Evalution of precision farming with regard to horticulture

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Summary: The global positioning system was made available for public use, which made it possible to apply a new management tool in agriculture. Precision farming gives much more information on plant-growing than former methods, which makes it possible to use technologies more suitable for micro-sites. It is supposed that more profitable production can be realised with its aid and the strain on the environment can be reduced, not to mention other economic advantages.

The study makes economic conclusions about the method more and more widely used in plant production taking the yield mapping of Józsefmajor Experimental Farm as a basis and starts ideas about its possible application in arable land olericulture, viticulture and fruit production.

These issues are important because precision farming has existed in glass-culture for a long time from another perspective, which should be spread to open ground horticultural enterprises that are labour and asset intensive, qualitative farming forms with great plantation value.

Key words: precision farming, economic analysis

The possibility of the application of GPS in agriculture

The increase of expenses used for the obtainment of information necessary for the preparation of economic decisions is an economic decision, which can be made according to principles equivalent to those of other input optimisation decisions. In case of animal husbandry the economic importance of the use of continuously registered information on individual animals is well known for a long time (e.g. computerised systems of individual animal identification, milk measuring, fodder proportioning and data storage of reproduction for instance). But in plant growing the approach of taking the plat of any size as the basis of production was kept, a homogenous cultivation method and equivalent inputs had to be used within this unit of production. This approach which was the result of technical constraints existed for long despite the fact, that every farmer knew that the soil, the features of the ground and other factors influencing the yield are very varied within a plate. In the practice the exploration of these differences and the development of the corresponding technology did not even occur because of the lack of suitable facilities and the expensiveness of experimental examinations.

The application of DGPS and the attached facilities makes it possible to develop site specific technologies and to make operational actions differentiated according to the site. This method is also known as site specific management, which well expresses the plant growing dimensions of precision farming.

Site specific management was mainly used to employ the different quantities of seeds, fertilisers, insecticides and pesticides exactly at the desired places. It is well known how the quantity of seed influences the quantity of the yield, its quality and the period of maturation. In case of fertilising the areas with higher yield potential can be better utilised on the one hand, or the unnecessary N burden on the environment at areas of lower yield can be avoided. In case of spraying the exact application of insecticides and pesticides is possible with the aid of supplemental site exposures, which may save more money than targeted seed and fertiliser application, since the price of these chemicals is high. In some parts of th plates where there are no offenders, the cost of plant protection can be neglected.

The application of GPS has additional features of rationalisation and increase of effectiveness that can be explored better with the development of techniques and the growing number of data available (e.g. husbandry of water resources, erosion protection, operative interventions, detection of operational errors, e.t.c.). Its precondition is its broader application and the publicity of the practical experiences.

Yield mapping in Józsefmajor Experimental Farm

The DGPS aerial, the Quantimeter (sensors measuring the yield, the humidity of the grain, the rev of the barrel and other technical parameters), the ACT board computer were installed in the CLAAS Classic combine in May 2000, at Józsefmajor Experimental Farm of Szent István University. The data of the board computer can be transferred to a personal computer with the aid of a PCMCIA chip card. The yield maps and other evaluations are made by the personal computer with AGRO-MAP software[1].

[1] AGROCOM GmbH and AGRÁRIN Ltd. gave free run of facilities and software that made yield mapping possible.

Yield maps were made on every grain plat of the farm during harvesting in June and during rental harvesting, which itself gave a lot of useful information.

During yield mapping the first step is to determine the hectolitre weight of the grain with the aid of sampling. The instruments have to be calibrated and then the several information characteristic for the plats must be stored in the personal computer. When the combine starts at the plat, the measurements start automatically. On its way the instrument determines the position of the combine at discrete points (the distance between two subsequent points is several meters), the measured quantities (yield, humidity) are linked to the corresponding co-ordinates. The continuously measured data are stored by the board computer on the chip card, which can be taken out of the computer after the operations and the data can be examined with AGRO-MAP computer program.

Maps of several types can be made from the data of the plats. A linear map shows the route of the combine, from which the computer may calculate the border (adding half of the width of the cutting adapter) and the size of the plat. Then a contour map is made, which connects places of equivalent yields and which shows the different yields with different colours. The differences between yield levels can be modified. The computer calculates the average yield and the sizes of areas of the different yield levels, which is also shown in a histogram.

All maps made in Józsefmajor Experimental Farm increased the knowledge of the different plats with a lot of new information. Even the first surveying makes it possible to have conclusions according to which important economic decisions can be made. *Figure 1* shows the yield map of a 35 hectare wheat plat of the farm.

