Reviewer 1

General comments

This paper reports the findings of a study of erosion processes in the Ethiopian Highlands. The paper is well written and provides valuable insights into the relative impact of gully and rill erosion. A few points:

The estimated gully erosion rates in 2008 are acknowledged to be very high in comparison to rates measured elsewhere in the World but no explanation is given as to why this might be the case, nor indeed why the rates in this year appear to be much higher than the historical average in the same catchment. There is no discussion of possible errors/accuracy in the measurements made. This is really needed to provide confidence that the very high rates presented are indeed credible.

- The mechanism of erosion through sub-surface flow seems plausible and probable and is supported by the evidence presented. However, it is still a supposition and so should be presented in this manner rather than as an absolute fact.
- The paper would benefit from being re-structured slightly with some of the information presented in the results section moved into the methods section.

Response We would like to thank Dr. McCartney for his productive and insightful comments. We have incorporated the comments and suggestions into the manuscript, and as a result the manuscript is significantly improved

Specific comments

Introduction

Comment: Page 5237 – I would debate the assertion (lines 13-14) that little has been done to promote soil conservation. Since 1985 the government of Ethiopia has run an ambitious soil and water conservation (SWC) program supported by donors and NGOs and backed by the largest food-for-work program in Africa (Hoben 1996). Today the Productive Safety Net Program continues to implement many SWC measures in places where food security is an issue. The results may be mixed but things are being attempted.

Response: The reviewer is correct. But with our experience there has been little done, in practice, to identify the cause and extent of subsurface erosion to promote selective integrated soil erosion control mechanisms, and indeed much of the work has focused on more well understood erosion control (e.g., sheet, rill or inter-rill erosion). We have changed the text to acknowledge this.

Material and methods

Comment: Page 5240 – It would be useful to include a slightly more detailed description of the general catchment including more detail of the land–cover and farming systems (e.g. what are typical slopes in the catchment?; what crops are grown, and at what time of year?; what is the land preparation and when does this occur?; what is the role of livestock in the catchment?; have there been any SWC measures (e.g. terracing) attempted in the past?).

Response: The major crops cultivated in the watershed are tef, finger millet, maize and wheat. Livestock consisting of cows, oxen, sheep, goats and donkeys commonly graze in the communal grazing lands particularly in the upper slope and the valley-bottom gully areas. Oxen are used for plowing, and the land is tilled three to seven times before

planting depending on the crop. Very few soil and water conservation structures like stone bunds were practiced rarely. We have added additional details about the watershed in the watershed description section.

Comment: Page 5241 (line 17): what is the floodplain zone?
Response: We are referring to the valley bottom adjacent to the river, we have changed this to add clarity.

Comment: Page 5242 (line 24): would be useful to include a comment on the accuracy of the GPS – a 2m positioning accuracy does not seem very great when trying to measure changes in a gully. It is not clear if the GPS was also used to measure differences in elevation, but GPS vertical accuracy is often a lot less than in the horizontal directions so may well have been less than the 2m indicated.
Response: We used GPS to delineate the gully boundaries. In 2007 and 2008, the surface area of the gully system was delineated with a GPS with 2 m total accuracy (that includes the vertical and horizontal accuracy). The horizontal accuracy of the GPS is typically much lower than the total accuracy and varied in the decimeter range. GPS derived surface areas were cross checked with the gully surface area estimated through measurements of width and length in several gully cross sections using a 50 m long surveyor tape. Vertical measurements were also made with the tape. We have added additional detail to the text:
"On July 1 and October 1, 2008, the volume and surface area of the entire gully system was estimated through measurements of width, depth, and length of several cross-sectional and length profiles using a 50 m long survivor`s tape. We labeled 43 gully cross- sections based on homogeneity of a gully profile and proximity to a piezometer. For each gully cross-section, two or more widths and three or more depths were measured at locations where the cross section changed abruptly. The surface area of the entire gully system was digitized using GPS points that were cross-checked with the estimated measurement of surface area using the physical measurements made with the survey tape."

Comment: Page 5242 (line25-27): it is not clear how the measurements of width, depth and length were made. Was this done with a tape measure and pegs? Were identical locations visited on the latter date? How many locations and how were they selected? This needs to be made clear.
Response: The volume and surface area of the entire gully system was estimated through measurements of width, depth, and length of several cross-sectional and length profiles using a 50 m long surveyor tape. For each gully cross-section, two or more widths and three or more depths were measured at locations where the cross section changed abruptly

Comment: Page 5243 (line 14) – would be useful to know when the rainy season commenced and how rainfall was determined. Were rain gauges installed in the catchment? More generally it would be good to know if rainfall in 2008 season was above or below average.

