

## Soil hydrophysical characteristics in the Nitra river basin (Slovakia): Their monitoring, analysis, online publishing

Dusan Igaz <sup>a,\*</sup> Jan Horak <sup>a</sup>, Karol Sinka <sup>b</sup>, Elena Kondrlova <sup>a</sup>

<sup>a</sup> Slovak University of Agriculture in Nitra, Department of Biometeorology and Hydrology, Nitra, Slovakia

<sup>b</sup> Slovak University of Agriculture in Nitra, Department of Landscape Planning and Ground Design, Nitra, Slovakia

### Abstract

The paper is focused on the purpose made, or local monitoring of areal unit of the Nitra river basin (Slovakia, Central EU with total area 4501 km<sup>2</sup>) in order to obtain the inputs on soil, moisture and hydrophysical characteristics of the given area. In this study, there was evaluated the share of individual soil texture classes in the Nitra river basin on the basis of map records and its comparison with the soil samples taken from the 111 selected sites. Soil samples were taken from two depths of soil profile (15-20 cm, 40-45 cm). The sites were chosen according to the percentage representation of individual soil texture classes. Based on the identification of sampling points localization and following analysis of granularity ratio, it can be concluded that the grain composition from the soil samplings does not correspond fully with the map records. Subsequently, drainage branches of moisture retention curves were measured for all sites. Obtained hydrophysical data were enabled on the web-portal. With the use of OpenGeo Suite software, version 4.0.2 and its components Geoserver and Geoexplorer, the data on soil characteristics were published online at:

<http://fzki.uniag.sk/02FacultyStructure/02Departments/KBH/02Research/Hydrophysics>. Thus, information about the soil characteristics in the basin is available to specialists.

**Keywords:** the Nitra River Basin, hydrophysical characteristics

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### Introduction

Anthropogenic activity in a combination with land use changes, particularly its vegetation cover but also other possible factors, such as flow changes of ocean currents, solar activity, etc., may affect the overall water balance of regions and the large territorial units. The escalation of these processes in recent decades threatens and visibly affects the individual components of agricultural land (Bárek et al. 2008; Skalová, 2009; Szilagy, 2011). The question remains to what extent is it possible to put a strain on the landscape system without resulting in irreversible negative changes. To address these problems, it is necessary to obtain the number of available, objective and comparable information which will contribute to more effective decisions and follow-up measures for improvement of the landscape space and preservation of its sustainable development.

A systematic, well-defined temporal and spatial observation and recording of predetermined characteristics of individual environmental parameters is called monitoring. Informative value of monitoring depends on the spatial requirement of the representativeness of the monitoring results. The monitoring itself can not be understood as a science, but as a tool for scientific research based on the scientific observation and measurement methods, analysis methods of the obtained results, their interpolation, modeling and models

\* Corresponding author.

Slovak University of Agriculture in Nitra, Department of Biometeorology and Hydrology, Hospodárska 7, 94901 Nitra, Slovakia

Tel.: +421376000000

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E-mail address: [dusan.igaz@uniag.sk](mailto:dusan.igaz@uniag.sk)

verification. These methods were used in a series of scientific papers focusing on the hydrology and hydrogeology research (Sridhar 2007; Yurekli and Kurunc, 2006; Šraj, 2010; Hunt et al., 2008; Brus, 2011; Kempen, 2010). Large sets of data collected by monitoring were also used for developing of pedotransfer soil functions (PTF) (Vereecken et al., 1989; Scheinost et al., 1997; Wösten et al., 2001; Pachepsky et al., 1996; Šútor and Štekauerová, 2000; Skalová, 2003; Rodný and Igaz, 2010). The basis is always point monitoring which may be included in the network of so-called global monitoring that with some degree of notice ability represents the monitored area and then a larger territorial unit.

