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DIGITAL SPATIAL DATA AS SUPPORT FOR RIVER BASIN MANAGEMENT: THE CASE OF SOTLA RIVER BASIN

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Many real-world spatially related problems, including river-basin planning and management, give rise to geographical information system based decision making, since the performance of spatial policy alternatives were traditionally and are still often represented by thematic maps. Advanced technologies and approaches, such as geographical information systems (GIS), offer a unique opportunity to tackle spatial problems traditionally associated with more efficient and effective data collection, analysis, and alternative evaluation. This paper discusses the advantages and challenges of the use of digital spatial data and geographical information systems in river basis management. Spatial data on social, environmental and other spatial conditions for the study area of 451.77 km², the Slovenian part of the Sotla river basin, are used to study the GIS capabilities of supporting spatial decisions in the framework of river basin management.

Key words: river basin management, spatial data, GIS, spatial evaluation, Sotla river basin.

INTRODUCTION

In the last decades, the extent and intensity of different forms of degradation of the environment have proven the need to follow the guidelines of the long-term sustainability in all fields of human activities. In order to provide a platform for suitable decisions in accordance with the paradigm of sustainable development, a qualitative, unified and holistic approach to inventory of real world and institutional entities in the environment concerned should be applied. In the environmental protection framework, a special attention is given to water, since it has always remained at the foundation of human existence as a precious natural resource. Nowadays the quantity of potable water on earth is limited and its availability per person is reducing day by day due to increase in global population and damage to environment (Gowda and Doddaswamy, 2011).

It is widely known that watershed hydrology and water quality is dependent on many factors, including land use and soil conditions. In the article, we focus on the river basin management as an important step towards the protection of water resources. A river basin covers the entire river system, including its groundwater. In this paper, the river basin is defined as a catchment, the topographic area from which all runoff finally reach one single given point; watersheds refer to the topographic barriers that divide catchments from each other. Here, the ground water system might be neglected.

Decision making related to river basin management poses very difficult and challenging problems. Data and information which are the basis for river basin management decisions are directly or indirectly linked with the geographical location, with the spatial entity. For this reason, geographical information systems (GIS) can play an important role in this process, since GIS is providing a convenient environment in spatial decision problem domain.

Volk *et al.* (2008) have already introduced the idea, that the implementation of the European Water Framework Directive (Council Directive 2000/60/EC) posed new challenges, including the increased demand for new GIS solutions that incorporate simulation models and tools to analyze, interpret, and display spatial information for river basin planning. It is becoming clear, that new approaches are needed which take on board important research findings emanating also from geographical information science (McDonnell, 2008). The Integrated Water Resources Management (IWRM) that has been widely accepted as the proper strategy to handle river basins is based on comprehensive, spatially distributed information (GWP-TAC). Flügel (2007) stresses the need for corresponding data model to transfer the concept of IWRM approach into a corresponding information system. McDonnell (2008) claims that the data alone cannot supply all the information required to support IWRM, but there is a need for analysis which enables bringing together the disparate datasets to consider the impacts, interactions and broader context of phenomena. The importance of GIS and digital geospatial data in water resources management has been emphasized also by McKinney and Cai (2002) in the debate about linking GIS and water resources management models. The authors argued that unique aspects of water resource management problems required a special approach to development of GIS data structures, which would bring spatial dimensions into the traditional water resource data base (Ibid.).

This paper explores the use of spatial data in GIS

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as the basis for transparent decision making and management of the river basin. The research has been done in the study area of the Sotla river basin in the Eastern part of Slovenia, at the Slovenian-Croatian state border. The advanced approach to the river basin management requires the holistic approach and study of the whole river basin area. For the purpose of our study only the Slovenian part of the river basin has been considered. The main reason was the availability of spatial data.

GIS IN RIVER BASIN MANAGEMENT – REVIEW

Nowadays, GIS techniques and procedures have assumed an important position in decision making, where decisions are directly or indirectly related to the spatial entities, in the sense that they offer unique capabilities for automating, managing, and analysing a variety of spatial data for decision making (Drobne and Lisec, 2009). Here, decision problems that involve geographical data are referred to as spatial or geographical decision problems.

Focusing on the geographical data support for the river basin planning and management, numerous variables linked to different spatial units are involved. The use of digital geospatial data for the management of water resources and river basin means a series of certain activities, as can be seen in Figure 1. Research, analysis and evaluation of water resources and river basins are only one step towards advanced river basin management; development of appropriate models, simulation tools and environmental decision support systems is the crucial step in the management of water resources and river basin. From the geographical point of view the latter means applicative geography. Krevs (2002) recognized close connection between GIS and applicative geography; at the same time he exposed relatively poor utilization of possibilities that GIS offers to geography. McDonnell (2008) recognized provision of information as one of basic challenges for integrated water resources management. Matejiček, Engst and Zbynek (2006) found out that many environmental data analyses had been coupled with GIS in the previous decades to simulate environmental processes. Those authors were more precise with defining that various strategies for data integration and functionality in GIS could be divided into a few classes (Ibid.; see also Matejiček 1996, 1998, 1999).

