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Pilot study for irrigation modelling of a pear plantation

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Summary: Our investigation was carried out in the area of Fruit growing Research and Consultant non-profit company, at Újfehértó. The pear requires large water quantity, but this pear plantation hasn't irrigation system not yet. This study reviews the drainage conditions of the area based on digital elevation model, and examined the canopy cover of pear trees by evaluating of the hyperspectral image. Our aims were to determine the exact watershed based irrigation modelling and determining of the canopy% of the pear orchard to facilitate a precision irrigation decision support system.

Key words: digital elevation model, pear orchard, irrigation, hyperspectral imagine

Introduction

In Hungary, 2% of all cultivated land is irrigated. The orchard is relatively not highly water consumer comparison with cereal species. However, to ensure optimal water capacity values calculating breeding season it is the most important risk factor. It cannot imagine the fruit production without modern irrigation system even in the humid French and German areas. Nowadays, in Hungary there isn't any intensive apple and pear orchard, where they would question the importance of the irrigation. The agricultural water management is the unkindly area of the plan based on the Water Framework Directive accepted in December 2009. The irrigation technique is neglected unfairly comparing with the other technology elements. The plan determined present conditions of the 42 surface water catchments and subsurface water bodies in Hungary, and worked out the water management aims. The common aim is the achievement of the good ecological status in our water bodies. There are no farmers, who can leave this out of consideration: developing the irrigation system. The ecological, sociological and environmental respects were significantly upgraded over and above technology point of view. Following we emphasize the critical points that farmers requirement for improving successfully growing technology based on irrigation in a middle time, without completeness.

Materials and methods

The research field was the genetic collection of pear at Újfehértó, in Hungary, which is situated in Nyírség meso-region. The area of the site is 2,74 ha, with 1660 possible spaces of pear trees. The physical characteristic of the soil is sandy and the pear orchard is not irrigated. Hyperspectral imagery is also appropriate for vegetation analysis (*Clark,* 1999; *Kruse,* 2003; *Milics* et al. 2008; *Polder* et al. 2001; *Sabins,* 1997; *Tamás* et al. 2009). Minimum at the visible spectral range is related to pigments in plant leaves. Chlorophyll absorbs markedly spectral range between 450–670 nm. Healthy vegetation reflects the 40–50% of the incoming energy between 700–1300 nm spectral ranges due to the internal structure of the canopy. In this way, the measured reflectance plays an important role in distinguishing different plant species, even if these species are seems to be similar based on visible spectral range (*Berke* et al., 2004).

In 2006, an AISA DUAL airborne hyperspectral cam system were installed and operated in cooperation the University of Debrecen, AMTC, Department of Water and Environmental Management with the Mechanization Institute of Agricultural Ministry in Gödöllő. The most important parts of the hyperspectral sensors are the spectrograph, which dissolve the electric waves arrived through the optical rift with the help of prisms and optical screen. The hyperspectral sensor consists of one optic, one spectrograph and one digital cam. The two hyperspectral sensors are assemble in a house, therefore it is known ASIA DUAL system. The two cams can perceive in the visible wavelength, near infrared range and short wave infrared range. The Eagle camera takes images in visible and near infrared range (VNIR), while Hawk operates in the middle infrared range (SWIR). By means of establishing of two camera a DUAL system were installed. The full range 400–2450 nm, which can be set 1,25–10 nm wavelength band and maximum 498 spectral channels. Two sensors can also be operated separately, so it makes possible to utilize the wider wavelength of higher resolution (1024 pixels) VNIR sensor.

