SEPARABILITY OF TRANSPLANTED AND DIRECT SEEDED RICE USING MULTI-TEMPORAL SENTINEL-1A DATA

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Commission IV

KEY WORDS: crop establishment, transplanting, direct seeding, SAR, Philippines

ABSTRACT:

Occurrence of pests and diseases are influenced by several factors including weather, landscape and field-level factors such as crop management practices including crop establishment method. In this paper, we adopted and applied a method using Sentinel-1A (S-1A) Synthetic Aperture Radar (SAR) intensity to discriminate between rice fields that are transplanted and direct seeded to come up with a robust method for automated classification of crop establishment method. Multi-temporal S-1A C-band dual polarization images at 20m resolution covering the wet cropping season over four provinces in the Philippines were acquired from March to November 2018. Field measurements, observations and interviews were conducted on 186 sample fields and mean backscatter values for each of the sampled fields were generated from S-1A data acquired during the season. The reported dates of land preparation and estimated dates of crop growth stages were matched with the corresponding SAR acquisition dates. We used the Mann-Whitney U test to identify growth stages for which there are significant differences in backscatter values between transplanted and direct seeded rice. The results are generally consistent with the findings of a previous study conducted in one province in the Philippines in the dry season of 2017. We found, however, some inconsistencies in terms of the polarization where the significant differences were observed. These findings demonstrate the possibility of discriminating transplanted from direct seeded rice using SAR temporal data but suggests further fine tuning in the methodology is needed for different locations and seasons.

1. INTRODUCTION

Food security is a global challenge which needs to be addressed with the continuous population growth and rapid urbanization. Rice is the main staple of majority of the world's population, and its production needs to keep pace with increasing demand. However, several factors constrain rice production including limited and declining resources (e.g., land, water and labour), climate change, and pests and diseases.

Pests and diseases cause yield losses ranging between 20% and 40% of global production annually and these have indirect costs such as in public health associated with plant protection (Savary et al., 2012). In the Philippines, farmers reported that insect pests and diseases accounted for 26% of their total yield loss for the wet season and 16% for the dry season (Hossain et al., 1995). Some of the factors which are known to influence the incidence of pests and diseases include weather (e.g., temperature, relative humidity and rainfall), landscape-level factors (e.g., planting synchrony, cropping pattern), and field-level factors (e.g., variety, crop establishment method, N inputs, pesticide application).

Rice is grown in diverse environments. Farmers adopt crop management strategies depending on their available resources and other factors such as occurrence of abiotic and biotic stresses.

To boost production, it is important to understand the current crop management situation in the different rice environments. Accurate and regular monitoring of rice areas and characterization of rice-based systems will help researchers, extension agents and decision makers to effectively target specific technologies, and recommend appropriate crop management strategies.

The capability of Synthetic Aperture Radar (SAR) to accurately detect rice based on its temporal backscatter signature has been proven in several studies (Bouvet et al., 2009; Le Toan et al., 1997; Inoue et al., 2002; Nelson et al., 2014; Laborte et al., 2015). Different SAR wavelengths were explored to look into the relationship between rice crop characteristics and backscattering coefficients to detect and map rice areas. The effectiveness of SAR in mapping rice during the monsoon season when majority of rice is grown is the main advantage over optical images (Bouvet et al., 2009). Since the launching of Sentinel-1A (in 2014) and Sentinel-1B (in 2016), several studies have utilized these data for rice area mapping (Nguyen et al., 2016; Raviz et al., 2015; Chen et al., 2016; Lasko et al., 2018; Mansaray et al., 2017; Onojeghuo et al., 2018; Torbick et al., 2017). The Sentinel-1 twin satellite constellation from the Copernicus Programme provides freely accessible high temporal resolution images making it a valuable source of data for rice crop monitoring. Although several studies in rice mapping and monitoring have been conducted, not many have attempted to delineate rice ecosystems and crop management practices such as cropping intensity, planting synchrony, and crop establishment methods.

Rice can be established either by transplanting (TP) or direct seeding (DS). Transplanting is done by first sowing seeds in nurseries and transplanting the seedlings into puddled fields ideally within 20 days after seeding (IRRI, 2007a). Actual transplanting of seedling, however, may take longer depending on the availability of resources such as labour and water, particularly in rainfed ecosystems. In the Philippines, TP is

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLII-4-W19-471-2019 |

usually done manually on puddled soil using the straight-row transplanting method which follows a uniform spacing of 20 to 25 cm between seedlings.

