Linking Research, Policy and Practice for Managing Dynamic Water Resources in a Protected Area

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Faculty of Geography and Regional Studies, Warsaw University, Krakowskie Przedmiescie 30, 00-927 Warsaw, Poland (somorows@mercury.ci.uw.edu.pl)

Abstract: Restoration of wetlands involves the necessity of maintaining the high moisture content of the sites involved. Managing adequate hydrological conditions means supporting successful habitat restoration of wetland ecosystems. Before the management practices are implemented, the formulation of objectives in the development of restoration policies is required. It should be based on an understanding of the primary natural controls of the water regimes. This research focuses on practical approaches to the management of dynamic water resources in the protected area of the Kampinos National Park in Poland. The area has the status of UNESCO MAB Biosphere Reserve. Valuable wetland ecosystems are present in the area. They had been influenced in the past by agricultural drainage, before the area gained the protection status. Dynamic water resources in top soil layers are ranked here as one of the highest priority issue due to symptoms of drying. In order to avoid and reverse negative trends, restoration policies have been addressed. The basis for the formulation of water policies was an analysis of surface wetness conditions. Specific question to be answered is what are particular water demands to support restoration of vegetation, and how high are deficits of soil water storage appearing in contemporary conditions. The answer to this question was given in the form of wetness criteria which have to be fulfilled by water management practice. These are the minimum target values of soil moisture and groundwater level. Simple correlation model was used as a tool for the evaluation of water deficits appearing in dry seasons. The model developed was the water storage decrease function which allows an estimation of soil water deficits depending on groundwater level change. In practice it can be applied to predict water demands which should be compensated if groundwater levels drop below hazard level.

Keywords: Wetness conditions; Restoration policies; Implementation

1. INTRODUCTION

As general concern grows about managing natural resources, the need for environmental monitoring and decision support systems is becoming more and more obvious. Management of water resources on the watershed scale is one of the contemporary targets addressed to mitigate the water shortage and - in much wider sense - to contribute to sustainability. Many examples of water management programs and practices are reported in the literature under such labels as Remedial Action Programs, Best Management Practices or Recovery and Rehabilitation initiatives. Effectiveness of such actions depends, among others, on the relevance of decision making that should be preceded by the forecasting of the consequences of possible decisions. A modeling approach is often considered as an essential element supporting the environmental decision making, since models enable simulations of different scenarios [Venterink and Wassen, 1999]. Thus they may provide an insight into the relations between possible decisions and their consequences [Wessels, 2001].

Hydrological models are often used to analyze different options of water management, before the management practices are implemented [Schouwenaars, 1993]. In this study a simple correlation model was used as a tool for the evaluation of water deficits appearing in the protected area of the Kampinos National Park (KNP) in Poland (Figure 1). The area has the status of UNESCO MAB Biosphere Reserve. Dynamic water resources stored in the top soil layers are ranked here as one of the highest priority issue due to observed over-drying symptoms. Therefore steps are necessary to prevent and restore valuable natural and transformed

Figure 1. Location of the study area.

ecosystems. The question is how to manage dynamic soil water resources, especially in wet zones of the KNP.

This study defines wetness criteria for water management aimed at rewetting of altered wetlands. Criteria are derived based on the analysis of contemporary hydrological conditions and those set as target for re-development of vegetation. Quantification of effects of hazard hydrological situations is assessed using water storage decrease function. This is a correlation model which allows estimation of water deficits as an effect of groundwater level change. Stabilization of groundwater level fluctuations is regarded as the most important management option.

2. NEED FOR REHABILITATION OF WETNESS CONDITIONS

In the area of the KNP substantial human interference in the natural environment had taken place in the past, before the year 1956 when the area became protected. Land drainage, the construction of the embankments, river regulations and expansion of agriculture have considerably modified the natural hydrological and ecological conditions. Large scale agricultural drainage and groundwater exploitation have led to the substantial changes in the soil substrate and in the soil moisture conditions. Declining quantity and quality of water resources has resulted in the changes of the functioning or disappearing of ecosystems.

