ANKARA SCIENCE UNIVERSITY, RESEARCHER
Vol. 4, No. 2, Decmber 2024
e-ISSN: 2717-9494
Research Article/Araştırma Makalesi

Analyzing the Causes of Deforestation with Statistical Quality Control Methods in Turkey

Melike ERDOGAN [1*], Rabia TORMAN [2]
[1]Duzce University, Department of Industrial Engineering, 81620, Duzce; ORCID: 0000-0003-0329-8562
[2] Duzce University, Department of Industrial Engineering, 81620, Duzce; ORCID: 0009-0004-4609-4556
*Corresponding Author: melikeerdogan@duzce.edu.tr

Received: 6 September 2024; Accepted: 19 December 2024

Reference/Atıf: M. Erdoğan and R. Torman, "Analyzing the Causes of Deforestation with Statistical Quality Control Methods in Turkey", Researcher, vol. 04, no. 02, pp. 192–210, 2024.

Abstract

The forests that cover the earth are the main source of everything for living things. The sustainability of forests is of great importance for ecosystems, biodiversity, erosion prevention, climate diversity, tourism, protection of global balance and water resources. Today, forests are subject to change and destruction among the resources on earth. As a result of human interventions and actions, forests are damaged unpredictably. With the combination of many reasons, the negative concept called deforestation has come to the agenda as an issue that is increasingly attracting attention today. Deforestation is a problem that should be discussed, studied and urgent solutions should be sought for Turkey. In this study, the causes of deforestation in Turkey are examined and analyzed using statistical quality control methods. In this context, the effects of agricultural activities, forest crimes, forest fires, global warming and climate change, urbanization and overpopulation on deforestation have been investigated. Whether the causes are statistically under control or not are analyzed, out-of-control points are identified with the help of control charts and suggestions are presented for the elimination of these causes. The causes of deforestation have been evaluated using MINITAB software with the help of systematic statistical quality control tools. With the effect of the study, it is aimed to develop awareness in cooperation with the authorities and society and to determine relevant actions to prevent deforestation. By identifying the reasons that cause most to deforestation, policies are revealed to eliminate the problem of deforestation in Turkey. With this paper, it is foreseen that the actions to be taken regarding deforestation in the forest area of Turkey will have an impact on the global forest area and will create an international awareness and example and will serve as a guiding study for decision-makers.

Keywords: Control Chart, Deforestation, Policy Development, Statistical Quality Control

1. Introduction

Forests are of great economic, ecological and socio-cultural importance. Today, great efforts are made to protect forests and manage their life sustainably. The United Nations Conference on Environment and Development in Rio in 1992, it was recognised that deforestation a threat to the environment in terms of both change and biodiversity and forests are a 'life-support system' for humanity was made. Forests are home to about 6,000 different species that we need at every stage of our lives being a source of raw material for wood and non-wood forest products with a place of use. In addition, today forests come to the fore in terms of biodiversity, carbon storage, oxygen, carbon storage and oxygen storage. Being a source of water, regulating surface and groundwater, having a positive impact on climate, the world's indispensable common values with social benefits such as preventing erosion among them. Almost all of Turkey's forests are under the jurisdiction of the state. The vast majority of the forests are under the control of the General Directorate of Forestry. Privately owned forest area is less than two thousandths of the total forest area (approximately 30,000 hectares) [1]. Turkey's forests are managed on the basis of forest management plans prepared on the basis of the smallest management unit, the forest management chief, with 10 - 20 year return periods. As a general evaluation, it can be said that the area, richness and annual increase of forests today are increasing compared to the past. In recent planning and implementation activities, the consideration of other product and service functions of forests other than wood production is effective in this change. In addition, the activities carried out for the protection and evolution of forests are also effective in increasing forests in terms of area, wealth

and increase. The size and changes in forest areas are based on the results of forest inventory assessments carried out to date and by years in the following [1];

- 1999: 20,763,248 hectares (26.7% of the country),
- 2004: 21,188,747 hectares (27.2% of the country),
- 2012: 21,678,134 hectares (27.7% of the country),
- 2015: 22,342,935 hectares (28.6% of the country),
- 2020: 22,933,000 hectares (29.4% of the country) .

According to this statistics, there has been an increase of approximately 2.7 million hectares in forest area in the last 47 years. Turkey today has an ecologically rich diversity with an area of 78 million hectares. Within this richness, forests have an important place in terms of species and composition [1].

With the understanding of the importance of forests in combating climate change, new concepts have entered the forestry literature such as "deforestation". Although deforestation is defined in various ways by different institutions, it means long-term conversion of forest areas to other uses [2]. Forests play a vital role in combating climate change, erosion, protecting biodiversity and increasing water availability, and are also a source of food and shelter for humans and wildlife. World the majority of threatened species live in forests and and 1.6 billion people depend on forests for food, fresh water, clothing, traditional medicine and shelter [3].

In this study, the reasons of deforestation in Turkey is aimed to analyze in detail with statistical quality control methods. The effects of agricultural activities, forest crimes, forest fires, global warming and climate change, urbanization and overpopulation on deforestation in Turkey have examined through statistical analysis. It is aimed to analyze the effects of the area used for agricultural activities and the effect of uncontrolled agriculture on deforestation in Turkey, land occupation and land opening activities within forest crimes, forest area lost as a result of forest fires, the effect of global warming and climate change on forest life, the effect of population growth as a result of urbanization and overpopulation on deforestation in Turkey by adopting control charts. In this context, in order to ensure a sustainable forest life and to eliminate the causes or effects of deforestation, the most critical causes are identified and policies are recommended to reduce or eliminate these causes. With the reasons examined, it is aimed to offer solutions to this problem, which attracts attention today and will continue to be talked about and worried about in the future. The research questions (RQ) of the paper can be presented as:

RQ1: What are the causes of deforestation in Turkey?

RQ2: Are these causes statistically under control? If there is an out of control situation When, if ever, has it happened?

RQ3: When did the detected out-of-control points occur?

RQ4: What is the most important cause of deforestation in Turkey?

RQ5: Which policies can be recommended to reduce and eliminate the occurrence of these causes?

In thelight of these questions, the rest of the paper is organized as follows. Section 2 gives the literature review fot the research. Section 3 includes the adopted methodology. Section 4 gives real case statistical analysis for the deforestration in Turkey. Finally, Section 4 give results and future directions.

2. Literature Review

Similar studies in the literature have been examined to undertand the problem and current applications. Table 1 presents the results of the literature review with he keywords used “deforestation”, “deforestation in Turkey”, “statistical quality control”, “statistical process control” and “Shewhart control charts” via scopus platform.

