We appreciate the thorough and helpful comments of Anonymous Referee #2. A point-by-point response to the comments is as follows:

General comments:

A: Foremost, the rationale for the study is not strongly communicated.…the authors do not provide a convincing case that the current practice of predicting land-mass movement is inadequate specifically due to the failure to accurately represent groundwater recharge. The reader is left wondering if this work is really needed in the specific case study discussed in this paper.

We agree with this comment. In the introduction, the incriminated sentences are replaced by:

'These approaches can over-estimate the groundwater recharge and can thus bias the characterisation of the relationship between rainfall and destabilisation. A more accurate estimation of the groundwater recharge signal can improve the accuracy of these studies.'

Please refer to additional answers to this comment in the answers to the specific comments 3 and 22.

B: The authors also present this work as a method that can be readily adapted and used by practitioners and non-hydrologist… it is doubtful that this method can be easily adapted and used by practitioners or other researchers.

We agree with this comment. The revised manuscript has been modified accordingly (please refer to the answer to the specific comment 1).

C: The soil-water-balance model is used in this paper to estimate groundwater recharge.

There is no evidence provided to indicate if the model is even remotely accurate (e.g. measurements of water table fluctuations)… of the utility of their more complicated scheme. These points are further discussed in specific comment 22.

Please refer to the answer to the specific comment 22

D: In my opinion, a workflow, which presents no new quantitative representation of any process, does not constitute new scientific knowledge. It could be a potentially useful tool

for practitioners. As such, I recommend that when this article is resubmitted, it is resubmitted as a technical brief rather than an original research article.

Although the proposed workflow does not constitute a new scientific progress for hydrologists for who the recharge characterisation is a common knowledge, this is not the case of the scientific community working on landslides. Indeed, several studies estimate the recharge without calibration of the ET_0 reduced-set methods and without soil-water balance by only subtracting the evapotranspiration from the precipitation data or by the use of empirical methods (Canuti et al., 1985; Alfonsi, 1997; Hong et al., 2005; Binet et al., 2007b; Durville et al., 2009; Pisani et al., 2010; Prokešová et al., 2013). In addition, several studies use precipitation data instead of recharge (Rochet et al., 1994; Zêzere et al., 2005; Meric et al., 2006; Helmstetter and Garambois, 2010; Belle et al., 2013). The proposed study is intended for non-hydrologists and aims at showing that an accurate estimation of the recharge is crucial and we provide a guideline workflow to remove this scientific obstacle. For all these reasons, we consider that our manuscript should be published as an original research article rather a technical brief note. In addition, this manuscript was initially submitted to NHESS at the intention of the landslide scientific community, but was rejected before review. The reason of the rejection was “out of scope for NHESS”, and the editor told us to submit our manuscript to HESS.

I would strongly encourage the authors to develop a simple software tool (in Microsoft Excel, or other readily available platform like R). The authors suggest this was one of their primary motivations. Providing a readily usable tool might prompt people to use this workflow, otherwise it is doubtful that many people will wade through this 18-page methods section and appendices and develop their own software to execute the workflow.

We are aware that the implementation of the workflow for a non-hydrologist mainly interested in characterising the rainfall-destabilisation relationship can be laborious. We have been planning to develop a free software is the near future but, before starting this development, we logically wait for the validation of the scientific rationale of the proposed workflow. The software will be based on this manuscript and will require an additional detailed user guide. The software in the form of either a standalone software or a toolbox from an available platform such as R or Matlab (still in discussion). As the purpose of this work is to provide a readily usable tool, we will develop this software with a software engineer in order to design an easy-to-use and friendly interface. This clarification is added in the conclusion:

‘Within this scope, a software is planned to be developed in the near future in order to provide a user-friendly tool for recharge estimation.’

Specific comments/questions:

1: We agree with this comment. It is modified in the revised manuscript as follows:

‘*The workflow requires the records of precipitation, air temperature, relative humidity, solar radiation and wind speed within or close to the landslide. The determination of the parameters of the recharge area is based on a spatial analysis requiring field observations and spatial datasets (digital elevation models, aerial photographs and geological maps). Once determined, the parameters will be refined with a sensitivity analysis.’*

2: We agree with this comment. It is modified in the revised manuscript.

3: We agree with this comment. The introduction of the revised manuscript has been modified (please refer to Appendix A of this document)

Regarding the already published studies, given the difficulty to obtain the complete dataset and the details of the methods used in these studies, we could not recalculate the recharge and therefore we cannot determine the benefit of our method for these studies. Moreover, to carry out such recalculations would require several months and would bring the manuscript to an unacceptable length. We rather propose a new test, based on a suggestion in the specific comment 22, which allows the reader to realize the benefit of our method with respect to one common assumption related to the estimation of the recharge (please refer to answer to the specific comment 22).

Regarding the following comment: **Again, more detail is needed here about what exactly is wrong with the assumption that the infiltration rate at the soil surface is equivalent to precipitation.**

We apologise for this ambiguous wording. By “infiltration”, we mean “deep percolation”. This was modified in the revised manuscript and replaced by recharge.

4: We agree with this comment. It is modified in the revised manuscript.

