



**A REGIONAL APPROACH FOR ANALYZING MARKETS FOR
MINERAL FERTILIZERS: GEOGRAPHIC INFORMATIONAL
SYSTEMS (GIS) AS A TOOL TO PREPARE
RECOMMENDATIONS ON BALANCED FERTILIZER USE**

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A Regional Approach for Analyzing Markets for Mineral Fertilizers: Geographic Informational Systems (GIS) as a Tool to Prepare Recommendations on Balanced Fertilizer Use

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Geographic Informational Systems (GIS) are widely used in the land registry in many foreign countries. The GIS are used by individual households for soil cultivation, for sowing and for other production related operations. The GIS are taking into account the micro-features of the territory and serves to develop so-called high precision farming – 'precision agriculture'. In our opinion, it is very promising to use GIS technologies and solutions to perform such practical tasks as monitoring of the balance of nutrients in soils, assessment and prediction of efficiency of fertilizers use, as well as determination of the optimal doses, timing and methods of the fertilizers introduction. The tasks listed above are especially relevant for management of large territories with diverse agricultural conditions, which are particularly characteristic for Russia. In the process of transforming of the agrarian economy from planned and regulated to market driven, the models similar to GIS can come to be an important tool for decision making for both agricultural producers and for mineral fertilizers industry, because such models give a possibility to evaluate the productive potential of regional markets.

The Brazilian project (under realization), which uses GIS technology to determine the balance of potassium in the agricultural systems of the country can be taken as an example. The project was based on a joint research program "Fertilize Brazil", which was conducted by the International Potash Institute (IPI) and by the National Center for the Soils Research of the Brazilian Agricultural Research Corporation (EMBRAPA Solos).¹

Brazil, a country with vast land resources (the total area of agricultural land - 263 million hectares, including arable land and land with the "zero cultivation" - about 60 million ha), is characterized by great geographical contrasts in the levels of use of mineral fertilizers.

According to the Agricultural Census of 1995/96, in only 8 out of the 26 states of Brazil, more than half of the farmers have regularly used fertilizers for crops. In the most states, the proportion of farmers using fertilizers was less than ¼. And in 5 Brazilian states – fertilizers were used only by 10-12% of the farmers.²

During the first two stages of the project, the works of the mapping of the balance of potassium in soils were carried out at the state level (in 2004 - for 27 states and territories) and at the level of municipalities (in 2007 - for more than 4 thousand municipalities within the lands used for agriculture on the territory of the country).

¹ Managers of the project: RB Prado (EMBRAPA Solos) and AS Naumov

² Censo Agropecuario 1995-1996. IBGE -

http://www.ibge.com.br/home/estatistica/economia/agropecuaria/censoagro/1995_1996/default.shtm

For mapping the presence of potassium in soils, data from 3 thousand soil profile pits (profiles), collected by the EMBRAPA Solos, were used. The works to create the GIS layers, containing these data, proved to be technically difficult because of the complexity of data, binding the given profiles to the maps of administrative territorial division, to the soil types and landscapes of Brazil. For some soil profiles, it was required to repeat the gridding. Therefore it was necessary to travel to the area and determine the coordinates with a help of with sub-satellite positioning (GPS) devices.

Data on the enleaching of potassium in crop yields were calculated state by state (later – municipality by municipality) of the country. The computing was based on agricultural statistics on the gross harvests and yielding capacity of the 19 main agricultural crops of Brazil (soybeans, corn, sugar cane, coffee, cocoa, oranges, beans, etc.), as well as that of the cultivated eucalyptus plantations. The mean values of potassium enleaching from 1 ton of the yields of agricultural crops were used for the calculations.

As it can be seen from the obtained detailed map, in Brazil, the high levels of potassium enleaching are observed in relatively small number of the municipalities with concentrated commercial farming that is mainly export-oriented. Those are geographic ranges of: sugar cane and oranges production in the interior parts of São Paulo state; soybean and maize - in the newly cultivated states of the Center-West (Mato Grosso, Mato Grosso do Sul, Goiás) and in the long ago cultivated Southern states (Parana), as well as in islands of tropical fruit production in the North-East (Petrolina-Juazeiro on the river San Francisco, the coastal strip).

To determine the reserves of potassium in soils, it was planned to use data of 300 soil profiles, which were collected since 1970-ties by the EMBRAPA Solos. It appeared that these profiles are distributed throughout the country very unevenly. Particularly scarce amount of profiles were from Savannah Cerrado, which occupy nearly 200 million hectares of land in Brazil. Approximately 20 million hectares of these areas have been developed for agriculture in 1980-2000.³ According to various estimates, the additional 40 to 60 million hectares can be used for agricultural turnover.⁴ Due to the physical geographical heterogeneity, Cerrado soils are characterized by significant differences in terms of potassium reserves (from 15 to 150 mg kg⁻¹).⁵ Originally, only the parts of the Cerrado with the most fertile soils were cultivated. Currently, the agricultural colonization has reached the marginal areas with poor soils. Extrapolation of the data available at our disposal on soil profiles throughout the Cerrado territory in order to determine the actual balance of potassium in the soil for making the recommendations to the farmers, could lead to significant errors. It was therefore decided to undertake a more detailed research and to develop a problem oriented GIS to assess the balance of potassium in agricultural systems. South West state of Goias was taken as an example since it is one of the most important agricultural areas of the Brazilian Cerrado.

