# THE BENEFITS AND EFFICIENCY OF PRECISION IRRIGATION

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***ABSTRACT:****The contribution was to develop methods for irrigation management using knowledge in the field of precision agriculture. In the monitoring points were established basic hydrolimits: Field capacity (FC) and wilting point (WP). Irrigation rate ranged from 0 to 40 mm for a specific term assessment of soil moisture. Throughout the growing season used to be applied precisely five irrigation benefits. A high savings were observed between conventional and precise irrigation (water, energy and economic savings). The results show that it is a fully effective system of precision agriculture, although the procurement and introduction of new technology and the software requires first expending a considerable financial cost. Higher demands are placed on the skill and education services.*
***KEY WORDS:*** *PRECISION IRRIGATION, HYDROLIMITS, SOIL MOISTURE CONTENT*

## INTRODUCTION

Precision farming has different approach to the farming practices when compared with the traditional farming (Nozdrovický et al., 2010). The system precision irrigation can occur internal error affecting the accuracy of the control unit to comply with not only set a variable dose, but also the accuracy of the unit set to the value observed variability of the speed of movement of the irrigation system (Chavéz et al., 2010).

Precision irrigation as part of precision agriculture is just the beginning of an examination and application of water to a precise location and the exact dose. This also takes into account the reduction in consumption of irrigation water and thus meets the global trend resulting from a lack of strategic raw materials (Sourell, 2003). Evans et al. (2007) describes an automated sensing of soil electrical conductivity through a wireless network of sensors linked to a microcomputer control and spraying equipment.

The implementation of precision irrigation requires additional equipment to control water rates, information on soil properties and crop condition. The potential of irrigation water with variable dose is an increase in yield, quality and economic return (King et al. 2006). Lack of basic knowledge about the properties of spatially variable crop and soil, restrict the use of precision irrigation. Experiments were positive assessment of the implementation of precision agriculture in the management of irrigation (Sadler et al., 2002). Fraisse et al. (1995) simulate the variable application of irrigation followed with proven results. Uniformity coefficient reached over 90%.

The irrigating practice of irrigation water applied to land as a whole - uniformly. In real life, however, are very few parcels of land with high homogeneity. Hence the need to divide the land into individual subunits, which are independent of each other in terms of claims processing, nutrition and irrigation (Sourell, Al-Karadsheh, 2003).

The paper aimed to develop methods and provide the benefits of introducing the principles of precision agriculture for irrigation.

## MATERIALS AND METHODS

The processing and managing the work proceeded according to the method, as shown in Fig.1. The first information say about the plot in terms of location and the area come from farms. Since the information is not sufficient for the introduction of the principles of precision agriculture is to be the geographical parameters (land area and its location, number and location of monitoring points) investigated the plot. In determining the boundaries used handheld satellite navigation device - Garmin Emap GPS navigator.

Subsequently, it is possible to determine the starting points for monitoring soil properties (moisture and essential hydrolimits). The detection of soil moisture is using moisture meter HH2 with WET sensor (Fig.2). After determining the input characteristics of move to construct the maps application on the basis of observed maps of spatial variability of moisture due to the work scope of sprayer, the number of sprinklers, the water supply options and implementation of irrigation.

Implementation of irrigation will be conducted by irrigation deployed on land. On the map are marked zone. In implementing the irrigation will be taken into account the possibility of connection to supply irrigation water to the status of irrigation (irrigation), the number of irrigation, which can irrigate at once (depending on the performance of the water source) and width of scope of work sprayer.

After determining the application the map is a table set schedule irrigation.

Finally, the work is completed the amount of fruit set and evaluate the economic benefit of the use of precision irrigation. To determine the size of the harvest will be the methodology proposed by the Department of machines and production systems. This methodology is based on sampling of produce from area 10 $m^2$ (in each monitoring point). The samples are placed in bags bearing the code number. You will then need to weigh the sample in the farm and the results entered in the table. In determining the operating costs of the algorithm is used by Rataj (2005).

The calculations will reflect the changes in input parameters (irrigation requirement, insurance of the tractor, the price of fuel, electricity price, the price of water, hourly wage, and plot size) associated with the selected plot and carry out the experiment given year.

Water for irrigation under the Act is not subject to fees. Subject to fees the cost of services for water supply.

In our case the team had their own wells and pumps. Team was thus the cost of electricity and the cost of water. Costs are calculated in case the team did not receive grants for water.

The irrigation variable is still value the cost of living work in irrigation costs will increase the value of a worker who will be responsible for change in water rates for each irrigation.

The annual cost to change the irrigation benefits of variable irrigation (relationship applies if a worker performs the work):

$$ {}_{r}N_{zm} = {}_{h}N_{zp} \, . \, 1{,}352 \, . \, {}_{r}W_{zm} \qquad (1)$$

where:

${}_{h}N_{zp}$ – pay of the establishment, €.$h^{-1}$
1,352 – Coefficient on insurance tax
${}_{r}W_{zm}$ – total time of all changing irrigation depth, h.$rok^{-1}$

