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Combined traffic control of irrigation on heterogeneous field

Andrea Szabó[1]* – Csaba Juhász[2] – Bernadett Gálya Farkasné[1] – Ádám Kövesdi[3] – János Tamás[1] – Attila Nagy[1]

[1]University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management, Institute of Water and Environmental Management 138. Böszörményi str. Debrecen H-4032, Hungary

[2]University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management Institute of Land Use, Engineering and Precision Farming Technology 138. Böszörményi str. Debrecen H-4032, Hungary

[3]Magtár Kft. 2. Kombájn srt. Szolnok H-5000, Hungary

*Correspondence: szabo.andrea@agr.unideb.hu

SUMMARY

In arid areas, such as Hungary, most climate models forecast a rise in water scarcity. Irrigated land accounts for 2% of agricultural land in Hungary, with most irrigation technology being relatively outdated. The aim of this research was to lay the foundation for a combined traffic management system for a water-saving precision irrigation system on an 85-ha field in the Tisza River basin's reference region. High-precision soil maps were created to support the water-efficient variable-rate irrigation system by selecting and selecting areas for different agrotechnical implementations and precision farming zones.

Keywords: *variable rate irrigation, water balance, high precision soil map*

INTRODUCTION

Water scarcity is becoming a big problem that will require agricultural production and management practices to change, especially in arid and semi-arid areas (Falkenmark, 2013; Nagy et al., 2018). Annual precipitation trends in our region are still very uncertain, with the frequency of droughts already significantly increasing due to rising temperatures and decreasing precipitation (Juhász et al., 2020; Tamás et al., 2015). The world population is projected to reach 9.2 billion by 2050. Therefore, world food demand will increase by 60% (Bindraban & Rabbinge, 2011), water demand by 35% (Panella, 2020) and energy demand by 35% (Beddington, 2013). It is not only food demand that will increase, but also market demand for high quality (protein and vitamin rich) fruit and vegetable foods (HLPE, 2015; Aiking, 2011). This also requires a continuous, even and physiologically optimal water supply for plants (Takács et al., 2019). In addition to water retention measures, these needs can only be met in a sustainable way through water and energy efficient irrigation, which implies different innovative irrigation solutions, especially in the Central European region. In this region, large fields (Cartwright & Batory, 2012) (50 ha >) and often longer than 1 km are characterized by a linear or pivot irrigation system with a corner turn at the end, which would be optimal for irrigation. Moreover, considering the spatial and temporal heterogeneity of soil, water management and vegetation in the field, precision agriculture tools can enhance crop production, water and energy efficient irrigation. Numerous experiments have been conducted worldwide to evaluate the effectiveness of variable rate irrigation (VRI) and its impact on crops and soil. Based on the condition of the vegetation, treatment zones can be established that can be effective in water control (Neupane & Guo, 2019). In order to avoid the need to set up multiple central pivot irrigation systems, which would significantly increase costs, a novel way of combining linear and central pivot movement was needed and the necessary traffic management had to be developed. The innovation has not only transformed the operation of the irrigation equipment, but also the sensor network for precision irrigation, the recording of crop water demand. The aim of the research was to develop a combined traffic management for a water-saving precision irrigation system for a field area (85 ha) located in the reference area of the Tisza Riven basin.

MATERIALS AND METHODS

Study area

During the research, a real-time eco-potential measurement methodology for water management was developed for water-saving precision sprinkler irrigation system on an arable land (85 ha), which is located in South-East Nyírség, Szabolcs-Szatmár-Bereg county in the North-Eastern region of Hungary (*Figure 1*).

The number of sunshine hours is less than 2000 and is closer to 1900. On average, approximately 800 hours in the summer, 170 hours in the winter, the temporal distribution of sunlight. The average annual temperature is 9.5–9.7 °C, which increases during the growing season and reaches a value of around 16.6 °C. On the hottest summer days, the maximum temperatures are around 34 °C. Calculating the average temperature of the coldest winter days we get between -17.0 °C and -18.0 °C. The annual rainfall is 570–600 mm, in the summer it is about 350–360 mm. The most common wind direction in the north is north-east and south-east, with an average speed of 2.5 m s^{-1}. Summary, the climate of small region of Southeast Nyírség is suitable for not very heat and water intensive agricultural crop production.

