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Temporal Analysis of Riparian Buffer Zones and Demographic Trends in the Coastal Districts of Kastamonu

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Abstract

Aim of study: This study investigates the temporal changes of forest areas within and outside the Riparian Buffer Zones (RBZs) and examines their correlation with demographic trends in the coastal districts of Kastamonu from 1987, 2000, and 2016 to assess how population dynamics influence forest cover.

Area of study: The study was conducted in four coastal districts in northern Kastamonu province, Türkiye, covering approximately 1000 square kilometers and focusing on 153 forest villages.

Material and methods: Geographic Information Systems and remote sensing data delineated and analyzed land cover and population changes. The study used Landsat imagery and population data to explore spatial and temporal dynamics within the RBZs

Main results: The study found a significant increase in forest area from 1987 to 2000 and a subsequent decrease from 2000 to 2016, with these changes showing a weak but significant negative correlation with the declining local population.

Research highlihts: The findings suggest that declining rural populations may reduce anthropogenic pressures on forests and pose challenges to effective forest management and conservation. The research highlights the need for sustainable strategies integrating demographic change with forest conservation efforts to maintain ecosystem services and biodiversity.

Keywords: Riparian Zones, Forest Cover Change, Population Shift, Image Processing, Landsat

Kastamonu'nun Kıyı Bölgelerinde Riparian Zonların Zamansal Analizi ve Demografik Eğilimler

Öz

Çalışmanın amacı: Bu çalışma, 1987, 2000 ve 2016 yılları arasında Kastamonu ilinin kıyı bölgelerinin riparian zonların içinde ve dışında kalan orman alanlarında meydana gelen zamana bağlı değişimleri ve demografik etmenler ile ilgili olan ilişkilerini inceleyerek nüfus dinamiklerinin orman örtüsü üzerindeki etkisini değerlendirmeyi amaçlamaktadır.

Çalışma alanı: Araştırma, Kastamonu ilinin kuzeyinde yaklaşık 1000 kilometrekarelik bir alanı kapsayan ve 153 orman köyünü içeren dört kıyı ilçesinde gerçekleştirilmiştir.

Materyal ve yöntem: Çalışmada arazi örtüsü ve nüfus değişikliklerini saptayıp analiz etmek için coğrafi bilgi sistemleri ve uzaktan algılama verileri kullanılmıştır. Riparian zonlar içerisindeki mekânsal ve zamansal dinamikleri araştırmak için de Landsat uydu görüntüleri ve nüfus verileri kullanmıştır.

Temel sonuçlar: Araştırma sonuçları, 1987'den 2000'e kadar ormanlık alanlarda önemli bir artış ve 2000'den 2016'ya kadar takip eden bir azalma olduğunu ortaya çıkarmış ve bu değişimlerin, azalan yerel nüfusla zayıf ancak anlamlı negatif bir korelasyona sahip olduğunu göstermiştir.

Araştırma vurguları: Bulgular, kırsal nüfuslardaki azalmanın ormanlara yönelik antropojenik baskıları azaltabileceğini ve etkili orman yönetimi ve korumasına yönelik bazı zorluklar oluşturabileceğini öne sürmektedir. Araştırma, demografik değişikliklerle orman koruma çabalarını bütünleştiren sürdürülebilir stratejilerin gerekliliğini ve ekosistem hizmetleri ile biyoçeşitliliğin korunmasını vurgulamaktadır.

Anahtar Kelimeler: Riparian Zonlar, Orman Alanı Değişimi, Nüfus Değişimi, Görüntü İşleme, Landsat

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Introduction

Riparian buffer zones (RBZs) play a critical role in maintaining the ecological integrity of various ecosystems. These zones, often characterized by strips of vegetation along watercourses, play a key role in mitigating non-point source pollution from agricultural fields, thereby protecting water quality (Narumalani et al., 1997). They also play an important role in filtering sediments, nutrients, and pesticides, which is essential to protect stream water quality from the effects of surrounding land use activities (Lee et al., 2003; Dosskey et al., 2005). The biotic diversity within riparian areas reflects a highly heterogeneous environment shaped by various processes, such as fluvial disturbance, variable soil and light conditions, and other upland influences (Lee et al., 2004). This highlights the essential role of riparian buffers in maintaining a dynamic and healthy riparian ecosystem.

