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Hydrology and Earth System Sciences Discussions

Interactive comment on "Hillslope hydrology under glass: confronting fundamental questions of soil-water-biota co-evolution at Biosphere 2" *by* L. Hopp et al.

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1. General comments

The paper presents the hydrologic studies for designing three experimental hillslopes at Biosphere 2. The ongoing research program at Biosphere 2 is unique for many aspects. The long-term experiments in controlled environmental conditions are proposed to provide significant advances in eco-hydrology. Initial design efforts for this type of experiments deserve to be published in specific papers.

This paper illustrates:

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Interactive Discussion

Discussion Paper

- the main design criteria followed by the authors to ensure that the experimental hillslopes will be capable of answering the key scientific questions;

- the application of different models as design tools;

- the application of a 3-D numerical model for simulating the response of the recommended design hillslope to different climatic regimes.

I found many parts of the paper interesting, in particular those discussing the general design criteria (Section 2.1) and the difficult tradeoffs in the hillslope hydrologic design (Section 4.1).

However, I have some reservations about the design approach employed. I also think that the paper structure does not help the reader in understanding the overall design process.

I report these specific comments below, starting with the analysis of the paper contents and structure.

2. Specific comments

2.1 About the paper structure

I think that the paper should better introduce the main research questions that are going to be addressed in Biopshere 2 experiments or at least those research questions that are more relevant for the following hillslope design process. This would help the reader in understanding what are the main hydrological processes being investigated and what are the corresponding spatial and temporal scales of interest. Some research questions are just briefly presented in the introduction (page 4414 lines 14-16). Surprisingly, research questions are also presented in the discussion section, after the hillslope design has been already presented (page 4435 lines 9-21).

The paper should then illustrate the main hillslope features that are going to be designed. These are listed at the end of Section 2.1 "Design criteria" (page 4420 lines

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15-17), while I think that they should presented before the design criteria are illustrated.

The design study focuses on the identification of the following hillslope features: 1) hillslope surface topography; 2) subsurface topography; 3) permeability of the base; 4) overall slope; 5) soil depth and 6) soil hydraulic properties.

The first three hillslope features have been chosen by pragmatic decisions according to some general design criteria:

- hillslope surface (1) topography is designed with a zero order basin geometry, this to enhance spatial variability in the eco-hydrological processes;

- subsurface topography (2) has been designed equal to the surface topography (i.e. uniform soil depth);

- base (3) has been designed as impervious.

These pragmatic decisions are presented in the Section 2.2 "Modelling approach" (page 4421 lines 1-17). However, I think that these should not be considered as part of the "modelling approach", which has been followed only for designing the other three hillslope features. These pragmatic decisions should be discussed in a preceding section, as preliminary constraints for the following hillslope design.

Hydrologic models have been employed as design tools in order to identify the most suitable combination of the remaining three hillslope features (see points 4-6 listed above), given the following design objectives:

- avoiding the occurrence of overland flow in order to minimise surface soil erosion;

- ensuring that the soil water dynamics during the dry season will not lead to desiccation of the vegetation.

The Authors apply two types of models with increasing level of numerical complexity:

- the first is a combination of a model simulating the vertical infiltration and flow dynamics in the unsaturated zone and a model simulating the saturated flow through the hillslope;

- the second is Hydrus-3D, which solves the Richards' equation in the three-dimensional hillslope domain.

The first model is employed essentially to identify the most suitable soil type after evaluating the hillslope response with several sets of model parameters derived by combining 12 soil types, four soil depths, two time-series of potential evaporation and various average mean surface slopes. The second model is employed to indentify the most suitable soil depth and surface slope.

I found this part of the paper difficult to read. Section 2.2.2 "Hydrus-3D modeling" anticipates some of the first model results which are discussed in the following section. Figure 4 is mentioned before Figure 3.

I think that this part of the paper could be structured in a better way. I would illustrate the design rainfall pattern in a separate figure, since the small graphics in Figure 4 are unclear. It could be important to discuss the maximum average rainfall intensities for different time intervals in order to understand the simulated surface and subsurface hillslope responses. I would also present the first model setup and the corresponding model results prior discussing Hydrus-3D setup and results.

Tables summarising the model parameterisations could be helpful for the readers.

2.2 About the design approach

I do not think that the selection of the "climatic properties" could be deferred, as stated by the authors (page 4420 lines 21-22).

