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Land Use/Change and Local Population Movements in Stone Pine Forests: A Case Study of Western Türkiye

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Abstract: One of the important distribution areas of stone pine (*Pinus pinea* L.), a native tree species of the Mediterranean Basin in Türkiye, is the Kozak Basin. Pine nut production plays an important role in the livelihood of the rural people of the Kozak Basin. However, in recent years, as a result of mining activities, climate change, and damage caused by the alien invasive species, the western conifer seed bug (*Leptoglossus occidentalis* Heidemann 1910 (Hemiptera; Coreidae), the decrease in cone and seed yield in the basin has reached significant dimensions. This process has caused the local people's income sources to decrease. In this study, land use and land cover (LULC) changes and population changes in the Kozak Basin were discussed during the process, where changing forest land functions, especially economic effects, triggered vulnerable communities due to various factors such as climate change and insect damage. LULC classes of the Kozak Basin and their changes in three time periods are presented using the maximum likelihood method. In addition, the exponential population growth rates of the local people in three different time periods were calculated and these rates were interpolated in the spatial plane with a Kriging analysis. In conclusion, the responses of vulnerable communities to the cone and seed yield decline in the Kozak Basin are manifested by LULC changes and migration from the basin. Therefore, in the management of *P. pinea* areas, the creation of regulations within the framework of sustainability understanding regardless of ownership difference, stakeholder participatory approach management, close monitoring of ecological events occurring in the basin, awareness of vulnerable communities, and alternative livelihoods can be supported.

Keywords: human–forest interaction; ecosystem services; land use and land cover simulations; pine nuts; rural migration

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1. Introduction

The effects of global economic, social, and political movements, climate change, and the traditional habits of local communities on land use and land cover (LULC) are quite complex. Therefore, it is important to examine LULC changes in terms of the socio-economic and biophysical drivers based on human–nature interactions [1]. The LULC changes, triggered by changes in land functions due to various ecological, economic, and

social reasons, can be explained as a result of interdisciplinary studies [2]. The human–forest relationship based on utilization often causes forests to change in temporal and spatial planes [3–5]. In a process in which the consequences of changes in LULC become apparent at regional and global scales, it is crucial to observe the reasons for the initiation of anthropogenic activities, which are especially effective on forest ecosystems, and the changes that occur. LULC maps, created from satellite images regarding these changes in forest areas, were evaluated using LULC change analyses, and forest–human relations in forest areas were discussed more objectively [6–9]. Thus, projections can be created on both regional (local) and global scales [10–12]. Creating LULC change projections can increase the applicability of plans and policies for forest assets with long management periods.

The general results of forest–human relations can be revealed through LULC change studies on forest land. It is difficult to attribute this to a general hypothesis. The fact that forest ecosystems have different characteristics and that human communities have very different cultural, economic, and social structures further increases the importance of locality in research. For example, ownership of forest lands is an important factor in the LULC changes in forest areas [13–15]. Temporal and spatial changes in forests include the transition from abandoned agricultural land to forest cover [16–18], the suppression of forest areas for social and economic reasons [19,20], and the suppression of forests due to urbanization [17,21]. Although it is known that forest availability tends to decrease worldwide [22], the authors of [6] reported that tree cover increased in the Northern Hemisphere in response to ongoing deforestation in the Southern Hemisphere.

The Mediterranean Basin, an important ecological region of the Northern Hemisphere, has been involved in economic activities throughout history through the influence of its ports. Mediterranean forests are constantly exposed to human intervention and changing environmental conditions [23–26]. The Mediterranean Basin has two distinct characteristics in its northern and southern parts. The forests in the south of the basin are exposed to fires for social, economic, and climatic reasons, and LULC changes occur to the detriment of the forests [27–29]. Abandoned agricultural areas in the northern regions of the Mediterranean Basin are becoming forested [28,30–34]. The fact that the Mediterranean Basin (the south of Europe) is expected to face drought according to climate projections [35] has made ensuring the continuity of forest communities in the Mediterranean Basin even more important.

The use of non-wood products in forests by different communities living in the Mediterranean Basin and their efforts to continue to use them reveal the positive impact of human intervention, apart from its general negative connotation [28,36]. Located mostly in the north of the Mediterranean Basin, stone pine (*Pinus pinea* L.) forests can be described as special areas for the regulation of forest–human relations due to the production of valuable non-wood forest products [37–39]. These areas are also valuable areas where changes in land functions and LULC can be observed.

P. pinea forests have a unique characteristic in Turkish forestry. In general, almost all of forests in Türkiye are public property managed by the state [40]. *P. pinea* forests generally appear as private enterprises in state forests, private forests, and agricultural areas, which can be considered an exception to Turkish forestry. *P. pinea* forms natural and plantation forest communities, especially in western Türkiye. Located in the Bergama district of Izmir province, the Kozak Basin is an important area in Türkiye where the production and trade of *P. pinea* seeds (pine nuts) have continued since ancient times, and forest–human relations have been established beyond the ordinary [38,41–43].

In general, the high market value of pine nuts [37–39] causes the local people to be supportive and tolerant of the protection and development of stone pine forests. Changes in LULC that are in favor of forests were observed due to the economic expectations of the local people regarding the functions of forest lands [44]. However, the low cone–seed yield

recorded in the Mediterranean Basin in recent years [45,46] has started to be experienced in the Kozak Basin as well [38,42,43]. The western conifer seed bug (*Leptoglossus occidentalis* Heidemann 1910 (Hemiptera; Coreidae) [47] causes low productivity in stone pine cones and seeds, which is triggered by the effects of climate change [38,48–50]. While the empty seed rate in Izmir was 23% in 1980, this rate increased to 57% in 2016 [51]. In the Kozak Basin, stone pine communities develop on granite, and the natural environment is damaged during granite stone mining; traces of these activities can be observed extensively in the basin [38,52,53]. With the discovery of new gold reserves in the Kozak Basin, cyanide gold mining has expanded, which threatens the natural environment [54].

As a result of these developments, due to low productivity and income loss, people started to sell *P. pinea* areas to granite stone enterprises, facilities with root resin demand, and people looking for land to settle in rural areas from metropolitan cities, or earned income by cutting down some of their trees [38,42,43,55]. LULC changes can be defined as the response of vulnerable local people living around stone pine forests to changes in forest land functions. This situation can be revealed spatially and temporally through satellite images. Therefore, the subject of this study is the spatiotemporal change in local people and LULC changes in stone pine forests in the Mediterranean Basin.

In this study, we focus on the reaction of local people in the Kozak Basin to a decrease in pine nut production—an important source of income—due to various reasons during the climate change process. The reactions of the local people of the Kozak Basin were evaluated under the headings of LULC changes and migration from rural areas, depending on the change in forest land functions. In this study, we aimed to (1) determine the LULC classification in the study area, (2) explore LULC changes and predict future change, (3) calculate inhabitant changes, and (4) examine changes in LULC and the population in the Kozak Basin on spatial and temporal scales to reveal the associations of these factors with the period when basic livelihood resources began to decline.

2. Materials and Methods

2.1. Study Area

This study was conducted in the Kozak Basin in the Bergama district of Izmir. Kozak is a basin of approximately 29,600 hectares, located between the following coordinates (degrees, minutes, and seconds): latitude 39°14′17″–39°20′15″ N and longitude 26°53′10″–27°13′40″ E (Figure 1). There are 17 villages in the Kozak Basin. The villages that are located at low altitudes are Okçular, Ayvatlar, Demircidere, Aşağıbey, Kaplan, Hisarköy, Göbeller, Bağyüzü, Aşağıcuma, Hacıhamzalar, and Yukarıbey. Yukarıcuma, Güneşli, Çamavlu, Kıranlı, Karaveliler, and Terzihaliller are located at high altitudes of the basin, where stone pine forests are plantation areas [44]. LULC changes from agriculture to forest have occurred in the northern upper regions of the basin due to the attraction of income generation from pine nut production in natural areas. Granite bedrock is found throughout the Kozak Basin, and granite mining is carried out in the villages of Terzihaliller, Okçular, Aşağıcuma, and Hacıhamzalar [53]. In addition, the pastures in the north of the basin are actively used for animal husbandry by the people living in the villages located in the upper part of the basin [55].

