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A dynamic landscape evolution model for P export estimation from crops through sediment volume assessment: the case of the lake Bolsena watershed, Italy.

UNIVERSITÀ DEGLI STUDI DELLA Tuscia
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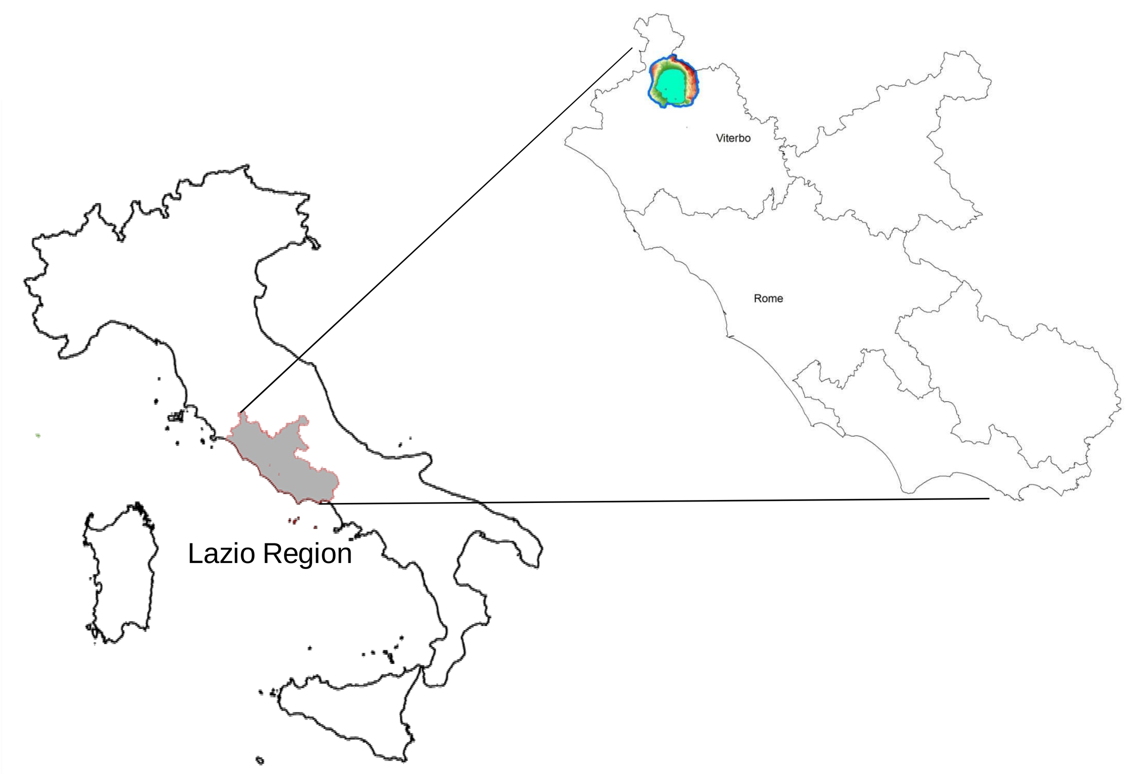
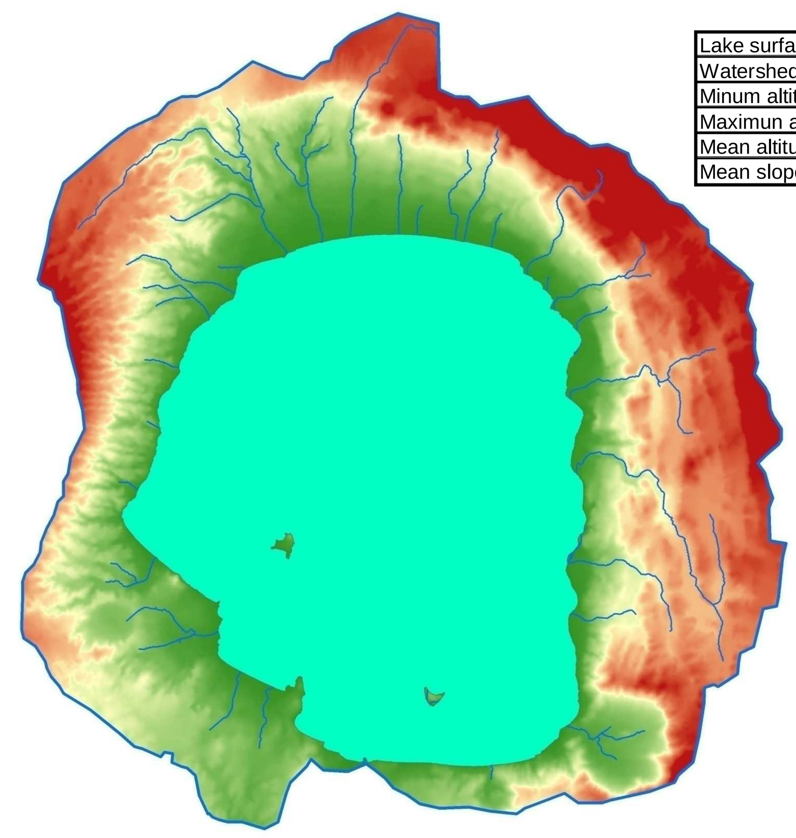
Study area



