Dear Editor and Reviewers,

all the reviewers comments have been addressed and the exact position in the text (page and lines) of the changes made, has been indicated in the point-by-point reply to the comments.

Thank you, kind regards.

The authors

Interactive comment on "Use of satellite and modelled soil moisture data for predicting event soil loss at plot scale" by F. Todisco et al.

Anonymous Referee #1.

Thank you very much for your insightful comments. We will address all the points highlighted, valuable to enhance this work

1. the writing style is quite varied throughout the manuscript. Some sections e.g. the abstract and introduction are reasonably well writ-ten with clearly stated arguments. Other sections require extensive language editing to ensure that the manuscript flows nicely.

REPLY. An extensive language revision to improve the readability of manuscript has been carried out by a native English speaker.

2. In the abstract the abbreviation USLE must be written in full at first mention as some readers may not be familiar with it.
3. On the results it is bad practice to duplicate results except if there is a clear benefit in doing so. For example, in Fig 3, the modeled and satellite derived soil moisture values are presented first as a line graph (a) and then again as a regression relationship (b). Choose one format that best projects your results.
4. Remove the raster in Fig 3a and 5a, respectively.

REPLY. The suggested corrections 2, 3 and 4 have been implemented (see respectively page 1 line 14; Fig. 2; Fig. 2 and Fig. 5).

SPECIFIC COMMENTS

5. Firstly the authors use satellite derived soil water content data at a spatial resolution of 25 km for a plot level study of 22 m x 8 m. Given the large spatial variation in soil water content, clarity is required on the methods used to downscale the satellite soil water content to the plot scale. This detail is necessary in order for the study to be repeatable. Examples of downscaling approaches can be found in Friesen et al., 2008 and Gharari et al., 2011, among others.

REPLY. The reviewer is right, soil moisture exhibits large spatial and temporal variability. However, it is widely known that the temporal dynamics of soil moisture field is often very similar across a wide range of scales; a phenomenon usually referred to as ''temporal stability'' (e.g., Brocca et al., 2010a; 2012a). Therefore, local point measurements can be used for obtaining an estimate of soil moisture over large areas (Brocca et al., 2009) and, viceversa, coarse scale soil moisture measurements can be properly used for small scale applications (Brocca et al., 2010b; 2012b). Based on the previous results obtained in the same study area, we are confident that coarse-scale soil moisture data obtained from ASCAT can provide an index of the soil saturation conditions to be used also at very small scale for erosion modelling. Indeed, in two previous studies, Brocca et al. (2010c; 2011) have already shown the good performance of the ASCAT soil moisture product in the study area. In the revised manuscript, we have added the details needed to clarify these points (see page 11, lines 9-16).

<u>REFERENCES</u>

Brocca, L., Melone, F., Moramarco, T., Singh, V.P. (2009). Assimilation of observed soil moisture data in storm rainfall-runoff modelling. Journal of Hydrologic Engineering, 14 (2), 153-165, doi:10.1061/(ASCE)1084-0699(2009)14:2(153).
Brocca, L., Melone, F., Moramarco, T., Morbidelli, R. (2010a). Spatial-temporal variability of soil moisture and its estimation across scales. Water Resources Research, 46, W02516, doi:10.1029/2009WR008016.
Brocca, L., Melone, F., Moramarco, T., Wagner, W., Naeimi, V., Bartalis, Z., Hasenauer, S. (2010b). Improving runoff prediction through the assimilation of the ASCAT soil moisture product. Hydrology and Earth System Sciences, 14, 1881-1893, doi:10.5194/hess-14-1881-2010.
Brocca, L., Melone, F., Moramarco, T., Wagner, W., Hasenauer, S. (2010c). ASCAT Soil Wetness Index validation through in-situ and modeled soil moisture data in central Italy. Remote Sensing of Environment, 114 (11), 2745-2755, doi:10.1016/j.rse.2010.06.009.
Brocca, L., Hasenauer, S., Lacava, T., Melone, F., Moramarco, T., Wagner, W., Dorigo, W., Matgen, P., Martínez-Fernández, J., Llorens, P., Latron, J., Martin, C., Bittelli, M. (2011). Soil moisture estimation through ASCAT and AMSR-E sensors: an intercomparison and validation study across Europe. Remote Sensing of Environment, 115, 3390-3408, doi:10.1016/j.rse.2011.08.003.
Brocca, L., Tullo, T., Melone, F., Moramarco, T., Morbidelli, R. (2012a). Catchment scale soil moisture spatial-temporal variability. Journal of Hydrology, 422-423, 63-75, doi:10.1016/j.jhydrol.2011.12.039.
Brocca, L., Ponziani, F., Moramarco, T., Melone, F., Berni, N., Wagner, W. (2012b). Improving landslide forecasting using ASCAT-derived soil moisture data: A case study of the Torgiovannetto landslide in central Italy. Remote Sensing, 4(5), 1232-1244, doi:10.3390/rs4051232.

