Referee comment to:
Journal: HESS
Title: Reducing the hydrological connectivity of gully systems through vegetation restoration: Combined field experiment and numerical modelling approach.
Author(s): A. Molina et al.
MS No.: hess-2009-77

General comments:
The paper is discussing an interesting issue of hydrological connectivity of gully systems in the Ecuadorian Andes. The modeled runoff and sediment dynamics based on field investigations represent a novel approach in the area investigated, but not innovative in general. However, the obtained results are relevant to understand runoff and infiltration dynamics as well as the role of vegetation roughness for sediment transport and deposition. Consequently, the topics addressed in the paper are adequate to be published in HESS. The paper is well structured and written. Nevertheless some general and specific remarks should be considered before publishing.

Reply to Comments of Reviewer3

It is not clear what the criteria have been to select the gully systems. Therefore it is also not clear if the derived model covers only local conditions or could be applied in a larger context. Please explain in what geologic and geomorphic settings the gully systems are located. Where in the landscape the gullies occur and why? Please specify the gully genesis (e.g. retrogressive or backward erosion, head erosion, structural reasons?) Since the gully development stage is important for the general behavior of the system especially for sediment dynamics (erosion transport and deposition) a rough classification of the studied systems in different development stages (active, passive transient) would be very helpful. Thus, you might be able to explain dynamics as reported for gully San Miguel 2.

REPLY: In a previous paper (Molina et al., 2009), we analysed sediment deposition in vegetated gully channels. These gully channels were later used for the concentrated flow experiments. In our previous paper, we describe in much detail the general setting of the gully systems, and give detailed information about the genesis and development of the gully channels. In order to avoid too much overlap with this earlier work, we preferred to refer to this manuscript for more details on the gully systems.

In this manuscript, we now added a small section in the chapter 2.1 (Study Area) where we describe the criteria that were used to select the gully systems. We have also added some characteristics of the gully systems (geologic and geomorphic setting), without entering in too much detail. We also clarify that the gullies represent various stages of development of gully systems, and that some of the observations made for the nine gullies are transferable to other gully systems. In Table 2, we now give the development state of each gully system (active, passive or transient). It is clear that the development is highly related with the overall vegetation cover of the gully bed.

In the introduction a short review of similar studies conducted elsewhere in the world would be interesting especially to judge the obtained results. (e.g. Kosov et al. 1978).

REPLY : In the introduction, we give a review of related studies that analyzed the effect of vegetation on gully beds. We mainly focus on studies that have used a quantitative, analytical approach to assess the effect of vegetation on water and sediment transfer in vegetated channels. First, we provide a brief discussion of previous studies that quantified the effect of vegetation on sediment deposition and gully stabilization. A lot of research has been done in regions with low to moderate relief, such as the European loess belt (see e.g. Nachtergaele et al., 2002). For steep mountain terrain, Rey (2003, 2004) has provided excellent data on the effect of vegetation on gully stabilization. The effect of vegetation on the hydrological connectivity has been studied in much detail for grassed waterways. The work of Fiener and Auerswald (2003, 2005) has quantified the effect of vegetation on the transfer of water in vegetated waterways. We now extend this work for steep gully channels in highly degraded mountain terrain, and provide quantitative data on the transfer of water in vegetated gully beds.

The role of vegetation is only considered through the roughness parameters but not directly for the infiltration dynamics. Moreover soil structural issues like cracking or sealing are also not taken into account but often they play an important role for infiltration dynamics. Especially in soils with high clay contents this might be essential. Furthermore also soil depth should be considered. The above mentioned issues should be discussed in the paper.

REPLY: In the gully systems that were studied here, the soil material has been completely removed by erosion. In the gully bed, there is no original soil material left. In most cases, we found a layer of sediments that was recently deposited on top of the weathered bedrock. The thickness of the deposition depends on the development stage of the gullies. The gully bed of active channels is characterized by a mixture of rock outcrops and patches of sediment deposition (often less than 5cm thick). The gully bed of passive gully systems typically has a layer of sediments deposited on top of the bedrock. This is discussed in much detail in an earlier paper (Molina et al., 2009), and we make reference to this study in the text.

As the channel bed of the gullies is covered by a layer of loose sandy and silty sediments, soil structure is not a major element that is governing infiltration in the gully bed. We observe that the gullies with the highest infiltration rates correspond with the gully channels with the best vegetation cover and the thickest sediment deposition (see results Table 3). This is discussed in the chapter 3.1. (Role of vegetation on infiltration and runoff transfer).

Model calibration should be validated with measured K values (e.g. Hood infiltrometer).

REPLY: In this study, we have chosen to calibrate the S and K parameters by comparing the observed with the modeled hydrograph. A comparison of measured and modeled K values would indeed add additional information for the validation of the kinematic wave model. However, the hydraulic conductivity was not measured in the field, as this was simply not possible. The hydraulic conditions of the gully bed are often highly variable, and are considered to depend on the presence/absence of sediment deposition and vegetation, the presence/absence of rock outcrops etc. To obtain a realistic value of the infiltration rate in the field, we would have been obliged to conduct a large number of infiltration experiments along the gully bed. As the gully bed is often far too narrow to allow double ring infiltrometer experiments, we decided to calibrate the parameter 'K'.

You should discuss in the final section whether the model can be applied elsewhere in the world or not.