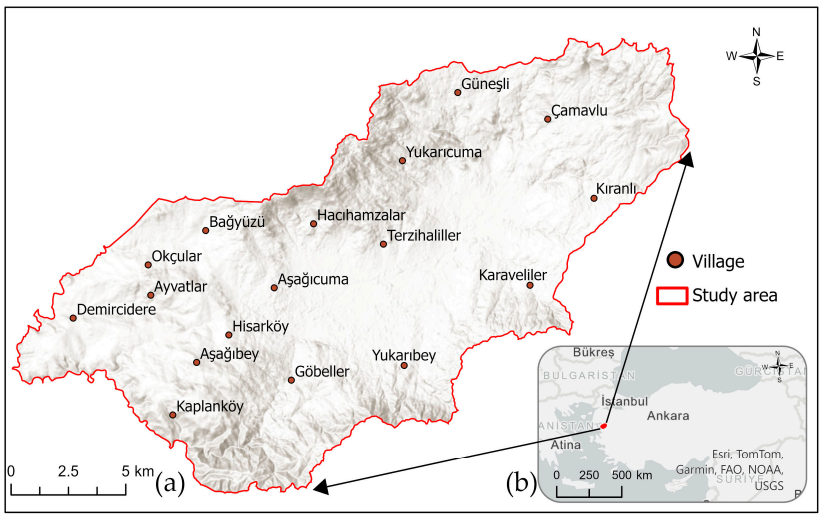


Figure 1. Location of the study area: (**a**) Kozak Basin; (**b**) location of the Kozak Basin in Türkiye.

2.2. Methodological Process of Spatial Data Analysis

Location data of the provincial borders, highways, village roads, forest roads, and village settlements in the study area were obtained from the database of the İzmir Regional Directorate of Forestry, the Bergama Forest District [56]. Population data for the villages in the Kozak Basin from 1965 to 2022 were obtained from the Turkish Statistical Institute [57]. The flow chart of this study consists of three parts: the first part includes the database and the spatial variables; the second part includes the analysis, detection, and verification of LULC and the calculation of LULC changes; and finally, the third part includes modeling of population data for the next 10-year prediction (Figure 2).

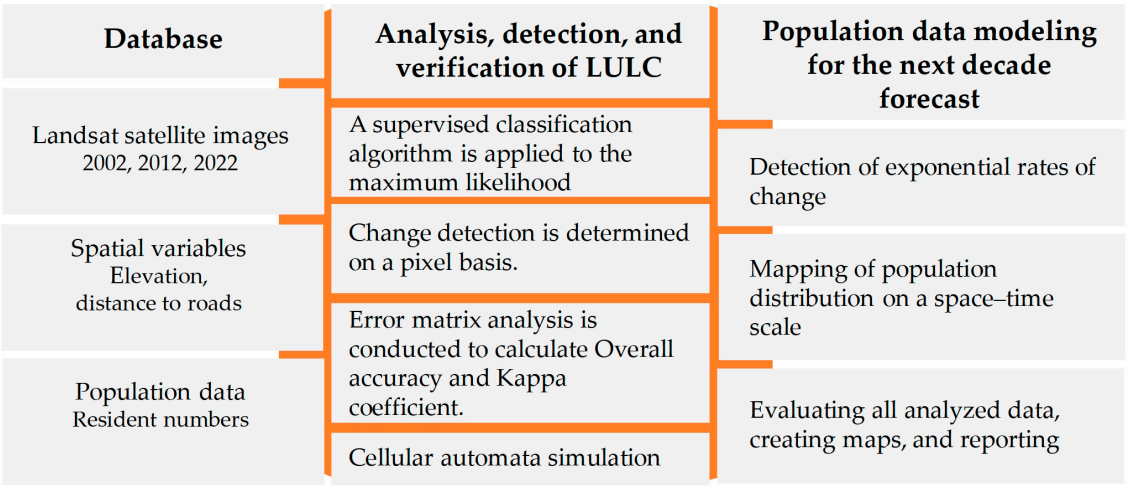


Figure 2. The study flowchart.

2.3. Data Acquirement

In this study, Landsat 7 Enhanced Thematic Mapper Plus (ETM+), dated 15/07/2002 and 10/07/2012, and Landsat 9 Operational Land Imager (OLI) corrected satellite images, dated 22/07/2022, obtained in the same months, were used to make a more accurate comparison of LULC (earthexplorer.usgs.gov online). The path/row value of all satellite images was 181/33. Current satellite images with less than 10% cloudiness and appropriate image quality were preferred. The atmospheric correction was only performed using QGIS 2.18 software. In addition, the digital elevation model (DEM) (a 30 m spatial resolution) was obtained from this website in accordance with the study area boundaries. All GIS data

in this study were based on the WGS 84 (World Geodetic System) reference system and Universal Transverse Mercator coordinates (CM 35N). All raster data used in this study were resampled at a 30 m spatial resolution.

2.4. LULC Classification and Accuracy Assessment

A supervised classification algorithm was applied to the maximum likelihood (ML). The ML algorithm classifies data by calculating the probability of each pixel belonging to different classes, assuming each class follows a Gaussian distribution, and assigns the pixel to the class with the highest probability. A total of 70% of the dataset was employed for training, with the remaining 30% utilized for validation. Error matrix analysis was conducted to calculate the overall accuracy and Kappa coefficient. Kappa serves as a statistical metric for assessing the precision of classifications in LULC change analyses. This index fundamentally evaluates the disparity between observed and expected agreement. The Kappa coefficient ranges from 0 to 1, where a value of 1 indicates perfect agreement, and 0 indicates random agreement. The Kappa value is calculated methodologically by subtracting the expected accuracy from the observed accuracy, thereby yielding a measure of classification reliability. Consequently, Kappa is instrumental in evaluating the dependability of LULC data, and it functions as a critical tool for comparative analyses of classifications across varying temporal or spatial contexts [58,59]. The thematic class definitions for the forest, agriculture, barren, built-up, and water area categories are as follows: Forest area refers to densely forested regions, including deciduous, evergreen, and mixed forests. Barren area includes woodlands with shorter trees and shrubs and is less dense than forests. Agriculture area covers various land uses, including regions where perennial and annual crops are cultivated, as well as irrigated zones, and scattered rural settlements. Built-up area consists of commercial, urban, and rural settlements. Water area includes rivers, streams, and reservoirs (water bodies).

2.5. LULC Change Detection and Future LULC

After completing the classification processes, a change detection technique was applied using a change in the pixel value and image difference. This selected technique was applied to reveal the changes between the periods from 2002 to 2012 and 2012 to 2022. Modules of the Land Use Change Evaluation (MOLUSCE) module in QGIS 2.18 software were used to determine LULC and land classes in the future [60]. First, using this module, the classified LULC data from the two identified study periods (2002 to 2012 and 2012 to 2022) were selected. Then, the spatial variable elevation and distance to road maps were loaded into the system. The statistics of categories and the transition matrix were calculated using the MOLUSCE module [61]. Land elevation is regarded as a pivotal topographic variable influencing LULC changes. Distance to roads, which governs accessibility, constitutes a key determinant of urban expansion. In this study, the prediction of LULC changes was achieved through a two-step process involving artificial neural networks (ANNs) [62] and cellular automata (CA) [63] simulations. Initially, historical LULC data from two distinct time periods were employed to train an ANN using the multilayer perceptron (MLP) method, enabling the model to learn the spatial dynamics of land use transitions. Subsequently, the trained ANN model was utilized to generate a LULC prediction map for the next decade, targeting the year 2032, by incorporating the learned patterns into a CA simulation framework. CA, a computational model based on grid cells with evolving states, was used to predict LULC changes by considering the local interactions and transition rules. To assess the accuracy of the predicted LULC map for 2022, the CA-generated map was compared with the actual observed 2022 LULC data, thereby validating the reliability of the prediction methodology.

2.6. Detection of Population Changes

According to the assumption of exponential population growth in the obtained population data, population growth rates were calculated for the years 1990–2000, 2000–2010, and 2010–2022. In the calculation, the formula exponential population growth rate (r) = (ln(P1/P0))/t was used (P1: population at the end of the period, P0: population at the beginning of the period, and t: time) [64]. The exponential population growth rates obtained for each village for the years 1990–2000, 2000–2010, and 2010–2022 were evaluated on the spatial level. For this purpose, a prediction surface for exponential population growth rates in villages (in the spatial plane) was created using a Kriging analysis, which is one of the geostatistical methods [65]. It was analyzed on a spatial plane using the spatial analysis tools > interpolation > Kriging tool in ArcGIS 10.3. In the Kriging analysis, the ordinary method and the spherical semivariogram model were used as default models, and the Kozak Basin was determined as the processing extent. Village exponential population growth rates were interpolated at the village level in the maps obtained, and the relationship between the population growth rates between villages was revealed.

3. Results

The elevation map was created from the DEM dataset, and the distance to roads dataset was created from the public roads vector dataset using the ArcGIS Multiring Buffer module (Figure 3).