RBZs are integral to achieving several of the United Nations Sustainable Development Goals (SDGs), particularly Goal 6 (clean water and sanitation), Goal 13 (climate action), and Goal 15 (life on land) (Hák et al., 2016). RBZs contribute to clean water and sanitation by filtering pollutants and sediments and maintaining water quality, which aligns with SDG 6 (Lee et al., 2003). Their role in providing habitat connectivity and creating thermal shelter for wildlife supports SDG 15 by promoting life on land through biodiversity conservation (Davies & Nelson, 1994; Albertson et al., 2018). In addition, their resilience and adaptability to climate change underscore their importance in SDG 13, providing a natural solution to climate adaptation challenges. As climate change continues to impact natural resource management, the conservation and restoration of RBZs will become increasingly important. Not only do these areas maintain ecological balance, but they also play a pivotal role in mitigating the impacts of climate change, which requires a place-based understanding of their role in ecological systems (Seavy et al., 2009).

As mentioned above, global population growth is increasing pressure on environmental sources and areas (Khan et al., 2021), like riparian zones, which are vital for ecological balance and biodiversity. As populations grow, these areas are increasingly threatened by urbanization, agriculture, and industrial activities, leading to habitat degradation and loss of ecosystem services (Öztürk & Özdemir, 2013). These escalating impacts underscore the urgent need for sustainable management and conservation strategies to protect these critical environments.

Geographic Information Systems (GIS) and remote sensing technologies have become important tools for managing and protecting RBZs. These tools allow the assessment of riparian vegetation, stream conditions, and macrophyte biomass over large areas, overcoming the limitations of time-consuming field-based monitoring (Pace et al., 2022). For example, remotely sensed metrics such as riparian forest buffer width and vegetation density have proven effective in correlating with riparian vegetation quality and water quality indicators (Akturk et al., 2020; Huylenbroeck et al., 2020; Eishoeei et al., 2022; Akturk et al., 2024). In addition, recent advances in GIS-based planning have led to the development of variable-width buffer zones that are more effective in protecting riparian biodiversity and stream ecosystems than fixed-width approaches. Studies using depth-to-water (DTW) indices have shown that such variable-width buffer zones not only improve biodiversity protection but also prove to be more cost-effective when normalized by area (Mykrä et al., 2023). These technologies thus offer a promising way to accurately delineate and effectively manage RBZs, which are essential for conserving riparian ecosystems and their functions.

This study was conducted in 153 forest villages along the coastal strip of Kastamonu province, specifically in Inebolu, Abana, Bozkurt, and Catalzeytin districts. The scope of the paper was to examine the forest assets and their temporal changes in these forest villages and RBZs for the years 1987, 2000, and 2016. In addition, this investigation extended to the demographic data corresponding to these villages for the relevant years. The primary objective of this study is to investigate the potential impact of population data, a fundamental variable that could cause temporal changes in forest assets, on forest cover. This effort aligns with a growing body of research emphasizing the importance of demographic trends in influencing environmental resources and, by extension, the health and sustainability of RBZs.

Material and Method

Study Area

The study area encompasses four coastal districts within the northern part of Kastamonu province: Inebolu, Abana, Bozkurt, and Catalzeytin, collectively covering an approximate area of 1,000 square kilometers (Figure 1). Within these districts, 186 villages were identified as potential study sites. However, this study focuses on 154 of these villages due to the availability of demographic information, which is crucial for understanding population dynamics and their impact on riparian zones.

