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Final Thesis

Assessing the Impacts of Land Use and Land Cover Changes on Organic Carbon Content and Electrical Conductivity of Soil in Northeast Italy and Khyber Pakhtunkhwa Pakistan

Supervisor

Ch. Prof. Fabio Pranovi

Assistant supervisor
Dott.ssa Alice Stocco

Graduate
Usman Khan
893181

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Abstract

Major variations in the environment caused by anthropogenic and natural factors have caused significant changes in the land use and land cover (LULC) worldwide over the past few decades. The present thesis investigated this phenomenon in two areas of study, Northeastern Italy and Khyber Pakhtunkhwa Province in Pakistan, by considering the impact of LULC changes occurring in the period 2018 – 2021 on soil properties, focusing especially on Organic Carbon and Electronic conductivity. Starting with a comprehensive review of the studies that have been carried out, a multitemporal GIS-based analysis was performed to assess the changes in LULC from 2018 to 2021 in both the study areas. It has been found that land cover in Pakistan was dominated by crops and settlements in 2018, which underwent a noticeable change since crops decreased from 44.63% to 41.83%, while built-up settlement areas increased from 23.01% to 28.37%. However, the central part of the study area of Pakistan, which is mostly urban, was still presenting high OC in soils. Conversely, in Italy the changes in LULC were not as high as in Pakistan, but a land degradation and soil consumption occurred as well: although trees-covered areas remained almost unchanged, crops decreased from 46.42% in 2018 to 45.74% in 2021, while built-up increased from 12.99% in 2018 to 13.52% in 2021. Here, the soil properties were totally different, with less OC and higher EC, along with excess salts risk. Therefore, the changes in LULC that took place between these years have likely impacted the soils availability and soil properties, as testified by the resulting spatial pattern. The results are discussed by making additional considerations about the possible consequences on the suitability of soils for agriculture and food production in the upcoming future. Overall, this study highlights the need to plan and manage LULC changes, along with implementation of Nature-based solutions that should be applied throughout the study region to reduce negative effects on the soil.

Introduction

In the past centuries, the priorities of the economy and those of ecology have often been different, if not opposed. As a response to the growing concerns about environmental and social impacts of industrialization and economic growth, the concept of sustainable development came into play (Elliott, 2013). It advocates for meeting the needs of the present without compromising the ability of future generations to meet their own needs. This approach, that recognized the interconnectedness of environmental, social, and economic systems, represented the basis for the development of the concept of ecosystem services (ES).

In reaction to traditional environmental management approaches, grounded on the paradigm that asked for 'control change in systems' (Quay 2010), ecosystem services (ES) have emerged as a novel way of understanding the interactions and flows between human and natural systems, along with ecosystems and landscape dynamics. ESs have recently been redefined as the 'contributions of ecosystem structure and function – in combination with other inputs – to human well-being' (Burkhard et al. 2012, p. 2).

Therefore, ESs can be interpreted as resulting from a co-production process of knowledge between scientists, stakeholders and decision-makers. This new notion of 'other inputs' refers to the significant, mainly anthropogenic, modifications of ecosystem functions in form of, for example, inputs of energy, fertilizers, labour, knowledge or other forms of material or information. Other definitions refer to ES as benefits for societies deriving from some ecosystem functions (Haines-Young & Potschin 2010). This definition puts in evidence that not all ecosystem functions are identified or constitute benefits for human societies, but are instead subjected to a process of selection and recognition by the beneficiaries of the final ES (Wolff et al. 2015) . ESs have become a central issue for researchers and decision makers since the late '90s, and particularly after the publication of Millennium Ecosystem Assessment (MEA 2005), filling the gap between natural protection and human welfare (Fisher et al. 2009).

The economic evaluation of the environment has found a scientific dimension through the concept of ecosystem services (ESs) (Gissi et al. 2015).

Despite the increasing awareness, during the last decades, that human well-being strongly depends on natural ecosystems (Egoh et al. 2007), human populations continue to alter the landscape and natural lands, because of socio-economic and socio-ecological phenomena (Lambin and Meyfroidt 2010; Lambin et al. 2001), at extraordinarily high rates (Lambin et al. 2003). Global and regional land covers and, in particular, land uses are poorly enumerated (IPCC, 2000). Scientists recognize, however, that the magnitude of change is large. One estimate, for example, holds that the global expansion of croplands since 1850 has converted some 6 million km^2 of forests/woodlands and 4.7 million km^2 of savannas/grasslands/steppes. Within these categories, respectively, 1.5 and 0.6 million km^2 of cropland has been abandoned (Ramankutty and Foley, 1999).

An increasing human population and civilization making advances in technology in agriculture, forestry, mining and trade have caused massive changes in forest vegetation (Williams 2000). This resulted in an estimated loss of natural forest/woodland area of 6% by A.D. 1700, 14% by 1850 and 34% by 1990 (Klein Goldewijk 2001). Soil organic matter and soil organic carbon (SOC) play an important role in enhancing crop production (Stevenson and Cole, 1999) and mitigating greenhouse gas emissions (Lal et al., 1995; Flach, et al., 1997). Therefore, maintaining adequate soil organic matter content and proper soil structure are required for the sustainability of the land-use systems. The effects of land use and soil management practice on SOC and other soil properties on an aspect need to be studied on a catchment scale (Symeonakis et al., 2007).

The capacity of the soil to function can be determined by soil physical, chemical, and biological properties, also termed as soil quality indicators (Shukla et al., 2006; Wang and Gong, 1998). Soil properties that are responsive to the change in the land use dynamics on a short-term basis are considered as suitable soil quality indicators (Carter et al., 1998). A soil quality indicator is a measurable soil property that affects the capacity of a soil to perform a specified function (Karlen et al. 1997). For evaluation of soil quality, it is desirable to select indicators that are directly related to soil quality. If a set of attributes is selected to represent the soil functions and if the appropriate measurements are made, the data may be used to assess the soil quality (Heil and Sposito, 1997).

For millennia, humans have reshaped the form and process of ecosystems across the terrestrial biosphere, both intentionally and unintentionally (Turner IIet al., 1990; Redman, 1999; Kirch, 2005; Dearinget al., 2006;).Practices like hunting and gathering and building towards the increasingly permanent use of land for agriculture and settlements, the widespread and sustained presence of human populations has transformed ecosystems locally, regionally and globally Human activities have facilitated species extinctions, invasions, introductions and domestications, increased soil erosion, altered fire frequency and hydrology, and incited profound changes in primary productivity and other key bio-geochemical and ecosystems processes (Turner IIet al., 1990;Vitouseket al., 1997; Defrieset al., 2004; Foleyet al., 2005;Dearinget al., 2006; Hobbset al., 2006; Ellis & Ramankutty,2008; Hansen & Galetti, 2009). Therefore, Land Use/Land Cover (LULC) changes are considered the major form of anthropogenic pressure on the environment (Ellis et al. 2010), causing changes in ESs patterns, and a loss of biodiversity affecting ecological functions (Daily 1997; Millennium Ecosystem Assessment 2005; Haines-Young and Potschin 2010)

Human activity has altered between a third and a half of Earth's land surface through cropping, pasture, forestry and urbanization (Vitousek et al. 1997). This had consequences for key biogeochemical cycles, changing the atmospheric composition and resulting in considerable modification of ecosystems (Foley et al. 2005). Such as alterations in vegetation and soil carbon pools (Houghton and Goodale 2004), which influence atmospheric greenhouse gas levels and global climate (Foley et al. 2003).

Most changes in land use affect the amount of carbon held in vegetation and soil, thereby, either it is releasing carbon dioxide (a greenhouse gas) or removing it from the atmosphere. The greatest fluxes of carbon result from conversion of forests to open lands (and vice versa) (Houghton and Goodale, 2004). Soil organic matter and soil organic carbon (SOC) play an important role in enhancing crop production (Stevenson and Cole, 1999) and mitigating greenhouse gas emissions (Lal et al., 1995; Flach, et al., 1997). Therefore, maintaining adequate soil organic matter content and proper soil structure are required for the sustainability of the land-use systems. The effects of land use and soil management practice on SOC and other soil properties on an aspect need to be studied on a catchment scale (Symeonakis et al., 2007).

Soil is one of the most complex biomaterials on earth (Young and Crawford, 2004), and a key component of the terrestrial ecosystem operating at the interface of the lithosphere, biosphere, hydrosphere, and atmosphere (Szabolcs, 1994). In spite of its importance, most studies (Costanza et al., 1997, de Groot et al., 2002, MEA, 2005) have described ecosystem focusing on the services only (i.e., provisioning, supporting, regulating, and cultural services) with little emphasis on soil. We have considerable knowledge about soils, its formation and distribution, but our understanding on its functions and soil ecosystem services is incomplete (Daily et al., 1997, Swinton et al., 2006). Hewitt et al. (2015) mentioned that soil is as an overlooked component in ecosystem services studies and policy level decisions. Daily et al. (1997) suggested that soils are one of the important determinants of a nation's economic status, and that the inclusion of soils in ecosystem services frameworks and policy and decision-making is essential. The need for soil ecosystem services assessment and promoting soil–ecosystem linkage in the development of land resource policy and management was emphasized by McBratney et al. (2014) and Robinson et al. (2012). Using the UN-Sustainable Development Goals (SDGs), Bouma et al. (2015) emphasized soil science contribution to ecosystem services.

Ecosystem services are closely linked to land use patterns as well. Studying LULC changes helps assess the impacts on these services and informs conservation efforts to maintain ecological balance.

The impacts of conventional agriculture permeate various aspects of our environment, society, and economy. With its heavy reliance on synthetic fertilizers, pesticides, and mechanization, conventional agriculture has significantly altered ecosystems, leading to soil degradation, water pollution, biodiversity loss, and greenhouse gas emissions (Foley et al., 2005; Tilman et al., 2011). Moreover, the use of chemical inputs has raised concerns about human health risks, including pesticide exposure and the development of antibiotic resistance (Pretty et al., 2008; Altieri, 2018). Socio-economically, conventional agriculture has contributed to the consolidation of large-scale industrial farming, often at the expense of small-scale farmers and rural communities (De Schutter, 2010).

In response to these challenges, alternative approaches such as Conservation Agriculture (CA) have emerged as potential strategies for mitigating the negative impacts of conventional agriculture. By emphasizing minimal soil disturbance, crop rotation, and cover cropping, CA aims to promote soil health, reduce chemical inputs, and enhance ecosystem resilience (Hobbs et al., 2008). Therefore, understanding the multifaceted impacts of conventional agriculture is crucial for evaluating the potential of CA as a sustainable alternative in agricultural systems.

Conservation Agriculture (CA) Corsi et al. (2012) define CA as a method of managing agroecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. They added that minimum mechanical soil disturbance, permanent organic soil cover and crop diversification are the three basic principles of CA.

Tillage is defined as the mechanical manipulation of the soil for the purpose of crop production affecting significantly the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes. This suggests that tillage exerts impact on the soil purposely to produce crop and consequently affects the environment.

