Using SWAT to predict climate change effects on runoff and soil losses in a small rainfed catchment with Mediterranean climate of NE Spain

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SWAT 2013
Toulouse France

Outlines

Climate change

Increase of temperatures → Increase of water demands

↓

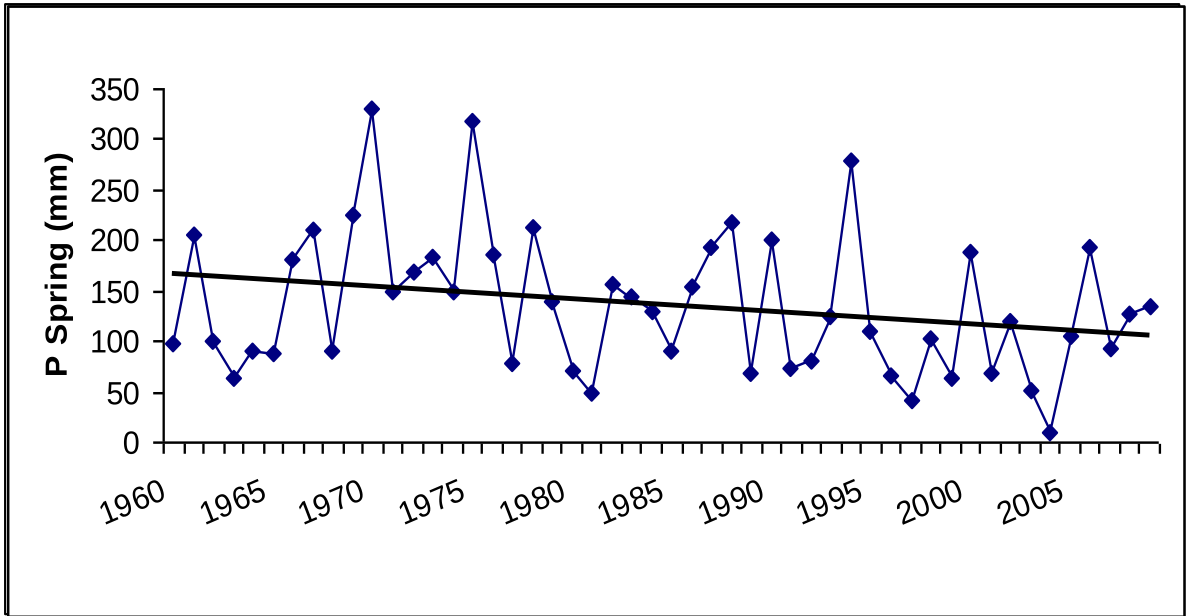
Crop production

Increase of precipitation variabilility

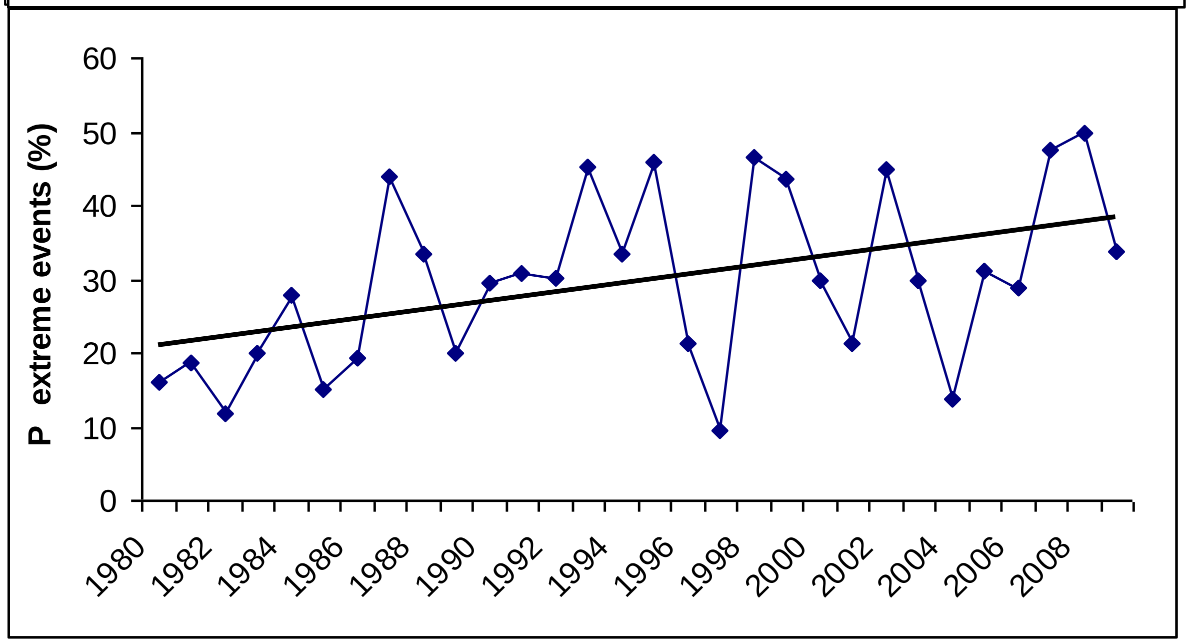
Some specific land uses, like vines, olives, almonds or hazelnuts, typical in the Mediterranean area and that are usually cultivated without soil cover, may suffer an increase of erosion rates.