5: We agree with this comment and we follow the recommendation of Referee 2 by inserting his suggested sentences in the revised manuscript. However we do not insert the following sentence “**In principle, the actual groundwater recharge flux controls the dynamics of**

pore-water pressures and water table fluctuations, rather than the precipitation flux at the land surface". Instead, we suggest to insert the following sentence in the introduction of the revised manuscript *'In the absence of piezometric measurements, the groundwater recharge is used as the most relevant parameter to characterize the pore water pressure of the landslide aquifer'*.

6: We agree with this comment. The entire section 2.1 is deleted in the revised manuscript. Only the sentences from lines 5 to 12 (p 6347) and from lines 24 (p 6347) to 2 (p 6348) are kept and moved to the section 2.2.

7: We partly agree with this comment.

In the revised manuscript, the standard equation FAO-56 PM is now defined in the introduction. Appendix A with the details equations is now announced in the beginning of the section 2.2.

The calibration of the reduced-set equations is a common method acknowledged by the scientific community (Allen et al., 1994; Itenfisu et al., 2003; Alkaeed et al., 2006; Lu et al., 2005; Tabari et al., 2013; Alexandris et al., 2008; Shahidian et al., 2012). We refer the reader to these studies. However, we agree with Referee 2 to move the statement from page 6345 (line 18-20) and to be more explicit. The following sentence is added to the section 2.3:

'ET_0 Reduced-set and R_S temperature methods were developed for given regions or sites with their own climatic conditions and must be calibrated to take into account the weather conditions specific to the study site. Details about calibration can be found in the literature (Allen et al., 1994; Itenfisu et al., 2003; Alkaeed et al., 2006; Lu et al., 2005; Tabari et al., 2013; Alexandris et al., 2008; Shahidian et al., 2012).'

The purpose of the calibration is to account for the weather conditions specific to the study site. Although three stations can appear as a small sample size, the network density of weather stations recording the required parameters at a daily rate is generally weak. Increasing the number of reference stations can lead to use remote stations that might be located in remote areas not representative of the climatic conditions of the study site. The user has to maintain a balance between the sample size and the representativeness of the reference weather stations. One reference weather station can be sufficient, provided that the weather conditions are the same at the reference station as at the study site. In the case of the Séchilienne landslide, in order to rely on three stations, we had to look for stations located as 60 kilometres from the study site. The section 2.3 is modified as follows in the revised manuscript:

‘The user has to maintain a balance between the number of selected reference stations and the necessity for these stations to be located in areas with climatic conditions similar to those of the study site.

The median is an interesting estimator if the data number is significantly high or if the studied dataset shows outliers. In the proposed calibration, the number of required weather reference stations can be limited. The selected reference weather station(s) should be representative of the study site conditions and the calibration coefficient should be within the same range. Consequently, the median estimator is not relevant and the calibration parameters should be within the same range (no outliers). The average estimator allows integrating in one estimator small variations between the various reference stations used. We do not think we need to elaborate on that point in the required effort to reduce the manuscript length.

8: We agree with this comment. The paragraph is clarified in the revised manuscript as follows:

‘The performance assessment of regional-scale calibrated methods is based on the comparison between observed measurements and calibrated estimates for R_s *and between FAO-56 PM estimates and calibrated estimates for* ET_0*.’*

Regarding the sub-comment “**though again, we have not yet seen the actual Equations**” in the revised manuscript, the standard equation FAO-56 PM is now defined in the introduction. Appendix A with detailed equations is now announced in the beginning of the section 2.2.

9: We agree with this comment. The revised manuscript has been revised accordingly.

10: We agree with this comment. The equations pertaining to solar radiation have been moved to the Appendix A.

11: We agree with this comment. The manuscript has been revised as follows:

‘*The α coefficient is applied for the two first rain-event days since, for a rain period longer than two days, the value of the Rs estimated from* ΔT *and the actual* R_s *value become almost identical.*’

12: We agree with this comment. The first part of this comment **(Page 6353; lines 10-18: The description of methods here is wholly inadequate. You say, “For one given parameter, the recharge area was divided into sub-areas, each being characterized by a constant value estimated according to field measurements, literature values or calculation.” A methods section should be written with sufficient detail that another scientist could replicate your work based solely on its description within the manuscript. That would be impossible given only this description of how the average parameter values were determined based on landscape characteristics. The subsections that follow (within section 2.4) are similarly vague. For example, in section 2.4.2 the authors state that “SAWC is deduced from soil properties (type of horizon, texture and bulk density) and depth extent from auger hole cores, using a pedotransfer function.” Did you actually measure the soil texture and bulk density using a laboratory method, or did you assume a value based on some soil survey data?)** has been addressed by a complete rewriting of the incriminated section (please refer to Appendix B of this document).

Regarding the second part of this comment (**Did you assume that the maximum depth of your auger hole was the maximum depth of the soil? Or do you have other information that indicates the depth of the soil? What is the depth to bedrock, and is the bedrock impermeable, fractured, other? Do you think one core is sufficient to extrapolate to the entire sub-area for which you are estimating the SAWC parameter? Soil texture and hydraulic properties can vary by orders of magnitude over small distances.),** our answer is as follows:

All these questions need no longer to be asked because our analysis just requires rough estimates of the various parameters. These estimates will subsequently be refined by a sensitivity analysis. We further refer to Appendix B of this document for improvement of this section.

