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Le Corps professoral de

Gembloux Agro-Bio Tech - Université de Liège vous prie

de lui faire l'honneur d'assister à la défense publique de la dissertation originale que

Monsieur BAI Tiecheng,

Titulaire d'un master's degree of Measuring and Testing Technologies and Instruments,

présentera en vue de l'obtention du grade et du diplôme de

DOCTEUR EN SCIENCES AGRONOMIQUES ET INGENIERIE BIOLOGIQUE,

le 28 septembre 2020, à 9h00 précises, (personne ne sera admis après cette heure),

en visioconférence.

https://meeting.tencent.com/p/6970342718

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Cette dissertation originale a pour titre :

« Improving jujube fruit yield estimation by assimilating a remotely sensed leaf area index into the WOFOST model ».

Le jury est composé comme suit :

Président : Prof. P. du JARDIN, Professeur ordinaire,
Membres : Prof. B. MERCATORIS (Promoteur), Prof. Y. CHEN (Copromoteur - CAAS, Chine), Prof. H. SOYEURT, Dr V. LEEMANS, Dr. G. LIGOT, Dr Y. CURNEL (CRA-W).

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Abstract

Jujube fruit has important nutritional and medicinal qualities, and is one of the most economically valuable fruits in China. Field-scale jujube fruit yield estimation using site-specific techniques can provide indicators of the reasons for yield gaps, which could be promising to better understand spatial yield variation in jujube orchards, thereby analysing the possible causes to improve fruit orchard management decision-making. Both remote sensing and assimilation methods have been widely used for yield assessments of annual crops. There are few reports focusing on the use of assimilation methods to estimate yields for fruit crops, especially jujube trees. The main goal of this thesis is to make full use of the advantages of crop growth models and remote sensing technology to improve the accuracy of jujube fruit yield estimation. The first aim is to introduce phenological length into the yield regression model, based on a remotely sensed vegetation index, to enhance the accuracy of yield estimation. The second aim is to develop and evaluate remote sensing assimilation methods to reduce the uncertainty of key input parameters or state variables in the jujube growth simulation process, thereby improving yield estimation at the field scale for local jujube orchards.

Firstly, the performance of the calibrated WOFOST (World Food Studies) model was evaluated by simulating jujube fruit tree growth in potential mode. The model was calibrated and validated using data collected in field experiments performed in three growth seasons. The R^2 and RMSE of the field-scale yield estimation for 181 orchards were 0.22 and 1.07 t ha^{-1} (16.3%) for 2016, 0.04 and 1.33 t ha^{-1} (17.2%) for 2017, respectively. Although the calibrated WOFOST model can provide a fundamental strategy for simulating the growth of jujube fruit trees, there may still be some uncertainty in the method of setting the fixed TDWI for the same aged jujube orchards, resulting in a slightly low estimation accuracy.

Secondly, this thesis evaluated the yield estimation performance of regression methods based on remotely sensed vegetation indices that are widely used for crop yield estimation. An approach that used the phenological length to improve remotely sensed estimates of inter-annual variability for yields was explored and tested. The optimal time for determining jujube yield estimation was during the fruit filling period, which showed higher R^2 between vegetation indices (VIs) and fruit yields. The potential of using Landsat-NDVI for jujube yield estimation, combined with the phenological length, was proved based on observed fruit yields of 181 jujube orchards, showing a validated R^2 of 0.64 and RMSE of 0.73 t ha^{-1} (11.1%) for 2016, 0.71 and 0.73 t ha^{-1} (9.5%) for 2017, respectively.

Thirdly, this study presented an attempt to assimilate a single LAI at near to maximum vegetative development stage, derived from Landsat satellite data, into a calibrated WOFOST model to improve fruit yield estimation at the field scale. The assimilation after forcing LAI improved the yield estimation performance compared with the unassimilated simulation, showing a R^2 of 0.62 and RMSE of 0.74 t ha^{-1} (11.3%) for 2016, and R^2 of 0.59 and RMSE of 0.87 t ha^{-1} (11.3%) for 2017, respectively.

Finally, the main contribution of this study was to develop a SUBPLEX algorithm to assimilate a time series of remotely sensed LAI during the main growth stages into the calibrated WOFOST model, and compared the yield estimation accuracy of the SUBPLEX algorithm with a widely used Ensemble Kalman Filter (EnKF) assimilation. The results showed that both SUBPLEX and EnKF assimilations significantly improved yield estimation performance compared with the un-assimilated simulation. The SUBPLEX (R^2 = 0.78, RMSE = 0.64 t ha^{-1} (8.3%) and RPD (Standard Deviation (SD)/RMSE) = 2.13) also showed slightly better yield estimation accuracy compared with EnKF assimilation (R^2 = 0.66, RMSE = 0.79 t ha^{-1} (10.2%) and RPD = 1.73). The study provides a new assimilation scheme based on a SUBPLEX algorithm to employ remotely sensed data and a crop growth model to improve field-scale jujube fruit yield estimates.