Mediterranean Climate

rainfall variability



increase number of extreme events



Erosion processes in Mediterranean vineyards

The erosion processes, frequently observed in the Mediterranean area, could be seriously affected according to the predicted changes in rainfall characteristics

Objective

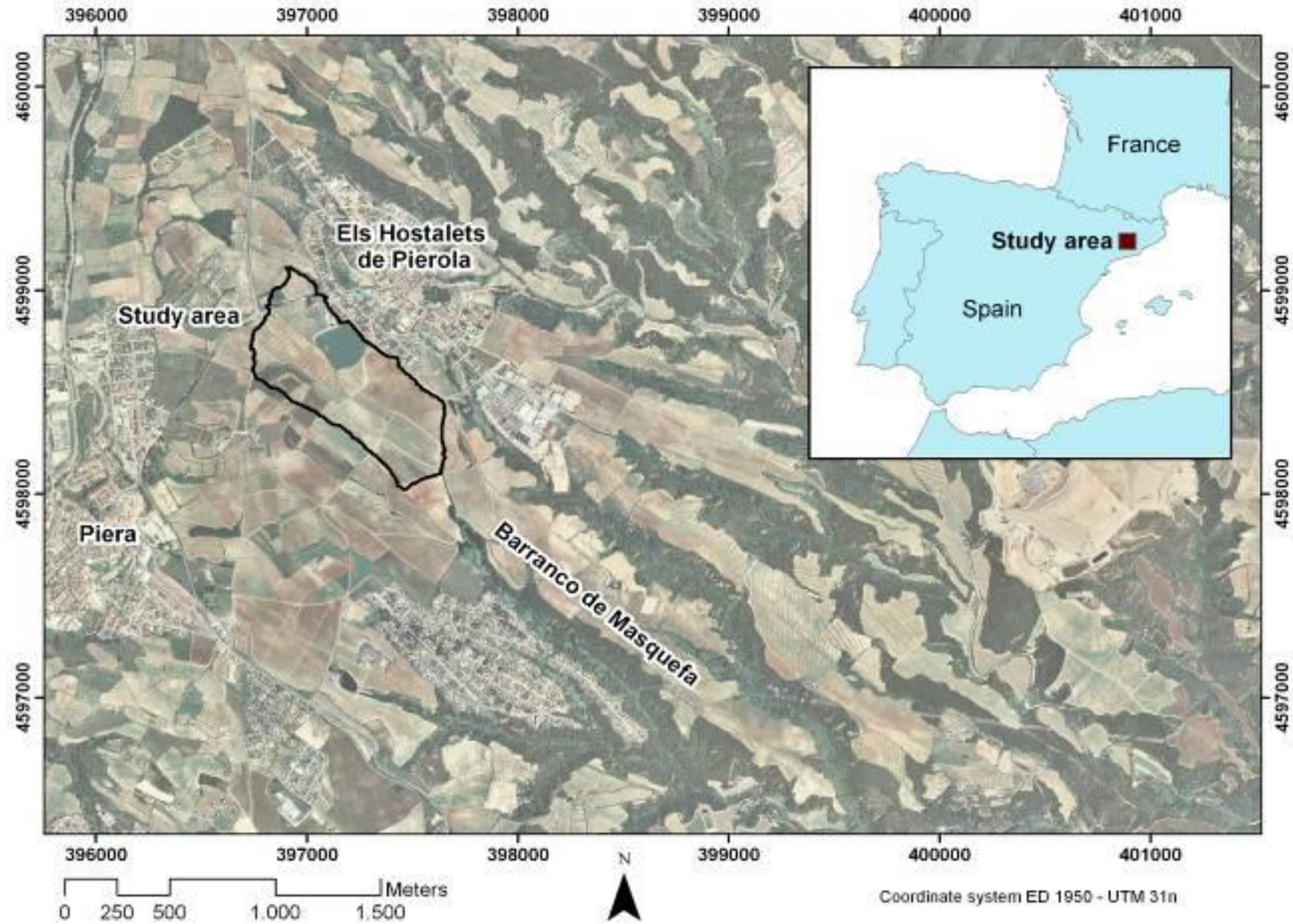
To analyse the possibilities of SWAT to predict the impacts of climate change on erosion processes in a small catchmentin a Mediterranean climate area of North East Spain. In this catchment the main land use are vines, which are cultivated under rainfed conditions.

