DYNAMIC DATA EXCHANGE IN AGRICULTURAL WATER MANAGEMENT STRATEGY

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Abstract

Space-based remote sensing provides an opportunity for continuous tracking the biomass growth of plants. GPS registered samples were collected on the field on the plant transpiration surface with ACD-type leaf area scanner in different phenological phases. In our research, normalized difference vegetation index (NDVI) time series were used on the sample plot to determinate K_c values which indicate the phenological state with higher accuracy. Vegetation indices are mainly derived from reflectance data from discrete red (R) and near-infrared (NIR) bands.

Principal components analysis showed the variances for the test area. Clustering was made from the first principal components image, and 5 parts of the plot that considered homogeneous were selected by this to calculate sugar beet crop water requirements on rainfed water condition. The average NDVI values that are covered by these region of interest were calculated from the 9 time steps. Regression equation was fitted for these average values, determining the parameters, and strength of the correlation. The model is suitable for not only the development of water management strategies based on natural moisture, but also for different irrigation variants, such as irrigation time period and technical optimization of water distribution.

Keywords: remote sensing, leaf scanner, GPS

INTRODUCTION

The possibility of the amount and distribution of extreme rain event is increased in Hungary, so the plants often suffer from drought and, on the other hand, sometimes harmful water surplus causes problems in the crop production, occasionally in the same year, in the same area (Nagy, 1995; Várallyay, 2000). Water management and especially pressurized irrigation are less introduced into GPS-based precision agricultural technology (Marques Da Silva and Alexandre, 2003). In an irrigation model there are many input parameters that changing dynamically in time, like crop and climatic data (TAKÁCS et al., 2004). Determination of the changeable parameters became easier by using satellite, airborne and near field remote sensing data sources. A major disadvantage of widely used robust point-based practical water management models (WMM) is that they unable to provide proper information for farmers about those parameters that change dynamically in time and field level, so as they could not efficiently adjust several elements of the integrated small scale water management (KOVAR and Nachtnebel, 1996). This management practice is not only includes irrigation, but also other more important technological parameters such as water stress tolerant crops, cultivation or nutrition management. In this study the authors present a GPS-RS-WMM model integration, as a possible solution for making farm management more effective.

MATERIAL AND METHODS

In our research we analyzed the water management system of a 19 hectare sugar beet field in Northeast-Hungary. Sample points were selected by geostatistical evaluation, which was based on 1:10000 scale digital elevation TIN model and digital soil maps (Isaaks and Srivastava, 1989; Cressie, 1993). The time-series were calculated from nine different Landsat images that cover the sample plot and the full phenological period (Image source: FÖMI, 2005). Space-based remote sensing provides an opportunity for continuous tracking the biomass growth of plants. GPS registered samples were collected on the field on the plant transpiration surface with ACD-type leaf area scanner in different phenological phases. Crop coefficient (K_c), a basic input of farm level irrigation models, was defined by the leaf area and the transpirating area can be connect to the phenological changes in time by this. The widely used FAO CROPWAT irrigation planning and managing software (developed by Smith (1992)) that was applied by using the climatic, soil characteristics and water management attributes and data of the field to calculate crop water requirement and irrigation requirements, estimated K_c for a given place with large error by 3 point. In our research, normalized difference vegetation index (NDVI) time series were used on the sample plot to determinate K_c values which indicate the phenological state with higher accuracy. Vegetation indices are mainly derived from reflectance data from discrete red (R) and near-infrared (NIR) bands. They operate by contrasting intense chlorophyll pigment absorption in the R against the high reflectance of plant materials in the NIR. Calculation of NDVI is as follows: NDVI=(NIR-R)/(NIR+R) (ROUSE et al., 1973). We also sampled and measured actual soil water content by TDR method in every 0.2 m layers till 1.5 m depth to prepare available water content profile of root zone (RAJKAI and RYDÉN, 1992). The soil type on site is chernozem. Plant agro-technological data was prepared in ArcGIS environment. We computed and evaluated heterogeneity by running principal components analysis that was performed on the time-series of the biomass. With the help of the software and the utilization of Penman-Monteith equation, reference crop evapotranspiration (ET_o) can be calculated. For the equation the following variables are required: minimum-maximum temperature, air humidity, windspeed and daily sunshine. The data used were collected from the weather station of Debrecen (45°N, 21°E). In the crop coefficient approach the crop evapotranspiration, ET_c, is calculated by multiplying the reference crop evapotranspiration, ET_o, by a crop coefficient, K_c. The value of the K_c is between 0,3-1,2 depending on crop varieties, so its average estimation error can reach the 200-300 %. Since the value of the actual crop water requirement based on model sensitivity analyses depends on the actual value of K_c significantly, the error propagation influences the reliability of the whole model. One of the aims of our searches is the rise of the accuracy of this parameter using remote sensing data source. Considering runoff direction, the amount of effective rain was calculated by D8 runoff algorithm (published by MOORE et al., (1993)) from the digital elevation model. Statistical and image analyses were performed by different software packages: SPSS 12., IDRISI Kilimanjaro and ENVI 4.2. The results assisted and enabled the precision water management planning of the sample plot, as well as the calculation of different water management scenarios and finally the sustainable water management by timely dynamic data exchange of GIS and CROPWAT input/output.

