ESTIMATING CROP LEAF AREA INDEX FROM REMOTELY SENSED DATA: SCALE EFFECTS AND SCALING METHODS

Y.Y. Dong, J.H. Wang, C.J. Li, G.J. Yang, X.Y. Song, and W.J Huang

Beijing Research Center for Information Technology in Agriculture
Beijing, China

Y.Y. Dong, and J.H. Wang
Institute of Agricultural Remote Sensing & Information System Application
Zhejiang University
Hangzhou, China

ABSTRACT

Leaf area index (LAI) of crop canopies is significant for growth condition monitoring and crop yield estimation, and estimating LAI based on remote sensing observations is the normal way to assess regional crop growth. However, the scale effects of LAI make multi-scale remotely sensed observations harder to be fully and effectively utilized for LAI estimation. A systematical statistical strategy is proposed to analyze scale effects of LAI in this paper. Firstly, appropriate model is selected for crop LAI estimation. Secondly, the best spatial resolution for regional LAI monitoring is extracted by analyzing the spatial heterogeneity of LAI. Finally, scaling method and ground observations are selected for results analysis and validation. Winter wheat in Beijing in 2008 is selected as experimental object. Taking ground observations and remote sensing observations as data sources, results and performances confirm the feasibility and validity of this new proposed strategy in scale effects of LAI analyzing.

Keywords: Precision agriculture, Scale effects, Scaling methods, Leaf area index (LAI)

INTRODUCTION

Leaf area index (LAI) of crop canopies as an important agricultural parameter is significant for crop growth monitoring and yield estimation in the research field of precision agriculture (Wang et al., 2008). Quantitative remote sensing technology has been rapidly developing in recent years, and based on remote sensing observations for crop LAI estimation is the universal approach to monitor regional crop growth (Friedl et al., 1994). However, much of the remote sensing observations at different spatial scales are not fully and effectively utilized for LAI estimation, and one of the main reasons is the scale effects of LAI (Bolschl, 1999; Ma, 2008; Woodcock et al., 1987; Western et al., 1999; Wu, 2010). Scale effects mean the differences as describing the same surface parameter with different spatial resolution data, and the spatial heterogeneity of LAI and the nonlinearity of the model for LAI estimation are the two aspects for the scale effects of LAI producing (Garrigues et al., 2006; Raffy et al., 1998). Considering the demands of comprehensive exploitation and validation of remote sensing observations in practical applications, and the contradictions between local observing ability of traditional "point" observations and actual demands of large and dynamic "area" observations, a systematical statistical strategy is proposed in this work to quantitatively analyze the scale effects of LAI.

Winter wheat in Beijing in 2008 is selected as object for numerical experiments to quantitatively analyze scale effects of LAI, and do scaling among different spatial resolution data for LAI estimation at the best spatial resolution. Taking ground observations and remote sensing observations as data sources, results and performances are analyzed in this study.

MATERIALS AND METHODS

The field experiments of winter wheat conducted in 2008 at Xiaotangshan National Precision Agriculture Experimental Base in Changping district, Beijing (40^{o}10'43''N, 116^{o}26'36''E). Several different fertilizer treatments were conducted to produce varied crop growth conditions. In May 29, ground investigation was carried out to get observations of winter wheat with the spatial resolution as 3m, and in May 25, a QuickBird multispectral image covered the same experimental area was achieved. The location of the experimental field and the distribution of the sampling points are intuitively shown in Fig. 1. In order to analyze the scale effects of crop LAI and do data validation, the ground observations and remote sensing observations are selected as data sources, and a new systematical statistical strategy is proposed in this work.

For this strategy, firstly, introducing, analyzing, and selecting appropriate model for LAI estimation based on remotely sensed data. Secondly, analyzing spatial heterogeneity of crop LAI, and further determining the appropriate spatial resolution, while it is the resolution containing necessary information for practical application and meeting the minimum data amount at the same time. Finally, introducing, analyzing, and selecting universal scaling methods for data processing, and results analysis and validation.