The region predominantly experiences a typical Black Sea climate; however, variations are notable, especially during spring, due to frequent fog, which slightly deviates from conventional Black Sea weather patterns. The winters are mild and rainy, while summers are warm but not arid (Keser, 2013). The terrain elevates from sea level up to 2000 meters, predominantly along the slopes of the Küre Mountains, characterized by steep and elevated terrains. Urbanization is primarily concentrated in lower altitudes near sea level, with the degree of slope and Türkiye's position as one of the rainy regions contributing to the area's susceptibility to flood disasters (Bilgen et al., 2022; Altunel & Kara, 2023). One of the fundamental reasons for the area's vulnerability to flooding is the modification of stream paths by human-made constructions and the degradation of riparian zones. The topographic nature of the region hosts numerous stream channels, and determining their status and, if necessary, conducting restoration work is vital.

Consequently, this makes the study area a critical zone for analysis and interventions related to flood management and ecological conservation. This region's unique climatic and topographical characteristics necessitate a comprehensive assessment of its RBZs, particularly in light of the increasing pressures from population growth, urbanization, and climate change. Understanding and mitigating the impacts of human alterations and natural factors on these sensitive areas are crucial for sustainable management and protection of the local ecosystem.

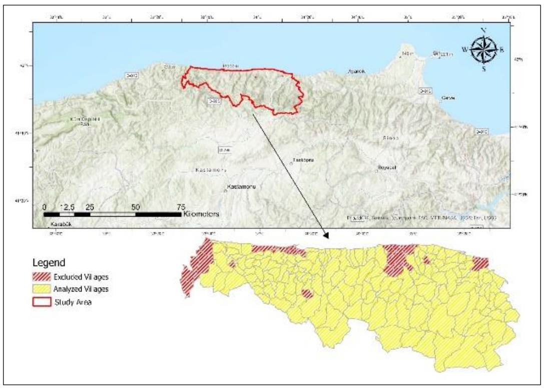

Figure 1. Study area, location, and selected villages

Datasets and Stream Delineation

The primary objective of this study is the temporal analysis of RBZs and the examination of their correlation with demographic changes. This necessitates the delineation of streams within the study area and the subsequent creation of various temporal land cover maps. Procuring the study area's Digital Elevation Model (DEM) data is essential to stream delineation. The Shuttle Radar Topography Mission (SRTM) Global DEM, with a spatial resolution of 30 meters and sourced from the United States Geological Survey's (USGS) Earth Explorer platform (EROS, 2018), has been utilized for this study. The acquired DEM was clipped and subjected to cut-and-fill analyses within the study boundaries to minimize dataset errors. The 'Hydrology' tools within ArcMap 10.8 software facilitated the stream delineation, revealing the main tributaries across the study area (Figure 2). As a result of the hydrology analysis, it was determined that the length of the streams in the region was approximately 670 kilometers.

Determining the width of the RBZs is critical following the delineation of the primary tributaries. RBZ widths can be influenced by factors such as vegetative cover, plant ages, diversity, and soil characteristics, and can be more effective and adaptable to local ecological conditions and management practices (Xiang, 1993; Blinn & Kilgore, 2001; Anderson & Lockaby, 2011). Despite that, Türkiye has no specific guidelines regarding the appropriate width of RBZs. In contrast, countries like the United States have established Best Management Practices (BMP) guidelines for RBZ conservation (Liu et al., 2017; Akturk et al., 2020). Using strategic management options, BMPs are practical methods to reduce both point and non-point source pollutants to manageable levels. According to South Carolina's BMPs, the width of RBZs is correlated with land slope. As the slope increases, so does the width of the RBZs, with a maximum width for each side reaching up to 48 meters. However, this research intends to use an auxiliary land cover dataset whose spatial resolution directly affects the width size of RBZs. This research was planned to generate land cover maps using processed Landsat satellite imagery. Given the 30-meter spatial resolution of Landsat images, it has been decided to establish RBZs with a total width of 120 meters, incorporating 60 meters (two pixels) on each side of the stream.

