Summary of the doctoral dissertation

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Hierarchization of areas exposed to the consequences of drought and mitigation measures in the water regions of Upper Odra River and Small Vistula River

The issue of drought in Poland has become an important issue in recent years, with the warmest and driest periods ever observed. Since 2013, when the *Drought Protection in Water Management Planning* methodology was developed, more and more actions have been taken to minimise the effects of drought and water scarcity. According to the cited methodology, prior to the 2017 water management reform, drought plans were developed for water regions at the level of the Regional Water Management Boards. These plans, with the exception of the Warta Water Region, have not been enacted. An amendment to the Water Law Act has resulted in the fact that planning in this aspect is currently taking place at central level. The 2021 *Drought Plan* (pl. *Plan przeciwdziałania skutkom suszy)* and the related *Water Scarcity Plan* (pl. *Plan przeciwdziałania niedoborom wody)* that is being developed are essential planning documents that aim to minimise the problems associated with increasingly limited access to water. These documents are developed on the basis of expert methodologies and consequently recommend a series of actions that address the diagnosed problems. An analysis of these documents and, in particular, of the investment solution proposals defined in them, gives rise to the feeling that these measures may worsen water conditions in Poland and even increase the threat of drought. The plans do not focus on restoring lost natural retention, although it is mentioned as one of the remedies.

Wetlands are characterised by the greatest retention capacity of the landscape. A requirement for their high effectiveness in regulating the water cycle in nature is that they are in good, natural condition. Wetlands, and in particular rivers and their valleys (including peatlands), have been significantly transformed in Poland. This is indicated both by planning work to achieve good water status and by studies of the natural state of peatlands. There are no research results to show on a national scale how these transformations affect nature, society and the economy. However, studies conducted at smaller scales indicate that restoration of degraded, damaged or destroyed ecosystems should find an essential, underlying place in drought risk management.

The restoration of degraded ecosystems can be achieved through the introduction of restoration measures which support the restoration of ecosystems or natural processes in ecosystems. *The National programme for surfaces' water restoration*, which diagnoses the degree of transformation of rivers and lakes in Poland and indicates a dedicated set of restoration measures for each planning unit (surface water bodies), is devoted to this issue. The implementation of restoration measures, which have been identified for more than 90% of Polish rivers, can play an important role in rebuilding lost retention, thereby improving the ecological condition of river ecosystems and reducing the causes of both water deficit and excess problems.

The aim of the research undertaken was **to develop assessment and verification principles to hierarchise the areas of the Upper Odra River and Little Vistula River in terms of their exposure to the consequences of drought.** This objective was achieved by:

(1) to propose a method to prioritise areas exposed to the consequences of drought due to hydro morphological transformations that pose a risk of not achieving the environmental objectives (WFD 2000);

(2) proposing dedicated drought mitigation measures that will, in parallel, support the achievement of environmental objectives and

(3) to develop a decision-making scheme for the selection of drought mitigation measures, taking into account their effectiveness and compatibility with the principles of sustainability and adaptation to a changing climate, which fits into existing legislation for the protection of water resources and biodiversity.

This dissertation relates to the current problems of drought and water scarcity and the ongoing discussion related to changing the approach to water management in Poland. The research successfully verified the research **hypothesis** of this dissertation with the following content: "**Effective drought management should be based on the analysis of anthropogenic transformation of river ecosystems and defining the needs for their restoration**".

The study was carried out at the scale of two water regions - the Upper Odra River and the Little Vistula River - for 710 two-kilometre river sections that are part of the work carried out under the Initiative "The most valuable rivers and streams in Poland", for which flood hazard maps were developed. The main element of the study was to determine for each section the extent of the lack of connectivity of the watercourse with the valley during floods, taking into account the degree of embankment of the watercourses and contact with wetlands. Spatial analyses were carried out to determine the degree of transformation of watercourses resulting in increased vulnerability to drought. This was cross-referenced with information on agricultural, hydrological, hydrogeological drought risks and the sum of these risks as defined in the *Drought Plan*. This contributed to defining, for each river section analysed, a drought exposure scale due to hydro morphological transformation of the watercourse and/or its valley, which allowed them to be hierarchised on a four-level scale.