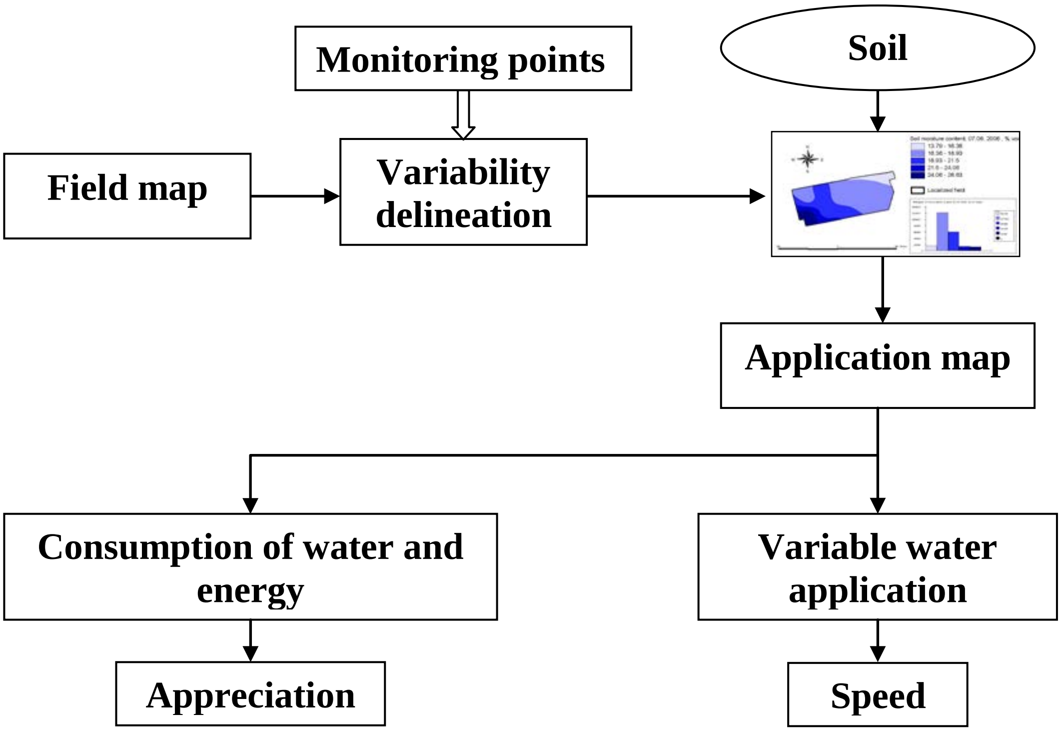


***Figure 1*** *Strategy of precision irrigation in the scope of precision agriculture*

Time to change the benefits of irrigation will depend on:

- plot size (number of irrigation),
- time needed for one shift,
- the time required to transfer between irrigation,
- number of changes for the entire irrigation period for all the irrigation equipment.

Precise comparison with conventional irrigation, the irrigation method will change the total cost. Will the following items:

- variable costs for irrigation (these costs are to change the annual use of electric pump,
- the cost of change is not considered) cost of water (amount of water consumed).

**RESULTS AND DISCUSSION**

Based on the experience of many years of good cooperation has been chosen as the holding Agrocoop Imeľ to continue as a base for experiments. The firm is located in southwestern Slovakia in the district of Komárno. Landscape farm land is flat, with slopes in the range of 0-2 °.

According to the soil and climate conditions are firm in corn production area. Rainfall can be classified into the arid, dry areas with strong long-term average annual rainfall of 547mm (for the period 1951-1980), the rainfall is unevenly distributed. The average annual temperature is 9.9°C and average temperature for the growing season is 16.6°C, precipitation in the growing season is 355 mm (years 1951-1980). Altitude area is around 107 to 110 m Total area of agricultural land, the company makes the 1,822 ha of arable land of 1,730 ha with a dominant clay-type soils to sandy loam. A very special place in agriculture takes up potatoes. They are an area of approximately 200 ha. Irrigation was performed with irrigation Bauer 90/300.


***Figure 2*** *Moisture meter HH2 with Wet sensor*

The position is focused on land with an area of Fig.3 and 22 ha with a number of monitoring points, $19^{th}$ (the output of the program ArcView 3.2). Potatoes have been bred crop - the variety Victoria. The soil was alkaline (pH 7.4) and muck. Significant impact on crop production has rainfall. Precipitation team follows a classic. The results are reported in Table 1.

***Table 1*** *Rainfall of localized field, 2005 and 2006*

| **Month** | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Rainfall 2005, mm** | **1/2** | 4,4 | 19,2 | 4,4 | 14 | 9,6 | 51,8 | 59 | 57,7 | 14,1 | 15,3 | 0 | 55,9 |
| | **2/2** | 12,6 | 27 | 3,6 | 34,4 | 40,6 | 0 | 3,9 | 18 | 24,3 | 0 | 32,6 | 54,9 |
| | **Month** | 17 | 46,2 | 8 | 48,4 | 50,2 | 51,8 | 62,9 | 75,7 | 38,4 | 15,3 | 32,6 | 110,8 |
| **Rainfall 2006, mm** | **1/2** | 47,2 | 21,8 | 16,6 | 8,9 | 11,5 | 16,4 | 12 | 25 | - | - | - | - |
| | **2/2** | 1,7 | 5,9 | 9,8 | 17,7 | 83,7 | 14,5 | 13,2 | 60,7 | | | | |
| | **Month** | 48,9 | 27,7 | 26,4 | 26,6 | 95,2 | 30,9 | 25,2 | 85,7 | | | | |

***Soil moisture and hydrolimits***

The resulting map hydrolimits field water capacity (FC) is shown in Fig. 4. Field capacity ranged from (28.8 to 30.88) %vol. The largest representation was the interval (29.22 to 29.63) % 8.75 ha in area. Surface modification wilting point (WP) in the plot is shown in Fig. 5. Ranged (from 8.49 to 11.44) %vol. Interval (8.49 to 9.08) % showed up to 7.86 ha. All set hydrolimits volume% match water supplies in millimeters 10 cm layer of soil.

