The role of catchment characteristics, sewer network, SWMM model parameters in urban catchment management based on stormwater flooding: modelling, sensitivity analysis, risk assessment

Bartosz Szeląg[1], Adam Kiczko[2], Grzegorz Wałek[3], Ewa Wojciechowska[4], Michał Stachura[5], Francesco Fatone[6]

[1] Faculty of Environmental, Geomatic and Energy Engineering, Kielce University of Technology, 25-314 Kielce, Poland
[2] Institute of Environmental Engineering, Warsaw University of Life Sciences-SGGW, 02-797 Warsaw, Poland
[3] Institute of Geography and Environmental Sciences, Jan Kochanowski University in Kielce, 25 – 406, Kielce, Poland
[4] Faculty of Civil and Environmental Engineering, Gdansk University of Technology, 80-233 Gdansk, Poland
[5] Faculty of Law and Social Sciences, Jan Kochanowski University, 25 – 406, Kielce, Poland
[6] Department of Science and Engineering of Materials, Environment and Urban Planning-SIMAU, Polytechnic University of Marche Ancona, 60121 Ancona, Italy

Correspondence to: Bartosz Szeląg (bszelag@tu.kielce.pl)

Section 1

Measures of fit between computed results and measurements in a logistic regression model

- accuracy (Acc)

$$Acc = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

- sensitivity (SENS)

$$Sens = \frac{TP}{TP+FN} \quad (2)$$

and specificity (SPEC)

$$Spec = \frac{TN}{TN+FP} \quad (3)$$

where $TP, TN, FP,$ and FN denote true positives (correctly identified of the $\kappa \geq 13$ m^3·ha^{-1}), true negatives (correctly identified lack of $\kappa \geq 13$ m^3·ha^{-1}), false positives ($\kappa < 13$ m^3·ha^{-1} incorrectly identified as $\kappa \geq 13$ m^3·ha^{-1}) and false negatives ($\kappa \geq 13$ m^3·ha^{-1} incorrectly identified as $\kappa < 13$ m^3·ha^{-1}), respectively.

Section 2

Regional model of convective rainfall

To calculate the convective rainfall, the regional rainfall model for Poland was used (Kupczyk and Suligowski, 2000; Suligowski, 2004). In this model the rainfall depth for the assumed rainfall duration is determined from the formula:

$$P_{con}(t_r) = a_1 \cdot t_r^2 + a_2 \cdot t_r + a_0 \quad (4)$$

where: t_r – duration of rainfall (min); $P_{con}(t_r)$ – maximum convective rainfall depth (mm); a_0, a_1, a_2 – empirical coefficients determined by the method of least squares. The model includes data for 30 rainfall stations in Poland, for which a_i (a_0, a_1, a_2) coefficients were determined using rainfall data from the period of 20 - 30 years (Suligowski 2004). For the catchment area covered by the calculations (świętokrzyskie voivodship) the values are as follows: $a_0 = 6.55$; $a_1 = -1.10$, $a_2 = 6.68$.

Table S1. Ranges of SWMM model parameters

Parameters	Unit	Range	
		Min	Max
Coefficient for flow path width (α)	-	2.7	4.7
Retention depth of impervious areas (d_{imp})	mm	0.8	4.8
Retention depth of pervious areas (d_{per})	mm	0.8	6.8
Manning roughness coefficient for impervious areas (n_{imp})	$m^{-1/3}\cdot s$	0.01	0.022
Manning roughness coefficient for pervious areas (n_{per})	$m^{-1/3}\cdot s$	0.16	0.2
Manning roughness coefficient for sewer channels (n_{sew})	$m^{-1/3}\cdot s$	0.01	0.048
Correction coefficient for sub-catchments slope (γ)	-	0.7	1.275
Correction coefficient for percentage of impervious areas (β)	-	0.8	1.375

Table. S2. Values of coefficients (α_i), standard deviations (σ_i), test probabilities (p) for the logit model to calculate the probability of specific flood volume.

Variable	Value (α_i)	St. derivation (σ_i)	p – test
Intercept	-54.146	1.863	< 0.0001
t_r	-0.218	0.001	< 0.0001
P_t	4.055	0.036	< 0.0001
α	0.235	0.012	< 0.0001
n_{imp}	-79.397	1.251	< 0.0001
d_{imp}	-0.072	0.006	< 0.0001
β	6.233	0.051	< 0.0001
γ	0.333	0.043	< 0.0001
n_{sew}	234.125	1.145	< 0.0001
Imp	79.403	4.836	< 0.0001
Vk	-0.010	0.000	< 0.0001
Gk	-1967.036	113.936	< 0.0001
Jkp	-20.331	6.775	0.0027
Impd	42.912	2.389	< 0.0001
Gkd	-1169.004	66.862	< 0.0001

Table. S3. Agreement of the results of calculating the probability of exceeding the specific flood volume with the logistic regression model and the hydrodynamic SWMM

	Sub - catchment								
t_r [min]	J	K	L	M	N	O	P	R	S
				variant I					
30	+	+	+	+	+	+	+	+	+
40	+	+	+	+	+	+	+	+	+
50	+	+	+	+	+	+	+	+	+
60	+	+	+	+	+	+	+	-	-
				variant III					
30	+	+	+	+	+	+	+	+	+
40	+	+	+	+	+	+	+	+	+
50	+	+	+	+	+	+	+	+	+
60	+	+	+	+	+	+	-	-	+

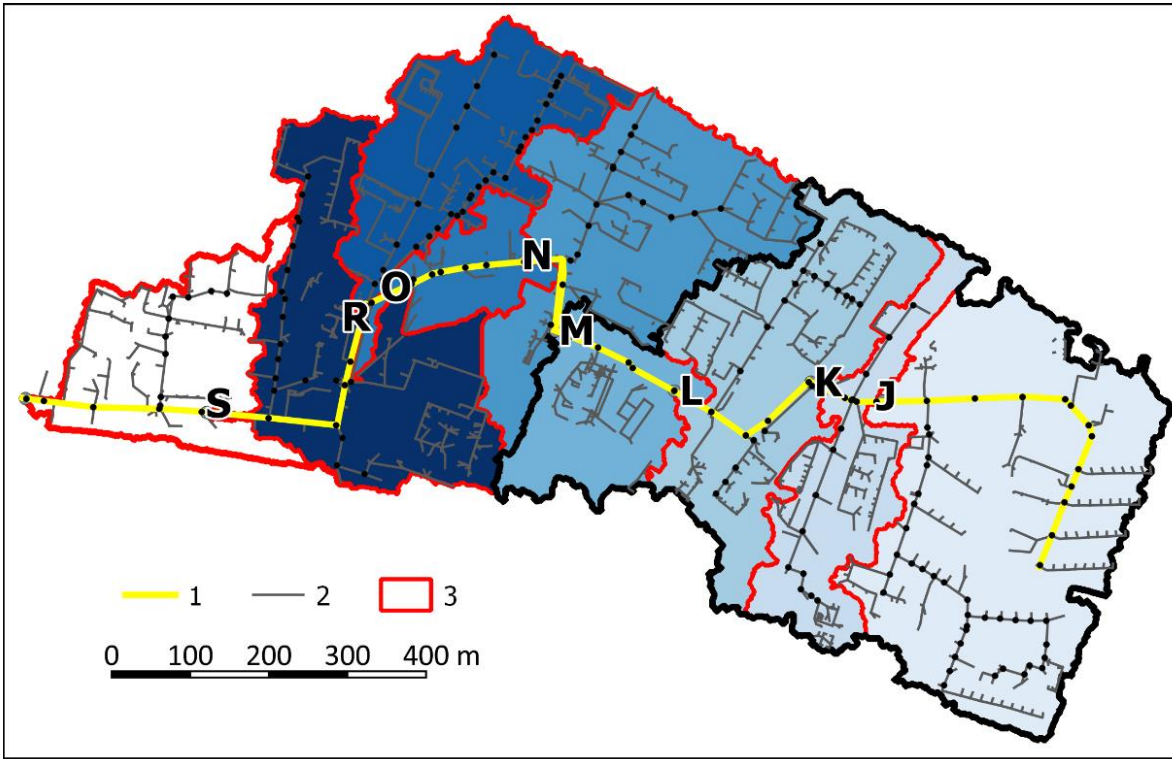


Figure. S1. Scheme of analysed catchment (Wałek, 2019).

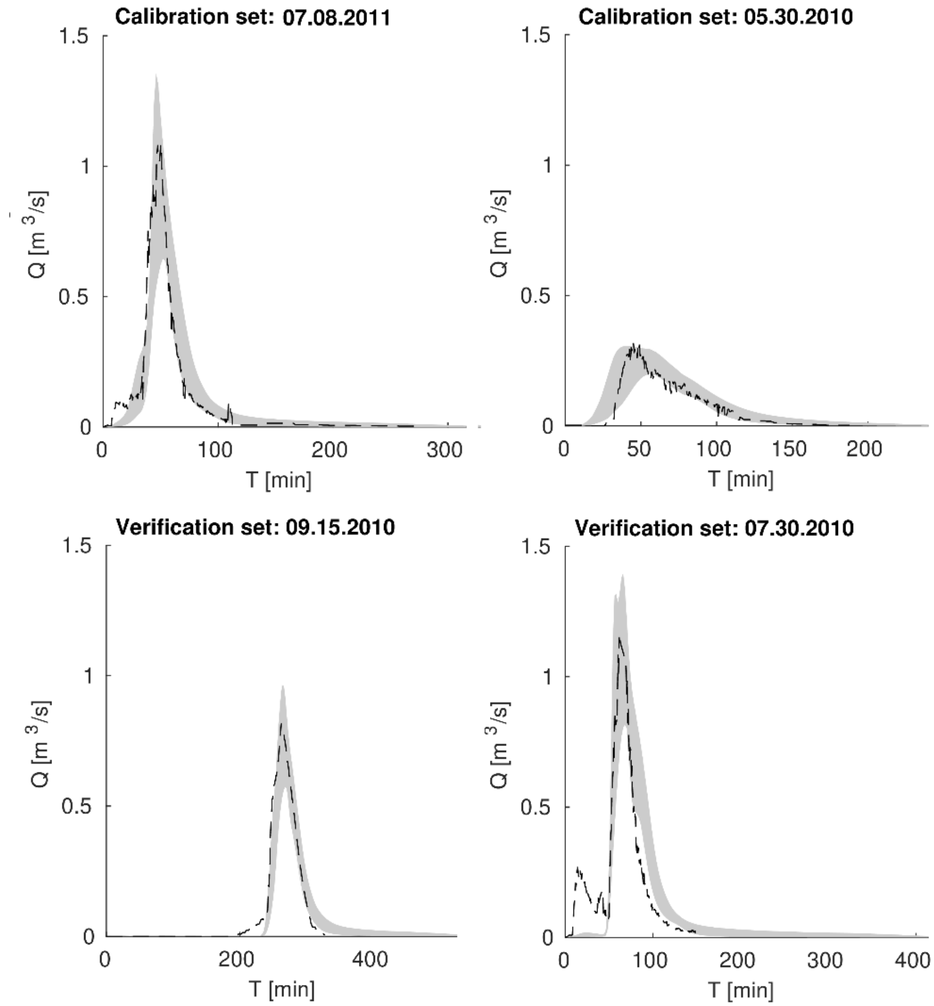


Figure S2. Comparison of the measured hydrographs of storm water runoff from the catchment with 95% confidence intervals determined via the SWMM model.