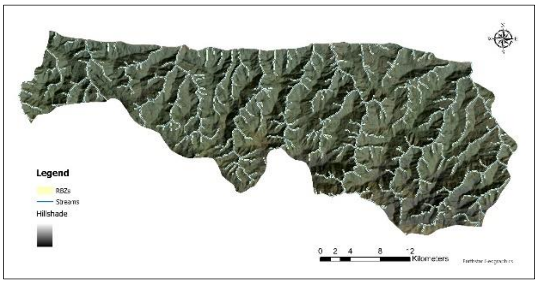

Figure 2. Stream channels and RBZs around them in the study area

The assessment of RBZ conditions and their temporal transformations necessitates the production of land cover maps. This study has utilized Landsat satellite imagery, accessible at no cost since 2008, to produce these maps. Satellite images from three distinct periods were selected to illuminate the temporal dynamics. Relatively up-to-date land cover map was produced using the Landsat 8 satellite image, while historical land cover maps were generated using Landsat 4 and 5 images. Images from Landsat 7 were not preferred due to scan line errors.

In the processing of satellite imagery, rigorous criteria were adhered to. Selections were primarily from June, July, and August, months characterized by robust vegetation presence, thus enhancing satellite detection efficacy. From the image repository, those exhibiting minimal cloud cover, fog, and atmospheric interference were prioritized. Furthermore, selections were constrained to those where 'Land Cloud Cover' and 'Image Cloudiness' were below a 10% threshold. Preference was given to geometrically corrected 'Landsat Level-1 TP (Terrain Corrected)' products for their accuracy and reliability. Conforming to these specifications, images from July 17, 2016, July 5, 2000, and July 2, 1987, were chosen for comprehensive analysis.

The initiation of image processing was preceded by a meticulous classification of land cover types, a pivotal step in ensuring alignment with the study's primary objectives. This study delineated the landscape into five principal classes: forests, agricultural lands, pastures, sparsely vegetated areas, and wetlands. This land cover classification scheme, which distinguishes between classes based on variations in spectral reflectance, has been intentionally simplified into two classes to separate forest and non-forest fields to reduce potential errors due to class size. For the purposes of this study, the scheme was condensed to include only two land cover classes, improving the accuracy and manageability of the classification process.

This study used various methods and algorithms to classify images, exploring pixel and object-based image processing techniques. The algorithms used included Support Vector Machine (SVM), Maximum Likelihood (ML), and Decision Trees (DT), which were specifically applied to the Landsat image acquired in 2016. The effectiveness of these methods was evaluated by examining the results obtained at 300 randomly distributed test points within the study area using the Collect Earth product validation methodology (Akturk et al., 2023). The evaluation showed that the land cover map generated by pixel-based classification combined with the DT algorithm had the highest kappa value (kappa = 0.849). Consequently, this combination of pixel-based classification and the DT algorithm was preferred for image-processing tasks in subsequent years. The criteria for algorithm selection and the rationale for prioritizing specific methods were based on their robustness and accuracy in representing land cover variations.

The demographic data related to temporal forest cover changes were accessed through the website of the Turkish Statistical Institute (URL-1). In Türkiye, general population censuses were conducted every five years before 2000. Due to the availability of appropriate Landsat 4-5 satellite imagery from 1987, the population data for 1985 was used in this study as it is the closest available dataset that meets the criteria. For the 2000 and 2016 imagery, there were no problems accessing the corresponding population data.

Statistical Analysis

In this study, due to the non-normal distribution of the data, Spearman's rank correlation analysis, a non-parametric measure of statistical dependence, was used to determine the relationship between forest cover and population variables. This analysis determines the dependence between two variables (Spearman, 1987). In addition, the Friedman test was used to determine if there was a statistically significant difference between the forested areas inside and outside the RBZs over the years. The Friedman test is a non-parametric equivalent of a two-way analysis of variance used to detect statistically significant differences across multiple test trials within a group (Friedman, 1937). In cases where this analysis indicated a statistically significant difference, the Wilcoxon signed-rank test was used to determine which group or groups contributed to the difference (Wilcoxon, 1992). This approach provides a robust framework for analyzing temporal changes in forest cover and demographic trends, ensuring the validity of the results despite the challenges posed by non-normally distributed data.

