LANDSIM-Regional: hands-on training

Tutorial

Wageningen, The Netherlands
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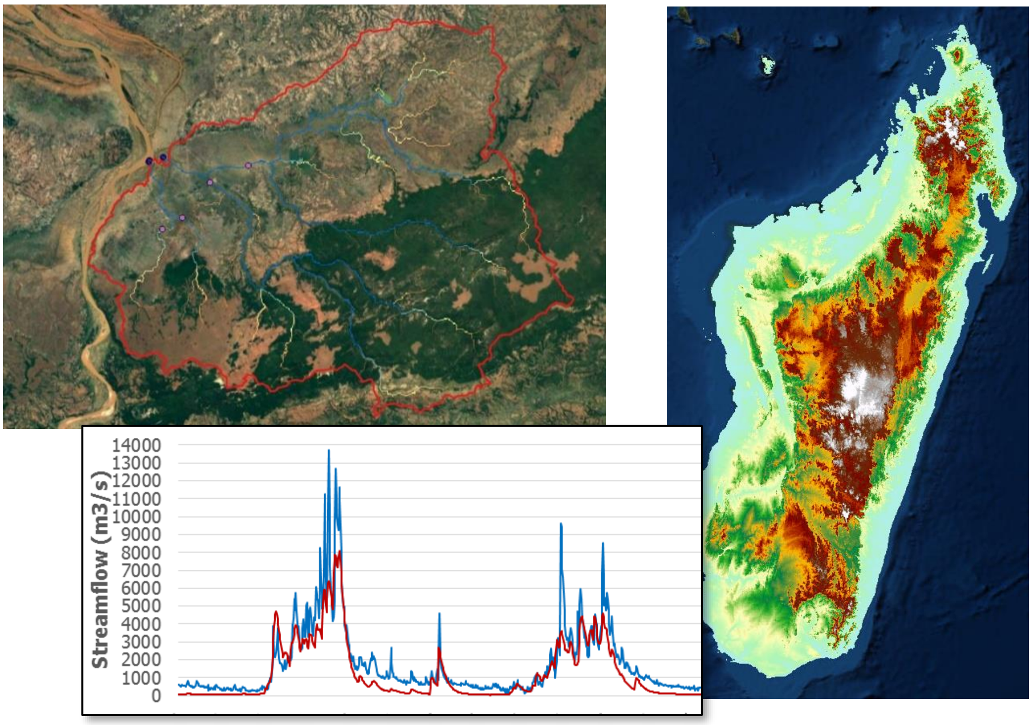

Authors
G.W.H. Simons
J.P.C. Eekhout

FutureWater
Costerweg 1V
6702 AA Wageningen
The Netherlands

+31 (0)317 460050

info@futurewater.nl

www.futurewater.nl

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1 Introduction

1.1 Background

The World Bank has initiated a program of technical assistance in Mozambique and Madagascar (LAUREL), intended to support integrated decision making for landscape management across sectors and levels of government. Within the LAUREL project the LANDSIM-P platform is being developed, which has the objective of supporting policy makers by providing an integrated assessment of the impact of current and future land use and land management on the status and risk of land degradation and land-based ecosystem services. To achieve this aim, LANDSIM-P offers a flexible number of high-level strategic output variables (SOV) indicative of core environmental and socio-economic performance. The core components of LANDSIM-P are an integrated assessment model (IAM), operated at the national scale, and a more detailed hydrology and erosion modelling toolbox, run at the regional (catchment) scale (LANDSIM-R).

As part of an extension of the LAUREL project, a selected group of representatives from the *Projet Agriculture Durable par une Approche Paysage* (PADAP) program are trained by FutureWater in hands-on use of LANDSIM-R, to support planning and implementation of Sustainable Land Management (SLM) interventions. This tutorial serves as training material to gain proficiency in setting up and running LANDSIM-R, interpreting simulation results, and tailoring the tool to a specific application or catchment.

1.2 LANDSIM-R description

The specific purpose of LANDSIM-R is to assess the effects of changes in land use and management, and ensuing land degradation or restoration, on downstream water availability and sedimentation. More specifically, the main strategic output variables to be gained from the toolbox are:

- River discharge / water availability (m^3/s)
- Sediment concentration (g/m^3)
- Soil erosion rate (tons/ha)

Development of a LANDSIM-R prototype has been completed and the tool is now available for testing and usage by end users in Madagascar. Rather than just comprising a simulation model, LANDSIM-R is provided as a toolbox, consisting of input data and pre-processing tools required to set up the biophysical model for a catchment of choice. This minimizes the number of steps that need to be taken by an end user before results can be obtained and analyzed. At the same time, the LANDSIM-R toolbox source files are flexible, and its functionality can be modified and expanded by the user, if so desired. This includes both the incorporation of new, updated input data, as well as configuration of additional SLM scenario runs. LANDSIM-R and all its components, as well as required supporting software, are open-source and freely available.

LANDSIM-R consists of three components (Figure 1). The national database contains national-scale data of all required model inputs, most of which is provided in spatial (rasterized) format. The database is composed of state-of-art geospatial products. By navigating a simple Graphical User Interface (GUI), the LANDSIM-R user can automatically generate detailed models for specific catchments of interest, based on the reference database with national-scale data and the hydrological boundaries. For example, in case the user is interested in the inflow of water and sediments into an irrigation scheme, the upstream catchment is automatically delineated based on an elevation map and all required model inputs will be produced by the pre-processing tools, with the appropriate coordinate projection and spatial resolution. The core of the biophysical modelling is a modified version of the Spatial Processes in HYdrology (SPHY) model, tailored to conditions in Madagascar and SLM applications.