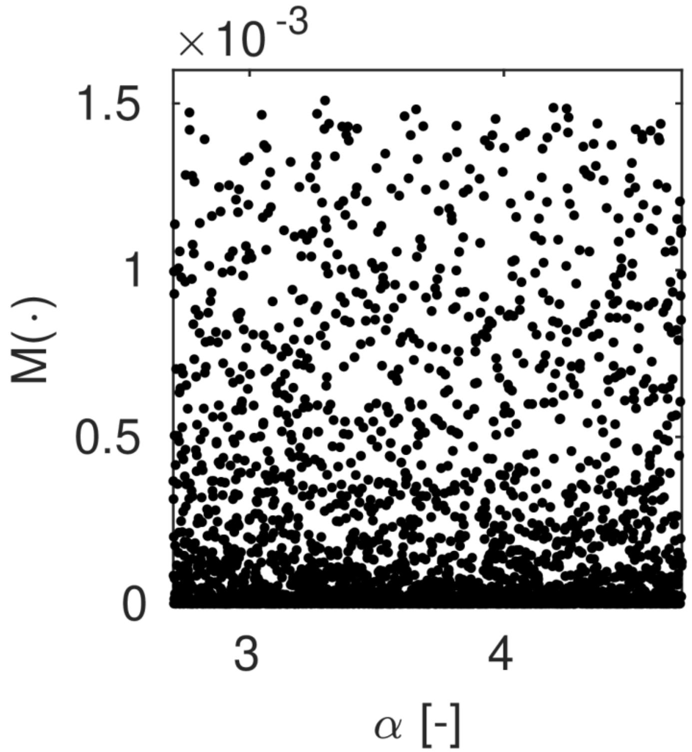


Figure. S3. Influence of coefficient for flow path width (α) on the likelihood function (M).

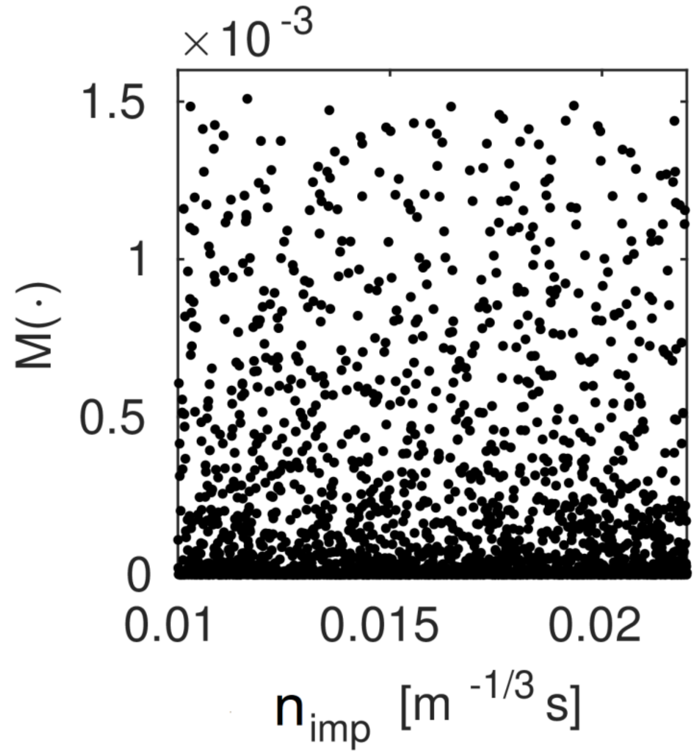


Figure S4. Influence of Manning roughness coefficient for impervious areas (n_{imp}) on the likelihood function (M).

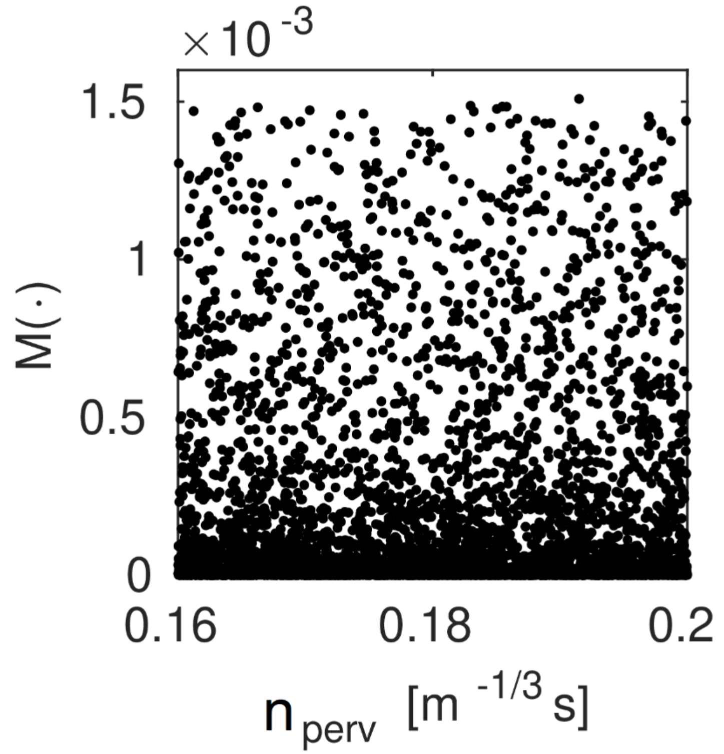


Figure S5. Influence of Manning roughness coefficient for pervious areas (n_{per}) on the likelihood function (M).

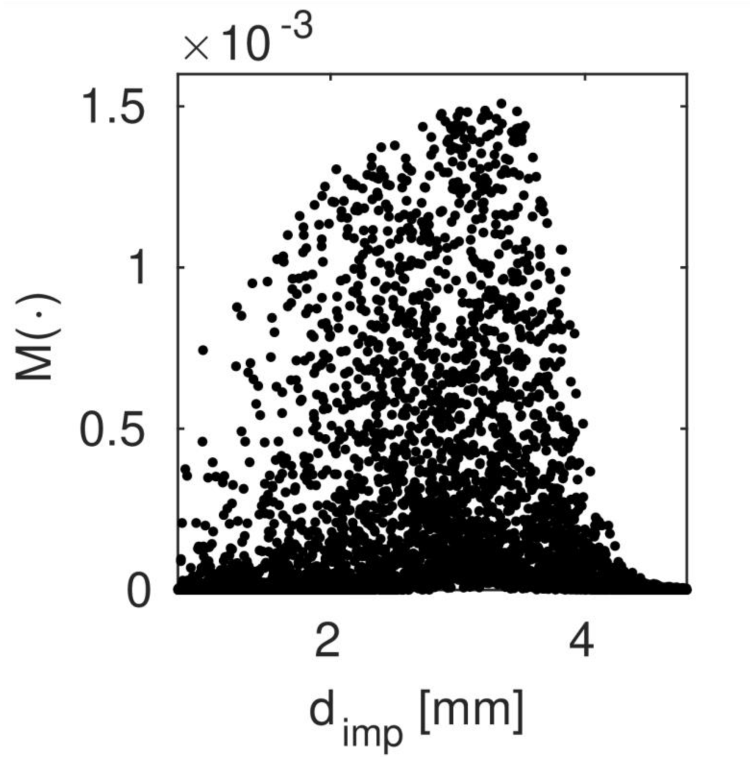


Figure S6. Influence of retention depth of impervious areas (d_{imp}) on the likelihood function (M).

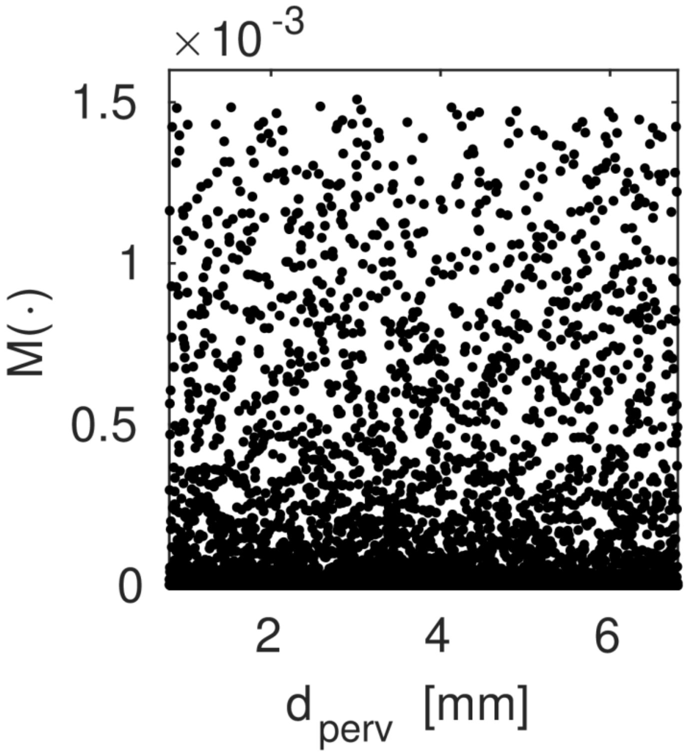


Figure S7. Influence of retention depth of pervious areas (d_{per}) on the likelihood function (M).

