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THE SCALE PROBLEM IN MODERN SOIL MAPPING

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One of the features of the transition from traditional soil cartography to digital technologies for compiling and using soil maps is a qualitative change in both the concept of "map" and the concept of "map scale". A map in digital cartography is a spatially coordinated database that can consist of many layers of information and can be visualized at any scale. The scale of traditionally compiled paper soil maps is of great importance for understanding the semantic load of the map and the degree of its generalization. When using digital soil mapping, the concept of "scale" loses its meaning. This happens because the level of generalization of soil information in this case is not determined by the scale at which the map is visualized on the computer monitor or printed, but by what pixel size the map was created (in the case of raster maps) or which map served the basis for creating a vector layer of the soil map. For raster soil maps it is more logical to use the concept of "pixel size" instead of "scale". For vector soil maps it is more important to indicate the scale of the original soil map (which was vectorized), rather than the scale of their visualization. The scale of visualization of the digital soil map is not important in the computer (digital) applied analysis of soil data. When creating raster soil maps, it is impossible to use source materials of different scales without bringing them to a unified level of generalization. All this must be taken into account when using digital soil mapping technology.

Keywords: soil map, generalization, soil mapping.

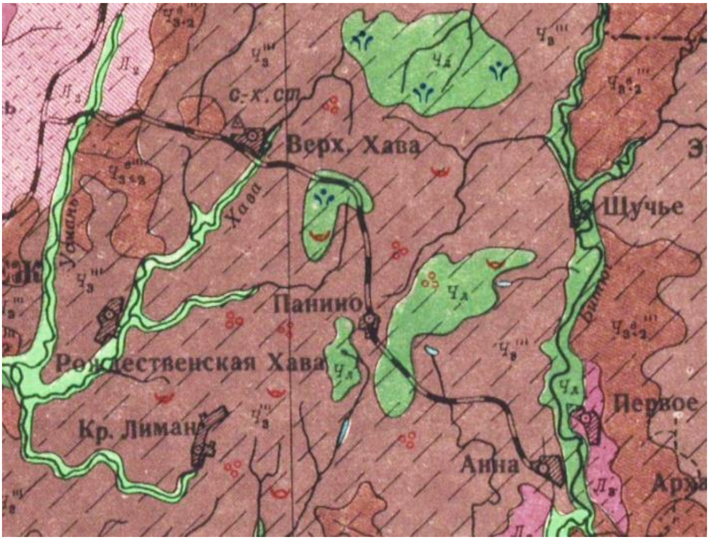
INTRODUCTION

Traditional soil mapping is a time-consuming and expensive procedure. That is why it is still impossible worldwide to create detailed or at least large-scale soil maps for large territories. This is also a reason why in traditional (and not only soil) cartography, it is accepted to allocate a set of (scale) generalization levels to solve practical problems (Salishchev, 1987). So in the Soviet times, the creation of soil maps to solve production problems was carried out at the farmstead level (scale 1 : 10 000 – 1 : 50 000), at the administrative district level (scale 1 : 50 000 – 1 : 100 000), at the regional level (scale 1 : 200 000 – 1 : 500 000) and at the whole country level (scale 1 : 1 000 000 – 1 : 4 000 000) (Dolgova, 1979; Savin et al., 2015).

At each generalization level soil maps were created with the help of different approaches. The creation of large-scale soil maps was based on a large-scale topography, sometimes detailed aerial photographs as well as field surveys results by site investigation or site soil exploration methods. Medium-scale soil maps were created mainly with the use of medium-scale topographic maps, sometimes with the deciphering results of vegetation and soils from satellite images, as well as the generalization of existing large-scale soil maps. Very rarely, but still the results of site-investigation and surveys were used. Small-scale soil maps have always been conceptual and were created primarily by generalizing medium-sized soil maps and applying the generalization results to a small-scale topographic basis (Dolgova, 1979; Compilation of regional..., 1990).

It should be noted that map generalization was very rarely carried out by a purely mechanical reduction of map outline part to the desired scale. This process was creative, expert. The soil cartographer normally tried to preserve characteristic features of a territory soil cover and reflect them, even if in exaggerated way, on a map of a smaller scale. So, for example, floodplain soils of many rivers and a lot of intrazonal soils are shown in exaggerated way on the maps of small and even medium scale. Often the soils not expressed on the map scale but important for understanding the soil cover structures were marked with point symbols on the map, which could be either localized or evenly distributed along the map outline (Fig. 1).

