Sensitivity analysis of green roof design parameters in SWMM for its improved understanding of hydrological performance

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Motivation

- Understanding of hydrological behaviour of green roof under various design configurations towards different model responses at multiple perturbation scale is crucial to improve its design at unit-scale, which leads to enhance collective efficiency and effectiveness at a catchment-scale.
- Optimal selection of design parameters of green roof (i.e., in SWMM modelling and in practice) can significantly contribute to achieve different target design goals (i.e., stormwater' runoff and peak flow reduction, urban flood reduction, peak flow control, etc.) by improving its design efficiency with maximization of its infiltration and storage capacities.

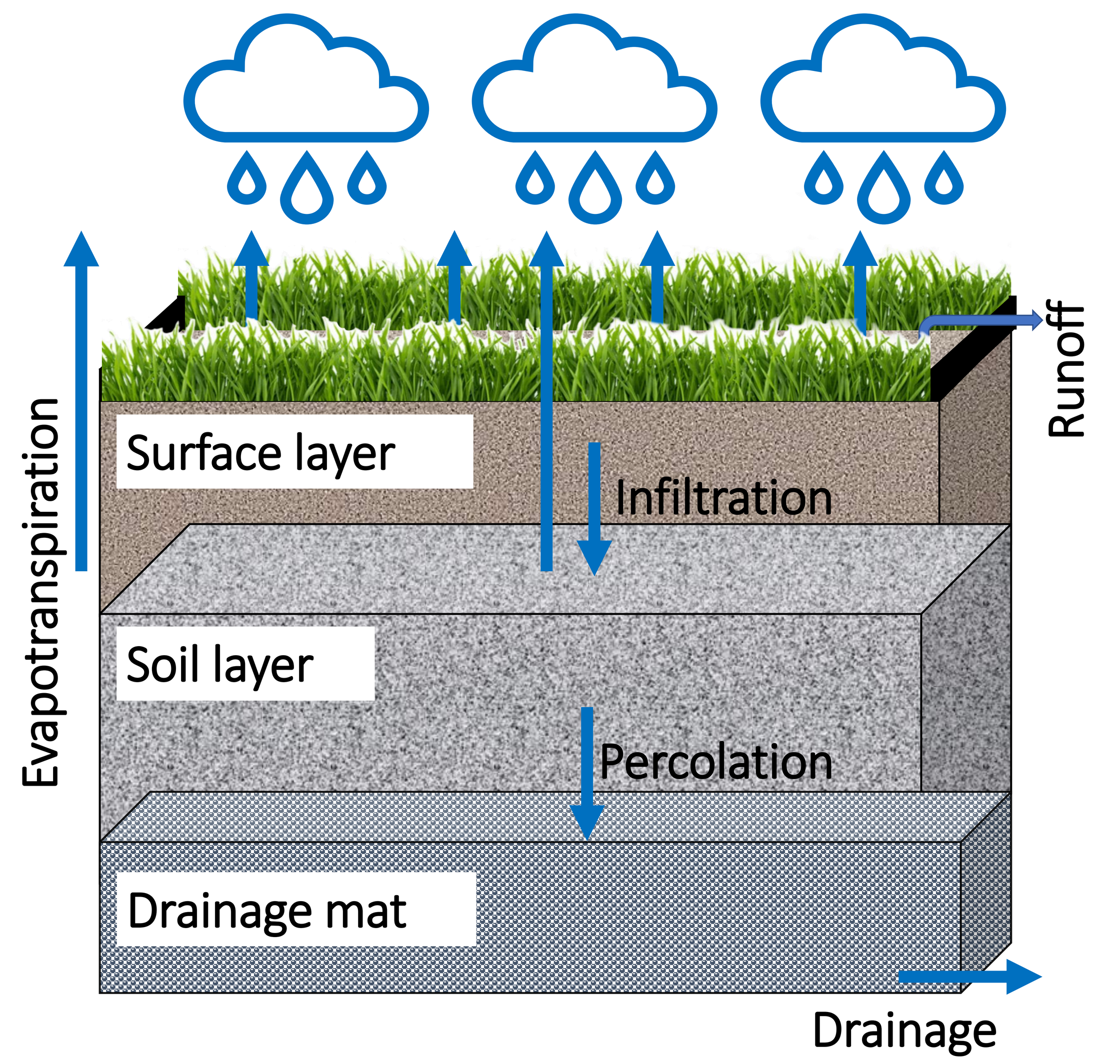

Figure 1. Conceptual unit-area of green roof

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Materials and Methods

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Methods and Models

Sensitivity method: variogram analysis of response surfaces (VARS)

Hydrological and hydraulic model: PySWMM

Sensitivity analysis set-up

Hypothetical catchment's area: 0.01 km^2 ($100m^2 \times 100m^2$)

Green roof area: 50% of catchment area

Number of design parameters: 14

Numer of samples: 13,999

Design rainfall: 5-year return period with 6hrs duration

