Adapting SWAT model for the evaluation of water harvesting systems in an arid environment: a case from Jordan

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SWAT conference 2013, France

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Introduction:

- Jordan is one of the countries that are suffering from water shortage and land degradation.

- Arid environments, such as Al-Badia, in Jordan are characterized by sporadic, low average annual rainfall and very high rainfall intensities that may cause runoff and erosion.

- Water harvesting in dry areas is becoming a more reliable option to optimize the benefit of available rainwater for crop production and to decrease the soil erosion. In addition to use runoff water for recharge aquifers tapped for irrigation.

- The effect of water harvesting on the reduction of soil erosion and runoff is not adequately known.

- **Main goal:**

- Adapting the SWAT model to predict the impacts of water harvesting interventions on bio-physical and hydrological parameters and to test the applicability to similar arid environments.

- **Specific objectives:**

1. To study the effects of selected water harvesting interventions on sediment quantity, quality, and runoff.

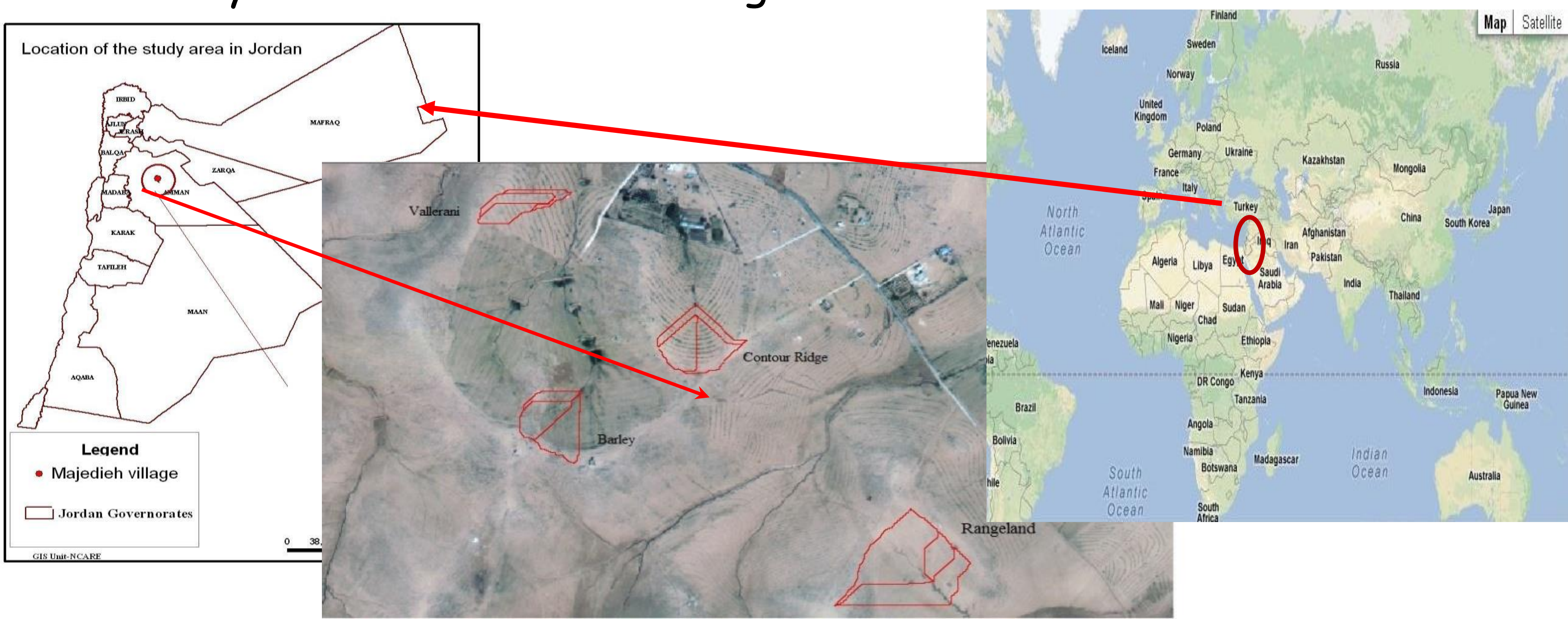
2. To adapt and evaluate the applicability of SWAT model in a typical arid area of Jordan.

Methodology :

➢ **Sites/sub-watersheds selection and description:**

- Four sites, representing small sub-watersheds (hill slopes) were selected for modeling purposes in Al-Majidyya village 40 km south-east of Amman.

