УДК: 631.559

WHEAT YIELD FORECASTING USING NDVI AND CROP STATISTICS IN TASHKENT PROVINCE

Pulatov B.A. - Associate professor, PhD Lund Unviersity, EcoGIS center, TIIM
Boogard H. - Researcher, PhD, Wageningen University
Pulatov A.S. - Associate professor, PhD, EcoGIS center, TIIM

Аннотация

Қишлоқ хўжалиги экинларини кузатиш мамлакатнинг қишлоқ хўжалигини ривожлантиришда катта аҳамиятга эга ҳисобланади. Буғдой ҳосилдорлигини ишлаб чиқариш ва башорат қилиш миллий ва халқаро иқтисодиётга бевосита таъсир кўрсатиб, Ўзбекистонда озиқ овқат таъминотни бошқаришда муҳим роль ўйнайди. Ҳозирги кунда Ўзбекистонда давлат муасасалари ва фермерлар томонидан буғдой ҳосилдорлигини оширишга катта аҳамият берилмоқда. Бу ишнинг мақсади Тошкент вилоятидаги буғдой ҳосилдорлигини вегетация даврида башоратлаш усулларини ўрнанишдан иборатдир. Ушбу изланишда қўлланиладиган ёндошув, қишлоқ хўжалик экинлари ривожланиши моделига асосан, об- ҳаво таъсирини экин ривожланишига миқдорий баҳо бера олади. Тошкент вилоятидаги буғдой ҳосилдорлигига баҳо беришда ўсимлик ўсиши кузатув системаси ва масофадан зондлаш моделлари ишлатилади. Таҳлилий натижалар, статистик маълумотлар ва буғдой ҳосилдорлик параметрлари (ёки индекслари) орасида ижобий корреляция (R^2=0.87) ни кўрсатади.

Abstract

Monitoring of crop conditions is important part for the agricultural development system of the country. The production and prediction of wheat yield have direct impact on national and international economies, and play an important role in the food management in Uzbekistan. Today wheat yield production in Uzbekistan is receiving considerable attention from governmental organizations and farmers. The objective of this study is to investigate how we can best predict wheat yield during the vegetation period in Tashkent province. The approach used in this study is based on a crop growth model which is able to quantify the effect of weather conditions on crop growth. The model focuses on indicators from Crop Growth Monitoring System (CGMS) and Remote Sensing data to use year to year variation of wheat yield in Tashkent province. The results showed the positive correlation between the predicted yield and field data (R^2 = 0.87) and indicators maximum NDVI and maximum DMP which are driven from remote sensing data are performing the best at regional level.

Аннотация

Мониторинг урожайности сельскохозяйственных культур имеет важное значение для развития страны. Производство и прогнозирование урожайности пшеницы имеют непосредственное влияние на национальную и международную экономики, и играет важную роль в управлении обеспечения продовольствием в Узбекистане. В Узбекистане особое внимание уделяется производству пшеницы со стороны государственных учреждений и фермеров. Целью данного исследования является изучение наилучших методов прогнозирования урожайности пшеницы в течении вегитационного периода в Ташкентской области. Подход, используемый в данном исследовании, основан на модели развития сельскохозяйственных культур, способной дать количественную оценку влияния погодных условий на их развитие. Модель использует индикаторы Мониторинговой системы развития растений (CGMS) и данные дистанционного зондирования для оценки урожайности пшеницы в Ташкентской области. Результаты анализов показали положительную корреляцию (R^2 = 0,87) между статистическими данными и параметрами (или индексами) урожайности пшеницы.

Introduction. Uzbekistan is a good example in changing agricultural land use in Central Asia. An introduction of winter wheat in the irrigated areas at large scale for reasons of food security was started in 1996. In the past, basically, the wheat consumed in Uzbekistan was imported either from Russia or neighboring Kazakhstan. In Uzbekistan the area for winter wheat production has increased from 0.61 million tons in 1991 to 8 million tons in 2015 according to National Statistical Committee of Republic of Uzbekistan (NSC, Uzbekistan 2015). Wheat production in Uzbekistan for 2011-2014 was estimated at 6.8-7.6 million tons (NSA, Uzbekistan, 2007). In order to improve land use, it is suggested to develop or introduce a yield forecasting system in Uzbekistan. The European Commission launched the Monitoring Agriculture with Remote Sensing (MARS) project in 1988 in order to predict crop yields, crop areas and crop productions. Currently, some research centers are also using the CGMS model to predict crop yields in Central Asia. However, this is still a prototype. Because of the importance of wheat for Uzbekistan, the adaptation of current model will provide for national level a tool to predict the wheat production in the following years. Improved understanding of the potential effects of climate change on crop yields is central to planning appropriate and timely responses. Numerical models that emulate the main processes of crop growth and development rely on prediction method. The main objective of this model is to generate country-wide information during the wheat cropping season on the state of the crops and yield outlook. This approach is based on crop growth simulation to quantify the effect of weather conditions on crop growth and on statistical analysis of the selected years of crop model output and observed regional yields.