Water content dynamic is an indicator of the natural environment, through which the anthropogenic impacts and changes of a global nature are monitored. Monitoring of water content and its dynamic is defined as the systematic observation of water content in the individual horizons in the temporal and spatial expression (Šútor, 2007b). Water content monitoring in the soil is usually carried out in the vertical axis of soil profile in its unsaturated zone, ie. aeration zone, ideally, to the groundwater table level (Skalová and Jaroš, 2008, Halaj and Bárek, 2001). Subsequently, the readings are homogenized and stored in the logical database files. The process of monitoring the water content in the soil covers a wide aspect of the problems on several levels, such as selection and localization of representative sites of the study area, selection of appropriate measurement equipment and measurement methodology, determining the time step of measurement - frequency and creating a database. The result of the ideal state of water content monitoring in the soil is soil moisture spatial database, or water supplies for the selected soil profile, which is geographically defined. This means that the point has recorded an explicit geographic reference such as latitude and longitude, or coordinates in the national coordinate system and elevation. Building a spatial database requires considerable time and financial investment. Particular attention should be paid to it, considering the possible negative effects of incorrect conclusions and decisions on its future use. To create it, it is necessary to take into account the sources of available data, working procedures used for obtaining them, applied methodologies and technical equipment for soil moisture determination, but mainly on the proper structure and parameters of the database.

The aim of this paper is a purpose-made or local monitoring of territorial unit Nitra river basin in order to receive input information on the soil and hydrophysical characteristics of the study site and their subsequent analysis. Further, we inform about our approach to distribute the hydrophysical data from the soil probes in the basins of the Slovak Republic through a web interface, in order to meet the continuously increasing demand for spatial information.

## Material and Methods

### Definition and characteristics of the Nitra river basin

The Nitra river basin stretches between the two basins, the Váh river basin from the north and west and the Hron river basin from the east. The Nitra river rises in the southern part of Lesser Fatra mountain range. It flows through Prievidská and Upper Nitra basins among the mountain ranges of Žiar, Vtáčnik and Trábeč on the left side of the flow and Strážovské Hills, Little Magura, and Nitrické Hills on the right side. The flow passes to the Danubian Upland, where it forms an individual geomorphological section – Nitrianska River Plain between the mountain ranges of Tribeč and Považský Inovec. After passing the Danubian Upland, it flows into the Váh river in the area of Danubian Flat (Mazúr and Lukniš, 1980). The average altitude of the river basin is 326 m a.s.l. The highest place is the peak of Vtáčnik, which has an elevation of 1346 m a.s.l. The biggest difference in altitude is 1238 m. The total area of the Nitra river basin is 4501 km<sup>2</sup>, which represents 28,3% of the total area of Váh river basin. The Nitra river sub-basin is divided into four basic catchments: the Upper Nitra 188,5 km<sup>2</sup>, the Central Nitra 1142,3 km<sup>2</sup>, Žitava 906,7 km<sup>2</sup>, and the Lower Nitra 566,7 km<sup>2</sup>. Total length of river network in the basin is 3655 km, its density is 0,81 km/km<sup>2</sup>. The basin is asymmetric with a predominance of right-sided tributaries. The length of main flow of Nitra river is 168,4 km, the average width of the basin is 26,7 km. The total gradient of the Nitra river is 673 m, the longitudinal slope is 4.0 ‰. The forest cover conditions of the basin are different in its lowland and upland part. In the Upper Nitra basin the average forested area is about 47%, in the Central Nitra basin 28%, in the Žitava basin 22% and in the Lower Nitra basin only 2,4%, respectively. From these data, it is clear that while the Upper Nitra is a predominantly forested area, the Lower Nitra is almost entirely agricultural area with minimal forest cover. The total area of forests in the basin is 1430 km<sup>2</sup>, from which in the Upper Nitra basin it is 892 km<sup>2</sup> (Borgula, 2004).

## Representation of soil types

On the basis of map sources provided by the Research Institute of Soil Science and Conservation in Bratislava (SSCRI, 2009), there are in terms of soil texture classes represented all soil types in the Nitra river basin. The percentage of soil types is as follows: light soils 3,66%, medium heavy soils - lighter 4,96%, medium heavy soils - heavier 72,98%, heavy soils 13,56% and very heavy soils 4,84%.

