

Interactive comment on “Rainfall intermittency and vegetation feedbacks in drylands” by M. Baudena and A. Provenzale

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Referee 1

We thank the referee for his/her useful comments.

Major:

1: “ The authors start by introducing the lack of understanding the interplay between climate and biosphere, however, they do not address this issue. They address the interplay between vegetation and soil moisture given certain climatic conditions. So, the authors first argue that it is essential to take the interplay between climate and biosphere into account and then they seek to ignore it by considering climate as a given condition that does not depend on the vegetation and soil water dynamics that

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they model. I think that is not good enough and could be better justified. I do not disagree with their approach, but I would like to see an argument in the introduction that they ignore something that they first acknowledge to be so important, and I would appreciate at least a comment on that in the discussion”

Answer: We agree with the referee. Since we explore soil-vegetation feedbacks for fixed external rainfall input, we opted for reducing the references to climate dynamics, and stating more clearly our focus on soil-vegetation modeling. The first and second paragraphs of the introduction have been modified accordingly.

2. “Then, the authors mention things like “correct description”, “accurate climate modeling” and “relevant parameters and processes” and then they come up with a mechanistic, minimalistic modeling approach. I am in favor of such approach for the reason that the authors give. Now, interestingly, they come up with the main conclusion that it turns out that whenever one of the components rainfall intermittency or vegetation feedbacks are present in the model, the addition of the other component does not really matter. I like this result because it suggests that one of these components can be safely ignored without having too much of an effect. Now, coming back to “correct description”, “accurate climate modeling”, and “relevant parameters and processes” statements, I would like to see a reflection on this in the discussion. In particular I am wondering if there may be an elegant explanation for this.”

Answer: The changes in the first two paragraphs of the Introduction eliminated statements such as “correct description” and so on. As for the reason why rainfall intermittency and vegetation feedbacks have similar effects, we now added in the discussion a more detailed discussion of this issue. Vegetation feedbacks and rainfall intermittency have overlapping effects because both have the final effect of increasing (deep) soil moisture in vegetated sites. Vegetation is favored by the increased soil moisture in the root layer, but the vegetation colonization rate grows only until soil moisture is equal to s^* . Thus, once this level is reached, vegetation does not have any further advantage from additional increases of soil moisture.

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3. “The same basically counts for incorporating the colonization rate being dependent on soil moisture in bare soil. One would expect a significant effect at least in case bare soils have lower infiltration rates and higher evaporation rates, but apparently adding this effect does not matter.”

Answer: When the colonization rate depends only on soil moisture in bare soil, as we report in the discussion, the advantages coming from the feedbacks are exclusively due to diminished mortality, while the infiltration feedback now plays a negative role and it reduces plants ability to colonize new sites at low rainfall values. When the colonization rate depends on soil moisture in both vegetated and empty sites, the disadvantage brought in by the lower bare soil moisture when the infiltration feedback is present is largely compensated by the correspondent advantages due to larger soil moisture in vegetated soil. In this case, one does not observe large differences with respect to the case without dependence of the colonization rate on bare soil moisture. We modified the part of the discussion concerning this topic and we hope that it is clearer now.

Minor

4. “I would like to see the motivation why soil moisture in deep layers below bare soil is not explicitly modeled earlier in the text. I agree with it, but the point needs to be made earlier so that the reader is not kept wondering about this when the model is introduced. ”

Answer: We anticipated the sentence “We do not explicitly model soil moisture in the deep layer in bare soil, as we assumed that the water stored there cannot be used by plants and it is effectively lost from the system.” earlier in the model description, in the second paragraph of Section 2.

5. “ Several times in the manuscript the authors mention colonization rate being dependent on soil moisture in the root layer. I would like to see a clear and consistent separation of two processes: colonization rate being dependent on bare soil moisture and seed production rate being dependent on soil moisture in the root layer of vege-

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tated soil. Otherwise it does not make any sense.”

Answer: We followed Tilman (1994) and according to its definition, colonization rate is the “rate of production of newly colonized sites”, including both the seed production rate and the seed establishment probability. We assumed the colonization rate as dependent on soil moisture of either bare or vegetated sites, or both, according to the different hypothesis explained in the text. We have modified the paragraphs in Section 2 where we introduce the colonization rate g , to express more clearly the distinction between seed production and seed germination. At the level of the present description, we believe that a more detailed distinction between these two processes is beyond the scope of the analysis.

Referee 2

We thank this reviewer for his/her useful comments.

The model:

1. “How deep are the soil layers? ”

Answer: 50 mm and 250 mm respectively for the upper and the lower layer. These depths were reported only in the table, now also in the model description.

2. “Why does the vegetation have no access (= transpiration) to the upper soil layer? ”

Answer: As explained in the text, “Transpiration contributions from the top layer are implicitly included in the evaporation term, because transpirational losses from the first few centimeters of soil are negligible compared to vegetation shadowing effects (Scanlon et al., 2003, Borgogno et al., 2007, D’Odorico et al., 2005).”