Regarding the third part of this comment **(Last, you state that the dependency of SAWC on vegetation species is taken into account through the Kc coefficient. More detail is needed here. The description of Kc in the preceding section indicates that it is a function of vegetation height, albedo, canopy resistance and soil evaporation. It is not immediately apparent how any of those factors are related to the SAWC, which is a theoretical (and questionable) value indicating the fraction of the total soil-pore volume that can be utilized by plants for solution uptake. Also, you already stated that the SAWC was**

estimated from a pedotransfer function (all of which are rough approximations for any individual soil), so how is that estimate of SAWC from the pedotransfer function modified based on the Kc coefficient?), our answer is as follows:

The K_c coefficient takes into account the specificity of the vegetation involved in the evapotranspiration process and therefore integrates the specific extent of the root zone. This point is not necessary to understand the method and is removed from the revised manuscript.

13: The estimated runoff in our study includes both the overland flow and the subsurface flow. The distinction between the two is therefore useless.

14: We do not entirely agree with this comment. Since this study also targets non-hydrologists, we believe it is important to keep this section to help the reader to understand the soil-water balance procedure.

15: We agree with this comment. The revised manuscript has been modified accordingly.

16: According to Verstraeten et al. (2005), the specific vegetation evapotranspiration (ET_c) is a lumped parameter including potential transpiration, potential soil evaporation and canopy interception evaporation. This is why, in our approach, the interception component does not appear on the diagram of Figure 2b since it is taken into account by the ET_C. We agree with Referee 2 that this paragraph is confusing regarding the interception component. The paragraph is modified as follows:

'*The ET_c is a lumped parameter including potential transpiration, potential soil evaporation and canopy interception evaporation (Verstraeten et al., 2005). Therefore, in the proposed diagram workflow (Fig. 2b) the interception component is integrated in the ET_C component.*'

17: We agree with this comment and we modified the revised manuscript accordingly.

18: We agree with this comment. The phrase 'aquifer saturation state' has been removed from the manuscript. Same for 'decreasing sum'.

19: We agree with this comment and the manuscript is modified accordingly as follows:

'The correlation between water input and displacement requires measurements of landslide displacements at the same temporal frequency (daily frequency in this study) as the

measurements of water input (precipitation or recharge). The groundwater hydrodynamic processes in aquifers are non-linear. A former rainfall event displays less impact (though not negligible) than a recent one on the aquifer hydrodynamic fluctuations (Canuti et al., 1985; Crozier, 1986). The daily precipitation/recharge time series cannot therefore be used without appropriate corrections. An antecedent cumulative sum of precipitation/recharge weighted by a factor α *is applied as a moving window to the daily precipitation/recharge time series (Equation 5). The antecedent cumulative sum allows to approximate the daily triggering impact of the aquifer on the landslide destabilisation* A_t *at the target date t. In order to take into account the groundwater transit time, a* β *time-lag factor is introduced. This factor can shift the moving window from date t.*

$$A_t = \sum_{i=t+\beta}^{t+\beta+n} \frac{W_i}{1+\alpha\ (\mathrm{i}-(\mathrm{t}+\beta))} \qquad (5)$$

where:

At	*aquifer triggering impact at the date t (in mm)*
t	*target date*
β	*time shift of the moving window (in days)*
i	i^{th} *day from the date t (*$i=t+\beta$*: start of the moving window and* $i= t+\beta+n$*: end of the moving window)*
n	*length of the moving window of the cumulative period (in days)*
W_i	*water input, i.e., precipitation or recharge at the* i^{th} *day (in mm)*
α	*weighting factor*

An iterative grid search algorithm is used to find the optimal set of parameters of the antecedent cumulative sum. The optimal set of parameters is the set that maximizes the correlation performance itself based on the R^2 *indicator. The grid search algorithm investigates the following parameter ranges: n from 1 to 250 days (increment: 1 day),* α *from 0 to 0.5 (increment: 0.001) and* β *from 1 to 10 days (increment: 1 day).’*

20: The site description is improved in the revised manuscript. For further details please refer to the answer to the general comment 1 of Referee 1.

21: We partly agree with this comment which is actually more general than specific. We added a one-page long "general workflow" section that summarizes the workflow. So far, the revised manuscript is more than one thousand words shorter than the previous submission. We prefer to separate the method details from the application of the method to the Séchilienne landslide. By doing so, any reader who is interested either by the method or by the results for the Séchilienne landslide can select the relevant part.

22: We are aware of the existence of recharge-weighting functions, but these functions are used in the case of tracer-based studies. In our opinion, relying only on ET_0 and precipitation data, and without tracer data, the recharge-weighting functions cannot be used in this study.

Regarding the comment (**Comparing estimated recharge versus precipitation is a fairly weak test. We know, in principle, that recharge is more relevant than simply precipitation for influencing pore-water pressure.**), we answer as follows:

First, several landslide studies use precipitation data instead of the recharge (Rochet et al., 1994; Zêzere et al., 2005; Meric et al., 2006; Helmstetter and Garambois, 2010; Belle et al., 2013). This demonstrates that our precipitation vs. recharge test is not an useless effort.