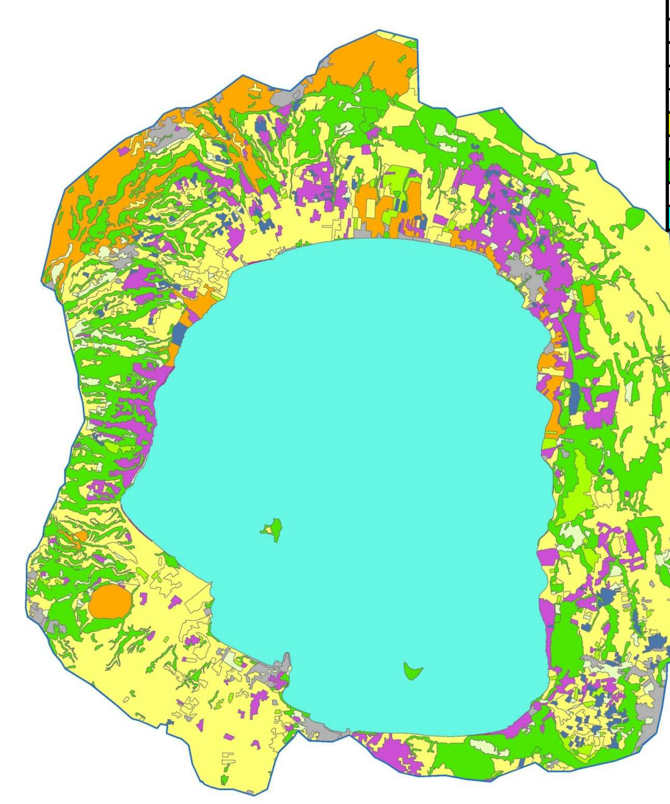
The study area corresponds to Lake **Bolsena** watershed and it's located in the northern part of Lazio Region. It's one of the most important and above all the greatest volcanic lake in Europe. A Special Protection Area and Sites of Community Importance have been established on it to protect the biodiversity of its habitat. A Management Plan and specific conservation measures have been elaborated for lake Bolsena and Martana and Bisentina islands in order to ensure the conservation of species and ecosystems according to European Directives (Habitats and Birds directives) taking into account the P exportation from the land uses inside the watershed to the lake.



Lake surface (ha)	11442.70
Watershed surface (ha)	28290.80
Minum altitude (m)	303
Maximun altitude (m)	685
Mean altitude (m)	382
Mean slope (%)	12.6

Morphology

Legend
Bolsena watershed
reaches
Lake
Altitude (m)
High : 685
Low : 302



LAND COVER	area (ha)	%
urban	531.07	1.88
vineyards	350.60	1.24
orchards	350.42	1.24
olives	1517.75	5.36
pasture	575.40	2.03
non irrigated crops	7668.52	27.11
irrigated crops	1381.42	4.88
forest	4466.70	15.79
beaches	8.37	0.03
water bodies	11440.55	40.44

