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THE GENERAL CHARACTERISTICS OF EXCESS SURFACE WATERS IN THE LOWER TISZA REGION, HUNGARY

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Abstract

Excess surface waters termed as inland waters are uniquely Hungarian phenomena. Their spatial distribution is characterized with the help of numeric and topographic data. The latest survey and comprehensive analysis of the distribution of these inland waters was concerned with observations up to 1980. Several excess surface waters have developed in the study area, which may serve as standards since the implementation of the survey. The aim of the present study on the one hand was to analyze the data of this extended study period. Furthermore, we were to test whether the so-called congregation or accumulation theory is applicable for the sizing of a planned drainage system. Our final results contributed to a more accurate understanding of the development of inland waters as well as a better evaluation.

The aim of the study

Excess surface waters termed as inland waters are uniquely Hungarian phenomena, with serious impact on the productivity of agriculture in its temporary developmental timing. No wonder their developmental mechanism, spatial distribution as well as questions of a proper definition have received much attention in Hungary since the beginning of the 1940s. The latest comprehensive spatial evaluation, embracing the period up to 1980, is from the hands of PÁLFAI (1994). He was also the one, who managed to come up with a complex overview surrounding the rather controversial definitions of the phenomenon (PÁLFAI, 2001).

The observed inland waters at the end of the 1990s and in 2000 called for an extension of the original study period regarding the frequency of inland water development. The present study involves the compilation of the results for the whole spectrum of data available for the Lower Tisza Region.

The process of inland water development

Struggle against water hazards in lowland areas generally involves uniquely special lowland measures, the so-called protection against inland waters. This activity is of crucial importance, as about 60% of the cultivated areas in Hungary are prone to temporary flooding by inland waters, affecting approximately more than 4 million hectars.

The major task of these protection measures is to prevent hazards resulting from unwanted water surplus on the lands. As natural ditches and other natural drainage channels, enabling the drainage of surface and seepage waters are generally lacking in lowland areas, surplus waters unable to infiltrate into the ground usually either accumulate in one place on the surface, or are collected in minor depressions lacking drainage.

In the 19th century, via the river regulation works, rivers were forced between artificial dikes enabling a control of the floodwaters and a gradual cessation or reduction of floods from that time onwards. However, with the cessation of one type of water hazard another one turned up: inland waters.

This term was collectively applied to waters, which accumulated on the protected flood free plains lacking free drainage because of the flood protection dikes. The problem was somewhat eased by first the construction of flood gates in the dikes, and later on that of pumping stations from 1878.

This way the inland waters could have been driven into the rivers, even in times of high waters in the riverbed constrained between the dikes, during the floods. However, due to the natural endowments of the lowlands and the special topographic setting (low relief, many closed drainage areas.), and the lack of a comprehensive artificial drainage system the efforts of driving these inland waters away from the affected areas into the rivers could not keep up with the pace of their development resulting in extensive flooded areas experiencing shorter-longer inland water coverage.

Unfortunately, not only the protected low-lying floodplain areas were affected by these inland waters, but the adjacent higher areas as well. Thus waters affecting these elevated areas are also referred to as inland waters. When these inland waters managed to filtrate into the lower-lying areas, they have significantly increased the floodwater coverage.

Regarding their hazardous effects, to put it short, inland waters are practically flood waters affecting lowland areas and resulting from a high watertable perching the surface of the ground. Similarly to the floodwaters of rivers, inland waters also derive from rainfall (melting snow or rain).

However, excess waters unable to infiltrate into the ground are not drained on the spot but accumulate in the minor depressions of this low relief area, and by being stored there for shorter or longer periods causes inland water inundations.

Excess surface waters can also develop as a result of a high watertable perching the ground surface in areas where the hydrology and geomorphology allows. Nevertheless, the source of these waters in this case is also rainfall.

If we consider this latter developmental mode of the excess surface waters as well, we can give the following definition of the phenomenon: *excess surface waters are surficial waters either temporary inundating lowland areas in lack of any natural mode of drainage or develop as a result of a high watertable perching the surface of the ground.*

Studies dealing with the occurrences of excess surfaces waters were usually put forth and advocated after major inundation events. The most recent survey on the whole area of the Great Hungarian Plains was implemented during the first half of the 1980s following the major inundations of the second half of the 1970s (PÁLFAI,. 1984).

However, the more recent considerable inundation events by these excess surface waters called for the complementation and reevaluation of these former data and results.

