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WATER MANAGEMENT DECISION SUPPORT SYSTEM FOR BIEBRZA NATIONAL PARK

The environmental changes occurring in the Biebrza River Valley (NE Poland) during the last two centuries have enforced a number of conservation activities in Biebrza National Park (BNP). In order to optimise planning processes, a Decision Support System (DSS) was developed. The DSS consists of a Data Catalogue and Geographic Information System (GIS), as well as a Hydrological and an Ecological Modules. In this paper, we present the use of the DSS in a scenario study, in which the changes of water conditions on the floodplain were estimated after different vegetation management scenarios leading to different vegetation successions.

1. INTRODUCTION

The Biebrza River Valley is situated in NE Poland (figure 2) in the geographical region of Podlaskie Lowlands. The valley contains non-drained floodplains, marshes and fens surrounded by a post-glacial landscape with ice-pushed hills, moraines and outwash plains [9]. An almost natural character of the Biebrza mires is reflected in a regular pattern of peat-forming plant communities which run along the length and breadth of the valley. The river, meandering in the whole valley, is not regulated and it has many ox bow lakes. However, a number of its tributaries has been trained or turned into drainage canals [10]. Extensive areas are flooded by the river in spring. Further away from the river, at the edge of the valley, groundwater-fed rich fens cover large areas.

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The floodplain contains highly-productive rich fen types which belong syntaxonomically to *Glycerietum maximae*, *Caricetum gracilis* and *Caricetum elatae* [13]. These are tall sedge, grass and herb vegetations, relatively poor in species. Typical associations of the occasionally flooded belt are *Caricetum caespitosae* and *Peucedano-Caricetum appropinquatae*. Transitional fen is found in an intermediate belt, outside the reach of the seasonal river floods on the places where the calcareous groundwater from the moraines does not reach the fen surface. It is fed mainly by rainwater [17] and belongs syntaxonomically to *Betuletum humilis* with affinity to *Caricetum rostrato-diandrae*. This is a thin dwarf-shrub vegetation with low sedges and occasionally some *Sphagnum* hummocks. The moss layer has a fairly high standing crop [3]. In a belt along the moraines, as well as further away, provided that the calcareous groundwater still reaches the fen surface, low sedge rich fen types are abundant. In the Biebrza River Valley, several species-rich associations of this fen type (*Caricion diandrae*) are present [13]. These are sedge and herb vegetation of low-productivity with a well-developed moss layer of *Hypnaceae*.

The immense ecological values of the Biebrza Wetlands were recognized in a number of publications, e.g. [14], [1], [18], as well as in international and national protection measures. The Biebrza River Valley is designated as a wetland site of a global significance in the frame of the Ramsar Convention. It belongs to Natura 2000 EU Ecological Network and it has the status of a National Park (BNP), which covers an area of 59,800 ha.

Protection of this unique area requires specific management activities on more than 166,000 parcels, which are either privately owned (40% of the park area) or belong to the State. These activities mainly focus on halting the scrub encroachment process, which decreases the area of the open spaces needed for bird breeding and endangers the sedge-moss communities. Another management challenge is the decreasing of peat mineralization in the areas affected by drainage. This requires restoration of the natural hydrographical network (which is particularly relevant in the so-called Middle Biebrza Basin [8]) and decreasing or halting the outflow through artificial canals [11].

In order to find feasible solutions for these kinds of problems, a Decision Support System (DSS) was developed within the frames of PINMATRA Program [2]. The DSS was oriented towards assisting in the following management tasks: operational data acquisition from different monitoring networks, sharing the data sets with scientific and administration institutions, preparing annual environmental reports, planning land exchanges with private land-owners, planning conservation measures and selecting specific sites for restoration measures.

The DSS had to be specifically designed for the Biebrza region because of its unique characteristics such as a large area of the park and the presence of many different wetland habitats. DSSs available in water management institutions are strongly oriented towards water balances and/or water allocation issues [4], whereas in the

case of the Biebrza, water quality and ecological services of surface water and groundwater are very important. A “tailor made” approach was essential for creating a DSS which can address specific problems of BNP, and which can be used for multi-user demand for data processing and the need for sustainable development of the river valley which is used not only by conservationists or resource managers but also by researchers, farmers and tourists [7].

