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Allegra!

It is a privilege to write this editorial as a new member of the eco.mont editorial team. Dedicated to research and management in alpine protected areas, the journal serves as an important platform to promote interdisciplinary and transdisciplinary research and to foster dialogue between scientists, practitioners, managers and policy makers.

Building on the strong foundation laid by my predecessors, whose efforts have been instrumental in shaping the identity of the journal, I hope to contribute to the development of eco.mont. My background as a mathematician and as a climate and permafrost scientist has reinforced my belief that today's pressing challenges cannot be addressed within disciplinary silos. They require ongoing, in-depth collaboration between the natural and social sciences, coupled with active and meaningful engagement with practitioners and policy makers to ensure that different perspectives are integrated into the search for sustainable solutions. eco.mont bridges an important gap between scientific research and practical implementation in mountain protected areas, addressing real-world challenges at the science–policy interface.

In my current role as head of the Research Commission of the Swiss National Park in collaboration with the UNESCO Biosphere Reserve Engiadina Val Müstair and the Regional Nature Park Val Müstair, I am involved in projects that highlight the importance of interdisciplinary approaches to the challenges facing mountain ecosystems. These efforts address issues such as climate change impacts, balancing ecosystem use and protection, understanding trophic cascades, or understanding and managing aquatic systems, among many others. By facilitating collaboration between researchers, practitioners and policy-makers, the Research Commission ensures that scientific knowledge is effectively integrated into management strategies and policy frameworks in these three parks in a mountainous region of south-eastern Switzerland.

Climate change poses major challenges for mountain regions. These include the increasing frequency of natural hazards, the impact of droughts on agriculture and forestry, reduced snowfall affecting winter tourism, and even the increased activity of forest decomposers. Addressing these challenges requires interdisciplinary cooperation, bringing together different sectors and stakeholders to identify needs and potential adaptation strategies. It is crucial to recognize that climate change is not only an environmental issue, but also one that directly affects livelihoods and communities. As such, protected areas can play a fundamental role in fostering communication and outreach between science and local communities. By facilitating this dialogue, protected areas act as repositories of long-term local knowledge, help build greater understanding, trust and cooperation, and local communities become empowered to take an active role in addressing the impacts of climate change while ensuring the resilience of their environment.

The growing demand for renewable energy, such as hydropower, solar and wind, highlights the tension between environmental protection and societal needs. In the Alps, these pressures often target pristine mountain areas, requiring careful consideration of sustainability issues, local acceptance and potential long-term ecological impacts. Ensuring that different stakeholders such as local communities are involved in the decision-making process and that their concerns are addressed is essential to the success of renewable energy projects in these regions, which need to take into account environmental sustainability, cultural heritage and social equity to create solutions that are not only technically feasible but also socially inclusive and ecologically responsible. Here, too, protected area researchers and managers can make a difference through dialogue and communication. The return of large carnivores to mountain regions, for example, while beneficial for regulating deer populations and protecting forests, has sparked social and political debates that reflect urban–rural divides and highlight the need for inclusive conservation strategies.

Protected areas such as biosphere reserves, national parks or regional parks are particularly well placed to take a leading role in addressing the complex challenges facing mountain ecosystems. These areas can act as platforms for dialogue, bringing together stakeholders from different sectors to exchange knowledge and ideas. They may also serve as pilot regions, providing a space to test new approaches to conservation and sustainable development in a real-world setting. Protected areas can, furthermore, act as role models, demonstrating how environmental protection can be reconciled with the needs of local communities. And last but not least, they can play essential roles in education by bringing school children closer to nature, fostering environmental awareness, promoting sustainable practices, and inspiring the next generation to take an active role in protecting the planet. By suc-



Stefanie Gubler © SCNAT

cessfully addressing local challenges, they provide valuable examples that can be scaled up and adapted to other regions facing similar pressures. Through these efforts, protected areas play a critical role not only in the conservation of biodiversity, but also in the development of sustainable livelihoods.

This is where eco.mont, too, plays a crucial role. As a platform for knowledge exchange and a driver of innovation, it supports the essential work of communication, exchange and collaboration in protected mountain areas. In my role as co-editor, I look forward to contributing to this mission and to fostering the dialogue and collaboration needed to safeguard extraordinary mountain landscapes for future generations.

Stefanie Gubler, *Head of the Research Commission of the Swiss National Park (FOK SNP), Swiss Academy of Sciences (SCNAT)*

Successional changes in woody floristic composition and diversity in karst mountain tropical seasonal rainforests in southwestern China

Feng Chen, Cong Hu, Chaohao Xu, Chaofang Zhong, Siyu Chen, Zhonghua Zhang & Gang Hu

Keywords: karst mountains, seasonal rainforest, succession, floristic composition, species diversity

Abstract

The seasonal tropical rainforests in karst regions of southwestern China are well known for their high biodiversity and rich array of endemic species. However, changes in the woody floristic composition and diversity during forest succession remain unclear. In this study, we used the space-for-time substitution method to analyse the floristic composition and diversity of woody plants across three successional stages (young secondary forests, old secondary forests and primary forests). Our results indicated significant differences in species composition among the various successional stages, with species richness peaking in the old secondary forests. Additionally, as succession progresses, the proportion of the relative importance values of dominant species in the community gradually decreases compared to the total importance values. In the β -diversity, the species richness, Simpson index and Shannon–Wiener index all reached an apex in the old secondary forest, whereas the Pielou evenness index gradually increased over time, reaching its maximum in the PF. The β -diversity analysis suggested that species turnover occurred during succession, with no significant similarity between communities at different stages. This study demonstrated that the floristic composition and diversity of woody plants underwent continuous changes as succession progressed in karst forests. Anthropogenic disturbances and competitive exclusion may co-regulate the floristic composition and diversity at different forest stages in mountainous karst areas.

Profile

Protected area

Nonggang National

Nature Reserve

Country

China

Introduction

Vegetation succession is a critical ecological issue (Chang & Turner 2019). According to Clements' theory of climax communities (Yang et al. 2015; Yıldız et al. 2022), under relatively stable environmental conditions, plant communities transition from pioneer to stable climax stages. Throughout this process, changes in species composition and diversity occur dynamically (Collins 1990). Currently, two main hypotheses exist regarding the changes in species richness during vegetation succession. The classic hypothesis suggests that species diversity increases as succession progresses and peaks in climax communities (Margalef 1963). In contrast, Odum (1969) proposed that species diversity increases during the early and middle stages of succession as forest ecosystems develop, but declines in later stages. Understanding the patterns and mechanisms of vegetation succession can contribute to the optimization and management of forest ecosystems (Geng et al. 2022).

Karst landscapes are geological formations that have developed primarily on limestone and dolomite (He et al. 2008). Globally, karst areas cover 22 million km², approximately 15% of the Earth's land surface (Xu et al. 2021; Zhang et al. 2023). China has one of the largest karst distributions worldwide, with an area of 3.44 million km², accounting for approximately 36% of the total land area (Ni et al. 2015). Owing to

their unique geochemical background of high calcium and alkaline conditions and diverse habitat conditions, karst regions have extremely diverse vegetation types and are rich in endemic and rare species (Zhang et al. 2012; Liu et al. 2020). Tropical karst seasonal rainforests, which are typical of the karst mountains of southwestern China, are characterized by complex community structures, rich species compositions and prominent endemic elements. This particular region of China is recognized as having one of the world's most distinct tropical karst forests (Guo et al. 2015), a forest type that provides essential ecosystem services such as biodiversity conservation, surface karst zone regulation, and carbon storage (Lang & Song 2018; Gao et al. 2021). The forests of the area serve as a valuable ecological research site for karst forest vegetation more generally, and an important reference model for biodiversity conservation and restoration of degraded vegetation in karst mountains (Guo et al. 2017).

The Nonggang National Nature Reserve (NNNR) protects the largest and most representative karst seasonal rainforest in China. The NNNR serves as a unique and vast genetic reservoir of biodiversity and has been recognized as one of the world's 36 key biodiversity hotspots (Wang et al. 2014). Located at the northern edge of the tropics, the flora of the reserve exhibit a tropical marginal nature with transitional characteristics towards the subtropical zone, establishing

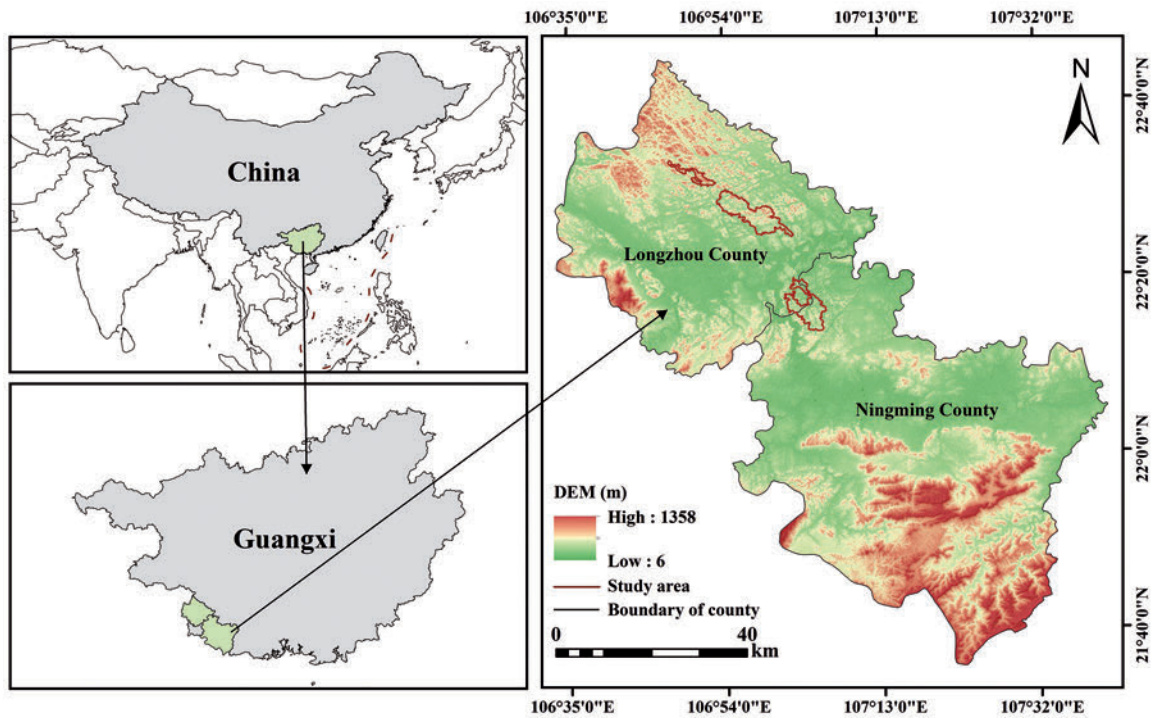


Figure 1 – Geographical location and spatial extent of Nonggang National Nature Reserve, China. Data source: geospatial data provider <https://www.gscloud.cn/>, maintained by the Chinese Academy of Sciences.

this as an ecological transition zone between tropical and subtropical regions (Wang et al. 2014; Zhu & Tan 2023). From the 1940s to the 1980s, rapid population growth significantly exacerbated the human–land conflict. In response to the need for resources, activities such as logging, land reclamation and grazing became widespread, leading to long-term disturbances and the degradation of fragile karst ecosystems in the NNNR (Huang et al. 2018). Extreme weather events driven by climate change, including typhoons and seasonal karst droughts, further stress the forest ecosystem and hinder vegetation growth and recovery (Geekiyana et al. 2019). However, after years of conservation and restoration efforts, vegetation and ecosystems within the reserve have gradually recovered. Both primary and secondary forest coverage have increased, and vegetation diversity has been partially restored (Zhang et al. 2024).

To understand this forest, research has been conducted on plant species composition, community structure, and plant–environment relationships. Based on a large monitoring plot of 15 ha in NNNR, Wang et al. (2014) identified 223 species from 56 families and 157 genera of woody plants with a diameter at breast height (DBH) ≥ 1 cm, totalling 68,010 individual plants. These species exhibit significantly different spatial distributions. Fu et al. (2023) discovered that with succession, the community species and phylogenetic diversity initially increased and then decreased, with the phylogenetic structure shifting from clustering to dispersal. They also observed functional diversity peaks in shrublands and young forests. However,

understanding of how the floristic composition and diversity of woody plants change in karst seasonal rainforests during succession remains relatively limited.

Floristic composition is one of the most critical ecological attributes of forest ecosystems (Rufino et al. 2023). Species diversity reflects community productivity and is a vital indicator of long-term community stability and development (Cheng 2020). Woody plants are essential components of forest ecosystems that significantly influence the overall composition of forest communities (Naidu & Kumar 2016). Therefore, understanding the changes in floristic composition and woody plant diversity in seasonal karst rainforests during succession is crucial for enhancing forest management, improving ecosystem services, and addressing future climate change.

In this study, we used the space-for-time substitution method to investigate three major natural successional communities in the tropical karst seasonal rainforests of the NNNR. Based on extensive plot surveys, we focused on the following questions: (1) How does the floristic composition of woody plants change across successional stages in seasonal karst rainforests? (2) How does community species diversity change during succession? The results of this study enhance our understanding of the successional processes in karst seasonal rainforests and provide a theoretical basis for restoring ecological functions and vegetation reconstruction in karst ecosystems.

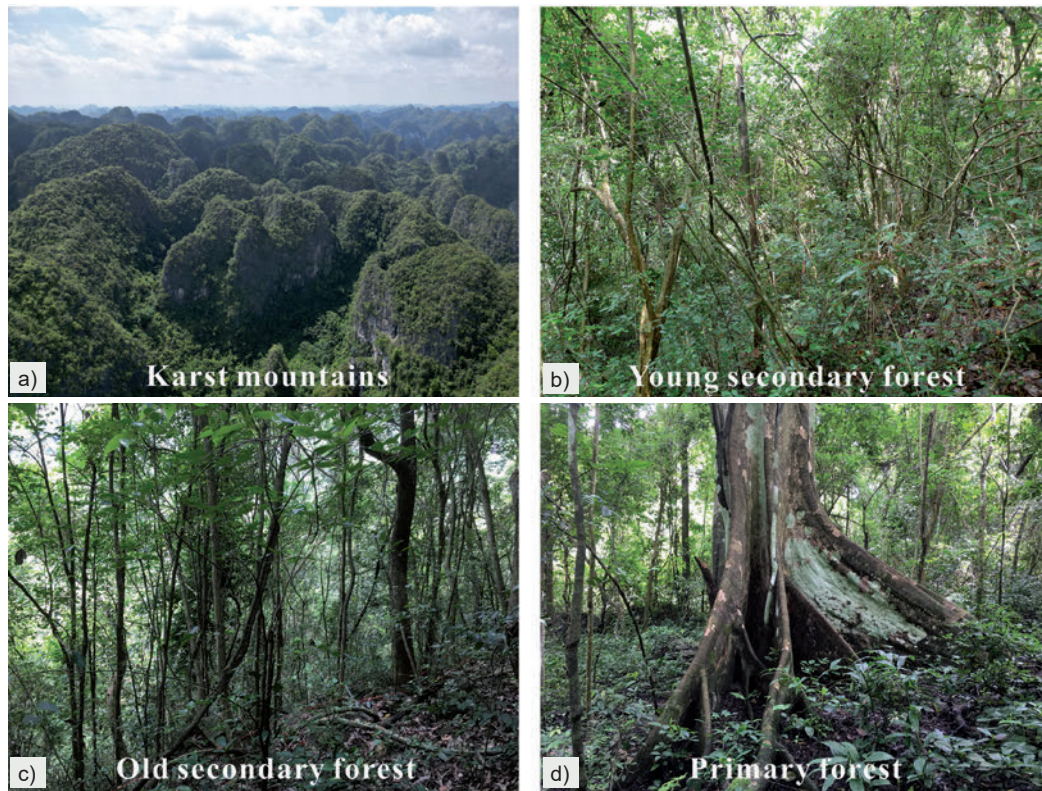


Figure 2 – Karst landscape (a) and three successional stages (b–d) of the tropical seasonal rainforests in southwestern China. © Gang Hu

Methods

Study area

The NNNR (106°42'28" to 107°04'54" E, 22°13'56" to 22°39'09" N) is situated in Longzhou and Ningming counties of Chongzuo City, Guangxi, China (Figure 1). This region has a tropical monsoon climate, with an average annual temperature of 22°C. The frost-free period typically lasts for more than 330 days per year, and the average annual rainfall is between 1,150 and 1,550 mm. The region typically encounters two to three typhoons each year, which can vary in severity, during the summer and autumn months. The geomorphology is predominantly karst peak cluster depressions from 300 to 600 m asl (Figure 2). The relative height from the bottom of the depressions to the top of the peaks typically ranges from 200 to 300 m. The soil is predominantly composed of black and brown limestone. In depressions, the bedrock exposure is low, with a thick soil layer. On slopes, bedrock exposure is high and the soil layer is shallow. Established in 1980, the NNNR is dedicated to safeguarding rainforest ecosystems and the rare flora and fauna they harbour. To achieve this, the reserve has introduced a variety of management strategies such as enhancing patrols and monitoring, promoting community co-management, conducting ecological restoration projects, and facilitating scientific research and education. As a result of these efforts, the reserve has seen a notable recovery in vegetation and ecosystems,

alongside enhanced protection of habitats for rare and endangered species. Currently, the reserve contains 1,725 species of vascular plants belonging to 184 families and 810 genera. These include 33 nationally rare and endangered species, 101 species endemic to Guangxi, and 278 karst species. It is one of 14 key terrestrial biodiversity areas of international importance in China.

Plot establishment and data collection

During the peak growing seasons from 2019 to 2021, we used the space-for-time substitution method to select forest plots in the NNNR. Three typical successional stages representing the transition from secondary to primary forests were selected: young secondary forests (YSF), old secondary forests (OSF), and primary forests (PF) (Figure 2). Specifically, based on the disturbance history of the plots, we classified plots with forest ages between 15 and 30 years as YSF, those between 30 and 100 years as OSF, and plots with forest ages exceeding 100 years as PF (Sattichanh et al. 2019; Teixeira et al. 2020). Three experienced forest rangers assisted in determining the forest age. Using a total station (Topcon GTS-336, Topcon Positioning Systems, Tokyo, Japan), we established 35 plots of 20 m × 20 m at each successional stage, totalling 105 plots. In each plot, all the woody plants with a DBH of ≥1 cm were tagged and identified. The data recorded included plant ID, species name, DBH, height and relative coordinates. Environmental parameters, such

Table 1 – Information on forest plots at three successional stages. The data are expressed as average $\pm$ standard deviation.

