GEOINFORMATION METHODICAL SUPPORT FOR AGROECOLOGICAL OPTIMIZATION OF PRECISSION FARMING AT THE CHERNOZEM ZONE, RUSSIA[1]

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Abstract

This study presents the brief description of priorities and basic programs of geoinformation methodology for agroecological optimization of precision and adaptive-landscape agriculture in the Russian conditions. The examples of their application in the Central Chernozem region of the Russian Federation are investigated.

Analysis of existing tendencies of global agricultural development indicate an active role and distribution of agroecological computer models, higher technologies (especially precision farming) [6-8, 13] and a specialized geoinformation support for solving multiple agroecological problems to optimize land-use [5]. Countries that are leading in the world market of food supply and agricultural raw materials are those that are daily actively practicing agriculture using optimization models, precise agrotechnologies and decision support systems (DSS) aimed at sustainable increase of crop production profitability and minimizing economic and ecological risks [3, 9, 10].

The wide distribution and fast growing variety of precision farming technologies presents a film demands to rational selection and necessary observation of land agroecological quality for effective application. Application of these technologies is complicated by the increased agrogenic variability of soil cover patterns, uncertainty of suitable climatic condition forecasts, high dynamics costs and agroecological problem situations and drastic financial resource deficiency concerns.

One of the basic elements of precision agriculture technology is the application of relevant variable dozes of fertilizers and relevant measures of plant protection - based on intra-field variation of soil cover, crop current states and soil fertility limiting factors [1]. Detailed observation on site - specific results in the reduction of nonproductive costs in crop production which considerably increases profit. The application of differentiated dozers of fertilizers and pesticides leads to significant improvement of the environment, land and water ecological state, and production qualities. Increasing crop production profitability improves social-economic state of the farm.

Russia considerably lagged behind in precision farming technology compare to economic developments of the country - despite the reach history of the detailed researches on soil cover structures and fertility variations and significant amount of information gathered through them. Meanwhile, the open conditions of modem technology and food market, the prevalence of major agricultural producers and traditional production unification, severe deficiency of material-technical resources and necessity of machinery stock replacement - that would create favorable conditions to accelerate development and implementation of these perspective technologies in Russia.

Geoinformation methodical support for soil-agroecological of precision farming includes:

- analysis of basic mechanism of actual crop yield variability within field - *in different soil-agroecological conditions',*

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- research of uncontrollable factors of crop yield variability (*soil cover patterns, geomorphological and climatic conditions, seeds)',*

- research of controllable factors of crop yield variability *{growth and development of plants, stress conditions, pests and diseases)-,*

- geoinformation modelling of intra-field variability of crop yields and main agroecological factors of variability formation;

- formation of detailed agroecological requirements of main zonal crops *(perspectives, varieties) - during the main phases of their development',*

- development of algorithms and standards of land agroecological evaluations - *for producing differential agroecological maps',*

-development of rational differential techniques *(norm, dozes* ...) for agrotechnologies applications — *for reducing crop yield variability, nonproductiv losses and ecological damage of agro landscapes.*

It is important to note researches by different authors Ref. in [18, 19] that have shown a strong variability of crop yields of cereals on Chernozems. In this variability erosion processes also play an essential role. At the same time, traditionally Chernozem zone of Russian Federation was attributed to the regions with less contrast of soil cover patterns and favorable conditions for applying uniform zonal technologies in large fields undifferentiated with regard to agricultural production.

Erosion processes activated by agrogenic factors, and other types of degradation processes have significantly complicated soil cover patterns. It raised the soil cover contrast and promoted the formation of intra-field variability of main parameters of fertility, soil agrotechnical and agroecological features [16-18]. This has led to significant decrease in efficiency of undifferentiated (uniformly within fields) applying of technologies, and increase pollution of ground water and ponds.

The research on detailed study of soil cover patterns (SCP) of the sample plots of old arable lands with Chernozems have shown a high variability and increased contrast of soil cover patterns and soils fertility, especially, on slopes where soil erosion is active, and proportion of calcareous Chernozems increases [20].