Urbanization and land use change (LULC) are fundamental processes with far-reaching consequences for environmental sustainability and land management (Foley et al., 2005). As populations grow and urban areas expand, the demand for land increases, leading to changes in land use patterns and the conversion of natural landscapes into built environments (Turner et al., 2007). These transformations not only alter the physical characteristics of the land but also have profound impacts on ecosystem services, biodiversity, and soil quality (Lambin et al., 2003).

This research aims at analysing the pattern of LULC in the study areas, which will be helpful in Assessment of Land Use Changes and in estimating how these changes have affected the soil properties through the comparison of electronic conductivity and organic carbon in two different time steps also comparing two different areas.

Analysing the pattern of Land Use and Land Cover (LULC) in the study areas serves as a foundational step in understanding the dynamics of land use changes over time. By mapping changes in land cover types will give us insights into how human activities and natural processes are reshaping the landscape. This information is crucial for assessing the extent and direction of land use changes, identifying areas of conservation concern, and informing land management decisions.

By comparing LULC patterns across different time steps, researchers can discern trends and patterns of change, such as urban expansion, agricultural intensification, or deforestation. Understanding these temporal dynamics is essential for predicting future land use trajectories and anticipating potential environmental impacts.

Moreover, by linking changes in LULC with variations in soil properties, such as electronic conductivity and organic carbon content, researchers can elucidate the complex interactions between land use changes and soil health. For example, urbanization and agricultural expansion may lead to soil degradation through increased soil compaction, erosion, and loss of organic matter, impacting soil fertility and ecosystem services. The knowledge is crucial for implementing targeted soil conservation measures, enhancing agricultural productivity, and mitigating the adverse impacts of land use changes on soil resources and ecosystem functioning.

Considering Pakistan's status as an agricultural nation and the discernible impact of urbanization on its soil quality, this study aims to conduct a comparative analysis with a developed country, namely Italy. The study will unfold across two diverse regions: Northeast Italy and Khyber Pakhtunkhwa, Pakistan. The research seeks to unveil the differential impacts of land use and land cover changes on soil health. The investigation aims to quantify and compare the soil change in both regions, providing valuable insights into the consequences of urbanization on soil dynamics in diverse socio-economic and environmental settings.

Rapid urbanization and infrastructure development often lead to significant land transformations. Investigating these changes is vital for planning and managing urban growth, minimizing environmental impacts, and enhancing the liveability of urban areas.
Therefore, the specific aims of this thesis are the following:

1. To analyse the LULC changes and spatial distribution of different land cover classes in two different time steps, 2018 and 2021
2. To analyse the consequent changes in the spatial distribution of organic carbon and electronic conductivity from 2018 to 2021
3. To investigate the impact of LULC changes on EC and OC during 2018-21

Material and Methods

Study Area

This study includes two different study areas, one in Italy and the other in Pakistan. The study area in Italy comprises of three regions which comprises of Veneto, Emilia-Romagna, and Friuli-Venezia Giulia in **Figure 1.**

Veneto offers a diverse landscape that encompasses both coastal and mountainous areas. The region is known for its iconic Venetian Lagoon, which includes the city of Venice and its surrounding islands. Emilia-Romagna features a mix of landscapes ranging from flat plains to rolling hills. The region includes the fertile Po Valley, which is known for its extensive agriculture, including fields of wheat, corn, and sunflowers. Friuli-Venezia Giulia boasts a diverse landscape that encompasses coastal areas, plains, and mountains. The region has a portion of the Adriatic coastline, which includes sandy beaches and cliffs.

Veneto have typically warm with average high temperatures ranging from 25°C to 30°C (77°F to 86°F), and occasionally exceeding 30°C (86°F). Winters (December to February) are relatively cold with average low temperatures ranging from 0°C to 5°C (32°F to 41°F). Snowfall is common in the mountainous areas during winter. In Emilia Summers are generally warm and humid, with average high temperatures ranging from 26°C to 32°C (79°F to 90°F). Inland areas tend to be slightly hotter than the coastal areas due to less influence from the sea.
Winters are cool to cold, with average low temperatures ranging from 0°C to 5°C (32°F to 41°F). Snowfall is possible, especially in the hilly and mountainous areas. Friuli-Venezia Giulia experiences a mix of climates due to its geographical diversity. In the coastal areas, summers are typically warm with average high temperatures ranging from 25°C to 30°C (77°F to 86°F). Winters are mild with average low temperatures ranging from 2°C to 6°C (36°F to 43°F).in Veneto you will find sandy and alluvial soils. These soils are well-drained and suitable for agriculture, including the cultivation of vegetables and vineyards. The soils in Emilia-Romagna can vary depending on the location within the region. In the Po Valley, the soil is primarily alluvial, consisting of a mixture of clay, silt, and sand. This fertile soil is well-suited for intensive agriculture, including the cultivation of crops like rice, wheat, corn, and vegetables. In the hilly and mountainous areas of Emilia-Romagna, the soil tends to be loamy and stony, providing a good environment for vineyards, orchards, and olive groves. The soil composition in Friuli-Venezia Giulia is diverse due to the region's varied landscape. In the coastal areas, you'll find sandy and well-drained soils, suitable for agriculture and viticulture. The plains of Friuli are characterized by alluvial soils, formed by the deposition of sediment from rivers, which are highly fertile and ideal for crop cultivation. In the mountainous regions of the Carnic and Julian Alps, the soil varies depending on elevation but is often rocky and less suitable for agriculture.

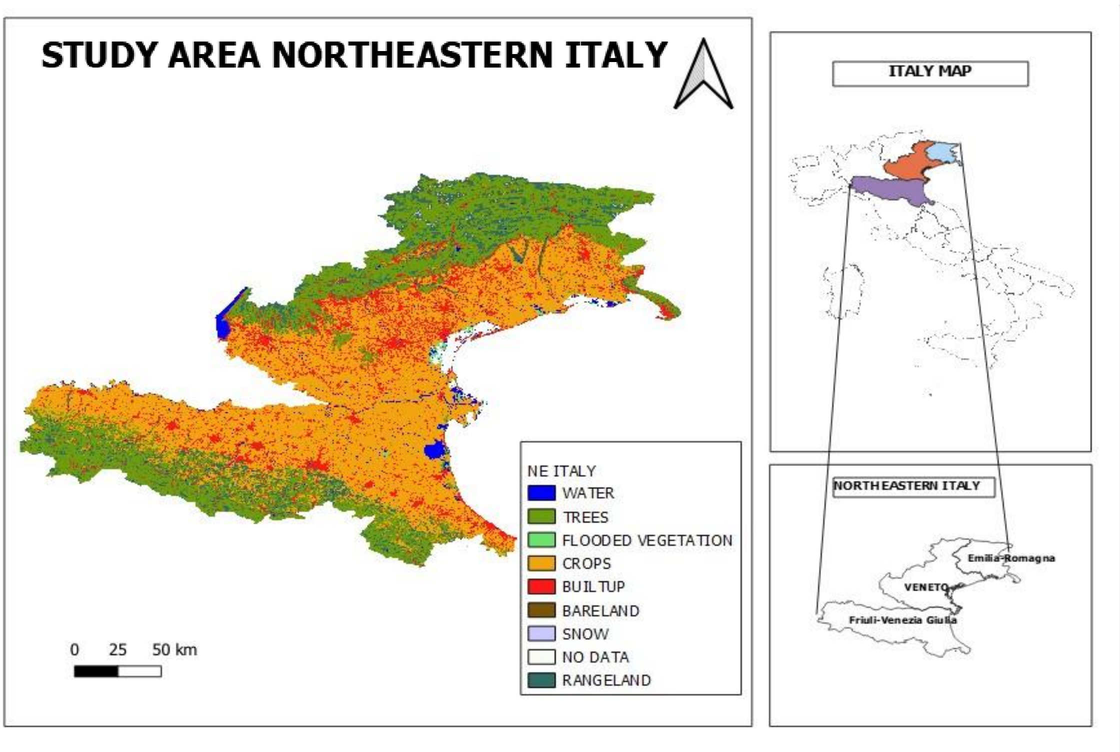

FIGURE: 1 STUDY AREA ITALY

The Federally Administered Tribal Areas (FATA), which was merged with Khyber Pakhtunkhwa province in 2018, FATA encompassed multiple districts and tribal areas can be seen in **Figu re 2**

Peshawar has a diverse land cover that includes Urban Areas: where we have bustling city with developed urban areas, including residential, commercial, and industrial zones.

Agricultural Lands are characterized by fertile agricultural lands, where crops such as wheat, maize, sugarcane, and vegetables are grown where Green Spaces: has parks, gardens, and green spaces that provide recreational areas for residents and contribute to the city's land cover.

FATA comprised various districts and tribal agencies, each with its own unique land cover. The region encompassed mountainous areas, valleys, plains, and arid landscapes. FATA had portions of the Hindu Kush Mountain range, including peaks and valleys. The region had numerous valleys with fertile soils and agricultural activities, such as the Swat Valley, Kurram Valley, and Orakzai Valley and had flat plains and agricultural lands in certain districts, including Bajaur and Mohmand

The average annual temperature in FATA ranged from around 20°C to 25°C (68°F to 77°F). During the summer months (June to August), temperatures could reach high levels, with average maximum temperatures ranging from 35°C to 40°C (95°F to 104°F). Winters (December to February) were milder, with average minimum temperatures ranging from 5°C to 10°C (41°F to 50°F) and the average annual temperature in Peshawar ranges from around 20°C to 25°C (68°F to 77°F). Summers (June to August) are hot, with average maximum temperatures ranging from 35°C to 40°C (95°F to

104°F). Winters (December to February) are relatively mild, with average minimum temperatures ranging from 5°C to 10°C (41°F to 50°F)

Peshawar has a range of soil types influenced by its location in the Indus River Basin. The predominant soil types in Peshawar include Alluvial Soil, Loam and Sandy Loam. Some common soil types in FATA includes Arid Soils, Mountain Soils and Valley Soils