Sampling technique: Latin hypercube sampling

Bootstrap confidence size: 1000

Bootstrap confidence intervals: 90%

Table 1. Green roof design parameters with their short names and ranges

Layers	Parameters (Units)	Short Name	Min	Max
Surface	Berm height (mm)	BH	0	76
	Vegetation volume (fraction)	VV	0	1
	Surface roughness (Manning's n)	SSR	0.01	0.4
	Surface slope (%)	SS	0.01	2.6
Soil	Soil Thickness (mm)	SOT	51	152
	Porosity (volume fraction)	P	0.50	0.60
	Field capacity (volume fraction)	FC	0.30	0.50
	Wilting point (volume fraction)	WP	0.05	0.2
	Conductivity (mm/hr)	C	1016	3556
	Conductivity slope	CS	30	55
	Suction head (mm)	SH	51	102
Drainage mat	Thickness (mm)	DT	13	51
	Void ratio (Voids/Solids)	VR	0.2	0.4
	Seepage rate (mm/hr)	SR	0.01	0.03

Methodology

Firstly, the VARS toolbox generates 13,999 random samples of 14 design parameters of green roof according to their pre-defined factor space by using Latin hypercube sampling technique. These set of design parameters are iteratively simulated on a conceptual catchment of $0.01km^2$ ($100m^2 \times 100m^2$) with 50% treatment area by using PySWMM to calculate different model responses responses (e.g., surface infiltration, surface outflow, storage volume, and peak flow). Lastly, VARS calculates different sensitivity indices including directional variograms and Integrated Variogram Across a Range of Scales, here only showed with 50% perturbation scale (IVARS50) with associated uncertainties.