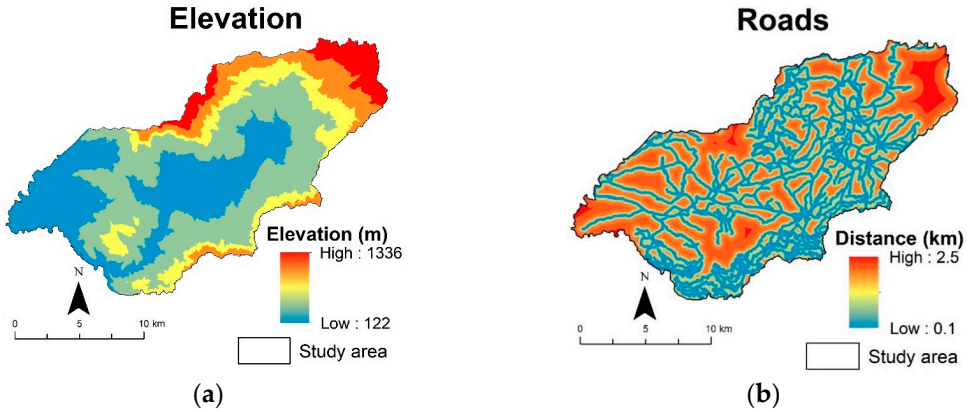


Figure 3. Spatial variables in this study: (**a**) elevation (m) and (**b**) distance to roads (km).

The study area encompasses an elevation range spanning from a minimum of 122 m to a maximum of 1336 m, with the mean elevation calculated at 601.6 m. Furthermore, the distances to roads were classified into the following categories: 0.1 km, 0.5 km, 1 km, and 2.5 km.

3.1. LULC Classification and Accuracy Assessment

LULC maps, including forest, agriculture, barren, built-up, and water area categories, were prepared for the years 2002, 2012, and 2022 (Figure 4), which helped us detect the LULC changes in the Kozak Basin between 2002–2012 and 2012–2022 (Table 1).

When evaluating the current and 20-year LULC of the Kozak Basin, it is evident that the basin is largely covered by forests. The forest areas are followed by barren and agricultural areas, respectively (Table 1).

The most significant change over the 20-year period occurred in forest areas. While forest areas have decreased by 6.67%, water bodies have remained relatively unchanged (0.03%), and other LULCs have increased. The most substantial increase has been observed in agricultural land. Considering the 20-year period, a significant portion of the change

occurred between 2002 and 2012, characterized by a 5.43% decrease in forested areas and a 3.26% increase in agricultural lands.

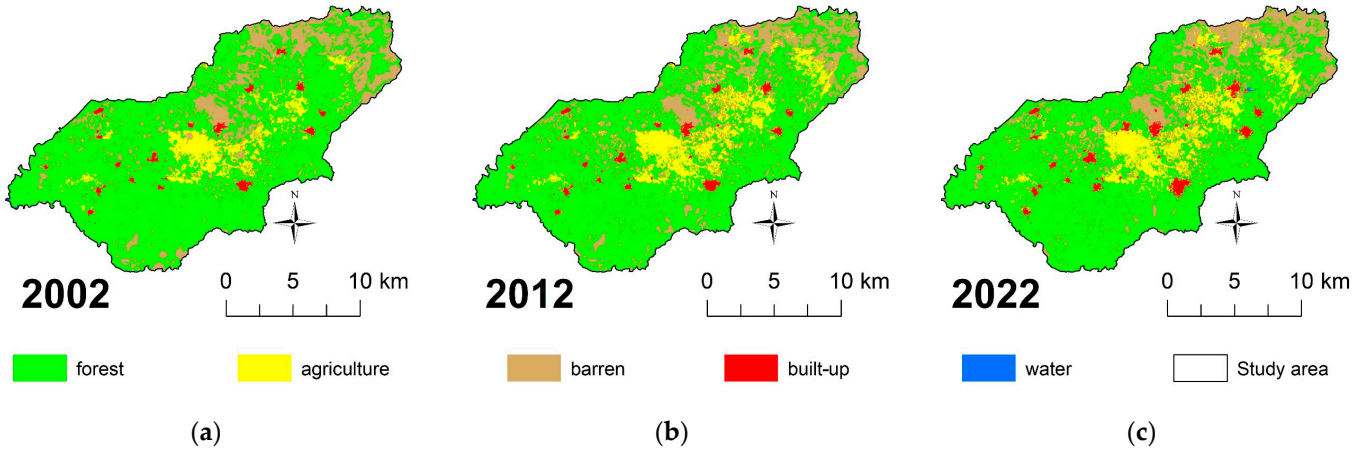


Figure 4. LULC maps of the Kozak Basin in (**a**) 2002, (**b**) 2012, and (**c**) 2022.

Table 1. Coverage and change rates (Δ) of LULC in the Kozak Basin between 2002 and 2022.

Classes	2002		2002–2012	2012		2012–2022	2022		2002–2022
	ha	%	Δ (%)	ha	%	Δ (%)	ha	%	Δ (%)
Forest	21,498.72	72.63	−5.43	19,890.63	67.20	−1.23	19,525.19	65.96	−6.67
Barren	5708.274	19.28	1.89	6266.869	21.17	−0.17	6217.632	21.00	1.72
Agriculture	1954.376	6.60	3.26	2919.342	9.86	0.57	3088.92	10.44	3.83
Built-up	416.9484	1.41	0.29	501.4763	1.69	0.80	737.12	2.49	1.08
Water	22.5	0.08	0.00	22.5	0.08	0.03	31.95	0.11	0.03
Total	29,600.82	100		29,600.82	100		29,600.82	100	

The overall (OA), producer's accuracy (PA), user's accuracy (UA), and Kappa values of satellite images regarding the obtained LULC values were calculated and are presented in Table 2.

Table 2. Classified satellite images overall, producer's accuracy, user's accuracy, and Kappa values.

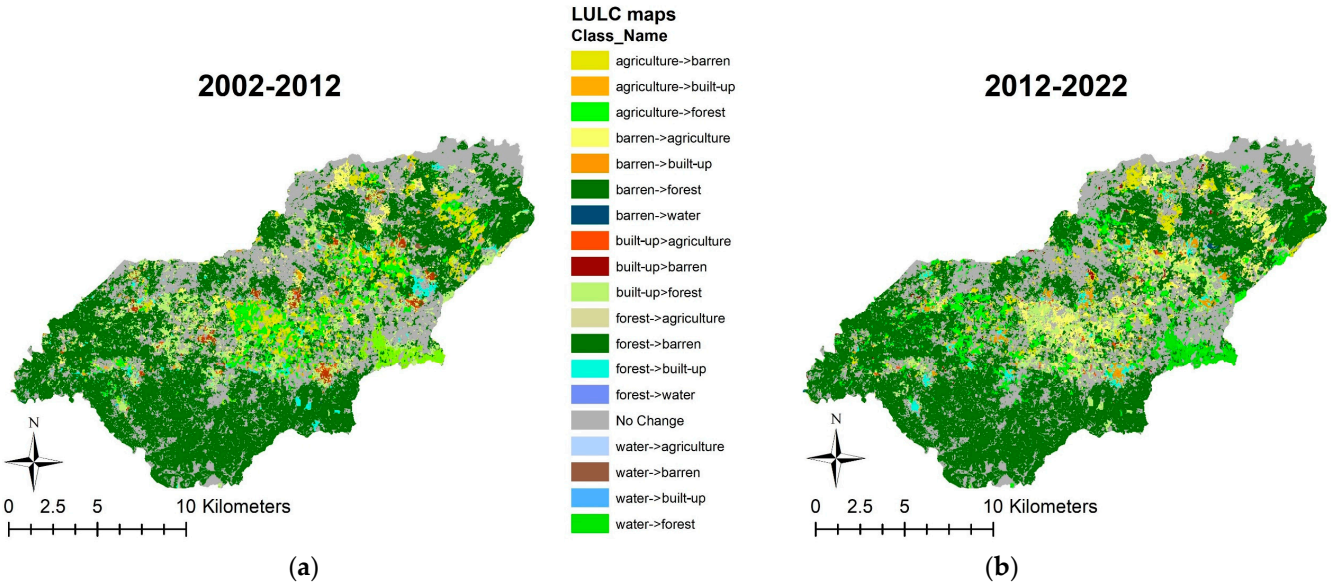
Classes	2002		2012		2022	
	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)
Forest	97.15733	96.27946	92.12487	95.04185	97.27946	98.43406
Barren	95.04185	94.06848	90.31582	91.15733	96.27946	98.04004
Agriculture	93.08711	94.46255	85.24779	89.24779	95.49781	96.48951
Built-up	91.29893	95.24202	91.61	89.30385	93.38106	95.04189
Water	98.49781	99.13756	95.24202	96.04004	99.42476	99.99893
Overall accuracy	94.39		90.87		97.03	
Kappa value	0.95		0.89		0.96	

The analysis of the satellite imagery, which covered LULC categories such as forest, agriculture, barren, built-up, and water areas, demonstrated high-performance metrics, including both producer's and user's accuracies, across several temporal intervals. The Kappa values in the classification carried out on the satellite images were 95% (2002), 89% (2012), and 96% (2022). The results demonstrated that the classification was carried out with high precision and showed that the derived estimates of LULC categories were statistically robust and reliable for temporal analysis.