The result of soil erosion in years with different characteristics are compared with the ones simulated for years 2020 and 2050 according to the climate trends observed in the study area.

Material and methods

Study area:

Basin: 46 ha

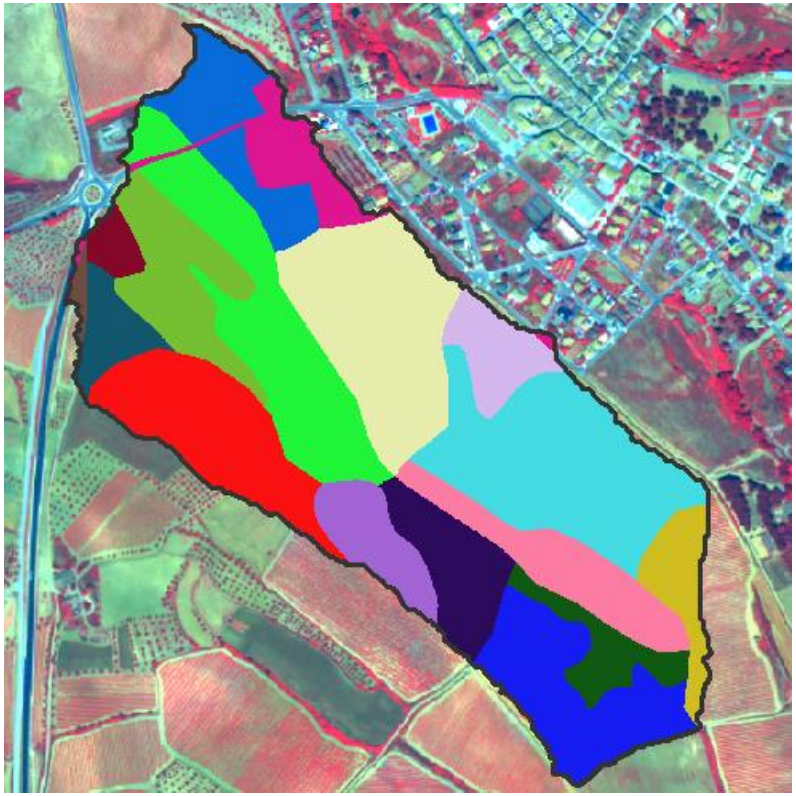


ArcSWAT 2009.93.5 daily time scale

Soil data

Soil map (1:25,000)- Instituto Geológico de Cataluña

Soil survey: 40 additional points



texture,
bulk density,
organic carbon content,
steady infiltration rate,
available water capacity
K-erodibility factor

Main type soils :

Typic Xerorthents

Fluventic Haploxerepts.

