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Spatiotemporal Dynamics of Land Cover in Taji District: A Remote Sensing Approach

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Abstract

This study aims to reveal the extent of buildings and urbanization increases in the Taji district. The Taji District faces a problem in determining the judiciary's direction from an area of a rural nature to an area of a civil nature. The importance of this study lies in shedding light on the problem of lack of urban planning that occurs on the outskirts of urban cities in general and in Baghdad in particular. Taji District is located within Baghdad Governorate, one of the governorates of Iraq. Satellite images from Landsat 7 for 2003, 8 for 2014, and 9 for 2023 were acquired to cover the study area. Each image was cropped according to the administrative boundaries of the Taji region. Each image was cropped according to the administrative boundaries of the Taji region using the QGIS program, and the ENVI program was used for classification and statistical operations. The maximum likelihood classification was chosen as the main classifier to distinguish different land cover types in the study region. The areas of each feature of the image were calculated, and then the percentage of each feature was calculated. The graphical relationship between time in years and urban areas during each year showed that urbanization increases at a constant rate, which is the constant increase in urban area and equals 1.06% for each year. This increase is considered relatively high since the Taji district is considered a rural agricultural area, and the explanation for the change in this percentage is due to several reasons, the most important of which is the increase in population and lack of water resources.

.**Keywords:** urban, period, land cover, urban expansion, classes constancy rate, false urban class, uninhabited area

الديناميكيات الزمانية المكانية للغطاء الأرضي في قضاءالتاجي: نهج الاستشعار عن بعد

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الخلاصة

تعنى هذه الدراسة في الكشف عن مدى زيادة الأبنية والعمران على مستوى قضاء التاجي. حيث يواجه قضاء التاجي مشكلة في تحديد توجه القضاء من منطقة ذات طابع ريفي الى منطقة ذات طابع مدني.وتكمن أهمية هذه الدراسة في تسليط الضوء على مشكلة نقص التخطيط الحضري الذي يحدث في أطراف المدن الحضرية بشكل عام وفي بغداد بشكل خاص .يقع قضاء التاجي ضمن محافظة بغداد إحدى محافظات العراق تم تحميل مرئية من قمر لاندسات (7) لعام 2003 ولاندسات (8) لعام 2014 ولاندسات (9) لعام 2023. تم عمل اقتطاع لكل صورة حسب الحدود الإدارية لمنطقة التاجي باستخدام برنامج QGIS ، كما تم استخدام برنامج ENVI للتصنيف والعمليات الإحصائية .تم اختيار تصنيف تقدير الأرجحية الأعلى باعتباره المصنف الرئيسي لتمييز أنواع الغطاء الأرضي المختلفة في منطقة الدراسة. تم حساب مساحات كل ميزة في الصورة،.ومن ثم حساب النسبة المئوية لكل معلم. من خلال العلاقة البيانية بين الزمن بالسنين ومساحات العمران خلال كل سنة وجد ان العمران يزداد بنسبة ثابتة وهي ثابت الزيادة في مساحة العمران وتساوي 1.06% لكل عام. وان هذه الزيادة تعتبر عالية نسبيا كون ان قضاء التاجي يعد منطقة ريفية زراعية، وتعليل تغير هذه النسبة يعود لعدة أسباب أهمها هو زيادة عدد السكان وقلة الموارد المائية.

1. Introduction

Remote sensing helps measure, identify, and analyze properties and features that are helpful in various applications through image analysis [1] [2]. Physical processes include reflection and emission [3] without close contact with the target or item. Most remote sensors capture a variety of wavelengths, including visible (near, mid, and far) infrared, some ultraviolet, and other wavelengths[4] [5]. Urbanization is one of the most prevalent land use changes that alter a region's hydrology. The term "urbanization" refers to the process of population growth occurring at the expense of agricultural land, leading to the loss of greenery [6] [7]. In Earth observation operations, the study of urban change is considered one of the most important studies that give us an idea of the demographic and urban change that prevails in cities, rural areas, and populated areas [8] [9]. It can investigate the conditions and characteristics within the spatiotemporal levels to track environmental and urban changes and most human activity connected to land cover using the information and data provided by remote sensors over successive years [10] [11]. This clearly shows that land uses and changes in land cover are related on a global scale. Two key components will help us understand environmental changes and the actions that go along with managing natural resources [12] [13]. Rain plays a significant role in influencing land use patterns; the distribution of rain amounts becomes crucial in the formation of groundwater, and the importance of rain in agriculture is evident in the way that agricultural productivity varies with the amount of rain received during the growing season each year [14] [15]. Rain is regarded as one of the fundamental climatic elements.