3.2. LULC Change Detection

The Kozak Basin LULC changes were created using the land change detection tab in the Semi-Automatic Classification (SCP) module. The LULC changes in areas categorized

as forest, agriculture, barren, built-up, and water between 2002–2012 and 2012–2022 are presented in Figure 5, and the numerical values of the LULC changes are presented in Table 3.



(**a**) (**b**)

Figure 5. LULC changes map between (**a**) 2002–2012 and (**b**) 2012–2022.

Table 3. Values of LULC changes between 2002–2012 and 2012–2022.

Class	2002–2012		2012–2022	
	(ha)	%	(ha)	%
Forest	19,643.22	66.360	19,157.67	64.720
Forest–agriculture	445.32	1.504	57.15	0.193
Forest–barren	1335.60	4.512	513.09	1.733
Forest–built-up	73.71	0.249	153.18	0.517
Forest–water	0.00	0.000	10.08	0.034
Barren	4915.71	16.607	5693.13	19.233
Barren–agriculture	548.55	1.853	127.98	0.432
Barren–built-up	15.03	0.051	83.52	0.282
Barren–forest	229.86	0.777	361.89	1.223
Agriculture	1924.47	6.501	2901.15	9.801
Agriculture–barren	13.59	0.046	8.82	0.030
Agriculture–built-up	0.00	0.000	4.86	0.016
Agriculture–forest	16.38	0.055	4.59	0.016
Built-up	412.47	1.393	495.18	1.673
Built-up–agriculture	1.08	0.004	2.79	0.009
Built-up–barren	1.62	0.005	1.89	0.006
Built-up–forest	1.71	0.006	1.35	0.005
Water	22.50	0.076	21.87	0.074
Water–barren	0.00	0.000	0.63	0.002
Total	29,600.82	100.00	29,600.82	100.00

The analysis of LULC changes over two decades revealed significant changes in land cover, especially in forested areas. Between 2002 and 2012, forest land was significantly decreased by 6.265%. Only 0.838% of new forest land was established during this period. In contrast, the following decade (2012–2022) saw a 2.478% decrease in forest land and a modest increase in newly formed forest area to 1.243%. The most significant transformation was the conversion of forested land to barren land, which accounted for 4.512% of the total LULC changes. This trend is followed by the transition from barren land to agricultural use (1.853%) and from forested land to agricultural land, which accounts for 1.504%. In addition, the conversion of barren land to forest accounts for 0.777%, while the conversion of forested land to residential area accounts for 0.249% (Figure 5 and Table 3).

3.3. LULC in the Future

In general, LULC changes were determined between 2002 and 2022. According to these changes, projections for 2022 and 2032 were created (Figure 6). The SCP module was used to predict LULC in 2022 and 2032 using 2002 and 2012 data. For transition potential modeling training data, the neighborhood of 1 pixel, a learning rate of 0.01, a maximum number of iterations of 1000, hidden layers of 10, and a momentum of 0.05 were preferred in the ANN-MLP method [66]. The validation Kappa value for the 2022 prediction was 0.78; for the 2032 prediction, it was 0.88; and the overall Kappa value was 0.9081.

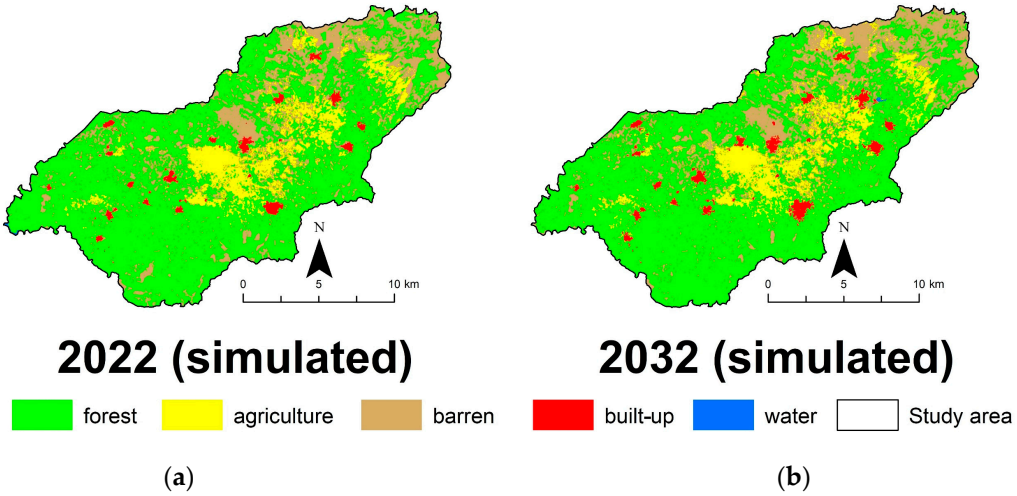


Figure 6. Simulated LULC maps for (**a**) 2022 and (**b**) 2032.

Satellite imagery from 2002 and 2012 was employed to develop a predictive model for LULC in 2022. The predicted LULC map for 2022 was subsequently validated by comparing it with the actual LULC map of the same year, ensuring the accuracy and reliability of the forecasting method. Building upon this, the same approach was applied to project LULC for the year 2032. The 2022 LULC values and 2032 simulation values are presented in Table 4.

Table 4. Prediction values of 2032 LULC.

	2022 Year (ha)	2032 Year (ha)	Change Δ (ha)	2022 Year (%)	2032 Year (%)	Change Δ (%)
Forest	19,525.19	19,376.83	−148.36	65.96	65.46	−0.50
Barren	6217.63	6058.10	−159.53	21.00	20.47	−0.54
Agriculture	3088.92	3390.85	301.93	10.44	11.46	1.02
Built-up	737.12	739.40	2.28	2.49	2.50	0.01
Water	31.95	35.64	3.69	0.11	0.12	0.01
Total	29,600.82	29,600.82		100.00	100.00	0.00

The estimated change between 2022 and 2032 is −0.50% for forest areas, −0.54% for barren areas, +1.02% for agricultural areas, +0.01% for built-up areas, and +0.01% for water areas (Table 4).

3.4. Population Change

The population changes in the 17 villages in the Kozak Basin between 1965 and 2032 are presented in Figure 7.