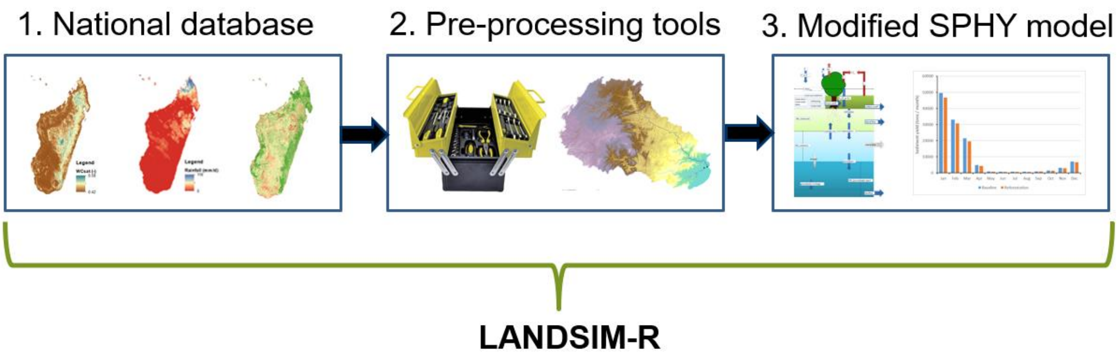

Figure 1: Schematic overview of the three components of the LANDSIM-R toolbox.

For a detailed description of LANDSIM-R's theoretical background, installation, and operation, the reader is referred to the LANDSIM-R user manual. This tutorial provides a set of exercises and questions targeted at a novice LANDSIM-R user, who is already acquainted with common GIS operations (particularly raster calculations and conversions between common formats) and Microsoft Excel. The tutorial is supplemented with datasets and presentations provided by the trainers.

2 Building a LANDSIM-R model

We are going to build a model for the Marovoay catchment, one of five pilot sites selected within the PADAP program. The Marovoay plain is an important rice-producing area in Madagascar. However, it is threatened by extensive land degradation in the upstream catchment and increasing climate variability. LANDSIM-R can be useful for evaluating different scenarios of land management and climate change.

Figure 2: The location of the Marovoay catchment.

As this is the first LANDSIM-R model you will build, it will be done by following the demonstration given by the trainers. All necessary steps to create a catchment-specific LANDSIM-R model are also extensively documented in the LANDSIM-R user manual, Chapter 5.

After completion of the exercises and questions in this tutorial for the Marovoay catchment, feel free to build your own LANDSIM-R model for any area in Madagascar.

Exercise 2A:

Follow the on-screen instructions provided by the trainer to build a catchment-scale model of Marovoay.

3 Sensitivity analysis

3.1 General

A sensitivity analysis (what-if analysis) is a technique used to determine how projected model performance is affected by changes in the inputs. Sensitivity is generally measured as the response of an output variable to a change in an input parameter, with larger output response changes corresponding to larger sensitivities. It evaluates how different parameters influence a predicted output. Sensitivity analysis is often used to compare different scenarios and their potential outcomes based on changing conditions. Parameters identified in sensitivity analysis that influence predicted outputs are generally used to calibrate a model.

The main objective of the sensitivity analysis is to understand the contribution of the model parameters to the physical processes in the hydrological system. This exercise will help the users to identify the most sensitive parameter(s) and eventually help the model calibration process. At the end of this exercise, you will have a better understanding of the model parameters.

3.2 Methodology

The model is first run with an initial parameter set, which will be referred to as the reference model run. The parameters will be changed one at a time and compared with reference model run. In this way the effect of a change in a model parameter can be obtained by comparing the two simulated output datasets. A sensitivity analysis will be performed for parameters related to hydrology, soil erosion and sediment transport.

3.3 Hydrology

Exercise 3A:

Select *01-01-2003 as* your starting day and *31-12-2005* as end day for the simulation in the config file. Change the parameter values in the config file corresponding to the values shown in the Table 1. Now run the model and open the **PrecSubBasinTSS.tss, ETaSubBasinTSS.tss** and **QTOTSubBasinTSS.tss** from the output folder. Copy all the content of these files to the **Water balance** work sheet of **Sensitivity_analysis_hydrology.xlsx**. In the top right corner, the annual water balance will be shown. Copy the time series of the total runoff (from cell J9 onwards) to the **Sensitivity** worksheet under Reference run.

Table 1: Initial values of several model parameters.

Section	Parameter	Initial value
[SOILPARS]	RootDepthFlat	2000 (forest)
	RootDepthFlat	200 (other land use classes)
	CapRiseMax	2
[GROUNDW_PARS]	deltaGw	200
[ROUTING]	Kx	0.93

Q3.1: For each of the parameters in Table 1, explain which impact you expect on hydrology when their values become higher or lower.

Exercise 3B:

Now fill the **Parameter set** worksheet in the same excel file. The reference parameter set is based on the values from Table 1. Try to tabulate the other parameter sets. Make sure you follow the same convention as followed in the worksheet (first a 50% increase and then 50% decrease). After completing the table, run the model again with changed parameter values. So, for the first sensitivity model run set the value for root depth to 1000 mm for forest and keep all the other parameter values to the reference values.

