Éva Konkoly-Gyuró[*], Géza Király[**], Nagy Dezső[***], Pál Balázs[*****], Ágnes Tirászi[*****]

Overview of the 18th-20th century military surveys in the light of the land cover change assessment in Eastern Central Europe

Keywords: historic maps, military surveys, land use, land cover change

Summary: Land cover change is the key issue of landscape history as it reflects the most relevant transformation of the use of natural resources, the land- and water management, the development of settlement structure and the changing environmental quality. Long term assessment of land cover change allows us to understand man-nature relationships and the positive and negative consequences of the changes both in environmental and in the socio-economic sense. Historical topographic maps of medium scale (1:50000-1:20000) from the late 18th century, made primarily for military purposes, covering large geographic areas in several time layers in Europe, represent extremely rich sources for the landscape historical research. Amongst the several regular European map series we can find the Habsburg Military Surveys (HMSs), prepared from the mid 18th till the beginning of 20th century in three time layers, at a scale of 1:28800 and 1:25000, for a particularly large area of Europe. Although the map sheets of the 18th century have several geometrical and content related drawbacks, they provide invaluable information about the landscapes before the huge water reclamation and the regular statistical data collection. After the First World War, the countries becoming independent following the disintegration of the Austro-Hungarian Monarchy started to create their own mapping systems; however the methodology, the content, the scale and accuracy have been highly similar, especially after the Second World War during the communist period. The growing accuracy of the military surveys provide ever more valid information about land cover changes of the last two centuries.
This paper describes, compares and evaluates the geometric and thematic content and accuracy of the 18th-20th century military surveys from the point of view of the land cover and land use change. By highlighting the opportunities and the constraints of their use, it is intended to guide researchers in using these old maps.

Introduction

Landscapes, as complex, spatial environmental systems, reflect the result of the permanent man-nature interactions. Landscape history reveals the facts and the driving forces of changes both in natural and human systems. Landscape transformation influences the environmental quality of our everyday living spaces. Land use and land cover are key issues of the landscape dynamic, showing the results of multiple impacts. Landscape history therefore focuses primarily on the land cover changes. A growing number of scientific studies on land cover change generally contribute to

[*] Professor, Institute of Forest Management and Rural Development, Chair of Landscape Science, University of Sopron, Bajcsy-Zsilinszky u. 4, H-9400 Sopron, Hungary, +36 30 9494 883 [konkoly-gyuro.eva@uni-sopron.hu]
[**] Associate Professor, Institute of Geomatics, Forest Opening-up and Water Management, University of Sopron, Bajcsy- Zsilinszky u. 4, H-9400 Sopron, Hungary
[***] MsC in Ecology. Municipality of Miskolc, Városház tér 8. H-3525 Miskolc, Hungary
[*****] MsC in Environmental Sciences, Institute of Environmental and Earth Sciences. University of Sopron, Bajcsy-Zsilinszky u. 4, H-9400 Sopron, Hungary
[*****] Assistant Professor Institute of Forest Management and Rural Development, Chair of Landscape Science, University of Sopron, Bajcsy- Zsilinszky u. 4, H-9400 Sopron, Hungary

landscape historical assessment even though the underlying concept and the purpose of the use of the results may be different. One concept is the *biological/ecological approach* that considers landscape as a complex of mostly natural, semi-natural habitats. These studies refer predominantly to land cover changes of forests, grasslands and wetlands[1] as well as to the *change of hemeroby/naturalness.*[2] In that concept it is assumed that with additional information of field work or ecological factors, land cover types can be considered as equivalent with habitat types in a definite study area. Historical assessments based on an ecological approach have predominantly the purpose of providing basic information for habitat restoration or landscape reconstruction.[3] Second is the *land use, landscape management, planning and policy approach,* where the landscape dynamic and their driving forces are taken into account as basic information for future strategies In these studies natural and artificial surfaces are considered as equally significant, dealing mostly both with land use (impact) and land cover (state).[4] Despite the fact that the terms "land cover" and "land use" have different meanings and partly different categorisations, they are often used and understood as synonyms. Their similarities and dissimilarities can be seen in Figure 1.

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[1] Change in forests using old historical land use maps is dicussed for example by K. Verheyen, B. Bossuyt, M. Hermy, G. Tack, *The land use history (1278–1990) of a mixed hardwood forest in western Belgium and its relationship with chemical soil characteristics*, Journal of Biogeography 26(5) (1999) 1115-1128; and J. Kozak, *Forest Cover Change in the Western Carpathians in the Past 180 Years - a case study in the Orawa Region in Poland*, Mountain Research and Development 23(4) (2003) 369-375.
Botanical interpretation of grassland loss is presented in M. Biró, Z. Molnár, F. Horváth, A. Révész, *Measuring habitat loss in the Kiskunság based on historical and actual habitat maps*, in: E. Kovács-Láng, E. Molnár, G. Kröel-Dulay, B. S. (Eds.), The KISKUN LTER: Long-term ecological research in the Kiskunság, Hungary 2008, 13-14. and M. Biró, B. Czúcz, F. Horváth, A. Révész, B. Csatári, Zs. Molnár, *Drivers of grassland loss in Hungary during the post-socialist transformation* (1987-1999), Landsc. Ecol. 28(5) (2013) 789-803.
Changes of wetlands due to the floodplain reclamation and intensification of agriculture and land cover conversions is described by K. Varga, G. Dévai, B. Tóthmérész, *Land use history of a floodplain area during the* last 200 years in the Upper-Tisza region (Hungary), Regional Environmental Change 13(5) (2013) 1109-1118. and G. Takács, *Tájalakítás és a felszínborítás változásai a Hanságban a XVIII –XX. században, (Changes in landscape transformation and land cover in the Hanság over the 18th-20th centuries)* Tájökológiai Lapok *(Hungarian Journal of Landscape Ecology)* 9(1) (2011) 13-42.

[2] Hemeroby describes gradients of human influence on landscape and is dicussed in T. Wrbka, K.-H. Erb, N.B. Schulz, J. Peterseil, C. Hahn, H. Haberl, *Linking pattern and process in cultural landscapes. An empirical study based on spatially explicit indicators*, Land Use Policy 21(3) (2004) 289-306. For naturalness see A. Catorci, M. Foglia, F. Maria Tardella, A. Vitanzi, D. Sparvoli, R. Gatti, P. Galli, L. Paradisi, Map of changes in landscape naturalness in the Fiastra and Salino catchment basins (central Italy), Journal of Maps 8(1) (2012) 97-106.

[3] Landscape restoration studies see D. Nagy, *Tájtörténeti kutatások a Gömör-Tornai-karszton. (Landscape historical research in the Karstic region Gömör-Torna)* I. A történelmi táj rekonstrukciója az ANP környezetében az I-III. Katonai Felmérések alapján, Jósvafő, 2003.; A. Czinege, A. Kiss, M. Horváth, Elhagyott teraszok és a történeti tájhasználat rekonstrukciós lehetőségei *(Abandoned terraces and options for reconstruction of historical land use)*: A nagymarosi teraszrendszer példája, in: G. Barton, G. Dormány (Eds.), A magyar földrajz kurrens eredményei, SZTE TTK Természeti Földrajzi és Geoinformatikai Tanszék, Szeged, 2004, 1-12.

[4] T. Kuemmerle, D. Müller, P. Griffiths, M. Rusu, *Land use change in Southern Romania after the collapse of socialism*, Regional Environmental Change 9(1) (2009) 1-12. See also a Hungarian example É. Konkoly-Gyuró, Á. Tirászi, P. Balázs, D. Nagy, G. Király, A vízrendszer, a felszínborítás és a tájkarakter változása a Fertő-Hanság medencében. *(Changes in water system, land cover and landscape character in Fertő-Hanság Basin)* in: Gy. Füleky (Eds): A táj változásai a Kárpát-medencében. A vízgazdálkodás története a Kárpát-medencében. X. Tájtörténeti Konferencia kötete. Környezetkímélő Agrokémiáért Alapítvány. 2014, 42-48.

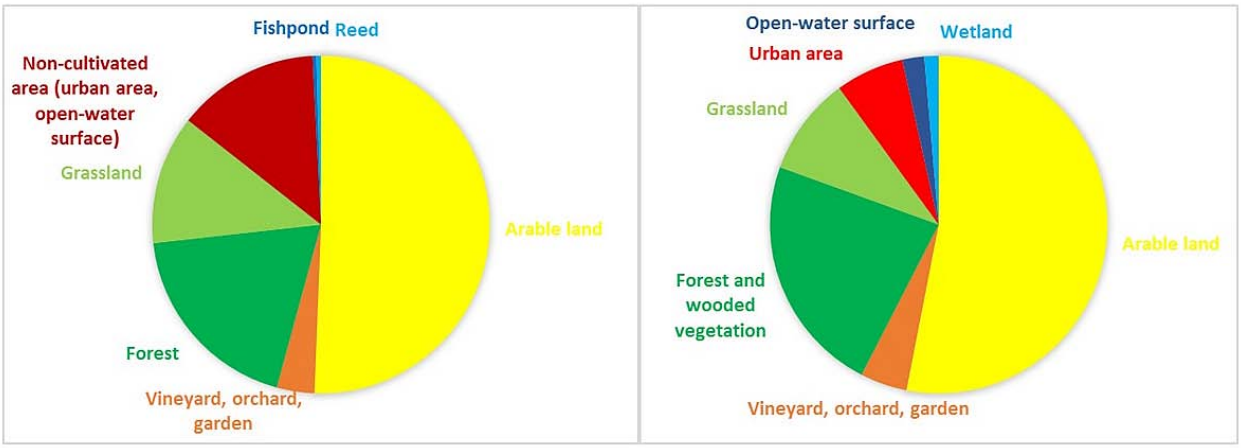

Figure 1: Land use (1998) and land cover (1998-1999) statistics of Hungary (Institute of Geodesy, Cartography and Remote Sensing, FÖMI; Hungarian Central Statistical Office, KSH)

It should be highlighted, that amongst studies of Land Cover and Land Use Change (LCLUC) special attention has recently been given to the *water* and water related landscape restoration, water management and flood prevention. In these studies, the ecological and the planning approaches overlap.[5]

Furthermore, the *spatial extent* and the *time span* of the change analysis are most decisive in many of research studies. Concerning the spatial dimension firstly, there are an increasing number of studies at a *local scale* comprising areas of several km^2, dominated mostly by the ecological approach and focusing on habitats[6]. The second is the *regional or landscape scale*, assessing geographical landscapes (e.g. Provence, Schwarzwald, Pannonian Plain) or landscape types (e.g. river basin, hill, mountain range, or biogeographical region). The landscape scale is therefore broad, and can divided into *micro landscapes* e.g. Fertő/Neusiedlersee basin[7], and *macro landscape scale* e.g. the Carpathian basin[8]. There are also assessments on a *national scale* as case studies[9], or map series available in national atlases. In these cases, political borders obviously divide natural landscape units. The

[5] See examples on the River Tisza in Hungary by D. Nagy, *A történeti felszínborítás térképezése a Tisza-völgyben, (Mapping of the historical land cover of the Tisza Valley)* in: Z. Flachner, A. Kovács, É. Kelemen (Eds.), A történeti felszínborítás térképezése a Tisza-völgyben. A Tisza biológiai változatosságának megőrzése integrált ártéri gazdálkodás segítségével, SZÖVET, Nagykörű, Eger, Budapest, 2008, 40-59. and K. Varga, G. Dévai, B. Tóthmérész, *Land use history of a floodplain area during the last 200 years in the Upper-Tisza region (Hungary)*, Regional Environmental Change 13(5) (2013) 1109-1118.; Zs. Pinke, *Modernization and decline: an eco-historical perspective on regulation of the Tisza Valley, Hungary*, Journal of Historical Geography 45 (2014) 92-105.

[6] See for instance M. Biró, F. Horváth, O. Papp, Z. Molnár, Historical landscape changes near Fülöpháza in the Kiskunság, in: E. Kovács-Láng, E. Molnár, G. Kröel-Dulay, B. S. (Eds.), The KISKUN LTER: Long-term ecological research in the Kiskunság, Hungary, Institute of Ecology and Botany, Vácrátót, 2008, 11-12.

[7] M.A. Prinz, T. Wrbka, K. Reiter, Landscape Change in the Seewinkel: Comparisons Among Centuries, in: J. Anděl, I. Bičík, P. Dostál, Z. Lipský, G.S. Shahneshin (Eds.), Landscape Modelling: Geographical Space, Transformation and Future Scenarios, Springer Netherlands, Dordrecht, 2010, 123-132.

[8] See C. Munteanu, T. Kuemmerle, M. Boltiziar, V. Butsic, U. Gimmi, H. Lúboš, D. Kaim, G. Király, É. Konkoly-Gyuró, J. Kozak, J. Lieskovský, M. Mojses, D. Müller, K. Ostafin, K. Ostapowicz, O. Shandra, P. Štych, S. Walker, V.C. Radeloff, Forest and agricultural land change in the Carpathian region - A meta-analysis of long-term patterns and drivers of change, Land Use Policy 38 (2014) 685-697.

[9] See for example J. Feranec, J. Oťahel, *Land cover/land use change research and mapping in Slovakia*, Geographica Slovaca 26 (2009) 169–190.

research of landscape changes in *border landscapes*, where the human impact is dissimilar due different political regimes, provides useful information on the role of human impact.[10] Recently there have also been land cover maps and studies on *continental*[11] or *global scale*.[12]

The time scale of the investigation – according to the availability of adequate historic maps - goes back to the 18th century.[13] That was the age when the first cadastral and military maps in Europe were drawn, containing accurate and topographically comparable information on the LCLUC at a medium scale (1:28800–75000), suitable for the historical assessment of landscapes. Formerly the maps of the sixteenth-seventeenth centuries at medium scale give useful, but only partial information on land cover.[14] To study the land cover change of the time before the 18th century other sources than maps should be additionally used.