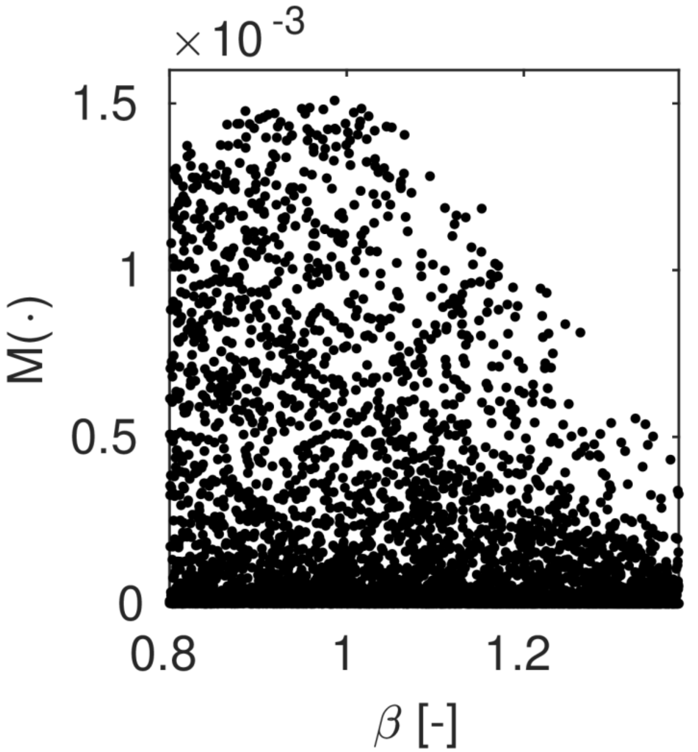


Figure S8. Influence of correction coefficient for percentage of impervious areas (β) on the likelihood function (M).

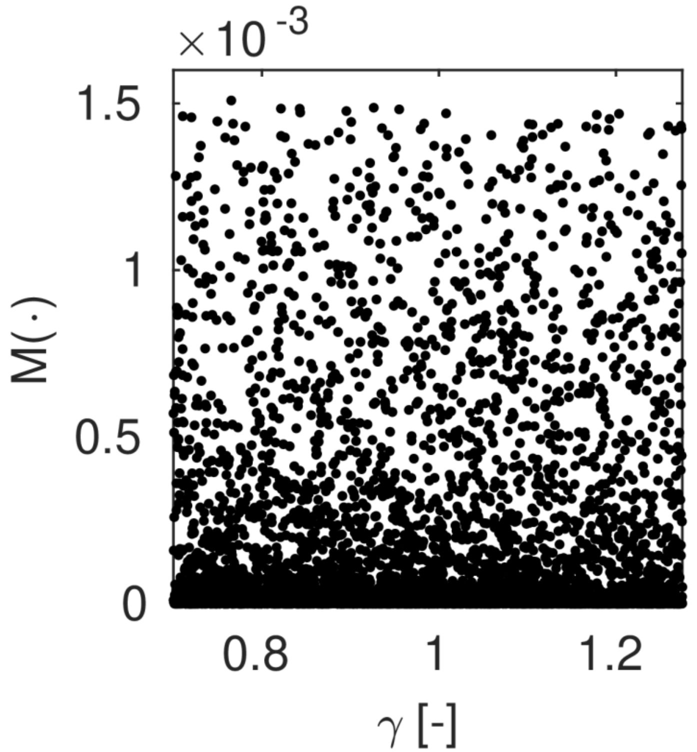


Figure. S9. Influence of correction coefficient for sub-catchments slope (γ) on the likelihood function (M).

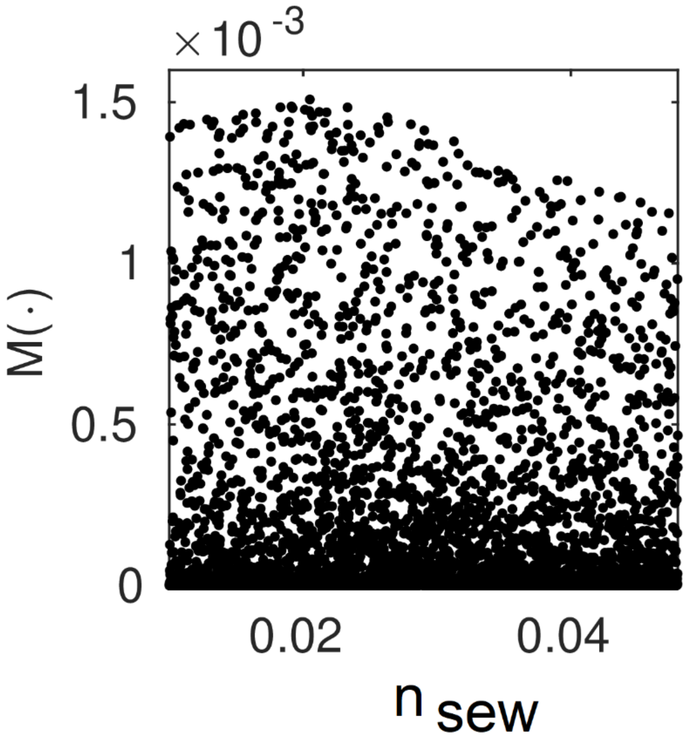


Figure S10. Influence of Manning roughness coefficient for sewer channels (n_{sew}) on the likelihood function (M).

145

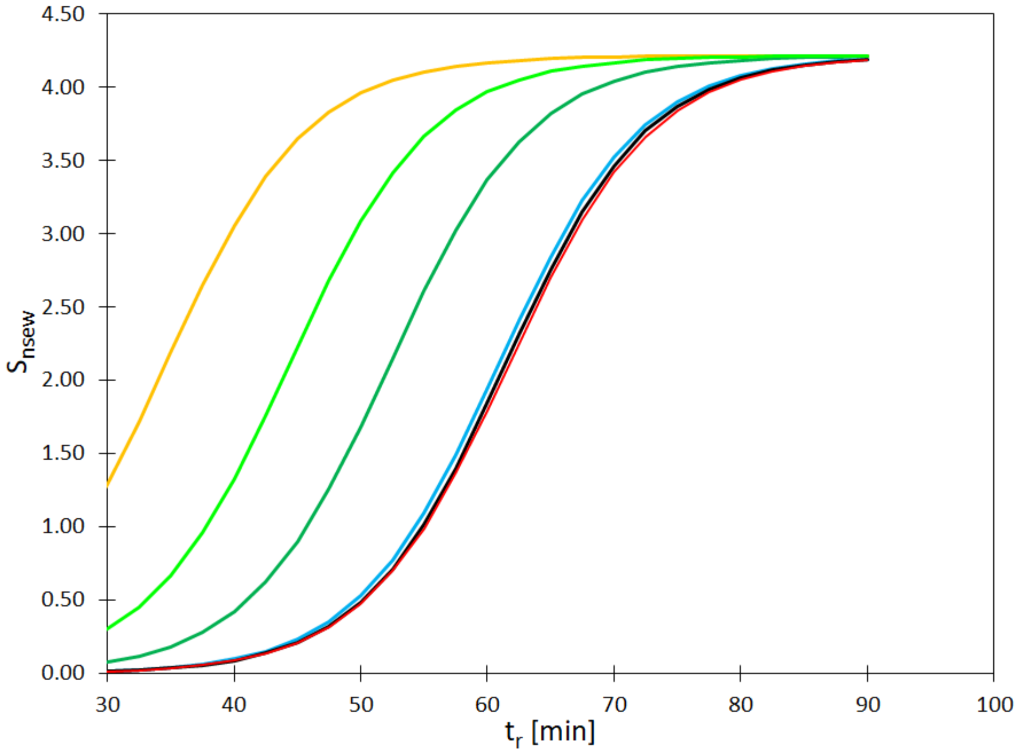


Figure S11. Influence of rainfall duration (t_r) depending on catchment and stormwater network characteristics (Imp, Impd, Vk, Jkp, Gk) on the sensitivity coefficient S_{nsew}.