The root depth values need to be prepared in a new input map. Use QGIS to set a value for the cells with forest cover (land use classes 111, 112, 114, 122 and 124) and a value for all other land use classes. Make sure to save the new map with a file name that includes the values of the root depth. For instance, root_depth_forest_2000_rest_250.map in case the root depth in forest is 2000 mm and 250 mm for the other land use classes. In the config file change the name of the map after *RootDepthFlat* **=** to the new file name.

After the end of each sensitivity run, copy the simulated actual evapotranspiration and total runoff to the **Water balance** worksheet. The precipitation time series won't change, so this will stay the same for all sensitivity and calibration model runs. Then select only the time series of the total runoff and copy the values to the **Sensitivity** worksheet in the column of the sensitivity model run.

In the upper part of the **Sensitivity** worksheet some metrics are determined based on the comparison between the sensitivity model runs and the reference model run. The bias in percentage is determined for the whole time series and for the rainy and dry season, respectively. The start and end of the rainy season can be adjusted in the top right corner of the worksheet.

After you have finished all sensitivity model runs, answer the following questions:

Q3.2: Which parameter is the most sensitive on annual basis?
Q3.3: Is this different for the rainy and dry seasons? If so, why do you think this is different?
Q3.4: Which season(s) is/are the most important for your modelling objectives and why?

Select the 3 most sensitive parameters to be used for calibration.

Q3.5: Now we have performed the sensitivity analysis focusing on discharge only. Which parameters do you think has the largest impact on simulated actual evapotranspiration?

3.4 Soil erosion

In the case of soil erosion, we will be looking at the average soil loss per land use class, which is determined as follows. We will be working with the **Sensitivity_analysis_soil_erosion.xlsx** document.

As with the sensitivity analysis of the hydrological parameters, we will first store the simulated soil loss from the reference model run in the **Simulation results** worksheet. These values will be compared with the values obtained from the sensitivity model runs where the parameters are changed.

We will focus on the model parameters from the Morgan-Morgan-Finney (MMF) table, which are land use specific. Hence, we can look at how the sensitive the model parameters are for each of the land use classes. This knowledge can be used in the calibration, to select the most sensitive model parameter per land use class. The table contains 10 parameters. Here we will focus on the most relevant parameters, i.e. plant height, stem density, stem diameter, ground cover and Manning's n.

Exercise 3C:

First, determine the long-term average soil loss based on the soil loss map output. The output maps get the following file names: **STransY0.366**, **STransY0.731**, **STransY1.096**, etc. In QGIS, you can determine the average of these maps by applying the **Statistics for Grids** tool in the Processing Toolbox. Then, the average per land use class can be determined with the **Zonal Grid Statistics** tool.

Q3.5: Which of these parameters can be easily obtained from field measurements?
Q3.6: Which parameter would be more difficult and could potentially be a good candidate for model calibration?

Exercise 3D:

Go to the **Parameter set** worksheet and change a parameter, i.e. set the value in the blue box to -50 or 50. Leave all other values in the blue boxes to 0. The values are automatically copied to the worksheet **Copy to mmf.tbl**. Select all values and copy these to **mmf.tbl**. Save **mmf.tbl** and run the model. Then determine the average yearly soil loss per land use class in QGIS as described above. Copy the data to the **Simulation results** worksheet, in the column referring to the model parameter and percentage change.

Not all model parameters are used for all land use classes. It is good practice to use the stem density and stem diameter for crops. These input parameters can be measured in the field. The ground cover can be determined from these two values. It is important to note that when the stem density and stem diameter are used, the Manning should be set to 0 and the ground cover should be determined with a formula. As an example, in the current exercise the ground cover for Cassava, Maize and Lowland rice are determined based on the stem density and stem diameter. Make sure that the Manning for these three land use classes are set to 0 and the ground cover is not manually set.

The **Sensitivity** worksheet shows the bias of the sensitivity run with respect to the reference model run. In this worksheet, mark per model parameter the land use classes with the highest sensitivity.

Q3.7: Which parameter per land use class is most sensitive?
Q3.8: Which land use classes are most sensitive?

Per land use class, select the most sensitive parameter to be used for calibration.

Exercise 3E:

The soil erosion module also allows to specify a sowing-harvest cycle, which is defined in **mmf_harvest.tbl**. We have set this up for the cropland classes, i.e. Cassava, Maize and Lowland rice. As an extra exercise, you can try to see how the soil erosion is affected by changes in the start date of this cycle or by changing the model parameters after the crop is harvested.

Q3.9: Which parameter of the harvest table is most sensitive?

Q3.10: How can these parameters be obtained from the field to get a better representation of the actual conditions?

3.5 Sediment transport

The sediment transport module only contains a few parameters. The transport capacity equation is the main equation used in this module. This equation contains two model parameters, i.e. beta and gamma. The sensitivity of these two parameters will be tested in the final part of the sensitivity analysis.

Exercise 3F:
Here, we will be working with the **Sensitivity_analysis_sediment_transport.xlsx** document. The sensitivity of the sediment transport module follows the same logic as the sensitivity of the hydrology. Instead of the total runoff, here the sediment flux at the catchment outlet will be used to determine the sensitivity of the model parameters. After each model run, copy the contents of **SFluxDTS.tss** to the **Model output** worksheet. Then only copy the values with the dark yellow background to the **Sensitivity** worksheet in the respective column. The bias with respect to the reference will be determined for each sensitivity model run.

Q3.11: Which parameter is most sensitive?

Select one of the two parameters to use in the calibration of the sediment transport.