The shown plat is situated next to the farmstead to the north-east. The northern edge is descending and eroded, the area west of the plat was therefore taken out and forested. Additional important information is that the sloping border of the western part of the plat is parallel with the fencing of the farmstead.

The most instructive information of the yield map and the belonging histogram is the great diversity of the yield. Yield map shows significant differences, that are between 1.5 ha and 7.0 ha. The calculated 4.2 average yield appeared to be real during the weighing of the grain transported in.

The harvested 146.6 tons of wheat was the result of well explainable reasons. The yield was the smallest at the descending, eroded parts. The degradation of the tilth, the less effective use of inputs resulted in a yield between 1.5–2.5 tons per ha, except for several higher yield spots. On the high yield southern and western parts contours show a well visible "yield peak" close to the fencing of the farmstead. Beyond the soil quality of this part of the plat that otherwise seems to be homogenous and smooth there should be a special reason to this. A part of the liquid manure of the dairy cattle kept in the farmstead was spread at this plat and it is assumed that the person responsible for the spreading of the manure favoured the plat part closer to the farmstead to increase the performance.

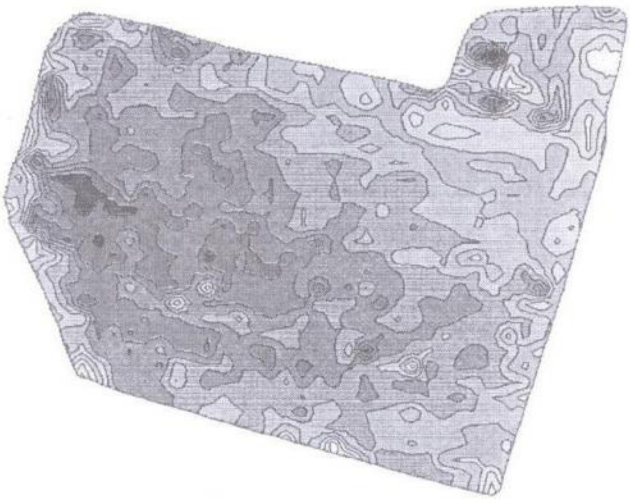

Figure 1 The yield map of F13 winter wheat plat of the farm

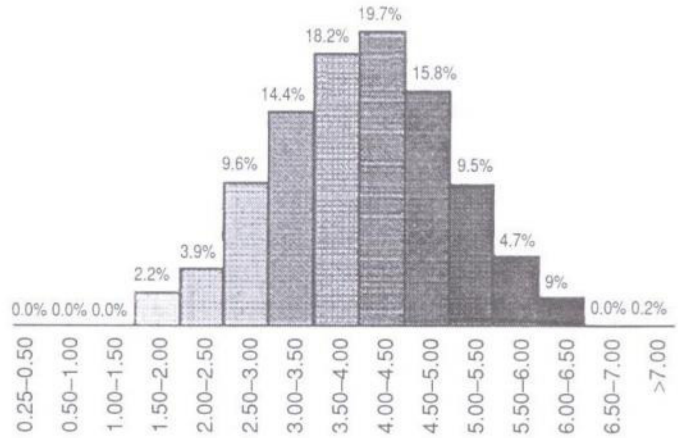

Figure 2 Histogram of the yield mapping of field F13

Beyond yield maps, other maps could be made on the humidity of the grain, that could show the humidity fluctuating from the morning to the evening (decreasing and then increasing) or the relationship between humidity and the features of the ground and other factors. But these information can be used to determine the critical humidity of the produce reading the values from the monitor and to make the related organisational decisions (e.g. can harvesting be started, when is it advisable to stop in the daytime).

The evaluation of the information of precision farming

Yield map shows actually the symptoms and the results. It can be seen that conclusions can be made from the symptoms, but the detailed analysis of the reasons may give better-based results. There are experiments in Hungary for example on the realisation of fertilisation consulting based on geographic information systems (3, 5), the essence of which is the mapping of inter-plat differences and fertiliser dosage performed according to it. With the aid of DGPS soil sampling can automatically be made and such maps can be made much faster. The exact, numerical knowledge of topographical forms, the comparison of the contour map and the yield map may also be important. All these information may establish decision making on potential measures. Independently of this, useful economic decisions can be made from the shown yield maps and the histogram quantifying the distribution of yields without performing further complicated examinations.