Present environmental targets in the Kampinos National Park comprise maintaining the ecological values by sustaining biodiversity, and ensuring that the water policies reflect requirements imposed by different ecosystems. As symptoms of drying in the KNP are evident the restoration process of old habitats does require rehabilitation of wetness conditions. Possible water shortage should be avoided to support the rehabilitation process. It has to be underlined that vegetation has already adopted to the hydrological conditions introduced in the area in fifties. In many cases natural wetlands have been substituted by agricultural grasslands. Re-development of pristine vegetation requires setting up favorable abiotic conditions.

At present the protection plans are legal instruments defining strategic activities for environment protection that should be undertaken in national parks. In 1995 the Protection Plan was elaborated for the Kampinos National Park. With regards to the management of water resources, the recommendations indicate the necessity of adopting the water system to ecological targets. Endeavors aim at slowing down runoff and raising groundwater levels, especially in wetland zones. In 1995 monitoring of the soil water resources started in response to the strong requirement to control the dynamic soil water resources available for protected ecosystems. Additionally groundwater monitoring started in 1998 as a continuation of former investigations conducted in the region since 1956. The main aim is to monitor the current state of hydrological conditions and to restore retention in the shallow soil layers.

The focus of this research is on the soil water resources stored in wet zones that appear within low lying flat areas of the Lasica basin (Figure 2). Most of its territory is situated in the boundaries of the KNP. The east part of the basin which is affected by Warsaw agglomeration was not considered. The investigations were conducted for very shallow groundwater levels.

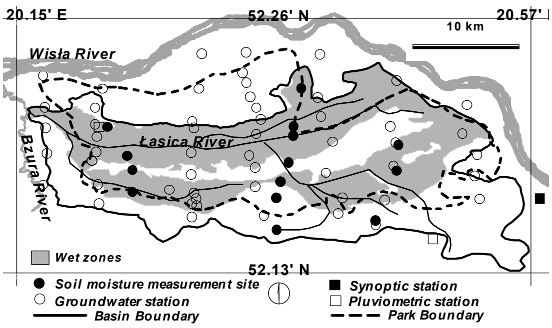

Figure 2. Wet zones of the lowland basin of the Lasica river situated within the Kampinos National Park.

3. CRITERIA FOR ENVIRONMENTALLY ORIENTED WATER MANAGEMENT

The task for hydrological research is to express general demands by means of specific objectives and, ultimately, by measurable criteria. They should be expressed in a facile way so that water demands could be recognized and appropriate actions undertaken.

A specific objective in the area considered is to improve hydrological conditions in the top soil layers. This requires evaluating particular water deficits to support the restoration of vegetation. For this purpose wetness criteria have been defined as a basis for water management practice. The scheme of the analysis conducted is presented in Figure 3. The analysis was a two-step process involving: (1) Evaluation of variability of precipitation, groundwater levels and soil water storage, and, in this context, (2) Evaluation of the impact of different hydrological scenarios on the development of water deficits. Data used in this study comprise precipitation and groundwater heads available for the period 1956-2000 as well as soil moisture from measurements conducted in years 1995-2000 [Somorowska, 2001].

Variability of precipitation, groundwater levels and soil water storage appeared to be significant, both on annual as well as on inter-annual time scales. The natural recharge by precipitation incoming to the area is a sequence of dry and wet years [Somorowska, 2002a]. Variable precipitation directly affects temporal stages of soil water storage and groundwater levels. Extreme dry situations can be characterized by means of soil moisture profile and groundwater depletion curves.

