Revision Notes

Ref: hess-2011-84,
Original Title: "Water harvest- and storage- location assessment model using GIS and remote sensing",
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Article Type: Special Issue: Looking at catchments in colors: new ways of generating, combining and filtering information in hydrology

Response to referee #3

(1) I find the suitability of the SCS-CN method for this framework to be questionable. I hope I misunderstood the presentation of the study, but I seem to understand that the potential runoff production is evaluated by applying the classical SCS-CN method at monthly timescale. The model is unsuitable for this purpose as it is well known that SCS-CN method is an event-based approach (e.g., "It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area", http://en.wikipedia.org/wiki/Runoff_curve_number) that ignores evapotranspiration, which may be extremely significant at monthly timescale Modifications are needed to adapt SCS-CN for continuous simulation (e.g. Moretti and Montanari, 2007) and, hence, for an application of the method at monthly timescale. As I already said above, I hope I misunderstood the presentation, if not, this is a serious theoretical concern.

- p.3, line 9: "Runoff is calculated endogenously in GWAMP model using the SCS-CN method". Unsuitable for monthly timescale. Evapotranspiration?

Response:
The reviewer is correct that our method does not compute actual runoff, i.e. the amount of runoff after evaporation.Our method estimates only gross runoff, i.e.the volume of rainfall that can potentially generate runoff. We do not estimate the actual runoff because this is a function of land-use.

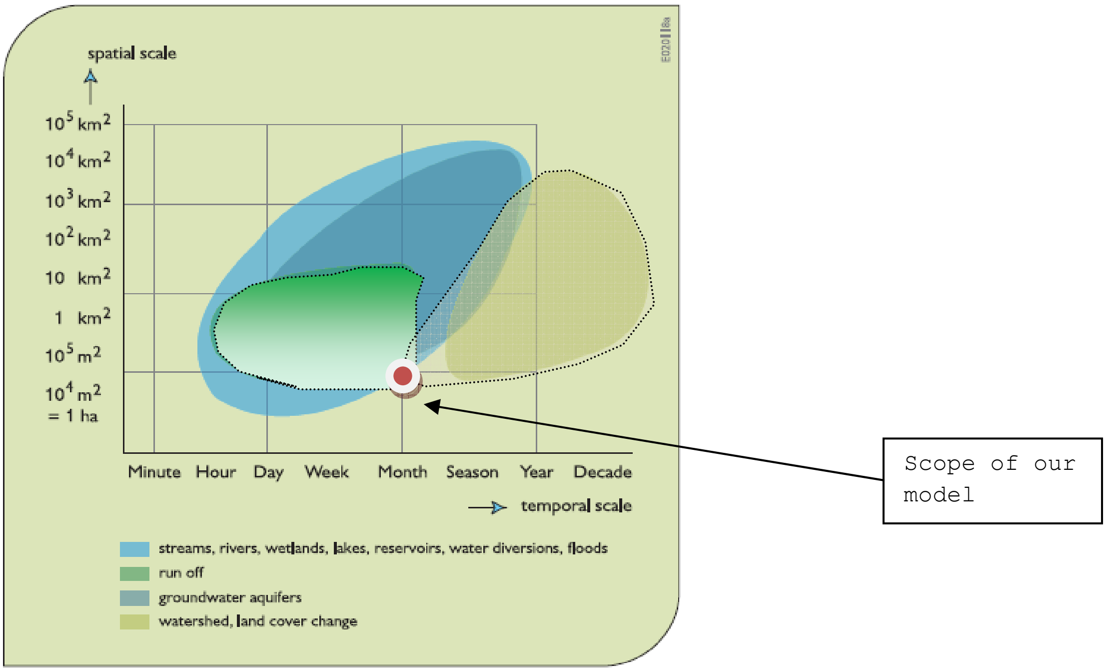
As explained above, our major objective is to establish water harvesting and storage potentials, which can improve the representation of water management adaptation in global integrated land use models. These land use models, e.g. GLOBIOM (http://www.iiasa.ac.at/Research/FOR/globiom.html?sb=14), solve for the optimal land use and land management distribution under various climate, policy, and development scenarios.Currently, most of these models do not adequately reflect locally diverse water management adaptation options.