Simultaneously the intra-field crop yield variability increases. Based on the eight-year researches (Vasenev, etc., 2001; 2002; 2004), crop yields of the representative key plots at the Experimental Production Farm of ARR1 ASEC [17, 20] were characterized by high spatial variability in different years with changing weather conditions:

- barley yield varied in more than 4 times (from 14-15 to 61-64 dt/ha) within 8 ha sample plot in 1996 and within 64 hectares field in 2000;

- winter wheat yield varied in more than 3 times (from 18 to 60 dt/ha) within 4 ha sample plot in 1998;

- sugar beet yields varied in 2-3 times (from 110 to 242 dt/ha - based on preliminary results in 1999 and from 200 to 590 dt/ha in 2002) within two fields (56 and 63 hectares);

- barley yields varied in 2,5 times (from 21 to 50 dt/ha) within the same fields in 2000;

-peas yield (green forage) varied in 3 times (from 100 to 300 dt/ha) within slope field of 63 hectares in 2001;

- winter wheat, peas (grain) and barley yield varied in more than 1.5 times even within the seed plots with the increased level of soil fertility and farming level.

Amongst all factors of crop yield intra-field variability are usually dominated by: slope steepness (0° - 8°), level of Chernozems erosion and leaching, productive (available) moisture supply during the flowering phase (from 88 up to 148 mm m^{-1}), the content of available phosphorus and potassium and the level of weeding. It is important to note the prevailing role of land agroecological types, indicated by tree correlation method (Fig. 1).

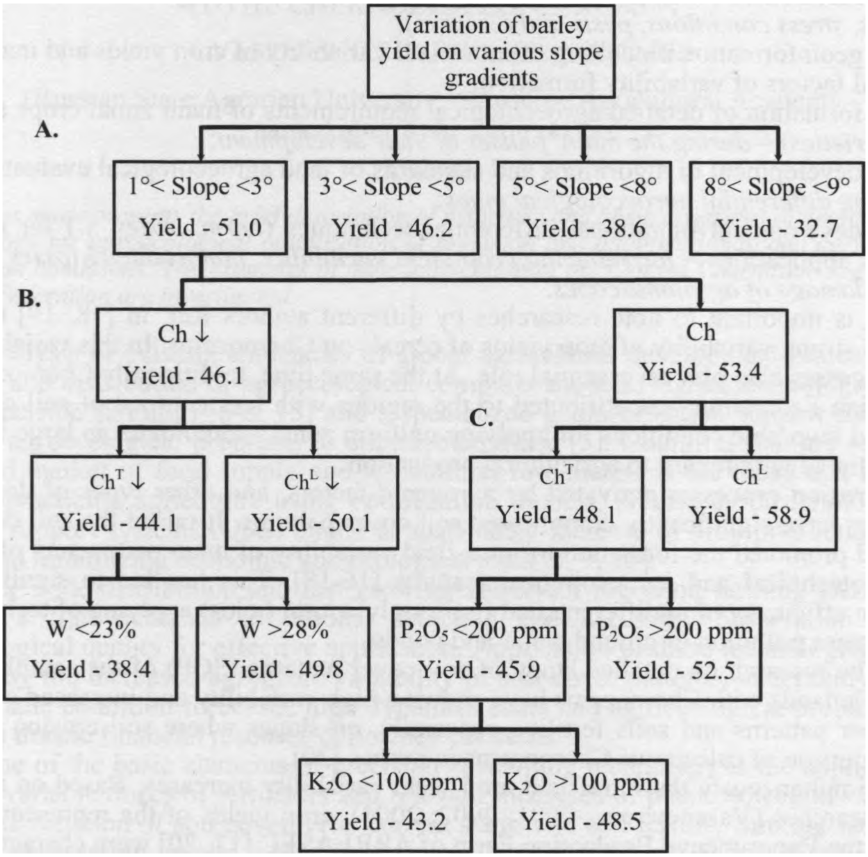

Fig. 1. Analysis of hierarchy limiting factors of crop yields (dt/ha) on the slope plots with tree correlation method: A — Level 1: Variability by slope steepness; B — Levels 2-4: Variability by level of Chernozems erosion, subtypes of Chernozems and soil moisture; C — Levels 3-5: Variability by Chernozem subtype and available soil nutrient contents; Ch , Ch - typical and leached Chernozems, i - Slightly eroded Chernozems, W - soil humidity during harvesting, P_2O_5 and K_20 - Available forms by Machigin and Chirikov methods [2]