RESULTS AND DISCUSSION

Principal components analysis showed the variances for the test area. Clustering was made from the first principal components image, and 5 parts of the plot that considered homogeneous were selected by this. We created ROI (Region Of Interest) that covered the 5 sites. The average NDVI values that are covered by these ROI were calculated from the 9 time steps. Regression equation was fitted for these average values, determining the parameters, and strength of the correlation. We could appreciate the NDVI values which were estimated between 2 measuring dates with the help of the regression equation. We found strong correlation between NDVI and Leaf Area Index (LAI), and LAI is in strong correlation with K_c. Daily values of the tertiary equation had to be suited for the K_c values. Since K_c=1,2 is equal with the maximum of the tertiary equation, we have NDVI value enumerated to K_c value by proportional matching. The model was fed with the actual water supply data using the soil-cartograms, and with the help of the field measurements considering rooting depth which is increasing in time. To calculate sugar beet crop water requirements was taken into account five homogenous plot size actual water regime based on rainfed water condition. The amount of total rain was modified by the value of the runoff and we calculated the maximum rain infiltration rate. Dry matter production and also the length of the individual growing stages were measured on site. Crops factors (K_c) and a field response factor to estimate yield reduction due to drought stress (K_y) were determined, and rooting depth measured. K_c and K_y factors have to be given for each growing stages. We examined the difference between ET_o values estimated with the Penman-Monteith equation by CROPWAT model and calculated ET_o values based on the A-type pan evoporation measured on the weather station. We found that estimated ET_o values have exceeded calculated values with 7-12%. We also compared the difference of crop water requirement (CWR) values between the 5 sites and the CWR values estimated by CROPWAT. We determined that CROPWAT model is overestimates the CWR in the initial stage and in the mid-season, but it correlates well in the crop development stage.

CONCLUSIONS

The ET_o and the crop water requirement values estimated by CROPWAT model have exceeded the calculated values that based on measured data. Because of the gained results it is suggested to use the measured data in practice. The model is suitable for not only the development of water management strategies based on natural moisture, but also for different irrigation variants, such as irrigation time period and technical optimization of water distribution. As the result of the scheme we calculated the crop irrigation requirement, the net scheme irrigation requirements in mm day $^{-1}$, 1 s^{-1} ha and 1 s^{-1}, irrigated area as percentage of total scheme area, and irrigation requirement in 1 s $^{-1}$ ha $^{-1}$ for actually irrigated area. Crop water requirement was determined and it is suitable for optimization the irrigation requirement by this. GIS-RS-WMM integration is suitable for the analysis of the effectiveness of environmental sound water management strategy, the development of irrigation schemes in Hungary as well and also to reduce costs and save water. With low inputs it is also suitable to test the water regime of different plant varieties and precision soil cultivation alternatives.

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