Table 1: Literature Review Details

	Author(s)	Publication Year	Aim of the Study	Adopted Methodology
1	Podur et al. [4]	2002	In Canada, Ontario and the northwest Annual fire occurrence in Ontario and in the mean and variance of the burning area detect significant changes	Statistical Quality Methods
2	Hennemuth et al. [5]	2012	Statistical methods for the analysis of simulated data and observed climate data to analyze the impact of climate change and adaptation applied in projects and institutions	General Statistical Methods
3	Gunsen and Atmis [6]	2019	Deforestation and deforestation analysis in Turkey	Correlation Analysis
4	Devecioğlu et al. [7]	2019	To examine the factors causing deforestation in Turkey and to measure public knowledge and interest in environmental problems (desertification, erosion, etc.)	Correlation Analysis, Survey
5	Rehana and Mujumdar [8]	2012	Present an integrated river water quality management modeling framework using GCM projections of modeled hydroclimatic variables	Statistical Quality Methods
6	Kuvan [9]	2011	Examination of the negative environmental impacts of tourism	Qualitative Analysis
7	Unal et al. [10]	2018	Regression analysis between forest area and urbanization	Regression Analysis
8	Akkemik et al. [11]	2012	Examining the relationship between archaeological data and deforestation	Data Analysis
9	Telkenaroglu and Dikmen [12]	2017	To examine deforestation due to urbanization in Trabzon, Turkey between 2006 and 2016	Data Analysis
10	Sabuncu [13]	2019	Mapping and monitoring of the land	Data Analysis
11	Coskun and Gencay [14]	2011	To analyze deforestation according to the Kyoto Protocol for the adequacy of Turkish environmental and forest legislation	Legal Analysis
12	Colak [15]	2009	Examination and interpretation of restored, rehabilitated, deforested and degraded forest areas in Turkey with data	Data Analysis
13	Gulser et al. [16]	2021	Effects of deforestation on soil properties and soil organic C (SOC) stock in adjacent pasture and forest areas on the same slope position	Data Analysis
14	Zambrano-Monserrate et al. [17]	2018	An empirical investigation of the relationship between deforestation and economic growth	DEF Analysis
15	Avsar [18]	1997	To examine the extent of deforestation in Kahramanmaraş-Elbistan region and the problems caused by it	Statistical Analysis

16	Malkoc and Nurlu [19]	2016	Calculating the deforestation rate and modeling the Reference and Carbon Emission Reduction Scenarios under the REDD+ Project through guiding factors	Statistical Analysis
17	Gumuscu et al. [20]	2014	To examine deforestation in the historical process	Qualitative Analysis

When the study in the researched field has been analyzed by years, most studies have been found in 2019. The scarcity of studies in the literature related to the researched topic and the applied method is also visualized in Figure 1. By checking this histogram, it can be claimed that the issue of deforestation has become popular in recent years and addressing it will benefit the whole world.

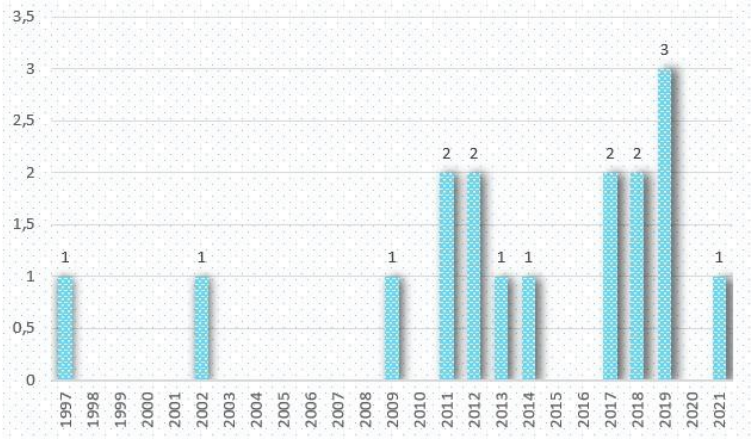

Figure 1: Literature Search Histogram

As a result of the literature review, there is no study on analyzing deforestation and its causes in Turkey with statistical quality control methods. This indicates that the adopted method will be used for the first time in the field and shows the originality of the study. It can be said that this study will be a guiding study to fill the literature gap in the related field.

The authors may claim that there is no study that investigates the causes of deforestation for a country, as in this study, and furthermore, that there is no study that addresses this with numerical approaches such as statistical quality control methods.

3. Materials and Methods

In this section, control charts which adopted in the analysis of the problem addressed in this paper is presented.

3.1 Control Charts

Control charts are the main tools used to realize process control economically and reliably with statistical methods. Armand V. Feigenbaum defines the control diagram as a graphic tool for chronologically comparing the quality specifications of the product, its constituent parts or other components according to the limits determined on the basis of past experience [21]. Control charts can be grouped into two groups, control charts for variables and control charts for attibutes. Control charts for variables are Xbar - R Charts, Xbar - S Charts, I - MR Charts while control charts for attibutes are p chart, np chart, u chart and c chart. The details of these control charts are given in the following sub-sections.

3.1.1 Control Charts for Variables

i. $\bar{\bar{X}}$- R Charts

Xbar- R charts are control charts used in variables where quality characteristics can be measured and expressed numerically. Assuming that a quality characteristic fits a normal distribution with mean μ and standard deviation σ and that the process parameters (μ and σ) are known, control limits can be calculated as in the following equations (UCL: Upper control limit, CL: Center Line, LCL: Lower Control Limit) [22], [23]:

$\bar{X}$Chart Control Limits

$$UCL: \mu+A\sigma \quad (1)$$

$$CL:\mu \quad (2)$$

$$LCL:\mu-A\sigma \quad (3)$$

R Chart Control Limits

$$UCL : D_2\sigma \quad (4)$$

$$CL: \quad d_2\sigma \quad (5)$$

$$LCL: \quad D_1\sigma \quad (6)$$

If the mean μ and the standard deviation σ are not known, control limits can be calculated as in the following equations:

$\bar{X}$ Chart Control Limits

$$UCL: \bar{\bar{X}}+ A_2\bar{\bar{R}} \quad (7)$$

$$CL: \bar{\bar{X}} \quad (8)$$

$$LCL: \bar{\bar{X}}- A_2\bar{\bar{R}} \quad (9)$$

R Chart Control Limits

$$UCL : D_4\bar{\bar{R}} \quad (10)$$

$$CL: \quad \bar{\bar{R}} \quad (11)$$

$$LCL:D_3\bar{\bar{R}} \quad (12)$$

ii. $\bar{\bar{X}}$- S Charts

If the sample volume in a production process is greater than or equal to 10, the S chart is used instead of the R Chart. Because if the sample volume is equal to or greater than 10, the efficiency and reliability of the range of variation decreases. Although the s diagram can also be used in cases where the sample volume is less than 10, the R diagram is preferred for ease of calculation [23].

$\bar{X}$Chart Control Limits

UCL: $\mu+A\sigma$ (13)

CL:μ (14)

LCL:$\mu-A\sigma$ (15)

S Chart Control Limits

UCL : $B_6\sigma$ (16)

CL: $c_4\sigma$ (17)

LCL: $B_5\sigma$ (18)

If the mean μ and the standard deviation σ are not known, control limits can be calculated as in the following equations:

$\bar{\bar{X}}$ Chart Control Limits

UCL: $\bar{\bar{X}}+ A_3\bar{S}$ (19)

CL: $\bar{\bar{X}}$ (20)

LCL: $\bar{\bar{X}}- A_3\bar{S}$ (21)

S Chart Control Limits

UCL : $B_4\bar{S}$ (22)

CL: $\bar{S}$ (23)

LCL:$B_3\bar{S}$ (24)

iii. I - mR Charts

To understand the state of the process, the design of the control scheme will be based on unit or individual measures and two basic measures will be controlled. On the one hand, the mean, which is a measure of central tendency and used to measure the variability of individual observations, and on the other hand, the range of variation, which is used to measure the spread between individual observations [23].