DS, on the other hand, can be done in either dry or wet land. Dry direct seeding (DDS) is mostly implemented in rainfed environments by sowing seed on dry soil followed by ploughing or by harrowing to incorporate the seeds or by drilling of seeds using a machine or a drum seeder. Wet direct seeding (WDS) on the other hand, is typically done by broadcasting pre-germinated seeds onto fields that are recently drained, well-puddled or with shallow standing water. Drained fields are irrigated 10 to 15 days after broadcasting. Another way is by drilling the seeds using a drum seeder on wet and smoothly levelled field (IRRI, 2007b).

DS requires less labour and water compared with TP rice. DS also has a shorter maturity duration by 8 to 10 days than TP as it is not subjected to stress due to transplanting shock. However, DS requires more seeds with seeding rate recommendation of 80 to 100 kg per hectare, and is more prone to weed problems. In contrast, TP rice requires only 35 to 65 kg of seeds per hectare (IRRI, 2007a; IRRI, 2007b).

Majority of the farmers in the Philippines practice TP, however adoption of DS has been increasing due to labour and water scarcity. Despite the advantages of DS, several problems may also be encountered with inappropriate management such as weed infestation and disease outbreak (Farooq et al., 2011). High seeding rate resulting to relatively higher plant density can lead to a more severe disease outbreak in direct seeded environment (Pandey et al., 2000). Water deficit, poor water management practices and shift from TP to DS favours host susceptibility and blast development (Farooq et al., 2011). Hence, proper management is important to avoid these factors which limit and reduce the yield in direct seeded rice.

While many studies using SAR have been conducted to accurately map and monitor rice areas, very few attempts have been made to further classify rice areas by crop establishment method (Gumma et al., 2015; Yang et al., 2014; Yang et al., 2017; Fikriyah et al., 2019). Both studies by Gumma et al. (2015) and Yang et al. (2014) found that TP and DS rice have different backscatter responses during crop establishment. Gumma et al. (2015) used RISAT-1 HH polarisation, with 25 day revisit cycle while Yang et al. (2014) used RADARSAT-2 quad polarisations with 24 day revisit cycle. Both are C-band SAR data. The recent study of Fikriyah et al. (2019) used S-1A VH-, VV-polarized, and VV/VH band ratio to discriminate TP and WDS rice in Nueva Ecija, Philippines by looking at the statistical differences in backscattering between land management conditions at different crop growth stages. The study took advantage of the higher temporal resolution of S-1A data with 12 days acquisition interval to analyse the temporal backscatter of rice throughout the growing season.

This study adapted the method developed by Fikriyah et al. (2019) and further investigated the separability of TP and WDS rice by incorporating additional temporal feature descriptors before and after crop establishment. We then compared our findings with their results to assess the reliability and consistency of the method. The findings from these initial studies will help in the development of a robust method for automated classification of crop establishment method.

2. STUDY AREA

Four provinces in the Philippines including Pangasinan, Cagayan, Iloilo, and Leyte were included in the study. These provinces are geographically distributed in the Luzon and the Visayas island groups (Figure 1).

The selected provinces fall into different climate types according to Corona's classification (PAGASA, 2011): Pangasinan has a Type I climate with distinct dry and wet seasons: wet from May to October and dry for the remaining months; Cagayan and Iloilo both have Type III climate with wet season running from May to October; and Leyte falls under Type IV climate with more or less evenly distributed rainfall throughout the year.

The primary cropping system in the four provinces is double rice, with some triple rice cropping in some irrigated areas in Iloilo. While in the western municipalities of Pangasinan, rice is mainly rainfed and planted only once a year due to limited water during the dry season. TP is still a widely practiced crop establishment method in the provinces, except in Iloilo where there is a relatively high proportion of farmers adopting DS.

3. DATA AND METHOD

3.1 Data

3.1.1 Field data and farmer interviews: A field campaign was conducted between February and March 2019 in the four selected provinces in the Philippines. The following criteria were used in the selection of the sample fields: rice-based; surrounded by at least 1 ha of rice fields of the same ecosystem; at least 60 m away from paved roads, settlements, and hills to avoid radar signal interference and impurity; field size and dimension should be at least 60m x 60m and the sample fields should be at least 500m away from each other.