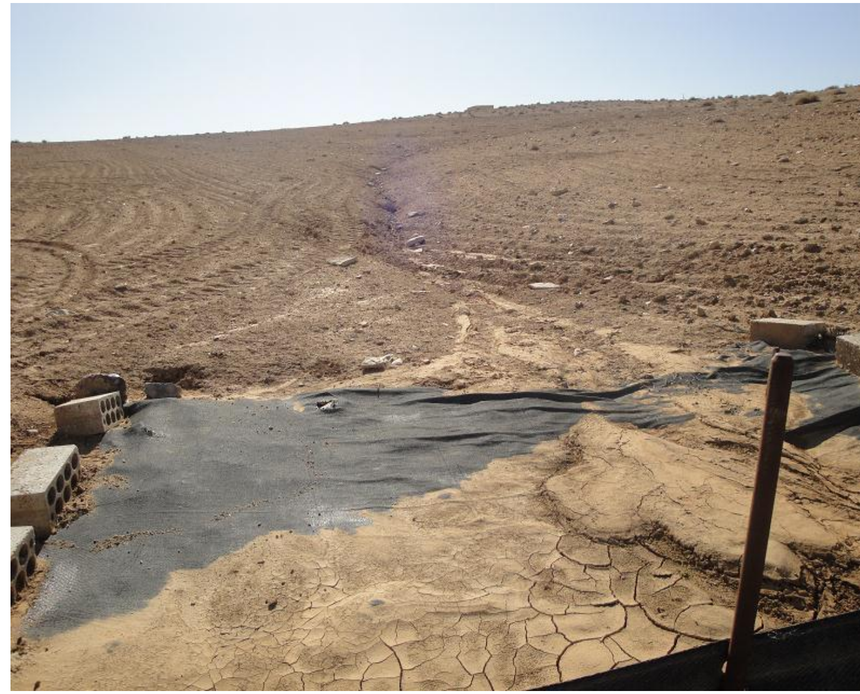
- The sites are representing an arid area of Jordan (known locally as Al-Badia).
- The sites are located in close proximity to each other to minimize differences in climate, soils, vegetation, topography (elevation, aspect, and slope).
- The study area receives an average annual rainfall less than 150 mm.



➢Two small sub-watersheds (paired swales) were selected to **measure soil erosion (sediment yield only),** using *geo-textile* trap (silt fences) established at each outlet.

✓ one contains continuous contour ridges as water harvesting measures and planted with `Atriplex halimus shrubs.

✓the other one was control site planted with Barley as farmer practices.



- Two small sub-watersheds were selected to **measure runoff** by establishing a weir as a control section at each outlet.

- ✓ One contains (Vallerani intermittent pits) as water harvesting intervention planted by Salsola shrubs.

✓ and the control site was rangeland (without any interventions).

➢ SWAT model:

- SWAT2012 version with its interface of ArcGIS 10.0 was used to execute this study.

The basic data required to develop the model input parameters using the SWAT ArcGIS Interface were :

- ✓ Digital elevation model (DEM)
- ✓ Soil map
- ✓ Landuse map
- ✓ Climate data
- ✓ Rainfall data using tipping bucket rain gauge with data pod.

➢ Hydrological and sediment data:

✓The required information of eroded sediment yields on the geotextile traps was estimated and sampled.

✓information and samples of generated runoff at the weirs edge were recorded using flow meter probes and ISCO automatic samplers.

- **runoff monitoring (field measurements):**
  - runoff data :the depth and the flow of generated runoff water were recorded using water measurements devices at the weir outlets.
  - runoff water samples weretaken using an ISCO automatic sampler at the weir outlets.
  - Runoff plots were constructed and samples of runoff water collected in the barrels after each significant rainfall event will be taken.
  - Amounts and nutrient (N, P, K) for all collected samples were analyzed in the laboratory.
  - Moisture contents using TDR were taken as transects in all sites. Water component balance were calculated.
- **soil erosion monitoring (field measurements):**
  - The sediment quantities were estimated and sampled after each rainfall event.
  - Nutrients (organic matter, N, P,K) and texture for collected samples were analyzed in the laboratory .

Results

- **Setup the model:**
- Some of the parameters were modified to suit the arid conditions and to consider the water harvesting interventions as followings:
- ✓ Consider the contour ridges planted with Atriplex in the produced HRUs: by adding a new landuse class represents the WH.
- ✓ modifying the crop databases for the paramters ((HVI), (LAI), heat units) for each class of existing landuse .
- ✓ Modifying the management practices (SCS Curve number values) and the operations.

