapper (TM) data and SPOT data to identify paddy rice fields. Some studies use NDVI data derived from optical remote sensing data to analyze and develop an algorithm for mapping paddy rice fields such as previous research by [6]. A number of studies have shown that vegetation index (VI) can be used as an indicator of the status of vegetation and crops. There are many vegetation indices such as NDVI, EVI (enhanced vegetation index) and SAVI (soil–adjusted vegetation index), which have been used to discriminate crops and monitor crop growth conditions. Among these vegetation indices, the NDVI is the most widely used VI and other indices are its refined form. There is a consensus that NDVI can be used as an effective measure of photosynthetically active biomass and chlorophyll activity of vegetation and crop.

The optical multispectral image has been used as an ancillary data for rice parameter retrieval. In a previous research by [7], NDVI range 0.6152, 0.6748, 0.6852, 0.7102 and 0.7322 have been found as an average parameter for rice mapping in the middle of Jiangsu, Province China. However, studies by [6] found that the pixel with greater value than 0.65 in NDVI can be identified as 60 – 75 days of rice in Guangdong Province, China. Like most other crops, planting date varies among the rice fields. Mapping rice fields are a fundamental step for growth monitoring and yield prediction. The rice calendar is significantly affected by temperature differences due to latitude [1].

The originally normalized difference vegetation index (NDVI) is an effective vegetation measure since it is sufficiently stable to permit meaningful comparisons between seasonal and inter annual changes in vegetation growth and activity. This is because it can reduce different forms of multiplicative noise (illumination differences, cloud shadows, atmospheric attenuation and certain topographic variations) [8].

Traditionally, rice growth monitoring methods based on field checking are still used for collection or rice paddy production information. However, the result is that accuracy of the collected data is in doubt and limited in local scale, particularly that concerning planted or harvested area [7]. This research aims to perform further analysis to see the relationship between NDVI range > 0.62 and the rice age 60-75 days on the ground and also the number of NPK fertilizer use by rice farmers in every rice parcel.
2.1. NPK fertilizer

Different rates of Nitrogen (N), phosphorus (P) and potassium (K) (NPK), in intensive rice monoculture do have the effect of healthiest rice growth. Soil and fertilizer management is very complex and dynamic in nature. Fertilizer recommendation for crops in a cropping pattern needs change over a certain period of time. With the advancement of technology and with a progress fertility and fertilizer management research in the country, there has been a continuous need for updating the Fertilizer Recommendation guide. The application of fertilizer in a proper amounts must be done to boost up agricultural production to an economically describe level [9].

The result of mean data of two years showed that paddy yield, increase in yield, number of grains per panicle, 1000 grain weight, gross return (GR), value cost ratio (VCR) and a grain nutrient ratio (GNR) were significantly influenced by different NPK levels [9]. Improved management of nitrogen (N) in low fertile soil is critical for increased land productivity and economic sustainability [10].

It is known that fertilization is crucial for maintaining soil available nutrient levels, because fertilization ensure the largely constant presence of active microorganisms and the regular dynamic of biomass carbon [11]. The increase in plant height, number of tillers per hill, spikelet number per panicle, grain yield and 1000-grain weight in response to the application of organic and chemical fertilizers is probably due to enhanced availability of nutrients. The variation in plant height due to nutrient sources was considered to be due to variation in the availability of nutrients [12].

In a previous previous research by [12] have found that using 1.5 ton/ha organic fertilizer treatments along with 50% recommended chemical fertilizer like NPK could give a similar yield of rice. From the economic point of view farmers can use the combination of organic fertilizer and reduce the rate of inorganic fertilizers to boost the yield of rice as well as maintain and improve soil health.

To sustain food security, the land-scarce Asian countries would need to increase fertilizer intake to over 250 kg of NPK/ha by the year 2020 from the present level of less than 100kg/ha [13]. The increase in demand for fertilizer is, however, constrained by the efficiency of nutrient uptake of the crop, unstable supply of soil moisture, the risk of investments due to fluctuation in yield from climatic variations, and fertilizer-grain price ratio. The intensity fertilizer-use is higher for modern varieties of cereals compared to traditional ones, on irrigated farming compared to the rain-fed, and on well-drained land with medium elevation than on lands that are subjected to droughts and floods.

