Estimation of Winter Wheat Sown Area Using Temporal Characteristics of NDVI

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Abstract: Agricultural land use generally shows specific temporal characteristics of NDVI obtained from satellite data. In terms of winter wheat, a higher value compared with other land use types in May and a considerably low value in June could be discriminative features of temporal change of NDVI. In this study, the author examined methods for estimating winter wheat sown area in sub-pixel level of coarse resolution satellite data using temporal characteristics of NDVI. Application of the methods to the major grain production area in China exhibited properly a spatial distribution pattern of winter wheat sown area.
Keywords: Agricultural Land Use, Temporal NDVI, Sub-Pixel Classification.

1. Introduction

Satellite remote sensing has been expected as a promising technique to produce land use data over wide area. Above all, production of agricultural land use data would be a major target because its spatial distribution could change year by year. One of the feasible methods to produce agricultural land use data is to classify by using middle to high spatial resolution multi-spectral sensor data. However, disadvantage of this method exists in a constraint of adaptable data during the appropriate period of crop growth. On the other hand, coarse resolution sensor data may overcome the missing of data at the required time. But a various mixing condition by pixel to pixel could cause a large range of error of estimation, if the classification is pixel bases. Therefore, the author attempted to develop a method to estimate winter wheat sown area as a representative grain crop cultivated in the temperate to cool climate zones in Asia by using coarse resolution data on sub-pixel bases in this study.

2. Materials and Methods

1) Study Site

The study site is Huang-Huai-Hai plain, which is the major grain production area, located in the eastern part of China. In most parts of the plain, winter wheat is normally sown in September to October and harvested in May to June. During the summer season, maize is the most popular crop, and is cultivated during the period from June to September. In some districts, where double cropping is rather difficult due to the constraint of water and soil conditions, cotton is cultivated as the summer crop. Although wheat is still one of the most common food crops in China, in recent years conversion of agricultural land use from traditional cropping pattern to vegetable production has increased, especially in Shandong province and the suburban area of Beijing.

2) Data

The data adopted to estimate land use was a dataset of 10-day maximum composite NDVI of NOAA/AVHRR. This dataset is provided by SIDaB (Satellite Image Database System), which is operated by Agriculture, Forestry and Fisheries Research Information Center. The author downloaded the data, which was standardized its pixel size as 1 km and geo-referenced on UTM coordinate system, for the period from 1994 to 2003.

LANDSAT-ETM+ data were used to obtain end-member values of NDVI of each land use type as well as to evaluate the accuracy of estimation. The scenes of these data were located along the Path 122 of Row from 32 to 35 observed on May 12, 2001 and the Path 123 of Row from 32 to 35 on May 19, 2001.

3) Methods

In this study, the author examined two methods to estimate winter wheat sown area using 10-day maximum composite NDVI of NOAA/AVHRR.

One was a sub-pixel classification method, which assumed that a value of NDVI at pixel was represented as a linear mixture of end-member value of each land use type [1]. In order to obtain end-member value of NDVI for each land use, first LANDSAT-ETM+ data was classified by maximum likelihood method and converted to probability density value of objective land use within 33 by 33 pixels window. The author drew a linear regression line in the figure of probability density against NDVI of NOAA/AVHRR at the same position, and extrapolated it to the value of one of probability density.

Another method was to estimate the ratio of winter wheat sown area in a pixel by using a scattergram of 2 temporal NDVI value. As we recognized by previous studies, NDVI of winter wheat shows a maximum at its flowering stage in May and considerably low value after harvesting in June. This temporal feature of NDVI could be discriminative from the patterns of other land use types and also might bring a formula of estimation of winter wheat sown area. The advantageous point of this

method is that no higher spatial resolution data would be required, if the formula is once set up and applied commonly to the case of different years.

3. Results

In order to perform a linear unmixing method, first the author examined the temporal changes of end-member values of NDVI for each land use. Within the area of Huang-Huai-Hai plain, 7 counties were selected for estimating end-member values. These counties were Shunyi in Beijing capital area, Xushui, Dacheng, Wuyi and Feixiang in Hebei province, and Yangxin and Gaotang in Shandong province. Land use in the study site could be classified largely into 3 types based on temporal profiles of NDVI. These 3 types were exemplified by winter wheat, mixed vegetation including rural settlement, and bare land including urban land use.

Estimation of end-member values of NDVI calculated by NOAA/AVHRR was performed based on existing probability density of specific classified data by LANDSAT-ETM+ within 33 by 33 pixels window. Although the variation of end-member value for specific land use among counties was recognized, the temporal profile of end-member value for winter wheat was distinctive from those of other types. Fig.1 shows the end-member values for three land use types mentioned above averaged over 7 counties.