Typic Haploxeralfs

Climatic data

Mediterranean– Maritime influence

Els Hostalest de Pierola (1.809 E; 41.5328 N, 316 m.a.s.l.)
(Instituto Meteorológico de Cataluña)

16-year series (1996-2012) daily data:
- temperatures (maximum and minimum),
- precipitation,
- solar radiation,
- relative humidity
- wind velocity

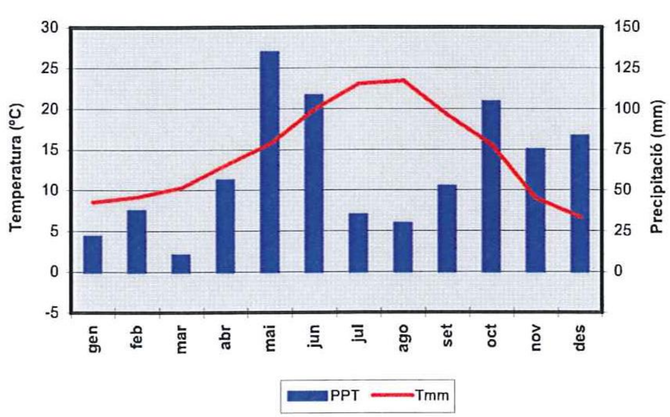
Tm = 15°C (9-25 °C)

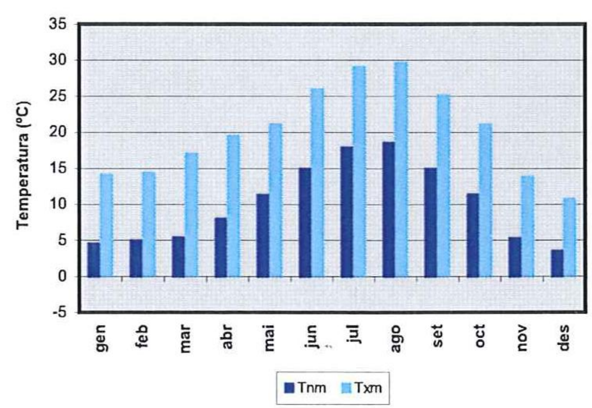
Tmax = 20 °C (10.3-29.7 °C)

Tmin = 9 ° C (2.5-19.5 °C)

Pm = 520 mm

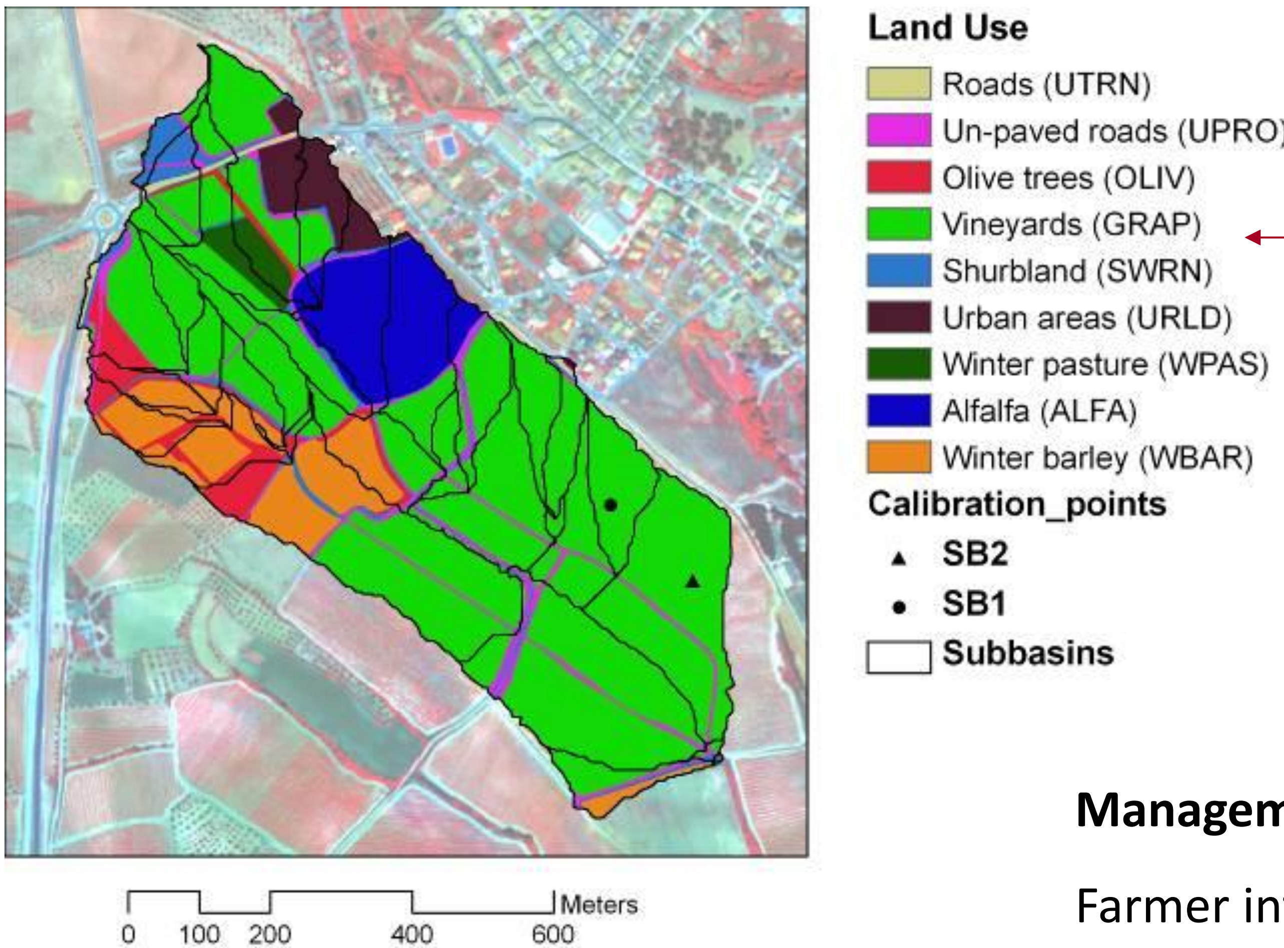
High intensity rainfall events
(I> 100 mm/h in short intervals)