Results

The study analyzed the changes in forest areas inside and outside the RBZs in 154 forest villages in Inebolu, Abana, Bozkurt, and Catalzeytin districts and examined their correlation with population changes. First, the Friedman test was used to determine whether statistically significant differences existed between the forest areas inside and outside the RBZs over the years. The results of the Friedman test indicated that at least one year was significantly different from the others ($p < 0.05$). The Wilcoxon signed-rank test was then used to identify which specific years differed. According to this test, the forest areas inside and outside the RBZs in 1987, 2000, and 2016 showed significant differences ($p < 0.05$) (Table 1).

Table 1. The Wilcoxon signed-rank test results for forest areas inside and outside RBZs over the years

Forest Area (ha)		2000-1987	2016-2000	2016-1987
Outside RBZs	Z	-10.730[b]	-2.259[c]	-8.536[b]
	Asymp. Sig. (2-tailed)	0.001	0.024	0.001
Inside RBZs	Z	-10.323[b]	-6.407[b]	-4.596[c]
	Asymp. Sig. (2-tailed)	0.001	0.001	0.001

The results presented illustrate the temporal dynamics between forest areas within and outside the RBZs, highlighting significant differences between years. Detailed numerical values provided in the supplementary files illustrate these trends: From 1987 to 2000, forest areas increased significantly. However, between 2000 and 2016, a subsequent decline in forest cover was observed. Specifically, the forest area outside the RBZs increased from 47.142 hectares in 1987 to 56.225 hectares in 2000. This expansion was followed by a decline to 54.906 hectares in 2016. Similarly, the forest area inside the RBZs increased from 3.493 hectares in 1987 to 4.534 hectares in 2000 before decreasing to 4.140 hectares in 2016. These changes highlight the fluctuations in forest cover over the years, influenced by different conservation practices and possibly demographic pressures. Statistical analysis was conducted to determine whether there were significant differences in forest areas inside and outside the RBZs in three different periods: 1987-2000, 2000-2016, and 1987-2016. The Friedman test indicated significant differences between at least one period compared to the others ($p < 0.05$). The Wilcoxon signed-rank test was then used to identify which specific periods differed. The results showed that the forest areas inside and outside the RBZs differed significantly in all three periods in the villages within the study area ($p < 0.05$).

Table 2. Wilcoxon signed-rank test results for forest areas inside and outside RBZs across different periods

Forest Area (ha)		2000-1987 between 2016-2000	2000-1987 between 2016-1987	2016-1987 between 2016-2000
Outside RBZs	Z	-10.064[b]	-2.259[b]	-10.730[c]
	Asymp. Sig. (2-tailed)	0.001	0.024	0.001
Inside RBZs	Z	-9.931[b]	-4.596[b]	-10.323[c]
	Asymp. Sig. (2-tailed)	0.001	0.001	0.001

From 1987 to 2000, forest cover was increased in areas outside the RBZs, amounting to 9.083 hectares. However, between 2000 and 2016, a decrease of 1.319 hectares was observed in these areas. Over the entire period from 1987 to 2016, forests outside the RBZs experienced a total increase of 7.763 hectares. Similarly, within the RBZs, forest cover increased by 1.040 hectares from 1987 to 2000, followed by a decrease of 393 hectares from 2000 to 2016. From 1987 to 2016, forest cover within the RBZs showed a cumulative increase of 646 hectares. These data highlight the dynamic changes in forest cover over time inside and outside the designated riparian zones.

The statistical analysis of the population numbers in the villages within the study area over the years was also conducted using the Friedman test. The results indicated a statistically significant difference between at least one year and another ($p < 0.05$). To further determine which specific years were different, the Wilcoxon Signed Rank Test was used. The results of this test are shown in Table 3. This analysis helps to understand how demographic changes correlate with observed environmental changes within the study area.

Table 3. Wilcoxon signed-rank test results for population different periods

Population	2000-1985	2016-2000	2016-1985
Z	-10.170	-8.094	-10.260
Asymp. Sig. (2-tailed)	0.001	0.001	0.001

According to Table 3, the population of the villages for the years 1987, 2000, and 2016 are statistically different from each other ($p < 0.05$). In 1987, the total population of the 153 villages was 43.983 which decreased significantly to 25.025 in 2000 and further to 19.405 in 2016. This represents a decline in population of approximately 56% over the period from 1987 to 2016.

