SHORT TERM MOBILITY 2015
SCIENTIFIC REPORT

"Modelling of landslide phenomena and erosion processes triggered by meteo-climatic factors"

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1. Introduction

Landslide phenomena and erosion processes are widespread and cause every year extensive damages to the environment and to the society. These processes are in competition and their complex interaction controls directly the morphological evolution of the landscape. They can influence significantly all the other processes occurring in the slopes, controlling directly the sediment movement and availability and affecting significantly the soil formation and the related processes. Their impact is not only limited to abiotic ecosystem components, but they can strongly affect the biological ones. Moreover, introducing significant disturbances to the ecosystems, they can control their services and functions availability. Consequently, predicting the spatial and temporal occurrence of landslide and erosion phenomena is a problem of scientific and societal interest. Rainfall is the primary trigger of landslide and erosion processes, even if other physical factors can contribute significantly to their initiation. Landslide and erosion processes can be influenced strongly by soil characteristics, vegetation, land use, and anthropic factors. The fully understanding of their triggering mechanisms should consider all the factors, processes, and characteristics coexisting and interacting in a slope. However, even if in the literature these are acknowledged fundamental in the analysis of landslide and erosion processes, few studies consider all these elements and processes in a common modelling framework, and often the two processes are modelled separately. LANDPLANER (LANdscape, PLants, LANdslide and ERosion) is a model designed and implemented to overcome some of these limitations (M. Rossi 2014). LANDPLANER integrates different modeling schemas. Empirical, conceptual and physically based approaches are combined to provide different methods for the analysis of the landslide and erosion processes. LANDPLANER is raster-based and distributed and is able to estimate the effects of a given rainfall on the triggering of landslide and erosion processes. The model is mainly designed to describe the dynamic response of slopes (or basins) under different changing scenarios including: (i) changes of meteorological factors, (ii) changes of vegetation or land-use, (iii) and changes of slope morphology. The model is open source, it is coded in R and require/produce standard spatial inputs and outputs.

Such model, or at least some of its components, were tested in different geo-environmental conditions, with the main objective of verifying the proper model functioning, but also to analyse the triggering mechanisms of landslide and erosion processes in different conditions.

However, given the different processes considered by the model and its complex structure, it is difficult to find comprehensive study cases to test the model and all its components simultaneously.

2. Hosting institute

The USDA ARS SWRC United States Department of Agriculture, Agricultural Research Service, Tucson, Southwest Watershed Research, AZ (USA) was selected as hosting institute for the Short Term Mobility program, given its contribution in the field of the erosion processes internationally recognized by the scientific community. In particular, some of the SWRC activities are specifically focused on “Soil Erosion, Sediment Yield, and Decision Support

Systems for Improved Land Management on Semiarid Rangeland on Semiarid Rangeland Watersheds" with the main objectives of:

- Providing databases, knowledge, and information on rangeland erosion at a range of spatial scales for the development, validation, and implementation of erosion decision tools
- Developing decision tools including a rangeland specific hydrology and erosion model for improved planning and evaluation of rangeland management practices.

In addition, Southwest Watershed Research Center has outdoor laboratories at the Walnut Gulch Experimental Watershed, located in Tombstone, Arizona (since 1953) and at the Santa Rita Experimental Range south of Tucson (since 1975). The Walnut Gulch Experimental Watershed is the most densely gaged and monitored semiarid rangeland watershed in the world and is critical to improving scientific understanding of semiarid ecosystems. Long term experimental data related to the rainfall, runoff, sediment yield and other environmental variables, are available in the Walnut Gulch Experimental Watershed (WGEW). This unique set of data was used during the STM program for the application, calibration and verification of the LANDPLANER model.

3. USDA-ARS SWRC researcher involved in the STM activities

Several researchers of the USDA-ARS SWRC were involved or give feedbacks for the proper developments of the STM activities. In the following their names, addresses, degree and main research interests are reported.

Mark A. Nearing

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Research Agricultural Engineer

Research Interest: Soil erosion and conservation, including the understanding of basic erosion processes, field measurement of erosion rates, and the development and testing of soil erosion models. Recent work focuses on erosion in semi-arid rangeland environments.

Dave, Goodrich

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Research Hydraulic Engineer

Research Interest: Scaling issues in rainfall-runoff modeling, identification of dominant hydrologic processes over a range of basin scales, climatic change impacts on semiarid hydrologic response, incorporation of remotely sensed data into hydrologic models, functioning of semiarid riparian systems, and recharge from ephemeral channels.

Nichols, Mary

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Research Hydraulic Engineer

Research Interest: Erosion and sedimentation processes in arid and semiarid regions with emphasis on technologies for soil and water conservation and rangeland management.

Hernandez, Mariano
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Hydrologist
Research Interest: Modelling, coding of Kinerous model and other runoff and erosion related models.

Ponce, Guillermo
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Remote Sensing Specialist
Research Interest: Data, Regressive modeling

Armendariz, Gerardo
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Information Technology Specialist (Data Management)
Research Interest: IT, Web Interfaces, Data visualization

Haiyan, Wei
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Research Interest: Erosion modelling, atrophic impact of on drainage, land use and cover and on erosion processes occurrence

Ying, Zhao
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PhD
Research Interest: Spatial weather rainfall generators, taking into account multiple gages and high resolution spatial and temporal data, runoff and erosion modelling

Li, Li
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PhD
Research Interest: Experimental lab erosion tests, Soil box experiments, rock roughness and slope relations with water flow velocity.