6. Secondly, the soil water content data is also derived from a soil water balance model. Validation of the modeled or the satellite derived soil water content data with actual water content measurements on the plots is needed. The authors should, at least, give an indication of how accurate their soil water content data is given that inclusion of soil moisture in the erosion model is their main contribution.

REPLY. The soil water balance model was extensively validated with actual soil moisture measurements in different studies already published in the scientific literature (Brocca et al., 2008; 2013; 2014; Lacava et al., 2012). Specifically, in Brocca et al. (2013) the model was validated exactly in the same area of this study by obtaining reliable and satisfactory results. On this basis, we believe the soil water balance model is an appropriate tool for soil moisture estimation in the area, and in the revised manuscript more details on its validation have been added. Moreover, the accuracy of the soil water balance model has been explicitly quantified (see page 9, lines 1-9).

<u>REFERENCES</u>

Brocca, L., Melone, F., Moramarco, T. (2008). On the estimation of antecedent wetness conditions in rainfall-runoff modelling. Hydrological Processes, 22 (5), 629-642, doi:10.1002/hyp.6629.
Brocca, L., Zucco, G., Moramarco, T., Morbidelli, R. (2013). Developing and testing a long-term soil moisture dataset at the catchment scale. Journal of Hydrology, 490, 144-151, doi:10.1016/j.jhydrol.2013.03.029.
Brocca, L., Camici, S., Melone, F., Moramarco, T., Martinez-Fernandez, J., Didon-Lescot, J.-F., Morbidelli, R. (2014). Improving the representation of soil moisture by using a semi-analytical infiltration model. Hydrological Processes, 28(4), 2103-2115, doi:10.1002/hyp.9766.
Lacava, T., Matgen, P., Brocca, L., Bittelli, M., Moramarco, T. (2012). A first assessment of the SMOS soil moisture product with in-situ and modelled data in Italy and Luxembourg. IEEE Transaction on Geoscience and Remote Sensing, 50(5), 1612-1622, doi:10.1109/TGRS.2012.2186819.

7. Thirdly, the quality of the soil water content estimates from the soil water balance method can be improved by replacing the empirical Blaney-Criddle method of estimating evapotranspiration (section 3.2) with the physically based and more accurate Penman-Monteith approach. The authors are well placed to implement this given that they had a weather station at the site (second par, pg 2951).

REPLY. We have implemented the Penmann Monteith method in the soil water balance model for two years (2010-2011). Indeed, only in this period the time series of climatic data required by the Penmann Monteith method (maximum and minimum temperature, solar radiation, wind speed, air humidity) was complete. The figure below shows the comparison between simulated soil moisture data by using the Penmann Monteith and the Blaney-Criddle approaches. It is evident that the two time series are nearly identical (R^2=0.998) due to the bare soil conditions (evapotranspiration process is limited to evaporation from the soil surface) and, mainly, the high value of the saturated hydraulic conductivity that controls the fast decreasing trends of soil moisture after rainfall.
Based on these results, we have used the Blaney-Criddle approach for estimating evapotranspiration as in the original manuscript.

