Digital mapping of lowland excess water hazard

Pásztor, L.[1] – Pálfai, I. – Bozán, Cs. – Kőrösparti, J. –
Szabó, J. – Bakacsi, Zs. – Kuti, L.

Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Herman Ottó út 15., Budapest H-1022 Hungary. Tel: 36-1-356-3694; Fax: 36-1-355-1440; E-mail: pasztor@rissac.hu

1. Abstract

For the territory of three counties situated in the lowland featured southern-eastern Hungary GIS based quantification and large scale mapping of inland inundation hazard was carried out. Limited numbers of affecting environmental factors were taken into consideration. However information on these factors was available in a harmonized manner i.e. the spatial resolution and information density as well as reliability was comparable in opposite to approaches where numerous but incompatible factors are treated together providing unreliable results. One well-defined and quantified parameter representing the affect of relief, soil, agrogeology, groundwater, land use and hydrometeorology on the formulation of excess water was defined and derived. Each factor was spatially represented. Generalized versions of the quantified spatial layers were jointly statistically analysed with the map of relative frequency of excess water events. Multiple regression was used for the determination of the role of various factors in the formulation of excess water thus providing weights for its stochastic linear estimation by the applied factors. The derived weights then were used with the more detailed original map layers to produce the inundation hazard map. The resulted risk map can be utilized in numerous land related activities.

2. Introduction

As a direct consequence of physiographical conditions of Hungary, one-quarter of the country was exposed to extended or periodic inundation by the middle of the 19th century. With the huge river training project -flood control was introduced over 25,000 km^2 of the ancient flood plains, flooding now is more or less confined to the area between the flood levees. As a consequence of the construction of levees artificial drainage is needed to vast areas at times of high stages.

In the flat-land regions of Hungary (on nearly half of the total area of the country) excess inland waters cause several problems in addition to floods. The total area inundated by excess waters might be as high as 5,000-6,000 km^2. With the progress of flood defence the fighting of excess waters gains a new priority. Flood levees along the rivers enhanced the avoidance of flooding of protected areas and flood damages but prevented the draining of excess inland waters. The term excess (inland) water defines the occurrence of inundations outside the flood levee, in the protected area (from sources other than flood overflow). There is a multiplicity of definitions used for this term, which also indicates the complexity of processes that govern this phenomena (Pálfai, 2001). Most of the definitions have a common part, namely, that excess water is a kind of temporary water inundation that occurs in flat lands. Many of the definitions emphasise that in addition to precipitation the other substantial source is the groundwater, which emerges on the surface. From the second half of the 20th century the term also included the inundation of areas outside the levee-protected area. More recently the over-moistening of the soil of arable land is also considered excess-water, as it also causes damage. Nevertheless, excess water may be a favourable phenomenon too, in certain cases.

Bad climatic conditions can cause harmful effects on the areas, which formerly represented floodplains but presently used as arable lands. More and more frequent extremities of the global climate change can be experienced in the Carpathian Basin, too. After couple of dry years the highly over-average precipitation of some recent years made the seasonal and permanent waterlogging the most serious agro-environmental problem in the Great Hungarian Plain.

Reasonable and preventive management of agricultural areas requires satisfactory information on the spatial and temporal distribution of excess water. The first attempts to display water excess hazard of lowlands on maps dates back to early ’80s in Hungary. National and regional overview maps were compiled based on mainly event frequency records (Pálfai, 1994). These maps are however don’t fit the requirements set up by agriculture and rural development, which require more accurate and reliable maps from both spatial and thematic point of view (Pásztor et al., 2002). Excess water is a complex process whose characteristics can only be determined through taking numerous factors into consideration. GIS together with large-scale spatial information on those factors, which significantly affect formulation of excess water, can provide suitable background for the compilation of maps with the expected accuracy. There were some initiatives for GIS based mapping of excess water risk on pilot areas (Bíró & Thyll, 1999, Tamás, 2003, Pásztor et al., 2004).