3. Methodology

Rice mapping with such imagery is often challenging where paddy rice grows in a warm, humid season with frequent cloud cover and heavy precipitation. Although cloud-free optical imagery could be more easily acquired in the dry season, the complicated farming practices make it less optimal in rice mapping [14]. In this research, statistical regression and correlation analysis were chosen, both area estimation for 217 farmer’s fields, using threshold expert knowledge classification NDVI range > 0.62 and on the ground area estimation for rice age 60-75 days, also a number of NPK fertilizer (17:3:25:2MgO) use by farmers were used to evaluate their relationship in rice mapping. Statistical software SPSS v21 was used in this study.

3.1. Study area

The study area is located at Kerian district in Perak, Malaysia approximately (5° 2′20.86″N 100°34′0.71″E, 5° 2′18.79″N 100°42′13.96″E, 4°55′35.32″N 100°42′12.09″E, 4°55′39.83″N 100°34′8.02″E). It is one of the rice growing areas in the state. Its local government is Majlis Daerah Kerian or Kerian District Council, which is based at Parit Buntar. From the 2010 population and housing census, Kerian has a population of 173,625.

The major town is Parit Buntar, which is located near the border of Penang and Kedah States. Other towns in Kerian are Bagan Serai, Kuala Kurau, Kamula Sarji and Tanjung Piandang. Sungai
Kerian is the major river flowing through this district. The majority of the people here are Malays, with a sizeable population of Banjar People. Integrated Agriculture Development Area (IADA Kerian) has 25 Sections. In this study, we will focus on 217 farmer’s field at Kerian Section 2 which is reported planted by rice age 60-75 days of rice age during 05/06/2012.

3.2. Existing cadastral maps
This includes the existing 217 farmer’s field cadastral maps for extracting information on land parcel and their boundaries. These maps were requested from department survey and mapping to analyze with image analysis and integrate with ancillary data from farmers organization authority.

3.3. Remote sensing (RS) imagery
This includes the existing 217 farmer’s field cadastral maps for extracting information on land parcel and their boundaries. The NDVI is the best indication factor for vegetation cover and grow stage. Traditional study mainly introduces vegetation index, especially normalize different vegetation index (NDVI) to extract, rice from remote sensing image [15]. There is a consensus that the NDVI can be used as an effective measure of photosynthetically active biomass and chlorophyll activity of vegetation and crop. In addition to serving as an indication of the “greenness” of the vegetation, the NDVI is also able to offer valuable information on the dynamic changes of crop groups. The principle of applying NDVI in crop mapping is that the crop is highly reflective in the near infrared and highly absorbed in the visible green. The contrast between these channels can be used as an indicator of the status of vegetation and crop. Consider the other vegetation indices has different calculation based on certain crop and soil conditions, the NDVI and soil conditions, the NDVI is employed to analyze spectral of rice and other crops in the study area. The NDVI can be calculated as follows:

\[
NDVI = \frac{R_{nir} - R_{red}}{R_{nir} + R_{red}}
\]

The equation (1), where \(R_{nir}\) and \(R_{red}\) represent reflectance of near infrared and red bands, respectively, which correspond to one and two bands for multispectral SPOT-5 level 1A 5/6/2012 images for Kerian district in Perak Malaysia. Before transplanting, NDVI has low values of 0.11 for bare soil. During the transplanting period, rice fields are flooded, which makes the NDVI value decrease to about 0.02 after 10 days after transplanting. After transplanting, the NDVI values increase rapidly with the growth of rice and reaches a peak of 0.73 during the ear differentiation period about 63 days after transplanting. The NDVI values decrease after the holding period with decrease in water content and photosynthesis activities. After harvesting, rice field turned into bare soil with an NDVI value of 0.09. For other ground types, the NDVI of water and fish pond varied little over the whole period with values about –0.43 and -0.26 because of the absorption in the near infrared [6].