Furthermore, following Referee 2 comment, we carried out an additional test to compare the performance of our proposed method with an estimated recharge signal itself obtained with the commonly used simplification: Recharge = precipitation minus ***non-calibrated*** ET_0, as used by the following authors (Canuti et al., 1985; Binet et al., 2007b; Pisani et al., 2010; Prokešová et al., 2013). In this additional test, we use the non-calibrated Turc evapotranspiration equation as it is the most appropriate equation for the Séchilienne site. Indeed, the Turc equation has been developed initially for the French climate.

In the revised manuscript, the recharge estimated with our workflow (named LRIW in the revised manuscript: Landslide Recharge Input Workflow) is called R_{LRIW} and the recharge estimated by subtracting the non-calibrated ET_0 from precipitation is called R_{PMNE} (PMNE standing for Precipitation Minus Non-calibrated ET_0).

Accordingly, new Null Hypothesis tests have been performed as follows:

To estimate whether the R_{PMNE} /displacement correlation R^2 is significantly better than the precipitation/displacement correlation R^2 value, the Null Hypothesis 1 (NH1) is tested. The

NH1 states that the R_{PMNE} /displacement correlation R^2 value is not significantly greater than the R^2 value obtained with precipitation. In other words, the NH1 statistic test is the difference between the R_{PMNE} R^2 value and the precipitation R^2 value, expected to be 0 if no difference. Similarly, the Null Hypothesis 2 (NH2) and the Null Hypothesis 3 (NH3) are tested. NH2 estimates whether the R_{LRIW}/displacement correlation R^2 is significantly better than the precipitation/displacement correlation R^2 value. NH3 estimates whether the R_{LRIW} /displacement correlation R^2 is significantly better than the R_{PMNE} /displacement correlation R^2 value.

The results of this additional test are added in the revised manuscript and Figure 10 is modified as follows:

*'All LBCI values from bootstrap testing of NH1, NH2 and NH3 are greater than zero, allowing to reject the three null hypotheses for the four stations (Fig. 10*A*). Rejection of the NH1 null hypothesis shows that the* R^2 *obtained with* R_{PMNE} *are significantly higher than those computed with precipitation. Rejection of the NH2 null hypothesis shows that the* R^2 *obtained with* R_{LRIW} *are significantly higher than those computed with precipitation. Similarly, rejection of the NH3 null hypothesis shows that the* R^2 *obtained with* R_{LRIW} *are significantly higher than those computed with* R_{PMNE}*.* R^2 *values vary from 0.0006 to 0.343 for precipitation, from 0.076 to 0.444 for* R_{PMNE} *and from 0.243 to 0.586 for recharge, for G5 and A16 extensometer respectively (Table 6). On average,* R_{PMNE} *allows to increase the* R^2 *value by 29% relatively to precipitation, while* R_{LRIW} *allows to increase the* R^2 *by 78% (Fig. 10*B*). The* R^2 *obtained with* R_{LRIW} *are 38% higher on average than those obtained with* R_{PMNE}*. These results are confirmed by the LBCI and by the observed values of the NH2 test which are always greater than those from the NH1 test as well as by the positive LBCI values of the NH3 test (Fig. 10). The correlation performance for the recharge estimated with the LRIW method significantly exceeds the performances of the two other signals, making the LRIW method particularly appropriate to be used in landslide studies.'*