The data sources used in the study

Due to the extensive nature of hazards attributed to excess surface waters, the monitoring and recording process of the spatial distribution of these inundation events was implemented by several different monitoring organizations yielding data of different resolution and quality, thanks to differences in the methods applied during data collections and evaluations.

The units of water conservancy in Hungary have been continuously collecting hydrological data regarding the actual conditions of the watershed areas and those on the development of excess surface waters. While the units of agricultural administration (Regional County Agricultural Offices, Water Conservacy Units) were collecting data only in areas under their direct authority. Local governments were also dealing with cases in their areas. CD organizations recorded information on excess surface waters only in case of actual crisis. Data collected by these authorities were used primarily for developing operative defense plans and taking accurate measures. However, research institutes were more interested in using these data for elucidating the backgrounds of the development of excess surface waters along with the more accurate determination of the extension of affected areas, which might be helpful in future protection measures (e.g. BAUKÓ et al., 1981).

This slight difference must be the result of the deviations observable in the methods applied for data collection in operative defense work using surficial field data, and those applied in scientific work relying more and more on remote sensing data for an earlier event (RAKONCZAI et al., 2001). Unfortunately, these latter works are generally concerned with relatively recent data, hampering the availability of long-term data series. Furthermore, use of data from other resources is rather limited in these investigations.

Relatively uniform and continuous data for a longer time period (say more than 50 years) on these excess surface waters is available from the water conservancy authorities exclusively including such details as the proportion of runoff from these waters, the size and spatial distribution of inundated areas and other important hydrological parameters like temperature, rainfall, ground frosts etc. Consequently, all the information in this database was used as a major starting point in our investigations.

In water conservancy practice the initial evaluation of the excess water hazard events determines the possible effects of these excess waters accumulated in an area on the local hydrological measures. The following situations are generally considered to be excess water hazard events:

- In times when high water levels in the natural outlet streams of the watershed area (rivers, creeks etc) prevent the natural gravitational transportation of the excess waters into them (in these cases stable or mobile pumps located next to the influx serve to pump these waters into the outlet), *or*
- Excess surface waters inundate larger areas.

Besides the quantitative numeric parameters of these excess surface waters, the approximate spatial extension of the inundations is also continuously monitored and recorded just like any changes by the local experts of the water conservancy authorities.

Surface monitoring and data collection generally involves field measurements and predictions as well as the systematic use of cadastre maps, during the course of which data on the approximate distribution of these excess surface waters and the inundated areas are applied to maps of 1:10000 and 1:25000 in relation to clearly identifiable objects.

After the cessation of the hazard event, the locally collected map data regarding maximum extension of inundations is applied onto a collective comprehensive map.

The resolution of the maps is in accordance with the expected resolutions required by the given protection measures. For the times preceding the 1950s, maps depicting the spatial distribution of inundated areas by excess surface waters are generally lacking with only recorded numeric information available.

The available maps depict the most significant inundation events in the country with the exception of the years 1941-42, which otherwise were the mostly affected periods in modern history. From the second half of the 1950s maps depicting maximum inundation are readily available in the hydrological archives. So these were primarily used in our investigations.

Methods applied

As a first step the available maps were converted into a raster digital format via scanning and the contours of the inundated areas were digitized. After the necessary topographic transformations, the resulting vector data was depicted in a cumulative map of unified national projection system (EOV).

From the resulting maps and database containing information on annual inundations the frequency of excess surface water inundation events was determined with the help of geoinformatical tools and methods for the areas monitored by the Lower Tisza Region Water Conservancy Authority (ATIVIZIG) (**Fig.1.**).

The resolution of the digital database was fundamentally determined by the original scales of the paper maps being between 1:50000–1:100000. The layer embedding vector information on the hydrography of the area was applied onto the received working map.

A major problem we had to face derived from the fact, that in several cases a single map contained multiple information on a single inundation event, but with different contours of the borderline of inundated areas in certain cases..

The resolution of the prepared final map hampered the possibility of drawing local, high resolution conclusions at the scale of plots. However, these maps are generally adequate for strategic planning in hazard protection measures.

Consequently, our evaluations were restricted to the files with events of the period for the past 50 years (1957-1959, 1962-1963, 1965, 1967-1982, 1986-1987, 1991, 1993, 1999-2001).

