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Discussions

Interactive comment on "Analysis of the drought resilience of Andosols on southern Ecuadorian Andean páramos" *by* V. I niguez et al.

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Detailed comments from Anonymous referee # 1.

The Anonymous referee # 1 said:

Abstract, Major: The abstract is based on a comparison – however no results from the second catchment are presented.

Answer: we propose to include at the end of the abstract the following text.

This did not occur at lower altitudes (Cumbe) where mineral soils needed about eight months to recover from the drought in 2010. The soil moisture depletion observed in the mineral soils was similar to the Andosols (25%), decreasing from a normal value

of about 0.52 to ca. 0.39 cm3 cm-3, but the recovery was slower. Although, the rainfall pattern during the subsequent wet season was quite similar in both catchments (with 860 mm at Calluancay and 710 mm at Cumbe), the recovery of the páramo ecosystem was faster. This may be explained by the larger soil water storage capacity of Andosols and a lower atmospheric evaporative demand and the typical vegetation at higher altitudes.

Abstract, line 22, minor: delete "only".

Answer: the suggestion will be implemented in the new version of the manuscript

Page 11451, line 12-15, minor: support your statements about the hydrological behaviour of these soils/catchments and quantify the immense storage. If the catchment is wet, the response could be really fast; if it is dry it will respond slowly. Their behaviour (or the behaviour of the catchments in which they are located) could also be due to the type of rainfall i.e. no large events?

Answer: In the wet páramos that we investigated –and which have a low seasonal climate variability– the high water production can be explained by the combination of a somewhat higher precipitation and -more importantly- a lower water consumption by the vegetation. In these conditions, the role of the soil water storage capacity would not be significant. This is in contrast with páramos with a more distinct rainfall seasonal variability (as e.g. in the western part of the highlands of the Paute river basin), where the hydrological behaviour of the páramo ecosystem is more influenced by the water holding capacity of the soils (Buytaert et al., 2006). Rainfall ranges between 1000 and 1500 mm year-1 and is characterized by frequent, low volume events (drizzle) (Buytaert et al., 2007). The annual runoff is often 2/3 of the annual rainfall (Buytaert et al., 2006). During wet periods the soil moisture content may be as high as 87%, with a wilting point of ca. 40%. So the soil water holding capacity is high as compared to mineral soils. This is a very important factor in the hydrological behaviour of the páramo. This larger storage is important during dry periods and explains the sustained base flow throughout the year. The soil physical characteristics such as porosity and microporosity –which is much higher than what is commonly found in most soil types– explains an important part of the regulation capacity during dry periods. The water buffering capacity of these ecosystems can also be explained by the topography, as the irregular landscape is home to abundant concavities and local depressions where bogs and small lakes have developed (Buytaert et al., 2006).

References:

Buytaert, W., Célleri, R., De Bièvre, B., Cisneros, F., Wyseure, G., Deckers, J. and Hofstede, R.: Human impact on the hydrology of the Andean páramos, Earth-Science Reviews, 79(1-2), 53–72, doi:10.1016/j.earscirev.2006.06.002, 2006.

Buytaert, W., Iñiguez, V. and Bièvre, B. De: The effects of afforestation and cultivation on water yield in the Andean páramo, Forest Ecology and Management, 251(1-2), 22–30, doi:10.1016/j.foreco.2007.06.035, 2007.

Page 11453, line 17-18, minor: quantification of sensitivity -or resilience- to drought of the land cover and soil systems. This suggests that resilience is a kind of sensitivity. Suggest to delete.

Answer: This suggestion has been analysed in the context of the definition of the "recovery resilience" (please see also the Response to the RC: hessd-12-C5629-2015). And so the aforementioned sentence has been modified as follow: "quantification of drought recovery resilience in land cover and soil systems."

Page 11453, line 8, major: The notion hydrological drought is introduced but not defined and not used further. The use of a model is therefore not clearly motivated.

Answer: One can refer to the review article by Van Loon (2015) who classifies the droughts into the following four categories:

-"Meteorological drought refers to period with a precipitation deficiency, possibly combined with increased potential evapotranspiration, extending over a large area and

spanning an extensive period of time."

-"Soil moisture drought is linked to a deficit of soil moisture (mostly in the root zone), reducing the supply of moisture to vegetation."

-"Hydrological drought is a broad term related to lower than usual surface and subsurface water resources. This can be observed by below-normal groundwater levels, lower water levels in lakes, declining wetland area, and decreased river discharge as compared to normal situations."

-"Socioeconomic drought is associated with the impacts of the three above-mentioned types."

In our manuscript (page 11452, line 28-29) we wrote: "The drought analysed is a soil moisture drought as defined by Van Loon (2015)". In the next paragraph (page 11453, line 7) we also mentioned: "The hydrological drought is compared and related to this soil water drought". Hence, the droughts definitions are according to this reference. If needed, we repeat shortly the definitions according to the article by Van Loon (2015). In our first version we considered that the reference was sufficient.

In this context, the hydrological model used in the research (PDM model) is the link between the soil moisture storage (as indicator for soil water drought) and the stream discharge (as indicator for the hydrological drought). We demonstrated by means of the PDM model the strong relationship between the soil moisture storage and the streamflow at the catchment scale.

Therefore, to clarify the definition of drought in more detail in a new version and discuss figures 5a and 5b (page 11483) with more explicit attention to the "Drought Propagation" (Van Loon, 2015). These figures show the drought period recorded in 2011 for both catchments. In these graphs, a representative sample of rainfall (top), runoff (middle) and soil moisture (bottom) time series is displayed. And so, it is clear to see the propagation of the drought, starting with a deficit of rainfall or dry days (meteorological drought), which are reflected by low values of stream flow observed or simulated (hydrological drought) and finally the impact in the soil moisture storage (soil moisture drought). The recovery phase is also observed in those graphs when the subsequent wet periods appear.

