PRECISION AGRICULTURE METHODS IN A FIELD EXPERIMENT OF RUSSIAN TIMIRYAZEV STATE AGRICULTURAL UNIVERSITY

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Abstract: the comparison of two agriculture technology (traditional and precision) is conducted in a field research.

Key words: precision agriculture, Autopilot, guess row spacing, N-sensor, inter-field variability, crop mapping.

Precision agriculture is a concept of farming management based on observing and responding to inter-field soil property and crop variations. Three pillars of this concept are satellite imagery, information technology, and geospatial tools, using satellite positioning system like GPS. The concept of precision agriculture first emerged in the UK and the United States in the 1980s. Before the end of 1990s there was widely used only one aspect of precision agriculture - navigation satellite system. Now other components, such as N-sensor, crop-meter and so on, are expanding as well. All information about fields and crops can be displayed as maps: maps of soil properties, biomass, yield, weeds-patches and crop-diseases distribution. These maps are used for crop management [5]. In Russia the concept of Precision agriculture began to develop from the 2000s [5, 7].

Scientific Centre of Precision Agriculture of Russian Timiryazev State Agricultural University was established in 2007 [3, 4]. It is the first academic Precision Agriculture centre in Russia. The main functions of Centre are: learning and introduction the technology of precision agriculture, demonstration of new methods, education for students, post-graduated, farmers and all persons being interested of precision agriculture.

In the field experiment the technology of precision agriculture is specialized in local conditions for effective crop management.

Materials and Methods

Site Description of the Place and Soil. The experimental field is situated in the Moscow at the cropland area of Field Station of Russian Timiryazev State Agricultural University.

The soils of this area are faintly acid sod-podzol, loamy-sandy and sabulous-clayey underlaied of glacial clay. Plowing layer is about 22-24 cm. Percentage of humus in the plowing layer is 2,1-2,5. Availability of nitrogen, phosphorus and potassium is high. Soil is well-suitable for cereal crops planting.

Description of the Field Experiment and Equipment. Precision Agriculture Centre is based on the field experiment at the area about 6 ha. There is a crop rotation in four fields: green crop of vetch-oat mix, winter wheat with break crop of mustard for green manure, potato and barley.

Soil properties (pH, amount of phosphorus and potassium) were inspected in the all area of field experiment for creating maps of soil fertility. For mapping we use special program for precision agriculture SMS Advanced 9.0 (AG Leader, USA).

Two factors of crop cultivation are investigated in field experiment. Factor A is technology of crop management, and factor B is soil tillage treatment.

Factor A. A_1 is traditional technology: using of marker disc for plowing, cultivation, sowing, crop-tending operations and giving even equal fertilizer dozes for all field area. A_2 is precision technology: using GPS-navigator and autopilot system for plowing, cultivation, sowing, crop-tending operations and giving different fertilizer dozes for crop development according to N-sensors indicator.

Factor B. B_2 is moldboard plowing for 22-24 cm depth, B_2 is reduced tillage, i.e. cultivation for 10 cm, B_3 is no-till, direct seeding. For the winter wheat we use and compare moldboard plowing (spinner plow Eur Opal, seeder AMAZONE D-9-30) and no-till technology (Pneumatic seed drills AMAZONE DMC-3001). For barley we use and compare moldboard plowing (spinner plow Eur Opal) and reduced tillage (cultivation for 10 cm with AMAZONE BBG Pegasus tractor mounted disc cultivator).

In 2008, 2009 and 2010 there were investigated guess row spacing under the spiked cereals and vetch-oat crop, sowing by different seeder. At the potato plantation guess row spacing and deviation from the central line of row were measured.

