Final report of the research project KH-126725 entitled

"*Elaboration of spatial predictions together with modelling of their uncertainty for specific functions and processes of soils applying spatial statistical and machine learning methods*"

Summary

The aim of our work was (i) the elaboration of spatial predictions for specific soil functions, processes and services, furthermore (ii) the modelling of their uncertainty by proper digital soil mapping approaches based on applied mathematical and GI methods.

Spatially explicit assessment of soil functions, processes and services is still a challenge. Basically, there are two approaches for the mapping of higher level soil features (functions, services, processes). The direct method starts with the inference of higher level features from basic soil properties at the field-plot, observation level using appropriate methods and models. The thematically inferred values are then spatially extended with a specific mapping procedure. There might be two difficulties in the feasibility: data shortage and the lack of a suitable mapping method. Complex and accurate inference methods may require the availability of various parameters, which are not necessary accessible for identical or at least (cor)related locations even if specific component information is obtainable for numerous locations. This may involve the failure of inference for the majority of the affordable reference sites, which also makes the mapping procedure troublesome. The indirect method starts from existing soil property maps, which provide spatially exhaustive raw data, and thematic inference is carried out on the spatial object (soil mapping unit or rather pixel) level. This approach is based on available map products and optimizes data usage, since the applied maps can be produced from different sources, using various base datasets of observations. Furthermore, error originating from the spatial inference of raw data as well as its propagation can be accounted for in a more straightforward manner taking into consideration the inherently produced predictions on the spatial accuracy of the input maps.

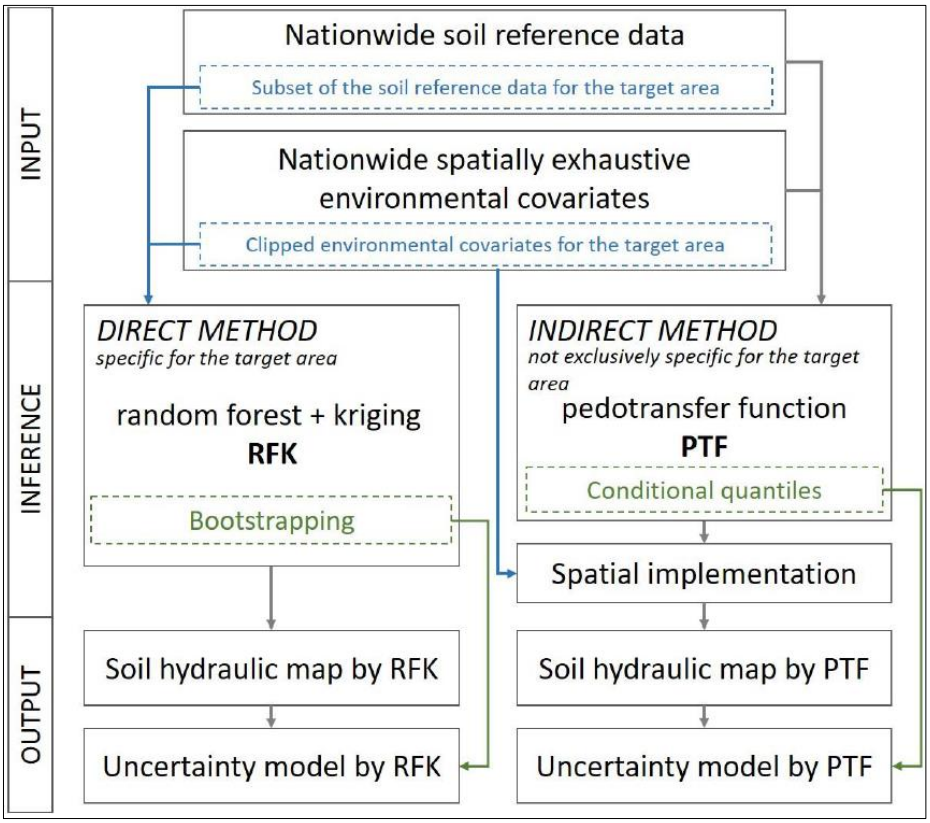
We concentrated on and achieved results in the following topics (while some further challenges were also targeted and approaches were tested, but so far without publicable results).

- Soil physical properties and soil water regime play important role in various environmental processes and hazards, like waterlogging and drought. Soil hydraulic properties were mapped applying generalized pedotransfer functions on available, primary soil property maps supplemented with further environmental co-variables. Alternative mapping of soil hydraulic properties were tested on the catchment of Lake Balaton to study the differences in performance and spatial patterns between soil hydraulic maps derived with indirect and direct spatial inference methods.
- The national soil water management category system and legacy map were renewed by formalizing the built-in soil-landscape model(s), together with the quantification of its categories. The deliverables of the work are disaggregated maps with the legend of the traditional water management classes at both national and catchment level; interval estimation of the applied hydro-physical properties for the individual water management categories, together with the estimations of accuracy.
- For supporting the national Hungarian irrigation strategy a series of country-wide functional soil maps was created, which reveal the pedological constraints, conditions and circumstances of irrigation by spatial modelling the relevant functional features of the soil mantle.
- Spatial assessment of certain provisioning and regulating soil functions and services was carried out by the involvement of soil property maps in digital process/crop models, which properly simulate the soil-plant-water environment conditioned by various factors based on actual, predicted or presumed data. Specific outputs of the modelled processes provided adequate information on functional behavior of soils like their filtering and production functions.
- Soil erosion as a crucial threat to soil resources together with soil erosion control as a regulating ecosystem service and inland excess water as a major land degradation problem in the agricultural areas were mapped and spatially assessed applying combined process models and hybrid prediction methods. Both the maps and the performance/importance of the used predictor variables were evaluated using (semi-)quantitative validation data.
- Organic carbon content of soils determines numerous soil functions, delivers ecosystem services and is extremely important in soil processes, consequently to map its spatial distribution and to predict its pool is widely demanded. We compared the suitability of several commonly applied digital soil mapping techniques to compile maps for the topsoil organic carbon stock and quantify prediction uncertainty for the years 1992 and 2010. In addition to identify the best performing methods, we assessed the spatio-temporal change of SOC stocks on the territory of Hungary at 100 m resolution.

Random forest based pedotransfer functions and geostatistical methods for mapping soil hydraulic properties

3D spatial information on soil hydraulic properties is important for modelling hydrological, ecological, meteorological processes or planning land use and management. The current measurement methods of the most widely used soil hydraulic parameters, such as water retention capacity and hydraulic conductivity are time consuming, labour intensive and costly. In this way spatial information on those are usually indirectly derived with pedotransfer functions (PTFs) from easily available soil properties. Based on available soil maps these hydraulic parameters can be spatially predicted with the PTFs. This indirect mapping method can be an alternative approach when density of measured soil hydraulic properties does not satisfy the needs of geostatistical analysis.

Our aim was to compare performance of soil water retention maps derived with i) pedotransfer functions (PTFs) and ii) geostatistical methods, both using random forest algorithm. Maps of saturated water content (THS), field capacity (FC) and wilting point (WP) were prepared at 0–30, 30–60 and 60–90 cm depths at 100 m resolution for the Balaton catchment (5,775 km^2).



Flowchart for mapping soil hydraulic properties and for quantifying prediction uncertainty.

For the construction of the PTFs we related the soil water retention values to basic soil properties and other environmental parameters, which are available for the catchment. The analysis was performed with random forest method on some 10,000 samples of the Hungarian Detailed Soil Hydrophysical Database (Hungarian acronym: MARTHA) complemented with information on topography, climate, parent material, vegetation and land use. As a geostatistical method we used random forest combined with kriging (RFK). For this direct mapping data of 359 soil profiles located in the Balaton catchment was used from the MARTHA dataset.

The performance of the PTFs based and RFK maps were similar in case of six out of nine layers. The PTF significantly outperformed the RFK in mapping THS at 30–60 and 60–90 cm soil depth. In case of WP at 60–90 cm depth RFK was significantly more accurate. The difference between predicted soil hydraulic values derived by RFK and applying PTFs were less than 0.025 cm^3cm^{-3} for 65–86 % of the mapped area. Introduction of generalized PTFs applied on soil property maps and spatial auxiliary data was found to be an efficient alternate for mapping soil moisture retention capacity when the database used for the establishment of the predictions is hydropedologically similar to that of the mapped area.