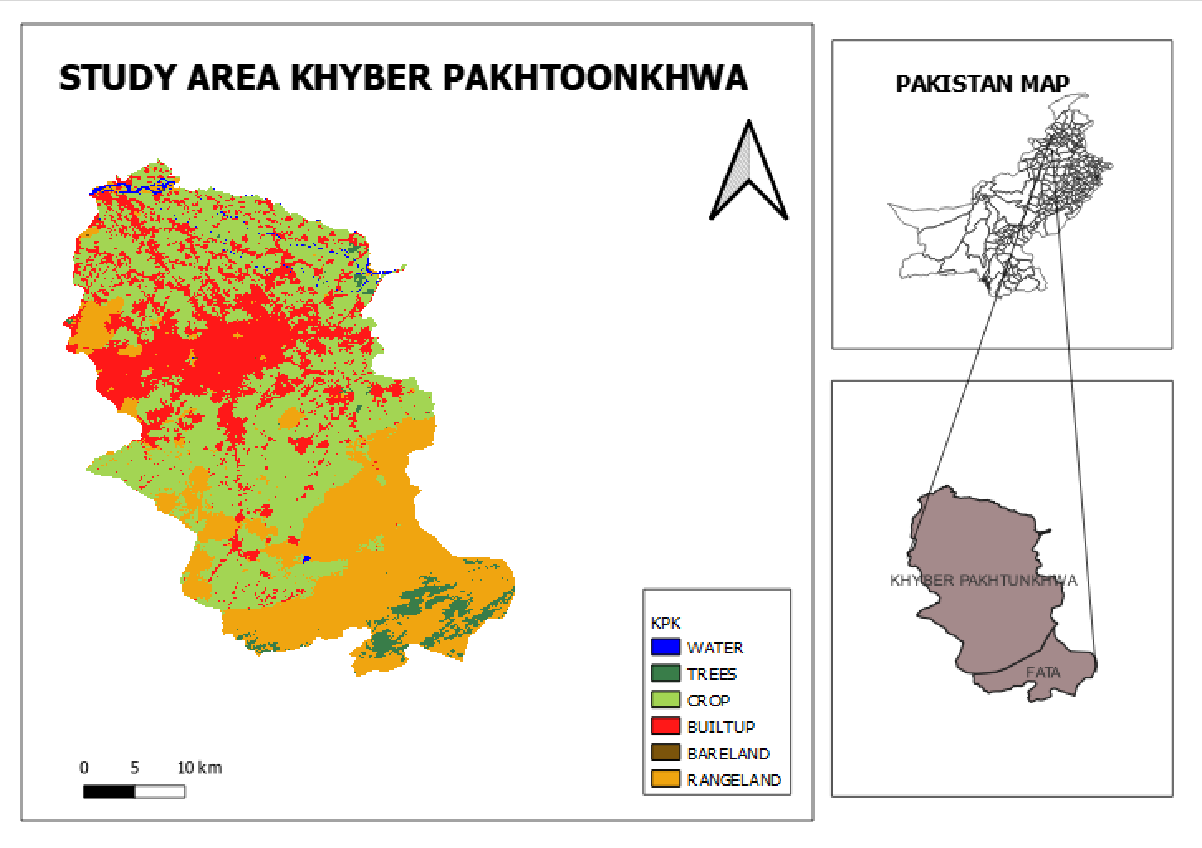

FIGURE 2: STUDY AREA PAKISTAN

Data sources

The data for this study includes LULC data for different time steps and a series of spatially explicit databases of two measured physical and chemical properties of soil: Electronic Conductivity and Organic Carbon. The LULC data was collected from free open source ESRI Sentinel 2 Living Atlas, which provides a 10 m resolution categorical raster for both Italy and Pakistan. The study in this research was carried out for 2018 and year 2021 to analyse the land cover change and investigate how it could have impacted the EC and OC in soils over the years. We authenticated the accuracy of the LULC map with the open-source software QGIS (QGIS 3.24, 2023) that is a tool to visualize, manage, analyse and generate geographical data. We generated ~200 random points in each one of the study areas using the QGIS core tool "Random point in the extent". Each random point was manually labelled with the land cover class, as interpreted by optical photointerpretation with the basemap ESRI Imagery (available through the HCMGIS plugin). After the labelling operation, a comparison between the assigned labels and the LULC class reported by the map was run on a spreadsheet. This workflow allowed us to check if each point falls into the correct land cover class. The results testified that the classification was quite accurate; in the rare cases where it was not, a correction was done within the LULC raster of the study area that were chosen to proceed with the analysis.

The soil data for Italy was downloaded from the official repository provided by the European Joint Research Centre (https://esdac.jrc.ec.europa.eu/content/lucas2018-topsoil-data). This report summarizes the soil dataset collected as part of the 2018 Land Use/Cover Area field survey (generally referred to as LUCAS Soil Module). It presents an overview of the various laboratory analyses and describes the spatial variability of soil properties by land cover (LC) class and a comparative analysis of the soil properties for NUTS 2 regions (Fernandez-Ugalde et al., 2018).

An important detail of this dataset is that the LUCAS project was carried out only in European regions. Therefore, we needed to find a suitable and comparable dataset for Pakistan. We compared a series of different datasets of soil properties to find the most suitable through a second workflow performed in QGIS. All the previously labelled points were used as input to an algorithm that extracts raster values sampling the cells of a raster layer underneath the input points. With this tool, we were able to investigate the values of different raster datasets and assessing the most accurate for the Pakistan study area. A series of measurements of soil properties taken in the field in 2017, of which we knew the geographical coordinates and the LULC class of the place where soil sampling was performed, we extracted the values reported in the layers under evaluation and we performed a regression analysis to observe how much the values reported into the rasters were different from the values obtained in the field. Based on the results of this process, we decided to retrieve the soil data for Pakistan from the Harmonized World Soil Database v 1.2 (HWSD) for Electronic Conductivity, and to refer to the Global Soil Organic Carbon Map v1.5 (GSOC) for Organic Carbon, which has a little lower resolution than the LUCAS Soil Module but is built over a long time series of field retrieved data. Both datasets are available through an open-source access data portal. To assess the spatial pattern of EC and OC in soils within the study areas, two matrices were used by taking the average values of OC and EC for each land cover class.

A reclassification was executed with a reclassification tool available in Grass plugin for QGIS (r. reclass), which creates a new map layer whose category values are based upon a reclassification process that assigns new values to the categories in an existing raster map layer. This way, EC and OC maps for both the study areas were created showing us the values of these soil properties over the land cover classes. This allowed us to associate average values of OC and EC in each LULC class in the first-time step (2018) and to infer the values in the second time step (2021).

To identify and analyse, in the period between 2018 and 2021, how much land has change and toward which class, and what were the consequences on OC and EC of soils, the QGIS-core raster calculator was used along with LibreOffice spreadsheet, to provide an overview through raster maps, graph and tables.

Results and discussion

The LULC analysis of the study area (Northeastern Italy) highlighted that there was a slight change from year 2018 to 2021 in land cover and land use (Table 1). There have been changes in the different land uses with a decrease in crops, rangeland, and vegetated land; on the other hand, there was an increase in built-up, water and bare-soil percentage. Table 2 and 3 and Figure 3 show the details about area covered by each class from the year 2018 to 2021; table 1 show that crops have been covering a larger area that was about 46% followed by trees and built-up area. Figures 4 and 5 shows the LULC change map for the year 2018 and 2021 respectively, in 8 different classes.

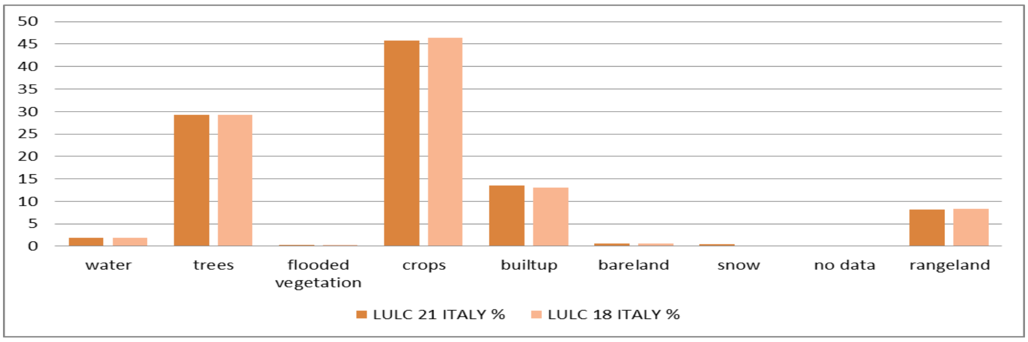

Figure 3: LULC AREA COVERED CLASSES PERCENTAGE 2018-21

class	LULC 2018 ITALY%	LULC 2021 ITALY %
water	1.89	1.96
trees	29.20	29.20
flooded vegetation	0.31	0.30
crops	46.42	45.74
built-up	12.99	13.52
bare land	0.69	0.67
snow	0.12	0.47
rangeland	8.32	8.11

TABLE 1: CHANGES IN LULC 2018-21 NORTHEASTERN ITALY

class	LULC 21 ITALY %	Area [km^2]
water	1.96	938.30
trees	29.20	13967.03
flooded vegetation	0.30	1450.72
crops	45.74	21873.48
built-up	13.52	64653.58
bare land	0.67	324.35
snow	0.47	225.89
rangeland	8.11	3880.50

TABLE 2: LAND USE LAND COVER NORTHEASTERN ITALY 2021

class	LULC18 ITALY %	Area [km^2]
water	1.89	907.68
trees	29.20	13965.63
flooded vegetation	0.31	1499.891
crops	46.42	22202.06
built-up	12.99	62158.14
bare land	0.69	333.89
snow	0.12	618.18
rangeland	8.32	3983.25

