Article

Fertility and ecology assessment of 100 year old rare indigenous spider web shape paddy field in semiarid ecosystem of Flores island using NDVI

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Abstract. Paddy field is an old agriculture practice that very common especially in Asia. The earliest paddy field found dated back to 4330 BC. Most paddy fields in the world are having rectangular shapes. Whereas, in Flores island, indigenous people have developed a spider web or circular paddy field instead of regular rectangular shape and this driven by culture and local wisdom. In here, the objectives of this study are to assess the characteristic, ecology and fertility of circular paddy field compared to common rectangular shape. Fertility values were assessed using Landsat 8 remote sensing with RGB combination of NIR, SWIR 1 and blue. The study site was paddy field within Flores island. The result shows that spider web paddy field appeared in many sizes, number, altitude, ecosystem and terrain. Remote sensing result confirms that the fertility of circular paddy field is similar to the rectangular shape. Likewise, circular field has higher NDVI than rectangular field. Considering semiarid environment, limited labor and resources in Flores island, circular paddy field shape can allow the use of pivot irrigation that more efficient.

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1. Introduction

Rice has long been the main staple of the people in the world nowadays. The original source for the practice of rice cultivation is estimated originated from the Yangtze delta in China. Continuous waves of migrants bearing knowledge of the rice cultivation technique from the China around 2400 years ago has introduced rice to the world (Kiple & Ornelas 2000). Dependency on rice consumption has led to the extensive rice cultivation including managing and development of the paddy field.

Many techniques have been developed to increase paddy field yield including optimization of paddy plot size (Masood et al. 2012), cropping system change (Zeng et al. 2007) and fertilizer uses (Ulluwishewa 2008). Whereas most studies are focusing only on the small management scale rather than spatial scale including the size and shape of paddy field.

Indonesia is one of countries in Asia that has high dependency on rice (Widyantia et al. 2014). While Flores island is one of areas in here that has growing paddy field. This island is different to the other islands in Indonesia due to its semiarid ecosystems and driest climate (Mulyani et al, 2013, Wake et al. 2018). Despite harsh environment, local people in Flores have developed agriculture practices with agricultural land occupies 46.0% of the total land area of 4.73 million ha and this include 89.0% of dry-land agriculture and 11.0% are lowland rice production (Santosa & Sugiyama 2016). In regards to this

situation, this study aims to assess types of paddy field that have been developed by local people in Flores and along with paddy field performance and fertility.

2. Materials and Methods

The assessment of spider web circular paddy field was based on the remote sensing. This included determination of fertility in term of vegetation health and NDVI variables. The study area was the Flores island.

Fertility and health of vegetation

Health status of paddy field in this study was assessed using remote sensing with Landsat8 Band combination and following Kavak et al. (2014). For this study, Landsat 8 scenes covering Flores island areas were selected and particular Landsat 8 bands of NIR, SWIR 1 and blue were opted. Those bands then combined with following sequence of red: NIR, green: SWIR 1 and blue: blue. Healthy vegetation will appear in dark red and orange and less healthy appears in yellow and green.

NDVI

NDVI stands for Normalized Difference Vegetation Index and used to determine vegetation greenness value obtained from the digital signal processing brightness value data (brightness)of some Landsat bands. This NDVI can distinguish the vegetated and non vegetated areas based on its value. The NDVI value is calculated based on the difference between the maximum absorption of radiation in the red band as a result of the pigment chlorophyll and maximum reflectance in the NIR band as a result of the cellular structure of the leaves. The NDVI formulation is as follows (Sukmono & Ardiansyah 2017:

$NDVI = (\rho NIR - \rho Red)/(\rho NIR + \rho Red)$

With ρNIR = reflectance value of NIR band and ρRed = reflectance value of red band

3.Results and Discussion

Cultivation technique includes the design, size and shape of paddy fields have received attention recently. Masood et al. (2012) have succeeded to formulate that 6 m x 12 m rectangular paddy field shape was the optimum shape and size. Islam and Hossain (2017) have observed how the shape of paddy field can influence the efficiency of the farmer to plant the seed. Irregular paddy field can cause inaccessible access for transplanter and increase manual labor to transplant seedlings. Whereas recent studies only discussing the contemporary paddy fields. In contrary to current paddy field research, this study is the first that assess the rare yet unique circular paddy field in term of ecology, performance and fertility.