4. STM activities

LANDPLANER is mostly designed as a tool to estimate the relative impacts of different changes to the instability slope processes dynamics and not to provide their absolute values. Nevertheless, calibration activities are necessary to allow a proper scaling of the erosion index implemented in the model and to estimate the sediment moved inside the catchments accordingly. This information is essential for simulating the erosion-driven slope surface changes and their impact on the rest of the processes existing in a slope (in particular on the landslide occurrence).

During the collaboration, diversified approaches were identified to calibrate LANDPLANER, in order to account for the different experimental data, analyses and models available at USDA-ARS SWRC. Indeed, different experimental data (rainfall, runoff, and sediment yield data) with diversified spatial and temporal resolutions are available at USDA-ARS SWRC. Particularly, the most appropriate datasets for the LANDPLANER calibration are:

- the Walnut Gulch Experimental Watershed at catchment or sub-catchment scale dataset;
- the US plots database.

In addition to the experimental data, the results of the RHEM model developed by SWRC (Al-Hamdan et al. 2015) are available in the US territory. The model is designed to provide sound, science-based technology to model and predict runoff and erosion rates on rangelands and to assist in assessing rangeland conservation practice effects. RHEM is a newly conceptualized, process-based erosion prediction tool specific for rangeland application, based on fundamentals of infiltration, hydrology, plant science, hydraulics and erosion mechanics. RHEM relies upon a set of equations derived mainly for rangelands, using the plot data (at hillslope scale) available in different US locations. In addition, extensive calibration activities were performed in the Walnut Gulch Experimental Watershed. Given the above, RHEM can be used as a benchmark for a possible LANPLANER calibration in the US territory and in particular in the Walnut Gulch Experimental Watershed.

During the STM period, calibration activities were carried out using the observed and modelled data available for the Walnut Gulch Experimental Watershed (WGEW) at catchment or sub-catchment scale. Data at daily or at least event based temporal scale were selected for the analysis. Such choice was mainly driven by the assumptions and constrains inherent to the rainfall-runoff procedure implemented in LANPLANER, which is based on the Curve Number method (USDA NCRS 2012). The method, originally developed in the 1950s by the Soil Conservation Service (SCS), now called Natural Resources Conservation Service (NRCS), of the United States Department of Agriculture (USDA), give also spatial constraints to LANDPLANER. Indeed, being derived using plot data, the minimum area (i.e. the minimum cell size) should be at least greater than few square meters: 5×5 m is a reasonable minimum cell resolution.

5. Walnut Gulch Experimental Watershed (WGEW) description

The Walnut Gulch Experimental Watershed is located in south eastern Arizona near Tombstone, AZ, USA. In the watershed extensive and exhaustive dataset on rainfall, runoff, peak runoff, sediment yield and other environmental characteristics are available, in addition to RHEM modelling results. In the watershed, data at the catchment outlet or at different sub-catchments outlets are available.

During the STM, two sub-catchments in the WGEW (**Figure**) were selected for the possible calibration of LANDPLANER:

- Watershed 103 in the Lucky Hills area, and
- Watershed 112 in the Kendall area.