TABLE 3: LAND USE LAND COVER NORTHEASTERN ITALY 2018

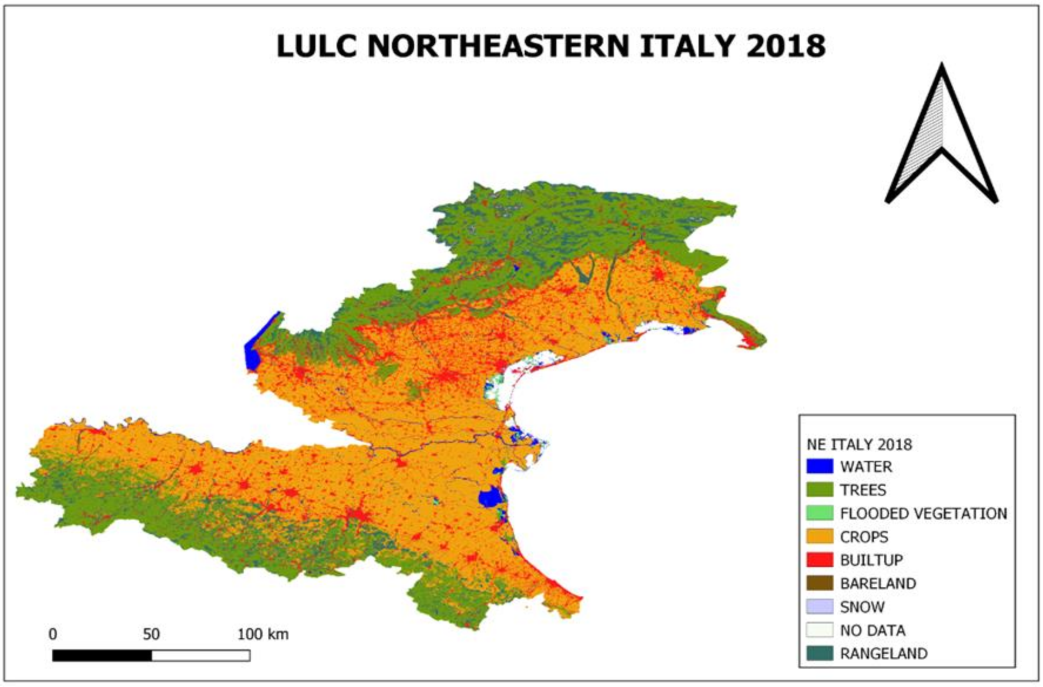

Figure 4: LULC NORTHEASTERN ITALY 2018

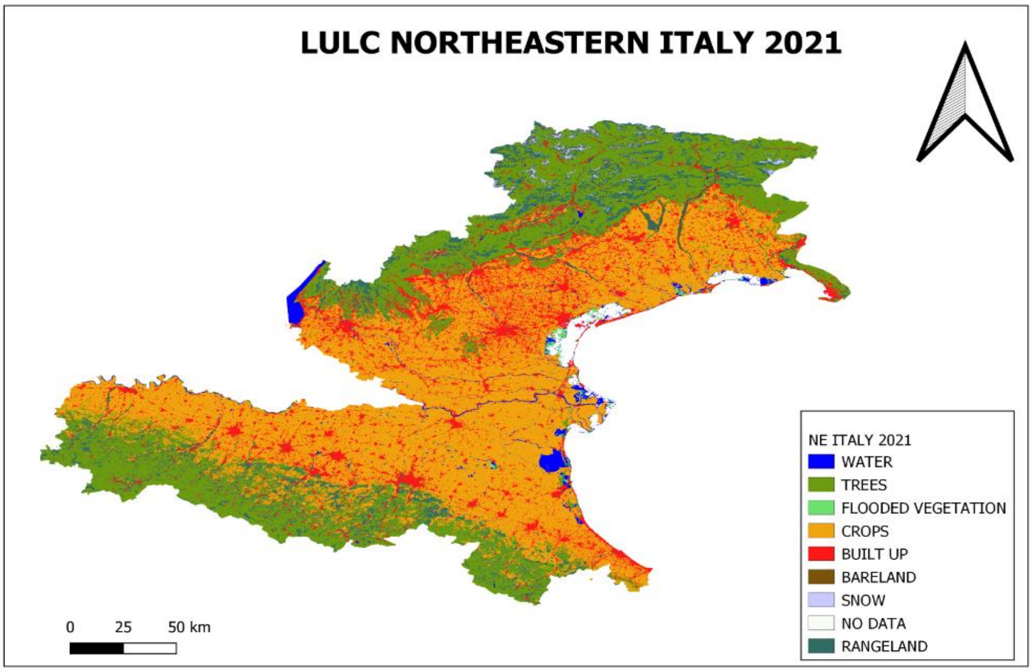

Figure 5: LULC NORTHEASTERN ITALY 2021

In the Pakistan study area, several LULC changes have been registered as well (Table 4). From 2018 to 2021, there was a decrease in water, trees and crops, which was particularly relevant for tree-covered areas. On the contrary there has been a significant increase in the built-up area. According to the Figure 6 and tables 5 and 6 it's clear that the area is more dominated by crops and built-up.

The construction of the Ring Road surrounding the Old Peshawar city region has significantly influenced the spatial dynamics and land use patterns in the area from 2018 to 2021. This infrastructure project, resembling a circular ring around the city, has emerged as a vital transportation corridor, facilitating enhanced connectivity and accessibility to and from various parts of the city and its surroundings. As consequence, the region along the Ring Road has experienced noticeable urban sprawl, characterized by the outward expansion of settlements and the conversion of agricultural lands into built-up areas.
In the context of the Old Peshawar city region, the construction of the Ring Road has acted as a catalyst for urban expansion, attracting residential, commercial, and industrial developments along its corridors. This outward growth of settlements beyond the city limits has led to the gradual transformation of peri-urban landscapes, resulting in the fragmentation of natural habitats, loss of agricultural land, and changes in land cover patterns.

The trend of urbanization in Khyber Pakhtunkhwa (KPK) from 2018 to 2021 displayed a positive and high growth rate, particularly evident in the expansion of settlements surrounding the Old Peshawar city region along the extended Ring Road infrastructure.

The conversion of agricultural land into built-up areas signifies a shift in land use patterns driven by factors such as population growth, economic development, and infrastructural investments (Seto et al., 2011)

The study area in Italy encompasses three regions: Emilia Romagna, Veneto, and Friuli Venezia Giulia. From 2018 to 2021, analysis of land use and land cover changes revealed varying trends across these regions. In Friuli Venezia Giulia, there was minimal change observed, indicating relatively stable land use patterns over the study period. Similarly, in the Veneto region, including major urban areas such as Padua, Mestre, and Venice, only slight changes were noted, suggesting a gradual and limited extent of urbanization. In the Emilia Romagna region, near the main city areas, minor changes were observed, with urbanization trends also exhibiting a slow pace compared to other regions. Overall, the trends of urbanization in the study areas of Veneto, Emilia Romagna, and Friuli Venezia Giulia were characterized by a cautious and gradual rate of change, in contrast to the more pronounced urbanization trends observed in other regions such as Khyber Pakhtunkhwa (KPK). These findings highlight the nuanced dynamics of urbanization across different regions, influenced by factors such as local development policies, economic conditions, and geographical features. Understanding these trends is essential for informed land use planning and sustainable development efforts in the respective regions.

The expansion of urban settlements into agricultural areas alters the natural landscape and ecosystem services, leading to implications for biodiversity, water resources, and soil quality (McDonald et al., 2008). The conversion of croplands to built-up areas not only impacts agricultural productivity and food security but also contributes to land degradation and loss of green spaces, affecting the overall sustainability of the region (Foley et al., 2005).

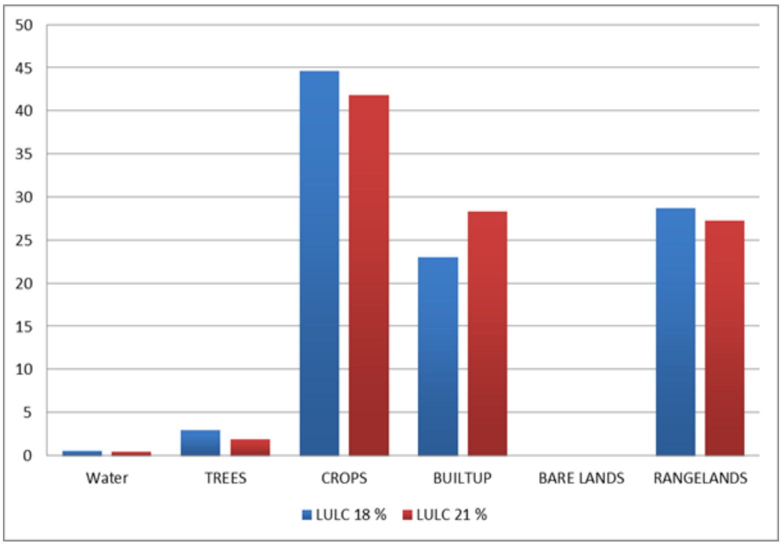

Figure 6: LULC AREA COVERED CLASSES PERCENTAGE 2018-21

Classes	LULC 2018PAKISTAN%	LULC 2021 PAKISTAN %
Water	0.54	0.50
TREES	3.00	1.93
CROPS	44.63	41.83
BUILTUP	23.01	28.37
BARE LANDS	0.03	0.02
RANGELANDS	28.76	27.32

TABLE 4: CHANGE IN LULC 2018-21 KPK

Classes	LULC 21 %	Area [km^2]
Water	0.50	7.68
TREES	1.93	29.31
CROPS	41.83	634.95
BUILTUP	28.37	430.69
BARE LANDS	0.026	0.40
RANGELANDS	27.32	414.74

TABLE 5: LAND USE LAND COVER KPK 2021

classes	LULC 18 %	Area [km^2]
Water	0.54	8.1976
TREES	3.00	45.59
CROPS	44.63	677.4404
BUILTUP	23.01	349.38
BARE LANDS	0.03	0.55
RANGELANDS	28.76	436.63

TABLE 6: LAND USE LAND COVER KPK 2018

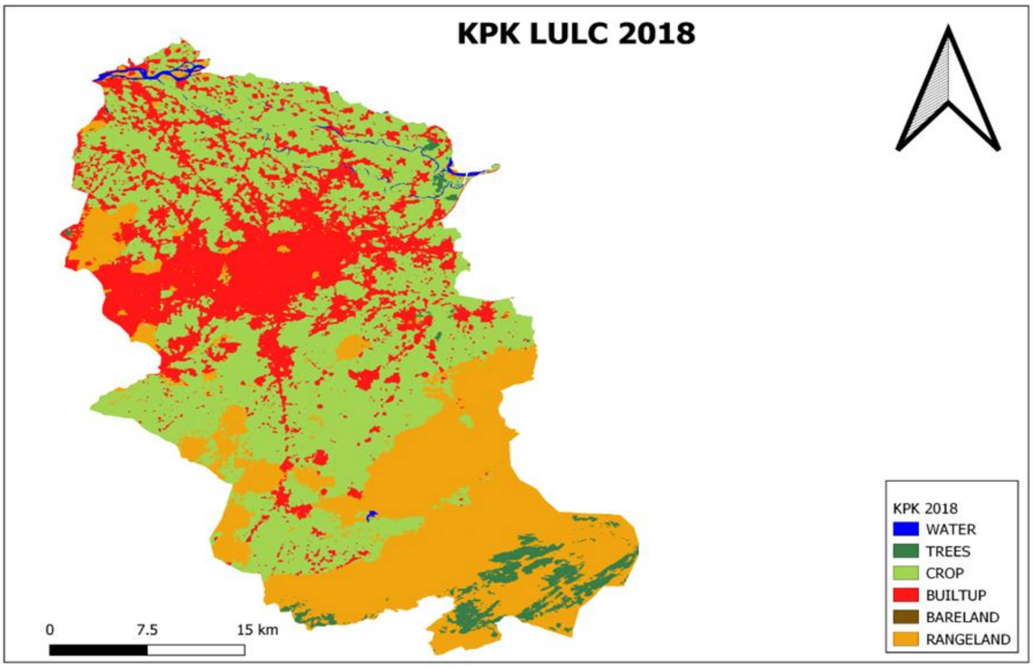

Figure 7: LULC KPK 2018

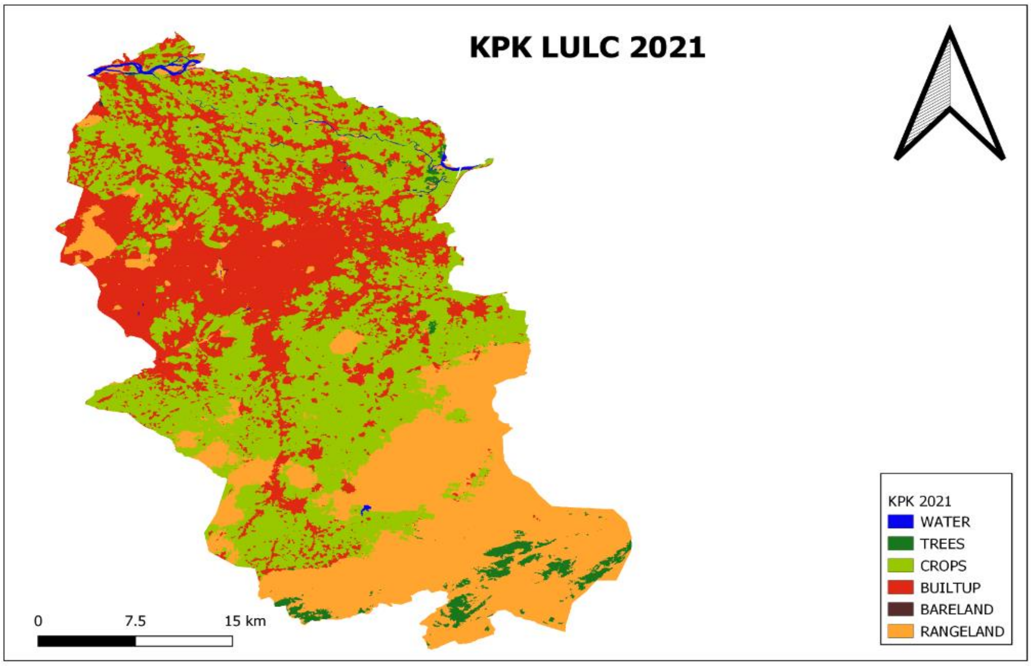

Figure 8: LULC KPK 2021

To analyse the spatial distribution of soil characteristics we referred to two important chemical factors, namely organic carbon and electronic conductivity; this allowed making the comparison between different years and the different study areas of Italy and Pakistan.