111 sites were selected according to percentage distribution on every soil texture group in the Nitra river basin. The initial information on soil texture in the basin was provided by map inputs provided by SSCRI. All sites were selected on the agricultural land (cultivated agricultural land, grassland and fallow land) in the 5x5 km grid. Subsequently, taking soil samples was carried out from the two depths 15 – 20 cm and 40 – 45 cm. The soil samples were taken into Kopecký's cylinders (100 cm<sup>3</sup>) and at the same time, an undisturbed soil sample (0,5 kg) was taken for the grain size analysis. Figure 1 indicates the position of sampling sites within Nitra river basin. All sampling points were designed using GPS and subsequently identified in a GIS environment.

The pF curves were determined for all soil samples and subsequent grain size analyses were made using the pipette method, from which the following percentage representation of grain categories was found according to Kopecký approach (I. up to IV. categories).

## Distribution of the data

One of objects of our interest was the web-distribution of hydrophysical data from soil probes of the Lower and Upper Nitra river basin, using the above-mentioned OpenGeo Suite version 4.0.2. Among the six components, "Geoserver" and "Geoexplorer" deserved our special attention.

## Results and Discussion

Information on the soil texture composition and hydrophysical characteristics of soil profiles in which monitoring takes place, are the base for surface soil moisture monitoring. Based on the identification of sampling location and subsequent particle size analysis of individual soil samples can be concluded that the grain size composition of soil samples does not correspond with the map inputs of SSCRI (Table 1).

Table 1. Assumed representation of soil texture classes according to the map inputs of SSCRI and found representation under the grain size analysis in the Nitra river basin.

Soil texture class	Area (ha)	Assumed representation of soil texture (SSCRI)		Found representation of soil texture	
		Number	%	Number	%
1. light soils	11391.77	9	4	13	6
2. medium soils - lighter	15463.49	8	4	64	29
3. medium soils - heavier	227371.63	165	73	129	58
4. heavy soils	42245.22	30	14	16	7
5. very heavy soils	15093.40	10	5	0	0
Total	311565.51	222	100	222	100

The found differences between the map inputs and measurements were as follows - from sampling depth of 15 - 20 cm and total number of 111 sites, there was found match only at 58 locations. It was similar at 40-45 cm soil depth, where there was found match only at 55 locations from the total number of 111 sites. The resulting percentage representation of individual soil texture classes is – light soils 6%, medium heavy soils – lighter 29% (there was found the highest increase of number at this class), medium heavy soils – heavier 58%, heavy soils 7% and very heavy soils did not occur in our data file at all. Assumed and actual representation of soil texture at different depths is shown in the figures 2, 3, 4 and 5. Each sampling site was localized by GPS and subsequently identified on the map in GIS environment. In the context of the above requirements for building a spatial database, there was confirmed the principle, that by the database construction, it is necessary to pay particular attention to input data, their sources and working practices of their acquisition, used methodology, instrumentation and interpretation.