3. “What about the limitation of infiltration speed? You speak about loamy soils, where the hydraulic conductivity can be a limiting factor for infiltration. In your model, infiltration is only limited by saturation (or the factor f for soil crusts at bare sites)”

Answer: In our model infiltration is limited only by saturation, but at the same time

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leakage occurs, thus introducing the hydraulic conductivity limit at saturation. With the temporal resolution (integration step) adopted here, of a few hours, infiltration speed in the upper 30 cm is not a limiting factor.

4. “Evaporation: suddenly, the value s_w comes into play which is not defined here (but later)”

Answer: we opted for not using s_w here, and introducing it only later, when we discuss evaporation from vegetated soil. In this way, the description of bare soil dynamics does not contain any reference to vegetated soil.

5. “Why is there no infiltration into the deeper layer of bare sites? I know that you assume water to be lost from the system, when it goes into the deeper layer of bare sites. And that you therefore neglect this layer (which I find valid). However, if there were infiltration into the lower layer, it would also be lost from the system and could not be redistributed to other sites. So it might still be important.”

Answer: soil moisture in the deep soil layer of bare sites is not modeled, and thus no assumption is made about infiltration into it. This process becomes potentially important only when the infiltration feedback is present, because the water not infiltrating in bare sites spread over vegetated sites. In case of crusted soils, however, infiltration is limited by the biophysical crust, and the runoff speed is much larger than the infiltration speed, and we thus assume that the infiltration into the deep layer of bare soil is in this case negligible.

6. “A clear description of E_w is missing”

Answer: We added the description of E_w at the beginning of the paragraph where we discuss evaporation from vegetated soil.

Analyses:

7. “You speak about including or excluding the positive feedback of vegetation on infiltration. However, in your model infiltration is not directly positively affected by veg-

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etation. You only change the factor f , which reduces infiltration at bare sites and thus increases runoff to the vegetated sites. This also results water availability at vegetated sites but only because of the limited infiltration are bare sites and not because of a better infiltration at vegetated sites.”

Answer: the factor f that limits infiltration at bare sites could be rescaled to give higher infiltration capacity over vegetated soil and thus increased runoff towards them. The factor f actually combines the limited infiltration in bare soil, due to the presence of biogenic crust, and the enhanced infiltration at vegetated sites, due to the presence of roots, litter and soil mounds in proximity of plants. In arid and semi-arid regions, the presence of the biogenic crust is probably the most important reason for the different infiltration in bare and vegetated sites; hence, our choice of limiting infiltration in bare sites rather than enhancing it in vegetated sites. Mathematically, however, it does not make any difference (provided we appropriately rescale the variables).

8. “You come to the conclusion that each, shading and infiltration, have a positive influence on water availability, but if you introduce both feedbacks, the results do not improve any further. However, this could be an effect of your parameterization. Additionally, if you included evaporation of surface water (when it is redistributed by runoff from bare to vegetated patches) this could also change. Testing for the latter would be beyond the scope of the publication, but you could discuss this. And did you check for different parameter combinations?”

Answer: The two feedbacks acting together do not favor vegetation significantly more than when acting individually because when soil moisture in the root layer becomes larger than the threshold s^* , the colonization rate does not increase any further, and vegetation does not have much advantage then (see answer to quest. 2. of referee 1). This effect was observed for different parameter combinations. Following the referee suggestion, in the model description we added a sentence explicitly stating that we consider evaporation of runoff water negligible (after eq.(8)).

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9. “p. 4254 ll.10-12: this should be explained”

Answer: The mechanism behind this is considered in detail later in the discussion, when comparing the effects of the feedbacks and of rainfall intermittency (see also answer to quest. 2. of referee 1).

10. “The order of the model description is a bit confusing: First, the equations for bare sites are introduced, then the ones for vegetated sites. But for the latter, only processes are described that differ from those of bare patches. If you do it that way, you should already mention at the description for bare sites that these equations hold as well for vegetated sites.

Answer: We now state clearly that the infiltration, evaporation and leakage terms adopted in the bare soil description are used also in the equation for vegetated soil.

Technical Corrections

11. “I am not a native speaker. However, some parts seem to be written in colloquial language or imprecise, e.g. p. 4243, l. 15 "in which it lives in many different ways”

Answer: We corrected the expression.

12. “I am also not sure, if you can use "differential infiltration" (e.g. p. 4244, l. 23, but also elsewhere) in this context or if it would not be better e.g. to write "differing infiltration for bare soil and vegetated patches”.

Answer: According to the New Oxford American Dictionary, differential means “showing, or depending on a difference; differing or varying according to circumstances or relevant factors” and therefore we used it in the above context.

13. p. 4250, under equation 13: substitute "where plants grow" by "on vegetated sites”

Answer: Done.

14. “Caption of Fig3: "Symbols represent the average vegetation cover for" If I under-

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stand the figure correctly, it should be average soil moisture and not vegetation cover”

Answer: Done.

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