Comments by Editor:

Dear Authors,

You - as the contact author - are requested to individually respond to all referee comments (RCs) by posting final author comments on behalf of all co-authors no later than 13 Jan 2019 (final response phase) at: https://editor.copernicus.org/nhess-2018-192/final-response.

Comments by Anonymous Referee #3 (nhess-2018-192-RC3)

[Answers in blue]

GENERAL COMMENTS

(1)The aim of this work/manuscript **is the development of a software for single slope stability**. A case study and a comparison with another software is presented. **In my opinion, the main originality of the paper is represented by the inclusion in the software of the infiltration effects, according to the lacking in other software slope stability based, but the used theory (Spencer's method)** and the way to calculate the interstitial pressure on the slice base is well known. Therefore, the proposed model is not innovative and the authors should give more emphasis to the originality of the developed software, clarifying the advantages also in term of time simulation.

(2) We appreciate the interest in our work and thank you for your encouraging comments. Your suggestion of making more emphasis to the originality of the developed software is very important.

(3) *failure curve and surface area, including the infiltration effects.*"

(1) I Suggest the authors to include a block diagram of the software in order to explain better their algorithm from the user definitions to outputs/results.

(2) It seems to us a very good suggestion for the understanding of the proposed algorithm. We have developed the block diagrams, according to the following figure:

(3)

