Modelling and evaluation of the effect of afforestation on the runoff generation within the Glinščica catchment (Slovenia)

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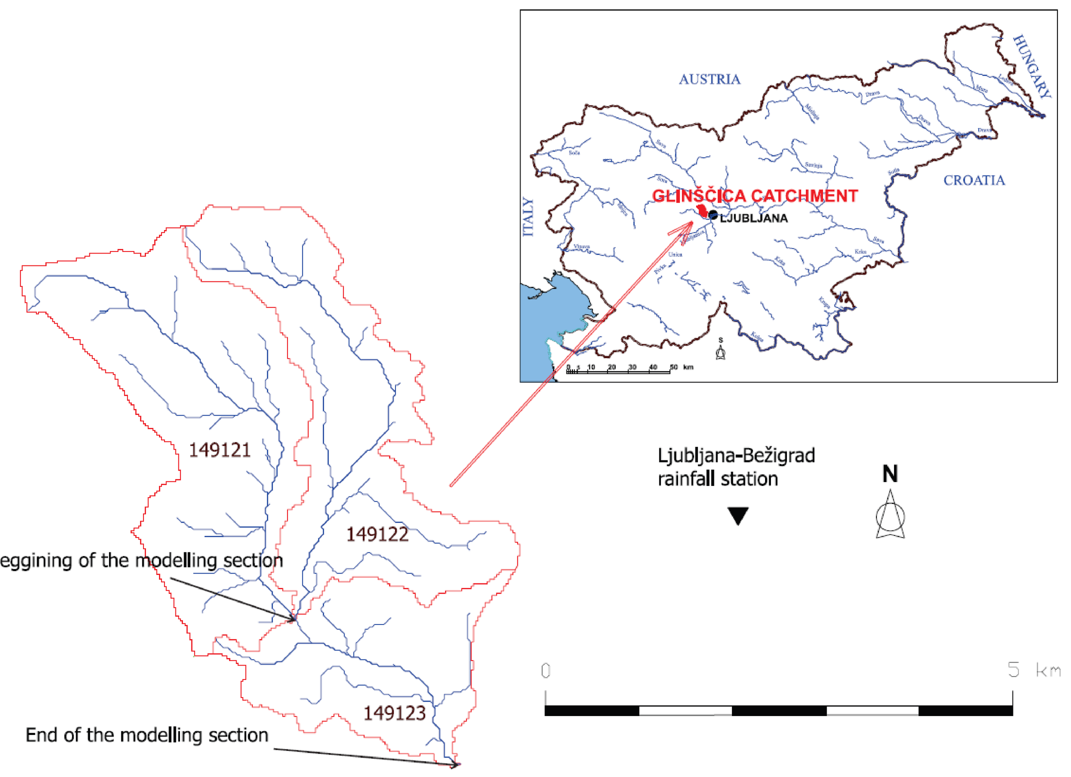
INTRODUCTION

Increases in the frequency of flood events are one of the major risk factors induced by climate change that lead to a higher vulnerability of affected communities. Natural water retention measures such as afforestation on hillslopes and floodplains are increasingly discussed as cost-effective alternatives to hard engineering structures for providing flood regulation, particularly when the evaluation also considers beneficial ecosystem services other than flood regulation. The present study provides combined modelling approach and a cost-benefit analysis (CBA) of the impacts of afforestation on peak river flows and on selected ecosystem services within the Glinščica river catchment in Slovenia. In order to investigate the effects, the hydrological model HEC-HMS, the hydraulic model HEC-RAS and the flood damage model KRPAN, that was developed specifically for Slovenia, are used.

CASE STUDY

The catchment area of the Glinščica river is a relatively small area with 16.9 km² located on the eastern part of Ljubljana, Slovenia. The catchment is located in temperate continental climate and has torrential characteristics. The mean annual precipitation in the area is around 1,500 mm while snow falls regularly in winter. Moreover, floods are most often generated by either summer thunderstorms or by spring and autumn prolonged rainfall events. Since part of the catchment is also covering the urban part of the Ljubljana city the population density is relatively high for the Slovene conditions. Moreover, investigated area is already accessible and touristically quite developed, especially local people tend to use it for recreational activities such as hiking, running or cycling.



