https://doi.org/10.17221/84/2019-SWR

Spatiotemporal analysis of landscape patterns and its effect on soil loss in the Rmel river basin, Tunisia

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Citation: Bouguerra S., Jebari S., Tarhouni J. (2021): Spatiotemporal analysis of landscape patterns and its effect on soil loss in the Rmel river basin, Tunisia. Soil & Water Res., 16: 39–49.

Abstract: Changes in land use and land cover (LULC) are generally associated with environment pollution and the degradation of natural resources. Detecting LULC changes is essential to assess the impact on ecosystem services. The current research studies the impact of the LULC change on the soil loss and sediment export in a period of 43 years from 1972 to 2015. Landsat imageries were classified into five classes using a supervised classification method and the maximum likelihood Algorithm. Then, the sediment retention service for avoiding reservoir sedimentation was assessed using the InVEST SDR (integrated valuation of ecosystem services and trade-offs sediment delivery ratio) model. The results showed that the changes are very important in this study period (1972–2015). Forests were reduced by 18.72% and croplands were increased by approximately 54%. The InVEST SDR model simulation results reveal an increase in the sediment export and soil loss, respectively, from 1.68 to 5.57 t/ha/year and from 15.22 to 43.61 t/ha/year from the year 1972 to 2015. These results highlight the need for targeted policies on integrated land and water resource management. Then, it is important to improve the common understanding of land use and land cover dynamics to the different stakeholders. All these can help in projecting future changes in the LULC and to investigate more appropriate policy interventions for achieving better land and water management.

Keywords: erosion; InVEST SDR model; land use and land cover (LULC) change

Studies on the changes in land use and land cover (LULC) and their interactions with human societies and their territories is a major challenge for the scientific community in a context of global change (Tadesse et al. 2017). According to (Gete & Hurni 2001), the change in the LULC is due to human activities and natural processes. Lambin et al. (2003) also reported that changes in land cover and land use were influenced by the increase in a given population and because of the rapidly growing demand on natural resources (MEA 2003). Actually, the rural population of Tunisia lives in a rural environment in crisis that does not have enough opportunities to develop and to provide jobs and sources of income for them. Public investment programmes in rural areas have not been sufficient to provide rural populations with the necessary services in education, health, transportation and travel.

Changes in the LULC can significantly alter ecosystem services. The availability and quality of water can change by changing the type or amount of vegetation (Tang et al. 2005; White & Greer 2006; Zampella et al. 2007), the permeability of the soil and other surfaces, and the introduction of contaminants by human activities. Logging, grazing and other land use activities that compact soils can reduce the

Supported by the European Project "BEWATER" 7th Framework Programme, Science in Society, (Grant No. 612385), by the 'INFORMED Project (Integrated Research on Forest Resilience and Management in the mEDiterranean' Project) and by the European Project Faster, H2020 widespread - twinning framework, (Grant No. 810812).

https://doi.org/10.17221/84/2019-SWR

amount of surface water that seeps into the ground to become groundwater. In addition, vegetation areas or wetlands can reduce the severity of peak and low flows in rivers, promoting the infiltration of the surface water into the groundwater (Brauman et al. 2007). The vegetation cover plays an important role in protecting watersheds by delaying water erosion and the water supply (Zhao et al. 2019). It regulates the water cycle and distribution in evapotranspiration, infiltration and runoff. Forest ecosystems play an important role in soil protection against erosion and in the preservation of water resources by avoiding the problem of dam siltation. In fact, in 1998, the rate of siltation of Tunisian dams was 17.7%. It was over 20% in 2002 and could reach more than 40% in 2030 (Ben Mammou & Louati 2007). Forest ecosystems are also involved in the fight against climate change, through carbon sequestered in the vegetation and soil. The amount of carbon fixed by Tunisian forest formations in 2012 was estimated at one million tonnes of equivalent CO_2 (MEE 2013). The Tunisian forest also plays a key role in adapting to climate change, in the face of a significant rise in temperatures and a decrease in precipitation in the horizons of 2020 and the 2050 forecast by the projection models of climate change (MEE 2013).

In most developing countries, population growth has been a dominant cause of land use and change in land cover relative to other forces (Meyer & Turner 1996). There is a significant statistical correlation between the population growth and vegetation cover conversion in most countries in Africa, Asia and Latin America. Due to increasing demands for food production, agricultural land is growing at the expense of natural vegetation and grasslands (Lambin et al. 2003).