Land Use

Visual interpretation of very detail ortho-rectified aerial photos taken in 2010 at 1:3,000 scale and field work



62.81%

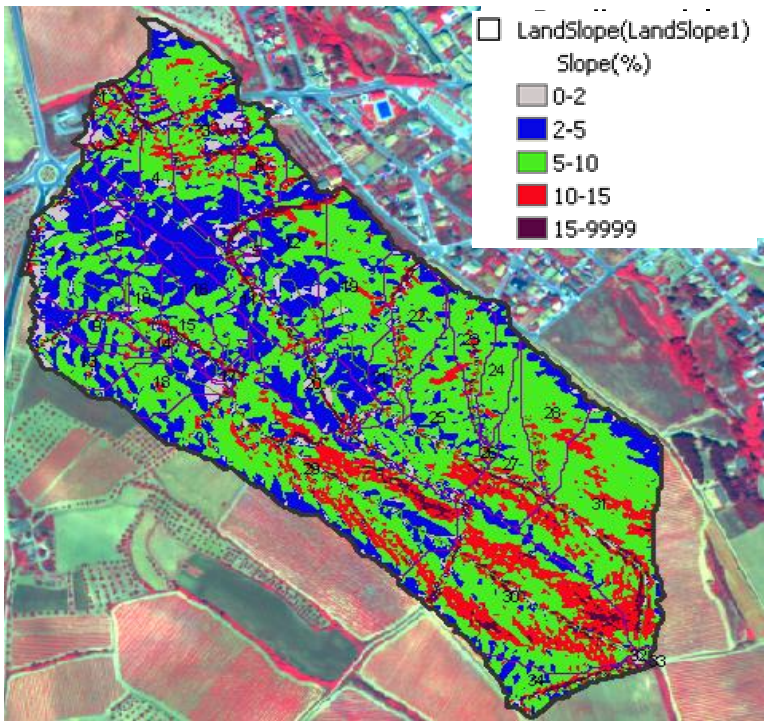
Management practices

Farmer information

Topography

A 1m-resolution digital elevation model:

altitude photogrammetric aerial survey (2010)→ slope



Sub-basins	34
HRU	1182

Climatic change scenarios

Changes in temperature and precipitation (Ramos et al., 2012)- extrapolated to 2020 and 2050

Changes in humidity and solar radiation were obtained using the CCWorldWeatherGen climate change weather file generator V1.6 for the same scenarios (Jentsch et al., 2012)