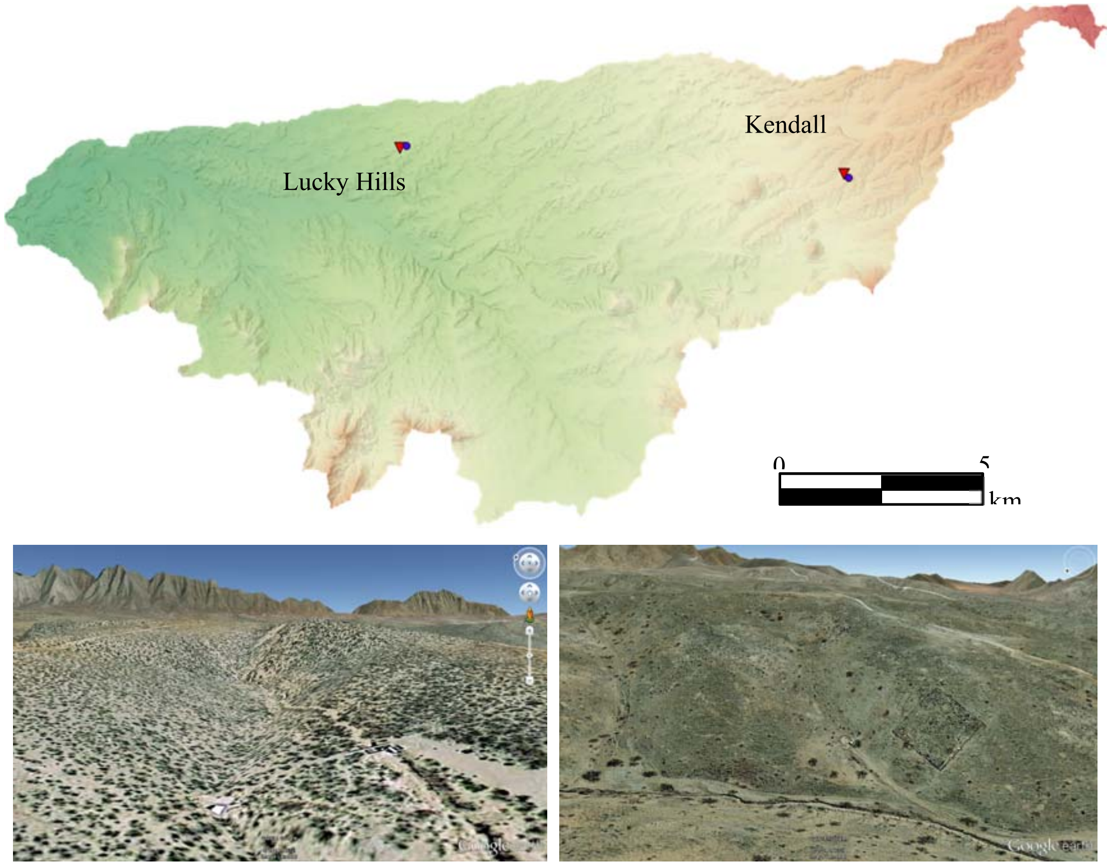

Figure 2. Relief of the Walnut Gulch Experimental Watershed. Red triangles show location of the flumes, blue dots the location on the rain gauges. Right: Watershed 103 in the Lucky Hills area. Left: Watershed 112 in the Kendall area.

The two selected sub-catchments have data at the hillslope scale and for their relative small size and internal homogeneity represent a optimal study case for the LANDPLANER calibration.

In the watershed the annual temperature average is 18°C, and the mean monthly maximum temperatures is 35°C (June), with a mean monthly minimum temperature of 2°C (December). The 60 % of rainfall is mainly concentrated in the period from July to September, while the remaining is concentrated in the period from December to February. An important characteristic of the area is that the channels are dry for the 99% of time. The watershed served as grazing land for cattle and horses. In the past, the over-grazing caused intense erosion in the watershed, affecting more severely the "Lucky Hills" site (**Figure**). The area is located on a deep, Cenozoic alluvial fan (Nearing et al 2007). In the shrub areas the soil in mainly composed by a gravelly sandy loam with approximately 52% sand, 26% silt, and 22% clay. At Kendall site (112), the soil is gravelly sandy loam with approximately 55% sand, 20% silt, and 25% clay. The organic carbon content of the soils is generally low (less than 1%), though slightly greater in the watershed 112 (between 1 and 2%) than in the other watersheds studied. **Figure** show the soil map of the entire study area and **Figure** the complete the soil class description with textural information.

The vegetation map of the Walnut Gulch Experimental Watershed (Skirvin et al 2008) shows cover type labels referred to the dominant life forms (grass, tree, and shrub) with additional information on the soil type (e.g., rocky outcrop, sandy loam) (**Figure**). A primary distinction between shrub-dominated and grass-dominated vegetation types exists within the watershed. As visible form the images in the lower part of **Figure** the vegetation in the area is mainly desert shrub, while the canopy cover in the rainy season is approximately the 25%. The 60% of the ground area are covered with rocks (alluvial outwash consisting predominantly of gravel- and cobble-sized material) and the remaining is covered by bare soil (Nearing et al 2007).