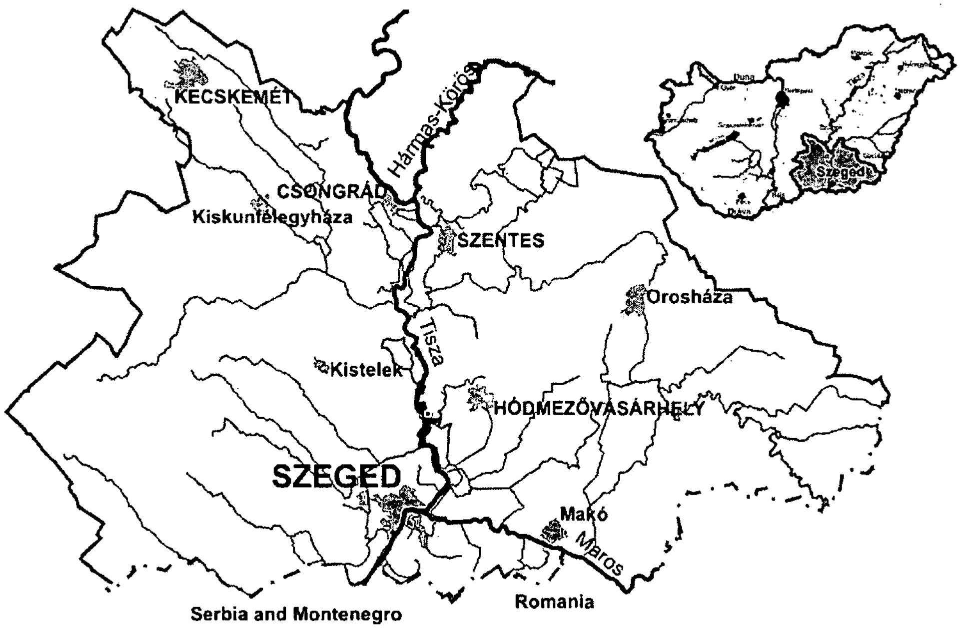

Figure 1. The areas monitored by the Lower Tisza Region Water Conservation Authority (ATIKÖVIZIG)

Results

According to our findings the area of the Lower Tisza Region can be subdivided into three, well-distinguished subregions, characterized by differing excess surface water parameters (areas on the right banks of the river Tisza, those on the left banks including the[1] alluvial fan of the river Maros, and the Torontál). This subdivision is not congruent with the actual spatial extension of the mentioned landscape areas in all cases, but seems to be adequate from the point of view of our investigation results.

In case of the areas located on the right banks of the Tisza excess surface waters generally accumulate and are being stored *in natural depressions.* In this area runoff coming from the direction of the Danube-Tisza Interfluve ridge is collected in the valleys hosting the outlet streams and generally inundate the areas adjacent these outlets. The most frequently inundated areas are those at Gátér-Fehér Pond, Sós Pond plus their vicinities, as well as the drainage channel network Percsora. It is important to note, however the areas of Gátér-Fehér Pond, Sós Pond were included in the drainage network as potential storage areas.

Thus channels usually drive runoff from the upper parts of the watershed into these reservoirs until the development of favorable hydrological conditions. Possibilities preventing the drainage of these waters are generally low here.

[1] Collection of excess surface water data is restricted to separate watershed areas. In order to get a comprehensive view, these pieces of information are sometimes unified involving data deriving from several adjacent watersheds, and the term inland water landscape unit is applied.

The process of water accumulation is well-suited for analysis thanks to the favorable topography of the studied area. The frequency and value for the development of excess surface waters in areas located larger distances from the drainage channels is uniform and low. Thus the collection of these waters can be explained by the traditional accumulation theory as far as the rim of the channels (**Fig. 2.**). However, the areas running along the channels are much more frequently inundated than their more distant counterparts, which can not be fully explained by the traditional accumulation theory alone.

Rather the so-called "line up theory" should be applied onto these cases (VÁGÁS, 1989). According to this, the drainage capacity and directions is determined by not the quantities of the accumulated excess waters, but the storage and carrying capacity as well as general hydrological conditions of the outlet. When too much water arrives at the outlet, the volumetric difference will be stored in the vicinity of the influx points starting out from the first point upstream along the drainage channel.

This clearly explains the greater frequency of inundations along the drainage channels, and is especially true to the mouth areas of streams.