Information about the crop management practices of the farmers in the past three cropping seasons were collected including water source, crop establishment method, crop calendar, and cropping pattern. The estimated dates of crop establishment and harvest, rice variety planted, and other inputs were also asked from the farmers. For the field data collection, both coordinates and tracks of the farmer's field boundary were collected using handheld GPS receiver.

Although information for three seasons were collected in the survey, only the wet season cropping 2018 data were used in this study due to the presence of dry spell in the first quarter of 2019 in the provinces of Cagayan and Pangasinan reducing the samples significantly during the dry season. Moreover, many farmers had difficulty in recalling crop establishment dates in the past dry season (2017/18) hence making the data collected for this season less reliable so we opted to exclude data for this season.

3.1.2 Sentinel-1A SAR images: Time series S-1A SAR Level-1 Ground Range Detected (GRD) in Interferometric Wide swath (IW) mode VV + VH dual polarization at 20 m spatial resolution images were used in the analysis. A total of 85 images between March and November 2018 were acquired from Orbits 32, 61, 105 and 134 in descending mode to cover the wet season cropping in the four surveyed provinces (Figure 1 and Table 1). Sentinel-1B (S-1B) images were not used in the study because the combined S-1A and S-1B time series interval differ among the study sites, with three days difference in Pangasinan and Cagayan and five days in Iloilo and Leyte which will cause some complications in the combined analysis.

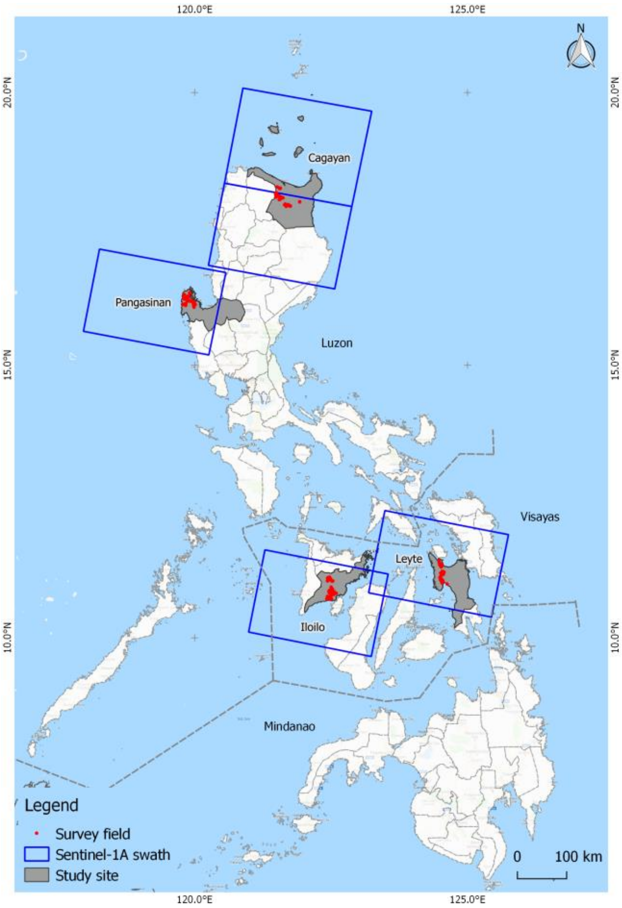

Figure 1. Map showing the location of the surveyed sites and the Sentinel-1A swaths covering the study area.

3.2 Method

3.2.1 Pre-processing of Sentinel-1A data: The multi-temporal S-1A SAR VV + VH images were pre-processed to transform them into terrain-geocoded backscatter coefficient (σ°), following the steps discussed in detail in Nelson et al. (2014). A temporal smoothing procedure was then applied to deal with the anomalously high backscatter in the time series data. The process adjusted the unexpected increase of the backscatter values within the temporal images acquired with the same viewing geometry and polarization (IRRI and PhilRice, 2018). These processing were done using the MAPscape-RICE® software. The corresponding VV/VH band ratios were derived from the VV and VH data.

