Review on Agriculture and Rural Development 2023 vol. 12 (3-4) ISSN 2677-0792
DOI: 10.14232/rard.2023.3-4.89-96

INVESTIGATING THE EFFECT OF CLIMATE CHANGE ON THE LAND USE AND LAND COVER OF THE JORDAN RIVER BASIN

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Abstract: Climate change impacts the world's ecosystems and alters many regions' land use and land cover (LULC). The Jordan River Basin is an important region for both its natural and cultural heritage, making it essential to understand the effect of climate change on its LULC. This study aims to use Correlation analysis, including GIS techniques, to investigate the impact of climate change on the LULC of a selected area in the Jordan River Basin. The analysis was performed using climate change data as the independent variables and LULC data as the dependent variable. The data was collected over a period from 2017-2021, and GIS data is used to analyze the LULC data and identify changes over time. The results showed that most of the correlations are statistically significant. The study found that changes in the climate variables were associated with changes in LULC, including changes in urbanization and vegetation patterns. The study concludes that climate change impacts the LULC of the Jordan River Basin. The use of Correlation analysis, and GIS techniques is an effective method to study this impact. The results of this study provide important information for decision-makers and local communities to protect the resources of the area. These findings highlight the importance of continuous monitoring and analysis of LULC changes, to better understand the effects of climate change and to mitigate and adapt to these impacts.

Keywords: Spatial Analysis, Climate Change, Jordan River Basin, LULC.

1. Introduction

Climate change is a major global environmental issue that affects both human societies and natural ecosystems. According to Kogan (2019), it causes vegetation growth and coverage changes. Human activities such as burning fossil fuels and deforestation have increased the concentration of greenhouse gases, leading to changes in temperature, precipitation, and weather patterns worldwide (IPCC, 2014).

The Middle East is particularly vulnerable to the effects of climate change due to existing water scarcity issues (FAO, 2021). The Jordan River Basin, located in the eastern Mediterranean region, is an area that is particularly vulnerable to the effects of climate change. To develop effective strategies for mitigating and adapting to the impacts of climate change, policymakers and scientists need to understand how it affects land use and land cover (LULC).

Land use and Land cover (LULC) refer to the way humans use land and the resulting changes in its physical characteristics, including vegetation cover, soil type, and water resources (Turner II et al. 2007). In the Jordan River Basin, LULC changes have occurred due to various factors, including population growth, urbanization, deforestation, and climate change (Malki et al. 2020).

These changes have had significant impacts on the natural environment, including the loss of biodiversity, soil degradation, and water scarcity.

To better understand the potential impacts of climate change on land use and land cover (LULC) patterns, numerous studies have been conducted in various regions worldwide. For instance, Ma et al. (2019) conducted a study in China and found that changes in temperature and precipitation variability had resulted in changes in LULC patterns, particularly in grassland and forest ecosystems. Similarly, Seto et al. (2012) investigated the effects of climate change on urbanization patterns in the United States and observed that cities in coastal areas were particularly vulnerable to sea-level rise and flooding. These studies highlight the need for further research to better understand the complex and dynamic nature of the interactions between climate change and LULC patterns.

Several research studies have explored the influence of climate change on the Jordan River Basin, yet they have yielded contradictory outcomes. A significant difficulty in this field is the intricate and evolving nature of both climate and land use systems, as well as the interplay between them. There are controversial and conflicting hypotheses about the precise mechanisms through which climate change is anticipated to impact land use and land cover in the Jordan River Basin. Certain studies suggest that increasing temperatures and declining precipitation will cause greater desertification, while others forecast more severe weather events that could cause flooding and erosion (Al-Weshah & Sabatinh 2018).

In the Jordan River Basin context, previous research has focused on the impacts of water scarcity on LULC patterns, particularly in agricultural land (Aboaljoud et al. 2020). However, few studies have investigated the effects of climate change on LULC in the region, particularly in the Upper Jordan River Basin. Therefore, the aim of this study is to investigate the effect of climate change on the land use and land cover of the Jordan River Basin. Specifically, using high-resolution satellite imagery, we will analyze changes over time in the percentage coverage of water, forest, flooded vegetation, agricultural lands, built-up areas, and shrubs. We will also examine climate data from the region, including temperature, precipitation, river flow rates, river discharge rates, evaporation, and river flood rates, to determine how these factors relate to changes in land use and land cover.

To the best of our knowledge, this study represents a comprehensive analysis to study the effects of climate change on the land use and land cover of the Jordan River Basin. By providing a detailed and nuanced understanding of how climate change affects this vital region, we hope to contribute to ongoing efforts to develop effective strategies for mitigating and adapting to its impacts.