Every vegetation seasons there were observed and mapped biomasses of crops. N-sensor ALS ® Yara and GreenSeeker ® RT 200 were used for mapping biomass (fig. 1). In the end of vegetation there were conducted complete harvesting at the split plots and created yield maps for every crop. Program SMS Advanced was used for mapping. For processing of observation field results we use analysis of variance. All these investigations and calculations enabled to compare different technology of crop growing.

a b

Fig. 1. Biomass-measured equipment: a - GreenSeeker ® RT 200; b - N-Sensor ALS® Yara

Results and discussion

Soil properties mapping. The map of soil properties was created in 2007, at the beginning of our long-term field experiment. Soil cover at the field is patchy. There were drawing maps of pH, amount of phosphorus, potassium distribution and other agronomical characteristics of soil. As the example we use one field (1,4 ha) for demonstrate variability of phosphorus distribution in topsoil (fig. 2).

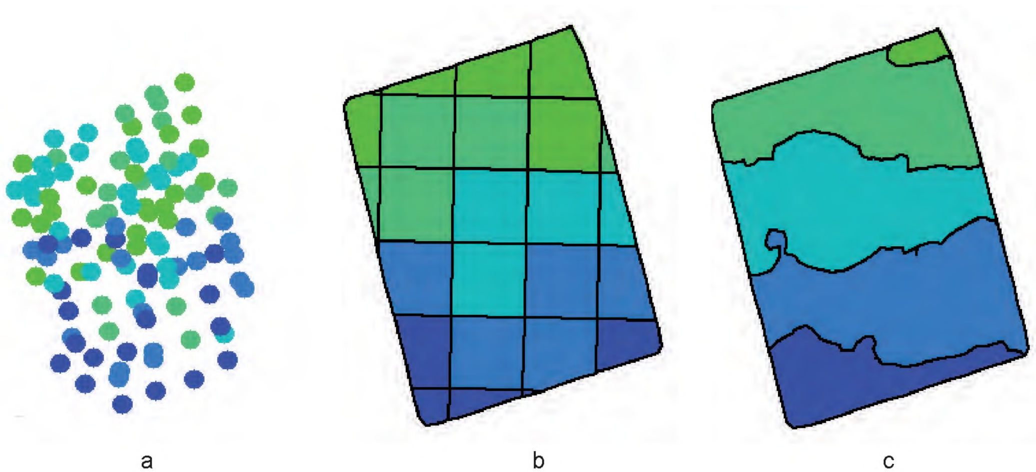


Fig. 2. Different manner for mapping[1] and presentation of phosphorus distribution in the plowing layer of soil: a - point (caliber 10 m); b - grid (30x30 m); c - contour

Point presentation of phosphorus distribution in soil (fig. 1 a) makes a good showing of variability. When we use grid or contour presentation we can lose some information because of smoothing nearby points. So three maps seem differ. The question that has to be answered is what kind of map is more suitable? It depends. If you would like to find the correlation between soil property and harvest or weed distribution it will be better to use point presentation. For fertilizer or pesticide treatment and lime application using of grid map is more useful and practic. The size of grid probably could be equal distributing width of trailed fertilizer spreader or sprayer. Contour map can be used for mapping frequency of occurrence in agro-ecology investigation for prediction weed or insect populations. Contour map can be used for presentation of agronomical characteristics of soil a field experiments limitedly.