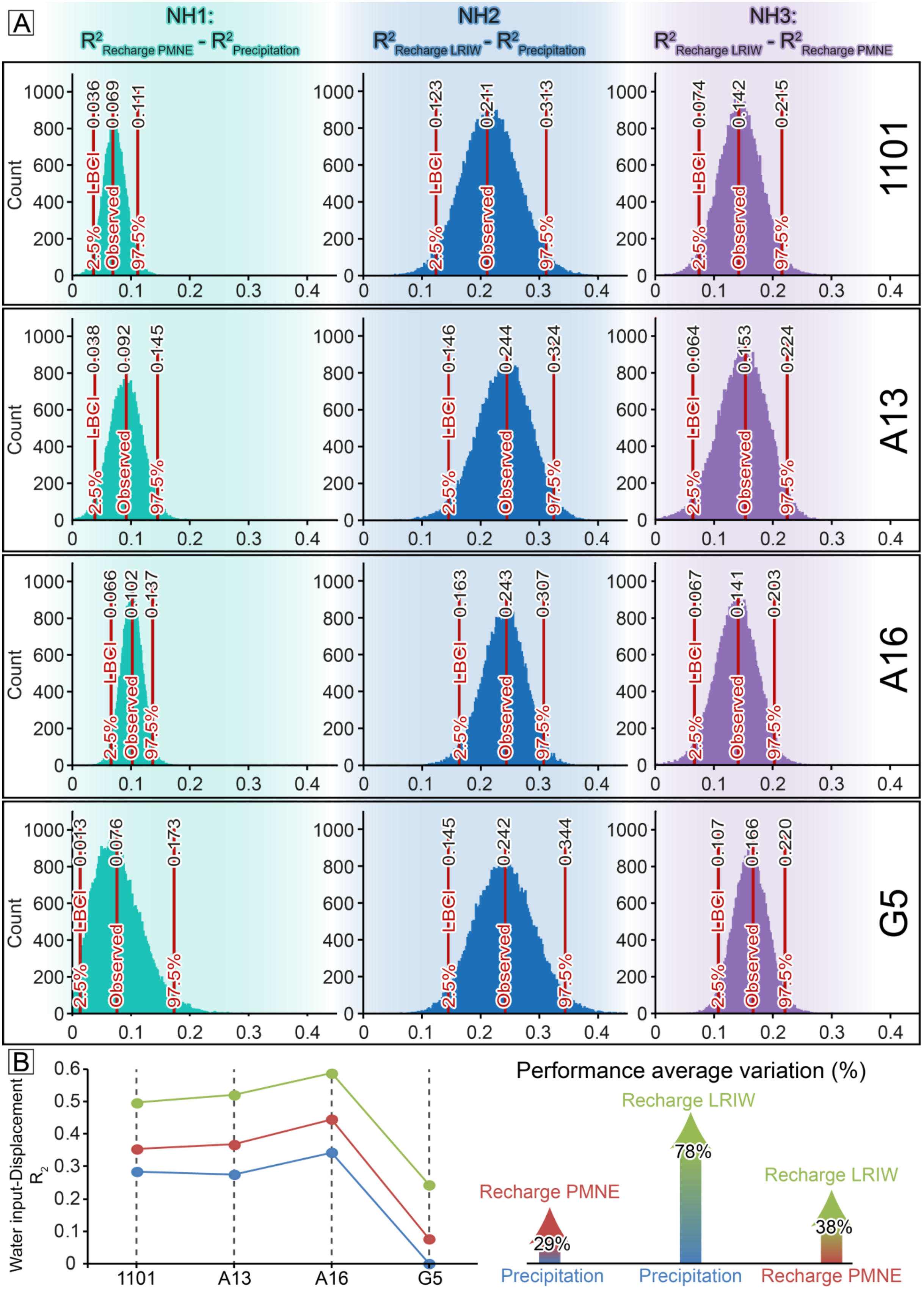

Fig. 10: Performance of the LRIW workflow. A: Bootstrap distribution of null hypothesis NH1, NH2 and NH3 tests for four displacement recording stations. LBCI is the lower bound

of the confidence interval. B: R^2 values for the four displacement recording stations obtained with the precipitation, R_{PMNE}, and R_{LRIW}. LBCI is the lower bound of the confidence interval.

Technical corrections:

Most technical corrections have been taken into account. Those not taken into account are discussed below:

Page 6366: methods rather than results. We partly agree with this comment.

Lines 5 to 10 are moved to the section ‘Application to the Séchilienne landslide’. The rest is kept at the same place as it is the result of the GIS composite analysis.

Page 6389: relative error of 25% seems non-trivial.

We misused the phrase ‘relative error’. In the former manuscript, the coefficient of variation of the RMSE (root mean square error) should have been used instead of ‘relative error’. The CV(RMSE) is equal to RMSE divided by the observed dataset mean. The CV(RMSE) indicator is used to compare models with different units, which is not the case of this study. In the revised manuscript, the CV(RMSE) is replaced by the RMSE performance indicator. Table 2 is modified as follows:

Method	a	b	R^2	RMSE
HS Et_0	0.920	0.130	0.917	0.548
Turc ET_0	0.880	0.434	0.900	0.588
PS ET_0	0.352	0.365	0.919	0.533
M ET_0	1.107	-0.018	0.910	0.565
PM_{red} ET_0	0.994	0.013	0.932	0.505

Appendix A: Introduction

Pore water pressure built-up by recharge of aquifers is one of the main triggering factors of the destabilisation of deep-seated landslides (Noverraz et al., 1998; Van Asch et al., 1999; Bonzanigo et al., 2007; Guglielmi et al., 2005; Bogaard et al., 2007). In most deep-seated landslides, pore water pressure data are not available since piezometers, if any, have a very short lifespan because of slope movements. In addition, landslides show heterogeneous, anisotropic and discontinuous properties (Cappa et al., 2004; Binet et al., 2007a) and local measurements are rarely representative of the overall behaviour of the landslide aquifers. In the absence of piezometric measurements, the groundwater recharge is used as the most relevant parameter to characterize the pore water pressure of the landslide aquifers Groundwater recharge (hereafter recharge), also referred to as deep percolation, is the part of the precipitation which recharges the saturated zones (aquifers).

Landslide studies involve a wide range of specialities (sub-surface geophysics, structural geology, modelling, geotechnics, and geomechanics), for which scientists or engineers may not have the required hydrology knowledge to accurately estimate the recharge. In most cases, deep-seated landslide studies devoted to characterise the rainfall-destabilisation relationships do not take into account recharge with enough accuracy. In particular, some studies estimate the recharge without calibration of the evapotranspiration estimation methods and without soil-water balance (Canuti et al., 1985; Alfonsi, 1997; Hong et al., 2005; Binet et al., 2007b; Durville et al., 2009; Pisani et al., 2010; Prokešová et al., 2013). Lastly, several studies use precipitation data instead of the recharge (Rochet et al., 1994; Zêzere et al., 2005; Meric et al., 2006; Helmstetter and Garambois, 2010; Belle et al., 2013). These approaches can over-estimate the triggering impact of the meteorological input on destabilisation. A more rigorous estimation of the groundwater recharge signal can improve the reliability of these studies. So far, no computation workflow method has been proposed to estimate simply and accurately the recharge in the context of landslide studies.