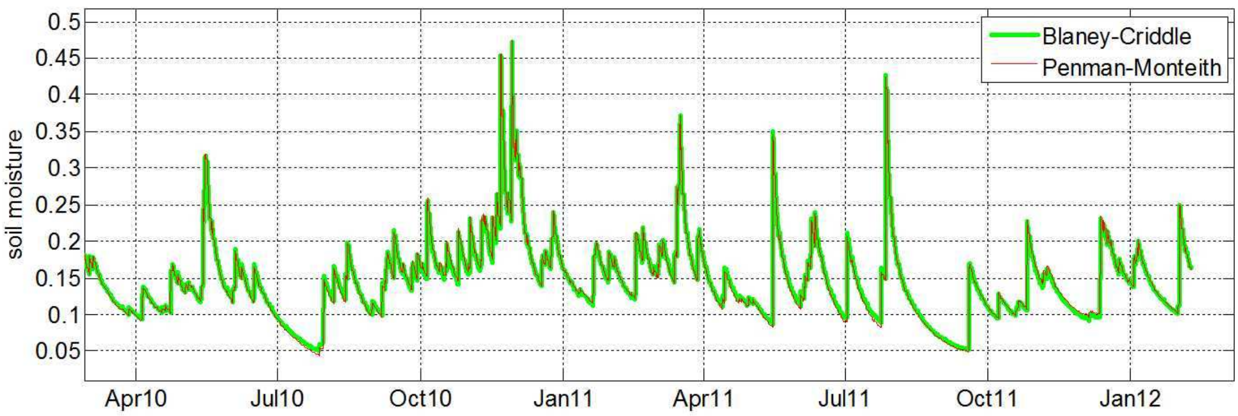

Figure 1 – Comparison of simulated soil moisture from the SWBM by using the Penmann Monteith and the Blaney-Criddle approaches for potential evapotranspiration computation.

8. Lastly, claims that power relations in the SM4E model gave better estimates than linear relations (pg 2957 line 20-25) should be supported by suitable statistics which is another area of weakness in the paper.

REPLY. The linear and the power models have been compared in terms of confidence intervals of the regression coefficients. The uncertainty has been estimated as the percentage of the size of the 90% confidence interval with regard to the corresponding coefficient value. Furthermore, for model comparison, two criteria, namely Akaike information criterion (AIC, Akaike, 1974) and Bayesian information criterion (BIC, Burnham and Anderson, 2002), have been used. According to these criteria the best model provides the lowest AIC and BIC values. Moreover, according to Nagin and Roeder (2001), the difference between the BIC values obtained for the linear and power models has been computed to verify that the difference is statistically significant (see page 12, lines 14-30).

TECHNICAL CORRECTIONS

9. Abstract, write the abbreviation USLE in full at first mention
10. Pg 2950 line 4: replace the phrase “large availability” with “widespread availability”;
11. Pg 2950 line 20: replace the phrase “compared with” with “evaluated against” ;
12. Pg 2951 line 9: Replace “gauging station” with “weather station”

REPLY. The suggested corrections 9, 10, 11, and 12 have been implemented. (see page 1, line 14; see pag 4, line 30; see pag 5, line 16; see pag 5, line 27)

13. Pg 2951 line 23-27: This sentence is too long, consider splitting.

REPLY. The sentence have been split in two or more short sentences (see pag. 6, lines 8-14)

14. Pg 2952 lines 1-2: indicate the source of the remote sensing data. A website will do;

REPLY. The source of remote sensing data will be specified in the revised manuscript. Specifically, data have been obtained from the "Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF)" project (see page 6, lines 18-20).

15. Pg 2952 line 12: Indicate the depth of the root zone;

REPLY. An exact quantification of the depth of the root zone is not possible. However, we expect that for erosion modelling an estimate of the soil moisture conditions for a layer depth of 15 cm is required. It has been clarified in the revised manuscript (see page 6, lines 25-31).