3.2.2 Temporal mean backscatter extraction: Portions of sampled rice fields within 60m distance from paved roads were masked out. The backscatter values of pixels over the boundary were also removed before computing for the mean backscatter for every field. This is to prevent signal disturbance from bunds, adjacent fields and other land use/land cover surrounding the surveyed fields. The mean backscatter values were then grouped based on the reported crop establishment method.

Product details				
Mission identifier	S-1A			
Mode/beam	Interferometric Wide swath (IW)			
Product type/ resolution	Ground Range Detected (GRD)/ High resolution			
Incidence angle	40° (at scene center); 29.1° - 46.0° (range)			
Band	C (5.6 cm)			
Polarization	VV + VH			
Swath (km) width × length	250			
Spatial resolution (m)	20			
Revisit period	12 days			
Pass	descending			
Data acquired				
Relative orbit	105	32	134	61
Province covered	Pangasi-nan	Cagayan	Iloilo	Leyte
No. of frames	1	2	1	1
Acquisition dates*				
start	25-Mar-18	20-Mar-18	27-Mar-18	22-Mar-18
end	20-Nov-18	27-Nov-18	22-Nov-18	29-Nov-18
Total no. of images	20	22	21	22

Table 1. Sentinel-1A sensor specifications and data acquisition.
* Acquisitions on 15 Mar 2018 from orbit 134 and 28 Aug 2018 from orbit 105 were cancelled.

In this study the method developed by Fikriyah et al. (2019) to discriminate between TP and DS rice fields was adopted and modified by incorporating additional backscatter observations extracted from the acquisitions before and after crop establishment to explore additional potential differences between TP and WDS. The temporal mean backscatter of the TP and WDS rice fields were analysed together with the field data.

Based on the rice phenological stages (IRRI, 2007c) the length of the rice growth cycle primarily depends on the maturity duration of the variety. Maturity duration is also affected by certain factors such as the weather (e.g., temperature, solar radiation), water availability and crop establishment method. The main phase of rice growth includes vegetative, reproductive and ripening. The vegetative phase from germination to stem elongation varies from 30 to 65 days depending on the maturity of the variety (e.g., short, medium, or long duration). Most rice varieties grown in Philippines have maturity duration of 100-120 days. Next is reproductive phase, which is from panicle initiation to flowering, lasts for 35 days. The final phase is the ripening, from flowering to maturity, which lasts for 30 days.

This classification (IRRI, 2007c) and the collected field survey information on timing of land preparation, crop establishment and harvest were used to identify and estimate the end of each crop growth stage including tillering and stem elongation, heading and flowering, and maturity. The dates reported by farmers were in weeks (i.e., first week, second week, and so on of a particular month). The crop establishment date refers to the transplanting of the seedlings into the rice fields for TP or the sowing of seeds for DS.

The maturity was estimated based on the farmer's reported crop establishment and harvest dates. From the harvest date, we subtracted 30 days to estimate the heading and flowering stage. Then from the heading and flowering stage, 35 days was subtracted to estimate the tillering and stem elongation stage.

In contrast with the procedure followed by Fikriyah et al. (2019), we did not subtract 10 days for WDS rice to account for the faster tillering compared with TP. We assumed that these factors are already accounted for since we used actual harvest dates to estimate the maturity.

The mean backscatter extraction was done by matching farmer's reported dates of land preparation and harvest, and the estimated crop growth stages (tillering to stem elongation, and heading to flowering) with the corresponding S-1A acquisition dates during or immediately after each stage. The maturity stage was estimated using the backscatter from the acquisition right before the matched harvest acquisition date to make sure that the backscatter represents a non-harvested field.

Additional mean backscatter values from one acquisition before and two acquisitions after crop establishment (hereafter called temporal feature descriptors) were also extracted to explore other possible features to discriminate TP and WDS rice during the early crop growth stages. Moreover, flooding stage before crop establishment was not included in our analysis since this information was not explicitly asked during the interview. Backscatter extraction was done using the 'raster' package (Hijmans, 2019) implemented in R (R Core Team, 2018).

3.2.3 Statistical test of differences between crop establishment methods: The Mann-Whitney U test was used to test for statistical differences in backscatter values between TP and DS by growth stage. This statistical test is non-parametric and does not require normal data distribution. We used the test to assess the difference between the two groups based on their median (McCrum-Gardner, 2008).