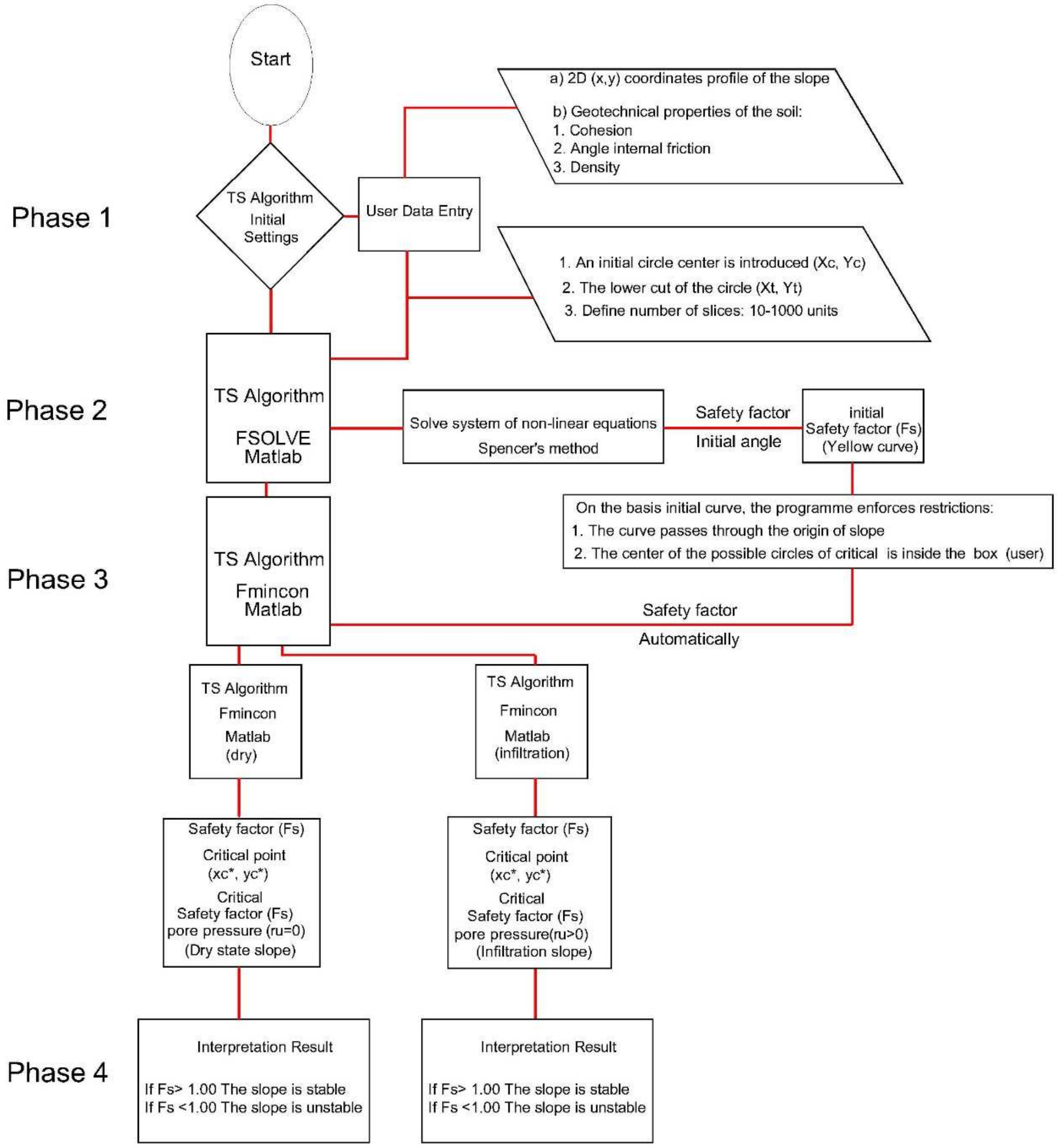

Figure 11. Sequential TS algorithm (block diagrams). Numbers in parentheses refer to numbers in the text.

(1) Moreover, a sensitivity analysis of the parameters is missing: I suggest for example to add some plot, e.g., the safety factor varying the interstitial pressure coefficient ru, the center of failure curve, the number of slices, the density of soil, etc.

(2) A sensitivity analysis has not been considered here as we have introduced a 3.Terrain stability (TS) model behaviour tests.

(1) To me, in conclusion, the paper needs some improvements and major revisions should be required.

(2) We conduct all the improvements suggested by the reviewer and, we have made changes to the SPECIFIC COMMENTS section as indicated by the reviewer, which substantially improve the final result of the manuscript.

SPECIFIC COMMENTS:

(1) The **section 1 (Introduction)** must be expanded citing other works that develop/use stability model, e.g.:

(2) The comment seems right to us and we introduce the change. We introduce the proposed references and others from other authors and define slope stability models in the introduction to complete the study.

(3) *"Landslides, one of the natural disasters, have resulted into significant injury and loss to the human life and damaged property and infrastructure throughout the world (Crozier and Glade, 2005; Dai et al., 2002; Parise and Jibson, 2000; Varnes, 1996).*

Normally, heavy rainfall, high relative relief and complex fragile geology with increased manmade activities, have resulted in increased landslide (Gutiérrez-Martin, 2015) It is essential to identify, evaluate and delineate landslide hazard prone areas for proper strategic planning and mitigation (Bisson et al., 2014). Therefore, to delineate landslide susceptible slopes over large areas, landslide hazard zonation (LHZ) techniques can be employed (Fall et al., 2006; Casagli et al., 2004; Guzzetti et al., 1999; Anbalagan, 1992).

Landslides are resulted because of intrinsic and external triggering factors. The intrinsic factors are mainly; geological factors, geometry of the slope (Wang and Niu, 2009; Ayalew et al., 2004; Anbalagan, 1992; Hoek and Bray, 1981).

The external factors which generally trigger landslides are rainfall (Dai and Lee, 2001; Collison et al., 2000; Anderson, 1985). Several LHZ techniques have been developed over the past and these can be broadly classified into three categories; expert evaluation, statistical methods and deterministic approaches (Canili et al., 2018; Zhang et al.; 2018; Lari et al., 2016; Raia et al., 2014; Rossi et al., 2013; Lu and Godt, 2008; Fall et al., 2006; Casagli et al., 2004; Crosta and Frattini, 2003; Inverson, 2000; Guzzetti et al., 1999; Leroi, 1997; Wu and Sidle, 1995). Within these models, we want to highlight the empirical models that are *based on rainfall thresholds (Matelloni et al., 2011; Gruzzetti et al., 2007; Aleotti, 2004; Wilson, 1997).*

Each of these LHZ techniques has its own advantage and disadvantage owing to certain uncertainties on account of factors considered or methods by which factor data are derived (Carrara et al.,1995).