Location of the Glinščica River catchment on the map of Slovenia

A combined modelling approach was used:

-HEC-HMS model was used for hydrological modelling;

-HEC-RAS model was used for hydraulic modelling;

-KRPAN model was used for flood damage modelling.

Additional information about models can be found at:

Bezak, N., Šraj, M., Rusjan, S., & Mikoš, M. (2018). Impact of the rainfall duration and temporal rainfall distribution defined using the Huff curves on the hydraulic flood modelling results. Geoscienes, 8(2), 69.

Vidmar, A., Zabret, K., Sapač, K., Pergar, P., & Kryžanowski, (2019). Development of an application for estimating the benefits of structural and non-structural measures for flood risk reduction. In: Biondić, D., Holjević, D., Vizner, M. (Ed.). Croatian waters in environmental and nature protection: Proceedings of 7th Croatian water conference. 2019

SCENARIOS

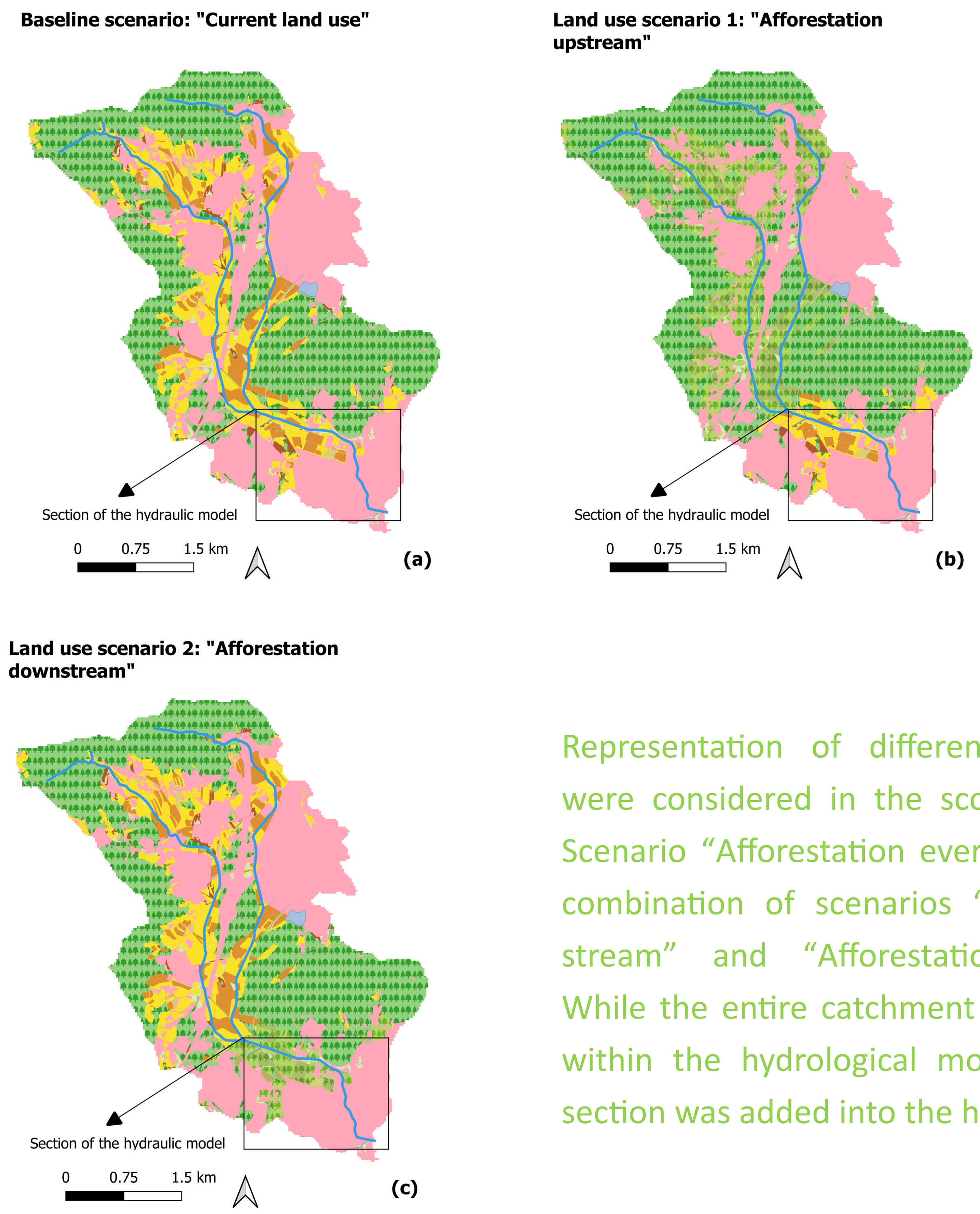
In the scope of the presented study, next four scenarios were considered:

-Scenario "Current land use" where hydrological and hydraulic models represent current situation;

-Scenario "Afforestation upstream" where afforestation is considered in the hydrological model in upper part of the catchment (afforestation area is 244 ha);

-Scenario "Afforestation downstream" where afforestation is considered in the hydrological in hydraulic models both only in the lower part of the catchment (afforestation area is 77 ha);

-Scenario "Afforestation everywhere" where afforestation is considered in the hydrological in hydraulic models in all parts of the catchment (afforestation area is 321 ha).



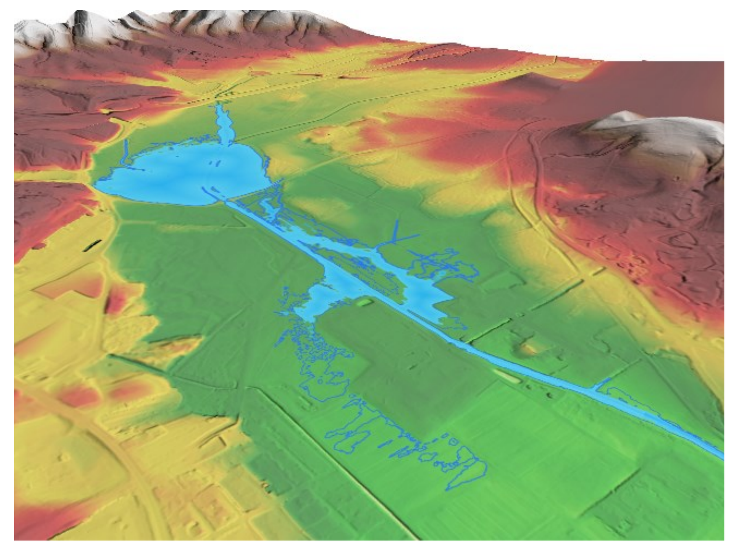
Representation of different scenarios that were considered in the scope of this study. Scenario "Afforestation everywhere" presents combination of scenarios "Afforestation upstream" and "Afforestation downstream". While the entire catchment was incorporated within the hydrological model, only smaller section was added into the hydraulic model.

COST BENEFIT ANALYSIS (CBA)

The chosen time frame of the anticipated CBA was 100 years. Next elements were considered in the scope of the CBA: cost of afforestation, benefits of flood protection measures, biodiversity, carbon, recreation and water quality.