I Chart Control Limits

UCL: $\bar{X} + 2.66m\bar{R}$ (25)

CL:$\bar{X}$ (26)

LCL: $\bar{X} - 2.66m\bar{R}$ (27)

mR Chart Control Limits

UCL : $3.268m\bar{R}$ (28)

CL: $m\bar{R}$ (29)

LCL:0 (30)

3.1.2 Control Charts for Attributes

Control charts can be used for qualitative variables where the quality attribute is countable. Similarly to variables, the decision is made whether the process is under control or not. In this case, the number of defective items in a batch and the number of defects contained in a unit can be identified and analyzed [23]. Four types of attribute control charts can be identified, and divided into two groups. These are the (p) (np) group, which focuses on sample characteristics, and the (c) (u) group, which focuses on functional characteristics of products.

i. p-Control Charts

A defect rate control chart, commonly called a p-chart, is used to understand whether the ratio of non-conforming output to the total number of outputs in the population is under control. The non-conformance value can usually be expressed as a decimal or percentage number. The following steps should be followed when creating these graphs. Defect rate (p) is defined as the ratio of the number of defective products/services in a subgroup to the subgroup size. The number of observations made gives the sample (n). The average failure rate (p) is the ratio of the sum of the errors in the subgroups to the sum of the number of observations in the subgroups[23].

$$UCL = p + 3\sqrt{\frac{p(1-p)}{n}} \quad (31)$$

$$CL = p \quad (32)$$

$$LCL = p - 3\sqrt{\frac{p(1-p)}{n}} \quad (33)$$

ii. np- Control Charts

The np-charts apply to sampling characteristics in the same way as the plot described in the previous section. Unlike the (p) plot, (np) is related to the number of failures in a given population [23].

$$UCL = np + 3\sqrt{np(1-p)} \quad (34)$$

$$CL = np \quad (35)$$

$$LCL = np - 3\sqrt{np(1-p)} \quad (36)$$

iii. c- Control Charts

While keeping the sample size constant, the calculation of control limits requires some values, such as the calculation of the number of defects per sample. The mean number of nonconformities per sample is the total number of nonconforming units divided by the number of samples [23].

$$UCL = c + 3\sqrt{c} \quad (37)$$

$$CL = c \quad (38)$$

$$LCL = c - 3\sqrt{c} \quad (39)$$

iv. u-Control Charts

The (u) graph is a control chart for the average number of defects per unit. It is useful for determining the number of defects in a unit. In many ways, it is very similar to the control chart (c) but differs in terms of sample size [23].

$$\mathrm{UC}L = u + 3\sqrt{\frac{u}{n}} \tag{40}$$

$$CL = u \tag{41}$$

$$LCL = u - 3\sqrt{\frac{u}{n}} \tag{42}$$

4. Real Case Application

As a result of literature research, deforestation in Turkey is assessed in terms of five main causes in this paper. After analyzing the data types, I-MR control charts have been created for each cause. Individual Moving Range (I-MR) chart is a tool used to monitor and control process performance and widely used especially in continuous data collection processes. The I-MR control charts shows each measurement value followed by consecutive moving ranges of these measurement values. In this paper, for analyzing the out-of-control points, points outside the lower control limit have not been included in the interpretation of the results. Because the points below the lower limit actually show us low values for the reasons that cause deforestation, which is a desired result. It is true that sub-control points have the potential to indicate a real change in the process, but it does not always mean that these points are a definite problem with the performance of the process. Instead, these points are taken into account, considered in conjunction with other data, and treated as a signpost for a more detailed examination of the process if necessary. In order to examine the impact on deforestation, statistical analysis has been conducted for 5 causes. These causes are “Agricultural activities”, “Forest fires”, “Forest crimes”, “Global warming and Climate change”, “Urbanization and overpopulation”. Data on forest fires and forest crimes are taken from official reports of the General Directorate of Forestry. Agricultural activity and total greenhouse gas emission data are taken from TurkStat reports. Population growth data are from The World Bank. In order to examine the compliance with Nelson's Rules in the control graphs plotted, this section was enabled while plotting the graphs in Minitab. Thus, the analysis has been revealed deeply. Nelson's Rules is a method in process control that determines whether some measured variable is out of control (unpredictable or consistent). Rules for detecting "out of control" or non-random conditions were first proposed by Walter A. Shewhart in the 1920s [24]. The rules are applied to a control chart where the magnitude of some variable is plotted against time. The rules are based on the mean value and standard deviation of the samples. Figure 2 shows the Nelson rules [25].

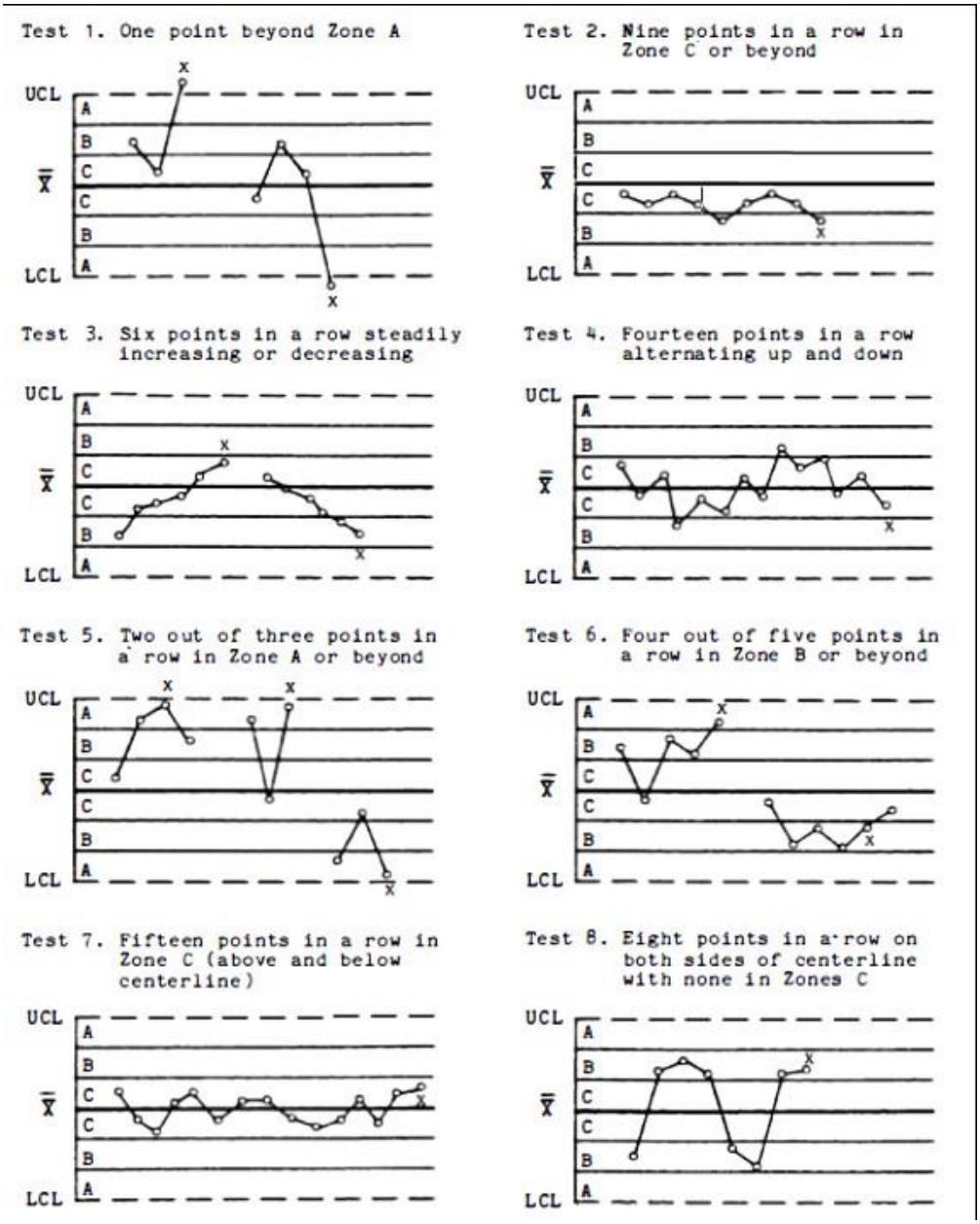

Figure 2: Nelson Rules [25]