3.4. Rice field mapping algorithm
SPOT-5 multispectral high resolution visible level 1A data at study area has been requested from Malaysian Remote Sensing Agency with radiometric and geometric correction. The key to mapping rice fields is to find proper remote sensing data combinations. The above NDVI profiles can suggest that the NDVI can be used as a possible factor to discriminate rice fields from other ground types in the study area though their unique genealogy and dynamic profiles of NDVI. Based on the above analysis, an algorithm for mapping rice fields was proposed as follows.

(i) First, SPOT-5 HRV multispectral images are processed for removing cloudy areas, if the study areas infected with cloud cover. There are some cloud removal methods which have been used for TM, MODIS and SPOT Images.

(ii) The mask is made to exclude water areas and fish pond with NDVI values below 0 in the NDVI images.
(iii) Other ground types are detected and excluded using masks with the NDVI values more than 0.0 – 0.62
(iv) The pixels with a value greater than 0.62 in the images are identified as rice fields.

Remote Sensing can help predict the 60-75 days of rice field area by using the NDVI images integrated with cadastral data of this study area. This is by means, all of the rice field area can be integrated with cadastral information and thus information on every pixel classification in NDVI can help discriminate rice with other ground types. In this study, the result of the NDVI value > 0.62 will be classified as rice field and will then be intersected and clip with the cadastral and thus can be extracted to calculate the geometry of the rice granary area in the cadastral. Threshold and expert knowledge classification for rice age 60-75 days were then having performed using threshold and expert knowledge classification. At last, accuracy assessment will then be performed using statistical correlation and regression analysis with on the ground data surveyed by the farmers organization authority.

![Diagram](image)

**Figure 1.** Rice field mapping algorithm.
4. Results and discussion

![SPOT-5 image acquired 05/06/2012  3:1:2  band combination.](image)

The offer of high spectral and high spatial resolution images has grown in the last decade. It is now possible to obtain data from different sources with different spatial and spectral resolution. In this study SPOT-5 image acquired from the Malaysian remote sensing agency. This data product name is level 1A and the acquisition date is 5/6/2012. The Sun Azimuth degrees is 46.34 Sun Elevation degrees is 63.61 and off-nadir degrees is 24.64. Wavelength (NM) is contained in this data is near infrared is 780-890, Red is 610-680, green is 500-590 and short wave Infrared is 1580-1750 nm. The pixel size is 3.627173 x 3.627173 meters as confirmed with Envi version 5 software in pixel information.
Figure 3. NDVI image.

The NDVI is the best indication factor for vegetation cover and grow stage. Traditional study mainly introduces vegetation index, especially normalize different vegetation index (NDVI) to extract, rice from remote sensing image [15]. Reflectance of near infrared and red bands, respectively, which correspond to one and two bands for multispectral SPOT-5 level 1A 5/6/2012 images for Kerian district in Perak Malaysia.
Figure 4. Rice age 60-75 days / non-rice map.

A good quality image of the study area has been developed using threshold and expert knowledge classification in NDVI images. Rice field age 60-75 days were categorized as (0.62 – 0.75), Non-Rice is (0-0.62) and Water is (-0.409836 – 0).
A good quality of 217 cadastral shapefile for the study area was acquired from department of survey and mapping. Cadastral shapefile were then overlaid with the NDVI classification image and the raster split tool were performed to split the raster for 217 parcels. The raster split tool is a new Arc Toolbox command implemented by importing a toolbox (.tbx) file into the users’ standard Arc Toolbox. This is accomplished by right clicking on the standard Arc Toolbox and selecting “Add Toolbox”. The purpose of the tool is to automate the process of breaking up large rasters into a small pieces which may be desired such as countries, watershed, etc. and allowing the multiple output rasters to be named according to an attribute in the split shapefile. Without automation this process can be quite time-consuming and tedious. After this process 217 split raster classification was then calculated for the number of rice pixel which is valued 0.62 - 0.75 to calculate the hectares of rice in every parcel. Statistical analysis was then being performed using SPSS v21.