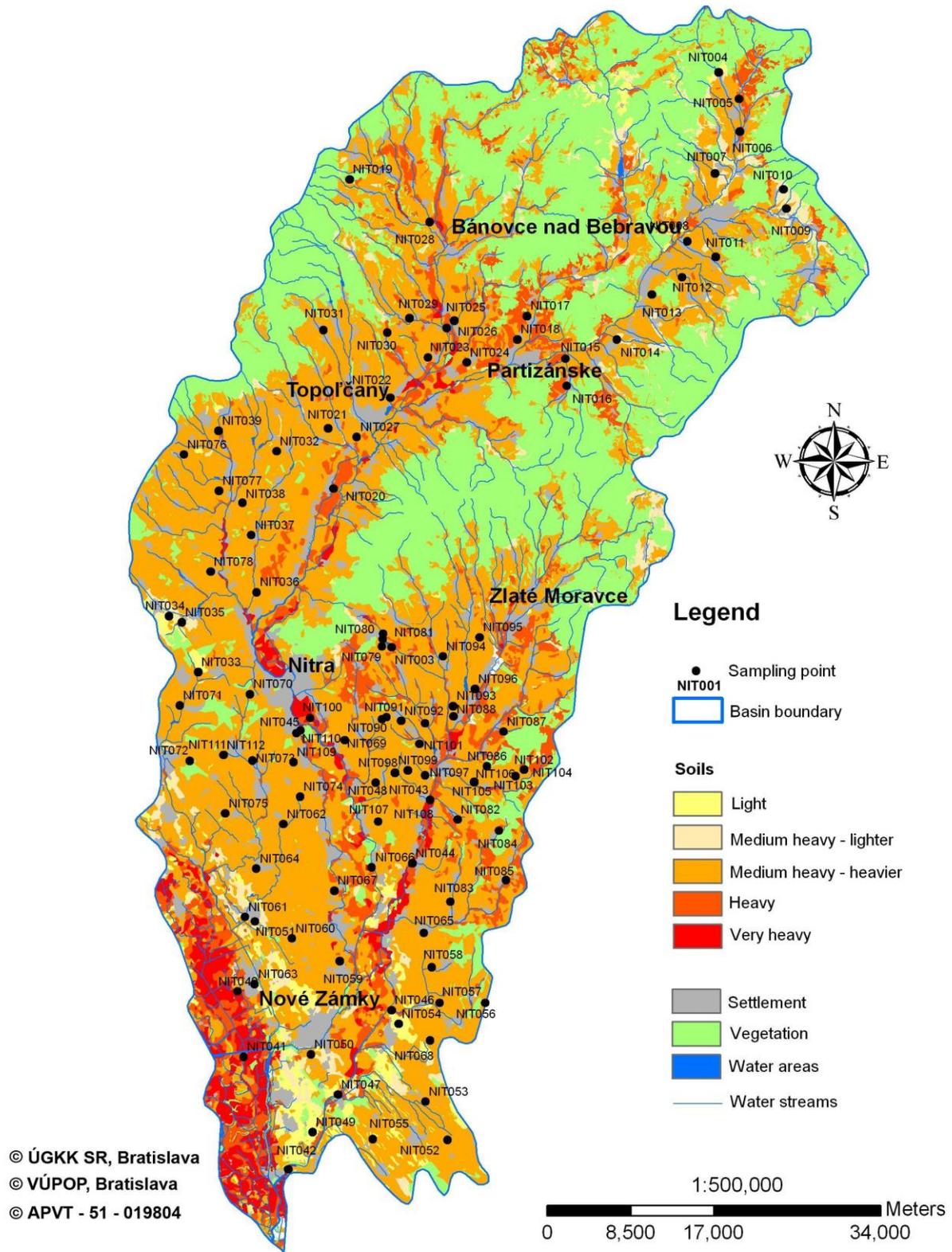


Figure 1. Localisation of sampling sites in the Nitra river basin.

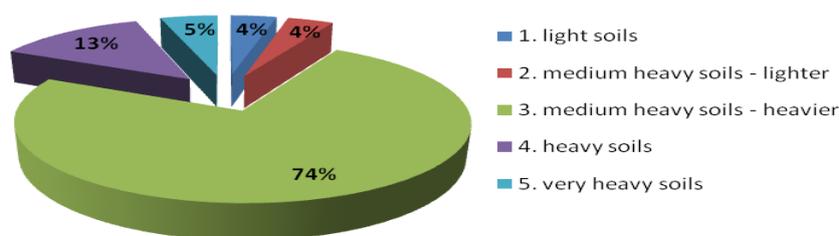


Figure 2. Assumed percentage representation of soil texture classes according to the data of SSCRI at the depth of 15 – 20 cm.

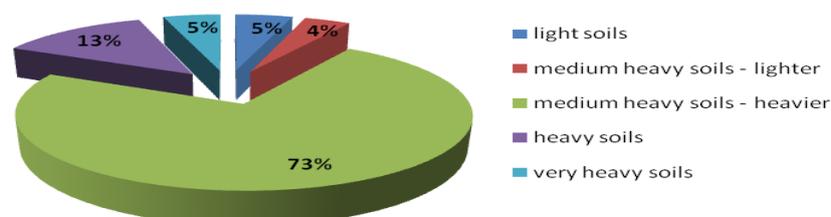


Figure 3. Assumed percentage representation of soil texture classes according to the data of SSCRI at the depth of 40 – 45 cm.

