Note: All changes in the manuscript are shown in bold.

Anonymous Referee #1

The paper presents a methodology for performing a sensitivity analysis with compositional data, and applies it to quantify sensitivity of simulated soil moisture content to changes in soil texture using the TOPLATS hydrological model. Overall I enjoyed reading this paper. It is well written, the methodology is clearly explained, and the results are interesting.

General comments:

My main comment relates to the need for additional discussion on the following points:

- generality of results: can the results be generalized to other PTFs, hydrological models, or even other parameter values of the same model? For example, it seems the TOPLATS makes the relatively strong assumption of moisture equilibrium above the water table, then what do the results imply for more general unsaturated flow models?

- We think that it is important to pay attention when generalizing the results from the sensitivity analysis to other model set-ups, *i.e.* using other PTFs or flow models. Unfortunately, it is impossible to derive general guidelines for sampling strategies based on the evaluation of a single model set-up and it would be very timeconsuming to evaluate the results from the SA for an ensemble of other flow models and PTFs. However, we can make some assumptions about the generality of the results. In Loosvelt et al. (2010), it has been shown that different PTFs result in a different response surface of the soil parameter values and predicted soil moisture values such that transferring the results of the SA towards other PTFs is very dubious.

- Concerning the generalization towards other flow models, some considerations can be made without performing additional experiments. All flow models that calculate the soil moisture content by solving the water balance equation, and describing soil properties based on the Brooks and Corey model, are likely to show a similar response in simulated soil moisture to changes in soil texture. For these models, the sensitivity results can be transferred If, of course, the soil hydraulic parameters are calculated with the same PTFs, here the PTFs of Rawls and Brakensiek. For models with another internal structure or other ways to calculate the SHPs, the presented sensitivity analysis needs to be conducted for the given model set-up. In order to avoid repeated application of the time-demanding SA, it would be interesting to investigate whether the pattern in sensitivity can be generalized towards all flow models. Therefore, additional experiments should be carried out.
- Lines 571-573 (section 4) were added to the manuscript to raise the issue of generality.

Lien Loosvelt, Valentijn R. N. Pauwels, Wim M. Cornelis, Gabriëlle J. M. De Lannoy, and Niko E. C. Verhoest, Impact of soil hydraulic parameter uncertainty on soil moisture modelling, Water Resources Research, vol. 47, W03505,2010.

- other uncertainties: the computed sensitivity values are classified from very high to low (P8863, L20-25); how do these values compare to other model uncertainties? Some discussion is needed to put these results into broader perspective of other model uncertainties (e.g. accuracy of the PTFs, which is not mentioned), also in the context of using the results for guiding sampling strategies (section 3.2).

- It is a pertinent remark that other model uncertainties are involved in the simulation of soil moisture and that the sensitivity results should be seen in a broader context. With this study, we only addressed one aspect of model uncertainty, while there are numerous other sources of uncertainty. Related to the SHP prediction, there is uncertainty due to measurement inaccuracies, PTF accuracy, validity and reliability of the PTF, which has not been discussed in the paper. Interpretation of the results w.r.t other uncertainties therefore depends on the choices made to estimate the SHPs. This again raises the issue of generalizing the SA results as interpretation of the results depends on the choices made during the modelling process. It has been shown that the accuracy and the reliability of the PTFs have a profound effect on the soil parameter prediction (e.g. Wagner et al., 2001; Nemes et al. 2001). We believe that the uncertainty related to PTF application has a larger impact than the potential bias in the representative soil texture due to spatial variability and that an optimal identification and application of the PTFs is the first step towards uncertainty reduction. Only then it is useful to optimize the sampling strategy w.r.t. the results of the sensitivity analysis.

- Besides the uncertainty aspects related to PTF application, there is also the issue of textural variability. As the hydraulic parameters are attributed to soil map units, the variability within such a unit is not taken into account. The sensitivity analysis is only useful to identify the regions for which textural variability will have a huge impact on the soil moisture simulation and to optimize the representative texture for that unit. Despite this uncertainty reduction, uncertainty due to spatial variability remains present.
- Lines 573-577 (section 4) are added to note that other uncertainties should be evaluated as well (prior to the sensitivity analysis).