"Limit equilibrium types of analyses for assessing the stability of earth slopes have been in use in geotechnical engineering for many decades. The idea of discretizing a potential sliding mass into vertical slices was introduced in the 20th century. During the next few decades, Fellenius introduced the Ordinary method of slices (Fellenius, 1936) . In the mid1950s Janbu and Bishop developed advances in the method (Janbu, 1954; Bishop, 1955). The advent of electronic computers in the 1960's made it possible to more readily handle the iterative procedures inherent in the method, which led to mathematically more rigorous formulations such as those developed by Morgenstern and Price and by Spencer (Morgenstern and Price, 1965; Spencer, 1967)."

(1) There are plenty of free software (see for example TRIGRS model of USGS). You should cite them too and specify the differences with your model. Line 36-38.

(2) To address this question the following text (including new references) has been added into the introduction section:

(3) *"Limit equilibrium types of analyses for assessing the stability of earth slopes have been in use in geotechnical engineering for las year. Currently, the vast majority of stability analyses using* ***this method of equilibrium limit*** *are performed with commercial software like SLIDE V5, SLOPE/W, Phase2, GEO-Slope, GALENA, GSTABL7, GEO5 and GeoStudio, entre otros [Mousavi, 2017; Acharya et al., 2016a; Acharya et al., 2016b; Jiao et al., 2013; Gonzalez de Vallejo et al., 2002). Other models of slope stability based on the theory of limit equilibrium are still being studied, as is the case of the SSAP model (Borselli, 2016), but in this case a General equilibrium method model is applied."*

"There are other types of software based on the modeling of the probability of occurrence of shallow landslides LHZ, in more extensive areas using GIS technology and MDE, as is the case of deterministic software TRIGRS ,SINMAP, SHALSTAB, GEOtop/GEO-FS, R-Slope.stability among others (Tran et al., 2018;

Alvioli and Baum, 2016; Reid et al., 2015; Mergili et al., 2014a; Mergili et al., 2014b; Mergili et al., 2014c; Baum, 2008; Simoni et al., 2008; Rigon et al., 2006; Pack, 2001). They are widely used models for calculating the time and location of the occurrence of shallow landslides caused by rainfall at the territorial level; some even in three dimensions, in order to obtain a probabilistic interpretation of the factor of safety.
Currently other approaches / theoretical studies for landslide prediction are used (for triggering and / or propagation) (Matelloni et al., 2017; Martelloni and Bagnoli, 2014).

The idea of discretizing through this tool proposed (TS), the potential slip mass in the critical section of the slope, once we have detected through the HZD programs unstable areas, is one of the achievements of this model. This calculation tool is not limited to shallow landslides and debris flows, but allows analysis of deep and rotational landslides, which others do not allow. Using the infiltration factor of Spencer r_u, we introduce the hydrological variable by infiltration to the stability calculation of the slope."

(1) The **section 2 (Terrain Stability model development)** needs some corrections:

The meaning of some parameters is missing in the text, e.g., in the equation 3 *R* is the radius of the curvature and α is the angle of the slope referred to each slice (I suppose);

(2) The comment is correct and the change is introduced in lines 95-101 and 160-163.

(3) *"In this equation, Q is the resultant of the pair of forces between slices, and α is the angle of the resultant (Figure 1). From this, it can be stated that the sum of the moments of the forces between slices around the critical rotation centre is zero, conformed to equation 3:*

$$\sum[QR\cos(\alpha-\theta)=0] \quad 3$$

When the R is the radius of the curvature, α is the angle of the slope referred to each slice. This takes into account that the sliding surface is considered circular, so the radius of the curvature is constant."