4.1. Statistical Analysis for Agricultural Activities

The first reason examined is agricultural activities in Turkey. Data has been taken from Tuik to be examined and analyzed [26]. The graph created with the I-MR control chart by looking at 22 years of agricultural area data in Turkey is shown in Figure 3.

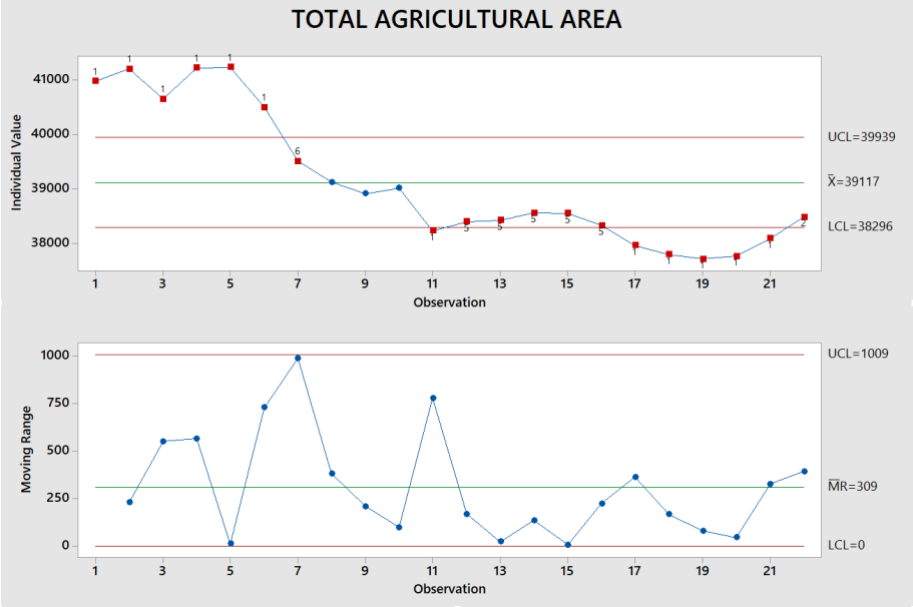

Figure 3: I-MR Chart of Agricultural Activities

According to the control chart in Figure 3, there is a decreasing trend in agricultural areas. In 2001, 2002, 2003, 2004, 2005 and 2006, the data has been exceeded the upper control limit. In 2011, 2016, 2017, 2018, 2019, 2020 and 2021, the points have been detected below the lower control limit. A detailed analysis of the reasons for the out-of-limit points is shown in Figure 4 Fishbone Diagram which shows the causes of the narrowing of agricultural areas.

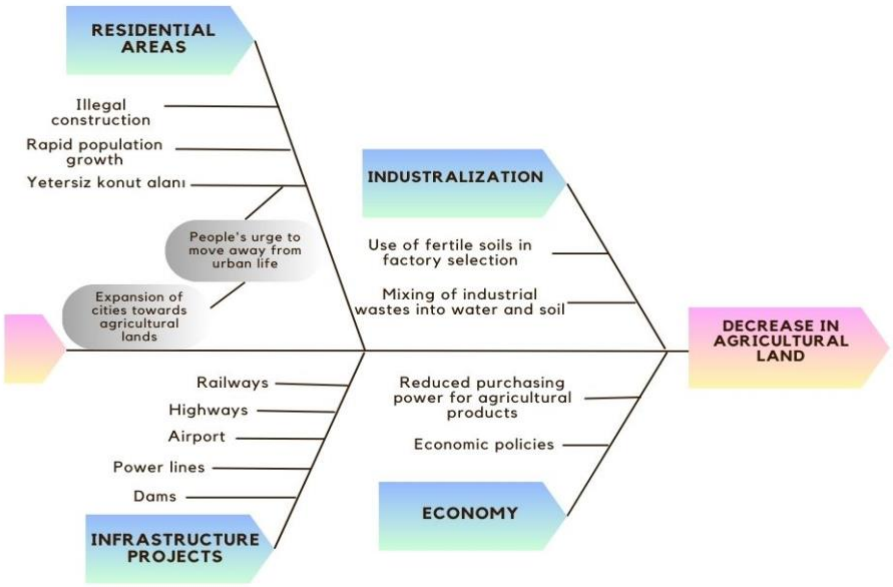

Figure 4: Fishbone Diagram for Decrease in Agricultural Areas

The reason for the declining trend of agricultural areas over the years is the use of fertile lands for factory areas under the name of industrialization and the mixing of industrial wastes into water and soil. Infrastructure projects such as railroads, highways, airports, energy lines and dam construction have caused shrinkage in agricultural areas. Housing areas surrounding agricultural lands, illegal construction, rapid population growth, and the urge of people to move away from urban life due to

insufficient housing space are the reasons why agricultural lands are used for different purposes. Economic policies and reduced purchasing power for agricultural products, farmers being affected by changes in the country's economy, explain the out-of-control points [27]. According to the MR control charts, the variation between consecutive observations shows that the process variation is high which means data for 22 years show large variations.

4.2. Statistical Analysis for Forest Fires

The second cause analyzed is forest fires in Turkey. The data has been taken from the General Directorate of Forestry to be examined and analyzed in detail [28]. The control chart created with the I-MR control graph by looking at 26 years of forest fire data in Turkey is shown in Figure 5.