4 Model calibration

4.1 General

Model calibration is the process of selecting suitable values for model parameters such that the hydrological behavior of a catchment can be simulated closely to the real situation. The goal of model calibration is to "optimize" the model so that the simulated output resembles the observed output as close as possible.

The calibration process can be either manual or automatic. In practice, however, it is often a combination of the two. Manual calibration relies on the modeler's knowledge; being familiar with the SPHY model concepts and river basin characteristics allows you to speed-up the calibration process by manual adjusting the model parameters, and going through the trial-and-error process more efficiently. Through automatic calibration the model is forced to run with either a predefined or random set of initial parameter values. The advantages of automatic calibration are to i) speed-up (in terms of computational efficiency) the calibration process and ii) end up with a better optimized model. For this training we use the manual calibration approach.

4.2 Methodology

It is best practice to use a longer time series for model calibration. This will give more confidence that the model performance well under different climatic conditions. Select **01-01-2003** as your starting day and **31-12-2010** as end day for the simulation in the config file. Each hydrological model needs a spin-up period to arrive to a stable storage situation. Here we use a spin-up period of 1 year, which is sufficient in most cases. Take this into account when analyzing the data. For the time series output (total runoff and sediment flux) the excel sheets are already prepared to discard the data for the first year. For the soil erosion maps, you should use all the output maps, except the map from the first year, ending with *.365*.

We will follow the same order as in the sensitivity analysis, hence, we will first calibrate the hydrological part of the model, then the soil erosion module and at last the sediment transport module. In the first part of the calibration process, we can switch of the soil erosion and sediment transport modules to speed-up the process.

A commonly accepted criterion to indicate how well a model is able to simulate observations is the Nash-Sutcliffe model efficiency coefficient (*NSE*, Nash and Sutcliffe, 1970). The *NSE* is defined as:

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

where $\bar{Q}_o$ is the mean of observed discharges, and Q_m is modeled discharge. $Q_o{}^t$ is observed discharge at time t.

The table below provides an indication of how the model performance can be characterized by the Nash-Sutcliffe efficiency.

Table 2: Description of fit linked to Nash-Sutcliffe model efficiency coefficient (Adapted from Foglia et al., 2009).

Fit	Nash-Sutcliffe efficiency
Observed mean is a better predictor than the model	<0
Insufficient	0- 0.2
Sufficient	0.2-0.4
Good	0.4-0.6
Very good	0.6-0.8
Excellent	>0.8

4.3 Hydrology

Exercise 4A:

We are going to calibrate the hydrological model with the model parameters selected from the sensitivity analysis. For the first calibration model run, we use the values from the reference run of the sensitivity analysis, see Table 1. We will use the same model output as in the sensitivity analysis and the same procedure to copy the time series to the excel document (**Calibration_hydrology.xlsx**). After each calibration model run, fill the **Parameter set** worksheet with the model parameter values used in the respective model run. Also you will need to copy all the content of the three TSS files to the **Water balance** worksheet of **Calibration_hydrology.xlsx** and copy only the total runoff time series to the **Calibration** worksheet.

Monthly total runoff will be determined from the daily time series. These data will be compared with runoff observations. Calibration metrics from two objective functions will be determined, i.e. the bias in percentage (0 is best) and the Nash-Sutcliffe model efficiency (1 is best). These two model parameters need to be optimized. The monthly time series are plotted in the **Plot timeseries** worksheet.

As you have seen from the sensitivity analysis, the routing parameter *kx* does not affect the annual bias. It is therefore best to first optimize the bias with the other parameters (water balance calibration) and in a last step optimize the Nash-Sutcliffe model efficiency with the routing parameter *kx* (time series calibration).

4.4 Soil erosion

Exercise 4B:

Soil erosion rates and sediment yield can be obtained from field studies, such as soil erosion plots studies and sediment flux measurements in rivers. Due to the intermittent nature of soil erosion, long-term plot studies are needed to get a reliable estimate of soil erosion. Therefore, here we use a database obtained from a large amount of plot studies that were performed under different climate and land use conditions. For reference, see the Literature data worksheet from the Calibration_soil_erosion.xlsx document with the reference values for all climate and land use classes. The values are obtained from Maetens et al. (2012) and are in ton ha-1 yr-1. We have preselected the data that would be most appropriate for Madagascar, i.e. a temperate climate. No data is available for rice fields. For rice fields we assume an erosion rate of 0.25 ton ha^{-1} yr^{-1}.

The soil erosion rates per land use class will be determined similarly as during the sensitivity analysis. The only difference is that only the most upstream located cells will be used here. The data obtained from Maetens et al. (2012) are from plot studies with a maximum slope length of 250 m. This only corresponds to the most upstream located cells, where the accuflux map equals 1. In QGIS, first the average soil erosion rate needs to be determined as described in the sensitivity analysis. But here, discard the data from the first year and only use the data from the last 7 years (from 2004 onwards). Then use, the land use map for soil erosion calibration (**landuse_calibration.map**) to determine the average soil erosion per land use class. Copy these values to the upper table of the **Calibration** worksheet from the **Calibration_soil_erosion.xlsx** document. In the lower table the bias per land use class will be determined based on the Calibration values.

