***Interactive comment on* "Physically-based model for gully simulation: application to the Brazilian Semiarid Region" *by* Pedro Henrique Lima Alencar et al.**

Answer to comments of Anonymous Referee #2

We would like to truthfully thank the Referee for his/her work, efforts and interesting observations. They helped making our work clearer.

The mains points highlighted by the Referee **Writing**, **citations**, **missing information** and **Content** . Below, we comment the suggestions point-by-point.

Physically-based model for gully simulation: application to the Brazilian Semiarid Region
Dear Editor I have went through the above article. I think there are the following comments before making an acceptance decision. At present there are moderate to major comments. My decision is Major correction. Best

We thank the reviewer for his/her comments.

Manuscript need to check by a native for removing some language errors.

Although much effort has been devoted to the paper writing, we acknowledge the persisting problem. We will hire a professional proof-reader for this task, after the required modifications are finished.

Abstract I cant see any quantitative results in abstract. This part need to write again.

The abstract was completely rewritten and the results were stated more clearly, please refer to lines 10-12.
In the box bellow we present the proposed new abstract:

Gullies lead to land degradation and desertification, an increasing environmental and societal threat especially in arid and semiarid regions, despite of which there is a lack of research initiatives in this regard. As an effort to better understand soil loss in those systems, we studied small permanent gullies, a recurrent problem in the Brazilian North-eastern semiarid region. The increase of sediment connectivity and reduction of soil moisture, among other deleterious consequences, endangers this desertification-prone region and reduces its capacity to support life and economic activities. Hereafter, we propose a model to simulate gully-erosion dynamics, derived from the previous physically-based models by Foster and Lane and by Sidorchuk. The models were adapted so as to simulate long-term erosion. A threshold area shows the scale dependency of gully erosion internal processes (bed scouring and wall erosion). To validate the model, we used three gullies ageing over six decades in an agricultural basin in the State of Ceará. The geometry of the channels was assessed using UAV (Unmanned Aerial Vehicle) and Structure-from-Motion technique. Laboratory analyses to obtain soil properties were performed. Local and regional rainfall data were gauged to obtain sub daily rainfall intensities. The threshold value (cross-section area of 2 m^2) characterise when erosion in the walls due to loss of stability becomes more significant than the detachment of sediments in the wet perimeter. The 30-minute intensity can be used when no complete hydrographs from the rainfalls are available. Our model can satisfactorily simulate the gully-channel cross-section area growth over time, yielding Nash efficiency of 0.85 and R^2 of 0.94.

1 Introduction Lines 16-17: this sentence needs to reference.

These sentences were rewritten and rearranged as follows:

The impact of water-driven soil erosion, on economy and food supply alone, represents an annual loss of US$ 8 to 40 billion (Pimentel et al., 1995); a reduction in food production of 33.7 million tonnes and an increase in water consumption *by 48 km^3 (Sartori et al., 2019). These effects are felt more severely in countries like Brazil, China and India; and in low-income households worldwide (Nkonya et al., 2016)*

There are too many citation in this part. Please decrease them and try to just use from newest citations. Please clearly specify innovative of the current study

A complete checking of references was conducted. Redundant citations were removed. We identified 18 non-essential references (present only to state a time-line of each specific topic).

2.1 Study area Please add geographical coordinate of the study area.

The coordinates will be included:

Area	Latitude	Longitude
Gully 1	04°58'54.32"S	39°29'36.41"W
Gully 2	04°59'53.12"S	39°29'49.38"W
Gully 3	05° 00'02.37"S	39°29'59.42"W

Lines 83-84: please add a reference. The same lines 85-86.

The paragraph was rewritten, as shown below. The information contained in lines 81-86 can be found in Gaiser et al. (2003).

The study area is located in the Madalena Representative Basin (MRB, 75 km^2, state of Ceará, north-eastern Brazil; see Figure 1), inserted in the Caatinga biome, a dry environment with a semiarid hot BSh climate, according to the Köppen classification. The annual precipitation averages 600 mm, concentrated between January and June (Figure 2); and the potential evapotranspiration totals 2,500 mm.yr^{-1}. Geologically, the basin is located on top of the crystalline bedrock with shallow soils and limited water storage capacity. The rivers are intermittent and runoff is low, typically ranging from 40 to 60 mm.yr^{-1} (Gaiser et al., 2003). The basin is located within a land-reform settlement with 20 inhabitants per km^2, whose main economic activities are agriculture (especially Zea mays), livestock and fishing (Coelho et al., 2017; Zhang et al., 2018).

