TERRAENVISION 2025
Vol. 5 TNV-3480
Granada, Spain, 8-11 July, 2025

Multi-objective, stakeholder-oriented planning of nature-based small water retention measures in an agricultural catchment

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Abstract

The growing frequency of extreme weather events, such as droughts and heavy rainfall, has made water retention a critical challenge in agriculture and environmental protection. Nature-based small water retention measures (NSWRMs) have emerged as key tools to improve soil moisture, groundwater recharge, water quality, reduce runoff and erosion, and enhance landscape resilience.
The aim of this study was to determine the optimal placement of four NSWRMs – no-till with cover crops, cropland-to-grassland conversion, forested riparian buffers, and hedges – within the catchment of Tetves stream, located in the Southern Transdanubia region of Hungary. The catchment area covers 79 km², with cropland accounting for 26% of the total area. A genetic algorithm for Constrained Multi-objective Optimization of Land use Allocation (CoMOLA), implemented as a Python script in conjunction with an R-based model processor, was used to identify the best possible combination of these measures within the study area. Four objectives were simultaneously considered in the optimisation process: nitrogen load at the catchment outlet (average annual sum in kg N) - to be minimized, soil moisture content in cropland (average annual value in mm) - to be maximized, implementation and maintenance costs of the NSWRM (average annual sum in EUR) - to be minimized, and agricultural production (average annual sum in grain units) - to be maximized. Input data preparation, model setup, verification, calibration,

and validation, as well as NSWRM scenario implementation, were carried out following the OPTAIN modelling protocol (https://doi.org/10.5281/zenodo.7463395). The optimization resulted in 192 Pareto optimal solutions, which represent trade-offs where improving one objective would lead to a decline in at least one other objective. These solutions were analysed using an R-based application, ParetoPick-R, which allowed for the identification of distinct solutions, each with different advantages and disadvantages in terms of their impact on the selected environmental and economic objectives. One solution that has been found to be very effective in reducing nitrogen load suggests applying no-till management with cover crops on 45% of the cropland (~920 ha) and converting an additional 13% (~262 ha) to grassland. Forested riparian buffer strips should be established along 16% of the Tetves stream (~5.9 km), ideally on both sides. While optimal for reducing nitrogen load, this solution may not be feasible for farmers due to the grassland conversion. The ParetoPick-R app helps to visualize, filter and navigate through the set of Pareto optimal solutions, explore trade-offs and synergies between optimization objectives, enable in-depth analysis and stakeholder discussions, compare sector-specific advantages and disadvantages of selected solutions and identify the most acceptable ones.

Keywords: water and nutrient retention, sustainable agriculture, multi-objective optimization, CoMOLA, ParetoPick-R

Acknowledgments: This work was supported by the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 862756, project OPTAIN.