Using satellite images to determine the urban change in the Iraqi governorates has been subject to many studies, including Mushtaq Abdul Karim (2022) [16]; the calculation of change in the urban areas of Mahmudiya, south of Baghdad, was carried out, and the study period spanned from 1986 to 2021, with a five-year interval between each consecutive scene.was low due to environmental influences and human factors. Additionally, there was an upward urban expansion at the expense of other layers, characterized by a somewhat random expansion. The layer-wise stability rate of land cover was calculated compared to 1986, which served as a reference year to identify changes in the land cover of the study area. Classification processes revealed that some areas within the study region were falsely categorized as urban, indicating an inverse relationship between the false urban layer and environmental factors, especially its correlation with rainfall amounts. Hamoodi et al. (2006) [17] used a combination of geographic information systems (GIS) techniques and an image by the sensor TM on Landsat 5; this study examined the urban growth of Baghdad from 1961 to 2004. It concluded that, as a result of rapid economic growth, urban expansion increased by approximately seven times the urban reality of the city in 1961, as depicted on official maps. Al-Yasery et al. (2012) [18] mentioned that the proportion of impervious surfaces in the Kufa, in the province of Najaf, was estimated to determine the urban construction of highways, airports, buildings, and other structures. Statistical models from STATISTIC software, ERDAS 9.2, and ArcGIS were utilized. The study aimed to locate, classify, and differentiate urban areas from other land cover groups. The study found that the moisture percentage in the ground is the main issue preventing the data from being accurate.

Jasim et al. (2014) [19] mentioned that the study encompassed the decline of Iraq's land cover. The study area is the Tikrit region within Salah Al-Din governorate from 1972 to 2010. The study found that urban growth increased by 8.8% between 1990 and 2000 but by a significant 47.5% between 2000 and 2010. These increases were due to several factors, including migration brought on by war, desertification, and climate change. Ahmad, Murad Ismail, 2012 [20] Investigated the use of R.S. and GIS techniques to monitor changes in land cover in the provinces of Kirkuk, Sulaymaniyah, and Erbil. The objective is to create a geographic information base to generate digital land cover maps by analyzing satellite pictures and field surveys. Based on two photographs from two distinct years, he analyzed this area and corrected the three provinces researched between 1987 and 2007 by dropping one image into the Iraqi map. He distinguished between the places that have already changed and those that have not, as well as the nature of the change. Helou Ali, Mostafa, 2018 [21] based on the United States Geological Survey (USGS) classification, remote sensing, and GIS methodologies as an integrated strategy to identify changes in land use and land cover in Maysan province, as well as knowledge of the directions of these changes throughout the period 1972 - 2016. Because of their capacity for analysis, control, and forecasting, he concluded that remote sensing and GIS techniques can be integrated to produce many studies, detailed land cover maps, and follow-up changes. The researcher also urged farmers to invest in the barren land by urging them to continue farming, as the province's lack of arable land has transformed into barren land. This study aims to determine the extent of variable areas due to urban encroachment on agricultural lands resulting from the scarcity of irrigation water in the Taji district from 2003 to 2023, additionally, to calculate the areas of different land cover types using Landsat images 7 for 2003, Landsat 8 for 2014, and Landsat 9 for 2023.