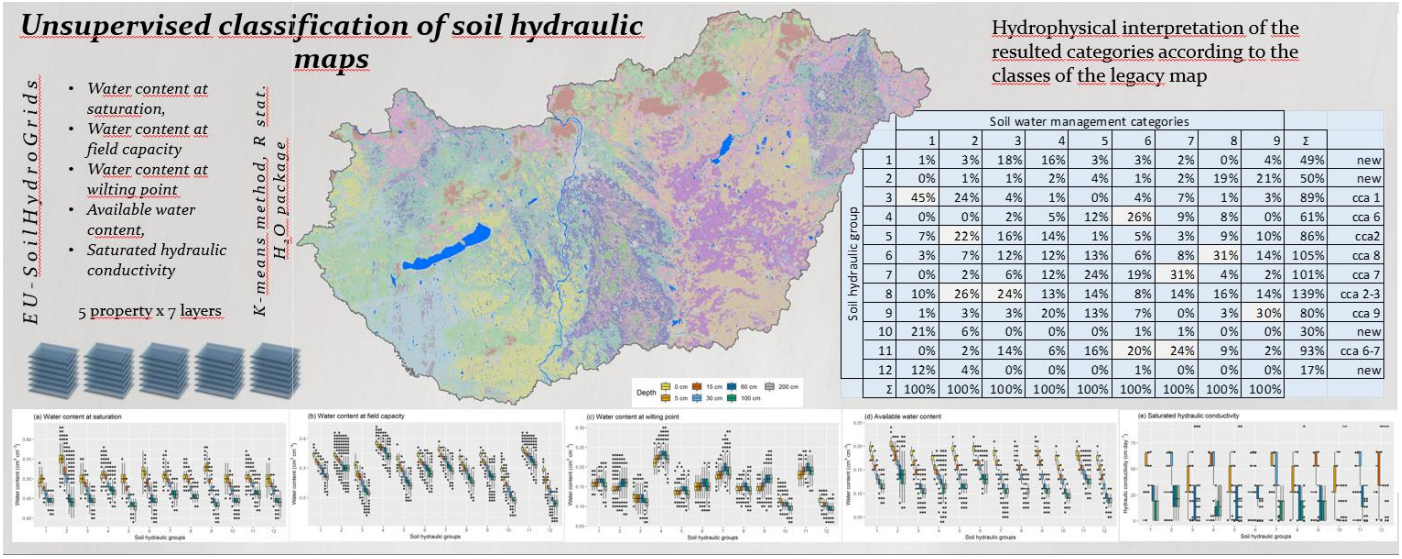
For better understanding the processes occurring during extreme events, e.g.: floods, drought, extreme rainfall, etc. it is also important to provide information on the uncertainty of the calculated soil hydraulic properties. Therefore, we also studied the quantified uncertainty derived with indirect (based on PTFs) and direct (geostatistical) spatial

inference methods. In the case of the indirect mapping method the uncertainty of the mapped values was provided based on the calculation of quantiles within the random forest algorithm, whereas for direct mapping method the uncertainty of spatial prediction was quantified by bootstrapping. The quantified uncertainties of the two approaches were communicated as prediction interval coverage probability plots and G statistics. The results represent useful contribution to understand, how uncertainty propagates in complex spatial soil modelling.

SZABÓ, B., SZATMÁRI, G., TAKÁCS, K., LABORCZI, A., MAKÓ, A., RAJKAI, K., PÁSZTOR, L.: Mapping soil hydraulic properties using random forest based pedotransfer functions and geostatistics, manuscript under open discussion and review for the journal Hydrology and Earth System Sciences (HESS), 23: (6) 2615-2635, 2019

Understanding and quantifying the categories of a national legacy map on water management by data mining methods and newly elaborated, digital hydro-physical soil property maps

Soil physical properties and soil water regime have been in the focus of soil surveys and mapping in Hungary due to their importance in various environmental processes and hazards, like waterlogging and drought, which endanger extended areas. In the late '70s a category system was elaborated for the planning of water management, which was used as the legend of a nationwide map prepared in the scale of 1:500.000. Soils were characterized qualitatively (e.g.: soil with unfavorable water management was defined with low infiltration rate, very low permeability and hydraulic conductivity, and high water retention), without quantification of these features. The category system was also used for creating large-scale (1:10.000) water management maps, which are contained legally by expert's reports prepared on the subject of drainage, irrigation, liquid manure, sewage or sewage-sludge disposal. These maps were prepared eventually, essentially for individual plots and are not managed centrally and are not available for further applications.

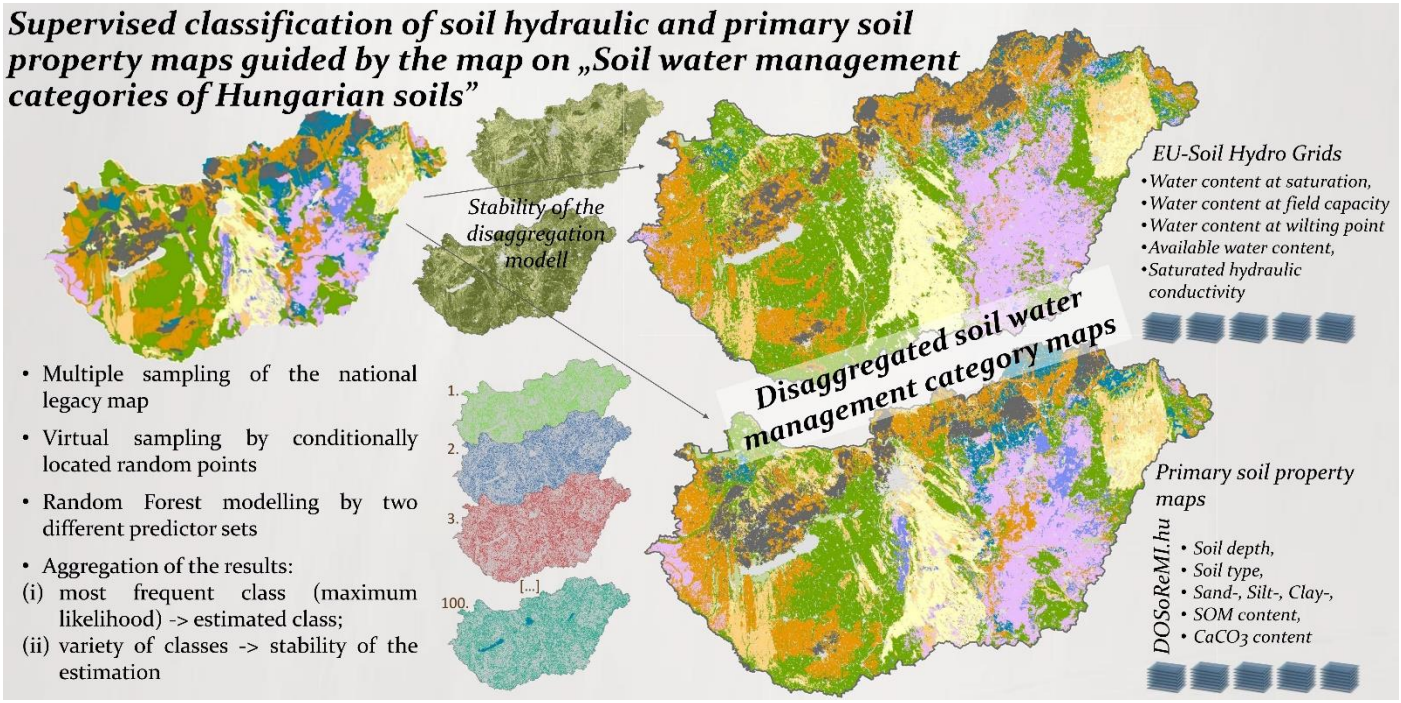


	1	2	3	4	5	6	7	8	9	Σ	
1	1%	3%	18%	16%	3%	3%	2%	0%	4%	49%	new
2	0%	1%	1%	2%	4%	1%	2%	19%	21%	50%	new
3	45%	24%	4%	1%	0%	4%	7%	1%	3%	89%	cca 1
4	0%	0%	2%	5%	12%	26%	9%	8%	0%	61%	cca 6
5	7%	22%	16%	14%	1%	5%	3%	9%	10%	86%	cca2
6	3%	7%	12%	12%	13%	6%	8%	31%	14%	105%	cca 8
7	0%	2%	6%	12%	24%	19%	31%	4%	2%	101%	cca 7
8	10%	26%	24%	13%	14%	8%	14%	16%	14%	139%	cca 2-3
9	1%	3%	3%	20%	13%	7%	0%	3%	30%	80%	cca 9
10	21%	6%	0%	0%	0%	1%	1%	0%	0%	30%	new
11	0%	2%	14%	6%	16%	20%	24%	9%	2%	93%	cca 6-7
12	12%	4%	0%	0%	0%	1%	0%	0%	0%	17%	new
Σ	100%	100%	100%	100%	100%	100%	100%	100%	100%		