Forest type	Altitude (m)	Slope (°)	Canopy coverage (%)	Rock exposure rate (%)
Young secondary forest	305.28 $\pm$ 13.04	22.50 $\pm$ 6.95	67.50 $\pm$ 4.18	44.20 $\pm$ 13.63
Old secondary forest	215.71 $\pm$ 22.42	13.20 $\pm$ 13.74	72.00 $\pm$ 2.74	39.40 $\pm$ 18.35
Primary forest	219.07 $\pm$ 11.74	16.40 $\pm$ 13.28	66.00 $\pm$ 4.18	41.00 $\pm$ 13.21

as elevation, slope, canopy cover and rock exposure, were also documented. Elevation was measured using a handheld global positioning system (GPS) receiver (Garmin GPSmap 62s). Canopy cover was determined using the Canopeo application on a smartphone with a fisheye lens (Kase FISHEYE LENS II, Guangdong, China). Three experienced observers estimated the slope and rock exposure. The information on forest plots at the three successional stages is presented in Table 1.

Data analysis

The importance value index (IVI) of a species is determined by adding its relative abundance, frequency and dominance (Curtis & McIntosh 1951). The family importance value (FIV) is calculated by summing the relative diversity, density and dominance of the family (Mori et al. 1983).

α - and β -diversities are used to describe changes in species diversity during succession. The α -diversity is assessed using species richness (S), the Simpson index (D), the Shannon–Wiener index (H'), and the Pielou evenness index (E) to reflect variations in species richness and evenness within a community (Spellerberg & Fedor 2003). β -diversity measures the similarity in species composition between communities using the Jaccard index (C_j) and Sørensen index (C_s) (Small et al. 2004). The calculation methods for α - and β -diversity are as follows:

Species Richness (S): number of species in a community. (1)

Simpson Index (D): $D = 1 / \sum_{i=1}^S (P_i)^2$ (2)

Shannon–Wiener Index (H'): $H' = 1 / \sum_{i=1}^S (P_i \ln P_i)$ (3)

Pielou Evenness Index (E): $E = H' / \ln S$ (4)

S – total number of species,

P_i – proportion of the abundance of a specific species to the total abundance of all species ($P_i = N_i / N$),

N_i – number of individuals of the specific species,

N – total number of individuals of all species.

Jaccard Index (C_j): $C_j = j / (a + b - j)$ (5)

Sørensen Index (C_s): $C_s = 2j / (a + b)$ (6)

j – number of species common to both communities,

a and b – number of species in each community.

The Jaccard index (C_j) ranges from 0 to 1. Specifically, $0 < C_j < 0.25$ indicates extremely dissimilar; $0.25 < C_j < 0.50$ indicates moderately dissimilar; $0.50 < C_j < 0.75$ indicates moderately similar, and $0.75 < C_j < 1$ indicates very similar (Geng et al. 2022).

The Kruskal–Wallis test was used to analyse the α -diversity indices of communities at different succes-

sional stages, with significance determined at $P < 0.05$. A rank-abundance curve was generated by plotting the log of the relative abundance of a species against the species rank. Here, species rank refers to the relative ranking of a species based on its abundance within a community. All statistical analyses were performed using SPSS 25.0 and R 4.0.3.

Results

Floristic composition

A total of 16,825 woody plants with a DBH ≥ 1 cm, belonging to 68 families 194 genera and 281 species, were recorded across 105 plots. In the YSF, 6,197 individuals were recorded, representing 49 families 111 genera and 151 species. In the OSF, 6,233 individuals representing 58 families 148 genera and 192 species were recorded. In the PF, 4,395 individuals were recorded, representing 52 families 129 genera and 170 species (Table 2).

Based on the number of species within each family (Table 3), the three most species-rich families at different successional stages were as follows. In the YSF, these were Moraceae (12 species), Fabaceae (11 species), and Phyllanthaceae (11 species); in the OSF, Euphorbiaceae (15 species), Phyllanthaceae (12 species), and Moraceae (11 species); and in the PF, Euphorbiaceae (12 species), Rubiaceae (12 species), and Phyllanthaceae (12 species). *Ficus* exhibited the highest species richness at each successional stage. *Litsea* also had a high species richness, ranking as the second most species-rich genus in both the YSF and OSF (Table 4). Based on stem counts in each plot (Table 5), *Ficus hispida*, *Ardisia thyrsoiflora* and *Streblus tonkinensis* were the most common species in the YSF and OSF, while *Litsea variabilis* var. *oblonga*, *Leea indica* and *Cryptocarya lyoniifolia* were the most common species in the PF. As succession progressed, the species composition within the community changed continuously, with the highest family, genus and species richness recorded in the OSF.

Table 2 – Tree species richness in three tropical seasonal rain-forest successional stages. YSF – Young secondary forest; OSF – Old secondary forest; PF – Primary forest.

Forest type	Number of			Sum of individuals
	families	genera	species	
YSF	49	111	151	6,197
OSF	58	148	192	6,233
PF	52	129	170	4,395
Total	68	194	281	16,825

Table 3 – The ten most important families of woody plants in decreasing order of family importance value (FIV) at three succession stages. NG – number of genera; NS, number of species; NI – number of individuals in a family; FIV – family importance value.

Family	NG	NS	NI	FIV
Young secondary forest				
Moraceae	4	12	2,184	19.91
Malvaceae	6	8	444	9.03
Primulaceae	3	5	1,165	7.99
Euphorbiaceae	5	7	182	7.47
Lamiaceae	4	4	212	6.52
Phyllanthaceae	6	11	323	5.73
Rubiaceae	7	9	300	5.69
Fabaceae	9	11	60	4.44
Annonaceae	4	6	257	3.00
Lauraceae	3	7	205	2.90
Old secondary forest				
Moraceae	6	11	1,760	21.49
Euphorbiaceae	10	15	361	8.42
Phyllanthaceae	6	12	567	7.18
Malvaceae	7	8	401	6.73
Rubiaceae	7	8	507	4.66
Lauraceae	3	7	511	4.44
Araliaceae	7	8	137	4.20
Lamiaceae	5	6	195	4.10
Primulaceae	2	4	523	3.89
Arecaceae	1	1	34	2.97
Primary forest				
Lauraceae	3	6	1,056	13.62
Euphorbiaceae	11	12	464	10.05
Phyllanthaceae	6	12	414	8.76
Anacardiaceae	2	2	52	7.09
Malvaceae	7	8	250	6.31
Moraceae	5	11	272	5.57
Fabaceae	6	8	202	4.76
Rubiaceae	11	12	199	4.56
Vitaceae	2	2	432	3.81
Rutaceae	3	7	144	3.33

Table 4 – The ten most important genera of woody plants in decreasing order of importance value index (IVI) at three succession stages. NS – number of species; NI – number of individuals in a genus.

Genus	Family	NS	NI	IVI
Young secondary forest				
Ficus	Moraceae	8	1,926	17.23
Ardisia	Primulaceae	2	1,141	7.81
Vitex	Lamiaceae	1	152	6.58
Deutzianthus	Euphorbiaceae	1	124	6.34
Sterculia	Malvaceae	2	184	4.01
Litsea	Lauraceae	5	189	2.64
Cleistanthus	Phyllanthaceae	1	239	2.63
Excentrodendron	Malvaceae	1	73	2.59
Catunaregam	Rubiaceae	1	219	2.57
Streblus	Moraceae	1	251	2.57
Old secondary forest				
Ficus	Moraceae	6	1,169	11.99
Streblus	Moraceae	1	582	10.19
Cleistanthus	Phyllanthaceae	2	456	5.11
Ardisia	Primulaceae	2	518	4.24
Litsea	Lauraceae	5	501	4.19
Sterculia	Malvaceae	2	248	3.96
Vitex	Lamiaceae	2	132	3.64
Caryota	Arecaceae	1	34	3.23
Deutzianthus	Euphorbiaceae	1	60	3.16
Metadina	Rubiaceae	1	448	3.03
Primary forest				
Litsea	Lauraceae	2	780	8.22
Dracontomelon	Anacardiaceae	1	47	6.37
Cryptocarya	Lauraceae	2	238	5.13
Leea	Vitaceae	1	430	4.14
Ficus	Moraceae	7	169	3.92
Cleistanthus	Phyllanthaceae	2	247	3.71
Cephalomappa	Euphorbiaceae	1	162	3.39
Excentrodendron	Malvaceae	1	103	3.20
Bischofia	Phyllanthaceae	2	59	2.96
Clausena	Rutaceae	2	108	2.66

Dominant families, genera and species

The 10 most important families accounted for approximately 70% of the total FIV at each successional stage (Table 3). In the YSF and OSF, Moraceae was the most important family because of its high species richness and abundance. However, Lauraceae emerged as the most important family in the PF. In the OSF and PF, Euphorbiaceae and Phyllanthaceae had high numbers of individuals, making them the second and third most important families respectively.

At the genus level (Table 4), the top 10 genera accounted for 54.97%, 52.74% and 43.71% of the total importance values of their respective communities. *Ficus* was the most abundant genus in the YSF and OSF. It was also the most important genus, with the highest species richness and number of individuals. Although *Ficus* was the most species-rich genus in the PF, *Litsea* was the most important.

In the YSF, OSF and PF, the 10 most important species accounted for 51.79%, 45.27% and 39.22% of

the total importance values of their respective communities (Table 5). In the YSF, *Ficus hispida* was the most important species, with the highest number of individuals (1,871). *Ardisia thyrsoiflora*, with 1,128 individuals, was the second most abundant species. In the OSF, *Streblus tonkinensis* had the highest importance because it had the largest basal area (5.25 m²). *Ficus hispida* was the second most important species in the OSF, with the highest number of individuals (962). In the PF, *Litsea variabilis* var. *oblonga* was the most important species, with the highest number of individuals (771). *Dracontomelon duperreanum* was the second most important species because it had the largest basal area (5.70 m²).

α -diversity analysis

Among the three successional stages, OSF had the highest values for species richness, Simpson's index and Shannon–Wiener index. PF had the highest Pielou evenness index (Figure 3). The order of species richness was OSF > YSF > PF. OSF significantly sur-

Table 5 – The ten most important woody species in decreasing order of importance value index (IVI) at three succession stages. NI – number of individuals in a species; BA – basal area (m^2).

Species	Family	NI	BA	IVI
Young secondary forest				
<i>Ficus hispida</i>	Moraceae	1,871	2.36	14.77
<i>Ardisia thyrsiflora</i>	Primulaceae	1,128	0.37	7.68
<i>Vitex kwangsiensis</i>	Verbenaceae	152	2.79	6.58
<i>Deutzianthus tonkinensis</i>	Euphorbiaceae	124	2.92	6.34
<i>Sterculia monosperma</i>	Malvaceae	175	1.02	3.71
<i>Cleistanthus sumatranus</i>	Phyllanthaceae	239	0.61	2.63
<i>Excentrodendron tonkinense</i>	Malvaceae	73	0.89	2.59
<i>Catunaregam spinosa</i>	Rubiaceae	219	0.18	2.57
<i>Streblus tonkinensis</i>	Moraceae	251	0.48	2.57
<i>Wendlandia uvariifolia</i>	Rubiaceae	48	0.98	2.35
Old secondary forest				
<i>Streblus tonkinensis</i>	Moraceae	582	5.25	10.19
<i>Ficus hispida</i>	Moraceae	962	1.72	8.00
<i>Ardisia thyrsiflora</i>	Primulaceae	500	0.27	4.01
<i>Litsea variabilis</i> var. <i>oblonga</i>	Lauraceae	486	0.27	3.61
<i>Sterculia monosperma</i>	Malvaceae	230	1.10	3.55
<i>Vitex kwangsiensis</i>	Verbenaceae	126	1.61	3.37
<i>Caryota obtusa</i>	Palmae	34	2.19	3.23
<i>Deutzianthus tonkinensis</i>	Euphorbiaceae	60	1.89	3.16
<i>Cleistanthus sumatranus</i>	Phyllanthaceae	321	0.33	3.12
<i>Metadina trichotoma</i>	Rubiaceae	448	0.14	3.03
Primary forest				
<i>Litsea variabilis</i> var. <i>oblonga</i>	Lauraceae	771	0.76	7.53
<i>Dracontomelon duperreanum</i>	Anacardiaceae	47	5.70	6.37
<i>Cryptocarya lyoniifolia</i>	Lauraceae	238	2.64	5.13
<i>Leea indica</i>	Vitaceae	430	0.14	4.14
<i>Cephalomappa sinensis</i>	Euphorbiaceae	162	1.98	3.39
<i>Excentrodendron tonkinense</i>	Malvaceae	103	1.95	3.20
<i>Bischofia javanica</i>	Euphorbiaceae	57	1.69	2.76
<i>Catunaregam spinosa</i>	Rubiaceae	152	0.52	2.31
<i>Strophoblachia fimbriolax</i>	Euphorbiaceae	223	0.06	2.24
<i>Cleistanthus petelotii</i>	Phyllanthaceae	123	1.06	2.15

passed YSF and PF in terms of species richness ($P < 0.05$), with no significant differences between YSF and PF ($P > 0.05$). The Simpson and Shannon–Wiener indices generally followed the order of OSF > PF > YSF. However, the differences between the OSF and PF groups were not significant ($P > 0.05$). Conversely, the Pielou evenness index followed the order PF > OSF > YSF, indicating an increase in the evenness of species distribution with succession (Figure 3). The rank-abundance curve (Figure 4) further illustrates that OSF had the highest species richness, whereas PF had the most even species distribution.

β -diversity analysis

As shown in Figure 5, the Jaccard and Sørensen indices showed a consistent trend of decreasing similarity. Among these, the similarity between YSF and OSF was the highest. According to the Jaccard simi-

larity principle, the similarity coefficients between the YSF and OSF, YSF and PF, and OSF and PF were all between 0.25 and 0.50. This indicates a moderate degree of difference among the communities.

Discussion

Floristic composition in tropical karst seasonal rainforests

In the present study, 281 woody plant species from 68 families and 194 genera were identified (Table 2). Species richness in the tropical karst seasonal rainforest plots of the NNNR was significantly higher than that in the non-karst subtropical evergreen broad-leaved forest plots on Dinghu Mountain (20 ha, 210 species, DBH ≥ 1 cm) and Gutian Mountain (24 ha, 159 species, DBH ≥ 1 cm) (Ye et al. 2008; Zhu et al. 2008). However, species richness in the NNNR was lower than that in the tropical rainforest in Xishuangbanna (1 ha, approximately 216 species, DBH ≥ 1 cm) (Lan et al. 2012). This may be related to the high proportion of endemic species in the NNNR region. Some drought-resistant and calcium-loving species, such as *Excentrodendron tonkinense*, *Garcinia paucineris* and *Cephalomappa sinensis*, have robust root systems that can grow in rock crevices but are adapted only to karst habitat conditions (Wang et al. 2014; Chen et al. 2022).

The results showed significant variation in the floristic composition of woody plants across the three successional stages, demonstrating clear species turnover, with OSF having the highest number of species. Contemporary succession theory emphasizes the availability of resources as the primary driver of species turnover (Dent & Estrada-Villegas 2021). However, in karst seasonal rainforests, which are characterized by both wet and hot conditions, the availability of light, water, and soil nutrients tends to decrease as succession progresses. Among these factors, light availability emerges as the most critical driver of species turnover (Guariguata & Ostertag 2001). During the secondary succession stage, pioneer species with high light-use efficiency, such as *Deutzianthus tonkinensis*, *Catunaregam spinosa* and *Diplodiscus trichospermus*, dominated the community. However, in shaded environments created by long-lived pioneer species, many shade-tolerant late-successional species (that is, climax species), such as *Excentrodendron tonkinense*, *Cephalomappa sinensis* and *Cleistanthus sumatranus*, begin to colonize and grow within the community. This stage exhibited the highest species diversity within the community. A strong vertical light gradient, however, limits the regeneration of pioneer species. Over time, shade-tolerant climax species dominate community composition (Wittmann et al. 2008; Matsuo et al. 2021). The evolution of community structure during succession can cause changes in habitat conditions. The spatiotemporal heterogeneity of habitats drives species competition, environmental filtering, niche partitioning and species turnover during succession (Albouy et al. 2012; de Assis et al. 2017).

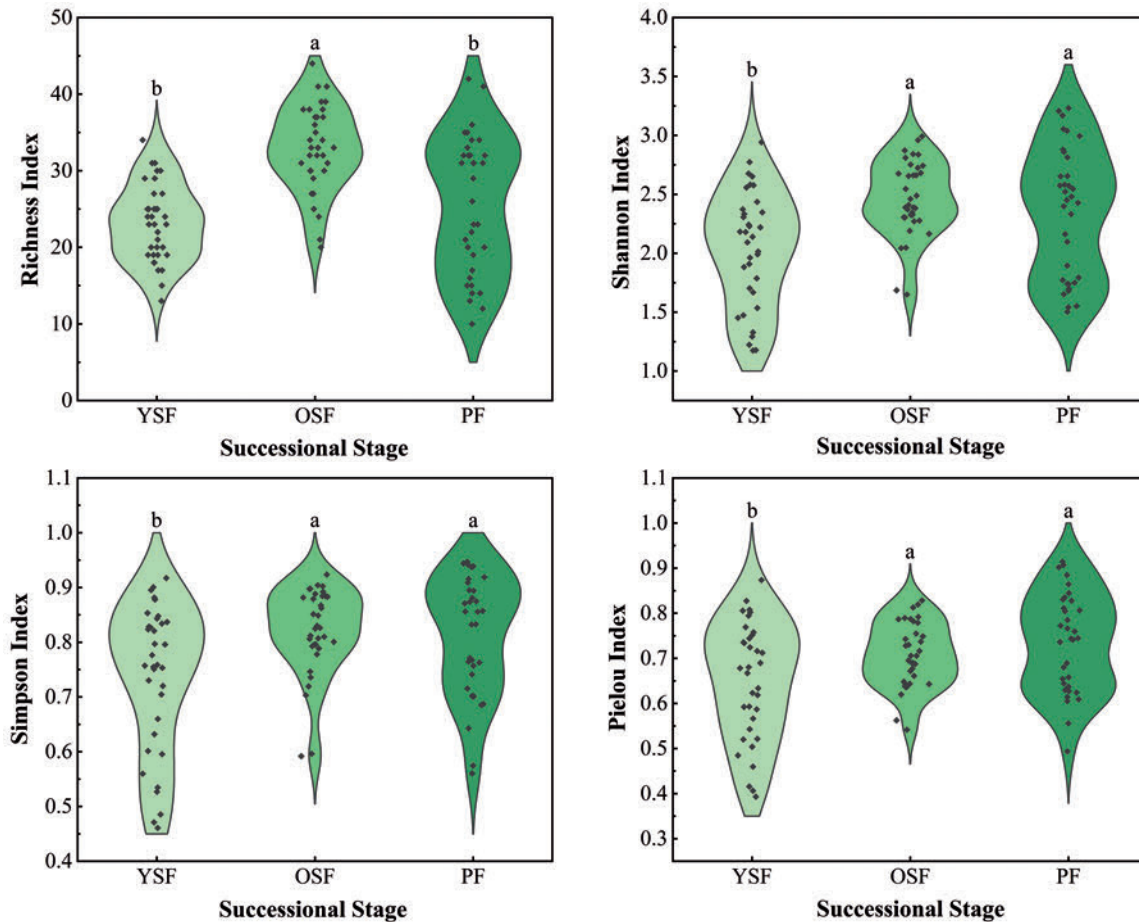


Figure 3 – Species α -diversity indices of communities at three successional stages. YSF, Young secondary forest; OSF, Old secondary forest; PF, Primary forest.