The purpose of this paper is onlyto determine the natural suitability of different locations for water harvesting and storage options. Evapotranspiration will be accounted for in the integrated model.Crop management specific evapotranspiration estimates are part of local water balance equations that make sure that the different pathways of water are accounted for.

(2) Within the section "Methodology", the manuscript simply presents how the methodology was applied to the two case studies (see subsection 2.3 and sub-subsections therein) prior to presenting the case studies themselves and without illustrating general guidelines for application elsewhere, in catchments with significantly different morphological features or areas. The presentation needs to address these points.

Response:

We have improved the presentation of the methodology.Following is an illustration of the distribution of existing models in hydrology (in shades). The scope of our model is shown with the extension of the distribution in scope with dotted lines.



Graph adopted from Loucks et al. (2005).

LOUCKS, D. P., BEEK, E. V., STEDINGER, J. R., DIJKMAN, J. P. M., & VILLARS, M. T. (2005). ***Water resources systems planning and management: an introduction to methods, models and applications***. Paris, UNESCO.

The SCS methods presented herein are subject to the following guidelines and limitations:

1. These methods provide a determination of total runoff or peak flow only, which we consider as the maximum potential generated.
2. The watershed must be hydrologically homogenous, that is, describable by one of the CN. Land use, soils, and cover are distributed uniformly throughout the tiles.
3. Ia/P values should be between 0.1 and 0.5

- p.4, line 28: how is the raw score computed

Response:

We derive a compound suitability index combiningtwo main approaches that yieldtwo indices. The first index prioritizes the objectives using different weights and the second index identifies the suitability for a particular objective. The following description is based on the published work bySatty(1977,2002).

The first index represents weights for a set of activities according to their importance for a certain adaptation option. Reason to use this method is; the parameters we have used do not have a numerical value for its suitability. Therefore it involves human judgments on decision-making and consistency on the measurement need to be maintained.

The main goal of this index is to calculate the relative importance or strength of each factor/parameter that contribute to decision making, with respect to each objective (i.e. each adaptation option). For example here we consider, soil, elevation, slope, land use, soil type, and soil depth as parameters. These are the factors we consider as which contribute to water harvesting and storage. The aim of the approach is to maximize the benefit of each factor making it the objective. Each objective contributes to a certain adaptation option at different levels and objectives can be arranged into a hierarchy according to its influence.

These priorities are then converted to factor weights using a scale. To achieve that we use a pair wise comparison matrix combining all the factors. There, scaling formulation is then transferred into largest eigenvalue problem. This method is designed based on Perron-Frobrnius theory to in-order to get the largest real positive eigenvalue for matrices with positive entries.

The eigenvector is the vector of weights. The vector is normalized using the sum. The activities in the lowest level have a vector of weights with respect to each criterion in the next level derived from a pairwise comparison matrix. Weight vectors at any one level are combined as the columns of a matrix for that level. The weight matrix of one level is multiplied on the right by the weight matrix of the next higher level. If the highest level of hierarchy consists of a single objective then these multiplications result in a single vector of weights that indicate the relative priorities of lowest level entities to accomplish the highest objective of the hierarchy.

The scale we used here is recommended by Satty(1977)and it has been tested and compared with some other scales. The values we assigned to the scales are the qualitative information from literature. In general we cannot expect 'cardinal' consistency to hold everywhere in the matrix since the all the findings do not conform to an exact formula. Also we cannot expect 'ordinal' consistency since the recommendations may not be transitive. At the same time it should be able to represent difference shades of qualitative information and make comparisons.Therefore to improve the consistency in the numerical judgments, for a factor f_{ij} is assigned in comparing the ith activity with the jth, the reciprocal value is assigned to f_{ji}. Therefore $f_{ji}= 1/f_{ij}$. In simple terms if one activity is judged to be α times stronger than another, then we record the latter as only 1/α strong as the former. This can be easily seen when we have consistency.

