J. Agric. Sci., Tokyo Univ. Agric., 58 (1), 21-28 (2013)
東京農大農学集報，58（1），21-28（2013）

Application of Wavelet Transform for Paddy Area Classification Using MODIS NDVI Data Series

By

Ramadhona SAVILLE* and Katsumori HATANAKA**

(Received November 22, 2012/Accepted March 11, 2013)

Summary : An algorithm for the classification of paddy area was proposed by utilizing wavelet transform as time frequency analysis of Normalized Difference Vegetation Index (NDVI) data series derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensor. The calculated wavelet powers of the NDVI wave correspond to the rice cropping calendar, and were used to obtain the characteristics of paddy area. After determining features of the paddy area, Linear Discriminant Analysis (LDA) is assessed for land-use classification using statistical values of NDVI data series and calculated wavelet powers. This research was conducted in the Mekong Delta, southern Vietnam. Three years, NDVI data series (January 2009 up to December 2011) of 10-day composite images with 250 m spatial resolution were applied. The result shows that the combination of wavelet powers and statistical values of NDVI data for LDA worked well for the classification, even when low resolution satellite images like MODIS were used. Furthermore, paddy classification can obtain the most appropriate result if the starting point of the calculation is adjusted to the rice planting period. However, verification of accuracy has not yet been done due to lack of the latest land-use data of the study area, and still remains as a future subject.

Key words : Paddy area classifications, Wavelet transform, Discriminant analysis, NDVI, MODIS

Introduction

Recently, industrialization and economic growth in South East Asia has been increasing rapidly, yet the agriculture sector is still positioned and remains as an important industry. Despite its rapid economic growth, Vietnam is still one of the largest rice exporting countries in the world. Based on the data from The Library of Congress of U.S (LOC, 2012), approximately 60% of the employed labor force is engaged in the field of agriculture, and more than 70% of the total population lives in rural areas. Despite the fact that Vietnamese agriculture is important for the country, the increase of rice export has caused the rice price in the domestic market in Vietnam to increase. Therefore the government of Vietnam needs to adjust the upper limit of rice export to control the rice price. In order to set the export limitation, the government has to estimate the yield of rice, which can be estimated by the detailed data of rice planting area (HATANAKA *et al.*, 2011).

Mekong Delta is a region in the southern part of Vietnam where Mekong River passes through. Mekong Delta region encompasses a large portion of southern Vietnam, with an area of 3.9 million hectares. According to International Rice Research Institute (IRRI, 2012) the district produces about half of the total of Vietnam's rice output, and 90% of exported rice comes from Mekong Delta (TOAN, 2012). In fact, the region produces more rice than Korea and Japan combined. Those reasons make Mekong Delta's existence very important to the food supply in the country and the national economy. However, it is difficult to estimate the rice planting area by field survey since Mekong Delta has millions of hectares of paddy fields. It became clear that the rice planting area varies often and drastically because of frequent flooding or other natural conditions, where double or triple cropping paddy areas are mixed. Those conditions make it even more difficult to do the field survey for estimating rice

* Department of International Bio-business Studies, Graduate School of Agriculture, Tokyo University of Agriculture
** Department of International Bio-business Studies, Faculty of International Agriculture and Food Studies, Tokyo University of Agriculture

yield or even just for estimating the area of paddy field.

The use of sophisticated information technologies such as Geographic Information System (GIS), Remote Sensing (RS), and Global Positioning Systems (GPS) offer many advantages, and they are becoming available at ever more reasonable cost compared to field survey of a huge area (DEMERS, 2000). Despite the fact that RS technology and GIS for land-use in Vietnam are developed, few studies of paddy area classification in Mekong Delta using low resolution satellite images have been done. Many of the commonly used satellites are high-resolution satellite, which means that the cost needed is still enormously expensive, and it usually requires special knowledge and technical skills. On the other hand, cost free and low-resolution satellites, such as Terra and Aqua with a MODIS sensor, can be used for obtaining image series of the target area. Even though the spatial resolution is low, the resolution in time itself is very high, so that time series data as well as various indices from the data can be obtained very frequently. Thus, if a low-cost algorithm for classification of paddy field using remote sensing can be obtained, it will be helpful for many people, especially those who are engaged in the agricultural sector.