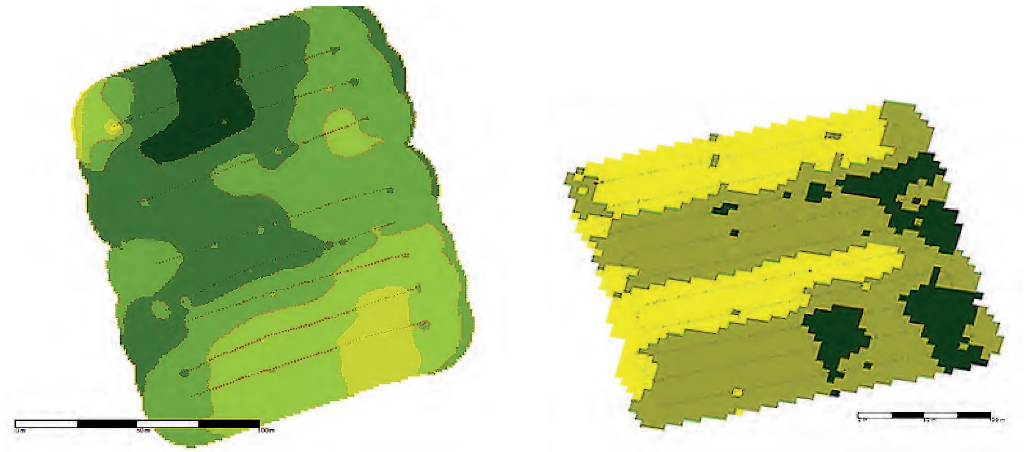
Biomass and yield mapping. Using of biomass scanners and crop-meters is broadly adapted in precision agriculture [3, 5, 6, 8, 9]. N-sensors are suitable for on-line application of fertilizers and pesticides [3, 6, 9]. N-sensor measures NDVI (Normalized Difference Vegetation Index), what can be used as a reflection of crop density and health. Well-developed crop is described with high NDVI. Low-level NDVI indicates depressed or diseased crop. According to NDVI-level the different doses of fertilizers and pesticide can be applied in the different points of field.

The search operating width of GreenSeeker is about 1 meter, the operation width of N-sensor is near 12-15 meters. We used both optical equipment for mapping biomass at

[1] Maps were created at the program SMS Advanced 9.0.

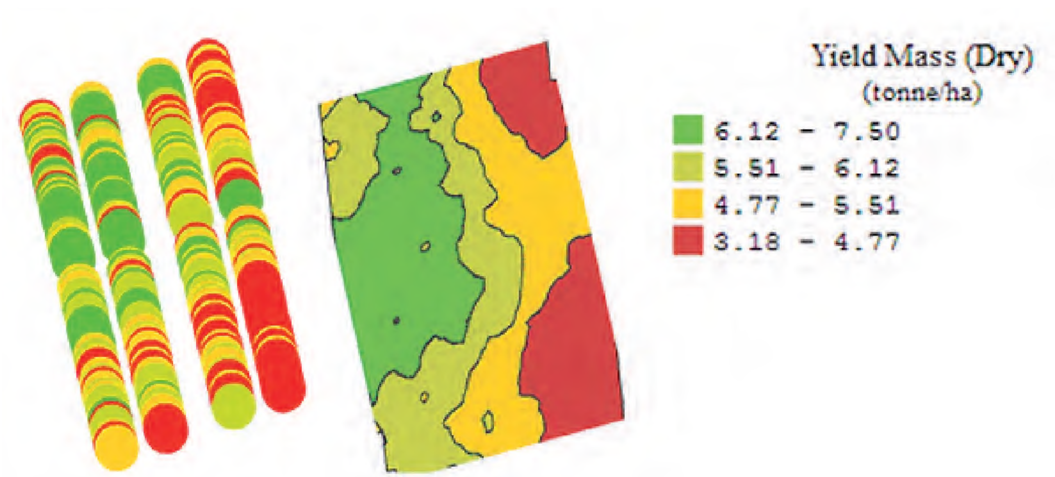
the same dates. The GreenSeeker and N-sensor maps were alike each others in every date of observing. So these actuating devices are comparable.

Both barley biomass map (fig. 3 a) and green mustard biomass map (fig. 3 b) demonstrated inequality of green canopy in the fields. The same appearance was observed at the harvesting (fig. 4, 5). Such heterogeneity of biomass and yield is a result of soil properties and different technology of planting. For example, biomass of mustard, determined by NDVI is higher at the plots under deep tillage (fig. 3 b).



a b

Fig. 3. Maps of biomass[2] (2009): a - barley at ear stage; b - mustard at the flowering stage



a b

Fig. 4. Barley yield map[3] (2009): a - point presentation (point caliber 18 m); b - contour map

[2] Map was created at the program of N-sensor ALS ® Yara.
[3] Map was created at the program SMS Advanced 9.0.