"

$$u = r_u \gamma h \quad 7$$

In this expression, u is the pore pressure (permanent interstitial pressure) at the base of the slice, γ is the density of soil, h is the mean height of slice (if the height is not constant) and the weight of it affects the W evaluation."

(1) In my opinion is not clear how the pore pressure is calculated by means of equation 7., i.e., how is the interstitial pressure coefficient ru calculated (according to heavy rainfall event)? Then, how does the equation 8 (Mohr-Coulomb law), for the calculus of u, come into play? In the article of Spencer (Spencer, 1967), assuming a homogeneous pore-pressure distribution as proposed by Bishop and Morgenstern (1960), the mean pore-pressure on the base of the slice can be written just like the equation 7 that is used for the calculation of the safety factor (substituting expression of u in equation 5). Please clarify the need of equation 8!

(2) The comment is correct and the change is introduced in lines 164-172. For the calculation of r_u, equation 8 is not necessary.

The pore pressure will be hydrostatic, defined by: $u = \gamma_w(\mathrm{h} - \mathrm{h}_w)$, γ_w is the saturated density of soil, h and h_w is the difference between saturated and dry height.

(3) *"The factor r_u is a coefficient of pore pressure (interstitial pressure coefficient), which determines the rain infiltration factor on the slopes. As it is well known, the water that infiltrates the soil may produce a modification of the pore pressure, affecting its resistant capacity. This factor may vary from 0 (dry conditions) to 0.5 (saturated conditions). In the article of Spencer (Spencer, 1967), assuming a homogeneous pore-pressure distribution as proposed by Bishop and Morgenstern (1960), the mean pore-pressure on the base of the slice can be written like the equation 7.*

This equation is used in our proposed algorithm for calculating the safety factor (substituting the expression of u in equation 5)."

(1) The **section 3 (Terrain Stability (TS) model behaviour tests)**, in my opinion, should be renamed **Terrain Stability (TS) algorithm and tests** adding these points:

(2) The comment is correct and the change is introduced in lines 173.

(3) *“3. Terrain stability (TS) algorithm and tests”*

(1) I suggest including a block diagram of the software in order to explain in detail your algorithm from the user definitions to outputs/results.

(2) The comment is correct and the change is introduced in lines 173. The proposed diagram is introduced

(1) As sensitivity analysis of the parameters is missing, I suggest for example to add some plot, e.g., the safety factor varying the interstitial pressure coefficient r_u, the center of failure curve, the number of slices, the density of soil, etc.

(2) Due to the length of the article and its focus we do not consider this point.

(1) Line 206: It is not “centre”, but center. Please, check the paper if other typos are present!

(2)The comment is correct and the change is introduced in line.

(3) *“The next step is to apply Spencer’s method to the different breakage surfaces until the curve with the lowest F_S, is found, and that will be the critical surface susceptible to a circular slip. To determine the minimal Fs using this model, calculate the displacement of the lower cut point of the critical slip from slope, as well as the rotation center position of the critical failure curve.”*

<u>Concerning the **section 4:**</u>

(1)Line 415: I would not say “our innovative TS model”, but “our original algorithm”.

(2)The comment seems right to us and we introduce the change.

(3)*“As mentioned earlier, the STB 2010 model does not allow stability calculations to apply to rainfall infiltration on a hillside. Hence, it is not capable of predicting a hillside’s instability in a critical rainfall scenario, which was critical in the slope analysed. The STB 2010 model found that the hillside studied had an Fs of FS = 2.063; that means it was a very stable slope. Consequently, our original algorithm TS model appears to be more efficient and accurate.”*

(1)Lines 421-444: I would add this part in the section 3 where is requested the explanation of the algorithm (software).

(2)The comment seems right to us and we introduce the change.