Figure 1. Spider web circular paddy field locations in 6 sites.

The observation shows that there were spider web (circular shape) paddy field appearances in many sizes, number, altitude, ecosystem and terrain. The circular shape paddy field in Flores island was a result of indigenous knowledge and inherited since Dutch colonialism in 1920. The spider web shape aims to guarantee that each of family members in a community or village got equal portion of cultivation lands. Small family will get the smaller land portion in the middle of circle. Whereas a large land portion located near the perimeter of the circle were belonging to the large family (Sumardi et al 2017).

This study has recorded the occurrence of circular paddy fields in 6 sites (Figure 1). The significant numbers of this paddy field can be seen in site 1 where there were 13 spider web fields covering areas of 107.08 Ha at 947 m above sea level (Figure 2). Eleven fields were in shape of circular shape and the others were in half circle. This area was bordered with hills in east and there was a settlement behind that hill. The rectangular paddy fields were located in south. This cluster was located in the flat terrain at 947 m. By comparing the surrounding geomorphological characters, this flat terrain was used to be a fertile high land valley. In this site, the smallest field has diameter of 176.89 m while diameter for the largest field is 319.66 m.

Use of Landsat 8 band combinations of NIR, SWIR 1 and blue to assess the health of spider web paddy field in this study was comparable to other studies. This combination has been used to assess from the health conditions of vineyard plantations (Kavak et al. 2014) to natural ecosystem (Nahdliyah 2017). According to Kavak et al. (2014), a NIR-SWIR 1-blue band combination can distinguish the healthy vegetation as it shows a color difference. This band combination can also be used to assess the health condition of vegetation tropic. Healthier vegetation was represented in dark red and orange colour and yellow for less healthy vegetation (Nahdliyah 2017).

Figure 2. Site 1 with cluster of 13 spider web paddy fields at 947 m asl. within areas of 107.08 Ha. and with terrain cross section from north west to south east.

Based on the results from Landsat 8 combination, it is apparent that the performance of vegetation in circular and rectangular field shapes is similar (Figure 3.A.). Both paddy fields exhibit dark red and orange color equally at spatial scale. It confirms that the health status of vegetation was on the same level. Some yellow and green colors were observed in the east of the field. This appearance was not related directly to the field. The paddy field in site 1 was bordered by settlement in the east side and this land use has no vegetation covers at all. The presence of this barren land next to the paddy field has led the yellow color appearance as classified by Landsat 8.

Figure 3.B presents the performance of both paddy fields using NDVI values. It is apparent that NDVI of circular shape was higher than the rectangular shape. Both NDVI shows a fluctuation trends following months with July-November period has the lowest value. NDVI peak was observed from February to July. This fluctuation is related to the precipitation pattern that reached its lowest values from April to November in 1 year (Perdinan 2017). NDVI of circular paddy field is comparable to the NDVI from other areas even that have less harsh ecosystems and more water availability (González-Betancourt &