2. Materials and Methodology

To study the impact of urban changes in the Taji region over two decades, ENVI program was employed using Landsat images 7 for 2003, Landsat 8 for 2014, and Landsat 9 for 2023, all of which underwent supervised classification using the Maximum Likelihood method. The following steps were undertaken for result comparison:

1-Acquiring three satellite images from the USGS site at disparate time intervals (approximately 10 years apart between the capture dates of each visual dataset).
2- Ensuring that the visual capture period falls between January 15^{th} and March 15^{th}.
3- Extracting the study area (Taji) from the three scenes.
4- Creating training sets for every image with the same number and arrangement of categories but different ROI locations.
5- Employing maximum likelihood classification for each image.
6- Calculating the area for every classified scene.

2.1 Study Site Description

The study site covers an area of 336 km^2, which represents the north of Baghdad Governorate, Iraq. It is bounded by the Al-Kadhimiya district to the south, with the Tigris River representing its eastern border with the Al-Adhamiya district. To the north, it is bordered by the At-Tarmiya district, and to the southwest, it is bordered by the Abu Ghraib district. As for the western side, it is bound by Anbar Governorate and located within a longitude of 44.8.0°E to 44.20.51°E and latitude of 33.26.11°N to 33.35.8°N, Figure 1. Three scenes monitored it: the first scene from Landsat 7 on March 8, 2003, the second from Landsat 8 on February 10, 2003, and the third scene from Landsat 9 on January 26, 2023. These scenes are present in Path =169 and Row =37, Figure 2. Satellite images are obtained from the USGS (United States Geological Survey) website [22]. The population of the Taji district is 190,297 [23]. The dominant feature of the study area is arable land with other types of urban areas, dry areas, fish lakes, and the Tigris River.