In the nineties of the past century, GIS was widely used in hydrology and well suited to developing input to distributed-runoff simulation models (Brilly *et al.*, 1999). At the turn of the millennium, GIS was dominantly used for data processing and visualization of available data sources as well as handling of data to apply environmental assessment models (Renschler *et al.*, 2000). Sivertun and Prange (2003) used GIS to carry out non-point source critical area analysis, where they found out that such a model allowed the analysis of a large area with a high resolution. Johnston *et al*. (2005) estimated GIS as valuable watershed assessment tool, while several authors studied GIS support for watershed modelling (Lian and Maackay, 2000; Sun *et al.*, 2003; Sathyamoorthy, 2008) and watershed management (Moss, 2004; Jessel and Jacobs, 2005; Lisec *et al.*, 2010). Matejiček *et al.* (2006) focused on spatio-temporal analysis of environmental pollution in urban areas. Twumasi and Merem (2007) used remote sensing and GIS in the analysis of ecosystem decline along the river. They characterize such approach as a conduit for environmental health within shared waters of the River Niger Basin. Assaf and Saadeh (2008) worked on assessing water quality management options in river basin and developed an integrated GIS-based decision support system. Consequently, the policy makers and other stakeholders in the Upper Litani Basin, Lebanon gained a clearer understanding of the key factors and processes involved in the sewage induced degradation of surface water quality. Flügel (2007) stressed the importance of the adaptive integrated data information system for global water research.

In our research, we consider models, simulation tools and environmental decision support systems as advanced and complex tools in water resources and river basin management. The principle of modelling is often based on elaboration of equation, which will relatively easily help to process equal or similar phenomena as in the reality (Dobravec, 2003). Because of the complexity of the real world, the problem of considering all factors in the input modules appears; furthermore, it is impossible to define all operands in the central part and it is impossible to define the course of the operation itself (Ibid.). Similarly Trajković (2004) concludes how no particular indicator set can satisfy the needs of all potential users. Models for the purpose of water resources and river basins management are complex as well; some of them are shortly presented in the continuation.

Cai (2008) stated that it was possible to implement a holistic water resources-economic optimization for river basin management with a model. McKinney and Cai (2002) saw important connection between GIS and models for water resource management. They offered an object-oriented method, which treated the landscape as a set of spatial objects, for example river reaches, and thematic objects, for example flow balance in a reservoir. A basin-wide GIS-based hydrologic watershed planning and management model was developed in the case of Cape Fear river basin in North Carolina; the aim of the model was to diminish strained water supply caused by explosive population growth (Holdstoc *et al.*, 2000). To analyse water productivity, which is an indicator of water use efficiency, the crop growth simulation models coupled with GIS were applied in Laoag river basin in Philippines; substantial strategies in irrigated agriculture were provided with those models (Ines *at al.*, 2002). Volk *et al*. (2008) developed GIS supported methods and tools for the planning process and measurement control for river basin management in the Upper Ems River Basin. Schlüter *et al*. (2005) recommended a water management model for the ecological impact assessment; with optimization of the long-term water allocation they tested model in the Amudarya River delta. Furthermore, a GIS-based simulation tool was used to illustrate implications of uncertainties for water management in the Amudarya river delta; the authors argued that the simulation tools could support a process of reasoning about the implications of uncertainties for the outcome of management policies in a specific river basin management context (Schlüter and Rüger, 2007).

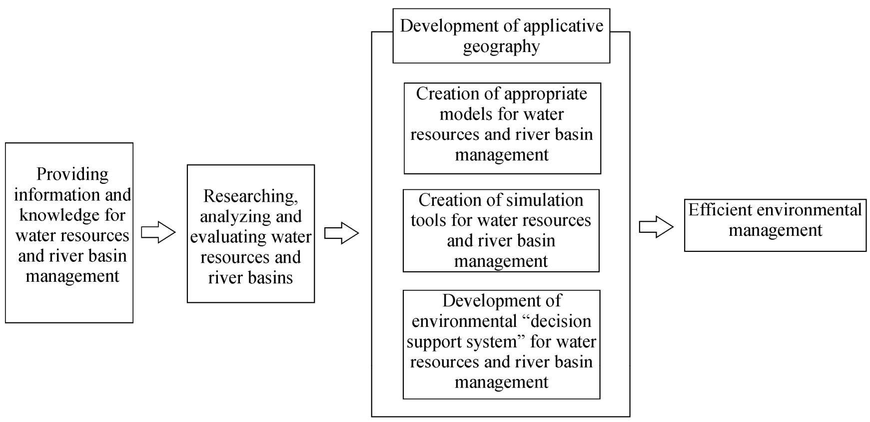

Figure 1. Use of digital geospatial data for efficient environmental management – from the base step to the efficient management