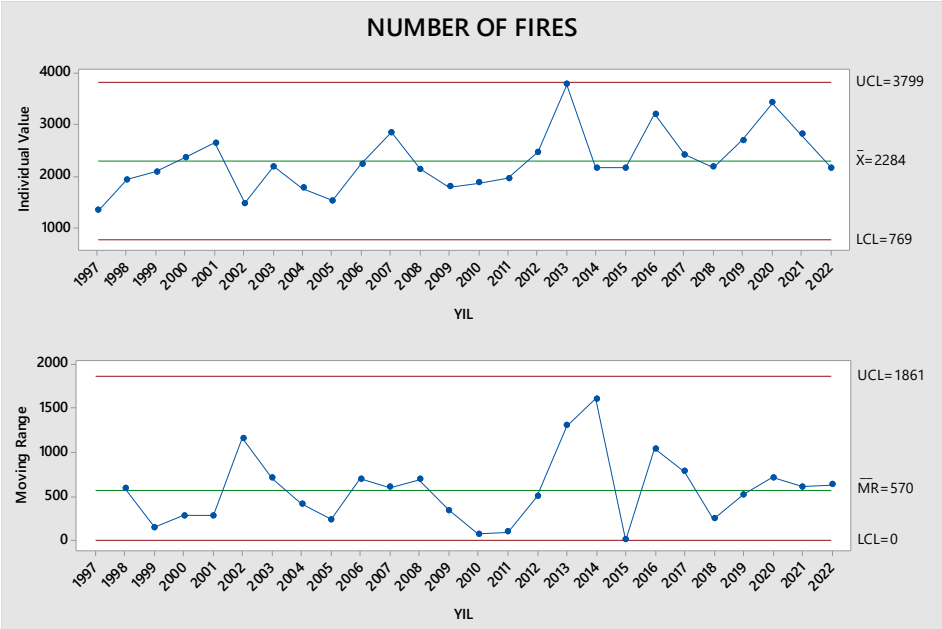

Figure 5: I-MR Chart of Forest Fires

When the data for fires have been analyzed, it is seen that there has been a significant increase in forest fires in 2001, 2003 and 2007 due to negligence and carelessness. In 2013, 2016 and 2020, in addition to these reasons, the highest number of fires in 20 years has been obtained with the effect of unidentified fires. In 2013, the number of forest fires reached its highest level with 3755 fires, burning 11446 hectares of forest area. In 2013, 15% of forest fires had been caused by smoking, 3% by field clearing, 3% by shepherds' fires, 1% by picnic fires, 2% by stubble burning, 1% by hunting, 6% by other causes, 35% by unknown causes and 2% by energy transmission lines [28]. According to the MR graph, it is observed that the process variation is high by looking at the change between consecutive observations. Looking at 26 years of data, large changes were observed at some times.

When the general causes of 26 years of forest fires are analyzed, 5 main topics has been stand out. The detailed analysis of the out-of-limit points is presented in the fishbone diagram in Figure 6.

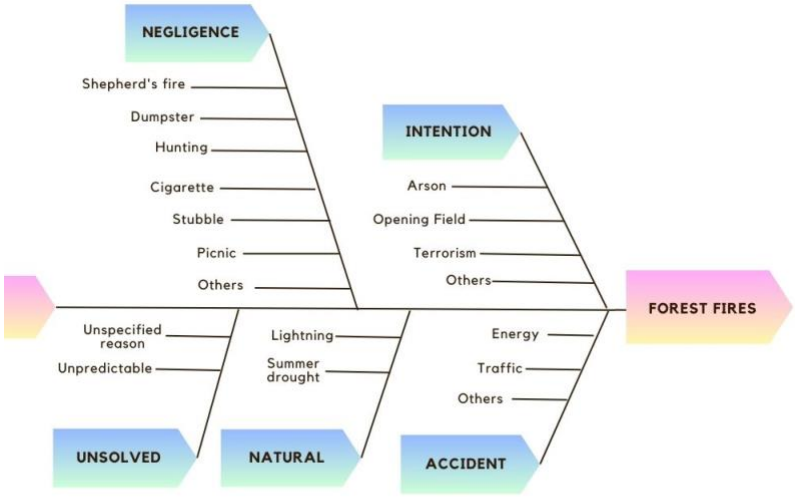

Figure 6: Fishbone Diagram for Forest Fires

As can be seen in the Fishbone Diagram, it has been determined that crimes such as deliberate arson and terrorism or such as land clearing are effective in forest fires. Apart from these crimes, fires caused by shepherd's fires, garbage dumps, hunting, cigarette butts, stubble burning and picnics were also experienced within the scope of social negligence. Traffic accidents and energy-related accidents were also observed. There are also natural causes such as unidentified unidentified fires and lightning.

4.3. Statistical Analysis for Forest Crimes

The third reason examined is forest crimes in Turkey. The data was taken from the General Directorate of Forestry to be examined and analyzed [43]. Figure 7 shows the graph drawn with the I-MR control chart by using the data of the crime of opening an area, which is included in 32 years of forest crime data in Turkey. Figure 8 shows the graph drawn with the I-MR control chart by using the data of the crime of land occupation, which is included in 23 years of forest crime data in Turkey.

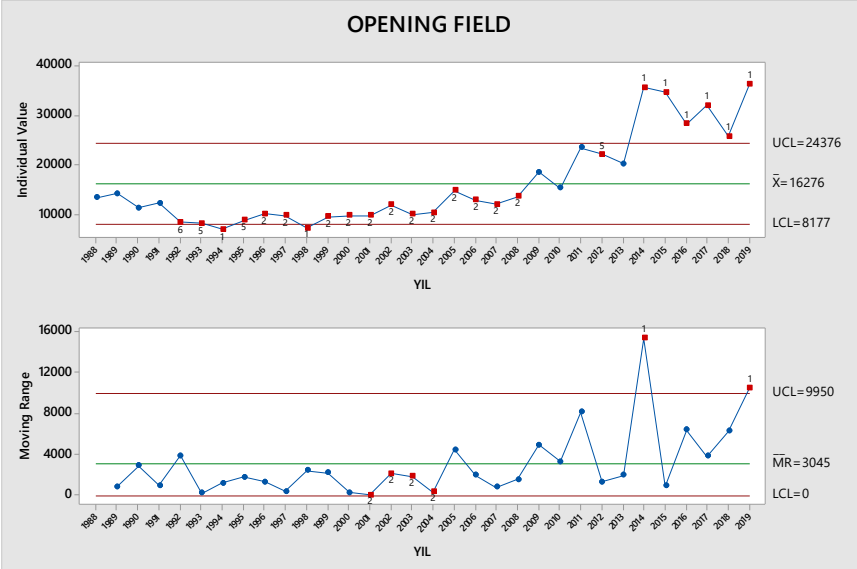

Figure 7: I-MR Control Chart of Opening Field in Forestry Areas

The red dots in the graph indicate that Nelson's rule is not fulfilled at that point. According to the I chart, the data from 1992 to 2008 are out of control because nine or more consecutive points are on the same side of the mean (points in red with 2 written on them). Two or three out of three consecutive points are more than 2 standard deviations from the mean in the same direction (points shown in red and labeled 5). Four or five out of five consecutive points are more than 1 standard deviation from the mean in the same direction (points shown in red and labeled 6). Between 2014 and 2019, the points exceeded the upper control limit and went out of control. The reason for this was found to be illegally built scouting facilities. When the I chart is analyzed, the data for the years 2001-2004 show that the 2nd rule of Nelson's rules, "Nine or more points in a row are on the same side of the mean." The data for 2014 and 2019 exceeded the upper control limit.