The analyses to select drought-minimising (mitigation) measures used information from The National programme for surfaces' water restoration, devoting attention to assessing the potential scale of improvement in natural water retention as a result of their implementation, additional indications for their implementation or the identification of indicators of potential implementation. In this field, an indicative assessment was made of the effectiveness of restoration measures in relation to water retention mechanisms, that is, slowing and collecting runoff and reducing runoff. This assessment was carried out for groups of measures dedicated to each of the studied sections. As additional indications for the implementation of restoration measures, the potential resulting from an increase in valley retention in the case of meliorated areas, contact with peatlands or the achievement of environmental objectives defined for protected areas were considered. Also identified were sections where significant water lowering was observed up to 2015 making water intake difficult or impossible or where water decay was observed. To determine the potential for implementation of restoration measures, assessments were proposed of: (1) the landscape management of the valley of the watercourse section, (2) the ownership of land in the valleys of the watercourses belonging to the State Treasury, (3) the land included in the subsidy for water retention in permanent grassland, (4) the potential constraints to undertaking restoration measures whose implementation may affect the pollution of the main groundwater reservoirs and (5) the link between environmental objectives and flood risk reduction measures.

The research carried out indicates that the scale of hydro morphological transformation of the analysed rivers may significantly exacerbate the impacts of drought in the study area. The study shows that as many as 70% of the watercourse sections can be considered respectively strongly and very strongly transformed. These transformations range from the lack of valley contact during floods to the cutting off of the watercourse valley by dikes and reduced cyclic flooding of wetlands. These

transformations translate into increased exposure to consequences of drought. By far the most significant problem of the study area is the severe and extreme exposure to hydrological drought, which was indicated for 66% of the surveyed watercourse sections. Using independent indicator data on the winding of the watercourses, it was shown that the large majority of these sections (more than 75%) are watercourses with simplified geometry - broken and/or straight.

In the study area, there is potential for greater effectiveness of restoration measures with regard to the restoration of natural retention for 46% of the studied sections of watercourses that are influenced by drainage systems. This is particularly the case for sections of watercourses in whose valleys peatlands are drained (22% of sections).

Surface water restoration is not a common activity in water management in Poland. It is hampered both by inadequate regulations to undertake large-scale restoration activities and by the state of ownership of riverside land. Some of the main barriers to implementing restoration activities can be the unregulated legal status of watersheds as well as the fragmented ownership of riverside land. Research indicates that more than half of the river sections analysed may not have designated watersheds, which may make it difficult to implement activities in the riparian zone of these rivers. However, the potential for implementation of measures may be strengthened by the presence of State Treasury land in the valleys of the watercourses (which applies to 60% of the analysed sections, or the possibility for farmers to benefit from a retention subsidy on permanent grassland (which applies to more than half of the analysed river sections).

The effectiveness of restoration measures in terms of water retention mechanisms, i.e. slowing and collecting runoff and reducing runoff, will relate to both drought mitigation and flood risk minimisation. Studies carried out in this direction indicate that a synergy of these objectives can be achieved in more than 50% of the analysed river sections.

The proposed, although simplified, way of conducting analyses at the scale of water regions can be used both for planning work in water management - subsequent updates of the Drought Plan, the Water Scarcity Plan, but also for updating the Water Maintenance Plan, Flood Risk Management Plans or River Basin Management Plans. Hydraulic models built for the development of flood hazard and flood risk maps can play a particularly important role in further research. These models can be used synergistically for simulations in terms of the restoration of valley retention and thus the off-channel flows that represent the upper limit of environmental flows.

Based on the experience gained over many years of developing planning documents in water management and the knowledge gained during the present study, decision-support schemes have been developed. These tools allow analyses to be carried out in a different area on both the input data used in this study and the improved input data. These diagrams can thus provide a starting point for in-depth analyses in multidisciplinary research teams.

Keywords

Drought mitigation, hierarchization of areas exposed to the consequences of drought, threat of drought, exposure to the effects of drought, vulnerability to drought, hydromorphological transformation, river restoration, Upper Odra River Region, Small Vistula River Region.