Table1: Some parameters values changed in the SWAT landuse code*

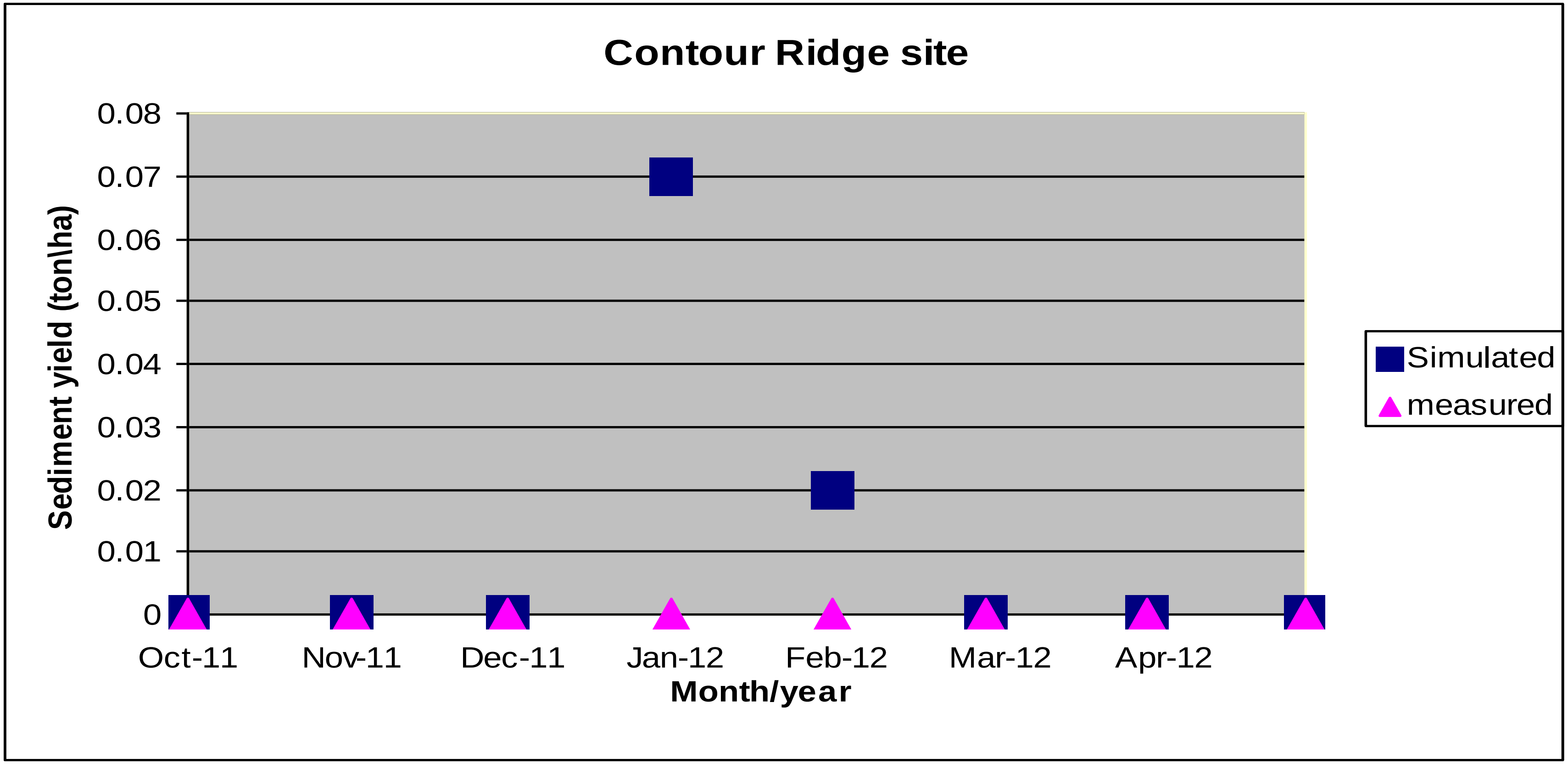
Site	Parameter	
	HVI	LAI
Continuous Contour Ridges	0.9	1.5
Winter Barley	0.54	4

(* these values were modified by Dr. Srinivasan, R., April,2012)

➢ Model simulation:

- the whole period used to simulate the model was Nov. 2005 to May. 2013.
- A period of 2005 till 2010 was used to warm up the model.
- However, Two years of measured data for soil erosion were collected during winter seasons of Nov. 2011/ May 2012 and Nov. 2012/ May. 2013.