Distribution of dominant families, genera and species in tropical karst seasonal rainforests

The dominant families in the community were Moraceae, Euphorbiaceae and Lauraceae. The dominant genera were *Ficus*, *Litsea* and *Streblus*, with the main dominant species being *Ficus hispida*, *Streblus tonkinensis* and *Litsea variabilis* var. *oblonga*. This result is consistent with the findings of Wang et al. (2014). As succession progressed, the composition of the dominant species within the community changed, and their importance tended to decrease. This phenomenon may be related to environmental heterogeneity, because changes in community habitat conditions during succession affect species selection and adaptation levels (Hilmers et al. 2018; Čepelová & Münzbergová 2012). Owing to their inability to adapt to environmental changes, some dominant species in the early succession stages lose competitiveness in terms of access to and use of resources, leading to a decline in their dominance (Lebrija-Trejos et al. 2011; Geng et al. 2022). *Ficus hispida*, which was a dominant species in the YSF, also appeared in abundance in the OSF but lost its dominance in the PF.

This study identified distinct dominant species during the YSF stage, but no distinct dominant species were observed during the PF stage. In the YSF, the

dominant species, *Ficus hispida*, had an importance value of 14.77. This was significantly higher than that of the second most important species, *Ardisia thyrsiflora*, with an importance value of 7.68. In contrast, in the PF, the dominant species, *Litsea variabilis* var. *oblonga*, had an importance value of 7.53, showing a marginal difference of 1.16 compared to *Dracontomelon duperre-*

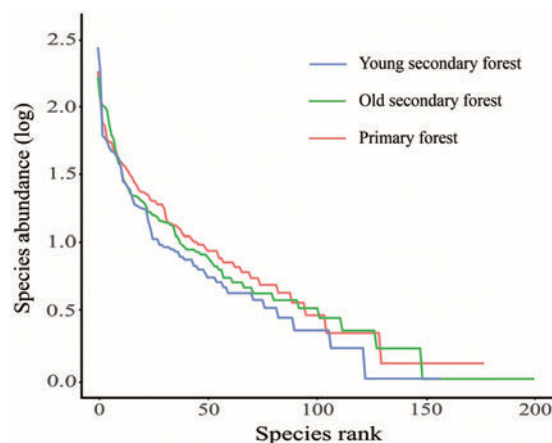


Figure 4 – Rank-abundance curves of woody species at three successional stages.

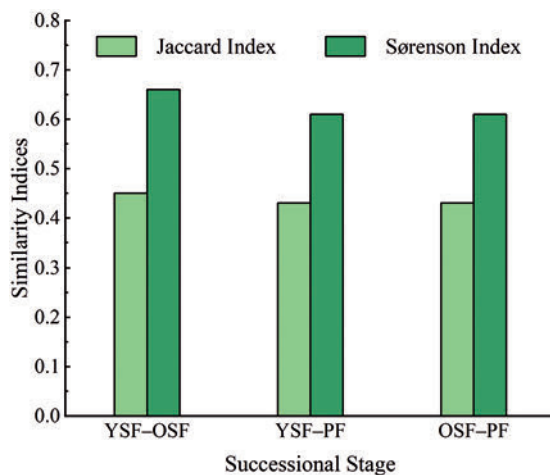


Figure 5 – Similarity indices (Jaccard and Sørensen indices) between communities at different successional stages. YSF, Young secondary forest; OSF, Old secondary forest; PF, Primary forest.

anum, the second most important species. This may stem from the simpler structure of the YSF, which has fewer species in the canopy but a higher density of individuals, thereby enhancing the importance of the dominant species. However, as succession progresses, the effect of similarity limitation among species strengthens owing to ecological niche convergence and the long-term accumulation of herbivorous insects and soil pathogens, potentially limiting the dominance of any single species (Liu et al. 2015; Chen et al. 2019).

Plant species diversity in tropical karst seasonal rainforests

Numerous studies indicate that species diversity tends to increase during the early and middle stages of succession, but it decreases during later stages (Gadow et al. 2016; Álvarez-Molina et al. 2012). Our findings support this conclusion. In the present study, species diversity followed a unimodal trend, increasing and then decreasing with succession, reaching a maximum in the OSF. Over the past century, sustained and intensive human activities, including logging, agricultural production and grazing, have caused significant damage and disturbances to the native vegetation of NNNR (Huang et al. 2018). However, since the implementation of a vegetation protection policy in 1979, anthropogenic disturbances have been notably reduced, allowing vegetation to enter a state of natural recovery (Zhang et al. 2024). Consequently, in areas affected by disturbances, numerous fast-growing pioneer species can establish themselves and proliferate during the early stages of vegetation recovery (Fu et al. 2023). As recovery progresses, the accumulation of forest biomass reduces the light conditions in the understorey, allowing climax species to thrive in shaded environments. The coexistence of pioneer and climax species significantly enhances species diversity (Lebri-

ja-Trejos et al. 2010). However, as the forest matures and climax species increasingly dominate the canopy, some pioneer species that are disadvantaged in resource use and competition gradually withdraw from the community because of their inability to adapt to their environments. This results in a reduction in species diversity (Lebrija-Trejos et al. 2011; Jin et al. 2018).

Our study indicated that the Pielou evenness index increased with succession. The rank-abundance curve (Figure 5) showed that the species distribution became more stable and uniform as succession progressed. According to the niche theory, resource availability changes continuously during succession, allowing species with strong resource acquisition abilities to occupy the corresponding niches because of their competitive advantages (Dent & Estrada-Villegas 2021). During this process, competitive exclusion (i.e., species competition) is gradually moderated, community stability increases, and species distribution within the community becomes more uniform (Gadow et al. 2016). Anthropogenic disturbances play a dominant and limiting role in community species diversity during secondary succession. As succession progresses, competitive exclusion gradually replaces the effects of anthropogenic disturbances and becomes a key factor influencing community species diversity (Fu et al. 2023).

In karst seasonal rainforests, it is crucial to note that natural disturbances like typhoons and seasonal droughts significantly affect forest vegetation (Geekiyangage et al. 2019). The strong winds and heavy rainfall from typhoons can lead to tree falls, canopy damage and soil erosion, causing temporary disruptions to the forest structure (Lu et al. 2020). Similarly, seasonal droughts place stress on plants, reducing their growth rates and increasing their vulnerability to wildfires (Wang et al. 2021). Despite these challenges, natural disturbances typically exhibit periodicity and recoverability, aiding in the natural regeneration of plant communities. In contrast, human-induced disturbances are often persistent and irreversible, leading to more prolonged and extensive damage to forest vegetation, including in the karst regions of China (Yue et al. 2024).

In accordance with Jaccard's similarity principle, the similarity between successive stages of succession in this study showed a decreasing trend, with a moderate level of dissimilarity between communities at different stages of succession (Figure 5). This difference may be related to the complex terrain and climatic conditions of the NNNR region. The niche theory suggests that increased environmental heterogeneity leads to reduced community similarity (Chang & Turner 2019; Hu et al. 2024). The high heterogeneity of karst environments might have caused habitat filtering, leading to a decrease in community similarity over time. As illustrated in Figure 5, the similarity between the YSF and OSF was the highest. However, over time, substantial changes in habitat conditions and increased species turnover rates have led to a gradual decrease in

community similarity. Therefore, in highly heterogeneous karst environments, variations in habitat conditions significantly influence the survival and development of species. This phenomenon is reflected in the overall species composition and distribution within the community (Burda et al. 2022).

Conclusion

Our study showed that, in the NNNR, the YSF included 151 woody species from 49 families and 111 genera. The OSF contained 192 woody species from 58 families and 148 genera, while the PF was home to 170 woody species from 52 families and 129 genera. The OSF exhibited the highest richness in terms of family, genus and species composition. The 10 most important species accounted for the highest proportion of the total importance value in the YSF; this proportion was lowest in the PF, indicating that the importance of the dominant species in the community gradually decreased as succession progressed. Species diversity followed a unimodal trend during succession, with the maximum value occurring in the OSF. This pattern could be attributed to anthropogenic disturbances and competitive exclusion. During the secondary succession stage, anthropogenic disturbances probably played a dominant limiting role in plant communities. In the later stages of succession, plant communities may be constrained by competitive exclusion among species owing to more intense competition for resources.

Based on these findings, effective vegetation management in karst mountains should consider key factors, including anthropogenic activities, vegetation distribution, soil properties, and light and moisture conditions. In addition, government agencies, research institutions, conservation organizations and local communities should collaborate closely to ensure the effective protection and management of forest vegetation within the NNNR. Collaboration should focus on several key areas such as strengthening law enforcement, improving management resources, advancing scientific research and promoting public education. Our study is the first to clarify successional changes in woody floristic composition and the diversity of tropical seasonal rainforests in a karst mountainous area of southwestern China. Future studies should include long-term forest monitoring to gather additional data on community dynamics over time. This approach will reveal the precise patterns and mechanisms of karst vegetation succession and development.

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Searching for the missing newts: notes on newt distribution in the Iron Gates Natural Park, Danube Gorge, Romania

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Keywords: amphibians, diversity, habitats, protected area, protected species

Abstract

Newts are in sharp decline in many regions. They have conservation value; thus, their presence is important in natural protected areas. The Iron Gates Natural Park (IGNP) in the Danube Gorge, Romania, is one protected area where, despite its rich general biodiversity, there are only a few old records of newts. However, several newt species are still present in the park. Between 2018 and 2024, we recorded three newt species in 15 distribution points in IGNP: *Triturus cristatus*, *Lissotriton vulgaris* and *Ichthyosaura alpestris*. The most widespread species was *L. vulgaris*. Our data prove that newts are still present in the region, especially in isolated habitats in cold wet valleys, and on mountains or hilltops. Nevertheless, newts remain rare within IGNP in the Danube Gorge area. With few exceptions, they are represented by a small number of individuals restricted to small-size habitats in a narrow area of the park. Although the region is considered a hotspot of research on amphibians, our data indicates how little is known about its fauna.

Profile

Protected area

Iron Gates Natural Park

Mountain range

Banat and Mehedinți

Mountains

Country

Romania

Introduction

Five newt species are present in Romania (*Triturus cristatus*, *Triturus dobrogicus*, *Lissotriton vulgaris*, *Lissotriton montandoni* and *Ichthyosaura alpestris*) (Cogălniceanu et al. 2013). All of them are protected, but the highest conservation value is that of the crested newts (O.U.G. 57/2007). Thus, for natural protected areas, newts have a high conservation value and have been the subject of various studies (e.g., Dobre et al. 2009; Ile & Sucea 2018; Vaissi & Sharifi 2019; Guinart et al. 2022; Covaciu-Marcov et al. 2023). In Romania, newts seem generally well represented (see e.g. Cogălniceanu et al. 2013), although in many other regions they are considered to be in decline (e.g., Denoël 2012; von Bülow & Kupfer 2019; Falaschi et al. 2022). Some parts of Romania, however, such as the southwest, have very few records of newts (see Cogălniceanu et al. 2013). Like other mountain areas in southern Romania (Iftime & Iftime 2010; Covaciu-Marcov et al. 2009a, 2020), the extreme southwest, namely the Danube Gorge, is considered unfavourable for newts because of its steep mountain slopes (Covaciu-Marcov et al. 2009b). Thus, there are only a few records of newts (*T. cristatus*, *T. dobrogicus*, *L. vulgaris*) for the region, which are very old (see Fuhn 1975; Stănescu et al. 2015); some have not subsequently been confirmed (Iftime 2005). Some newt species have not been mentioned in the region since at least 1971 (see Stănescu et al. 2015), even though it is a hotspot of research on the amphibians in Romania (Cogălniceanu et al. 2013). The data form of the Iron Gates Natura 2000 site (which overlaps with the Iron Gates Natural Park (IGNP) and the Danube Gorge), does not mention

Triturus cristatus (Laurenti, 1768), indicating only *Lissotriton vulgaris* (Linnaeus, 1758) (Natura 2000 Standard Data Form ROSCI0206). However, both newt species were included in the IGNP management plan (Management Plan, 2013) as definitely being present, but with the mention that their distribution in the park had not been mapped, as the information was taken from Cogălniceanu et al. 2013. No other newt species were mentioned in the Management Plan (2013), although historical records for *Triturus dobrogicus* (Kiritzescu, 1903) show its presence on an island that was flooded by the creation of the Iron Gates I Dam lake (see e.g. Fuhn 1975) and in the western-most part of IGNP (Cogălniceanu et al. 2013). This absence of records for newts is surprising given that IGNP is a protected area with great biodiversity, and numerous protected species (Rozyłowicz et al. 2019), where species new for Romania continue to be recorded (e.g., Ruicănescu & Dumbravă 2020; Dumbravă & Ruicănescu 2023). Nevertheless, recently a *T. cristatus* individual was recorded in the region, but in a road mortality study, in autumn, near Orșova (Covaciu-Marcov et al. 2022), an area where the species was registered previously (e.g., Fuhn 1975). A little outside the park limit, *Ichthyosaura alpestris* (Laurenti 1768) was also recently identified (Cicort-Lucaciu et al. 2017). Moreover, some newt species (*T. cristatus*, *T. dobrogicus*, *L. vulgaris*, *I. alpestris*) are present in the vicinity of IGNP in Serbia (Vukov et al. 2013; Vučić et al. 2020).

From the literature and available data just outlined, we hypothesized that despite the information regarding their supposed rarity or absence in the Danube Gorge (Fuhn 1975; Iftime 2005; Covaciu-Marcov et al. 2009b; Cogălniceanu et al. 2013; Stănescu et al.



Figure 1 – (a) *Triturus cristatus* and (b) its habitat at Jidoșțița West; (c) *Lissotriton vulgaris* and (d) its habitat at Eșelnița downstream; (e) *Ichthyosaura alpestris* and (f) its habitat at Moldovița / Cărbunari. © Sára Ferenți

2015), newts are present in the region, since they are killed by cars (Covaciu-Marcov et al. 2022), but they have not been searched for in the appropriate places, using appropriate methods and sufficient sampling effort. Thus, our objective was to establish the presence, species composition, and geographic distribution of newts in the IGNP region of the Danube Gorge.

Materials and methods

IGNP, situated in southwestern Romania, largely overlaps with the Danube Gorge, in a mountainous region with diverse habitats, but principally beech forest (Rozyłowicz 2008). We carried out the fieldwork in spring (March–May), in 2018 to 2024, when the newts were in aquatic habitats (Fuhn 1960; Cogălniceanu et al. 2000). Between 2018 and 2019, we only sporadically collected opportunistic observations of newt dis-

tribution. Subsequently, we aimed to realize detailed research on newts in IGNP, starting the field activity on 6 March 2020. Shortly after that, the study was stopped because of movement restrictions due to the COVID-19 pandemic (e.g., Dascălu 2020). These restrictions were softened only at the end of May (e.g., Dascălu 2020) when the newts' aquatic period was near its end (Fuhn 1960; Cogălniceanu et al. 2000). We resumed field activity in the spring of 2021, but even then movement restrictions were in force during nighttime, so our activity was further affected. We made detailed field studies in the spring of 2022 and 2023. In 2023, our activity was once more affected, this time by a landslide that closed the road on the Danube Gorge in spring.

The first step was to map potential newt habitats in IGNP. We thus investigated more than 100 aquatic habitats in IGNP which corresponded with the eco-

Table 1 –Newt distribution localities in Iron Gates Natural Park. Cs - Caraş-Severin County, Mh - Mehedinţi County.