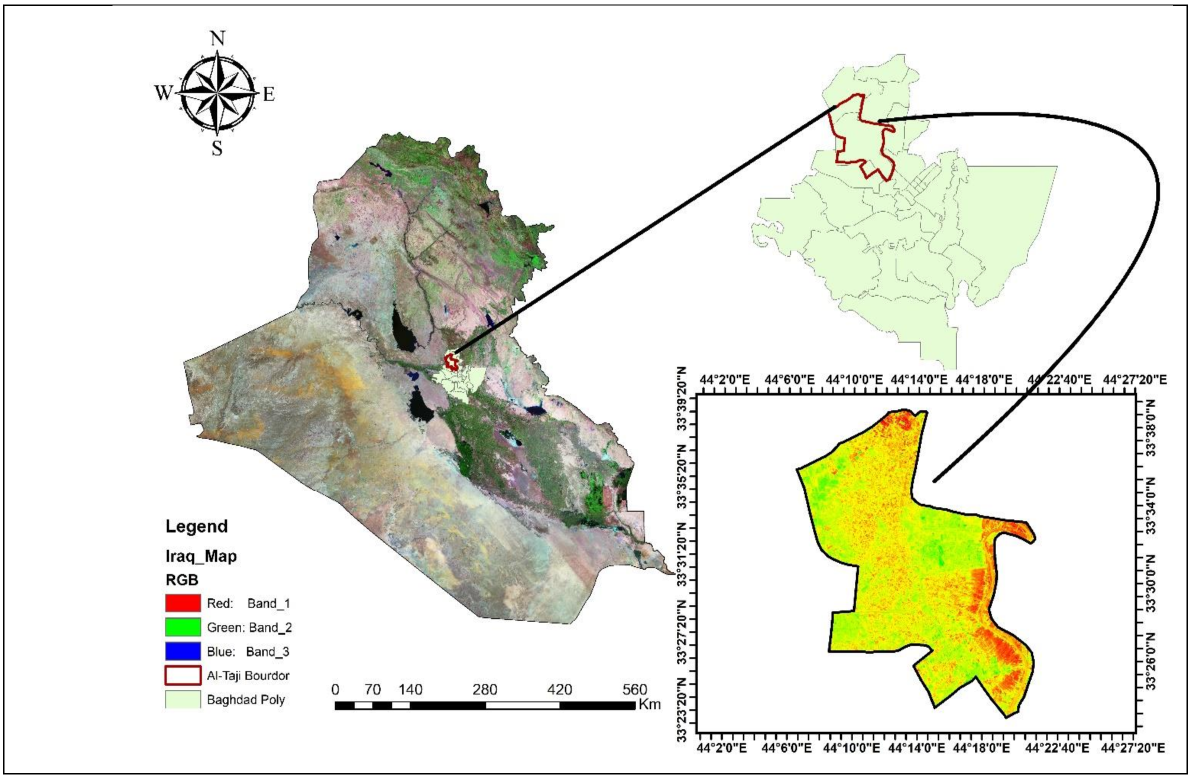

Figure 1: The map of Al-Taji District represents the location of the study area

2.2 Supervised Maximum Likelihood Classification (MLC)

Parametric and non-parametric classifications are the two primary categories into which algorithms for supervised classification are usually separated. Conventional parametric techniques, like minimum distance and maximum likelihood correction, depend on statistical presumptions like the data's normal distribution. Regretfully, the data does not always support this assumption. MLC is regarded as one of the most reliable algorithms for land cover change detection studies [24] and [25] despite the limitations of statistical assumptions. Electrical engineering is where MLC first emerged [26]. The MLC algorithm is predicated on the idea that each training class's statistics within each band should have a bell-shaped, or Gaussian, distribution. The probability distribution for each pixel in the image is formed to calculate the mean and variance for each training class [27]. The relative likelihood (probability) of each unclassified pixel appearing inside each category's probability density function assigns membership to all unclassified pixels throughout the classification process [28]. The unclassified picture has m bands if there are G-designated categories. The posterior probability of category k, P(Gk/x), is calculated using the Bayesian formula, which is (1) [29].

$$p(G_k\ /x) = \frac{\mathrm{p}\left(\frac{\mathrm{x}}{\mathrm{G}_k}\right)P\ (G_k)}{\mathrm{p}\ (\mathrm{x})} \quad (1)$$

where P(x/Gk) is the conditional probability of seeing x from Gk (the probability density function), P(x) is the same for each category, and P(Gk) is the prior probability of category k. Should we be ignorant about the previous distributions P(Gk), then we
Presume that each category is probable. Thus, P(x/Gk), also known as the probability of Gk concerning x, determines the likelihood function. The discriminant function may be written as (2) after taking the logarithm.[29].

$$M_k(x) = \ln p\ (G_k\ ) + \ln \frac{\left|S_k{}^{-1}\right|^{\frac{1}{2}}}{(2\pi)^{\frac{m}{2}}} - \frac{1}{2}(x - \mu_k\ )^T\ S_k{}^{-1}\ (x - \mu_k\ ) \quad (2)$$

where x = $(x_1, x_2,..., x_m)^T$ represents a pixel's vector; M_k (x) is the function likelihood of x falling into category k; μ_k and S_k are the category's means vector and covariance matrix, respectively.

3. Results and Discussion

To facilitate the land cover study of the entire study area, four main categories were taken into account in the land cover: vegetation, soil, urbanization, and water masses. Table 1 indicates the seven classes that were sub-scored within these major categories.

Table 1: The main and sub-classes that represent the land cover of the study site.

No.	Main Class	Subclass
1	plant	Trees
2		Grass
3	Soil	Clay soil
4		Salty soil
5	Urban	Buildings
6	Water	Deepwater
7		Shallow water