From the mid 18th century, the development of cartography made it possible to prepare maps that are adequate for LCLUC assessment. These ancient hand drawings, as piece of art take us on a trip in the previous centuries. Although written sources, object remnants, engravings, paintings etc. are also rich pools of information about past landscapes, maps remain the most relevant sources, especially for land-cover change research. The period we focus on is nearly 250 years from the mid 18th till the late 19th century, when the medium scale military surveys were prepared in a systematic way with adequate thematic details and geometric precision allowing a comparison of land use and land cover change assessment.

There are two types of literature describing the historical maps. The first is *cartographic studies* presenting the purpose and circumstances of the mapping and providing technical details, e.g.

[10] See further for cross-border comparison studies T. Kuemmerle, P. Hostert, V.C. Radeloff, S. van der Linden, K. Perzanowski, I. Kruhlov, *Cross-border Comparison of Post-socialist Farmland Abandonment in the Carpathians*, Ecosystems 11(4) (2008) 614.; P. Balázs, É. Konkoly-Gyuró, T. Wrbka, *Land cover continuity as a tool for nature conservation: Landscape changes in Lake Fertő/Neusiedler See transboundary region during the past 200 years*.Verhandlungen der Zoologisch-Botanischen Gesellschaft in Österreich 153 (2016) 47-65. ; P. Sklenicka, P. Šímová, K. Hrdinová, M. Salek, Changing rural landscapes along the border of Austria and the Czech Republic between 1952 and 2009: Roles of political, socioeconomic and environmental factors, Applied Geography 47 (2014) 89-98.

[11] Perhaps the most notably is the EEA, CORINE Land Cover, 1995. http://www.eea.europa.eu/publications/COR0-landcover last accessed 27 March 2017.

[12] K.K. Goldewijk, *Estimating global land use change over the past 300 years*: The HYDE Database, Global Biogeochemical Cycles 15(2) (2001) 417-433.;J.A. Foley, R. DeFries, G.P. Asner, C. Barford, G. Bonan, S.R. Carpenter, F.S. Chapin, M.T. Coe, G.C. Daily, H.K. Gibbs, J.H. Helkowski, T. Holloway, E.A. Howard, C.J. Kucharik, C. Monfreda, J.A. Patz, I.C. Prentice, N. Ramankutty, P.K. Snyder, Global Consequences of Land Use, Science 309(5734) (2005) 570-574.

[13] D. Nagy, A történeti felszínborítás térképezése, (*Mapping of the historical land cover)* in: Z. Flachner, A. Kovács, É. Kelemen (Eds.), A történeti felszínborítás térképezése a Tisza-völgyben. A Tisza biológiai változatosságának megőrzése integrált ártéri gazdálkodás segítségével, SZÖVET, Nagykörű, Eger, Budapest, 2008, 7-40; Nagy, Tájtörténeti kutatások a Gömör-Tornai-karszton *(Landscape historical research in the Karstic region Gömör-Torna)* I. A történelmi táj rekonstrukciója az ANP környezetében az I-III. Katonai Felmérések alapján, 107-143; J. Skaloš, M. Weber, Z. Lipský, I. Trpáková, M. Šantrůčková, L. Uhlířová, P. Kukla, Using old military survey maps and orthophotograph maps to analyse long-term land cover changes – Case study (Czech Republic), Applied Geography 31(2) (2011) 426-438.; H. Skokanová, M. Havlíček, R. Borovec, J. Demek, R. Eremiášová, Z. Chrudina, P. Mackovčin, R. Rysková, P. Slavík, T. Stránská, J. Svoboda, Development of land use and main land use change processes in the period 1836–2006: case study in the Czech Republic, Journal of Maps 8(1) (2012) 88-96.

[14] Á. Papp-Váry, P. Hrenkó, *Magyarország régi térképeken (Hungary on old maps)*, Gondolat-Officina Nova, Budapest, 1989.; L. Stegena, *Térképtörténet (Map history)*, Tankönyvkiadó, Budapest, 1981.

projection, geometrical accuracy, and availability.[15] The content related description, and thematic presentation e.g. legend are less detailed, and their potential usability is rarely mentioned. The second type consists of the user studies focusing on a certain topic, on the *methods of data processing and on the results and conclusions* derived from the maps.[16] Only a few studies assess the maps from a landscape historical point of view.[17] Because ancient maps going back several centuries have different content and accuracy, their comparability is often questionable, although it is a basic requirement for the quality of the results. To survey their content and geometry, thus the applicability of the old maps is highly relevant.

Till the end of the 20th century, maps and aerial photographs were interpreted on paper, but recently the development of GIS technologies offers much larger possibilities for processing historical maps. Different maps can be directly compared by overlaying them. However, the geometric and thematic harmonisation of these maps is inevitable for their GIS analysis and the further evaluation of the results. This paper gives an overview of medium scale (1:28800, 1:25000) topographic military maps over nearly 250 years in the geographical area of Eastern Central Europe. It is intended to assess and evaluate in detail the usability of these military maps from the point of view of the land cover and land use change research.

Material

Material of the present assessment are the Habsburg Military Surveys (HMS) from the 18th century and the New Survey (NS) from the mid 20th century. Due to strategic reasons, the systematic mapping of the Habsburg Empire started in the 1760s and continued till the First World War. These were the first regular map series of Eastern Central Europe. Original, coloured, manuscript map sheets are available in the Military Archive of Vienna and the reprints in Budapest at the Archives of the Hungarian War History, as well as in other archives of the countries of the former Habsburg Empire (17th century - 1867) and Austro-Hungarian Monarchy (1867-1920).

The HMS-s have a scale of 1:28800 and 1:25000 and represent a particularly rich information source of landscape and environmental history. Given that the relief, the land cover with special emphasis on

[15] See E. Hofstätter, *Beiträge zur Geschichte der österreichischen Landesaufnahmen*, Bundesamt für Eich- und Vermessungswesen1989.; U. Sporrong, Land survey maps as historical sources, in: S.U.H.-F. Wennström (Ed.), *Maps and Mapping. National Atlas of Sweden*, Stockholm, 1990, 136-145.; M. McGranaghan, A Cartographic View of Spatial Data Quality, Cartographica: The International Journal for Geographic Information and Geovisualization 30(2-3) (1993) 8-19.; G. Timár, G. Molnár, A második katonai felmérés térképeinek közelítő vetületi és alapfelületi leírása a térinformatikai alkalmazások számára, Geodézia és Kartográfia 55(5) (2003) 27-31.; G. Timár, S. Biszak, G. Molnár, B. Székely, Z. Imecs, A. Jankó, Digitized maps of the Habsburg Empire – First and Second Military Survey, Grossfürstenthum Siebenbürgen., DVD issue, Arcanum Database Ltd., Budapest, 2007.

[16] See F. Kienast, Analysis of historic landscape patterns with a Geographical Information System — a methodological outline, Landsc. Ecol. 8(2) (1993) 103-118.; J.T. McClure, G.H. Griffiths, Historic Landscape Reconstruction and Visualisation, West Oxfordshire, England, Transactions in GIS 6(1) (2002) 69-78.; C.C. Petit, E.F. Lambin, Impact of data integration technique on historical land-use/land-cover change: Comparing historical maps with remote sensing data in the Belgian Ardennes, Landsc. Ecol. 17(2) (2002) 117-132.; M. Boltižiar, V. Brůna, K. Křováková, Potential of antique maps and aerial photographs for landscape changes assessment - An example of the High Tatra Mts, Ekologia 27(1) (2008) 65-81.

[17] N. Vuorela, P. Alho, R. Kalliola, Systematic Assessment of Maps as Source Information in Landscape-change Research, Landscape Research 27(2) (2002) 141-166.; P. Mackovcin, Land use categorization based on topographic maps, Acta Pruhoniciana 91 (2009) 5-13.

wooded vegetation, watercourses, roads, settlements, sacral buildings, and industrial facilities were indicated on the map sheets, they enable us to study the landscape transformation of Eastern Central Europe during the last 250 years in a systematic, standardized way. The scale, the content, and the quality of the HMSs make them among the best European cartographic works in this period.

Applicability of the HMSs have been promoted by publishing them in a digitized and georeferenced format in Hungary by ARCANUM Ltd "making this valuable cultural heritage available for both professionals and non-professionals."[18] DVDs cover not only the present territory of Hungary, but also Slovakia, the Zakarpatska territory of Ukraine, Burgenland, the Voivodina in Serbia, the border zone of Romania to Hungary and small parts of Poland, Croatia and Slovenia. The mosaicked content can be exported to the GIS software of the user in various projection systems used in these countries. Using the two georeferenced sets of Transylvania, in 2007 Arcanum provided a synchronized DVD with the First and Second Surveys of the region. The map sheets of the Third Survey were also published in 2007, in two scales.1:25000 scale survey sheets cover the historical Hungary (the whole above mentioned territory and Croatia), based on the Budapest archives.[19] 1:75000 scale general sheets of the whole Monarchy were published as it was originally a printed product in the 1880s." [20]

A reambulation and new mapping, according to the political interest started after the First World War, but the result is rather scattered, the corrected and new maps of the 1920-40th-s do not cover the entire area of the countries succeeding the Austro-Hungarian Monarchy. The New Survey after the Second World War started in the 1950s. These topographic military maps were prepared in several scale (1:25000; 1:50000; 1:100000) and covered the whole areas of countries of Central-Eastern Europe.

Method

The overview and valuation of the map series has three parts. Based on relevant publications, the first part summarises the main characteristics of the HMS-s and the NS. Second part presents in detail the land cover categories that can be identified on the map sheets. The third part gives a valuation of the maps according to the experience of several land cover change studies of the authors. Thematic comparability, geometric uncertainties and the limitations of the use are also expressed.

General description of the military map series based on literature survey covers the topics as follows: historical time period and purpose of the mapping; area coverage; scale, projection system, geometric accuracy; number, extent and surveying years of the map sheets; symbols and colouring used for displaying the thematic content; graphics for indicating relief; identifiable land cover categories and additional information if relevant.

Presentation and description of the *land cover categories* gives a detailed illustrated overview of the identifiable areal land cover categories. It is based on a series of former studies on land cover transformation[21] by showing examples from the original map sheets. This part allows us to compare

[18] Timár, Biszak, Molnár, Székely, Imecs, Jankó, Digitized maps of the Habsburg Empire – First and Second Military Survey

[19] S. Biszak, G. Timár, G. Molnár, A. Jankó, Digitized maps of the Habsburg Empire – The Third Military Survey, Ungarn, Siebenbürgen, Kroatien-Slawonien, 1867-1887. 1:25000, Arcanum Database Ltd., Budapest, 2007.

[20] S. Biszak, G. Timár, G. Molnár, A. Jankó, Digitized maps of the Habsburg Empire – The Third Military Survey, Österreichisch-Ungarische Monarchie, 1867-1887, 1:75000, Arcanum Database Ltd., Budapest, 2007

[21] Nagy, A történeti felszínborítás térképezése a Tisza-völgyben *(Mapping of the historical land cover of the Tisza Valley)*, 40-59.; É. Konkoly-Gyuró, D. Nagy, P. Balázs, G. Király, Assessment of land cover change in western

visually the thematic content of the maps. The paper excludes linear and point features because of the extent limitation.

In the third part the *geometric and thematic accuracy* and is valuated. Geometric accuracy is shown by comparing the scale and the mean and maximum deviation from the reference map. Thematic accuracy is presented by indicating information about the existence of unified legend concerning relief signs (hachure, contour lines), land cover (number of all land cover categories, as well as artificial/urban, agricultural, grassland, forest, of wetland and water categories), content signs (colour, quality of borderlines and other graphical signs), edition (paper format, digital raster format, digital vector format).

Finally the relevance of the HMS-s and NS-s for research and planning is summarised by main land cover categories based on the own experience of the authors.

Results

General description of the military map series

First Military Survey (MS I)

Maria Theresa ordered the First Military Survey of the Habsburg Empire after the Seven Years' War (1756-63), but the effective cartographic work was mostly done later, under Joseph II between 1763-1787.Therefore it is named "Josephinische Aufnahme". The First Military Survey covers 680,887 km^2, the area of the whole Habsburg Empire[22] (Fig. 2). The period of the survey was 1782-1785 in the Hungarian Kingdom, 1769-1773 in the Transylvanian Principality and 1769-1772 in the Temes Banship.[23] These maps are particularly valuable as they permit researchers to identify the land cover before the huge water reclamations and the systematic statistical surveys.

Geographically the First Survey extends from the Danube to Moravia and a north-western island of Batavia belongs to it too. The survey had the scale of 1:28800 (1 inch: 400 fathoms). The geodetic base was a graphic triangulation with surveying tables, without any projection. The initial map sheet is located in the centre of the surveyed area; all the other sheets are just continuously connected to their neighbours. One map-sheet is 24 * 16 inch (~63.2 * 42.1 cm), and covers an area of 9,600 * 6,400 fathoms (~18.2 *12.1 km^2). Altogether 3245 map-sheets cover the surveyed area. The digital edition of the Arcanum covering the Carpathian basin consists of the former Hungarian Kingdom, Transylvania and Temes Banship, Croatian-Slavonia and their Borderland.[24] The map sheet system can be seen in Figure 3.

