Simulation model on optimizing the sowing structure of precision plant production

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During the past decade, many people deal a lot with the Hungarian agriculture, its views and opportunities in the future. In order to the Hungarian agriculture be competitive on the European market it is needed to be able to follow the market motions and its changes. To do this, it needs making investments on certain areas which requires capital. The agricultural producing can only be competitive if the farmers keep the environmental viewpoints and the sustainable farming with an eye.

The precision cultivation can be one of the implement of the so many voiced sustainable development at the field of agriculture. The precision cultivation requires surplus expenditures (purchase devices, operating the devices, etc.) but it has advantages too (yield increase, decreasing of material costs and yield insecurity, etc.). The comparison of the surplus expenditures and surplus yields serves as a basis of a complex economical analysis where not only the costs and revenues but the sowing structure changes are also appearing. The aim of this paper is to determine an optimal sowing structure for a 250 ha farm which provides the highest income with the technology of precision plant cultivation.

Keywords: sustainable agriculture, precision cultivation, simulation

1. Introduction

Nowadays, there could be heard a lot about the environmental protection, **environment friendly agriculture and sustainable growth**. The **precision agriculture** is a farming method which takes part in sustainable development. (Swinton 1997) This was the main reason why the precision agriculture is on the focus of this paper.

The main tasks of the modern agriculture are the **efficient utilization of the resources**, integrating the biological processes and regulating mechanisms of the production where it is possible and through this, confirm the cost-effectiveness of the agricultural manipulation, preserve agricultural human resources and retain

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living-standard of provincial society. (Barkaszi et al. 2006, Csiba et al. 2009, Sándor et al. 2009)

Agriculture needs to face the challenge that it should produce the food for greater population on smaller field all over the world. The **site-specific (precision farming) technology** which **optimizes inputs** (fertilizer, herbicide, pesticide, etc.) on parcel-level might be a solution for this problem. Due to the site-specific optimizing this technology increases the yield and decreases the environmental damages. (Batte 1999, Székely et al. 2000, Takácsné 2003, Takács–Barkaszi 2006, Kis–Takácsné 2006, Pecze 2008)

The environmental debit of the production could be decreased for example by **precision weed-management technology** that results cost saving (only those parcels are treated that contain weeds). The amount of the savings which comes from the site-specific treatment is different according to the various researches (between 20% and 60%). (Leive et al. 1997, Batte 1999, Luschei et al. 2001, Takács-György et al. 2002, Reisinger 2004)

The parameters of the soil are: (1) the features of ground, water- and nutrient supply, (2) injuries, and (3) yield. These factors show the heterogeneity of the field. The soil is handled in **precision farming technology (PFT)** as a heterogenic unit which influences positively the success of farming by the meaning of site-specific treatment. The more detailed information we have about the heterogeneity the better treatment could be realized with site-specific treatment. (Weiss 1996, Pecze-Horváth 2004, Reisinger 2004, Csathó et al. 2007)

The PFT could not be applicable completely for every crop. For instance in the case of sunflower production the problem of yield-measure is not solved, while in the case of maize production every technology elements are applicable by site-specific method. (Table 1)

Table 1. Applicability of the precision plant production elements in different plant culture

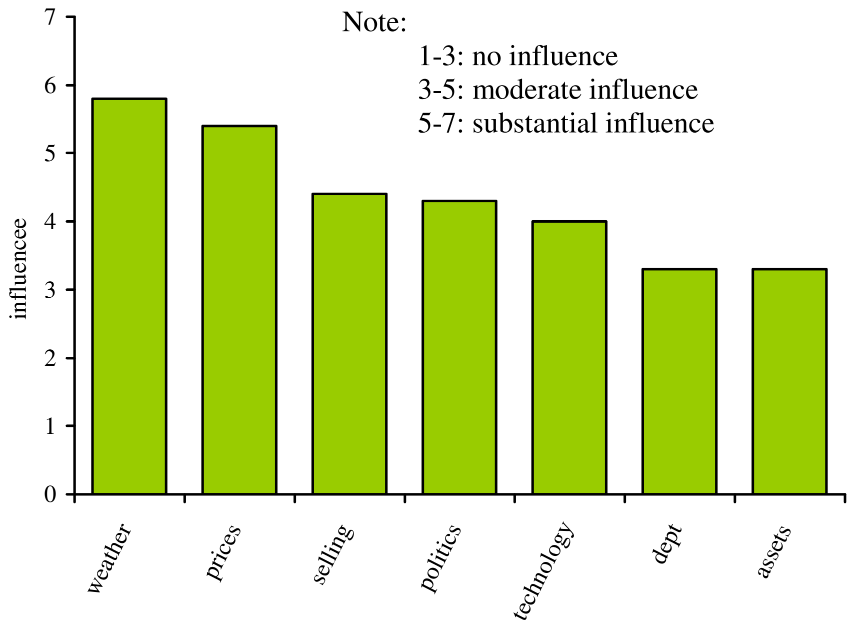
	Precision soil-sampling	Yield mapping	Differential fertilization	Precision weed management
Winter wheat	+	+	+	+
Maize	+	+	+	+
Sunflower	+	-	-	+
Alfalfa	+	-	-	-
Potato	+	-	-	-
Green bean	+	+	+	+
Soya	+	+	+	+
Colza	+	-	-	-