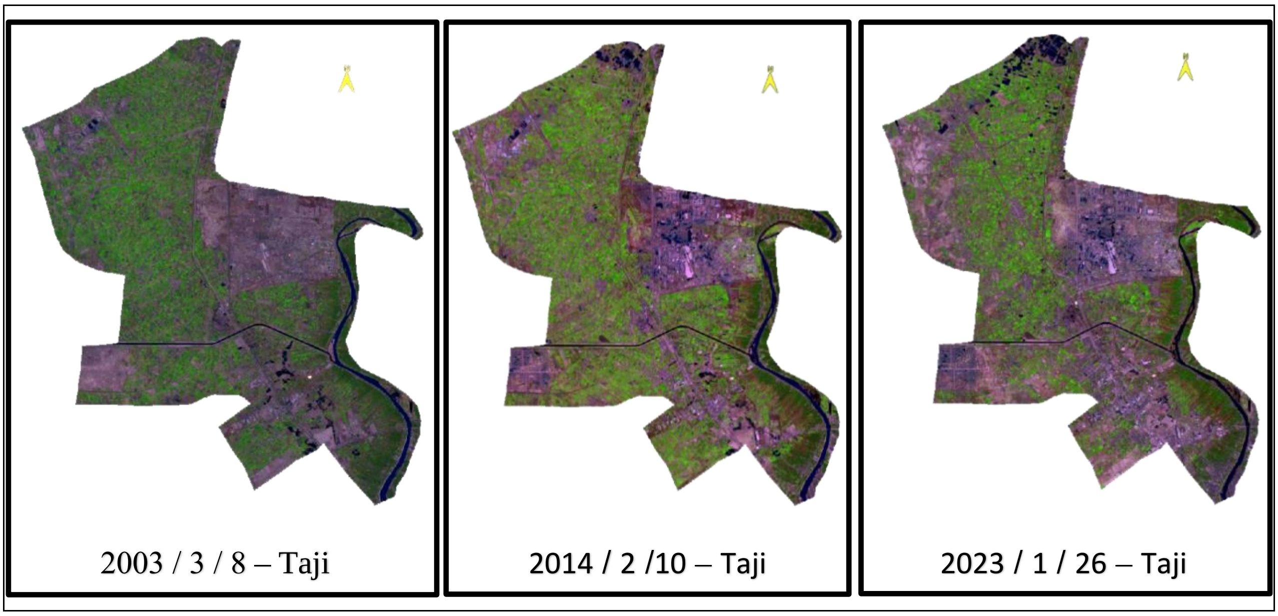

Figure 2. Study area during 2003, 2014 and 2023

A maximum likelihood classification was conducted for the visuals, and the classification data was saved as shown in Figure 3, where yellow represents buildings, cyan represents deep water, blue represents shallow water, red represents trees, green represents grass, coral represents clay soil, and sienna represents salty soil.