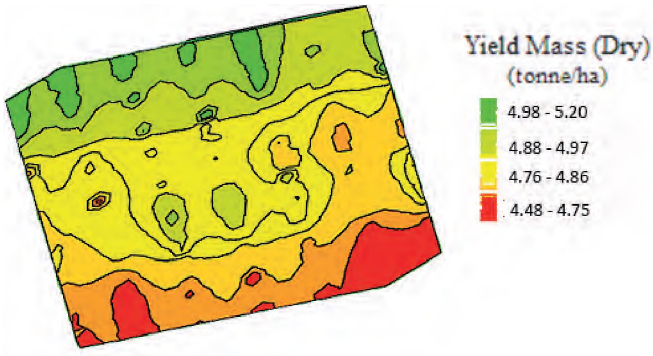


Fig. 5. Winter wheat yield map[4] (2009)

We compared two technologies (precision and traditional) and two soil tillage treatment under the four field crops and biomass of mustard for green manure. Comparison harvest data at the seasons of 2009 and 2010 demonstrates different response of crop yield for planting technologies (tables 2 and 3). So, in drouthy season 2010 the yield of barley, winter wheat and potato was higher under the moldboard plowing system, than under the surface tillage and no-till technologies (table 2). In 2009 yield of cereal crops was significantly higher under reduced and no-till systems (table 1). There was no significant differences between precision and traditional technology at both growth seasons 2009 and 2010 (table 1,2).

Estimate of sowing and crop-tending operations accuracy. In our field experiment we compared the accuracy of different agrotechnology operations, which were conducted

Table 1

Crops yield (tonne/ha) **at field experiment in 2009**

Field Crop	Technology of crop management (factor A)	Soil treatment (factor B)	Yield average, t/ha		LSD_{05}, t/ha	
			A	B	A	B
Vetch-oat mix	Precision	Moldboard plowing	---	21,3	---	3,40
		Reduced tillage		25,0		
Winter wheat	Precision	Moldboard plowing	4,76	4,23	0,14	0,23
		No-till		5,29		
	Traditional	Moldboard plowing	4,83	4,28		
		No-till		5,38		
Potato	Precision	Moldboard plowing	39,50	41,54	3,51	1,74
		Reduced tillage		37,45		
	Traditional	Moldboard plowing	37,63	38,93		
		Reduced tillage		36,33		
Barley	Precision	Moldboard plowing	5,49	5,40	0,21	0,26
		Reduced tillage		5,78		
	Traditional	Moldboard plowing	5,24	5,09		
		Reduced tillage		5,39		

[4] Map was created at the program SMS Advanced 9.0.

Table 2

Crops yield (tonne/ha) **at field experiment in 2010**

Field Crop	Technology of crop management (factor A)	Soil treatment (factor B)	Yield average, t/ha		LSD_{05}, t/ha	
			A	B	A	B
Vetch-oat mix	Precision	Moldboard plowing	20,0	20,5	—	1,08
		Reduced tillage		19,4		
Winter wheat	Precision	Moldboard plowing	4,37	4,63	0,19	0,25
		No-till		4,11		
	Traditional	Moldboard plowing	4,13	4,59		
		No-till		3,75		
Potato	Precision	Moldboard plowing	21,2	21,7	1,02	1,42
		Reduced tillage		20,7		
	Traditional	Moldboard plowing	21,7	24,2		
		Reduced tillage		19,2		
Barley	Precision	Moldboard plowing	3,17	3,35	0,08	0,21
		Reduced tillage		2,99		
	Traditional	Moldboard plowing	3,27	3,47		
		Reduced tillage		3,06		

with or without GPS-navigator and autopilot system. This system allows to escape overlap fail-place and blank spots at the field and to keep equal sowing distance. The results of three-year observations are presented at table 3.