Leung *et al*. (2005) developed an environmental decision-support system for the management of water pollution in a tidal river network. The common problem that most authors have coupled with is the availability, quality and connectivity of digital geospatial data and interoperability of different geographical information systems. For this reason a special attention is given to this problem in the continuation.

The use of digital geospatial data for the purpose of river basin management is tightly connected with the quality and connectivity of data. The quality of spatial data is considered in accordance with international standards that involve positional and attribute accuracy, logical consistency, completeness etc., but also in the wider context such as semantic accuracy and usage, and connectivity with other datasets. The connectivity means a functional connectivity of specific geospatial data. Seamless integration of geospatial data from different sources and establishment of common patterns of objects in space mean perfect infrastructure of geospatial data, which is a condition for advanced analytical work. An important step towards integration of spatial data and establishment of common spatial data infrastructure in Europe has been done by the INSPIRE Directive - Infrastructure for Spatial Information in the European Community (*Council Directive 2007/2/EC*).

MATERIALS AND METHODS

For the purpose of our study, we tried to define indicators which are of crucial importance for the sustainable river basin management. The main idea derived from the study of Guimarães and Magrini (2008), authors of the indicators for sustainable development in the management of river basin, who find out that the systemic formulation of river basin indicators creates an information system that helps in river basin planning, allows efficient management of environmental resources and standardizes the comparison among basins. They evaluated 32 indicators as sufficient to determine the degree of sustainability of the watershed management. The proposed structure of the indicators is (Ibid.):

– social dimension: 8 indicators (Population growth rate, Gini index of income inequality, Per capita family earnings, Life expectancy at birth, Infant mortality rate, Literacy rate, Years of schooling, Unemployment rate);

– environmental dimension: 20 indicators (Air quality in urban areas, Participation of renewable sources in the supply of energy, Use of fertilizers, Use of agricultural pesticides, Land being used in agriculture, cattle raising and forest management, Remaining area and deforestation of woods

Table 1. A set of available digital geospatial databases and indicators for river basin management planning and the relevance with Guimarães' and Magrini's indicators for sustainable development of river basins

Dimension	Geospatial database name	Owner	Indicator	Relevance with Guimarães' and Magrini's indicators
Social	Population density	Statistical office of the Republic of Slovenia	- population density 200 inhabitants/km^2 and more	
Environmental	SOIL			
	Soil	Ministry of Agriculture, Forestry and Food of the Republic of Slovenia	- soil type	
	Land Cover	Ministry of Agriculture, Forestry and Food of the Republic of Slovenia	- proportion of intensive agricultural land - proportion of forest land - proportion of urban land - presence of extensive wetlands	✓ ✓
	Building Cadastre	Surveying and Mapping Authority of the Republic of Slovenia	- number and distribution of industrial buildings - number and distribution of catering buildings	
	Protected areas	Environmental Agency of the Republic of Slovenia	- presence of protected nature areas	✓
	Natura 2000 areas	Environmental Agency of the Republic of Slovenia	- presence of protected sites Natura 2000	✓
	WATER			
	Hydrography - Topographic Database	Surveying and Mapping Authority of the Republic of Slovenia	- number of stagnant water	
	Floodplains	Environmental Agency of the Republic of Slovenia	- areas of fewer and more frequent floods	
	Categorization of degraded watercourses	Institute for Water of the Republic of Slovenia	- length of significantly and strongly to very strongly modified river channels in the hydrographic area	
	Industrial effluent and fish-farms	Institute for Water of the Republic of Slovenia	- number of fish-farms - emissions higher than 80% of the limit value	
	Municipal infrastructure	Environmental Agency of the Republic of Slovenia	- presence of municipal waste landfills - presence of industrial waste landfills - presence of sewage treatment plants	✓ ✓ ✓
	Vulnerability of groundwater aquifers	Geological Survey of Slovenia	- groundwater vulnerability	
	Natural heritage	Environmental Agency of the Republic of Slovenia	- share of hydrological values	✓
	Protected areas of water resources	Geological Survey of Slovenia	- number of captured springs and drainage captures of drinking water	✓

and coastal vegetation species, Desertification and transformation of soil to sand, Protected areas, Access to garbage / waste collection, Quantity of garbage / waste produced, Quantity of garbage / waste collected, Quantity of garbage / waste recycled, Quantity of garbage / waste for sanitation discharge, Access to water distribution system, Access to sewage sanitation system, Sewage treatment, Water supply, Water demand, Quality of water, Intensity of water use);

– economic dimension: 2 indicators (Public expenditures with environmental protection, Existence of a river basin master plan);

– institutional dimension: 2 indicators (Per capita energy consumption, Energy intensity).