ENVI 4.7 software was applied for the analysis of hyperspectral images. First the determination of NDVI (Normalized Difference Vegetation Index) is necessary in order to obtain the location of the barren spots, because the assessment of the mineral distribution is only carried out if no disturbance effect of the canopy appears. Values of the NDVI index are calculated from the reflected solar radiation in the near-infrared (NIR) and red (R) wavelength bands, 580-680 nm, and 730-1100 nm, respectively. NDVI can be determined using the following formula:

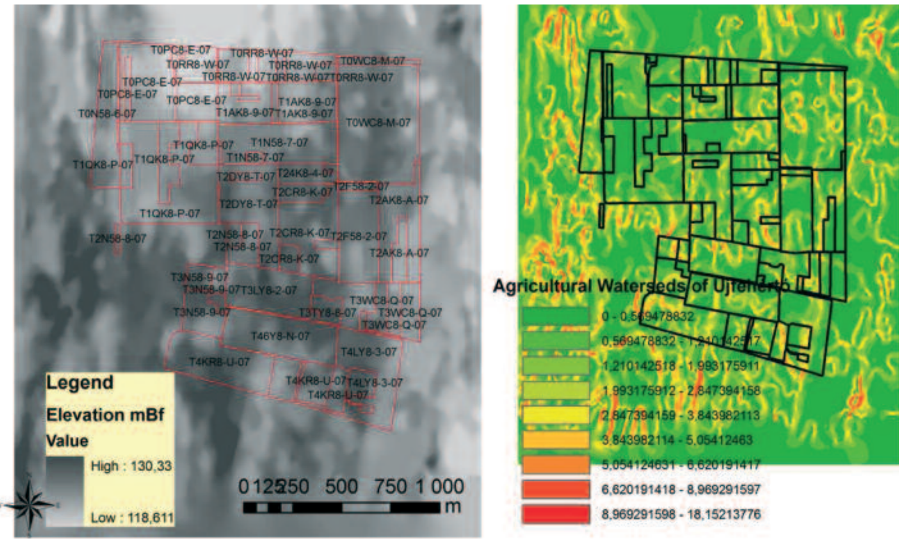

Figure 1. Digital elevation model and the slope gradient map (%) of investigation area

$$NDVI=(NIR-R)/(NIR+R).$$

The digital elevation model and drainage conditions of the investigation area were determined by the Spatial Analyst module of ArcGis 9.2 software. We carried out several field works to survey the species and tree parameters of pear genetic collection and to draw map of plantation.

Results and discussion

The meso-landscape of Nyírség is poor in surface waters. The well based irrigation needs to use deeper and deeper aquifers and even the danger of overutilization of these layers is continually increasing. The water saving micro watering couldn't use the raw lifted water without cleaning because of its manganese and iron content. The built up of the surface works don't admits to withdraw water from surface waters.

However the fruit orchard has great responsibility to save the subsurface water quality. In the case of the pesticide treated pear plantations the soluble contaminations could get into the water stock in two ways: in sandy soils with infiltration, in hard ground with overland flow. The 49% of the country is above water stocks which are vulnerable against nitrate contamination and in case of fruit orchards this assumes even greater dimensions.

Since the water resources are limited in time and in space, significant part of the orchard owners are using – if they can afford it – water supplement watering. Because the actual water cycle of the fruit orchards are not exactly known, the impact of this watering is accidental. In practice in greater drought periods the results of the supplementary watering are compared to the relations without watering, but without knowing the optimal water supply the whole harvest falling out could be only estimated. According to the meteorological time series in case of Pomaceae on the average 200–300 mm watering norm would be optimal with 7–14 days watering turn-rounds.

The watering planning and operational tasks needs differentiated solving in time and in space. The professional decisions precondition is to value the risks and expectable advantages of watering in a scientific level.

Below we look over shortly the decisional and planning point of views in connection with watering. The watering has an influence on every cultivation elements, but to take advantage of all its benefits we must re-plan the area according to the following standpoints. The integrated soil and water management plays a key role in achieving long-term sustainable and profitable fruit production, which safeguards the environment and ensures a high-quality product. In general, for good tree-crop growth, the soil needs to be loose, with good aggregation to facilitate the circulation of air, water and nutrients and the penetration of roots. Strongly degraded soils with reduced and non-interconnected porosity, and reduced levels of organic matter, do not have the capacity to store as much water as they should, and thus have less water available for crop growth. Soil-structure degradation, often called soil compaction, is regarded as the most serious form of land degradation caused by conventional farming practices (*McGarry*, 2003).