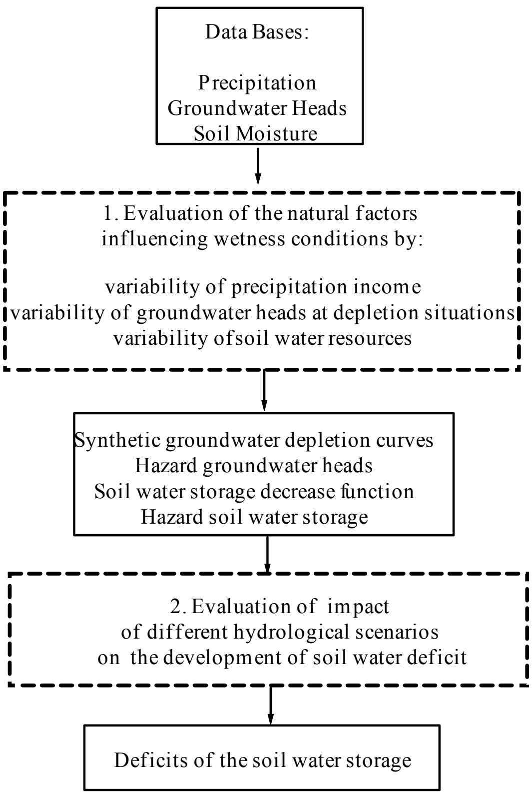

Figure 3. The procedure of derivation of wetness criteria for environmentally oriented water management.

To evaluate water deficits, the volumetric soil moisture value can be used. It reflects the degree of soil saturation which can be directly measured in the field by soil moisture meter. Based on field measurements the soil moisture profiles can be derived and then the volume of soil water storage estimated [Somorowska, 2002b]. For undisturbed wetlands the volumetric soil moisture of the organic soil layers optimal for re-development of potential wetland habitats in the area should be within the range 70–90% porosity [Kazimierski et al., 1995]. The values of volumetric soil moisture below the lower limit of the specified range should be considered as hazard situations. Thus the volumetric soil moisture of 70% porosity is set as minimum target value and is considered as basic wetness criterion to be fulfilled by water management practice.

A supplementary wetness criterion that can be applied is groundwater level. Its fluctuations have an impact on the soil water storage. Depth to the groundwater determined by field measurements which corresponds to the moisture target value of 70% porosity was found to be approximately 0.6m. The soil moisture of 90% porosity was found for depth of groundwater of approximately 0.4m below the surface.

The above relationship has a practical meaning if established in the form of a function relating groundwater levels to the temporal stages of soil water storage. In this study the relationship between the change in soil water storage and groundwater level has been expressed as the soil water storage decrease function (Figure 4). This

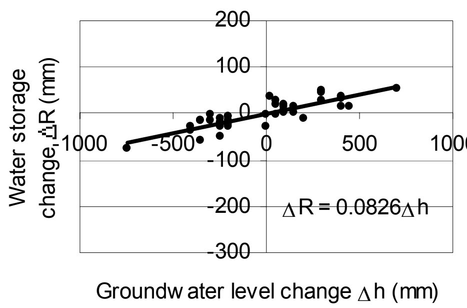

Figure 4. Soil water storage decrease function for wet sites with very shallow groundwater level.

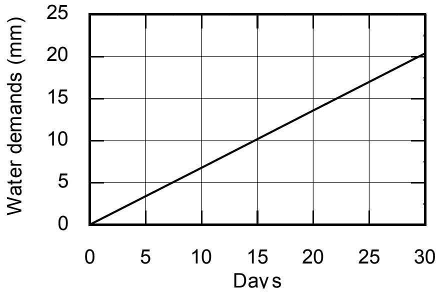

Figure 5. Water demands simulated by water storage decrease function.

simple correlation model enables the simulations of possible soil water storage deficits or surpluses depending on the groundwater level fluctuations.

In practice the simulated changes in soil water storage should be interpreted as indices of the volume of water that should be compensated if the groundwater level drops below the hazard depth of 0.6m. The 30 days' period of groundwater depletion, if starting from the critical value of groundwater levels, may lead to the development of approximately 20 mm of soil water deficit in sites with very shallow groundwater levels (Figure 5). In longer periods of groundwater decrease the water demands can increase. These simulated water demands are derived using groundwater depletion rate of approximately 8 mm/day which is characteristic for summer depletion curves with the steepest slopes.