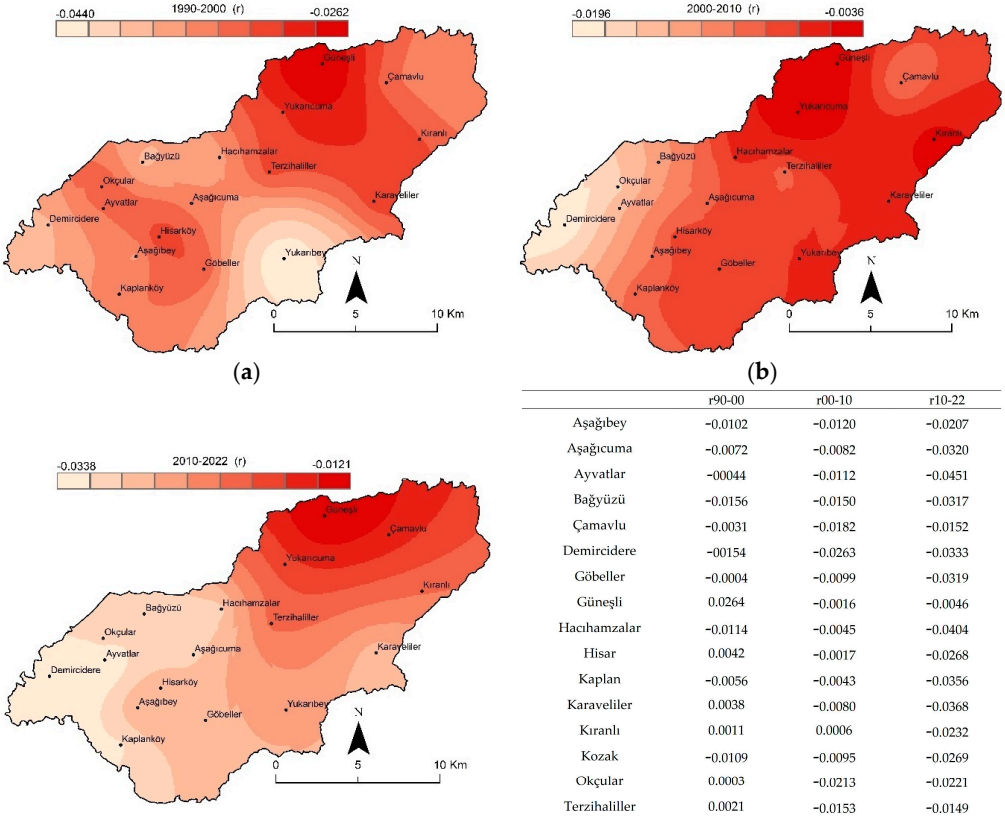
	Aşağıbey	Aşağıcuma	Ayvatlar	Bağyüzü	Çamavlu	Demircidere	Göbeller	Güneşli	Hacıhamzalar	Hisar	Kaplan	Karaveliler	Kıranlı	Okçular	Terzihaliller	Yukarıbey	Yukarıcuma	Total
1965	813	643	367	1102	756	182	414	195	289	247	444	778	440	340	351	1186	206	8753
1970	797	697	354	1084	697	202	443	216	288	262	443	769	454	322	341	1166	209	8744
1975	806	743	377	1048	707	215	434	212	298	278	483	760	487	335	341	1235	215	8974
1980	789	780	375	1029	745	234	463	220	302	279	497	838	470	355	377	1265	242	9260
1985	837	782	394	1109	752	232	440	224	326	284	531	833	469	372	466	1427	290	9768
1990	795	793	396	1124	730	252	447	192	307	232	457	802	461	354	372	2030	217	9961
2000	718	738	379	962	708	216	445	250	274	242	432	833	466	355	380	1306	232	8936
2007	647	680	356	856	607	196	427	237	259	236	413	771	470	315	328	1272	237	8307
2010	637	680	339	828	590	166	403	246	262	238	414	769	469	287	326	1235	239	8128
2015	565	597	250	721	533	132	378	227	227	185	350	654	444	265	296	1076	239	7139
2020	528	540	223	653	509	127	304	243	191	187	309	559	407	247	279	1009	220	6535
2022	518	494	216	603	507	119	293	235	175	182	290	532	372	230	281	966	199	6212
2032	421	359	138	439	436	85	213	224	117	139	203	368	295	184	242	756	166	4786

from high population to low population
high low

Figure 7. Population changes in 17 villages in the Kozak Basin between 1965 and 2032.

The population in the Kozak Basin began to decrease at the beginning of the 2000s. In high-altitude villages (Güneşli, Kıranlı, and Yukarıcuma) located in the north of the basin, the population was found to have increased, contrary to migration in the general Kozak Basin. The estimated population in 2032 was calculated exponentially. In general, it was estimated that the population will decrease in all villages in the Kozak Basin.

The exponential population growth rates of the villages in the Kozak Basin between 1990–2000, 2000–2010, and 2010–2020 were calculated and analyzed on a spatial level (Figure 8).



(**a**) (**b**)

	r90-00	r00-10	r10-22
Aşağıbey	−0.0102	−0.0120	−0.0207
Aşağıcuma	−0.0072	−0.0082	−0.0320
Ayvatlar	−00044	−0.0112	−0.0451
Bağyüzü	−0.0156	−0.0150	−0.0317
Çamavlu	−0.0031	−0.0182	−0.0152
Demircidere	−00154	−0.0263	−0.0333
Göbeller	−0.0004	−0.0099	−0.0319
Güneşli	0.0264	−0.0016	−0.0046
Hacıhamzalar	−0.0114	−0.0045	−0.0404
Hisar	0.0042	−0.0017	−0.0268
Kaplan	−0.0056	−0.0043	−0.0356
Karaveliler	0.0038	−0.0080	−0.0368
Kıranlı	0.0011	0.0006	−0.0232
Kozak	−0.0109	−0.0095	−0.0269
Okçular	0.0003	−0.0213	−0.0221
Terzihaliller	0.0021	−0.0153	−0.0149
Yukarıbey	0.0441	−0.0056	−0.0246
Yukarı cuma	0.0067	0.0030	−0.0183

(**c**) (**d**)

Figure 8. Population growth rate maps at the spatial level between (**a**) 1990–2000, (**b**) 2000–2010, and (**c**) 2010–2020; (**d**) population growth rate values.

Between 2000 and 2010, the population growth rates decreased relatively more in low-altitude villages in the basin. Between 2010 and 2022, population growth began to decrease toward the middle of the basin. Moreover, the population decline in the Kozak Basin decreased with increasing altitude.

4. Discussion

This study reveals the LULC and population changes in the Kozak Basin during the process in which changing forest land functions—especially economic effects—due to the impact of various factors, such as climate change and insect damage, that trigger vulnerable communities. As a result of this study, the decreases in forest land and rural population in the Kozak Basin and the changes in LULC were detected, which can be associated with the decrease in cone and seed yields observed in the Mediterranean Basin stone pine forests [38,42,43,45,46]. According to the results of the population data analysis, for a long time, the people of the region had moved in opposite directions to the migration movements throughout the country, and the population remained stable (Figure 7). The population of the Kozak Basin, which remained generally stable during the period when migration from rural areas to cities was most intense in Türkiye, started to decrease from the 2010s onwards. LULC changes and rural migration triggered by low stone pine (*Pinus pinea* L.) cone and seed yields is a phenomenon that has occurred in different regions of Türkiye due to various reasons such as 'unemployment', 'regional inequalities', and the 'desire for urbanization'. The decrease in the rural population in Türkiye results in the abandonment of agricultural lands, reforestation of agricultural lands bordering the forest [16], and a lack of labor force to work in the region [67].

In the literature, the early 2010s are considered the turning point in the decline in pine cone and seed yields [37,45,46] and the increase in their prices [68]. the western conifer seed bug (*Leptoglossus occidentalis* Heidemann 1910 (Hemiptera; Coreidae), which is also associated with a decrease in cone and seed yields, was first reported in northwestern Türkiye in 2009–2010 [69,70]. According to the results of this study, the decrease in productivity that started in the Kozak Basin [38,71] and population mobility coincide with the same period. The authors of [38] stated that rural migration, which is widespread in rural areas of Türkiye, has also started in the Kozak Basin and that the low cone yield emphasizes that a loss of income will increase the migration rate. In studies conducted in the Kozak Basin, 6.3% of the pine nut producers planned to migrate, 4.76% planned to migrate only due to low yields [38], and 30% of the pine cone pickers tended to migrate due to low yields [42]. While migration is generally observed in villages located in high-altitude lands in Türkiye [72], the population in the high-altitude regions of the Kozak Basin increased until the early 2020s. It can be concluded that animal husbandry in the pastures located in the north of the Basin, which is the reason for this increase, allowed pine nut producers to overcome the crisis they have experienced in recent years. However, there were no natural stone pine areas in the upper section of the Kozak Basin in the past, and these villages created stone pine areas after seeing the profit of the lower villages. In other words, the historical livelihoods of the villages below and above the basin differ. The animal husbandry and dairy product industries were prioritized in the upper villages; stone pine production was their secondary livelihood. Therefore, it can be concluded that the upper villages are not significantly affected by this vulnerability. Based on these findings, the Kozak Basin is a good example of reducing pathogen damage due to the effects of climate change in vulnerable communities in rural areas. It can be observed that the villagers downstream of the basin who live on a single product are more vulnerable.

As a result of this study, 94% OA and 93% Kappa values were obtained for the LULC classifications, and these values are in close agreement with the literature results using a

similar methodology [9,63]. The changes and decreases in *P. pinea* areas were detected in the Kozak Basin, and the most important change in the Kozak Basin occurred in the forest areas (Table 1). The largest decrease in forest area was observed between 2002 and 2012. The rate of decrease in forest area between 2012 and 2022 was relatively lower (Tables 1 and 3). Furthermore, the 2032 projection estimated that LULC changes by the local people will continue, albeit to a lesser extent, due to socio-economic and biophysical drivers, as these people depend on the income they obtain from the Kozak Basin's land for their livelihood (Table 4).

In the ecological distribution modeling of *P. pinea*, it is predicted that its distribution in the southern and eastern Mediterranean countries [73] and Türkiye [74] will narrow in the future. Regional studies indicate that urbanization areas and *P. pinea* areas are increasing, and agricultural areas are decreasing in the coastal areas of Italy [75,76]. It is also predicted that there will be an expansion of forest areas in the south of Spain in favor of *P. pinea* [77]. LULC changes (1987–2000) were observed in 35% of the Madra Mountain region, which includes the Kozak Basin [53].