1. Increase profit by decreasing land

Figure 3. shows the variable costs and revenues as a function of yield using the actual costs and market prices. Since we used equal quantities of inputs and homogeneous operations during production we did not know the differences in yield, variable cost (84,000 HUF/ha) was the same at every area of the plat (except for the mentioned liquid manure use, which was intended to be homogeneous too). Revenue, which is linearly increasing with yield crosses variable costs at about 3 t/ha, which means that in a part of the plat, where yield was bellow 3 t/ha, gross margin was negative. This loss can be calculated if we know the geographical distribution of yield.

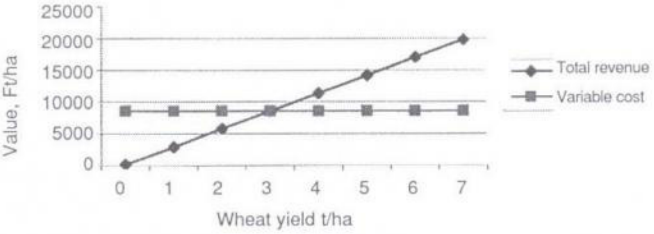

Figure 3 Total revenue and variable cost per hectare at the different yield levels of the plat in case of homogeneous inputs

In theory, if we had known the different yields we could have increased the profit of the plat by fallowing all the areas bellow 3 t/ha, since their variable costs could have been saved. If the next years show the same tendency for this plat, and areas bellow 0 gross margin are at the edge of the plat, well confinably, it can be considered to use these parts differently, extensively (e.g. foresting, grassing). With its aid not only loss can be avoided, but further erosive damages could be evitated and the N taint would also reduce.

2. Increase profit by site specific fertiliser dosage

Profit can be increased if the differences in yield appear to be constant results of differences in fertility and if this fact is taken into account during the preparation of the technology. Yields of 2000 were reached with an input of 200 kg/ha 34% ammonium nitrate, the cost of artificial fertilising was HUF 262.5 ,thousand. But we need further information if we intend to adjust fertiliser input to the sites.

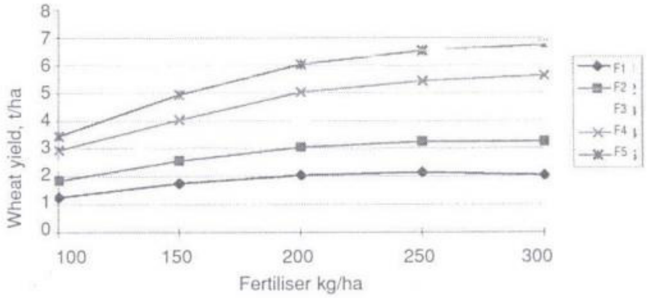

Figure 4 The assumed wheat yield as a function of the different soils and N inputs (model data)

Having had no local experiments, we assume according to other similar examinations (4, 6), that the relationship between the different levels of fertiliser inputs and wheat yield is as follows in *Figure 4.*

F1–F3 production functions that are only intended to be model calculations, contain real data in case of 200 kg/ha fertiliser input, since the satellite system has shown these yield levels for the given input level. The form of the functions can be a debating point, but its tendency. The form of the functions can be fined with the calculation system, which was worked out in case of real experimental results and the propounded calculated results may become more accurate.

If we use the production functions and the actual cost and revenue data of the farm, the gross margins of the different soils in case of different levels of inputs can be calculated. *Table 1.* shows these hypothetical gross margins, indicating the values that are supposed to be optimal levels of input.

The table shows that the assumed production functions have different optimal input levels, which are 250 or 300 kg/ha. In addition, no positive gross margin can be reached in case of F1 production function because of the low yield level. Therefore it is advisable to examine, what is the overall

Table 1 Gross margins of the different plat parts in case of different fertiliser inputs (HUF/ha)

Plat parts characterised by F1–F5 production functions	Fertiliser input levels, kg/ha				
	100	150	200	250	300
F1	–46650	–34525	–28000	–27075	–31750
F2	–29850	–12125	0	3725	1850
F3	–13050	10275	28000	34525	32650
F4	950	29875	56000	65325	69050
F5	14950	55075	84000	96125	99850

Table 2 Gross margins of the different fertilising strategies (Ft)

Plat parts	Size (ha)	Homogeneous input levels, kg/ha					Input adjusted to site
		100	150	200	250	300	
F1	4	–186600	–138100	–112000	–108300	–127000	0
F2	7	–208950	–84875	0	26075	12950	26075
F3	14	–182700	143850	392000	483350	457100	483350
F4	7	6650	209125	392000	457275	483350	483350
F5	3	44850	165225	252000	290550	299550	299550
Total	**35**	**–526750**	**295225**	**924000**	**1148950**	**1125950**	**1292325**
GM difference		1819075	997100	368325	143375	166375	0

outcome of the different fertiliser input strategies. In *Table 2*, beyond the five homogeneous fertilising variants, the results of the DPGS technology are also included, that excludes the cultivation of F1 field and in which 250 kg/ha fertiliser is thrown at F2 and F3 fields and 300 kg/ha at F4–F5 fields. Calculations are based on the data of the former 35 ha plat of the farm and a yield distribution that was experienced on that plat.