The maps of the First Survey are hand drawn and coloured. Every sheet is a piece of art. This artistic

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Hungarian landscapes, in: P. Balázs, É. Konkoly-Gyuró (Eds.) TransEcoNet Workshop on Landscape History, Proceedings, University of West Hungary Press, Sopron, 2010, 5-10.; TransEcoNet, TransEcoNet – Transnational Ecological Networks in Central Europe, http://transeconet.nyme.hu/index.php?id=15838 last accessed 8 March 2007; LCLUC, NASA Land-Cover/Land-Use Change Science Program, http://lcluc.umd.edu/ last accessed 8 March 2007

[22] Skaloš, Weber, Lipský, Trpáková, Šantrůčková, Uhlířová, Kukla, Using old military survey maps and orthophotograph maps to analyse long-term land cover changes – Case study (Czech Republic), 428.

[23] A. Jankó, *Magyarország katonai felmérései: 1763-1950. Military Surveys of Hungary*: 1763-1950, 19.

[24] G. Timár, S. Biszak, B. Székely, G. Molnár, Digitized Maps of the Habsburg Military Surveys – Overview of the Project of ARCANUM Ltd. (Hungary), in: M. Jobst (Ed.), Preservation in Digital Cartography: Archiving Aspects, Springer Berlin Heidelberg, Berlin, Heidelberg, 2010, 273-283.

quality implicates its drawbacks: the content and accuracy depends to some extent on the person who drew the map. Geometrically the sheets have a mean inaccuracy of 30-100 m and maximum 400 m.[25] The relief is indicated with hatching. The density of the lines represents the steepness of the slopes, using the so-called Lehmann hatching.[26] The land cover information of the sheets varies, depending on the person drawing or copying them as surveyors did not used a standardised legend.

Figure 2: The surveyed area and periods of the First Military Survey (Arcanum, 2004)

[25] Nagy, *A történeti felszínborítás térképezése (Mapping of the historical land cover)*, 15.

[26] See Gunther Koch Wolf J. G. Lehmann's system of slope hachures - an investigation on the quality of relief representation at the beginning of the 19th century, Proceedings of the 26th International Cartographic Conference, August 25-30, 2013, Dresden, Germany http://icaci.org/files/documents/ICC_proceedings/ICC2013/_extendedAbstract/265_proceeding.pdf last accessed 3 April, 2007

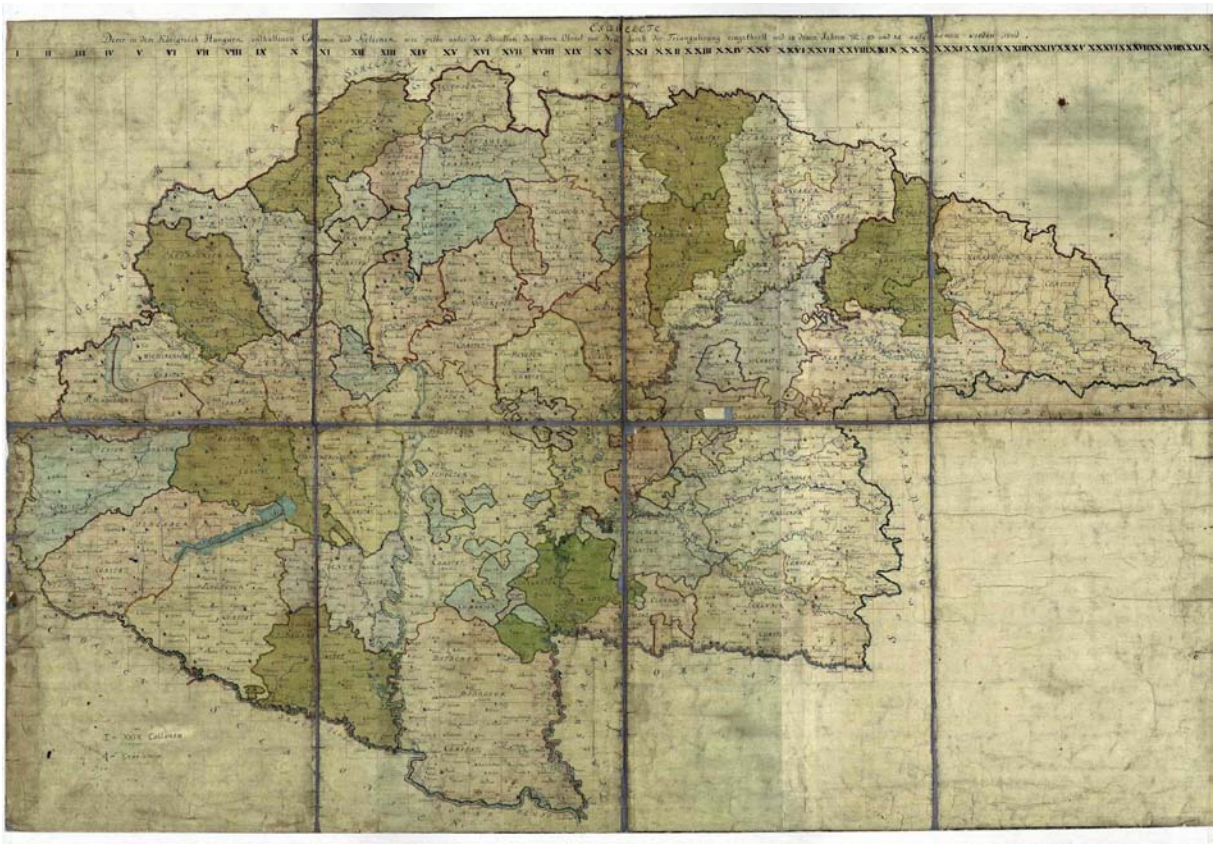

Figure 3: The map-sheet system of the First Military Survey in the former Hungarian Kingdom (Arcanum, 2004)

An a posteriori legend was prepared for the Hungarian map sheets encompassing the symbols which are on them.[27] Twenty-four land cover categories can be distinguished on the maps; (see them in detail in the next chapter). Some of them could be considered as linear features, e.g. roads and streams, or points e.g. industrial buildings, depending on the minimum mapping unit. Beyond the graphical signs and the colouring, the labels and toponyms also provide valuable information. See some examples in Figure 4.

[27] A. Borbély, J. Nagy, *Magyarország I. Katonai felvétele II. József korában (First Military Survey of Hungary in II. Joseph era)*, Térképészeti Közlöny 2(1-2.) (1932).

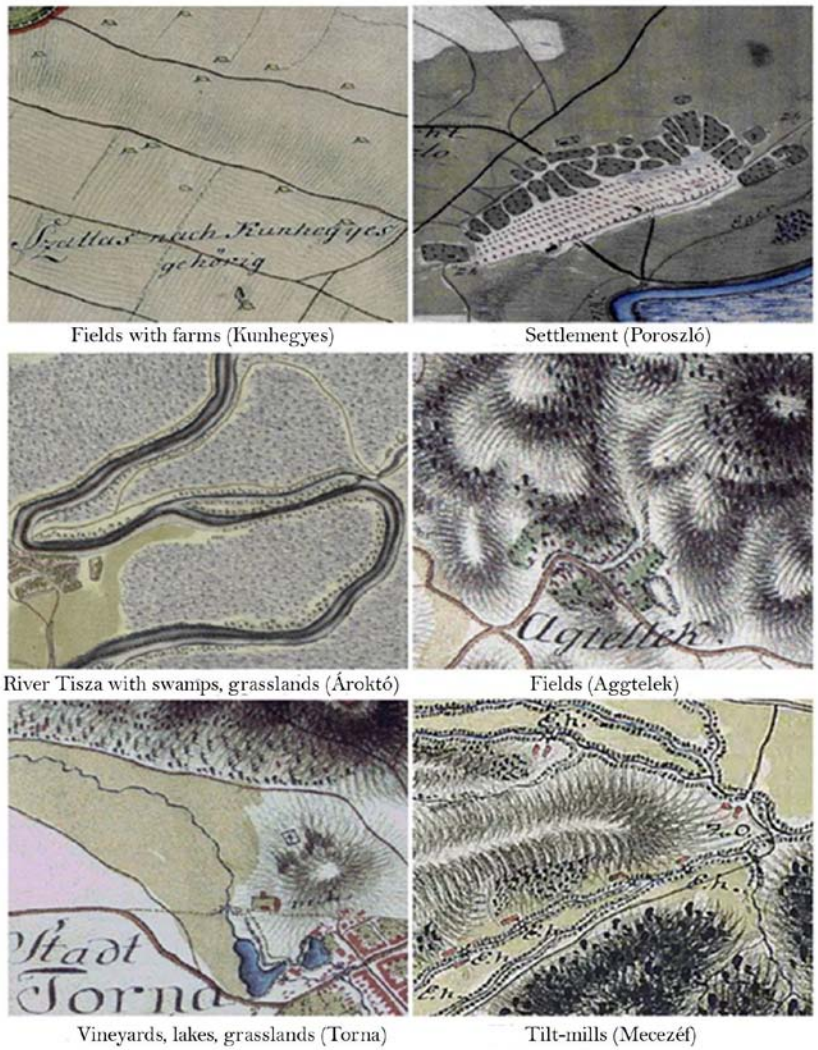

Figure 4: Examples of land cover categories of the First Military Survey (fields with farms; settlement; River Tisza with swamps and grasslands; fields; vineyards, lakes and grasslands; tilt-mills)[28]

Map sheets were completed with the "*Description of the Country*" that contains important additions, predominantly for military purposes at that time, but provide valuable information for the landscape historical research as well. It was written in German and has a definite structure, referring to:

- walking distance of the settlements from each other;
- rivers indicating their depth, the width, the suitability of the shore for walkers, riders or coaches, and the passing places;
- roads, paths and their quality;
- forests with information on their stands (young, old, dense, sparse) on the roads, paths crossing them and describing the relief and occurring wetlands;
- marches and bogs indicating whether they can be crossed by walking, riding, all the time or just temporarily, in which season they dry out;

[28]Nagy, A történeti felszínborítás térképezése *(Mapping of the historical land cover)*, 10.

- water bodies with regards to their water quality, whether they have drinking water for people or horses; describing if the bottom is sandy or marshy;
- mountains and high elevations, emphasizing the highest peaks providing a large panoramic view;
- quality of the roads and paths in bad weather; also the churches, graveyards, hamlets, mills, industrial buildings at the entrance of the settlements and farmsteads.[29]

Second Military Survey (MS II)

The First Military Survey became outdated because of the geodetic inaccuracies, the 'à la vue' representation of the topography and the uncertainties and changes of the land cover. The development in geodesy made it possible to enhance the accuracy of the surveys and the wars of Napoleon also urged the preparation of a new map series. In 1806 the Second Military Survey was ordered by Kaiser Franz I. This survey was called "*Franziszeische Landesaufnahme.*" It was still not finished during the reign of Franz I. The period of mapping was more than a half century from 1809 till 1869 (until 1873 in Transylvania) with multiple interruptions. The scale was the same as used in the First Military Survey, 1:28800. It had a real geodetic basis and a mapping protocol that can be more or less approximated by the Cassini projection.[30] This survey was based on a coherent triangulation network. Its main base-point was the tower of the Cathedral St. Stephens in Vienna.[31] The Second Military Survey covers a large, continuous area in Central Europe from the Po Plains in northern Italy to Galicia in western Ukraine.[32] The area of the Hungarian Kingdom has a uniform legend and is covered by 1079 sheets, made between 1810-1866.[33] The area coverage and the map-sheet system is shown in Figure 5-6.

The map sheets kept the artistic character of the First Survey but the accuracy is far greater; it is better than 200 meters in most cases; for the most populated and important parts of the Empire, it is between 50 and 100 meters.[34] Relief is featured similarly to the First Survey, but contains more precise land cover information. The borderlines are more clearly identifiable and more land cover categories can be distinguished. Most important is the distinction between meadows and pastures as well as deciduous and coniferous forests. Labels and signs are more detailed, containing many more objects and toponyms than the maps of the former survey. Land use symbols are clear and easy to

[29] L. Csendes, Az I. Katonai felméréshez készült országleírás katonaföldrajzi és történelmi forrásértéke *(Military geographical and historical source value of the country description prepared for the First Military Survey),*, Hadtörténeti Közlemények 79 (1975) 349-371.

[30] See further in B. Veverka, M. Čechurová, Georeferencování map II. a III. vojenského mapování, Kartografické listy 11 (2003) 103-113.; G. Timár, GIS integration of the second military survey sections – a solution valid on the territory of Slovakia and Hungary, Kartografické listy 12 (2004) 119-126.; G. Timár, G. Molnár, B. Székely, S. Biszak, J. Varga, A. Jankó, Digitized maps of the Habsburg Empire – The map sheets of the Second Military Survey and their georeferenced version, Arcanum, Budapest, 2006.

[31] A. Jankó, *Magyarország katonai felmérései: 1763-1950. Military Surveys of Hungary: 1763-1950*, 64.

[32] Timár, Biszak, Székely, Molnár, Digitized Maps of the Habsburg Military Surveys – Overview of the Project of ARCANUM Ltd. (Hungary), 278.

[33] Arcanum, Második Katonai Felmérés: Magyar Királyság (1806-1869) 1:28800. Georeferált változat - The Second Military Survey: Kingdom of Hungary (1806-1869) 1:28.800. Georeferenced version. DVD-ROM, Arcanum Adatbázis Kft., Budapest, 2005.

[34] Timár, Biszak, Székely, Molnár, Digitized Maps of the Habsburg Military Surveys – Overview of the Project of ARCANUM Ltd. (Hungary), 278.

read. See examples in Figure 7.