During the French occupation of Tunisia, the forest cover decreased from 1.25 million ha in 1881 to 386 000 ha in 1956 (Merlo & Croitoru 2005). Cultivation resulted in the loss of 864 000 ha of forest and 2 million ha of rangelands that were cleared for cultivation. Thus, the area of cultivated land increased from 1.2 million ha in 1920 to 4 million ha in 1956 (Merlo & Croitoru 2005). However, since the independence of the country, the trends have been changed thanks to reforestation policies and the creation of a forest code, resulting in the planting of a total of 457 000 ha of forests between 1956 and 1994. This allowed the country to increase the forest area to 843 000 ha. Despite these conservation measures, the illegal conversion of forests to croplands has continued, but in small areas of a few hundred ha per year (Merlo & Croitoru 2005).

Chriha and Sghari (2013) recorded that Tunisian forests are, as always, vulnerable to degradation caused by extensive sheep and goat farming, coupled with deforestation by local populations, especially during dry years or when winters are very cold. Fires can be added to the causes of degradation, which remain, by far, the first threat because of their ability to quickly ravage large areas. Tunisian forests record fires at a rate comparable to other Mediterranean countries. Indeed, during the period of 1985–2000, more than a hundred fires broke out each year, ravaging an average of 1500 ha of forest. The years 1987–1988 and 1993–1994, characterised by long summers and increased drought, were exceptional and resulted in a remarkable weakening of the forest cover (Frigui 2010).

The political events that shook Tunisian society at the end of 2010 caused the fall of the regime in 2011. The decline of the state is pushing many individuals to transgress the legal framework in many areas. The forest area is being ravaged on a large scale. Fires are deliberately triggered to allow the spontaneous extraction of the destroyed lands (Chriha & Sghari 2013). The partial restoration of the state authority from March 2011 did not eradicate the massive dangers placed on Tunisian forests, with 300 fires recorded in 2012, double the number of fires compared to usual. Achouri et al. (2018) recorded that forest losses have almost tripled from 32 to 90 km^2 between the two periods of 2007–2010 and 2011–014.

Soil erosion is one of the major and widespread environmental threats that the planet has been facing for a long time (Xu et al. 2012; Ganasri & Ramesh 2016). Numerous studies have shown that the LULC change directly affects soil erosion and dam siltation. Soil erosion control is a key ecosystem service delivered by terrestrial ecosystems, mainly through vegetation cover.

A watershed management tends to approach the management based on the recognition and the evaluation of the environmental services today. It operates through the payment of ecosystem services (Mayrand & Paquin 2004). It is then necessary to understand the interaction between the hydrological and biological processes and the factors that regulate them (Zalewski & Wagner-Lotkowska 2004).

The general objective of this study is to evaluate the spatial and temporal dynamics of the LULC of the Rmel river watershed, located in North-East

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Tunisia and its impact on the sediment retention service. Evaluation and quantification of the service: Determine the current level of the economic good or service and the expected level in the event of a change in the ecosystem. Hydrological services, especially the protection of water reserves against sedimentation, provided by ecosystems are often considered to be very important benefits in Southern Mediterranean countries. Indeed, these are characterised by the scarcity of water and the sensitivity of the land to erosion (Daly-Hassen 2016).

The specific objectives are; to generate multi-temporal LULC maps using the Landsat thematic mapper (TM), to analyse factors determining the LULC changes, to spatially model and quantify the critical areas impacted by the soil loss and sediment yield using the InVEST SDR (integrated valuation of ecosystem services and trade-offs sediment delivery ratio) model.

MATERIAL AND METHODS

Study area. The Rmel watershed is located in the North eastern part of Tunisia (Figure 1). The mean annual precipitation is approximately 450 mm. It mostly occurs during winter. The average temperature is about 18.5 °C annually. The study area is located in a semi-arid climate. It lies between 10.09° and 10.34° E longitude and 36.51° and 36.26° N latitude. It covers an area of approximately 623 km^2 and has a population of 135 438 inhabitants. It ensures the transition between the different regions: the north of the Tunisian Dorsal, the Sahel and Cape Bon. This basin extends mainly to the Zriba delegation of the Zaghouan governorate.

The Jbels are covered by forest formations ranging from degraded scrubland to dense forest. On the slope deposits, which form the slopes, scrubland as well as relics of the Aleppo pine forest appear in places. Generally, the forests that occupy the adjoining parts of the cultivated fields undergo continuous clearing. Olive trees interspersed with cereal crops occupy the glacis soils, the hills that form the connecting areas between the mountain slopes, and the lowlands. The basin axis, consisting of alluvial deposits and quaternary deposits, is occupied, for the most part, by annual cereal crops, sometimes associated with arboriculture. The downstream portion of the watershed has recently been converted into an irrigated perimeter. The entire region is affected by the extensive grazing of goats, causing many problems such as overexploitation, accelerated soil erosion and the depletion of natural vegetation (Jebari et al. 2016). In this study area, the forest is exploited to meet the needs of the population, such as: wood, pasture, beekeeping, coal, etc. It is also a source of employment for the elderly population. Recently, the national management programmes have made the forest more accessible and exploitable because of its resources in Aleppo pine, rosemary, wood and medicinal plants.