Locality	County	Geographic coordinates	Altitude [m]	<i>Triturus cristatus</i>	<i>Lissotriton vulgaris</i>	<i>Ichthyosaura alpestris</i>
Sfânta Elena	Cs	44°40'57" N / 21°42'27" E	352	-	X	-
Măceşti	Cs	44°47'38" N / 21°39'20" E	585	-	X	X
Gârnic	Cs	44°46'35" N / 21°46'11" E	648	-	X	X
Moldoviţa	Cs	44°47'43" N / 21°41'45" E	604	-	-	X
Gornea monastery	Cs	44°39'50" N / 21°51'31" E	69	-	X	-
Orsova (Coramnic pond)	Mh	44°44'48" N / 22°24'02" E	72	X	-	-
Eşelniţa downstream	Mh	44°43'21" N / 22°21'12" E	140	X	X	-
Eşelniţa upstream	Mh	44°46'21" N / 22°13'52" E	548	-	X	X
Eşelniţa artificial pond	Mh	44°43'25" N / 22°21'09" E	135	-	X	-
Moldoviţa / Cărbunari	Cs	44°48'05" N / 21°42'36" E	431	-	X	X
Jidoştiţa South (near IGNP)	Mh	44°42'18" N / 22°35'07" E	246	X	X	-
Jidoştiţa West	Mh	44°42'58" N / 22°33'13" E	456	X	X	-
Moldova Nouă island	Cs	44°41'55" N / 21°37'14" E	68	-	X	-
Cruşoviţa	Cs	44°40'14" N / 21°48'41" E	115	-	X	-
Mala valley (quarry)	Mh	44°42'15" N / 22°19'57" E	179	-	X	-
Total distribution records				4	13	5

logical requirements of the newt species (*T. cristatus*, *T. dobrogicus*, *L. vulgaris*, *I. alpestris*) that could be present in the region according to the literature (e.g., Fuhn 1960; Cogălniceanu et al. 2000, 2013; Cicort-Lucaciu et al. 2017). Some habitats were visited only once, but others (especially those in which we encountered newts or those which seemed very favourable) were visited several times, usually once during each study year. We collected qualitative data only, aiming only to establish the presence of newts in the region and their geographic distribution. The methods used in the field depended on the habitat. In small-sized habitats with clear water, we observed newts directly from the shores. In larger habitats with turbid water, we captured the newts using round nets mounted on two-metre-long handles, as used in other studies (e.g., Covaciu-Marcov et al. 2006, 2009b; Cupşa et al. 2020). As in previous cases, the nets were used both from the shores and from the water. The captured newts were returned immediately into their habitat following identification.

Results

Although we encountered newts in 15 sites within IGNP, in most of the 100+ habitats investigated we did not register any. The three newt species that we identified in the park (Figure 1) were: *Triturus cristatus*, *Lissotriton vulgaris* and *Ichthyosaura alpestris*. The most common was *L. vulgaris*, identified in 13 sites, and the rarest was *T. cristatus* (Table 1). We found *T. cristatus* and *I. alpestris* in four and five sites respectively. The newts' distributions in IGNP were not uniform. We identified *T. cristatus* only in the eastern areas of the park (Figure 2) and *I. alpestris* only in the northern area. *Ichthyosaura alpestris* was present in the north-western (where it seems more numerous), and probably the north-eastern areas (we identified it just a few kilometres outside the park limit). We did not identify all three newt species together in the same habitat in any

of the 15 sites. *Lissotriton vulgaris* was present both beside *T. cristatus* (three records from the lower altitude sites in IGNP's eastern regions) and beside *I. alpestris* (four records from the higher altitude sites from IGNP's northern regions). At some sites, only one newt species was identified.

In many aquatic habitats, we observed only a few newt individuals. Some habitats (including Eşelniţa upstream and Moldoviţa / Cărbunari) were very small (i.e. less than 10 cm deep, and less than 1m in diameter), and the number of newts was certainly small in those sites. In other cases (Orşova Coramnic pond), on the contrary, the water body was large and deep; thus, the number of newts encountered probably did not reflect the real size of the population. Only one site (Jidoştiţa west) seems to shelter a large number of newts. This is a large wetland, crossed by the park's boundary. It is located in an open area, covered with grassy vegetation, and used as a pasture, but in its proximity (tens of metres) there are beech, hornbeam and oak forests. At least in spring, this site measures several tens of square metres, and has a depth of more than 0.5m; there are many bulrushes on the shores. We did not undertake an exact count of the newts at this site, but judging by the number of individuals caught in just a few nets in this wetland, at the peak of their breeding season, the total population is high.

In IGNP, *L. vulgaris* occupies various aquatic habitat types. The species was present both in large wetlands like Jidoştiţa, and in small forest puddles. It also uses artificial ponds (the excavation in Eşelniţa and the abandoned fishponds near Gornea monastery). *Triturus cristatus* was usually present in larger water bodies. At Orşova, the Coramnic pond is more than 1m deep; it has reeds and bulrushes on the shores but also rich aquatic vegetation. Although we did not observe fish at this site, it seems to be connected with the Danube, as their water levels correlated. In this habitat, newts were encountered only once, at the beginning of a

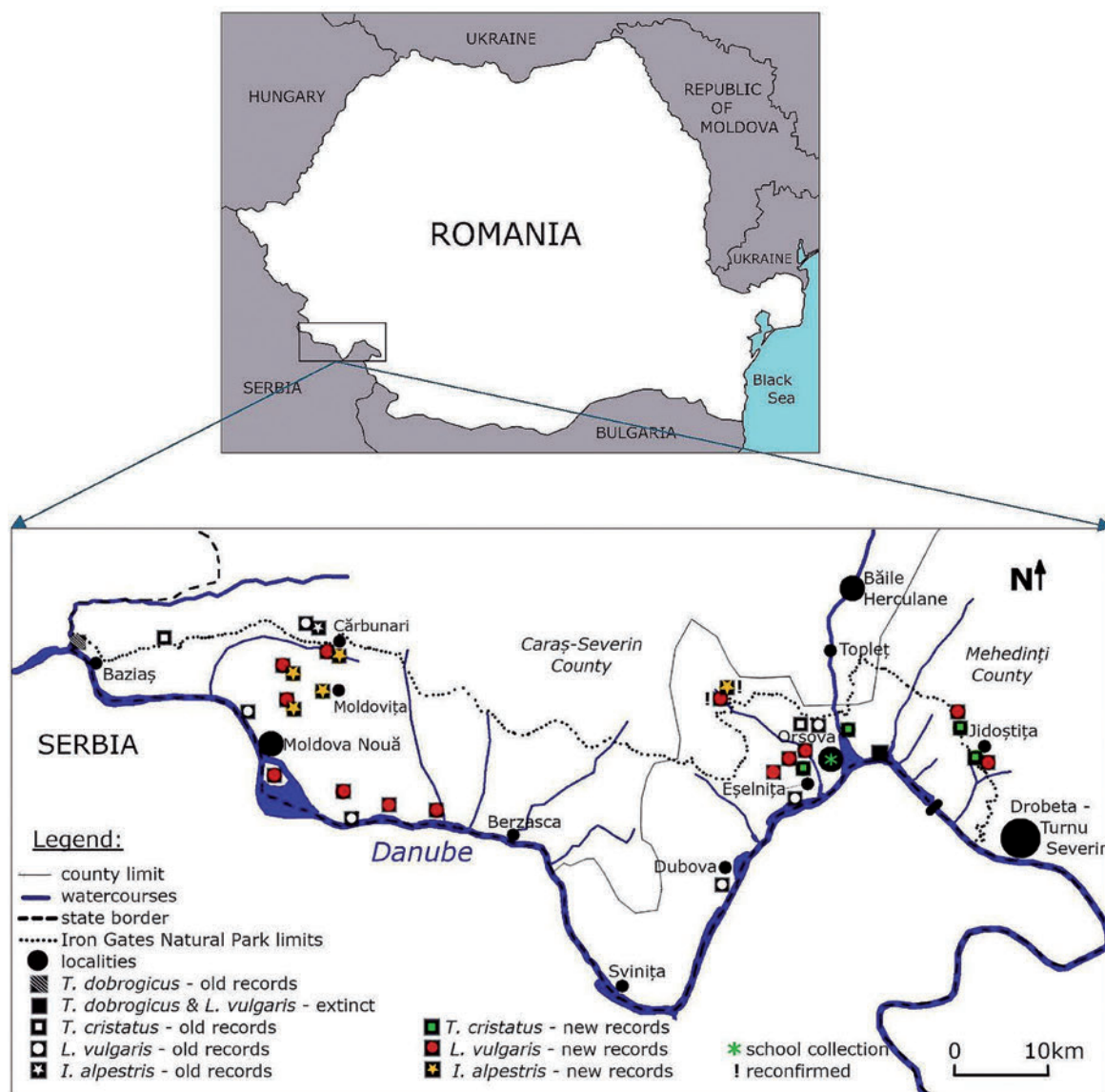


Figure 2 – New and old distribution records of newts in the Iron Gates Natural Park, Romania (old records after Fuhn 1975, Cogălniceanu et al. 2013, Covaciu-Marcov et al. 2022).

cold spring (7 March 2020), near the shores, under bulrushes. The following years, the spring water levels were low, and the bulrushes were outside the water line. Thus, in 2021–2023 we did not encounter newts, although they were probably present in the middle of the pond. This pond has been affected to some extent by human activities, as it neighbours a railway and houses, but it is probably situated in the place of a former natural wetland. The wetland from Jidoștița west provides the typical requirements of the species found here; the other habitats are smaller but permanent and surrounded by forests. Unlike *L. vulgaris* and *T. cristatus*, *I. alpestris* was always encountered in small-sized aquatic habitats, even in wheel ruts.

Discussion

Our results clearly indicate that IGNP shelters three newt species (*T. cristatus*, *L. vulgaris*, *I. alpestris*). In

addition to these, *T. dobrogicus* was recorded previously (Cogălniceanu et al. 2013; Stănescu et al. 2015) but it was not identified during our study. The three species found corresponded to those that could be present in the region according to the literature on their ecological requirements (Fuhn 1960; Cogălniceanu et al. 2000), their distribution in Romania (Fuhn 1960; Cogălniceanu et al. 2000, 2013), and in neighbouring regions (Vukov et al. 2013; Vučić et al. 2020). The idea of newt rarity in the region is not new, but it has only recently been clearly stated (Covaciu-Marcov et al. 2009b). Even in the past, newts were very rarely identified in the area (see Fuhn 1975) or were not detected at all (Ifime 2005). Thus, *T. cristatus* was not identified at all in the Danube Gorge, but the existence of a preserved individual in the collection of a local high school was mentioned by Fuhn (1975). *Triturus dobrogicus* was mentioned only in the eastern end of IGNP, on an island which has since been submerged

by the Iron Gates I Dam Lake, which eliminated that population (Fuhn 1975). However, the species was subsequently recorded at the western limit of the park (e.g., Cogălniceanu et al. 2013; Stănescu et al. 2015). In the IGNP management plan (Management Plan 2013), the newts' distribution is stated as not known in the park, as the information was obtained from the literature (Cogălniceanu et al. 2013). In the Natura 2000 site data form (which overlaps with IGNP), there is no information about *T. cristatus* (Natura 2000 Standard Data form ROSCI0206). In the literature, *T. cristatus* and *L. vulgaris* appeared as not reported in the area for more than 50 years, and *I. alpestris* was not mentioned (Stănescu et al. 2015). Subsequently road-killed *T. cristatus* and *L. vulgaris* were encountered (Covaciu-Marcov et al. 2022). Thus, the majority of the newts' distribution records presented in this paper are completely new. Only the Eşelnița upstream newts had been recorded previously (Cicort-Lucaciu et al. 2017), reconfirmed by us. In the case of Orșova, it is difficult to state whether the record is new or a reconfirmation, as the previous record is based on a specimen preserved in a school collection (see Fuhn 1975).

Unlike the other newts, *L. vulgaris* was more frequently registered in the past in the region (e.g., Fuhn 1975; Cogălniceanu et al. 2013; Stănescu et al. 2015). It has also proved to be the most common newt species in IGNP, which is true for Romania more widely (e.g., Cogălniceanu et al. 2013). The actual distribution of *L. vulgaris* is probably wider than the 13 sites where we encountered it, as in the road mortality study it was also recorded in other areas of IGNP (Covaciu-Marcov et al. 2022).

The habitats populated by newts in IGNP are generally typical for them (Fuhn 1960; Cogălniceanu et al. 2000). For *I. alpestris*, small-sized habitats, even wheel ruts, are characteristic (Covaciu-Marcov et al. 2009c; Naumov et al. 2020; Kopecký 2023). *Lissotriton vulgaris* was the least demanding in terms of preferred habitat type or size, as found in other studies (Rannap et al. 2012). *T. cristatus* preferred larger habitats, again echoing findings in other regions (Skei et al. 2006). All newt species generally used natural habitats, but they were also present in artificial habitats, as in other cases presented in the literature (e.g., Ile & Sucea 2018; Naumov et al. 2020, 2023). All newt aquatic habitats are situated inside or close to forests, which are important terrestrial habitats for these species (e.g., Müllner 2001; Vuorio et al. 2013).

Lissotriton vulgaris had the largest altitudinal distribution in IGNP, while *I. alpestris* was present at higher altitudes, a fact consistent with their requirements in Romania (Fuhn 1960; Cogălniceanu et al. 2000, 2013). However, *I. alpestris* was identified below 500 m (431 m), which is lower than the usual altitude in Romania (Cogălniceanu et al. 2000), but not as low as in some Romanian regions (Covaciu-Marcov et al. 2009c). What is slightly unusual is the presence of *T. cristatus* at an altitude of only 72 m at Orșova. This is

the only region in IGNP where the species was repeatedly mentioned in the past (e.g., Fuhn 1960, 1975; Cogălniceanu et al. 2013; Stănescu et al. 2015), based on an individual from a school collection (see Fuhn 1975). The Orșova region still seems suitable for *T. cristatus*, as it was encountered in the pond in Coramnic, at Eşelnița (5 km west of Orșova), and between them as a road-killed individual (Covaciu-Marcov et al. 2022). The altitude at Coramnic is very low for this species, probably one of the lowest in the country. Previously, in western Romania *T. cristatus* was recorded only above 120–150 m (see e.g. Covaciu-Marcov et al. 2006, 2007, 2008), but in western Romania at such altitudes there are plains (Covaciu-Marcov et al. 2006, 2008, 2007), while at Orșova there are steep rocky slopes. The variety of the terrains at this altitude probably explains the presence of *T. cristatus* at such low altitudes, as in the case of other species from different groups, both in the Danube Gorge (e.g., Paşcovschi 1956; Iftime 2005; Covaciu-Marcov et al. 2009b) and in neighbouring regions (e.g., Ferenti & Covaciu-Marcov 2018; Groza et al. 2021). Moreover, *T. cristatus* has been recorded at lower altitudes in Bulgaria (Naumov et al. 2023).

The two *T. cristatus* females from the pond in Coramnic (Orșova) present some chromatic characteristics of *T. dobrogicus*, a fact mentioned for this species in other regions in Romania (Covaciu-Marcov et al. 2008), suggesting possible hybridization. The pond is situated only 30 m from the Danube, where 10 km downstream a *T. dobrogicus* population was present in the past on Ada Kaleh Island (Fuhn 1975), and a known hybrid population is present nearby in Serbia (Vučić et al. 2020). For hybridization in these two individuals to be confirmed, genetic analysis is needed. Another individual with typical *T. cristatus* morphology but with some *T. dobrogicus* chromatic characters was identified at Jidoștița west, at an altitude of 456 m. This site is situated only 10 km (in a straight line) from the Danube. At Eşelnița downstream, identification was recorded at 140 m, an altitude normal for *T. cristatus* in other regions in Romania too (Covaciu-Marcov et al. 2006, 2007).

The information on newt distribution in IGNP has solved an old issue. Nevertheless, the data should be considered incomplete because of the large area of the park (e.g., Rozyłowicz et al. 2019) and the COVID-19 pandemic, which made it impossible to survey the park in its entirety. And the question still remains: why are newts rare in the area, at least compared with other regions? The answer is that appropriate aquatic habitats are rare because of the relief (Covaciu-Marcov et al. 2009b). However, at least at Orșova, there is an old *T. cristatus* metapopulation which still stubbornly survives, despite the Iron Gates dam lake, roads, and other forms of human impact. But the question is for how long it can survive, because the only sustainable population of *T. cristatus* in IGNP seems to be at Jidoștița. At Eşelnița downstream, however, we

identified each year just one female (probably the same one), but in 2023 it was absent. Thus, this is a relict of a former population, probably affected by the human activities in the region. Close to Eşelnița downstream, there are ruins of former industrial activities, where an artificial aquatic habitat was colonized by newts as recently as 2023, after the cessation of human activity; we did not encounter these individuals in previous years. *T. cristatus*, at least at Eşelnița, was probably subject to intense human pressure in the past. So, will the newly identified newt populations close to the Danube disappear because of human activity? This seems less probable because, at least at Eşelnița, at the time of our study human activity had ceased. Also, in other cases, the presence of *T. cristatus* was explained by landscape characteristics, such as the distance to the nearest populated pond or the number of nearby ponds (Priol et al. 2023; Schleimer et al. 2024).

Climate change presents a great danger for newts nowadays; it appears to affect numerous amphibian species (e.g., Corn 2005; Alves-Ferreira et al. 2022; Mi et al. 2023), including in Romania (Popescu et al. 2013). In southern Romania, the summers seem increasingly hot and dry (Dragotă et al. 2011; Prăvălie 2013, 2014; Prăvălie et al. 2016), a fact that will certainly affect the newts further. During the study, we investigated more than 100 aquatic habitats which appeared to be suitable for newts, but newts were absent from most of them, although other amphibians were identified. This indicates that newts are rare in the region and were probably rare in the past, before they were affected by the Iron Gates I Dam and other human activity (including road mortality). In this context, the responsibility of IGNP in maintaining the newt populations becomes even greater. Our data do not solve the problem of newt distribution, but they do prove their presence. Thus, IGNP should aim to complete the distribution data, not least because newts are protected (O.U.G. 57/2007). Because at the majority of sites we observed only a few newts, studies of population sizes could be made in the future, at least in larger habitats.

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An integrative approach to recreational trail planning in mountain protected areas: a case study of Kaçkar Mountains National Park, Turkey

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Keywords: Trail planning, protected areas, nature-based tourism

Abstract

Economic, social and technological changes, as well as a global epidemic, have altered people's needs and influenced travel cultures, shifting tourism from mass forms to alternative, nature-based ones, thereby stimulating economic development. The growing popularity of outdoor recreation activities highlights the need to balance conservation and use in protected areas. This study focuses on trail planning in the Kaçkar Mountains National Park, an area ideal for outdoor activities but threatened by excessive and unplanned use. The Park aims to guide visitors safely along appropriate routes, ensuring access to nature while maintaining a balance between resource use and protection. The research for this study included the selection of 10 trails, expert interviews, field studies, digitization of inventory and routes, assessment of difficulty using AHP, theming of routes, and development of management strategies. Using the AHP method to grade trail difficulty resulted in four low-, four medium- and two high-difficulty paths, which were divided into four themes (Glacial Age, Wild, Victory Climbing, Cloud Sea). Safety problems and management deficiencies of the routes were identified, route maps were prepared, and suggestions for the management of the routes were developed.