In general, time series Normalized Difference Vegetation Index (NDVI) data obtained by satellite include various noise components due to aerosols, bidirectional reflectance distribution factors and so on. There are a lot of tools for preprocessing, for example, smoothers such as moving window to select the local maximum VI (VIOVY *et al.*, 1992), Logistic curve fitting (ZHANG *et al.*, 2003), and so on. The noise reduction or fitting a model to the observed data is preferred for phenological stages to be determined, and one of the ways is to use a wavelet transform as the filter. SAKAMOTO *et al.*, (2006) have presented a method of land-use classification in Mekong Delta based on MODIS data using a wavelet filter and Enhanced Vegetation Index (EVI) data series. After filtering the EVI data series, they classified the paddy area directly by comparing to the local maximum point of rice-heading date. Then if it passes some threshold it will be counted as a single, double, triple cropping paddy or other area. In their method, the wavelet transform was only used as a smoother tool, even though the calculated wavelet coefficients include much important information for the classification. In this study, the wavelet transform was applied as a time frequency analysis tool to detect features of land-use especially paddy area, and then classification is done by making use of Linear Discrimination Analysis (LDA). In this research, LDA is used for assessing land-use classification using statistical values of original NDVI data series and wavelet powers of NDVI data series as parameters.

HATANAKA *et al.,* (2011) also presented a method of land-use classification by wavelet transform and LDA. They classified paddy area by using SPOT with 1 km spatial resolution (which is composed from the smoothing and unification of the original 20 m mesh data). Yet in this study, the data series from MODIS with 250 m spatial resolution was used. HATANAKA *et al.,* (2011) directly classified all of the land-use into six different areas, such single, double, triple cropping paddy, field, double cropping mixed with field and non-paddy area. However, in this study land-use data was classified into paddy area, mixed area and non paddy area first, and then paddy areas were classified into double or triple cropping. In this paper, the authors show the basic idea of the present method and discuss the applicability of the method through the results of the classification of paddy area using MODIS data in Mekong Delta region, Vietnam.

Characteristics of NDVI Waves in Different Land-Use

This research was conducted in the Mekong Delta, in the southern part of Vietnam within the latitude of 8°54′0.00″N–10°54′7.50″N and longitude of 104°35′52.50″E–106°35′59.99″E, an area of 57,600 square kilometers. The 10-day composite images with 250 m grid of spatial resolution from MODIS sensor onboard NASA Earth Observing System, Terra and Aqua satellite were used. The total number of the grid of one composite image is 921,600 points (240 km divided by 250 m). The raw data used are the data from January 1st 2009 up to 31st of December 2011, which are downloaded every single day. The utilization of 10-day composite image makes the output of 36 data series per year for this study, and due to the utilization of three years data, it makes 108 composite images. NDVI data series in each pixel can be assigned in each grid and this makes more than 99 million records in total. However, such a large amount of data cannot be processed using an ordinary computer. Thus, a database system called Posgresql on a Linux server was used, and the data processing as well as numerical computation was done using PHP programming language.

NDVI value changes along with the growth and the quantity of vegetation on the earth surface, since they are the most affected by the absorption of chlorophyll in green leafy vegetation, which makes the value of NDVI change along with the rice cropping calendar. The chronology of rice cropping calendar and NDVI changes is as follows. The area of paddy field is particularly covered by soil or mud before the rice planting period, and the color of that area would be dark brownish and the value of NDVI is nearly zero. During the rice planting period, the mud is planted with paddy which is green,

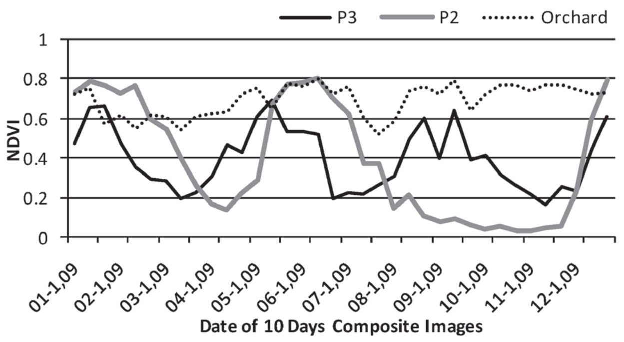


Fig. 1 Comparison of several land-use NDVI data series' sample in 2009

and the value of NDVI would be increased. Along with the growth of paddy, NDVI value will get higher and higher, until its peak they will cover the mud area, so that the satellite will recognize the paddy area as green vegetation, which makes NDVI value higher until its peak. Then the paddy will become mature and yellowish, so that the NDVI value will decrease. After the harvest, the NDVI decreases rapidly to near zero, because the color of land cover is not green-yellowish anymore but becomes dark brown as it is covered by soil or mud. Then the rice planting will be repeated again and go back to the first circle. The changes of NDVI along the rice growth are shown in Fig 1.