Land use land cover change detection. In this study, Landsat (MSS, TM, ETM+ and OLI) imageries

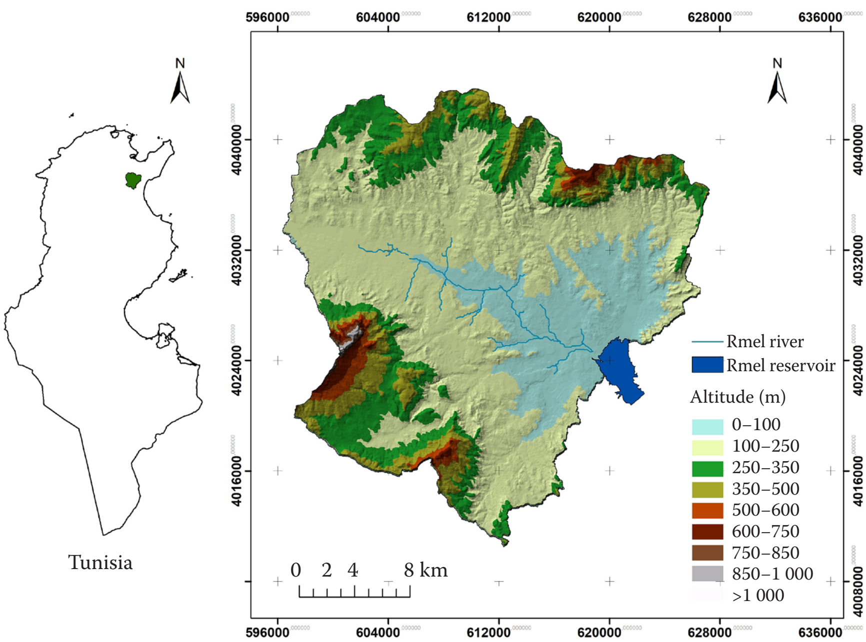

Figure 1. Location of the study area

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Table 1. The characteristics of the Landsat imageries

Landsat type	Date of image acquisition	Row/Path	Spatial resolution (m)	Sources
Landsat1 MSS	09/11/1972	35/191	60	https://earthexplorer.usgs.gov/
Landsat5 TM	05/08/1987		30	
Landsat7 ETM+	25/07/1999		30	
Landsat8 OLI	03/09/2015		30	

for the years 1972, 1987, 1999 and 2015, were used in this study. They provide an excellent baseline resource for the LULC change detection (Minwer Alkharabsheh et al. 2013). Landsat data files have been collected from the website of the US Geological Survey (https://earthexplorer.usgs.gov/). The characteristics of the Landsat are summarised in Table 1. Field observations were also conducted to fix up training sites, to check ground truth and to verify the final output maps.

All imageries were rectified with the help of a topographic map. We focused the research on five LULC classes: forests, scrubland, cultivated land, bare soil and constructed areas. In order to avoid any seasonal variation and the distribution of vegetation during the year, the image selection of the acquired data was made during the same time period and in the summers to avoid confusion between croplands and natural vegetation lands. The classification was performed based on a supervised maximum likelihood classifier. In fact, several studies have shown that the supervised classification is the most efficient (Hasmadi et al. 2009; Guerra et al. 2011). It consists of visually identifying a number of natural or artificial elements or objects that may be punctual, linear or surface-area in the image. During the classification of the images, twenty-five training points were marked and used to determine the different classes. These points were used for the sample representative signatures for the different types of land cover identified with the Google Earth software. Following this, a supervised classification was carried out and the changes in land use in the periods were determined using ENVI 4.5 software. Maps were generated to indicate the variability of the LULC classes for each year (1972, 1987, 1999 and 2015) and to display the land use dynamics.

The evaluation of the accuracy of the classification was performed from the confusion matrix. It determines the total number of correctly classified pixels. The Kappa coefficient reflects the reduction of the error made during the classification. It is a statistical coefficient, which represents the degree of precision and reliability. It is a concordance index calculated as a function of the ratio between the actual and expected agreement by chance. The Kappa coefficient was calculated by the method described by Mather (1999).

$$K = \frac{P_0 - P_e}{1 - P_e} \quad (1)$$

where:

P_0 – the proportion of the observed agreement,

P_e – the proportion of the random agreement.

The Kappa coefficient is usually on a scale of 0 to 1. Its values are also characterised in 3 groups: values greater than 0.80 (80%) represent a strong agreement, values between 0.4 and 0.8 (40% and 80%) represent a moderate agreement and values less than 0.4 (40%) correspond to a mediocre agreement (Rahman 2004).