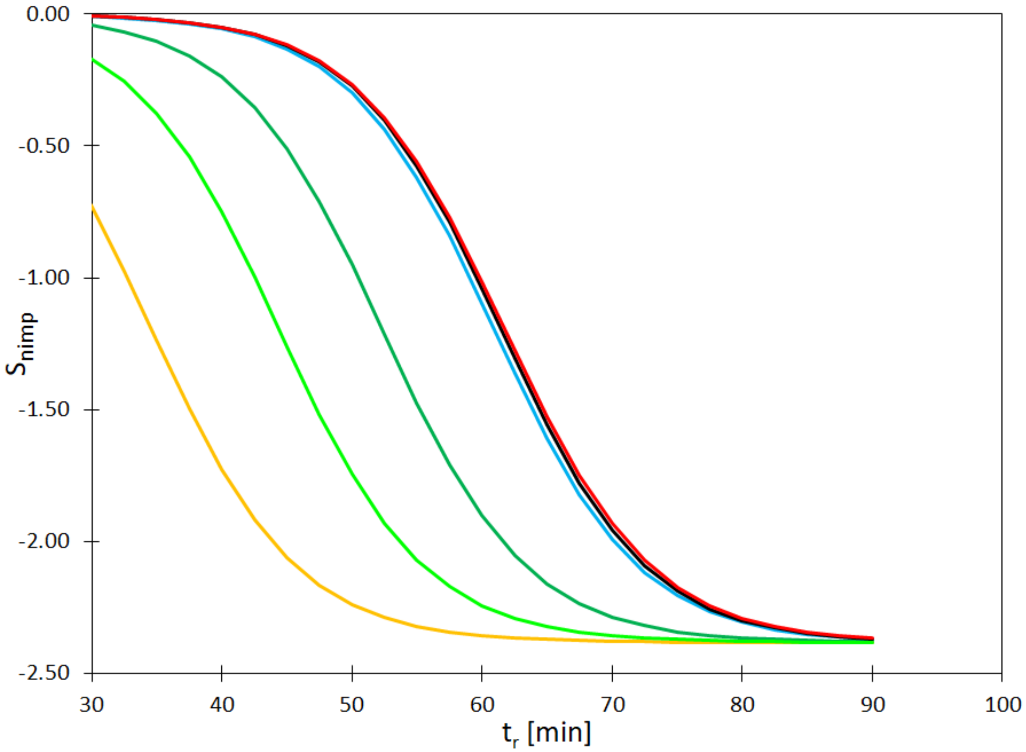
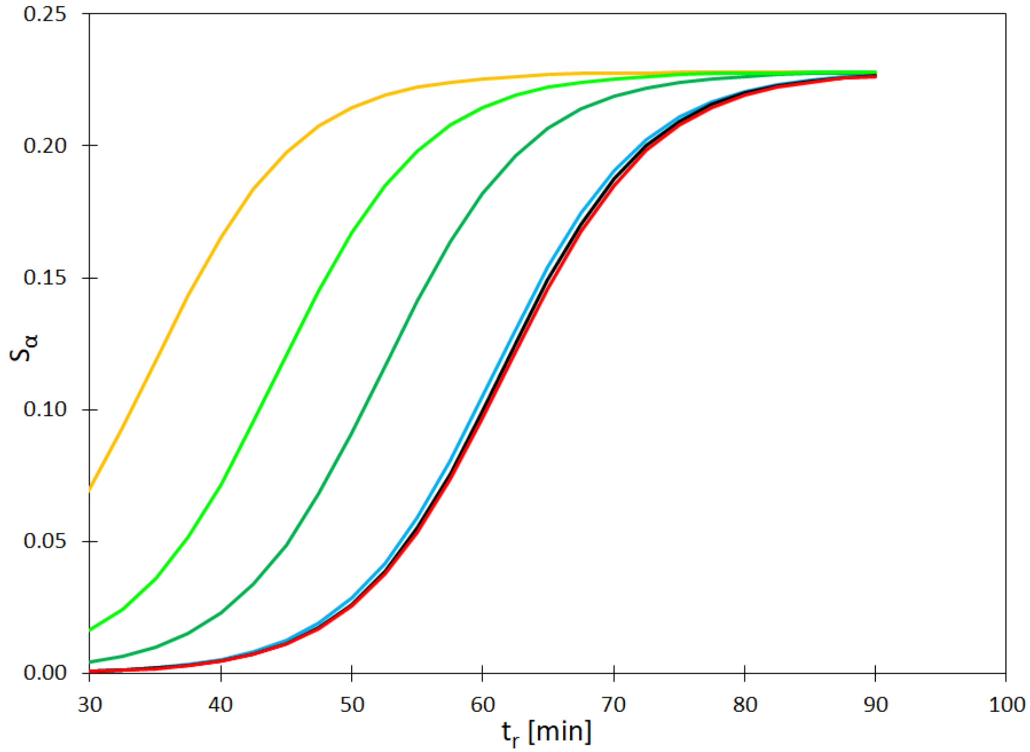


Figure S12. Influence of rainfall duration (t_r) depending on catchment and stormwater network characteristics (Imp, Impd, Vk, Jkp, Gk) on the sensitivity coefficient S_{nimp}.



155 **Figure S13. Influence of rainfall duration (t_r) depending on catchment and stormwater network characteristics (Imp, Impd, Vk, Jkp, Gk) on the sensitivity coefficient S_α.**

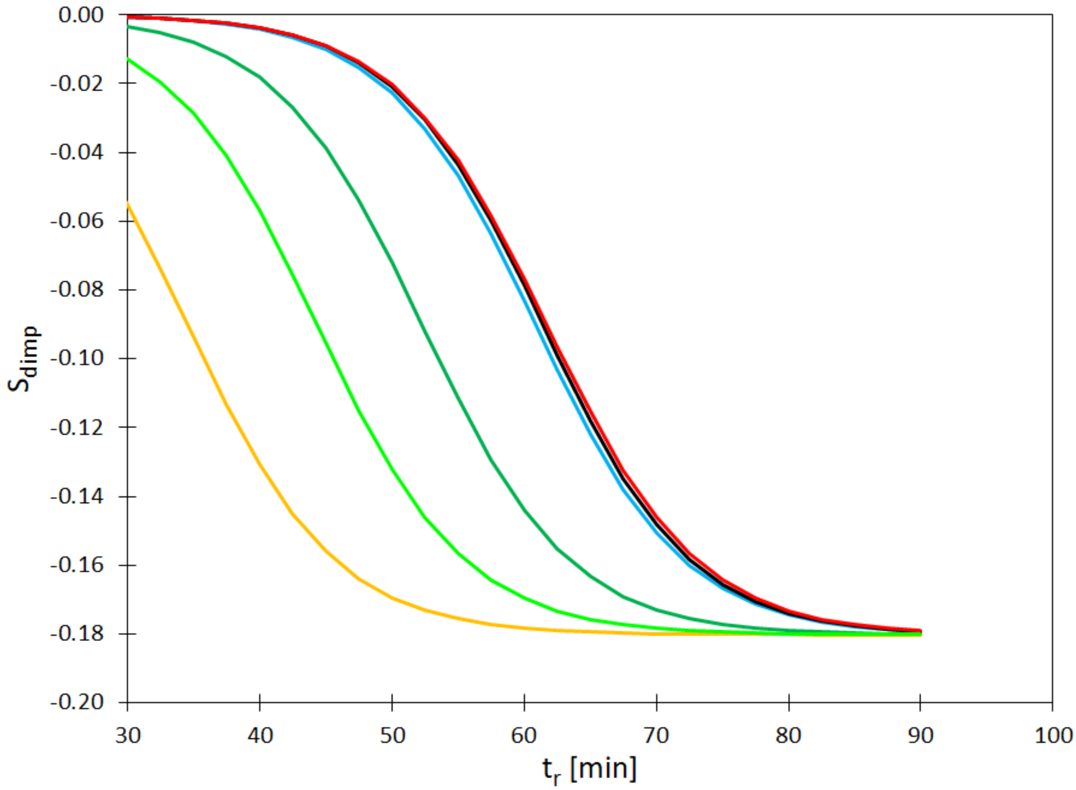


Figure S14. Influence of rainfall duration (t_r) depending on catchment and stormwater network characteristics (Imp, Impd, Vk, Jkp, Gk) on the sensitivity coefficient S_{dimp}.

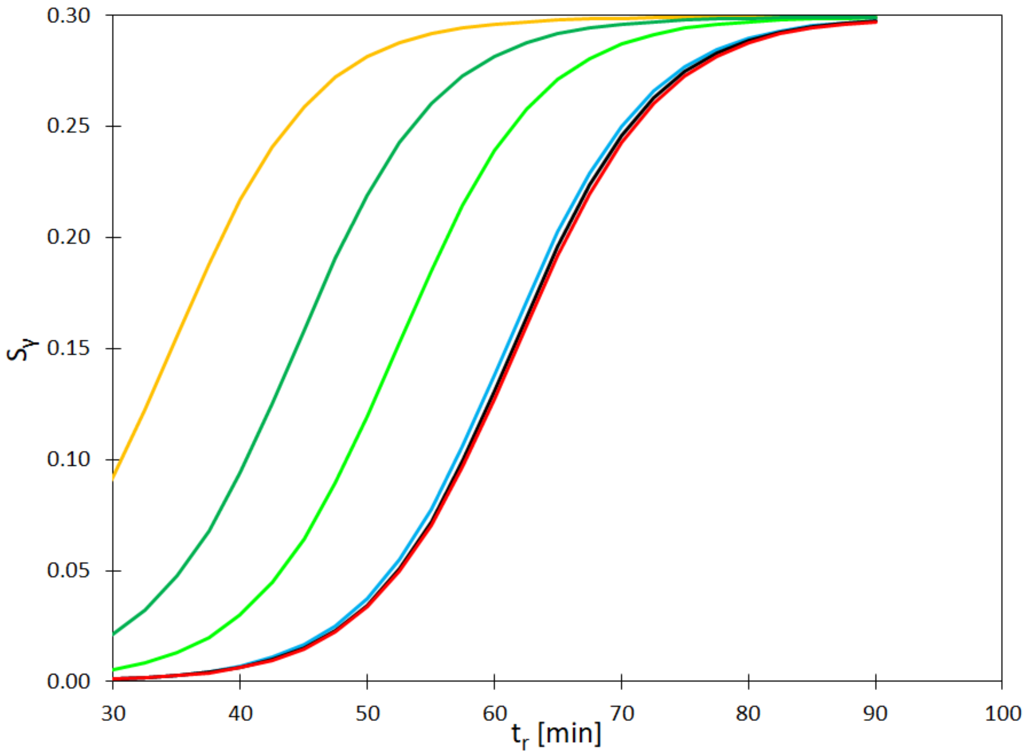


Figure S15. Influence of rainfall duration (t_r) depending on catchment and stormwater network characteristics (Imp, Impd, Vk, Jkp, Gk) on the sensitivity coefficient S_γ.

