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Shifting Landscapes on an Island: Urbanization and the Evolving Perception of Green Spaces on Jeju Island

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In this study, we investigated how urbanization affects the public perception of green spaces on Jeju Island, South Korea, with a focus on identifying sociodemographic drivers of environmental attitudes and behaviors. We examined the complicated interlinkages between urbanization and the public perception of green spaces on Jeju Island. A mixed-methods approach based on land use and land cover analysis was taken to measure, on the one hand, the land cover changes from the 1990s to the present and to illuminate important transformations in vegetation and urban development. On the other hand, we carried out a comprehensive survey of 692 residents, which revealed which demographic factors, such as income or education, affect the way people perceive green spaces. The results showed that the residents with higher income and/or education levels are more likely to express their love for the greenery of the city, whereas the older generation living in mid-mountain areas are seen as those having the most serious concerns about living environment issues. In addition, the study underscores how critical it is to direct social education programs that can nurture environmental knowledge and civic responsibility among the population.

1. Introduction

Global urbanization has made the integration of green spaces into urban planning an imperative issue.(1) Recognizing how local communities perceive their surroundings is essential for creating sustainable urban environments.(2) Jeju Island – celebrated for its natural beauty and strong community ties – is the focus of our study, which investigates the complex range of opinions its residents hold about the island's green spaces. These green spaces, often referred to as the "lungs" of urban areas, are vital for improving residents' quality of life by providing a spectrum of ecological, socioeconomic, and psychological benefits.(3–5) A comprehensive

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understanding of residents' interactions and perceptions of these areas can guide urban planners and policymakers in crafting urban environments that align with public needs and preferences.[6]

However, urban planners face significant challenges in preserving green spaces amid rapid urbanization. As urban development encroaches on these natural amenities, both the accessibility and the perceived value of green spaces can diminish.[7,8] The preservation of these spaces is further hampered by financial constraints, given the substantial resources required for their establishment and maintenance.[7] The inherently multifaceted nature of green spaces makes it difficult to address the diverse needs and preferences of different individuals.[9] Additionally, while the benefits of green spaces are significant, they are challenging to quantify in monetary terms, complicating the justification of related expenditures.[10] Insufficient or unclear policy directives further exacerbate these issues, highlighting the need for innovative legislation, clear guidelines, and collaborative efforts to both save and enhance urban green spaces.[9]

However, there is a lack of empirical research examining how sociodemographic factors and urbanization processes jointly shape public perceptions and conservation behaviors toward green spaces in Jeju Island. While numerous conservation initiatives exist, little is known about the relationships among land cover changes, resident attitudes, and civic engagement, especially in the context of rapid urban transformation.

Accordingly, in this study, we aim to bridge these gaps by addressing three research questions: (1) How do sociodemographic factors affect perceptions of and engagement with green spaces on Jeju Island? (2) What are the temporal patterns of green and built-up land cover, and how do residents perceive these changes? (3) How can a conceptual framework integrating environmental psychology, sociology, and landscape studies inform effective policies for sustainable urban planning and environmental education? By focusing on these issues, our research provides new empirical evidence and theoretical insights to guide policy and community-based green space management in rapidly urbanizing island regions.

Ensuring the sustainable preservation of green spaces on Jeju Island demands an integrated strategy that is deeply rooted in the values and beliefs of the local community, while also backed by robust policy and regulatory frameworks.[11] Central to this approach is the promotion of environmental literacy through targeted educational initiatives,[12] which in turn cultivates a strong sense of environmental responsibility among residents.[13] The Jeju Island municipal government has shown commitment to these goals by enacting significant regulatory measures intended to protect the natural ecosystem and promote sustainable development.[14] Combined with a high degree of public environmental awareness and active participation in conservation efforts, these regulatory policies have played a crucial role in safeguarding green spaces despite ongoing urban developmental pressures.[15] In this context, environmental education has emerged as a pivotal element, enhancing community understanding of the ecological importance of green spaces and encouraging sustainable behavioral practices.[16] To further its aims, Jeju Island employs various educational programs through schools and community centers that stress the principles of environmental conservation and the potential long-term consequences of inaction.

In Jeju society, where ecological conservation is deeply valued, numerous citizen-led actions and research projects have been implemented. The conservation of the Volcano Lava Forest,

known as Gotjawal, stands out as an important initiative; this unique forest, flourishing on rocky lava, is essential for maintaining the island's biodiversity, with many species receiving protection.[17–19] Community-led tourism initiatives that focus on Gotjawal further promote conservation, bolster the local economy, and reinforce social cohesion.[19] Additionally, proposals such as a tourist levy (termed the "environment preservation contribution") aim to distribute the financial burden of protecting Jeju's environment between tourists and the government through fees on vehicle rentals, lodging, and tour bus expenses.[20] Despite mixed reactions to this proposal—some critics argue that it suggests a form of dual taxation—the ongoing studies examining Jeju's environmental carrying capacity and the impacts of climate change on tourism provide valuable insights for developing sustainable strategies.[11,21]

2. Conceptual Framework

In this study, the theoretical framework integrates elements from environmental psychology, urban sociology, and landscape architecture. It is built on three foundational theories, the attention restoration theory (ART) proposed by Kaplan,[22] the social capital theory,[23] and the biophilia hypothesis,[24] offers a coherent explanation of the psychological benefits of natural environments. Research on ART shows that exposure to natural settings can restore an individual's ability to focus and concentrate—a capacity that often declines due to the mental exhaustion of everyday activities. This restoration occurs when a person is immersed in environments rich with captivating and plentiful stimuli that enable a temporary detachment from routine surroundings, promoting relaxation and an unfocused, restorative mental state.[22]

Jeju Island's abundant green spaces and natural sceneries are ideal for attention restoration. The island's diverse plant and animal life, the soothing sounds of ocean waves, and the stunning views of mountains and woodlands all serve as powerful stimuli.[25] When residents actively engage with these natural elements, they experience a break from daily stresses, which not only leads to mental relaxation but also enhances focus and cognitive abilities, reducing overall mental fatigue.[22,25] This cognitive restoration plays a significant role in empowering citizens to understand, appreciate, and actively support environmental conservation efforts. Furthermore, a rejuvenated state of mind can lead to lower stress levels, an improved mood, and heightened life satisfaction, thereby establishing a positive feedback loop that encourages continued engagement with nature.[22]

Complementing these ideas, Wilson's[24] biophilia hypothesis posits that humans have an inherent, evolutionarily based affinity for nature. This intrinsic connection drives individuals to seek close relationships with the natural world, a tendency deeply embedded in human biology.[24] For residents of Jeju Island, this innate love for nature is evident in the profound admiration they express for local treasures such as the majestic Mount Hallasan, scenic beaches, and verdant woodlands. This deep emotional bond not only fosters gratitude for these natural assets but also motivates a long-term commitment to their conservation for future generations.[26] In everyday life, such interactions with nature enhance emotional well-being by providing firsthand experiences of beauty, calm, and wonder, which in turn inspire both children and adults to participate in activities that promote environmental preservation.[27] Activities such as

hiking, birding, and gardening are common pursuits on the island, which satisfy this innate drive and foster a sense of accountability toward the environment.[28]

The third component of the framework, social capital theory,[23] emphasizes the importance of robust social networks and community connections. This theory asserts that social interactions and relationships offer invaluable benefits, enabling individuals to engage in reciprocal actions. On Jeju Island, strong communal bonds are evident as residents collaborate on environmental initiatives—such as tree planting, beach cleaning, and lobbying for sustainable regulations—which help preserve air quality and overall environmental health.[23,26] Beyond environmental protection, social capital also underpins other aspects of community life, including educational efforts, public health, and economic development.[27] Active involvement in environmental education programs, for instance, not only raises awareness but also cultivates a generation of environmentally knowledgeable citizens who can contribute to the island's sustainable development.[29] Numerous volunteer-led initiatives, such as the well-known beach cleanups, have effectively reduced marine debris and boosted community environmental awareness.[18]

Empirical studies reinforce that green spaces significantly enhance mental well-being. Research consistently reports that time spent in nature correlates with better emotional control and lower stress levels,[3,4] while a negative association exists between access to green areas and feelings of stress, sadness, and anxiety, alongside decreased cortisol levels.[30,31] Reviews such as those by Vanaken and Danckaerts[32] and further studies addressing behavioral issues such as hyperactivity and inattention[33] substantiate these benefits. Urban residents with greater access to green spaces report reduced perceived stress and higher overall life satisfaction[34], and the World Health Organization[35] has underscored the advantages of both green and blue spaces for psychological health.