Source: Pecze 2006 and own creation

The international literature of PFT is considerably wide. The center of the research of Weiss, Lowenberg-DeBoer and Boehlje is the microeconomic questions of PFT especially the classic production economic analysis. Due to employing this technology smaller and smaller farm size could realize **profit**. Kalmár et al. argued in a study (in 2004) that this technology is viable on the farm-size that includes more than 1,000 ha. Kovács and Székely claimed in 2006 that 250 ha are enough to viability. According to the latest researches this number could be 206 ha depending on the sowing structure. (Kalmár et al. 2004, Kovács–Székely 2006, Takács-György 2007)

The **sowing structure and PFT** are not the only key factors of success because agribusiness has many factors of risk as well. According to Székely and Pálinkás the **most common risk factors** are: (1) production risk, (2) market (price) risk, (3) financial risk, (4) institutional risk and (5) personal risk. Their research which was made in 6 EU members namely Hungary, Poland, Holland, Spain and Germany claimed that the most significant risk factor is the weather- and natural risk (production risk). The volatility of the prices had only the second place in the ranking list (Figure 1). (Székely–Pálinkás 2008)

Figure 1. Ranking of risk factors by influence on production



Source: Székely–Pálinkás 2008

Technological development could be one aspect of **risk management**. The technology of precision plant production may lead to savings by site-specific treatment that saves material costs and exploitation of yield potential that improves yield security.

2. Data and methods

The main aim of this paper is to determinate an **optimal sowing structure for a 250 ha farm** which provides the highest income with the technology of **precision plant production**. The examined period is 10 year long. Main conditions of the simulation model are:

- Stipulations of **corp rotation**[3] and **intercropping**[4]: winter wheat and maize cannot be sawed in the same soil for 2 years. This number is 6 years for sunflower and 4 years for colza.
- **Weather conditions**: during the examination the model supposed that in 70% of the cases there were non-draught period and in the rest 30% there were draught period.
- **Input prices** (seeds, corp protection chemicals, artificial fertilizer) were changed according to the weather conditions.

Maximizing the gross margin is the decision criterion during optimizing the sowing structure.

The used data relating to the input costs, expenses and incomes come from the database of AKI (Research Institute of Agricultural Economics). The following changes were made on these figures: the costs of the seeds (-4%), the artificial fertilizer (-15%) and the crop protection chemicals (-10%) were decreased – the latter one is true only for those corps that has wide row spacing (e.g. sunflower and maize). Besides, the expenditures connected with the machinery were raised by 20%.

Average costs and values of production data were determined separately for non-draught and draught periods and for each corps according to the data of the period 2000-2006. The simulation model uses these figures considering the standard deviations namely the value of randomized data could be somewhere between the maximum and minimum marginal values (Table 2).

[3] temporal diversification
[4] spatial diversification

Table 2. Marginal values of operating expenses and sales price (data in HUF)

non-draught period	**winter wheat**		**maize**		**sunflower**		**colza**	
	min	**max**	**min**	**max**	**min**	**max**	**min**	**max**
cost of seed	10 752	12 965	14 839	20 143	10 248	14 444	7 258	12 414
cost of artificial fertilizer	12 198	15 741	13 593	15 518	6 127	11 997	14 742	17 889
cost of corp protection chemical	8 841	10 816	8 280	9 293	9 640	10 388	11 253	15 901
cost of machinery	24 007	29 342	29 361	32 165	22 217	33 767	22 186	30 442
sales price	21 000	25 200	19 427	24 445	48 470	58 125	48 359	55 744

draught period	**winter wheat**		**maize**		**sunflower**		**colza**	
	min	**max**	**min**	**max**	**min**	**max**	**min**	**max**
cost of seed	10 369	11 228	15 009	16 471	10 988	11 842	7 842	10 447
cost of artificial fertilizer	11 797	11 871	12 191	14 674	6 494	8 182	12 769	16 033
cost of corp protection chemical	9 137	9 300	8 380	9 667	10 422	10 559	11 940	16 631
cost of machinery	20 580	28 726	26 004	36 416	26 052	33 703	20 900	32 515
sales price	21 499	31 880	19 433	33 007	49 692	65 526	50 930	55 841