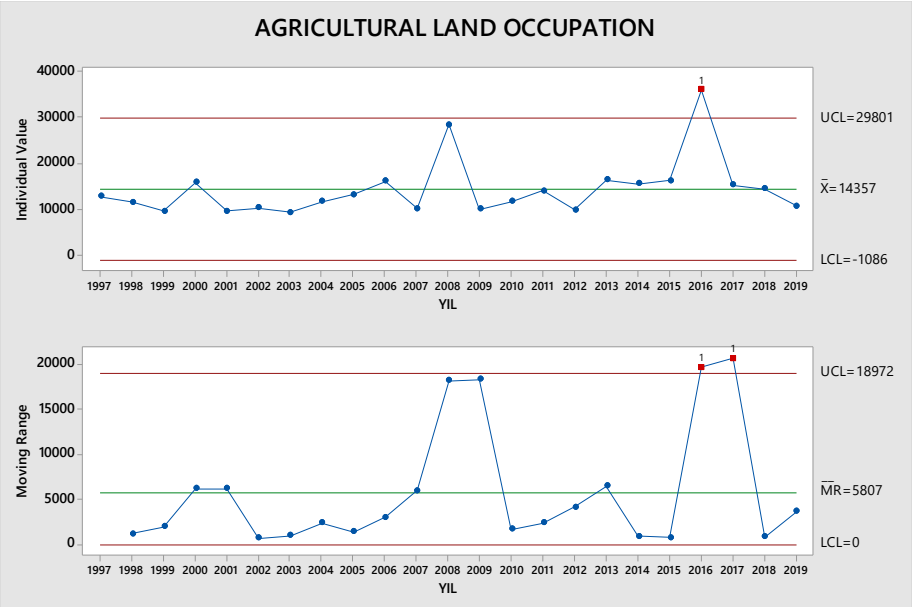

Figure 8: I-MR Control Chart of Agricultural Land Occupation

When the control charts were investigated for Agricultural Land Occupation, the upper control limit was exceeded for the I-control chart in 2016. The reason for the out-of-control point is that according to the 2018 Regularity Audit Report of the Court of Accounts of the General Directorate of Forestry, approximately seven thousand hectares of forest area have been occupied by the Turkish Scouting Federation since 2016 by building wooden bungalows, classrooms, haystacks, guard huts, toilets, ski center and chairlift facilities in the forest area in Bolu Aladağ Başalan Plateau without permission from the forest administration. It was evaluated that the provisions of Articles 17, 79 and 93 of the Forestry Law No. 6831 were not complied with and the current situation posed a risk of public damage by not calculating the amount of public receivable arising from the unauthorized occupation and use [29]. The main reason for out-of-control point can be based on yhis occupation.

When the MR chart is analyzed, it is also seen that the upper control limit was exceeded in 2016 and 2017 when the occupation happened. Occupation of forestry land is a criminal offense. The penalty for opening, cultivating and settling fields in forest areas is included in Article 93/1 of the Forestry Law. Therefore, those who commit the prohibited acts specified in Article 17 of the Forestry Law are sentenced to imprisonment from 6 months to 2 years [30].

Despite this, forest crimes continue to be committed today. The deterrent effect of punishment decreases due to economic reasons such as livelihood concerns, insufficient land ownership and heating problems. Administrative reasons, the state of forest cadastre and social reasons such as demographic structure, migration, settlement status, and cultural structure are the reasons that push people to open and occupy areas.

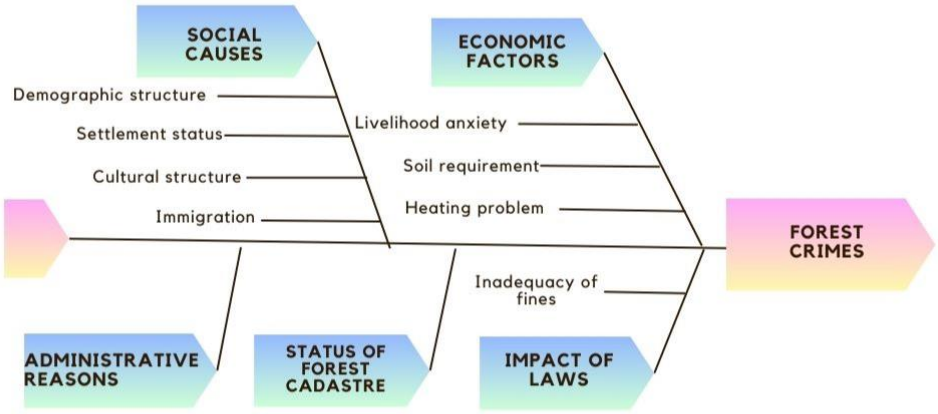

Figure 9: Fishbone Diagram for Forest Crimes

4.4. Statistical Analysis for Global Warming and Climate Change

The fourth reason examined is global warming and climate change for deforestation. To analyze this cause, greenhouse gas emissions in Turkey are analyzed. The data was taken from TurkStat to be examined and analyzed. The graph drawn with the I-MR control chart by looking at 32 years of greenhouse gas data in the atmosphere in Turkey is shown in Figure 10.

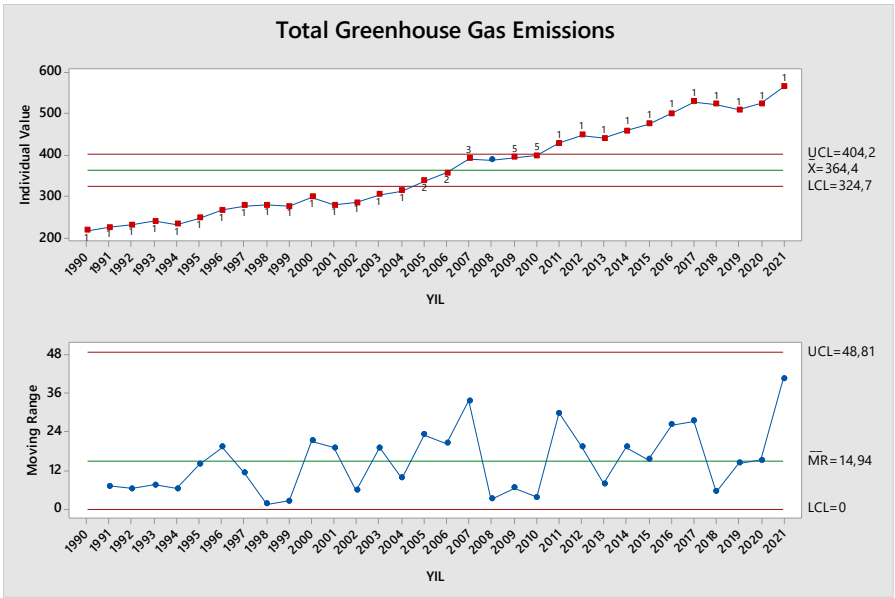

Figure 10: I-MR Control Chart of Total Greenhouse Gas Emissions

When the control charts are analyzed, it can be said that greenhouse gas emissions in Turkey are not under control. According to Turkish Statistical Institute data, Turkey's greenhouse gas emissions increased by 157.1% between 1990 and 2021 [26]. In the 2020-2021 period, with an increase of 7.7

percent, Turkey's greenhouse gas emissions reached 564.4 million tons of carbon dioxide equivalent (CO2). According to experts, the increase in 20 years shows that Turkey has not been able to separate the link between economic growth and greenhouse gas emissions. Figure 11 shows the possible reasons why the points are out of control.

Accordingly, it is said that more assertive steps should be taken towards clean production techniques, energy conversion and electrification. Fossil fuels such as Lignite, Fuel-Oil, Diesel, LPG, Naphtha, Natural Gas, excessive use of hard coal in industry and daily life, heat production and gases released after it, and of course gases released after electricity production increase greenhouse gas emissions in the long term [31].