Unlike the above mentioned indicators we proposed a set of those indicators that could be determined through digital geospatial data, available for the study area. Our set of indicators is more modest and shows that availability of digital geospatial data is not sufficient for the holistic and sustainable river basin management. Based on the available digital geospatial data we created 21 indicators. One of them falls within the social dimension and twenty of them within the environmental dimension. Furthermore, the relevance between a set of Guimarães' and Magrini's (2008) indicators and our set of indicators is poor, what can be figured out in Table 1 – there are only nine selected indicators for our research that correspond to the above mentioned authors' indicators. In some cases more of our indicators refer to one Guimarães' and Magrini's indicator. Ultimately, we have found that with our indicators we met only four Guimarães' and Magrini's indicators. While only some of the proposed indicators for sustainable river basin management can be created on the basis of existing and available digital geospatial data, the others can be created on existing and available statistical and other set of data. Such indicators are for example share of unemployment, the amount of recycled waste, energy consumption per capita etc. For both types of indicators we have found out that some were still not easily obtained for application to river basins, which implies the need for field work at the local level, noted also by Guimarães and Magrini (2008).

In some cases we considered reasonable to simplify or adapt the categorisation of an indicator. In this way we can obtain new functionality and improve the transparency of the indicator. Simplifications or adaptations of the categorisations can refer for example on indicators such as proportion of intensive agricultural land, length of significantly and strongly to very strongly modified river channels etc.

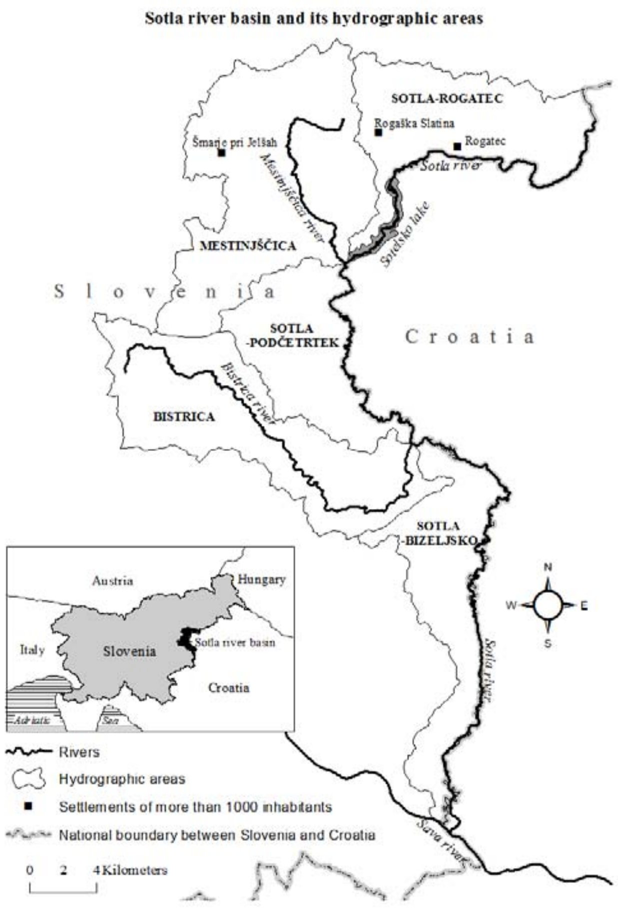

Figure 2. Sotla river basin and its hydrographic areas

CASE STUDY

The Sotla river basin is located on the margins of Pannonian plain and it spreads from the north to the south along the Slovenian-Croatian border. Sotla River is a left tributary of the Sava River. The total area of river basin is 583.8 km^2 and 81.7% of it belongs to Slovenia. As already mentioned, we have focused on the Slovenian part of the river basin (below Sotla river basin), which extends on 451.8 km^2. The Sotla river basin is exceptionally asymmetric since most of the tributaries are at the Slovenian side in the upper and middle flow. The basin is characteristic for its fan branching and is therefore more exposed to floods. It consists of 5 hydrographic areas: the Sotla-Rogatec (upper stream of the Sotla till the Mestinjščica tributary), Mestinjščcica river basin, Sotla-Podčetrtek (central part of the Sotla river basin till the Bistrica tributary) the Bistrica river basin, and Sotla-Bizeljsko (lower part of the Sotla river basin) (Figure 2).