Methods and materials. The study area for the forecasting model to be adapted in Tashkent province, Uzbekistan locates in the south of Kazakhstan, north of Turkmenistan, and on the western borders of Tajikistan and Kyrgyzstan (Fig. 1). The climate of Uzbekistan is continental, with hot summers and cool winters. Summer temperature reaches 40°C, averaging 32°C. Winter temperature reaches –23°C, averaging –12°C. Rainfall varies between 100 millimeters per year in the northwest and 800 millimeters per year in the Tashkent province. Precipitation is mainly in the winter and spring. Arable land: 10.51%, permanent crops: 0.76%, and other: 88.73% (2005) (Wikipedia, 2007).

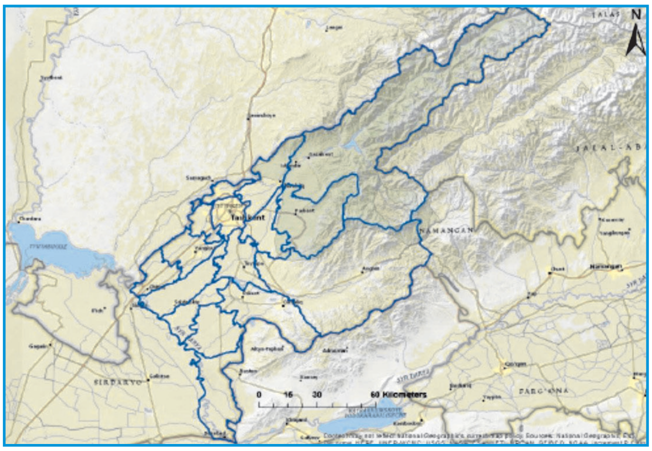

Figure 1. Map of Tashkent province, Uzbekistan

The yield prediction system used in the European Union also known as the Crop Growth Monitoring System (CGMS) has been adapted to run for Tashkent province. The main objective of CGMS is to monitor agricultural season conditions over the whole of the European Union (EU) and neighboring countries, and to make quantitative within season yield forecasts at regional and national scale for specific crops. CGMS uses daily meteorological observations from a network of some 2000 weather stations to estimate crop status under water-limited and irrigated (potential) conditions in the course of the growing season and to estimate final crop yield at the end of the season.

The main agricultural crops in Tashkent province are winter wheat and cotton. This study is focusing on winter wheat, mainly in irrigated winter wheat in slopes is producing. The winter wheat season is starts in September and harvested in June. In study the data of 10 years (1997-2006) was applied. Total area (in 2006) under winter wheat in Uzbekistan was about 1,2 million (NSA, Uzbekistan, 2007). This data is for all regions and is called national and regional level in the CGMS model. The French government has undertaken the development of the Systeme Pour

l'Observation de la Terre (SPOT) program. (http://www.agrecon.caberra.edu.au/products/Satellite_Imagery/Spot_Veg/Spot_Veg.htm). The SPOT program was conceived by the Centre National d'Etudes Spatiales (CNES) and has developed into an international program with ground receiving stations and data distribution outlets in more than 30 countries. The Vegetation Instrument system is the result of a co-operation between the European Union, France, Sweden, Belgium and Italy. It aims at ensuring a regional and global monitoring of the continental biosphere and its crops. In this study an operational approach was developed using time series of Normalized Difference Vegetation Index (NDVI, Fig.2) and Dry Matter Productivity (DMP) derived from SPOT-Vegetation using the crop yield forecasting tool in Uzbekistan during a nine-year period (1998-2006). The starting point is a series of geographically congruent and periodic (mostly 10-daily) images over the area of interest. The NDVI values vary from 0.15 for bare soils to ±0.80 for full green vegetations, with all gradations in-between.