Notably, climate change's effects on the Jordan River Basin have implications beyond the local area and can have widespread consequences. Changes in water availability and quality in the basin may have an impact on downstream areas, the effects of climate change on the Jordan River Basin can also have implications for regional and global food security since the region is a significant agricultural producer and exporter.

Thus, raises the question regarding what the impacts of climate change on land use and land cover (LULC) in the Jordan River Basin are, and how have these changes evolved over time. Also, what are the potential downstream and regional consequences of climate change's impacts on the Jordan River Basin, particularly regarding food security, and how can policymakers and scientists develop effective strategies to mitigate and adapt to these impacts?

2. Materials and methods

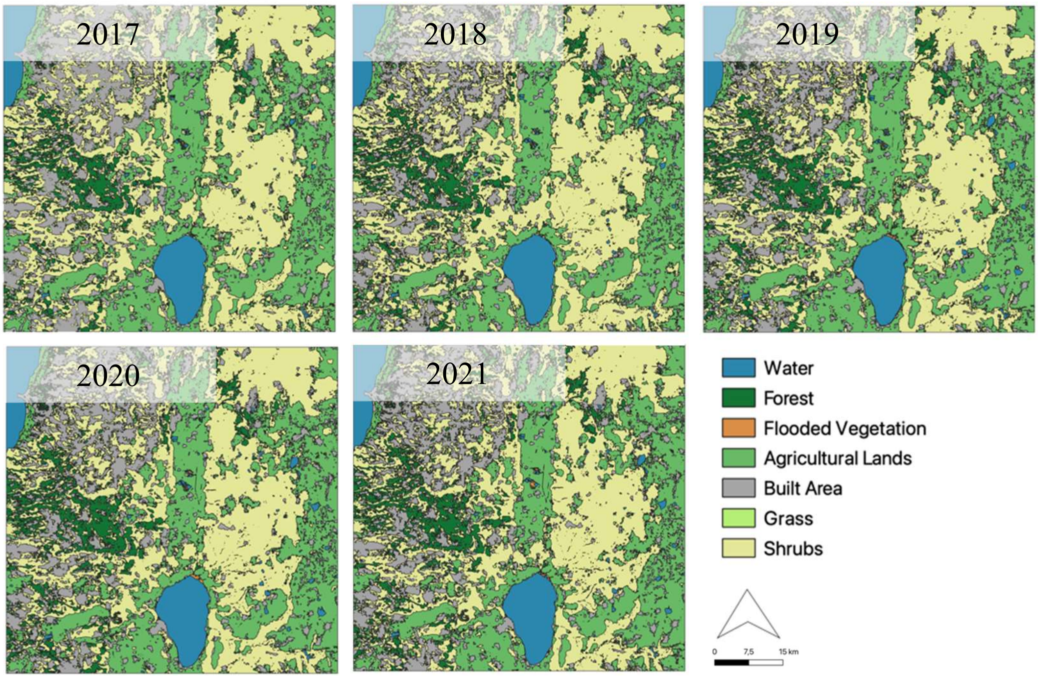
This research is examined in the Upper Jordan River Basin which is located in the Eastern Mediterranean region. The study area encompasses approximately 5700km² and is considered part of the Jordan River watershed. The region is characterized and known by the diverse landscapes with various topographic features including steep slopes, deep valleys, and mountains starting from Mount Hermon in the north which forms the highest point reaching an altitude of 2,814m above sea level, and the Jordan River that forms the main watercourse in the area and is fed by several tributaries (Givati et al. 2019).

The selection of the study area is based on the availability of resources and the diversity of land use containing water sources, forest, and agricultural lands. The study area is defined in QGIS using EPSG code (32636) for the spatial reference system, which corresponds to the WGS 84/UTM zone 36N coordinate reference system. The study area is delimited by the coordinate's longitude 53.563362 and latitude 32.465717.

The research was conducted within the selected area between 2017 and 2021. To understand the impact of climate change on the LULC of the Upper Jordan River, Sentinel-2 images were used and obtained from ESRI Sentinel-2 10m; a web-based platform that provides access to Sentinel-2 satellite data which offers high-resolution imagery with a 10-meter spatial resolution (https1://www.arcgis.com).

The research methodology employed in this study was based on two primary variables: the land use and land cover of the study area and the climate data during the designated period. To analyze changes over time, the first step was to select specific indicators within each variable. The land use and land cover data which was collected from Sentinal-2 images were characterized by the percentage coverage of water, forest, flooded vegetation, agricultural lands, built-up areas, and shrubs. Climate data was represented by several parameters, including temperature values (ºC), precipitation (mm), river flow rates (MCM), river discharge rates (MCM), evaporation (m^3), and river flood rates. The climate change data pertaining to the upper Jordan River Basin were sourced from the Climate Knowledge Portal Governmental Archives in both Jordan and Israel and the data reported the average values. The second step of the study involved using QGIS 3.28 software to compute the area and proportion of each land use and land cover variable from the Sentinal-2 satellite images. The following maps in Figure 2 visualize the spatial pattern of LULC in the study area (*Figure 1.*: LULC 2017-2021).