InVEST SDR model. InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) is a suite of different models for mapping and valuing ecosystem services. It is developed by the Natural Capital Project (Tallis et al. 2014). This geospatial tool helps one to evaluate the land use change impact on ecosystem services (Polasky et al. 2011). It is fully distributed on an annual time scale. InVEST SDR has been applied in many studies around the world, in Thailand (Arunyawat & Shrestha 2016), in China (Zhu & Zhu 2014), in Romania (Bodgan et al. 2016), in the United States (Podolak et al. 2017) and in Morocco (Ben Salem et al. 2020). It has been found that this model provides an effective tool to allow decision makers to define the highest priority areas to intervene upon in order to conserve soil and water resources.

The InVEST SDR model was selected to map and quantify the sediment retention service on our study area (Hamel & Guswa 2015; Sharp et al. 2015). It was chosen because it is widely used for mapping ecosystem services and their variability within the LULC change (Polasky et al. 2011). The model inputs and calibration of the model for the current situation are shown in detail in Bouguerra and Jebari (2017).

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The SDR model is a spatially explicit model working on the spatial resolution of a digital elevation model (DEM) raster. For each pixel, the model first calculates the amount of eroded sediment, then the sediment delivery ratio (SDR), which is the proportion of the soil loss actually reaching the outlet. It is calculated as a function of the hydrologic connectivity of the area, following the approach proposed by (Vigiak et al. 2012). The amount of annual soil loss in pixel i, A_i (t/ha/year), is given by the Revised Universal Soil Loss Equation (RUSLE) as follows:

$$A_i = \mathrm{R} \times \mathrm{K} \times \mathrm{LS} \times \mathrm{C} \times \mathrm{P} \tag{2}$$

where:
R – the rainfall erosivity factor,
K – the erodibility factor (t·ha·h $(\mathrm{MJ{\cdot}ha{\cdot}mm})^{-1}$),
LS – the slope length gradient,
C – the cover management factor,
P – the support practice factor (Renard et al. 1997).

The sediment export of a given pixel i, E_i (t/ha per year) is given by:

$$E_i = A_i \times \mathrm{SDR}_i \tag{3}$$

The total sediment load of catchment E (t/ha/year):

$$E_i = \Sigma_i E_i \tag{4}$$

The SDR was estimated using a connectivity index (IC) reflecting the attributes of each LULC type, threshold flow accumulation and maximum SDR. The SDR value was calculated as suggested by (Borselli et al. 2008) as:

$$\mathrm{SDR}_i = \frac{\mathrm{SDR_{max}}}{\dfrac{(1+\exp)(IC_0 - IC_i)}{k}} \tag{5}$$

where:
$\mathrm{SDR_{max}}$ – the maximum theoretical SDR, set to an average value of 0.8 as reported by (Vigiak et al. 2012),
IC_0, k – the calibration parameters that define the shape of the SDR-IC relationship.

The sediment retention was estimated as suggested by (Sharp et al. 2015) as:

$$\text{Sediment retention} = \mathrm{R} \times \mathrm{K} \times \mathrm{S} \times (1 - \mathrm{CP}) \times \mathrm{SDR} \tag{6}$$

The model requires the DEM of the catchment area, the LULC map, the rainfall erosivity (R factor) and the soil erodibility (K factor) raster datasets. The biophysical table contains different LULC classes and their corresponding C and P factor (Table 2). The soil erodibility in the Rmel watershed are ranged from 0 in the rivers to 0.99 t·ha·h $(\mathrm{MJ{\cdot}ha{\cdot}mm})^{-1}$ in constructed areas.

Table 2. The biophysical data

LULC_class	lucode	RUSLE_C	RUSLE_P
Forest	1	0.01	1
Scrubland	2	0.25	1
Cultivated land	3	0.65	1
Constructed area	4	0	1
Cultivated land plus bench terraces	5	0.65	0.11
Cultivated land plus contour stone bunding	7	0.65	0.35
Bare soil	8	1	1

LULC – land use and land cover; lucode – LULC pixel values; C, P – RUSLE factors

The R factor was calculated using the method proposed by Renard et al (1997). We used the rainfall intensity data (I_{15}) from the Sbaihia rainfall station which is located within the study area. The model input K and C factors and the calibration parameters are described in more detail in a previous study (Bouguerra & Jebari 2017). In order to understand the impact of the LULC on soil degradation, we considered the change in the LULC map only. The other factors and parameters are considered to be constant.