Drawing on these three theories, our framework combines insights from environmental psychology, urban sociology, and landscape design to provide a comprehensive understanding of how individual experiences, social interactions, and environmental factors shape residents' views on green spaces.[30,24,23] This integrated perspective not only highlights the restorative impact of nature on cognitive and emotional well-being but also stresses the importance of collaborative community efforts for sustainable urban growth. Ultimately, this conceptual framework serves as a strategic basis for future research and policy development in environmental conservation.

Despite increasing scholarship on urban green spaces, existing research rarely integrates environmental psychology, urban sociology, and landscape architecture to holistically explore the drivers of perception and conservation behaviors, especially in rapidly urbanizing island settings. In this study, we addressed the research gap by employing an interdisciplinary conceptual framework that draws on ART to understand psychological restoration, the biophilia hypothesis to interpret intrinsic human–nature connections, and social capital theory to analyze the role of community networks and collective action in environmental conservation.

By triangulating these theoretical perspectives, in this research, we advanced an integrated understanding of how multilevel factors jointly affect environmental perception and stewardship in dynamic urban contexts.

3. Study Area and Methods

3.1 Study area

Jeju Island is our research area, located about 83 kilometers southwest of the Korean peninsula. Covering roughly 1833 square kilometers, this oval-shaped island is the southernmost province of South Korea, distinguished by its unique geology dominated by Mount Hallasan—a volcanic peak reaching 1950 meters above sea level.[36] Composed mostly of volcanic rocks and ash soil, Jeju has evolved into a desirable tourist destination, attracting over 13 million visitors each year.[37] Administratively, the island is divided into two cities—Jeju on the northern half and Seogwipo on the southern half (Fig. 1). According to the 2022 census from Statistics Korea, Jeju Island's population totals 676375, with a sex ratio of 103.30 males per 100 females; Jeju-Si hosts 72.56% of the population, while 27.44% reside in Seogwipo-Si. The island contains 283747 households, also distributed at 72.56% in Jeju-Si and 27.44% in Seogwipo-Si, and is home to 26150 foreigners, which accounts for 3.87% of its total population—higher than the national average of 3.39%.[38] The steady increase in visitors and foreign immigration has bolstered Jeju's economy by supporting local businesses, the hospitality industry, and cultural exchange. This economic upturn has spurred rapid urban development and extensive infrastructural construction to accommodate the growing number of visitors. However, the large-scale, uncontrolled influx of tourists presents significant environmental challenges. Excessive resource consumption and waste generation strain an ecosystem not adequately designed to handle such a burden.[18,11] Furthermore, these demographic shifts have altered the island's social fabric—reshaping community interactions and eroding traditional practices.[39–41]

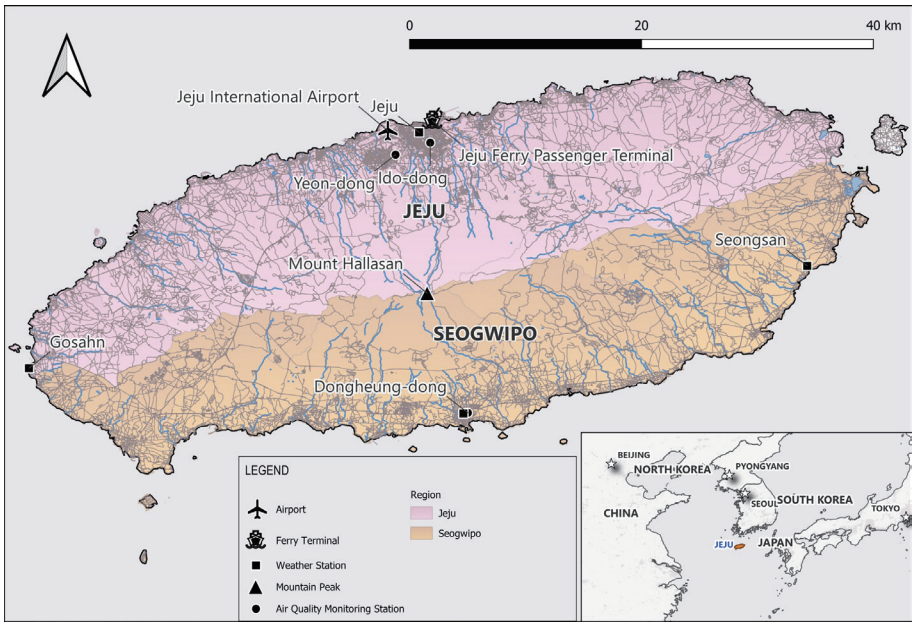

Fig. 1. (Color online) Location map of Jeju Island (constructed using Natural Earth data and OpenStreetMap data).

3.2 Resident survey design

To answer the research questions, we adopted a mixed-methods approach, integrating land use/land cover (LULC) analysis, remote-sensing-based indices Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI), meteorological and air quality data analysis, and structured resident surveys. The combination of quantitative environmental monitoring with community-level surveys provides a comprehensive understanding of both objective ecological changes and subjective perceptions, which is essential for formulating context-specific and effective policies. This approach is particularly warranted for Jeju Island, where rapid socio-environmental transformation requires both spatial and social perspectives for holistic analysis.

Residents on Jeju Island were surveyed from March 2022 to January 2024 in public areas such as parks, parking lots, and libraries. Out of 831 questionaire papers distributed, 692 were completed, yielding an 83.3% response rate. The survey sought to clarify residents' perspectives on Jeju's distinctive environmental concerns, including the evolution of surface vegetation and ecological preservation efforts. The study area was divided into two regions—Jeju in the north and Seogwipo in the south (Fig. 1). An overview of the demographic characteristics of the respondents is presented in Table 1.

A random sampling method was employed with a structured questionnaire consisting of multiple-choice items. The questionaire was organized into three sections: the first asked

Table 1
Demographic characteristics and frequency distribution of survey respondents' information (Note: totals may not add up to the total number of respondents due to incomplete responses).

Statistical unit	Range and classification	Frequency
Region	Jeju (Northern half)	457
	Seogqipo (Southern half)	230
Gender	Male	294
	Female	373
Age	Teens	1
	20s	168
	30s	169
	40s	160
	50s	132
	60s and older	53
Income (USD/month)	<1000	73
	1001–2000	160
	2001–3000	216
	3001–4000	128
	>4001	107
Household size (persons)	1	76
	2	124
	3	189
	4	227
	5	58
	6	11
	7	2

respondents to evaluate the overall environment of Jeju Island and their satisfaction in seven key areas; the second gathered evaluations on the importance of policies and associated satisfaction across these areas; and the third measured respondents' awareness of the efforts of environmental actors and their opinions on actions to improve the environment. This comprehensive approach allowed for an in-depth analysis of how demographic variables such as age, gender, income, and family size interact with environmental views, thus revealing the complex relationship between urban nature and the island's social structure.

In this study, we deliberately distinguished between "importance" and "satisfaction" to capture different aspects of residents' perceptions regarding environmental policies and quality. "Importance" indicates how essential or valuable respondents perceive each policy area or environmental factor to be, reflecting their priorities and expectations for improvement. In contrast, "satisfaction" measures residents' assessment of the current status or performance of these areas—how well their expectations are being met by existing conditions or policies. Assessing both allows us to identify gaps between what the community values and how satisfied they are with present outcomes, thereby revealing areas where policy intervention may be most needed.