Then look at the bias for that particular calibration run. If the bias is larger than 5%, go to the **Parameter set** worksheet and change the model parameter you have selected for each land use class. It is useful to highlight that parameter with a color to not get confused with another parameter. Change the parameter. Repeat this for all the land use classes that have a bias larger than 5%. Since the Literature database does not differentiate between the different forest types (open vs. closed and evergreen vs. deciduous) and the different shrubland types (shrubs and herbaceous vegetation), we advise to group these land use classes and give the same parameter value to each forest and shrubland class.

Make sure that you copy the contents of the **Copy to mmf.tbl** worksheet to the mmf table. If you also want to change something in the harvest table, then also copy the contents of the **Copy to mmf_harvest.tbl** worksheet to the harvest table.

4.5 Sediment transport

From the sensitivity analysis you have selected 1 model parameter (TC_beta or TC_gamma) to calibrate the sediment transport. Similar to the calibration of the hydrology, here we will calibrate the sediment flux with an observed monthly time series. Unfortunately, no sediment flux data are available, so here we use data obtained from a calibrated model as substitute for observations.

Exercise 4C:
Similar to the calibration of the total runoff, here the model results are evaluated with bias (%) and Nash-Sutcliffe (-). After each model run, copy the contents of **SFluxDTS.tss** to the **Model output** worksheet from the **Calibration_sediment_transport.xlsx** document. Then only copy the values to the Calibration worksheet, from which the monthly average sediment flux is determined. These values are subsequently used to determine the bias and Nash-Sutcliffe. Try to optimize the bias and Nash-Sutcliffe model efficiency to 0 and 1, respectively.

5 LANDSIM-R applications

5.1 Identification of erosion hotspots

LANDSIM-R can be used to map hotspots of erosion. The model simulates two types of erosion: erosion from rainfall, and erosion from runoff. Both are saved separately. Part of the detached material, however, is not transported downstream but remains in the pixel of origin.

Q5.1: Read Section 2.6 of the LANDSIM-R user manual to better understand how the tool handles erosion. Equation 53 is especially important to understand. Can you explain in your own words what happens here?

<u>Exercise 5A:</u>
Now, use GIS software such as QGIS or ArcGIS to make maps of the erosion caused by rainfall, runoff, and the total amount of sediment taken into transport. An example for Bealanana is provided in Figure 3.

Q5.2: Where are the erosion hotspots in Marovoay located?
Q5.3: Is erosion mainly caused by rainfall or by runoff in these areas?

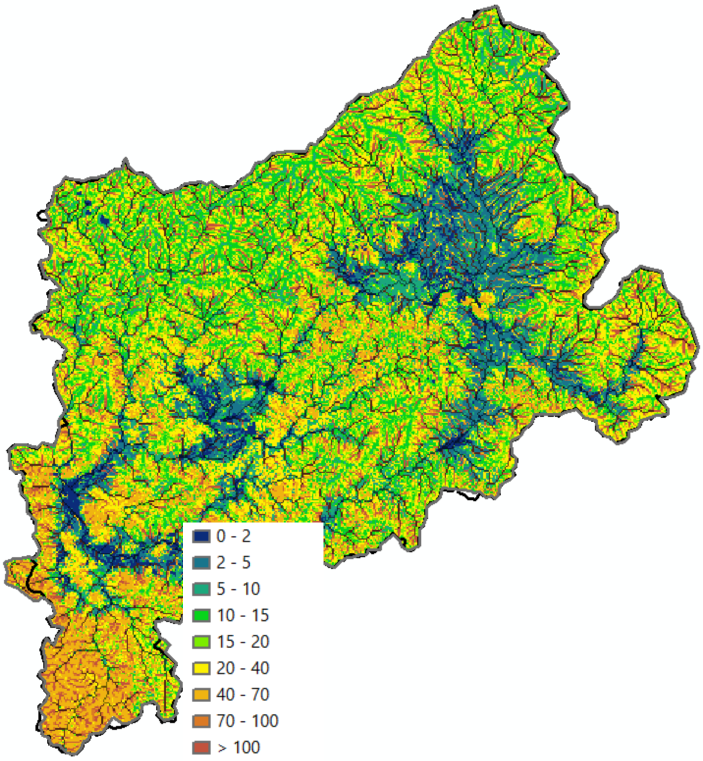

Figure 3. Map of total erosion in Bealanana catchment (values in tons per cell).

In order to understand why LANDSIM-R computes high values of erosion in a certain location, it is helpful to look at the model inputs. This may also give you further information on which SLM intervention may be effective at that specific location.

Q5.4: Think about which model input variables are likely to influence spatial erosion results, and open these maps in your GIS window. What do you see in the hotspot locations? Which variables seem to cause the erosion to be high there?

Exercise 5B:

Erosion is not only highly variable in space, but also in time. It is closely linked to climate and will therefore typically vary throughout the year. To examine this, we need LANDSIM-R to produce a time series of data, which can be plotted in a graph. As you know, LANDSIM-R saves tables with time series for each of the locations highlighted in the **stations.map**. Now, use QGIS to add a new station located in one of the erosion hotspots. This requires the creation of a new shapefile with a point on the selected location, and conversion of this shapefile to a raster. Convert the newly created raster file to a PCRaster .map by clicking **Raster** -> **Conversion** -> **Translate**.

Now, re-run your model with the new stations map and make an erosion graph in Excel for the selected location.

Q5.5: In which months do you typically observe high erosion rates? Can you explain why?