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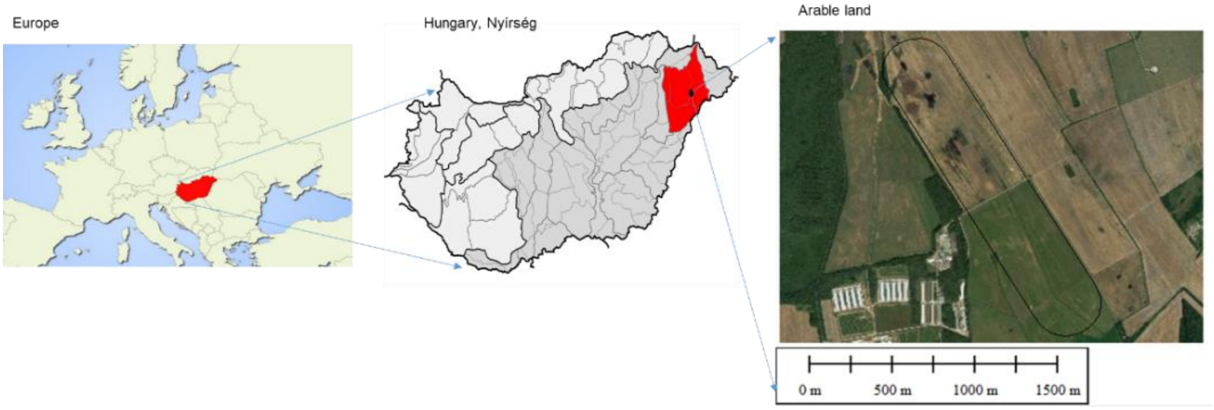
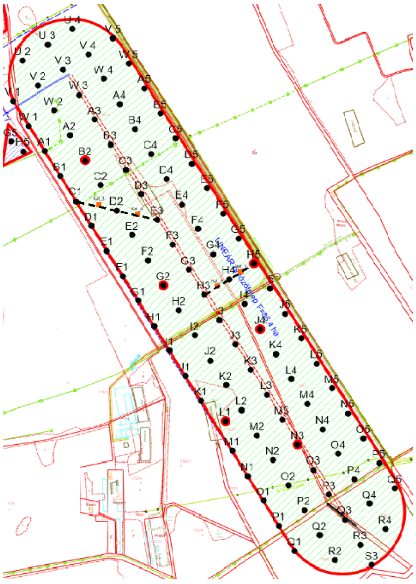
Figure1: **Location of the sample area**



Soil sampling and analysis

The precision grid-based soil sampling was carried out on an agricultural field (85.5 ha) in our investigation. Different databases and maps (for example Hungarian soil database, digital aerial photo archive, geological map by the Mining and Geological Survey of Hungary) were used to elaborate the soil sampling strategy. Core soil samples in two layers (30 cm and 60 cm) were taken. On the analysed arable land, we modelled at 102 points, representing more than 1 sample per hectare, form a total of 510 samples (*Figure 2*).

Figure 2: **Sampling strategy in the field**



Determining the soil structure and other important soil water content is major key to giving shape of this research of soil water requirements. The texture and soil water retention parameters (i.e. saturated water content, field capacity, moisture capacity, wilting point) were measured to determine soil density, total available water content, gravitational water content. Soil chemical properties were also measured (hu%, N, P, K) and were examined in the Laboratory of Soils of the University of Debrecen, Institute of Water and Environment Management. After laboratory testing, high precision soil maps and 3-D model of deep root zone were created to support the establishing water saving variable rate irrigation system by selecting and identifying sites for different agro- technical implementations and precision management zones.

Irrigation machine

A Reinke 2060 PL irrigation machine with a total structural length (including the basic machine and the end console) of 209.09 m was installed in the field. The irrigation system consists of four 47.54 m long irrigation sequences and an 18.59 m long end arm, with a total irrigation radius of approx 235 m. The maximum water demand of the system is 180 m^3 h^{-1} and the minimum water demand is depending on aim of the VRI, as the pump must operate at 65 m^3 h^{-1}, which requires a minimum operating pressure of 2.2 bar at the central tower. The type of nozzle used is NELSON R3000, which is equipped with 15 PSI pressure regulators and is located at a height of 2.1 m from the ground. The GPS control is located on the central tower consisting two AG25 Trimble antennas and a Trimble BD 970 receiver with steering electronics. It is worth dividing the irrigation system into separate circuits in terms of its operation. Pivoting operation and VRI operation in linear mode can be distinguished. 18 zones (A1-6; B1-6 and C1-6) have been created on the irrigation machine, of which 17 zones can be controlled in linear operation. The unit has two separate sets of spray heads, one for linear mode and one for center mode. In linear mode, the nozzles have nearly the same nozzle size, while the center set has smaller nozzles at the front of the system and larger and larger towards the end. The 8 nozzles in the middle of the unit dispense the same amount of water in both pivot and linear mode, so those two zones are active in both linear and pivot mode (*Figure 3*).

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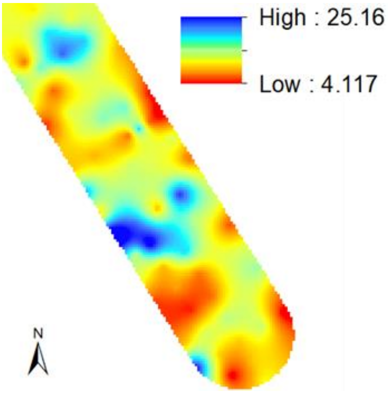
Figure 3: **Pivoting lateral moving irrigation system**