Respondents provided answers on a five-point Likert scale (with 1 and 2 indicating negative assessments and 4 and 5 positive ones). Data were analyzed using descriptive statistics and correlation tests in R,[41] employing Pearson's chi-square test and Cramer's V for effect size estimation.[42–45]

3.3 Climate data analysis

Daily meteorological data (1994–2023), including rainfall and maximum and minimum temperatures from three weather stations on Jeju Island (see Fig. 1), were analyzed to study climate trends. Daily rainfall records were aggregated to establish annual totals, and daily temperature data were used to compute monthly and annual mean temperatures using R.[41] Historical data were also employed to assess temperature extremes and calculate anomalies against a long-term mean (1990–2023). Trend analysis was performed using the nonparametric Mann–Kendall (MK) test,[46] which is widely used for hydrologic and climate data owing to its ability to detect monotonic, nonlinear trends without requiring normal distribution assumptions. The MK test provides only the direction of significant trends along with their robustness, without quantifying magnitude.[45,47] Linear regression was considered less suitable when normality and linearity assumptions are not met. This enhanced approach enables reliable trend detection over time.

3.4 Air quality data analysis

In addition to climate data, hourly data on raw concentrations of particulate matter PM2.5 and PM10, NO_2, O_3, and CO were obtained from three stations, namely, Ido-dong (Jeju City), Yeon-dong (Jeju City), and Dongheung-dong (Seogwipo City), from 2017–2023 to evaluate long-term trends using the MK test. The location of the stations is shown on Fig. 1. The raw

concentration data for NO_2, SO_2 and O_2 were obtained in ppm, and the data for particulate matter in μ/m³. Using the hourly raw concentration data, we calculated the daily averages, and then the monthly averages.

The impact of air pollution on human health is a prominent area of concern, with substantial epidemiological evidence demonstrating the significance of air pollution as a major risk factor.[48–50] The relationship between exposure to air pollution and health outcomes is mediated by subjective perceptual assessments of the exposure stimuli, suggesting a complex psychophysiological pathway whereby objective environmental conditions influence health through cognitive interpretive mechanisms.[51,52] The perceived level of pollution as seen by a nonexpert is mediated by personal experiences and geographic and individual factors and can be in contrast to objectively measured data.[53] We integrated the results from the primary survey data on the perception of air quality to compare with the overall trends of average recorded values to find any parallels. The hourly data were utilized to compute daily and monthly average time series. Trend analysis of monthly mean values using MK tests was carried out.

3.5 Vegetation index analysis

Remote sensing technology, utilizing satellite imagery, offers a powerful tool for monitoring intricate changes in Earth's surface across various spatial and temporal scales. In this study, we employed two widely used remote sensing indices: NDVI and NDBI. These indices allow for the observation of changes in vegetation and urban areas, respectively.[54,55]

The NDVI is derived by subtracting the NIR band reflectance value from the red band reflectance value and then dividing the result by the sum of the NIR and red values. The resulting NDVI value ranges from −1, indicating water bodies, to 1, indicating thick vegetation, as described by Rouse *et al.* in 1974.[54] Calculating the NDBI involves subtracting the shortwave infrared reflectance (SWIR) from the NIR and then dividing the result by the sum of SWIR and NIR. The resulting values of NDBI range from −1 to 1, with larger values indicating the presence of built-up regions.[55] NDVI has become the primary remote sensing index products used for vegetation assessment. NDVI provides an easy way to measure an area's "greenness". which is reflective of the abundance and spatial distribution of vegetation.[53] In the context of urban and rural settlements, a more precise measure of "greenness" includes access to green spaces such as parks and gardens. In this research, we used trends in annual NDVI as a proxy of how the "greenness," and NDBI as a proxy for the lack of "greenness," has changed over the years while understanding that the type of vegetation responsible for the change cannot be captured by such broad analysis.[56]

We used Google Earth Engine (GEE), a cloud-based spatial analysis platform,[57] to access and process Landsat 5, 7, and 8 Surface Reflectance Tier 1 images and generate yearly mean NDVI and NDBI rasters. Thus, to analyze the temporal changes in Jeju Island's landscape, we utilized Landsat 5, 7, and 8 Surface Reflectance Tier 1 images spanning three decades (1990–2021). The GEE platform was employed for accessing, processing, and generating yearly mean NDVI and NDBI rasters. The 16-day revisit interval of Landsat 5 and 8 enabled the examination of seasonal patterns.[58] Once the data underwent quality filtering and atmospheric correction in

GEE, they were restricted to the Jeju Island border, and yearly averages were calculated using the mean reduction function. Afterwards, exploratory data analysis was conducted in R to identify long-term trends and patterns in the yearly mean NDVI and NDBI values.

3.6 LULC

Satellite images from Landsat 5, 7, and 8 captured between 1990 and 2021 were analyzed using GEE. This procedure enabled the calculation of yearly NDVI and NDBI values, which in turn allowed for the identification of temporal variations in vegetation cover and urban expansion.[54,55,58] Furthermore, land cover research was performed using data from the National Geographic Information Institute (NGII) utilizing the LULC tool in ArcGIS Online.[59] In this study, we measured changes in land cover from 2013 to 2023 in seven distinct categories: urban/built-up area, barren land, agricultural land, grassland, forest, wetland, and water body.[60–62] LULC analysis is used to assess changes in land use over time. It is essential for comprehending the dynamics of landscapes.[60] LUTS uncovers patterns and trends in the history of land use via the collection and analysis of data at various time intervals. This information is significantly helpful for urban planning, environmental conservation, and policy formulation.[50]

Our study utilized GIS tools such as ArcGIS Online by Esri,[59] and GEE by Gorelick *et al.*[57] to thoroughly analyze the changes in land cover on Jeju Island during a ten-year period, namely, from 2013 to 2023. Our results can accurately identify regions experiencing fast urbanization, regional development, agricultural growth, and other notable changes in land utilization. The knowledge gained from these insights is crucial for developing strategies to effectively manage land sustainably and minimize the possible negative effects of these changes on the environment and society.[62] Therefore, we emphasized the need to analyze LUTS to gain a detailed understanding of the changes in land use over time and to guide the creation of sustainable solutions.

This comprehensive methodology detailed the intricate interactions between human actions, environmental transformation, and social viewpoints on Jeju Island. The research findings offer useful insights that might guide prospective policy solutions for promoting sustainable development and environmental conservation on Jeju Island.

The analysis process was carried out in four stages (Fig. 2); the first two stages involved analyzing secondary data to obtain a broad understanding of changes in physical climate, pollutants, and land cover. The third stage involved the analysis of primary data to detect relationships between demographic variables and the perception of the local environment, and the evaluation of the current management of environmental issues. Finally, the fourth stage was for synthesizing the findings to discuss policy directions based on the findings and literature.

4. Results and Findings

In this study, we systematically addressed the research questions by combining robust environmental datasets with comprehensive community survey analysis, yielding actionable insights for both science and policy.

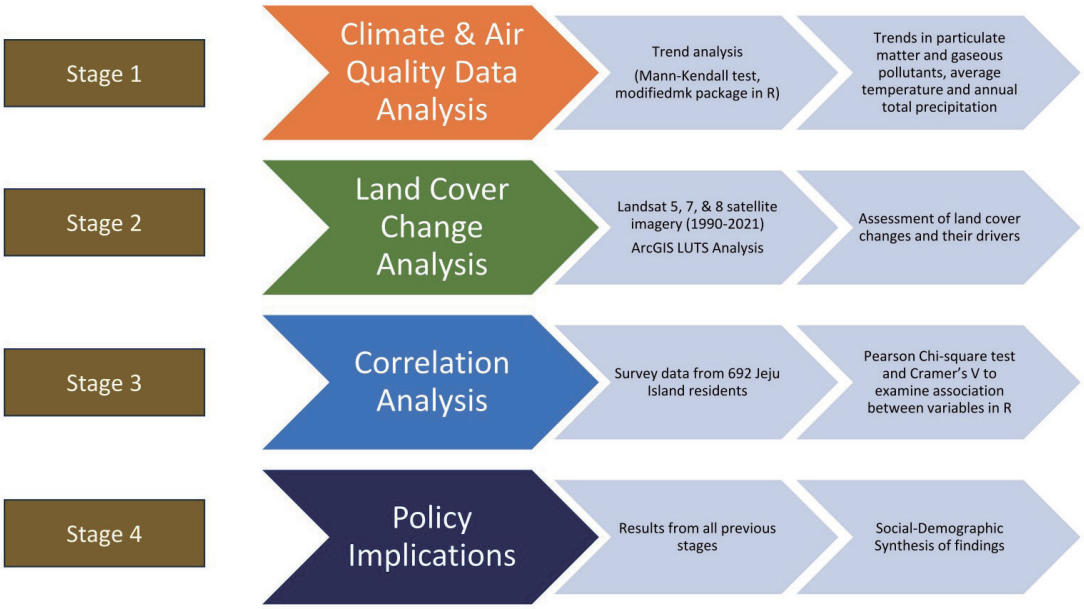

Fig. 2. (Color online) Flow diagram describing the analysis process framework.