High variability of soil moisture conditions detected in last years indicates that the minimum target value of soil moisture is often not fulfilled, especially during summer with long lasting dry seasons. Observed volumetric soil moisture content of the top soil layers is often below the minimum target value. In extreme dry conditions it drops to 42%. An example of the soil moisture profile characteristic for wet zones of the KNP considered is shown in Figure 6. Envelope curves of the soil moisture profile show a wide range of contemporary wetness conditions. If the target value of soil moisture is not fulfilled, soil water deficits develop which have to be overcome by management practices. To undertake proper management actions, not only the volume but also the duration of possible water deficits should be estimated.

In the second step of the analysis schematized in Figure 3, the duration of the hazard groundwater levels was studied using probability concept. The impact of dry and wet years on the duration of the groundwater levels was investigated by means of

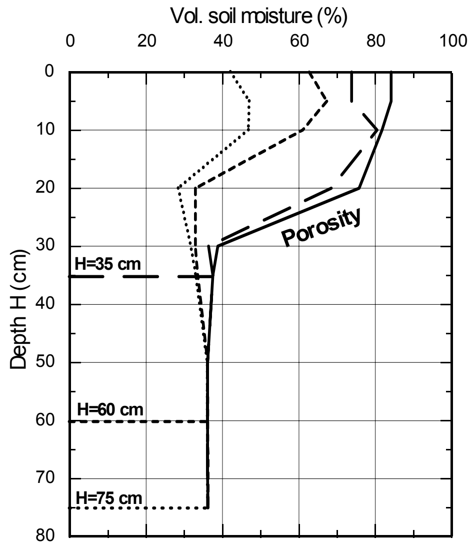

Figure 6. Selected soil moisture profiles observed in wet zone of the KNP.

Depth to the groundwater Duration Curves (Figure 7). The probability of groundwater level less than or equal to the target value at sites with very shallow groundwater levels is 25%, 35% and 47% in the wet, average and dry years respectively. Thus especially in dry years, with relatively low precipitation recharge, the target value of groundwater level is not fulfilled for most of the year. In wet years, with relatively high precipitation, the target value of the groundwater level is still not fulfilled for part of the year.

In practice regular observations of shallow groundwater are more affordable and less expensive than soil moisture measurements. Thus the stages of soil water resources can be monitored indirectly, applying the groundwater level as an rough indicator of soil water storage.

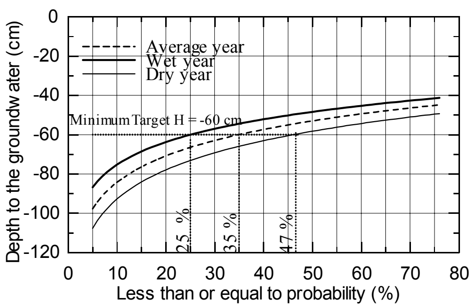

Figure 7. Depth to the groundwater Duration Curves (DDCs) for wet sites with very shallow groundwater levels.

4. MEANS OF IMPLEMENTATION

The criteria identified constitute the basis for water management practice. The analysis described in section 3 has proved that these criteria should be met to limit adverse effects of hydrological conditions. An increase of water storage near the surface is the most important management option. Stabilization of shallow groundwater level fluctuations is regarded as an effective rewetting practice aimed at the reduction of water deficits.

Figure 8 gives an example of groundwater level course observed in wet zones of the KNP in selected hydrological year. During winter and spring groundwater levels were found at optimum level that means above the minimum target value of 60cm. Very shallow groundwater levels, above the recommended optimum of 40cm, were observed in spring. Such hydrological conditions support the rewetting process. It is not necessary to lower groundwater levels as temporal water surplus or even inundation is regarded as supportive. In this case a permanent drop of groundwater levels started in June. This caused the appearance of hazard hydrological conditions in early August. Deficits in groundwater level lasted until late autumn. Using the water storage decrease function developed in section 3, calculated deficit of soil water storage reached the depth of approximately 38 mm (Figure 9). The depth of deficit was estimated for the observed groundwater depletion lasting 56 days.