Mayorga-Ruíz 2018). NDVI of paddy fields from rainforest ecosystem was as low as from 0.110 and as high as 0.684. (Sukmono & Ardiansyah 2017). In their research, NDVI was also fluctuated. NDVI values obtained from paddy field under semiarid ecosystem that has similarity with the NDVI of rainforest paddy field indicated water efficiency in circular paddy field.
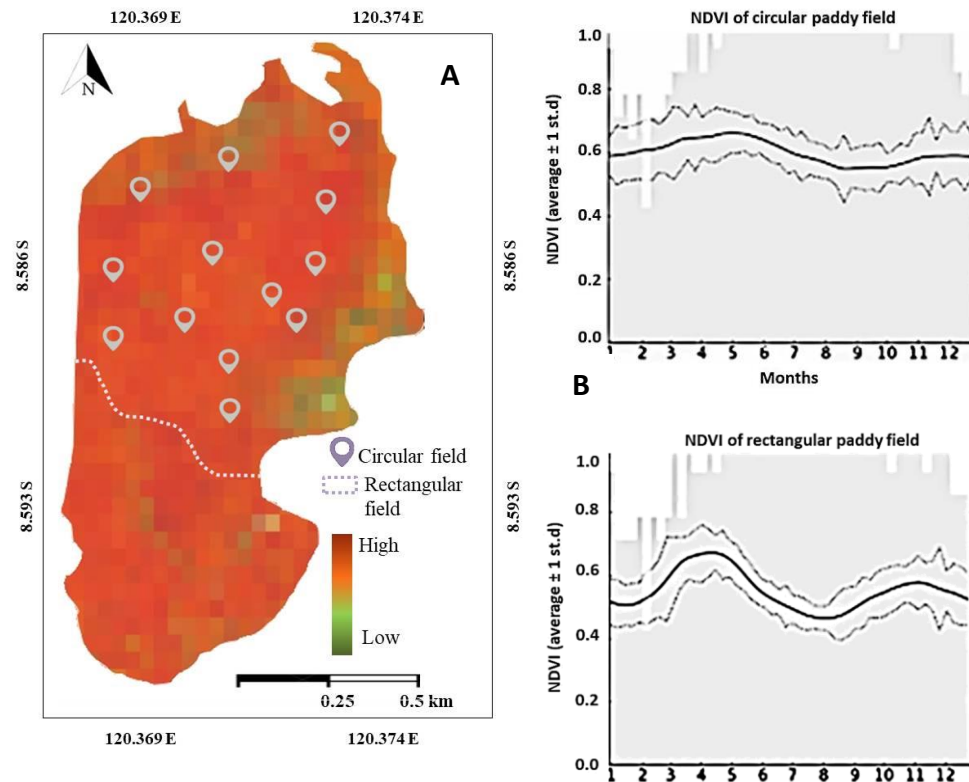

Figure 3.(A) Site 1 with healthy and fertile areas within 13 spider web circular paddy fields (north) and regular rectangular fields (south) based on Landsat 8 RGB combination of NIR, SWIR 1 and blue. (B) NDVI of areas with circular paddy fields (north) and regular rectangular fields (south) in site 1.

Several shapes beside circular spider web were also observed. In some examples, the spider web fields were in the form of half circular shape. This related to the several things. First, the fields were located in the middle of regular circular fields. Since circular fields were managed by contemporary community and not by indigenous community, then it limits the expansion of the spider web fields. This combination of spider web fields and or within the regular rectangular fields can be seen in site 2 (Figure 4.A). An example also can be seen in figure 4.B where a half web field was bordered by rectangular field and intact forest.
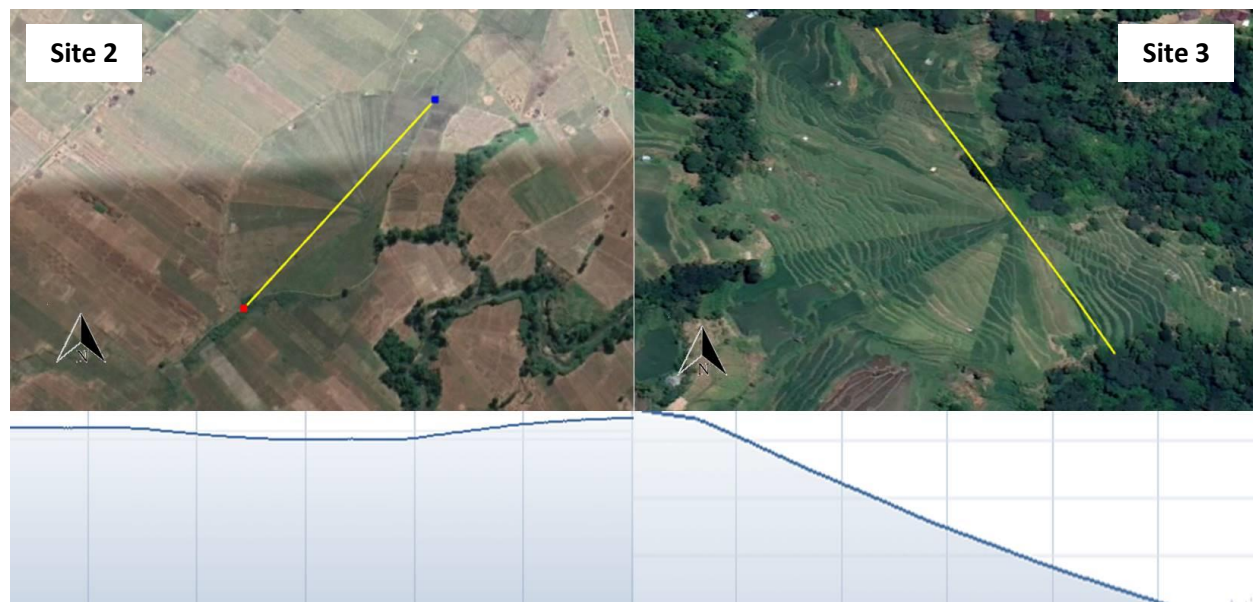
Figure 4. (A) Half spider web shape and contour at 14 m asl. with diameter of 397.94 m in site 2 and (B) diameter of 275.76 m at slope of 30% in the middle of rectangular paddy fields and forest in site 3.