Table 3

Inter-row pass-way distance under different crops, operation sowing systems and seeders

Crop	Moldboard plowing, seeder AMAZONE D-9-30*		No-till technology, seeder AMAZONE DMC-3001*
	marker	autopilot	autopilot
	Inter-row pass-way distance (average ± deviation), cm		
2008			
Barley	15,4 ± 3,4	13,5 ± 1,5	—
2009			
Barley	14,0 ±2,0	12,3 ± 0,3	17,3 ± 1,5
Vetch-oat mix	—	13,5 ± 1,5	18,1 ± 0,7
Winter wheat	16,3 ±4,3	14,3 ± 2,3	17,3 ± 1,5

Continued

Crop	Moldboard plowing, seeder AMAZON E D-9-30*		No-till technology, seeder AMAZONE DMC-3001*
	marker	autopilot	autopilot
	Inter-row pass-way distance (average ± deviation), cm		
2010			
Barley	15,2 ± 3,2	13,2 ± 1,2	18,1 ± 0,7
Vetch-oat mix	—	13,7 ± 1,7	19,1 ± 0,3
Winter wheat	17,0 ± 5,0	13,5 ± 1,5	20,2 ± 1,4

* Inter-row distance of seeder D-9-30 is 12 cm, DMC-3001 - 18,8 cm.

Table 4

Inter-row pass-way distance under potato crop and mean deviation plants from the ridge center under the autopilot and marker planting technology

Year	Inter-row distance, cm		Deviation plants from the ridge center, cm	
	marker	autopilot	marker	autopilot
2008	From 62 to 85	75 ± 3,5	±10-13	± 3,5
2009	From 65 to 81	75 ±2,8	± 6-10	± 2,8
2010	From 60 to 80	75 ± 3,3	± 5-15	± 3.3

Inter-row pass-way distance differs from one technology to another. Autopilot system allows to sow grain crops precise and accuracy without gap and oversow, therefore this technology is more profitable.

Potato planting was conducted with tuber planter Grimmer GL-34T. Ridging was made by ridge former Grimmer. We also used two technology (autopilot and marker) for comparison the precise of these operations. Autopilot system was more favorable for potato planting (table 4). Deviation of inter-row distance under traditional technology (marker) is about 7-13%, under precision technology (autopilot) is 3-5%. Location of potato plants exactly at the ridge center is requirement of correct potato planting. In traditional technology the deviation plans from ridge central line was about 5-15 cm, in precision technology - 2-4 cm (table 4).

Conclusion

Tree-year series of observation demonstrate benefit of precision agriculture technology in planting cereal crops and potato at the Central Region of Russia in loamy-sandy sod-podzol soils. Following elements and methods of precision agriculture were examined: soil properties mapping, autopilot for sowing and crop-tending operations, mapping green biomass with N-sensors.

1. Soil properties maps can be used for precise application of fertilizers and for prediction of yield. Different manners of map presentation (point, grid or contour) need for different aims of mapping.

2. Using of optical N-sensors is profitable for realization different norm of fertilizers application and for improving quality of yield.

3. Autopilot system for sowing and crop-tending operations is benefit because of avoid of over-sow and gaps.

4. Crop harvest was depend on technology, tillage system and weather condition of grow season.

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ЭЛЕМЕНТЫ ТЕХНОЛОГИИ ТОЧНОГО ЗЕМЛЕДЕЛИЯ В ПОЛЕВОМ ОПЫТЕ РГАУ-МСХА ИМЕНИ К. А. ТИМИРЯЗЕВА

Аннотация: рассматриваются вопросы реализации технологии точного земледелия в полевом опыте ЦТЗ в сравнении с традиционными технологиями возделывания сельскохозяйственных культур.

Ключевые слова: точное земледелие, автопилот, стыковые междурядья, N-сенсор, пестрота почвенного плодородия, карта урожайности.

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