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Preliminary results for the global sensitivity analysis of SALTIRSOIL model outputs

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Abstract

SALTIRSOIL is a model for the prediction of soil salinity, sodicity and alkalinity in irrigated well-drained lands. These three characteristics are respectively assessed through the electrical conductivity and the sodium adsorption ratio of the soil saturation extract (EC_{se} and SAR_{se}), and the pH of the soil saturated paste (pH_{sp}). A global sensitivity analysis (GSA) was carried out to ascertain what input variables are more influential on these three outputs. The standardised regression coefficients of the linear regression analyses were used to calculate sensitivity measures. The irrigation water quality represented by EC_{iw} and SAR_{iw} is the most influential factor on salinity and sodicity calculation, i.e. EC_{se} and SAR_{se} respectively, while the carbon dioxide partial pressure so is on alkalinity (pH_{sp}). Next there are the variables featuring the soil water balance: rainfall, average annual basal crop coefficient and reference evapotranspiration.

Keywords: SALTIRSOIL model; global sensitivity analysis; soil; salinity; sodicity; alkalinity

1. Main text

Soil salinisation is one of the main desertification processes decreasing agricultural productivity in lands under arid, semi-arid and dry-subhumid climates. Identification of areas under risk of salinisation is an important task for soil and water conservation purposes. This identification can be made through measurement or modelling provided the models are validated. SALTIRSOIL (SALTs in IRrigation SOILs) (Visconti *et al*., 2010) is a new model aimed at predicting soil salinity, sodicity and alkalinity in irrigated well-drained lands. The main factors affecting soil salinity, sodicity and alkalinity in such lands can be arranged in four classes: climate, soil, crop and irrigation. SALTIRSOIL uses basic data already available or that can be easily obtained by means of regular land surveys. The standards to assess soil salinity, sodicity and alkalinity are respectively, the following characteristics of the soil saturation extract: electrical conductivity at 25ºC (EC_{se}), sodium adsorption ratio (SAR_{se}), and pH of the soil saturated paste (pH_{sp}).
The aim of this work is to present the preliminary global sensitivity analysis (GSA) carried out to find what input variables are more influential on SALTIRSOIL outputs, i.e. EC_{se}, SAR_{se} and pH_{sp}.
The GSA was done according to a Factors' Prioritisation Setting (Saltelli *et al*., 2004), with the 16 + 3 input variables shown in table 1. A Monte Carlo experiment with 250 trial sets for the evaluation of SALTIRSOIL was

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devised. Two-hundred and fifty random values were independently calculated for each variable according to normal marginal distributions featured by the means and standard deviations shown in table 1. Each model run took 2.2 s.
A linear regression analysis (LRA) for each one of the outputs EC_{se}, SAR_{se}, and pH_{sp} was tried. According to the results of the LRAs the importance of the input variables could be calculated on basis the standardised regression coefficients (SRCs). The SRCs were squared, divided by the sum of squares and multiplied by 100 to obtain a percent measure of sensitivity.

Table 1. Statistical summary of the variables used for the GSA of SALTIRSOIL.

Class	Variable (abbreviation) / units	Mean	St. D.	Max.	Min.
Climate	Rainfall amount (R) / mm year^{-1}	450	120	719	88
	Reference evapotranspiration amount (ET_0) / mm year^{-1}	1200	150	1537	780
	Frequency of rainfall (fR) / day year^{-1}	70	20	121	18
Soil	Clay content (clay) / g (100g)$^{-1}$	36	11	70	0
	Sand content (sand) / g (100g)$^{-1}$	25	7	42	6
	Stone content (stone) / g (100g)$^{-1}$	15	5	28	3
	Calcium carbonate content (ECC) / g (100g)$^{-1}$	50	12	85	18
	Soil Organic Matter content (SOM) / g (100g)$^{-1}$	2.0	0.8	4.5	0.2
	Gypsum content (gypsum) / g (100g)$^{-1}$	0.40	0.15	0.76	0.01
	Carbon dioxide in saturated paste (log pCO_2)	-3.00	0.20	-2.42	-3.57
	Root depth (RD) / cm	100	10	130	70
Crop	Average annual basal crop coefficient (K_{cb})	0.8	0.2	1.25	0.19
	Percent of shaded soil (SS)	74	9	100	50
Irrigation	Irrigation water amount (I) / mm year^{-1}	700	100	1001	443
	Frequency of irrigation (fI) / day year^{-1}	40	10	71	10
	Percent of wetted soil (WS)	70	9	98	44
	Electrical conductivity (EC_{iw}) / dS m^{-1}	4.0	0.74	6.1	2.1
	Sodium adsorption ratio (SAR_{iw}) / (mmol L^{-1})$^{1/2}$	6.6	2.3	11.5	0.8
	pH_{iw}	7.76	0.31	8.63	6.83

The coefficients of determination (R^2) obtained in the LRAs were 0.86, 0.90 and 0.97 for EC_{se}, SAR_{se} and pH_{sp} respectively. According to these high R^2 SALTIRSOIL can be regarded as a monotonic model for the calculation of EC_{se}, SAR_{se} and pH_{sp}. Therefore the sensitivity analysis can be based on the SRCs (Saltelli *et al*., 2004).
The input variables can be ordered from highest to lowest influence on the output EC_{se} as follows: $R \approx EC_{iw} > K_{cb} > ET_0 > I \approx RD \approx WS \approx sand \approx SOM \approx ECC \approx fR > clay > fI > SS > gypsum > logpCO_2 \approx stone$. EC_{iw} and R explain 38% and 36% respectively of the variance of the output EC_{se}, then K_{cb} explains 16%, and the rest of variables explain the remainder variance (10%) starting from ET_0 (2.8%). The input variables can be ordered according to their influence on SAR_{se} as follows: $SAR_{iw} > R \approx K_{cb} > ET_0 > I \approx RD \approx sand \approx WS \approx SOM > fR \approx ECC > sand > fI > SS \approx logpCO_2 \approx stone > gypsum$. SAR_{iw} explains 55% of the variance of the output SAR_{se}, next the same input variables as with EC_{se} but with lower percents of explained variance: R (18%), K_{cb} (13%) and ET_0 (8%). Finally in the case of pH_{sp} the input variables can be ordered as follows: $logpCO_2 > R \approx K_{cb} > ET_0 > RD \approx fR \approx sand \approx I \approx WS > gypsum > SOM > stone \approx fI \approx pH_{iw} > clay \approx SS \approx ECC$. Carbon dioxide pressure (log pCO_2) explains 94% of the variance of the output pH_{sp}. Next there are the same variables as with EC_{se} and SAR_{se} but with even lower percents: R (2.8%), K_{cb} (2.0%) and ET_0 (0.4%). The pH_{iw} and ECC have practically no influence on the pH_{sp}: less than 0.02%.
The most influential input variables on soil salinity and sodicity calculation are, on the one hand the salinity and sodicity of irrigation water (EC_{iw} and SAR_{iw}), and on the other the variables featuring the soil water balance: rainfall (R), average annual basal crop coefficient (K_{cb}), and reference evapotranspiration (ET_0).
The preliminary GSA of SALTIRSOIL model has provided the relative importance of the input variables on the outputs EC_{se}, SAR_{se} and pH_{sp}.

2. References

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