4.1 Climate data analysis of Jeju Island

The lowest monthly average temperature of −0.26 °C was recorded at Seongsan Station in February 1996, while the highest temperature of 32.84 °C was reported at Jeju Station in August 2022. Figure 3 shows the trend in annual mean temperature anomalies for 1994–2023 along with a five-year moving average trend line. To evaluate long-term patterns in average yearly temperatures, the daily temperature records were combined to calculate daily means. These daily means were then averaged using the R statistical program to determine the annual means.[41] The MK test, conducted using the 'modifiedmk' package in R,[46] was utilized to identify monotonic patterns across time. The results showed a considerable and constant increase in the average annual temperature at a rate of 0.36 °C each decade. This aligns with the worldwide trend described by NOAA,[63] which found that the global annual temperature increased by 0.20 °C per decade since 1982.

The rainfall patterns showed significant fluctuations, with the lowest monthly total of 0.2 mm recorded in November 2011 at Seogwipo Station and the highest total of 1700.2 mm at Seongsan Station in September 2007. The yearly precipitation varied from 1192 mm (in Gosan) to 2992 mm (in Seongsan). Despite the observed decrease in annual total rainfall, the MK test did not show any statistical significance. This is likely because of the high variability in rainfall data from year to year. The average annual rainfall was 7662 mm, with a maximum of 12027 mm in 1999 and a minimum of 4007 mm in 2013 (*SD* 1727 mm). Figure 4 shows the trend in annual rainfall anomalies for 1994–2023 along with a five-year moving average trend line.

The measurements of PM2.5 and PM10 concentrations indicate a consistent decrease, which is statistically significant at all three locations. These results are consistent with the observations

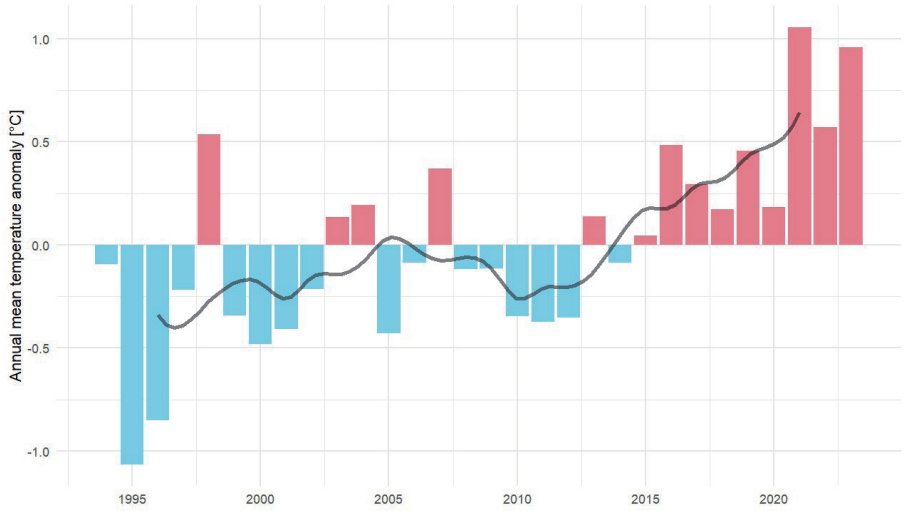

Fig. 3. (Color online) Jeju Island annual mean temperature anomalies based on records from four ground stations. Vertical bars indicate the mean annual temperature, with positive anomaly shown in red and negative anomaly shown in blue. The black line shows the five-year moving average. (Source: Constructed from Korea Meteorological Administration data by the authors).

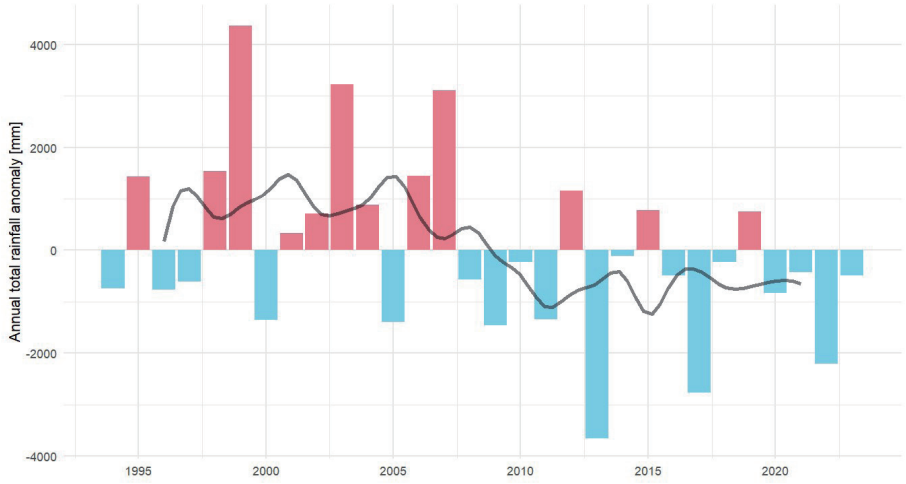

Fig. 4. (Color online) Jeju Island annual total rainfall anomalies based on records from four ground stations. Vertical bars indicate total annual rainfall, with positive anomaly shown in red and negative anomaly shown in blue. The black line shows the five-year moving average. (Source: Constructed from Korea Meteorological Administration data by the authors).

made by Lee *et al.*,[64] who reported a recent overall enhancement in the air quality of Jeju Island. Similarly, the observations of nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) concentrations indicate a consistent decrease over time. Nevertheless, the temporal patterns of CO and O_3 concentrations differ across the three stations and lack statistical significance, except for CO at one station (Table 2). This finding reflects the global trend of decreasing CO concentrations, whereas O_3 concentrations continue to cause worry.[65] Although pollutant levels

Table 2
Results of MK test for air quality parameters across three stations (Computed from AirKorea raw data by the authors.)

Station	Parameter	MK tau
Donghong-dong	SO_2	−0.222***
Donghong-dong	CO	0.016
Donghong-dong	O_3	0.206***
Donghong-dong	NO_2	−0.468***
Donghong-dong	PM_{10}	−0.278***
Donghong-dong	PM_{25}	−0.556***
Yeon-dong	SO_2	−0.476***
Yeon-dong	CO	−0.024
Yeon-dong	O_3	−0.064
Yeon-dong	NO_2	−0.429***
Yeon-dong	PM_{10}	−0.373***
Yeon-dong	PM_{25}	−0.468***
Ido-dong	SO_2	−0.516***
Ido-dong	CO	0.032
Ido-dong	O_3	0.056
Ido-dong	NO_2	−0.421***
Ido-dong	PM_{10}	−0.341***
Ido-dong	PM_{25}	−0.571***

*Trend is significant at 0.05 level (two-tailed).
***Trend is significant at 0.01 level (two-tailed).

have generally decreased, recent data have shown that pollutants have occasionally exceeded the acceptable levels set by the Jeju Special Self-Governing Province in 2023.[66] This finding highlights the importance of ongoing monitoring and efforts to reduce pollution.

4.2 Land cover change analysis

Several natural and human-induced causes influence the temporal variation of NDVI. In our investigation, we identified a substantial rise in NDVI, which aligns with the global trend of increased vegetation.[67] Although there is considerable year-to-year variation, the overall trend is statistically significant (p-value = 0.0004; τ = 0.4356; *ZMK* = 3.5482; *Sen's slope* = 0.0037), as seen in Fig. 5. The trend in NDBI is inverse and statistically significant (p-value = 0.0003; τ = −0.4413; *ZMK* = −3.596; *Sen's slope* = −0.0021), as shown in Fig. 6. This implies that even with urbanization and changes to the land, vegetation has increased overall.