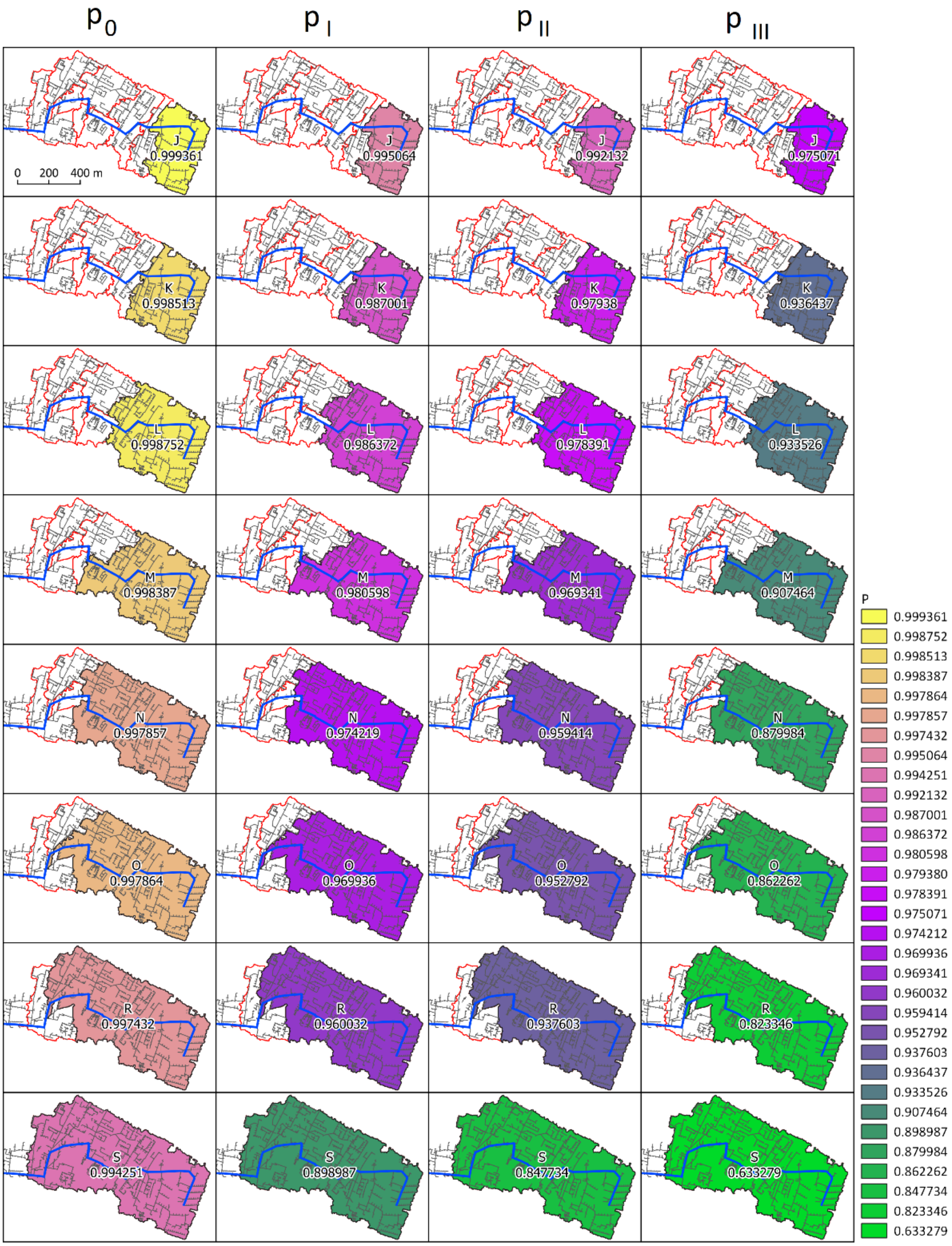


Figure S16. Probability of specific flood volume for separate sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

185

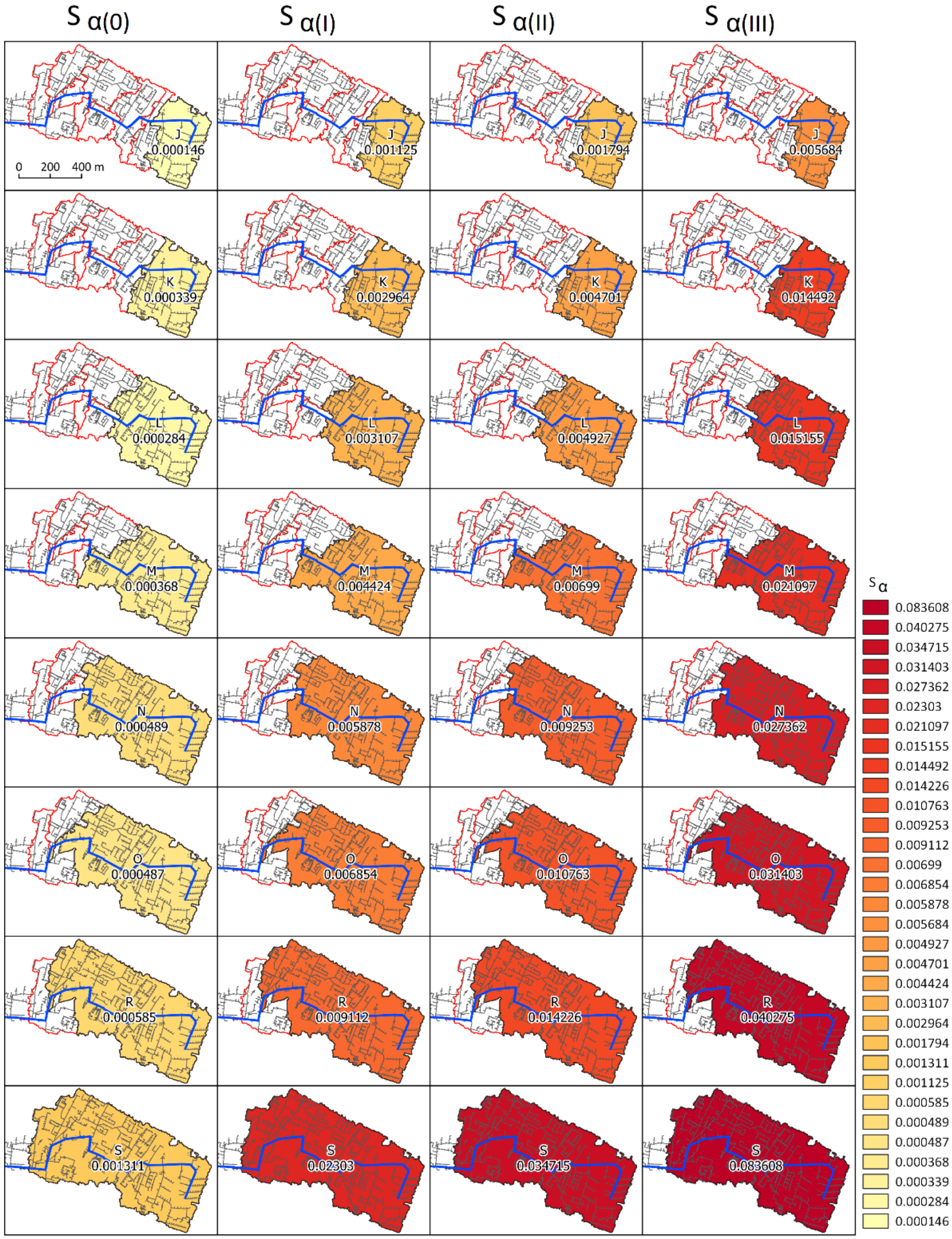


Figure S17. Sensitivity coefficient S_α for separated of the sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

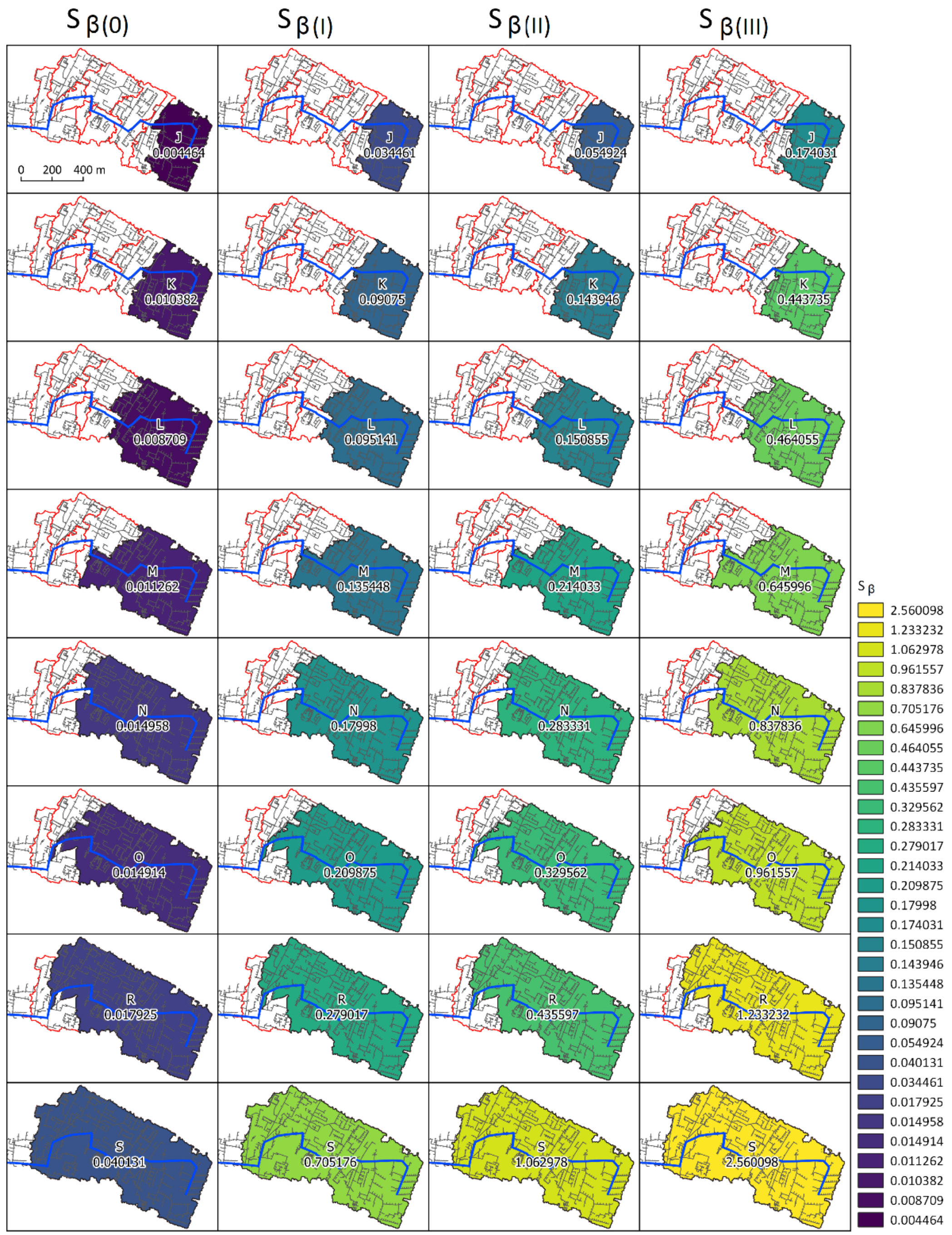


Figure S18. Sensitivity coefficient S_β for separated of the sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