Profile

Protected area

Kaçkar Mountains

National Park

Mountain range

Pontic Mountains

Country

Turkey

Introduction

According to the World Tourism Organisation, the recent increase in people's desire to experience nature, natural areas and local culture (Silva et al. 2021), and the COVID-19 crisis, which has led to a change in people's expectations and demands, have increased interest in and experience of nature tourism (Smith et al. 2023). But these dynamics have also created problems, such as uncontrolled over-capacity and illegal construction in natural areas (Altun et al. 2021). The main purposes of protected areas (PAs) and national parks, which are the most attractive areas for outdoor and nature-based tourism (Çağlayan 2019) due to their natural and cultural richness (Birinçi 2018), are to protect the natural environment from degradation while providing recreational opportunities (Dudley 2008). The continued attractiveness of these areas can only be achieved by keeping the impacts of their use to a minimum (Akten & Gül 2014). The increasing demand for PAs and national parks has highlighted the need for their controlled use, making the planning, construction and maintenance of trails a key task for park managers (Tomczyk & Ewertowski 2013). Hiking is the most important recreational activity in PAs (Pomfret 2006; Chhetri et al. 2004; Fredman & Tyrväinen 2010) and has considerable potential to generate income for local communities (Wöran & Arnberger 2012; Molokáč et al. 2022). Trail networks enable activities like hiking, cycling, photography and wildlife observation, facilitating movement within PAs (Hugo 1999; Weston & Mota 2012; Santarém et al.

2015). The creation and improvement of recreational trails have increased to prevent uncontrolled use that damages the values of PAs, and to help manage visitors (Marion & Leung 2001; Marion & Leung 2004; Cole 2004; Ballantyne & Pickering 2015), reducing their environmental impacts. Rather than restricting users, this approach assesses the intensity and type of use and tailors trail development accordingly, helping to control environmental damage even under heavy use (Marion 2023), thus enhancing trail sustainability.

Ancient trails, historically used for travel and trade, have gained popularity as recreational paths for activities such as watching wildlife, visiting natural and cultural sites, and educational experiences (Godtman Kling et al. 2017). In nature-based tourism, trails enhance visitor experience and wellbeing through access to nature, and help manage crowds. They provide access to natural areas, and prevent visitors from getting lost while protecting them from potential dangers; they also help to avoid damage to sensitive areas (Lekies & Whitworth 2011).

Determining difficulty levels as part of trail planning is essential for safety, user experience, sustainability and visitor management. This classification helps hikers choose appropriate trails, reducing accidents and increasing satisfaction. It also assists PA managers in resource allocation and maintenance, balancing visitor flows, minimizing environmental impact and supporting conservation.

National and regional mountaineering organizations use different systems to classify trails. In North America, the Yosemite decimal system has five lev-

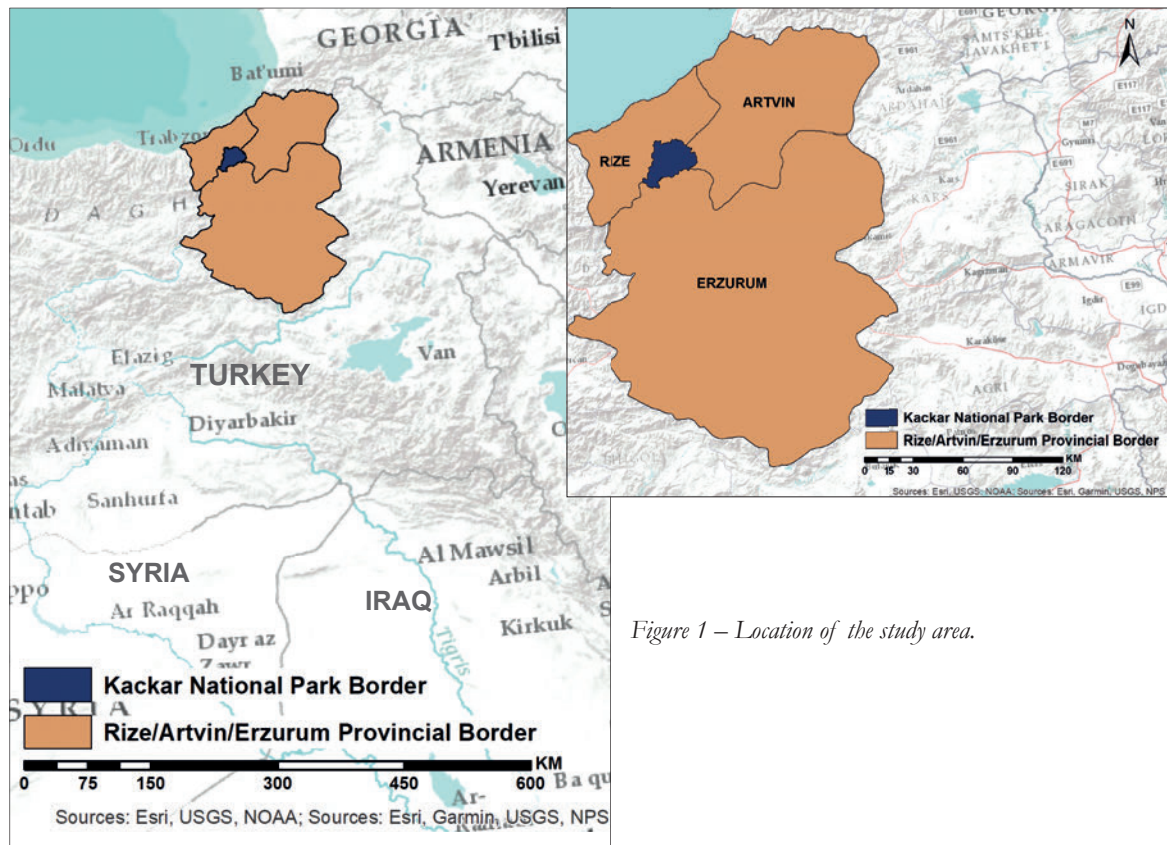


Figure 1 – Location of the study area.

els, from non-technical to expert. The International Mountaineering and Climbing Federation uses six Roman numerals, and in Europe the French Alpine Grades system ranges from F (easiest) to ABO (most difficult). The Swiss Alpine Club classifies trails from T1 (easy, no special equipment needed) to T6 (demanding and technical) (Molokáč et al. 2022; UIAA 2024). Trail classification studies exist, but the classifications they propose are not standardized, varying regionally and often lacking objective measures like elevation and average duration. Based on subjective individual experience, they also often lack sufficient detail for managers to improve the hiking experience (Calbimonte et al. 2021). Krevs et al. (2023) introduced Experimental Trail Classification (ETC), which uses GIS and other analytical tools to provide more objective assessments. ETC helps to plan and manage hiking activities, ensure visitor safety, enhance the experience and promote sustainable use of PAs.

This study addresses the lack of standardized difficulty criteria and the gap in the use of multi-criteria decision making and GIS in trail classification, aiming to standardize the classification on an international scale, and to improve reliability and hiking experience by introducing objective GIS-based methods in Kaçkar Mountains National Park (KMNP), Turkey. The research will help to answer the following questions:

- Which physical and environmental factors play the most critical role in determining difficulty?

- How can difficulty be modelled using multi-criteria decision support systems?
- How can difficulty be mapped and visualized using GIS?
- How can natural and cultural inventories be used to classify trails?

Material and method

Study Area

KMNP, which was declared a national park in 1994, was chosen as the study area. The Park has an area of 52,970 ha and includes the fourth highest peak (3,932 m) in Turkey (Figure 1), in an area just 40 km from the coast where peaks reach 3,492 m (Bayrakdar & Özdemir 2010). The area is subject to erosion by streams and freeze-thaw action at higher altitudes, resulting in topography characterized by steep slopes of impermeable igneous rock. The terrain is forested up to 2,200 m and gives way to alpine meadows above this altitude (Figure 2). The impermeability of the rocks hinders the replenishment of underground water resources, resulting in extensive river networks with high flow rates (Ülker 1992).

The Kaçkar Mountains in the eastern Black Sea region is the second most diverse area in Turkey in terms of glacial morphology, with four glacial valleys, multiple moraine types, and glacial lakes, some of which cover an area of 750 m² (Doğu et al. 1993; Çiner 2003; Gürgen 2016). The study area, situated in the Colchis

section of the European-Siberian floristic region, features forests with deciduous and evergreen trees, endemic and relict species, and is dominated by subalpine and alpine vegetation with high mountain meadows (Acar et. al. 2006). The Kaçkar Mountains, rich in fauna due to their diverse vegetation, river networks and varied topography, straddle humid and semi-arid climates. Kurdoğlu's (2002) study recorded 30 species of mammals. Recognized as an Important Bird Area, the Eastern Black Sea Mountains, part of the Kaçkar, support dense forest and alpine vegetation (Magnin & Yazar 1997). These mountains are crucial for migrating diurnal birds of prey in the Western Palearctic. The region is home to the Mountain Rooster (*Tetrao mlokosiewiczii*), the presence of which qualifies the area as one of the world's 217 Priority Areas of Conservation for endemism. KMNP includes ancient caravan and local trails, historically used for trade and grazing, which now attract tourists for scenic walks.

Method

The study aimed to classify trails in the KMNP using measurable criteria, in two stages. The first involved trail selection, inventory, surveys, observational data and experimental walks. Environmental, physical, cultural and climatic features were inventoried using geographic data platforms and field observations. The authors carried out walks to assess walking difficulties, technical trail requirements and safety measures. In the second stage, the Analytical Hierarchy Process (AHP) was used to select and weight criteria, dividing complex problems into hierarchical levels and determining the relative weight of variables (slope, altitude

etc.). Surveys and interviews with walkers were used to incorporate user and expert experience into the planning process. Quantitative criteria weights from the literature review were used to calculate and visualize data using GIS.

Selection of trails and taking inventory

Due to its purpose and the limitations of the study (in terms of finance and of the individual effort required), it was decided to select just 10 of the total of 64 trails to analyse. To identify appropriate trails appropriate, personal interviews were conducted with 19 individuals, including experienced regional guides (5), local residents (4), tourism sector workers (5), and members of the Kaçkar Mountaineering Rafting and Ski Sports Specialization Club (KMRSC) (5). Participants were chosen based on their trekking experience and diversity of background in terms of age, physical characteristics and profession. The trails were chosen to form a network that would encompass many natural and cultural assets from the south to the north of KMNP. The information gathered during the field surveys was recorded using the Maps3D application and transferred to a computer environment.

Selection and weighting of criteria

Since the criteria used in trail classification studies vary depending on the geographical features of the region and the visitors' characteristics, the criteria for this study were based on a literature review (Kiper & Arslan 2007; Kiracioğlu et al. 2013; Vías-Martínez & Ocaña-Ocaña 2014; Vías et al. 2018; Ayhan et. al. 2020; Ha & Yang 2020; Turgut et al. 2021), input from members of the KMRSC and hiking guides, and the knowledge of the local people. Sub-criteria were also based on those found in the literature. These were re-scored for the present study in the ArcGIS environment, using the Reclassify tool, in the range of 0–100. The criteria selected for the degree of difficulty and the scores prepared for the subsequent eligibility analysis are shown in Table 1.

Slope

Slope criteria for trail suitability were classified according to Vías-Martínez & Ocaña-Ocaña (2014). The USGS SRTM Digital Elevation Model (USGS 2021) and 1/25,000 scale national maps were used for slope analysis. As the USGS and Ordnance Survey maps are derived from different databases and cover different years, there were some discrepancies. To address this, contours from both data systems were compared, differences were updated and resolved, and 1m x 1m resolution DEM data were generated. The ArcGIS Add Surface Information tool was used to calculate the average slope of the trails.

Altitude

Ha & Yang (2020) note that as altitude increases, temperature and air pressure decrease while wind in-

Table 1 – Classification of criteria.

Criterion	Sub-Criterion Class	Score	References
Slope (%)	0–5	100	Vías-Martínez & Ocaña-Ocaña (2014)
	5–15	75	
	15–30	50	
	30–45	25	
	>45	1	
Surface	Grassy ground	4	Vías-Martínez & Ocaña-Ocaña (2014)
	Rock	12	
	Grass over stony ground	1	
Altitude (m a.s.l.)	0–1,800	100	Ha & Yang (2020)
	1,800–2,300	75	
	2,300–2,800	50	
	2,800–3,300	25	
Length (km)	0.25	100	Normalization
	0.50	75	
	0.75	50	
	1	25	
Average duration (min)	0–180	100	Vías et al. (2018)
	180–360	75	
	360–540	50	
	>540	25	

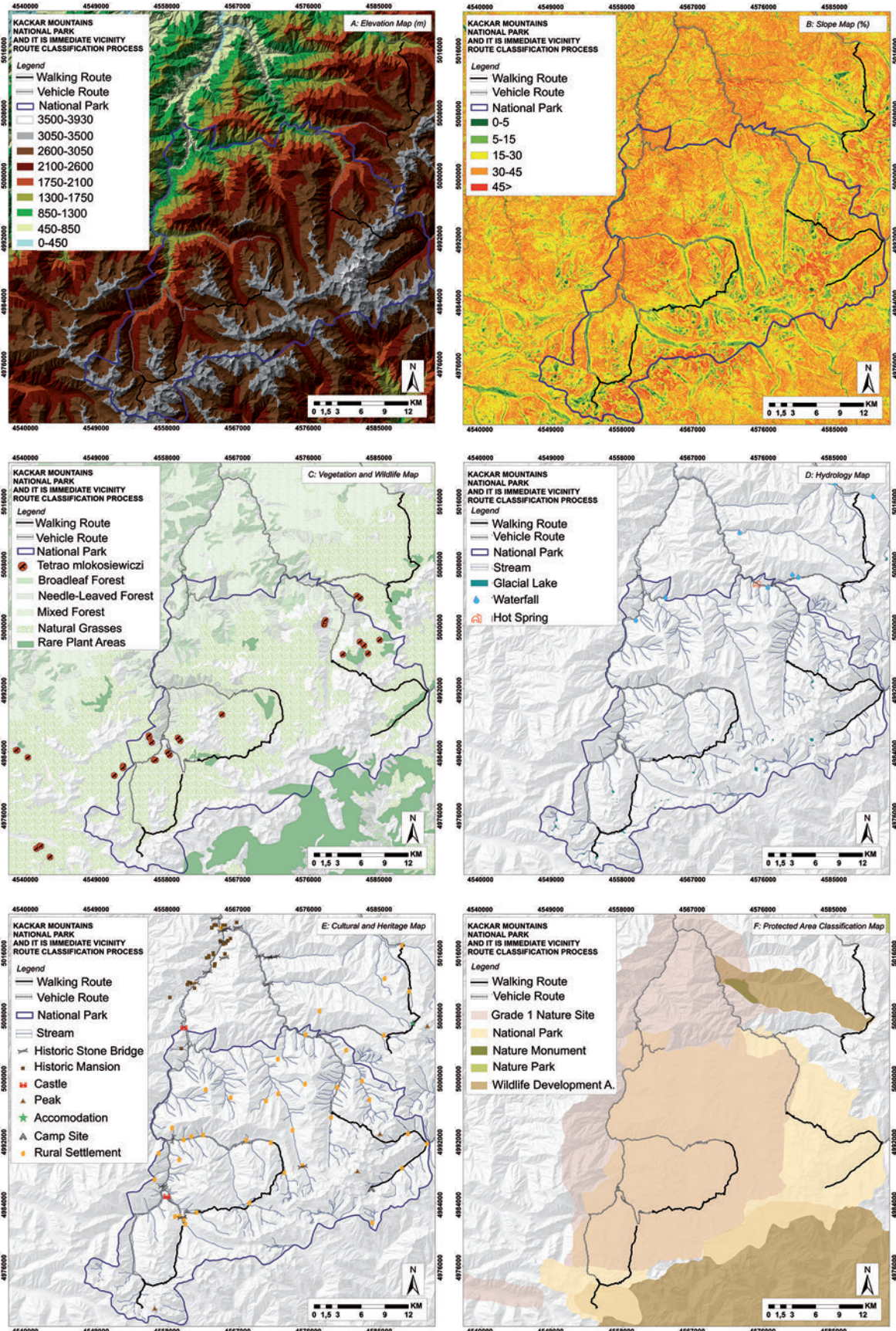


Figure 2 – Inventory of the study area (A: Elevation; B: Slope; C: Vegetation and Wildlife; D: Hydrology; E: Cultural Heritage; F: Protected Area Classification). Source: Authors' figure, Data sources: USGS; Corine Land Cover 2018; General Directorate of Forestry 2021; Isfendiyaroglu 2007; Esri.

Table 2 – Criterion weights.

Criterion	Slope	Surface	Elevation difference	Length	Average time	Weight
Slope	1	1	4	5	5	0.366
Surface	1	1	3	6	5	0.356
Elevation difference	1/4	1/3	1	3	3	0.141
Length	1/5	1/6	1/3	1	3	0.083
Average time	1/5	1/5	1/3	1/3	1	0.054

Table 3 – Classification of hiking-trail difficulty levels.

Difficulty Level	Score Range	Difficulty Class Points
Low (L)	$[(\bar{x} + \frac{1}{2}\sigma) - \text{Maximum}]$	[45–61]
Medium (M)	$[(\bar{x} - \frac{1}{2}\sigma) - (\bar{x} + \frac{1}{2}\sigma)]$	[35–45]
High (H)	$[\text{Minimum} - (\bar{x} - \frac{1}{2}\sigma)]$	[10–35]

$\bar{x}$: Arithmetic mean, σ : Standard deviation

tensity increases, challenging an individual's physical fitness. Following Ha & Yang (2020), we categorized altitude into five classes. Altitude data were derived from the Z_Mean table calculated using the tool for the slope criterion analysis.

Length

The data for path length came from GPS records, with path lengths in the study area ranging from 2.16 km to 13.09 km. Based on the perception that *shorter distances are easier* derived from interviews, lengths were categorized into four classes.

Average Duration

Walking times vary according to the individual's physical condition and physique. In most walking time calculation studies, the Naismith-Langmuir rule and Tobler's walking function are used (Márquez Pérez et al. 2017; Irmischer & Clarke 2018; Kim & Park 2019). Our study used the Tobler walking function, which takes into account the slope of the terrain. The Python module prepared by Alexandre Neto (Neto 2014) was loaded into QGIS, and walking times were calculated using DEM and trail data. In the Tobler function, the walking speed is accepted as 5 km/h, although the actual speeds will be different for flat and sloping ter-

rain. Therefore, in this study, to calculate the duration the walking speed was considered to be 4 km/h.