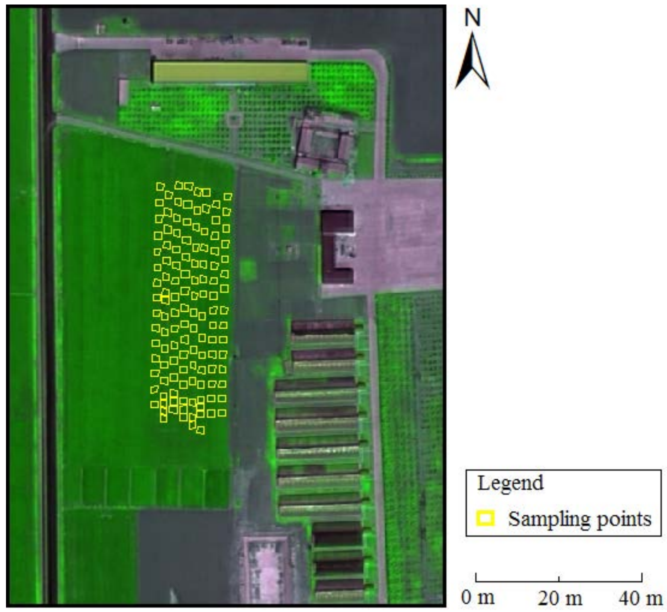

Fig. 1. Location of the experimental field and sampling points

RESULTS AND ANALYSIS

In the numerical experiments of winter wheat, scale effects of LAI are quantitatively analyzed according to the new proposed strategy. The details are as follows. Taking the QuickBird multispectral image as the data source, firstly, selecting the semi-experimental model constructed based on the Beer-Lambert Law (Ma, 2008) as the model for crop LAI estimation. Secondly, analyzing the complexity and variability of LAI at different spatial scales based on statistical parameters, such as mean value, variance, and their variations. And then, the appropriate spatial resolution of LAI is determined based on the analyzing results of spatial heterogeneity of crop LAI. Thirdly, constructing the remote sensing observations at the appropriate spatial resolution, i.e., the best spatial resolution for regional LAI monitoring, based on the QuickBird multispectral image through the polymerization method. Taking the ground observations at 3m as the baseline data, firstly upscaling the observations to construct the observations at the appropriate spatial resolution, and then to quantitatively analyze the reliability and effectiveness of the new proposed strategy on analyzing scale effects of LAI.

CONCLUSION AND DISCUSSION

Fully considered the practical demands of crop observations at the appropriate spatial scales, a new scale effects analyzing strategy is proposed in this work to construct the demanded observations at the best spatial resolution, and then based on the ground observations to do data analysis and validation. The new proposed strategy fully considers the applicability and nonlinearity of the model for LAI estimation, and the advantages of statistical analysis in extracting variations of multi-scale observations. Theory analysis and numerical practices not only confirm the feasibility and validity of the new proposed strategy in scale effects of LAI analyzing, but also manifest its stability and robustness.

REFERENCES

Bolschl G. 1999. Scaling issues in snow hydrology. Hydrol Process. 13(14-15): p. 2149-2175.

Friedl M. A., Michaelsen J., Davis F. W., Walker H., and Schimel D. S. 1994. Estimating grassland biomass and leaf-area index using ground and satellite data. Int J Remote Sens. 15(7): p. 1401-1420.

Garrigues S., Allard D., Baret F., and Weiss M. 2006. Influence of landscape spatial heterogeneity on the non-linear estimation of leaf area index from moderate spatial resolution remote sensing data. Remote Sens Environ. 105(4): p. 286-298.

Ma L. L. 2008. Study on spatial scaling analyses and transform method of land parameters retrieved from remote sensing data. PhD thesis, Institute of Remote Sensing Applications, CAS, Beijing.

Raffy M., and Gregoire C. 1998. Semi-empirical models and scaling: a least square method for remote sensing experiments. Int J Remote Sens. 19(13): p. 2527-2541.

Woodcock C. E., and Strahler A. H. 1987. The factor of scale in remote sensing. Remote Sens Environ. 21(3): p. 311-332.

Western A. W., and Bolschl G. 1999. On the spatial scaling of soil moisture. J Hydrol. 217(3-4): p. 203-224.

Wang J. H., Zhao C. J., and Huang W. J. 2008. Basis and application of agriculture quantitative remote sensing. Science Press, Beijing.

Wu H. 2010. Study on scale effects and scaling method for land surface key parameters: case studies for leaf area index and surface temperature. PhD thesis, Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing, China.