Research associated with precision irrigation and to implement hydrolimits Agricultural Experiment Station in Idaho. Deal with the field water capacity (25 to 44.6 %vol.), Wilting point (10 to 18.4 %vol.) and Available water holding capacity (13.9 to 28.4 cm/m) ( King et al, 2006).

Field water capacity, wilting point and reduced water capacity of the nine areas examined for mapping variability as input values for precision irrigation management. In the first three zones was the pasture for a further three potatoes and for the last three grown corn. Values of field water capacity were 10 to 37 %vol., Wilting point 3-11 %vol., and reduced the water capacity of 7-31% vol. (Hedley et al, 2009).

In Fig.6 is shown the variability of soil moisture content map provided 7.6 2006th Humidity ranged in the interval (13.79 to 26.63) %vol. The measured values of soil moisture content were within limits which provide hydrolimits. The smallest representation had periods of moisture (21.5 to 24.05%vol) by area of 1.4 ha (5.7% of the land) and (24.06 to 26.63) % in area 1.3 ha (5.5 % of land). The largest representation was the interval (16.36 to 18.93) % to 12.2 ha area (55% of the land). The resulting map of the moisture it can be stated that it is necessary to irrigate approximately to 19.4 ha (88.18% of the area).

The next scheduled term of soil moisture measurements was set on 28/06/2006. The resulting map is shown in Fig. 7. Soil moisture varied in the range (9.79 to 26.32) %. The largest representation was the interval (16.41 to 19.71%) by area 10.8 ha (46.6% of the area). The smallest representation of the moisture has been shown in the interval (23.02 to 26.32) % in area 0.8 ha (3.4%). The resulting maps of moisture is evident that it is necessary to irrigate the 100% plot (22 ha) in the range (10-40 mm).

After application of irrigation benefits, it was decided to establish a map of soil moisture variability on the 13th term 7th 2006th Soil moisture as a result of pic.8 were in the interval (12.87 to 25.63)% volume. The measured values were within the range of border hydrolimits. The largest share of moisture has been shown in the interval (17.97 to 20.52) % in area 8.7 ha (39.3% from the third area of land). The smallest representation of the moisture had interval (23.08 to 25.63)% in area 0.7 ha which represents 3.18% of land area. The resulting map of soil moisture content reveals the need for irrigation water of 19,2ha (87.27% of the land).

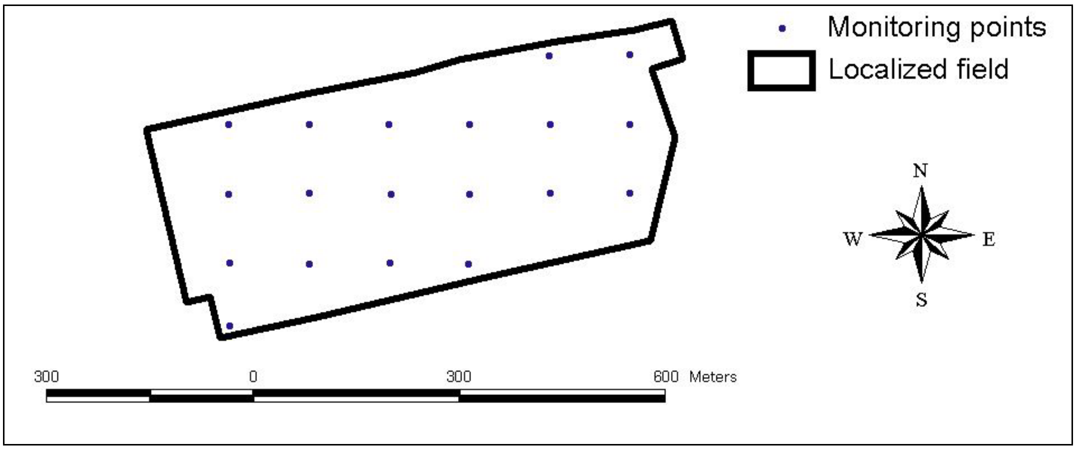


**Figure 3** Localized field and monitoring points

***Construction and application maps feasibility irrigation***

For the land is available to a gas station. Since each service station is limited by its maximum performance, it was necessary to set limits to our field. Filling station consists of the motor performance of 55 kW and a flow pump 144m$^3$/h. According to the technical parameters of the scheduled irrigation was using 20.0mm diameter nozzle and nozzle pressure of 0.3MPa to determine water flow 26.6 m$^3$/h. To achieve the desired flow rate could be the one connected to a service station just five drips. After finding this information was necessary to map out the distribution of irrigation in order to irrigate the plot (obr.9). Spacing between adjacent tracks was 60m (range of jet spray is 30m). The maximum length of the runway end sprayer was 318m. Take advantage of all 12 positions for irrigation. In determining the benefits of irrigation it was based on maps of soil moisture and hydrolimits set for the plot. Irrigation started in places where it was needed most - places with the lowest soil moisture content.