Land cover map

Legend
Land cover classes
beaches
forest
irrigated crops
non irrigated crops
olives
orchards
pasture
urban
vineyards
water bodies

Materials and Method

LAPSUS model (Schoorl et al., 2002)

This modelling approach is based on the principle of the potential energy content of flowing water over a landscape surface as the driving force for sediment transport (Kirkby, 1986) and the use of the continuity equation for sediment movement (Foster and Meyer, 1975). The model evaluates the rates of sediment transport calculating the transport capacity of water flowing downslope from one grid cell to another as a function of discharge and slope gradient.

Under the assumption that the transport capacity C and the detachment capacity D or settlement capacity T remain constant within one finite element, the sediment transport rate is evaluated as follows:

$$S = C + (S_0 - C)e^{-dx/h}$$

where the sediment transport rate S (m^2/year) along dx (m) length of a finite element is calculated as a function of transport capacity C (m^2/year) compared with the amount of sediment already in transport S_0 (m^2/year). Term h (m) refers to the transport capacity divided by the detachment capacity (C/D) with D (m/year), or to the transport capacity in proportion to the settlement capacity (C/T) with T (−m/year).
A surplus of capacity is compensated by detachment of sediment, depending on the erodibility of the surface, which provokes erosion.
When the rate of sediment in transport exceeds the local capacity, the surplus is deposited, causing sedimentation.
Lapsus model was settled and implemented for the lake Bolsena watershed in order to estimate the amount of sediment loss from the catchment.

1. COLLECTING DATA

- Land cover map (1:25.000),
- River networks,
- Soil and geological maps (1:100.000),
- Climatic data of 7 meteorological stations (P and T),
- DEM, Digital Elevation Model at 20 m resolution,
- Agricultural data on fertilizer applications and crops,
-P concentration measures in lake Bolsena water.

2. LAPSUS MODEL INPUTS

-DEM at 20x20m resolution

4 Climatic stations to derive:
-Rainfall map
-Infiltration map
-Evapotranspiration map

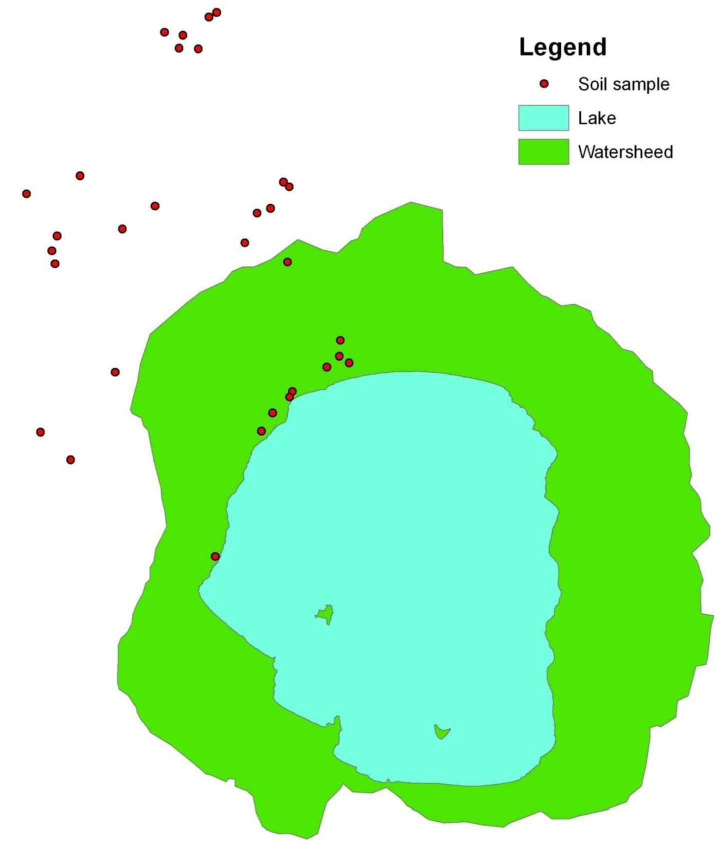
The estimation of infiltration was based on soil permeability coefficients depending on soil characteristics and hydrological group while evapotranspiration was calculated on the basis of temperature and mean annual precipitation values.