Some numbers of land-use samples data were selected by observing Google Earth image as well as checking the NDVI waves. By observing the wave and matching the coordinate in Google earth, several land-use samples (paddy double, triple cropping area and non-paddy area) can be obtained. Fig 1 contains several examples of NDVI data series using 10-day composite images from the first ten days period of January 2009 until the last ten days in December 2009. The graph contains land-use which is recognized as triple cropping (P3), double cropping (P2), and orchard area. It is clear that orchard area's NDVI changes are quite small compared to paddy areas which have large changes. The small change is because the orchard is green almost all the time. The triple cropping area is defined as three times harvesting in a year with three peaks in a year, and double cropping is defined as two times harvesting in a year with two peaks as shown in Fig 1. The important thing that can be obtained from Fig 1 is that every land-use has its own data series which is shaped as a wave, and every wave has its own characteristics. Thus, once the characteristics of the wave are determined, it is possible to use them in the classification of land-use.

Application of Wavelet Transform

MODIS data contains a lot of noise due to some cloud, aerosols and so on. Sakamoto *et al.*, (2006) used a wavelet filter for noise reduction as well as smoothing EVI data series and directly classified paddy area by comparing to local maximum point in each heading-date. However, in this research Discrete Wavelet Transform (DWT) was used to perform time frequency analysis in order to determine the characteristics of the wave, especially the characteristics of paddy area. The wave-like object will be detected by DWT through dimension of time or space, and the wavelet coefficients for each level of frequency in a data series will be given. So it is possible to use original NDVI data series and value of calculated wavelet transform data to detect the characteristics of a wave-like object. The equations of wavelet transform in general form can be written as (Chui, 1992),

$$(W\psi f)\left(\frac{k}{2^j},\frac{1}{2^j}\right)=c_{j,k}=\sqrt{2^j}\int_{-\infty}^{\infty}\overline{\psi(2^jx-k)}\,f(x)\,dx, \qquad (1)$$

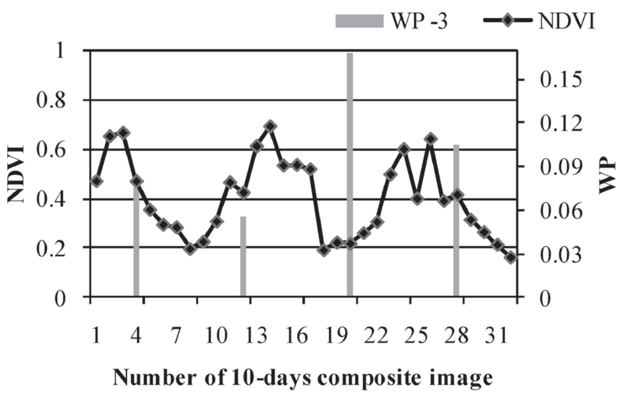
$$f(x)\approx\sum_j\sum_k c_k^j\psi(2^jx-k), \qquad (2)$$

where W_ψ in eq. (1) indicates the wavelet transform for the function of $f(x)$ data series and eq. (2) is its inverse transform. DWT is formed from dyadic translation $k2^{-j}$ and binary dilation 2^{-j}. While ψ implies a mother wavelet function, and c_j is transformed data of function f. Based on the binary dilation, value of j is increased, calculated wavelet coefficient will be decreased with the value of 2^{-j}. And the subscript j indicates the level in DWT, while k is the number of records in a data series. The subscript characters indicate frequency information and time information. The merit using wavelet transform as the time frequency analysis tool is because some of the transformation method usually only enable the obtaining of frequency information, without time information of the data series (Polikar, 2012). The other advantage for using DWT is the flexibility to select data series number. Spectrum analysis that is commonly used in the frequency analysis has the restriction in choosing data series. For example, let n be a number of data series, and in spectrum analysis, n must be two to the power of some positive integer. But n in DWT is freely selectable ; n can be two to the power of some integer times other integer, depending on the user's selection. As mentioned above, 10-day composite images from January 1st 2009 up to 31st of December 2011, 108 data series with 36 data series per year were used. Due to the requirement of wavelet transform based on binary dilation, which require two to the power of some number data series, the whole data cannot be used. 32 data series per year which are equal to 2^5 are divided into five levels of DWT, -1 up to -5. And 48 data series, which means 2^4 times 3 are divided into the frequency level -1 up to level -4. The utilization of 36 data series is useless because 36 is equal to 2^2 times