Figure 5:. The surveying area and period of the Second Military Survey (Arcanum, 2005)

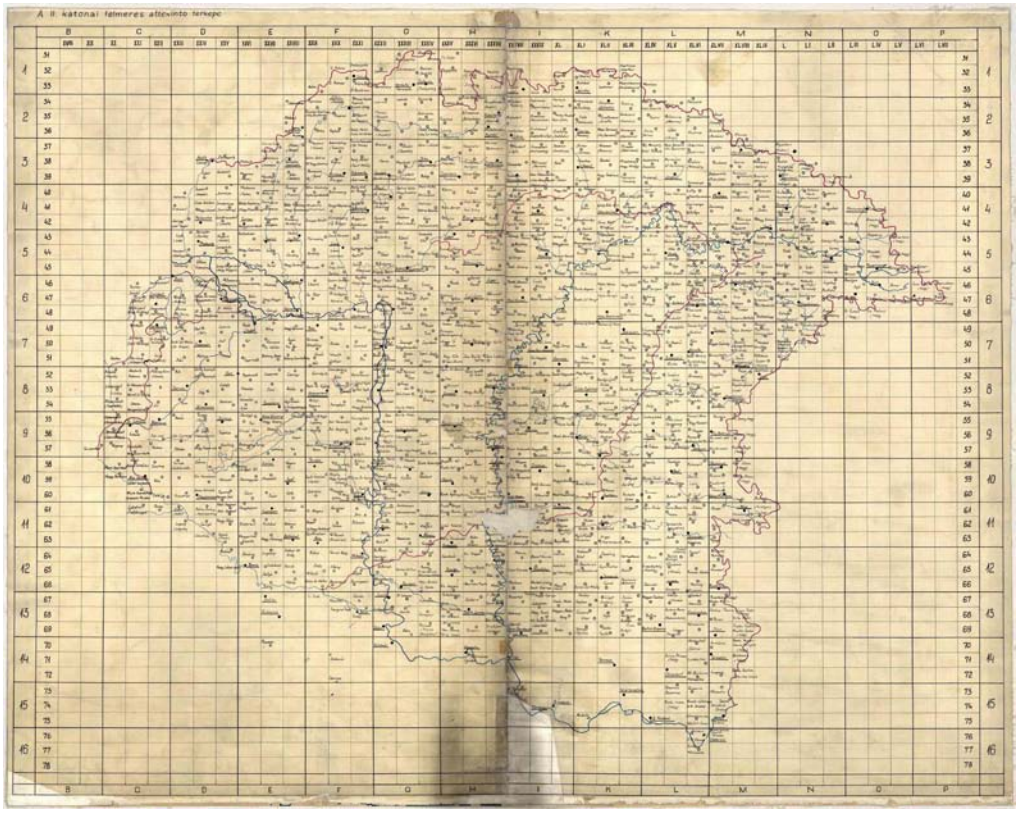

Figure 6: The map sheet system of the Second Military Survey for the Hungarian Kingdom (Arcanum, 2005)

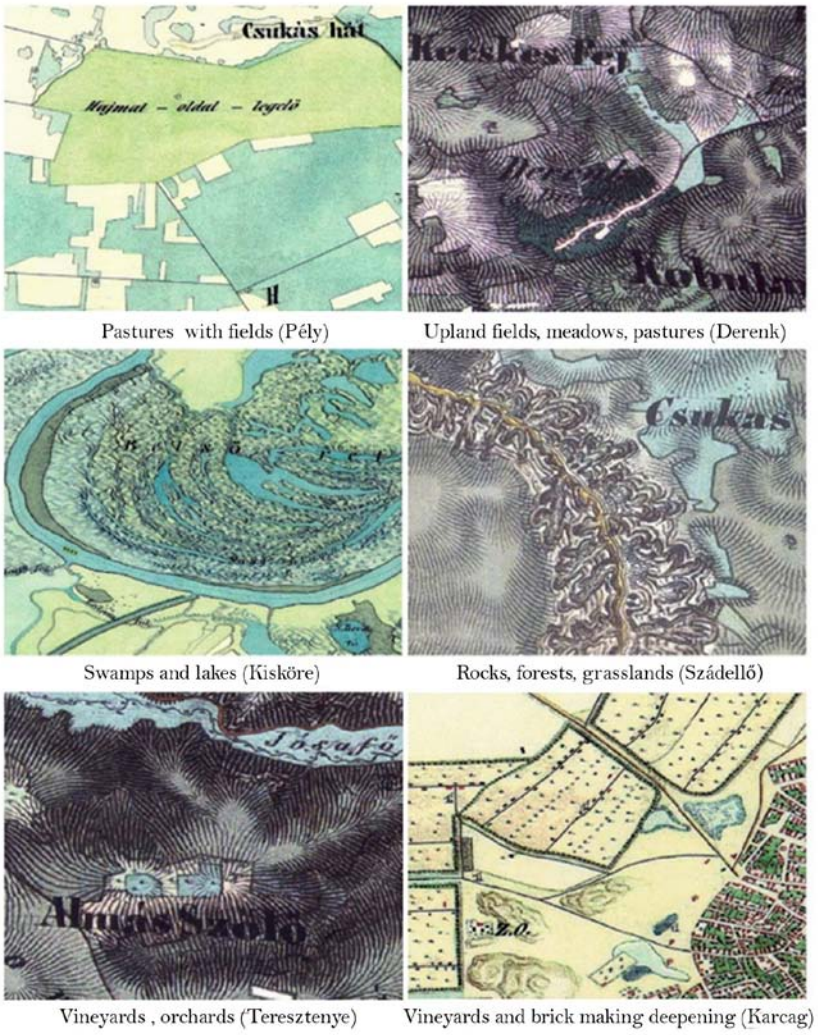

Figure 7:. Some of the categories of the Second Military Survey (pasture with fields; upland fields, meadows, pastures; swamps and lakes; rocks, forests, meadows; orchard, vineyard, brick making quarries).[35]

Third Military Survey (MS III)

Although the Second Military Survey was more accurate than the First Survey, the period of the mapping was far too long, while equipment, methods and requirements of geodesy have all changed. It became outdated before being completed, and Kaiser Franz Joseph decided to start a new mapping, thus ordered the Third Military Survey in 1869. The whole territory of the Monarchy was surveyed between 1869-1887, the counties of the Carpathian basin, and the Hungarian Kingdom and Transylvanian Principality was surveyed between 1872 to 1885.

The scale of the HMS III was 1:25000, after the introduction of the metric measurement system in 1872. The coverage is a bit different according to the territorial changes of the Monarchy. It does not cover the south-western provinces, Lombardy and Veneto since they became independent when Italy

[35] Nagy, A történeti felszínborítás térképezése *(Mapping of the historical land cover)*, 13.

was reunified in 1861 but it contains Bosnia-Herzegovina. The covered area (676615 km2) and period is shown in Figure 8.

Figure 8: The surveying area and period of the Third Military Survey (Arcanum, 2007)

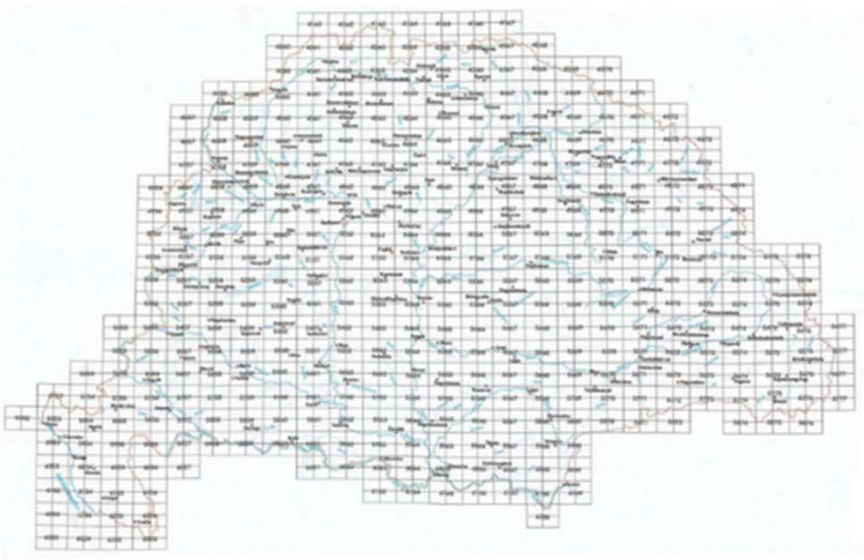

Figure 9:The map sheet system of the Third Military Survey (Arcanum, 2007)

The mapping base was mostly the second, partly the third triangulation network of the Austro-Hungarian Monarchy. The trigonometric height calculation was widely used; the accurate levelling based upon the prime benchmarks was only partly utilised. A polyhedron projection based upon the Bessel ellipsoid was used and the longitudes were calculated from Ferro. The territory of the Hungarian Kingdom and Transylvania is covered by 1,354 sheets.[36] See the map-sheet system in Figure 9.

36 A. Jankó, Magyarország katonai felmérései: 1763-1950. Military Surveys of Hungary: 1763-1950, 92.

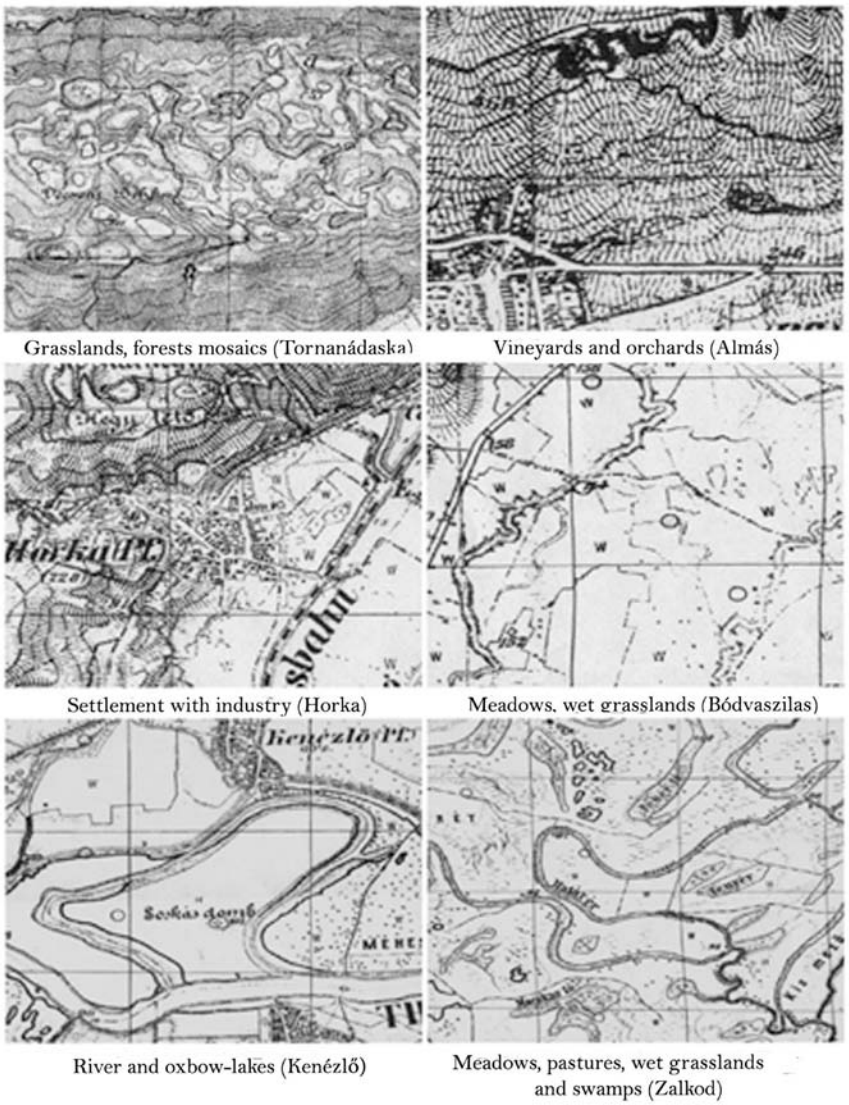

Figure 10: Some of the categories of the Third Military Survey (forests with grass; vineyards and orchard; settlements with industry; meadows, wet grasslands; river and oxbow-lakes; meadows, pastures, wet grassland and swamps)[37]

Original maps are coloured manuscript sheets. The relief was represented by contour lines. The majorities of the copies covering the Carpathian basin, available both in Hungary and Austria are black-and-white. Only relief contour lines and forests are coloured on the smaller part of the sheets. The detailed and correct land cover information is indicated by graphical signs and partly by colouring (on colour maps) or acronyms (on black-and-white maps). The accuracy is higher, both geometrically and thematically. Geometric distortions occur only on steep, wooded areas. Interpretation is though much more difficult on the black and white sheets as relief contour lines, roads and hydrography are merged into borderlines of land cover categories (Fig. 10).

[37] Nagy, A történeti felszínborítás térképezése a Tisza-völgyben *(Mapping of the historical land cover of the Tisza Valley)*, 14.

New Survey

After the First World War, the nations of the Austro-Hungarian Monarchy formed new independent states (Austria, Hungary, Czechoslovakia, Yugoslavia and Romania) and the mapping continued in these countries. Between the two world wars only partial corrections, and reambulations were carried out.