Patwardhan et al. (1990) showed that the soil-water balance method is an accurate way to estimate groundwater recharge. Recharge computation with a soil-water balance depends mainly on the surface runoff, the soil available water capacity (SAWC) and the specific vegetation (so-called crop) evapotranspiration ($ET_{c,}$ also referred as potential evapotranspiration) which is deduced from reference vegetation evapotranspiration (ET_0). The

Penman-Monteith method developed in the paper FAO-56 (Food and Agriculture Organization of the United Nations) is considered by the scientific community as a global standard method to estimate ET_0 worldwide (hereafter referred to as the ET_0 standard equation or FAO-56 PM, Eq. (A4), Jensen et al., 1990; Allen et al., 1998). This method requires the knowledge of the air relative humidity, the air temperature, the wind speed and the solar radiation. However, most weather stations in landslide areas record only air temperature and rainfall. Unlike the FAO-56 PM method, methods based only on air temperature and/or solar radiation (R_s) allow a simpler expression of ET_0 (Tabari et al., 2013). The R_s can also be estimated only from air temperature (Almorox, 2011), thus allowing ET_0 to be obtained only from air temperature records. These reduced-set methods are developed under specific site conditions and must be calibrated in order to improve accuracy (Allen et al., 1994; Shahidian et al., 2012).

The objective of this study is to develop a parsimonious, yet robust, guideline workflow to calculate time series of groundwater recharge that can be used as a deterministic variable in studies of landslides. To maximize accessibility to diverse user groups, we strive to develop an efficient method, balancing technical accuracy with operational simplicity. The proposed workflow is tested on the deep-seated Séchilienne landslide. To test the utility of the proposed workflow, correlation analysis is used to evaluate whether the calculated groundwater recharge is more strongly correlated with measured land mass displacement velocities than with precipitation or with recharge estimated with a common simplification in landslide studies (recharge = precipitation minus non-calibrated ET_0, Canuti et al., 1985; Binet et al., 2007; Pisani et al., 2010; Prokešová et al., 2013). The significance of the correlations is assessed with bootstrap tests. The proposed study aims at showing that an accurate estimation of the recharge can significantly improve the results of rainfall-displacement studies.

Appendix B: Step 2: Estimation of the parameters of the recharge area

The estimation of the recharge with the soil-water balance (Step 3) requires the calculation, at the scale of the recharge area, of three parameters which are SAWC, runoff coefficient R_{coeff}, and $K_{c.}$ These three parameters are controlled by one or several factors which are, in this study, the slope gradient, the geological nature of the substratum and the type of vegetation cover. Besides, at the scale of the recharge area, the controlling factors are commonly heterogeneous and thus cannot be readily computed. For each controlling factor, the recharge area is divided into sub-areas (hereafter referred to as factor sub-areas) characterized by homogenous factors. Factor sub-areas can be either continuous or discontinuous, and their number and shape can differ, depending of the spatial distribution of the factors. Relevant factor sub-areas are in turn used to define parameter sub-areas. For a given parameter sub-area, the value of the parameter is estimated from either field measurements or from the literature. The parameter values at the scale of the recharge area are then calculated by taking into account the relative surface of the parameter sub-areas (Fig. 1 – Step 2). Lastly, if preferential infiltration structures such as sinkholes, cracks, reverse slope areas, bare ground or any topographical depressions which can collect the surface runoff are present in the recharge area, the above-mentioned parameters have to be adjusted. For such areas, the SAWC and R_{coeff} , being very low, will be set at zero in the calculations. Similarly, for such areas, ET_0 is negligible and therefore the surface of these areas is disregarded for the K_c computation. The parameter values are then refined by a sensitivity analysis in order to find the optimal set of recharge-area parameters.

The K_c parameter takes into account four key characteristics (vegetation height, albedo, canopy resistance and evaporation from soil) that distinguish the vegetation type of a given sub-area from the reference grass used to estimate the ET_0 (Allen et al., 1998). The K_c sub-areas are defined according to the type of vegetation (e.g., meadow, forest…) obtained from aerial photographs. The dominant vegetation species assigned to each vegetation type can be obtained from literature (e.g., forest agency data) or field observations. Since the K_c parameter depends on the stage of development of the vegetation, it varies from a minimum value during winter to a maximum value during summer. The minimum and maximum K_c values are estimated from the literature and are assigned respectively to the 4th of February (middle of winter) and the 6th of August (middle of summer) of each year. A daily linear interpolation is performed for K_c between these two dates (Verstraeten et al., 2005).