It has been stated that barren areas were formed within the forest blocks in the Kozak Basin and that these areas were formerly stone pine forests that were later converted into mining areas [53]. In this study, it was observed that barren areas similar to mining areas continued to form within the forest block. In addition, local people believe that mines opened on owned lands provide employment opportunities, even if they are limited. Due to the decrease in pine nut production, local people are cutting down trees in the pine nut areas and turning them into income by selling them to mining companies or turning to other production methods, especially animal husbandry [38]. This situation can be defined as the local people's reaction to the problems experienced in pine nut production in the Kozak Basin or as a way to escape the economic bottleneck. The processing of granite resources and, especially, agricultural activities, which have existed in the Kozak Basin for many years but have been overshadowed by pine nut production, are gaining interest again due to low cone and seed yields. This situation is changing the LULC of the Kozak Basin due to economic reasons (loss of yield) triggered by ecological reasons (climate change and insect damage). It is observed that the LULC changes in the Kozak Basin are in the process of change as a result of both socio-economic and biophysical drivers.

The fact that there are more privately owned areas in the region compared with Türkiye's average can be considered as a situation that paves the way for a decrease in stone pine areas in the region, contrary to Türkiye's forestry statistics. In fact, while the sustainability approach in state forests continues, the easy cutting of stone pine trees on private lands because of the decrease in cone or seed yields is important in terms of revealing the economic sensitivities of two different business types.

There is a need for legal regulations in order to evaluate the *P. pinea* areas in private ownership as a whole for the region they are located in and to ensure their sustainability, protect the integrity of the landscape, support private owners, and prevent fragmentation in the area with individual movements. In addition, supporting cooperatives to economically support these vulnerable communities and supporting cooperative members with subsidies during transitional periods can prevent rapid and uncontrolled LULC in the region. The existence of *P. pinea* forests belonging to both state and private property in the region reveals the need for management with a state–public interaction and stakeholder participation approach. In order to develop solutions and monitor the region, an organization can be established to define the ecological and economic problems encountered in the management and operation of *P. pinea* areas in the region.

This study has some limitations. Due to the fact that local people may not accurately record their pine cone production in order to reduce taxation, and because there is a high

number of imported products entering the region, the annual harvest amounts of the region could not be numerically determined. In future studies in this field, the pine nut harvests of local people can be monitored on a tree basis, and the social and economic reactions to the changes in harvest can be examined. Furthermore, the relationships between the population growth rate and household income, unit tree, and area yield changes can be identified. In addition, LULC classes can be defined in greater detail using higher-resolution satellite images. Using lidar technology, changes in the stone pine population in the small-scale areas and the reasons for these changes can be determined.

5. Conclusions

The results of this study revealed a LULC change and a decrease in both forest area and population in the Kozak Basin; this situation can be defined as the reaction of the Turkish socio-economic structure to the decrease in cone and seed yields observed in the Mediterranean Basin stone pine forests. It is inevitable that the migration to cities throughout the country will affect the Kozak Basin; however, pine nut production, a non-forest product with high economic value, was able to temporarily prevent this migration.

Our findings suggest that the villagers living in the lower part of the basin, whose livelihood is mostly pine nut production, are more vulnerable than the villagers in the upper part, who have alternative livelihoods such as animal husbandry. Therefore, the diversity of production methods and subsistence income sources is important in the Kozak Basin. Rural people with alternative income sources are less affected by the negative consequences of climate change. In this sense, the diversity of production or livelihood diversity is important for the continuity of land use and population in rural areas.

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References

1. Lambin, E.F.; Turner, B.L.; Geist, H.J.; Agbola, S.B.; Angelsen, A.; Bruce, J.W.; Coomes, O.T.; Dirzo, R.; Fischer, G.; Folke, C.; et al. The Causes of Land-Use and Land-Cover Change: Moving beyond the Myths. *Glob. Environ. Chang.* **2001**, *11*, 261–269. [CrossRef]
2. Verburg, P.H.; Van De Steeg, J.; Veldkamp, A.; Willemen, L. From Land Cover Change to Land Function Dynamics: A Major Challenge to Improve Land Characterization. *J. Environ. Manag.* **2009**, *90*, 1327–1335. [CrossRef] [PubMed]
3. Anaya, J.A.; Gutiérrez-Vélez, V.H.; Pacheco-Pascagaza, A.M.; Palomino-Ángel, S.; Han, N.; Balzter, H. Drivers of Forest Loss in a Megadiverse Hotspot on the Pacific Coast of Colombia. *Remote Sens.* **2020**, *12*, 1235. [CrossRef]
4. Negassa, M.D.; Mallie, D.T.; Gemeda, D.O. Forest Cover Change Detection Using Geographic Information Systems and Remote Sensing Techniques: A Spatio-Temporal Study on Komto Protected Forest Priority Area, East Wollega Zone, Ethiopia. *Environ. Syst. Res.* **2020**, *9*, 1. [CrossRef]
5. Kyere-Boateng, R.; Marek, M.V. Analysis of the Social-Ecological Causes of Deforestation and Forest Degradation in Ghana: Application of the DPSIR Framework. *Forests* **2021**, *12*, 409. [CrossRef]
6. Song, X.-P.; Hansen, M.C.; Stehman, S.V.; Potapov, P.V.; Tyukavina, A.; Vermote, E.F.; Townshend, J.R. Global Land Change from 1982 to 2016. *Nature* **2018**, *560*, 639–643. [CrossRef]