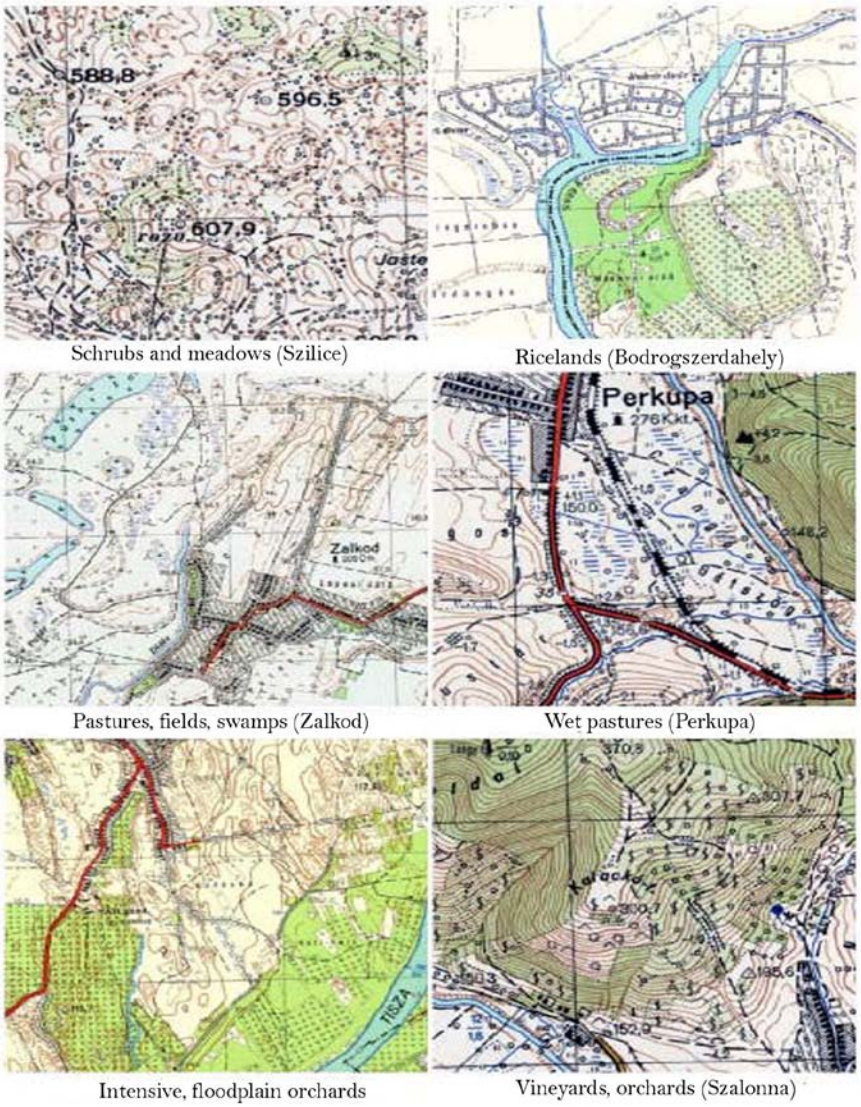

Figure 11: Some of the categories of the New Survey (shrubs and meadows; rice fields; pastures, fields, swamps; wet pastures; intensive, floodplain orchards; vineyards, orchards) Nagy, 2008.

After the Second World War, a new era of the military mapping started. From the 1950s the map series of the so called “New Surveys” was prepared and reambulated nearly in each decade. Thus, series of the 1960s, 70s and 80s were issued in paper format on a scale of 1:25000, 1:50000, and 1:100000. These new coloured maps had better accuracy, identical content and scale in all Eastern-Central European countries belonging to the soviet sphere of influence. These maps are similar to the Western

Europeans of the same historical period. Map sheets are available in the Military Archives in all countries.

The aim of the New Survey (1953-1959) in Eastern-Central Europe was to enhance the quality of the previous topographic maps. Because of the short schedule, and requirements based on the new political system, it was impossible to resurvey the whole area of the countries. That is why only a correction was made where maps from 1930s-40s were available (23% of Hungary). Aerial photographs, accurate field surveys, completed by multi-level supervision were applied for correction and new surveying. These map sheets were prepared in the Gauss-Krüger projection. The map-sheet system and the detailed legend were unified in all countries from the Socialist block. Relief was represented by contour-lines and altitudes reference is the Baltic Mean Sea level. Land cover information, combining colouring and symbols, are accurate and detailed; thus it is easily to interpret.[38] An example of the New Survey is shown in Figure 11.

Comparison and valuation of the land cover related content of the military surveys

Presentation and description of the land cover categories occurring on the maps

In this chapter the identifiable land cover categories of the Habsburg Military Surveys and the New Survey are presented. The identifiable categories are listed in three levels. The list has been finalised (see Table 1) based upon the experience of several research projects where the digitalisation of the Military Surveys was carried out.[39]

[38]Nagy, *A történeti felszínborítás térképezése a Tisza-völgyben (Mapping of the historical land cover of the Tisza Valley)*, 40-59; L. Alabér, *A topográfiai térképrendszer átalakításának lehetőségei a Magyar honvédség igényeinek és a NATO-csatlakozás követelményeinek figyelembevételével (Possibilities of the transformation of topographic map system, taking into account the Hungarian Army's needs and requirements of NATO membership)*, Zrínyi Miklós Nemzetvédelmi Egyetem. Budapest 2004; Á. Tremmel, *Magyarország negyedik katonai felmérése, (Fourth Military Survey of Hungary*) Geodézia és kartográfia 62(1) (2010) 26-29.

[39]See included but not limited to Nagy, *A történeti felszínborítás térképezése (Mapping of the historical land cover)*, 19-21. , Kuemmerle, Boltiziar, Butsic, Gimmi, Lúboš, Kaim, Király, Konkoly-Gyuró, Kozak, Lieskovský, Mojses, Müller, Ostafin, Ostapowicz, Shandra, Štych, Walker, Radeloff, *Forest and agricultural land change in the Carpathian region - A meta-analysis of long-term patterns and drivers of change*, 685-697.

I. Márkus, G. Király, *Land use and land use changes in the Fertő-Hanság National Park*, in: E. Csaplovics, S. Wagenknecht, U. Seiler (Eds.), Spatial Information Systems for Transnational Environmental Management of Protected Areas and Regions in the Central European Space, Rhombos Verlag – Fachverlag für Politik, Wissenschaft und Kultur, Berlin, 2008, 67-79.

G. Király, É. Konkoly-Gyuró, I. Márkus, D. Nagy, É. Sági, *A Fertő tónak és környékének változásai régi térképek alapján (Changes of Lake Fertő and its sorroundings based on old maps),* in: É. Konkoly-Gyuró, Á. Tirászi, G.M. Nagy (Eds.) Tájtudomány-Tájtervezés. V. Magyar Tájökológiai Konferencia, Nyugat-magyarországi Egyetem Kiadó, Sopron, 2013, 55-61.

É. Konkoly-Gyuró, P. Balázs, Á. Tirászi, G. Király, *Felszínborítás-változások a történelmi Magyarország tájain a 19. század közepétől napjainkig (Land cover changes in the historical parts of Hungary from the mid-19th century until the present day)*, in: G. Horváth (Ed.) Tájhasználat és tájvédelem – kihívások és lehetőségek. VI. Magyar Tájökológai Konferencia, Eötvös Loránd Tudományegyetem, Földrajz- és Földtudományi Intézet, Környezet- és Tájföldrajzi Tanszék, Budapest, 2015, 87-96.

I. Márkus, L. Bácsatyai, D. Bartha, É. Konkolyné Gyuró, G. Király, K. Czimber, Development of GIS of Fertő-Hanság National Park and Szigetköz Land Protection District: Trilaterális Phare CBC Ausztria-Magyarország-Szlovákia 1995 Program, 1999.

G. Király, U. Walz, T. Podobnikar, K. Czimber, M. Neubert, Ž. Kokalj, *Georeferencing of historical maps – methods and experiences*, in: E. Csaplovics, S. Wagenknecht, U. Seiler (Eds.), Spatial Information Systems for Transnational Environmental Management of Protected Areas and Regions in the Central European Space. Selected Results and Outputs of the Interreg IIIB Project SISTEMaPARC, Rhombos-Verlag, Berlin, 2008, 53-63.

Areal categories			MS I	MS II	MS III	NS
1	**Artificial - Urban fabric**					
	11	Urban settlements/continuous urban fabric	x	x	x	x
	12	Rural settlements/Discontinuous urban fabric	x	x	x	x
		121 Buildings and courtyards	x	x	x	x
	13	Farms, hamlets	x	x	x	x
	14	Green urban fabric				
		141 Parks	x	x	x	x
		142 Graveyards	x	x	x	x
		143 Utility gardens in settlements	x	x	x	x
	15	Industrial, commercial and transport units				
		151 Industrial and commercial units	x	x	x	x
		152 Road and rail networks	x	x	x	x
	16	Open cast mining or dump sites	x	x	x	x
	17	Farmsteads, agricultural buildings	x	x	x	x
2	**Agricultural area**					
	21	Arable land	x	x	x	x
	22	Vineyards, orchards				
		221 Vineyards	x	x	x	x
		222 Orchards - fruit tree or berry plantations	x	x	x	x
3	**Forest and wooded vegetation**					
	31	Deciduous forests	x	x	x	x
	32	Coniferous forests		x		x
	33	Transitional woodland shrubs, wooded pastures	x	x	x	x
	34	Mixed deciduous and coniferous forests		x		x
4	**Grassland**					
	41	Dry grasslands	x			
		411 Dry pastures		x	x	x
		412 Dry meadows		x	x	x
	42	Wet grasslands	x			
		421 Wet pastures		x	x	x
		422 Wet meadows		x	x	x
5	**Wetlands**					
	51	Inland marshes				
		511 Inland marshes with low vegetation	x	x	x	x
		512 Inland marshes with high vegetation	x	x	x	x
	52	Peatbog			x	x
6	**Water bodies**					
	61	Water courses	x	x	x	x
	62	Water bodies				
		621 Natural water bodies	x	x	x	x
		622 Artificial lakes, ponds or reservoirs		x	x	x
7	**Bare and other surfaces**					
	71	Bare rock	x	x	x	x
	72	Beaches, dunes or sand plains	x	x	x	x
	73	Erosion ditches	x	x	x	x

Table 1: Land cover categories of the HMSs and the New Survey of the 1950s.

Nagy, *Tájtörténeti kutatások a Gömör-Tornai-karszton (Landscape historical research in the Karstic region Gömör-Torna)* I. A történelmi táj rekonstrukciója az ANP környezetében az I-III. Katonai Felmérések alapján, 107-143

É. Konkoly-Gyuró, D. Nagy, P. Balázs, G. Király, Assessment of land cover change in western Hungarian landscapes, 5-10.

In the following section the identifiable land cover categories of each map series are presented, illustrated by examples from the original sheets (MS I, MS II, MS III, NS) and with recommendations of categorisations for digitalisation.

1. Artificial - urban fabric

1.1 Urban settlements/continuous urban fabric

Built up surfaces, city centres with a dense building structure and road network, area covered by vegetation do not exceed 80%.

Figure 12: Urban settlements

1.2 Rural settlements/discontinuous urban fabric

Built up surfaces of settlements, rural residential areas, peri-urban garden cities or recreational settlements, where buildings are surrounded with gardens and artificial surfaces do not exceed 30%.

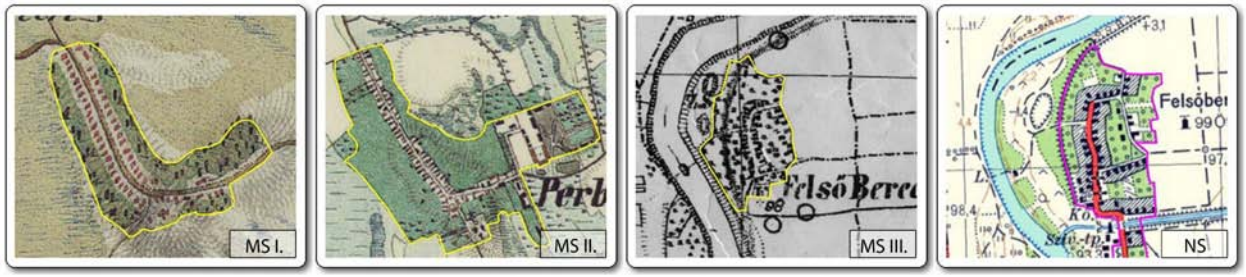

Figure 13: Rural settlements

1.2.1 Buildings and courtyards

Built up surfaces within discontinuous urban fabric.

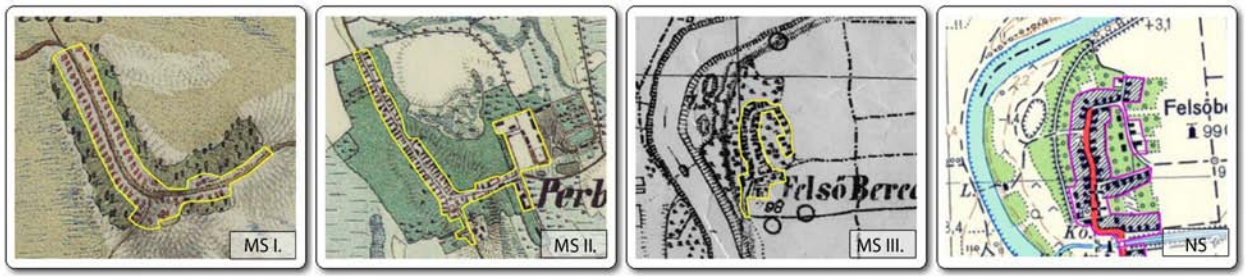

Figure 14: Buildings and courtyards

1.3 Farms, hamlets

Building groups outside settlements where residences and farms occur. Special buildings like inns, shacks of weir keeper houses and railway watch-boxes are also included.

Figure 15: Farms, hamlets

1.4 Green urban fabrics

1.4.1 Parks

Urban public parks, large green areas, castle gardens and botanical gardens with recreational and information functions.