In the course of establishment of plantations the relief and the soil parameters are determinative factors. Beside the slope gradient there is a less significant factor the aspect. In the case of micro-relief the ratio of the convex / concave slopes determine the drainage and the water gathering, which can be model with the help of the digital elevation model. In this case we used the 1:10000 scale of DEM of investigation area at Újfehértó prepared by Inverse Distance Weighted method. In this area there is a 12 m relative relief. But the DEM shows that the area has very significant micro-relief differences (*Figure 1*). According to relief data it could not be prospective 18% of local gradient, which is characteristic of hilly country. The sand-dunes caused the forming of varied spatial pattern of the local drainage divides and water catchments in a relatively small area (*Figure 2*). The longest flow length is 562,4 m in this area.

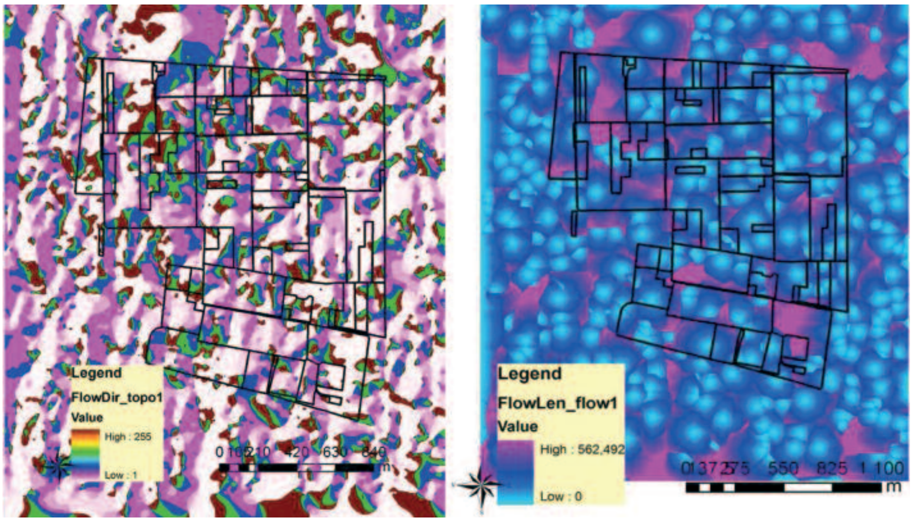

Figure 2. The flow direction and length in the investigation area at Újfehértó

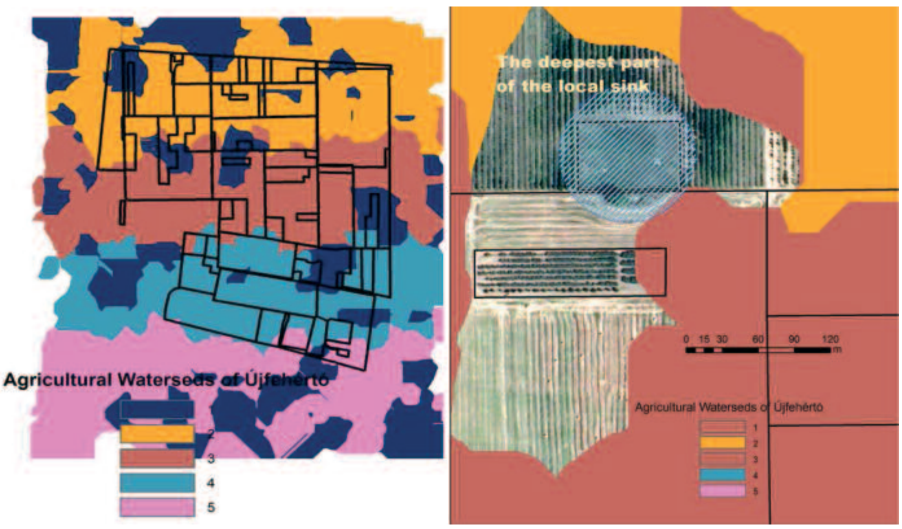

Figure 3. Small water catchments in the investigation area

On the basis of catchment segments bordered by flow directions 5 different types can be found on this area (*Figure 3*). The first catchment category is located separately along four other zones in North-South direction. These include several local sink without an outlet keeping up anaerobe conditions.