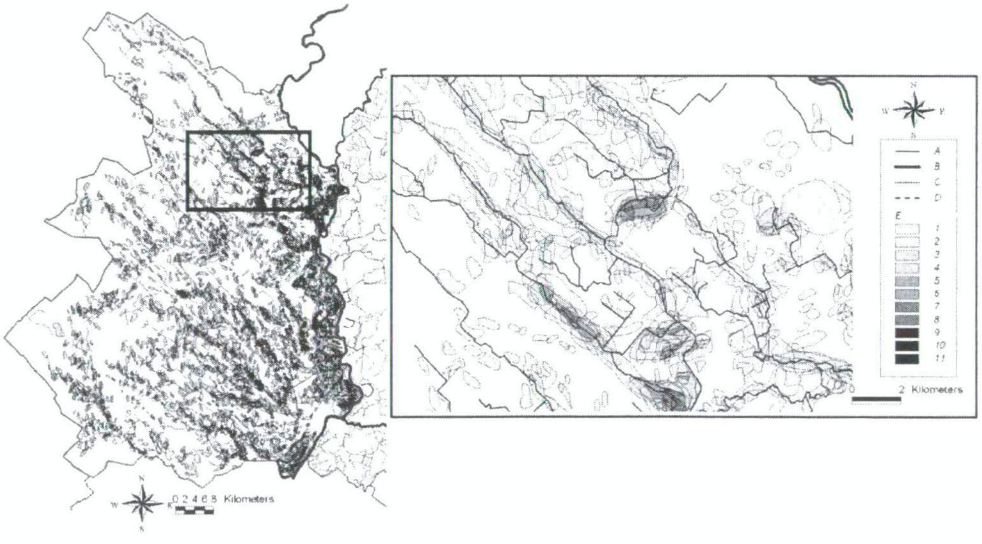

Figure 2. The frequency of inundations by excess surface waters in the monitored region on the right banks of the river Tisza

Legend: **A** – channel network; **B** – rivers; **C** – boundaries of administration units; **D** – operational area boundary of ATIKÖVIZIG; **E** – categories of frequency of excess surface water

Another characteristic feature of this area is the increase in the relative frequency of inundations in the areas adjacent to the river Tisza parallely with its course. The first adequate explanation of this phenomenon can be found in the work of SALAMIN (1942): the high waters during floods are of crucial importance in the formation of inland waters along the rivers, as these waters may infiltrate through or below the dikes into the adjacent protected areas causing inundations.

By applying the "line-up theory" this explanation of SALAMIN (1942) can be complemented as follows: *the development of inland waters is determined primarily not by seepage through the dikes in areas adjacent to rivers, but rather the upper limit of the carrying capacities of pumps located at the influx of the drainage channels into the outlet stream. The range of inland waters deriving from seepage through the dikes is only about 100-300 m.*

Three areas most affected by inundations could have been identified in the region *in the left banks of the river Tisza* (**Fig.3.**): northeast of the city of Szentes, south of the cities of Orosháza and Hódmezővásárhely. In this unit *there is no characteristic increase in the frequency of inundations and excess surface waters along the drainage channels.* This must be attributed to the fact that runoff waters tend not to rush directly into the drainage outlets due to a lower relief.

Conversely, this lower relief also limits the carrying capacity of the drainage channels.

The affected area in the vicinity of Orosháza is located at the end point of the drainage network, where the carrying and storage capacity of the system is generally low.

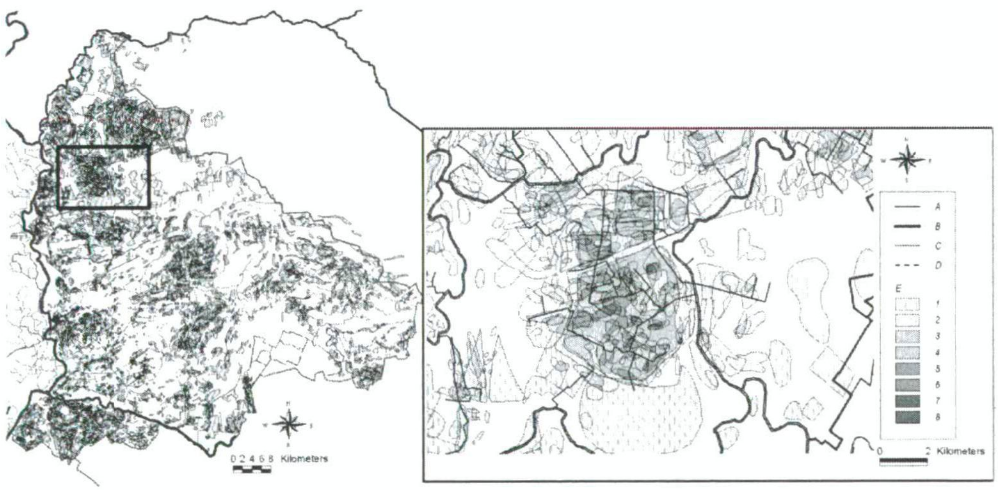

Figure 3. The frequency of inundations by excess surface waters in the monitored region on the left banks of the river Tisza