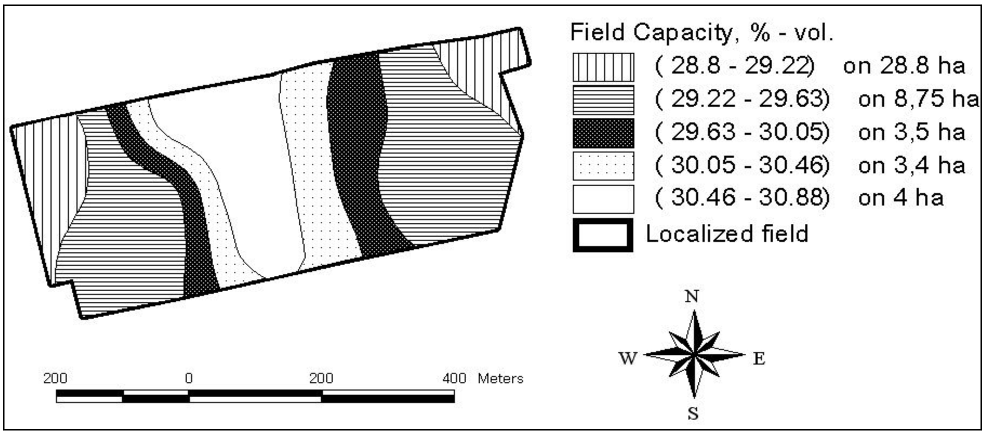


**Figure 4** Maps of Field capacity

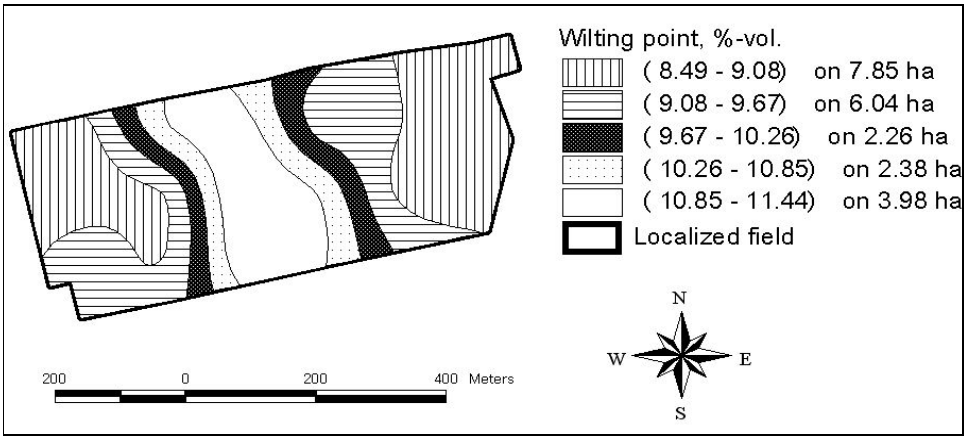


**Figure 5** Map of wilting point (BV)

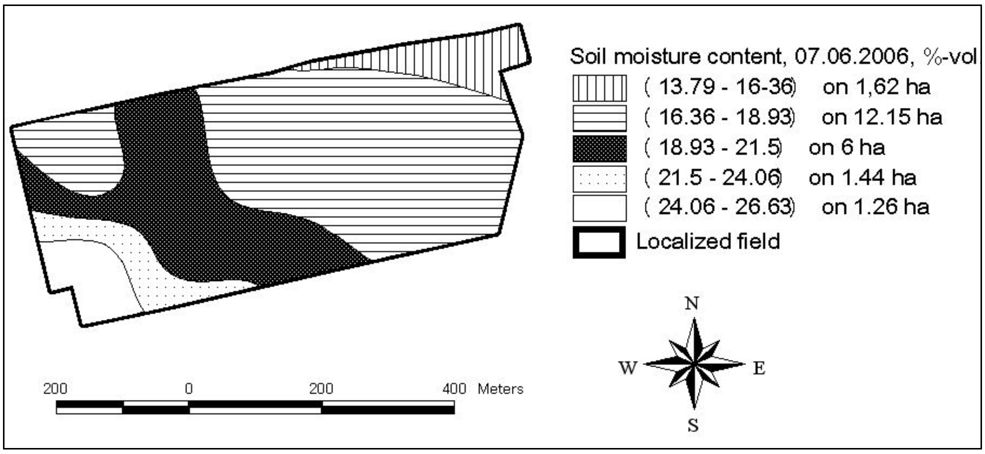


**Figure 6** Maps of soil moisture content, 7.6. 2006

**The first irrigation rate** ranged from 0 to 35mm (lot 35, 25, 15mm, Fig. 10). Applied was to an area of 19.4 ha (88.18% of the area). The diameter of the nozzle used for spraying was 20 mm with the nozzle inlet pressure of 0.3MPa.

Irrigation rate with a value of 35 mm was applied to the area of 1.6 ha. The surface area of 12.1 ha, the irrigation norm applied to the value of 25 mm. The rest of the land to irrigation dose was 15 mm (2.7 ha) and 0 mm. Before the application in practice and had to be constructed a table for the irrigators, which is controlled by different irrigation (Table 2-4). Each table is a paid position for a deployment of irrigation land. Tables are built so much as to exploit all the numbered positions irrigation status (1-12 to fig.9).

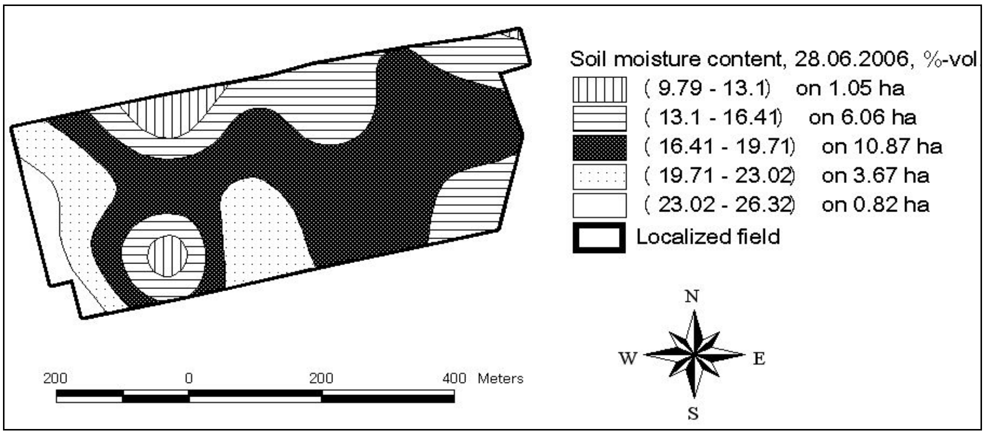


**Figure 7** Maps of soil moisture content, 28.06.2006

**The second irrigation rate** ranged from 10 to 40 mm (40, 30, 20, 10 mm, Fig. 11). The irrigation rate was applied to the whole plot (22 ha). The largest share was 20 mm irrigation rate of 10.8 ha area. The smallest representation of the irrigation dose was 40 mm (an area of 1.1 ha). 30 mm irrigation rate was applied to the area of 6.1 ha.