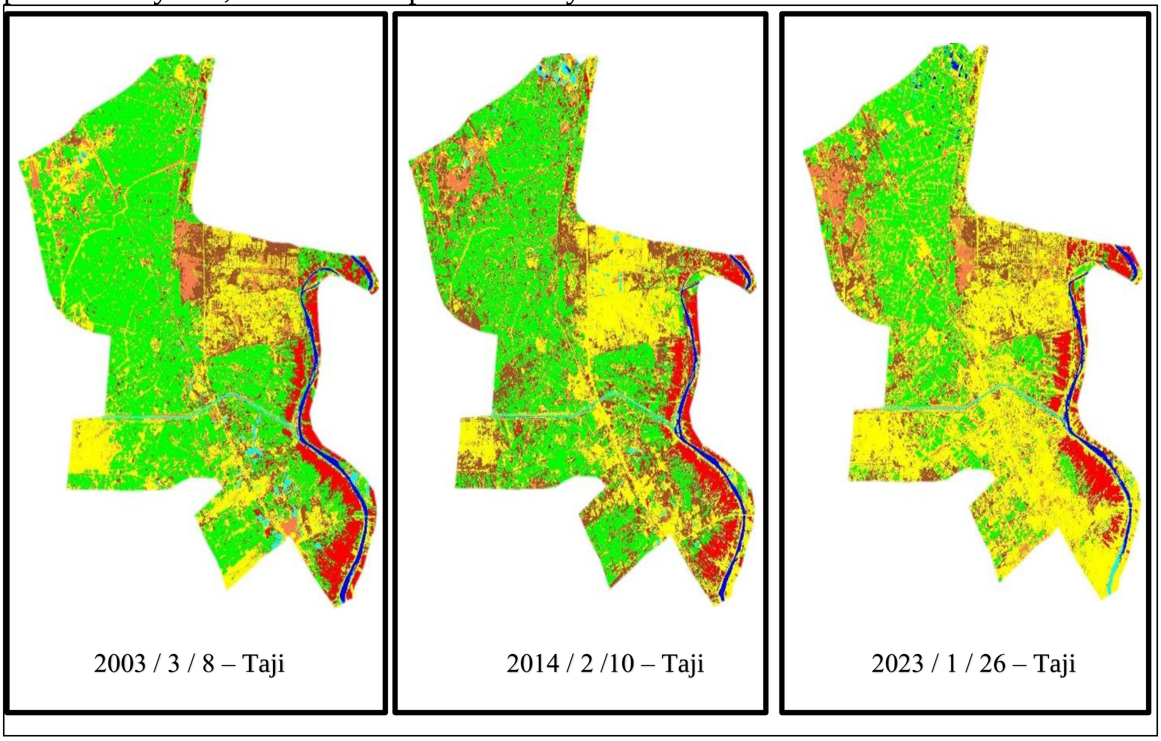

Figure 3: The study area during 2003, 2014, and 2023 after performing the Maximum Likelihood Classification

The spatial resolution of the satellite image (30 m) was reflected by the satellite, where the values were recorded between the subcategories mentioned in Table 2. This is due to an essential main reason: asphalt and limestone soil's spectral fingerprint is close to urban buildings' spectral fingerprint. Thus, it is difficult to separate them from each other in small areas relative to the area of one pixel, which is equal to 900 m^2.

The areas and percentages of the subcategories of the three images (2003, 2014, and 2023) were calculated in Table 2. A clear difference was noticed in the area values for each category during these periods. This result is due to the increase in population and the lack of water resources, which led to a lack of interest in agriculture.

Table 2: Subclasses covering percentage and their areas.

Colors	class	Area (Km^2)	Percent	Area (Km^2)	Percent	Area (Km^2)	Percent
	Buildings	92.09	27.39%	104.67	31.14%	166.32	49.48%
	Deep water	5.32	1.58%	6.55	1.95%	3.02	0.90%
	Shallow water	4.74	1.41%	4.57	1.36%	5.20	1.55%
	trees	26.40	7.85%	28.36	8.43%	18.51	5.51%
	Grass	158.26	47.08%	118.27	35.19%	81.37	24.21%
	Clay soil	34.91	10.38%	65.39	19.45%	46.91	13.95%
	Salty soil	14.45	4.30%	8.34	2.48%	14.84	4.41%
-	Total Area	336.17	100.00%	336.17	100.00%	336.17	100.00%

The areas and percentages of the main classes were calculated for the previous three images in Table 3. A clear difference was noticed in the values of the areas for each class during these periods for the same reason.

Table 3: The main classes cover percentages and their areas

class	2003		2014		2023	
	Area (Km^2)	Percent	*Area* (Km^2)	Percent	*Area* (Km^2)	Percent
plant	184.67	54.93%	146.64	43.62%	99.88	29.71%
Soil	49.36	14.68%	73.73	21.93%	61.74	18.37%
Urban	92.09	27.39%	104.67	31.14%	166.32	49.48%
Water	10.06	2.99%	11.12	3.31%	8.22	2.45%
Total area	336.17	100.0%	336.17	100.0%	336.17	100.0%

The classification accuracy and kappa coefficient were computed for all classes, revealing a significant increase in classification accuracy, Table 4.

