Could be hydrological model parameters inferred from a soil texture?

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Summary

- Parameters of surface runoff model were derived for each soil texture (past work)
- Newly the parameters were derived with optimization on extended set of data
- Sensitivity analysis and Monte Carlo model uncertainty assessment were performed
- New open source GIS (Geographic Information System) model provider is presented

1 Material and Methods

Presented work has been done within a framework on a SMODEPR2D runoff/erosion model which is being developed at the CTU in Prague.

1.1 Model structure

Based on a balance equation $\frac{Storage}{\Delta t} = Inflow - Outflow$ is inferred bucket model with kinematic wave approach for momentum

$$\frac{\partial h_i}{\partial t} = es_i + \sum_j^n q_j - inf_i - q_i - ret_i$$

where h is water level $[L]$, es is effective precipitation $[L.T^{-1}]$, inf is infiltration $[L.T^{-1}]$, ret surface retention $[L]$, and q is the Manning-Strickler formula

$$q = Xi^Y h^b. \qquad (1)$$

Parameters X $[T^{-1}]$, Y $[-]$, and b $[-]$ were inferred for each soil textural class. Variability of those parameters within and among textural classes is assessed in this poster. Infiltration is solved with Phillip's infiltration equation:

$$inf = 1/2St^{-1/2} + Ks, \qquad (2)$$

where saturated hydraulic conductivity Ks $[L.T^{-1}]$ and sorptivity S $[L.T^{-1/2}]$ were fitted with measured data.

1.2 Current parameter values

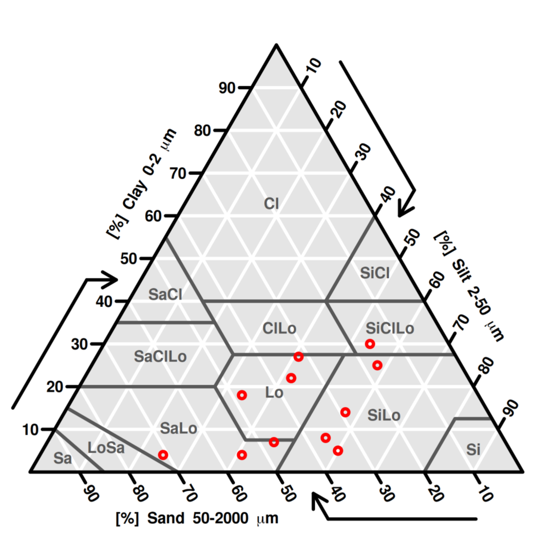
Actual parameter values were inferred based on rainfall simulations and shallow water flow experiments Kavka (2011)

Current parameter set for soil textural classes

Textural class	ID	b	X	Y	Textural class	ID	b	X	Y
sand	SS	1.82	8.81	0.366	sandy clay loam	SCL	1.7	10.7	0.603
loamy sand	LS	1.82	8.81	0.366	clay loam	CL	1.7	10.7	0.603
sandy loam	SL	1.79	9.2	0.462	silty clay loam	SICL	1.7	10.7	0.603
loam	LL	1.74	10.1	0.561	sandy clay	SC	1.67	11.3	0.636
silt loam	SIL	1.74	10.1	0.561	silty clay	SIC	1.67	11.3	0.636
silt	SI	1.74	10.1	0.561	clay	CC	1.67	11.3	0.636

1.3 Soil classes and experiments

- 266 experiments with artificial rainfall were performed
- Various slopes and rainfall intensities were tested for each location



Soil classification for all locations

Overview of artificial rainfall experiments

location	year	no. of exper.	soil texture [%] clay	silt	sand	soil class
Horoměřice	2002	25	25	58	17	silty loam
Třebsín I	2004	22	5	60	35	silty loam
Neustupov	2006	14	4	41	55	sandy loam
Klapý	2007	25	30	54	16	silty clay loam
Třebsín II	2008	28	5	60	35	silty loam
Třebešice I	2009	27	4	25	71	sandy loam
Třebešice II	2010	36	7	46	47	sandy loam
Nučice	2011	35	14	57	29	silty loam
Všetaty I	2012	24	22	42	36	loam
Všetaty II	2013	17	22	42	36	loam
Třebešice III	2014	22	8	56	36	silty loam
Nové Strašecí	2015	20	27	41	32	loam
Řisuty	2017	21	18	34	48	loam