A living or dead vegetative soil cover absorbs most of the energy of the raindrops that fall on it and by the time this rainwater reaches the soil below, its ability to disintegrate soil aggregates and detach fine particles is greatly reduced. Furthermore, it is the contact cover that is immediately accessible to soil macro organisms and can stimulate their activity. Thus, greater numbers of bio-pores are likely to be formed in association with cover crops, leading to more rapid water infiltration and movement within the soil.

Shoot length, number of buds and plant health are influenced by the physical-chemical fertility of soil. For example, leaf colour is related strictly to water and nutrient availability and especially to nitrogen content – the better the soil fertility, the greener the leaf. The number of flowers is related to soil physical status; its intensity depends on energy and plant-available carbohydrates, which relate in part to soil fertility (physical, chemical and microbiological). Shoot length is an expression of plant vigour and general plant growth, which are regulated by nutrient and water availability. Moreover, although flower development at budding is influenced in part by climate conditions and the amount of stored reserves, it depends considerably on soil conditions and root functionality.

Diseases, especially *Venturia sp*., can cause serious water losses on apple and pearl varieties. Under high relative humidity and moisture, disease attack seems to be more common in plantation managed with soil tillage rather than in those with permanent cover crops (*Holb,* 2006). Indeed soil health in orchards is also related to microbial populations capable of suppressing soil-borne disease. Microbes that live in the plant rhizosphere, the surrounding soil influenced directly by the root, can contribute to soil-disease suppressiveness, reducing the effect of many soil-borne diseases. Disease control by rhizosphere microbial communities has also been shown to extend to systemic and foliar diseases through the activation of the chemical and physical defence mechanisms of the plant.

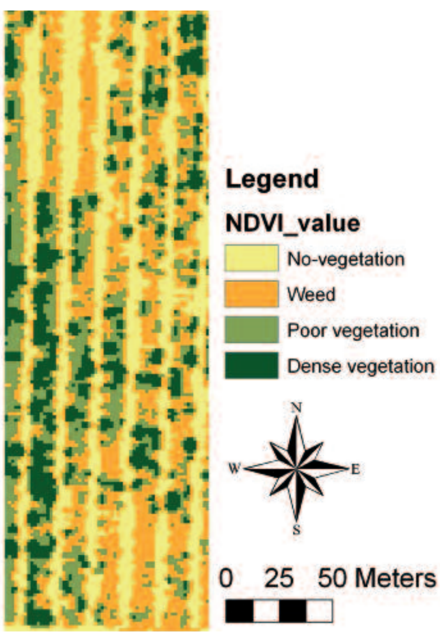

Figure 4. NDVI values of the pear trees

On the basis of the results of NDVI examination, we determined four different categories (*Figure 4*) as follows:

1. No vegetation- soil surface: 0,889 ha
2. Weed: 0,674 ha
3. Poor vegetation: 0,925 ha
4. Dense vegetation: 0,464 ha.

It can be mentioned, that the second and third categories contain the new plantations (2-5 years old), because of small foliage.

Conclusion

There is a need to quantify a whole cropping system – a very complex, but important task. The concept of using "crop coefficients" as generalisms of tree/crop types are too broad and vague in irrigation scheduling work. Based on our experiences we conclude that better information could be gained using remote sensing and measures such as leaf-area index.

The growing demand is to link such work with precision agriculture; particularly as private (commercial) companies have a great interest in this. However, they require a very soft (user friendly) "front-end" to such simulation models – a very demanding task. There is scope to research the combined approach of simulation models with geographical information systems and digital terrain (elevation) models, and remote sensing. The plan is to combine these in order to gain a closer approximation of reality.

Acknowledgement

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