P fertilization

Values derived from farmer interviews		
Land use class	Mean Fertilization	P exported*
	P_2O_5 kg/ha/year	3%
Vineyards	30	0.90
Orchards (kiwi)	30	0.90
Olives	20	0.60
Non irrigated crops (wheat,alphalpha)	90	2.70
Irrigated crops (potato, corn)	120	3.60

* Values taken into account in the Management Plan for Lake Bolsena SPA for P export from crops according to the *mean export coefficients* suggested by the Water Research Institute, CNR.

Soil samples distribution



3. PHOSPHORUS ESTIMATION IN SEDIMENTS

Potential P may deliver from an agricultural field as: P adsorbed to soil particles, P soluble in runoff water and P soluble in leaching water but about 90% of it can be exported in the adsorbed form during erosion processes. So the total P in sediments can be used to estimate P loss from soil and, as a consequence, assessing erosion sediment amount can be a tool to evaluate the total maximum P load from soil.

The loss of P can be estimated from:

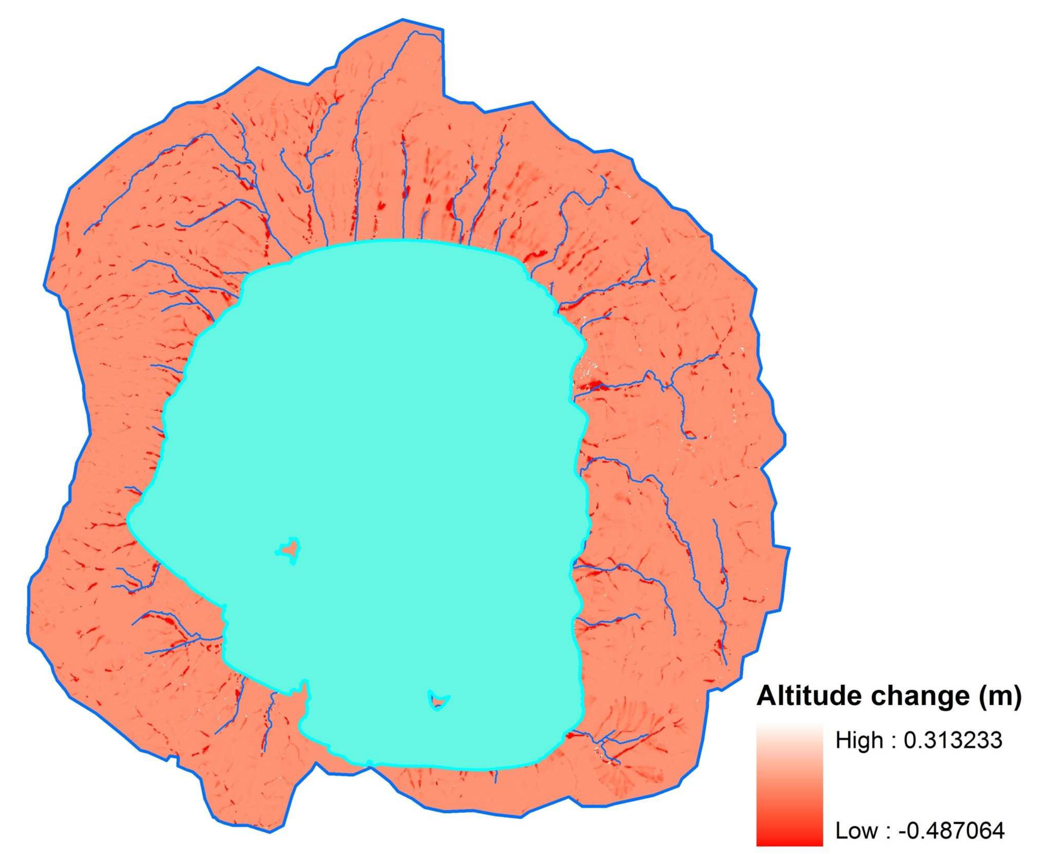
-erosion ← Altitude change (m) ⇐ LAPSUS OUTPUT; Soil Bulk density (kg/m^3)