3. Materials and methods

The whole territory of three counties (Bács-Kiskun, Békés and Csongrád altogether Southern Plain Region) is almost 18,500 km^2 and they are situated in the southern-eastern part of the country, in the Great Hungarian Plain. Excess water hazard was stochastically modelled taking into consideration compatible spatial information on six affecting environmental factors (Fig 1).

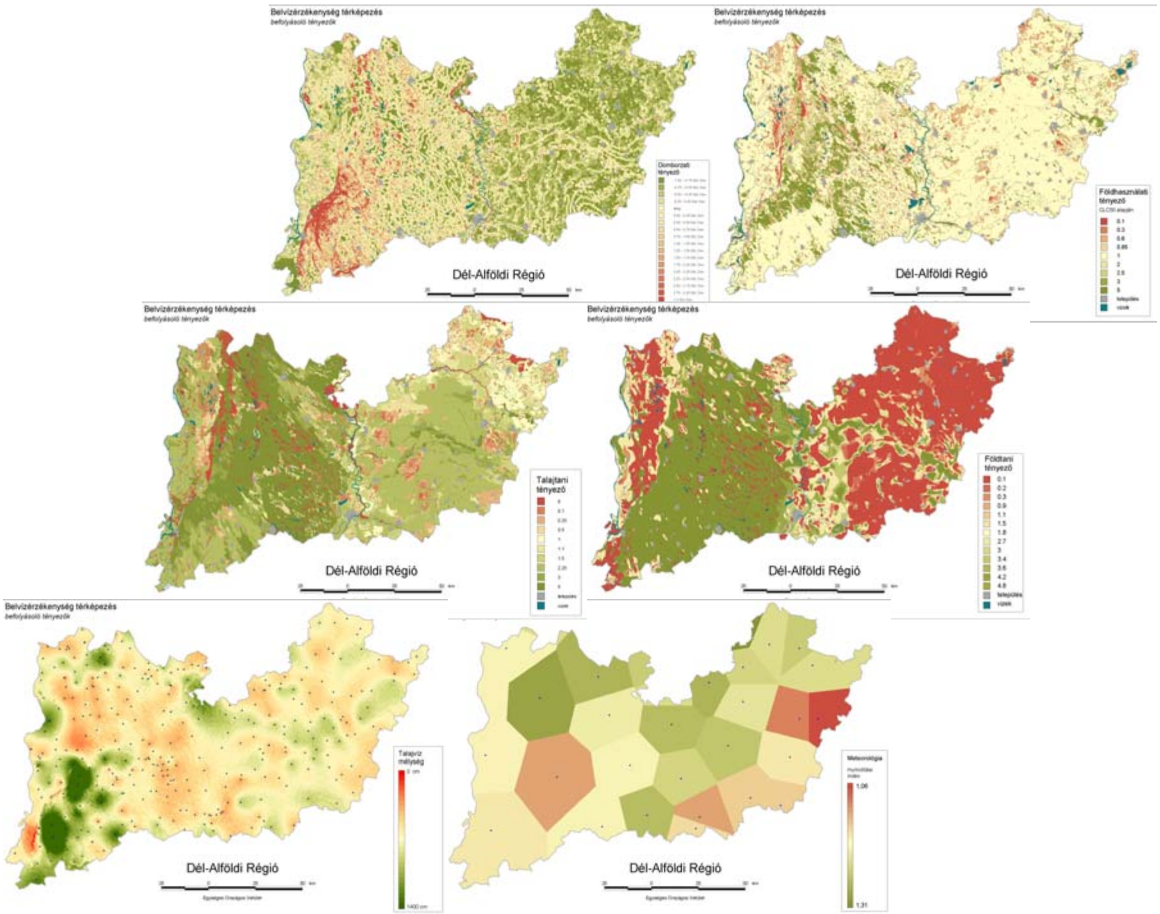

Figure 1 Spatial representation of the influencing factors: relief, landuse, soil, geology, groundwater and hydrometeorology