Unsupervised classification of soil hydraulic maps to compile novel water management map and build respective category system

We initiated a study in order to formalize the built-in soil-landscape model(s) of the national legacy map on water management, together with the quantification of its categories and its potential disaggregation. The relation of the legacy map with the newly elaborated 3D estimations were evaluated at two scales: nationwide with 250 m resolution and at catchment scale with 100 m resolution. Hydrological and primary soil property maps were used as predictor variables. Unsupervised classifications were performed for spatial-thematic aggregation of the soil hydraulic datasets to identify their intrinsic characteristics, which were used for the elaboration of a renewed water management classification. Hydrological interpretation of the categories provided by the optimum classifications has been carried out (i) by their spatial cross-tabulation with the categories of the legacy map and (ii) using the interval estimation of the applied soil hydraulic properties provided for the individual water management categories. Machine learning approaches were used to analyze the information content of the legacy maps's category system, whose results were used for its disaggregation. Conditionally located random points were sequentially generated for virtual sampling of the legacy map to produce reference information. The disaggregated maps with the legend of the traditional water management classes were produced both on national and catchment level. The deliverables of the study are disaggregated maps with the legend of the traditional water management classes at both national and catchment level; interval estimation of the applied hydro-physical properties for the individual water management categories, together with some primary estimations on the accuracy of the results.

The map based on primary soil property maps reflects better the structure of the legacy map. Its not surprising, because the mental model could have been supported by soil properties. Known limits of the map deduced on EU-SHG: (i) it is based on global soil property maps and (ii) European PTFs, furthermore (iii) its spatial resolution is 250 m as opposed to the 100 m applied on the national soil property maps. The best validation could be provided by their application in process based hydrological/meteorological models, which is planned to be carried out.



Supervised classification of soil hydraulic and primary soil property maps to build novel disaggregated water management map with the traditional category system

PÁSZTOR, L., TÓTH, B., SZATMÁRI, G., LABORCZI, A.: Understanding and quantifying the categories of a national legacy map on water management by data mining methods and newly elaborated, digital hydro-physical soil property maps. Paper presented at Pedometrics 2019, Guelph Canada.

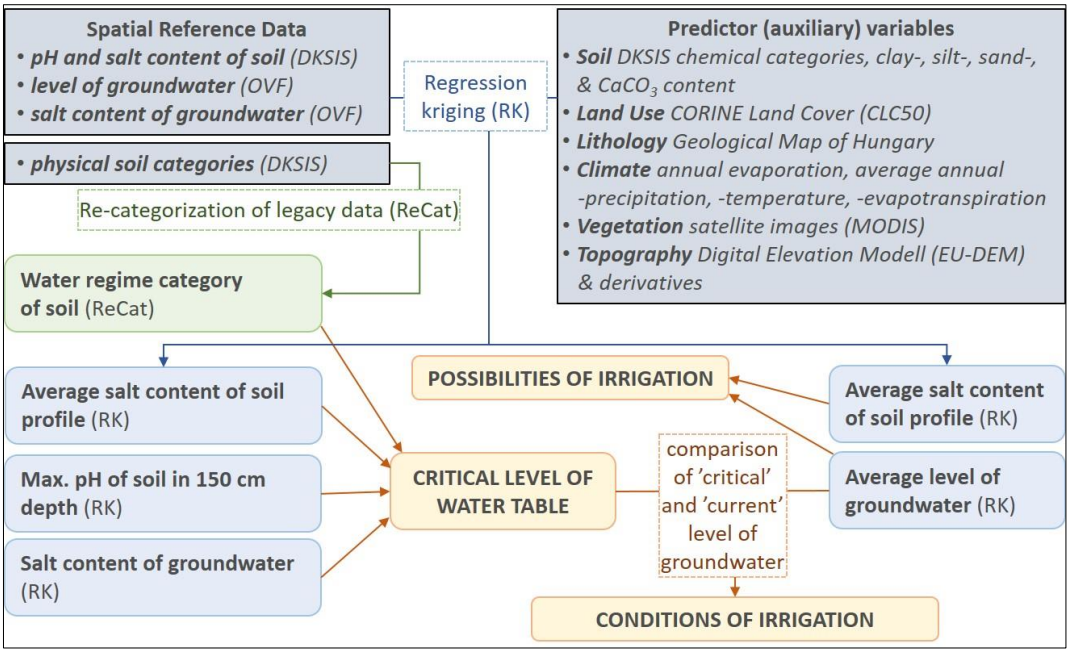
LABORCZI, A., SZABÓ, B., SZATMÁRI, G., MAKÓ, A., BAKACSI, Zs., PÁSZTOR, L.: Talaj-vízgazdálkodási kategóriák térképezése digitális hidrofizikai talajtulajdonság térképek és archív talajtérképek alapján, adatbányászati módszerekkel. In: Molnár, Vanda Éva (szerk.) Az elmélet és a gyakorlat találkozása a térinformatikában X.: Theory meets practice in GIS Debrecen, Magyarország: Debreceni Egyetemi Kiadó, pp. 175-176, 2019

PÁSZTOR, L., LABORCZI, A., BAKACSI, ZS., SZATMÁRI, G., MAKÓ, A., SZABÓ B., Understanding and quantifying the categories of a national legacy map on water management by data mining methods and newly elaborated, digital hydro-physical soil property maps (manuscript in progress)

Supporting irrigation nationwide planning by functional soil maps

Sustaining proper soil moisture is essentially important in agricultural management. However, irrigation can be really worth only, if sufficient emphasis is laid on soil conservation. Nationwide planning of irrigation needs spatially exhaustive, functional soil maps, which may support proper recommendations for the different areas. For supporting the national Hungarian irrigation strategy a series of country-wide functional soil maps was created, which reveal the pedological constraints, conditions and circumstances of irrigation by spatial modelling the relevant functional features of the soil mantle. Irrigation can improve productivity, while its negative effects may lead to soil degradation. The thematic maps spatially model the irrigability of soils, as well as their vulnerability. Estimation of salt accumulation hazard, and soil compaction and structure degradation risks were targeted. The salinization hazard assessment was carried out in two ways. We applied the steady state concept of critical watertable depth and a more dynamic, process-based method.

Productivity was expressed by land quality for the agricultural areas of the country along various management forms (extensive, intensive, irrigated, non-irrigated). The production increase due to irrigation was estimated by the consideration of soils agricultural potential, where the anthropogenic management factors, which have effect on the efficiency of the production, were integrated in the form of scenarios in lack of the availability of proper, spatially exhaustive data.