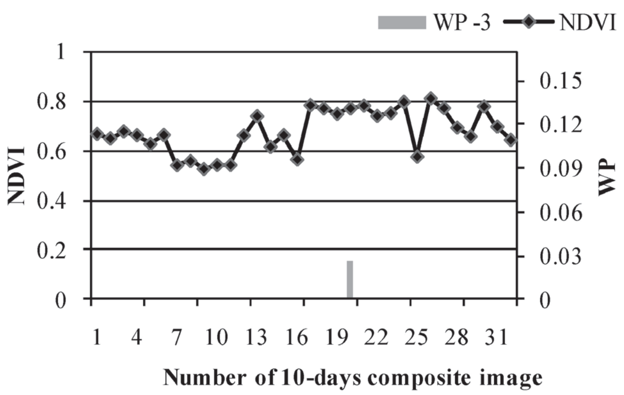
3^2 and this can only be decomposed into two levels in wavelet transform. That is not enough for detecting the features of paddy area.

DWT becomes simple if it has compact support in two scale functions such as mother wavelet and scaling functions (CHUI, 1992). In this research, the Daubechies' was selected as the mother wavelet and scaling functions. Daubechies has proposed a set of scaling function and mother wavelet numbered by a series of natural number N. The wavelet number, N, were verified from 1 to 3, and the most stable and appropriate result were given for N=3, therefore Daubechies' N=3 were used as the mother wavelet and scaling functions. The next step of time series analysis using DWT is calculating the Wavelet Power (WP). WP is defined as the quadrate of wavelet coefficient. In case of using 10-days composite data, the frequency level -1 in DWT calculation corresponds to the 10-20 days period, level -2 corresponds to 20-40 days, level -3 to 40-80 days, level -4 to 80-160 days and level -5 is 160-320 days, respectively.

Fig 2 shows comparison of WPs at level -3 and the original NDVI wave in a triple cropping paddy area with respect to an orchard area. As shown in Fig 2 (a), high values of WP are observed in cases when the change of NDVI wave is relatively high and WP in a paddy area becomes much higher than that of orchard area as shown in Fig 2 (b). The authors have confirmed that the same can be seen in single and double cropping paddy areas and remarked that the high WPs at level -3 and -4 are the characteristics of paddy field. This is quite reasonable because the level -3 corresponds to 40-80 days period and level -4 corresponds to 80-160 days period, and those are very close to the rice cropping period in Mekong Delta of which approximately 80-110 days period were estimated by the interview from researchers in Cuu Long Rice Research Center, Vietnam in 2010 and 2012. The same has been reported by HATANAKA *et al.*, (2011) in their results using smoothed NDVI data series calculated from SPOT satellite images. Even though the use of oscillated NDVI data including noises due to lower resolution sensor like MODIS, the wavelet transform could distinguish the characteristics of paddy areas and the authors concluded that the present idea can be applicable to the classification of paddy area.



(a) Calculated WP value in triple cropping paddy area



(b) Calculated WP value in Orchard area

Fig. 2 Comparison sample of calculated WP value in triple cropping paddy area with orchard area using 32 data series

Classification Algorithm

After applying DWT to some NDVI waves at sampling points in which land-use is already known, the LDA was carried out in order to determine the discrimination function z in eq. (3) for the classification,

$$z = c_0 + \sum_{i}^{m} c_i p_i, \quad (3)$$

where c_i are coefficient for parameters of p_i, but c_o are constant and m is the number of parameters. The function of LDA, which is shown in eq. (3), is called Linear Discriminant Function (LDF). In LDA, maximum and average values of WP at level -1 to -4 were chosen and statistics values of NDVI data at sampling points such as average, maximum, minimum and standard deviation were used. Those parameters were calculated using the original program based on the wavelet transform, and the entire coefficient values of LDF were calculated by SPSS using 1,168 known sample points. After getting the constant number and the coefficient of each parameter, the calculation and classification of the rest 920,432 points were done. Since sea area has nearly zero NDVI value or even negative, the authors decided to classify the sea area by the case when average of NDVI data is lower than 0.05 before the classification of other land-use.