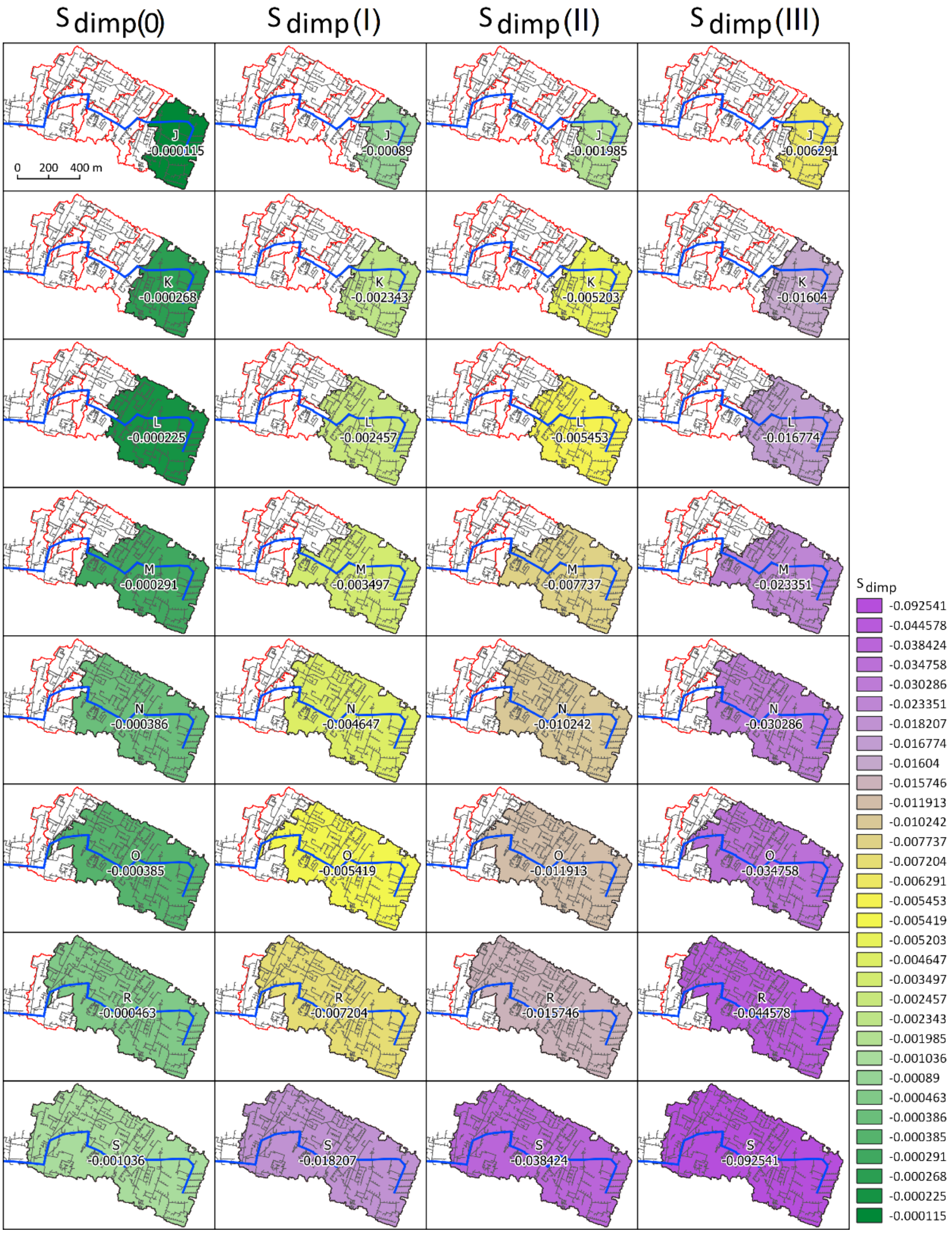


Figure S19. Sensitivity coefficient S_{dimp} for separated of the sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

200

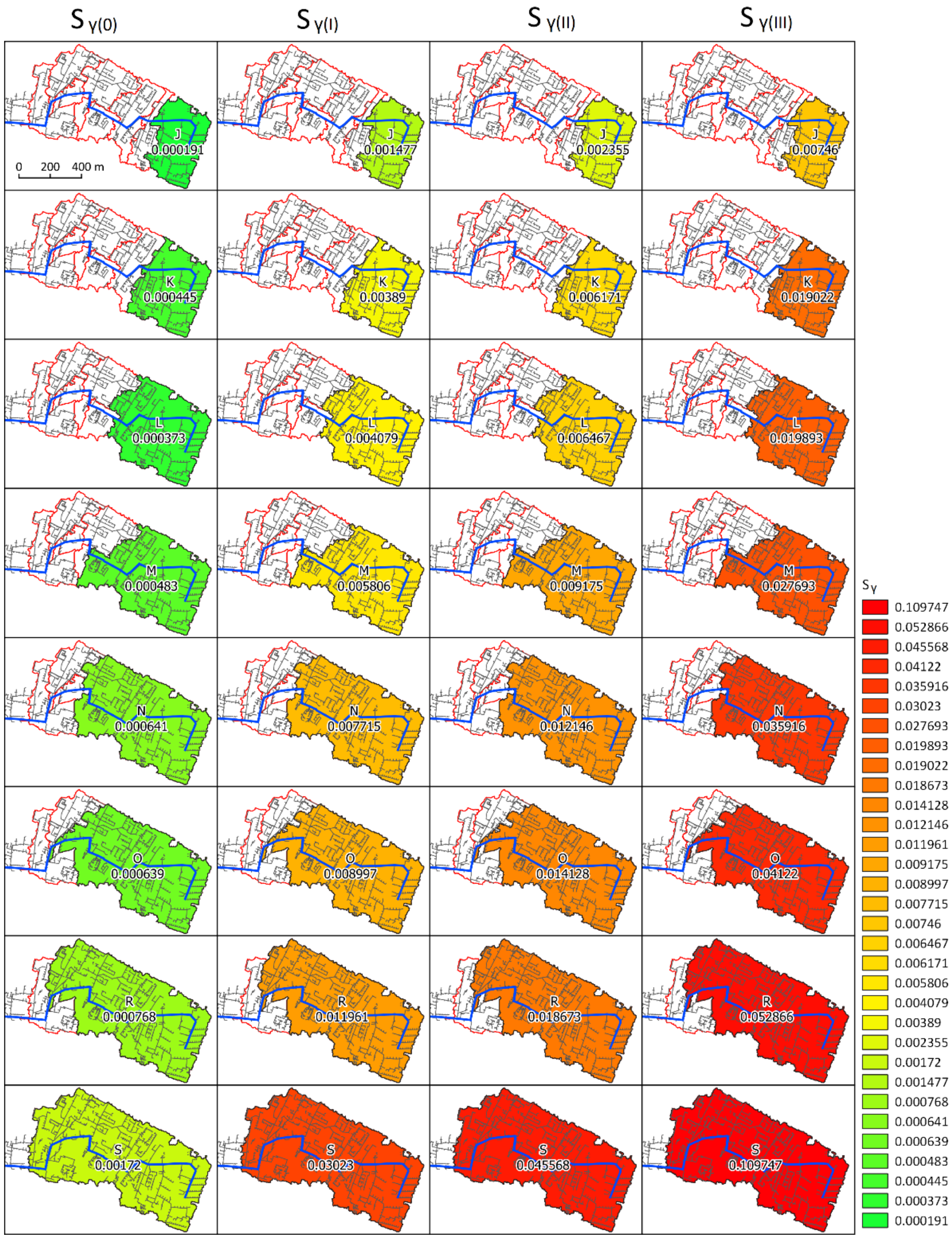


Figure S20. Sensitivity coefficient S_γ for separated of the sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