16. Pg 2956: line 12: Good agreement between the ASCAT and SWBM soil moisture does not necessarily mean that they are accurate. Ground-truthing seems necessary here.

REPLY. As mentioned above, both the soil water balance model and the ASCAT soil moisture product were extensively validate with actual soil moisture measurements in several studies. Anyhow, in the revised manuscript we have added the details of the expected accuracy of both modelled and satellite soil moisture data (see page 7, lines 6-8 and page 9, lines 1-7).

17. Pg 2958 lines line 1: Statistics needed to indicate that the power functions gave significantly more accurate results.

REPLY. As mentioned above, a more detailed statistical analysis have been performed (see page 12, lines 14-30; see pag 13, lines 26-30).

Interactive comment on "Use of satellite and modelled soil moisture data for predicting event soil loss at plot scale" by F. Todisco et al.

Anonymous Referee #2.

Thank you very much for your insightful comments. We will address all the points highlighted, valuable to enhance this work

General Comments:

1. The use of satellite soil moisture products (level of soil moisture saturation) and the conversion to soil moisture content comes with uncertainties which the authors have not addressed.

REPLY The uncertainties of both modelled and satellite-derived soil moisture datasets has been explicitly quantified in the revised manuscript. Indeed, the model was extensively validate in the study area in several previous studies (Brocca et al., 2008; 2013; 2014; Lacava et al., 2012) and also the comparison between satellite and in situ soil moisture measurements was carried out in Brocca et al. (2010; 2011). Therefore, we have quantified the expected accuracy of both datasets (see page 7, lines 6-8 and page 9, lines 1-7) and also its impact on the results obtained in this study (see page 12, lines 11-13).

REFERENCES

Brocca, L., Melone, F., Moramarco, T. (2008). On the estimation of antecedent wetness conditions in rainfall-runoff modelling. Hydrological Processes, 22 (5), 629-642, doi:10.1002/hyp.6629.

Brocca, L., Melone, F., Moramarco, T., Wagner, W., Hasenauer, S. (2010). ASCAT Soil Wetness Index validation through in-situ and modeled soil moisture data in central Italy. Remote Sensing of Environment, 114 (11), 2745-2755, doi:10.1016/j.rse.2010.06.009.

Brocca, L., Hasenauer, S., Lacava, T., Melone, F., Moramarco, T., Wagner, W., Dorigo, W., Matgen, P., Martínez-Fernández, J., Llorens, P., Latron, J., Martin, C., Bittelli, M. (2011). Soil moisture estimation through ASCAT and AMSR-E sensors: an intercomparison and validation study across Europe. Remote Sensing of Environment, 115, 3390-3408, doi:10.1016/j.rse.2011.08.003.

Brocca, L., Zucco, G., Moramarco, T., Morbidelli, R. (2013). Developing and testing a long-term soil moisture dataset at the catchment scale. Journal of Hydrology, 490, 144-151, doi:10.1016/j.jhydrol.2013.03.029.

Brocca, L., Camici, S., Melone, F., Moramarco, T., Martinez-Fernandez, J., Didon-Lescot, J.-F., Morbidelli, R. (2014). Improving the representation of soil moisture by using a semi-analytical infiltration model. Hydrological Processes, 28(4), 2103-2115, doi:10.1002/hyp.9766.

Lacava, T., Matgen, P., Brocca, L., Bittelli, M., Moramarco, T. (2012). A first assessment of the SMOS soil moisture product with in-situ and modelled data in Italy and Luxembourg. IEEE Transaction on Geoscience and Remote Sensing, 50(5), 1612-1622, doi:10.1109/TGRS.2012.2186819.