The next step of the algorithm is classification of non-sea area (land data) using LDF as shown in eq. (3). In this study, divided land use were divided into paddy field area (which was then classified as paddy triple cropping area or double cropping area by applying the second LDF to the results of paddy areas), mixed area and other area.

Paddy field area is defined as pure paddy field area, while other area is defined as the area that does not have paddy field inside of it (it can be an orchard area, a river, a village and so on). Mixed area is defined as the area that has paddy field and other area mixed inside it.

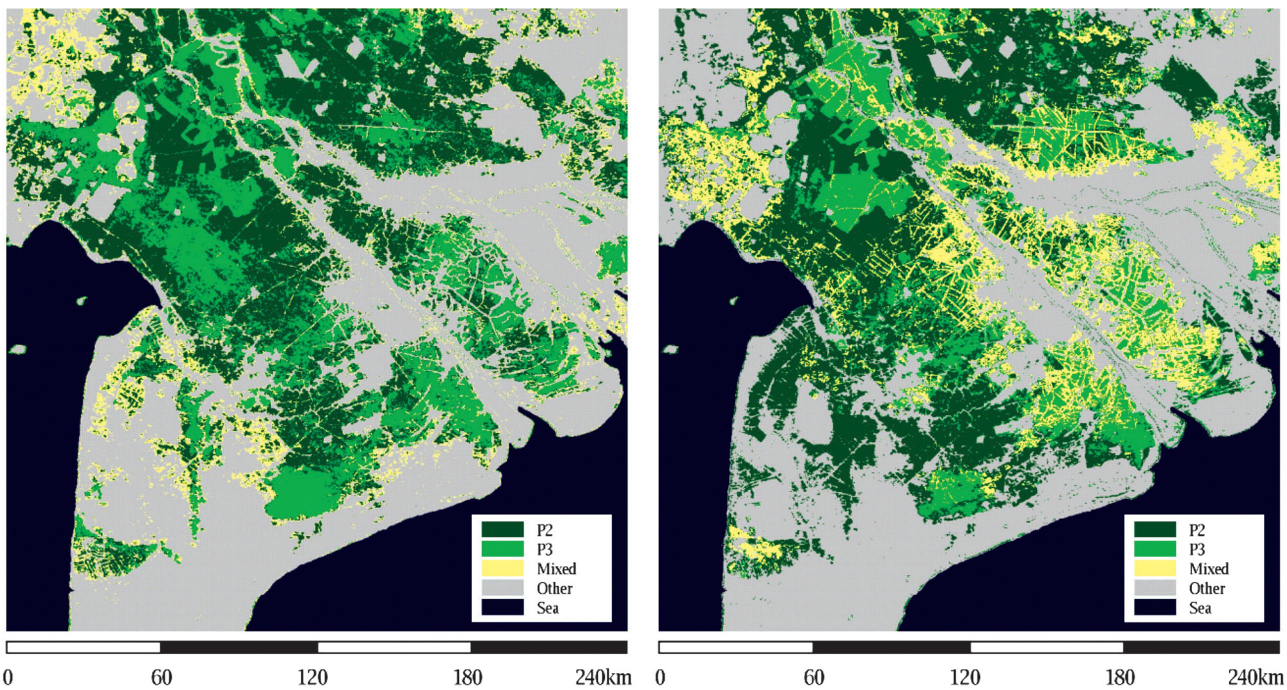
Result and Discussion

In order to get an appropriate result as well as testing the algorithm, the authors tried to classify paddy area by dividing into some classification cases. The first case (case 1) of the classification is using 32 data series ($=2^5$) with the starting point of the first 10-days of January 2009, 2010 and 2011. The second case (case 2) also used 32 data series, of which the starting point is the third 10-days of November 2009 and November 2010. The reason for using November as the starting point is because the authors tried to adjust with the rice planting period in Mekong Delta region which was known during the field survey. And the third case (case 3) would be using 48 data series ($=2^4 \times 3$) with the starting point similar to case 2.