Based on the environmental status of the Sotla river basin and fundamental objectives of the river basin management we defined certain measures for Sotla river basin management. Environmental status means the current situation of various geographical parameters in the river basin (for example soil type, riparian land use, etc.). The river basin management objectives are defined on the legal bases and predict the optimal condition of the environment. Conceptually we leaned on ecoremediation approach, which means the protection and expansion of natural ecosystems while allowing human activities (Vrhovšek and Vovk Korže, 2009).

Environmental status of the Sotla river basin indicates the rich diversity of surface waters (rivers, streams, still waters) and ground waters (spring, mineral and thermal water). There are obvious certain impact factors on water resources such as agriculture, urban areas (settlement of Rogaška Slatina had 5105 inhabitants and Šmarje pri Jelšah had 1765 inhabitants according to the statistical data for 2012), industry and tourism infrastructure of health resorts in Rogaška Slatina and Podčetrtek, an also dispersed numerous settlements in the countryside. Hydrological characteristics point at considerably high vulnerability of the Sotla river and its tributaries according to its specific outflow, which comes to 16 l/s/km², average annual flow which comes to 9 m³/s, and average low flow, which comes to 0.9 m³/s (all results are for the lower part of the Sotla river). In the Sotla river basin there is a trend of gradual decrease in average annual precipitation and increase in average annual air temperature, which leads to reduction of water resources amounts. Slovenia has enough water on average according to water balance (Slovenian Environment Agency, 2008); however, some annual periods are critical, in the Sotla river basin as well. These periods are usually at the end of summer as the consequence of a precipitation lack accompanied by high summer temperatures. The streams in the river basin are naturally preserved since they are naturally slightly to moderately modified. In addition, there are many hydro-technical regulations of the river bed from the 1970s and 1980s, which are usually outdated and not maintained. The biggest environmental problem in the Sotla river basin is significant pollution in the upper part of the river stream. Chemical status of the Sotla in Rogaška Slatina is unfavourable but it is getting improved gradually along the river stream. Point pollution sources (sewage, industrial, agricultural and other facilities and activities) also burden mostly the upper part of the Sotla river basin (hydrographic area of the Sotla-Rogatec) while disperse pollution sources, headed by intensive agriculture, burden mostly lower part of the river basin (hydrographic area of the Sotla-Bizeljsko).

RESULTS AND DISUSSIONS

Definition of fundamental objectives of the river basin management means definition of global objectives which regulate the coexistence between human and water. The fundamental objectives have been studied and defined on the legal basis, which includes the European Community regulations and international conventions, national legislation, bilateral agreements and municipal ordinances. It has been ascertained that not only the state but also the local municipalities have many obligations in relation to the environment and water resources. In Slovenia, there is a huge issue to achieve the fundamental objective of the Water Framework Directive, namely to reach a good status for all waters, including surface water. The main reason for the concern about the implementation of the Directive until 2015 is sector approach in water resources management.

In our study, the Sotla river basin management measures have been defined based on main spatial entities and digital geospatial data sources. Measures mean actual solutions to achieve fundamental objectives and to preserve or improve the environmental status. The spatial placements of the measures have been organized in different GIS layers geo-referenced in the Slovenian national spatial reference system D48/GK. The measures were geo-referenced directly (through transformation parameters between the original and national spatial reference systems if needed) and indirectly (geo-referencing of data through geo-referenced spatial units). Some of measures are shown in Table 2 and Figure 3.

For better transparency and illustration we present cartographically the selected measures only for the hydrographic area Sotla-Podčetrtek, and the measure of improving the hydro-morphological status with eco-remediation techniques also for the hydrographic area Mestinjščica. For the measure of creation of ponds, pools and wetlands for natural water retention we considered land use and soil type; here, the areas of meadows, pastures or marshy grasslands coincided with riparian or gley soils are considered as appropriate. There is 21.1 km² of such area in the Sotla river basin, which represents 4.7% of the entire river basin. There is 1.5 km² of such area in the hydrographic area Sotla-Podčetrtek, which represents 2.5% of the entire hydrographic area. Simple GIS analysis of spatial determination of this measure is shown in Figure 4. Intersection of both spatial elements

Table 2. Definition of some measures for Sotla river basin management with main spatial elements, digital geospatial data sources, the geospatial data attributes and geometrical forms of the measures