The conceptual model of critical watertable level-based evaluation

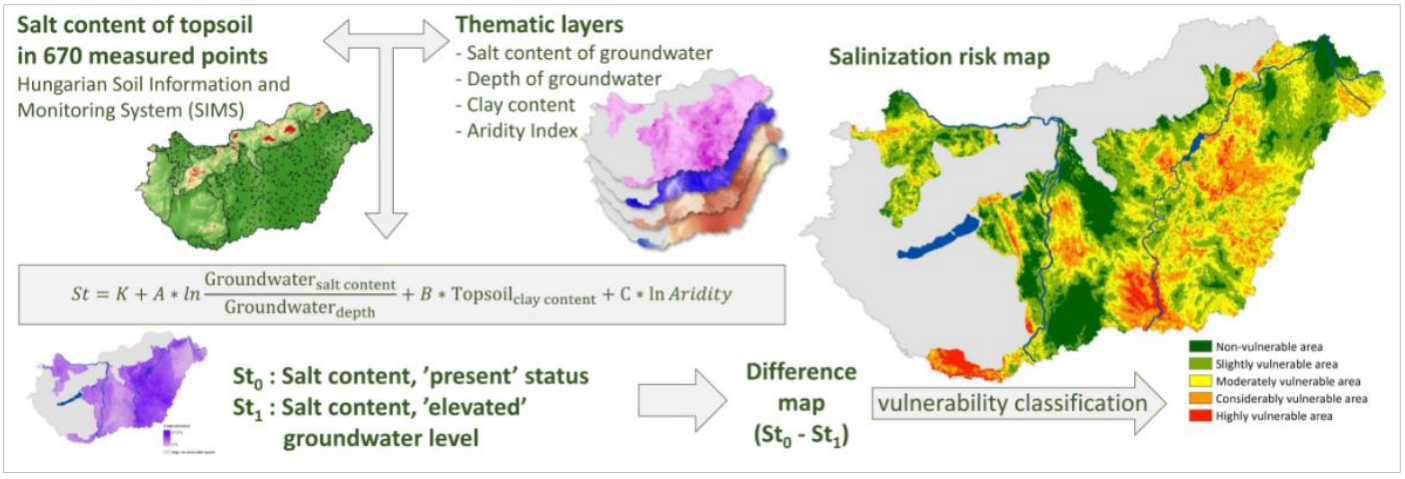
Negative consequence of irrigation were taken into account in two forms:

(i) Estimation of salt accumulation hazard, secondary salinization.

Based on the original factors of salt accumulation, estimation algorithm was established for the salt content of soils providing their significance in the occurrence of salt affected soils. Using monitoring observation, the trend type changes in the depth and salt content of groundwater were also taken into consideration.

(ii) Estimation of soil compaction, structure degradation risk.

Vulnerability of soil compaction and structural degradation are closely related issues. Differential porosity changes (e.g. ratio of macropores) within a given soil group could be taken as primary indicator of structural degradation, while the changes in bulk density can indicate the susceptibility for compaction. To estimate soil structural degradation hazard, class-based relationships were developed based on soil profile data of MARTHA 1.0 (Hungarian detailed soil hydraulic database). Soil taxonomic main type, organic matter content, carbonate content, soil reaction and texture class (USDA) were taken into consideration to develop pedotransfer functions for modeling the correlations between primary soil properties and threats indicators.



Process-based method for evaluation of salt accumulation in the topsoil

The newly compiled maps support decision makers to improve land use management, taking soil conservation into consideration.

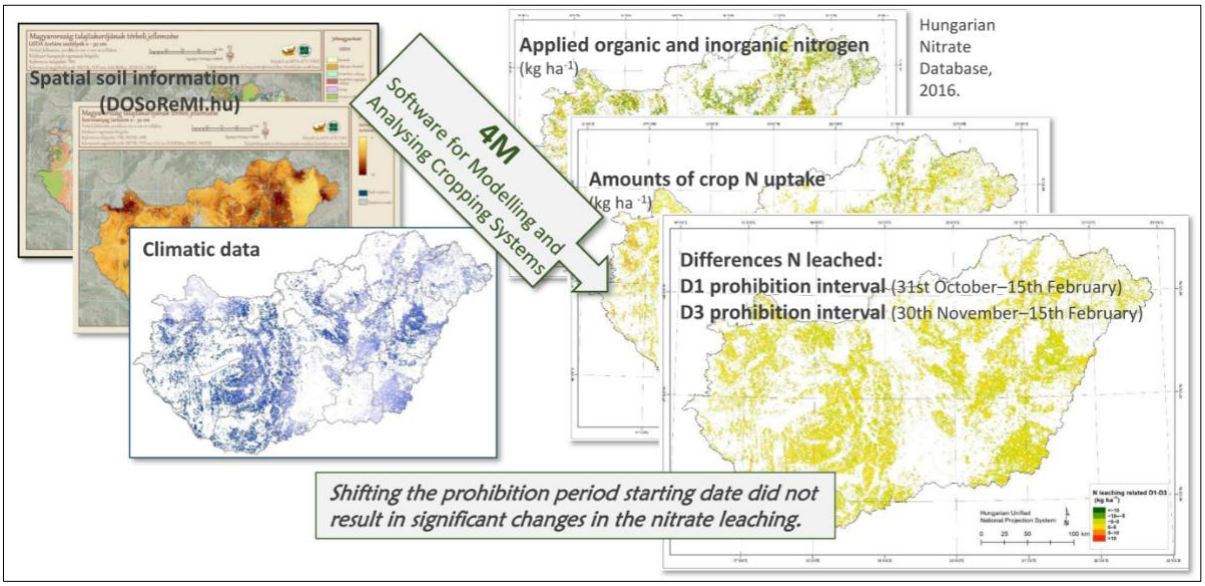
BAKACSI, ZS., TÓTH, T., MAKÓ, A., BARNA, GY., LABORCZI, A., SZABÓ, J., SZATMÁRI, G., PÁSZTOR, L.: Assessing the risk of soil salinization and structural degradation under irrigation, submitted manuscript to Hungarian Geographical Bulletin 68: (2) 141-156, 2019

Process model based, joint spatial assessment of agricultural soils' filtering and provisioning function in Hungary

Digital process or crop models properly simulate the soil-plant-water environment conditioned by various factors based on actual, predicted or presumed data. Specific outputs of the modelled processes provide adequate information on certain soil functions. Although these models do not necessarily work in space, they can be built in as engines into spatial inference systems, thus soil property maps can be properly utilized in the spatial inference of soil functions and services.

Nitrogen is one of the most important nutrient for plants (also for animals and humans), but at the same time it is harmful in concentrated and high doses to our environment and health. For this reason, the Council of the European Union has established the Nitrates Directive (91/676/EC) covering all Member States to avoid nitrate pollution, which is also valid for Hungary in regulation. Good Agricultural Practice describes in detail the elements of the protection against nitrate pollution, according to which farmers are obliged to provide data on their nutrition supply (organic and fertilizer placement) each year in the areas classified as nitrate sensitive (affects nearly 70% of the territory of Hungary). From ecosystem service point of view, agricultural soils in these areas provide simultaneously filtering and provisioning functions, which are heavily affected by anthropogenic factors realized in their management.

We carried out the agri-environmental assessment of the nitrate database for the year 2016 using the 4M crop model with appropriate spatial soil information on primary soil properties provide by DOSoReMI.hu. By the crop production simulation model, the expected yields of the 5 main crops (wheat, maize, barley, sunflower and rapeseed) and the amount of nitrogen uptaken by crops were estimated at total of 1.3 million hectares on 50,000 Agricultural Parcel Identification System (MePAR) blocks. The needed input parameters to model running were supplied by the Nitrate Database (manure amounts, cultivated crop, and yield) and 100 meter resolution digital soil property maps, in depth of 0-30 cm, 30-60 cm, 60-100 cm, and 100-200 cm (clay, silt and sand and organic matter content aggregated for MePAR physical blocks). In view of the total amount of nitrates from nitrate database (organic manure and fertilizer) we estimated the nitrogen balance as well as the nitrate content that leach under the 0-90 cm soil layer. The model also allowed to run different fertilization time scenarios using the year of 2016 nitrate database.