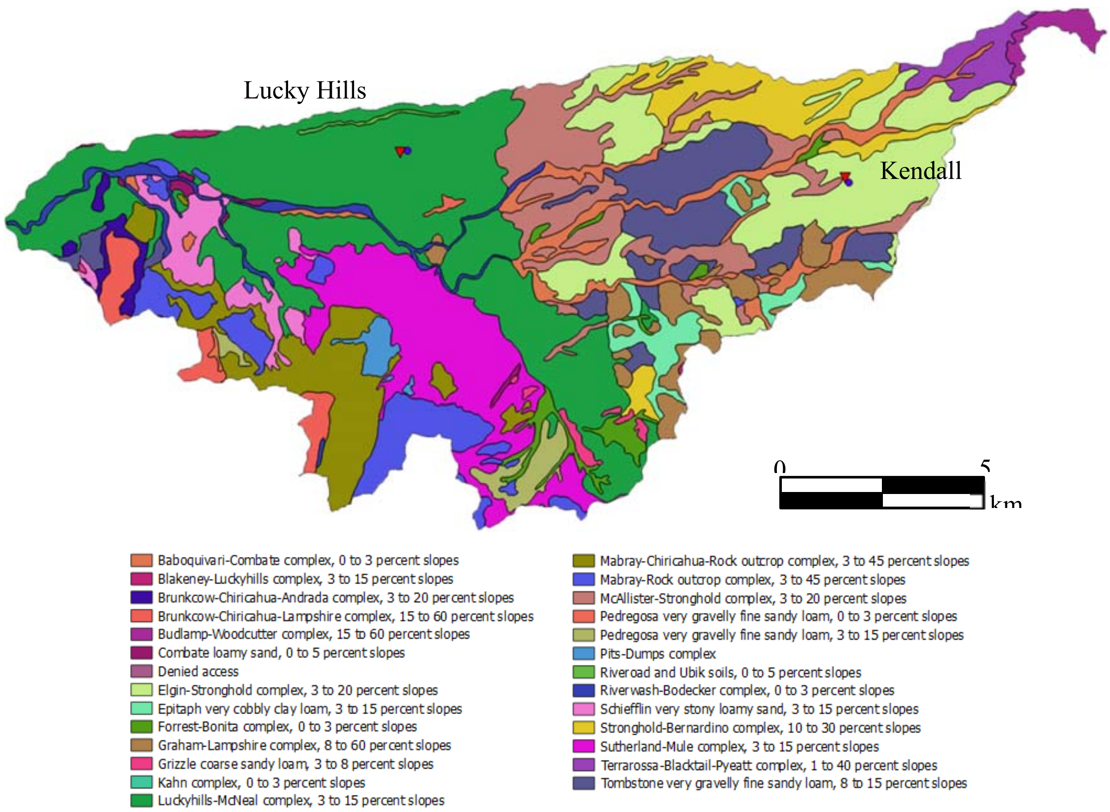

Figure 2. Soil map of Walnut Gulch Experimental Watershed (Osterkamp 2008). Red triangles show location of the flumes, blue dots the location on the rain gauges. See Table for the textural description of the classes.

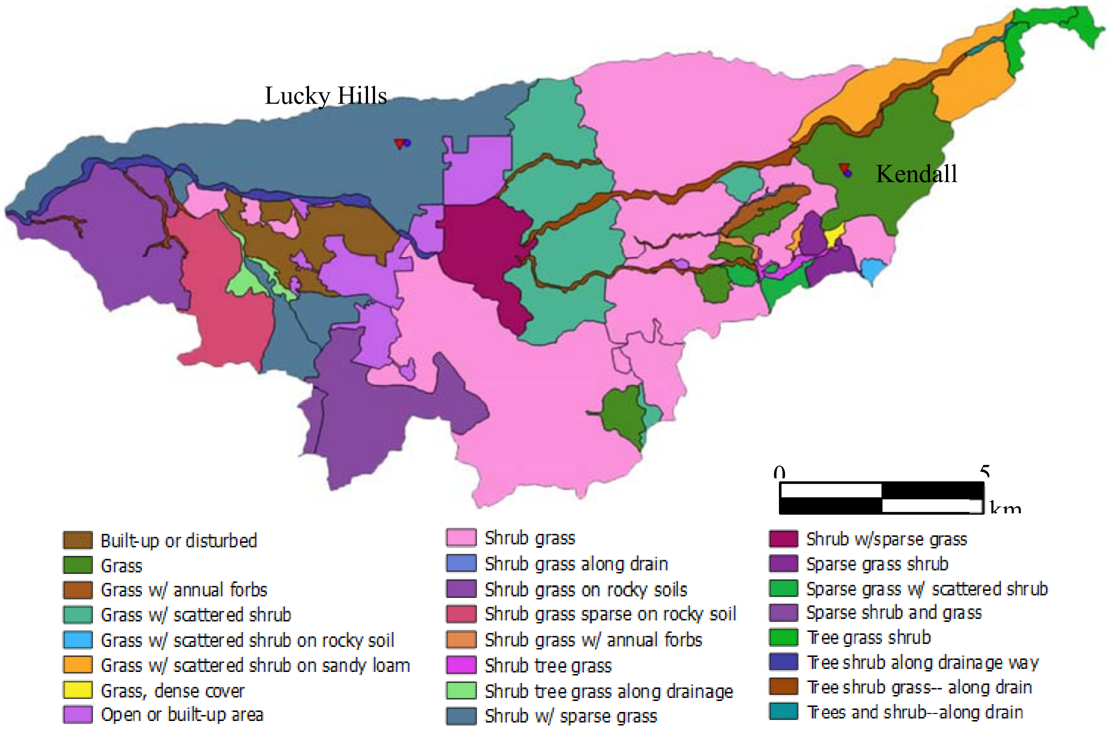

Figure 3. Vegetation map of the Walnut Gulch Experimental Watershed (Skirvin et al 2008).

The watershed 112, is located in an area referred to as ‘‘Kendall’’ at a higher elevation in the watershed. Differently from the previous watersheds, the vegetation on this watershed is mainly composed by grass and forbs with a minor presence of shrubs and succulents. Here the canopy cover is approximately 35%., while the ground cover during the rainy season if rock (28%), litter (42%), and area covered by plant bases (14%). In the Kendall site there is a predominance of herbaceous vegetation, like black grama, sideoats grama, three-awn, Lehman’s Lovegrass, and cane beardgrass (Nearing et al 2007).

For the analysis, I used data from rain gauge and flumes available in the two sub-watersheds 103 “Lucky Hills” and 102 “Kendall”.

Table 1. Map units, areal extent, and textural class of soils in the Walnut Gulch Experimental Watershed (Osterkamp 2008).