4. RESULTS AND DISCUSSION

4.1 Field data and farmer interviews

The 186 sample fields represented diverse rice-based cropping systems in the selected sites in terms of ecosystems (rainfed and irrigated) and crop establishment methods (TP and WDS) (Tables 2 and 3). Majority of fields is transplanted, which is the common method of crop establishment in the country.

Field sizes ranged from 0.4 ha to 7 ha. The top three popular varieties among the surveyed fields (45%) are NSIC (National Seed Industry Council) Rc222 (Tubigan 18), NSIC Rc216 (Tubigan 17) and PSB (Philippine Seedboard) Rc18 (Ala) which have maturity duration of 112-123 days. Nearly all of the TP fields transplanted their seedlings at 18-35 days after sowing.

Province	Crop establishment method		Total
	Transplanted (TP)	Wet direct seeded (WDS)	
Cagayan	40	1	41
Iloilo	10	46	56
Leyte	46	0	46
Pangasinan	39	4	43
Total	135	51	186

Table 2. Distribution of rice fields surveyed during the wet season 2018 by province and crop establishment method.

Ecosystem	Crop establishment method		
	Transplanted (TP)	Wet direct seeded (WDS)	Total
Irrigated	42	19	61
Rainfed	93	32	125
Total	135	50	186

Table 3. Distribution of rice fields surveyed by ecosystem and crop establishment method, 2018 wet season.

4.2 Analysis of temporal SAR backscatter

Figure 2(A-D) shows the temporal signatures of TP and WDS rice from the Iloilo field samples and the corresponding crop calendar based on the farmers interview. We observed large variations in the start of the season in the surveyed fields across and within provinces. Land preparation in Iloilo, for instance, started as early as April and ended in July as shown in Figure 2D. Additionally, the duration of land preparation also varied from less than two weeks to two months. While some fields were still being prepared, others started crop establishment or were already at vegetative stage. It is therefore inappropriate to directly extract and analyse backscatters from the same acquisition dates which capture different land conditions and growth stages in discriminating TP and WDS rice. Moreover, different provinces are covered by different S-1A orbits, hence having different sets of acquisitions.

Figure 3(A-C) shows the backscatter variation of TP and WDS rice across land management and crop growth stages throughout the growing season and two additional temporal feature descriptors: before and after crop establishment. The temporal signature of TP and WDS in VH appeared to follow a similar trend, typical of a rice temporal signature, with low dB during crop establishment and increasing until heading-flowering stage, and slow drop at harvest stage. Although the differences are not very large, TP rice had consistently lower backscatter than that of the WDS rice from one acquisition before crop establishment to tillering-stem elongation stage in VH. These differences are more evident in VV. The VV/VH ratio also showed large differences between TP and WDS rice from land preparation to tillering-stem elongation.

In contrast to the findings by Fikriyah et al. (2019), our results show that dB is higher in WDS than in TP. A possible reason could be the presence of water in puddled field, and the evenly spaced seedlings at transplanting resulting to wider gaps between young seedlings, and fewer volume and double-bounce scattering interactions. Moreover, the presence of water in newly transplanted fields could have resulted to a lower backscatter attenuated by the plant, than that of a rough wet soil surface from the WDS fields (Lam-Dao et al., 2009). On the other hand, there is no obvious difference in dB at crop establishment stage between TP and WDS rice at VH.