RESULTS

LULC change detection. The accuracy of LULC classification is summarised in the confusion matrix (Table 3). The table demonstrates that the accuracy of the individual categories ranged from 83.5% to 93%. The Kappa coefficient value is equal to 0.8. The latter value indicates that image classification represents a strong agreement.

The Landsat images of the four dates were classified into five land cover classes (Figure 2A, B). The examination of the thematic maps revealed a varying degree in the changes of the composition of the LULC categories in the study areas over a span of 43 years. The total extent or composition of the individual LULC classes and their gain/loss are presented in Table 4. Between 1972–1987 and 1999–2015, the forest area decreased, respectively, from 15% to 11.5%

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Table 3. The confusion matrix (2015)

	Forests	Scrublands	Croplands	Bare Soil	Constructed area	Total	Precision (%)
Forests	259	22	3	0	0	284	91.20
Scrubland	17	239	15	0	2	273	87.55
Croplands	25	33	1808	3	1	1870	96.68
Bare Soil	0	2	4	72	3	81	0.89
Constructed area	0	2	3	7	218	230	0.95
Total	301	298	1833	82	224	2738	

and from 14.8 to 11% of the watershed area. While it increased by approximately 22% between 1987 and 1999. Figure 2A, indicates that the cropland area remained the dominant land cover class. It occupies more than 50% of the watershed area. The cropland area increased during the study period, especially between 1999 and 2015 by 21%. The largest increased category is related to the constructed area, which displays an extension of more than 300% between 1972 and 1987; while the scrubland area decreased from 54.2% in 1972 to 10% ha in 2015.

The increase in the constructed area after 1972 may be explained by the creation of the Zaghouan governorate in 1975. The city of Zaghouan lived through a rapid increase in the population during this period.

Impact of land use land cover change on soil loss. Figure 3 presents the distribution of the soil loss class per LULC category in the year 2015. It demonstrates that 90% of the forest area is under slight erosion (0–5 t/ha/year). In this category class, severe erosion is very low (< 5%). The bare soil class presents the