Measure	Main spatial elements	Digital geospatial data sources	Attributes	Geometrical form of the display of the measure
Creation of ponds, pools and wetlands for natural water retention	land use soil type	- Agricultural land use - Soil	- meadows, pastures, marshy grasslands - riparian soils, gley soils	polygon
Preserving and creating protective vegetation belts	rivers and streams land use	- Hydrography - Agricultural land use	- main water streams (Sotla, Mestinjscica and Bistrica) - borders of fields and meadows in a belt 30 metres from the river bank	polygon
Revitalisation of degraded riverbeds	degraded rivers and streams water dams	- Categorization of degraded watercourses - Water level in the reservoir lake Sotelsko jezero	- water streams of 2nd, 3rd and 4th hydromorphological category -water dams Vonarje and Prislin	line
Rehabilitation of critical erosion places	rivers and streams land use	- Hydrography - Actual agricultural land use	- built areas in a 10 m belt on each side of the meander of the rivers Sotla, Mestinjscica and Bistrica	point
Reduction of plantation farming, encouraging the ploughing transversally to the land slope, supplementing farming by growing industrial hemp, growing reed	rivers and streams soil type land use	- Hydrography - Soil - Agricultural land use	- rivers Sotla, Mestinjscica and Bistrica and their tributaries - riparian soils, gley soils - fields and meadows	polygon
Planting willows along the rivers and streams	soil type rivers and streams land use	- Soil - Hydrography - Agricultural land use	- riparian and gley soils, infertile areas (water areas) - 30m belt on each side of the rivers Sotla, Mestinjscica and Bistrica - fields, meadows, pastures, marshy grasslands, overgrown areas, areas of trees and bushes, wetlands	line

(land use and soil type) results appropriate areas for the implementation of the above mentioned measure.

The measure of preserving and creating protective vegetation belts is appropriate for the areas where surface water streams contact areas of intensive agriculture. We recommend implementation of this measure inside of the belt up to 30 m on each side of the rivers Sotla, Mestinjščica and Bistrica, where those rivers contact agricultural fields and meadows. According to the results of the analysis, there is 1.07 km^2 of such area in the Sotla river basin, which represents 0.24% of entire basin area. In the hydrographic area Sotla-Podčetrtek there is 0.03 km^2 of such area, which represents 0.05% of the entire hydrographic area. The measure of rehabilitation of critical erosion places is proposed where meanders along the Sotla, Mestinjščica and Bistrica threaten built up areas due to lateral erosion. There are 45 such places in the Sotla river basin; 3 of them in the hydrographic area Sotla-Podčetrtek. Geometrical form of the measure in spatial data model is the point. Plains along the Sotla river and its tributaries are often areas of intensive agricultural production, which is the source of dispersed pollution for water resources. This are areas of riparian or gley soils. As mitigation measures we suggest reduction of plantation farming, encouraging ploughing transversally to the land slope, supplementing farming by growing industrial hemp and growing reeds (Phragmites australis). By ploughing transversally to the slope we prevent rinsing of plant protection products directly to the river and we reduce soil erosion.

Industrial hemp is suitable for crop rotation on the wet ground and riparian areas along the river Sotla and its tributaries are such. Reeds are a source of biomass, appropriate for heating, as a building material in the restoration of cultural landscapes, as well as a shelter for endangered animals. There is 40.5 km^2 of dispersed pollution area in the Sotla river basin, which represents 8.96% of the entire basin area. In the hydrographic area Sotla-Podčetrtek there is 10.6 km^2 of such area, which represents 17.2% of the entire hydrographic area. The measure of planting willows along the rivers Sotla, Mestinjščica and Bistrica means an opportunity to revive basketry as a landscape property as well as an opportunity for additional income for farmers. We suggest the implementation of this measure in the areas where riparian and clay soils coincide with one of the following land use: fields, meadows, marshy grasslands, areas in overgrowing, individual trees and bushes, wetlands. There is riparian belt along

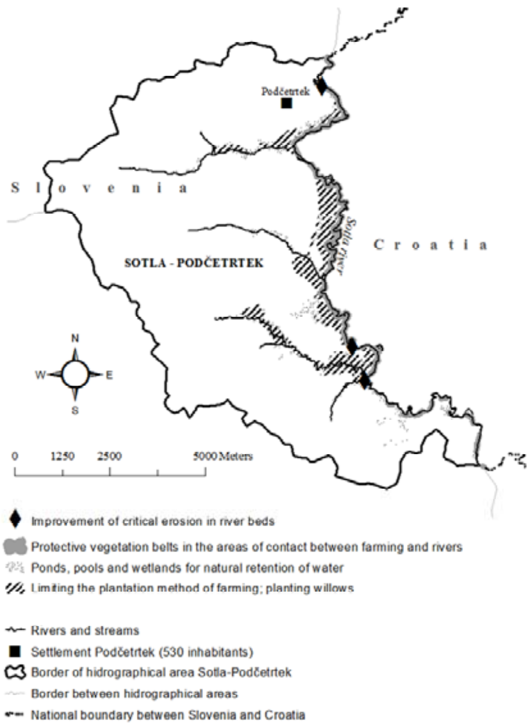

Figure 3. Spatial determination of some measures of river basin management for hydrographic area Sotla-Podčetrtek