Results

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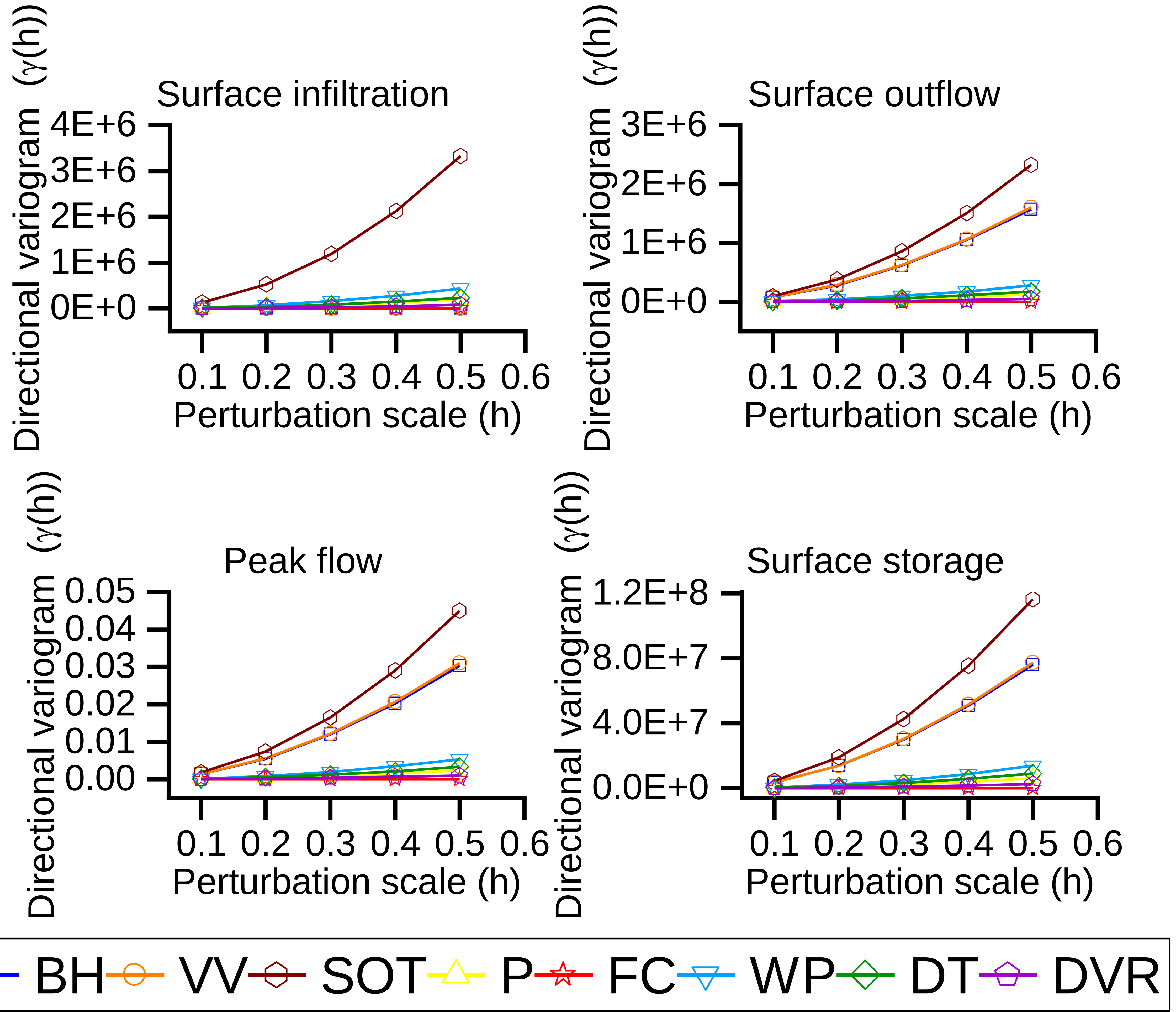