It is difficult to draw some design conclusions by running relatively complex models with just a half year generated rainfall time-series and two different potential evapotranspiration time-series, without verifying that the statistics of these time-series are representative of the extreme conditions that are going to be applied to the experimental hillslopes. This approach could lead to identify just a small part of the parametric space that could fit the actual design objectives. In the worst case, the model simulations could provide just a partial view of the actual issues that could be faced during the experiments.

The first step in any hydrologic design study is to characterise the design climatic forcing, such as: the maximum average rainfall intensities within different time intervals, the mean extent of the inter-storm periods, the temporal extent of the dry periods, the maximum average (reference) potential evapotranspiration rate during the dry periods.

Then the hillslope features (or better, their constraints or limiting values) should be designed by evaluating separately the most relevant hydrologic processes at the corresponding characteristic time-scales, with the design climatic conditions, possibly by using simpler design models, specific for each process analysed, as it is normally done in applied hydrology.

For instance, the maximum rainfall intensities could be employed to indentify the minimum value required for the saturated hydraulic conductivity in order to avoid any infiltration excess runoff. Similarly, rainfall intensities at small time scales could be employed for evaluating the maximum splash erosion rates for different physical soil properties and different surface slopes, since splash erosion could be also a problem as stated by the Authors.

Small time-scale design rainfall could be also employed to evaluate the maximum overland flow rate for a given saturated area extent and thus for evaluating the maximum expected soil erosion in case overland flow is generated by saturation excess mechanism, again for different surface soil properties and surface slopes.

As reported also by the Authors (Figure 4), the subsurface flow response as well as the most relevant features of the surface soil moisture patterns at the peak discharge, are not sensitive to the rainfall variability at small time scales. Thus from a design perspective, in order to identify further constraints to some hillslope features (such as

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the hydraulic conductivity at high soil pressure heads, the soil depth and the slope), it could be more effective to compare the simulated hillslope subsurface responses with design rainfalls at large time scales, corresponding for instance to the maximum average rainfall intensity at seasonal scale, for given initial conditions at the beginning of the rainy season.

Similarly, in order to identify constraints to the soil hydraulic properties (hydraulic conductivity and soil water retention) at small soil pressure heads, it could be more effective to evaluate the pressure head dynamics with design dry seasons, corresponding for instance to the maximum average potential evapotranspiration rates and the maximum duration of the dry season, for given initial conditions at the beginning of the dry season.

I also have some doubts about the choice of the 12 sets of soil hydraulic parameters. It should be considered that soil types are affected by the climatic conditions. Thus once semi-arid climatic conditions have been selected, only those soil types potentially occurring in semi-arid areas should be evaluated. I also think that it is not technically correct to employ soil hydraulic parameters derived by averaging parameters values suggested for given textural classes. These are parameters of soil hydraulic functions that are fitted to measured values. Averaging directly the parameters is not the same as averaging the corresponding water retention and hydraulic conductivity functions. The risk of using average parameters for given textural classes is to get "unrealistic" soil hydraulic properties. This is probably the type of issue that lead the Authors to change the hydraulic parameters with values corresponding to "potential soil materials" (see page 4428 lines 25-29 and page 4429 line 1). In fact, it would have been more effective to explore the soil parameter space by considering just the soil types that could be employed for Biosphere 2 and representative of semi-arid areas.

2.3 Further specific comments

Beside the hillslope experiments, monolith or small plots experiments on, such as infiltration and evaporation tests, could provide important reference data for interpreting the results on the large hillslopes and for a better characterisation of the soil hydraulic properties.

3. Technical corrections

Page 4420 line 16-17: I think that the sentence "....6) soil texture (i.e. hydraulic properties)" is not technically correct. Soil texture alone cannot be representative of the soil hydraulic properties, since other soil properties could affect the soil water retention and the soil hydraulic conductivity. "Soil properties" could be more appropriate than "soil texture".

Figure 3. The variables "Rs" and "Rw" are mentioned in the figure caption and in the manuscript text, but are not indicated in the graphic.

Figure 3. Why not showing the results for the 10 degree mean slope angle as in Figure 4? This would help in comparing the results of the two different models.

Figure 5. In the figure caption, "Figure 2" should be written instead of "Fig. 1".

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 6, 4411, 2009.