Changes in rainfall intensity 10% and 20% : 2003 and 2012

Season	Variable	Trend/year (ºC/year)
Winter	Tm (ºC)	**0.034** *
	Tmax (ºC)	**0.039** *
	Tmin (ºC)	**0.029** *
	PW	**0.441** *
Spring	Tm (ºC)	**0.039** *
	Tmax (ºC)	**0.043** *
	Tmin (ºC)	**0.035** *
	P Sp	**0.413** *
Summer	Tm (ºC)	**0.038** *
	Tmax (ºC)	**0.034** *
	Tmin (ºC)	0.028
	PSum	-0.057
Autumn	Tm (ºC)	**0.031** *
	Tmax (ºC)	**0.037** *
	Tmin (ºCp	0.024
	PAut	-0.048

SWAT application

Sensitivity analysis

Model calibration and validation

Soil moisture:

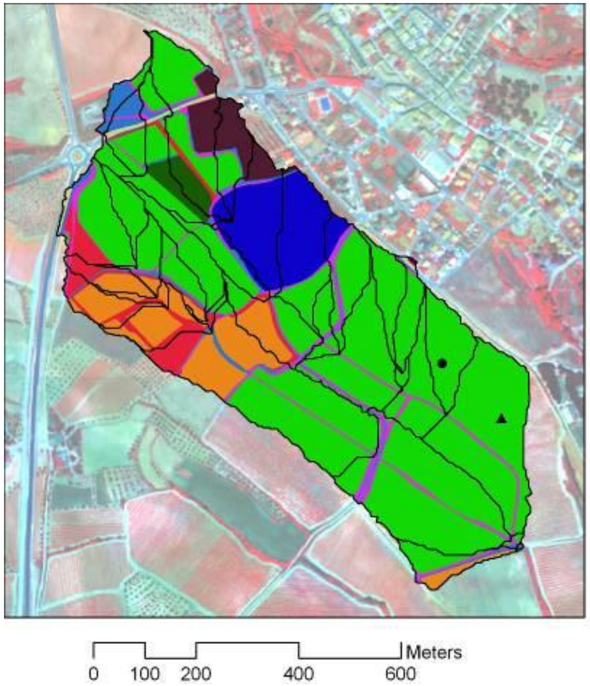
TFR probes (Decagon) at four depths:

10-30, 30-50, 50-70 and 70-90 cm

Sediment concentration in runoff in 3 HRUs

2010-2011- calibration

2011-2012 validation



Model run

Years with different climatic characteristics
1998-1999
2000-2012

Results

Parameters used in SWAT after the sensitivity analysis

Parameter Description	value
1- ESCO: Soil evaporation compensation factor	0.9
2- CN2 _SCS runoff curve number for moisture condition II	72-79 agric. 92-96 urban
3- EPCO Plant evaporation compensation factor	0.9
4- GW_REVAP Groundwater 'revap' coefficient	0.15
5- GW_DELAY Groundwater delay (days)	14
6- REVAPMIN Threshold depth of water in the shallow aquifer required for "revap" to occur (mm)	10
7- Sol_K Soil conductivity (mm h^{-1})	10
8- Ch_K2 Effective hydraulic conductivity in main channel alluvium (mm h^{-1})	0.045
9- CH_N Manning coefficient for channel	0.020
10-GWQMN Threshold depth of water in shallow aquifer required for return flow to occur (mm)	1000
11- Alpha_Bf Baseflow Alpha factor (days)	0.05

Statistics of the comparisons between simulated and measured data during calibration and validation periods

	RSR	PBIAS %	NSE	RSR	PBIAS %	NSE
	calibration			validation		
Soil water SB1	0.49	-1.75	0.69	0.44	0.33	0.86
Soil water SB2	0.67	2.68	0.69	0.74	2.25	0.85
Runoff rates SB1	0.38	-16.33	0.88	0.53	-13.82	0.82
Runoff rates SB2	0.42	-16.20	0.64	0.38	-8.96	0.88
Soil loss SB1	0.52	-15.79	0.66	0.71	8.63	0.71
Soil loss SB2	0.14	-28.70	0.33	0.28	23.12	0.91