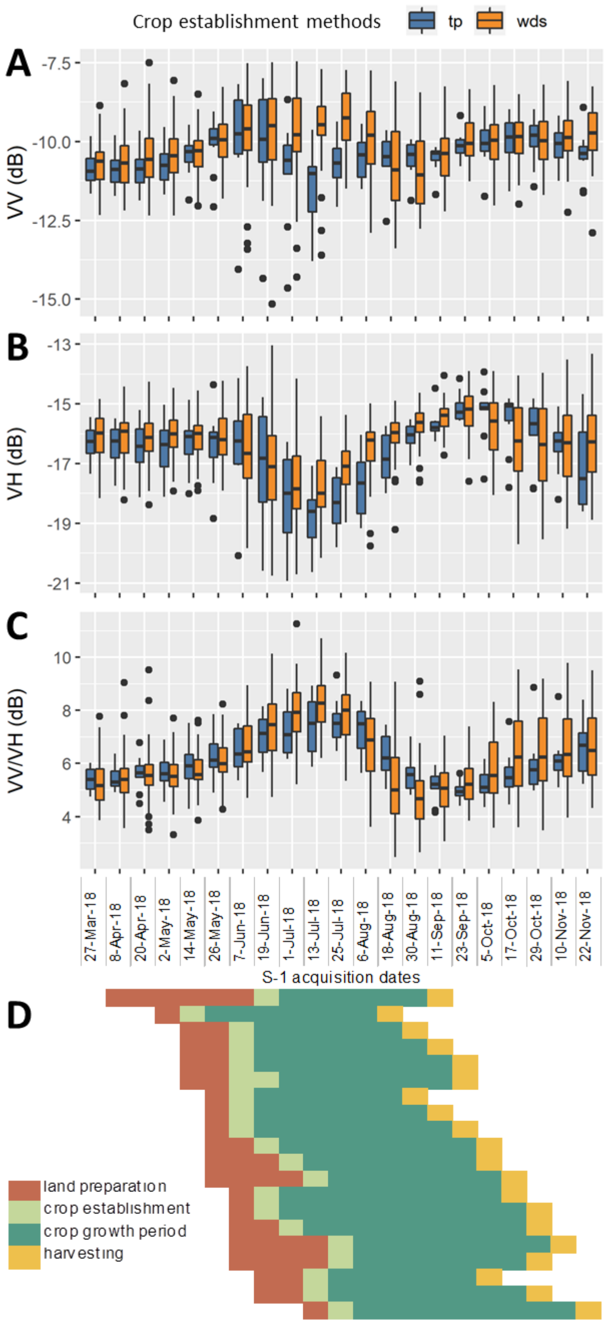

Figure 2. Temporal backscatter signature of transplanted rice (TP) and wet direct rice (WDS) in Iloilo province in the wet season 2018 in (A) VV, (B) VH, and (C) VV/VH ratio (*n* : TP=10, WDS=46). Boxplot shows the backscatter extracted for each field and each Sentinel-1 acquisition date. Graph D shows the corresponding crop calendar in the 2018 wet season based on farmer interviews in Iloilo.

From crop establishment to tillering-stem elongation, WDS had higher and rapid increase in dB than TP (VV), in agreement with the findings of Fikriyah et al. (2019). The backscatter observed from the additional temporal features after crop establishment supported the direction and the rate of increase in dB during the vegetative phase. These results could be explained by the faster tillering of WDS rice, due to the absence of transplanting shock caused by uprooting of seedlings (Pandey et al,. 2000; IRRI, 2007a; IRRI, 2007b). Also, high seeding rate of broadcasted seeds are mostly observed from the sample fields (at 140 kg/ha on the average), which would result to higher plant density in the field in comparison with that of