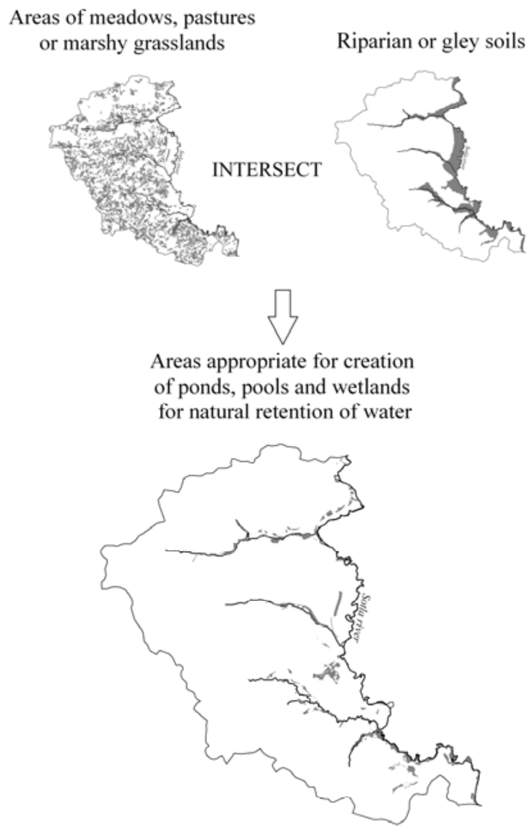

Figure 4. Data overlay in GIS for spatial determination of the appropriate areas for creation of ponds, pools and wetlands for natural water retention in the hydrographic area Sotla-Podčetrtek

119.5 km length of mentioned water streams appropriate for planting willows representing 84% of total length of those streams. In the hydrographic area Sotla-Podčetrtek there is 22.5 km length of the river Sotla appropriate for implementing this measure, which represents 98.3% of total length of this river in mentioned hydrographic area.

The last measure that we are presenting is revitalisation of degraded riverbeds and means prevention or restoration of aquatic and riparian ecosystems and their parts with pools, rapids, sediment banks, river beds overgrown with reeds, side river channels etc. For definition of the areas suitable for this measure we considered two spatial elements: degraded rivers and streams, and water dams. The latter because there is more than 165 hectares of the reservoir lake in the lower part of the hydrographic area Sotla-Rogatec, dammed by two concrete barriers. The water had to be released from the reservoir in 1988 because of high pollution. Digital geospatial data sources for the definition of the measure are Categorization of degraded watercourses and Water level in the reservoir lake Sotelsko jezero. Revitalisation of degraded river bed is necessary in all streams of 2nd (slightly to moderately modified streams), 3rd (significantly modified streams) or 4th (strongly to very strongly modified streams) hydromorphological category, while both dams require improvement. The length of the streams in Sotla river basin that need revitalisation is 96.3 km, representing 68.5% of the total length of those streams. The length of the streams that need revitalisation is 22.2 km in the hydrographic area Sotla-Podčetrtek, representing 88% of the total length of those streams.

As another example of the measure of revitalisation of degraded riverbeds we focus on the hydrographic area Mestinjščica (Figure 5). With numbers from 1 to 5 segments of the streams are marked that are classified as significantly and strongly to very strongly modified streams and were modified in 50-ies and later of past century in purposes of urbanization, industry, traffic, and melioration of agricultural land. Stream segment number 2, for example, represents the brook Lemberžica, which was channeled in 80-ies of past century with classical hydro-technical interventions in purpose of building the wood factory on the 85,000 square meters big industrial area. Eco-remediation techniques such as artificial indentations, rapids, gravel banks, and shading sunny (right) bank would be appropriate for revitalization of the brook.

