A FRAMEWORK TO ASSESS THE RELIABILITY OF A MULTI-PURPOSE RESERVOIR UNDER UNCERTAINTY IN LAND USE

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Aims

Available fresh water resources are becoming scarce due to higher demands by industrial, recreational, municipal, and agricultural sectors. Reservoirs are one of the most efficient types of structures used to manage water resources for multiple purposes. Nevertheless, demands from individual sectors result in a variety of constraints that need to be addressed. Furthermore, socio-economic development in reservoirs' catchments result in potential changes in forest, agriculture and urbanisation cover which can significantly affected inflows into reservoirs. There have been a number of studies quantifying the impact of land use changes on stream flow, but few of them have considered that impact on a reservoir's water supply. Thus, the main aim of this study is to develop a framework using a reliability-based optimisation model in conjunction with the Soil and Water Assessments Tool Plus (SWAT+) model (Arnold et al., 2012) to assess the reliability of a multi-purpose reservoir's water supply under uncertainty in land use.

Method

The framework combines a reliability-based optimisation model with the SWAT+ model. The reliability of a reservoir's water supply is defined as the probability that a reservoir operates in the set of satisfactory constraints. A Genetic optimization model was developed with the objective of minimizing the gap between water demands and water releases and satisfying water use and policy constraints.

A calibrated SWAT+ model was used to simulate reservoir inflows under various possible catchment land use scenarios. The inflows generated by the SWAT+ model were input for the optimisation model to obtain the reliability of reservoir's water supply.

Within a reservoir's operational timeframe under each land use scenario, inflows and water demands vary randomly. To account for this, a probabilistic approach is used. Inflows and demands are generated using a Monte-Carlo routine. Each inflow and a water demand combination results in a reliability of water supply. The different combinations lead to a possible range of water supply reliability of a reservoir (Figure 1).

To test the framework, the Nuicoc reservoir in the north of Vietnam was used as a case study. The reservoir has a capacity of 175 million cubic meters and supplies water for irrigation, urban use, river downstream and recreation. Initial simulations were conducted for 11 years with the baseline land use and three projected land use scenarios (S1, S2 and S3). The main driver for land use changes in the case study is urbanisation. Therefore, in comparison with the baseline land use, the Scenario S1 and S2 had a higher urban area. Scenario S3 considered replacement of forests with orchards (Table 1).

Table 1: Percentage of land uses in Baseline and Scenarios

Land use	Baseline	Land use scenarios					
		S1	Change	S2	Change	S3	Change
ORCHARD	14.12	16.38	2.26	9.63	-4.49	29.60	15.48
FOREST	52.99	52.87	-0.12	52.87	-0.12	39.65	-13.34
PADDY	14.83	8.93	-5.91	7.79	-7.05	11.90	-2.93
RURAL AREA	9.34	7.02	-2.31	5.62	-3.72	8.43	-0.91
URBAN AREA	1.18	7.24	6.06	16.54	15.36	2.86	1.68
OTHER	7.54	7.56	0.02	7.56	0.02	7.56	0.02

Results

Modelling results showed that under the same climate the growth in urban area resulted in an increase of the water supply reliability (Figure 2). Urban areas in the scenario S1 increased from roughly 1 % to about 7 %, and generated higher inflow resulting in an increase from 87% to 91% in mean reliability of water supply. Scenario S2, which had the largest urban area (17%) produced the highest inflow and a mean water supply reliability of 96%. In Scenario 3, the considerable decline in forest area from 52% to 40% created increased inflows into the reservoir. This resulted in 90% chance that the reliability could range from 98% to 100%.

In summary, this study confirms that land use changes have considerable impacts on stream flow as well as the reliability of reservoir water supply. However, the study did not considered the risk of floods caused by increased discharges or other risk factors. Furthermore, although lower forest area seems to result in higher reliability of water supply, this will result in larger amounts of sediment transferring from the catchment into the reservoir and negatively affect its volume capacity. Trade-offs needs to be considered in detail.

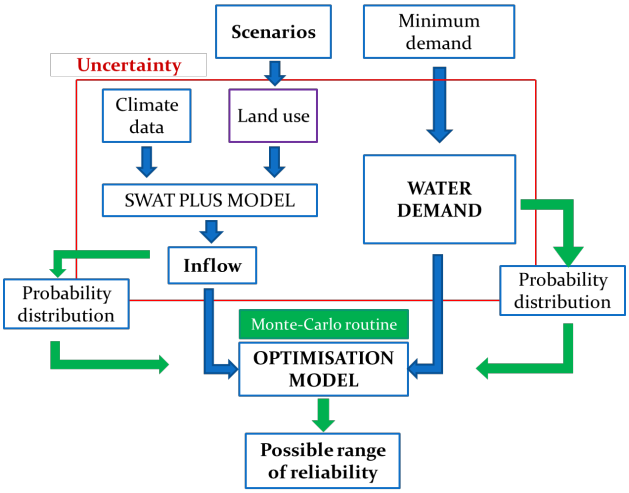

Figure 1: Framework to quantify impacts of land use changes on the reliability of a reservoir's water supply

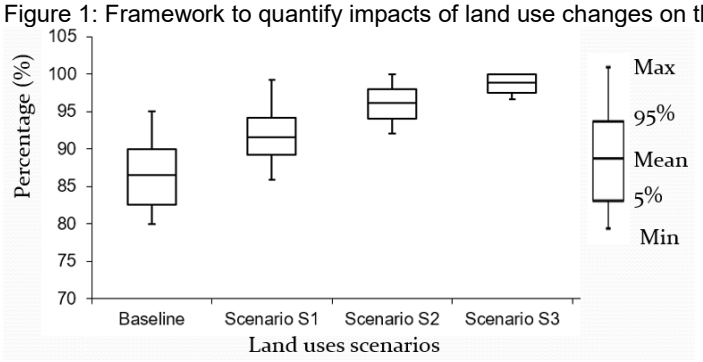

Figure 2. Range of the reliability of reservoir's water supply under land uses scenarios

References

Arnold, JG, Moriasi, DN, Gassman, PW, Abbaspour, KC, White, MJ, Srinivasan, R, Santhi, C, Harmel, R, Van Griensven, A & Van Liew, MW 2012, 'SWAT: Model use, calibration, and validation', *Transactions of the ASABE,* vol. 55, no. 4, pp. 1491-1508.

Nicklow, J, Reed, P, Savic, D, Dessalegne, T, Harrell, L, Chan-Hilton, A, Karamouz, M, Minsker, B, Ostfeld, A, Singh, A & Zechman, E 2010, 'State of the Art for Genetic Algorithms and Beyond in Water Resources Planning and Management', *Journal of Water Resources Planning and Management,* vol. 136, no. 4, pp. 412-432.