Source: own creation

Figure 2. The used formulas during interval determination

average: $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$ standard deviation: $\sigma = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

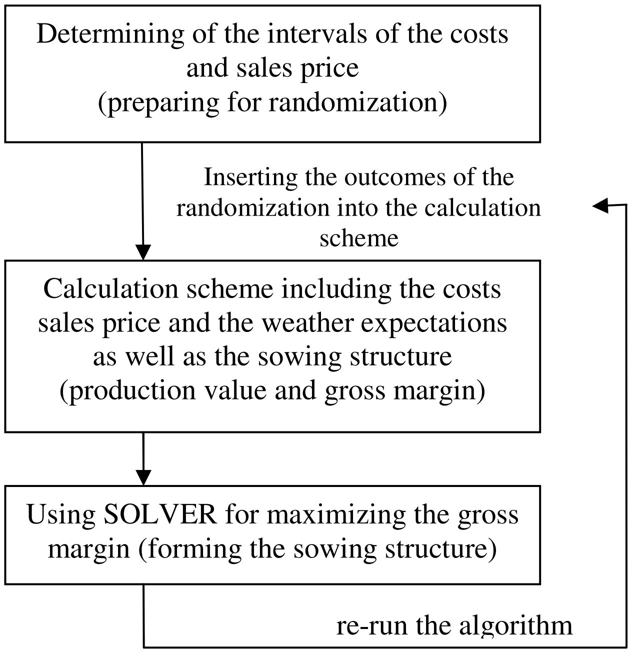
min: $\bar{x} - \sigma = \frac{\sum_{i=1}^{n} x_i}{n} - \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

max: $\bar{x} + \sigma = \frac{\sum_{i=1}^{n} x_i}{n} + \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$

Source: own creation

The following flow-chart shows how the simulation model works. (Excel 2007 program was used for calculations.)

Figure 3. Flowchart of the model



Source: own creation

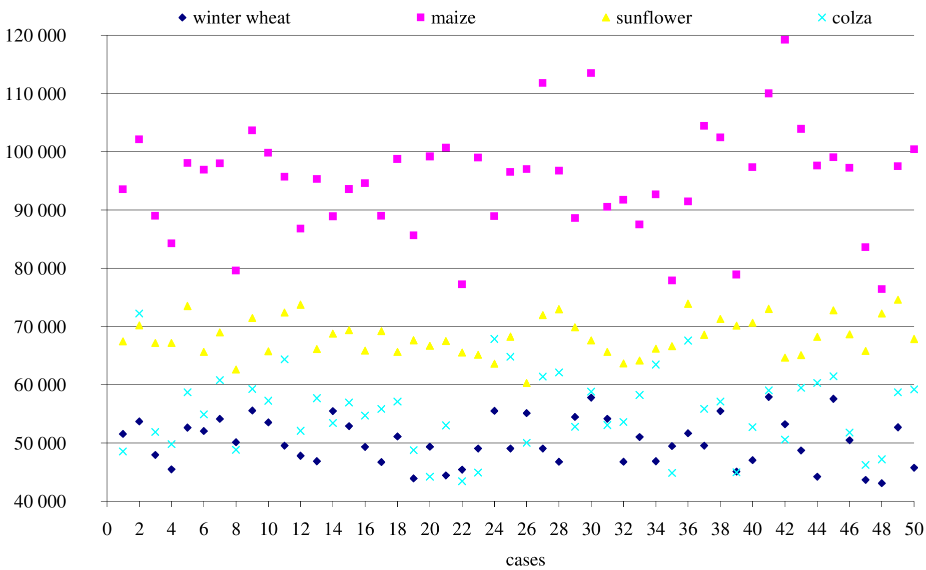
Constrains of the simulation model are typed into the solver (the formerly mentioned provisions and bounds for the model). It is very important that the result must be set to zero before running the solver – it means that the former result must be deleted before re-running the algorithm.

The simulation model was executed 50 times in order to obtain sophisticated results as the way it was previously mentioned. We found that this is enough because the results were very similar to each other.