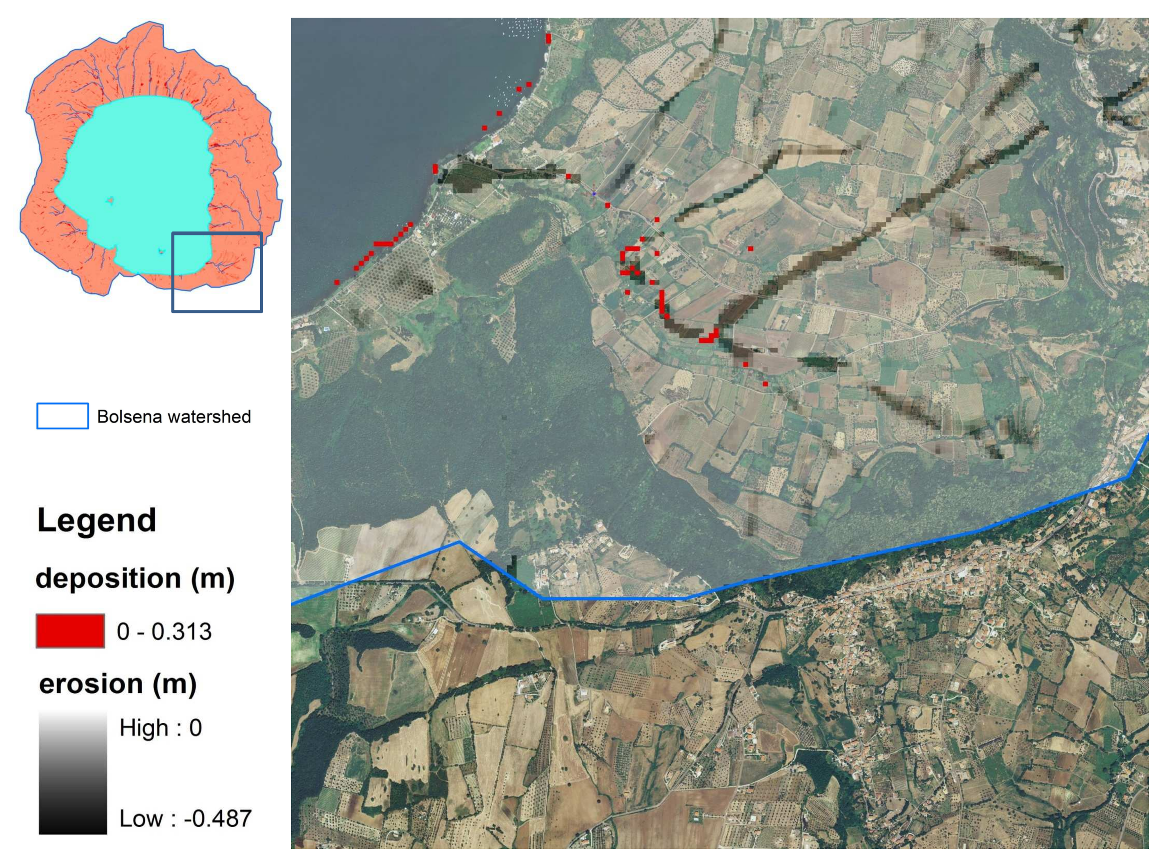
-soil P content ← Natural soil P content (Active Mineral + Stable Mineral); Fertilizer application

Enrichment factor — P content is higher in clay-enriched sediment because finer and more fertile soil particles are dislodged first during erosion (Cogle et al., 2002)