2. As presented by Kinnell (2014; 2015), soil moisture data (also from satellite) can be used to estimate event surface runoff. If rainfall intensity is known or precipitation for that matter (which can easily be measured) for certain storm period together with the catchment characteristics (curve number) and soil moisture, the event surface runoff can be accurately (and easily) be determined for different landscapes. I expected to authors compared these two approaches using the satellite based soil moisture data (locally validated using the water balanced approach) and possibly downscaled to appropriate (plot) scale.

REPLY The main objective of this paper is to demonstrate that the antecedent soil moisture is effective to enhance the USLE model performance at the event temporal scale. Nevertheless we agree with the reviewer that the runoff is appropriate too. In fact, in the paper the performance of the SM4E models is compared with that of the USLE-M and USLE-MM models by using modelled event surface runoff from MISDc model. The rainfall-runoff model used to estimate the runoff has been described (see pag 10, lines 9-22). In the original manuscript, the results were presented, perhaps too briefly, in section 4.4 and in the Figure 5a. Taking into account the reviewer comment, we have presented these results more extensively (see page 13, lines 19-30; page 14, lines 1-8). The results are illustrated in the Figures 3 and 4. Here we have reported the modified version of Figures 3 and 4 in which the results of the SM4E models are illustrated along with that of the models including the estimated runoff (USLE-M and USLE-MM). As already stated in the paper, the results in terms of model accuracy and model performance are slightly better when the antecedent soil moisture is used (SM4E).

3. The authors cannot also run away from the inability of their model to predict well soil loss during high intensity summer (dry) event because it is directly influenced by the soil moisture conditions.

REPLY. In the manuscript, we have already highlighted that SM4E model is not able to reproduce the observed soil losses in dry conditions (see page 15, lines 5-18). Specifically, the incorporation of mechanism for the formation of superficial crusts in the developed soil water balance model will be the object of future investigations (see Conclusions at page 16, lines 20-29). For the current study, we believe that mainly during wet conditions, SM4E model is able to satisfactorily estimate soil losses at plot scale, with the great advantage of using satellite soil moisture data that are available on a global scale. Therefore, the further improvement of the model is out of the scope for this study.

4. The manuscript also dealt a lot on the comparison between satellite soil moisture vs modeled. For example the comparisons in Fig. 3 could have been useful if the comparison was between SM4E and USLE-M / USLE-MM model results. The results could have provided clearer explanation for the disparities in wet and dry periods than what is given in this manuscript.

REPLY. In the revised manuscript, Figures 3 and 4 have been modified by giving more details on the comparison between SM4E and USLE-M / USLE-MM models.

5. It's not convincing why the authors choose to use two sets of soil moisture data in the analysis.

REPLY. Thanks for the comment. Indeed, it is not specified in the manuscript. We used both modelled and satellite soil moisture data as they represent two (out of three) of the methods currently available for estimating soil moisture (beside in situ measurements, not currently available for the selected study area). Specifically, we expect to obtain better results with modelled data, that however require good-quality input observations of rainfall and evapotranspiration and model parameters calibration. Satellite observations have the enormous advantage to be available on a global scale (and currently from different sensors). Therefore, we expect slightly worse results with satellite data, but with the potential to apply SM4E model everywhere. These points have been clarified in the revised manuscript (see page 5, lines 5-8).

6. Another weakness of the manuscript is the lack of uncertainty analysis. The satellite based soil moisture data is subject to levels of uncertainty from the satellite product to the process of converting into root zone soil moisture data (using Soil Water Index, subject to calibration). And so is the soil moisture estimated from soil water balance model (involves calibration parameters). The robustness of the model performance presented is lacking.

REPLY. As mentioned above, the uncertainties of both modelled and satellite-derived soil moisture datasets have been explicitly quantified in the revised manuscript (see page 7, lines 6-8 and page 9, lines 1-7).

SPECIFIC COMMENTS

7. Pg 2952 line 7 & 14: provide additional description of satellite soil moisture & soil water index method used extensively (underlying mathematical formulations) and possible errors/uncertainties.