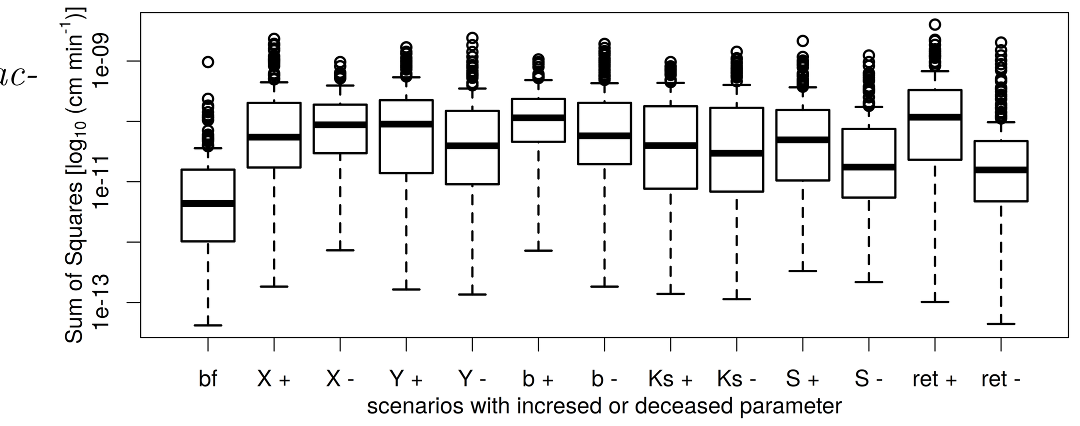
2 Results

2.1 Sensitivity analyses

- Sensitivity of model parameters
- Each parameter changed with a factor and compared to optimized parameter set
- Sum of squares (SS) for comparison
- Parameter specific factor increases SS by ca. order of magnitude

Tab. 1: Increase/decrease factor for each parameter

Parameter	increase factor (+)	decrease factor (-)
X	80	1/3.5
Y	1.3	1/1.6
b	1.125	1/1.5
Ks	2.0	1/5.0
S	2.0	1/5.0
ret	1.5	1/5.0



Sensitivity of model parameters. bf - best fit: SS for all optimized model runs; parameter (+) and (-) stands for parameter increase based on factors in Tab. 1

Functionalities of the python package Scipy were used to perform the optimization (Jones et al., 01).