3. Results and discussion

Applying the framework of the simulation model **maize is the most profitable corp**. The average gross margin was **94,834 HUF/ha** (StDev 9,186 HUF). Sunflower has the second place with averagely 68,223 HUF/ha gross margin (StDev 3,296 HUF). The third crop is Colza that reached 55,426 HUF/ha gross margin (StDev 6,617 HUF). And the least income could be realized by growing winter wheat that has a gross margin 50,201 HUF/ha (StDev 4,039) (Figure 4).

Figure 4. Gross margin (HUF/ha)



Source: own creation

The average **production cost** per hectare of the winter wheat was 59,945 HUF/ha. This number was 70,554 in the case of maize, 59,429 in the case of sunflower and 65,311 HUF/ha in the case of colza.

The average **production values** per hectare of the corps are the follows: (1) winter wheat: 110,146 HUF, (2) maize: 70,554 HUF, (3) sunflower: 127,652 HUF and (4) colza: 120,737 HUF (Table 3).

Table 3. Annual average values of production cost, production value and gross margin

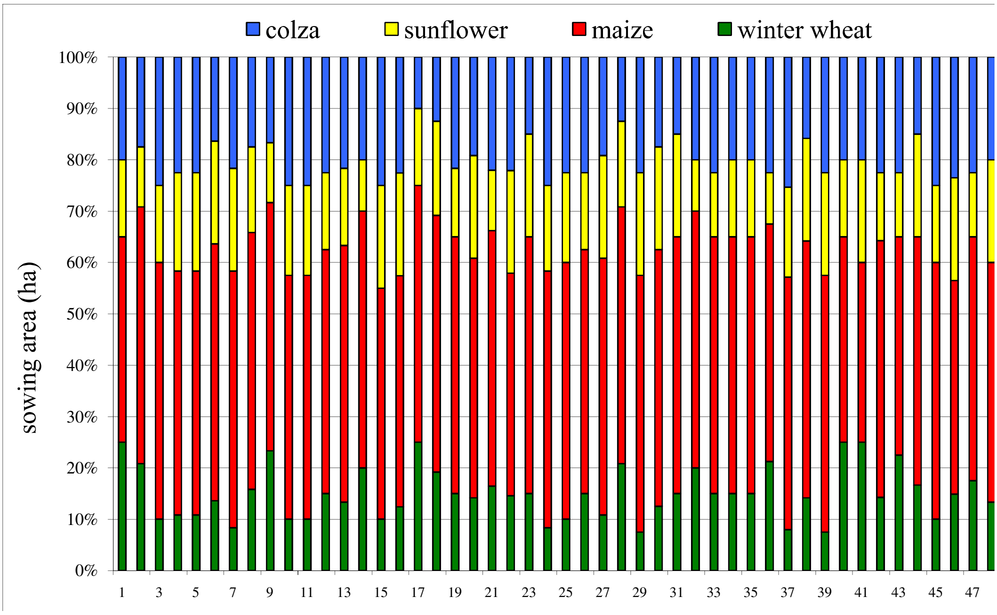
	no. of years	**1st**	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**Avg**
winter wheat	area (ha)	82	25	32	6	32	72	39	28	34	28	**38**
	PC	60 314	59 878	59 668	61 909	60 270	56 150	60 393	59 977	60 187	60 709	**59 945**
	PV	113 908	111 087	107 673	115 441	115 082	95 200	110 524	108 477	112 581	111 494	**110 147**
	GM	53 593	51 209	48 005	53 533	54 812	39 050	50 131	48 500	52 394	50 785	**50 201**
maize	area (ha)	106	127	64	180	168	76	130	106	103	139	**120**
	PC	71 007	69 871	71 089	70 745	71 107	69 629	70 350	70 166	70 683	70 890	**70 554**
	PV	166 578	172 308	157 531	175 360	168 214	141 883	168 065	169 417	167 935	166 583	**165 387**
	GM	95 571	102 437	86 441	104 615	97 108	72 254	97 715	99 251	97 252	95 693	**94 834**
sunflower	area (ha)	24	54	80	21	12	46	14	58	74	34	**42**
	PC	59 338	59 613	59 606	59 199	59 512	59 172	60 027	59 101	59 521	59 204	**59 429**
	PV	129 399	131 323	128 487	129702	127 603	122 284	125 449	127 582	126 985	127 709	**127 652**
	GM	70 062	71 711	68 881	70 502	68 090	63 112	65 423	68 481	67 464	68 504	**68 223**
colza	area (ha)	37	44	74	43	38	57	66	57	39	49	**50**
	PC	65 715	66 332	64 771	65340	65887	64 883	65 032	64 500	65 209	65 446	**65 311**
	PV	121 161	125 271	121 946	126 225	125009	98 831	119 967	122 878	121 333	124 749	**120 737**
	GM	55 446	58 939	57 174	60 885	59 122	33 948	54 935	58 378	56 124	59 303	**55 426**