Legend: **A** – channel network; **B** – rivers; **C** – boundaries of administration units; **D** – operational area boundary of ATIKÖVIZIG; **E** – categories of frequency of excess surface water

In case of the examples from the vicinities of Szentes just like the measured regional maximum of Hódmezővásárhely, the reduced carrying capacity of the channels deriving from the low relief must be blamed for the higher frequency of inland water inundations. Here, the area of the alluvial fan of the river Maros must be separately mentioned, as excess surface waters also tend to have an underground source there (from groundwaters).

It must be noted, that higher frequencies in inundation were observable in areas running along the major watercourse, the river Tisza only. While such an increase in case of the two other marginal watercourses of the Hármas-Körös and Maros was not so unambiguous.

In case of the area of the *Torontál* (**Fig.4.**) inundations by excess surface waters tend to be more frequent than in case of the two former studied areas, *in a relatively homogenous distribution for the whole region.* The storage capacity of the drainage system has very low future resources, with inundated areas often appearing adjacently to the drainage channels as well. This must be attributed to the fact, that this landscape unit is the one with the lowest elevation in Hungary. The frequency of inundations along the rivers can not be clearly differentiated from other distant parts of the mentioned area.

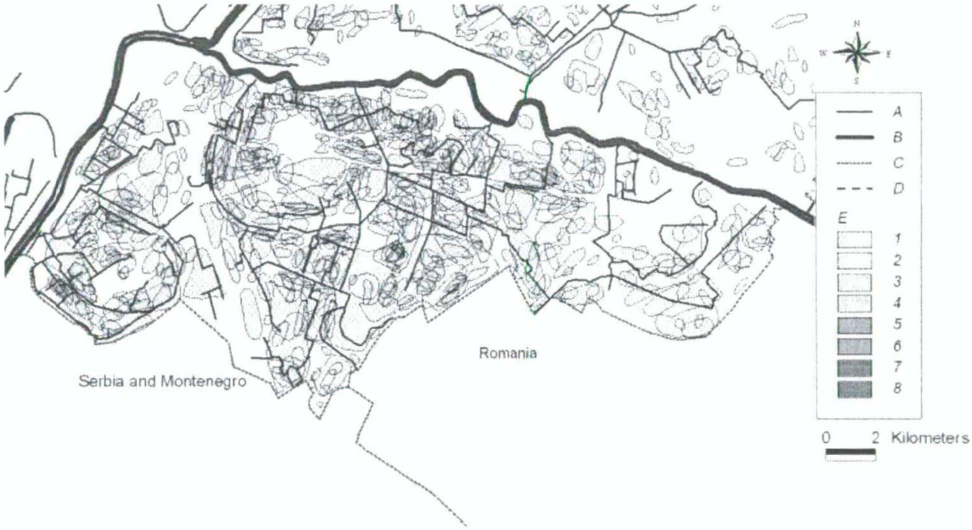

Figure 4. The frequency of inundations by excess surface waters in the Torontál landscape unit

Legend: **A** – channel network; **B** – rivers; **C** – boundaries of administration units; **D** – operational area boundary of ATIKÖVIZIG; **E** – categories of frequency of excess surface water

Possibilities for practical usage

Since the exact delineation of the areas inundated by excess surface waters is a factor of the geomorphological characteristics of the studied landscape primarily, as well as the technical background used in the surveys (RAKONCZAI et al., 2001), the application of modern remote sensing techniques besides the regular surficial field monitoring would be highly desirable. The resulting data by the application of these new analytical methods would largely increase the accuracy of the prepared database, as well as the reliability of the evaluations. Thus the utilization of these modern remote sensing methods (satellite and aerial photos) during the field surveys is highly advocated. This way on the one hand, more accurate maps could be prepared.

On the other hand, it also gives a possibility for the calibration of these extensive, and rapidly available survey data from remote sensing with those actually recorded on the field.

During the improvement of the drainage network not only the water carrying capacities of the channel systems should be improved, but their storage capacities as well, especially in areas highly prone to inundation by excess surface waters. This is especially applicable to areas located on the left banks of the river Tisza and the Torontál. An increase in the storage capacity of these systems would largely reduce maintenance costs, as the construction of new drainage channels into the original system would require higher financial resources than the expenditures related to increasing the storage capacity of the present system.

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