Further analysis using the Friedman test was conducted to determine if there were statistically significant differences between these periods in the population counts of the villages within the study area. The results of the Friedman test confirmed that at least one period was significantly different from the others ($p < 0.05$). The Wilcoxon signed-rank test was then used to determine which specific periods showed differences. The results of this test are shown in Table 4. This step helps to delineate better population trends and their potential impacts on the surrounding environment and riparian zones.

Table 4. Wilcoxon signed-rank test results for population difference different periods

Population Difference	2016-2000 between 2000-1985	2016-1985 between 2000-1985	2016-1985 between 2016-2000
Z	-7.757^{b}	-8.094^{c}	-10.170^{c}
Asymp. Sig. (2-tailed)	0.001	0.001	0.001

According to Table 4, the statistical analysis confirmed that the population differences between all periods in the villages are significantly different from each other ($p < 0.05$).

In the villages within the study area, population changes in three periods - 1987-2000, 2000-2016, and 1987-2016 - were analyzed regarding changes in forest areas within and outside the RBZs. Because the data did not meet the conditions for parametric tests, Spearman's rank correlation analysis was used to examine these relationships. The results of this analysis are detailed in Table 5 and provide insight into the correlations between demographic shifts and changes in forest area, highlighting the impact of human activities and demographic dynamics on forest conservation within and surrounding RBZs.

Table 5. Spearman's rank correlation analysis

			Population Difference from 1987-2000	Population Difference from 2000-2016	Population Difference from 1987-2016
Spearman's rho	Forest Cover Change Outside RBZ from 1987 to 2000 (ha)	Correlation Coefficient	-0.334**	-0.034	-0.340**
		Sig. (2-tailed)	0.001	0.680	0.001
		N	153	153	153
	Forest Cover Change Outside RBZ from 2000 to 2016 (ha)	Correlation Coefficient	-0.151	0.039	-0.092
		Sig. (2-tailed)	0.063	0.633	0.257
		N	153	153	153
	Forest Cover Change Outside RBZ from 1987 to 2016 (ha)	Correlation Coefficient	-0.315**	0.015	-0.261**
		Sig. (2-tailed)	0.001	0.856	0.001
		N	153	153	153
	Forest Cover Change inside RBZ from 1987 to 2000 (ha)	Correlation Coefficient	-0.353**	-0.051	-0.361**
		Sig. (2-tailed)	0.001	0.533	0.001
		N	153	153	153
	Forest Cover Change inside RBZ from 2000 to 2016 (ha)	Correlation Coefficient	0.057	-0.061	0.064
		Sig. (2-tailed)	0.485	0.456	0.430
		N	153	153	153
	Forest Cover Change inside RBZ from 1987 to 2016 (ha)	Correlation Coefficient	-0.228**	-0.122	-0.244**
		Sig. (2-tailed)	0.005	0.133	0.002
		N	153	153	153

** Correlation is significant at the 0.01 level.

Table 5 shows a statistically significant but weak negative correlation of -0.261 between the change in forest areas outside the RBZs and the population difference from 1987 to 2016 within the village boundaries ($p<0.01$). In addition, a similarly weak negative correlation of -0.244 was found between the change in forest area within the RBZs and the population difference over the same period. These results suggest that the impact of population on forest cover within RBZs during this period was less than its impact on cover outside RBZs.

During the 13 years from 1987 to 2000, a moderate negative correlation of -0.334 was observed between the change in forest area outside the RBZs and the population difference ($p<0.01$). During the same period, the change in forest cover within the RBZs also showed a moderate negative correlation with the population gap of -0.353. This suggests that from 1987 to 2000, the influence of population on forest areas within the RBZs was more significant than on those outside the zones.

Between 2000 and 2016, no statistically significant correlation was found between population and forest area changes, either inside or outside the RBZs ($p>0.05$). This indicates that during these 16 years, demographic changes did not significantly impact forest cover changes in and around the RBZs.