2. DSS DESCRIPTION

DSS was developed as a GIS database, which links point-data gathered in the base or spatial data on maps with the output calculated by models. DSS consists of three parts: Data Catalogue and GIS, Hydrological Module and Ecological Module (figure 1). The first part, Data Catalogue and GIS, aims at inventory of all important characteristics of BNP and contains several thematic databases (Fauna, Flora, Soils, Hydrology & Meteorology, Water Quality, Pollution Sources, Land Ownerships, Fire Events, Forest Management, Non-Forest Management Activities), mostly related to GIS by SQL language. The spatial part of the database developed in a GIS environment was included as ArcView GIS themes. The thematic basis contains: information gathered from different research activities conducted since the establishment of BNP in 1993, biota and abiotic resources inventory, which was made during BNP management plan development in the late 1990s, as well as historical and current management practices recorded by the park staff.

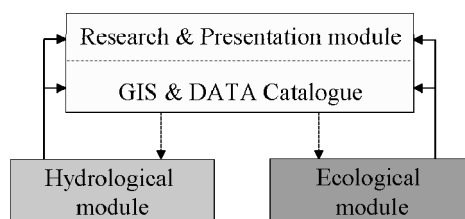


Fig. 1. Scheme of logical structure of DSS

The Hydrological Module predicts the changes in water conditions as a function of climate change and different water and habitat management strategies. The Hydrological Module consists of the results of existing mathematical and statistical models for surface and groundwater developed in the last decade within the frames of different research programmes. The regional groundwater model was the basic tool for simulating the impact of planned infrastructure modifications (e.g. blocking the outflow from drainage canals, partial restoration of the historical river network, rising the water level in the tributaries) on the groundwater level in the phreatic zone. The model was developed using the SIMGRO program [12], which simulates groundwater

flow as well as the flow of surface water. The examples of simulation scenarios were produced separately for the Middle [8] and Lower [16] Basins for a historical hydro-meteorological data set of 1990–1995.

The predictions of the river flow were based again on two separate models: the model of the Middle Basin and the model of the Lower Basin. The models are based on the one-dimensional St. Venant equation. The model of the Middle Basin uses the specially developed calculation program [6], and the flow simulation in the Lower Basin was calculated using HECRAS-UNET [5] software. The steady state hydraulic model was used for water level calculation. Next, the Digital Elevation Model of the floodplain constructed with the use of GIS techniques was coupled with the water levels calculated for spatial flood extent in the valley. The model was successfully verified with the help of processed Landsat satellite images and field measurements [15]. Both models of the surface water flow were used to generate hydrological data for developing thematic maps showing extent of floods under different hydrological conditions.

The Ecological Module aims at predicting the direction of changes in plant communities and the plants presence on the Red List of Threatened Species. It also predicts the suitability of specific habitats for breeding birds as a function of changes in abiotic conditions (soil, water) and conservation measures (hay-making, grazing, burning). The ecological module uses statistical correlations and expert knowledge. Expert knowledge was used for formulating decision rules about ecological relations. Additionally, expert judgement was used to replace the empirical model, which could not be satisfactorily calibrated [2].

The DSS usability was demonstrated soon after its completion, when it was repeatedly assisting in the planning of the management activities predicting the habitat status for different scenarios or actions in particular sections of the park. In most cases, DSS was used in order to plan small-scale management activities (mowing, shrub removal, blocking of drainage ditches, etc.) on different land parcels, taking into account the ecological value of the area and the ownership status. The Data Base and the GIS Module were used mainly for this purpose. However, for the middle to long term strategic planning of the natural resources such as the mire ecosystems, some kind of scenario studies were performed, aiming at larger-scale changes. Such a study involved hydrological calculation of flooding phenomena in the Lower Basin of the Biebrza River Valley.