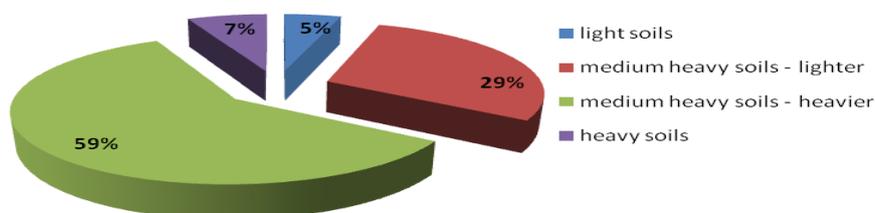


Figure 4. Ascertained percentage representation of soil texture according to the soil texture analyses at the depth of 15 – 20 cm.

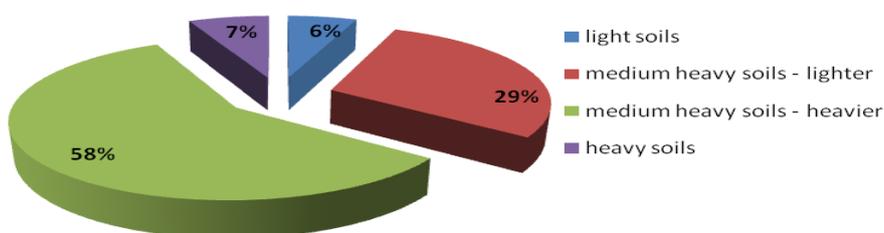


Figure 5. Ascertained percentage representation of soil texture according to the soil texture analyses at the depth of 40 – 45 cm.

### Web-distribution of information on hydrophysical characteristics

Under Geoserver (a part of OpenGeo Suite), the spatial data represented by the vector data model (SHP) were imported. It was necessary that the data would have defined coordinate system, which is included in the EPSG database. It is a database of geodetic parameters required to unequivocal identification of coordinate system, definition of transformations and conversions between individual reference systems. The S-JTSK system, still rather used in Slovakia is not included in this database (S-42, WGS 84, ETRS 89 should be considered). Of course, in addition to vectors, it is possible to import also various image (TIFF) and raster (GRID) data. For our purposes, a polygon vector layer of the Slovak Republic basins and a point vector layer of probes in the Nitra river basin were imported (Figure 6). Styler, a separately-occurring component of Geoserver serves to define the style and color palette of the spatial elements with the possibility of their description according to the selected attribute. After this step, geodata were ready for distribution through the web - applications (creation WMS).

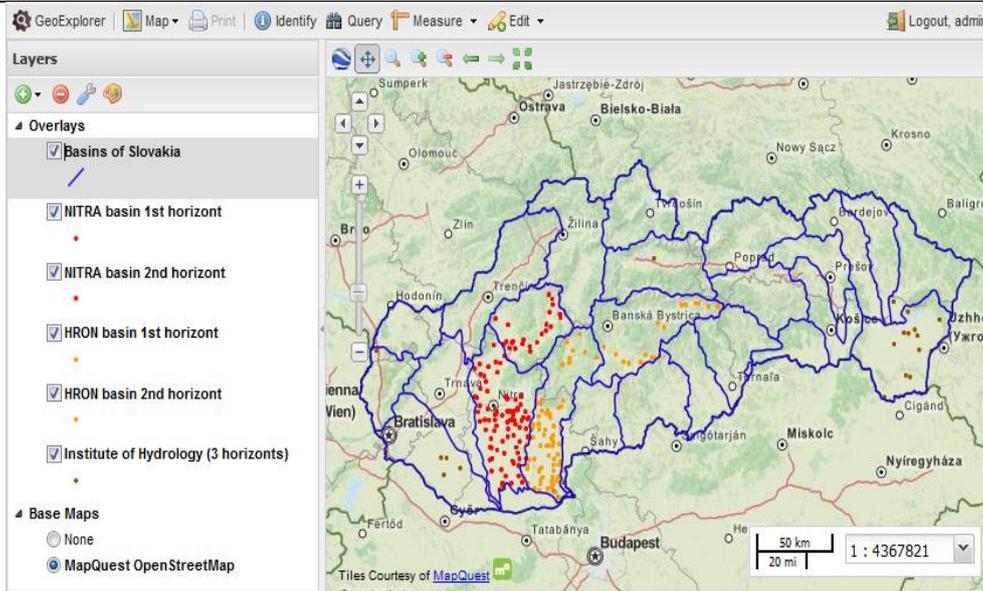


Figure 6. The Slovak river basins network of Slovakia and the localization of sample sites in the Nitra river basin.