- Effect of relief on the formulation of excess water was modelled and spatially represented by a normalized version relief intensity; i.e. variation in elevation per square kilometre multiplied by elevation-max. elevation ratio: *RELI*.
- Effect of soil on the formulation of excess water was modelled and spatially represented by the soil's water management characteristics; i.e. soil water conductivity: *SOIL*.
- Effect of (agro)geology on the formulation of excess water was modelled and spatially represented by a complex index taking into consideration the depth and thickness of the uppermost aquitard: *GEOL*.
- Effect of groundwater on the formulation of excess water was modelled and spatially represented by the standard depth of groundwater; i.e. the average of its ten highest values within 50 years: *GW*. Groundwater parameter was interpolated using elevation as a covariable.

- Effect of land use on the formulation of excess water was modelled and spatially represented by a numeric coefficient based on CORINE Land Cover (CLC100) database and individually attributed to its categories: *LU*.

- Effect of hydrometeorology on the formulation of excess water was modelled and spatially represented by humidity index (10% possibility of occurrence of root square of sum of monthly weighted precipitation and sum of monthly weighted potential evapotranspiration ratio): *HI*.

The map of relative frequency of excess water events was also compiled. Its source is the yearly mapping of the areas damaged by inundation. The serial maps were overlaid providing an independent estimation of the spatial distribution of the most risky areas, as well as the dependent variable of a multiple statistical analysis. Since both its spatial resolution and confidence was weaker than those of the above listed factors, generalized versions of the quantified spatial layers (as independent variables) were jointly analysed with the relative frequency map in a grid with cell size of 1x1 km^2. Multiple regression was used for the determination of the role of various factors in the formulation of excess water thus providing weights for its linear estimation by the applied factors.

The regression procedure was carried out for various sub-datasets : for the two counties together and for one by one respectively as well as for five distinct geographical landscape units covering the pilot area.