3. EXAMPLE OF DSS APPLICATION

The system developed was used as a tool for evaluating the impact of different land use management practices on the flood extent in the BNP area in the Lower Biebrza Basin (figure 2a). Vegetation in the valley was determined from DSS databases

for four different land use scenarios. The first one (scenario 1) presents the current state of agricultural and protection activities. The second one (scenario 2) takes under consideration a situation where tall sedge, grass and herb vegetations are used much more intensively for hay making and pastures compared with the current land use, resulting in short vegetation of wet meadows. Natural succession in the area leads to bush encroachment, which results in a decreasing biodiversity, including dramatic changes in bird populations. That is why the third scenario (scenario 3) takes into account the removal of willow shrubs and birch trees from the areas currently covered with this type of vegetation. The fourth scenario (scenario 4) allows for natural succession of willow and birch, resulting in almost complete disappearance of non-forest ecosystems from the area.

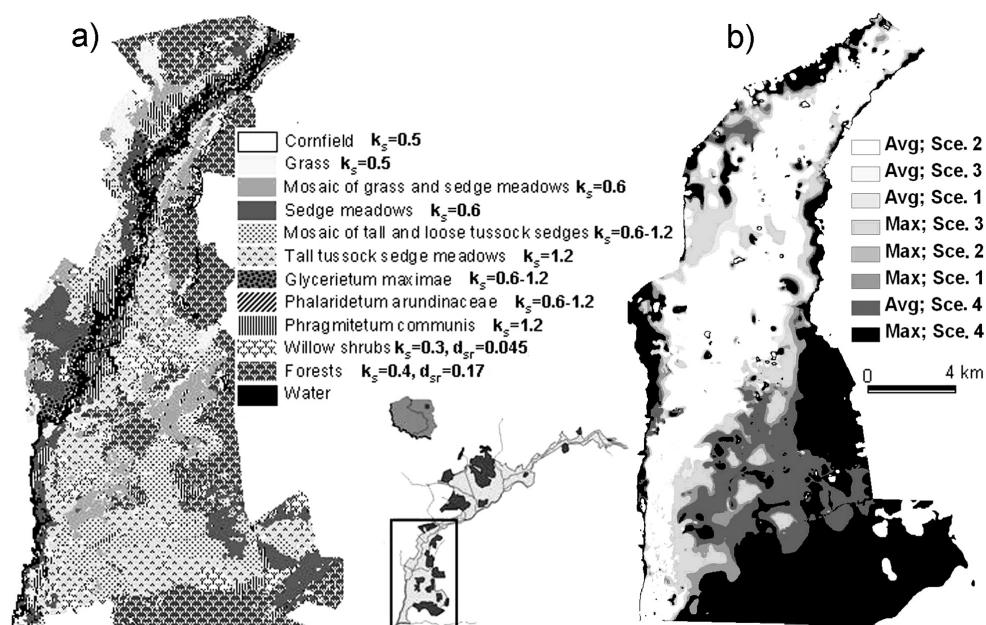


Fig. 2. Location of Lower Biebrza Basin: a) land use considered in this study, b) flooded area calculated for different management scenarios (k_s – roughness height, d_s – diameter plans)

The water profile in a steady, gradually-varied flow was calculated for all four land use scenarios. The data which were needed for the hydraulic model were automatically obtained from DSS database. The water surface calculation was performed for the two following cases: absolute maximum flow (MAX $Q = 229.2 \text{ m}^3/\text{s}$) and mean of maximum flows (AVG $Q = 70.5 \text{ m}^3/\text{s}$) of annual discharges for historical records from 1965 to 1996. The flood extent and average flood depth were determined by GIS analysis using DSS database.