The table unequivocally shows the advantage of adjusting the input to the micro-site. The differences from the largest gross margin value (HUF 1,292,325) are included in the bottom row of the table. The second best strategy is to throw 250 kg/ha at all the plat, the return of which is HUF 143.375 less amount that of the very best. It is on one hand caused by the negative gross margin of the 4 ha F1 land (HUF 108.300), and on the other hand by the reduced returns of F4–F5 lands (35075). The results of the DPGS system should be compared to this strategy.

We note that the formerly recited fertiliser advisory system (3, 5) does not determine the differentiated fertiliser inputs according to economic principles based on model calculations. It starts from the nutritive needs of the planned yield and the discovered nutritive content of the soil. The problem is that they suppose linear production functions when they use their method, which means that every additional 1 t of yield can be reached by the same additional input. It may be misleading when larger levels of yields are planned, since the effectiveness of fertiliser inputs may be far less than what was planned. In addition the method does not reckon with the fact, that it is likely that the planned large yields cannot be reached in parts of the plat because of the diverse yield maps. According to our calculations if we plan a consistent 5 t/ha yield, 25 ha will not reach it from the 35 ha assuming the given production functions and in case of 6 t/ha 32 ha respectively. The difference from the plans is 34 and 62 tons, which itself may question the usefulness of the method. The unification of yields therefore cannot be a suitable economic goal in case of GPS method.

If we intend to use site-specific fertiliser inputs, we need not only yield mapping and other pragmatic examinations, but an artificial distributor equipped with a planned input map and based on GPS system. This is technically feasible and these facilities are available to buy. There is a distributor that is able to throw different proportions of two different fertilisers in order to secure a site-specific N:P:K rate. The price of these machines is relatively high, it is advisable to take into consideration the difference in price from the same machines that are not equipped with such facilities.

3. Increase return by site-specific plant protection and sowing

According to data available in Józsefmajor Experimental Farm about production year 1999/2000, it is likely that site-specific plant protection that would help to use integrated plant protection, would increase profit better than nutrient management, since the cost of the applied abatement means would significantly be reduced. The cost of herbicides, fungicides and insecticides amounts to 44 thousand HUF/ha which is 52% of variable costs. If this cost could be reduced by 20% by assessing contamination and applying site specific plant protection, the overall cost reduction of the 35 ha plat would be 308 thousand HUF. (It is feasible, since the insecticide against *Lema melanopus* is 12 thousand HUF/ha, and it is well known that this pestiferous insect attacks in clouds. If only one third of the plat was sprayed, this cost would be 280 thousand HUF less.)

The quantity of the sown seed also has an effect on the yield (and on the quality of the produce), which may differ according to the different soils. The quantity and the distribution of the seed can also be optimised and such a machine can be equipped with a GPS based portioner.

4. Other information that derive from the practice of precision farming

The introduction of precision farming may have other advantages beyond the quantifiable profit increasing opportunities.

The anomaly of the placement of liquid manure has been mentioned, which would have been difficult to be discovered with other methods. Similarly, other mistakes and deficiencies can be found posteriorly, that the attention can be drawn at the following years. So field mapping can be a means of controlling too.

When we analysed the yield map of a 50 ha plat we found another opportunity of utilisation. The shooting of a part of the seeds was very insufficient, thus half of the plat had to be sown again with spring wheat. The droughty early summer period was not suitable for the growing of spring wheat, therefore the yield map showed a difference of 1,5–2 t/ha from the other part sown only with winter wheat, which also had deficient shooting. The deficiency of the seed could be evidenced during the autumn survey and compensation could be claimed, but yield map could also have been an evidence in the action for damages. Similarly, the reduction of yield due to disaster (storm, hail-storm) can be stated with the aid of yield maps, that can be the basis of influencing the compensation paid by the insurance company.

DGPS is not the only means of measuring continuously the humidity of the grain during harvest, but the humidity measuring sensor and the anyhow necessary board computer automatically measure it and give the data as a by-product. It has been mentioned that if we know the humidity of the grain, we can start and stop harvest at the right time, which may result in the reduction of siccation costs. Even siccation cannot be prevented, the required humidity limits are easier to be kept.