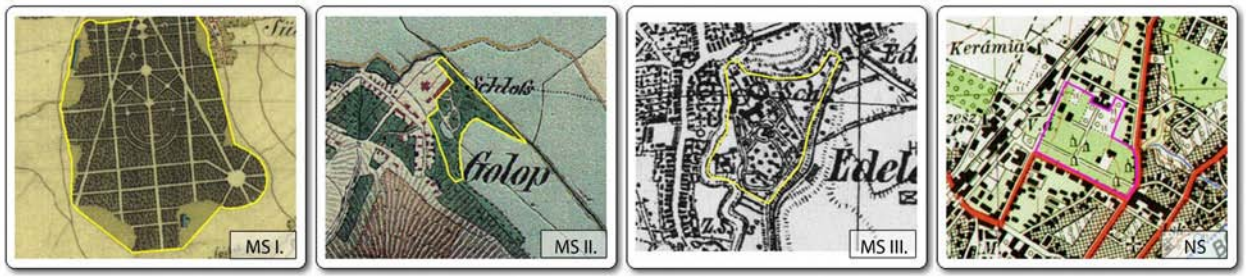

Figure 16: Parks

1.4.2 Graveyards

Graveyards within or outside settlements.

Figure 17: Graveyards

1.4.3 Gardens within settlement

Gardens within discontinuous urban fabric, around buildings.

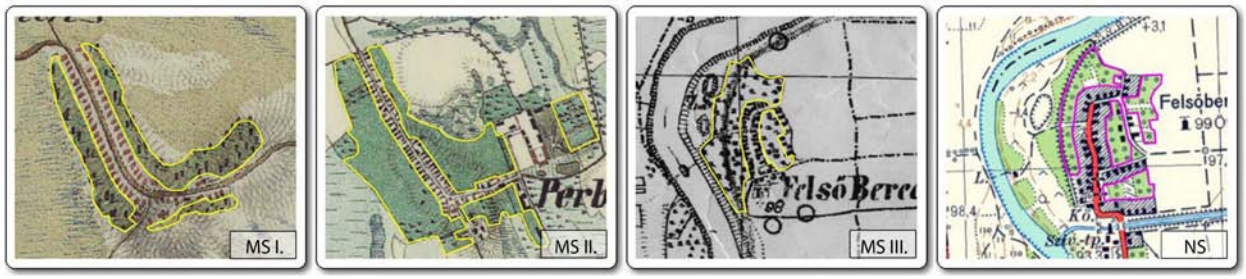

Figure 18:. Gardens

1.5 Industrial, commercial and transport units

1.5.1 Industrial and commercial units

Area of factories, depots, commercial buildings.

Figure 19: Industrial and commercial units

1.5.2 Road and rail networks

Areas of transport infrastructure, road and railway networks and associated facilities (parking lots, buildings, railway stations etc.).

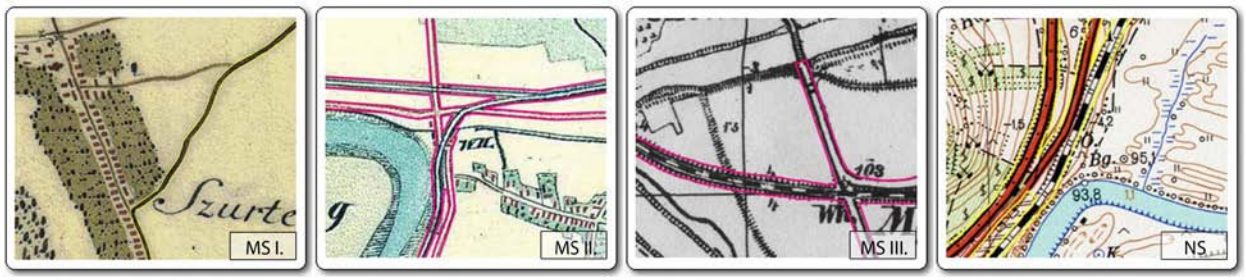

Figure 20: Road and rail network

1.6 Open cast mining and dump sites

Devastated surface of open cast mines, quarries and public, industrial or mine dumpsites.

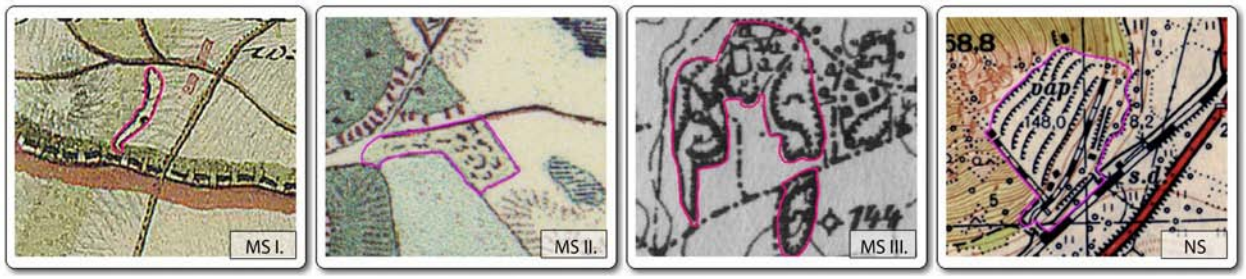

Figure 21: Open cast mining and dump sites

1.7 Farmsteads, agricultural buildings

Agricultural, agro-industrial buildings, depots without residential function.

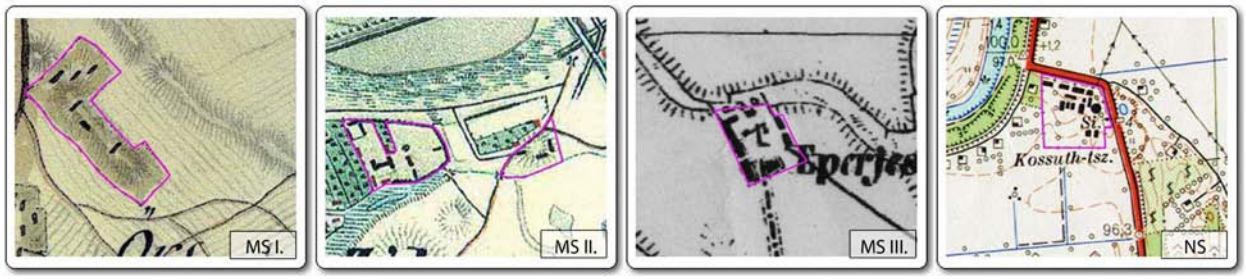

Figure 22: Farmstead, agricultural buildings

2. Agricultural area

2.1 Arable land

Areas of ploughed land, consisting of small or large parcels, without or with scattered grasslands, shrubs, groves or trees rows.

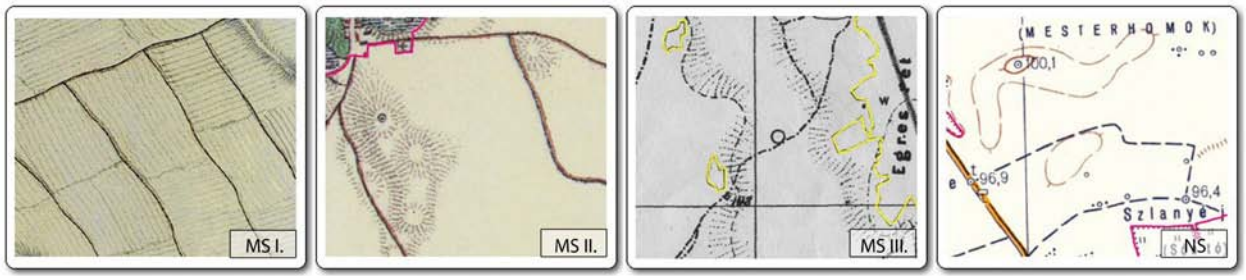

Figure 23: Arable land

2.2 Vineyards, orchards

2.2.1 Vineyards

Areas of viticulture, eventually with scattered shrubs, fruit trees, orchards.

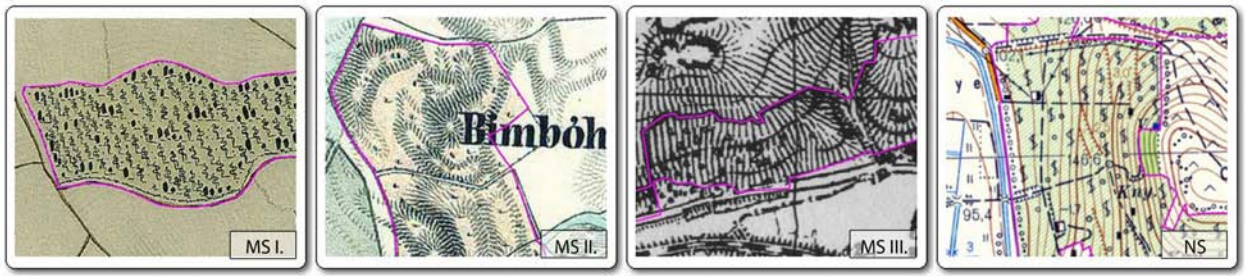

Figure 24: Vineyards

2.2.2 Orchards

Areas of fruit production consisting of small or large parcels of fruit tree and berry plantations, eventually with complex cultivation patterns, patches of shrubs.

Figure 25: Orchards

3. Forests, wooded vegetation

The First and the Third Military Survey do not distinguish between deciduous and coniferous forests; therefore the identification needs additional sources.

3.1. Deciduous forests

Open and closed, wet and dry broad leaved forests.

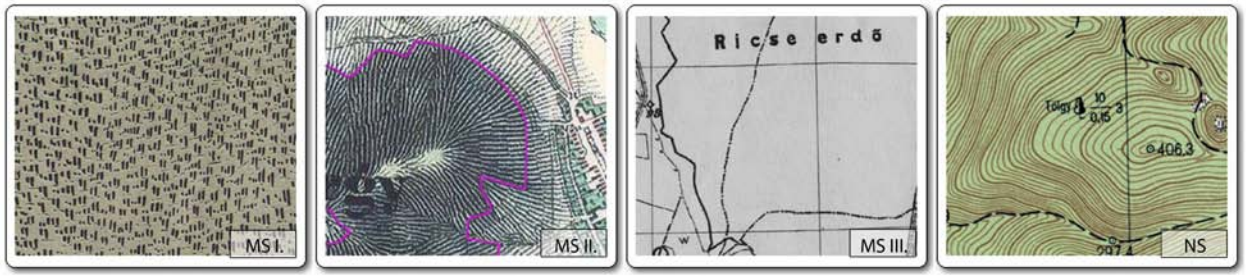

Figure 26: Deciduous forests

3.2 Coniferous forests

Open and closed, wet and dry coniferous forests.

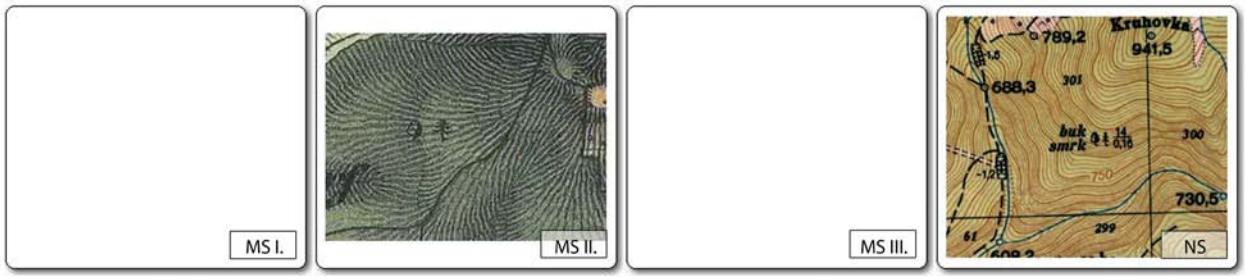

Figure 27: Coniferous forests

3.3 Transitional woodland shrubs

Areas covered by shrubs, or sparse trees. Wooded grasslands, young afforestation, dry open forests with a tree canopy of less than 30% are also included.

Figure 28: Transitional woodland shrubs

3.5 Mixed deciduous and coniferous forests

Forest stands consisting alternately of broad leaved and coniferous trees.

Figure 29: Mixed deciduous and coniferous forests

4. Grasslands

Military maps use graphical signs to identify dry and wet grassland. In this case “dry” does not mean exclusively extreme dry steppe vegetation but also the grasslands with a medium water supply.

4.1 Dry grasslands

Pastures and meadows cannot be distinguished on the First Survey. In this case the general category of dry grassland is identifiable.

Figure 30: Dry grasslands

4.1.1 Dry pastures

Grazed, predominantly dry grasslands. On the Third Survey, they are indicated with the sign ‘H’ (Heide). Trees and shrubs occur only sparsely.

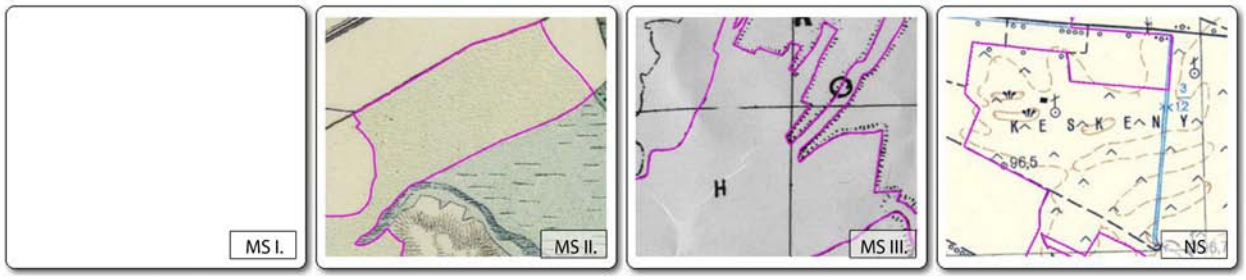

Figure 31: Dry pastures

4.1.2 Meadows

Hayfields that can be temporarily grazed. Meadows occur mainly on lower elevations, in valleys, along streams, and on floodplains where water supply is greater. On the Third Survey, they are indicated with the sign ‘W’ (Wiese). Trees and shrubs occur only sparsely.