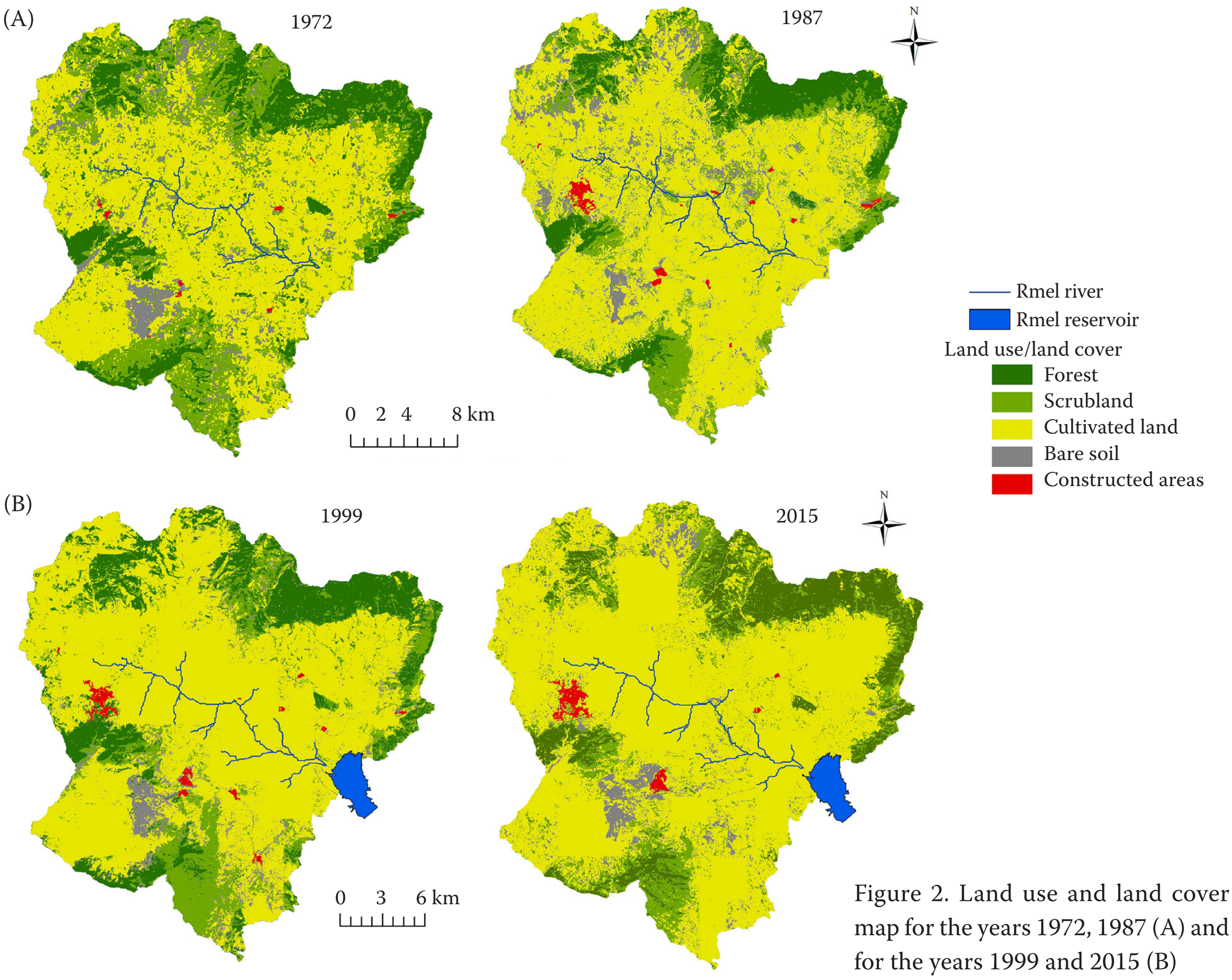

Figure 2. Land use and land cover map for the years 1972, 1987 (A) and for the years 1999 and 2015 (B)

Table 4. Areas of land use and land cover categories for the years 1972, 1987, 1999 and 2015

	1972		1987		1999		2015	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Forest	9 557.2	15	7 340.7	11.5	9 396.2	14.8	7 767.7	10.8
Scrubland	15 736.2	54.2	10 657.1	16.7	8 970	14.1	7 178.6	10
Cropland	34 521.1	54.2	41 683.6	65.4	42 375	66.6	54 240	75.3
Bare soil	3 739	5.9	3 528.7	5.5	2 472	3.9	2 174	3
Constructed area	116.8	0.2	455.6	0.7	483	0.8	652.5	0.9

highest soil loss class with more than 40% of its area. Sever erosion is mostly located in the scrubland and soil bare classes. In fact, these classes are located in an area with steep slope indexes, which is considered as the most important parameter for sedimentation (Ayadi et al. 2010). However, the cultivated lands are located areas where the slope indexes are very low.

As a result of the SDR model simulation, the sediment export was 1.68, 3.89, 4.01 and 5.57 t/ha/year in the year 1972, 1987, 1999 and 2015, respectively, for the entire watershed (Table 5). Table 5 also demonstrate that the soil loss has increased during the period 1972–2015 from 15.22 to 43.61 t/ha/year, respectively. However, the sediment retention service decreased by 5.5%. The sediment retention refers to the capacity of the ecosystem to regulate the quantity of the eroded sediment reaching the stream network. It represents the avoided soil loss by the current land use compared to the bare soil, weighted by the SDR factor. The InVEST Sediment Retention model estimates the capacity of a land parcel to retain sediment by using information on the LULC. This means that the LULC degradation

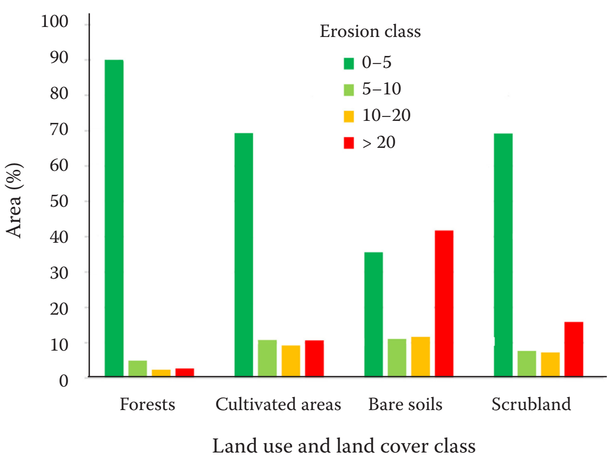

Figure 3. Soil loss classes for different land use and land cover classes

leads to a high soil loss and low sediment retention. In this study area, it was found that sediment retention rates are higher than the soil loss, which is generally revealed in a semi-arid context (Hamel & Guswa 2015; Ben Salem et al. 2020).

The sediment export and soil loss was generally low in 1972 (1.68 t/ha/year). In 2015, it clearly increased, especially in south-eastern and northern part of the watershed. During this study period, the sediment export and soil loss increased in the regions where the cultivated areas increased (Figure 4). However, the sediment retention services clearly decreased between the year 1972 and 2015.

The soil loss varies with different factors, such as the topography, LULC and the presence of anti-erosion techniques. The sediment export, soil loss and sediment retention for the different periods are given in Table 5.

In this study, we analysed the impact of the land use land cover change on the soil loss and sediment export using spatial variability techniques.