The application of tree correlation method allows to solve hierarchical factors structurization of crop yield intra-field variability in the given year [19, 20]. The analysis done in the slope plot allowed to divide all soil data base (at the first layer) into four land types by slope steepness which differentiated by average of barley yields (Fig. 1.AJI

Analysis of plots on slope with gradient 1 -3° shown important role of erosion (factor with second level of significant), which resulted into differentiation of eroded and non-eroded Chernozems, with a difference in average crop yield of 7 dt/ha (Fig. l.BJ. Further, analysis of crop yield variability in the areas of eroded Chernozems shown the important role of soil subtype[2] (third level of significance): difference in average crop

[2] Soil subtype: according to SU Soil Taxonomy Classification [4].

yield between typical slightly eroded and leached slightly eroded Chernozems was approximately 6 dt/ha.

Crop yields in areas of slightly eroded typical Chernozems depend on the level of available moisture *(relatively characterized by soil moisture content in the harvesting period).* Amongst the non-eroded Chernozems (with full profile) of the slope with gradient 1 -3° soil subtype has more influence on barley yield (Fig. l.Q. The difference in average barley yields between typical and leached Chernozems contours has exceeded 10 dt/ha. The following levels of crops yield variability in non-eroded typical Chernozems were defined by differences in supply levels of available phosphorus and potassium. The maximal difference in crop yields was about 10 dt/ha that collates with the expressed assumption of good prospects of application of technologies with different fertilizer doses within field in conditions of Chernozem zone.

The influence of relief on crop yield variability is visible, as well in a more detailed analysis *(in map scale 1:5000)* of intra-field variability of crop yields at the fields with steep slopes. At the bottom part of the steep slopes, on average, sugar beet intermediate yields can be 2 times lower than at the crest (summit) (Fig. 2). Thus profitability of crop cultivation in that field strongly depends on part of the field used.

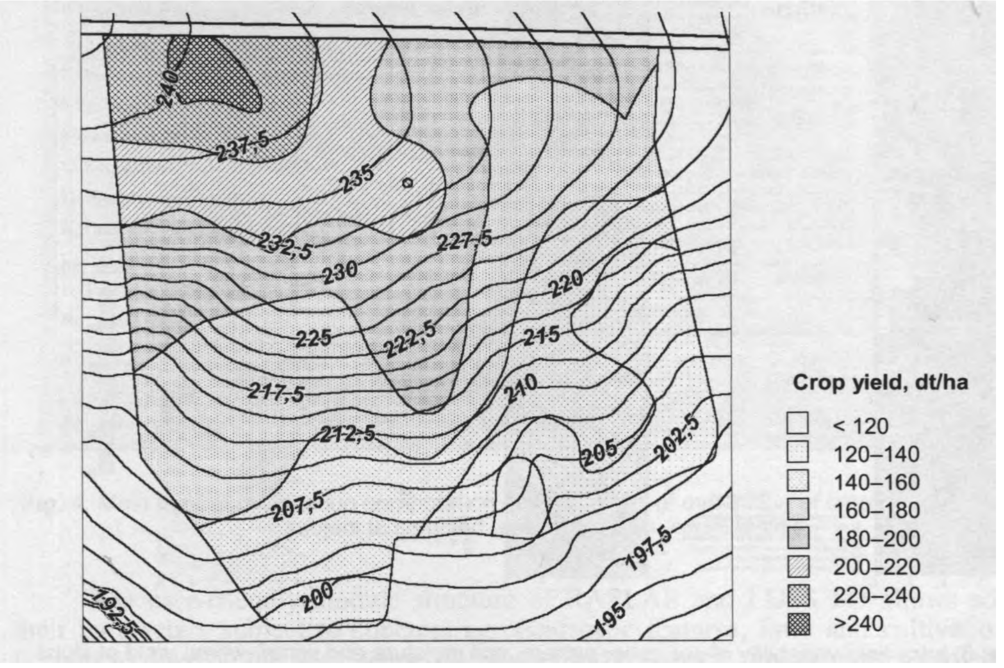

Fig. 2. Intra-field sugar beet intermediate yield variability at the different plot slopes with rich Chernozems and low-contrast soil cover patterns

Precision farming is required considerably in information methodical research for: accuracy in determining current crop yield, operation systems in different conditions, input level and economic effectiveness of technology. Of great importance is the estimation of data allowable variation, translation of standard maps of crop yield into local GIS and information analytic support for computational operations.