Figure 1.: LULC 2017-2021



Source: Author's own editing using GIS 3.28.

The data was then recorded in an Excel spreadsheet for each year, as presented in (*Table 1.*: Climate change and LULC variables).

Table 1.: Climate change and LULC variables

Year	Climate Change					
	Temperature (C)	Precipitation (mm)	River Flow	River Discharge	Evaporation (m3)	Floods
2017	20,18	242,07	99,1	176,34	7636	128
2018	20,83	641,12	95,3	97,88	6748	167
2019	20,27	620,69	92,1	68,21	8871	256,8
2020	20,31	746,26	85,4	37,63	10098	273
2021	20,74	509,05	83,2	22,01	13509	310,1
Year	LULC %					
	Water	Forest	Flooded Vegetation	Agricultural Lands	Built Area	Shrubs
2017	5,22%	0,0844	0,0015	0,2783	0,2701	0,2287
2018	5,25%	0,0873	0,0022	0,2545	0,1604	0,2771
2019	5,43%	0,0960	0,0020	0,2900	0,2626	0,2101
2020	5,56%	0,1013	0,0029	0,2723	0,1747	0,2012
2021	5,52%	0,0970	0,0017	0,2695	0,1835	0,2658

Source: Author's own editing.

This research aims to explore the influence of climate change on land use and land cover (LULC) within a specified timeframe, spanning from 2017 to 2021. Climate change, characterized by alterations in temperature and precipitation patterns, is acknowledged as a fundamental driver of changes in ecosystems and land utilization. To elucidate these intricate relationships, a comprehensive correlation analysis is employed. The dataset encompasses various climate change variables, including Temperature (in degrees Celsius), Precipitation (in millimeters), River Flow (in million cubic meters), River Discharge (in million cubic meters), Evaporation (in cubic meters), and Floods, for each of the five consecutive years. The dataset contains LULC percentages, incorporating Water, Forest, Flooded Vegetation, Agricultural Lands, Built Area, Grass, and Shrubs. Null Hypothesis (H0): No statistically significant relationship exists between climate change variables (Temperature, Precipitation, River Flow, River Discharge, Evaporation, Floods) and LULC percentages. Alternative Hypothesis (H1): A statistically significant relationship is present between climate change variables and LULC percentages. In this analysis, we have chosen to employ Pearson's correlation coefficient, as it is appropriate for assessing linear relationships between continuous variables. A common significance level, alpha (α), is set at 0.05. A p-value less than α denotes statistical significance. Pearson's correlation analysis was conducted to examine the associations between climate change variables and LULC percentages. This test calculates correlation coefficients and their associated statistical significance. The correlation coefficients and their corresponding p-values are interpreted to gauge the strength and statistical significance of the relationships. For example, coefficients close to 1 or -1 signify strong positive or negative correlations, while coefficients near 0 suggest weak or negligible associations. The analysis assumes that the relationships between climate change variables and LULC percentages are linear. This assumption is validated through exploratory data analysis. Acknowledging the limitations of this analysis is paramount. The dataset may not encompass all relevant factors influencing LULC. The potential for multicollinearity between climate variables should be considered. Correlation does not imply causation, and careful interpretation of results is imperative.

3. Results

The correlation analysis conducted in this study unveils substantial insights into the interplay between climate parameters and land use and land cover (LULC) changes within the years 2017 to 2021. Correlation coefficients, presented in Table 2, elucidate the strength and direction of these relationships. Temperature (C) displayed various associations with LULC categories. Notably, temperature exhibited a slight negative correlation with water (-0.0059), which suggests that rising temperatures might have a marginal cooling effect on water bodies. In contrast, a moderate positive correlation with precipitation (0.5909) implies that increased temperature often accompanies higher levels of precipitation. The most significant findings pertain to temperature's influence on land cover types. It negatively correlates strongly with agricultural lands (-0.8081), indicating potential adverse impacts on agriculture. Conversely, a strong positive correlation with shrubs (0.8962) suggests that higher temperatures may lead to the expansion of shrublands at the expense of other land cover types, with implications for ecosystem dynamics. Further exploration of climate variables revealed vital connections between river-related parameters and LULC. While river flow (MCW) and river discharge (MCM) exhibited strong positive correlations with each other (0.9465), river flow displayed a robust negative correlation with water (-0.9032), underscoring the potential consequences of reduced river flow on water availability. This relationship may have profound implications for ecosystems and human societies dependent on these resources. Floods played a distinctive role in shaping LULC. They exhibited strong positive correlations with water (0.7993) and forest (0.9246), suggesting that flood events have the potential to create new habitats and reshape landscapes. Floods negatively correlated with shrubs (-0.1599), possibly due to the inundation of shrublands. The analysis revealed that precipitation had a strong positive correlation with flooded vegetation (0.8649), hinting at the potential expansion of wetland habitats with increased rainfall. However, agricultural lands displayed a weak positive correlation with precipitation (0.0385), suggesting that more precipitation may have limited effects on this land cover type. Precipitation also negatively correlated with shrubs (-0.1505), indicating the possible suppression of shrubland expansion in wetter conditions.