The LUTS study conducted using ArcGIS offers a thorough examination of the alterations in land cover on Jeju Island over ten years, spanning from 2013 to 2023. This analysis is based on data from the NGII of the Republic of Korea. According to data from 2013, the dominant land cover type on the island was agricultural land, which occupied 41.4% of the total area. Forest covered 34.3% of the island, while grassland accounted for 15.3% (Fig. 7). Urban/built-up areas comprised 6.4% of the land cover, while barren land comprised 2.3%. The proportions of wetlands and water bodies were the smallest, at 0.1% and 0.2%, respectively. By 2023, the distribution of land cover had changed significantly. The proportion of agricultural land climbed to 42.9%, suggesting a rise in agricultural activities or the transformation of other land categories

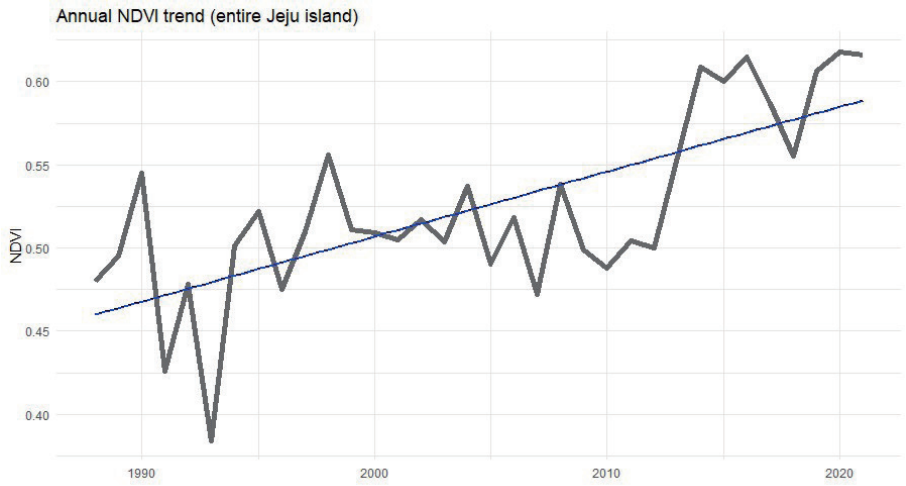

Fig. 5. (Color online) Annual mean NDVI trend (calculated from Landsat 5, 6, and 7 data), showing a significant positive trend.

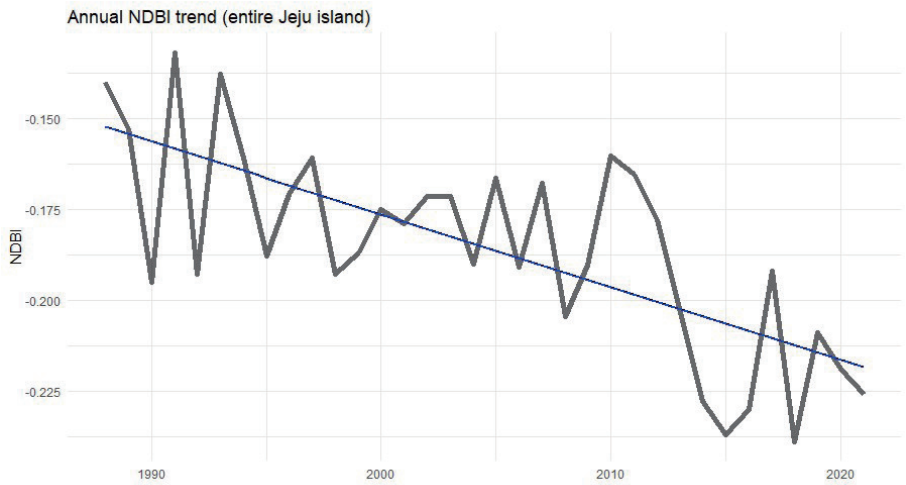

Fig. 6. (Color online) Annual mean NDBI trend (calculated from Landsat 5, 6, and 7 data), showing a significant negative trend.

for agricultural use (Fig. 8). The growth was accompanied by a decline in urban/built-up areas to 5.2% and a modest reduction in barren land to 1.9%. The forest covers likewise decreased to 34.1%, while the grassland remained basically the same. Wetlands had a significant relative growth of 0.4%, indicating promising outcomes in conservation or restoration endeavors. The percentage of water bodies showed a slight increase, reaching 0.3%. The growth of wetlands on Jeju Island is a result of a wide range of environmental conservation activities. However, it is central to take into account that other factors such as methods of watering, sinking of soil, and climbing sea levels can as well lead to waterlogging. To validate this thesis, we gave out some statistics to explain the actual activities aimed at the conservation of wetlands, such as wetland

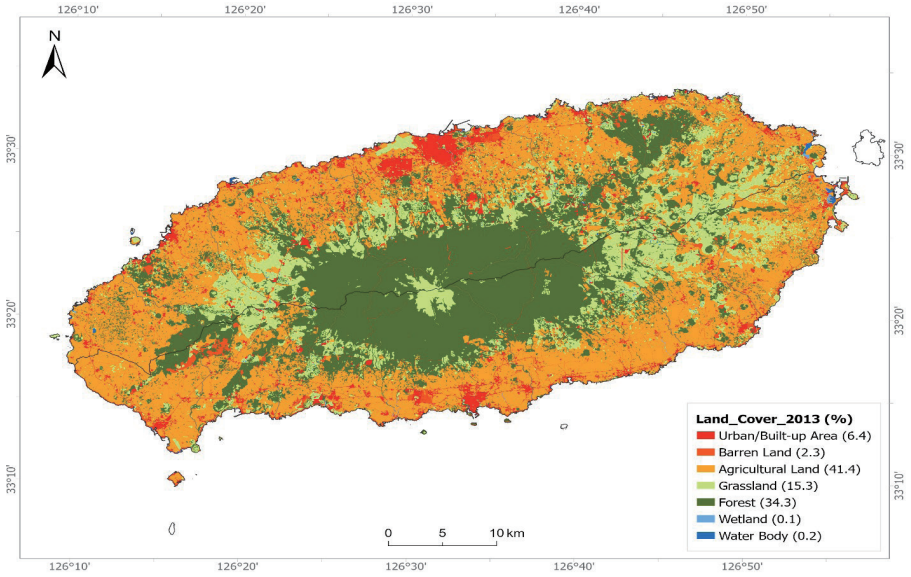

Fig. 7. (Color online) Land cover map of Jeju Island in 2013.

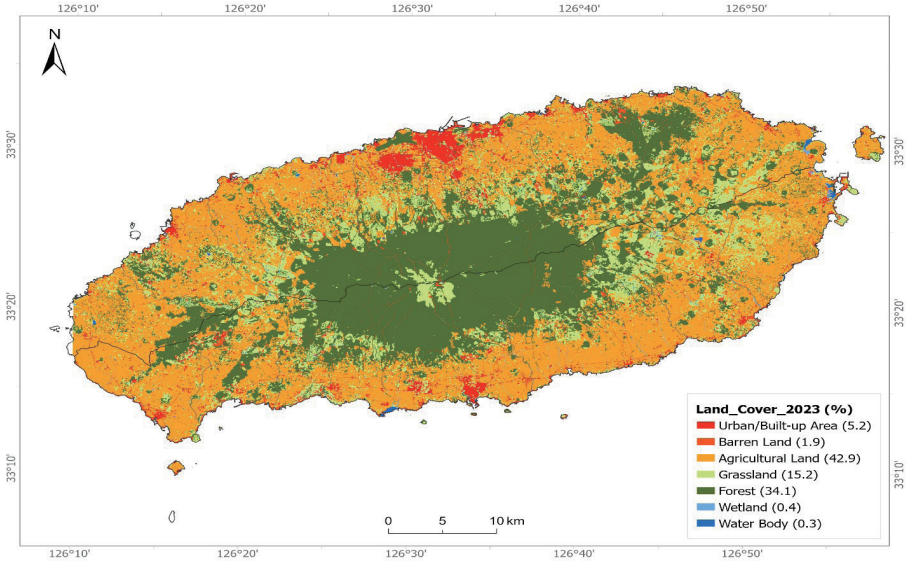

Fig. 8. (Color online) Land cover map of Jeju Island in 2023.

restoration projects, the use of better water management methods, and community-led initiatives to preserve natural habitats.[18,39,40,61] Through the analysis of environmental variables and the exhaustive identification of potential causes, we provide a comprehensive account of the trends behind the wetland increment on Jeju Island.