2.2 Model parameters and textural classes

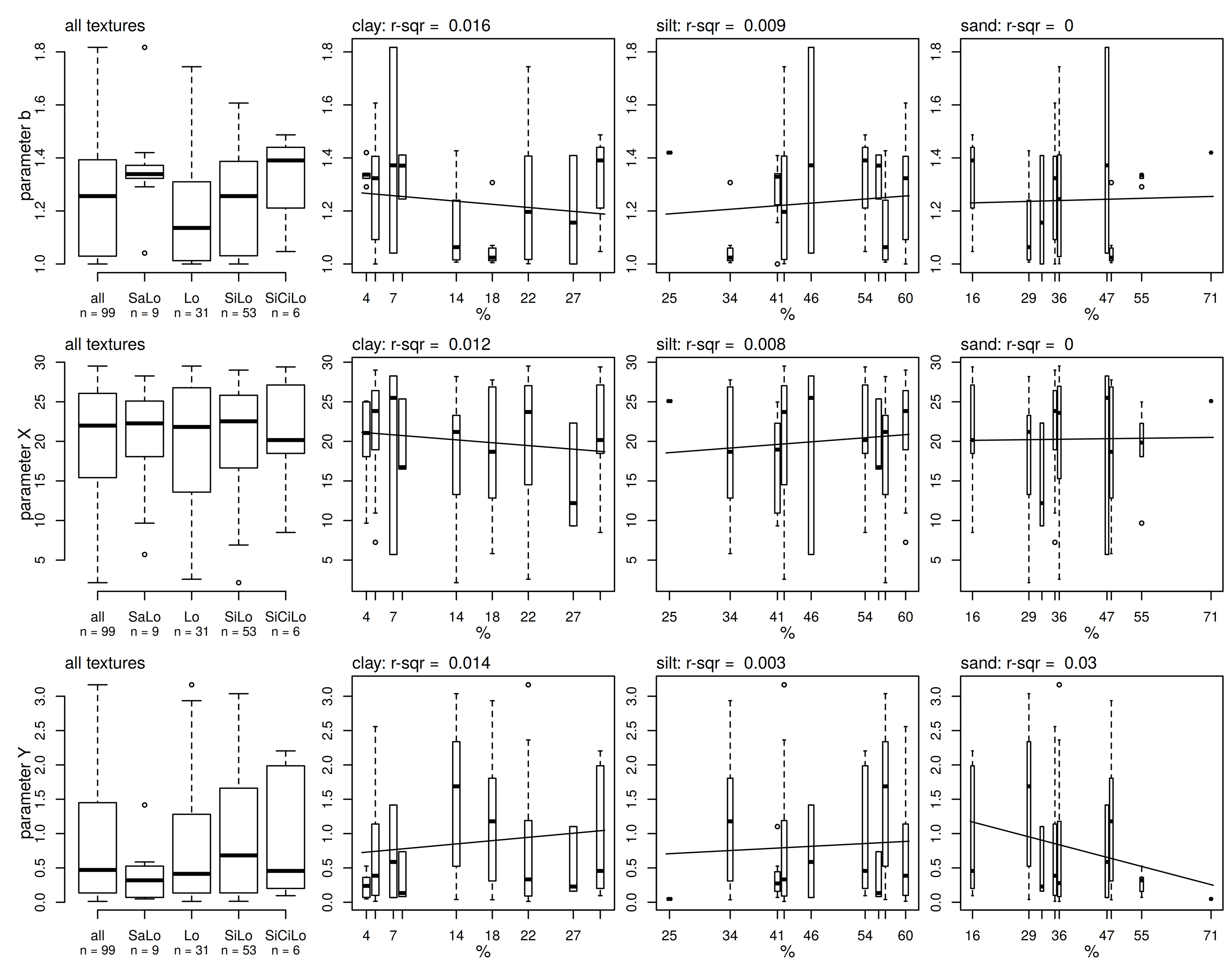
- Infiltration parameters fitted with data
- Eq. 1 parameters were optimized with differential evolution
- Effect of textural class and soil fraction to each parameter was tested
- Each experiment was optimized separately

Parameter margins for optimization

Parameter:	X	Z	b	ret
Max	30	5	4	0
Min	1	0.01	1	-0.5

Example of model output during optimization

```
In interation ;5;
model run ;32066;
runs ;0.56 [sec];
with ss = ;1.2348e-11;
with pars set ;
          1.6460e+01;
          2.2346e-01;
          1.2409e+00;
          3.5512e-06;
          6.5431e-05;
          -7.0449e-04
In interation ;5;
model run ;32067;
runs ;0.53 [sec];
with ss = ;1.6767e-12;
with pars set ;
          2.2231e+01;
          1.9315e-01;
          1.2864e+00;
          3.5512e-06;
          6.5431e-05;
          -7.0049e-04
```