Figures 9 and 10 show that the sites of Northern Italy that are mostly covered by trees and rangeland have the highest percentage of OC, whereas several areas of the Veneto region and the Emilia-Romagna plains that are more dominated by built up and crop areas, have low percentages of OC. On the other hand, as shown by the Electronic Conductivity map (Figures 11 and 12), the areas where there is high percentage of organic carbon also have the high EC and vice versa.

The study area Northern Italy soils have a high percentage of EC as compared to the built-up area. According to Abu-Hassanein et al. (1996), who reported experimental evidences and theoretical results with the aim of improving the understanding of the roles of the various geometrical and interfacial attributes of the soil and its solution in determining the effective electrical conductivity of the soil (EC), the soil EC and the soil volumetric water content are the main factors affecting the soil EC. Also, other author found similar results, confirming that the higher the water content, the higher the average EC values (Costa et al., 2010).

So for high EC in the northern side and southern part is mostly account on the basis of some factors one of them is the water content in terms of snow and river streams which can be visible from the figure 4 and 5 other important factors that includes are type of land so in the northern and Southern area we have mostly wood and grass land as compared to the urban area where we have crop and Urban land so this is due to having large pores in wood and grass as compared in crop and urban land so small pores restrict the movement of ions and water in the soil where larger pores helps in the exchange of ions which causes the high percentage of EC in Alpine region. On the other side the OC around the built-up area resulted to have low values, not only in settlements but even cultivated plains; such values are lower than those recorded in the Alpine region, which is more dominated by trees and vegetated non-crop soils.

Figures 13,14 and 20, 21 show the changes in terms of positive and negative differences: positive sign indicates decrease while negatives indicate the increase in the EC and OC from year 2018 to 2021.