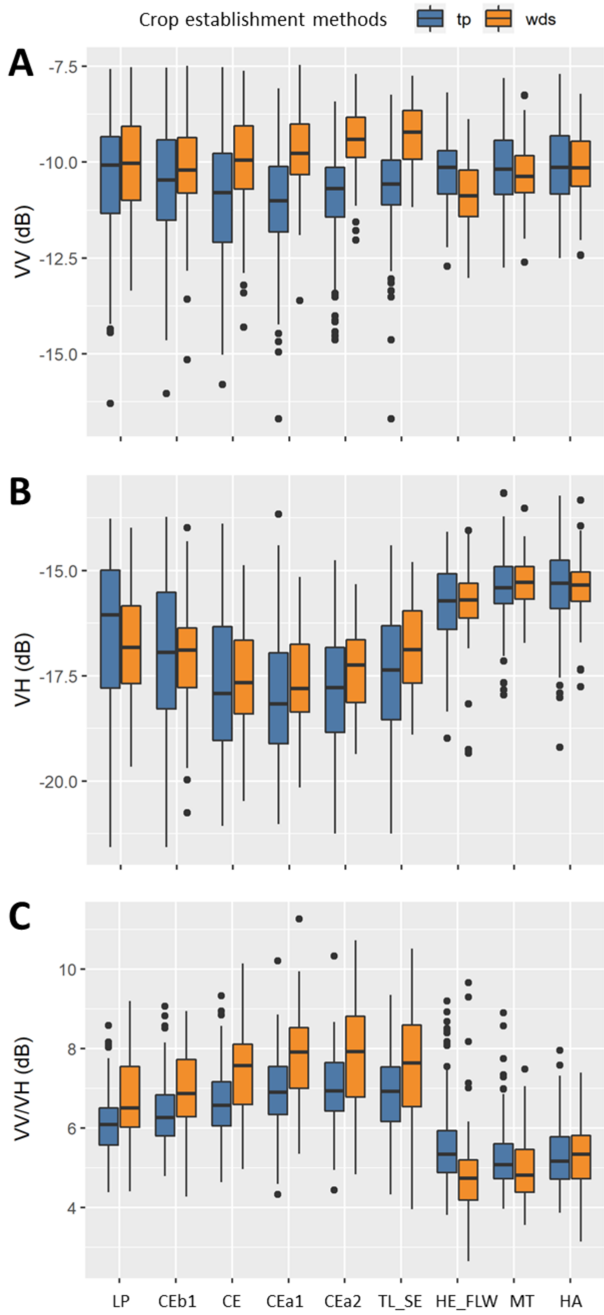

Figure 3. Temporal backscatter signatures in (A) VV, (B) VH, and (C) VV/VH ratio of transplanted rice (TP) and wet direct seeded rice (WDS) in 186 fields from the four provinces in the wet season 2018. Boxplot shows the backscatter values (in dB) for land preparation (LP), one acquisition before crop establishment (CEb1), crop establishment (CE), one acquisition after CE (CEa1), two acquisitions after CE (CEa2), tillering-stem elongation (TL_SE), heading-flowering (HE_FLW), maturity (MT), and harvesting (HA).

TP rice. This explains the higher dB (VV and VH) of WDS between crop establishment to tillering-stem elongation stage due to double-bounce scattering as the signal can still penetrate the canopy. The rapid increase in dB supports the findings of Le Toan et al. (1997) and Ferazolli (2001) regarding the strong backscatter at VV due to the dominant double-bounce effect from the vertical structure of the plant during the vegetative stage.

Lower backscatter values could signify a possible presence of more water in the TP rice fields compared with WDS fields during the above mentioned stages. It is a typical practice to drain the field for WDS broadcasting/sowing, while in TP rice, it is usual to have a little standing water in the field during transplanting. After crop establishment, the field is not irrigated until around two weeks for WDS rice to let the seed grow roots and leaves. For TP, standing water is maintained in the field and is irrigated accordingly as the plant grow more tillers and elongate. Hence more water is typically observed on TP rice fields than on WDS rice. Also, VV was verified to better detect the presence of water than VH (Stroppiana et al., 2019), which could probably explain a more pronounced difference between TP and WDS backscatter from the two polarizations. Moreover, during these early stages of the crop growth, the vegetation is relatively sparse so the C band signal penetrates the canopy.

No evident difference between TP and WDS backscatter values where observed from heading-flowering to harvesting stages (VV and VH). Although a sudden drop in backscatter from tillering-stem elongation to heading-flowering stage was observed at VV which may be due to the closing of the canopy reducing the signal from double-bounce scattering.

	Polarization		
	VV	VH	VV/VH ratio
LP	0.3826	0.08399	0.0002***
CEb1	0.0436*	0.8883	0.0001***
CE	0.0004***	0.3694	0.0000***
CEa1	0.0000***	0.0291*	0.0000***
CEa2	0.0000***	0.0187*	0.0000***
TL_SE	0.0000***	0.0101*	0.0020**
HE_FLW	0.0003***	0.9708	0.0000***
MT	0.3246	0.5084	0.0157*
HA	0.9198	0.422	0.6624

Table 4. Mann-Whitney U test results: p-values between transplanted (TP) and direct seeded (WDS) rice for every crop growth stages. *n* : TP=136, WDS=50
Land preparation (LP), one acquisition before crop establishment (CEb1), crop establishment (CE), one acquisition after CE (CEa1), two acquisitions after CE (CEa2), tillering-stem elongation (TL_SE), heading-flowering (HE_FLW), maturity (MT), and harvesting (HA).
* Significant at $p < 0.05$.
** Significant at $p < 0.01$.
*** Significant at $p < 0.001$.