$$NDVI = (\lambda Nir - \lambda Red) / (\lambda Nir + \lambda Red) \qquad (1)$$

Red and Nir stand for the spectral reflectance measurements acquired in the red and near-infrared regions, respectively (Fig.2). These spectral reflectance's are themselves ratios of the reflected radiation over the incoming radiation in each spectral band individually; hence they take on values between 0.0 and 1.0. By design, the NDVI itself thus varies between -1.0 and +1.0. NDVI indicators may be used for estimating deviations from the year to year yield trend (Bouman et al., 1992; Boogaard et al., 2002). Focus in this study will be on relating NDVI indicators to yield residuals. To predict wheat yield indicators should be selected that have good correlation between the residuals from the trend and indicators (NDVI or DMP) from the SPOT-Vegetation. SPOT-Vegetation data were used as a basis for calculation of remote sensing indicators for crop growth. Maximum NDVI, maximum DMP and sum NDVI are indicators, which provide information about wheat yield prediction. The maximum NDVI is derived as the highest NDVI values over the year and the maximum DMP is also derived as the highest DMP values over the year. However, sum of NDVI is integrated NDVI values over the year. At last, was built the yield estimation model based on linear regression analysis between the indicators and residuals just mentioned. These are combined with trend yield, residuals from the trend and satellite based indicators to forecast yields.

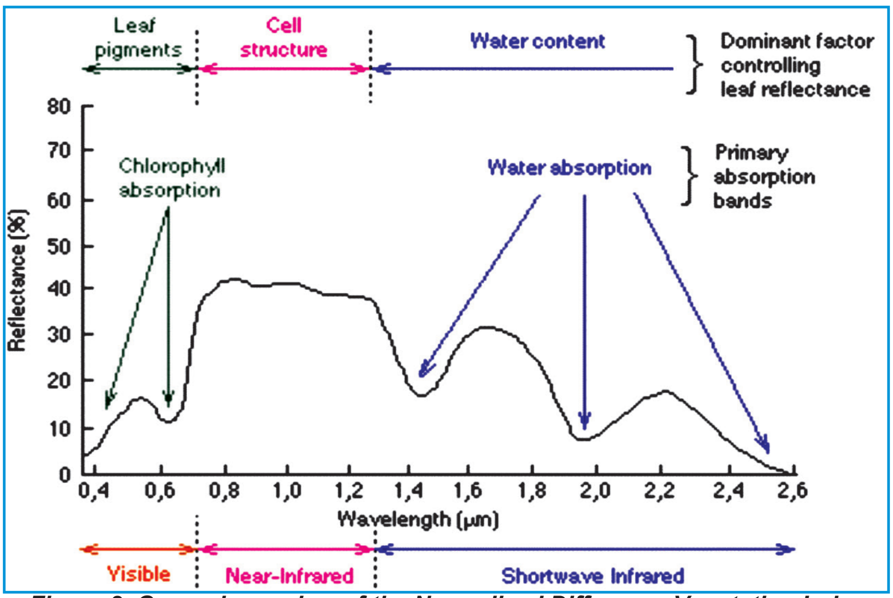

Figure 2. General overview of the Normalized Difference Vegetation Index

CGMS uses a running time series of yield statistics of at least 10 years to determine a linear technology trend assuming that the trend is stable over this period. The time series of crop simulation results are then used to explain the residual deviation. The system selects the best predictor out of four CGMS crop indicators (simulation results):

-CGMS_WYS: Uses as predictors the simulations of the total weight of the storage organs (grains) for wheat under water limited conditions

-CGMS_WYB: Uses as predictors the simulations of the total weight of the above ground biomass for wheat under water limited conditions

Results and Discussion. In this study our analyses showed that results of the predicted wheat yield in Tashkent province for irrigated areas at regional level. The model results show in total