After trying some cases as well as some compilations for algorithm of paddy classification, paddy area (triple and double cropping), mixed, sea region, and other areas were clearly classified. Resultant land-use maps of classification using 32 and 48 data series can be seen in Fig 3. In Fig 3, P2 means double cropping area, P3 is triple cropping, Mixed is mix of paddy and non paddy area, Other indicates non-paddy area and Sea is sea area. Fig 3 (a) shows the result of classification using 32 data series with the starting point of the third 10-days of November 2009 (case 2), while Fig 3 (b) shows the result of classification using 48 data series with the same starting point (case 3). Both of the paddy area in case 2 and 3 are identified, but cropping cycles are slightly different.

In Sakamoto *et al.*, (2006) results, several misclassified areas were found due to mixed-pixel effect caused by adjacent land surfaces. That condition led to classification of paddy area with more than four times cropping (or more) in a year and even an area with two land-uses. In this study misclassified area was not found in the entire classification result in contrast with Sakamoto *et al.*, (2006), because wavelet power and statistical values of NDVI were used as parameters for LDA and set some threshold for the classification of paddy area. Therefore, even there are several areas with adjacent pixel, the algorithm in this study would classify them as the areas that have been determined previously.

The comparison of land-use area estimated from case 1 to case 3 is shown in Fig 4 and 5. Fig 4 shows the comparison of classified area in each land-use from case 1 to 3. In Fig 4, the result of case 1 is corresponding to the first three bars in each land-use group. Despite the fact that the differences in calculated area among cases in triple cropping area is not so big, the differences in classi-



(a) Result of paddy classification result using 32 data series (case 2)

(b) Result of paddy classification result using 48 data series (case 3)

Fig. 3 Comparison of maps of paddy classification result using 32 data series and 48 data series with starting point of the third 10-days of November 2009

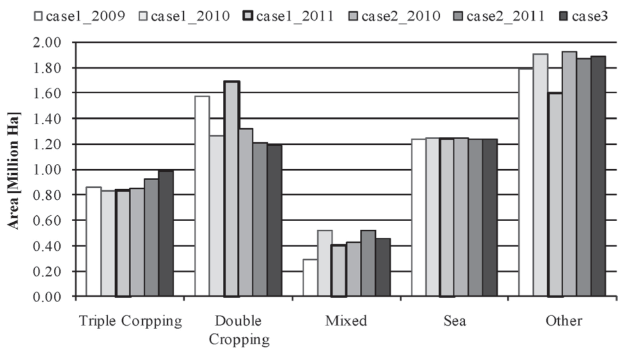


Fig. 4 Comparison of calculated total area in case 1, 2 and 3

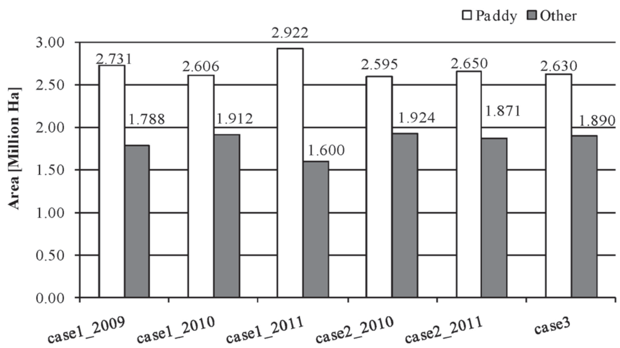


Fig. 5 Classification result of paddy and non paddy area comparison in each case

fication results of double cropping, mixed, and other areas are relatively big. As written above, rice planting period in Mekong Delta usually starts in the end of November, and January will be the growing period in each year. That makes the NDVI value in January quite high, which means that the calculation was starting from the middle of wave data (as shown in Fig 1) in the entire year in case 1. So the calculation possibly goes wrong and cannot classify paddy areas stably. It can be concluded that case 1 is not adequate in the selection of starting point of the classification with respect to case 2 and case 3.