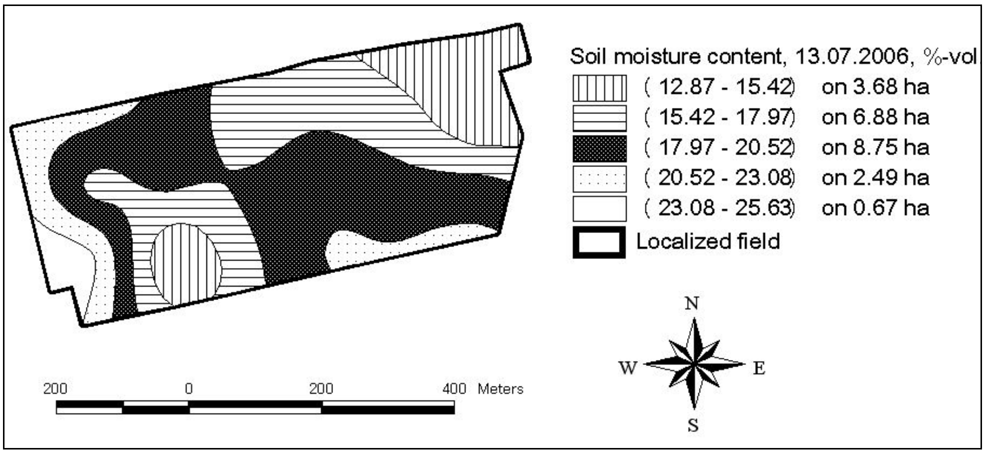


**Figure 8** Maps of soil moisture content, 13.07.2006

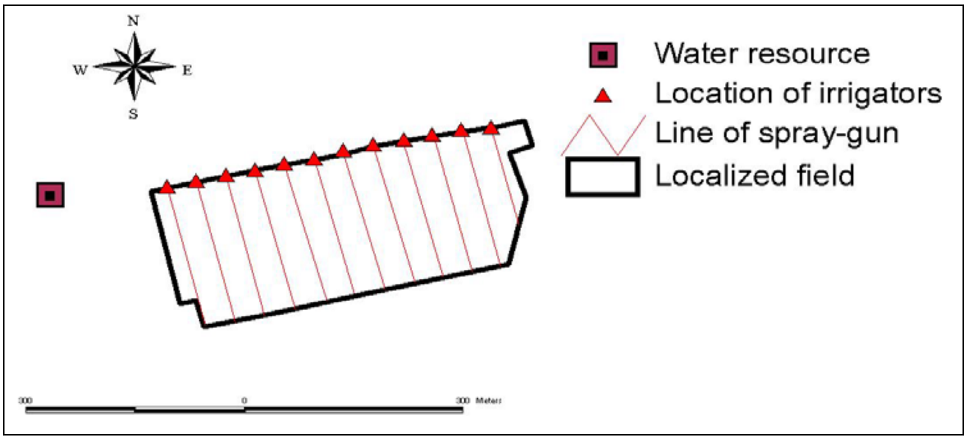


**Figure 9** Water resource and location of irrigators

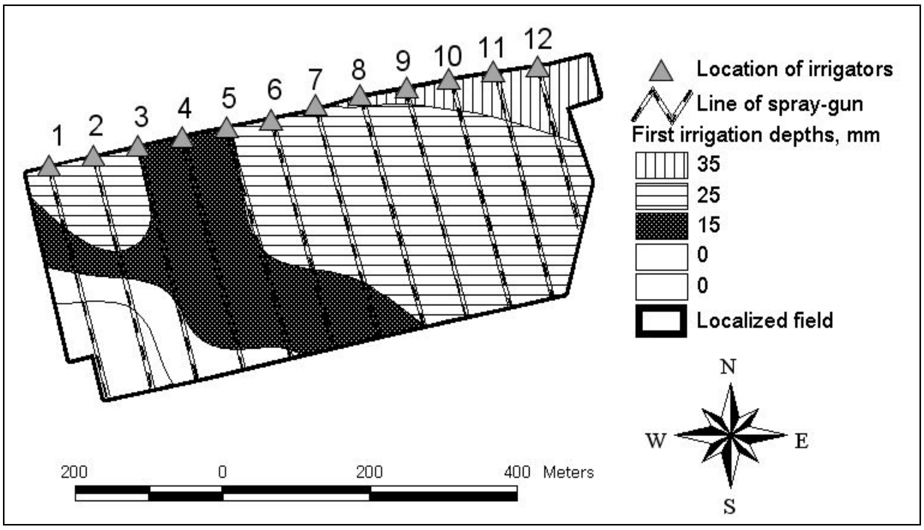


**Figure 10** First irrigation rate

**Table 2** First position of irrigation machine

| Irrigation machine | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | A | B | C | A | B | C | A | B | C |
| **9** | 285 | 1068 | 25 | 27 | 148 | 35 | - | - | - | - | - | - |
| **10** | 266 | 998 | 25 | 42 | 230 | 35 | - | - | - | - | - | - |
| **11** | 235 | 881 | 25 | 69 | 377 | 35 | - | - | - | - | - | - |
| **12** | 128 | 480 | 25 | 98 | 535 | 35 | - | - | - | - | - | - |