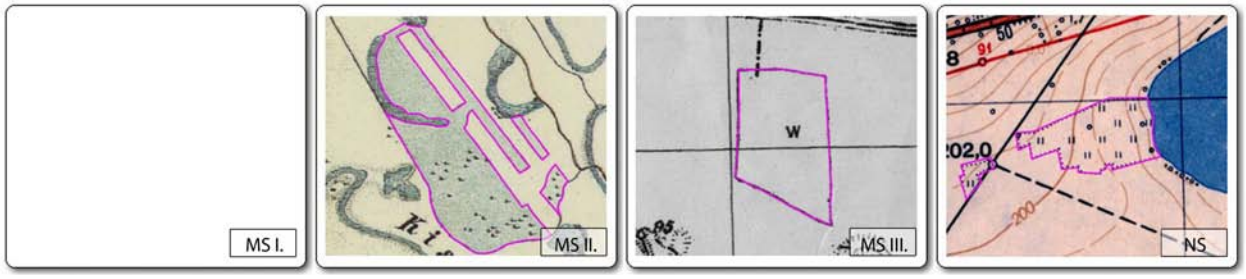

Figure 32: Meadows

4.2.Wet grasslands

Wet, periodically flooded grasslands at the lowest elevations.

Figure 33: Wet grasslands

4.2.1 Wet pastures

Wet, periodically flooded grazed grasslands at the lowest elevations.

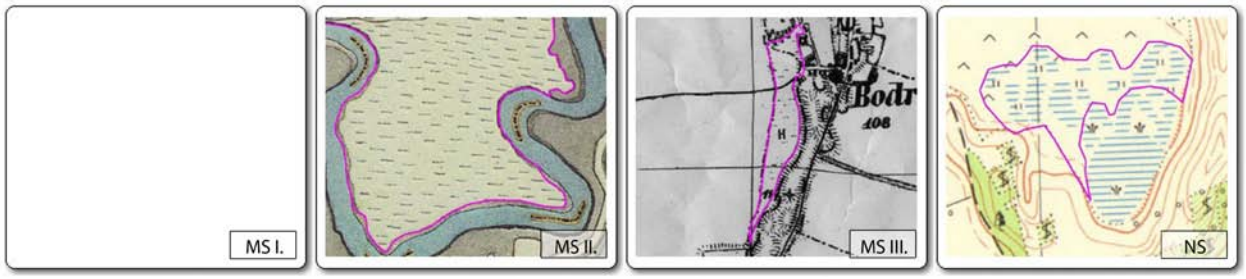

Figure 34: Wet pastures

4.2.2 Wet meadows

Wet, periodically flooded hayfields at the lowest elevations.

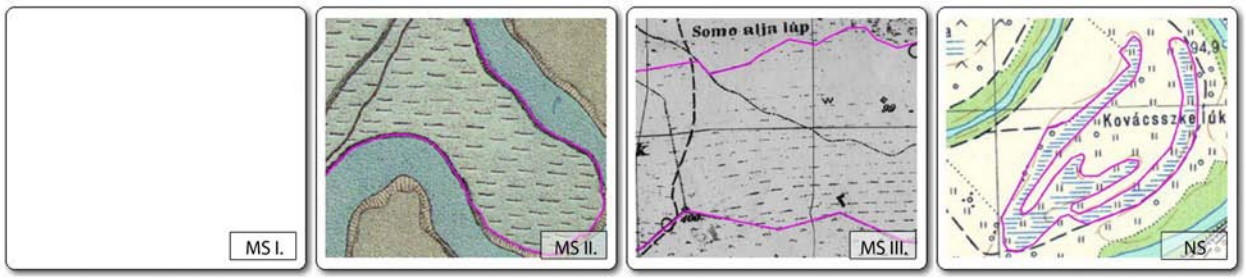

Figure 35: Wet meadows

5. Wetlands

5.1 Inland marches

Periodically or permanently wet or flooded area grown up with fen vegetation.

5.1.1 Inland marches with low herbaceous vegetation

Shallow marches, mires, bogs with bulrushes and pondweed periodically drying out or flooded.

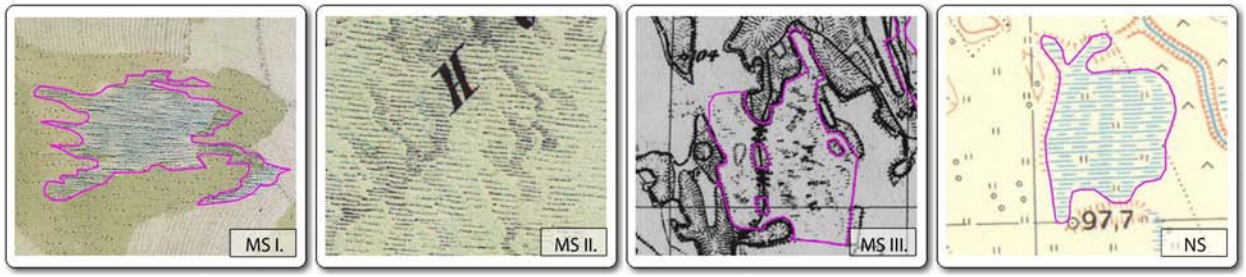

Figure 36: Inland marches with low vegetation

5.1.2 Inland marches with high herbaceous vegetation

Deeper marches, mires, bogs with reeds that are permanently wet or flooded.

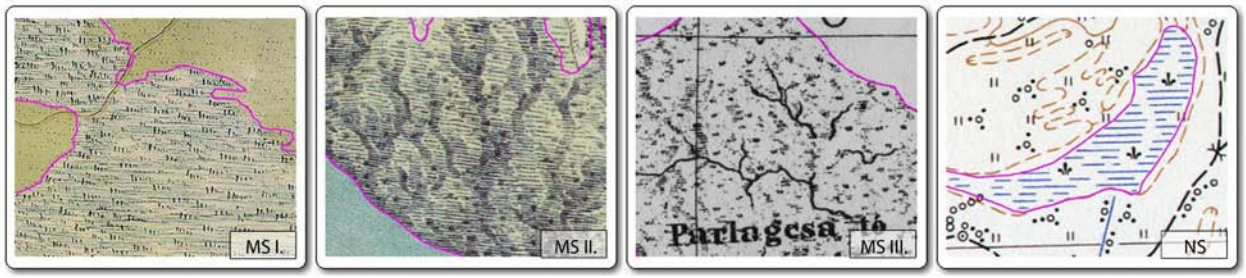

Figure 37: Inland marches with high vegetation

5.2 Peat bogs

Peat bogs and peat extraction areas.

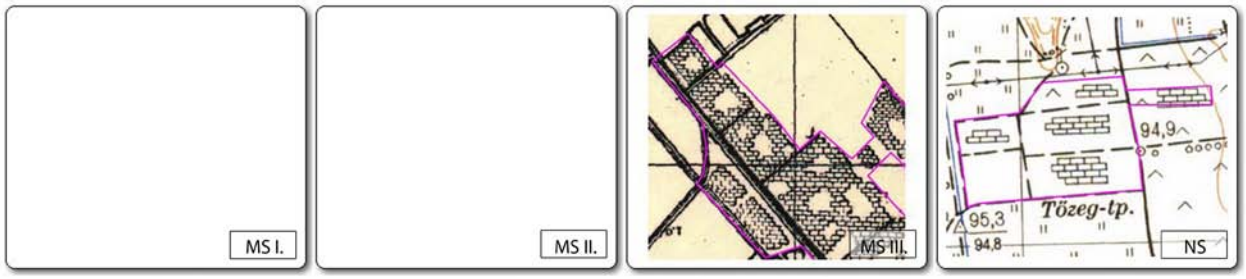

Figure 38: Peat bogs

6. Water surface

6.1 Water courses

Natural and artificial water courses, rivers, streams and canals.

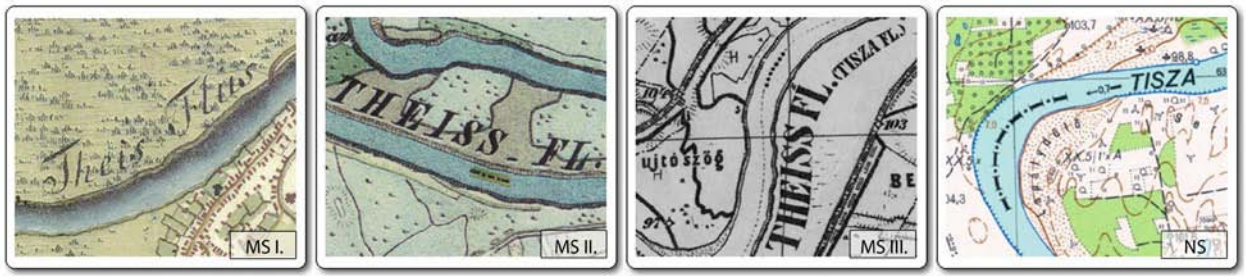

Figure 39: Water courses

6.2 Water bodies

Natural and artificial standing water bodies

6.1 Natural water bodies

Natural lakes with permanent or periodical water stands.

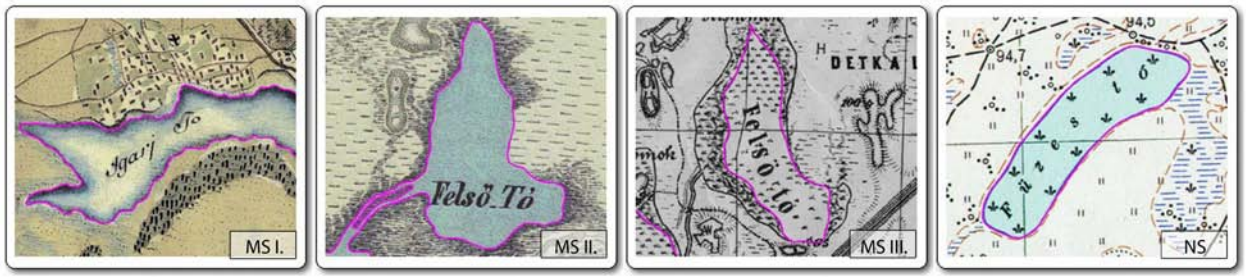

Figure 40: Natural water bodies

6.2 Artificial lakes, ponds and reservoirs

Intensively used man-made water bodies, artificial, fish ponds, water reservoirs.

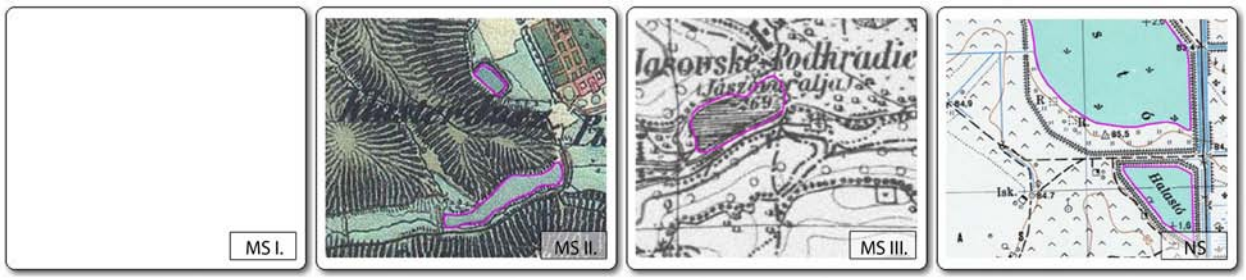

Figure 41: Artificial lakes, ponds and reservoirs

7. Bare and other surfaces

7.1 Bare rocks

Sparsely vegetated or bare rocks, tower rocks of abandoned quarries are also included.

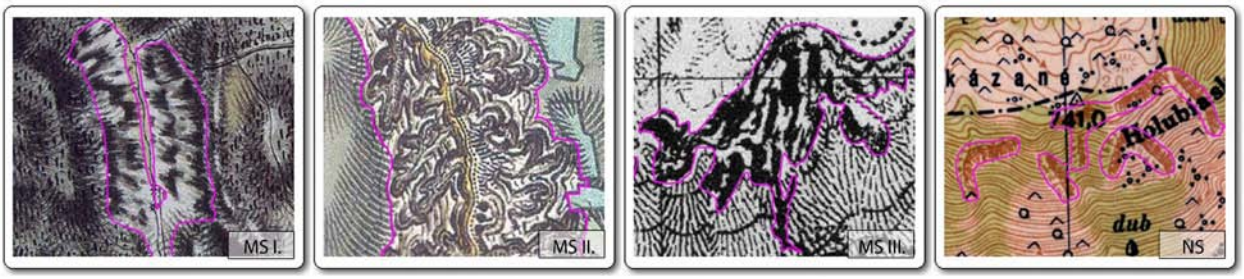

Figure 42: Bare rocks

7.2 Beeches, dunes and sand plains

Sparsely vegetated or bare sand surfaces on riverbanks, lake/sea shore or moving sand areas.