The concept of the mapping approach spatial assessment of agricultural soils' filtering and provisioning function

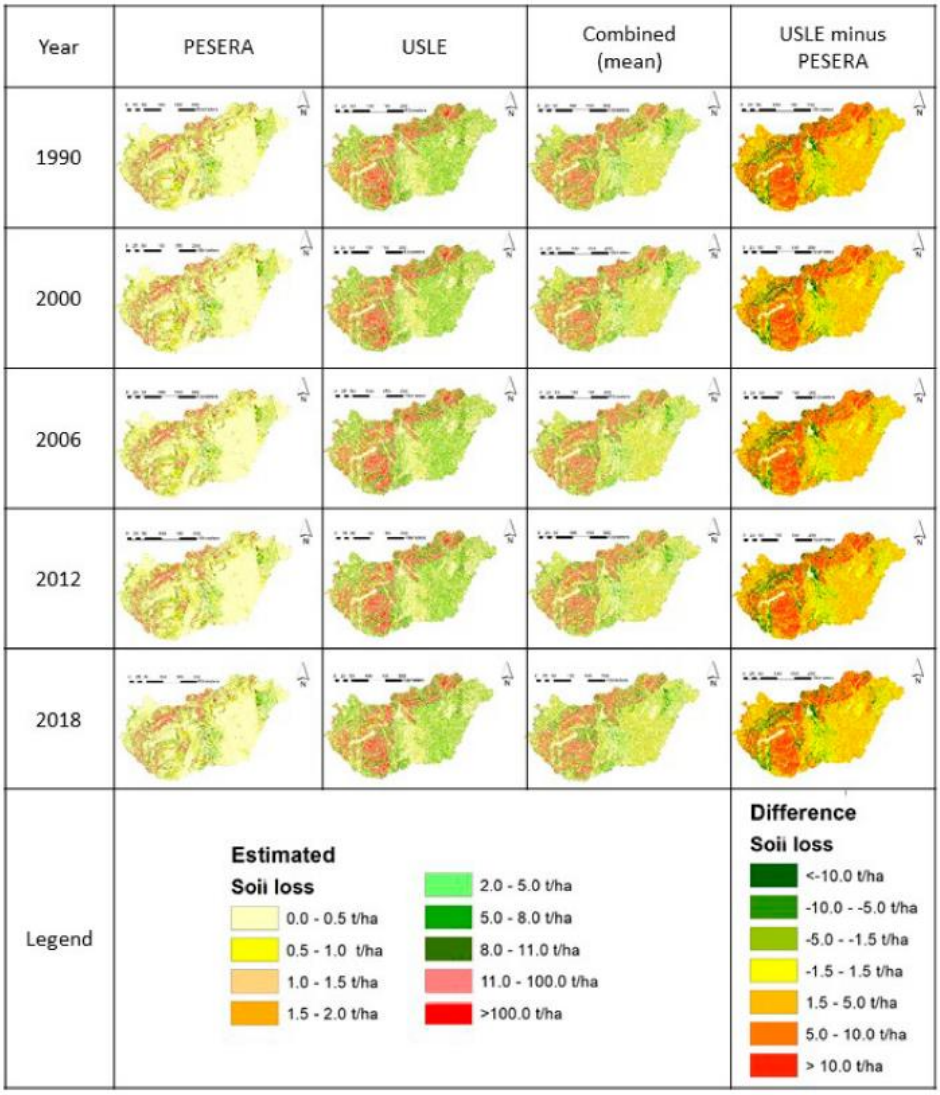
Our results verified that the nutrition of Hungarian agriculture is environmentally friendly, as the fertilizer doses are adapted to the needs of grown plants or in many cases it is under the requisite. In this context, the nutrient balances are negative. We found strong correlation between the adequacy of production site and the amount of used fertilizer, so the agri-ecological possibilities are taken into account by farmers in the planning of nutrient management.

According to results of 4M model runs, we established that the extension of manuring season (from 31 October to the 30 November) did not show any significant increase in agri-environmental risk, that is the soil nitrate content under the 90 cm layer do not increase. Based on the results, we suggested to change the relevant law, so the beginning of close season will be modified onwards 30 November.

KOÓS, S., PIRKO, B., SZATMÁRI, G., CSATHÓ, P., MAGYAR, M., SZABÓ, J., FODOR, N., PÁSZTOR, L., LABORCZI, A., POKOVAI, K., SZABÓ, A.: Influence of the shortening of the winter fertilization prohibition period in Hungary assessed by spatial crop simulation analysis, Sustainability 2021, 13(1), 417, 2021

Spatial assessment of soil erosion as a crucial threat to soil resources and soil erosion control as a regulating ecosystem service

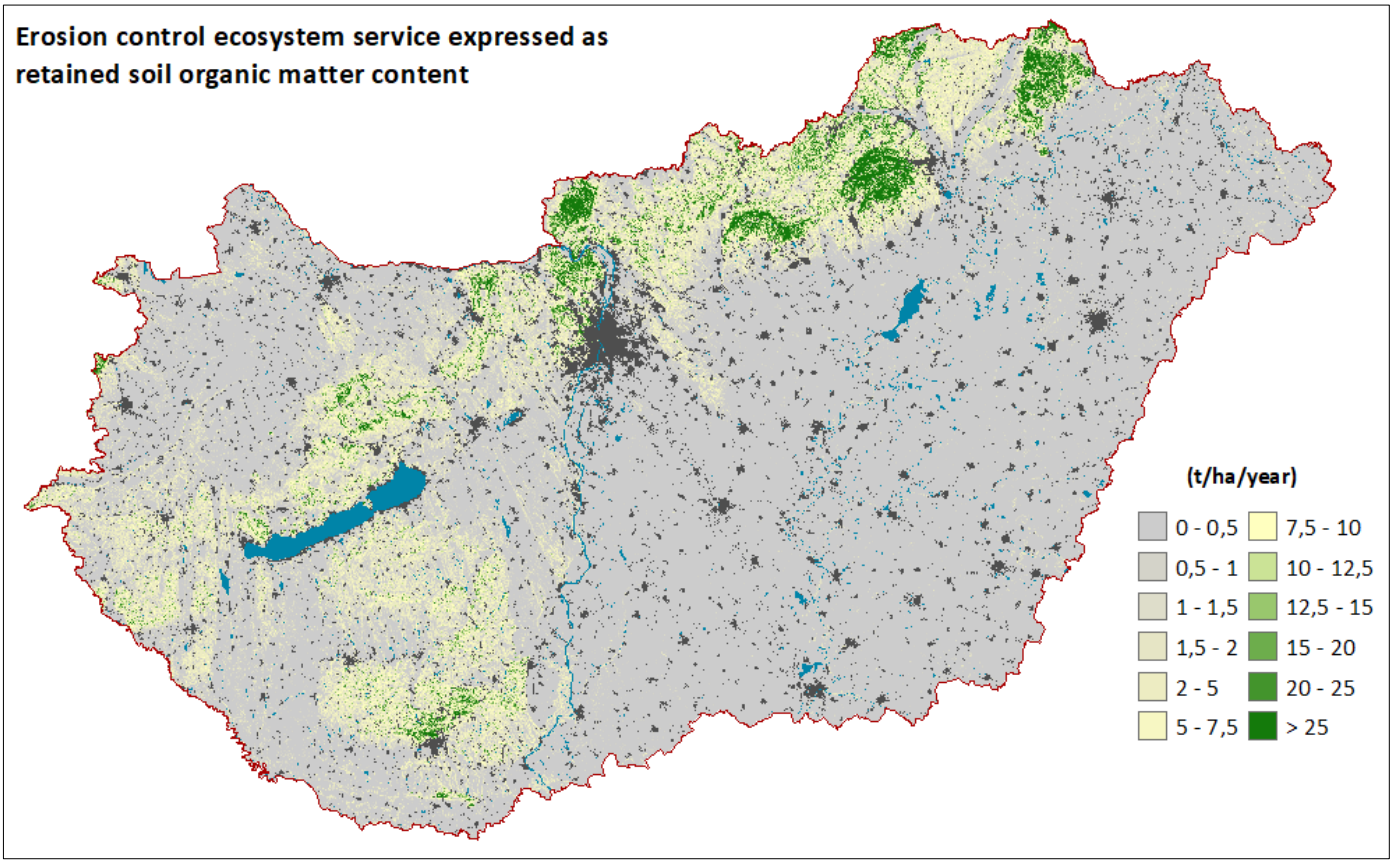
Soil erosion by water is one of the most significant forms of soil degradation not just globally, but also in Europe. A new soil erosion risk map of Hungary has been compiled and published recently in the frame of DOSoReMI initiative, using the combined outputs of the USLE and PESERA models without appropriate indication of its uncertainty. As a follow-up, we made a trial for providing post-evaluation of the map by using semi-quantitative validation data obtained from the Hungarian Soil Degradation Subsystem (TDR) of the National Environmental Information System (OKIR). The TDR database contained information at farm level as well as indicators based on laboratory data for 5 ha representative plots. Based on the semi-quantitative analysis, the map results align well with the farm-based degradation data, and provide viable information not only at the regional scale, but also at the farm scale. However, indicators from representative plots did not support model results, indicating possible conflict between farm level and plot level data. Cross-comparison of these indicators showed only limited correlation between farm and plot level indicators.