Wagner, B., V. R. Tarnawski, V. Hennings, U. Muller, G. Wessolek, and R. Plagge (2001), Evaluation of pedo-transfer functions for unsaturated soil hydraulic conductivity using an independent data set, Geoderma, 102(3–4), 275– 297.

Nemes, A., D. J. Timlin, Y. A. Pachepsky, and W. J. Rawls (2009), Evaluation of the Rawls et al. (1982), pedotransfer functions for their applicability at the U.S. national ccale, Soil Sci. Soc. Am. J., 73(5), 1638– 1645.

<u>Other comments:</u>

- P8842, L18-19: this sentence sounds very cryptic, try to reformulate

- This sentence contains the definition of compositional data. The definition is cryptic because it should be applicable to a broad range of disciplines, going from textural data to molar concentrations of chemical components. We prefer to stick to this formulation.

- P8842, L25: not clear what is meant here by "standard statistical methods"; the dirichlet distribution handles compositional data and is quite standard.

- We mean here the methods for statistical analysis such as Monte Carlo simulation.

- P8846, L21: it would be good to give more details about how moisture is computed in the model. This sentence implies that moisture is assumed at equilibrium above the water table, if so please state this explicitly. That means that soil moisture sensitivities are directly determined by the retention curve (as modeled by the PTFs) and depth of the water table (vertical location on the retention curve). This is important information for interpretation of the results (see also comment above about generality of the results).

- The soil moisture profile is calculated using a combined energy and water balance approach. The soil colum above the water table is divided into an upper and a lower layer. First, the potential evaporative demand for both layers is calculated using the energy balance and the root distribution. Initially, the actual evapotranspiration rate is set equal to the potential rate. The soil moisture content in both layers is then calculated using an analytical solution to the Richards equation [Crow et al., 2001]. If soil moisture values lower than the residual soil moisture content are estimated the actual evapotranspiration rate is reduced to ensure that the soil moisture content is never below the residual content. Using the actual evapotranspiration rate, the energy balance is then again used to calculate the sensible and ground heat fluxes at actual rates.
- Lines 114-124 (section 2.1) are added to explain the soil moisture calculation within TOPLATS.

- P8847, L9-10: I suggest removing quotes from accuracy and reliability

- Quotes removed.

- P8847, L13: please explicitly list the PTFs that were used in this study

- The regression equations are listed in Table 1.

- P8847, L17: particle density of 1.4 seems much too low, for example quartz has density around 2.6

- The density of 1.45 refers to the soil organic matter. The particle density of quartz, *i.e.* 2.65 g/cm³, was corrected for organic matter as follows: ρs=(2.65-1.45*orgmat/100) in which orgmat is the organic matter content, which was taken as the organic carbon content of 1.5% multiplied by 2.
- Lines 142-145 (section 2.1.1.) were corrected accordingly.

- P8848, L6: please list the model parameters and their values

- Only the relevant parameter values are listed on lines 157-160 (section 2.1.2.).