Table 4. The comprehensive accuracy classification.

	accuracy	Kappa Coefficient
2003	95.2530%	0.9448
2014	93.0661%	0.9134
2023	81.1899%	0.7816

The increase in urban change was calculated by taking a relationship between years and the percentage of urbanization and was found to be equal to 1.06% for each year, Figure 4.

$$slope = \frac{\Delta y}{\Delta X} = \frac{(43-27)\%}{(2020-2005)year} = \frac{16\%}{15} = 1.06\%\ per\ year$$

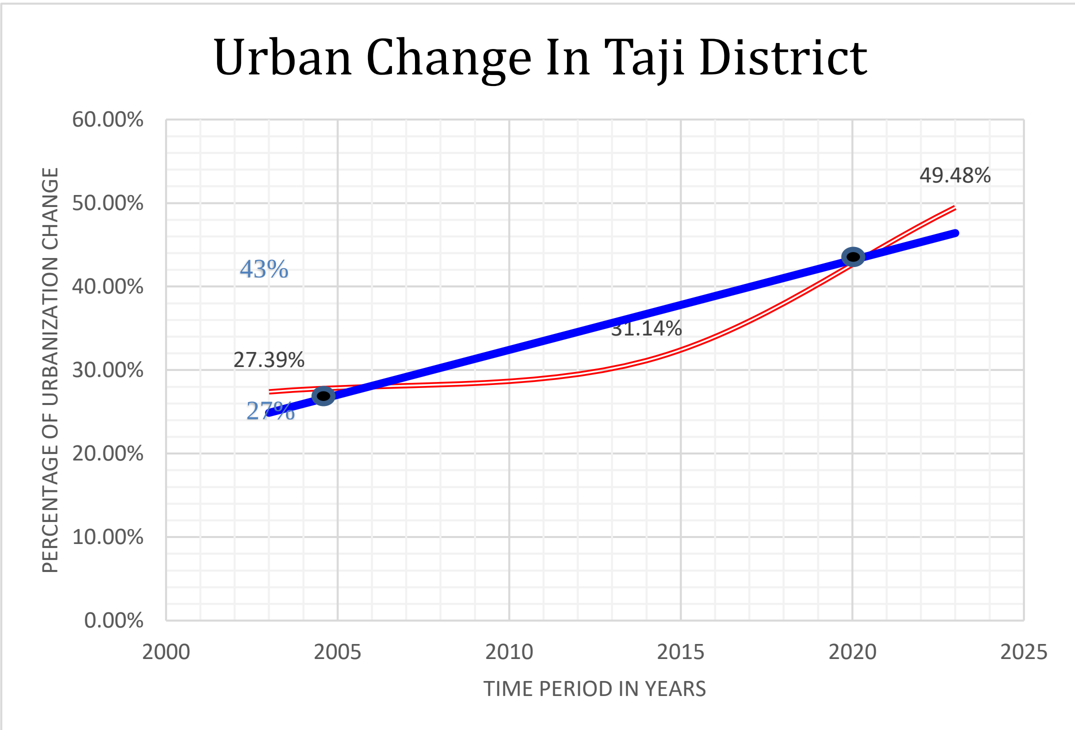

Figure 4: The relationship between time in years and percentage of urban change in Taji

4. Conclusion

From the results, it could be concluded that the following increase in the soil and water percentage during 2014 was at the expense of the rest of the species compared to 2003 and 2023. This reason is due to drought that affected the region due to global climate changes, with an increase in the number of fish lakes, which decreased during 2023. This was observed in Table 2 through the decrease in saline soil percentage in 2014. The explanation for this is the population's tendency to convert salty lands unsuitable for agriculture into fish lakes by digging wells. Thus, this explains the noticeable increase in the percentage of water during the same year. The reason is the deterioration of the security situation in 2014, which led to the halt of life, including agriculture and reconstruction, during this period.

The increase in urbanization change is generally evident during these periods. This is what was calculated in Figure 4. The study shows that it increases almost constantly yearly, 1.06%. The reason for this increase is due to many factors, the most important of which are:

1- An increase in the population in the district and thus an increase in the need for a more significant number of residential homes.

2- Lack of water resources in the district leads to a lack of crops, then pushes the people of the district to abandon agriculture and move toward civil behavior.

3- Overcrowding of housing inside Baghdad and increasing population density pushes residents inside Baghdad to buy lands on the outskirts of Baghdad, and its annexation by Taji thus means converting more agricultural lands into the urban area.

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