A



B

Fig. 1. Traditional generalization of soil cover image on soil maps (*A* is a fragment of a sheet of the State soil map where accompanying soils are marked with point symbols; *B* is a fragment of the geometric part of the Unified State Register of Soil Resources of Russia (2013) with an exaggerated representation of alluvial soils (highlighted by arrow)).

The situation significantly changed with the transition to digital technologies for soil maps creation and storage. (Berland, 1997, 2006; Koshkarev, Zinchuk, 1990; Lurye, 1997). At the first stage of the development of these technologies the paper soil maps, created traditionally, were vectorized and their legend was turned into an attributive part for the obtained soil-geographic database (Stolbovoi, 1993).

At this stage it already became possible to present and print out vector soil maps in GIS on any scale. That is, any initially large-scale map could be displayed on a monitor screen or printed out on the small scale and vice versa. At the same time increasing the small-scale soil map to a large-scale one certainly did not lead to an increase in its information content and accuracy but a strong decrease in large-scale maps led to the optical generalization of small sections, excessive border unevenness and some information loss. Upon that all information was stored unchanged in GIS database. (Savin, 2004).

Further “blurring” of the traditional concept of the soil map scale occurred during the transition from vector soil maps to raster ones, when trying to use digital satellite data for soil mapping (Korolyuk, Shcherbenko, 1994; Kravtsova, 2000) and the development of so-called “digital” soil mapping (Digital soil..., 2012; Kravtsova, 2014).

RESULTS AND DISCUSSION

It is known that raster maps differ from vector ones in their elementary spatial unit of information that is a pixel for the raster map and a geography-soil unit itself for the vector map. That is, the GIS database stores information about the soils of these particular objects (unit or pixel). And no matter how the scale of map visualization changes, the information in GIS database does not grow up or disappear. Along with that the level of informational generalization presented on the map is determined by a pixel size (on the raster map) and a minimum unit (on the vector map) and by the information about the soil cover attached to them rather than by the scale on which the map is visualized on the monitor screen or printed out.

Several important conclusions follow from the foregoing:

1. Generalization level of the digital soil map is determined by the level of initial information generalization which served as the basis *for the map creating rather than by the scale of its presentation and visualization.*

If the vector soil map was created by digitizing (vectorizing) of the traditionally created paper soil map of known scale, then the level of generalization for the map information completely corresponds to the level of generalization for the original soil map. If the soil map was originally created on the raster information basis, then the level of generalization for the information about the soil cover is determined by the pixel size and the information about the soil cover and the soils that is attached to it.

Currently computer technology allows us to visualize (on a monitor screen or as a print-out) a digital map on any scale and the amount of information reflected on the map and its generalization level are not changed (Fig. 2).

Obviously, the user gets a visually different picture, however, the information in GIS database at the same time remains and stores unchanged for any visualization option. This is the most important for digital soil data analysis.

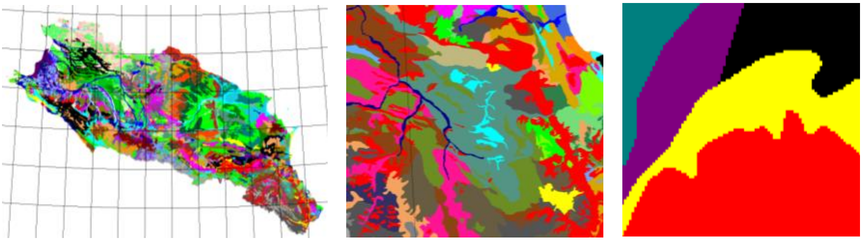


Fig. 2. Digital soil map of the North Caucasus (Drahavtseva et al., 2016) and its fragments (on the left – the scale of 1 : 5 million (degree grid plotted)), in the center – exaggerated to the scale of 1 : 500 000, on the right – exaggerated to the scale of 1 : 50 000).

2. For raster soil maps it is more logical to operate with the concept of "pixel size" instead of "scale". For vector soil maps it is more important to indicate the scale of the original soil map (which has been vectorized), rather than the scale of their visualization.