5.2 Exploring on-site impact of an SLM measure

After completing the previous section, you now have an idea of where the major source areas of sediment are located, and why erosion is so high on these locations. LANDSIM-R allows you to simulate 4 SLM interventions and examine their impact on on-site erosion. These are (i) terracing, (ii) reforestation and forest restoration, (iii) agroforestry, and (iv) reduced tillage. LANDSIM-R needs an **interventions.map** for this, of which you can see an example in Figure 4. By default, all values in this interventions map are set to 0.

Q5.6: Based on your findings in section 5.1: which of the four SLM interventions is most likely to reduce erosion in the hotspots?

When applying SLM measures in the model, input parameters are changed according to the values listed in **interventions.tbl**.

Exercise 5C:

For the SLM intervention you selected under Q5.6, carefully review the values in *interventions.tbl* and try to understand why they are there. If necessary, you are free to modify them.

Now, use QGIS or ArcGIS to create a new interventions map which introduces the selected SLM measure in the erosion hotspots. You could make this map for example by applying conditional functions as possible in the **Raster Calculator,** e.g. by using land cover type, slope and/or NDVI as conditions. Convert the newly created raster file to a PCRaster .map by clicking **Raster** -> **Conversion** -> **Translate**.

Run the model with the new **interventions.map** and investigate the impact of the applied intervention. You can do this for example by making a difference map of total erosion, by subtracting the baseline situation with the new map. You can also investigate the difference in erosion over time, e.g. by comparing time series results.

Q5.7: Look at the site you added for Q5.5. What is the reduction in erosion (in %) at this site on an annual basis?

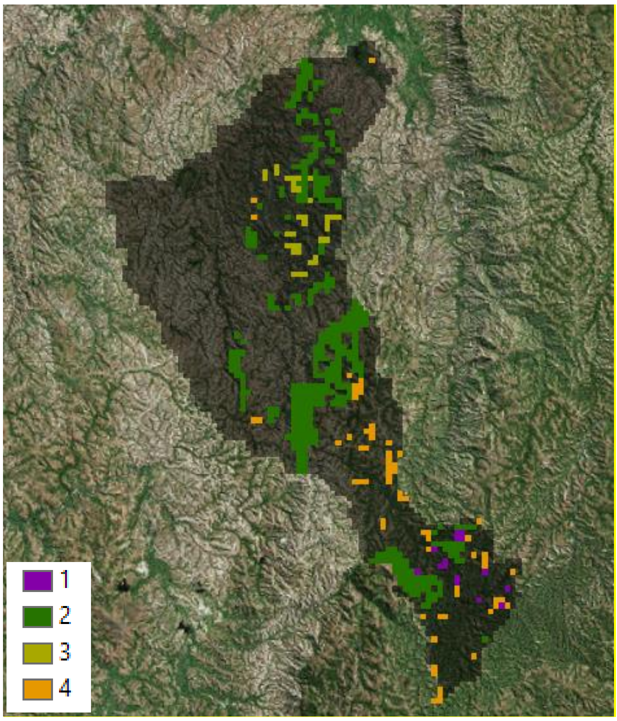

Figure 4: Example interventions map for a catchment in Madagascar (1 = Terracing, 2 = reforestation and forest restoration, 3 = Agroforestry, 4 = Reduced tillage).

5.3 Impact of an upstream SLM measure on downstream sediment flux

Apart from the on-site erosion, LANDSIM-R also simulates the transport of the sediment downstream. Daily time series of sediment flux in tons are saved for each station location in the file **SFluxDTS.tss.**

Q5.8: What are the most important locations in Marovoay for which you would like to report the sediment flux?

Exercise 5D:

Check if the location(s) of your interest is / are already included in **stations.map**. If not, use QGIS to add a new station located in one of the erosion hotspots. This requires the creation of a new shapefile with a point on the selected location, and conversion of this shapefile to a raster. Convert the newly created raster file to a PCRaster *.map* by clicking **Raster** -> **Conversion** -> **Translate**.

If you introduced a new station, first re-run the model with and without the SLM intervention. Then evaluate the results in **SFluxDTS.tss** by copying its contents to Excel.

Q5.9: How has the new intervention affected the downstream arrival of sediment at the various stations in Marovoay? Can you explain why?

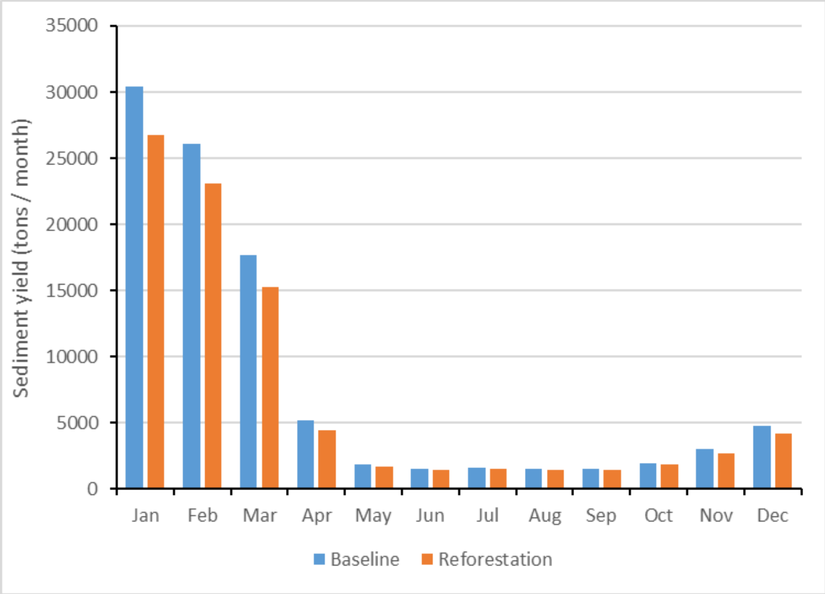

Figure 5: Example of downstream sediment flux analysis with and without upstream reforestation.