REPLY. The details on the satellite soil moisture product and on the implementation of the Soil Water Index method have been provided in the references (Wagner et al., 1999; 2013) and in many previous studies that used satellite soil moisture data. To avoid making the paper longer, we decided to not add the mathematical formulation of the soil moisture retrieval algorithm from remote sensing and of the Soil Water Index.

8. Pg 2956, section 4.5 – The SM4E model should account for high intensity rainfall under low antecedent soil moisture during summer (dry) events. The soil infiltration capacity is an influencing factor that the authors need to consider.

REPLY. As mentioned above, the modification of SM4E model for better reproducing soil losses in dry conditions will be the object of future investigations (see Conclusions at page 16, lines 17-29).

9. Pg 2960 line 14: 45% (37%) model performance - meaningful is the levels of uncertainty is presented Pg 2961 line 7 – 8: Not conclusively. Not supported by data / statistical analysis shown.

REPLY. Thanks for the comment. The linear and the power models have been compared in terms of confidence intervals of the regression coefficients. The uncertainty has been estimated as the percentage of the size of the 90% confidence interval with regard to the corresponding coefficient value. Furthermore, for model comparison, two criteria, namely Akaike information criterion (AIC, Akaike, 1974) and Bayesian information criterion (BIC, Burnham and Anderson, 2002), have been used. According to these criteria the best model provides the lowest AIC and BIC values. Moreover, according to Nagin and Roeder (2001), the difference between the BIC values obtained for the linear and power models has been computed to verify that the difference is statistically significant (see page 12, lines 14-30; page 13, lines 26-30).

TECHNICAL CORRECTIONS

REPLY. The suggested corrections from 10 to 22 have been implemented.

10. Pg 2946 line 24: Soil provides us with food, biomass and raw materials - is a mix of terminologies that mean the same
REPLY. The sentence have been changed (see page 2, line 7)

11. Pg 2947 lines 27, 28, 29: sentence is long, and not clear. No clear distinction between process-based models and USLE / RUSLE
REPLY. The sentence have been changed (see page 3, lines 1-4)

12. Pg 2951 line 24: insert the year
REPLY. The years have been inserted (see page 6, line 10)

13. Pg 2953 line 3: check units for K. Show the units for L, S, C, P for consistency
REPLY. The units have been checked (see page 7, line 17)

14. Pg. 2953 line 13 & 14: Shorten the sentence
REPLY. The sentence have been shortened (see page 7, line 26-28)

15. Pg 2954 line 2 – 5: not clear (re-write)
REPLY. The sentence have been changed (see page 8, lines 12-14)

16. Pg 2954 line 5: explain briefly what linear and power models
REPLY. The sentence have been changed (see page 8, lines 12-14)

17. Pg 2954 15 – 19: avoid long sentences
REPLY. The sentence have been changed (see page 8, lines 22-26)

18. Pg 2955 line 3 – 4: give the equations
REPLY. The equations have been inserted in the text (see page 9, lines 14-20)

19. Pg. 2958 line 2 – 6: too long sentence
REPLY. The sentence have been changed (see page 13, lines 4-9)

20. Pg 2958 section 4.4 – Mix up of methodology and results.
REPLY. The methodology have been described in section 3.3 (see page 10. lines 9-22). In section 4.4 the results of the comparison have been supported by a more detailed statistical analysis

21. Figure 4: maintain uniformity with figure 3 and edit captions
REPLY. Uniformity have been maintained

22. Figure 5: split A and B
REPLY. The figure have been split in Fig. 5 and Fig. 6

24. References: Kinnell, P. I. A.: Modelling event soil losses using QREI30 index with RUSLE2, Hydrol. Process., 28, 2761–2771, 2014.
25. Kinnell, P. I. A.: Accounting for the influence of runoff on event soil readabilities associated with the EI30 index in RUSLE2, Hydrol. Process., 29, 1397–1405, 2015.

REPLY. The reference Kinnell (2015) was already cited in the manuscript and it was only updated. References Kinnell (2014) has been added to the revised manuscript.