Discussion

In Türkiye, forest villages are mainly located in rural areas at high altitudes (Alkan & Toksoy, 2008; Alkan, 2014). When examining the population trends in these villages, a remarkable shift in demographic dynamics can be observed over the decades. Historically, the proportion of the rural population in Türkiye was significantly higher than the urban population, with 75.8% of the population living in rural areas in the 1930s. This proportion declined to 65.6 percent in the 1970s, further to 56.1 percent in the early 2000s, and plummeted to 24.5 percent in 2012 (Toksoy & Bayramoglu, 2017). According to 2022 data from the Turkish Statistical Institute (TUİK), only 17.3% of the population now resides in what constitutes 93.5% of Türkiye's geographical area classified as rural (URL-2). Furthermore, studies specific to Kastamonu province (Bulut, 2018; Özden & Buğday, 2015; Guloğlu et al., 2021) have shown a consistent decline in the population of forest villages from the 1970s to 2016. In this study, an analysis of the population of 153 villages in Kastamonu from 1987 to 2016 found a significant decline of 56%, reflecting the national trend of rural depopulation in Türkiye. These findings highlight rural-urban migration patterns, which reflect broader socioeconomic changes with significant implications for land use and conservation strategies in these regions.

This migration from rural to urban areas is a critical factor to consider in understanding changes in forest cover and the effectiveness of RBZs. Forest management and conservation face new challenges as rural populations decline, presumably in search of better economic opportunities in urban areas. Depopulation may reduce direct human pressures such as agriculture or logging in these areas. However, it could also lead to a reduction in local stewardship of these lands, potentially increasing the vulnerability of these ecosystems to unregulated use or neglect (Williamson, 1988). Thus, while demographic shifts may initially benefit forest conservation, they could undermine long-term sustainability without appropriate policies and management practices considering the changing human landscape.

The study found that forest areas within the RBZs increased from 1987 to 2016. A similar trend was observed for forest areas outside the RBZs. The total forest area in the forest villages increased from 50.635 hectares to 59.046 hectares. From 1987 to 2016, a statistically significant but weak negative correlation (0.244) was found between population and forest areas within the RBZs. As the population decreased, the forest area within the RBZs increased. This trend is also observed for forest areas outside the RBZs, with a correlation of -0.261. These results suggest that the pressure exerted by the population on the forest areas inside and outside the RBZs is quite similar.

The relationship between forest cover and population shown by these correlations mirrors the findings of other studies, such as those by (Bayramoğlu & Kadıoğulları, 2018; Guloglu et al., 2021). This consistency across studies suggests a broader pattern in which demographic changes are closely linked to changes in forest cover. The observed decline in population, especially in rural areas, is likely to reduce direct human impacts on these forests, such as clearing for agriculture or collecting fuelwood. However, it also means that fewer people are available to manage and protect these natural resources, which could pose different risks to forest sustainability.

As the total population in Türkiye increases, so does the area of forests. However, it is believed that this increase is primarily due to the decrease in the rural population and the subsequent reforestation of abandoned agricultural lands, as suggested by previously discussed studies. The decrease in population correlates with reduced pressure on forests, a conclusion supported by the results of this and similar studies (Myers, 1990; Mather & Needle, 2000).

According to Article 1 of Forest Law No. 6831, except for the exceptions specified therein, the ownership of areas that have subsequently become forested is considered irrelevant; these areas must be managed and operated as forests. In addition, between 2008 and 2012, as part of Türkiye's Afforestation and Erosion Control Mobilization Action Plan, efforts were made to increase forest cover by planting trees on 210.169 hectares, soil conservation forestry on 315.889 hectares, and special afforestation on 49.385 hectares (URL-3). This suggests that part of the increase in forest cover is also due to these extensive afforestation efforts in Türkiye.