Surface

In order to obtain the surface types of the trails, the CORINE land cover data for 2018 were used. The CORINE data for each trail section were then processed using the ArcGIS Extract by Mask tool. Surface types were checked against field observations and discrepancies were resolved. Reclassifications were based on the work of Vías-Martínez & Ocaña-Ocaña (2014).

Once the criteria had been identified, a survey of 14 experienced hikers was conducted. They were asked to rank the importance of each criterion using the pairwise comparison method developed by Saaty in 1980. This calculates the weight of each effect in the decision-making process (Table 2).

A consistency ratio is used to determine the acceptable accuracy of judgements in the pairwise comparison matrix. According to Saaty, a ratio below 0.10 indicates consistent judgements, allowing evaluations to proceed. Ratios above 0.10 indicate inconsistencies that require reassessment. The following equations are used to calculate the consistency ratio (Öztürk & Batuk 2010).

$$CI = (\lambda - n) / (n - 1) \text{ and } CR = CI / RI \quad (1)$$

CI – Consistency index of the pairwise comparison matrix

CR – Consistency Ratio

RI – Random Consistency Index

Results

Results from the field studies

The results of the field studies are presented in Table 4 for the trail experience as defined by Sport Ireland Outdoors (2020) (length, ascent/descent, level of difficulty, etc.), with the addition of duration. The plateaus at the start of the trail and along its length are used by local people for grazing in spring and summer. Field research has shown that most buildings in these areas are single-storey stone structures, a choice influenced by the ready availability of wood and stone.

Table 4 – Findings for trail experience.

Trail		Elevation (m)		Length (km)	Elevation Diff. (m)		Time (min.)		Diff. Level
Name	Abb.	Start	End		Ascent	Descent	Maps3D	Tobler	
Vercenik Plateau-Kapılı Lakes	T1	2,606	2,975	3.84	376	-	127	108	L
Vercenik Plateau-Tatos Lakes	T2	2,610	2,941	3.27	464	132	165	267	M
Tatos Lakes-Orta Sirt Plateau	T3	2,941	2,243	6.36	7	705	193	170	L
Baş Plateau-Hacıvanak Plateau	T4	2,481	2,446	6.62	511	410	277	204	M
Hacıvanak Plateau-Trovit Plateau	T5	2,792	2,446	9.62	616	769	369	286	M
Yukarı Kavron Plateau-Olgunlar Village	T6	2,260	2,110	13.09	1,066	1,209	533	505	H
Olgunlar Village-Dilberdüzü Campground	T7	2,110	2,860	7.5	746	-	250	272	L
Komatı Plateau-Topluca Plateau	T8	1,498	2,387	5.76	902	14	340	361	M
Topluca Plateau-Avusor Plateau	T9	2,387	2,379	8.53	735	745	337	327	H
Avusor Plateau-Büyük Lake	T10	2,370	2,675	2.16	301	-	58	92	L

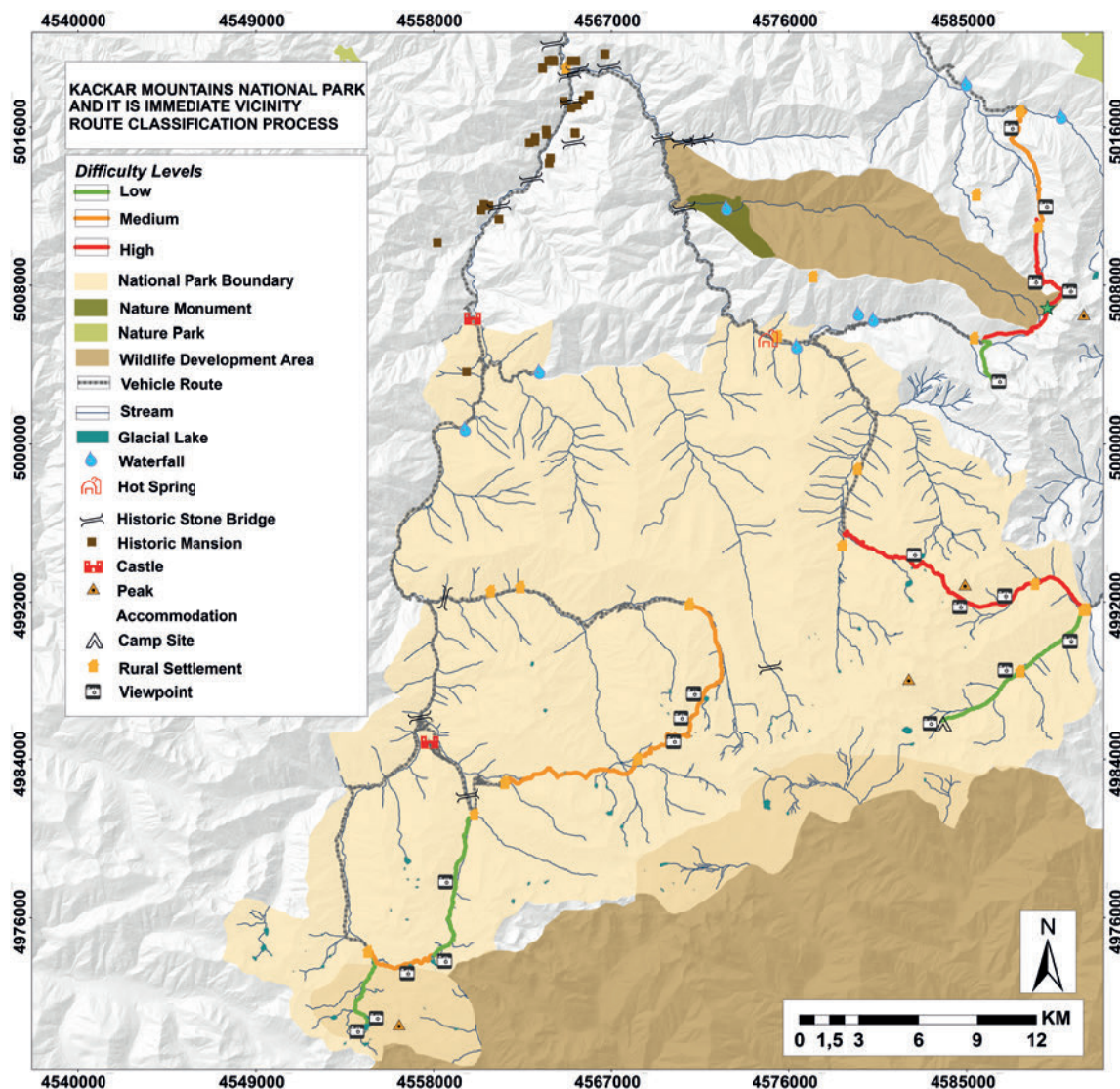


Figure 3 – Hiking-trail difficulty levels. Source: Authors' figure. Data sources: USGS; Corine Land Cover 2018; General Directorate of Forestry 2021; Isfendiyaroglu 2007; Esri.

The trail areas also have abundant surface water and numerous glacial lakes.

Results regarding trail difficulty levels

When looking at the average of the scores given by the experts, it was found that the slope and surface weights were quite close to the parameter weights used in the pairwise comparison matrix. The two most important parameters were slope followed by surface, then difference in elevation, length and average time (Table 2). The consistency ratio of the matrix created was calculated to be 0.0569, meaning that the matrix fell in the consistent and usable range ($0.0569 < 0.10$).

The scores of the sub-criteria were re-scored taking into account the studies in the literature. Adding the criterion weights and sub-criterion scores resulted in a score range of 10 to 61, where low scores indicate greater difficulty and high scores indicate lower difficulty. The difficulty of the trails is divided into three classes: low, medium and high. The score ranges of

the classification were determined by calculating the standard deviation (Table 3), which has the advantage of revealing the variations specific to the variables in the study area. Each trail's level of difficulty was determined by calculating the weighted average of its range of scores (Figure 3). Looking at the results (Table 4), trails T6 and T9 are of high difficulty; T2, T4, T5 and T8 are of medium difficulty, and T1, T3, T7 and T10 are of low difficulty.

This table is based on the information deemed necessary by Sport Ireland Outdoors (2020) in relation to assessing overall trail experience.

Results regarding the determination of themes

Thematic classification and grouping of trails allow for the identity of an area to be revealed, interpreted and promoted. The trails in KMNP were classified according to their natural, cultural, historical and social characteristics (Figure 4).

Name: Glacial Age Content: Glacial valleys, Moraine wall, cirque lakes, plant diversity, Kale-i Bala castle Trail: T1-T2-T3	Name: Wild Content: Observing wildlife, desolate Trail: T4-T5	Name: Victory Climb Content: Naletleme gateway, Kaçkar Pick, observing geological formations, vernacular architecture Trail: T6-T7	Name: Cloud Sea Content: Experiencing traditional highland life, experiencing cloud sea Trail: T8-T9-T10
			
			
			

Figure 4 – Photographs illustrating theme features. © Pinar Ozge Parlak

Discussion

Roads in natural areas, used for centuries for traditional needs (transportation, migration, etc.), have become important tourism and recreation resources in the last fifty years (Walker 1996). Today, trails and their management help to conserve nature and culture, improve quality of life, create local jobs and provide enjoyable activity areas (Timothy & Boyd 2015); typically, residents are involved in decision making. The sustainability of recreational activities in areas rich in natural and cultural resources depends on the protection of ecosystems, biodiversity and cultural heritage (Kurdoğlu 2001). Sustainable use in resource-rich areas therefore requires management plans to ensure that access provides quality recreation while balancing protection and use (California State Parks 2020).

Detailed planning and accurate information are essential for a quality walking experience. Classifying trails based on their characteristics helps visitors choose trails that best suit their needs. Without proper planning, visitors may face physical challenges and disappointment, leading to dissatisfaction (Chhetri 2015). Trail mapping studies (e.g. Gavilanes Montoya et al. 2021) which underline the importance of the management and organization of a geographical area are under-used in visitor research. GIS more broadly can also facilitate management and organisation, and needs to be exploited more fully. No planning study

has been made on how recreational activities will be carried out in the KMNP, the conditions for visitor participation or organization, and follow-up of activities (Yüksek et al. 2012). The lack of trail signage, a dedicated management committee and accessible trail information highlight the need for trail mapping.

The fact that all routes in the study area are closed to transport in winter may lead to increased visitor density in the summer months, thus endangering or damaging natural areas. The aim should be sustainable tourism by ensuring a balanced distribution of the number of visitors, taking seasonal density into account. Weather conditions affect visitor experience and satisfaction directly. Sudden changes in weather conditions (such as fog or blizzards) are very common in KMNP, and may make hiking difficult, while visitors may miss out on natural and cultural values. Park managers should advise visitors of seasonal conditions and encourage walking at appropriate times to avoid overcrowding.

The criteria determined in the literature for trail suitability and difficulty on the one hand, and the findings presented in this study that rely in part on expert opinion support each other (Vías-Martínez & Ocaña-Ocaña 2014; Turgut et al. 2021). Slope and elevation were found to be important factors influencing difficulty. Trails with an elevation difference of 700 m and a minimum length of 6 km emerged as being more difficult, while trails of the same length but with an

elevation difference of up to 300 m are classified as easy, demonstrating that the most important factor in walking difficulty is the slope.

Trail T5 was reported by Bektaş (2010) as being less well known and less frequented than other trails due to its altitude, as was also revealed by our own field studies. This situation allows the observation of wildlife – in our case of brown bears and birds of prey. Studies (Boulanger et al. 2012; Muntiferi et al. 2021) indicate that wildlife often flees from trails frequented by tourists, suggesting that increased human activity could reduce wildlife sightings and cause and lead to visitor dissatisfaction. It is therefore advisable to limit the number of visitors on trails and to educate them in the need to be quiet and careful when observing wildlife.

Permanent snow in the Naletleme Pass and frequent heavy fog and hail in the northern pass on T6, which has been the most popular trail since 1980 with the development of the Yukarı Kavron Plateau, make this the most challenging trail (Clow & Gardner 2014). These weather conditions, which were also encountered during fieldwork, highlight the need to inform visitors in advance so that they can take necessary precautions.

This study aims to improve management and visitor satisfaction in PAs by standardizing levels of walking difficulty. It uses a participatory approach, objective criteria weighting and GIS-based methods to improve the objectivity of classification studies and support the development of a globally applicable system. User, expert and local surveys, together with observational data collection and actual experience of walking the trails improve the accuracy and reliability of the data. AHP in combination with GIS technology allow for more objective and reproducible spatial data analysis. However, the scope of this study is limited to ten trails due to time constraints, individual effort and lack of funding, making generalisation difficult, while the complexity of applying AHP and the process of ensuring consistency are methodological difficulties of the study. The fact that characteristics such as an individual walker's age, health and general physical condition cannot be assessed is a further limitation.

Nevertheless, this study aims to help park managers develop more effective planning and management policies, develop sustainable tourism, and increase user satisfaction and safety. It supports the participation of local communities in the planning process and draws attention to the benefits of such participation. It also draws attention to the need to balance conservation and use, and provides an important foundation in the scientific literature for future research and educational activities.

Management implications

The study can be applied by park managers for trail classifications and themes. Strategies such as simple and useful maps, promotional brochures, clear sig-

nage, litter monitoring/collection, and management programmes that look into human impact should be developed for trail management and maintenance. An online database with websites, mobile applications, pocket information cards introducing plants and animals, and informative signs (e.g. warning of special areas and hazards) should be prepared to guide visitors. Ecological sensitivity should be analysed and risk analyses should be carried out to help ensure the sustainability of resources and recreational activities within the conservation/use balance; a seasonal calendar of trails should be established; trail monitoring and control should be carried out, and trails should be temporarily closed when necessary.

Conclusions

Tourism in national parks is seen as an alternative to mass tourism. If properly managed, it allows people to develop rewarding relationships with nature, protect the environment and strengthen communities (Ghazvini et al. 2020). On the other hand, when an area within a PA is transformed into a tourism destination, the first group to be affected are the people who live there. For tourism to be sustainable, local people should be involved through a participatory planning approach (Han et al. 2023). Establishing a national park policy is essential to protect nature and balance the interests of both tourists and locals (Sriarkarın & Lee 2018).

Footpaths are ideal for exploring a region or heritage site. This study assessed the difficulty of selected trails in KMNP, examined their natural and cultural values, and presented findings in line with international standards. Identifying and classifying trails in PAs promotes sustainable tourism by improving hiker safety and satisfaction. As a result of the analysis, trail difficulty was divided into three levels (low, medium and high), which helped hikers to make more informed choices when selecting trails.

The thematic classification of the trails highlights the natural and cultural richness of the area and informs visitors about these values. The results were consistent with similar studies in the international literature and contribute to the protection of natural and cultural values, increased visitor safety and satisfaction, the sustainability of tourism, and local economic development.

The objective consideration of difficulty levels and the creation of themes enables park managers to make strategic plans. This approach guides visitors to make choices while supporting the conservation and sustainable use of natural resources. As a result, this study makes a valuable contribution to the planning and management of walking trails and has the potential to be an important tool in achieving the goal of protecting ecosystems and cultural heritage. Further research into the ecological sensitivity and risks of the trails would further improve resource sustainability and visitor sa-

tisfaction. In this context, the implementation by park managers of recommended strategies will ensure the long-term sustainable use of the park by establishing a balance between conservation and use.

Acknowledgement

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The Gennargentu Mountains: Between National Park and Private Conservation Area

Domenico Branca & Daniele Pulino

Keywords: National Park, paper park, private conservation, Italy, Mediterranean mountains

Abstract

Various forms of local opposition have marked the history of the establishment of the Golfo di Orosei and Gennargentu National Park (GOGNP), resulting in a governance vacuum which makes it, de facto, a *paper park*. Despite this, both public and private bodies have multiplied initiatives aimed at enhancing local heritage and promoting tourism within the GOGNP territory. The Donnortei wildlife oasis provides a compelling case study, showcasing economic diversification within conservation practices on private land. Here, the intersection of traditional and innovative animal husbandry practices with experiential tourism offerings highlights the region's evolving landscape of sustainable development strategies in environmentally sensitive areas.

Profile

Protected area

Golfo di Orosei and
Gennargentu National
Park, Italy

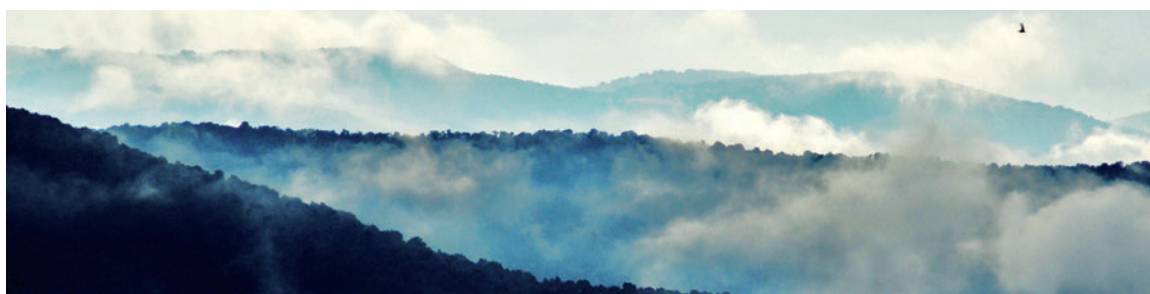


Figure 1 — Mountainous landscape in the Monti del Gennargentu SCI area. © Annamaria Pirellas

Introduction

The Gennargentu region, situated in central-eastern Sardinia (Italy), is recognized for its significant environmental value. Within this area, a Site of Community Importance (SCI), designated *Monti del Gennargentu* under Directive 92/43/EEC (SCI ITB001103), and a National Park, the *Golfo di Orosei and Gennargentu* (GOGNP) coexist. Although formally established in the 1990s, the GOGNP is presently non-operational because of the failure to set up protection bodies.

The unique territorial and environmental characteristics of the area led to a debate over its designation as an environmental protection area in the years following the Second World War. However, since the 1960s, the creation of the GOGNP has encountered opposition from a number of local communities because of the high level of human activity in the area, and they have impeded its realization. As a result, GOGNP authorities have not been appointed and the area is a prominent example of a *paper park* – that is, an *unimplemented protected area* or *under-managed protected area* (Dudley & Stolton 1999). However, the territory of Gennargentu continues to provide some environmental protection due to the presence of the Monti del Gennargentu SCI, which partially overlaps the territory of the GOGNP.