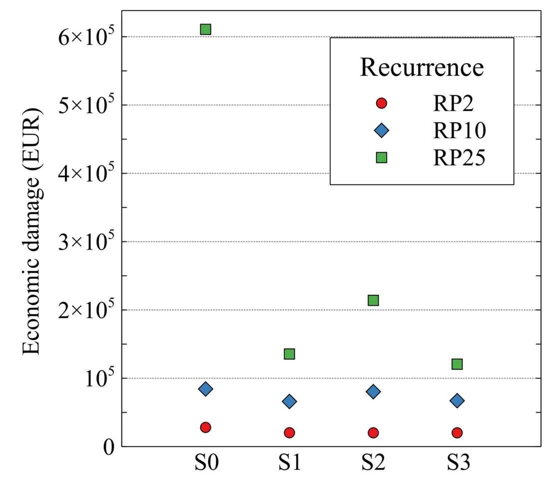
RESULTS AND DISCUSSION

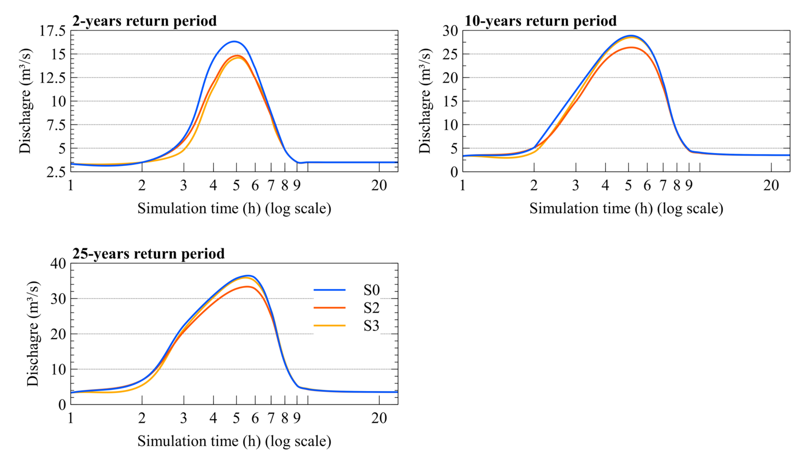
Relatively large peak flow reductions were calculated for different scenarios. Some differences in the flood extent can be seen below. The scenarios "Afforestation everywhere" and "Afforestation upstream" show negative NPV for a CBA period of 100 years. This means that only the scenario "Afforestation downstream" is economically sustainable and would be worth implementing from the economic point of view when taking into account flood protection measure benefits plus other ecosystem service co-benefits. The main reason for the negative NPV values lies in the fact that large areas would need to be afforested in case of "Afforestation everywhere" and "Afforestation upstream" scenarios. Consequently, costs of land accusation are high and obviously flood damage is smaller than these costs and costs of maintenance.



	"Afforestation upstream",	*"Afforestation downstream",*	*"Afforestation everywhere",*
Costs	€ 15,525,924	€ 4,868,351	€ 20,394,275
NPV	€ -2,836,497.85	€ 4,184,035.48	€ -6,124,130.82
IRR	3.28%	7.72%	2.59%
B/C	0.84	1.89	0.69

Main results of the presented study showing the reduction of inundated area of "afforestation upstream" in comparison to the baseline scenario (upper left), results of the CBA (upper right), economic damage of different scenarios (lower left) and comparison of outflow hydrographs for different return periods (lower right)





CONCLUSIONS

Three scenarios were evaluated where the main difference was the extent of afforestation. It was found that increasing the amount of tree cover (i.e. ≈15-60 %) results in a flood peak reduction ranging from 9 to 13%. Flood extensions were significantly lower for most scenarios leading to reduced economic losses. However, a 100-years cost-benefit analysis (CBA) only showed positive net present values (NPV) for one of the considered scenarios, where the afforestation was considered only on the floodplain areas, and the benefits were dominated by the benefits of flood protection measures, which were higher than for example biodiversity or recreational benefits. Based on our findings we conclude that afforestation as a sole natural water retention measure provides a positive NPV only in case of one of the three considered scenarios and if additional ecosystem co-benefits that are not directly linked with flood protection are considered.