Streszczenie rozprawy doktorskiej w języku angielskim

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Assessing the effectiveness of agricultural adaptation practices to climate change under different land scale scenarios in terms of hydrological balance

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Water management, especially in agriculture, is currently an important issue due to the increase in adverse weather events and also climate change in the 2050 horizon, which could have a serious impact on the quality and quantity of agricultural crops. It is becoming increasingly important to ensure the efficient and sustainable use of water in agriculture. Effective water management strategies in agriculture can help to reduce water wastage, increase yields and make agriculture more resilient to water scarcity.

The dissertation, through SWAT modelling tools, aimed to evaluate the effectiveness of the proposed scenarios and adaptation options created from BaU (Business as Usual) scenarios for the Bystra River catchment. The BaU scenarios (S-0 or V1) consisted of a combination of three regional climate models (RACMO22E, HIRHAM5, RCA4) derived from a global climate model (EC-EARTH) and two emission scenarios (RCP 4.5, RCP 8.5).

The adaptation scenario AS-1 assumed increased afforestation on poor soils. AS-2 assumed the creation of a forested buffer for the Bystra River and its tributaries. AS-3 assumed the use of filter strips. AS-4 assumed a reduction in ploughing on arable land. AS-5 assumed an increase in soil organic carbon content to 2%.

The adaptation options consisted of the following: V2 to increase the number of ponds and V3 to design large retention basins. Furthermore, V2 and V3 consisted of five adaptation scenarios each. V2.1 and V3.1 involved just increasing the number of ponds or designing retention basins for non-irrigated crops on arable land, i.e. WWHT (winter cereals), BARL (spring cereals), CANP (oilseed rape) and CRDY (other crops). V2.2 and V3.2 assume the cultivation of vegetables without irrigation (instead of cereals). V2.3 and V3.3 assume growing vegetables with irrigation (instead of cereals).

V2.4 and V3.4 assume partial cultivation of vegetables and cereals. V2.5 and V3.5 assume partial cultivation of orchards and cereals.

The effectiveness of adaptation practices was assessed in terms of reducing the negative impact of rainfall deficits in the catchment. An attempt was also analysed to increase water resources in the landscape through low-cost and rational rural water management resulting from the creation of small retention reservoirs in the integration process. In addition, it was analysed whether the retention of rainwater in the landscape through small-scale retention introduced as part of comprehensive land consolidation would reduce the threat of surface water erosion of the catchment area and decrease the inflow of area pollutants to the watercourse and reservoirs in the catchment.

Increased afforestation (AS–1), filter strips (AS–3), as well as increased organic carbon (AS–5) by reducing sediment yield will be able to offset the threat of surface water erosion of the catchment area and reduce the input of area pollutants to the watercourse and reservoirs in the catchment between 2041 and 2050 (comparing AS–1, AS–3, AS–5 to BaU (S–0)). For AS–2, the changes in water balance components were minimal.

The application of no-till (AS–4) increased the average annual soil water content by 0.1% (RCP 4.5) and 0.2% (RCP 8.5) compared to BaU (S–0) between 2041 and 2050. The annual sum of sediment yield decreased by 27% (RCP 4.5) and 28% (RCP 8.5). The annual sum of total runoff increased by 3% (RCP 4.5) and 2% (RCP 8.5). In contrast, the annual sum of actual evapotranspiration decreased by 1% for RCP 4.5 and for RCP 8.5. No-till also contributed to a reduction in soil erosion. The increase in runoff was mainly due to a reduction in evaporation from bare soil covered with crop residue mulch.

Increasing the number of small ponds (V2.1 variant) in the Bystra catchment had little effect on soil water content and actual evapotranspiration. However, the annual total runoff decreased by 1% for RCP 4.5 and RCP 8.5 compared to BaU (V1) between 2041 and 2050. The annual total sediment yield decreased by 18% for RCP 4.5 and RCP 8.5.

By way of deduction, allowing for the inadequacies of the SWAT model, it can be deduced that, through the use of ponds, the total amount of water available directly for agriculture in the water balance of the Bystra catchment will increase in the 2050 horizon. The study proves the rationale for constructing ponds in small catchments in order to increase water resources in the landscape, as well as to counteract the adverse effects of climate change, i.e. sediment runoff and surface water erosion. The introduction of variant V3.1 retention ponds had little impact on the components of the water balance of the catchment.

In the future, it would be appropriate to analyse a variety of crops in the SWAT model with a view to increasing retention and reducing erosion (comparison of V2.2, V3.2 with V2.1, V3.1) for 2041–2050 because of their impact on the water balance components shown in the study.

With the application of irrigation in both Variant 2 (V2.3) and Variant 3 (V3.3), the average annual soil water content increases by 0.5% (RCP 4.5), and 1% (RCP 8.5), as do the other water balance components analysed compared to V2.2 and V3.2 in the 2050 horizon. The SWAT model does not include precision irrigation, only traditional practices that are not optimal in a modern sense. There is a need to refine or create a more responsive irrigation algorithm in SWAT to better match irrigation parameters to the actual needs of growing plants with water savings as the main priority.

For V2.4 and V2.5, the average annual soil water content increases by 1% for RCP 4.5 and RCP 8.5 compared to V1 (BaU). For V3.4 there is little change. However, for V3.5 the average annual soil water content will be lower by 7% (RCP 4.5) and 4% (RCP 8.5). The annual total runoff for V2.3, V2.4, V2.5, V3.4 will be higher for RCP 4.5 and RCP 8.5. For V3.5 the total runoff will be lower. For V2.3, V2.4, V3.3, V3.4 the annual total sediment yield will be higher. However, for V2.5 and V3.5 sediment yields will decrease.

The increase in retention in most of the above irrigation scenarios, in addition to the benefits, can also have the effect of increasing surface water erosion. The exception is scenario V2.5 in which, with an increase in soil water content and total runoff, sediment yields decrease significantly.

Planning the ponds up to an area of 5000 m^2 during land consolidation, as well as their construction and arrangement during post-consolidation work, has, according to this study, a scientific basis for implementation in the coming decades, in order to increase water resources in the landscape and consequently make crops more resilient to droughts. Compared to large retention ponds, they can be a cheaper alternative. Moreover, planning for the construction of ponds does not require running a full land consolidation procedure, that covers creation of big reservoirs. The funding for pond construction may be indicated during the preparation process for land consolidation. In addition, ponds can be used as sources of irrigation water. They can also be used to reduce and prevent surface water erosion and to reduce the inflow of pollutants into the watercourse (reducing the total runoff and the sediment yield).

From the perspective of the present study, pond design is preferable above big reservoirs due to lower cost, potentially larger retention capacity, erosion reduction, versatility, accessibility, less interference with the landscape. However, there is a need for further research using the more modern SWAT+ model where reservoirs and ponds have extended possibilities to interact with aquifers and the surrounding landscape as separate spatial objects that can represent catchment features more realistically than in the current and previous SWAT models.

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