Response: Precipitation was measured daily using a calibrated rain gauge installed in the study site. The monthly rainfall distribution was above the mean value from the previous10 years. We have added:
"August 5, 2008 when the water table was elevated due to the onset of the rainy season. Precipitation was measured daily using a calibrated rain gauge installed in the study catchment. Based on these measurements, the monthly rainfall totals during the study period were greater than the corresponding mean values from the previous ten years."

Comment: Page 5244 (line 3-7): again would be useful to have a little more information on exactly how the measurements were made and how volumes and rates of erosion etc. were calculated.
Response: For each gully cross-section, two or more widths and three or more depths were measured at locations where the cross section changed abruptly. We have added: "Once gully size was determined, the rates of erosion were then calculated by determining the change in dimension (width, depth, length) of the different gully segments. The eroded volume of each gully segment was calculated using the cross sectional dimensions and the distance between cross sections."

Results
Comment: Page 5244 (line 14): why did people move to this location in 1980? Why it was not occupied before this date? What was the indigenous vegetation? This information would be more usefully included in the site description rather than the results section.
Response: These watersheds, while historically agricultural were not under active tillage or agricultural management from 1974-1987 due to the ruling class at the time (Dreg regime, a committee of military officers who ruled Ethiopia from 1974-1987) displacing native landholders. This cessation of active agriculture allowed indigenous vegetation to return and cover the catchment. Following the fall of the Dreg regime, native settlers returned to the catchment in the early 1990s, and active agricultural activity resumed. See discussion below for more detail

Comment: Page 5244 (line 18) - were the springs perennial or ephemeral?
Response: There were three ephemeral springs located in the valley bottom in the 1980's (Springs 1, 2 and 3, Fig. 3). Respondents agreed on the incision location and confirmed that the locations of the incisions were related to three ephemeral springs in the valley. We have added that the springs are generally ephemeral.

Comment: Page 5244 (line 24) – Fall of the Derg regime will not be understood by those readers who do not know Ethiopian history
Response: We have added discussion of the importance of the land tenure system as it relates to the Dreg regime. We have added this point in the area description section
"Two sub-watersheds were selected for closer study within the 800 ha Debre-Mawi watershed (Fig 1). These watersheds, while historically agricultural were not under active tillage or agricultural management from 1974-1987 due to the ruling class at the time (Dreg regime, a committee of military officers who ruled Ethiopia from 1974-1987) displacing

native landholders. This cessation of active agriculture allowed indigenous vegetation to return and cover the catchment. Following the fall of the Dreg regime, native settlers returned to the catchment in the early 1990s, and active agricultural activity resumed. “

Comment: Page 5244 (line 26): it is not clear why people were “returning” from Debre –Mawi town. Again maybe this should be included in the site description rather than results.
Response: The reviewer is correct we have made a change.

Comment: Page 5245 (line 10)**:** what is the reason for the very abrupt rise in water level in P13 on approximately 30th August? It seems that on this date flow commenced in this arm of the southern branch. Is that correct? What about the spring (3) had this been flowing prior to this date?
Response: The abrupt rise in water level in P13 occurred on August 28 due to the increase in rainfall amount. Yes spring (3) had been flowing prior this date. We have added these details to the text.

Comment: Page 5245 (line 15-24): as well as indicating the change in the width of the gully (bottom and top) it would also be useful to know the absolute values prior to and after the rainy season. Figure 5 shows the average water table depth at different locations. However, this is a bit confusing because 5a appears to show depth to the water table from the ground surface while b shows water table above the gulley bottom. Is this correct? If so it needs a bit better explanation. There are two P17s and two P24s shown in 5a.We assed the water table of two gully cross sections with P24 installed at the two gully cross-sections contributing area . Similarly P17 was located at the middle of the two gully cross-sections contributing area.
Response: We have expanded the explanations for the figures. We labeled gully cross-sections based on homogeneity of a gully profile so that in some areas a piezometer represents different gully cross-sections.
We have relabeled Figure 5 for clarity:
“Average water table depth and gully depths before and after the 2008 rainy season for the main stem (gully C) using the soil surface as a reference elevation point (a) and change in top and bottom width of the gully and average water table depth above the gully bottom (b).“

Comment: Page 5245 (line 25): this is a supposition? While seemingly plausible and reasonable is it possible to say this definitively without some sort of strength test? Maybe this should be put in the discussion.
Response: The reviewer is correct. We clarified this as *one* possible mechanism driving erosion.