Figure 2. Directional Variograms of green roof design parameters

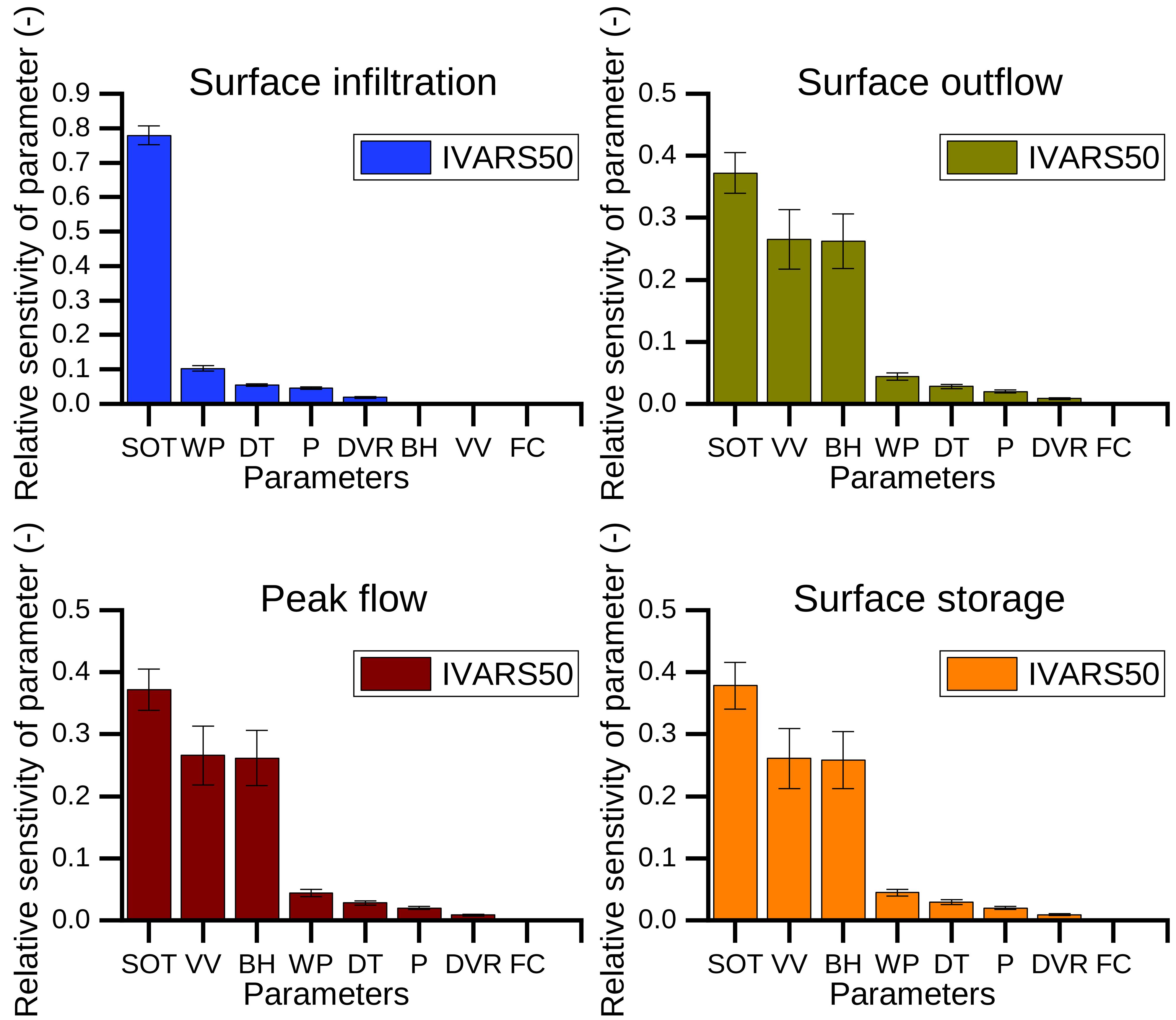

Figure 3. IVARS50 indices with 90% confidence intervals

Overall, soil thickness, vegetation volume and berm height are highly sensitivity design parameters compared to others. The engineering soil mixture, type and density, and height of berm need to carefully design to achieve higher design goals (i.e., surface runoff reduction, urban flood reduction, peak flow control, etc.) .Furthermore, directional variogram results (Figure 2) represent that sensitivity of design parameters significantly increases for higher perturbation scale compared to lower. Moreover, higher sensitivity design parameters have lager uncertainty level compared to lower, indicating careful consideration is required to optimally select design parameters' value of green roof for improvement of its effectiveness and design efficiency at the unit-scale, which ultimately significantly contribute to enhance benefits at a catchment-scale.

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Conclusions

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- Soil thickness, vegetation volume and berm height have significant contribution on model responses compared to other design parameters.
- Understanding of hydrological performance of different design parameters towards different model responses at multiple perturbation scale helps to optimally select design parameters during planning, designing, modelling, optimization and implementation of green roof.

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Further References

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Thank you for your attention

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