Comparison of predicted yield and field data collected in 2007

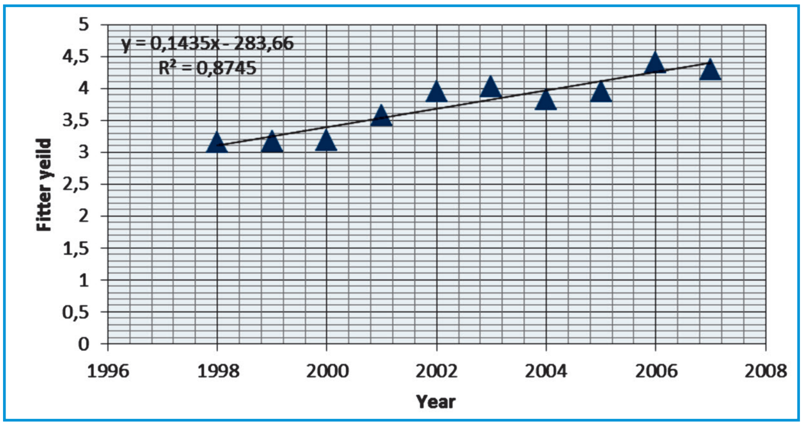

Figure 3. Correlation between predicted and field data yield for 2007

five indicators: CGMS_WYB and CGMS_WYS and SPOT Vegetation indicators: max_NDVI, max_DMP and sum_NDVI. For Tashkent province only two indicators WYB and PYB show 0.31 and 0.32 RMSE of predicted values biomass. The results of the CGMS illustrate lower production than the trend that explains better year to year variation in Tashkent province. In this case trend shows a lower value than the five indicators. For that reason the trend would be a second option as representative indicator for this region, to explain year to year variation for this season and period. However, indicator max_PYB showed best trend for Tashkent province (Fig.3).

The results represents correlation between statistical of winter wheat yield data and CGMS model data during 1996-2006. In general, the results indicate positive correlation between fitted yield and field data, i.e. R^2 equal to 0.87 (Fig. 3). In this study the we investigate whether indicators from CGMS or SPOT-Vegetation data can be used in a regression model to explain year to year variation of wheat yield in Tashkent province during the growing season well before harvest. The strategies for each model were identified and compared in order to evaluate the appropriate model for this research. The CGMS Statistical Tool was found more efficient to satisfy the objective of this research. It was therefore adopted and used to investigate which indicators show best results in explaining year to year variation. Numerous crop growth models has been developed since the 1980th, focusing the role of temperature in crop development, (using statistical analysis and simulation models) i.e. for example, empirical models (Boogaard et al., 2002), dynamic simulation models (Steduto et al., 2009), temperature dependent model (Supit et al., 2012) and statistical models (Montgomery et al., 2001). Direct comparison among the different crop growth models was not possible due to that the different varieties of crops are grown in different regions and in each region may differ in their growing conditions, i.e. depending on latitude and altitude (Haverkort 1990). Crop growth models uses a complex dynamic process (e.g., canopy growth, tuber formation, senescence of leaves) for predicting the development of the wheat under different temperature thresholds, resulting relatively more accurate predictions using field experiments. However, not all of them may able to predict the wheat yield in the Central Asia, especially in Uzbekistan since this country has high variety of soil and environmental conditions. The CGMS model was adapted for continental climatic conditions such as in Uzbekistan.

Conclusion. In conclusion of prediction of wheat yield could provide an example on how model simulations can be carried out to evaluate the impact of climate change and potential adaptation strategies This study has been work on finding out whether indicators from CGMS or SPOT-Vegetation data can be used in a regression model to explain year to year variation of wheat yield in Tashkent province during the growing season and before harvest. The strategies for each model were identified and compared in order to evaluate the appropriate model for this research. The CGMS Statistical Tool was found more efficient to satisfy the objective of this research. CGMS the indicator PYB performed best at regional level to explain year to year variation.

References:

1. Boogaard, H., Supit, I., K. van Diepen, C. Eerens, H., Piccard, I., Kempeneers, P., 2002. "Description of the MARC CROP YIELD FORECASTING SYSTEM (MCYFS)". METAMP report1/3, Alterra and VITO, JRC-contract 19226-2002-02-F1FED ISP NL
2. Bouman, B.A.M., 1992. Linking physical remote sensing models with crop growth simulation models, applied for sugar beet. Int. J. Remote Sensing 13:2565-2581.
3. Montgomery, D.C., Peck, E.A. and Vining, G.G., 2001. Introduction to Linear Regression Analysis, third edition. Wiley, New York. Monteith, J.L., 1972. Solar radiation and productivity in tropical ecosystems. J. Applied Ecology, 19: 747-766
4. Haverkort AJ (1990) Ecology of potato cropping systems in relation to latitude and altitude. Agricultural Systems 32:251-272
5. Steduto P, Hsiao TC, Raes D, Fereres E (2009) AquaCrop—The FAO Crop Model to Simulate Yield Response to Water: I. Concepts and Underlying Principles All rights reserved. No part of this periodical may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher. Agron J 101:426-437
6. Supit I, van Diepen CA, de Wit AJW, Wolf J, Kabat P, Baruth B, Ludwig F (2012) Assessing climate change effects on European crop yields using the Crop Growth Monitoring System and a weather generator. Agricultural and Forest Meteorology 164:96-111