Similarly to the examples above, further experiences can be gained with precision farming. It may be satisfying for many farmers to know better their land and to find answers to former questions.

The possibility of the application of the method in open ground horticulture

The use of uniform input quantities on field dominates in arable land olericulture, fruit production and viticulture, similarly to plant production. Naturally, it is supplemented with individual treatments especially in case of plantations (cutting, yield controlling, harvesting, etc.). Tilling, fertilisation, and plant protection is homogeneous in most of the cases. But it is likely that micro site differences can be found within the fields similarly to the example shown in case of plant production. The application of precision farming is even more important in case of horticultural products of larger value.

Some of the techniques used in case of precision plant production *can directly be used* in open ground horticulture. Such can be the selection of fields for this purpose. With preliminary soil investigation and yield mapping of the potential areas fields or field parts revealing homogeneity and the natural circumstances of which are best suiting the needs of a given plantation or vegetable can be found. The method of site specific fertilisation is not different and site-specific use of insecticides helps integrated plant protection. A process machine equipped with DGPS aerial and controlling automatics are similar to the used (or experimented) plant production.

However, *further examinations are necessary* in other areas, like yield mapping, which is routinely used in plant production. The harvesting techniques of horticultural enterprises are more complicated (sorting, multiple harvest, quality control, etc.), labour intensive and very different in case of the different species. While grain, corn, sunflower or rape are harvested by grain combine (with the application of an adapter for certain crops) and only certain adjustments have to be made and calibration performed for yield mapping, horticulture requires individual solutions. Site specific yield mapping is supposed to be more complicated and expensive than the already existing techniques, therefore it is especially important to make preliminary evaluations before introducing it. In certain cases other methods like aerial photography can be accurate and effective enough.

It is *not necessary to use* DGPS or other localisation technologies in certain areas like weed control in case of viticulture and fruit plantations. The significant differences of the crop and the weeds make it possible to apply "rough" techniques. But olericulture requires *even more refined precision techniques* in the field of weed control (digital plant recognition based on colour and form) there are advanced experiments in this area.

Findings

Precision farming is expected to spread in Hungary after clarifying the technical and technological points. It is very important that DGPS systems are on the rails and there is no technological gap between Hungary and the developed countries that could result in the loss of competitiveness. But there should not be too early, unnecessary investments in our agriculture lacking the adequate level of capital.

Yield mapping that was made during the harvest of winter wheat in Józsefmajor Experimental Farm itself gave a chance to make useful recommendations in the present stage of the introduction of precision farming. The examinations of the 35 ha plat showed that it is possible to increase profit by adjusting fertiliser inputs, plant protection and other technological element to the micro site. Calculations revealed that profit could be increased with HUF 500 thousand.

The aerial, the sensors, the board computer require an investment of HUF 3,5–4 million, if they are installed to an existing combine. The purchase of machines (artificial distributor, sprayer, sowing machine) equipped with DPGS technology and the additional modules (700 thousand HUF) require further investments. This investment cost does not devolve the new technology as a whole if the replacement of the machines is necessary anyway, the old machines can be sold or if a new enterprise is created. If the new system is used in 400–500 ha for several crops, profit can be increased with 5.7–7.1 million HUF, to which the investment cost can be compared, and the return on the investment can be calculated. We assume that a quick return can be expected in such or greater sizes (in case of own farm, or lease work).

Precision farming has other not quantifiable advantages too. The stricter environmental regulations can be kept more easily, N migration and the quantity of plant protective products can be reduced in case of site-specific inputs, thus external costs may decrease. The introduction of this technology has other advantages in the organisation of work, controlling and when settling debating points. These can be given as services for those who order it.

Further information is required for the introduction of precision farming beyond the data given by DGPS system. The importance of revealing the relationship between inputs and outputs and the analysis of production functions is increasing. The sites must be known better, which requires regular soil examinations (DGPS technology can give help in it too). Further investigations are necessary in case of integrated plant protection, nutritive management and husbandry of water resources. Thus precision farming requires a faster advancement in the field of scientific research and practical experiments.

The spreading of DGPS and other precision farming techniques to open ground horticulture is a new challenge. Some of the methods of plant production can directly be applied, but further research is necessary in case of the more complicated, special and labour intensive enterprises of olericulture, viticulture and fruit production in the field of yield mapping and certain inputs and operations. In these cases well-based economic examinations are necessary to determine the economy of the new methods.

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