Fig 5 shows the result of classification between paddy and non paddy area for cases 1, 2 and 3. The same as before, Fig 5 indicated the instability of case 1, as the difference of area between paddy area and other varied more than other cases. However the classification results of paddy area in case 2 and case 3 indicated similar area. It can be concluded that the utilization of starting point that is adjusted to rice planting period is important for paddy area classification by this method.

As exhibited in Fig 4 and 5, the stable classification was achieved by selecting the starting point of DWT on the rice planting period. In order to confirm the land cover and to verify the NDVI wavelet changes, the results

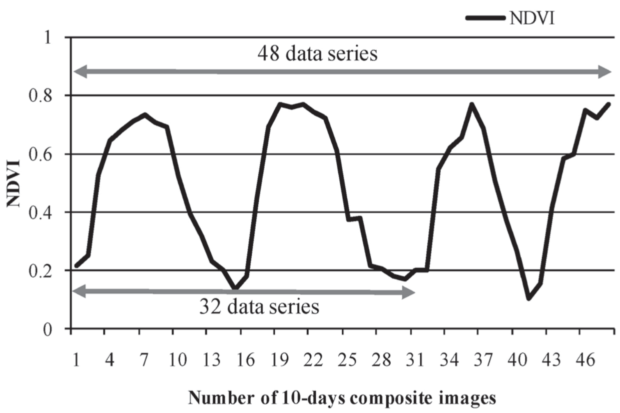


Fig. 6 Comparison example of using 32 (case 2) and 48 data series (case 3) for paddy area classification in triple cropping area using the third 10-days of November 2009 as the starting point

of every case were overlaid to Google Earth, to examine the original NDVI waves of some different areas. The case 3 produced the most appropriate classification result relative to the others. Unfortunately, the accuracy of this algorithm was not verified due to lack of the latest land-use data of Mekong Delta. Although the paddy area data was provided by the General Statistics Office of Vietnam (GSO, 2012), in some provinces, the area of paddies are even bigger than the area of that province, itself and failed to confirm the classification result.

As indicated in Fig 6, the 32 data series of 10-day composite images is not enough to cover a period of the triple cropping paddy. The 32 data series applied for case 1 and 2 caused the error in the classification of land-use area, although the classified area between case 2 and 3 was not significant. Despite the fact that the utilization of 32 data series is enough to distinguish features of paddy area, it is not enough to classify whether the area is double or triple cropping. In some areas the utilization of 32 data series will recognize the triple cropping area as double cropping area, and that makes the area of double cropping in case 2 bigger than the area in case 3. On the contrary, the utilization of 48 data series is long enough to include the data of triple cropping in a year, and it will detect features of land-use correctly.

In comparison to HATANAKA *et al.*, (2011), single cropping was not found in this study. That result was the same with the estimated condition by the interview from researchers in Cuu Long Rice Research Center, Vietnam in 2012. They stated that in this day, very few single cropping exist in research area, and considerably those might be classified into mixed area in this result. Moreover HATANAKA *et al.*, (2011) addressed that, even if the number of data series is 320 days (less than a year) the classification of the paddy area is possible. However, this study revealed that the utilization of data that is less than a year does not give good results. Thus, there might be misclassified areas in paddy double or triple cropping in HATANAKA *et al.,* (2011) result using 320 days data series.

Conclusion

In this paper, an algorithm for the classification of paddy area was examined by utilizing wavelet transform as time frequency analysis of NDVI data series to detect features of land use and classify paddy area using LDA. After discussing the algorithm, it can be concluded that wavelet powers can be used for distinguishing the features of land-use, especially for paddy area. The results show that the combination of wavelet powers and statistical values of NDVI data for LDA works well for the classification, even when low resolution satellite images were used. Furthermore, paddy classification can obtain the most appropriate result if the starting point of the calculation is adjusted to the rice planting period by using 48 data series. However, the accuracy verification of this study has not been done yet due to lack of the latest land-use data of the study area, and it still remains as a future subject.

Acknowledgement

The authors wish to thank Dr. NGUYEN Xuan Lai, the former vice president of Cuu Long Rice Research Center, for his help and fruitful discussions about the study. The authors also wish to thank Dr. Koji WAKAMORI and Dr. Dorj ICHIKAWA in Japan Manned Space System Corporation for their help in calculating NDVI data. The work of this study has been supported by the research project in Tokyo University of Information Sciences for a sustainable development of economic and social structure dependent on the environment of the eastern coast of Asia supported by the MEXT-Supported program for Strategic Research Foundation at Private Universities from 2008–2012.