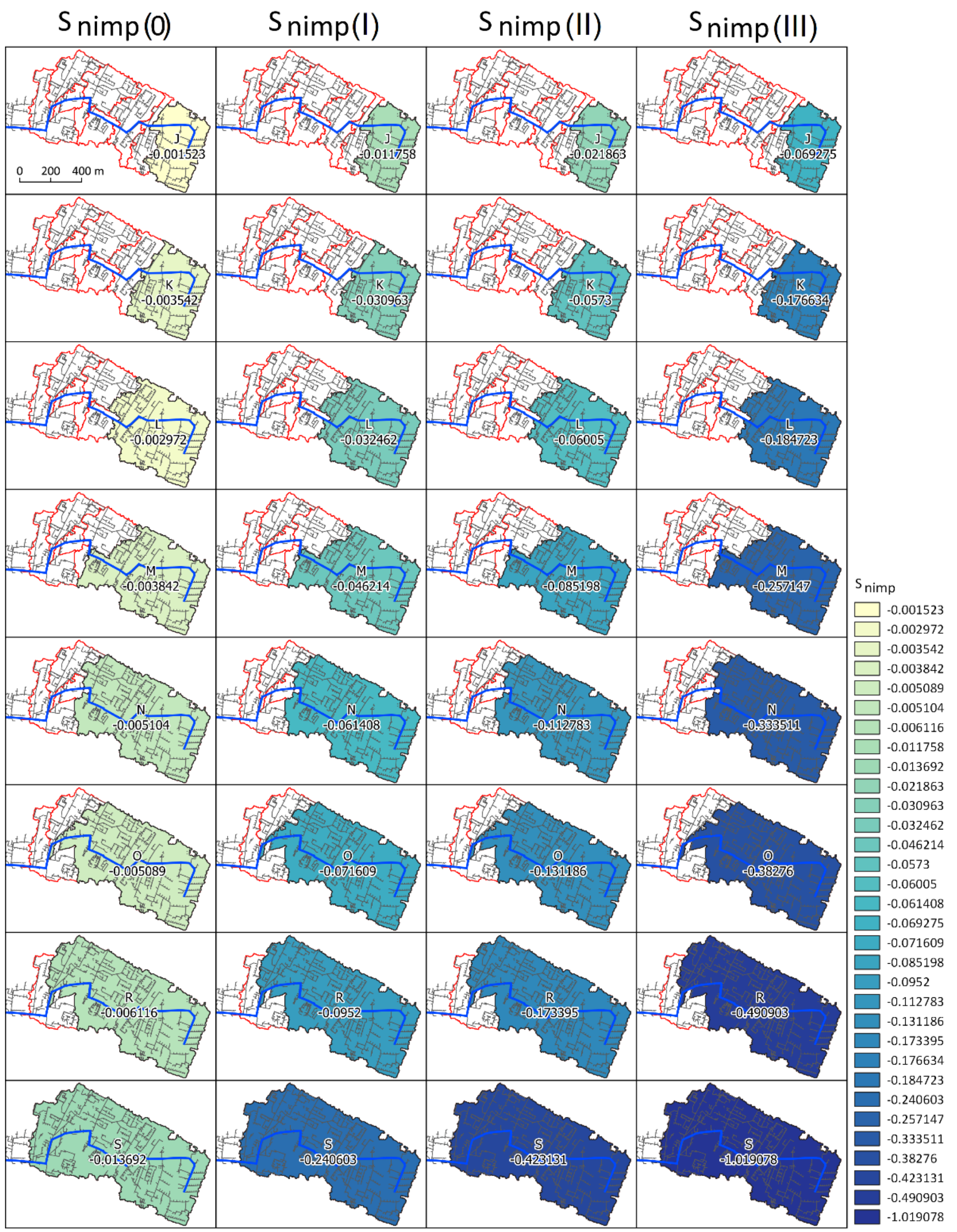


Figure S21. Sensitivity coefficient S_{nimp} for separated of the sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

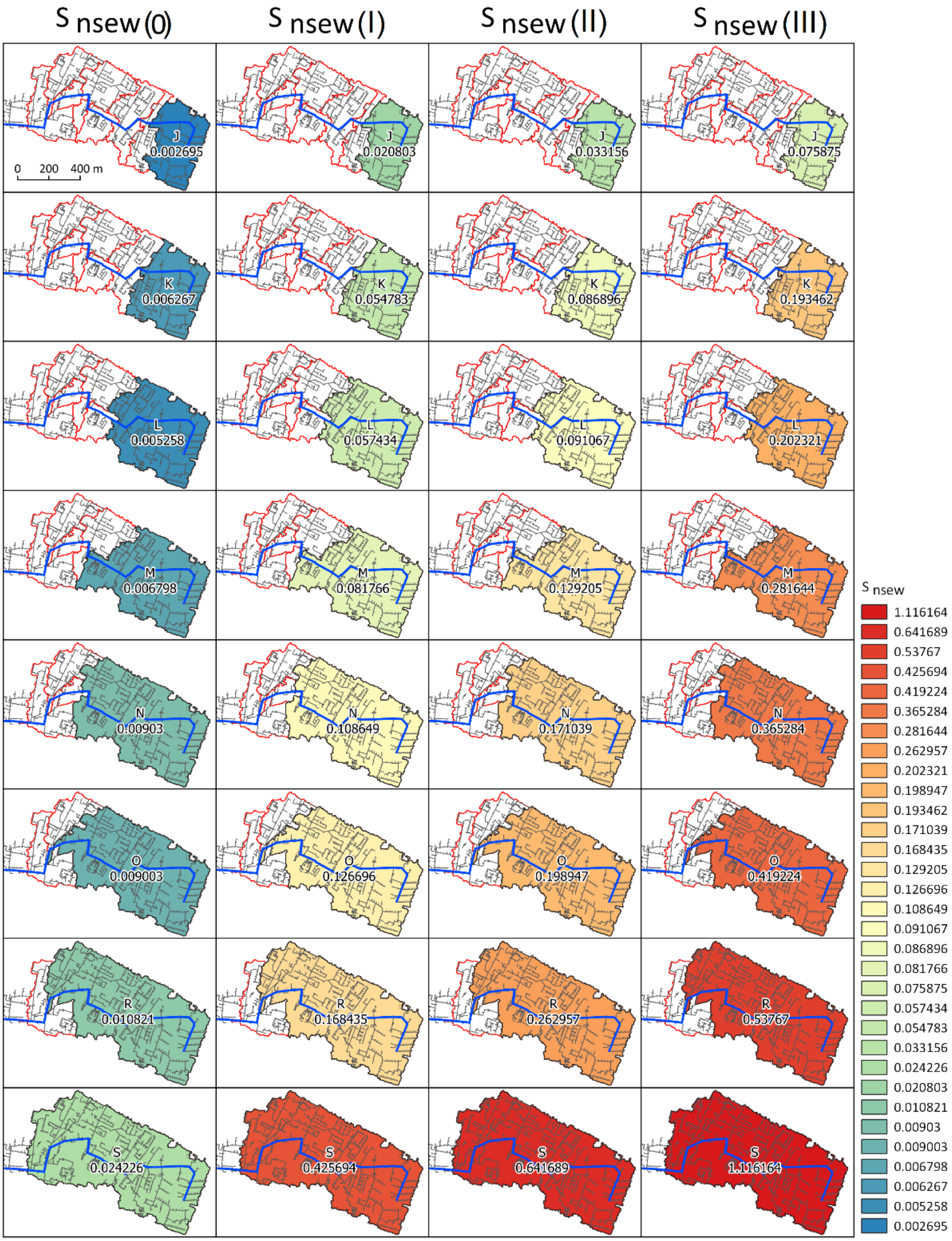


Figure S22. Sensitivity coefficient S_{nsew} for separated of the sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

215

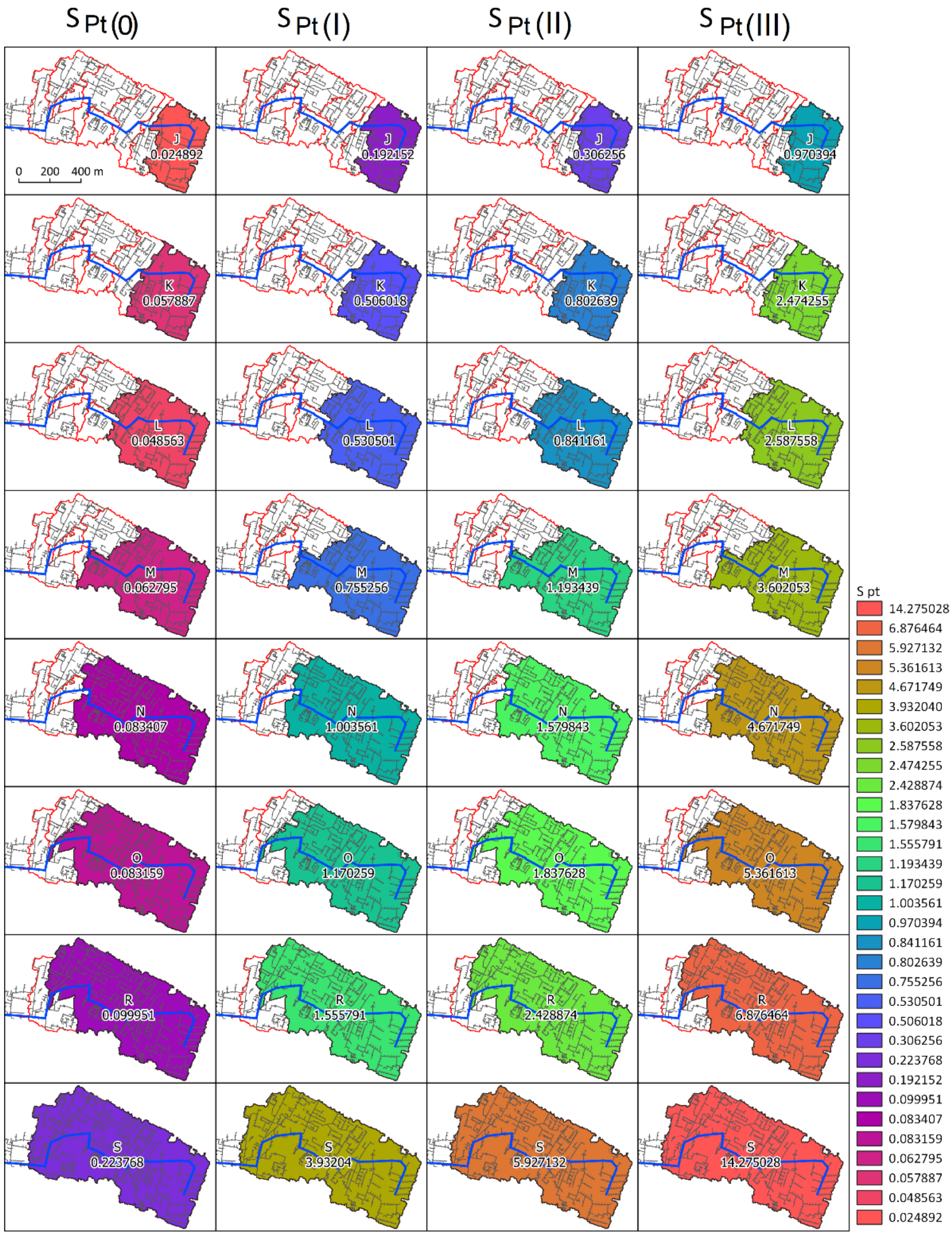


Figure S23. Sensitivity coefficient S_{Pt} for separated of the sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