Results of simulations for the period 2000-2012

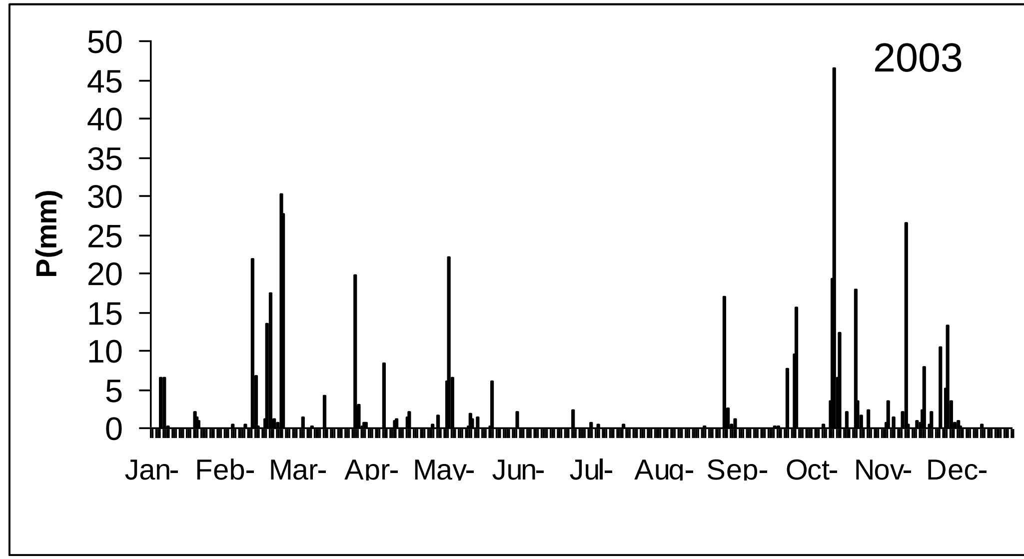
Year	PREC (mm)	Sur Q (mm)	Lat Q (mm)	GwQ (mm)	Percol (mm)	Water Yield (mm)	Sed Yield (Mg/ha)
2000	491.2	28.4	4.0	30.2	85.2	57.1	1.28
2001	447.8	28.3	5.1	93.9	99.5	118.8	1.37
2002	612.6	82.6	6.3	126.7	160.5	206.8	6.56
2003	496.0	67.7	5.4	114.7	126.9	178.6	5.99
2004	785.5	84.2	6.2	129.2	116.7	191.9	5.55
2005	365.0	15.1	3.3	44.0	67.7	54.1	0.19
2006	329.8	60.1	3.2	68.9	62.2	128.1	4.41
2007	548.0	37.7	5.5	74.7	107.6	111.3	1.63
2008	751.5	112.2	7.1	152.7	207.7	253.1	7.54
2009	541.9	93.5	5.4	108.7	83.0	194.9	7.33
2010	729.4	105.9	7.4	159.0	191.2	263.3	13.9
2011	655.7	119.3	7.4	184.4	207.1	293.2	7.33
2012	510.7	40.62	5.77	98.33	133.59	90.72	1.63
aver	**558.9**	**67.4**	**5.5**	**106.6**	**126.8**	**164.8**	**5.0**