The changes in the soil erosion potential and their spatial distribution is shown in Figure 3 and Figure 4. They demonstrate that the changes in the mountains and in the regions with high slopes is stronger than the other regions. This may be directly attributed to the degradation of the forest and scrubland.

The soil erosion potential changes that occurred during the period 1972–2015 can be attributed to the extension of the agricultural activities and the disappearance of some forest patches. In fact, the natural vegetation, such as forest, plays a role in

Table 5. Variation of the sediment export, soil loss and sediment retention service between 1972 and 2015 (in t/ha/year)

	1972	1987	1999	2015
Sediment export	1.68	3.89	4.01	5.57
Soil loss	15.22	31.32	30.61	43.61
Sediment retention	73.17	70.74	68.39	69.13

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being a barrier to sediment export. However, the transition from natural vegetation to a cultivated area is a source of sediment production.

Considering that approximately 75% of the area of the watershed is occupied by cultivated lands, the best agricultural practices would be an effective way to protect the soil from erosion and the sediments from being deposited elsewhere.

The main driver of the change in the Rmel watershed may be attributed to the population. Indeed, the demography depends on the attractiveness of the territory. It is, therefore, a consequence of the intensity and quality of the economy and the urbanisation of the given place. The trend in the population growth strongly affects the landscape. There are 135 438inhabitants in the basin. An important aspect of rural

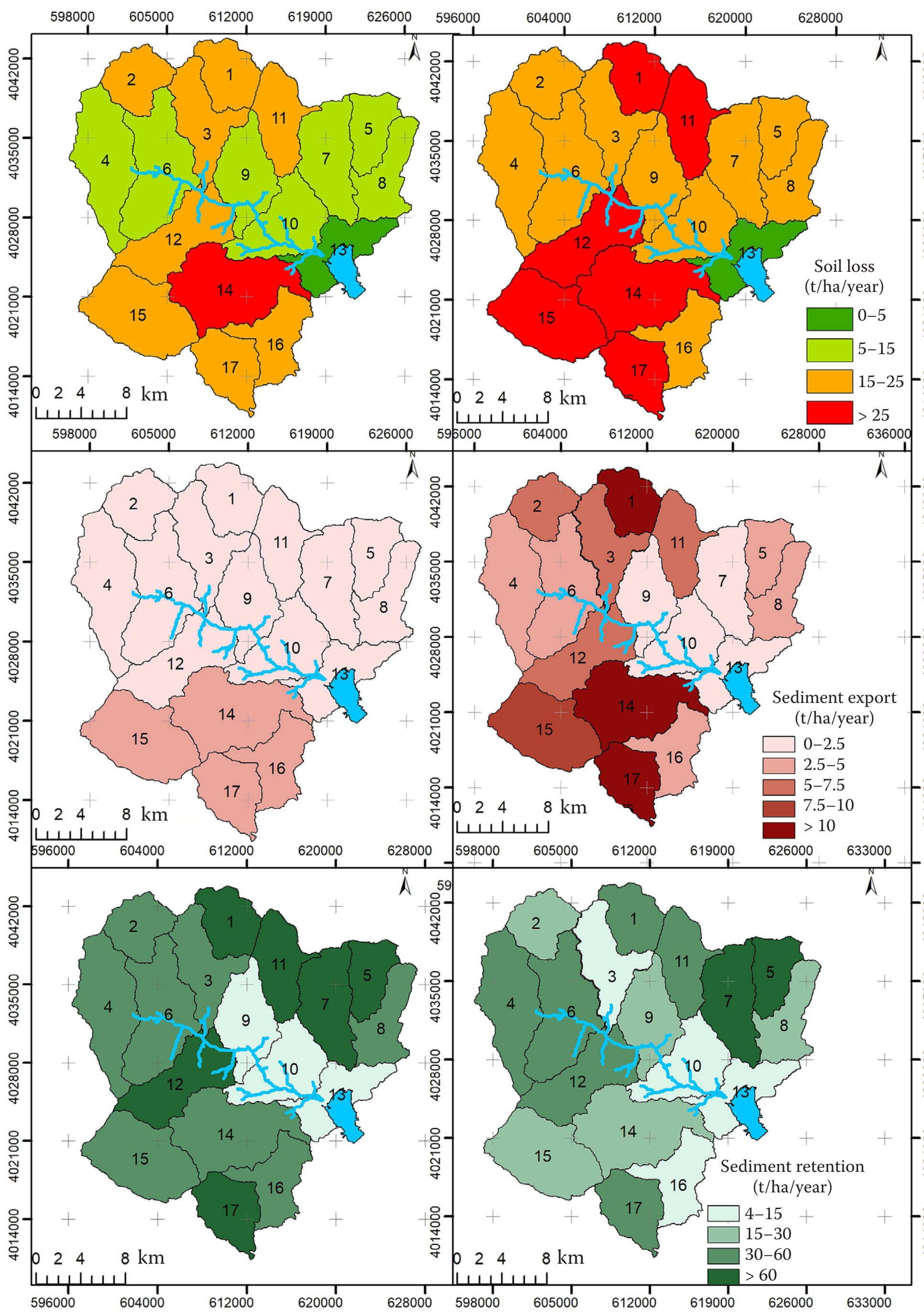

Figure 4. Spatial distribution of the sediment export, soil loss and sediment retention service for the years 1972 and 2015