4.1. Correlation analysis

Ho: There is no positive relationship between the Rice area estimate using NDVI range 0.62-0.75 for Rice Age 60-75 days and Rice area estimate on the ground of Farmers Organization Authority and Number of NPK Fertilizer use by farmers

Ha: There is a positive relationship between the Rice area estimate using NDVI range 0.62-0.75 for Rice Age 60-75 days Rice area estimate on the ground by Farmers Organization Authority Number of NPK Fertilizer use by farmers
### Correlations

|                        | Rice Planted Area Estimation using NDVI range 0.62-0.75 (Ha) | Rice Planted Area Estimation On The Ground by Farmers Organization Authority (Ha) | Number Of NPK 17:3:25:2MgO Used by Farmers 25Kg/ (Bag) |
|------------------------|-------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------|
| Rice Planted Area Estimation using NDVI range 0.62-0.75 (Ha) | 1 (Pearson Correlation) .850** (Sig. (2-tailed)) | .000 (N) 217 | .000 (N) 217 |
| Rice Planted Area Estimation On The Ground by Farmers Organization Authority (Ha) | .850** (Pearson Correlation) .000 (Sig. (2-tailed)) | 1 (N) 217 | .994** (N) 217 |
| Number Of NPK 17:3:25:2MgO Used by Farmers 25Kg/ (Bag) | .851** (Pearson Correlation) .000 (Sig. (2-tailed)) | .994** (N) 217 | 1 (N) 217 |

**. Correlation is significant at the 0.01 level (2-tailed).

**Figure 6.** Correlation table rice area estimation using NDVI vs rice area estimation on the ground by farmers organization authority.

If \( p > 0.01 \) we fail to reject \( H_0 \). Therefore, the NULL stands and the Ha are rejected. In this case we got \( p < 0.01 \), therefore we reject \( H_0 \) and we accept \( H_a \). There is therefore a strong positive relationship between the Rice area estimate using NDVI range 0.62-0.75 for Rice Age 60-75 days and Rice area estimate on the ground of Farmers Organization Authority and Number of NPK Fertilizer use by farmers 25Kg/Bag/Ha.

#### 4.2. Regression analysis

\( H_0 \): There is no significant relationship between the rice area estimate using NDVI range 0.62 -0.75 for rice age 60-75 days and rice area estimate on the ground by farmers organization authority.

\( H_a \): There is a significant relationship between the rice area estimate using NDVI range 0.62-0.75 for rice Age 60-75 days rice area estimate on the ground by farmers organization authority.
Model summary

| Model | R   | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-----|----------|-------------------|---------------------------|
| 1     | .850$^a$ | .722     | .721              | .23496                    |

a. Predictors: (Constant), Rice planted area estimation using NDVI range 0.62-0.75 (Ha)

Figure 7. Regression model 1.

Coefficients$^a$

| Model | Unstandardized Coefficients | Standardized Coefficients | t   | Sig.  |
|-------|------------------------------|---------------------------|-----|-------|
|       | B               | Std. Error | Beta |       |       |
| I     | (Constant)      | .197       | .032 | 6.107 | .000  |
|       | Rice Planted Area Estimation using NDVI range 0.62-0.75 (Ha) | .852 | .036 | .850 | 23.658 | .000 |

a. Dependent variable: Rice planted area estimation on the ground by farmers organization authority (Ha)

Figure 8. Coefficients model 1.

Figure 9. Scatter plot model 1.
If \( p > 0.05 \) we fail to reject \( H_0 \). Therefore, the NULL stands and the \( H_a \) is rejected. In this case we got \( p < 0.05 \), therefore we reject \( H_0 \) and we accept \( H_a \). Therefore, there is a significant relationship between the Rice area estimate using NDVI range 0.62-0.75 for Rice Age 60-75 days and Rice area estimate on the ground by farmers organization authority.