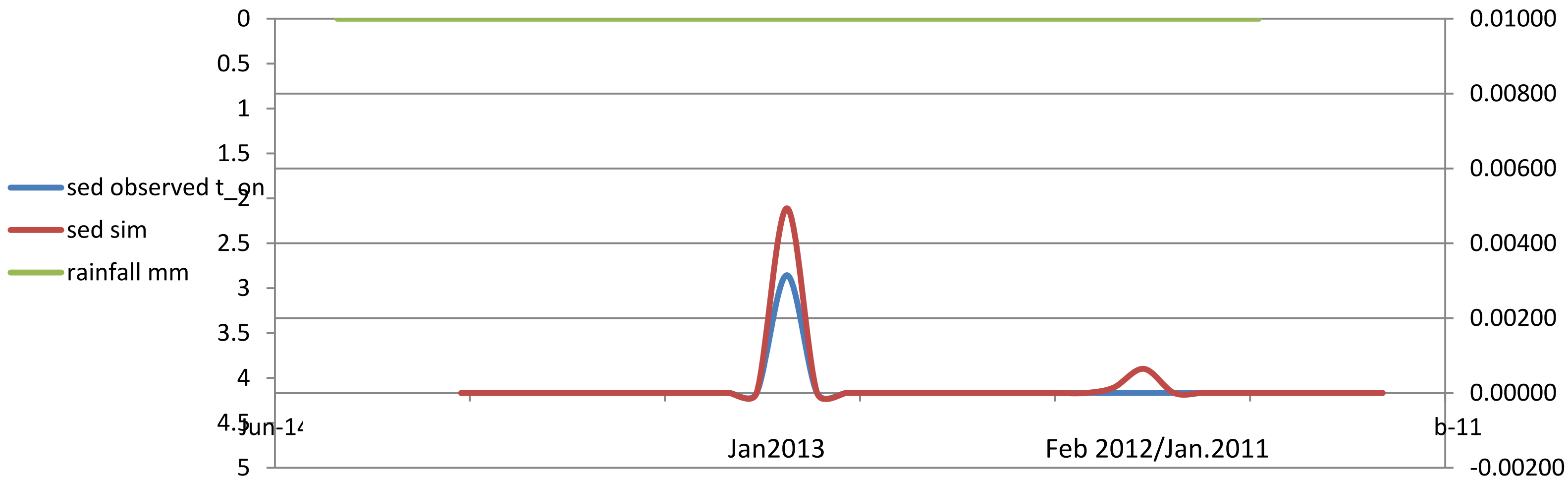
- Furthermore, these will be used for calibration and verification the model outputs.
- The results as followings:



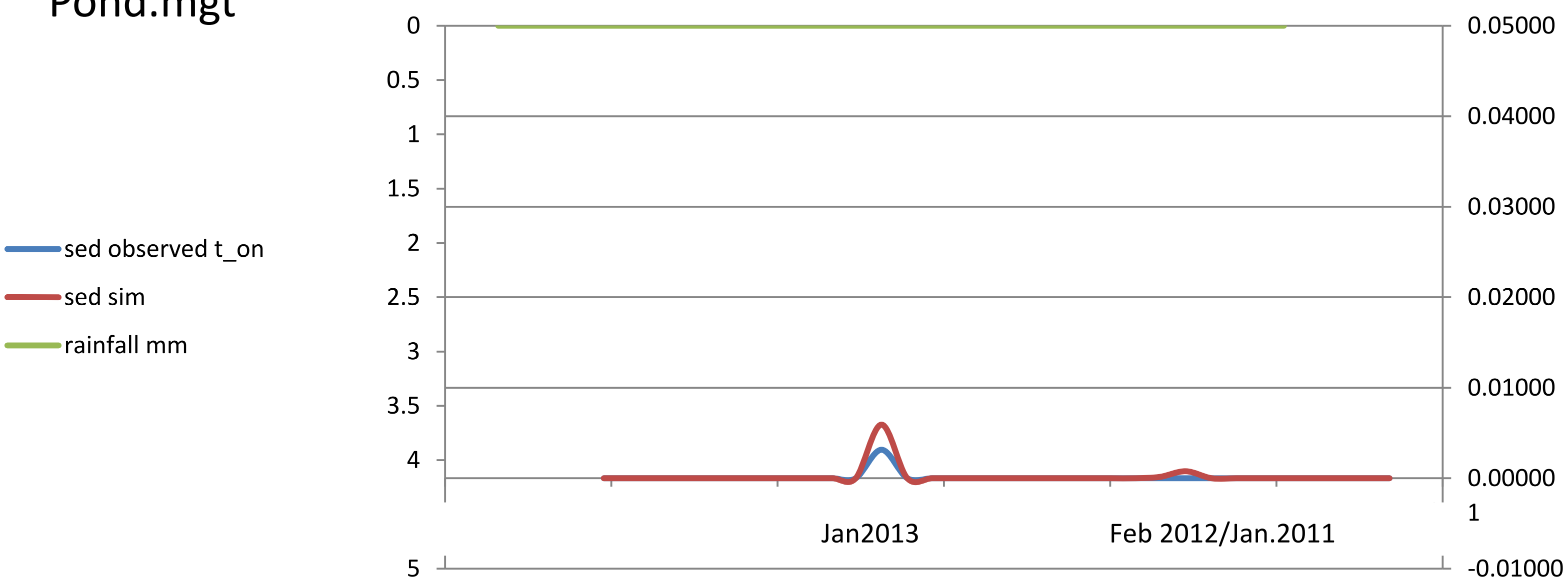
✓the model output without calibration for monthly sediment yield was over estimated as illustrated in the figure comparing with the measured one.