Map unit	Area (ha)	% total area	Textural Class
Baboquivari-Combate complex	543	3.67	sandy loam
Blacktail gravelly sandy loam	245	1.66	gravelly sandy loam
Budlamp-Woodcutter complex	65	0.44	very gravelly sandy loam
Chiricahua very gravelly clay loam	147	0.99	very gravelly sandy loam
Combate loamy sand	106	0.72	!loamy sand
Elgin-Stronghold complex	1,504	10.16	very gravelly fine sandy loam
Epitaph very cobbly clay loam	242	1.63	very cobbly clay loam

Forrest-Bonita complex	140	0.95	fine sandy loam
Graham cobbly clay loam	284	1.92	cobbly clay loam
Graham-Lampshire complex	244	1.65	very cobbly loam
Grizzle coarse sandy loam	81	0.55	coarse sandy loam
Lampshire-Rock outcrop complex	385	2.60	very cobbly loam
Luckyhills loamy sand	68	0.46	loamy sand
Luckyhills-McNeal complex	4,255	28.75	very gravelly sandy loam
Mabray-Chiricahua-Rock outcrop complex	495	3.35	very cobbly loam
Mabray-Rock outcrop complex	838	5.66	extremely cobbly loam
McAllister-Stronghold complex	1,358	9.17	gravelly fine sandy loam
Monterosa very gravelly fine sandy loam	284	1.92	very gravelly fine sandy loam
Riverwash-Bodecker complex	171	1.15	sand
Schiefflin very stony loamy sand	393	2.66	very stony loamy sand
Stronghold-Bernardino complex	760	5.13	very gravelly loam
Sutherland very gravelly fine sandy loam	674	4.55	very gravelly fine sandy loam
Sutherland-Mule complex	182	1.23	very gravelly fine sandy loam
Tombstone very gravelly fine sandy loam	1275	8.62	very gravelly fine sandy loam

6. Data input preparation

The raw rainfall and runoff data series where aggregated at a daily base, even if for the majority of the case the events where short and separated by period greater than a day.

The curve number associated to the different flumes was determined considering the vegetation cover and the soil type following the procedures described in the National Engineering Handbook (Part 630 Hydrology) realized by the Natural Resources Conservation Service of the United States Department of Agriculture (USDA NCRS 2012). In particular, *CN* values were estimated from the Table 9-2 in the Chapter 9 of the National Engineering Handbook summarizing the runoff curve numbers for arid and semiarid rangelands and reported here as **Figure**.

In the watershed 103 “Lucky Hills” the vegetation is composed by shrub with sparse grass and the soil unit is “Luckyhills-McNeal complex” mainly consisting of very gravelly sandy loam. The “reference” curve number assigned to this condition was 63 corresponding to the cover type “Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, paloverde, mesquite, and cactus” in poor conditions and to the hydrological soil group B.

In the watershed 112 “Kendall” the vegetation is mainly grass and the soil unit “Elgin-Stronghold complex” mainly consists of very gravelly fine sandy loam”. The “reference” curve number assigned to this condition were 62 corresponding to the cover type “Herbaceous, mixture of grass, weeds and low-growing brush, with brush the minor element” in poor conditions and to the hydrological soil group A. This last case in probably more a mixture of the two CN cover types previously illustrated rather than a single one.

To account for the variability necessarily associated to such type of classification, a range of CN was also identified for both test sites. This was chiefly done accounting the overall CN variability associated to the cover type “Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, paloverde, mesquite, and cactus" reported in **Figure**, where the CN maximum is 88 and the minimum is 49.

Table 2. Runoff curve numbers for arid and semiarid rangelands, corresponding to the Table 9-2 in the Chapter 9 of the National Engineering Handbook Agriculture (USDA NCRS 2012)[1/].

COVER DESCRIPTION		HYDROLOGIC SOIL GROUP			
Cover type	Hydrologic condition[2/]	A[3/]	B	C	D
Herbaceous—mixture of grass, weeds and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sage-grass—sage with an understory of grass	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, paloverde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1/ Average runoff condition, and $I_a = 0.2s$. For range in humid regions, use table 9–1.
2/ Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.
3/ Curve numbers for group A have been developed only for desert shrub.

7. Preliminary runoff and peak runoff comparison

Using LANDPLANER and exploiting the minimum, maximum and the reference curve number associated to the two sub-watersheds, the runoff and the peak runoff were calculated for all the rainfall events registered in the two sites. Finally, the runoff and peak runoff estimated by the model were compared with the observed once (**Figure** and **Figure**).

In the figures blue dots are the daily runoff values corresponding to different causative rainfall observed in the flumes, while red solid lines are the daily runoff values calculated for the observed rainfall values using the reference *CN* and the red dashed lines are the daily runoff values calculated for the minimum and maximum CN estimated for the sub-watersheds.