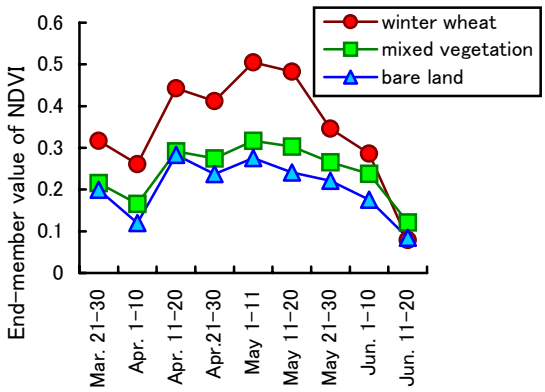

Fig. 1. Temporal change of end-member values of NDVI.

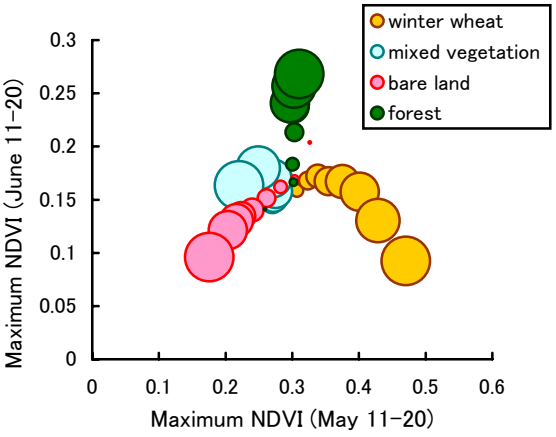

Fig. 2. Relation between 2-tempral NDVI and probability density of land use.

Fig.2 depicts the relation between 2-temporal values of NDVI at mid May and mid June and the probability density of land use in a pixel for the case of Shunyi county, where a larger circle indicates the higher probability density, e.g. the largest one is 95% followed by 85%, 75%, so on. This figure evidently shows the feature that the position would approach to the vertex of a triangle for the type of winter wheat, bare land and forest according to the increase of probability density. This could induce a schematic diagram described in Fig.3.

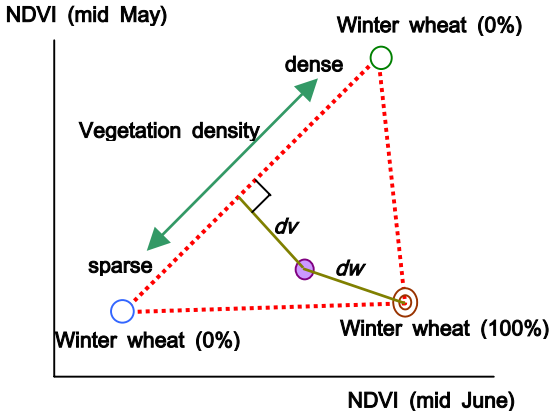

Fig. 3. Schematic diagram of relation between winter wheat percentage and 2-temporal NDVI.

Here, the author introduced a modified distance (**D**) from the line connecting two vertices, where the probability density of winter wheat was presumed as 0 %.

$$\mathbf{D}=dv/(dv+dw) \qquad (1)$$

As a result of examination between **D** and the ratio of winter wheat sown area in a pixel (**P**), the author discovered a relationship expressed by using logistic line expressed in Equation (2). The parameters used in Equation (2) were given in the case of 2001 and its coefficient of determination (R^2) was 0.8006.

$$\mathbf{P}(\%)=100/(1+89.1928\exp(-9.024\mathbf{D})) \qquad (2)$$

Fig.4 shows the estimated distribution of winter wheat sown area in and around Gaotang county for the case of 2001. The result by a linear unmixing method represents the averaged values over 4 temporal combinations, i.e. May 1-10 and June 1-10, May 1-10 and June 11-20, May 11-20 and June 1-10, and May 11-20 and June 11-20.

Fig.5 shows the comparison of percentage area of winter wheat by county between the values estimated by two methods of sub-pixel classification and values obtained from LANDSAT-ETM+. This result demonstrates the appropriateness of the methods for estimating areal distribution of major land use.

The estimated land use information could easily produce a map arranged by arbitrary spatial unit. Fig.6 represents an example of winter wheat distribution map as a unit of county estimated by the linear unmixing method introduced in this paper.