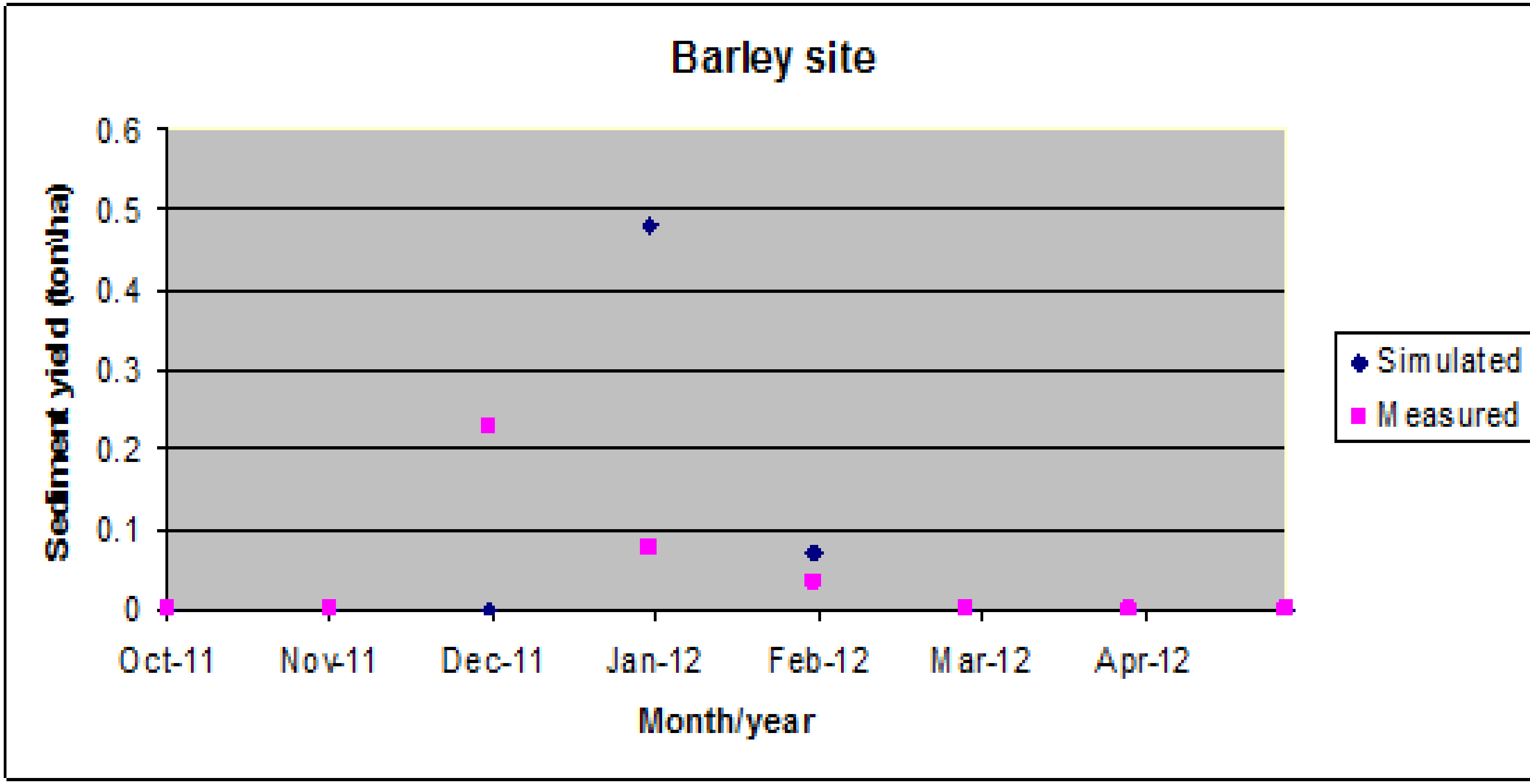
✓no sediments were observed in the field (CR) during all storms within the simulation period.