7. Souza, C.M.; Shimbo, J.Z.; Rosa, M.R.; Parente, L.L.; Alencar, A.A.; Rudorff, B.F.T.; Hasenack, H.; Matsumoto, M.; Ferreira, L.G.; Souza-Filho, P.W.M.; et al. Reconstructing Three Decades of Land Use and Land Cover Changes in Brazilian Biomes with Landsat Archive and Earth Engine. *Remote Sens.* **2020**, *12*, 2735. [CrossRef]
8. Oduro Appiah, J.; Agyemang-Duah, W.; Sobeng, A.K.; Kpienbaareh, D. Analysing Patterns of Forest Cover Change and Related Land Uses in the Tano-Offin Forest Reserve in Ghana: Implications for Forest Policy and Land Management. *Trees For. People* **2021**, *5*, 100105. [CrossRef]
9. Hu, Y.; Raza, A.; Syed, N.R.; Acharki, S.; Ray, R.L.; Hussain, S.; Dehghanisanij, H.; Zubair, M.; Elbeltagi, A. Land Use/Land Cover Change Detection and NDVI Estimation in Pakistan's Southern Punjab Province. *Sustainability* **2023**, *15*, 3572. [CrossRef]
10. Chen, M.; Vernon, C.R.; Graham, N.T.; Hejazi, M.; Huang, M.; Cheng, Y.; Calvin, K. Global Land Use for 2015–2100 at 0.05° Resolution under Diverse Socioeconomic and Climate Scenarios. *Sci. Data* **2020**, *7*, 320. [CrossRef]
11. Leta, M.K.; Demissie, T.A.; Tränckner, J. Modeling and Prediction of Land Use Land Cover Change Dynamics Based on Land Change Modeler (LCM) in Nashe Watershed, Upper Blue Nile Basin, Ethiopia. *Sustainability* **2021**, *13*, 3740. [CrossRef]
12. Tadese, S.; Soromessa, T.; Bekele, T. Analysis of the Current and Future Prediction of Land Use/Land Cover Change Using Remote Sensing and the CA-Markov Model in Majang Forest Biosphere Reserves of Gambella, Southwestern Ethiopia. *Sci. World J.* **2021**, *2021*, 6685045. [CrossRef] [PubMed]
13. Walker, K.L. Effect of Land Tenure on Forest Cover and the Paradox of Private Titling in Panama. *Land Use Policy* **2021**, *109*, 105632. [CrossRef]
14. Boillat, S.; Ceddia, M.G.; Bottazzi, P. The Role of Protected Areas and Land Tenure Regimes on Forest Loss in Bolivia: Accounting for Spatial Spillovers. *Glob. Environ. Change* **2022**, *76*, 102571. [CrossRef]
15. Prioli Duarte, D.; Peres, C.A.; Perdomo, E.F.C.; Guizar-Coutiño, A.; Nelson, B.W. Reducing Natural Vegetation Loss in Amazonia Critically Depends on the Formal Recognition of Indigenous Lands. *Biol. Conserv.* **2023**, *279*, 109936. [CrossRef]
16. Buğday, E.; Erkan Buğday, S. Modeling and Simulating Land Use/Cover Change Using Artificial Neural Network from Remotely Sensing Data. *CERNE* **2019**, *25*, 246–254. [CrossRef]
17. Günşen, H.B.; Atmiş, E. Analysis of Forest Change and Deforestation in Turkey. *Int. Forest. Rev.* **2019**, *21*, 182–194. [CrossRef]
18. Palmero-Iniesta, M.; Pino, J.; Pesquer, L.; Espelta, J.M. Recent Forest Area Increase in Europe: Expanding and Regenerating Forests Differ in Their Regional Patterns, Drivers and Productivity Trends. *Eur. J. For. Res.* **2021**, *140*, 793–805. [CrossRef]
19. Kouassi, J.-L.; Gyau, A.; Diby, L.; Bene, Y.; Kouamé, C. Assessing Land Use and Land Cover Change and Farmers' Perceptions of Deforestation and Land Degradation in South-West Côte d'Ivoire, West Africa. *Land* **2021**, *10*, 429. [CrossRef]
20. Miyamoto, M. Poverty Reduction Saves Forests Sustainably: Lessons for Deforestation Policies. *World Dev.* **2020**, *127*, 104746. [CrossRef]
21. Dogru, A.O.; Goksel, C.; David, R.M.; Tolunay, D.; Sözen, S.; Orhon, D. Detrimental Environmental Impact of Large Scale Land Use through Deforestation and Deterioration of Carbon Balance in Istanbul Northern Forest Area. *Environ. Earth Sci.* **2020**, *79*, 270. [CrossRef]
22. FAOSTAT. Food and Agriculture Organization of the United Nations FAOSTAT, Land Use. Available online: https://www.fao.org/faostat/en/#data/RL/visualize (accessed on 10 March 2024).
23. Symeonakis, E.; Calvo-Cases, A.; Arnau-Rosalen, E. Land Use Change and Land Degradation in Southeastern Mediterranean Spain. *Environ. Manag.* **2007**, *40*, 80–94. [CrossRef] [PubMed]
24. Newbold, T.; Oppenheimer, P.; Etard, A.; Williams, J.J. Tropical and Mediterranean Biodiversity Is Disproportionately Sensitive to Land-Use and Climate Change. *Nat. Ecol. Evol.* **2020**, *4*, 1630–1638. [CrossRef]
25. Ruiz, I.; Sanz-Sánchez, M.J. Effects of Historical Land-Use Change in the Mediterranean Environment. *Sci. Total Environ.* **2020**, *732*, 139315. [CrossRef]
26. Peñuelas, J.; Sardans, J. Global Change and Forest Disturbances in the Mediterranean Basin: Breakthroughs, Knowledge Gaps, and Recommendations. *Forests* **2021**, *12*, 603. [CrossRef]
27. Chebli, Y.; Chentouf, M.; Ozer, P.; Hornick, J.-L.; Cabaraux, J.-F. Forest and Silvopastoral Cover Changes and Its Drivers in Northern Morocco. *Appl. Geogr.* **2018**, *101*, 23–35. [CrossRef]
28. Gauquelin, T.; Michon, G.; Joffre, R.; Duponnois, R.; Génin, D.; Fady, B.; Bou Dagher-Kharrat, M.; Derridj, A.; Slimani, S.; Badri, W.; et al. Mediterranean Forests, Land Use and Climate Change: A Social-Ecological Perspective. *Reg. Environ. Chang.* **2018**, *18*, 623–636. [CrossRef]
29. Boubekraoui, H.; Maouni, Y.; Ghallab, A.; Draoui, M.; Maouni, A. Spatio-Temporal Analysis and Identification of Deforestation Hotspots in the Moroccan Western Rif. *Trees For. People* **2023**, *12*, 100388. [CrossRef]
30. Serra, P.; Pons, X.; Saurí, D. Land-Cover and Land-Use Change in a Mediterranean Landscape: A Spatial Analysis of Driving Forces Integrating Biophysical and Human Factors. *Appl. Geogr.* **2008**, *28*, 189–209. [CrossRef]
31. La Mela Veca, D.; Cullotta, S.; Sferlazza, S.; Maetzke, F. Anthropogenic Influences in Land Use/Land Cover Changes in Mediterranean Forest Landscapes in Sicily. *Land* **2016**, *5*, 3. [CrossRef]

32. Abadie, J.; Dupouey, J.-L.; Avon, C.; Rochel, X.; Tatoni, T.; Bergès, L. Forest Recovery since 1860 in a Mediterranean Region: Drivers and Implications for Land Use and Land Cover Spatial Distribution. *Landsc. Ecol.* **2018**, *33*, 289–305. [CrossRef]
33. Touhami, I.; Chirino, E.; Aouinti, H.; El Khorchani, A.; Elaieb, M.T.; Khaldi, A.; Nasr, Z. Decline and Dieback of Cork Oak (*Quercus suber* L.) Forests in the Mediterranean Basin: A Case Study of Kroumirie, Northwest Tunisia. *J. For. Res.* **2020**, *31*, 1461–1477. [CrossRef]
34. Delgado-Artés, R.; Garófano-Gómez, V.; Oliver-Villanueva, J.-V.; Rojas-Briales, E. Land Use/Cover Change Analysis in the Mediterranean Region: A Regional Case Study of Forest Evolution in Castelló (Spain) over 50 Years. *Land Use Policy* **2022**, *114*, 105967. [CrossRef]
35. Spinoni, J.; Barbosa, P.; Cherlet, M.; Forzieri, G.; McCormick, N.; Naumann, G.; Vogt, J.V.; Dosio, A. How Will the Progressive Global Increase of Arid Areas Affect Population and Land-Use in the 21st Century? *Glob. Planet. Chang.* **2021**, *205*, 103597. [CrossRef]
36. Scarascia-Mugnozza, G.; Oswald, H.; Piussi, P.; Radoglou, K. Forests of the Mediterranean Region: Gaps in Knowledge and Research Needs. *For. Ecol. Manag.* **2000**, *132*, 97–109. [CrossRef]
37. Mutke, S.; Martinez, J.; Gordo, J.; Nikolas, J.L.; Herrero, N.; Pastor, A.; Calama, R. Severe Seed Yield Loss in Mediterranean Stone Pine Cones. In Proceedings of the 5th International Conference on Mediterranean Pines (Medpine5), Solsona, Spain, 22–26 September 2014.
38. Özden, S.; Okan, T.; Buğday, S.E.; Köse, C. Perspectives of Farmers on the Decline in *Pinus pinea* Nut Yield and the Sustainability of the Production: A Case Study in Kozak Basin in Western Turkey. *Agriculture* **2022**, *12*, 1070. [CrossRef]
39. Campoy-Muñoz, P.; Cardenete, M.A.; Pérez-Hernández, P.P.; Martín-Lozano, J.M.; Martínez-Rueda, J. A SAM Approach for the Analysis of Small-Scale Forestry-Based Activities: A Case Study of a Landowner Cooperative for Non-Wooded Products from *Pinus pinea* L. in Southern Spain. *Small-Scale For.* **2022**, *21*, 249–273. [CrossRef]
40. GDF. 2020 Türkiye Orman Varlığı, T.C. Tarım ve Orman Bakanlığı Orman Genel Müdürlüğü, Orman İdaresi ve Planlama Dairesi Başkanlığı, Ankara. Available online: https://www.ogm.gov.tr/tr/ormanlarimiz-sitesi/TurkiyeOrmanVarligi/Yayinlar/2020%20T%C3%BCrkiye%20Orman%20Varl%C4%B1%C4%9F%C4%B1.pdf (accessed on 20 November 2024).
41. Saritaş, E.; Türker, M.F. The Effect of Cooperatives Producing Non-Wood Forest Products on Rural Development: The Example of Kozak Subdistrict Agricultural Development Cooperative in Turkey. *J. Sustain. For.* **2023**, *42*, 573–589. [CrossRef]
42. Erkan Buğday, S.; Okan, T.; Köse, C.; Özden, S. Kozak Yöresinde Fıstıkçamı (*Pinus pinea* L.) Geleneksel Kozalak Hasadı ve Kozalak İndiricilerin Profili. *Bartın Orman Fak. Derg.* **2024**, *26*, 72–85. [CrossRef]
43. Köse, C.; Okan, T.; Erkan Buğday, S.; Özden, S. Kozak Yöresi Çam Fıstığı İşleme Tesislerinin Mevcut Durumu. *Bartın Orman Fak. Derg.* **2024**, *26*, 86–99. [CrossRef]
44. Sülüşoğlu, M. *The Management of Villagers Owned Stone Pine (Pinus pinea L.) Plantations in Kozak Region, Turkey: A Case Study*, 1st ed.; Food and Agriculture Organization (FAO): Ankara, Turkey, 2004; Volume 1.
45. Calama, R.; Gordo, J.; Mutke, S.; Conde, M.; Madrigal, G.; Garriga, E.; Arias, M.; Piqué, M.; Gandía, R.; Montero, G.; et al. Decline in Commercial Pine Nut and Kernel Yield in Mediterranean Stone Pine (*Pinus pinea* L.) in Spain. *iForest* **2020**, *13*, 251–260. [CrossRef]
46. El Khoury, Y.; Noujeim, E.; Bubici, G.; Tarasco, E.; Al Khoury, C.; Nemer, N. Potential Factors behind the Decline of *Pinus pinea* Nut Production in Mediterranean Pine Forests. *Forests* **2021**, *12*, 1167. [CrossRef]
47. Heidemann, O. New Species of Leptoglossus from North America. In Proceedings of the Entomological Society of Washington; Entomological Society of Washington: Washington, DC, USA, 1910; Volume 12, pp. 191–197.
48. Ponce-Herrero, L.; Ponce Díaz, A.; Pando Fernández, V.; Alves-Santos, F.M.; Pajares Alonso, J.A. Damage Caused by *Leptoglossus occidentalis* Heidemann (Hemiptera: Coreidae) on *Pinus pinea* L. Cones Varies with Feeding Season. *Agric. For. Entomol.* **2024**, *26*, 386–400. [CrossRef]
49. Farinha, A.O.; Carvalho, C.; Correia, A.C.; Branco, M. Impact Assessment of *Leptoglossus Occidentalis* in *Pinus pinea*: Integrating Population Density and Seed Loss. *For. Ecol. Manag.* **2021**, *496*, 119422. [CrossRef]
50. Parlak, S.; Kilci, M.; Sayman, M.; Akkas, M.E. Climate Factors and Their Relations Regarding Cone Yield of Stone Pine Trees (*Pinus pinea* L.) in Kozak Basin. *Options Méditerr.* **2013**, *105*, 15–19.
51. Parlak, S. An Invasive Species: *Leptoglossus Occidentalis* (Heidemann) How Does It Affect Forestry Activities? *Kastamonu Üniv. Orman Fak. Derg.* **2017**, 531–542. [CrossRef]
52. Çetin, T. Doğal Ortam Ekonomik Faaliyet İlişkisine Bir Örnek Kozak Yöresi Bergama. *Gazi Üniv. Gazi Eğit. Fak. Derg.* **2003**, *23*, 23–46.
53. Uzun, A.; Somuncu, M. Madra Dağı ve Çevresinin Arazi Örtüsü/Kullanimindaki Zamansal Değişimin Uzaktan Algilama Yöntemi Ile Değerlendirilmesi. *Balikesir Univ. J. Soc. Sci. Inst.* **2013**, *16*, 1–21.
54. Kökalan Çımrın, F. Bergama Köylü Hareketinin Dünü ve Bugünü. *Electron. J. Soc. Sci.* **2015**, *14*, 310.
55. Yantut, Ü. Kozak Yaylasında (Bergama/İzmir) Doğal Ortam-İnsan İlişkileri. Master's Thesis, Balıkesir Üniversitesi Sosyal Bilimler Enstitüsü, Balıkesir, Turkey, 2023.