References

1) CHUI, C.K, (translated by SAKURAI, A and ARAI, T), (1992), An introduction to wavelet (In Japanese), Tokyo Denki University.
2) DEMERS, M.N, (2000), Fundamentals of geographic information systems, John Wiley & Sons Press.
3) Genneral Statistics Office of Vietnam (GSO), (2012), (Available at http : //www.gso.gov.vn/)
4) HATANAKA, K., SUZUKI, M., and KANADA, N, (2011), Study on the classification of paddy fields based on time frequency analysis of ndvi (In Japanese), *J. Agri. Sci., Tokyo Univ. of Agric.,* **56** (1), pp. 36–43.
5) International Rice Research Institute (IRRI), (2012), (Available at http : //www.irri.org/science/)
6) The Library of Congress of U.S (LOC), (2012), (Available at http : //lcweb2.loc.gov/frd/cs/)
7) POLIKAR, R, (2012), The engineer's ultimate guide to wavelet analysis, the wavelet tutorial. (Available at http : //users.rowan.edu/~polikar/WAVELETS/WTtutorial.html)
8) SAKAMOTO, T., NGUYEN, N.V., OHNO, H., ISHITSUKA, N. and YOKOZAWA, M, (2006), Spatio-temporal distribution of rice phenology and cropping systems in the mekong delta with special reference to the seasonal water flow of the mekong and bassac rivers, *Remote Sensing of Environment,* **100**, pp. 1–16.
9) TOAN, T.Q, (2012), Success story of lowland management in the mekong delta and planning for water resources management for sustainable agricultural cultivation adapting to climate change and sea level rise, Presentation in international workshop on sustainable management of lowland for rice production, held in Banjarmasin, Indonesia, 27–28 September 2012. National Research Council of Indonesia.
10) VIOVY, N., ARINO, O. and BELWARD, A.S, (1992), The best index slope extraction (BISE), A method for reducing noise in NDVI time series, *International Journal of Remote Sensing.,* **13**, pp. 1585–1590.
11) ZHANG, X., FRIEDL, M.A., STRAHLER, A.H., HODGES, J.C.F., GAO, F. and REED, B.C, (2003), Monitoring vegetation phenology using MODIS, *Remote Sensing of Environment,* **84**, pp. 471–475.

水稲圃場分類のための時系列 MODIS NDVI に対する Wavelet 変換の応用

ラマドナ サフィル*・畑中勝守**

(平成 24 年 11 月 22 日受付/平成 25 年 3 月 11 日受理)

要約：本報は，MODIS (Moderate Resolution Imaging Spectroradiometer) センサから取得された画像データより得られる正規化植生指数 (NDVI) に対し，Wavelet 変換による時間周波数応答解析を適用し水稲圃場を分類するアルゴリズムを提案する。NDVI の波形から計算される Wavelet パワーは，水稲作期に対応しており，水稲圃場の特徴抽出に利用できる。そこで，Wavelet パワーの値により水稲圃場の特徴を決定した後，NDVI の統計情報と Wavelet パワーを組み合わせた線形判別分析を行い，判別関数の値から自動的に土地利用分類を行う手法を提案する。本研究では，ベトナム南部のメコンデルタ地域を解析対象とする。本報では，250 m 解像度の 10 日間コンポジット画像から作成された，2009 年 1 月から 2011 年 12 月までの 3 ヶ年の NDVI データを使用し解析を実施した。解析結果から，MODIS センサのような空間的に低解像度の衛星画像データを使用した場合であっても，NDVI の Wavelet パワーと基本統計量の組み合わせによる線形判別分析が，水稲圃場分類において効果的である事が確認できた。さらに，水稲圃場分類に必要な NDVI データの解析開始時期を播種期に一致させて計算することで，最も妥当な分類結果が得られることが判明した。しかし，現地の正確な土地利用データが不在であることから，提案手法の精度検証が今後の課題として残った。

キーワード：水稲圃場分類，ウェーブレット変換，判別分析，正規化植生指数，MODIS

* 東京農業大学大学院農学研究科国際バイオビジネス学専攻
** 東京農業大学国際食料情報学部国際バイオビジネス学科