Table

Variation of flooded area and water depth on floodplain
for different land use scenarios (MAX $Q = 229.20 \text{ m}^3/\text{s}$, AVG $Q = 70.51 \text{ m}^3/\text{s}$)

Scenario	Flooded area (km ²)	Average depth (m)	Flow condition
1	93.29	0.65	MAX
2	83.84	0.61	MAX
3	83.21	0.60	MAX
4	179.55	1.44	MAX
1	61.35	0.49	AVG
2	56.54	0.46	AVG
3	56.27	0.45	AVG
4	113.74	0.68	AVG

Table 1 and figure 2b show the results of these calculations compared with those of the current state (scenario 1). Both management activities, i.e. grass mowing (scenario 2) and cutting shrubs and trees (scenario 3), decreased the flood extent by about 8% for the average flood conditions and 10% for high flood conditions. The average water depth decreased by 0.03 m and 0.05 m, respectively. However, the difference between these two management scenarios is not significant. Scenario 4 (natural succession) results in very significant differences in both flood extents and water depths. The flood extent increased by more than 100% under average and high flood conditions, while the simulated water depth increased by 0.2 m and 0.8 m under average and high flood conditions, respectively. In practical terms, this means that regular flooding would occur in both zones currently occupied by vegetation of occasional floods as well as in groundwater fed fens which are presently very rarely flooded.

The results obtained show that the variation of the flood extent is related to the vegetation structure of the floodplain. The most significant difference in the flood extent was found in the scenario in which human management was absent and the natural succession of vegetation was taking place. In this scenario, birch forest and willow shrubs occurred over large areas of wetland, resulting in a significant increase of the flood extent and water depth. The ecological consequences, i.e. changes of vegetation structure due to the modified flood characteristics, were not assessed due to the lack of decision rules on ecological relations in such a case.

4. CONCLUSIONS

A local branch of WWF was raised to facilitate the communication process on integration and dissemination of knowledge between the park authority and other relevant stakeholders such as water boards, farmers and tourism organisations. The results of the different scenarios were published on the web and were communicated with stakeholders in the area and with local and national policy makers [2]. It seemed that

the hydrological models had their function in pinpointing important aspects of optimization of the water management system. However, for successful implementation of the measures for restoring hydrology, communication was the key. Since then, Decision Support System has been used as a tool facilitating continuous dialogue and discussion.

The communication process as well as decision making are constrained by a huge number of landowners and the small size of the land parcels. This implies that DSS should be used for information sharing in an almost automatic way, as there is no room for personal communication in the case of bigger scale projects. Updating the landowners' map is also critical for a number of conservation measures.

Establishing DSS in the BNP headquarter led to an increased awareness of the importance of information and its value in preparing management plans and application of different financial grants supporting the conservation measures. This has built up some pressure on the research groups to share the results of their work in such a way that it can be incorporated in DSS, especially in the Data Base and GIS Module.

However, we also observed that there is a significant bias in the use of the Data Base module compared with the Hydrological and Ecological Modules. In the case of the Hydrological Module, significant organisational (and financial) efforts are needed in order to couple different hydrological models developed in several projects into one final operational unit, resulting in obtaining coherent data for different parts of the valley and surface and groundwater subsystems. If an operational link between the monitoring devices located in the BNP and the DSS Data Base could be designed, the process of effective and immediate data use could be enhanced. For the Ecological Module, it seems that the knowledge base is still a major constraint on producing the required quantitative predictions for different management and climate scenarios. This implies that basic research on ecological relations in wetland ecosystems has to be continued with full speed.

ACKNOWLEDGEMENT

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SYSTEM WSPOMAGAJĄCY DECYZJE O ZARZĄDZANIU ZASOBAMI WODY W BIEBRZAŃSKIM PARKU NARODOWYM

Przeobrażenia środowiskowe zachodzące w ciągu ostatnich dwóch wieków w otoczeniu doliny Biebrzy wymuszają czynną ochronę dużej części Biebrzańskiego Parku Narodowego. W celu optymalizacji działań ochronnych opracowano System Wspomagania Decyzji (DSS). W skład DSS wchodzi następujące elementy: Katalog danych z Geograficznym Systemem Informacyjnym (GIS) oraz moduły hydrologiczny i ekologiczny. Jako przykład wykorzystania DSS podano analizę zmian warunków wodnych w dolinie zalewowej wywołanych sukcesją roślinności.