A – Stage length, m, B – time of irrigation, min, C – irrigation rate, mm

**Table 3** Second position of irrigation machine

| Irrigation machine | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | A | B | C | A | B | C | A | B | C |
| **5** | 141 | 326 | 15 | 172 | 645 | 25 | - | - | - | - | - | - |
| **6** | 104 | 240 | 15 | 207 | 776 | 25 | - | - | - | - | - | - |
| **7** | 67 | 155 | 15 | 241 | 904 | 25 | - | - | - | - | - | - |
| **8** | 291 | 1092 | 25 | 21 | 115 | 35 | - | - | - | - | - | - |

The area of 19.2 ha (87.27% of the land) is the **third irrigation rate** applied in the range of 0-35 mm (35, 25, 15 mm, Fig.12). The figure shows that the applied rate of irrigation was 35 mm (an area of 3.6 ha), irrigation rate 25 mm (an area of 6.8 ha) and the remaining surface dose was 15 mm. Part of the area remained without applying the benefits of irrigation (3.2 ha). Since the surface area should be irrigated with sprinkler Nr.1 rate of 15 mm is the minimum, are not used.

**Table 4** Third position of irrigation machine

| Irrigation machine | Zone 1 | | | Zone 2 | | | Zone 3 | | | Zone 4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | A | B | C | A | B | C | A | B | C |
| **1** | 170 | 0 | 0 | 64 | 148 | 15 | 85 | 319 | 25 | - | - | - |
| **2** | 150 | 0 | 0 | 38 | 88 | 15 | 131 | 492 | 25 | - | - | - |
| **3** | 83 | 0 | 0 | 141 | 326 | 15 | 89 | 334 | 25 | - | - | - |
| **4** | 19 | 0 | 0 | 295 | 681 | 15 | - | - | - | - | - | - |

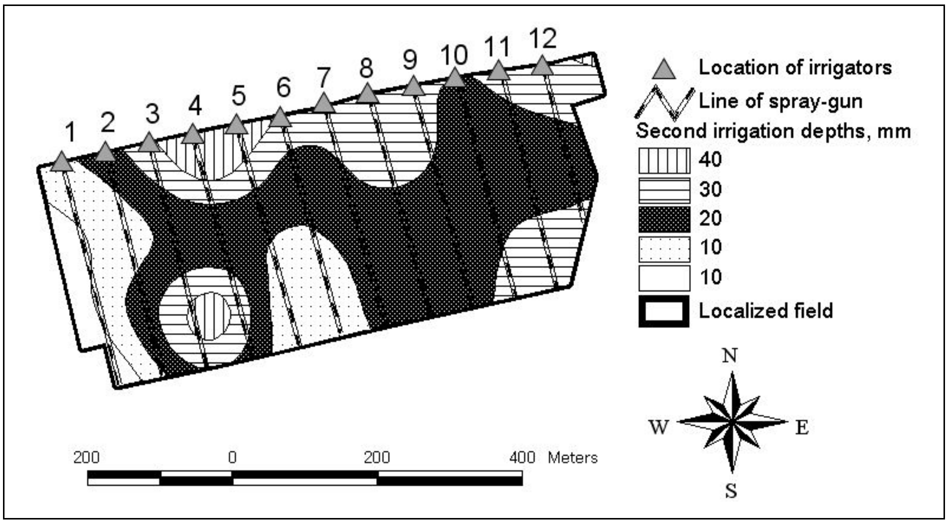


**Figure 11** Second irrigation rate

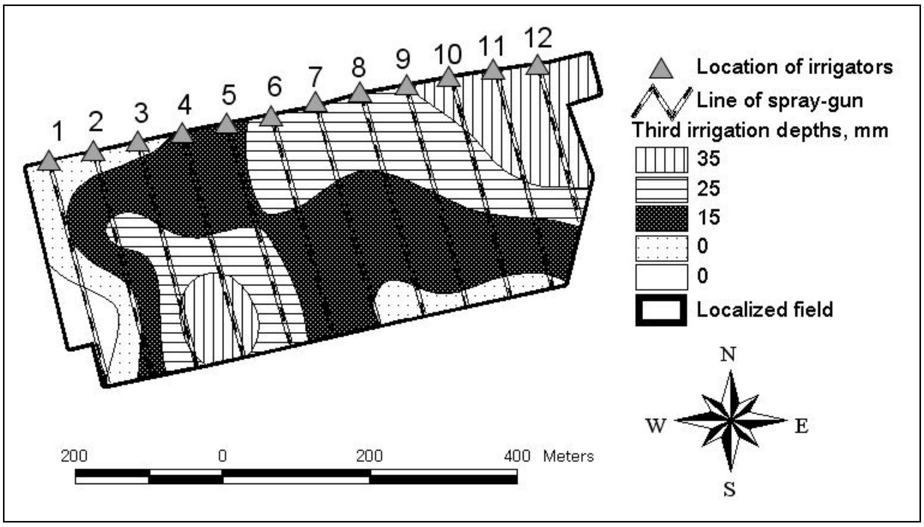


**Figure 12** Third irrigation rate

**Fourth irrigation rate** ranged from 0-35 mm (Fig. 13). The irrigation rate was applied to the area of 11.8 ha (54.09% of the area). Is the way to where it was before the irrigation rate 35 mm and 25 mm (Fig. 12, the irrigation norm 3) there is applicable, and where previously there dose of 0 mm was applied 25 mm (an area of 2.4 ha) or 35 mm (an area of 0.7 ha). 15 mm irrigation rate remained unchanged.