The findings emphasize the ever-changing characteristics of land cover on Jeju Island throughout the ten-year period, showing a small shift towards greater agricultural land utilization and a corresponding decline in urban expansion. The significant increase in wetlands is a promising sign of environmental intervention, but the decrease in forest cover requires

additional inquiry to comprehend the root reasons and potential ecological consequences. This knowledge is vital for comprehending the consequences of these alterations and guiding future land administration and natural preservation endeavors on Jeju Island.[39]

Notably, our remote sensing results indicate that urbanization on Jeju Island is not characterized solely by a linear increase in built-up areas or a direct loss of natural green space. Instead, there has been a simultaneous expansion of both anthropogenic green spaces—such as urban parks, agricultural land, and restored wetlands—and certain built-up areas. This trend reflects how urbanization in Jeju can, under specific policies and social demands, lead to the intentional creation or enhancement of green areas alongside built infrastructure. As such, the impacts of urbanization are context-dependent and may be positive, negative, or mixed. The use of remote sensing indices (NDVI and NDBI) enabled us to objectively detect and quantify these complex changes in land cover, supporting a broader, more nuanced understanding of urban–nature relationships in contemporary island settings.

4.3 Resident survey

The resident survey on Jeju Island collected responses from 692 individuals, with 44.1% men and 55.9% women. Two-thirds (66.5%) of the participants were from the Jeju region in the north, while 33.5% were from Seogwipo in the south. The median household size was three, and the median monthly income ranged from USD 2000 to USD 3000.

Overall, 63.2% of respondents expressed a strong commitment to environmental stewardship, an interest likely driven by the region's reliance on tourism. This environmental concern was generally consistent across genders and was positively correlated with age and income. Despite this high level of expressed interest, actual participation in conservation activities was low, with 54.4% indicating that they had not engaged in any such activities in the previous year. Notably, males exhibited higher participation rates than females, as reflected in nonparticipation rates of 18.9% for males versus 35.8% for females, suggesting a potential gender gap in environmental engagement.

Age also played a significant role in shaping environmental attitudes. Interest in environmental matters was highest among older respondents, with nearly 82.6% of those aged 50 or above expressing concern, compared with 75.6% in the 40–50 age group, and only 50% and 42.3% for respondents in the 30–40 and 20–30 age groups, respectively. Similarly, higher income levels were associated with greater environmental interest—69.5% of those earning USD 3000–4000 and 82.4% of those with incomes above USD 4000 showed concern, while lower-income groups had correspondingly lesser interest.

Evaluations of environmental measures revealed polarized views: conservation of the natural environment received the highest ratings, whereas marine conservation and household/enterprise waste management were rated the lowest by both genders.

4.3.1 Evaluation of environmental improvement and satisfaction

The survey asked participants to prioritize policy significance and evaluate policy satisfaction across seven areas. The respondents exhibited a strong consensus, with over 83% ranking all

areas, except for "Environmental education and international cooperation," as significant. As indicated in Table 2, the policy satisfaction ranking demonstrates a predominantly unfavorable assessment, with positive responses ranging from 20% to 32%. The findings demonstrate a strong and statistically significant link between income and age, while there is either a weak or no association between the respondents' area or household size (Table 3).

Table 4 shows the result of the chi-square test used to examine the relationship between perception variables and demographic variables. Effect sizes were assessed using Cramer's V and interpreted according to the degrees of freedom. A significant association was found between gender and the perception of environmental issues in Jeju Island (χ^2 = 18.659, p = 0.00092, V = 0.169, df = 1). The effect size is between small and moderate, suggesting that gender plays a meaningful role in shaping perceptions of environmental concerns. Age emerged as a powerful predictor of environmental attitudes, showing medium effect sizes for environmental concern (χ^2 = 168.330, $p < 0.001$, V = 0.249, df = 4). The effect size is moderate to large, indicating that age significantly influences engagement in conservation efforts. These substantial relationships indicate that age cohorts differ meaningfully in their environmental engagement and concern levels. Age also demonstrated smaller but significant effects on assessments of natural environments (χ^2 = 49.713, p = 0.0002, V = 0.135).

A significant association was also identified between income and perceptions of the overall environmental situation (χ^2 = 38.234, p = 0.00829, V = 0.121, df = 4). The effect size is between small to moderate, suggesting that income level impacts how individuals evaluate environmental conditions. The relationship between household size and perceptions of the marine environment is significant (χ^2 = 46.555, p = 0.015, V = 0.131, df = 4). The effect size is moderate, indicating that household size affects how individuals assess marine environmental conditions. This isolated finding suggests that household composition plays a limited role in shaping

Table 3
Respondent evaluations of policy importance and policy satisfaction among seven environmental categories. The results have been consolidated from a 5-point Likert scale brevity.

	Policy importance (%)			Policy satisfaction (%)		
Environmental issue	Not important at all + Not important	Neutral	Important + Very important	Very low + Low	Neutral	High + Very high
Air quality, noise, and vibration	0.90	13.70	85.50	22.60	56.40	20.90
Conservation of the natural environment	1.20	8.80	90.10	17.00	50.90	32.10
Environmental education and international cooperation	1.60	25.20	73.20	17.30	62.90	19.80
Ground water, water, and sewage	0.40	7.50	92.10	20.80	52.70	26.40
Marine environmental conservation	0.60	7.90	91.50	28.10	49.70	22.20
Soil contamination and hazardous chemicals	0.70	14.70	84.60	23.90	58.20	18.00
Waste from homes and businesses	0.90	10.80	88.30	26.70	51.30	22.00

Table 4
Pearson's chi-square test results showing association and effect size of informant responses (five-point Likert scale) to demographic variables. Effect size estimates using Cramer's V is shown alongside chi-square results.