Comment: Page 5246 (line 4) – the results shown in Figure 5 would suggest that it is not quite stable at P17 – there is some erosion although at a lot slower rate than lower down in the gully.
Response: The reviewer is correct that there is some erosion occurring at P17 (e.g., change in the bottom width and depth in Fig 5), but it is considerable less than in the

other areas of the gully, where there was clearly a relationship between the elevated water table height and the gully .erosion rates. We have clarified this point in the text

Comment: Page 5246 (line 8) – why is the gully depth in October 2008 not shown in figure 7a?
Response: The gully development in the gully branch A during 2008 was mainly a result of widening rather than deepening. We have added this to the text and figure.

Comment: Page 5246 (line 20): why is the gully depth in October 2008 not shown in figure 8a?
Response: The development of gully in the southern and gully branch in 2008 mainly occurred as widening rather than deepening. We have again clarified this in the text.

Comment: Page 5246 (line 26): What is not clear is why if the saprolite dams the water so lowering water table at 115 m, why this isn't also the case 263 m which is also down slope of the saprolite, but where there is significant erosion.
Response: The gully widening in the south gully is influenced by the sapprolite layer and rock close to surface. The rocky outcrop (dyke in figures) and sapprolite together with the gully depth is shown in Figure 8a. Figure 8b shows that the most active gully formation occurred at 263 m from the junction with the south branch just uphill from the dyke. Ground water table flow is blocked by the dyke and is therefore above the gully bottom. Only downhill from the dyke at 115 m from the junction the water table is below the ditch bottom. We have clarified this in the text

Comment: Page 5247 (line 6) – this is again a supposition? It might be best to put this in the discussion.
Response: The reviewer is correct; we have added this as speculation.

Comment: Page 5247 (lines 15-25) – this description of estimating eroded volume should really be in the methods section of the paper.
Response: We agree. This section is now in the methods section

Comment: Page 5247 (line 21) – need to explain what is meant by representative cross sectional area.
Response: We have added more detail in the methods section see comments above.

Comment: Page 5248 (line 5-6) – it is not entirely clear how the erosion was estimated for the period 1981 to 2007. Presumably this is a combination of estimates based on what local informants have described and the 2005 Quick Bird image. Is the assumption simply that there was no gully before 1980? How was gully depth estimated from the QuickBird image? This needs to be explained in more detail.
Response: The gully depth was not measured with the Quick Bird Image, it was only used in a comparison of the areal extent of the gullies. On July 1 and October 1, 2008, the volume and surface area of the entire gully system was estimated through measurements of width, depth, and length of several cross-sectional and length profiles using a 50 m long survivor`s tape. We labeled 43 gully cross-sections based on

homogeneity of a gully profile and different gully cross sections were represented with a piezometer in some locations. For each gully cross-section, two or more widths and three or more depths were measured at locations where the gully cross-section changed abruptly.

Comment: Page 5248 (line 6) Table 1 – needs to be consistent with the main text. I presume the "Branches" are A and B and the Main stem (C)? It is not clear why results from A and B are not disaggregated?
Response: We have changed the table for consistency. We have also added
"Note that the calculated erosion rates for gullies A and B were nearly identical, and are thus presented in aggregates"

Comment: Page 5248 (line 13) – It is not clear how the 27t ha-1 has been computed. This needs a better explanation in the methods section.
Response: On page 5243 we state: "For determining rill erosion, 15 cultivated fields were selected in the contributing area, representing a cumulative area of 3.56 ha. Based on their landscape position these fields were classified into three slope positions: upslope (with a slope length of 100 m), mid-slope (slope length equals 250 m), and toe-slope (slope length equals 100 m). A series of cross-slope transects were established with an average distance of 10 m between two transects; positioned one above another to minimize interference between transects (Hudson, 1993). During the rainy season, each field was visited immediately after rainfall events in July and August when the greatest rainfall amounts occur. During these visits the length, width and depth of the rills were measured along two successive transects. The length of a rill was measured from its upslope starting point down to where the eroded soil was deposited. Widths were measured at several points along a rill and averaged over the rill length (Herweg, 1996). From these measurements, different magnitudes of rill erosion were determined, including rill volumes, rates of erosion, density of rills, area impacted by the rills, and the percentage of area covered by the rills in relation to the total area of surveyed fields (Herweg, 1996, Hagmann, 1996, Bewket and Sterk, 2003). The rill magnitudes were calculated using the following equations:

$$X = \frac{\sum (L_i W_i D_i) N_i}{10000\, A} \quad (3)$$

$$AAD = \frac{\sum (L_i W_i) N_i}{100\, A} \quad (4)$$

$$D = \frac{\sum (L_i) N_i}{A} \quad (5)$$

Where X is the volume of rills in m^3/ha, L_i is the length of a rill in m, W_i is the width of a rill (cm), D_i is the depth of a rill (cm), AAD is the area of actual damage causedby rill erosion in m^2/ha, D is the density of rills in m/ha, A is the field area (ha), and N is the number of rills. X is equivalent to the volume of soil lost due to the formation of rills. The eroded soil volume was also expressed in terms of weight of eroded soil by multiplying X with the estimated soil bulk density of each of the 15 fields (Hagmann, 1996)."

Comment: Page 5248 (line 23) – is the lower crop cover of teff early in the wet season a function of farming practice (i.e. the teff is planted slightly later than the other crops).

Response: Yes, this is the case, at the initial time of estimate, fields intended for tef were not sown yet. So the teff plots had the greatest density of rills and generally the greatest erosion rates which correspond with the reduced crop coverage. We have added this to the text: "The teff fields had the greatest density of rills and generally the greatest erosion rates (Table 3), which correspond with the reduced crop coverage following planting (Table 3). Teff fields are planted in the middle of the rainy season when high intensity rains occur but the teff fields remain yet bare soil."

Comment: Page 5248 (line 25) - what is meant by rills "degrade"?
Response: degrade here was meant to collapse, or fill in, we have changed this.

Discussion

Comment: Page 5249 (lines 4 – 14) – the estimated gully erosion for 2008 seems very high compared to estimates elsewhere in the World. Is there a plausible explanation as to why this might be so? Is it possible to make some estimate of error bars on the estimates to provide some indication of the confidence that can be placed in the values derived?
Response: we do not have the data set of Poesen et al. (2003) on which to base error estimates, and while there is certainly error associated with our estimates, they are based on detailed measurements, and thus we have a good deal of confidence in it. We have, however, added possible reasoning for why these gully rates might indeed be representative:
"The gully erosion rates measured in this study, while indeed high, might represent un-representatively severe erosion. For instance, many of the rates reported by Poesen et al. (2003) represent long term averages, and thus if these gullies stabilize in the near future the erosion rates will fall, and might in fact act as depositional areas for new sediments and thus the erosion rates, presented as long term averages, will be lower."

Comment: Page 5250 (line 4) – this is the first mention of livestock. It would be useful to give some indication of livestock numbers in the catchment and the possible role that they might play in erosion processes.
Response: We have added this in the watershed description section, see earlier comment.

Comment: Page 5250 (line 22) – it would be interesting to learn if local people are concerned about the erosion and what if anything they are doing to try and reduce it.
Response: Indeed it would, and anecdotal evidence collected during the study indicated that the local people are concerned about the gully erosion in as much as it effects the productivity of their plot of land, however, once the initial gullies form and migrate rapidly upslope, they are, in practice beyond the control of the local land user.

Comment: Technical corrections
Page 5239 (line 5) – replace "intervals" with "periods"
Page 5239 (line 8 and 9) – for highlands be consistent in use of upper case or lower case H.
Page 5240 (lines 12 and 13) – should be written in the past tense – explored and compared

Page 5242 (line 17) – delete during
Page 5244 (line 18) – add full stop after long
Page 5244 (line 21) – replace “most bottom” with “lowest”
Page 5245 (line 16) – replace “are” with “were”
Page 5246 (line 23) – remove the “n” from dam
Page 5249 (line 8) – spelling of Lesotho
Page 5250 (line 10) – add “ed” to the end of report
Page 5250 (line 24) – delete “to”
Page 5250 (line 26 – add “than” after greater
Response: We have made all these changes.