The circular paddy field shape was also found in coastal areas (Figure 5). Site 4 was the only coastal location where the field present. This active field has diameter of 432.61 m. The practice of circular paddy field has been implemented since long time ago. This is supported by evidences of several abandoned fields as can be observed in sites 5 and 6 (Figure 6). Even though the soil has been used for agriculture purposes, it seems that it does not affect the fertility. It can be seen that the abandoned fields now already have been covered by vegetation.

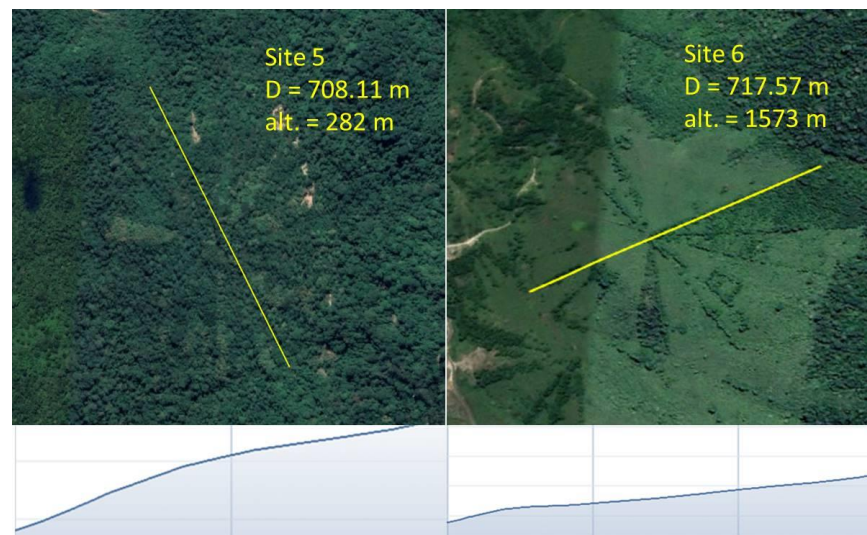Figure 5. A spider web paddy field observed in coastal areas in site 4.

Figure 6. Revegetated abandoned spider web fields in sites 5 and 6.

The circular paddy fields in Flores were adaptable with the slope and terrain. Fields that was made in a steep terrain at slope of 30% can be seen in site 3 (Figure 4), site 5 and 6 (Figure 6). A paddy field with steep terrain was also occurred in neighborhood Java island (Supriatna 2018). In this island, paddy fields were located in higher areas with the slopes of 21-55%. Some fields even located with the slope of 56-140%. Fields located at steep terrain may pose an erosion risk. However this condition has been managed by native people that left the fields for 1 and 2 years to recover the soil fertility.

4.Conclusion

Flores island is known for its semiarid ecosystem and this may influence the agriculture practices. In this regard, this study has provided an empirical evidence and analysis that indigenous based agriculture practice in the form of spider web circular paddy field can be the solution. Likewise, NDVI analysis has supported this by providing evidences regarding the performance of those fields in the term of plant physiology, fertility and crop production.

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