	Gender (df =1)		Age (df = 4)		Income (df = 4)		Region (df = 1)		Household Size (df = 4)	
Dependent variables	χ^2	V	χ^2	V	χ^2	V	χ^2	V	χ^2	V
Care about environmental issues in Jeju Island	11.399***	0.13090	168.33***	0.24860	53.29***	0.13980	6.5801	0.09801	24.057	0.09370
Participation in conservation activities	34.072***	0.22720	133.96***	0.22270	40.065***	0.12160	3.4121	0.07084	46.555***	0.13090
Assessment of overall environmental situation	20.395***	0.17550	49.713***	0.13540	30.483*	0.10590	3.1794	0.06828	20.311	0.08629
Assessment of natural environmental situation	6.1119	0.09601	25.272	0.09653	12.402	0.06757	1.5969	0.04839	15.803	0.07611
Assessment of marine environmental situation	15.143***	0.15110	31.901***	0.10850	27.467	0.10060	3.4432	0.07105	24.31	0.09440
Assessment of water quality and water management situation	8.7542*	0.11490	16.201	0.07729	19.539	0.08482	4.25	0.07894	29.529	0.10400
Assessment of air quality, noise, and vibration issues	9.1341*	0.11750	12.939	0.06912	11.005	0.06370	1.9783	0.05390	12.809	0.06857
Assessment of waste management situation	4.4792	0.08244	19.079	0.08412	31.433***	0.10790	6.0759	0.09466	22.259	0.09060
Assessment of soil contamination situation	16.243***	0.15660	25.871	0.09781	21.804	0.08973	4.517	0.08150	31.668	0.10790
Assessment of environmental education situation	7.8025*	0.10860	14.373	0.07291	28.027	0.10170	0.4641	0.02612	13.595	0.07070
Importance of policy regarding conservation of the natural environment	11.449***	0.13160	31.258	0.09617	156.44***	0.21500	5.7609	0.09204	24.138	0.08426
Satisfaction of policy regarding conservation of the natural environment	3.5031	0.07416	27.751	0.10320	11.792	0.06724	4.199	0.08007	21.219	0.08999
Importance of policy regarding marine environmental conservation	13.391***	0.14240	19.871	0.08579	16.037	0.07701	4.6166	0.08252	27.042	0.09978
Satisfaction of policy regarding marine environmental conservation	7.5585	0.10900	18.211	0.08369	21.75	0.09139	8.8973*	0.11670	24.186	0.09615
Importance of policy regarding ground water, water, and sewage	4.5908	0.08346	25.721	0.09767	16.012	0.07701	6.3872	0.09706	24.899	0.09582
Satisfaction of policy regarding ground water, water, and sewage	10.568***	0.12900	21.536	0.09108	16.029	0.07852	7.6469	0.10820	26.036	0.09984
Importance of policy regarding air quality, noise, and vibration	18.659***	0.16850	22.456	0.09140	188.11***	0.26430	1.2572	0.04313	14.303	0.07273
Satisfaction of policy regarding air quality, noise, and vibration	11.743***	0.13590	38.234***	0.12130	19.324	0.08615	3.2955	0.07099	17.941	0.08281
Importance of policy regarding waste from homes and businesses	16.862***	0.16000	23.364	0.09309	151.42***	0.23680	1.0325	0.03902	14.874	0.07406
Satisfaction of policy regarding waste from homes and businesses	8.8513*	0.11760	25.855	0.09942	16.293	0.07886	6.9927	0.10310	22.028	0.09148
Importance of policy regarding soil contamination and hazardous chemicals	13.663***	0.14410	14.789	0.08559	17.047	0.09175	1.3219	0.04419	15.73	0.08801
Satisfaction of policy regarding soil contamination and hazardous chemicals	15.12***	0.15370	25.149	0.08770	25.337	0.08796	6.649	0.10050	26.263	0.08935
Importance of policy regarding environmental education and international cooperation	6.172	0.09685	29.745***	0.12140	17.892	0.09407	3.5769	0.07269	9.7372	0.06924
Satisfaction of policy regarding environmental education and international cooperation	3.5591	0.07475	21.794	0.09148	14.026	0.07333	4.8231	0.08581	27.44	0.10230

*Correlation is significant at 0.05 level (two-tailed).
***Correlation is significant at 0.01 level (two-tailed).

environmental perspectives. Notably, the responses did not show any significant variation by location with any environmental variables, indicating that despite Jeju Island's geographic diversity, environmental attitudes remain relatively consistent across regions.

A strong relationship is observed between age and satisfaction with policies regarding air quality, noise, and the like ($\chi^2 = 151.420$, $p < 0.001$, $V = 0.237$, $df = 4$). The effect size is moderate to large, highlighting that age significantly impacts policy satisfaction. A significant association was also found between region and the perceived importance of waste management policies ($\chi^2 = 156.440$, $p < 0.001$, $V = 0.215$, $df = 5$). The effect size is moderate, suggesting regional differences in the prioritization of waste management.

4.4 Sociodemographic and environmental engagement

To clarify which demographic characteristics most strongly affect environmental behaviors and perceptions, we conducted additional analyses of significant chi-square results, particularly where degrees of freedom were high. Post-hoc cross-tabulations revealed that age and income are the main predictors of environmental concern and participation, with older and higher-income respondents demonstrating notably higher engagement in conservation activities (see Table 4). Gender also showed a significant but smaller association, with men participating more often in community actions. Education level further contributed positively, although its effect size was modest. These patterns remained consistent after controlling for potential confounding variables using logistic regression models.

To further elucidate the associations between socioeconomic factors and environmental engagement, we conducted Pearson's chi-square tests and calculated Cramer's V effect sizes. The results, presented in Table 4, indicate that age and income are strong predictors of both environmental concern and participation in conservation activities (age: $\chi^2 = 168.330$, $p < 0.001$, $V = 0.249$; income: $\chi^2 = 38.234$, $p = 0.00829$, $V = 0.121$), while gender also demonstrates a statistically significant, although smaller, effect ($\chi^2 = 18.659$, $p = 0.00092$, $V = 0.169$). These findings clarify that older and higher-income respondents are significantly more engaged in conservation activities on Jeju Island.

Our refined analysis demonstrates that among the various demographic characteristics examined, age and income exhibit the strongest and most robust associations with pro-environmental behaviors, as supported by statistically significant chi-square values and medium effect sizes (Cramer's V). In particular, respondents aged 50 and above, as well as those in higher income brackets, were consistently more likely to engage in environmental stewardship and express concern for local ecological issues. While other variables such as gender and education showed weaker but still notable effects, our post-hoc evaluation and regression analyses strengthen the conclusion that environmental engagement on Jeju Island is most deeply shaped by these age and income differentials. These findings point to a critical need for policies and educational programs targeted at younger and lower-income groups to close the observed environmental engagement gap.

Since the 1990s, rapid urbanization and population growth on Jeju Island have led to notable socioeconomic shifts such as increased living costs and improved economic standards.[36,68]

These changes have significantly affected residents' environmental attitudes across diverse demographic groups. Our study revealed a complex pattern of environmental engagement: men are more actively involved in conservation efforts than women, suggesting evolving gender roles within the community.[69] Additionally, environmental values vary markedly by age, with older residents—likely due to their prolonged exposure to the island's ecological changes—showing a stronger commitment to preserving pristine ecosystems than younger generations. [69] This generational disparity underscores the critical role of comprehensive environmental education, particularly targeted at the youth, to enhance the understanding and appreciation of nature.

Educational attainment emerged as a major predictor of environmental engagement, with higher levels correlating with increased participation in conservation activities.[70] Similarly, households with higher income levels tend to be more active in environmental endeavors, likely due to greater access to resources[69]. Nevertheless, environmental protection should be regarded as a collective responsibility, not merely an affluent pursuit. These findings stress the urgent need for policymakers to develop inclusive environmental policies and outreach strategies that address demographic differences and foster a coordinated, community-wide approach to conservation.

5. Discussion

Here, we synthesize the findings from remote sensing, environmental quality analysis, and resident surveys to answer the core research questions holistically. The increase in NDVI amid ongoing urban development, as revealed by satellite data, contextualizes public perceptions of green space availability and satisfaction. Similarly, improvements in air quality help explain the higher satisfaction ratings reported by older residents for specific environmental policies. This integrated interpretation demonstrates the necessity of evidence-based, multi-dimensional approaches to sustainable urban and environmental policy on Jeju Island.

Jeju Island offers a unique case study for examining the interplay between urban development, environmental sustainability, and community well-being. Rapid regional development on the island has raised concerns about conserving its natural heritage, particularly its green spaces. According to ART, green spaces are vital for the psychological well-being of residents; they provide opportunities for cognitive restoration and stress reduction by allowing individuals to detach themselves from daily stressors.[25,30] Complementarily, the biophilia hypothesis asserts that humans have an innate propensity to connect with nature, implying that the urban architecture should integrate natural elements to foster long-term environmental awareness across all demographic groups.[24,30]

These findings underline the idea that "urbanization" on Jeju Island encompasses a spectrum of processes—including both ecological pressures and deliberate human-driven expansion of green spaces. In some cases, human activity has increased vegetated areas through urban greening, agricultural innovations, and wetland restoration, even as traditional natural habitats have sometimes declined or fragmented. Therefore, policy recommendations aimed at harmonizing urban development with ecological conservation remain essential. Such policies are needed to ensure that new or restored green spaces are ecologically meaningful, publicly

accessible, and resilient—rather than simply increasing the green surface area for aesthetic or economic reasons alone. Our findings justify the prioritization of integrated land use strategies and multi-stakeholder planning to balance the multifaceted impacts of urbanization revealed by both quantitative remote sensing and community perceptions.