Furthermore, over the past two decades, numerous initiatives have emerged within the Gennargentu region focusing on enhancing both tangible and intangible heritage – that is, on the one hand, natural elements and physical artefacts and, on the other, aspects of local culture such as traditions and festivals. These initiatives help to promote and facilitate access to territorial and environmental assets, and foster the development of tourism. The initiatives provide potential solutions to address the challenges of depopulation and declining birth rates throughout the area.

This article seeks to outline the physical and demographic features of the GOGNP area and to trace the historical conflicts that have shaped its functioning. For an overall framing of the possible development of the area, we conduct an exploratory analysis of the cultural heritage and of the trajectory of tourism developments in the region. Finally, using this framework, we present a case study centred on the Donnortei wildlife oasis within the SCI area bordering the GOGNP. This case study highlights local initiatives that foster sustainable tourism and environmental conservation independently of GOGNP support.



Figure 2 — Abundant snowfalls typically occur in the winter months. © Annamaria Pirellas



Figure 3 — A male mouflon (*Ovis musimon*) in the woods. © Annamaria Pirellas

Geographical features

The GOGNP encompasses an area distinguished by prominent vertical relief. Including both coastal and mountain municipalities along the Gennargentu mountain chain, the GOGNP boasts the island's highest peaks, among them Punta La Marmora (1,834 m a.s.l.), Bruncu Spina (1,829 metres), and Su Sciuciu (1,823 a.s.l.). Situated within the Mediterranean bioregion, in central-eastern Sardinia, the second-largest island in the Mediterranean (24,090 km²), the GOGNP covers 73,935 hectares across the Provinces of Nuoro and South Sardinia. (Please insert figure 1).

Comprising territories historically belonging to Barbagia de Ollolài and Mandrolisài in the north and northwest, Sarcidàno and Barbagia de Belvì in the south, and Ogliastra in the east, the GOGNP hosts a population of around 41,650, although the region shows significant depopulation trends (Bachis et al. 2020).

The mountainous area features metamorphic rocks dating to the Carboniferous period, overlying Devonian-Silurian schists and Ordovician limestones (Barchetta et al. 2013). Karst systems are present, as in the Supramonte de Urzulèi area (Ginesu 1993). Where precipitation is concerned, the Gennargentu massif and Limbara in the island's northern sector receive more rainfall than any other areas in Sardinia (Motroni 2016), and abundant snowfall, particularly during winter months, with annual totals surpassing 1,200 mm (Figure 2).

With their sources in the eastern slopes of the Gennargentu are several mountain torrents, and the island's second-longest river, the Flumendosa (122 km). While Mediterranean scrub dominates the coastal regions of the GOGNP, higher elevations harbour a rich array of plant and animal species, including the European pine marten (*Martes martes*), Least weasel (*Mustela nivalis*), Sardinian wildcat (*Felis lybica sarda*), wild boar (*Sus scrofa meridionalis*), and mouflon (*Ovis musimon*) (Figure 3), as well as endemic plant species, including *Cynoglossum barbaricinum*, *Genista pichisermolliana* Vals., and *Orobancha denudata* Moris, to name but a few (Barchetta et al.

2013, 213–15). Barchetta et al. (2013, 212) provide extensive data on the flora, documenting “948 taxa, comprising 686 species, 249 subspecies, 10 varieties, and 3 hybrids, spanning 97 families and 427 genera”. Additionally, Carta et al. (2014) offer detailed insights into shrub and forest vegetation composition and distribution across the region, while the Nuragic villages, such as Ruinas (in the municipality of Arzana, altitude 1,197 m a.s.l.), attest to a longstanding human presence in the area.

The Golfo di Orosei and Gennargentu National Park and opposition to it

The history of the GOGNP, which was formally established in 1998, is closely entwined with collective actions that have continued to hinder its practical functionality. The GOGNP case symbolizes inadequate communication and collaboration mechanisms with pertinent local authorities and resident communities. These communities have persistently opposed the establishment of the protected area, fearing potential disruption to traditional civic and agro-pastoral activities (Heatherington 2011; Montaldo 2022).

Discussions about creating a park in the Gennargentu commenced as early as the 1920s, but it was not until the years immediately following World War II that establishing the GOGNP entered the political discourse. The process became entangled in contentious politics (Tilly & Tarrow 2015), intersecting with social and political history, mainly due to the implementation of various public policies by the Autonomous Region of Sardinia. Indeed, following World War II, the Region embarked on a series of extraordinary measures aimed at stimulating economic development. These initiatives, encapsulated within the *Plan for the Rebirth of Sardinia* (Regional law No. 588/1962), encompassed a range of interventions that catalysed the modernization process of the island. The primary objective of this plan was to establish industrial plants associated with a basic chemical industry, alongside various initiatives aimed at fostering tourism and developing the so-called *inner areas* of the island. Among these initiatives was the creation of the GOGNP (Scanu & Madau



Figure 4 — A group of red deer (*Cervus elaphus corsicanus*). © Annamaria Pirellas



Figure 5 — Donnortei Park offers summer camps and educational activities. © Annamaria Pirellas

2001, 243). In pursuit of this objective, a company appointed by the Region, Generalpiani, presented a project in 1966 (Cassola & Lovari 1976, 249).

However, having been developed without involving the resident population, the project encountered significant resistance from some local communities. Protests were emblematic of a broader pattern of dissent within inland municipalities that were unaffected by industrialization and characterized by substantial depopulation (Pigliaru 1971). The opposition gained momentum in 1969 following the Region's approval of a National Bill concerning the establishment of the GOGNP. The project proposed by Generalpiani entailed relocating part of the population and dividing the territory into zones, comprising a *zona di riserva integrale* (integral reserve zone, an area of strict protection), a *zona di riserva guidata* (a managed reserve zone) and a *zona controllata di sviluppo turistico* (controlled tourism development zone). However, the GOGNP itself remained theoretical due to vigorous protests, which were particularly prominent in the municipalities of Orgòsolo and Baunei. These communities viewed the entire endeavour as a catalyst for further depopulation and economic stagnation (Mazzette 1984; Ruju 1998; Heatherington 2011). Feeding these protests was the perception of the GOGNP as being imposed on local communities and municipalities by the Region. This perception subsequently served as a frame (Snow & Benford 1992) for the resurgence of new protests in the late 1980s. During this period, the Sardinian Region formally established the GOGNP with Regional Law No. 31 of 1989; the Italian Parliament followed with Law No. 394 of 1991 (Diana et al. 1998).

In the early 1990s, the issue of the designation of a national park generated widespread discussion and debate among the public. Certain environmental organizations, such as WWF, also initiated direct campaigns to underscore the benefits of a park for the region. Despite some surveys indicating majority support among Sardinians for the designation of a national park, a political obstacle persisted in the form of opposition from several municipalities in the area, including Orgòsolo, Baunei, Urzulei, Àrzana, Talana

and Villagrande Strisàili (Ruju 1998). This opposition endured until the Minister of the Environment designated the *Coordinamento del parco* (Park Coordination Committee) within the agreement of 29 December 1995 between the Ministry of Environment and the Autonomous Region of Sardinia. Subsequently, a 1998 government decree defined the GOGNP's boundaries, accommodating additional municipalities that sought inclusion. In fact, some municipalities that had initially been excluded from the GOGNP's perimeter saw the development opportunities it could represent. Conversely, in some municipalities opposition continued to prevail, especially concerning constraints on land use. It is notable that during this period dissent emanated primarily from the more educated segments of local communities, manifesting as criticism of top-down imposition and a general distrust of institutional actions (Diana et al. 1998).

The latest act in the story of the GOGNP unfolded in the early 21st century. Despite the Region's attempts to mediate with the Ministry of the Environment for appointments to the Coordination Committee, prompted by demonstrations, protests and pressure from local communities and interest groups (notably hunters and fishermen), no agreement with the government was reached on the establishment of governing bodies. Consequently, Law No. 266 of 23 December 2005 (a financial law) stipulated the need for a new State–Region agreement regarding the allocation of resources, postponing indefinitely the operationalization of the GOGNP.

Heritage and tourism

The municipalities of the Gennargentu territory are home to a rich tangible and intangible heritage. In the last two decades and despite the failure to realize the GOGNP, private and public actors have begun to exploit this natural and cultural heritage to develop the territory. Cultural traditions (such as local carnivals or local feast days), ethnographic and archaeological museums, archaeological areas and natural landmarks are used to promote the territory. There are also nu-

Table 1 — Local assets in Gennargentu municipalities. Source: Based on ISTAT data and *sardegnanatura.com*

Assets	Absolute value
Museums and archeological areas	18
Natural monuments	6
Public libraries	28
Farmhouses	60
IGT/DOP producers	733

merous protected food products, such as Barbagia wine (IGT; Indication of Geographical Typicality), Mandrolisai wine (DOC; Controlled Designation of Origin), or the cheese known as Fiore Sardo (DOP; Protected Designation of Origin) (Table 1).

If we look at the number of guest beds per 100 residents and their occupancy rate, it can be seen that tourism offer and demand have evolved significantly since 2003 (Table 2). The data show the consolidation over time of a network of non-hotel-based services aimed at tourism (Figure 6), including the growth of B&Bs and room rentals, and of agritourism businesses that combine accommodation and the offer of local products. Finally, it is worth mentioning the presence of a network of paths in the GOGNP which allow for *slow* forms of tourism and hiking (see Podda et al. 2020).

The analysis of the area's heritage indicates not only resources for development but also the initiatives of local community actors in revitalizing the area. In particular, several initiatives focusing on cultural heritage and tourism involve private actors as promoters. However, it is crucial to emphasize the role of public policies (both regional and European) in stimulating and supporting such initiatives, which often face challenges to become established within territories.

Case study: Donnordei wildlife oasis

Despite the GOGNP existing only on paper, parts of the area enjoy protected status, notably the Site of Community Importance (SCI) or Special Area of Conservation (SAC) and the Special Protection Area (SPA) of the Gennargentu Mountains, which form part of the Natura 2000 Network. Within this protective framework lies the Donnordei estate. This is a family-operated farm and includes a *nature oasis* which was conceived and established by the Serusi family in the 1990s on their land in the municipality of Fonni, stretching from Mount Spada to the Aratu Valley. The elevation of the oasis ranges from approximately 700 to 1,200 m a.s.l. Diversification is the estate's primary economic strategy, structured around two main areas of activity: livestock farming (both traditional and wild – i.e. farming of wild species), and hospitality services. Despite considerable opposition to the GOGNP from some local communities, which halted the establishment of the National Park, data indicates that public and private entities are using the region's

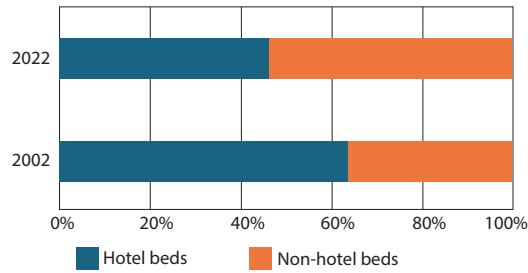


Figure 6 – Hospitality evolution in Gennargentu municipalities 2002–2022. Source: Based on ISTAT data

territorial capital to rejuvenate the area for tourism and environmental purposes. The case we present, that of the Donnordei wildlife oasis, exemplifies this trend, as its narrative intertwines with that of the GOGNP. Particularly in its inception, the wildlife oasis faced opposition and stigma similar to those faced by the GOGNP.

During the early 1990s, the Serusi family created the oasis amidst heightened opposition to the GOGNP. The establishment of another (albeit privately owned) area of protection – a *nature oasis* within a protected area – was perceived as a threat by segments of the local population who were against the GOGNP.

According to an interview conducted in Donnordei in February 2024, this land was unsuitable for grazing but was home to the mouflon, a species of ungulate typical of the Sardinian mountains. Serusi's concept was to integrate the traditional use of the land for sheep farming with the rugged mountain terrain to protect and increase the wild mouflon population, which is not amenable to domestication. Serusi received support from his wife Annamaria Pirellas, who also hailed from Fonni. Annamaria had lived in Argentina, where she was acquainted with deer and guanacos on farms, and agreed to replicate, in a local context, the traditional Argentinian form of *wild* husbandry. Consequently, the process of fencing off the land began.

However, the project encountered significant opposition from Serusi's own family (particularly his father) and the local community, and a clash emerged between an ethos of *traditional* livestock farming and a more *modern* environmentally conscious vision, as advocated by the Serusi couple, which also served economic ends. One segment of the local population opposed the project as part of wider protests against the GOGNP. Other opposition was voiced by hunters, mainly due to certain areas of land no longer being accessible because of fencing. The development of the oasis has been marked by intimidation and attacks on the family and the farm, including killing animals and arson. However, over the years, especially since the 2010s, opposition to the project has gradually diminished thanks to the regional and national recognition of what Donnordei wildlife oasis is beginning to achieve as a leading example of nature tourism activities.

Table 2 — Touristic impact indicators in Gennargentu municipalities. Source: Based on ISTAT data.

Municipality	Bed capacity index	Non-hotel bed index	Touristic pressure
Aritzo	20.4	3.8	0.89
Arzana	3.2	-	0.06
Atzara	1.2	1.2	0.00
Baunei	15.8	6.5	5.24
Belvi	5.7	1.4	0.00
Desulo	2.9	2.0	0.06
Fonni	6.3	3.6	0.20
Gairo	31.5	31.5	2.94
Gavoi	14.2	2.3	0.12
Lodine	17.0	17.0	0.00
Meana Sardo	18.9	8.5	0.15
Oliena	0.6	0.6	7.04
Ollolai	0.8	0.8	0.01
Olzai	21.7	14.5	0.00
Orgosolo	0.5	0.5	1.71
Ovodda	5.9	4.3	0.01
Seui	2.0	0.7	0.02
Seulo	-	-	0.28
Sorgono	70.0	57.4	0.17
Talana	7.0	3.1	0.05
Tiana	11.4	3.7	0.00
Tonara	0.4	0.4	0.72
Urzulei	0.5	0.5	0.53
Villagrande Strisaili	5.3	2.5	0.87
Municipalities Gennargentu area	11.0	7.0	0.9
Sardinia	14.1	7.0	2.84

Animal Breeding and Tourism

Tourism and animal husbandry constitute the primary activities within the oasis, which has chosen to diversify its farming approach (authors' interview with Daniele and Annamaria, 22 February 2024; unpublished). Alongside traditional livestock farming, notably sheep and horses, the farm also raises native wild species for the production and sale of food products, regulated in Sardinia by the Regional Department for the Defence of the Environment. In the present scenario, alongside the existing mouflon population, the farm also raises both fallow deer (*Dama dama*) and the Corsican red deer (*Cervus elaphus corsicanus*) (Figure 4). The red deer originate from the WWF reserve of Monte Arcosu in Sulcis, southwestern Sardinia, while the fallow deer were reintroduced from Liguria in 1999 in the context of a collaborative project with the Region of Sardinia to restore species that were extinct in their native habitats.

Dairy products and meat from traditional livestock farming are not commercially marketed; instead, they are consumed on-site by guests staying locally. The mouflon, red deer and fallow deer undergo controlled slaughter for human consumption. Crop production, constrained by the geographical context, focuses primarily on fodder for livestock and potatoes.

Diversification is seen also in the tourism offer more broadly, particularly experiential tourism. Tourists comprise mostly families and small groups, both local and foreign. Visitors from the Netherlands are

particularly noticeable, attributable to a partnership established with an agency catering specifically to that market segment. Additionally, there are significant numbers of French, Spanish and German visitors. The interview referred to above also revealed the notable fact that most Italian tourists originate from Sardinia, particularly from the province of Cagliari. These local tourists represent a significant influx, estimated by the interviewees to be approximately 20,000 per year. This level of visitation also extends to the town of Fonni and the surrounding territory.

Diversification is also evident in the activities provided by the oasis, which align with environmentally oriented tourism. For instance, Donnortei wildlife oasis has been designated an Educational Farm which welcomes schools (Figure 5) and offers educational activities about the region and the environment (such as recounting the history of the area's deforestation since the 19th century). Additionally, the farm organizes summer camps featuring excursions in the oasis and the Gennargentu massif, cookery workshops and horseriding lessons. Excursions take various forms (on horseback, on foot, by quad, or off-road), with the option of helicopter tours, even though these (especially the quad and helicopter tours) would not normally be deemed to be in line with environmental tourism.

Notable strengths of Donnortei wildlife oasis are its dedication to economic activities (tourism and animal husbandry) and fostering collaboration with scientific research, including the farm's participation in

a LIFE 2014–2020 project. This resulted in the farm being recognized as one of Italy's 38 exemplary farms within protected areas (Calvario et al. 2018).

Conclusion

The establishment of the GOGNP, which encompasses Sardinia's highest peaks and the Gennargentu Massif, has had a complex history marked by vigorous opposition from segments of the local population. This resistance stems from the perceived top-down imposition by the state and reluctance to adhere to restrictions on customary resource usage. Currently, *“the Park is [...] ‘temporarily coordinated’ by the province of Nuoro; therefore, its establishment ‘on paper’ remains, but in practice, the conditions necessary for it to be realized are all lacking”* (Redaelli 2015, 35). Consequently, *“the prospects for its possible implementation are fragile now. The Gennargentu and Gulf of Orosei National Park risks remaining a ghost park for a long time”* (ibid.). Nonetheless, in recent years, numerous public and private initiatives have emerged within the GOGNP's territory that target the enhancement of local tangible, intangible and environmental heritage, with a particular focus on tourism development.

The Donnortei wildlife oasis represents an innovative approach to conservation and economic development in the region, effectively balancing private land use with environmental conservation goals. The oasis is exemplary because it successfully combines multiple economic activities while conserving and enhancing the mountain environment, thus providing a model of sustainable development in the region. In the initial phase, it faced criticism and even physical attacks, mainly due to its association with the GOGNP, which was vehemently opposed by some in the surrounding municipalities. However, in a subsequent phase, the normalization of relations led to widespread acceptance. It is now a reference point for this mountainous region regarding conservation and tourist hospitality. Although Donnortei wildlife oasis is a family-run business, it employs about a dozen local people (depending on the season), and the fact that it attracts numerous tourists and visitors also has positive effects on Fonni and other neighbouring municipalities. It effectively illustrates the evolving landscape of conservation practices (Zupančič-Vičar 2006) and the array of economic activities possible within a private protected area, helping demonstrate the political, economic and socio-environmental complexity of protected areas (Paradiso 2024).