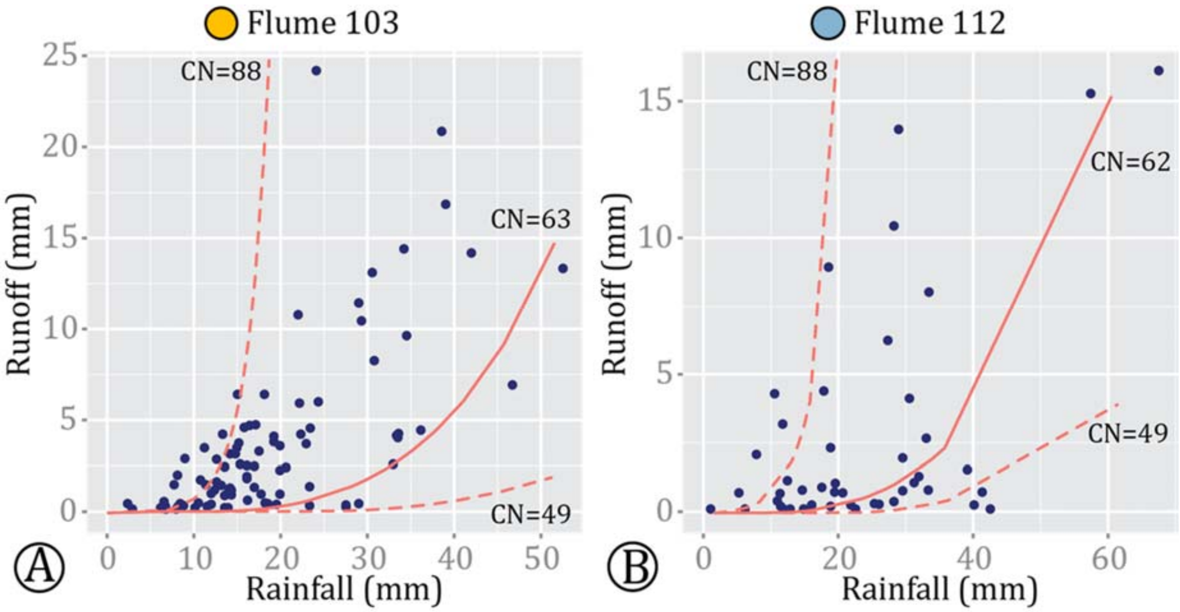

Figure 4. Daily runoff comparison in the flumes 103 (A) and 112 (B). Blue dots are the daily runoff values corresponding to different causative rainfall observed in the flumes. Red solid line are the daily runoff values calculated for the observed rainfall values using the reference CN. Red dashed lines are the daily runoff values calculated for the minimum and maximum CN.

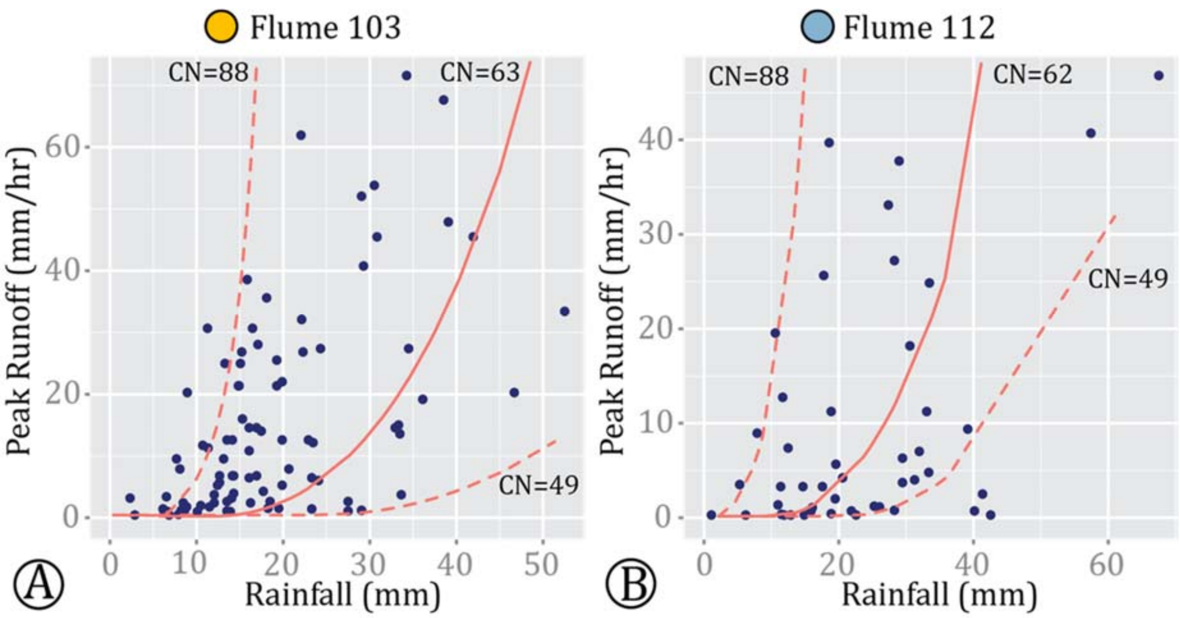

Figure5. Peak runoff comparison in the flumes 103 (A) and 112 (B). Blue dots are peak runoff values corresponding to different causative rainfall observed in the flumes. Red solid lines are the peak runoff values calculated for the observed rainfall values using the reference CN. Red dashed lines are the peak runoff values calculated for the minimum and maximum CN.

Results indicate that LANDPLANER reasonably models the rainfall-runoff trends in the observed data. The lower and upper curves obtained using the minimum and maximum CN are reasonable boundaries of the observed data, except for few data at low rainfall values. The higher the rainfall the higher is the difference between the boundaries, but this copies the observed data dispersion.

The difference between observed and modelled data can be have different explanations, and among all the specific modelling issues and assumptions can play a significant role. However, the differences can be explained by a number of possible reasons listed in the following:

- instrumental errors;
- variability of CN inside the sub-watersheds and in different moments;
- lack of adequate CN look up table (in particular when mixtures of cover types are present in the watersheds);
- lack of data for an adequate CN temporal characterization.

This last point is particular important, because the surface conditions may vary significantly in time in such type of environment during the year. Among all high saturation degrees, over grazing, soil sealing are processes that can favor runoff, while conversely dissection cracks can increase soil permeability.