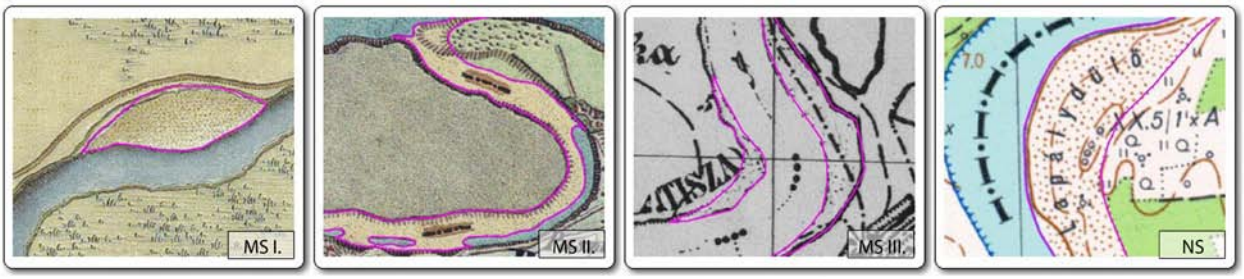

Figure 43: Beeches, dunes and sand plains

7.3 Erosion ditches

Periodic streams on steep slopes, formed by water erosion.

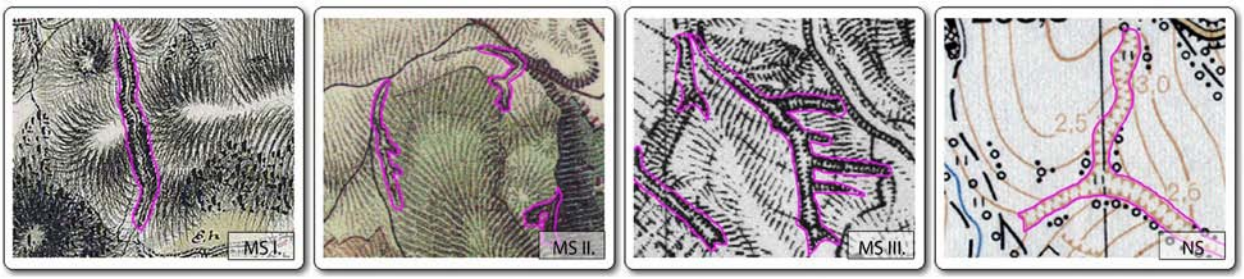

Figure 44: Erosion ditches

Valuation of the geometric and thematic accuracy of the military surveys

Geometric accuracy and relief representations of the military surveys

The MS I. had no projection system and therefore it is the less precise. Deviations of hundreds of meters can occur. Implementing the ”rubber sheet” method[40] we can use the churches, the crossroads and buildings that existed later or even today. However, there are not always sufficient reference points and the relief distortions can be significant, especially in sparsely inhabited mountainous and forested areas. A two-step transformation method[41] can significantly improve the accuracy and reduce the deviations between the map sheets, without additional control points.
The accuracy is higher on later MSs, where the maximum deviation became approximately the half of the previous in each map series. The matching of neighbouring sheets is often not exact on the MS I, II. The linear features and borderlines do not always fit together on the sheets. There are bigger deviations between sheets surveyed in different years. Large swamps and forests on the MS I. are very roughly drawn, and are topographically inaccurate because these areas were probably not surveyed at all.
Slopes indicated by hachure mean a rough representation of the relief on the MS I, II, but it became significantly more precise on the MS III, where contour lines were used. Both hatching and B&W contour lines can be confusing in the identification of the land cover borderlines or they make it difficult to read the labels.

Thematic accuracy and interpretability of the military surveys

Obviously both the geometric and the thematic accuracy is higher in each map series coming closer to the present time. More land cover categories are delineated and introduced on the newer map sheets. The logic of the categorisation is consequent on the military surveys. Taking into consideration both the HMSs legends and the New Survey, the land cover categories are divided into seven groups.

- *Artificial/urban surfaces:* on the HMSs urban and rural settlements, continuous and discontinuous urban fabric, buildings/courtyards, gardens around buildings and beyond settlement as well as farms/hamlets are identifiable. Industrial areas, mining surfaces can also be detected. That plays a role if we assess the real built up surfaces and the land use intensity of the settlements. On the NS however, the detail and precision of the different built up surfaces and infrastructural areas is higher. Commercial areas, ports, airports, sport and leisure facilities, recreational areas, urban parks are also indicated, giving information on settlement functions.
- *Agricultural surfaces:* arable land, vineyards and orchards can be distinguished on all of the map series. The signs on the maps of the MS II, III and NS shows the dispersed and linear

[40] See for „rubber sheet” method furthermore M.S. White, P. Griffin, *Piecewise linear rubber-sheet map transformations*, The American Cartographer 12(2) (1985) 123-131.; A. Saalfeld, *A fast rubber-sheeting transformation using simplical coordinates*, The American Cartographer 12(2) 169-173.;G.W. D., 7th International Symposium on Computer Assisted Cartography (AutoCarto 7), 1985, 191-199.
[41] G. Király, U. Walz, T. Podobnikar, K. Czimber, M. Neubert, Ž. Kokalj, *Georeferencing of historical maps – methods and experiences*, 53-63.

wooded vegetation within agricultural areas. Thus, the land cover pattern becomes more perceptible. The texture on the NS is more refined to indicate intensive vineyards, fruit plantations complex cultivation patterns and rice fields.

- *Grasslands*: meadows and pastures are not separated on the MS I, but dry and wet grassland are distinguished. The MS II, and III and NS show both dry and wet meadows and pastures.
- *Forest and wooded areas*: on the MS I and III there is only one general forest category and the transitional woodland shrub. On the MS II and NS there are labels and symbols indicating the coniferous stands. On the NS wood plantations are also distinguishable.
- *Wetlands*: beyond marches with low or high vegetation, peat extraction areas are identifiable on MS III and NS.
- *Waters*: watercourses and standing water bodies, artificial lakes and reservoirs are indicated on the MS II and later maps.
- *Bare and other surfaces*: Bare rocks and sandy areas can be seen on all the maps.

There was no unified legend for the MS I but it already existed for the MS II and later maps, which makes a higher accuracy and facilitates significantly the interpretation of the individual sheets.

Graphical signs, boundaries

Land cover symbols are mostly clear on each sheet of the MSs, e.g. wetlands are always indicated with graphical signs so they are clearly visible, similarly to the symbol of vineyards. But arable land is not consequently marked with stripes. In categories without graphical signs, borderlines are hard to recognise on MS I. Small watercourses cannot be separated from road lines, while symbols of some larger rivers are too wide. Small labels in mountainous areas are difficult to read, because of the slope hachures. Borders and symbols, as well as colours are best recognisable in most cases on the MS II. Borderlines are rarely drawn between coniferous and mixed forests, so they are difficult to distinguish, similarly to the MS III.

Orchards are mostly separated from vineyards but not on all sheets. They can be confused with scrubs on the MS II and III.

The fitting of neighbouring map sheets is sometimes contradictory on MS I, and II as well. Wetlands on a map sheet often continues as grassland on the next sheet. One possible reason can be the different water level according to the different surveying season or year.

On the black and white sheets of the MS III, grasses are marked by "H" = Hutweide, Heide as pasture, and "W" = Wiese as meadow, although these letters may be missing. On some sheets, other symbols are used. Symbols of vineyards are often missing and their borderlines are difficult to identify. Borderlines and labels in mountainous areas are blurred and difficult to read because of the dense contour lines. Surface waters, roads are often merged into borderlines and contour lines.

Colours

On the MS I, land cover colouring often has different tones on the individual map sheets, and are faded, making interpretation more difficult. Thus, identification of the land cover depends eventually on personal judgement and on the expertise of the interpreter. Arable land has mostly a beige tone but often is not coloured at all, like dry grasslands that are not always distinguished from arable land. It is also due to the farming techniques at that time, when only the half or two third of the land was ploughed and the rest was set aside alternately each year. Therefore, the shift between grassland and ploughed fields were part of the land management regime.

Colouring of the MS II is more accurate, although some faded sheets, occur which makes the distinction between arable fields and grassland difficult. Colours are hardly visible on the MS I, II, on steep slopes, where the dark hachure hides them.
Users must take into account that precipitation and accordingly the water level significantly influence the extent of wetlands and water surfaces. There is also a yearly alternation depending also on temperature. Another consideration is that changes in land cover are non-linear; several changes could occur between two time layers. Furthermore, the military purpose of the surveys implies the rough differentiation between forest stands, (e.g. coniferous and deciduous forests) as well as between various non-wooded vegetation (e.g. arable land and grassland).
The main characteristics of the maps are summarised in Table 2. The HMSs are evaluated geometrically by the comparison with the New Surveys as reference maps.

	MS I	**MS II**	**MS III**	**NS**
Geometrical accuracy				
Scale	1:28800	1:28800	1:25000	1:50000
Grid	no	no	yes	yes
Mean deviation from the reference map*	30-100m	20-60m	10-50m	0m
Max. deviation from the reference map*	400m	200m	100m	0m
Thematic accuracy				
Unified legend	no	yes	yes	yes
Relief	hachure	hachure	contour line	contour line
Land cover categories				
Number of Land cover categories sum	24	30	29	36
No. Artificial/urban categories	11	11	11	14
No. Agricultural categories	3	3	3	5
No. Grassland categories	2	4	4	4
No. Forest categories	2	4	2	5
No. Wetland categories	2	2	3	3
No. Water categories	2	3	3	3
No. Bare and other categories	3	3	3	3
Identification				
Colour	colored	colored	B/W**, colored	colored
Borderline of the categories	faded	exact	exact	exact
Graphical signs	poor	exact	exact	exact
Edition				
paper format	x	x	x	x
digital raster format***	x	x	x	x
digital vector format				

Table 2: The main characteristics of the military surveys

* Topography Map of Hungary 1:10000 (Uniform National Projection system) [42]

**forest is coloured on some sheets

***ARCANUM Edition for the Carpathian basin

Conclusions

The Habsburg Military Surveys and the New Surveys encompass a period of more than two centuries from the mid 18th to the late 20th century. This was a revolutionary era in the man-nature relationship in Central Europe, when adaptive land use and resource management techniques turned to transformative ones. The most important change in nature caused by humans was firstly the water regulation, the drying out of huge wetlands on the lowlands thus giving way to the climate change; secondly, the extended logging and the thinning forest cover in the mountain ranges. Intensification, industrialisation and urbanisation driven by the need of a growing population and productivity were significant from the end of 19th century, and speeded up after the Second World War. This was the period when the global environmental changes of today started, when the long term thinking, predominantly environmental friendly techniques of land and resource management transformed to the overwhelming need of maximum profit production in the minimum of time. Speeding technical development significantly contributed to all these processes.

Despite all constraints mentioned above, the spatio-temporal detection of land cover transformation provides valuable information for the assessment of changing land use intensity, hemeroby, landscape structure, ecological networks, green-infrastructure and the complex landscape services. Therefore the historic military topographic maps are extremely rich information sources for landscape research and planning. The relevance of the land cover categories is summarised in Table 3.

	Research	**Planning**
1. Built up surfaces	– spatial structure and pattern of settlement and infrastructure network – accessibility, agglomeration – fragmentation, ecological barriers – land use intensity, urbanisation – distribution and density of population – landscape functions: - provision of residential area, human and technical infrastructure - row material exploitation and industrial production - recreation - aesthetic and cultural information	– regional development – land use structure planning at regional and local scale – green infrastructure development – protection and management of cultural heritage

[42] Nagy, A történeti felszínborítás térképezése *(Mapping of the historical land cover)*, 15.

2. Agricultural and horticultural surfaces (arable land, utility gardens, orchards, vineyards)	– spatial structure and pattern of cultivated land – landscape functions: - food production - protection of cultural diversity - recreation - aesthetic, cultural information – land use intensity, hemeroby	– rural development and agricultural strategies – agro environmental schemes, – land use structure planning at a regional and local scale – green infrastructure development – protection, restoration and management of cultural landscapes
3. Forests and wooded areas	– spatial structure and patterns of forests, woods and arboreous vegetation – closedness of the landscape – landscape functions: - timber production - recreation - habitat preservation - water protection - climate change mitigation - aesthetic, cultural information	– rural development, forest, nature conservation and climate change strategies – land use structure planning at regional and local scale, – green infrastructure restoration and development – landscape restoration planning – landscape management
4. Grasslands (natural steppic areas, secondary pastures and meadows)	– spatial structure and pattern of grasslands – openness of the landscape – landscape functions: - food production - habitat function	– rural development – agro environmental schemes – nature conservation strategies – land use structure planning at regional and local scale – green infrastructure restoration and development – landscape restoration planning – protection and management of natural and cultural landscape
5. Wetlands	– spatial structure and pattern of wetland – landscape functions: - water protection function - climate change mitigation - habitat preservation	– water management, nature conservation strategies – landscape restoration planning – green infrastructure restoration and development
6. Water surfaces (rivers, streams, lakes and artificial reservoirs)	– spatial structure and pattern of water network – landscape functions: - water protection - climate change mitigation - food production - habitat preservation - aesthetic, cultural information	– water management, transportation, nature conservation strategies – landscape restoration planning – green infrastructure restoration and development
7. **Bare surfaces –** (natural rocks and devastated areas)	– environmental sensibility, threats – habitat preservation	– nature conservation strategies – landscape restoration planning

Table 3. The relevance of the land cover categories in research and planning

Land cover change studies give us the opportunity to follow and analyse the human induced landscape transformation, and to detect the regional and local differences. The dynamic of all landscape types can be revealed. The degraded and highly appreciated, emblematic sites as well as

everyday landscapes can be seen in their evolution. It is possible to see where are degradations and also where and when the positive examples are present. These lessons teach us how to make development strategies, to plan landscape protection and restoration, and finally how to reach sustainability.

The HMSs are best suitable for regional and micro-regional scale land cover surveys (1:25000-50000), for national and local scales can be used only with limitations or completed with additional information sources. In large geographic regions, as e.g. Central Europe or the Carpathian basin, the map series cannot be considered as one unitary snapshot of a definite time layer because of the long surveying period (60 years in case of the MS II). For local scale analysis of habitats and plant communities, additional information such as climatic, geological, and precise relief data are needed.

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