The next issue is what numerical scale to use in the pair wise matrix. The fact is that the numbers must be sensible and from these eigenvalue process would produce the scale. According to Satty (1977) the best argument in favor of the scale is whether it can be used to produce results known in subject domain and the scaly is better to have small values of n<10. According to Miller (1956), psychological experiments show that individual cannot simultaneously compare more than seven objects (±2). Therefore the scale Saaty has proposed has can be presented as following.

If scale values are $x_1, x_2, x_3 \ldots x_p$, thenlet

$$x_{i+1} - x_i = 1,\ i1,\ldots\ldots\ldots,P-1$$

$$\text{and } P = 7+2 \text{ AND } x_1 = 1$$

then the scale values will range from 1 to 9.

The representations of the scale values are presented in the following table. We have developed the comparison matrix using the 1-9 scale presented here.

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance is demonstrated in practice.
9	Absolute importance	The evidence favoring one activity over another is of the high highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	of If activity i has one of the above when compared with activity j, then j has the reciprocal value when compared with i	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

The second index; suitability level index defines its suitability for water harvesting and storage using the exact value of the factors. Combination of both factors makes the combined index that defines the overall suitability of a pixel.

- p.6, line 18: "1km", suitable for the main goal? Applicable elsewhere? Provide guidelines and references. See major point (2)

Response:
The model uses several input datasets including i) a 90mx90m STRM DEM dataset(3 arc second),(the NASA Shuttle Radar Topographic Mission (SRTM) has provided digital elevation data (DEMs) for over 80% of the globe), ii)a 5-arc minute land use dataset, and iii) a 5-arc minute soil type dataset. To our knowledge, these are the currently available datasets with the highest resolution at global scale.

- p.7, lines 3-4: The algorithm needs a depressionless DEM? Why? Please explain.Why interpolation is used among other alternatives?

Response:

We use a DEM to develop the water flow path on the terrain surface.A sink could interrupt thepotential flow path from higher to lower elevations and create anunrealistic end point.

The identification and removal of sinks is an iterative process when creating a DEM without depressions. Through interpolation, we avoid that the filling of a sink, create new sinks.

- p.7, line 13: ". . .surface to create contour lines in 10m intervals in raster (grid) format", is 10m suitable for applications in general? Applicable elsewhere? Provide guidelines and references. Plus, the sentence is unclear, contour lines in raster format on a 1m pixel?

Response:
We use 10m contour intervals because it is the highest resolution for the Sao Francisco watershed that is computationally feasible on standard PCs. We want to assess the variation of undulating topography within a 1km grid box.

- p.8, line 6: principal? Are the information on the arc minutes important?

Response:
Yes. The information is given to document the different spatial resolutions of the input data.

- Conclusions: "The application of GWAMP in the two case studies demonstrates its suitability to identify potential sites for rain water harvesting and storage." The take home message is misleading, only water storage was verified, in two case studies, and the analysis, as it is described and presented in this manuscript, is not replicable elsewhere nor in the same catchments considered in the study. I do not think the term “demonstration” is suitable in this context. Conclusions need in my opinion to be significantly revised.

Response:
This method attempts to estimate the natural suitability of a certain land parcel for water harvesting and storage. We can only compare our results to existing locations for water harvesting and storage but we cannot validate our results (see also explanation on difference between economic and natural suitability above). We have added more comparison in the revised version of the paper which include water harvesting structures.

On the other hand, we have adjusted the method so that it is globally applicable even in ungauged basins. We have converted the discrete scores to continuous scale to minimize the information loss and we have included salinity threat as additional criterion.

In addition we have improved the presentation of our results by adding computed suitability maps for different land use scenarios.