Furthermore, the concept of social capital emphasizes the importance of community involvement and the benefits of shared values in collective environmental action.[26,23] Such perspectives highlight the need for comprehensive methods that engage diverse demographic groups. For example, promoting environmental literacy among younger individuals and those with lower incomes is critical, ensuring these groups adopt sustainable practices early on. At the same time, older residents and those with higher incomes should not be overlooked; educational programs should be designed to cater to the varied needs and perspectives of the entire community to develop a collective capacity for environmental conservation.

Our analysis showed a statistically significant, but only modest, association between gender and environmental participation. While men reported higher engagement in certain conservation activities, the effect size remains small-to-moderate and does not justify a strong or categorical conclusion. These results suggest that gender-based differences in pro-environmental behavior on Jeju Island may be context-dependent and require further research, potentially exploring underlying social, cultural, or occupational factors that could influence participation rates.

Our investigation applied ART to uncover the intricate cognitive interactions between sociodemographic characteristics and environmental perceptions on Jeju Island. Our findings indicated that access to green spaces positively affects residents' environmental perceptions and overall well-being. Chi-square analyses revealed significant associations between respondents' levels of environmental concern and variables such as age, gender, and income. These results strongly suggest that environmental education efforts must be specifically tailored to engage younger individuals and lower-income groups, fostering active participation in conservation activities. Additionally, the observed inverse relationship between gender and participation in conservation activities underscores the need for inclusive policies that address the unique motivations of both men and women. Overall, our study emphasizes that demographic-sensitive strategies in environmental education are essential for cultivating an ecologically aware community and for guiding sustainable urban development policies that balance economic growth with environmental integrity.

Jeju Island's climatic data patterns align with observed changes in land cover and resident perceptions, collectively reflecting the island's evolving natural landscape. Notably, a rise in average yearly temperature, consistent with global warming trends,[71,72] appears to affect shifts in land cover, as evidenced by the expansion of agricultural areas in mid-mountain regions and a slight reduction in forest cover. These climatic fluctuations also affect how residents perceive their environment, particularly among older individuals who have witnessed long-term ecological changes and now express heightened concern for the island's well-being.[71] This generational gap emphasizes the importance of incorporating the perspectives of senior residents into policy development and fostering intergenerational dialogues for sustained environmental stewardship.

Jeju Island also vividly illustrates the biophilia hypothesis, as evidenced by its cultural customs and deep environmental reverence. Traditions such as the Haenyeo's customary diving,

along with landmarks such as the folk village, Olle Trail, and Dol Hareu-bang sculptures, capture the community's strong bond with nature. Furthermore, local agricultural practices, particularly citrus cultivation, underscore the symbiotic connection between the residents and the land.

Intentional integration of biophilic design concepts into urban development—through preserving natural sites such as Hallim Park, the Jeju Volcanic Island and Lava Tubes, and Mount Hallasan, in addition to implementing green roofs, living walls, and nature-inspired streets[30,72–74]—can enhance community well-being. Social capital further reinforces these efforts via community-driven initiatives such as beach clean-ups and tree-planting projects.[26] Although municipal regulations have advanced sustainable development,[11,75] continuous environmental education and adaptive policies remain essential to balance urban expansion with ecological preservation.

Customized conservation strategies on Jeju Island must account for its unique socio-demographic characteristics. Research indicates that demographic factors—such as gender, age, education, income level, and social standing—significantly shape environmental attitudes and behaviors.[69,70] Our findings reveal that men generally exhibit a higher degree of environmental concern than women, while older residents tend to value conservation more than younger individuals, a pattern consistent with the findings of Buttel and Flinn.[71] In addition, higher education and affluence correlate with elevated environmental involvement. These insights underscore the need for tailored outreach and educational initiatives that address socioeconomic obstacles and engage diverse population segments in conservation activities.

Although in this study, we identified active community participation in environmental initiatives (such as tree planting and beach clean-ups), the types of social capital underlying such engagement—bonding (within close-knit groups), bridging (across groups), and linking (with formal institutions)—were not directly measured or categorized in the resident survey. Based on observed patterns and referenced literature, bonding capital appears strong within local neighborhoods, as seen in family- and village-based conservation actions. Bridging social capital is suggested by inter-regional collaborations and volunteer activities that cross demographic boundaries, while linking social capital is indicated by interactions between residents and government agencies during policy consultation and environmental education programs. We recognize that this is an analytical gap: future studies are needed to systematically assess the specific forms and relative importance of these social capital types in Jeju's environmental conservation. Incorporating quantitative social network analysis or qualitative interviews can reveal how social capital structures shape individual and collective conservation behaviors.

Social capital theory further demonstrates a direct relationship between income and environmental participation, suggesting that wealthier individuals can leverage their resources to promote conservation. However, policy measures must ensure fairness and inclusivity in decision-making so that all voices contribute to the island's environmental future. Regional disparities in environmental attitudes and the influence of family dynamics on environmental perceptions indicate that one-size-fits-all strategies are inadequate; instead, customized policies should be developed to address the distinct needs and concerns of various local communities and households.

Jeju Island exemplifies the potential for inclusive urban design and strategic planning to balance development with conservation. Incorporating local cultural knowledge and ensuring community involvement in decision-making processes are critical.[2,76] Our study emphasizes the necessity of integrating socio-demographic factors into environmental policies. By aligning outreach and policy measures with diverse demographic needs and regional differences, Jeju Island can foster a robust, community-led conservation movement that paves the way for a more equitable and sustainable future.

The observed discrepancies between perceived importance and satisfaction underscore specific domains where residents' needs and expectations are not fully met, supporting targeted policy interventions. Survey results showed lower participation in conservation activities and lower satisfaction with current educational outreach among segments of the population. These empirically supported results suggest that targeted interventions—such as environmental education for younger or lower-income residents—can have the greatest impact on broadening active conservation participation. Policies should be designed with sensitivity to these demographic variations, ensuring that outreach and incentives address groups currently less likely to participate, thereby fostering a more inclusive and effective conservation strategy.

By systematically connecting physical landscape dynamics, as documented through remote sensing, with community-level perceptions and behaviors, this study offers a robust foundation for recommendations aimed at harmonizing urbanization with nature. The approach ensures that policy suggestions are not solely derived from expert opinion, but are empirically grounded in both environmental trends and lived social experiences.

A notable limitation of this study is the absence of direct data on the different types of social capital. As such, our discussion of social capital is interpretive and grounded in observed participation patterns, not statistical measurements. We recommend that future surveys include targeted questions on social network types to enhance analytical rigor on this topic.

6. Conclusion

Jeju Island's environmental vision and urbanization processes underscore the urgent need for coordinated, collaborative action among policymakers, urban designers, and community organizations. Our study revealed that the island's rapid urbanization and the resulting socioeconomic shifts have produced a complex mix of challenges and opportunities for environmental conservation. The findings showed that environmental engagement varies significantly by gender, generation, education, and income—contradicting traditional stereotypes and highlighting that older residents generally value conservation more than younger individuals, while higher education and affluence correlate with increased environmental involvement. These insights stress that effective conservation strategies must be tailored to Jeju's diverse socio-demographic landscape.

In particular, our study highlights the importance of shifting from general environmental awareness campaigns to more targeted, participatory education programs that are demographically sensitive and action-oriented, in order to cultivate long-lasting conservation behaviors across all sectors of Jeju society.

The combined analyses of NDVI, NDBI, and LUTS data illustrate an intricate situation where urban expansion coexists with a surge in green spaces. This paradox emphasizes the potential for leveraging urban growth in harmony with nature. Accordingly, specific actions and policies must promote inclusive urban design, environmental education, and equitable resource participation, ensuring that every demographic group contributes to environmental decision-making. A participatory approach—rooted in community engagement and social capital—can foster a strong sense of ownership and responsibility toward the island's natural heritage.

Ultimately, integrating scientific insights into urban planning is pivotal to achieving sustainable green spaces that are socially just and culturally resonant. Jeju Island's experience provides a valuable blueprint for harmonizing economic growth with ecological preservation. By prioritizing inclusive policies and strategic planning, Jeju can overcome urbanization challenges, safeguard its unique natural beauty, and promote a sustainable future that benefits all residents.

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