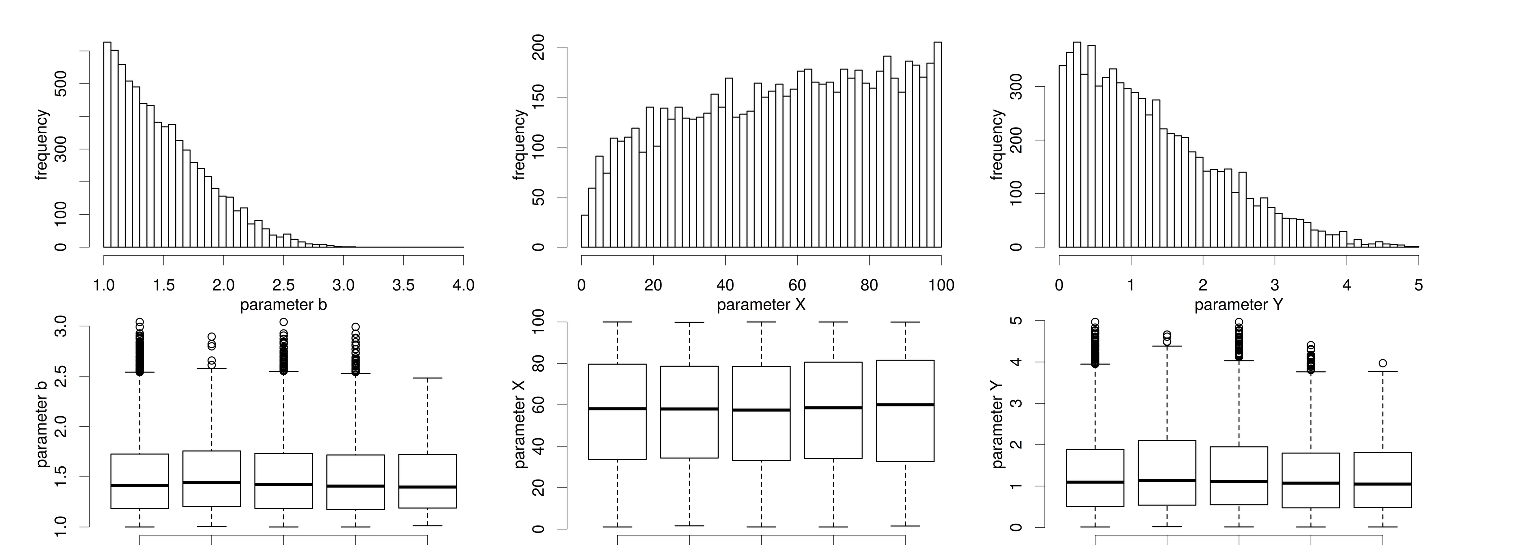


Figures shown optimized parameters. Top bar shown results of parameter b, middle bar shown results of parameter Y, and bottom bar shown results of parameter Y. Left graph shows values for textural class. Second to fourth graph shows parameter values for each soil fraction.

2.3 Uncertainty analyses: Monte Carlo runs

- 10000 Monte Carlo simulations for each experiment
- Random sampling in the parameter space
- Nash Sutcliffe model efficiency (NS) for model run comparison
- NS greater than one accepted
- Among and inter textural class variation is displayed

GNU Parallel software was used to run the Monte Carlo simulations (Tange, 2011).



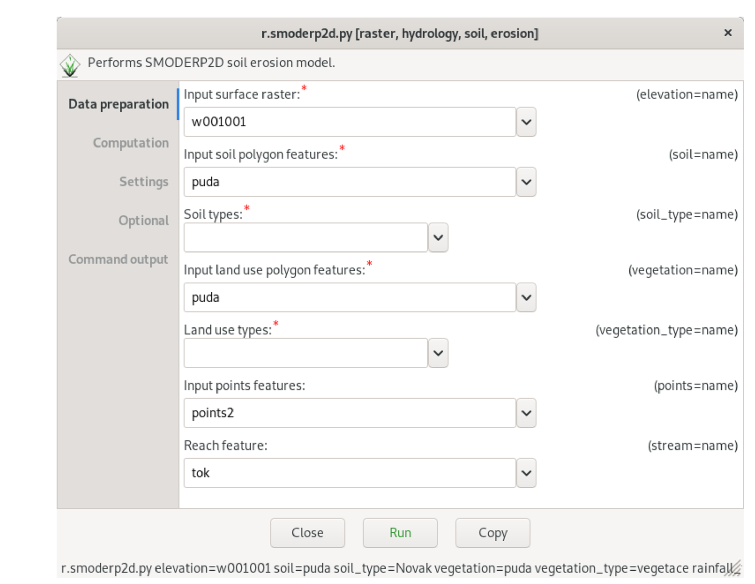
Histogram of excepted model runs for a given parameter (top); Box-plots for for all aggregated values and each soil textural class (bottom)