5.4 Impact of an upstream SLM measure on downstream water availability

It is well-known that changes in land management and / or land cover can also affect the water balance. This is not only noticeable on the site of the intervention, but typically also downstream. When important downstream water demand sites are present, such as the irrigated perimeter in Marovoay, the effect on hydrology and downstream water availability is especially important to assess.

Exercise 5E:
Use the results from your previous model runs to evaluate the impact of the SLM intervention on the water balance. Pay special attention to the yearly maps of *Baser* (generated baseflow) and *Rainr* (generated rain runoff, or "fast" runoff), and how results differ for the runs with and without the intervention.

Q5.10: By making maps of the difference between the two runs in terms of yearly average baseflow and rain runoff, can you explain how the SLM intervention has affected the water balance?

Exercise 5F:
In the same way that you analyzed the sediment flux at station sites, now also look at the river discharge at these locations (**QallDTS.tss**). Note that LANDSIM-R outputs allow you to investigated the specific contributions of baseflow (**BTotDTS.tss**) and rainfall runoff (**RTotDTS**) to the total river discharge, for a better understanding of the hydrological system.

Q5.9: How has the new intervention affected water availability in the river at the various stations in Marovoay? Can you explain why?

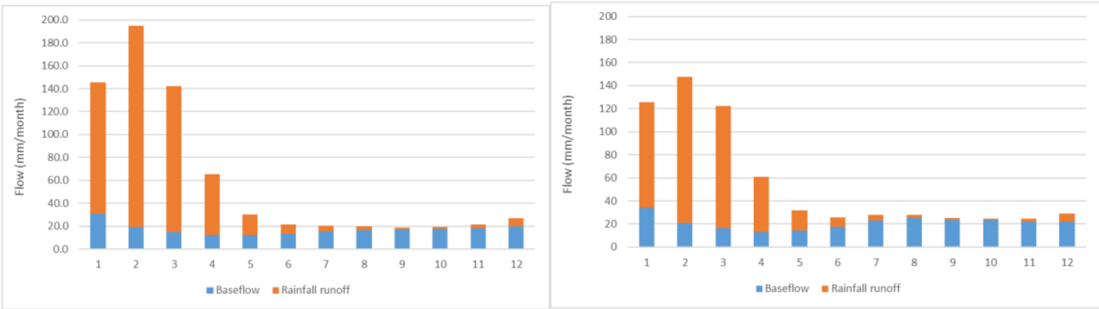

Figure 6: Example of river flow analysis without (left) and without (right) upstream reforestation. Note that total flow is partitioned in baseflow contribution and fast runoff.

6 How to modify and expand LANDSIM-R

6.1 Incorporating new data

LANDSIM-R is delivered with a default database, which is compiled based on current data availability. However, it is highly probable that improved data will come available over the next years. If these are data on model outputs, such as river flow or erosion, they can be used to update model calibration as described in Chapter 4. If these newly collected data concern model inputs, the LANDSIM-R database needs to be updated.

There are two options for updating LANDSIM-R data. Which one to choose depends on the spatial scale of the new dataset, i.e. whether it is available for the entire country or just for a specific catchment. In this training we are going to practice both cases, for a variable that is most likely to be updated over the next years: land cover.

6.1.1 Updating input data for a specific catchment model

In this section, we assume that a new land cover map has come available for a specific catchment that you are interested to run a model for. Likely, this map will have different land cover class ID values than the original land cover map. For this reason, it is also needed to modify the two tables **mmf.tbl** and **mmf_harvest.tbl**, which are lookup tables based on the land cover classes in the map.

Exercise 6A:

The trainers will provide you with an alternative land cover map for Madagascar from a different global product. Use QGIS to save this map for the same extent as the other model input files by right-clicking the raster layer name and choosing **Save As**, which will allow you to specify the appropriate spatial domain and resolution. Then, convert the newly created *.tif* file to a PCRaster *.map* by clicking **Raster** -> **Conversion** -> **Translate**.

Now, evaluate the IDs and classes occurring in this map, and modify **mmf.tbl** and **mmf_harvest.tbl** accordingly. Think carefully about appropriate values for each of the parameters in the tables.

When finished, execute your model with the new land cover map and evaluate the changes compared to the earlier runs.

6.1.2 Updating input data in the national database

The *database* folder contains a text file **metadata.cfg**, which lists the specification of all datasets included in the database. This file needs to be modified when a new dataset is introduced. For the land cover map, that means that the properties as listed in Figure 7 need to be adjusted. Currently, the Copernicus land cover map for Africa is included in the database.

Exercise 6B:

The trainers will provide you with an alternative land cover map for Madagascar from a different global product. Copy this file to a new folder in the **database** directory and adjust the **metadata.cfg** entries accordingly. Now, test your updated database by running the SPHY preprocessor and building a new model with this land use map.

```
[LANDUSE]

source = Copernicus
file = Land_use/LULC_Madagascar.tif
format = GTiff
EPSG = 4326
xmin = 43.15
xmax = 50.7
ymin = -25.8
ymax = -11.85
```

Figure 7: Screenshot of land cover metadata as currently included in the LANDSIM-R database metadata configuration file.