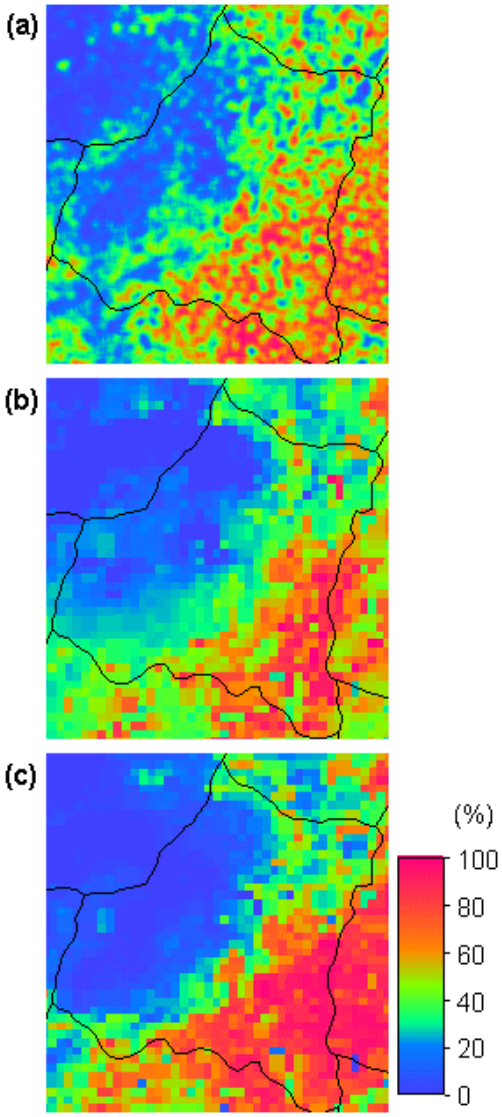

Fig. 4. Comparison between methods to estimate winter wheat sown area in around Gaotang county (2001). ((a)LANDSAT-ETM+, (b)linear unmixing, (c)logistic on 2-temporal NDVI)

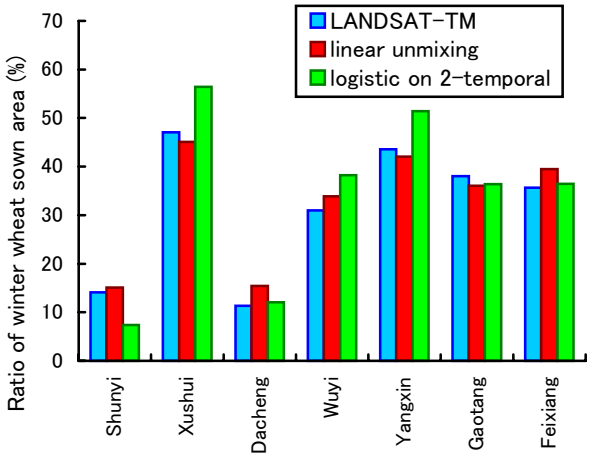

Fig. 5. Comparison of percentage area of winter wheat by county among different estimation methods.

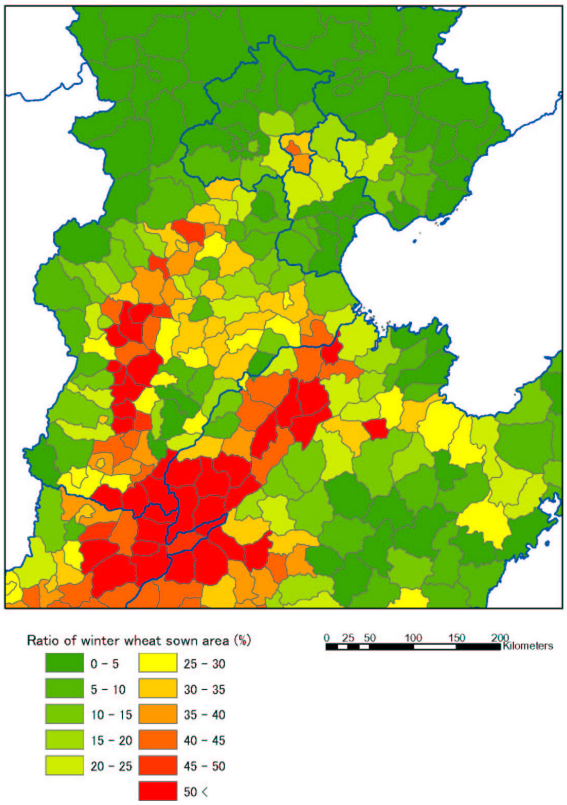

Fig. 6 Winter wheat distribution in Huang-Huai-Hai plain in China estimated by linear unmixing method.

4. Conclusions

For the purpose of producing information on agricultural land use in regional scale, two methods, which applied temporal characteristics of NDVI, were examined. Both the methods were recognized as promising to estimate winter wheat sown area. One method adopting linear unmixing technique was applicable if high spatial resolution satellite data taken in appropriate period could be obtained over a part of target site. The more simple technique, which utilized the changes of NDVI between two periods, would be effective to obtain information for multiple years, even in the condition that high spatial resolution satellite data was hardly adaptable.

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References

[1] Uchida, S., 2001. Sub-Pixel Classification of Land Use Using Temporal Profile of NDVI, *J. the Japan Society of Photogrammetry and Remote Sensing*, 40(1): 43-54.