3 Open source GIS-based implementation

The SMODERP2D model belongs to a family of so called GIS-based hydrological models utilizing capabilities of GIS software for geodata preprocessing. This part is performed by so-called *GIS providers*. Currently there are two GIS providers implemented.

- Originally only proprietary Esri ArcGIS platform (`http://desktop.arcgis.com`) supported
- New generation comes with a provider suited for open source GRASS GIS platform

3.1 GRASS GIS



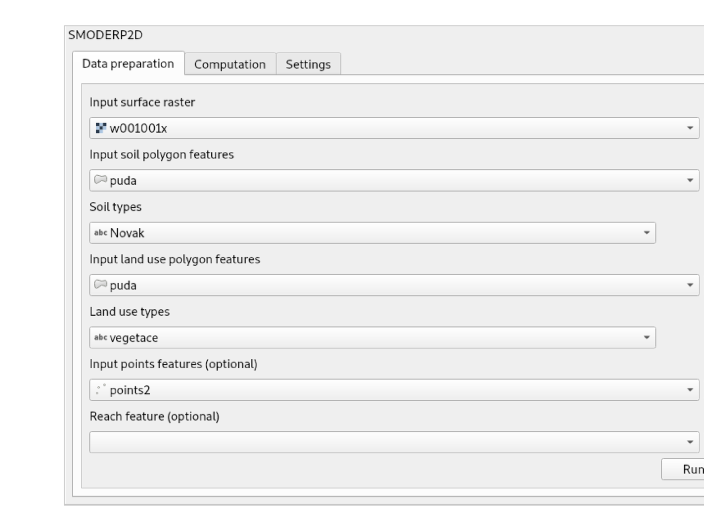
GRASS (Geographic Resources Analysis Support System) *GIS* is a free and open source GIS software suite used for geospatial data management and analysis, image processing, spatial modeling, and visualization. (`http://grass.osgeo.org`)

- GRASS-based GIS provider for data preprocessing integrated into SMODERP2D codebase
- `r.smoderp2d` GRASS Addons module for performing model computation including data preprocessing

3.2 QGIS

QGIS is a widely known free and open source cross-platform desktop geographic information system (GIS) application.

- A new QGIS plugin brings the model into QGIS environment while data preprocessing part is performed by integrated GRASS-based GIS provider
- QGIS plugin significantly increases accessibility of the SMODERP2D model for research purposes and also for engineering practice



4 Conclusions & Results

- Model is not sensitive to parameter X
- Value of newly derived par. b is lower compared with previous inference
- Value of parameter Y corresponds to the previous inference
- Soil fractions and textural classes explain only a small portion of parameter variation
- New generation of SMODERP2D model comes with Esri and GRASS-based GIS providers
- Accessible via ArcToolbox, GRASS Addons or QGIS plugin

powered by

5 References

Jones, E., Oliphant, T., Peterson, P., et al. (2001–). SciPy: Open source scientific tools for Python. http://www.scipy.org/. [Online; accessed <today>].

Kavka, P. (2011). Kalibrace a validace modelu smoderp. *Doctoral thesis (in: CZECH), ČVUT Praha.*

Tange, O. (2011). Gnu parallel - the command-line power tool. *;login: The USENIX Magazine*, 36(1):42–47.

SMODERP2D source code is licensed under GNU GPL (`https://github.com/storm-fsv-cvut/smoderp2d`).

7 Acknowledgement

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