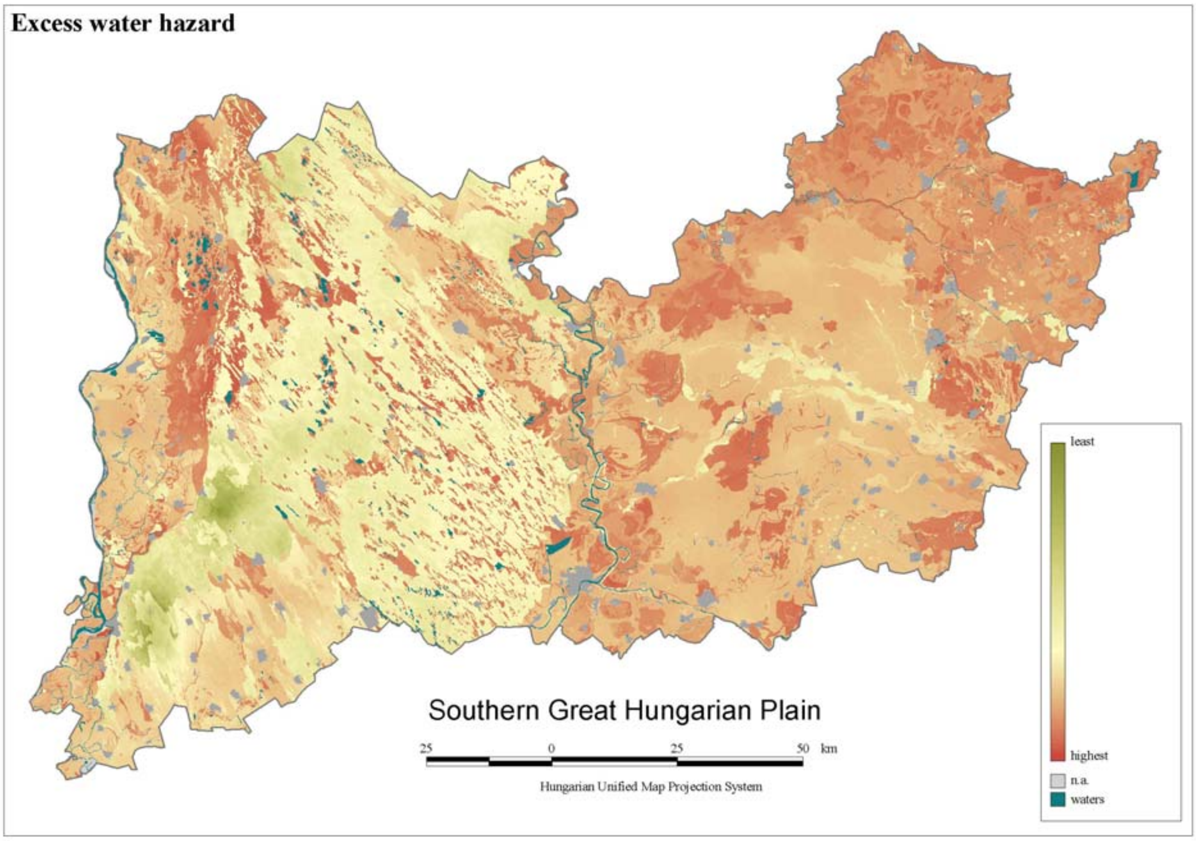

Figure 2 Excess water hazard map compiled for the Southern Plain Region

The goodness of fit was also considered. According to our experience involving humidity index in multiple regression rather worsened the fitness. As a consequence it was finally used just as a multiplying correction coefficient. Furthermore for the sake of standardization the values coming from the regression equation were multiplied by and added to a constant value, thus resulting in the *Complex Excess Water Hazard Index (CEWHI).* In the case of Csongrád county the resulted equation is as follows :

$$CEWHI_{Csongrád}=(2{,}417-0{,}021*GW-0{,}498*SOIL-0{,}038*RELI-0{,}074*LU-0{,}028*GEOL)*5*HI$$

The values provided by the equation were then used to compile the excess water hazard map based on the more detailed original map layers (Fig. 2).

4. Results and discussion

According to the final synthesis map the spatial distribution of excess water hazard can be studied in details. The most affected regions can be identified and delineated. The degree of hazard can be determined for various spatial element, e.g. affectation of settlements can be estimated, frequency of occurrences can be forecasted.

As a consequence the resulted risk map can be utilized in numerous land related activities: land use and agricultural planning, water management interventions, water oriented cultivation systems, wetland restoration etc.

The presented method could be refined. The resulted map is suggested to be more accurate using more detailed elevation model (based on larger scale topographic maps). Groundwater parameter should be also refined using denser monitoring network.

5. References

Bíró, T., Thyll, Sz., 1999, A belvíz-veszélyeztetettség térképezése. [Risk mapping of excess water (in Hungarian)], Vízügyi Közlemények 81(4), 709–718.

Pálfai, I., 1994, Az Alföld belvíz-veszélyeztetettségi térképe. [Excess water risk map of the Great Hungarian Plain (in Hungarian)], Vízügyi Közlemények 76(3), 278–290.

Pálfai, I., 2001, A belvíz definíciói. [Definitions of inland excess waters (in Hungarian)], Vízügyi Közlemények 89(3), 371–389.

Pásztor, L., Szabó, J., Bakacsi, Zs., 2002, GIS based quantification of depreciation of land due to inland water hazard, In: 'Proceedings of the 3rd International Conference on Land Degradation', CD-ROM (ISBN 85-85864-09-5), Embrapa Solos.

Pásztor L, Pálfai I, Bozán Cs, Körösparti J, Bakacsi Zs, Szabó J. Quantifying and mapping lowland excess water hazard. In: Faz A, Ortiz R, Garcia G eds. Extended abstracts of Fourth International Conference on Land Degradation, CD-ROM (ISBN 84-95781-40-9), Cartagena, 2004; pp.4.

Tamás J., 2003, Problems and solutions of field scale agro-ecological data acquisition and data interpretations in agroinformatical domain, Applied Ecology and Environmental Research 1(1-2), 143-157.