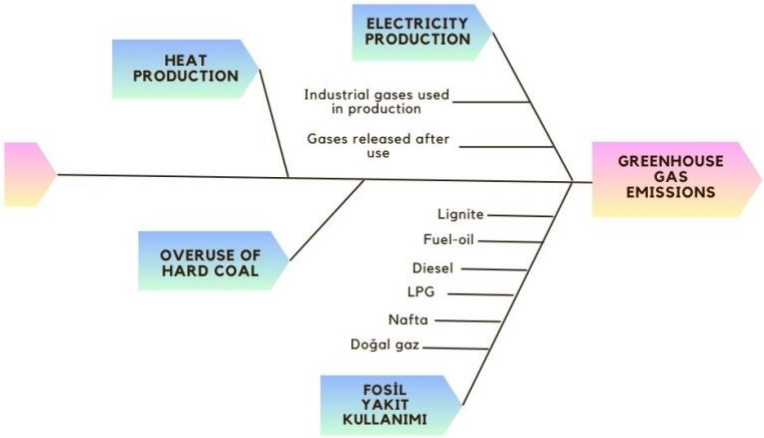

Figure 11: Fishbone Diagram for Greenhouse Gas Emission

According to the MR chart, it is observed that the process variation is high by looking at the change between consecutive observations.

4.5. Statistical Analysis for Urbanization and Overpopulation

The other cause examined is urbanization and overpopulation in Turkey for deforestation. Data from The World Bank was used to examine and analyze of urbanization and overpopulation. Figure 12 shows the I-MR control chart plotted against 37 years of population growth data for Turkey.

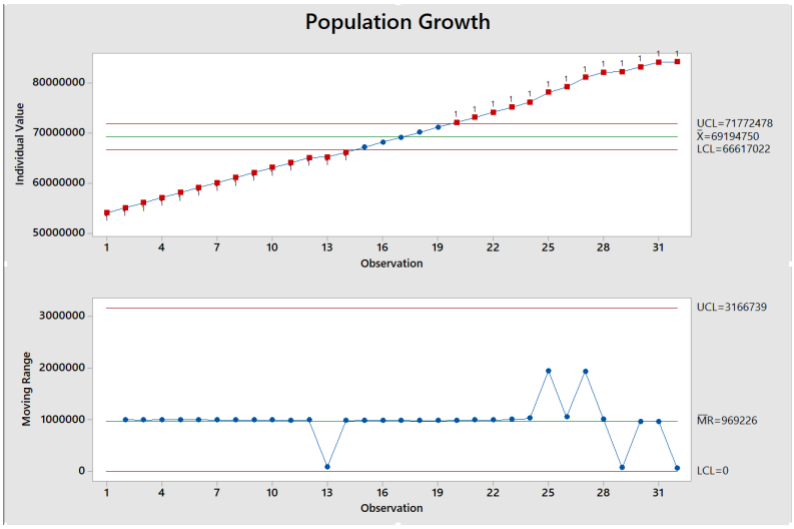

Figure 12: I-MR Control Chart of Population Growth

When the graph is analyzed, it can be said that urbanization due to population growth in Turkey are not under control. Economic growth due to labor supply and labor policies are the main reasons. Domestic and international migration, increase in fertility as a result of the improvement of health care opportunities in parallel with the developing country systems, solutions against infertility, increased survival rate in newborns and children, vaccine and drug treatments, newborn early disease screening, vaccine and drug treatments, increased survival chances in newborns and children explain the increase in population growth [32]. Population growth is oe of the important cause for deforestation in Turkey. Figure 13 shows the possible causes and sub-causes for the population increase.

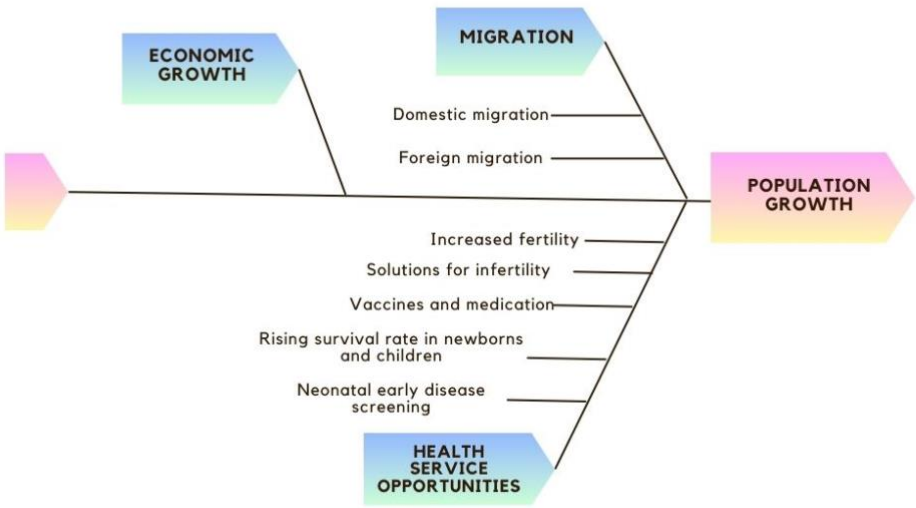

Figure 13: Fishbone Diagram for Population Growth

5. Conclusions and Future Suggestions

Deforestation, a problem that attracts attention and requires intervention today, is a major threat to forests, which contain essential resources for living things. Turkey, with its vast forest cover, is also facing this threat. In this study, the causes of deforestation in Turkey are examined and interpreted by using statistical quality control methods. After analyzing the studies in the literature, there is no research has been found that analyzed the causes of deforestation using the statistical quality control method. The data on the causes of deforestation were first determined, and organized in MS Excel application. Data on forest fires and forest crimes are taken from official reports of the General Directorate of Forestry. Agricultural activity and total greenhouse gas emission data are taken from TurkStat reports. Population growth data are from The World Bank. The data were transferred to the Minitab package program and the most appropriate control chart I-MR (Individual -Moving Range) control chart for the data was drawn. The analysis was explored in Minitab not only for out-of-control points but also for special cases called Nelson's Rules. As a result of the control charts drawn, control limits were examined, out-of-control points were identified and causes related to the deforestation were investigated. Some policies were proposed for out-of-control points and situations by conducting cause investigations.

As a result of this study, the effects of agricultural activities, forest fires, forest crimes, global warming and climate change, urbanization and overpopulation on deforestation were revealed. Global warming and climate change, urbanization and overpopulation have been found to have a major impact on deforestation. The effects of each cause on deforestation are examined in the paper in detail.

In general, many problems can be eliminated with social awareness and consciousness. Agricultural activities, forest crimes and forest fires are among the causes that can be easily addressed in the short term. It is clear that if society is educated on this issue, measures will be taken automatically. State policies should also support the elimination of the causes. However, not all of these causes are problems that can be prevented by state policies. A global awareness and action for deforestation beyond national borders has become essential.

In the long term, actions against deforestation in Turkey will have positive impacts on the international forest landscape and set an example for other countries. It can be one of the steps taken for global awareness beyond the borders of the country.

In future studies, other possible causes that may affect deforestation can be revealed and these factors can also be examined using statistical methods.

Contribution of Researchers

All researchers have contributed equally to writing this paper.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] "OGM | Anasayfa." [Online]. Available: https://www.ogm.gov.tr/tr. [Accessed: 05-Sep-2024].

[2] D. Tolunay, "Dünyada ve Türkiye'de Ormansızlaşma, Ormancılık Politikaları ve Köylülerin Durumu," 2017.

[3] "Status of the World's Soil Resources: Main Report," 2015.