Source: own creation

Note: PC – Production Cost (HUF/ha), PV – Production Value (HUF/ha), GM – Gross Margin (HUF/ha)

According to simulation results, industrial maize covers 48% (+ 3%), colza 20%, sunflower 17% and winter wheat 15% of the whole area (Figure 5).

Figure 5. Sowing structure per executions

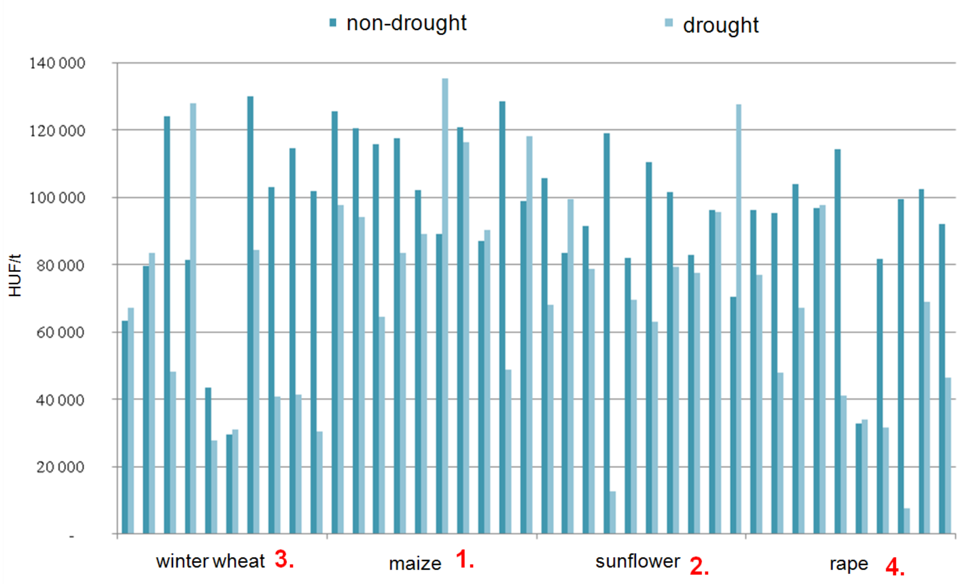


Source: own creation

Figure 5 shows how the sowing structure should be formed in order to obtain the **highest income** within 10 years considering the stipulations of crop rotation and intercropping and the probability of draught.

Finally, a **sensitivity examination** was performed on production values of the examined corps. If the weather conditions are not advantageous and drought is appearing then a **general decreasing** could be observed. Colza and winter wheat shows the highest decline (more than 750 HUF/ton each). The price of the sunflower also shows fall but the value of it is less significant (408 HUF/ton), and the smallest reduction was resulted by maize (140 HUF/ton) (Figure 6).

Figure 6. Effects of the drought on production value of the examined corps



Source: own creation
Note: rape = colza

4. Conclusion

The **optimal sowing structure of a 250 hectare large farm** is the following:

- winter wheat: 38 ha
- maize: 120 ha
- sunflower: 42 ha
- colza: 50 ha

If we would like to deviate from this sowing structure it is expedient to increase the proportion of those corps of which production values are less sensitive to weather changes. These corps are the maize and the sunflower in our case.

The adaptation of PFT could be viable mainly at medium size (250 ha) farms under Hungarian conditions especially when intensive production is used and the rate of the wide row spacing culture is at least 40% of the sowing structure (Lencsés 2009).

The farmers should carry out many technical, technological, informational and economical stipulations in order to be able to adopt PFT. The cost of investment in PFT adaptation is between 17 000 and 34 000 Euros which depends on the farm size. This financial question is the reason why the carefully considered economical analysis is so important. Besides, ecological aspect should not been forgotten either because PFT is more environmental friendly than the traditional technology of plant cultivation which means a kind of improvement as for sustainability of agribusiness.

Furthermore, the aspect of changes in inputs is also important. Apart from the fact that PFT requires investment in equipments that needs to be maintained, it has a lot of advantages as well for instance more stabile annual yields and reduction of operating expenses (fertilizer, chemicals, pesticides, herbicides, etc.).

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