The goal of Geoexplorer is to make it easy for anyone to assemble a browser based application with mapping functionality traditionally found in the desktop GIS world. The GeoExplorer preview release layer includes basic browsing capabilities and can be placed in front of any WMS compliant. Geoexplorer spans the wide range of base layers which then overlay with each, in the Geoserver created, WMS layers. Among the most commonly used base layers - forming a natural part of Geoexplorer - belongs MapQuest Open Street Map, defining the wider relations of distributed spatial data to a particular viewer. In order to obtain more detailed information about the location of distributed geodata, Google Satellite (Google MapData, 2001) was used. The user will find out not only the information on municipality adjacent to the soil probe placement but also the kind of land use in the area of soil probe placement (Figure 7).

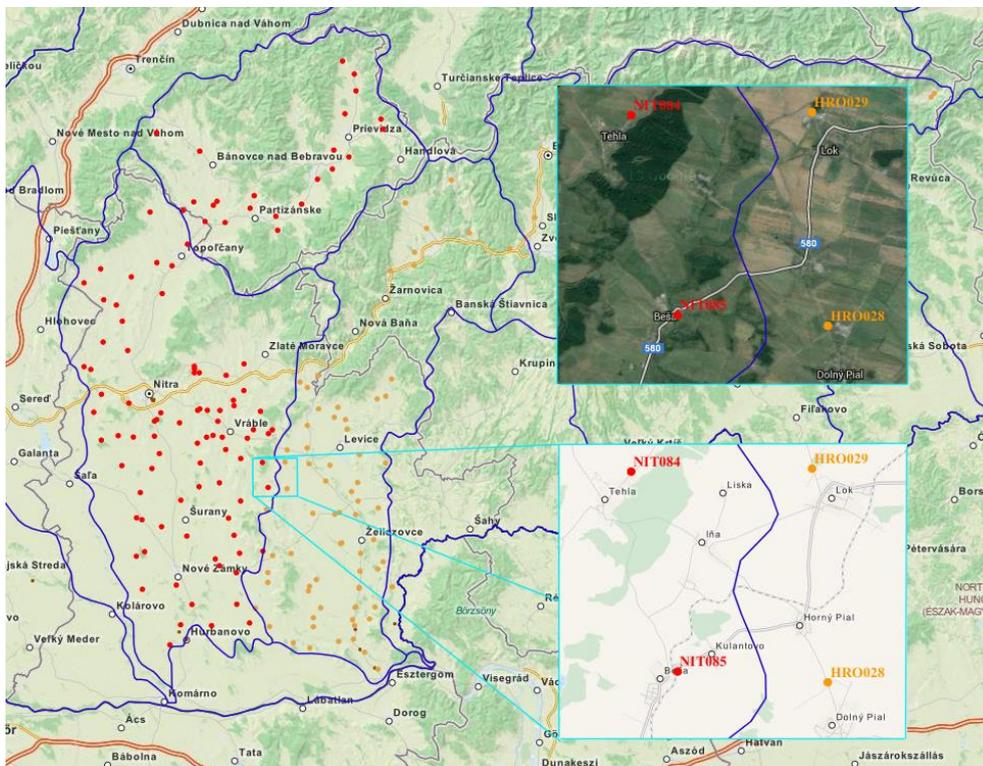


Figure 7. A comparison between less detailed Open Street Map and more detailed Google Satellite display on data position.

The database of individual geodata, i.e. Feature info is displayed in a table spreadsheet (Figure 8). The advantage of the spatial data distribution through OpenGeo Suite versus "simpler" export to Google Maps is that it facilitates the access of potential users to the geodata. It is not necessary to install any software to draw the information. The 3D Viewer for 3D display is included and freely available also in OpenGeo Suite. This web application will be available on the website.

<http://fzki.uniag.sk/02FacultyStructure/02Departments/KBH/02Research/Hydrophysics>.