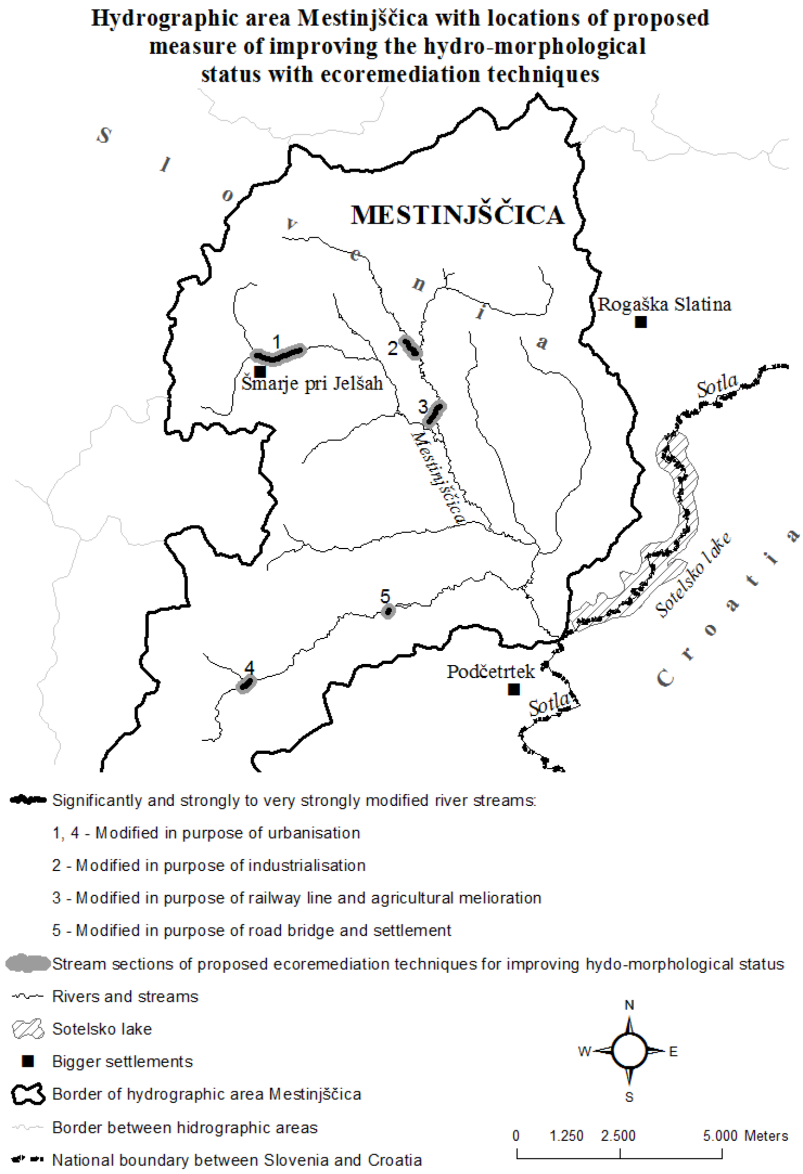

Figure 5. The hydrographic area Mestinjščica with the locations of significantly and strongly to very strongly modified streams, which represent also locations of proposed measure of improving the hydro-morphological status with eco-remediation techniques

CONCLUSIONS

Qualitative semantic integrated spatial data together with the GIS technology provides the basis to develop information that can support decisions on different governmental levels – from the local to the national and international level. This is true also in the field of river basin management when supported by advanced GIS technology. In the last decades, a bright future has been recognized by using GIS technology to support spatial decision making. However, there is still numerous of problems relating to the use of spatial data for river basin management – from the data quality and data accessibility points of view.

Based on foreign experiences we have tried to use digital geospatial data for determination of different indicators of the river basin planning. It has been shown that despite the variety of existing spatial data, there are only some appropriate to define the basin management indicators (for example protected areas), while for the others indicators we were constrained to use the statistical data (for example number of years of schooling) or descriptive data (for example the existence of basin management plan). However, these data are also related to the spatial entities therefore it is possible to georeference them indirectly. In this way we reach unification of the format of the information as well as georeferencing and visualization of data.

In the continuation, some of the possible measures for the river basin management which can be determined based on digital geospatial data, have been presented. The paper does not present the whole river basin management approach and does not include all measures which should be encompassed in the holistic river basin management. The extent of digital geospatial data use for defining measures has been dependent on availability, quality and connectivity of geospatial data. The main purpose of the research was to prove and illustrate the advantage of GIS use in the river basin management, obstacles in the sense of data availability and data quality, and in particular to show the complexity of the decision space in the field of the river basin management. Further work in this field calls for the inclusion of the other natural-geographic and also social-economic elements in the river basin management, in particular ecologically acceptable flow (EAF), buffer capacity of ecosystems, institutional alliances within municipalities in the management of water resources, etc. Here again the problem of digital geospatial data quality has to be mentioned, but also the availability of digital spatial data. The advanced spatial data infrastructure may positive affect also the praxis in the field of the environmental and natural resources management; this might further impact on service delivery and local policy implementation. Our study has in particular shown also the lack of cross-border integration of spatial data, when for example the river basin management require data from different countries/ administrations. A common spatial data infrastructure would be an aid to working in partnership across different agencies and across administrative boundaries.

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