Contour Ridge site _monthly basis



Pond.mgt





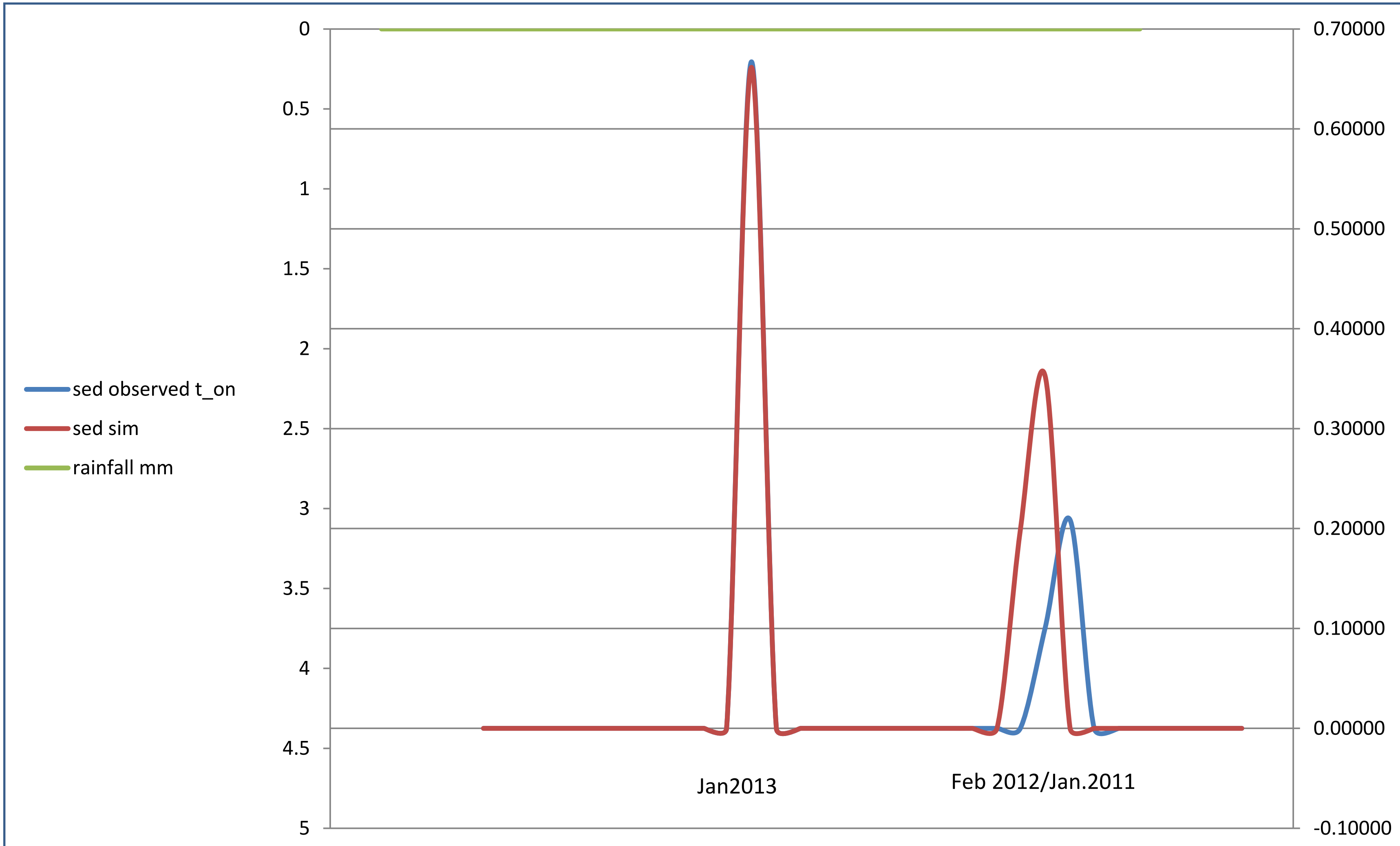
The figure shows that:

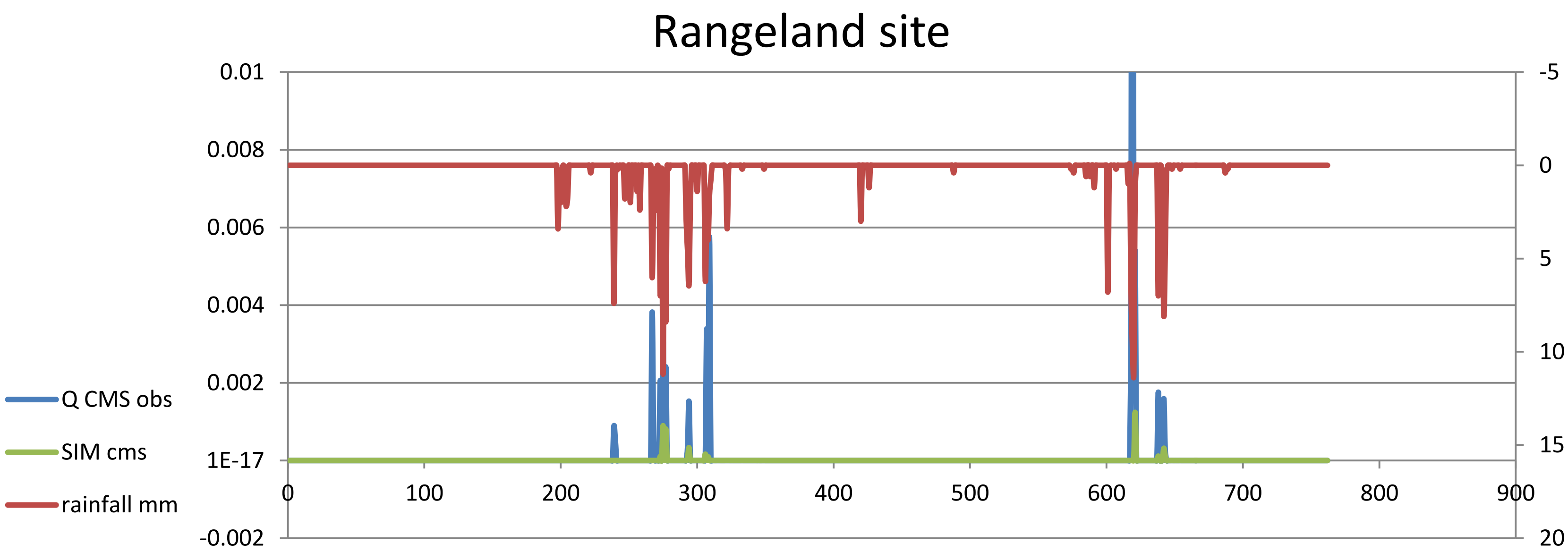
✓ the magnitude variation of simulated monthly sediment yield for the selected storms does not match the observed sediment loads.