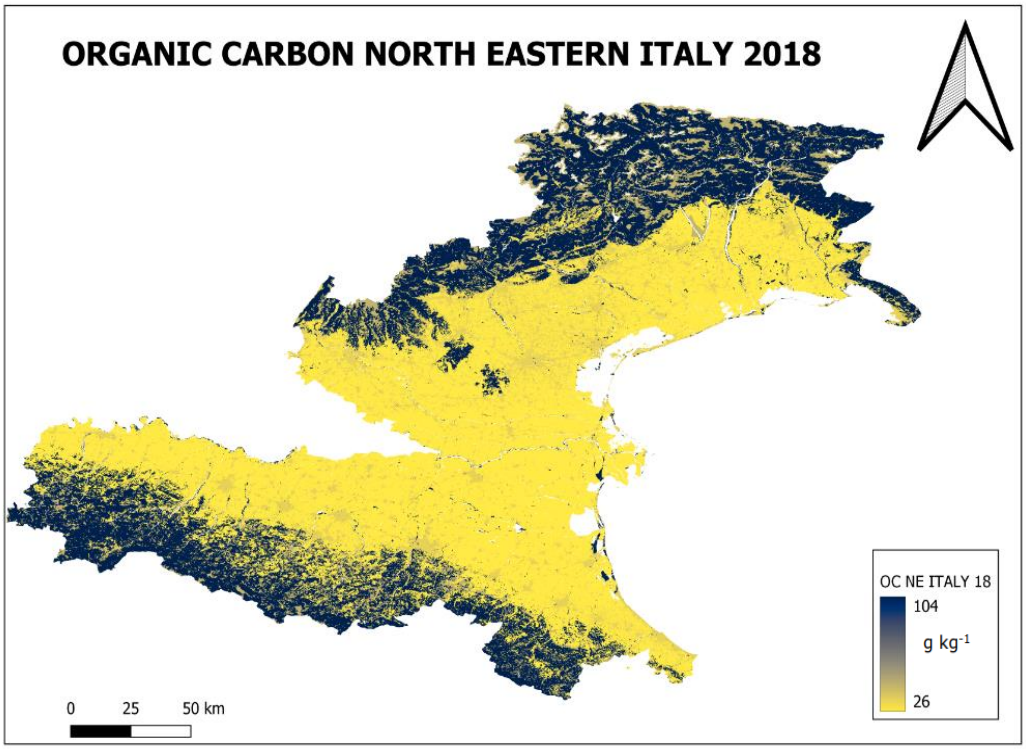

Figure 9: OC NORTHEASTERN ITALY 18

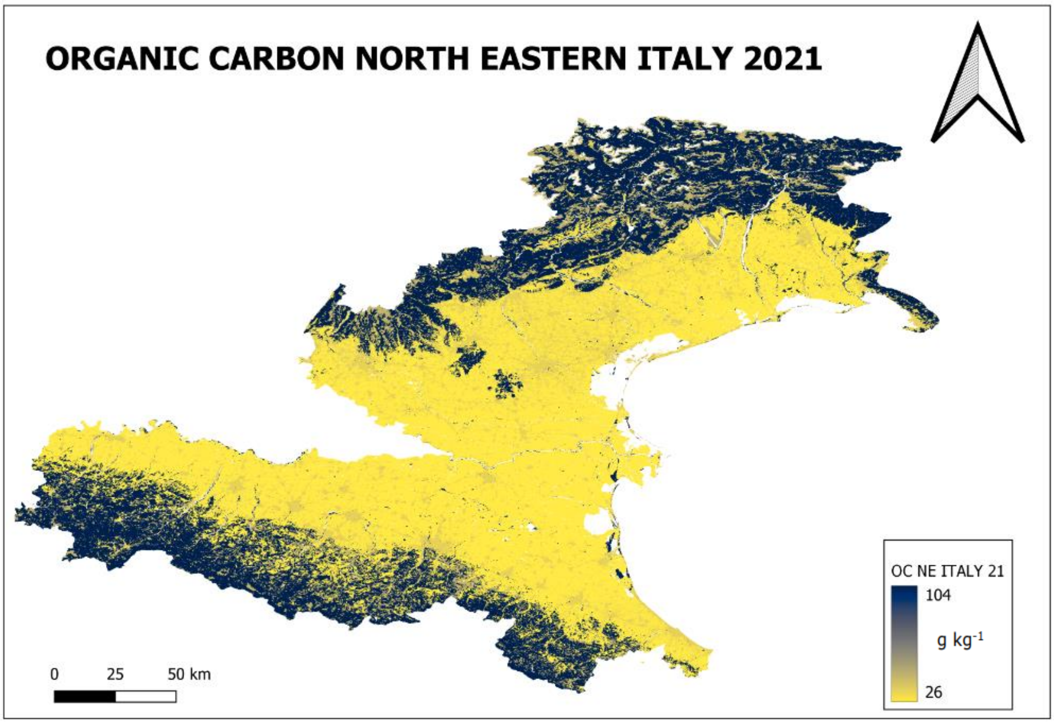

Figure 10: OC NORTHEASTERN ITALY 21

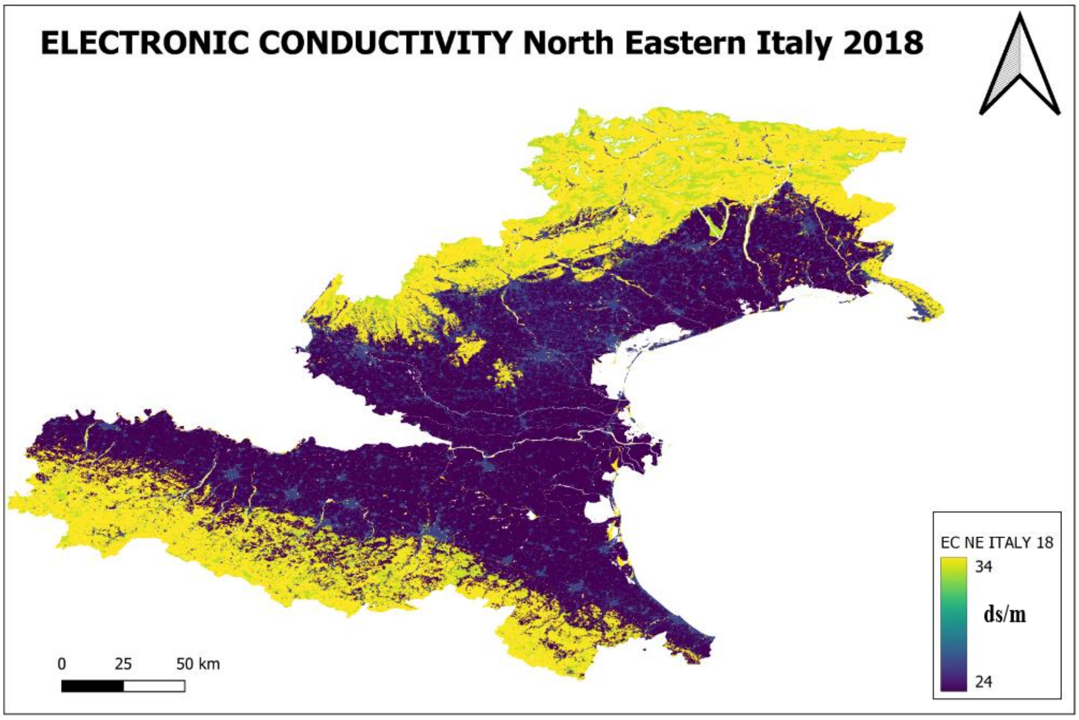

Figure 11: EC NORTHEASTERN ITALY 18

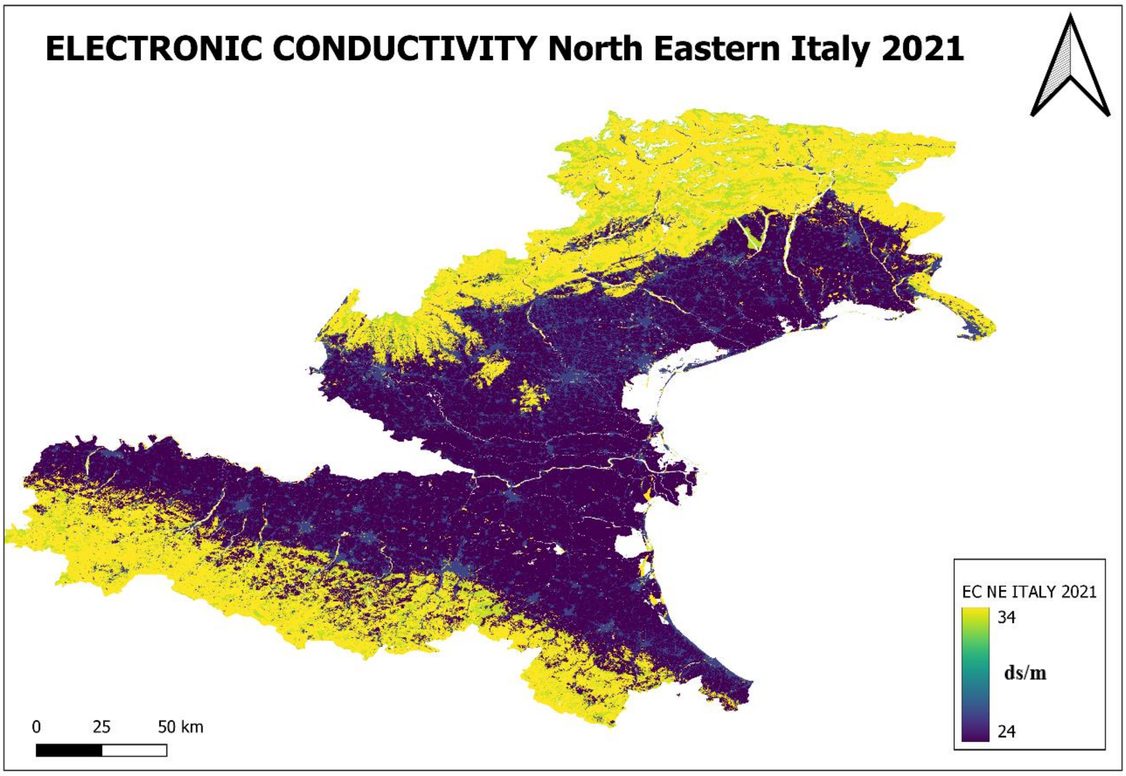

Figure 12: EC NORTHEASTERN ITALY 21

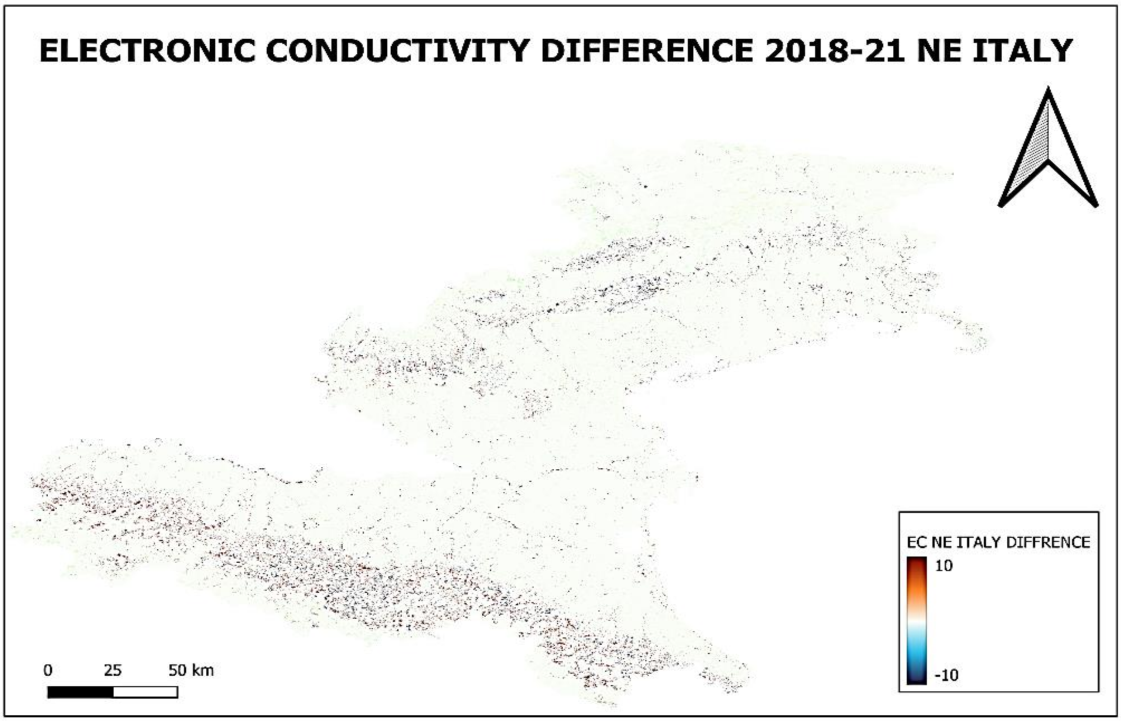

Figure 13: EC DIFFERENCE 2018-21 NORTHEASTERN ITALY

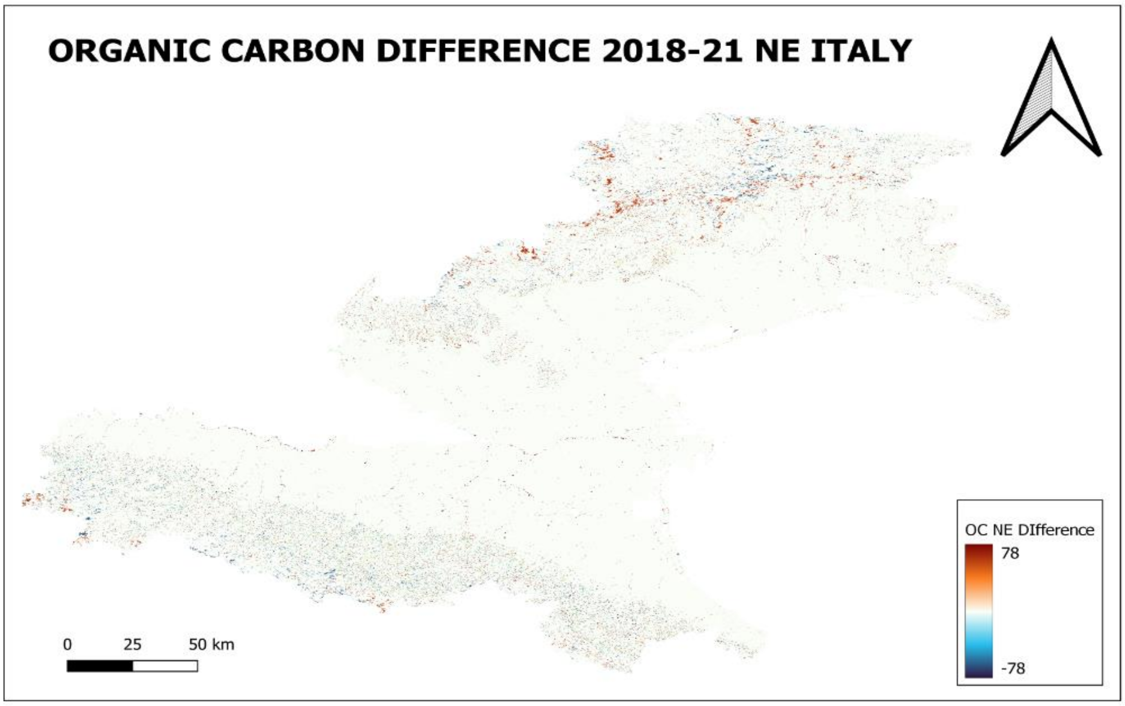

Figure 14: OC DIFFERENCE 2018-21 NORTHEASTERN ITALY

A characteristic of the Italian study area is that the soil facing the Adriatic coastline results more saline, that is richer in chlorides and sea salt, giving an excess of salts in arable lands. (Di Giuseppe et al. 2014) This usually causes reduced nutrient availability and increase in the osmotic tension for roots. Areas along the Po River delta, the Southern part of Venice lagoon and the areas facing the Marano lagoon in Friuli Venezia Giulia.