These afforestation initiatives expand forests and enhance ecological resilience and biodiversity conservation. The transformation of abandoned agricultural lands into forested areas, facilitated by natural succession and targeted afforestation efforts, highlights a significant land use shift consistent with environmental sustainability goals. As rural populations decline and migrate to urban centers, the opportunity to reclaim and rehabilitate these lands becomes increasingly viable. This trend presents both a challenge and an opportunity for forest management, requiring strategies that focus on increasing forest cover and maintaining the ecological integrity and functionality of these newly forested ecosystems. This holistic approach to forest management is critical to ensuring that afforestation and natural forest restoration are maximized and contribute positively to biodiversity, carbon sequestration, and overall ecosystem health.

In the last 10-15 years, forest certification has become a prominent issue in Türkiye, significantly as the demands of the forest products industry have escalated, requiring the certification of products derived from forestry activities. Certification bodies greatly emphasize management practices and the extent of forest activities in riparian zones. According to the Forest Stewardship Council (FSC) guidelines it is crucial for certified companies to protect natural waterways, water bodies, riparian areas, and their connections, especially within riparian zones. It also stipulates that actions that negatively affect water quality and quantity should be avoided. The FSC guidelines recommend the establishment of buffer zones of at least 50 feet on both sides of type F and S rivers and emphasize the preservation or restoration of vegetation, avoidance of soil disturbance, maintenance of large dead and living trees for shade, and restriction of road construction except at stream crossings (URL-4).

In this context, the Turkish General Directorate of Forestry adheres to these guidelines through the notification "Technical Principles of Silvicultural Practices," which enforces protection belts of 25-50 meters on either side of small and narrow wet streams and 50-100 meters on either side of large and wide wet streams on slopes and stream banks (URL-5). This Communication also advocates for moderate intervention in these areas according to forest structure, explicitly avoiding actions that would disrupt the forest canopy. In addition, the guideline specifies that mechanical cleaning of the live cover should start on the lower slopes and proceed downwards and that rooting should be ensured. It also states that streams should not be filled with cleared live cover and that approximately 10-15 meter-wide buffer zones along stream banks should remain untouched.

The increase in area within riparian zones observed between 2000 and 2016 can be partially explained by the efforts to align our country's forests with certification standards and the presence of certified forest management units within the Kastamonu Regional Forest Directorate. This alignment underscores a strategic shift in forestry practices towards more sustainable and internationally recognized standards, reflecting a broader commitment to improving forests' ecological integrity and management. The certification contributes to the global credibility of Türkiye's forest products and ensures that environmental protection is prioritized in forestry practices. Such initiatives are critical to maintaining the sustainability of forest ecosystems and optimizing the ecological benefits these areas provide.

Conclusion

This study, conducted in the coastal districts of Kastamonu Province, examined the temporal dynamics of forest areas within and outside the RBZs and their correlation with demographic changes from 1987 to 2016. The results highlighted significant temporal fluctuations in forest cover and correlated these changes with shifts in population density within the area. Forest cover increased from 1987 to 2000 inside and outside the RBZs, then experienced a decline from 2000 to 2016, coinciding with significant demographic declines in the local population, reflecting a broader national trend of rural depopulation.

A key finding of this research is identifying a statistically significant, albeit weak, negative correlation between population decline and changes in forest cover within the RBZs. This study is consistent with previous research suggesting that demographic decline can relieve immediate anthropogenic pressure on forest areas, potentially facilitating the natural recovery of ecosystems previously degraded by human activities. However, the study also notes that this demographic shift could lead to challenges in local governance and sustainable management of these ecosystems.

Future research would benefit from exploring the long-term ecological implications of the observed increase in forest cover within RBZs, particularly with biodiversity, ecosystem services, and climate resilience. Further studies could also assess the effectiveness of current forest management practices under different demographic scenarios and refine strategies for engaging remaining rural populations in sustainable practices. In addition, integrating more detailed socio-economic data could elucidate the direct and indirect impacts of human activities on RBZs, providing a more comprehensive understanding of the interplay between human and natural systems in the region. This holistic approach would strengthen conservation efforts and improve local communities' socio-economic well-being, thus ensuring the sustainability of these critical zones.

Ethics Committee Approval

N/A

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Author Contributions

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Conflict of Interest

The authors have no conflicts of interest to declare.

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