The Mann-Whitney U test (Table 4) showed significant difference between TP and WDS rice at VV during the early stage of crop growth: from crop establishment to heading-flowering stage including the temporal feature descriptors before and after the crop establishment stage. While at VH the significant differences were observed during land preparation, tillering-stem elongation stage, and in the two temporal features after crop establishment. The VV/VH band ratio has shown significant differences results in all the groups except at harvesting.

The results showed that TP and WDS rice can be best discriminated during the early growth stage in agreement with the findings of Fikriyah et al. (2019) and Yang et al. (2014). However, we found a contrasting result during the crop establishment stage wherein WDS had higher dB than TP. This could have resulted from the differences in season, and in the crop and water management in our study area in comparison to the previous studies. This suggests further testing and refinement is needed for a more robust method of discriminating crop establishment methods.

The capability of multi-temporal images from S-1 C band to capture the different stages of rice as shown in previous studies was confirmed by the results from this study. The high temporal resolution of S-1 was found suitable particularly in investigating the separability of TP and WDS rice during the crop growing season.

The additional temporal features provided more evidence about the development and differences in the backscatter between TP and WDS rice before and during the early vegetative stage.

4.3 Limitations and recommendations

Because of the 12-day repeat cycle of S-1A used in this study, the backscatter values during crop establishment may represent between 0 to 11 days difference from the actual date of crop establishment. This temporal difference may have resulted in differences in actual field conditions. Some of the WDS rice fields, for example, on sowing date will look very different at 11 days after sowing with germination and growth of seedlings. The use of both S-1A and S-1B acquisitions which would reduce the acquisition cycle to around six days would probably give better results and should be explored.

The S-1A incidence angles over the sample field locations were not analysed in this study. Hence, the possibility of having a wide range of incidence angles across the sample fields and its effect on the scattering mechanism and backscatter were not evaluated. This is something which can be evaluated in our further analysis.

In this study, we used field observations taken in one field survey. It would be useful to conduct field monitoring activities throughout the crop growing season in both TP and WDS fields to directly relate and analyse the backscatter signals with the corresponding current field or crop conditions. This will allow for better analysis of the temporal backscatter between the crop establishment methods.

5. CONCLUSION

In this study, we adapted the method developed by Fikriyah et al. (2019) to assess its reliability and consistency in discriminating transplanted and wet direct seeded rice by analysing the temporal backscatter signature from Sentinel-1 C band images together with field survey data from four provinces in the Philippines during the wet season of 2018.

Our results showed that differences between transplanted and wet direct seeded rice can be detected from C band VH-, VV-polarization and VV/VH ratio during the early growth stages of rice, mainly during crop establishment to tillering and stem elongation which is generally consistent with the findings of the previous studies. Differences are also found from the temporal feature descriptors before and after crop establishment. This can

https://doi.org/10.5194/isprs-archives-XLII-4-W19-471-2019

provide additional information on the early growing stage of rice when TP and WDS can be best detected. However, we found in our results a higher backscatter in the WDS than in TP during the crop establishment which is in contrast with the findings of the previous study. Moreover, there are also some inconsistencies in terms of the polarization where the significant differences were observed.

The findings presented here demonstrate the potential of discriminating TP from DS using SAR temporal data but suggest the need for further fine tuning in the methodology and testing for different locations and seasons. These initial studies will contribute to the development of a robust method for automated classification of crop establishment method in the future.

ACKNOWLEDGEMENTS

We acknowledge the Pest Risk Identification and Management (PRIME) project for funding this research. PRIME, a collaborative project among the Department of Agriculture (DA)-Philippine Rice Research Institute (PhilRice), International Rice Research Institute (IRRI), DA-Bureau of Plant Industry (BPI), DA-Regional Field Offices (RFOs) and University of Twente (ITC), Enschede, The Netherlands is funded by the DA through the DA-Bureau of Agricultural Research.

We thank the DA-RFO and Local Government Unit staff from participating regions for providing support during the field survey.

SAR data were provided by the Copernicus Sentinel Data (2018) from the European Space Agency. Pre-processed SAR images were provided by the Philippine Rice Information System (PRISM) of the DA and managed by the Philippine Rice Research Institute (PhilRice).

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