In a similar way, the database can be updated with the updated land cover map produced by the national LANDSIM-R component, which simulates e.g. changes in spatial agricultural and urban land use patterns.

Exercise 6C:

If time allows, the trainers will provide you with an updated climate forcing dataset (rainfall and temperature) based on climate model outputs for the 2030-2050 period. By including these in the national database, you can execute runs to examine the impact of climate change on the key LANDSIM-R output variables (see examples in Figure 8 and Figure 9).

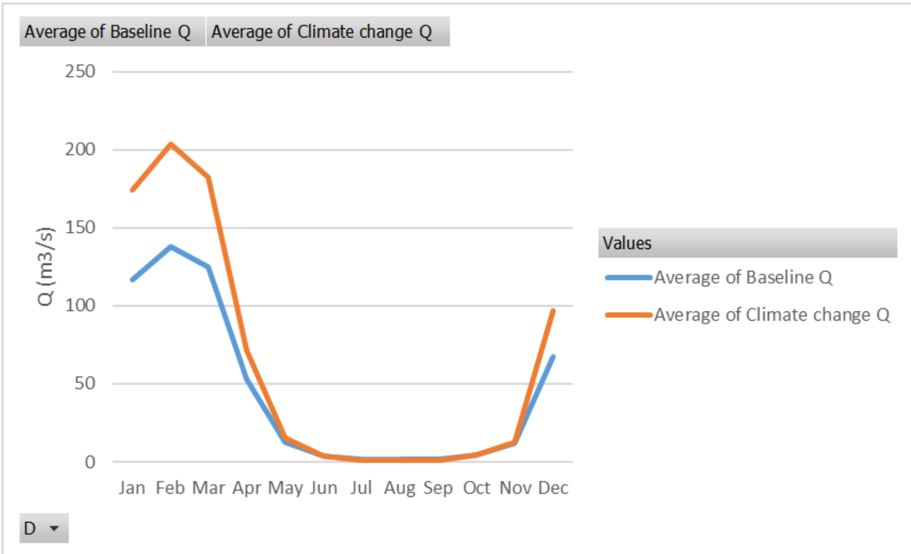

Figure 8: Example results of climate change impact on downstream river discharge in Bealanana.

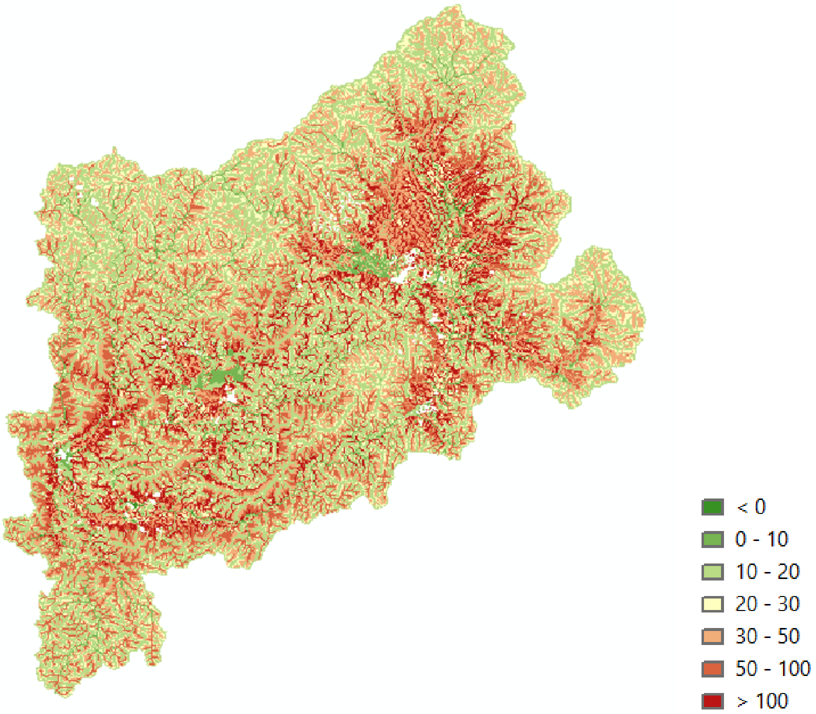

Figure 9: Example results of climate change impact on on-site erosion in Bealanana (values indicate increase of erosion in tons per cell.

6.2 Adding new SLM interventions

As explained before, LANDSIM-R in its standard configuration offers 4 preset SLM interventions that can be simulated. However, additional interventions can be parameterized if so desired, by modifying **interventions.tbl** in the input folder. This table prescribes, for each intervention, the changes to baseline values of different model input parameters. You can add a new row in the table with a new intervention ID and associated parameter values. The model will now recognize all pixels with this ID value in **interventions.map** as locations where this intervention is implemented.

Table 3: Parameterization of preset SLM intervention packages in LANDSIM-R (BL = baseline).

	ID	**Landuse ID**	**Landuse fraction**	**Slope factor**	**Ksat factor**	**Plant height harvest**	**Veg. parameters from mmf**
Terracing	1	BL	BL	0.7	1	BL	BL
Reforestation	2	122	1	BL	2	BL	BL
Agroforestry	3	122	0.2	BL	1.5	BL	BL
Reduced tillage	4	BL	BL	BL	1.25	0	1

<u>Exercise 6C:</u>
Now, think of an SLM intervention that is currently missing, and introduce it in the table and your Marovoay interventions map. Examine its impacts on hydrology, erosion and sediment yield.