The scale of map visualization can also be specified but it will not contain the information about the level of map generalization which it has on the traditional paper soil map (Fig. 3).

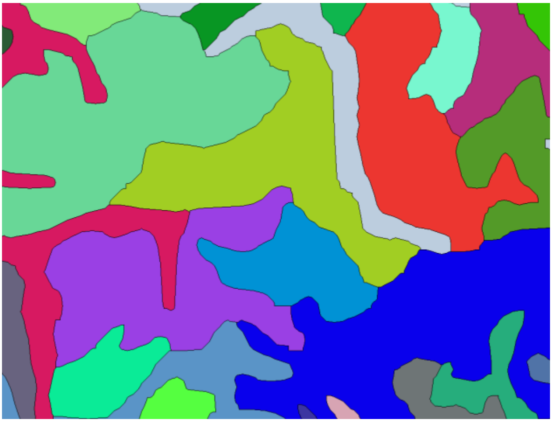


Fig. 3. Fragment of the contour part of the soil map (vector format) with original scale 1 : 2 500 000, visualized in 1 : 300 000 scale.

The map fragment in Figure 3 is visualized on average scale which does not mean that the map is in fact on medium scale. The generalization level of soil cover displayed on it remains on small scale. And specifically in order to be able to understand this it is necessary to indicate the scale of the original soil map.

3. When creating raster soil maps, one cannot use source materials of different scales without bringing them to a single generalization level.

Modern digital technologies have opened up great opportunities for simultaneous, related analysis of any spatial information. Thus, creating a digital soil map, all available maps of individual soil formation factors, remote sensing data and their analysis results, archived soil maps, etc. can be collected into a single GIS database. All these spatial data can be reduced to a single geographical projection and combined with each other (superposed on each other).

However, the level of generalization for information on these primary sources may remain different. For example, in recent years, SRTM digital models with a spatial resolution (pixel size) of 90 m (http://srtm.csi.cgiar.org) are often used for topography analysis. But it is hardly correct to analyze these data together with space images with a pixel size of 1–2 meters (sometimes up to 10–20 m) without preliminary generalization of satellite data. This is due to the fact that objects which are well deciphered with the satellite data of ultrahigh spatial resolution are often generalized on SRTM. Therefore, a joint analysis of these two data sources can lead to incorrect conclusions and spatial models of soil cover organization. For example, according to the SRTM data, the site is a flat territory (Fig. 4).

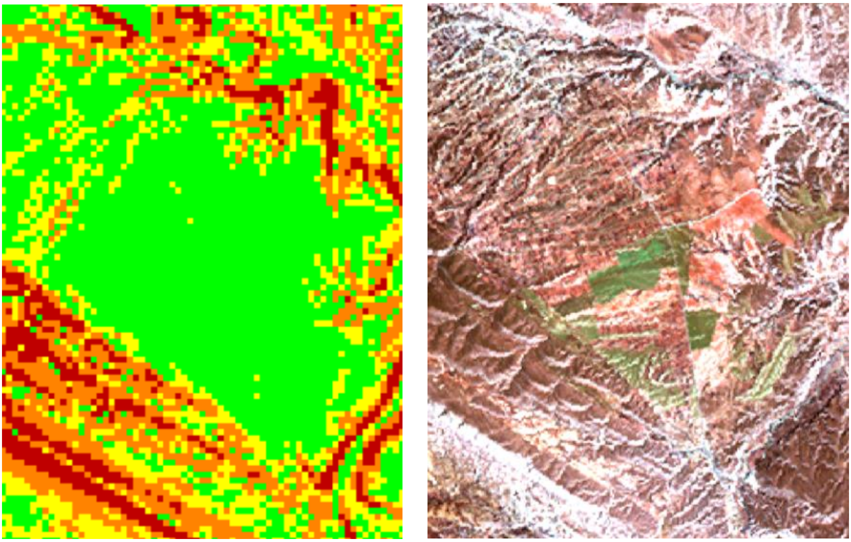


Fig. 4. The slopes of the SRTM test area (pixel having 90 m resolution, on the left, slopes less than 2 degrees are green coloured) and the Landsat image (30 m pixel resolution).

However, in Landsat space image in this area (Fig. 3, on the right) erosion inhomogeneity is clearly visible. In this case, a joint analysis of these sources may lead to the misconclusion that eroded soils are located on a flat surface rather than on abrupt downward slopes.

