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Winter Wheat Yield Forecasting Using Sentinel-2 Imagery at the Early Stages

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Abstract : Winter wheat is one of the main crops in Canada. Forecasting of within-field variability of yield in winter wheat at the early stages is essential for precision farming. However, the crop yield modelling based on high spatial resolution satellite data is generally affected by the lack of continuous satellite observations, resulting in reducing the generalization ability of the models and increasing the difficulty of crop yield forecasting at the early stages. In this study, the correlations between Sentinel-2 data (vegetation indices and reflectance) and yield data collected by combine harvester were investigated and a generalized multivariate linear regression (MLR) model was built and tested with data acquired in different years. It was found that the four-band reflectance (blue, green, red, near-infrared) performed better than their vegetation indices (NDVI, EVI, WDRVI and OSAVI) in wheat yield prediction. The optimum phenological stage for wheat yield prediction with highest accuracy was at the growing stages from the end of the flowering to the beginning of the filling stage. The best MLR model was therefore built to predict wheat yield before harvest using Sentinel-2 data acquired at the end of the flowering stage. Further, to improve the ability of the yield prediction at the early stages, three simple unsupervised domain adaptation (DA) methods were adopted to transform the reflectance data at the early stages to the optimum phenological stage. The winter wheat yield prediction using multiple vegetation indices showed higher accuracy than using single vegetation index. The optimum stage for winter wheat yield forecasting varied with different fields when using vegetation indices, while it was consistent when using multispectral reflectance and the optimum stage for winter wheat yield prediction was at the end of flowering stage. The average testing RMSE of the MLR model at the end of the flowering stage was 604.48 kg/ha. Near the booting stage, the average testing RMSE of yield prediction using the best MLR was reduced to 799.18 kg/ha when applying the mean matching domain adaptation approach to transform the data to the target domain (at the end of the flowering) compared to that using the original data based on the models developed at the booting stage directly (“MLR at the early stage”) (RMSE =1140.64 kg/ha). This study demonstrated that the simple mean matching (MM) performed better than other DA methods and it was found that “DA then MLR at the optimum stage” performed better than “MLR directly at the early stages” for winter wheat yield forecasting at the early stages. The results indicated that the DA had a great potential in near real-time crop yield forecasting at the early stages. This study indicated that the simple domain adaptation methods had a great potential in crop yield prediction at the early stages using remote sensing data.

Keywords : wheat yield prediction, domain adaptation, Sentinel-2, within-field scale
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