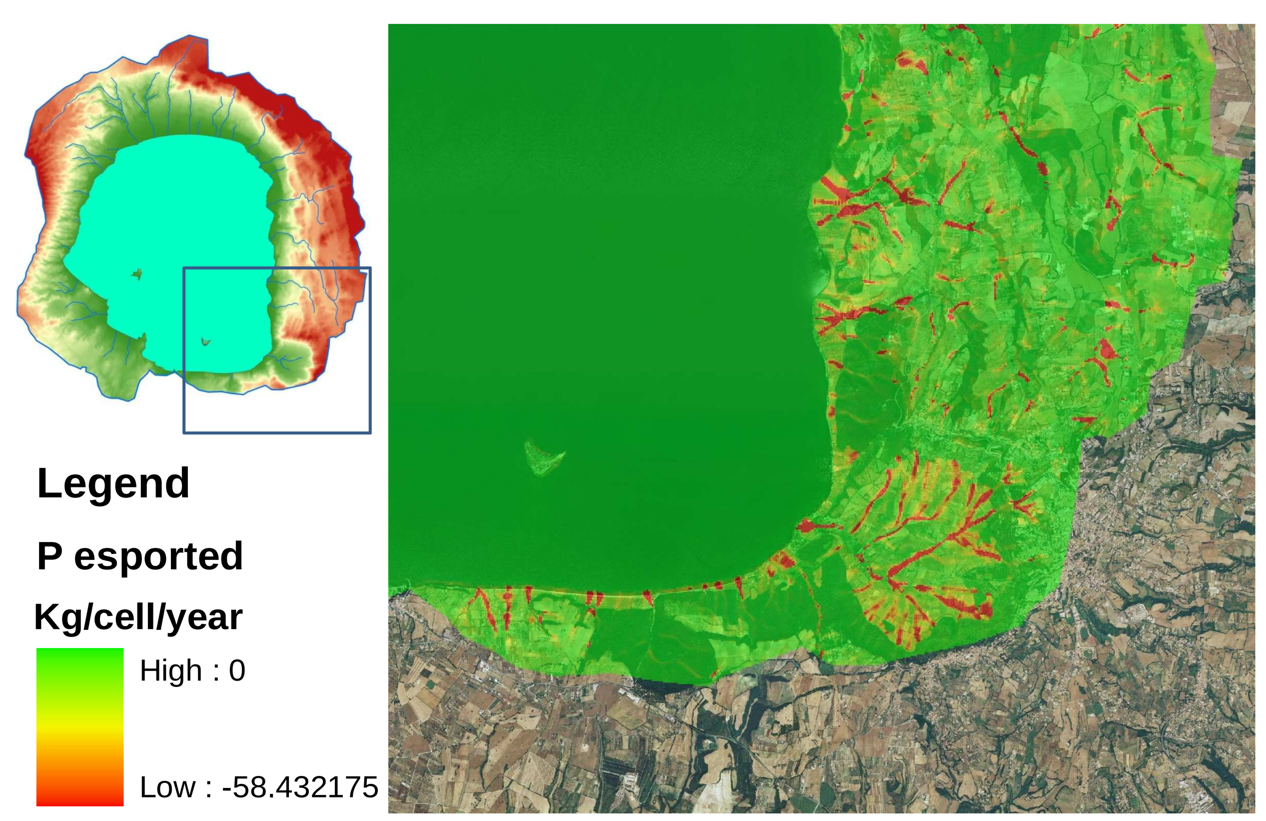
Results

Altitude change due to erosion and deposition phenomena (LAPSUS output)





P export from soils



Total P exported from land uses

Land use class	Max P export	Contribute %
Urban	15.28	0.04
Vineyards	958.76	2.65
Orchards	1336.52	3.69
Olives	6816.48	**18.84**
Non irrigated crops	22281.89	**61.58**
Irrigated crops	2763.40	7.64
Forest	1368.97	3.78
Beaches	35.06	0.10
Pasture	604.92	1.67
Total Max P	36181.27	100.00

Conclusions

Landscape evolution models are a very useful and powerful tool for Critical Source Areas (CSA) identification and P export estimation from crops through sediment amount assessment.
The maximum P export derived from the described procedure represents the total P stored in sediments that could reach the lake. The release of P from lake sediments undergoes very complex dynamics depending on different physical and chemical conditions (Ahlgren, 2011).
A key role is played by the integration of models in understanding and evaluating an environmental system.
To see the landscape as a unique system can help in pointing out its responses and reactions to natural external inputs and human actions (e.g. agriculture) and forecasting its evolution and modifications.

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