Erosion estimates for the observed years and applied methods.

As soil erosion is still a global threat to soil resources, the estimation of soil loss, particularly at a spatiotemporal setting, is still an existing challenge. We assessed changes in soil erosion potential in Hungary from 1990 to 2018, induced by the changes in land use and land cover. The modeling scheme included the application and cross-valuation of two internationally applied methods, the Universal Soil Loss Equation (USLE) and the Pan-European Soil Erosion Risk Assessment (PESERA) models. Results indicate that the changes in land cover resulted in a general reduction in predicted erosion rates, by up to 0.28 t/ha/year on average. Analysis has also revealed that the combined application of the two models has reduced the occurrence of extreme predictions, thus, increasing the robustness of the method. Random Forest regression analysis has revealed that the differences between the two models are mainly driven by their sensitivity to slope and land cover, followed by soil parameters. The resulting spatial predictions can be applied for qualitative spatial analysis. However, the question of extreme predictions still indicates that quantitative use of the output results should only be carried out with sufficient care.

Soil erosion control as a regulating ecosystem service was also mapped and assessed. The role of ecosystems in the control of soil erosion was evaluated following the guidelines of the EU MAES working group, and the so-called cascade model, which has four main levels. The USLE model was used for the evaluation of the plant cover in the reduction of soil and soil organic matter loss. The results show that 53% of the country is severely eroded if there is no plant cover and only 21% is eroded if there is plant cover on the soil. Following the same logic, the soil loss was combined with the soil organic matter content and showed that 8.72 times more soil organic matter is lost with removing the plants from the system. The results of the soil erosion mapping, soil loss and soil organic matter loss calculations assist the sustainable management of the environmental resources connected mainly to soil and water.



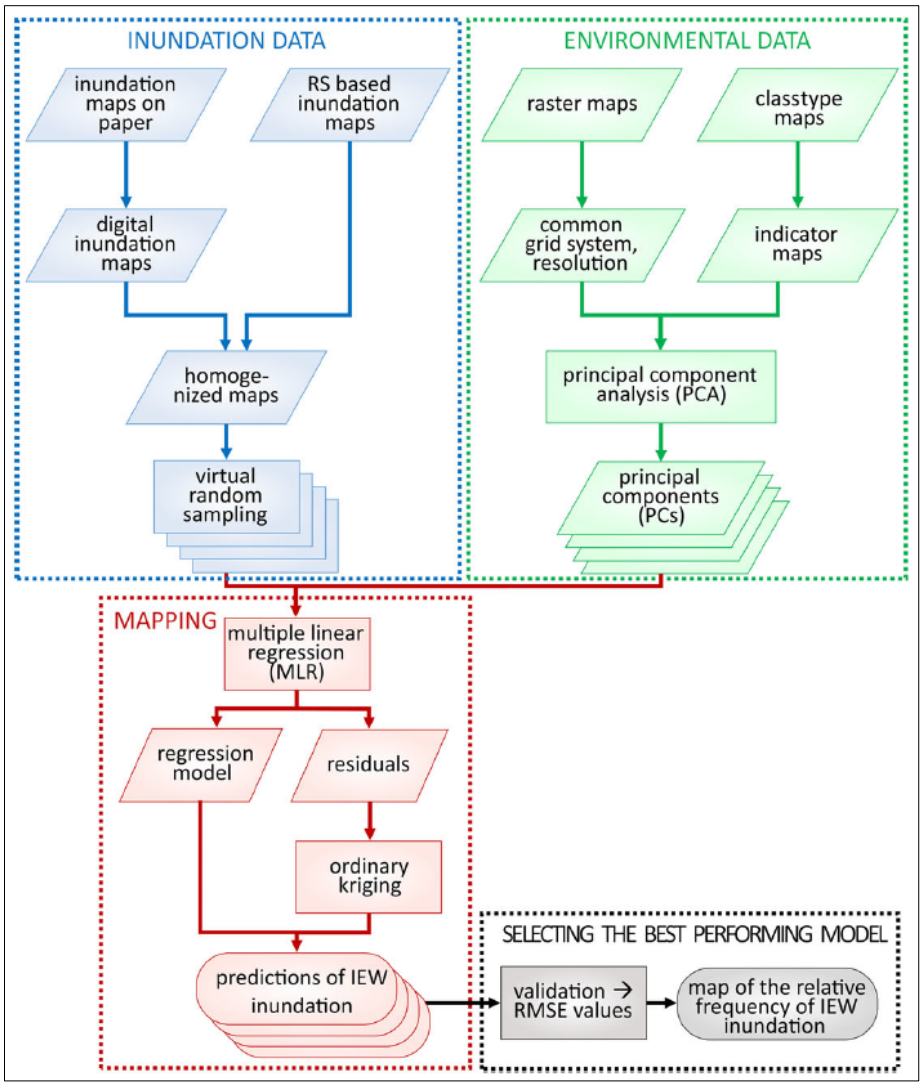
Soil erosion control as regulating ecosystem service expressed as retained soil organic matter content

WALTNER, I., PÁSZTOR, L., CENTERI, CS., TAKÁCS, K., PIRKÓ, B., KOÓS, S. & LÁSZLÓ P.: Evaluating the new soil erosion map of Hungary – a semi-quantitative approach, LAND DEGRADATION & DEVELOPMENT 29:(4) pp. 1295-1302, 2018.

WALTNER, I., SAEIDI, S., GRÓSZ, J., CENTERI, CS., LABORCZI, A., PÁSZTOR, L.: Spatial Assessment of the Effects of Land Cover Change on Soil Erosion in Hungary from 1990 to 2018, ISPRS INTERNATIONAL JOURNAL OF GEO-INFORMATION 9: (11) 667, 2020

Spatial assessment of inland excess water hazard

Inland excess water (IEW) is an interrelated natural and human induced land degradation phenomenon, it is a kind of surface water surplus, which is often regarded as a specific flooding type, but it occurs most frequently in the local depressions of large, flat areas, even irrespectively of river floods and surface water network. IEW is considered to be a typical Carpathian Basin problem, it can cause major land degradation problems in the agricultural areas of Hungary, which are mainly located on the Great Hungarian Plain. Identification of areas with high risk requires spatial modelling of the specific natural hazard. Various external environmental factors determine the behaviour of the occurrence, frequency of inland excess water. A digital mapping approach was introduced for the spatial assessment of this land malfunctioning to quantify the probability of IEW inundation as proxy. Spatial auxiliary information representing inland excess water forming environmental factors were taken into account to support the spatial inference of the locally experienced inland excess water frequency observations. This method is based on the geostatistical modelling of the relationship between the natural and human driving factors and the occurrence of IEW inundations. The results show that significant part of the GHP (about 500,000 hectares) is affected moderately or highly by IEW inundations, where the combination of multiple influencing factors simultaneously occurs. The resulted IEW inundation probability map can be used to meet the future challenges in agricultural management and the adaptation to climate change effects.