### 4.3. Regression analysis 2

**Ho:** There is no significant relationship between the Rice area estimate using NDVI range 0.62-0.75 for Rice Age 60-75 days and number of NPK Fertilizer 17:3:25:2 MgO use by rice farmers 25Kg/Ha  

**Ha:** There is a significant relationship between the Rice area estimate using NDVI range 0.62-0.75 for Rice Age 60-75 days and number of NPK Fertilizer 17:3:25:2 MgO use by rice farmers 25Kg/Ha  

#### Model Summary

| Model | \( R \) | \( R^2 \) | Adjusted \( R^2 \) | Std. Error of the Estimate |
|-------|---------|---------|-----------------|--------------------------|
| 1     | .851    | .725    | .724            | .23328                   |

a. Predictors: (Constant), Number Of NPK 17:3:25:2MgO Used by Farmers 25Kg/ (Bag)  
b. Dependent variable: Rice planted area estimation using NDVI range 0.62-0.75 (Ha)  

**Figure 10.** Regression model 2.

#### Coefficients

| Model | Unstandardized Coefficients | Standardized Coefficients | t | Sig. |
|-------|----------------------------|---------------------------|---|------|
|       | B | Std. Error | Beta |   |     |
|       |   |  |     |   |     |
| 1     | (Constant) | -0.023 | 0.037 | -.630 | .529 |
|       | Number Of NPK 17:3:25:2MgO Used by Farmers 25Kg/ (Bag) | .142 | .006 | .851 | 23.801 | .000 |

a. Dependent variable: Rice planted area estimation using NDVI range 0.62-0.75 (Ha)  

**Figure 11.** Coefficients model 2.
If \( p > 0.05 \) we fail to reject \( H_0 \). Therefore, the NULL stands and the \( H_a \) is rejected. In this case we got \( p < 0.05 \), therefore we reject \( H_0 \) and we accept \( H_a \). There is therefore a significant relationship between the rice area estimate using NDVI range 0.62-0.75 for Rice Age 60-75 days and the number of NPK fertilizer use by farmers 25Kg / Bag / Ha.

5. Conclusion
Remote Sensing can help predict the 60-75 days of rice field area by using the threshold and expert knowledge classification in NDVI images integrated with cadastral data of this study area. This is by means, all of the rice field area can be integrated with cadastral information and thus information on every parcel and pixel classification in NDVI can help discriminate rice with other ground types.

Traditionally, rice growth monitoring methods based on field checking are still used for collection or rice paddy production information. However, the result is that accuracy of the collected data is in doubt and limited in local scale, particularly that concerning planted or harvested area [7]. Therefore, in this study regression equation can be used to predict the rice area in every rice parcel which is age 60-75 days.

The results indicated that NDVI range 0.62 - 0.75 has a strong positive relationship with the ground survey area estimation with \( r = 0.85; \ p <0.01 \) ( \( r^2 = 0.722 \)). The \( r^2 \) value of 0.722 indicated a statistically significant linear relationship between the rice area estimate using NDVI range 0.62 - 0.75 and on the ground survey data for 217 farmers’s fields.

The equation of unstandardized distribution can be described as \( \hat{Y} = 0.0197 + 0.852x \) (2). The equation for standardized regression formula for this distribution is \( \hat{Y} = 0.850x \) (3). Thus, the results indicate that 60-75 days of rice area can be estimated from the following equation (2), where \( \hat{Y} \) is the predicted rice area and \( x \) is area calculated using NDVI range 0.62-0.75 in IADA Kerian Perak Malaysia.

There is also a significant relationship between the rice area estimate using NDVI range 0.62-0.75 for Rice Age 60-75 days and the number of NPK Fertilizer use by Farmers 25Kg/Bag/ Ha. The result indicated that NDVI range 0.62 – 0.75 has a strong positive relationship with a number of NPK.
fertilizer use by farmers with ($r=0.851; p<0.01$) ($r^2 = 0.725$). The $r^2$ value of 0.725 indicated a statistically linear relationship between the rice area estimate using NDVI range 0.62-0.75 and the number of NPK 17:3:25:2MgO fertilizer use by farmers.

The equation of unstandardarized distribution can be described as $\hat{Y} = -0.23 + 0.142x$ (4). The equation for standardized regression formula for this distribution is $\hat{Y} = 0.851x$ (5). Thus, the results indicate that number of NPK fertilizer 17:3:25:2MgO can be estimated from the following equation (4), where $\hat{Y}$ is the predicted number of NPK Fertilizer use by farmers and $x$ is area calculated using NDVI range 0.62-0.75 in IADA Kerian Perak Malaysia. The results appear promising and rice mapping operations using SPOT-5 multispectral image data can be foreseen.

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