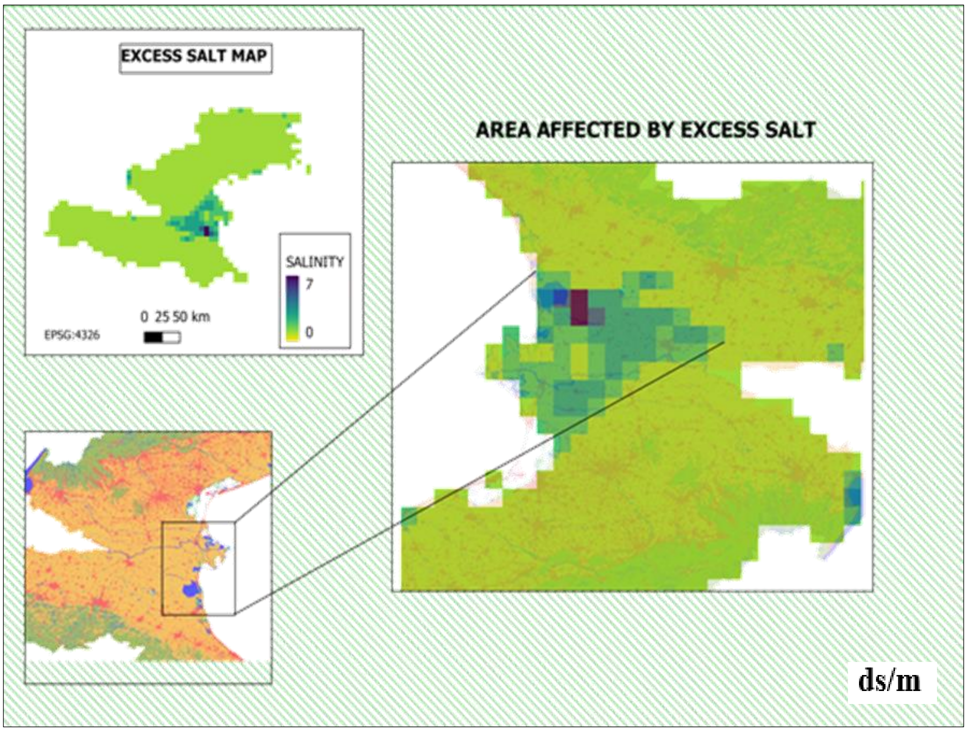

Figure 15: EXCESS SALT MAP NORTHEASTERN ITALY

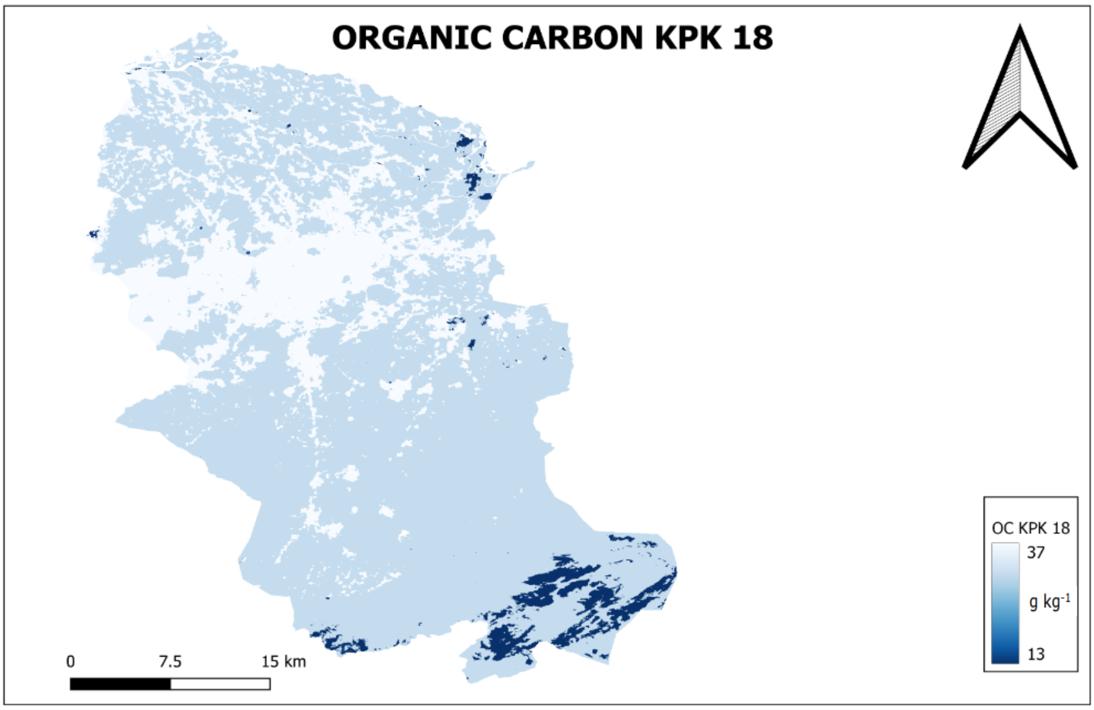

Figure 16: OC KPK 18

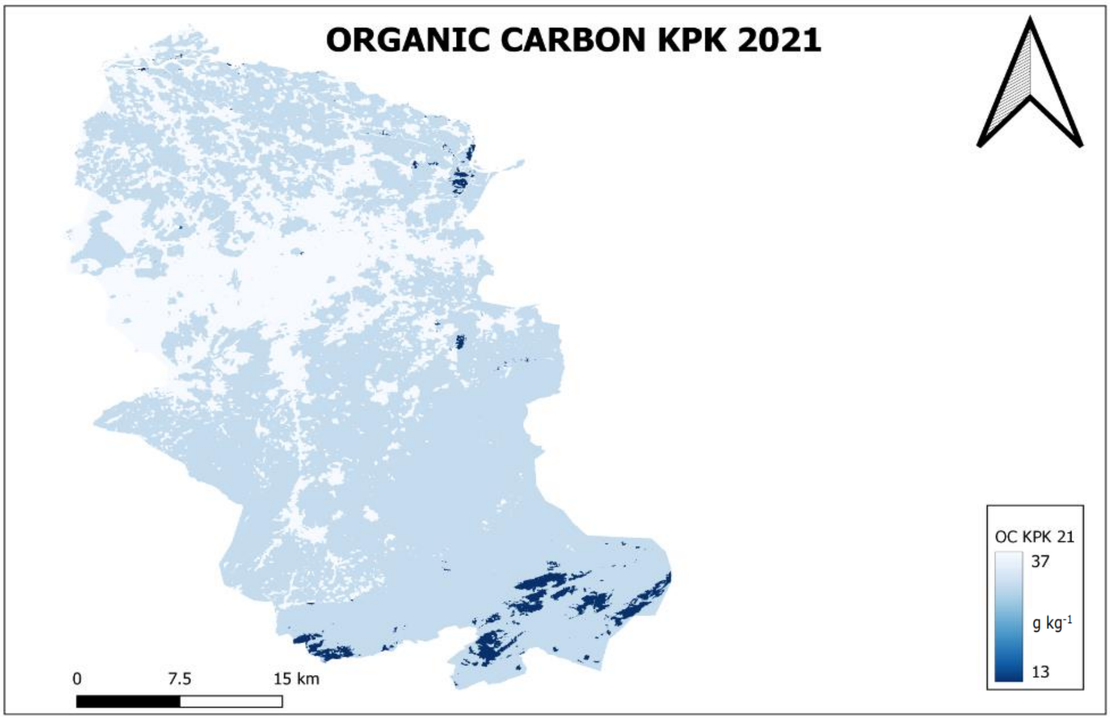

Figure 17: OC KPK 21

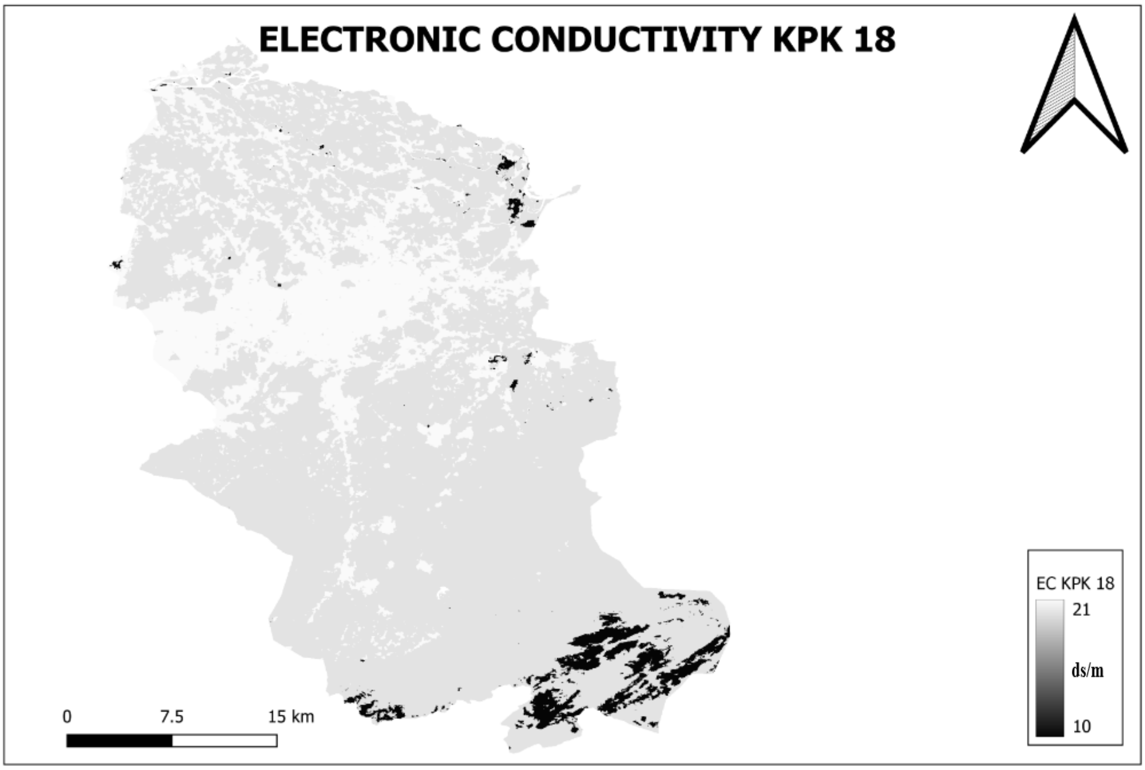

Figure 18: EC KPK 2018

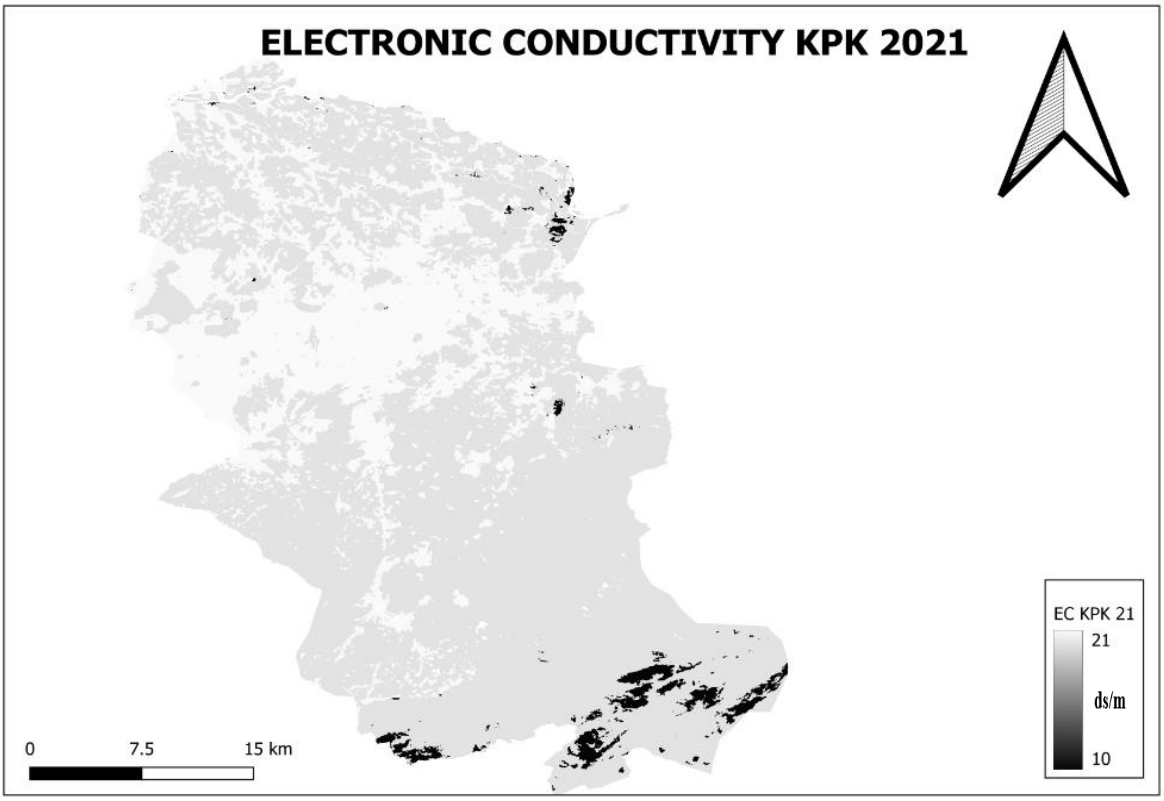

Figure 19:EC KPK 2021

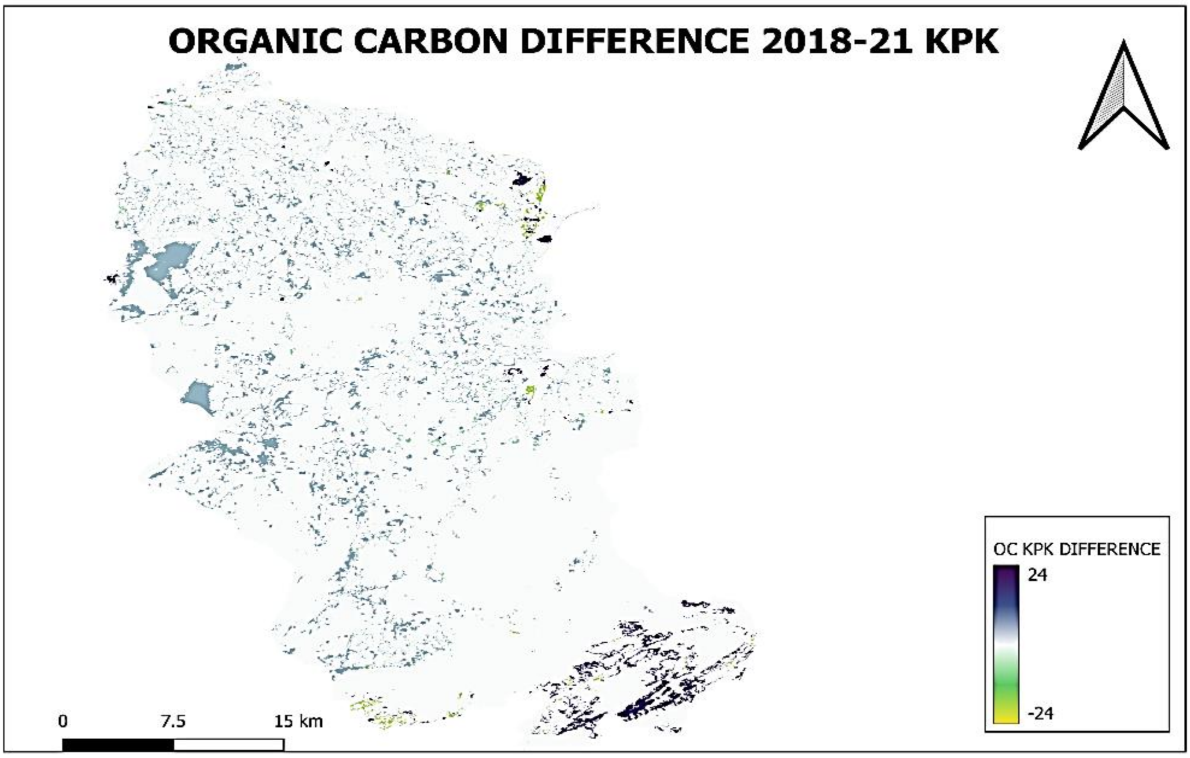

Figure 20: OC DIFFERENCE 2018-21 KPK

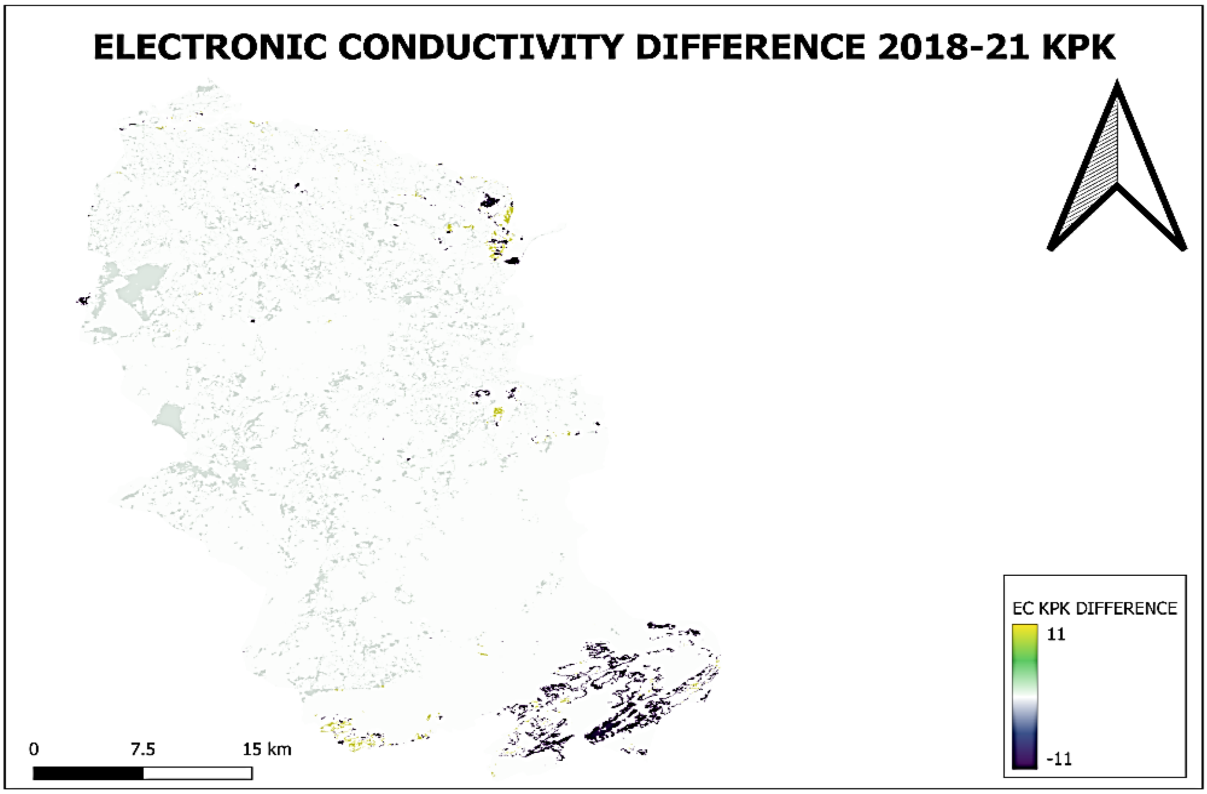

Figure 21: EC DIFFERENCE 2018-21 KPK

In the study area in Pakistan, high EC was recorded in the central region of KPK: this was an unexpected result due to the soil more dominated by built-up and anthropogenic activities, but the observations were confirmed also for OC that was at noticeable high values.

According to the study by Xiong Xiong et al. (2012), the effects of climate and land use/land cover change on soil organic carbon sequestration states that the urban soil has more SOC accumulation after converting the crop land to urban area.

Geographically the central part is surrounded by rivers and streams which is also causing for having high OC according to (Kaye et al. 2005; Lorenz and Lal 2009) an increased input of water, nutrients. In contrast, the southern region of the Federally Administered Tribal Areas (FATA), characterized by its dominance of trees and rangeland, exhibits low levels of Electrical Conductivity (EC) and Organic Carbon (OC) (Figures 16-19). This distinction can be attributed to the geographical constraints of the area, which lacks readily available water sources and streams. Additionally, the limited presence of settlements, to Khyber Pakhtunkhwa (KPK)

Visual analysis (Figures 7 and 8) from 2018 to 2021 indicates a noticeable shift in the southern FATA area, where tree cover decreased, transforming into rangeland (Table 4: 3.00% to 1.93%). This shift underscores the impact of land use changes on soil, specifically in terms of EC and OC, highlighting the need for further analysis of these dynamics in the study area.

The reason for low Organic carbon in the Fata region would be agriculture practices that are carried out because vegetation management practices are responsible for the export of material from vegetated soil (like removal of grass clippings, tree leaves, and other organic debris), and mechanical soil removal (usually restricted to topsoil, the layer richer in roots and humus) and the loss of highly active soil biota (Lorenz and Lal 2009; Craul 1999) are responsible for lowering SOC storage.

Most of the FATA region is a backward area, where people are dependent on their cattle that graze; those cattle are also a main cause of low Organic carbon in the soil which allows the soil to get disturbed more.

Conclusion

In this thesis, we have explored the significant impact of urbanization on environmental sustainability and land management practices. The rapid pace of urbanization, driven by population growth and economic development, has led to extensive land conversion, fragmentation, and loss of natural habitats. One consequence of urban expansion is the conversion of agricultural land to settlements, as arable land is repurposed to accommodate housing, infrastructure, and commercial developments; this transformation not only diminishes the availability of fertile land for agricultural production but also alters soil properties and dynamics.

From the data presented, it is evident that urbanization has accelerated in Khyber Pakhtunkhwa (KPK) province, with settlements increasing from 23.01% to 28.37% and a corresponding decline in crop area from 44.63% to 41.83%. This shift in land use patterns underscores the growing pressure on agricultural land and the challenges posed by urban expansion. While the increase in settlements reflects the growing demand for residential and commercial spaces, the reduction in agricultural land raises concerns about food security, agricultural productivity, and rural livelihoods in the region.

In contrast, the slower rate of urbanization observed in Northeastern Italy, with a slight increase in settlement area from 12.99% to 13.52% and a slight decrease in crop area from 46.42% to 45.74%, suggests a more controlled approach to urban development. This controlled approach prioritizes the preservation of agricultural land, cultural heritage, and environmental quality, supporting sustainable urban growth.