56. KFS. *Izmir Regional Forest Directorate, Bergama Forest District, Kozak Forest Sub-District (KFS) Management Plan*; KFS: Izmir, Turkey, 2016; p. 249.
57. TUIK Türkiye İstatistik Kurumu (TUIK). Available online: https://www.tuik.gov.tr (accessed on 14 March 2024).
58. Cohen, J. A Coefficient of Agreement for Nominal Scales. *Educ. Psychol. Meas.* **1960**, *20*, 37–46. [CrossRef]
59. Olofsson, P.; Foody, G.M.; Herold, M.; Stehman, S.V.; Woodcock, C.E.; Wulder, M.A. Good Practices for Estimating Area and Assessing Accuracy of Land Change. *Remote Sens. Environ.* **2014**, *148*, 42–57. [CrossRef]
60. Gao, C.; Cheng, D.; Iqbal, J.; Yao, S. Spatiotemporal Change Analysis and Prediction of the Great Yellow River Region (GYRR) Land Cover and the Relationship Analysis with Mountain Hazards. *Land* **2023**, *12*, 340. [CrossRef]
61. Luo, Y.; Chen, R.; Xiong, B.; Jia, N.; Guo, X.; Yin, C.; Song, W. The Impact of Household Dynamics on Land-Use Change in China: Past Experiences and Future Implications. *Land* **2024**, *13*, 124. [CrossRef]
62. Bravo-López, E.; Fernández Del Castillo, T.; Sellers, C.; Delgado-García, J. Landslide Susceptibility Mapping of Landslides with Artificial Neural Networks: Multi-Approach Analysis of Backpropagation Algorithm Applying the Neuralnet Package in Cuenca, Ecuador. *Remote Sens.* **2022**, *14*, 3495. [CrossRef]
63. Wang, S.; Zheng, X. Dominant Transition Probability: Combining CA-Markov Model to Simulate Land Use Change. *Environ. Dev Sustain.* **2023**, *25*, 6829–6847. [CrossRef]
64. Kocaman, T. *Plan Nüfus Projeksiyon Yöntemleri*; TC Başbakanlık Devlet Planlama Teşkilatı (DPT) Sosyal Sektörler Ve Koordinasyon Genel Müdürlüğü: Ankara, Turkey, 2002.
65. ESRI. Krigging. Available online: https://pro.arcgis.com/en/pro-app/latest/tool-reference/3d-analyst/how-kriging-works.htm (accessed on 10 April 2024).
66. Antomi, Y.; Angraina, D.; Arif, D.A.; Fitriawan, D. Exploring the Effects of Land Use Land Cover (LULC) Change on Menhir in 2053: Utilizing the Cellular Automata-Artificial Neural Network (CA-ANN) Algorithm: A Case Study of Menhir Tourist Site in Nagari Maek, Indonesia. *Int. J. Geoinform.* **2024**, *20*, 54–73. [CrossRef]
67. Özden, S.; Erkan Buğday, S. Üretim Faktörü Olarak Orman Köylüsünün Nüfus Hareketleri: Kastamonu Örneği. *Kastamonu Üniv. Orman Fak. Derg.* **2015**, *15*, 232–240. [CrossRef]
68. Jaouadi, W.; Alsubeie, M.; Mechergui, K.; Naghmouchi, S. Silviculture of *Pinus pinea* L. in North Africa and The Mediterranean Areas: Current Potentiality and Economic Value. *J. Sustain. For.* **2021**, *40*, 656–674. [CrossRef]
69. Arslangündoğdu, Z.; Hızal, E. The Western Conifer Seed Bug, *Leptoglossus occidentalis* (Heidemann, 1910), Recorded in Turkey (Heteroptera: Coreidae). *Zool. Middle East* **2010**, *50*, 138–139. [CrossRef]
70. Fent, M.; Kment, P. First Record of the Invasive Western Conifer Seed Bug *Leptoglossus Occidentalis* (Heteroptera: Coreidae) in Türkiye. *North-West. J. Zool.* **2011**, *7*, 72–80.
71. Güleç, A.; Tolunay, A. The Contribution of Umbrella Pinus Forests (*Pinus pinea* L.) to Village Legal Entities and Local Economy: The Case of Gediz Basin. *Int. Sci. Vocat. Stud. J.* **2021**, *5*, 19–33.
72. Erkan Buğday, S.; Özden, S. The Relationship between Terrain and Rural Migration (1965–2013) on the North of Turkey (the Case of Kastamonu). *Environ. Monit. Assess.* **2017**, *189*, 154. [CrossRef] [PubMed]
73. Akyol, A.; Örücü, Ö.K.; Arslan, E.S. Habitat Suitability Mapping of Stone Pine (*Pinus pinea* L.) under the Effects of Climate Change. *Biologia* **2020**, *75*, 2175–2187. [CrossRef]
74. Akyol, A.; Örücü, Ö.K. Investigation and Evaluation of Stone Pine (*Pinus pinea* L.) Current and Future Potential Distribution Under Climate Change in Turkey. *CERNE* **2019**, *25*, 415–423. [CrossRef]
75. Del Perugia, B.; Travaglini, D.; Bottalico, F.; Nocentini, S.; Rossi, P.; Salbitano, F.; Sanesi, G. Are Italian Stone Pine Forests (*Pinus pinea* L.) and Endangered Coastal Landscape? A Case Study in Tuscany. *L'Italia For. Mont.* **2017**, *72*, 103–121. [CrossRef]
76. Gasparella, L.; Tomao, A.; Agrimi, M.; Corona, P.; Portoghesi, L.; Barbati, A. Italian Stone Pine Forests under Rome's Siege: Learning from the Past to Protect Their Future. *Landsc. Res.* **2017**, *42*, 211–222. [CrossRef]
77. López-Tirado, J.; Hidalgo, P.J. Ecological Niche Modelling of Three Mediterranean Pine Species in the South of Spain: A Tool for Afforestation/Reforestation Programs in the Twenty-First Century. *New For.* **2016**, *47*, 411–429. [CrossRef]

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