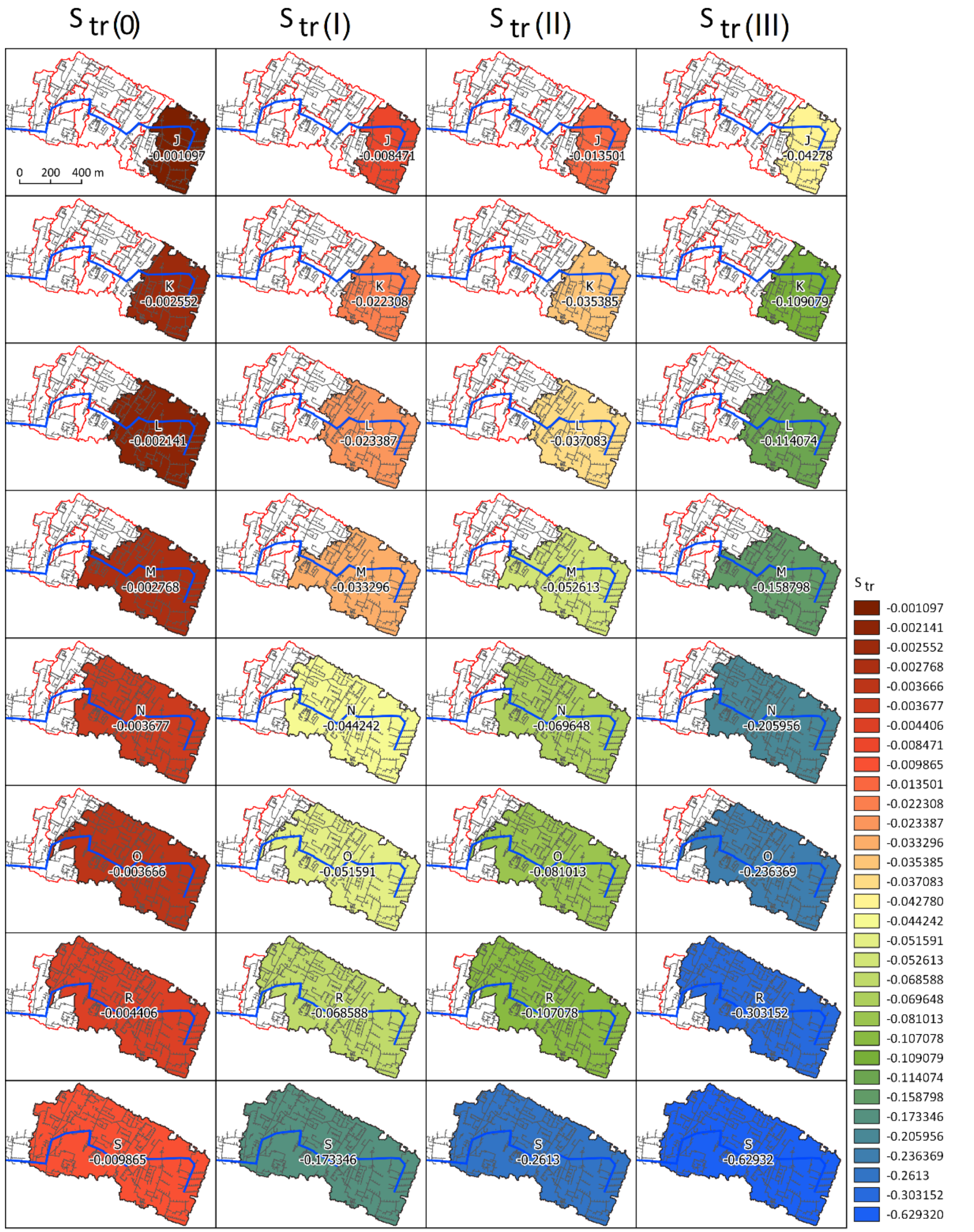


Figure S24. Sensitivity coefficient S_{tr} for separated of the sub-catchments (J, K, L, M, N, O, R, S) for the current state and modernisation options (I, II, III).

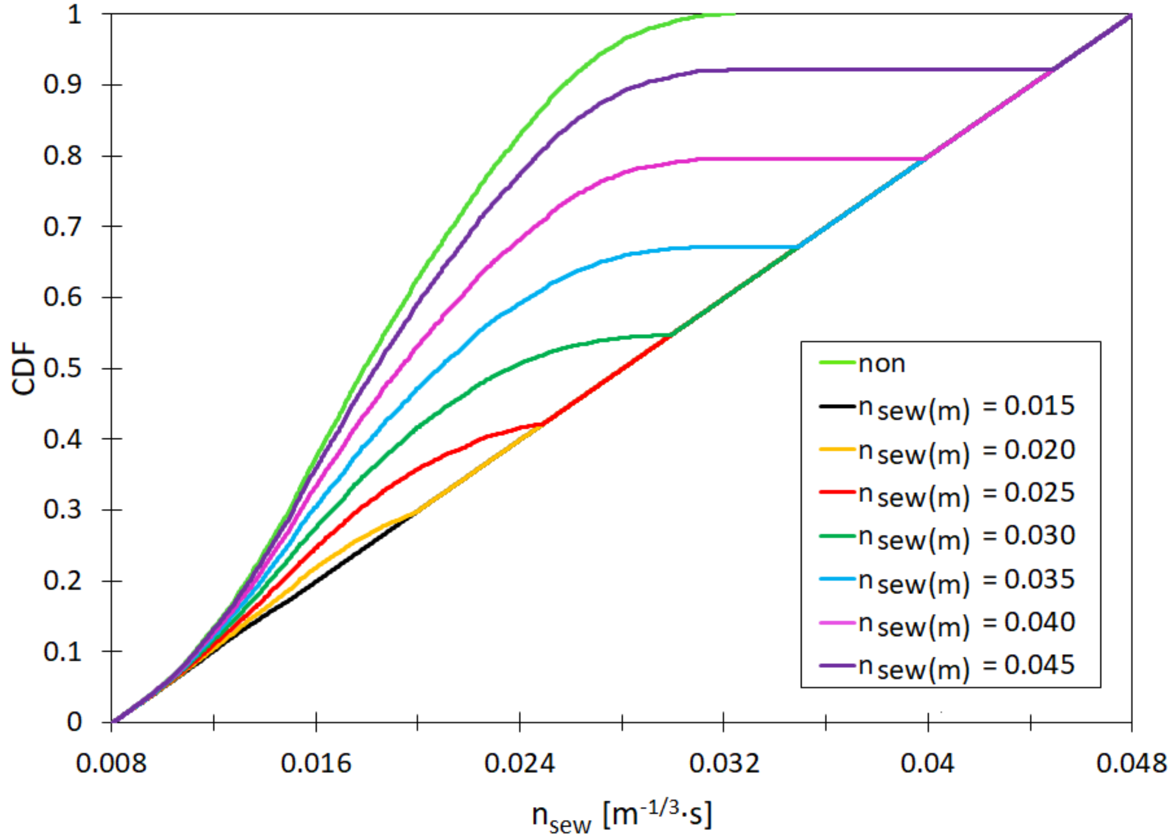


Figure S25. Empirical distributions of Manning roughness coefficients of channels (n_{sew}) for $n_{sew(m)}$=0.015 – 0.045 $m^{-1/3}·s$, Imp = 0.35 and Impd = 0.42.

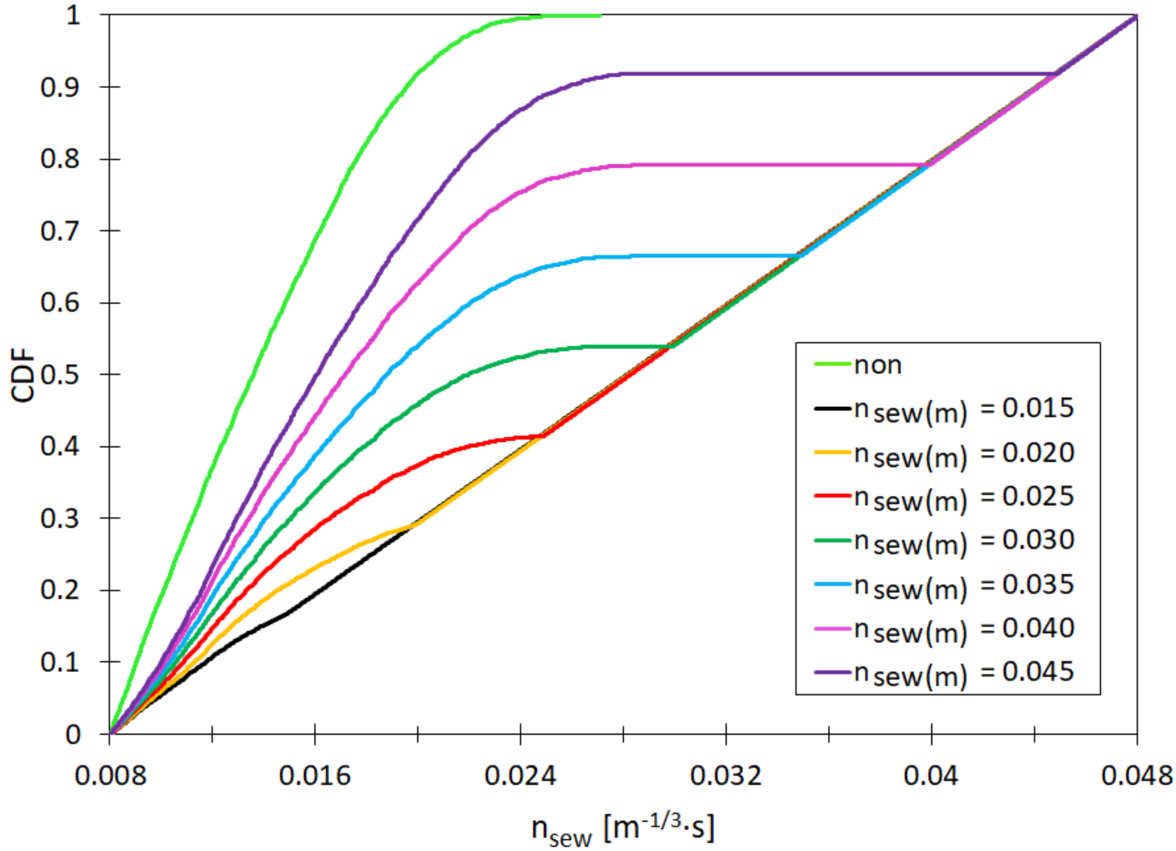


Figure S26. Empirical distributions of Manning roughness coefficients for channels (n_{sew}) for $n_{sew(m)}$=0.015 – 0.045 $m^{-1/3}\cdot s$, Imp = 0.35 and Impd = 0.40.