Also, one can often notice the cases when SRTM detects abrupt downward slopes but the satellite images show gullies with waterlogged soils. A joint analysis of the data can lead to the misconclusion that waterlogged soils are confined to abrupt downward slopes.

It follows that, when analyzing data with different spatial resolutions they must be initially brought to the same level of informational generalization or more detailed information should first be analyzed and then the analysis results should be generalized, after which it will be possible to analyze the data together.

4. Visualization scale of digital soil map is not important in computer (digital) applied analysis of soil data.

Applied analysis of soil data (for example, in assessing soils and lands suitability) in GIS is carried out in most cases on pixel level. Including the case when vector soil maps are used, they, as a rule, are first transformed into raster format. This should be done because soil map applied analysis in most cases is carried out together with other spatial layers of information – most often about topography and territory climate (Savin, 2004; Ivanov et al., 2014). And the combination of all these spatial data is most rationally carried out precisely on pixel level. For example, for geo-information analysis of any territory lands suitability for particular crop cultivation, one should create the database that includes spatial layers of soil parameters, topography, climate, which are brought to a single geographical projection and a single pixel size. Their intersection with each other leads to a map, each pixel of which is linked to all the parameters available (as attributes) in the database (soil, topography and climate). In this case, in fact, each pixel is an assessment spatial object based on the algorithm created by user. It follows that regardless of the scale on which the information is displayed on a monitor screen or printed out on paper, the assessment is done pixel by pixel and the degree of information generalization depends on the size of pixel rather than on which scale the data is visualized on a computer monitor screen.

5. About the accuracy and standard compliance of digital soil maps of various scale.

In traditional soil cartography the problem of map standard compliance is solved by establishing the number of necessary soil tests (open test pit, ascertaining shallow pit etc.) when creating maps of different scales. So, for different natural zones in Russia the instructions for field soil surveys establish the number of open pits that must be laid down and analyzed in order to create a standards-based map. (All-Union instruction..., 1973). To great extent, this, obviously, should be applied to large-scale and detailed soil maps since the maps of medium and small scales were mainly created by the generalization of large-scale soil maps but, certainly, with the use of available field data and the site exploration method.

In the transition to digital soil cartography the problem of soil sampling and their needed amount is still not totally resolved. The quality of digital soil maps is usually evaluated statistically based on trial selection of site-investigation points or points "read" from an updated traditionally created soil map. It is believed that for a statistical assessment of the accuracy of a digital soil map it is sufficient to have several tens of points with real data (Digital soil..., 2017). Moreover, these points are located in space either randomly or according to specified rules. At the same time map scale, as a rule, is not completely considered.

A drawback of such approach to assessing the quality of digital soil maps is that even good statistical assessments of quality do not guarantee the consistency of the resulting map from the perspective of expert knowledge on the soil geography of the research region. Inversely, the resulting map may look quite logical for an expert soil scientist but the statistical assessment of its quality could be low (Zhogolev, 2016).

So far, in the development of digital soil mapping a satisfactory solution to this problem has not been found yet.

CONCLUSIONS

A feature of the transition from traditional soil cartography to digital technologies for soil maps creation and use is a qualitative change in both concepts of "map" and "map scale". The map in digital mapping refers to a spatially-coordinated database that can consist of many information layers and can be visualized on any scale.

The scale of traditionally made paper soil maps is of great importance for understanding the semantic load of the map and the degree of its generalization. When using digital soil mapping the concept of "scale" loses its meaning, since the level of generalization of soil information in this case is determined by pixel size with which the map was created (in the case of raster maps) or which map served as the basis for creation the vector layer of soil map rather than by the scale on which the map is displayed on a computer screen or printed out.

For raster soil maps it is more logical to use a concept of "pixel size" instead of "scale". For vector soil maps it is more important to indicate the scale of the original soil map (which was vectorized) rather than the scale of their visualization. The scale of digital soil map visualization is not important in computer (digital) applied analysis of soil data.

Creating raster soil maps one cannot use source materials of different scales without bringing them to a single level of generalization.

Approaches to assessing the accuracy and standard of nowdays digital soil maps haven't been completely developed.

All this must be taken into account when using digital soil mapping technologies.

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