The rapid urbanization observed in Khyber Pakhtunkhwa raises concerns about the loss of agricultural land, degradation of natural habitats, and challenges related to urban infrastructure, service provision, and environmental sustainability. Addressing these challenges requires integrated land use planning, policy interventions, and community engagement strategies that promote sustainable urban development, preserve agricultural resources, and safeguard environmental integrity. Regarding agriculture practices, the major issues of soil fertility arising from urbanization-induced changes, including land conversion, changing land ownership patterns, inadequacy of housing, internal migration, deforestation, and pollution, poses significant challenges for agricultural sustainability. With a considerable increase in population in Khyber Pakhtunkhwa from 2018 to 2021, urbanization continues to impact soil fertility, threatening agricultural productivity in the region. On the other hand, increased necessity of cultivating land with intensive methods with the aim to increase yield has severe consequences in both the study areas. Tillage, namely the mechanical manipulation of the soil for the purpose of crop production, is to be regarded as one of the conventional methods that are significantly affecting the soil characteristics such as soil water conservation, soil temperature, infiltration and evapotranspiration processes. Tillage exerts impact on the soil purposely to produce crops and consequently affects the environment; despite this information being increasingly available, the abandonment of conventional tillage is still hard to achieve in the agricultural sector.

To address these challenges and ensure sustainable agriculture practices, conservation tillage emerges as a promising solution. Conservation tillage not only retains crop residue at the soil surface, but also enhances soil structure, water retention, and nutrient availability. Implementation of conservation tillage practices can mitigate the adverse effects of urbanization on soil fertility, promoting sustainable agricultural production in urbanizing areas. As José Graziano da Silva, Director General of the FAO, commented, "Conservation Agriculture offers the prospect of a better future to both large-scale and smallholder farmers, and a means to raise productivity and secure economic and environmental benefits" (Jat et al., 2013, p. xiv).

Although conservation agriculture was initially developed for large-scale commercial farms in the Americas (Thierfelder et al., 2013), much effort has gone into adapting conservation agriculture systems for smallholder farmers, especially in developing countries like Pakistan which is currently an underdeveloped country and such a technique respectful of the soil can be used on both large and small spatial scales.

Apart from LULC changes, other upcoming threats are expected because of the effects of climate change, namely lower rain and longer drought period. Increased drought is always detrimental for soil, but in the area near Venice and the Adriatic coastline, where the soil is already more saline, future droughts might present specific challenges for agriculture.

As result of reduced nutrient availability, excessive chlorides causing excessive osmotic pressures for plants, along with the increased risk of soil erosion and salt crusting, the area will not be suitable for agriculture and this excess salt situation will affect the ecosystem. This should push the governance to engage in methods to support water-saving cultivar and increase the diffusion of systems that can recycle and save waters to be used for irrigation purposes. Investments in research to understand the specific dynamics of soil salinity in the area and explore innovative solutions for managing highly saline soils are therefore seen as crucial tools to develop comprehensive, integrated soil and water management plans to address salinity issues over the long term.

To tackle the issues concerning the soil and the challenges of the future, monitoring programs and resource management plans should include regular soil testing to monitor soil properties values and impact levels and adjust management practices accordingly.

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