The assessment of introduction of potassium into soils was carried out at the level of Brazilian states according to the data from the National Association of Sellers of Fertilizers of Brazil (ANDSA). This GIS layer appeared to be the least accurate, due to specifics of the initial data.

³ Manzatto C. V., Freitas Junior, E., Perez, J. R. *Uso Agrícola dos Solos Brasileiros*. Rio de Janeiro : Embrapa, 2002

⁴ For example, according to the experts of the Department of Agriculture of USA (USDA) - 45 million.

⁵ Data obtained from the experts EMBRAPA Solos.

At the third and fourth stages of the project, a testing ground for a more detailed study of the territorial characteristics of the balance of potassium in the soils of Brazil was chosen. Such testing ground was the south west of Goiás state, which is one of the main agricultural areas of the country, specializing in the production of soybeans, corn, cotton, sugar cane and meat livestock, including the stage of store feeding. The analysis of the reserves of potassium in the soil was carried out according to a survey of soils in the farm units belonging to the local farmers, most of whom were members of the agricultural cooperative COMIGO. Extrapolation of these initial data on landscape contours, and then on a specially created for the project more detailed map of the fields (land utilization lots), which was based on the materials from LANDSAT satellite observations, has allowed to obtain precise data on the presence of potassium in the soils and on other characteristics of the earth within the plow layer. Data on use of mineral fertilizers and on yields of major agricultural crops were obtained directly from the farmers during the surveys (in 2006, over 500 persons were interviewed). The relevant data were also obtained from the cluster sampling of farms.

As a result, unique series of maps were created. Those maps gave a possibility to assess the balance of potassium in the agricultural systems and to identify the areas where the increases in doses of fertilizers were needed. Also, there was a possibility to note the areas, where farmers were introducing excessive doses of fertilizers, which significantly reduces the efficiency of agriculture. At the current stage of the project, the works on making the GIS more precise are carried out. They are based on processing of satellite images LANDSAT, which allow to lower the GIS taxonomic level to the landscape contours and to the individual large contour fields. Developers also expect that if the data on the precipitation regime and on the calendar cycle of production of major crops will be added to the GIS, there will be a possibility to develop place specific recommendations on the optimization of the timing of the introduction of mineral fertilizers.

In Brazil itself, the resonance created by the publication of the first outcomes of the project has attracted great attention stimulating the debate on the need to deploy the federal program for effective use of mineral fertilizers, in the implementation of which it is expected to employ the GIS developers.

We believe that the creation of such GIS is very important for Russia, whose territory is also characterized by sharp contrasts in levels of use of mineral fertilizers. This was shown by our study, conducted in 2007, which was aimed to assess the potential of regional markets for potassium fertilizers in the territorial subject of the Russian Federation (further - RF).⁶

According to the data of 2004, 69% of the total gross amount of mineral fertilizers (NPK in general) in Russia was used only by 15 territorial subject of RF. The leaders among them were the Republic of Tatarstan (respectively, 210 and 206 thousand tons), which together accounted for 23% of the total amount of NPK used; in third place was Rostov Region (136 tonnes). The top ten on the gross amount of mineral fertilizers used, have also included such RF territorial subjects as Stavropol, Voronezh, Belgorod, Lipetsk, Orel and Kursk regions as well as the Republic of Bashkortostan.⁷

Russia's average specific volume of mineral fertilizers in 2004 was 22.8 kg per 1 hectare of sown area of agricultural crops. Murmansk region was the leader in terms of mineral fertilizers use per 1 ha of cultivated area (153.3 kg / ha due to the specifics of protected ground agriculture). Among the regions within the main agricultural zone of Russia, the leader in the specific volume of mineral fertilizers used was the Republic of Tatarstan: 72.3 kg / ha.

⁶ In the presented study, under the guidance of AS Naumov, have also participated AV Puchkina, IN Rubanov, DV Snitko (all working at the Geography Faculty of Moscow State University of MV Lomonosov).

⁷ According to the Ministry of Agriculture and Food of Russian Federation.

The dynamics of gross and specific indicators of use of mineral fertilizers by regions of Russia for 1994-2004 years are particularly interesting. In leading RF territorial subjects, the gross volume of introduced NPK has decreased by 2-3 times. At the same time, in some regions even sharper decline was observed (for example, in the Ryazan region - almost 16-fold, from 279 tons in 1990 to 18 tons in 2004).

The largest declines, however, have occurred in the Asian part of Russia in the Republic of Tuva (decrease of more than 1000 times!) as well as in the European part of Russia - in the Pskov region (almost 90 times less, from 141 thousand to 1.6 thousand tons).