Figure 1. I cant see coordinate system on maps.

We believe the referee's observation concerns Figure 1. In this Figure the Datum and coordinates are available. The sentence "Projection: UTM24S" removed, once the map is no longer in UTM coordinates (as in a previous version; we apologize for this). We hope this modification solves the problem and wait for further comments.

2.3 Soil data How many sample do you use in this study?

We have collected three samples at each depth (10, 30 and 50 centimetres) in both areas (S1 and S2 – line 118-119), totalling 18 samples. This information will be included in the text (lines 112-114).

Figure 4. Correlations are so low. Why? What is its reason?

Due to lack of better data, we used correlation curves to assess rainfall intensity based on the total daily rainfall. Rainfall processes, especially in the Brazilian semiarid regions (where most rainfalls are convective) are rather unpredictable and nonlinear processes.

2.5.1 The Foster and Lane Model (FLM) and 2.5.2 The Sidorchuk Model (SM): These are routine and readers could find them in literatures.

The two models are indeed well known to many readers. Nevertheless, we find it important to have a brief presentation of both models, specially to stress their differences, strengths and weaknesses. This, in our point of view, will help the readers.

However, we understand the concerns of the Referee and, therefore, both subsections will be reformulated to present frontally the models' strengths and weaknesses, reducing the space used to present them.

You have to present your combined model very carefully. This is so important. Please edit this part.

We thank the Reviewer very much for the suggestion. The section will be edited and clarified. We have chosen to rename and rearrange the sections in order to give it a more concise and comprehensive presentation. The new items are:

2.5 Gully modelling

2.5.1 Foster and Lane Model (FLM)

2.5.2 Sidorchuk Model (SM)

2.5.3 Adapted Foster and Lane Model (FLM-λ)

2.5.4 Coupled Model – Foster and Lane & Sidorchuk Model (FL-SM)

A detailed description of the proposed model was added under the item 2.5.4, including a flowchart (modified from the current Supplementary material).

2.6 Model fitness evaluators Please add equations of the used evaluation methods.

The equations were included as required.

Results This part is written very carefully.

We thank your observation and will bring the rest of the paper to these standards.

Discussion I think it is important to add some discussions and comparisons by previous works

We thank the suggestion of discussion and believe it will improve the debate. Firstly, we decided to rearrange the discussion section, organizing its subsections as follows:

- 4.1 Model limitations
  - 4.1.1 Foster and Lane Model
  - 4.1.2 Sidorchuk Model
  - 4.1.3 Adapted models
- 4.2 Data limitations
  - 4.2.1 Topographic data
  - 4.2.2 Soil data
  - 4.2.3 Precipitation data

In the item **4.1.3 Adapted models** we will include a paragraph comparing the quality of our model with others, as follows:

Comparatively with other models, either physical or empirical (Haisine and Rose, 1992; Woodward, 1999; Wells et al., 2013; Dabney et al. 2015, etc), our proposed model (FL-SM) requires similar or less amount of data, little calibration (one parameter – the threshold) and is more versatile. Most models fail to account for multiple rainfall events (Foster and Lane; Woodward, 1999; Nachtergaele et al., 2001 and 2002; Torri and Boselli, 2003) and to consider multiple sources of sediment (Forter and Lane, 1983; Hairsine and Rose, 1992; Dabney et al. 2015). The FL-SM model (R^2 = 0.94) presented a better performance index than empirical models (e.g. R^2: 0.55 and 0.12 for Woodward (1999) and Wells (2013) respectively) and physical models (e.g. R^2: 0.87 and 0.84 for Foster and Lane (1983) and Sidorchuk (1999) respectively).

This enhancing in the performance can be accounted for the more detailed modelling, considering wall failure and non-rectangular cross-section.

5 Conclusions This part is so general. Please add some suggestion on this new model and etc…

- The conclusion was modified to include suggestions of following works, such as:
    - Stochastic modelling to account for lack of sub-daily rainfall data and to SSY (Sediment Yield) from the catchment into the gully.
    - Inclusion of other sediment sources such as headcut retreat and flow jets.