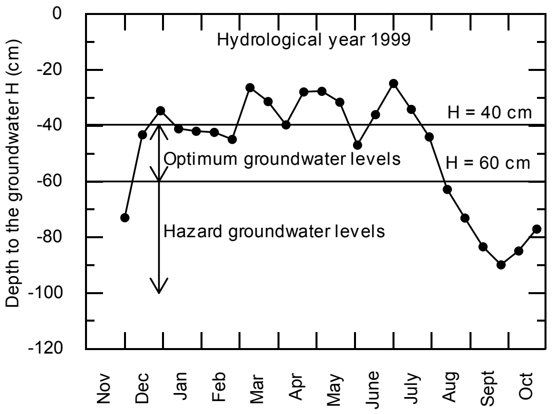

Figure 8. Observed and target groundwater levels in wet zones of the KNP.

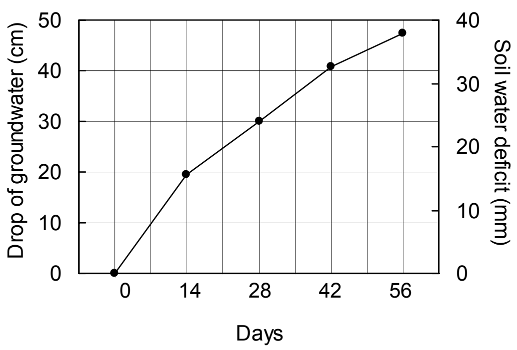

Figure 9. Drop of groundwater level below minimum target value of 60 cm and corresponding soil water deficit calculated using water storage decrease function.

The above example illustrates the application of derived water storage decrease function in the estimation of water demands. The function can be applied in practice in the prediction of water demands. A permanent system of groundwater monitoring allows the prediction of groundwater levels depletion, and consequently, expected water demands can be evaluated.

The necessary component of water resources management in the area is the monitoring system of soil moisture, surface and groundwater levels. It is necessary to maintain the monitoring of hydrological indices in the whole area of the KNP, at least at the existing scale. The network of soil moisture measurements should be supported by permanent installments to allow continuous monitoring of wetness conditions. The results of monitoring and research should continue to be the basis of steady improvement of adaptive management.

In practice the reduction of water deficits can be achieved by sustaining groundwater levels in the period of hazard depletion, i.e. during summer. Starting from early summer groundwater depletion should be especially limited reducing water losses in top soil layers and, as a result, sustaining the wetness conditions at the surface. An adoption of existing technical infrastructure of the Lasica basin is required to satisfy the water demands for increasing surface and subsurface retention. Reconstruction of dikes at channels, blocking of drains, creating bunds or compensating water shortage artificially must be regarded as required management. The success of adaptation depends not only on the reconstruction of the technical system but simultaneously on the efficient operation and maintenance.

5. CONCLUSIONS

Restoration of wetlands involves the necessity of maintaining the high moisture content of the sites involved. Managing favorable hydrological conditions supports habitat restoration of wetland ecosystems. Before management practices are implemented, the formulation of objectives is required. The case study of the Kampinos National Park has demonstrated setting water policies with the goal of maintaining ecological processes.

Defining specific environmental objectives is necessary to express the aims clearly through measurable criteria. The derived wetness criteria for the restoration of wetland zones of the Lasica basin deal with minimum target values of groundwater levels and corresponding soil water storage. Wetness investigations have facilitated an understanding of interactions between hydrological conditions and water availability for ecosystems. To overcome water shortage appearing during summer season criteria derived should be fulfilled by water management practice. In contemporary conditions water deficits appear in most of dry years. However even during wet years considered as those with relatively high precipitation recharge, soil water deficits can appear during 25% of the year.

Simple correlation model developed in the form of the water storage decrease function shows interactions between soil water storage and groundwater level changes. This model has practical applications as it enables simulation of soil water deficits that can develop in case of groundwater depletion below the hazard level. To mitigate the water shortage in the KNP developing in dry seasons, the maintenance and operation of hydro-technical infrastructure is necessary.

Rehabilitation of wetness conditions increases the probability of successful habitat management. However, the question is still not answered if specifically targeted wetland habitats will re-develop as a result of settled wetness targets. Further hydrological investigations should deal with the habitat patterns and stand structures.

6. ACKNOWLEDGEMENTS

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