8. Erosion index definition

Water runoff is a key parameter in determining the potential triggering of erosion phenomena, but a comprehensive investigation of such phenomena should consider local condition such as morphology, land use, soil characteristics and vegetation. To account for all this aspects, LANDPLANER includes an erosion index that was defined, by the following equation.

$$e_{pot} = \alpha \cdot \left(\frac{Q_{off} \cdot \sin s}{S_{0.05}}\right)^{\beta}$$

In the equation Q_{off} is the cell runoff, s is slope angle and $S_{0.05}$ is the storage index calculated from *CN*. In standard applications the coefficients α and β are assumed to be 1, but those should be calibrated for a proper erosion estimation.

During the STM this equation was rewritten to copy the power stream relations tested in WGEW (Polyakov et al. 2010):

$$e_{pot} = \alpha \cdot \frac{\sin s}{S_{0.05}} \cdot {Q_{off}}^{\beta}$$

The quantity e_{pot} is a “proxy” of the eroded material potentially erodible in a given cell, and possibly and estimation of the sediment yield produced in a basin. This quantity is transferred and cumulated downslope using a routing schema similar to that one used by LANDPLANER for the runoff calculation. During the downslope transfer, a deposition index (dep) is calculated comparing the material eroded coming from the upslope cells (e_{up}) with the cell maximum potential erosion value (epot).

$$dep = e_{pot} - \sum e_{up}$$

If dep is negative sedimentation is expected, otherwise all the available eroded material is transferred downslope. Even if roughly, those two indices consider all the parameters necessary to identify locations prone to erosion or not, and allow the analysis of the local erosion triggering conditions.

9. LANDPLANER calibration experiment in Lucky Hills

One critical aspect for the calibration of the erosion index, is related to the amount of sediment exiting from the basin outlet considered in the calibration analysis. Indeed, in some cases not all the sediment eroded in a basin in correspondence of a rainfall event reaches the basin outlet, but remains stored inside the basin. Basically, soil erosion is one of the element to be considered in the sedimentation processes which consist of erosion, transportation and deposition of sediment. A fraction of eroded soil may go in the channels and contributes to sediment yield, while a fraction of eroded material can be deposited in the channels. The sediment delivery ratio (SDR), is the percent of gross soil erosion induced by water delivered to a specific point of the channel network. SDR is a sort of a transmission coefficient and is given by the ratio of sediment yield at the basin outlet to the gross erosion in the entire basin. For a proper calibration of the erosion index, catchments characterised by an SDR close to one should be preferentially considered.

The two sub-catchments in the WGEW corresponding to Watershed 103 in the Lucky Hills area, and Watershed 112 in the Kendall area, show different SDR. While for the Watershed 103 was estimated an SDR of 0.89 for the Watershed 112 the SDR is close to 0, even if erosion is large inside the two catchments (M. A. Nearing et al. 2005). For this reason, in the calibration analysis we considered only the Watershed 103 in the Lucky Hills area.

We performed a two-step analysis:

1. LANDPLANER was executed to simulate the rainfall events occurred in the basin and find optimal CN values maximising the observed runoff and the runoff predicted by the model;
2. LANDPLANER was executed to find the optimal erosion calibration parameter set, maximizing (for all the rainfall events observed in the basin) the sediment yield observed and predicted by the model at a given outlet.

When performing the first step, one assumes that the CN value characterizing the basin was changed over time. This variation is justified by the possible changes in vegetation type and cover, but also by the possible phenological changes expected in the different seasons during which rainfall events and erosion occurred.

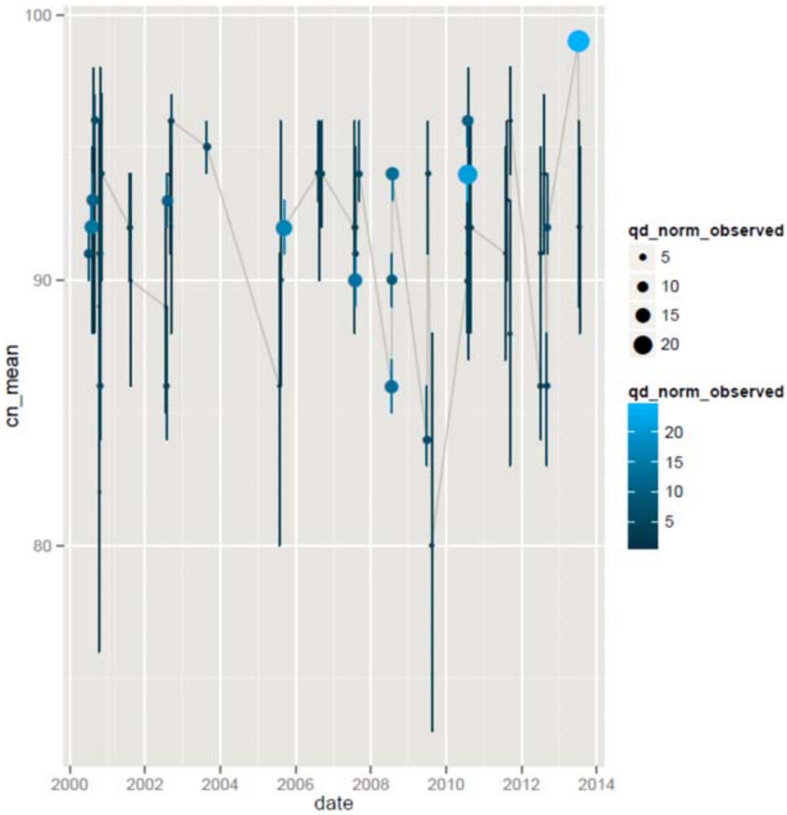

Figure 6. Daily runoff comparison in the flumes 103 (A) and 112 (B). Blue dots are the daily runoff values corresponding to different causative rainfall observed in the flumes. Red solid line are the daily runoff values calculated for the observed rainfall values using the reference CN. Red dashed lines are the daily runoff values calculated for the minimum and maximum CN.