The SAWC parameter refers to the difference between a maximum water content above which all free water is drained through gravity (field capacity) and a minimum moisture content below which plant roots cannot extract any water (permanent wilting point). The SAWC is mainly affected by soil texture and thickness, both depending primarily on the geological substratum and the vegetation. The SAWC also depends on the extent of the root zone and on the permanent wilting point, both varying according to the vegetation. The SAWC sub-areas are defined according to the type of vegetation (obtained from aerial photographs) and to the geological substratum (obtained from geological maps). SAWC values are calculated with pedotransfer functions (Jamagne et al., 1977; Bruand et al., 2004) from soil properties (type of horizon, texture and bulk density) and thickness. Soil properties and thickness can be obtained from the literature (e.g., pedological maps) or from laboratory measurements of auger hole cores.

The method used to estimate the surface runoff is similar to the commonly used ‘runoff rational method’. The R_{coeff} parameter depends mainly on the topography and vegetation. The R_{coeff} sub-areas are defined according to the vegetation (obtained from aerial photographs). An average slope gradient obtained from the DEM is assigned to each sub-area. The R_{coeff} values can then be calculated from vegetation cover and slope gradient through the use of charts such as the Sautier chart (Musy and Higy, 2011).

Infiltration structures are located through inspection of aerial photographs (lineaments analysis) and geological maps with control in the field.

References:

Alexandris, S., Stricevic, R., Petkovic, S., 2008. Comparative analysis of reference evapotranspiration from the surface of rainfed grass in central Serbia, calculated with six empirical methods against the Penman–Monteith formula. European Water 21/22, 17–28.

Alfonsi, P., 1997. Relation entre les paramètres hydrologiques et la vitesse dans les glissements de terrains. Exemples de La Clapière et de Séchilienne. Revue française de géotechnique 3–12.

Alkaeed, O.A., Flores, C., Jinno, K., Tsutsumi, A., 2006. Comparison of Several Reference Evapotranspiration Methods for Itoshima Peninsula Area, Fukuoka, Japan. Memoirs of the Faculty of Engineering, Kyushu University 66, 1–14.

Allen, R.E., Pereira, L.S., Raes, D., Smith, M., 1998. Crop evapotranspiration : guidelines for computing crop water requirements, FAO Irrigation and drainage paper 56. ed. Food and Agriculture Organization of the United Nations, Rome.

Allen, R.G., Smith, M., Pereira, L.S., Perrier, A., 1994. An Update for the Definition of Reference Evapotranspiration. ICID Bulletin of the International Commission on Irrigation and Drainage 43, 1–34.

Almorox, J., 2011. Estimating global solar radiation from common meteorological data in Aranjuez, Spain. Turkish Journal of Physics, Tübitak 35, 53–64.

Belle, P., Aunay, B., Bernardie, S., Grandjean, G., Ladouche, B., Mazué, R., Join, J.-L., 2013. The application of an innovative inverse model for understanding and predicting landslide movements (Salazie cirque landslides, Reunion Island). Landslides 1–13. doi:10.1007/s10346-013-0393-5

Binet, S., Guglielmi, Y., Bertrand, C., Mudry, J., 2007a. Unstable rock slope hydrogeology: insights from the large-scale study of western Argentera-Mercantour hillslopes (South-East France). Bulletin de la Societe Geologique de France 178, 159–168. doi:10.2113/gssgfbull.178.2.159

Binet, S., Mudry, J., Scavia, C., Campus, S., Bertrand, C., Guglielmi, Y., 2007b. In situ characterization of flows in a fractured unstable slope. Geomorphology 86, 193–203. doi:10.1016/j.geomorph.2006.08.013

Bogaard, T., Guglielmi, Y., Marc, V., Emblanch, C., Bertrand, C., Mudry, J., 2007. Hydrogeochemistry in landslide research: a review. Bulletin de la Société Géologique de France 178, 113–126. doi:10.2113/gssgfbull.178.2.113

Bonzanigo, L., Eberhardt, E., Loew, S., 2007. Long-term investigation of a deep-seated creeping landslide in crystalline rock. Part I. Geological and hydromechanical factors controlling the Campo Vallemaggia landslide. Can. Geotech. J. 44, 1157–1180. doi:10.1139/T07-043

Bruand, A., Duval, O., Cousin, I., 2004. Estimation des propriétés de rétention en eau des sols à partir de la base de données SOLHYDRO : Une première proposition combinant le type d'horizon, sa texture et sa densité apparente. Etude et Gestion des Sols 11, 3, 323–334.

Canuti, P., Focardi, P., Garzonio, C., 1985. Correlation between rainfall and landslides. Bulletin of Engineering Geology and the Environment 32, 49–54. doi:10.1007/BF02594765

Cappa, F., Guglielmi, Y., Soukatchoff, V.M., Mudry, J., Bertrand, C., Charmoille, A., 2004. Hydromechanical modeling of a large moving rock slope inferred from slope levelling coupled to spring long-term hydrochemical monitoring: example of the La Clapière landslide (Southern Alps, France). Journal of Hydrology 291, 67–90. doi:10.1016/j.jhydrol.2003.12.013

Crozier, M.J., 1986. Landslides: causes, consequences et environment. Croom Helm, London ; Dover, N.H.

Durville, J.-L., Kasperki, J., Duranthon, J.-P., 2009. The Séchilienne landslide: monitoring and kinematics, in: First Italian Workshop on Landslides. Presented at the First Italian Workshop on Landslides, Napoli, Italia, pp. 174–180.