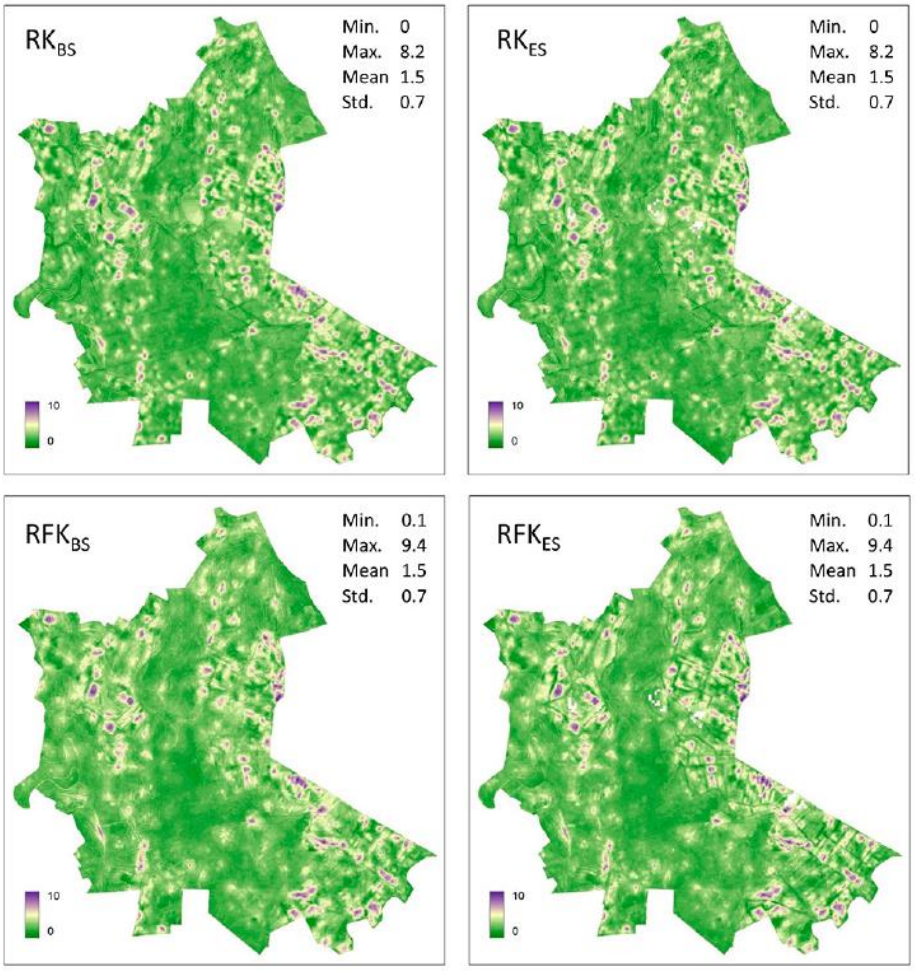
The complete process of IEW mapping

During the mapping of IEW hazard on GHP we identified some deficiencies of the work and we also suggested potential improvements of the mapping approach in order to refine the spatial and/or thematic resolution of the relative frequency map of IEW inundation. In a second round we studied the effect of a methodological change as well as the consequences of the thematic/spatial refinement of certain predictor variables together with the extension of their set on a pilot area. Two hybrid spatial prediction approaches were tested to construct reliable maps, namely Regression Kriging (RK) and Random Forest with Ordinary Kriging (RFK) using spatially exhaustive auxiliary data on soil, geology, topography, land use, and climate. Two combinations of auxiliary variables (also called environmental co-variables) were used for the comparision. Basic set (BS) consists of variables formerly used in GHP mapping. To test the effect of the introduction of new predictors (linked to at least one of the determining factors), an extended set (ES) was also compiled and used.

Comparing the results of the two approaches, we did not find significant differences in their accuracy. Although both methods are appropriate for predicting inland excess water hazard, we suggest the usage of RFK, since (i) it is more suitable for revealing non-linear and more complex relations than RK; (ii) it requires less presupposition on and preprocessing of the applied data (iii) keeps the range of the reference data, while RK tends more heavily to smooth the estimations and (iv) it provides a variable rank, providing explicit information on the importance of the used predictors.

Involving more co-variables into the mapping process for thematic extension did not prove to be effective according to the accuracy assessment. Presumably, due to the poor spatial resolution of soil hydrophysical data and the layer on recharge and discharge areas, we attribute this failure to the inference of the expected improvement in thematic extension with the relatively poor spatial representation of the potential key (inundation forming) factors. Although we did not find significant difference in accuracy provided by the two co-variable packages, we consider the co-variables in the ES package more than useful. We are planning to make further investigations on IEW hazard mapping with the application of more detailed spatial soil hydrophysical data, when it is available for the territory of Hungary.

Significant improvement in prediction accuracy could be expected from more frequently collected reference data. If IEW inundation events were monitored continuously, at unified spatial and temporal resolution, both inundation probability and hazard could be predicted more accurately. The recently developed National Earth Observation Information System and its services could provide and are also expected to make a significant step forward in this field.



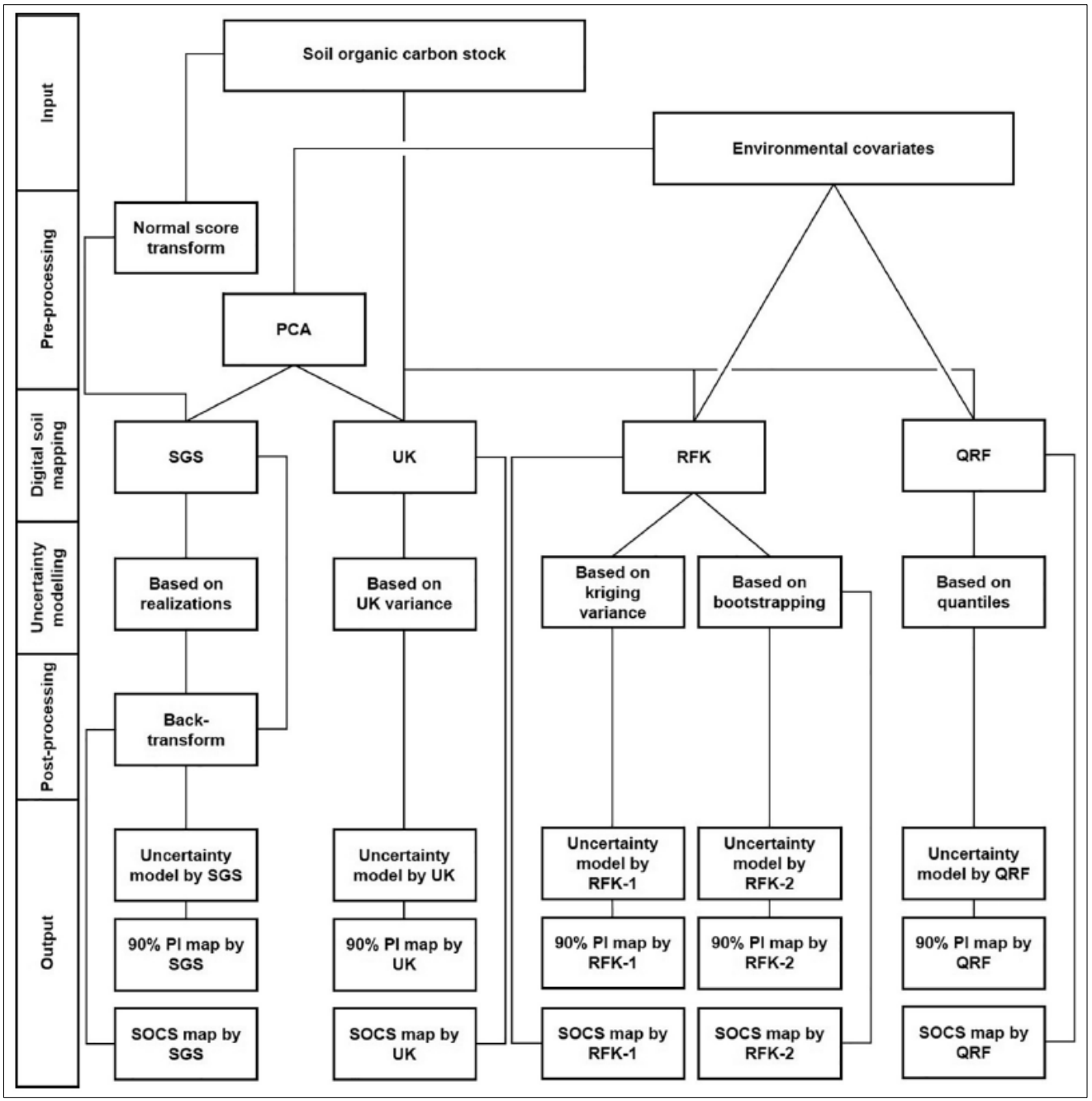
IEW indundation probability result maps of the two methods (RK – Regression Kriging, RFK – Regression Forest combined with Ordinary Kriging) by application of two co-variable packages (basic set (BS), extended set (ES))