References:

Van Loon, A. F.: Hydrological drought explained, Wiley Interdisciplinary Reviews: Water, 2(4), 359–392, doi:10.1002/wat2.1085, 2015

Page 11454, line 12, minor: gives – replace by defines

Answer: The suggestion will be included in the new version of the manuscript

Page 11455, line 10, minor: hosts replace by "can be characterized by"

Answer: The suggestion will be included in the new version of the manuscript

Page 11455, line 12, minor: delete "as the... by... and replace by "from"

Answer: The suggestion will be included in the new version of the manuscript

Page 11456, Line 21, major: In their description the authors refer to 6 TDR in each plot. This could be read as 6 plots of one TDR in each catchment, or it could be read as 1 plot with 6 TDR in each catchment. Could the authors clarify? I fear however that this number is not sufficient to discuss the selection of a representative soil moisture measurement site.

Answer: The sentence should be read as in each catchment there was one plot equipped with 6 TDR's with a datalogger. As TDR-sensors with data-logger per plot require a very large investment, the locations for the TDR measurements were carefully selected based on a digital terrain analysis, the soil and land cover maps and field surveys (soil profile pits). So, we selected representative locations. As consequence, we are convinced that those point measurements of soil moisture content formed a good estimation for the real catchment's average soil moisture storage. Our comparison be-

tween the catchment average simulated soil moisture storage (one of the internal state variable from PDM model) and the point measurements of soil water content shows that the differences are relatively low. As such we are confident that our soil moisture measurement sites are representative for the catchments.

Page11458, line 15, minor: will be constituted – delete and replace by will consist... of two kinds of flow

Answer: The suggestion will be included in the new version of the manuscript

Page 11461, line 1, minor: delete hereto, replace by to do so

Answer: The suggestion will be included in the new version of the manuscript

Page 11462, line 16: is a Nash-Sutcliffe efficiency a likelihood measure? This requires some explanation and a reference. this to me seems incorrect – to go for (maximum) likelihood estimation you would need some idea about the distribution of your measurement errors. I have seen Nash-Sutcliffe referred to as informal likelihood measure.

Answer: To implement the GLUE methodology, we need a quantitative measure of performance or goodness of fit. And so, there are formal and informal performance measures. Indeed, the Nash-Sutcliffe efficiency is an example of an informal performance measure and it is actually the most used model quality index in the hydrological literature. GLUE, as introduced by Beven and Binley (1992) allows for the elimination of parameter sets that do not perform "adequately" according to the modeller's judgement. There are several criteria to do that. The easiest option is to choose a behavioural threshold of the performance measure. So, it makes sense to give more weight to parameter sets that perform better than other parameters. We can do this easily by rescaling the performance measure to sum up to 1. Once we have behavioural parameter sets and weights, we can construct prediction bounds for a prediction period of choice, in other words a "likelihood measure". That is the reason because in the literature it is possible to find that "Nash-Sutcliffe efficiency was used as a likelihood measure" (Beven and Binley, 1992; Beven, 2009; Buytaert and Beven, 2011; Beven, 2012).

References:

Beven KJ, Binley A. 1992. The future of distributed models: model calibration and uncertainty prediction. Hydrological Processes 6: 279-298.

Beven KJ. 2009. Environmental Modelling: An Uncertain Future? Routeledge: London.

Buytaert, W. and Beven, KJ., 2011: Models as multiple working hypotheses: hydrological simulation of tropical alpine wetlands, Hydrological Processes, 25(11), 1784-1799, doi:10.1002/hyp.7936.

Beven KJ. 2012. Rainfall-runoff Modelling: The Primer. 2nd ed. John Wiley & sons, Ltd.: Chichester.

Page 11642, line 23: scaling your moisture content allows for two types of prediction error – a constant offset, and a constant over- or underestimation. Is your conclusion really warranted?

The equation 7 (page 11642, line 23) was used to adjust or standardize the soil moisture storage data –observed and simulated– in order to calculate a scaled wetness "Sr". A representative time series of standardized soil moisture storage is presented in the figures 5a and 5b. The analysis revealed that the temporal variability of the average soil moisture storage simulated by the PDM model mimics the pattern of the observed soil moisture measurements. The PDM calibration does not use the observed point measurements but uses the discharge data for calibration. So the simulated values by PDM are generated as an internal and conceptual state variable in the model. The scaling is therefore justified in order to compare the temporal pattern. A model calibrated on the runoff will also never grasp the real soil water storage below the wilting point as this can be considered as dead storage. As the lowest soil water content never

reaches wilting point we need an offset.

Supplemental material: Replace dotty plots by scatter plots. Whereas dotty seems to be used in literature, I am more familiar with dotty meaning "demented"

The term "dotty plot" was introduced by Beven and Binley (1992). It is part of the GLUE methodology. Because of the many points, normally several thousands, in the graph small dots are used. "Dotty plots" has as a consequence become the traditional name used for scatter plots in studies of uncertainty analysis in hydrological modelling. In a full text search for the word "dotty" on the HESS journal 29 articles are returned. We prefer to be in line with the hydrological literature (HESS journal). So, this a well-known special form of scatter plot and has no connotation in the GLUE approach of "dotty" as "demented". Moreover in the R-software the word dotty plot is also used in some packages.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 11449, 2015.