A good example of a framed system of computation is Regional automated system of land complex agroecological evaluation (RASLAE - RF registration № 2005610897 [15]) developed and approved with the support of the Russian Foundation for Basic Research (RFBR), Fulbright and MaeArthur foundations. In compliance with specific tasks, RASLAE evaluates lands quality according to their following factors or parameter groups: (A) agroclimatic condition of the land; (B) agrochemical factor of crops productivity; (C) agrophysical factor of crops yield and workability; (D) factor of the field spatial heterogeneity; (E) factor of soil sustainable fertility and its needs in amelioration; (F) ecological sanitation buffer capacity of the soil; (G) land ecological sanitation state.

Present results of agroecological evaluation are arranged by limiting factors and parameters of land-use [14, 16, 18, 20]. By including information analytic modules of RASCLAE in the functional structure of local GIS, one can produce electronic atlases of land agroecological state with easily update of thematic maps content (Fig. 3). Such systems are very useful for information support for precision and adaptive-landscape farming. These help to develop fast land agroecological certification, environmental and economical expertise of problem situations and projects of land- use at the field and farm scale [12].

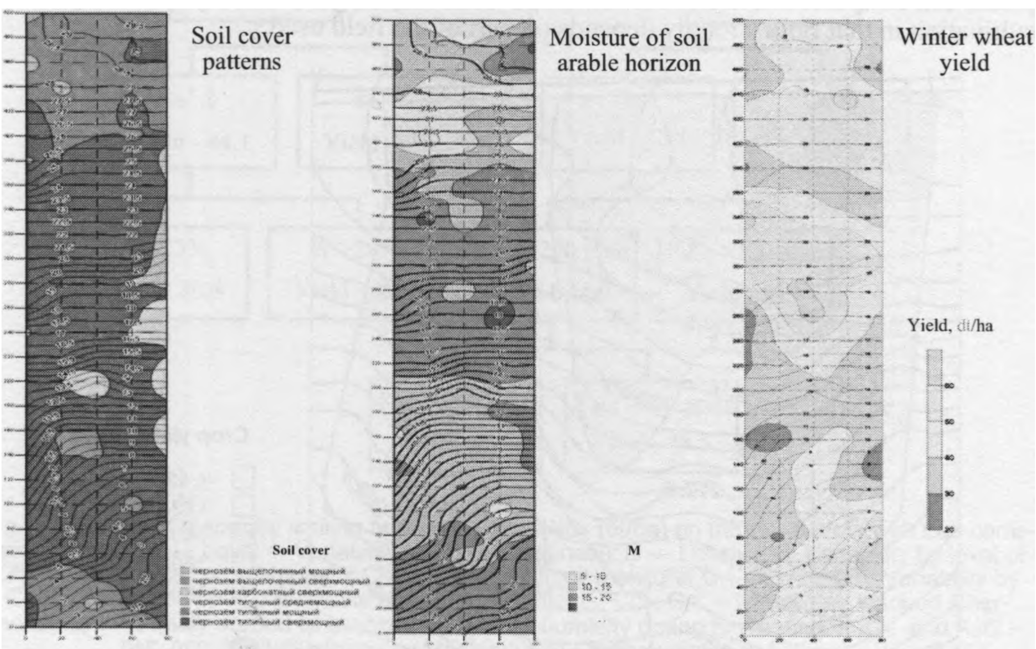

Fig. 3. Intra-field variability of soil cover pattern, soil moisture and winter wheat yield at slope

Local decision support system for farming optimization (LDSS FO - RF registration № 2005610898 [11]) was developed for agroecological optimization of agrotechnologies at the farm and concrete field scale. With its help, one can develop field certification and land-use record book, a rational crops choice and arrangement yield, prediction and simulation, optimization of technological operations - with an estimation of their predicted effectiveness [14, 17, 19].