[4] J. Podur, D. L. Martell, and K. Knight, "Statistical quality control analysis of forest fire activity in Canada," *https://doi.org/10.1139/x01-183*, vol. 32, no. 2, pp. 195–205, 2011, doi: 10.1139/X01-183.

[5] B. Hennemuth *et al.*, "Statistical methods for the analysis of simulated and observed climate data, applied in projects and institutions dealing with climate change impact and adaptation," 2012.

[6] H. B. Günşen and E. Atmiş, "Analysis of forest change and deforestation in Turkey," *Int. For. Rev.*, vol. 21, no. 2, pp. 182–194, May 2019, doi: 10.1505/146554819826606577.

[7] B. Devecioğlu, A. Tolunay, and M. Özmış, "ORMANSIZLAŞMANIN ÖNLENMESİNE YÖNELİK GÖRÜŞLERİN BELİRLENMESİ: ISPARTA İLİ ÖRNEĞİ," *Turkish J. For. Sci.*, vol. 3, no. 2, pp. 115–128, Oct. 2019, doi: 10.32328/TURKJFORSCI.571026.

[8] S. Rehana and P. P. Mujumdar, "Climate change induced risk in water quality control problems," *J. Hydrol.*, vol. 444–445, pp. 63–77, Jun. 2012, doi: 10.1016/J.JHYDROL.2012.03.042.

[9] Y. Kuvan, "Mass Tourism Development and Deforestation in Turkey," *Anatolia*, vol. 21, no. 1, pp. 155–168, 2010, doi: 10.1080/13032917.2010.9687096.

[10] H. E. Ünal, Ü. Birben, and F. Bolat, "Rural population mobility, deforestation, and urbanization: case of Turkey," *Environ. Monit. Assess.*, vol. 191, no. 1, pp. 1–12, Jan. 2019, doi: 10.1007/S10661-018-7149-6/TABLES/9.

[11] Ü. Akkemik *et al.*, "The archaeology of deforestation in south coastal Turkey," *Int. J. Sustain. Dev. World Ecol.*, vol. 19, no. 5, pp. 395–405, Oct. 2012, doi: 10.1080/13504509.2012.684363.

[12] C. Telkenaroglu and M. Dikmen, "DEFORESTATION DUE to URBANIZATION: A CASE STUDY for TRABZON, TURKEY," *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci.*, vol. 4, no. 4W4, pp. 379–382, Nov. 2017, doi: 10.5194/ISPRS-ANNALS-IV-4-W4-379-2017.

[13] A. Sabuncu, "Monitoring Deforestation by Multitemporal Data Using Remote Sensing Technologies: A Case Study of Sinop-Turkey," *Fresenius Environ. Bull.*, 2020.

[14] A. Aydin CoŞkun and G. Gençay, "Kyoto Protocol and 'deforestation': A legal analysis on Turkish environment and forest legislation," *For. Policy Econ.*, vol. 13, no. 5, pp. 366–377, Jun. 2011, doi: 10.1016/J.FORPOL.2011.03.013.

[15] A. Colak, S. Kırca, I. Rotherham, and A. Ince, "Restoration and Rehabilitation of Deforested and Degraded Forest Landscapes in Turkey.," p. 566, 2010.

[16] C. Gülser, İ. Ekberli, and F. Gülser, "Effects of deforestation on soil properties and organic carbon stock of a hillslope position land in Black Sea Region of Turkey," *Eurasian J. Soil Sci.*, vol. 10, no. 4, pp. 278–284, Oct. 2021, doi: 10.18393/EJSS.942488.

[17] M. A. Zambrano-Monserrate, C. Carvajal-Lara, R. Urgilés-Sanchez, and M. A. Ruano, "Deforestation as an indicator of environmental degradation: Analysis of five European countries," *Ecol. Indic.*, vol. 90, pp. 1–8, Jul. 2018, doi: 10.1016/J.ECOLIND.2018.02.049.

[18] M. D. Avşar, "K.Maraş-Elbistan Yöresinde Ormansızlaşma, Getirdiği Problemler ve Çözüm Önerileri," *KSÜ Fen ve Mühendislik Derg.*, Jan. 1997.

[19] E. Malkoç and E. Nurlu, "ORMAN PEYZAJINDA REDD EĞİLİM MODELLEMESİ: BOZDAĞ ÖRNEĞİ," in *6. UZAKTAN ALGILAMA-CBS SEMPOZYUMU*, 2016.

[20] O. Gümüşçü, A. Uğur, and T. Aygören, "Deforestation in Sixteenth Century Anatolia: The Case of Hüdavendigar (Bursa) Sancak," *BELLETEN*, vol. 78, no. 281, pp. 167–200, Apr. 2014, doi: 10.37879/BELLETEN.2014.167.

[21] A. V. Feigenbaum, *Total Quality Control*. New York: McGraw-Hill, 1991.

[22] Z. B. A. Aydın and V. S. A. Kargı, "İSTATİSTİKSEL KALİTE KONTROL TEKNİKLERİ İLE OTOMOTİV SEKTÖRÜNDE BİR UYGULAMA," *Yönetim ve Ekon. Araştırmaları Derg.*, vol. 16, no. 1, pp. 41–63, Mar. 2018, doi: 10.11611/YEAD.332129.

[23] D. C. Montgomery, "Statistical quality control: a modern introduction," *Stat. Qual. Control*, p. 380, 2013.

[24] W. A. Shewhart, "Quality Control Charts," *Bell Syst. Tech. J.*, vol. 5, no. 4, pp. 593–603, Oct. 1926, doi: 10.1002/j.1538-7305.1926.tb00125.x.

[25] L. S. Nelson, "SHEWHART CONTROL CHART - TESTS FOR SPECIAL CAUSES.," *J. Qual. Technol.*, vol. 16, no. 4, pp. 237–239, 1984, doi: 10.1080/00224065.1984.11978921/ASSET//CMS/ASSET/ADFFBA2F-2BD3-4F76-843D-DE0E4E9F451E/00224065.1984.11978921.FP.PNG.

[26] "Turkish Statistical Institute," 2014. [Online]. Available: http://www.tuik.gov.tr/Start.do. [Accessed: 14-Dec-2018].

[27] Z. KARAKAYACI, "Tarım Arazilerinin Dışı Kullanımının Sürdürülebilir Kalkınma Açısından Değerlendirilmesi," *Ziraat Mühendisliği*, no. 355, pp. 48–53, Jul. 2010.

[28] F. Erdemli, "2023 Yılı Orman Yangınları," 2023.

[29] "Sayıştay Denetim Raporu," 2022.

[30] N. Kahyaoğlu, E. Güvendi, and M. H. Ertuğrul, "Türkiye'deki Orman Suçlarının Değerlendirilmesi," *Bayburt Üniversitesi Fen Bilim. Derg.*, vol. 5, no. 1, pp. 115–123, Jun. 2022, doi: 10.55117/BUFBD.1025434.

[31] "İklim krizi: Türkiye'nin sera gazı salımları neden artıyor, tehlikeli F-gazları niçin kullanılıyor? - BBC News Türkçe."

[Online]. Available: https://www.bbc.com/turkce/articles/cjkyzkvxvg1o. [Accessed: 05-Sep-2024].

[32] R. Kasarcı, "Türkiye'de Nüfus Gelişimi," *Türkiye Coğrafyası Araştırma ve Uygul. Merk. Derg.*, 1993.