Specific volume of mineral fertilizers (NPK per unit area of agricultural land) on the countries average level fell almost 4-fold (from 88 kg / ha in 1990 to 23 kg / ha in 2004). Into the top five leaders in the specific volumes of use of mineral fertilizers in 2004 have entered Murmansk and Kaliningrad regions, as well as the Khabarovsk region, where the gross introduction of NPK was previously insignificant. In the regions, where large volumes of NPK were usually used, the most significant decline in unit volumes of NPK for 1990-2004 years was observed in Moscow region (decline by 4.9 times) and Kursk region (decline by 4.3 times). The introduction of NPK per unit area of farmland in the Belgorod region decreased by 3.1 times (from 179 kg / ha in 1990 to 58.3 kg / ha in 2004), in the Krasnodar region it has declined by 2.9 times and in Tatarstan – by 1.7 times.

The other indicators used to assess the potential of regional markets for potassium fertilizers in the RF territorial subjects, were:

- The total value of agricultural potential (integrated parameter that takes into account the size of arable lands and sown areas, the level of the land cultivation);
- The level of intensity of use of agricultural land (cost of production per unit of area);
- The amount of investments into the agricultural sector (calculated per unit of area and per 1 employee);
- The nature of specialization of agriculture.

In a first approximation, these groups of indicators formed the "layers" of GIS. On their base, the series of maps were created. In the cartographic forms, data on the agronomic characteristics and on the overall volumes of consumption of potassium fertilizers were also presented.

In addition to the analysis of natural geographic and economic indicators, we have also used the comparative analysis. To assess the prospects for the development of regional markets, under the two scenarios, the potential volumes of consumption of potassium fertilizers by the RF territorial subjects were estimated. Calculations were based on the amounts of potassium fertilizers used for the main crops. In the first scenario, the potassium will be consumed at 100%, the way it is done by the world's leading manufacturers of the respective types of agricultural products (in which the production is concentrated in the areas that are natural analogues of Russian productive regions). In the second scenario - at 50%.⁸

⁸By the standards of the most developed countries, the vast majority of Russian regions do not reach even the average doses of required quota of potassium fertilizers per unit area. For example, the required quota of introduction of K₂O for 8 crops, calculated for Russia as a whole (in line with the average doses used in Germany), is 9 times higher than the actual quota of fertilizers consumption.

Our analysis has shown that the most promising markets are situated in the regions within the southern plains of the European part of Russia (Krasnodar, Stavropol and Rostov regions). The potassium deficit in these areas equals to up to 100%, compared with doses used in foreign countries for the analogue regions. At the same time, these regions possess the largest total sown areas and the largest areas under crops that consume a lot of potassium. In all of them, there was a marked enlargement of areas used for such crops (primarily for sunflower), which causes an extensive growth in demand for potassium and for other macronutrients. Also, in these areas, there was observed a significant increase in investments per unit area of farmland. To this group of important regions can also be added Volgograd and Saratov regions, where the deficit of potassium consumption is about 90% compared to that of the foreign countries (which we have taken as a analogue etalons).

In the Central Chernoziom (Black Earth) economic region, primarily the markets of Belgorod and Voronezh regions that stand out. In contrast to the neighboring territorial subjects of the RF, the level of use of potassium fertilizers in these regions is significantly lower than by their foreign analogues. In these two areas, over the past 5 years, there was no notable changes in the dynamics of fertilizers use for the areas under the crops that consume potassium. However, a significant increase in investments per 1 hectare of the sown land, primarily in the Belgorod region, suggests the hypothesis of the subsequent increase in consumption of fertilizers in close future.

In the Asian part of Russia, the most promising markets are those of Altai and Omsk regions, which have high agricultural potential. In these areas, traditionally, an extensive way of agriculture was applied, which was characterized by low levels of the specific investments per 1 ha of arable land and also by the extremely low values of the average doses of mineral fertilizers used. The deficit of potassium consumption in these areas is especially high (in the Altai region - about 140%), compared to that of the foreign etalons. With the recent influx of investments, in the medium and long term prospects, the increase in demand for fertilizers can be expected.

Certainly, our study on regions of Russia can only be considered as a first approximation to the creation of problem oriented GIS. The experience of the project 'Fertilize, Brazil' has shown that to achieve required tasks, there is a need for a much more detailed study into a wide spectrum of soil characteristics as well as into that of landscape and geochemical features. Such parameters as land use, agricultural production, including the gross harvests of agricultural crops, as well as doses, timing and methods of the introduction of mineral fertilizers also have to be taken into consideration. Data for each of the layers of such integrated GIS are originally tied to specific nets (contours of soil areas, low level cultivation areas and borders of production units). The summarizing presentation of such variable features of natural and social economic spatial objects and their relationships (polygon overlay) is a technically difficult task. The solution to this problem can be found in use of already existing in our country developments in remote sensing of the ground surface. The territory of one of the several Russian Federation territorial subjects, notable by it's agricultural specialization in the inter-district division of labor, could become a practice ground for such a project, if supported by its agricultural producers, the mineral fertilizers industry, as well as by the government and by the independent research institutes and foundations.