Guglielmi, Y., Cappa, F., Binet, S., 2005. Coupling between hydrogeology and deformation of mountainous rock slopes: Insights from La Clapière area (southern Alps, France). Comptes Rendus Geoscience 337, 1154–1163. doi:10.1016/j.crte.2005.04.016

Helmstetter, A., Garambois, S., 2010. Seismic monitoring of Séchilienne rockslide (French Alps): Analysis of seismic signals and their correlation with rainfalls. Journal of Geophysical Research 115, F03016. doi:10.1029/2009JF001532

Hong, Y., Hiura, H., Shino, K., Sassa, K., Suemine, A., Fukuoka, H., Wang, G., 2005. The influence of intense rainfall on the activity of large-scale crystalline schist landslides in Shikoku Island, Japan. Landslides 2, 97–105. doi:10.1007/s10346-004-0043-z

Itenfisu, D., Elliott, R.L., Allen, R.G., Walter, I.A., 2003. Comparison of Reference Evapotranspiration Calculations as Part of the ASCE Standardization Effort. Journal of Irrigation and Drainage Engineering 129, 440–448. doi:10.1061/(ASCE)0733-9437(2003)129:6(440)

Jamagne, M., Bétrémieux, R., Bégon, J.C., Mori, A., 1977. Quelques données sur la variabilité dans le milieu naturel de la réserve en eau des sols. Bulletin Technique d'Information du Ministère de l'Agriculture 627–641.

Lu, J., Sun, G., McNulty, S.G., Amatya, D.M., 2005. A comparison of six potential evapotranspiration methods for regional use in the Southeastern United States. JAWRA Journal of the American Water Resources Association 41, 621–633. doi:10.1111/j.1752-1688.2005.tb03759.x

Meric, O., Garambois, S., Orengo, Y., 2006. Large Gravitational Movement Monitoring Using a Spontaneous Potential Network, in: Proc. 19th Annual Symposium on the

Application of Geophysics to Engineering and Environmental Problems. EEGS, Seattle, USA, pp. 202–209. doi:10.4133/1.2923649

Musy, A., Higy, C., 2011. Hydrology: A Science of Nature, English ed. ed. CRC Press ; Science Publishers, Boca Raton, FL. : Enfield, N.H.

Noverraz, F., Bonnard, C., Dupraz, H., Huguenin, L., 1998. Grands glissements de terrain et climat, VERSINCLIM - Comportement passé, présent et futur des grands versants instables subactifs en fonction de l'évolution climatique, et évolution en continu des mouvements en profondeur (Rapport final PNR31 (Programme National de Recherche) No. PNR31). vdf Hochschulverlag AG an der ETH Zürich, Zürich, Switzerland.

Patwardhan, A., Nieber, J., Johns, E., 1990. Effective Rainfall Estimation Methods. Journal of Irrigation and Drainage Engineering 116, 182–193. doi:10.1061/(ASCE)0733-9437(1990)116:2(182)

Pisani, G., Castelli, M., Scavia, C., 2010. Hydrogeological model and hydraulic behaviour of a large landslide in the Italian Western Alps. Nat. Hazards Earth Syst. Sci. 10, 2391–2406. doi:10.5194/nhess-10-2391-2010

Prokešová, R., Medveďová, A., Tábořík, P., Snopková, Z., 2013. Towards hydrological triggering mechanisms of large deep-seated landslides. Landslides 10, 239–254. doi:10.1007/s10346-012-0330-z

Rochet, L., Giraud, A., Antoine, P., Évrard, H., 1994. La déformation du versant sud du mont-sec dans le secteur des ruines de Séchilienne (Isère). Bulletin of the International Association of Engineering Geology 50, 75–87. doi:10.1007/BF02594959

Shahidian, S., Serralheiro, R., Serrano, J., Teixeira, J., Haie, N., Santos, F., 2012. Hargreaves and Other Reduced-Set Methods for Calculating Evapotranspiration, in: Irmak, A. (Ed.), Evapotranspiration - Remote Sensing and Modeling. InTech, Rijeka, Croatia, pp. 60–80.

Tabari, H., Grismer, M.E., Trajkovic, S., 2013. Comparative analysis of 31 reference evapotranspiration methods under humid conditions. Irrigation Science 31, 107–117. doi:10.1007/s00271-011-0295-z

Van Asch, T.W.J., Buma, J., van Beek, L.P.., 1999. A view on some hydrological triggering systems in landslides. Geomorphology 30, 25–32. doi:10.1016/S0169-555X(99)00042-2

Verstraeten, W.W., Muys, B., Feyen, J., Veroustraete, F., Minnaert, M., Meiresonne, L., De Schrijver, A., 2005. Comparative analysis of the actual evapotranspiration of Flemish forest and cropland, using the soil water balance model WAVE. Hydrol. Earth Syst. Sci. 9, 225–241. doi:10.5194/hess-9-225-2005

Zêzere, J.L., Trigo, R.M., Trigo, I.F., 2005. Shallow and deep landslides induced by rainfall in the Lisbon region (Portugal): assessment of relationships with the North Atlantic

Oscillation. Natural Hazards and Earth System Sciences 5, 331–344. doi:10.5194/nhess-5-331-2005