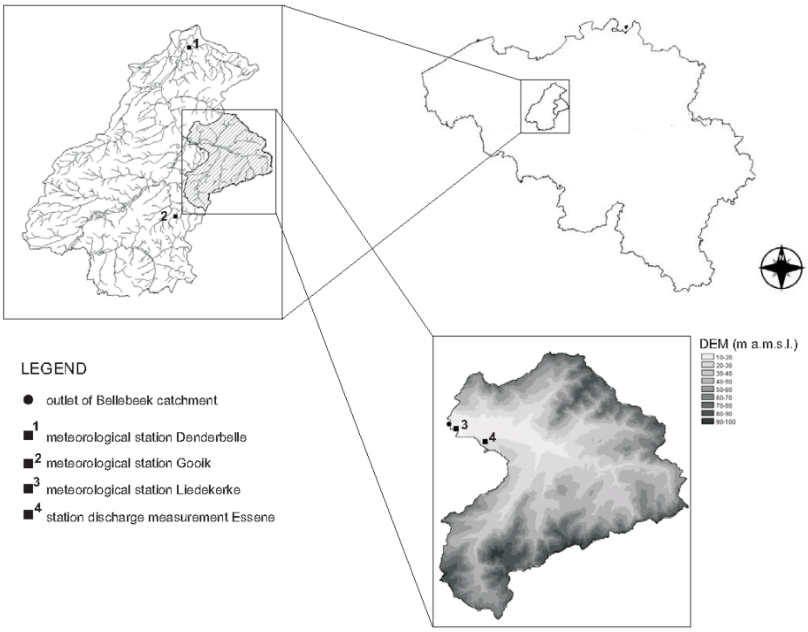

Figure 1:Situation of the watershed and the meteorological stations of Gooik, Liedekerke and Denderbelle

- P8848, L10-12: for completeness, specify how far these meteo stations are from the Basin

- The meteorological station of Denderbelle and Gooik is at respectively 10 and 3 km distance from the watershed (see Figure 1).
- Line 165 (section 2.1.2) was added to specify the distance of the meteo stations from the catchment.

- Eq. 8: the "omnidirectional" sensitivity index is computed using only three directions (M=3). Can you justify this? Did you do computations with M>3?

- The omnidirectional sensitivity index is ideally calculated from an infinite number of perturbed points. However, this is practically infeasible and forces us to restrict the calculation to a limited number of perturbed points. In this study, we made the assumption that perturbation in the direction of the ternary bisectors provides us with the best summary of the perturbation circle. This assumption is based on an extension of the principle for perturbation in the 2D-Euclidean space, where choosing the bisectors of the coordinate system as perturbation axes is self-evident. We did not perform the computation of the sensitivity index with M>3, but this is an interesting idea for future research. Using the formula 360/(2*M) we could vary M from 3 to for example 20 and investigate how the sensitivity index behaves w.r.t. the number of perturbation directions. Additionally, we could fix M=3 but vary the angles and directions of the perturbation axis. If our assumption is correct, it should demonstrate that when only 3 directions are selected, it is in general best to perturb in the direction of the bisectors, and that in such configuration the sensitivity index is a good approximation of the situation where M=20.

- Eq. 9: why take absolute values of the sensitivity functions? Don't you want to estimate curvature here, which should be small for the first-order analysis to be accurate.

- By taking the absolute value of the sensitivity functions, we allow that opposite changes in x result in non-opposite, but similar model responses. This is illustrated in Figure 2.
- Lines 353–354 were added to mention the purpose of taking absolute values.