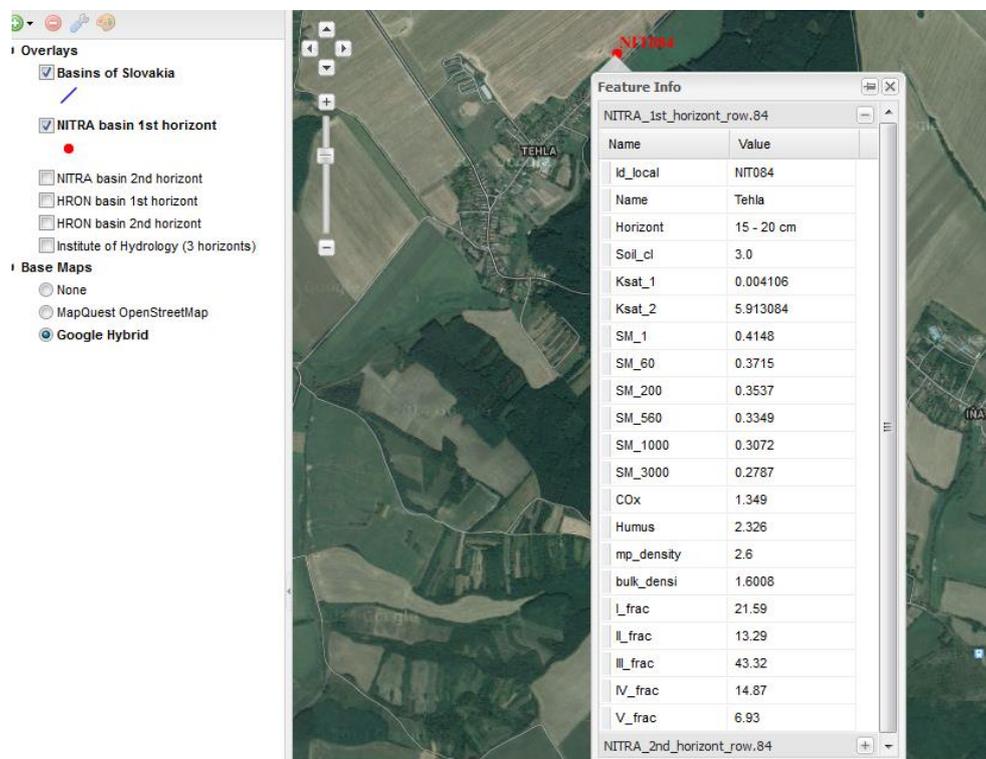


Figure 8. Demonstration of soil database – 1<sup>st</sup> horizon of NIT084 (Nitra basin)

## Conclusion

In this study, there was evaluated the share of individual soil texture classes in the Nitra river basin on the basis of map records and its comparison with the soil samples taken from the 111 selected sites. The sites were chosen according to the percentage representation of individual soil texture classes. Based on the identification of sampling points localization and following analysis of granularity ratio, it can be concluded that the grain composition from the soil samplings does not correspond fully with the map records. There was found the match only at 58 locations for the soil depth of 15-20 cm of the total 111 sampling points. For the soil depth of 40-45 cm the match was found only at 55 locations. Subsequently, drainage branches of moisture retention curves were measured for all sites. The demand for spatial information is still increasing. In order to meet the requirements, the various software are used. Among them OpenGeo Suite, which through its components - Geoserver (formation of WMS) and Geoexplorer (application of WMS) provides various ways of spatial data distribution (in our case the hydrophysical data from soil probes) based on web interface.

## Acknowledgements

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### List of symbols

EPSG - European Petroleum Survey Group  
 ETRS 89 - European Terrestrial Reference System 89  
 GIS- Geographical Information System  
 GPS - Global Positioning System  
 OGC - Open Geospatial Consortium  
 pF - soil moisture retention curve  
 S-JTSK – System of the Unified Trigonometrical Cadastral Network

SHP – shape file used in GIS  
 SSCRI – Soil Science and Conservation Research Institute  
 TIFF - Tagged Image File Format  
 USDA- United States Department of Agriculture  
 WGS 84 - World Geodetic System 84  
 WMS - Web Map Service

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