BOZÁN, CS., TAKÁCS, K., KÖRÖSPARTI, J., LABORCZI, A., TÚRI, N. & PÁSZTOR, L.: Integrated Spatial Assessment of Inland Excess Water Hazard on the Great Hungarian Plain, LAND DEGRADATION AND DEVELOPMENT 29:(12) pp. 4373-4386, 2018

LABORCZI, A., BOZÁN, CS., KŐRÖSPARTI, J., SZATMÁRI, G., KAJÁRI, B., TÚRI, N., KEREZSI, GY., PÁSZTOR, L.: Application of Hybrid Prediction Methods in Spatial Assessment of Inland Excess Water Hazard, ISPRS INTERNATIONAL JOURNAL OF GEO-INFORMATION 2020: (9) p. 4., 2020

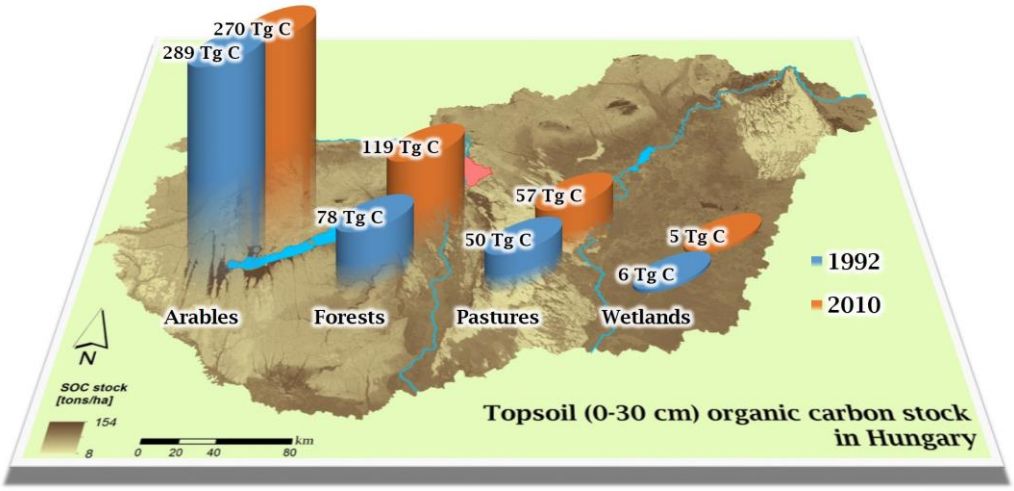
Spatio-temporal modelling of soil organic carbon content

Organic carbon content of soils determines numerous soil function, delivers ecosystem services and is extremely important in soil processes, consequently to map its spatial distribution and to predict its pool is widely demanded. We compared the suitability of several commonly applied digital soil mapping (DSM) techniques to quantify uncertainty with regards to a survey of soil organic carbon stock (SOCS) in Hungary. To represent the wide range of DSM techniques fairly, the followings were selected: universal kriging (UK), sequential Gaussian simulation (SGS), random forest combined with kriging (RFK) and quantile regression forest (QRF). For RFK two different uncertainty quantification approaches were adopted based on kriging variance (RFK-1) and bootstrapping (RFK-2). The selection of the potential environmental covariates was based on Jenny's factorial model of soil formation. The spatial predictions of SOCS and their uncertainty models were evaluated and compared using a control dataset. For this purpose, we applied the most common measures (i.e. mean error and root mean square error), furthermore, accuracy plot and G statistic. According to our results, QRF and SGS produced the best uncertainty models. UK and RFK-2 overestimated the uncertainty whereas RFK-1 produced the worst uncertainty quantification according to the accuracy plots and G statistics. We could draw the general conclusion that there is a need to validate the uncertainty models. Furthermore, great attention should be paid to the assumptions made in uncertainty modelling.



Workflow of the mapping process. Abbreviations: PCA: principal component analysis, SGS: sequential Gaussian simulation, UK: universal kriging, RFK: random forest combined with kriging, QRF: quantile regression forest and PI: prediction interval.

After identifying the optimal method for the spatial assessment of soil organic carbon content, we compiled maps for the topsoil (0-30 cm) organic carbon (SOC) stock and its prediction uncertainty in Hungary at 100 m resolution for the years 1992 and 2010 using quantile regression forest. 10-fold cross-validation was used for checking the accuracy of the spatial predictions and uncertainty quantifications for both years. The performance of the spatial predictions and uncertainty quantifications was appropriate, which was verified by the computed biases, root mean square errors, accuracy plots and the G statistics. Based on the compiled SOC stock maps, we assessed the spatio-temporal change of SOC stocks on the territory of Hungary. A scheme was elaborated based on the quantified uncertainty for detecting significant and tendentious change of SOC stock during the respective period. The total SOC stock in the topsoil was found to be 424.41 Tg in 1992 and 451.59 Tg in 2010. Thus SOC stock increased by 27.18 Tg over the respective period. On those areas where the land use types did not change, we observed that the SOC stock increased under forests (by 16.29 Tg) and pastures (by 2.48 Tg), decreased under wetlands (by 0.49 Tg) and did not change under agricultural areas. On those areas where the land use has been changed during the 18-year period, we found that afforestation has increased the SOC stock, whereas cultivation of pastures has decreased it. Due to soil sealing 34,000 ha of soil have been lost resulting in approximately 1.7 Tg carbon loss. We compared our total SOC stock estimate and map referring to 1992 with other estimates and maps provided by global and continental initiatives. The comparisons have pointed out that the SOC stock map of 1992 outperformed these maps. We recommend applying the SOC stock map of 1992 as a baseline to be able to track and assess the SOC stock change in Hungary.



Result of the spatio-temporal modelling: changes in topsoil organic carbon stock by main landuse types between 1992 and 2010

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Review on the main research results of wind erosion research in Hungary

Wind erosion is one of the most important land degradation processes in Hungary in the areas with low yearly precipitation values. The total land area suffering from wind erosion is approximately 10,000 km^2, 10 per cent of the country area. In a review paper we summarized the main research results of wind erosion research, and put forward some perspectives and suggestions on the problems of wind erosion research and control practices in Hungary.

NÉGYESI, G., LÓKI, J., BURÓ, B., BERTALAN-BALÁZS, B., PÁSZTOR, L.: Wind erosion researches in Hungary – past, present and future possibilities, Hungarian Geographical Bulletin 68: (3) 223-240, 2019

Review on the progress in the elaboration of the renewed national soil spatial data infrastructure and its functional utilization in Hungary

In a review paper we collected the main result of DOSoReMI.hu and its functional extension and discussed in details the possible directions in the follow-up. Primarily, DOSoReMI.hu is a collection of spatial soil information in the form of unique digital soil map products, which were optimally elaborated for the regionalization of specific soil features. The maps elaborated according to GSM specifications represent the Hungarian contribution to the GlobalSoilMap.net project. The accuracy of the produced maps is in line with the results achieved in other countries. The quantification of uncertainty of predictive soil maps make possible to improve the methods and the data environment to produce better and more reliable spatial information in the form of digital maps for the soil mantle and land surface. Special attention is paid on how to communicate uncertainty so that it can be easily interpretable not just for expert but for non-expert stakeholders as well. GSM conform products were successfully used as environmental co-variables in potential and actual vegetation mapping, and as basic inputs of process models. In the latter case, the availability of multiple soil layers and versatile quantitative variables have had a significant impact on the development and improvement of the 4M crop model. In addition to direct usage of GSM conform products, user demands may require their specifically transformed version. Not whole palette of GSM defined soil properties were mapped due to various reasons, nevertheless the full range of GlobalSoilMap.net products is targeted based upon the collected experiences. Elaboration of the predictions on hydraulic properties, applying generalized pedotransfer functions, is in progress. We have been striving to utilize the most promising approaches for spatial inference as well as for quantifying uncertainty.

PÁSZTOR, L., LABORCZI, A., TAKÁCS, K., ILLÉS, G., SZABÓ, J., SZATMÁRI, G: Progress in the elaboration of GSM conform DSM products and their functional utilization in Hungary, GEODERMA REGIONAL 21: e00269, 2020