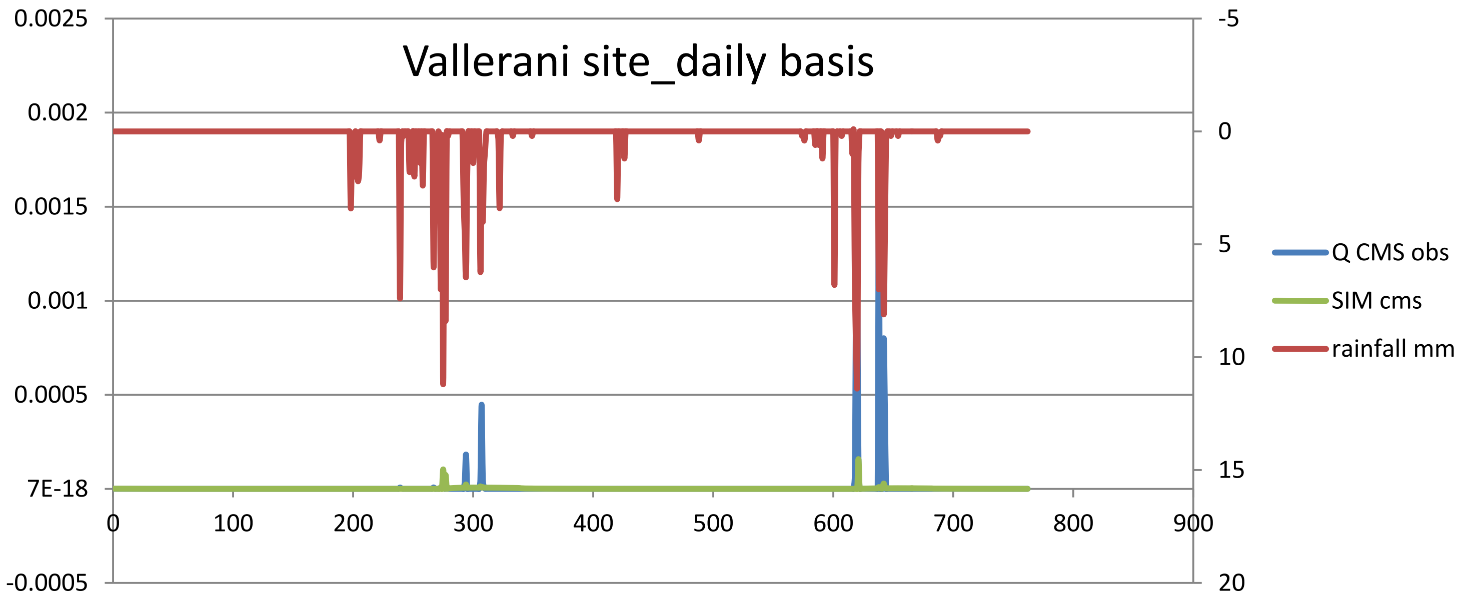
✓Timings of occurrence of the peaks for observed and simulated sediment yield as well.