**Last irrigation rate** was applied to the area of 19.2 ha (87.27% of the total area) in the range 0-35 mm (Fig. 14). 35 mm irrigation rate was applied to the area of 3.7 ha. 25 mm irrigation rate was applied to the area of 6.8 ha.

***Yields achieved in the plot and cost recovery***

Harvest of potatoes was determined according to the methodology. The focus of the plot (22 ha) is grown only one variety - Victoria with the average yield 41.89 t/ha.

In terms of precision applications, we distinguish two basic applications of irrigation benefits:

- application of irrigation uniform dose to the whole plot,
- application of irrigation with a variable dose on the plot.

Irrigation application method significantly influences the cost. In the implementation of precision irrigation can be used only technology that the company was available as follows: From Zetor 7211 tractor and belt with irrigation Bauer 90/300 base-board computer equipped with basic software.

The calculation of cost and precision in the variable application of irrigation was carried out according to the methodology. The variable application of irrigation benefits is yet to be considered with the following input (the work is not considered or foreseen):

- Cost of the program to produce maps, for example. ArcView 3.2,
- Price GPS, for example. eMap Garmin,
- the cost of laboratory analysis, laboratory testing hydrolimits (FC, WP),
- costs for the determination of moisture, for example. rollers, WET sensor logger HH2,
- cost of living work in creating maps.

In conventional irrigation is considered a constant dose of 30 mm.

Target property measurements made in 2006. This year, the average price of diesel was 0.83 €/l. Insurance on the tractor 7211 from amounted to 42.62 €/year. Tractor hourly wage was 2.65 €/h. The hourly wage of an irrigator was € 2.65 €/h. The Amendment irrigation benefits carried the irrigator and wages for this work carried out was also 2.65 €/h. The cost of garage machinery amounted to 2.16 €/m$^2$.

The plot area of 22 ha within the experimental precision application of irrigation water is consumed 1021.44m$^3$/ha water. Power consumption to drive the pump was 560.9kWh/ha. The rate of uniform irrigation water consumption should amount in 1500 m$^3$/ha of water. The application of a quantity of water (33.000m$^3$), the planned consumption of electricity was 17832.65kWh (810.58kWh/ha). Water savings amounted to 478.56m$^3$/ha (from 1500 to 1021.44). Saving energy was 249.68kWh/ha. The total cost to implement the irrigation amounted to 1,709.83 €/year (excluding subsidies on electricity, without the cost of water). Unit costs were 15.54 €/ha. The cost of water consumed was 1,491.85 €/year (no subsidies for water consumed). The unit cost of water was 13.56 €/ha. Total unit costs were thus 29.1 €/ha. Total unit cost at uniform water rates during the business enterprise was 38.2 €/ha, saving was 9.1 €/ha.

The research into the precise irrigation, so the application of irrigation water depending on the specific field conditions in the world is the subject of widespread interest. Hedley et al. (2009) clearly identify the performance indicators of irrigation water of varying dose, detailing their work mapping method to describe soil conditions with respect to soil hydraulic properties. This allowed them to accurately quantify the amount of water consumed, water loss and soil nitrogen leaching, depending on the specific conditions of the selected fields. Saving water is 9-19% with a corresponding reduction in energy consumption.

Perry and Pocknee (2003) reached the water-saving irrigation in precision field crops. Application maps are transformed into the control unit Canlink 3000$^{th}$.

The research found that took place abroad (research institute FAL in Germany) accounted for the smallest cost of pivots irrigator – 191 €/ha. Irrigated surface area should be around 57.6 ha. The highest costs during the irrigation season were given to the stationary drop irrigation – 911 €/ha. Between these extremes were mobile with drop irrigation costs 267 €/ha (Debrala, Sourell, 2002, S.121).