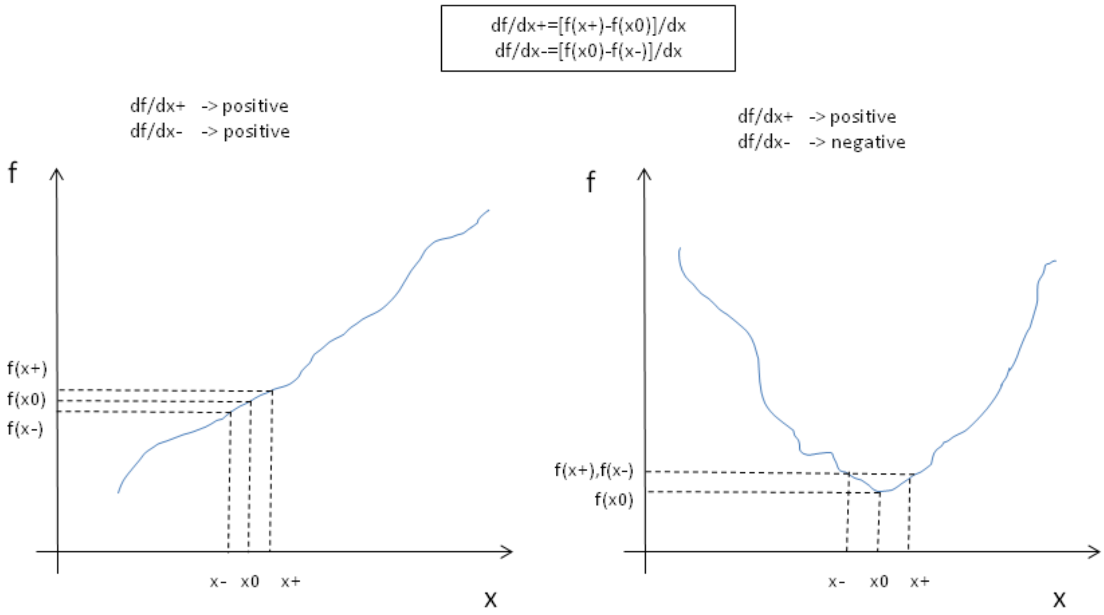

Figure 2: Sign of sensitivity functions under different situations

- *figure 4a: x-axis values are not clear*
  - ➢ The x-axis values have the same font size as in the other graphs. We think that this will be clear enough in the final journal style and will attend this in the further publication process of the paper.
- *figure 9: typically, porosity of sand is less than that of clay, so which soil types do the curves represent in this figure?*
  - ➢ It is true that the total porosity (volume pores/total volume) is typically less for sandy soils than for clayey soils. However, the effective or drainable porosity is typically less for clayey soils than for sandy soils (which is illustrated in Figure 3). The effective porosity can be defined in numerous ways, for example as the total porosity minus the clay-bound water. Here, we defined the effective porosity as the difference between the saturated and residual soil moisture content.

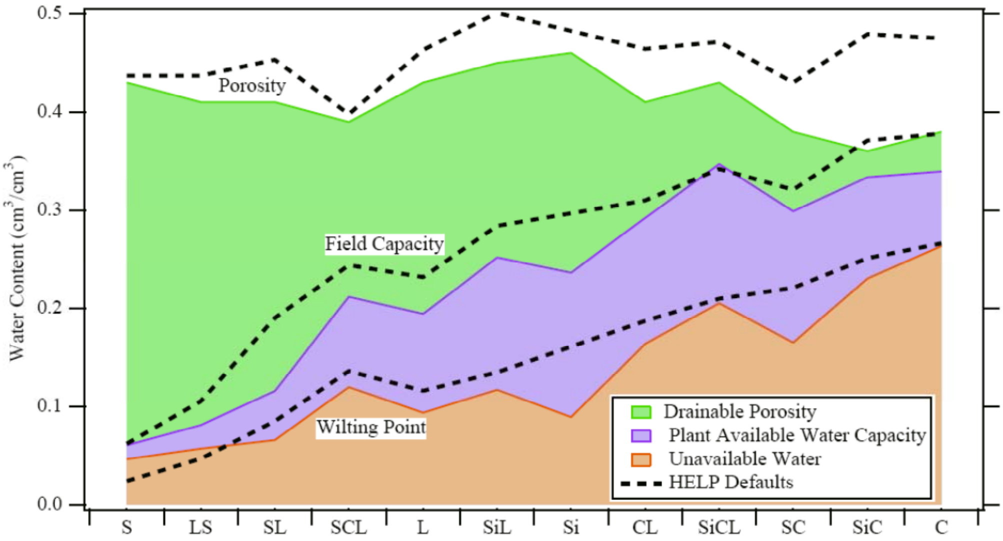

Figure 3: Drainable porosity, available water capacity, unavailable water using the average parameter values from the recommended distributions, and default HELP values for comparison (Meyer et al., 1997)

Meyer, P., M. Rockhold, and G. Gee (1997), Uncertainty analysis of infiltration and subsurface flow and transport for sdmp sites, NUREG/CR-6565; U.S. Nuclear Regulatory Commission.

- *figure 9: the y-axis is mislabeled as "hydraulic head", it should be suction or capillary pressure head.*
  - ➢ Figure 9 has been corrected. However, it is chosen to use the more general and contemporary term “matric head”.