RESULTS AND DISCUSSION

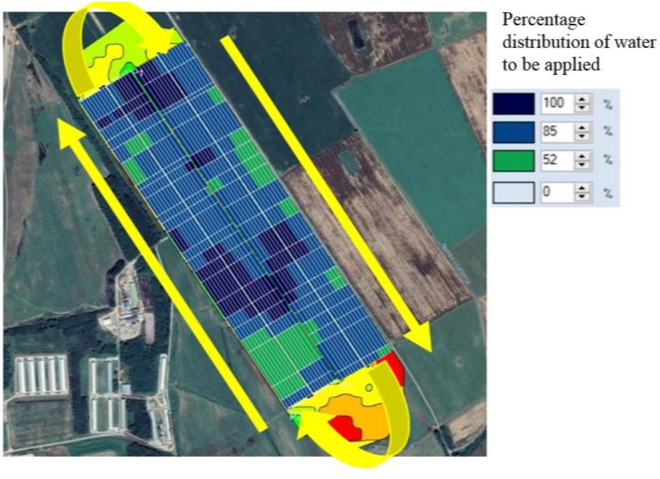
Irrigation water calculations for traffic control were based on total available water content. In general, it is advisable to start irrigation when the total available water content (TAW) is dropped to 60% (depletion rate 40%), so it was calculated with this value when calculating the actual moisture content. In the present study we used sandy soil with a hydraulic conductivity (k) in the saturated state of $3.29*10^{-4}$ m s^{-1}. To calculate the amount of irrigation water, it is necessary to know the water loss in addition to the thickness of the layer to be irrigated. The nozzle intensity was 20 mm h. The water loss can be calculated based on the field capacity, the actual moisture content, and the water content at wilting point. Total available water content of the upper layer has a minimum value for 4.01% and maximum of 25.85% and with mean values of 11.14% with a standard deviation of 4.12% (*Figure 4*) in the deeper layer we also noticed lower values of available water content, the minimum is 1.95% and maximum of 15.94% and the mean values are 10.78% with a standard deviation of 4.55%.

Figure 4: **Available water content at 30 cm depth**



Based on the depletion rate and TAW, the amount of water loss was calculated expressed in a volumetric %, which had to be converted to a mm. Since w=1% means 1 mm moisture in a 10 cm thick layer, the numerical value of volumetric water content% also gives the moisture content stored in 10 cm thick layer in mm. The same relation can be used if the amount of irrigation water wished to be calculated in mm. Based on this, the percentage distribution of water was determined for application in creating VRI zones (*Figure 5*).

Figure 5: **VRI based traffic control based on TAW (yellow arrows are the directions of the run of irrigation machine)**



For irrigation, a medium intensity (15 mm) was set as default 100% water allocation in the high TAW loam areas. In addition, the sandy loam and sandy soil categories were established as two additional application zones. Minimum zones of 45 metres perpendicular to the direction of linear advance were defined, because a nozzle covers an average of 15 metres, so the transition between zones is at least 15 metres. Therefore, we took two transition distances plus an additional nozzle distance and defined this as a minimum zone. There were three zones, 100% 85 and 52%, which were proportionalised by the TAW ratio.

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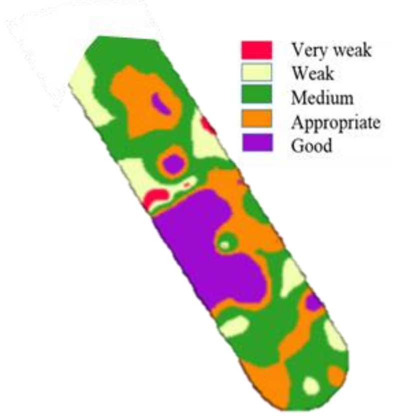
After passing through the field, the laterally moving irrigator stops and switches to oscillating mode, then reverses and irrigates on the other side of the canal. Therefore, forward and backward VRI maps had to be made. As the linear went along the forward side and turns the board end backwards VRI map was used for irrigation. The system is also suitable for fertilization. Knowledge of the nitrogen supply capacity of the soil is important for the nutrient supply to the crops. In Hungary, soil N supply is estimated by determining the humus content. This is used to calculate the total nitrogen content (*Figure 6*). The importance of chemically stable humus is thought by some to be the fertility. It helps the soil retain moisture by increasing microporosity, and encourages the formation of good soil structure.

Figure 6: **Nitrogen supply of the soil of the area**



CONCLUSIONS

The agro-ecological properties of the cultivating area were surveyed, where the amount of the supplied nutrients or fertigation solution can be regulated at the nozzle level according to the user requirements (flow-level control $l\ s^{-1}$, speed and zone control). In this research, presents high precision soil maps which were created to support the establishing water saving variable rate irrigation system by selecting and identifying sites for different agro-technical implementations and precision management zones. Quantified soil differences have been used to develop irrigation management zones based on the varying ability of soils to store and deliver water to the arable land under one irrigation system. As a result, it can be concluded that the data obtained and the VRI maps provide a good basis for establishing a basic guidance for lateral moving irrigation system in VRI mode. Based on the soil data and the water loss calculations, the appropriate amount of water application can be adjusted for each soil texture. However, it should be noted that irrigation planning and determining the optimal amount of irrigation water is a very complex task. In addition to soil properties, plant characteristics, relief, topology and terrain characteristics can play significant role in traffic control of VRI systems.

ACKNOWLEDGEMENTS

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