The correlation analysis underscores the intricate relationships between climate parameters and LULC. It highlights the potential consequences of climate change on water resources, agriculture, and the distribution of land cover types. Within the studied time frame, variations in temperature and precipitation did not exhibit statistically significant linear associations with changes in the distribution of land use and land cover categories. It is important to emphasize that these findings do not imply causation but rather indicate that, based on the dataset, the observed climate change variables were not significantly correlated with alterations in LULC percentages during the specified years.

Table 2.: Numeric and graphical results of the Correlation analysis

	Temperature (C)	*Precipitation (mm)*	*River Flow (MCM)*	*River Discharge (MCM)*	*Evaporation (m3)*	*Floods*
Water	-0,005882705	0,590921767	-0,946525748	-0,903199402	0,7992876	0,953616722
Forest	-0,047886573	0,69827744	-0,894343539	-0,897574333	0,683244188	0,924566798
Flooded Vegetation	-0,010585217	0,86485003	-0,408775354	-0,495358954	-0,042861652	0,326557542
Agricultural Lands	-0,808130568	-0,211289428	0,038530414	0,067058507	0,115893489	0,194249442
Built Area	-0,767589906	-0,628887164	0,531702611	0,57703894	-0,24801294	-0,329966724
Grass	-0,66907222	-0,557010006	-0,126343878	0,097139175	0,449774524	0,208423405
Shrubs	0,896244956	-0,150536595	0,057545112	0,010017861	0,04467821	-0,15988478

Source: Author's own editing using Microsoft Excel

4. Discussion

Current research suggests that temperature has a significant impact on land use and land cover (LULC) patterns in the Upper Jordan Basin. The findings are consistent with other research studies highlighting the impact of climate change on Jordan's water resources and agriculture. For example, (Al-Weshah & Sabatinh

2018) investigated the impact of climate change on Jordan's water resources and found that increased temperatures and reduced rainfall are expected to have significant impacts on agriculture and the environment. Similarly, another study by (Hamad et al. 2020) explored the impacts of climate change on water resources in Jordan and emphasized the need for adaptation measures to mitigate impacts on both the natural environment and human societies. In addition, a study (Khresat & Al-Qinna 2019) explored the potential impacts of climate change on land use and land cover in the Jordan Basin, considering the complex interactions between climate change, land use, and water resources.

The findings highlight the necessity of implementing adaptive measures to lessen climate change's effects on ecosystems and natural resources. The study clarifies the need to consider how climate change may affect ecosystems and natural resources while evaluating LULC trends.

The results of the current study are consistent with previous studies that have emphasized the importance of developing adaptation measures to manage the impacts of climate change on Jordan's natural resources and ecosystems. However, the study's reliance on correlation analysis and its focus on specific times and places may limit the generalizability of its results, and the relationship between climatic variables and his LULC patterns in different settings emphasizes the need for further research on the relationship between climate variables and LULC patterns in different contexts.

Future research should investigate the relationship between climate variables and LULC patterns and how this influence may vary across different geographical and temporal scales. To increase the resilience and sustainability of both natural ecosystems and human communities, it is essential to comprehend the complex interactions between climate change, land use, and water resources in the Jordan River Basin.

The results revealed that none of the correlations between the climate change variables and LULC categories were statistically significant at the 0.05 alpha level. This indicates that, within the specified timeframe, the changes in temperature and precipitation did not exhibit statistically significant linear relationships with the distribution of land use and land cover categories. It is important to note that these findings do not imply causation but provide evidence that climate change variables were not significantly correlated with changes in LULC percentages in the context of the available dataset. Further research and the inclusion of additional influencing factors may be necessary to gain a more comprehensive understanding of the complex relationship between climate change and land use and land cover alterations. It is important to consider expanding the temporal and spatial scope of the study, incorporating other relevant variables such as economic and political factors, and employing additional research methods.

To mitigate and adapt to climate change impact, policymakers and scientists must promote diversified and climate-resilient agriculture, sustainable water resource management, effective flood control measures, ecosystem conservation, climate-resilient infrastructure, and interdisciplinary research, fostering collaborative efforts tailored to the basin's specific conditions and evolving climate challenges. These measures are essential for safeguarding food security, water resources, and the region's delicate balance of land cover types.

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