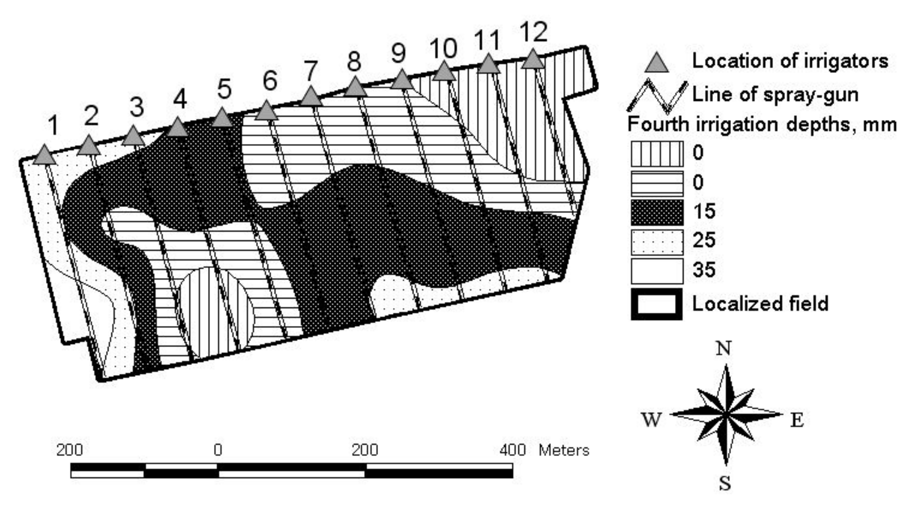


**Figure 13** Fourth irrigation rate

**Table 5** Cost of uniform and precision irrigation rate

| Indication | Item | Value | |
|---|---|---|---|
| | | **Uniform irrigation rate** | **Variable irrigation rate** |
| **Annual cost** | | | |
| ${}_rN_{m\,C}$ | Annual cost f irrigation, €/year | 2011,35 | 1709,83 |
| ${}_rN_{e\,V}$ | Annual cost of water, €/year | 2469,56 | 1491,85 |
| Sum, €/year | | 4480,92 | 3201,68 |
| ***Saving of cost,*** €/year | | ***1279,23*** | |
| **Unit cost** | | | |
| ${}_iN_{m\,C}$ | Unit cost of irrigation, €/ha | 18,28 | 15,54 |
| ${}_iN_{e\,V}$ | Unit cost of water, €/ha | 19,92 | 13,56 |
| Sum, €/ha | | 38,2 | 29,1 |
| ***Saving of cost***, €/ha | | ***9,1*** | |

Hedley et al (2009) evaluate the benefits of using variable water rates for irrigation of selected crops (dairy pasture, potatoes, maize grain). The irrigation water savings were 9% (dairy pasture), 13% (potatoes) and 19% (maize grain). It also achieved savings of operating costs 35 NZ$/ha (potatoes), 88 NZ$/ha (pasture) and 149 NZ$/ha (maize). The maximum water saving was presented at the corn.

The peer comparison and precision irrigation of uniform deal to land in humid Iowa State University. Land area is 20.25 ha which is divided into 100 spatially variable grids. Simulate the three variants of irrigation and without irrigation, irrigation uniform dose and precision irrigation. 30 mm irrigations were applied when the percent of available soil water fell below 50%. Precision irrigation showed slightly higher yields than scheduled uniform irrigation. (DeJonge, Kaleita, 2006).

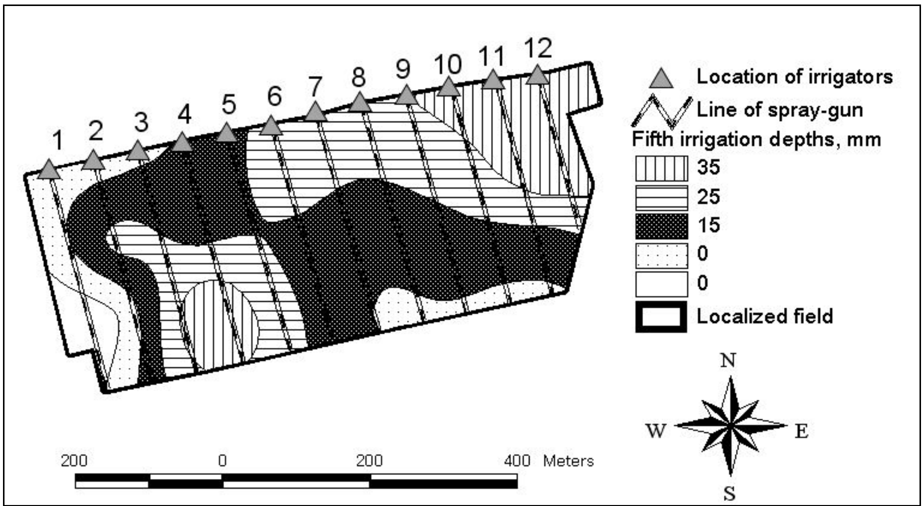


**Figure 14** Fifth irrigation rate

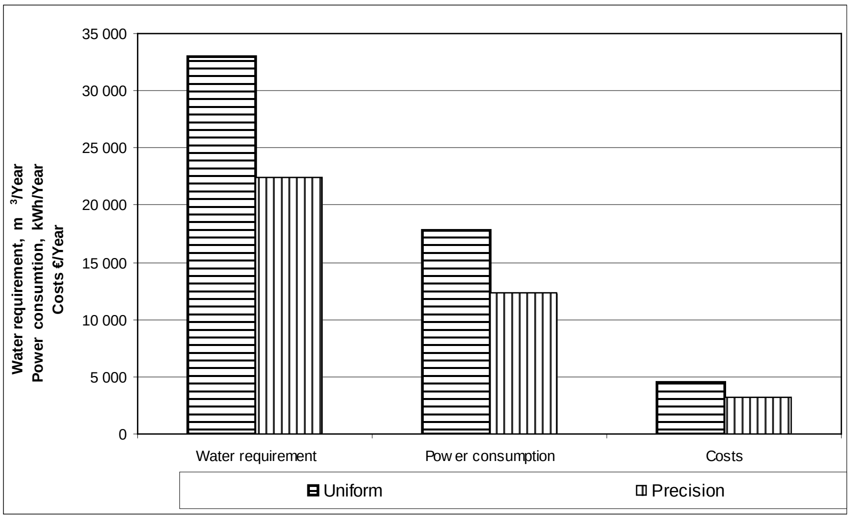


**Figure 15** Overall evaluations of results

## CONCLUSION

Currently are developing new directions in the economy, which raises new solutions in terms of economic use of inputs through information technology. The introduction of computer technology in principle allows us the operational management of production technology, technical support in various stages of production and ultimately leads to lower costs and saving resources, what is the aim of precision agriculture.

Variable irrigation was based on the measured data. Then were established the economic benefits of variable irrigation. The results obtained show that spatially variable technology allows precise application of irrigation water on soil and plant requirements. In this respect, it is a fully effective system of precision agriculture, although the procurement and introduction of new technology and the software requires first expending a considerable financial cost. The farm should therefore be in terms of the innovation process to take appropriate selection techniques such as initial investment, the task is to return the initial costs incurred for the purchase, management of resources for future investigation.

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