REPLY: We discuss this issue several times in the text, and have now clarified our statements. In Chapter 4.3., we discuss "Although we may not be able to model the response of each individual gully correctly, our analysis does allow to identify the major controls of water transmission losses on vegetated gully beds. These concepts are widely applicable for gully systems in different stages of development. The most important control appears to be the soil moisture status. However, vegetation cover and runoff width also play an important role. The latter two are to some extent interrelated: in a system that is recovering after an intense degradation phase, the re-appearance of vegetation on gully beds will lead to sediment trapping and hence to an increase in runoff width. Any model that aims at reflecting changes in hydrology due to vegetation recovery should therefore incorporate both factors. The model we used may be used to identify trends and estimate the direction and the order of magnitude of change. However, the correct calculation of transmission losses in individual gullies for a given inflow rate appears not to be possible as the necessary input parameter values cannot be estimated with the required accuracy from the available data."

And in the conclusion, we clearly mention that "Using a coupled kinematic wave-infiltration model allows to simulate the transfer of runoff water well. However, the applicability to simulate transmission losses for gully systems where no experimental data are available can be questionable, as our results indicate that it remains difficult to accurately simulate parameter values at the scale required for these analyses."

It would be good to have an outlook in the discussion or conclusion chapter where you should explain how the existing model could be improved. What are the most important parameters and how they could be measured more accurately?
We now added a sentence in the conclusion, and indicate that the model results are particularly sensitive to the parameter values of runoff width, hydraulic conductivity and sorptivity. It would be important to have better field measures of the hydraulic conductivity in order to be able to validate the model results.

Specific comments:
Page 2538, line 27: …parameters o predict the transfer of runoff …
We have rewritten the abstract based on the comments of reviewer 1 and 2. This sentence was rewritten.

Page 2539, line 22: …activities are considered to induce …. Ok.

Page 2539, line 22-24: The statement that overland flow is rarely observed in natural mountain forests is not correct especially in areas where shallow landslides occur overland flow processes are observed on the landslide scars unprotected by vegetation (see e.g. Beck et al. 2008:Gradients in a Tropical Mountain Ecosystem of Ecuador , Springer, Berlin.)
We have rewritten this sentence, and now mention that overland flow is hardly observed in mountain forests, with the exception of unprotected landslide scars. Reference has been added to the work of Beck et al.

Page 2541, line 15-25: It would be very helpful to get a rough sketch of the area showing the location of the gully systems within the catchment.
We now added one figure with the location of the gully systems (Figure 1). Reference to Figure 1 has been added in the text.

Page 2542, line 4: …altitudes. Ok.

Page 2542, line 5: …the term degradation seems more appropriate. Ok, we replaced 'deterioration' by 'degradation'.

Page 2542, line 20: Please explain the criteria for choosing the gully systems. Moreover especially for sediment transfer and hydrological dynamics it is important to characterize the development stage of the gully systems (see e.g. Sidorchuk et al 2003, Gully erosion modelling and landscape response in the Mbuluzi River catchment of Swaziland. Catena, 50, 507-525). To characterize the development stage you could determine the ratio between upstream area and total gully area. It would be also helpful to have a table with morphologic parameters for the 9 chosen gully systems t
See reply to comments above. We have added the criteria that were used to choose the gully systems (2.1. Study Area). Moreover, we have added information on the development stage of the gullies in Table 2. Please note that we refer to the paper of Molina et al. (2009) for a detailed description of the gully systems.

Page 2543, line 5: Figure 1 please give scale reference in figure 1
We added scale reference in this Figure, particularly for photo B and C. On the photos A and D, there are several persons and objects as scale reference.

Page 2543, line 11 eq 1; maybe better ….S = linear hydraulic head loss approximated by slope of gully bed. Ok, this was rephrased.

Page 2544, line 2: Please specify or define the term ephemeral gully. From the Fig 1.without scale I have the impression that the gully systems are rather permanent then ephemeral. The reviewer is correct. The gullies that were monitored in this study are too large to be erased by ploughing. They are permanent features. We have made the necessary changes in the text.

Page 2544, line 24: ..Philip's equation (Eq. 4) as infiltration component…. Ok, this was rephrased.

Page 2545, line 11: Please discuss if there are any effects that maybe different in small and incised gullies instead of larger grassed water ways.
We now clarify this in the text. As most of the ground vegetation cover in the gully beds is composed of grassy plants, the approach of Fiener and Auerswald is considered to be appropriate.

Page 2546, line 245: S is already defined. The parameter S was used for Sorptivity and Slope gradient of the gully bed. We have made the necessary changes, and now use Sgully for the slope gradient of the gully bed, and S for sorptivity.

Page 2548,18: is K or infiltration also measured in situ in order to validate the calibrated values? See reply to comments above. The hydraulic conductivity was not measured in the field, as this was simply not possible.

Page 2553, line 4: Relationship between optimized model parameters and gully characteristics Ok, this was rephrased.

Page 2553, line 25..gully systems do not reach steady state conditions….
Page 2553, line 27: …so part of these effects are covered by variations in hydraulic conductivity….? This paragraph was confusing. We have rewritten this paragraph completely (see also reply to comments, Reviewer1).

Page 2554, line 17: I would rather say a processed based model with calibrated parameters. We have rephrased this paragraph, and this sentence was removed.

Page 2554, line 18: why do you think so? Is it the model or the input parameters that do not allow a proper prediction? This is discussed in the following paragraph : "This shows once more that the applicability of process based models in hydrology is often strongly hampered by our inability to accurately estimate parameter values at the scale required, a problem that has often been discussed in the literature (e.g. Beven, 1995)."

Page 2558, line 3: Le Bissonnaise does notappear in the This reference has now been added in the introduction, see reply to Reviewer1.