The functional block scheme of the decision support system consists of information simulation and information reference modules. The main information simulation module provides:

- rational crops choice (subject to the field features and preceding crops);
- estimation of potential crop yield subject to predicted microclimatic conditions;
- correction of crop yield subject to main limitations in soil reclamation, agrotechnology and general organization;
- computation of NPK output with planned crop yield;
- correction of planned crop yields and main aspects of NPK balance - subject to soil-agrochemicals limitations and predicted profitability of fertilizer application at the concrete field;
- polyvariant analysis of crop cultivation inputs (Fig. 4);
- adjustment of technologies subject to results of current monitoring and integrated decision support system on crops protection.

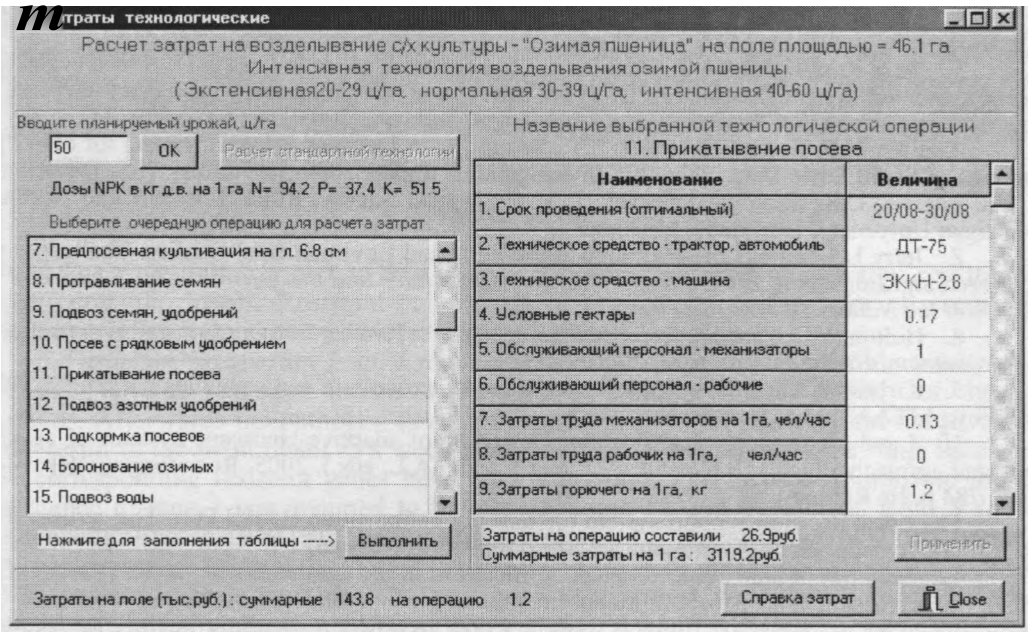

Fig. 4. Main form of information computation module (ICM) of evaluation of crops cultivation inputs subject to selected technology and concrete field

The user-friendly module structure of RASLAE and LDSS FO allows adjusting their parameters subject to concrete agrolandscape features, farm and cultivation year. It helps to develop the wide scope of information reference, computation, prediction and optimization tasks subject to possible variations of weather and price conditions [12, 20].

There is very important for successful extension of precision farming technologies in Russia to prepare experts and develop specialized decision support systems that are adapted to local prevailing conditions of the country agricultural regions. High provincial genetic and agroecological variety of agrolandscapes determine sustainable *priority* for development of framework systems of land agroecological evaluation and land-use agroecological optimization - with their subsequent adaptation and zoning to concrete region and farm conditions.

The most perspective RF area for initiating development and extension of precision farming technologies is the Central Chernozem region with very fertile soils. There is a widespread of high intra-field variability of soil fertility. Precision differentiation of agrotechnologies is capable to give fastest and significant effect - essential for minimizing economic and ecological risks of agricultural production, with considerable increasing its profitability.

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