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populations is constantly looking for occasional non-agricultural employment opportunities or migrating to neighbouring governorates (Jebari et al. 2016). The distribution of the population in the basin is closely related to the water resources. In fact, valleys, wadis, small lakes and groundwater are among the factors encouraging sedentary populations in the basin. In addition, the Rmel river basin has a strong cultural heritage around the water resources. An increases population leads to a diversity of negative human activities like overgrazing, unsustainable agricultural practices, etc. Meanwhile, the observed changes in the rainfall patterns and trend towards aridity has led to the lower productivity and higher soil degradation. This requires the agricultural sector to adapt, considering new and innovative technologies.

We particularly noticed the extension of the irrigation and the development of industry and tourism within the region. These can be considered as important landscape drivers. In the Rmel river basin, agriculture is still the largest economic sector for employment with 31.9%, closely followed by the manufacturing sector with 28% (MARHP 2015). Agricultural employment has gained momentum with an increase in 9.2% employment between 1999 and 2010. In rural areas, agriculture accounts for 34% the main source of employment and it provides jobs to almost all rural women (PDAI 2014). The Rmel river basin holds an industrial zone with an area of 44 ha. It is located in the delegation of Zriba and contains 38 companies with a total workforce of 4 500 employees. This area is causing a water pollution problem due to direct dumping of waste in the waterways (PDAI 2014). In addition to the agricultural and industrial activities, the Rmel river basin consists of 20% of forests that are used mainly for firewood, the extraction of oil, and the production of Alep seeds. Given the mountainous landscape, several areas of the watershed have been considered for agro-tourism projects. Tunisia's environmental protection policy has always been based on practical programmes to improve the conditions and quality of life in urban and rural areas and on targeted interventions for the conservation of natural resources.

DISCUSSION

The LULC change was detected for three time-dates by using data from 1972, 1987, 1999 and 2015. The forest and scrubland have decreased over the years 1972–2015 by about 18% and 54%, respectively. These two LULC classes have been encroached upon for cultivation areas. The overall results show values generally consistent with those specific to the semi-arid climatic context of Tunisia. Tolessa et al. (2019) demonstrated that the expansion of cultivated land to the detriment of natural vegetation is significantly affecting the natural resources. Also, Mathlouthi and Lebdi (2018) have reported that the pressure exerted on the soil by ploughing as well as overgrazing to meet the needs of the population of a specific watershed in Tunisia has led to the continued soil deterioration manifested by increased erosion and sedimentation in the reservoirs. In fact, agricultural and silvopastoral lands in Tunisia have undergone important changes, since the beginning of the 20th century. As a result, the overexploitation of the natural resources has led to a very severe erosion crisis (Bkhairi 2012). The spatial analysis revealed that expansion of cultivated land in the relatively more erosion prone soil was the main factor contributing toward the increased soil erosion potential of the watershed during the study period (1972–2015). Understanding the spatial distribution of the erosion is important to mitigate the soil loss problem by applying appropriate soil and water conservation techniques. Since 1990, agricultural areas in the Rmel have been treated with bench terraces. However, there was the continued problem of the natural forest reduction, the cultivation of steep slopes and overgrazing due to the rapid population growth (Jebari et al. 2016). Since agricultural areas are the dominant category of the LULC, the implementation of the best agricultural practices and tillage would be effective in reducing the potential of the soil erosion and sediment yield in this study area.

CONCLUSION

The results show that the Rmel river basin has been under a continual LULC change from 1972 to 2015. Decreasing the forest are due to agricultural activities and anthropogenic factors has led to the land degradation. In fact, this research showed a relationship between the LULC change and the soil erosion and sedimentation risks. This study also related the LULC dynamics to the human activities in the region, such as the expansion of settlements and agricultural activities. Therefore, it is essential to the assess LULC dynamics and the linkage for sustainable land management. This could assist decision makers in optimising land use and minimising environment degradation. In this case, soil and water conservation techniques are highly recommended.

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Received: July 6, 2019
Accepted: June 10, 2020
Published online: September 16, 2020