To account for the uncertainty related to the CN estimation, a range of the possible CN values was determine for each rainfall event. **Figure6** shows the mean CN values (dots) and their expected ranges (vertical bars), estimated for each rainfall event occurred in the period 2000-2014, as a function of the runoff observed during each event (size and colour of dots). As expected, the larger CN seems to be coupled with the larger runoff. The estimated CN values how a possible but reduced CN variation, with the majority of mean CN values ranging from 85 to 95. This finding highlights that changes occurred in the basins in the considered period, but also that the general basin behaviour remained similar.

The mean CN values associated to each rainfall event, were used in the second step for the simulation of the runoff and the erosion for selected couples of erosion calibration parameters. When the erosion values corresponding to the rainfall events occurred in basin, were estimated for a specific couple of erosion calibration parameters, they are compared with the corresponding observed sediment yield and several statistical metrics derived to quantify the degree of fitting.

In the analysis, the following statistical metrics (object functions) were used:

1. Root Mean Squared Error (RMSE) given by:

$$RMSE = \sqrt{\frac{\sum_1^n (\hat{y}_t - y)^2}{n}}$$

2. Normalized Root Mean Squared Error (NRMSE) given by:

$$NRMSE = \frac{RMSE}{y_{max} - y_{min}}$$

3. Coefficient of variation of the Root Mean Squared Error (CVRMSE) given by:

$$CVRMSE = \frac{RMSE}{\bar{y}}$$

4. Nash–Sutcliffe model efficiency coefficient (NSE) given by:

$$NSE = 1 - \frac{\sum_{t=1}^T (Q_0^t - Q_m^t)^2}{\sum_{t=1}^T (Q_0^t - \bar{Q}_0)^2}$$

5. Linear model coefficient assuming a constant term equal to 0 and the related R^2:

$$R^2 = \frac{\sum_{i=1}^n (\hat{y}_i - \bar{y})^2}{\sum_{i=1}^n (y_i - \bar{y})^2}$$

To limit the number of combination of calibration coefficients to be tested, a two-stage calibration procedure was followed during the analysis.

In the first stage (i) random sets of calibration coefficients were selected from predefined ranges and tested in LANDPLANER, (ii) the corresponding values of the object functions were determined, (iii) the best combinations optimizing (maximizing or minimizing) the object functions were selected.

In the second stage, a local search of the optimal set of calibration coefficients is performed in the region (in the coefficient space) surrounding the values previously selected.

The application of the procedure in the Watershed 103 in the Lucky Hills area, resulted in couples of calibration coefficients similar to that estimates empirically in the study area.

This result from one side, showed that the erosion index was able to reproduce observed sediment yield in the basin, but also demonstrated that the simplified index is able to model accurately erosion processes in this and hence probably in other study area.

During the STM the original LANDPLANER code was modified to include the aforementioned procedures but also to allow the batch execution of the model, limiting the user intervention in the calibration phase or in sensitivity analysis experiments.

10.Future possible collaboration

During the STM was also possible to identify additional calibration approaches that will possibly make use of observed data at plot scale available for the different US locations. Basically, such approach will allow the selection of the best set of erosion index parameters in the different US plots geo-environmental conditions. This kind of analysis will allow defining possible over or under parametrization in the LANDPLANER erosion modelling schema. The calibration will require the use of the revised version of the dataset of US plot scale data, which is currently in progress.

Performing calibrations in areas larger than single plots comparing modelling results and observed sediment yields at specific catchments outlets, may results in biased parameter calibration sets. Working in the WGEW study area, Nearing et al. (2005) highlighted that the sediment yield from a watershed may have a limited relation with the rates of erosion within the watershed. This implies that for a proper initial model calibration, one should be considered either (i) data in limited areas where the sediment budget in know appropriately, or (ii) areas with a correct spatial estimation of the erosion and sedimentation rates. Further possible calibration phases will consider different spatial and temporal scales. In such cases, the long term erosion and deposition rates estimated inside small sub-catchments in the Walnut Gulch Experimental Watershed (Nearing et al. 2005) could be used. Those data should be considered as a benchmark for a long term spatial erosion simulation of LANDPLANER.

Finally, during the collaboration an additional was identified for the possible comparison test, the SWAT model (http://swat.tamu.edu/). The objective of the SWAT model is to predict the effect of management decisions on water, sediment, nutrient and pesticide yields with reasonable accuracy on large, ungauged river basins and include a procedure for the erosion estimation.

The SWAT model together with the RHEM model could be used as a benchmark for LANDPLANER in particular in the US territory.

References

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