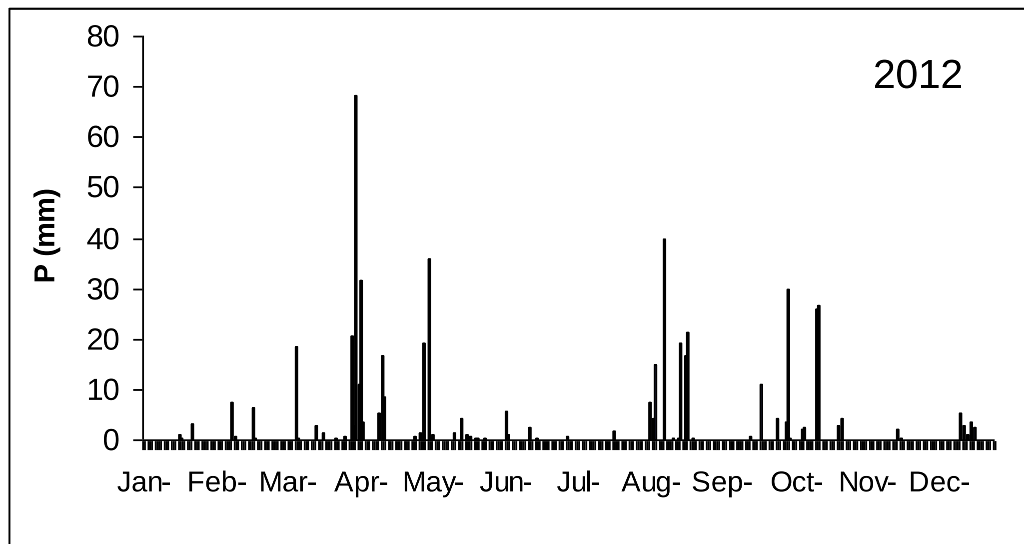
Climate effects on years 2003 and 2012

Temperature changes
2020: +1.7 °C
2050: +3.8 °C

Precipitation changes
Year1
(2020): 496 to 503 mm
(2050) 496 to 513.3 mm
Year 2
(2020): 510 to 538 mm
(2050): 510 to 548 mm

Intensity : 10 and 20%





Rainfall distribution throughout the year in the two selected years (2003 and 2012).

Water and sediment yield simulated according to climatic variables trends observed in the study area for year 1.

Scenario	P (mm)	Runoff (mm)	Lat Q (mm)	Ground water (mm)	Percol (mm)	SW (mm)	ET (mm)	Water yield (mm)	Sed Yield Mg/ha
Changing precipitation according to observed trends									
Present	496.0	63.19	5.23	112.36	124.22	98.13	302.58	171.53	5.99
2020	503.0	55.44	5.75	130.94	129.05	98.64	317.85	187.40	5.35
2050	513.3	71.61	5.44	120.33	128.55	98.57	305.41	183.89	9.50
Increasing Intensity (10%)									
2020	503.0	58.21	5.56	123.82	125.26	98.58	318.12	184.76	6.91
2050	513.3	77.99	5.22	112.37	123.15	98.38	306.20	181.55	11.90
Increasing intensity (20%)									
2020	503.0	58.14	5.56	123.80	125.29	98.58	318.14	184.58	7.04
2050	513.3	78.06	5.22	112.35	123.19	98.40	306.17	181.57	12.45

Water and sediment yield simulated according to climatic variables trends observed in the study area for year 2.

Scenario	P (mm)	Runoff (mm)	Lat Q (mm)	Ground water (mm)	Percol (mm)	SW (mm)	ET (mm)	Water yield (mm)	Sed Yield Mg/ha
Changing precipitation according to observed trends									
Present	510.7	40.62	5.77	98.33	133.59	90.72	327.14	131.08	1.63
2020	538.7	38.15	5.63	93.28	127.99	89.82	332.95	127.53	1.41
2050	548.0	40.36	5.56	88.48	119.60	89.75	321.2	138.60	2.01
Increasing Intensity (10%)									
2020	538.7	50.81	6.13	106.71	144.72	91.07	327.16	155.74	2.18
2050	548.0	56.69	6.11	109.45	145.17	92.18	326.82	162.65	2.68
Increasing intensity (20%)									
2020	538.7	49.76	6.14	108.26	147.10	85.48	327.88	156.43	2.38
2050	548.0	52.13	6.25	113.05	151.57	85.72	328.66	163.51	2.87

Conclusions

The first results of SWAT application to simulate the effects of climate change on soil erosion in a small catchment showed that SWAT responds to rainfall amount and to changes in temperature, which give rise to higher evaporation rates.

However, in the analysed case, where changes in precipitation are mainly due to changes in distribution and intensity but not in total amount, some difficulties arise for suitable predictions at the daily base in which the SWAT model was run.

Conclusions

Taking into account the characteristics of the Mediterranean area, where the most erosive events are usually of high intensity and short duration, it is needed to take into account changes rainfall intensity.

The increase of rainfall intensity was confirmed as the main factor to increase erosion rates under the 2020 and 2050 analysed scenarios. An increase of 10% of intensity may result in erosion rate increases up to 30% for 2020 and higher than 65% for 2050 with the temperature and precipitation observed trends.

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