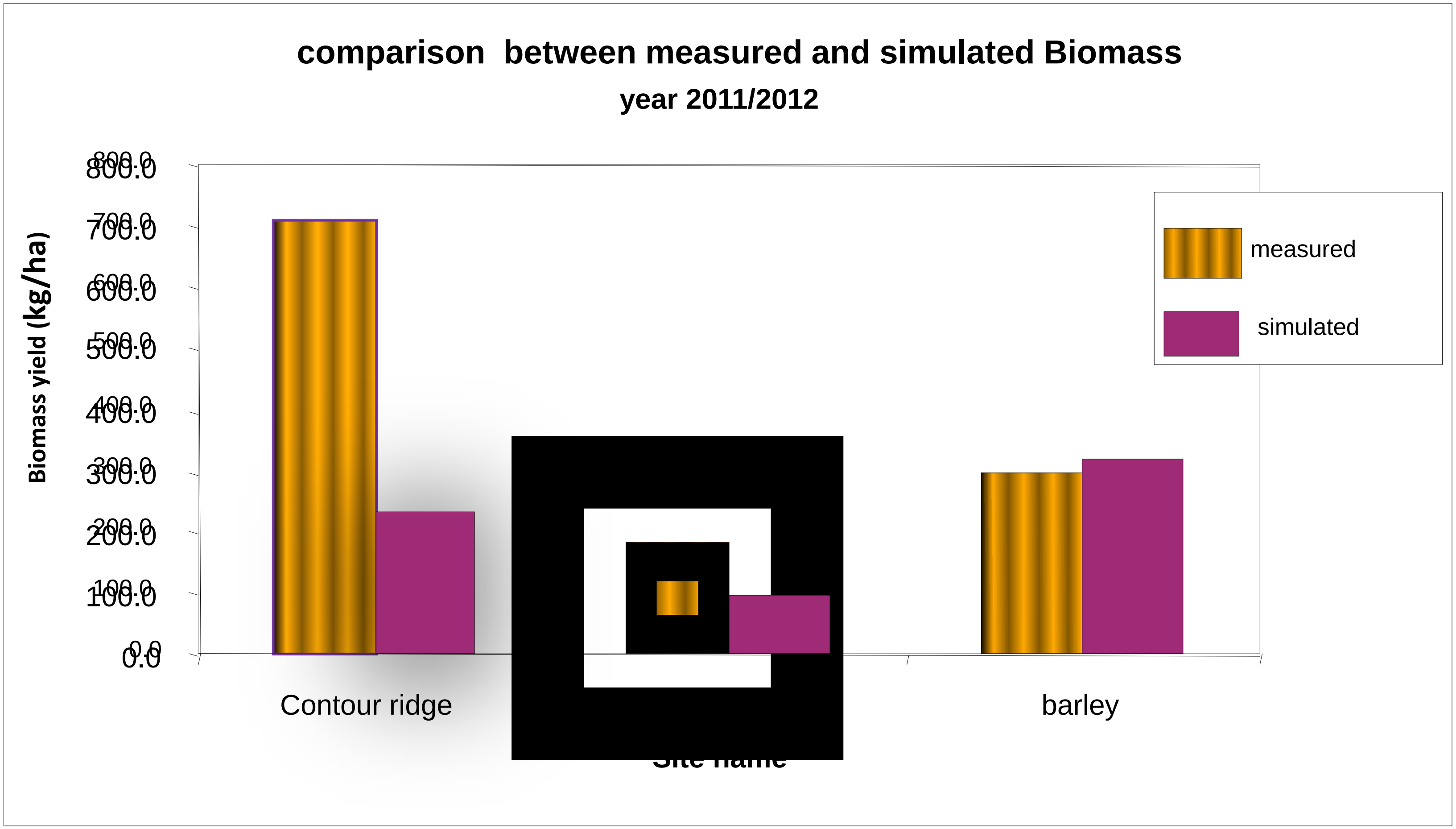
✓they look in the same pattern but the model over-predicted sediment amounts during the January and February, 2012 except the storm happened at December 2011.

Barley site _monthly basis




Rangeland site
0.01
0.008
0.006
0.004
0.002
1E-17
-0.002
-5
0
5
10
15
20
0
100
200
300
400
500
600
700
800
900
Q CMS obs
SIM cms
rainfall mm


Vallerani site_daily basis
0.0025
0.002
0.0015
0.001
0.0005
7E-18
-0.0005
-5
0
5
10
15
20
0
100
200
300
400
500
600
700
800
900
Q CMS obs
SIM cms
rainfall mm



✓The model is under predicted the biomass production for the sites implemented by water harvesting interventions.

✓the model is well matched with measured by assumption of applying fertilizers of 10 kg/ha N for barley site.

- ***challenges and limitations:***
- The application of the SWAT in arid regions requires modifications of the existing SWAT databases and parameters.
- little or no data or available literature for the crops planted in the study area (Atriplex, Salsola shrubs and winter barley).
- Another challenge was how to consider the continuous contour ridges / Vallerani intermittent as certain types of water harvesting interventions implemented in the sites to consider in the model.

Conclusions:

- The measured data for sediment yields present an evidence that the water harvesting interventions reduce the soil erosion and can aid in reducing losses where the soil erosion from watersheds contributes a large amount of top soil and nutrients each year.

- the water harvesting interventions have a potential to optimize the benefit of rainfall especially in the arid environment.

- The biomass results can be significant for the farmers to adopt the water harvesting interventions which maximize the productivity.

- The model requires fine-tuning to the input model parameters to include the established continuous contour ridges and vallerani pits (WH) interventions in the sites and its impacts that reduce the soil erosion and runoff.(need a suggestions ????????????)

Thank you