Discussion of the activation of the GOGNP is still ongoing, especially during local election campaigns, highlighting the strategic importance of environmental issues in the local political context. Several regional initiatives, both public and private, aimed at promoting sustainable tourism demonstrate a growing interest in nature-based tourism. In Sardinia, renewed interest in mountains, which are now considered not only places of work but also leisure destinations, represents a con-

stantly evolving phenomenon that needs to be closely monitored, particularly in inland areas.

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Embedded in the park: the Vanoi Ecomuseum as a lever for sustainable landscape management in the Italian Alps

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Keywords: nature park, vertical land use, heritage, sustainable development, applied historical geography

Abstract

The Paneveggio-Pale di San Martino Nature Park (*Parcopan*) is one of two nature parks in Trentino (Italy) and hosts several sites of the Vanoi Ecomuseum, a non-bounded and participative form of museum that also includes unprotected areas. In this paper we explore the integration of ecomuseums into protected areas through the case of the *Parcopan*. We focus especially on the role of the Vanoi Ecomuseum in preserving and enhancing the natural and cultural heritage of this area, in particular vertical land use and mobility within the historical landscape. We provide an overview of the Vanoi Ecomuseum's activities, and highlight the use of 'cylinders of mobility' as an effective method to visualize and understand the vertical land use and seasonal movements of people that have historically characterized the Alpine economy. We argue that the integration of ecomuseums into nature parks represents a valuable approach to sustainable landscape management and tourism, especially when natural parks seek to draw on the endogenous potential of their cultural and natural heritage as well as on modern adaptations of traditional land use.

Profile

Protected area

Paneveggio-Pale di San

Martino Nature Park

Mountain range

Alps, Italy

Introduction

Although the ecomuseum movement was initiated in France in the late 1960s, the word *ecomuseum* itself was formally introduced by Hugues de Varine in 1971 (quoted in Hubert 1985, and Davis 1999) for community initiatives that offered the opportunity to be creative or even audacious, develop new ideas, or adopt new approaches (de Varine 1985 and 1988; see also Rivière 1985). Early definitions of *ecomuseum* include the one by René Rivard (1985), who provided a comparison between traditional museums (building + collections + experts + public) and ecomuseums (territory + heritage + memory + population). Since then, ecomuseums have evolved further to include a wide range of community-heritage projects that foster a sense of place and community empowerment by integrating cultural heritage, community participation and sustainable development (Borrelli & Davis 2012). Because of their holistic and participative approach to natural and cultural heritage management, ecomuseums have gained significant traction worldwide, with notable growth in Europe, North America and Asia, where several cases demonstrate how they can be catalysts for community engagement, sustainable tourism and local economic development, while promoting environmental awareness and cultural preservation.

The connection between the natural and the cultural dimensions is proper to ecomuseums. As Pavlis (2024, 3) points out, *“the term ‘ecomuseum’ derives from the Greek word ‘oikos’ (eco) meaning the ‘natural environment’ and ‘museum’ which is the place or temple dedicated to the 9 Muses of Greek Mythology (goddesses of the arts). The Muses, origi-*

nally, were goddesses of mountains and lakes”. Unlike traditional museums, ecomuseums extend beyond physical buildings to encompass entire landscapes, emphasizing the interconnectedness of people, their environment and their cultural practices (Corsane et al. 2007). The aim of ecomuseums is to preserve, interpret and enhance the natural and cultural heritage of a specific geographical area – for instance, a protected area – and involve local communities in identifying, conserving and showcasing it. The holistic approach to heritage management aligns well with contemporary concerns about sustainability, community empowerment and resilience, and cultural diversity (Davis 1999).

The Vanoi Ecomuseum: foundation, activities and aims

According to the ecomuseum DROPS platform (<https://sites.google.com/view/drops-platform/home>), in Italy there are more than 263 ecomuseums, yet only 155 are officially recognized and supported financially by the public sector. The Vanoi Ecomuseum (only the second ecomuseum to be protected by a provincial law, issued by the Autonomous Province of Trento [Provincial law nr. 13/2000], the first being in the Piedmont [Regional law nr. 31/1995]) is part of the *Rete degli Ecomusei del Trentino* (Network of Trentino Ecomuseums). Established in 2011 and currently including nine ecomuseums, this network aims to provide a platform for mutual support, direct communication, and shared goals and actions.

The creation of ecomuseums within protected areas is currently being attempted in several of Italy's

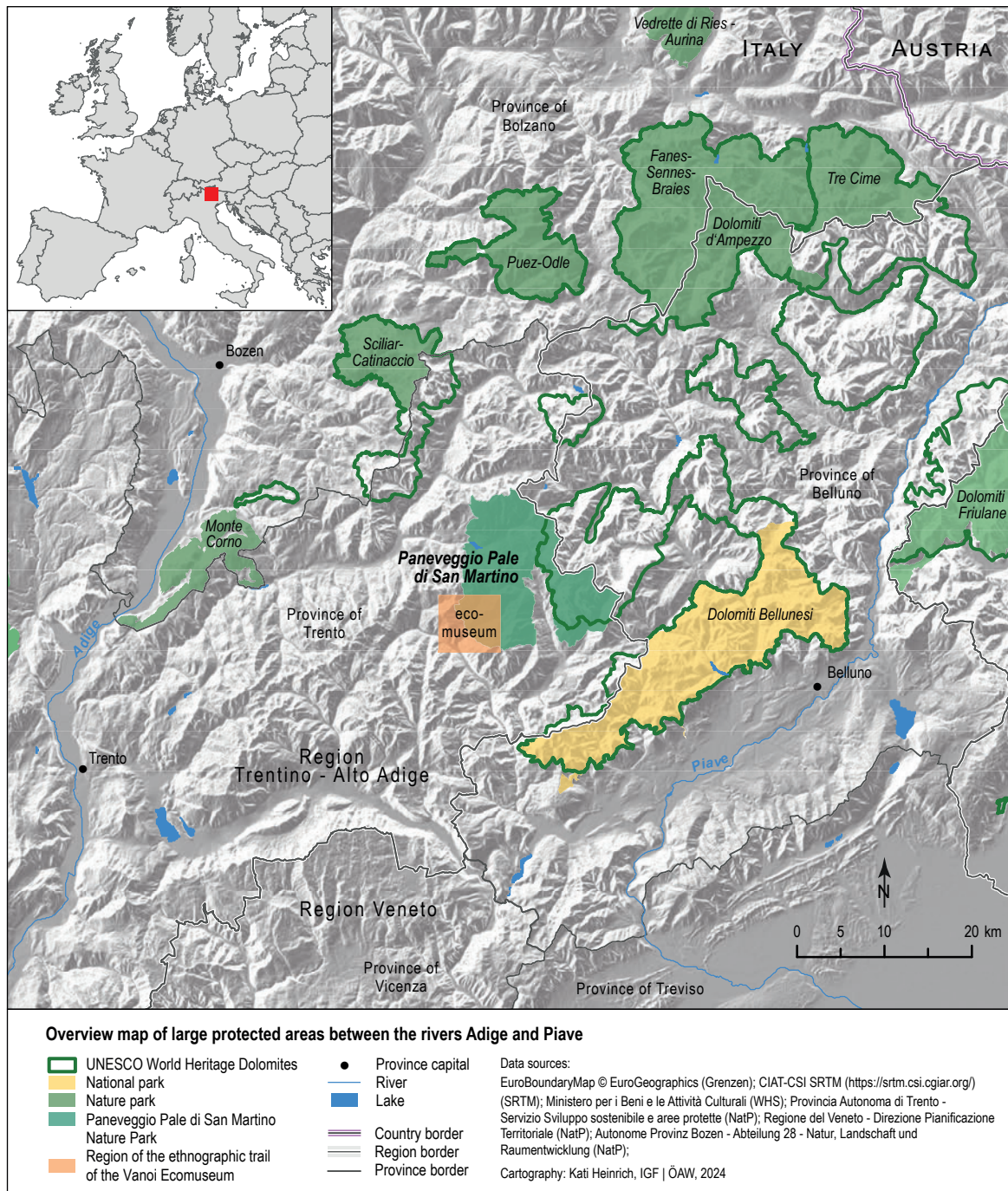


Figure 1 – General map of the large protected areas between the Adige and Piave rivers (with the ParcoPan in the centre of the map).

mountainous regions. Examples include the Capanne di Marcarolo Regional Nature Park (Apennines), Alpi Marittime Regional Nature Park (Alps), Alpi Cozie Regional Nature Park (Alps), Adamello Brenta Nature Park (Alps), and the Paneveggio-Pale di San Martino Nature Park (*ParcoPan*, Alps), which is discussed in this paper (see Figure 1).

The *ParcoPan* was established in 1967 and formally regulated by a provincial law (L.P. 18/1988; on the Park's management bodies, see Infobox). It covers 19,726 hectares in the western part of the limestone massif of the Pale di San Martino, a mountain range in the Dolomites that is part of a UNESCO Heritage

Site, and the eastern part of the Lagorai chain, which comprises mainly volcanic rocks. In 1993/94, the *ParcoPan* and the *Museo Etnografico Trentino San Michele* (in San Michele all'Adige, Trento) aimed to create an ethnographic trail to save and make known the local historical and cultural heritage, especially around the village of Caoria in the Vanoi valley. This project was co-financed by the Autonomous Province of Trento and the European Community (EEC Regulation 2081 of 20 July 1993, Objective 5b, ERDF sub-programme, measure no. 5). The idea of establishing an *ecomuseum* covering the entire Vanoi valley emerged in 1997 in the frame of the close collaboration between the *Parco-*

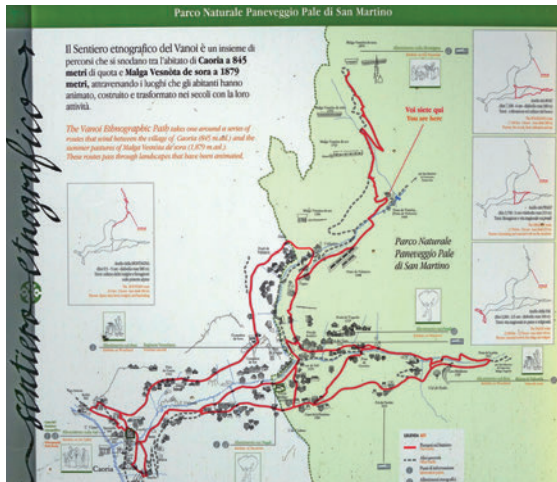


Figure 2 – Information board showing the loops of the ethnographic trail. © Oliver Bender

pan and the municipality of Canal San Bovo, leading to its foundation in 1999 (Bortolotti 2004). The Vanoi Ecomuseum is the first ecomuseum, and one of the largest and best-equipped, in Trentino, and played a pioneering role in establishing the *Rete degli Ecomusei del Trentino*. While it was officially recognized by the Autonomous Province of Trento in 2002, it was founded by the *Associazione Ecomuseo del Vanoi*, an association originally comprising 35 members (currently 133), including corporations, organizations and private individuals. The association, which is still in charge of the management and planning of the ecomuseum, is formally appointed by the municipality of Canal San Bovo every three years; it is directed by an Executive Board of five people nominated from among the members of the association. The Vanoi Ecomuseum benefits from partnerships with local, provincial and regional institutions, and relies on one full-time employee, several experts (e.g. cultural anthropologists and cultural mediators), seasonal employees, mountain guides, *Pro loco* (local grassroots) organizations, and volunteers. Importantly, the local community participate actively as first-hand sources of information for the conceptualization, contextualization and operationalization of activities.

The aim of the Vanoi Ecomuseum is to preserve, research and present the area's cultural landscape and cultural assets as a reminder of traditional life in the valley. More specifically, it aims to address the dimensions of *space, time, community and their knowledge* through seven key themes related to the history of the area: mobility, grass, wood, water, the spiritual dimension, stone and war. Visitors can explore these themes by following the *sentiero etnografico* (ethnographic trail) in the area of Caoria. In terms of the general maintenance of the paths, and of the structures which can be visited or booked for accommodation, the trail is managed by the Parcopan authority (Bortolotti 2004), in the frame of a three-year agreement with the municipality of Canal San Bovo. Stretching along the valleys



Figure 3 – Reconstructed channels for transporting logs (Forest loop of the ethnographic trail). © Oliver Bender

of both the Valzanca and the Valsorda for a total of 20 km, in the western part of the Parcopan, and with a 1000 m difference in altitude, the trail is divided into four different loops: the *anello della val* (valley loop), *anello dei prati* (meadow loop), *anello del bosc* (wood / forest loop), and *anello della montagna* (mountain pastures loop) (see Figure 2). The thematic loops were created with the support of the European Pathways to Cultural Landscape project and are core elements of the Vanoi Ecomuseum, preserving places and paths of the former Alpine economy both materially and in people's consciousness (Bortolotti 2004, 4). Several sites can be visited along the trail, such as the sawmill, and the channels for transporting logs (see Figure 3) to the creeks and rivers, on which they were then drifted and

Infobox

The management of the Paneveggio-Pale di San Martino Nature Park (Parcopan) and its connection with the Vanoi Ecomuseum

Parcopan's management bodies are the President, the Management Committee, the Executive Council, the Director and the Board of Auditors. The Management Committee is the largest body of the park: it decides the political-administrative guidelines and monitors their implementation. The Committee consists of 21 members nominated by the Provincial Council from among representatives of the public administrations (including the municipality of Canal San Bovo) and local stakeholders with cultural, social, economic and environmental competences.

The collaboration between the Parcopan and the Vanoi Ecomuseum is mediated by the municipality of Canal San Bovo with regards to financing and management. There is a formal agreement between the nature park and the municipality, designed specifically to ensure collaboration in the ecomuseum's management. Two municipal councillors are members of the park's Management Committee; one of them, along with the park's President, informally attends the Vanoi Ecomuseum's Executive Board meetings.



Figure 4 – Representation of the traditional agrarian Caoria community (up to mid-20th century), between the village (840 m) and the mountain pasture (*malga* Miesnotta, 1,880 m), beneath the peaks of the Lagorai chain. Painting by Roswitha Asche. © ParcoPan

rafted to Venice (Occhi 2006; Asche et al. 2010), and a typical hay barn (discussed below). The production of butter as a high-quality regional product, which was already part of the local economy in early modern times, has recently started again on one of the farms in the mountain pastures (the *malga Fossernica di fuori*) in collaboration with the Primo cheese cooperative and the Slowfood organization.

The Vanoi Ecomuseum also manages several collections of objects, mainly donated by inhabitants, in a small museum in Caoria (*Museo contadino del Vanoi*), and organizes diverse workshops in the *Home of the Ecomuseum* (*Casa dell'ecomuseo*) in Canal San Boivo, which is owned by the ParcoPan and can be used free of charge. The workshops mainly concern traditional knowledge and practices linked to the use of local natural resources and the cultural landscape. Furthermore, the

Ecomuseum collaborates with the ParcoPan and local schools, providing pupils with the opportunity to find out more about the valley's history, land use, and the traditional vertical mobility (explained below) of those working the land.

Vertical circulation mobility in the frame of traditional Alpine economy

Traditionally, the Alpine farming economy “was mainly based on four pillars: arable land, meadows, [...] forest and Alpine pastures” (Bundi 1989, 9; authors’ translation) – i. e. *la val, i prati, el bosc, la montagna* (Figures 4–8), as formulated in the regional dialect and used along the ethnographic trail. However, the Vanoi Ecomuseum is of outstanding importance for the demonstration of seasonally and vertically arranged land use, and the associated mobility of the local people, who covered countless metres of altitude change over the year. The peasant families had to visit the various farmlands at different altitudes again and again to carry out sowing and harvesting, fertilizing, mowing and grazing, milking, making cheese, and many other essential activities. This required long hikes on foot, and accommodation separated from the farmstead in the valley and other family members often for weeks. Zelinsky (1971, 226) refers to these former periodically (here: seasonally) recurring population movements as *circulation*, as also today’s everyday commuting. This traditional way of life existed in similar forms almost everywhere in the Southern European Alps. It can thus be regarded as the defining characteristic of Alpine peasant agriculture (Bender 2023, 6). Philippe Arbos (1922) called this type of *familial* mountain farming and the associated circulation of the local people *petite montagne*, in contrast to the shepherd’s economy of the *grande montagne*. He regarded it as a *genre de vie*, according to the well-known cultural-ecological concept of Paul Vidal de la Blache (1911), which deals with the *possibilistic* adaptations of specific cultures and peoples to their respective natural environments (see Mouthon 2018).

Evidence of Alpine pasture farming above the tree line dating from pre-Roman times is discussed by Grass (1980), and the practice is considered to have become widespread by the Early Middle Ages at the latest. In contrast, in the intermediate, naturally wooded, zone between permanent settlements and alpine pastures, called in the different Alpine Germanic and Romance languages *Maiensässe / Asten / Voralmen / maggenghi / montagne / monti* etc., the beginning of hay-making is of more recent origin, and due to increased population pressure in the mid- to late Middle Ages and early modern period (see Mathieu 2001, 18). For the Poschiavo valley (Grisons), haymaking in the intermediate, naturally wooded zone between permanent settlements and alpine pastures is documented as being introduced during the 12th to 14th centuries (see Simmen 1949, 34; Bundi 1989, 154ff.), and in Tyrol not earlier than the 14th century (see Wopfner 1997,

392). In the Primiero valley, which neighbours the Vanoi valley, it is thought to date from the 13th–15th centuries, with a gradual transition from sheep to cattle farming (Pistoia 2017, 13ff.). Finally, in Caoria (in the Vanoi valley), which has been documented as a settlement only since the 16th century, haymaking started quite late, in the 18th century (Bortolotti 2004, 15 and 33), when the peasant population here began to keep cows in order to produce butter to sell at market (Bettega 2017).

The typical settlement and production unit in the utilization of this altitudinal zone was the *prá*, with two separate buildings – the *tabia* (hay barn), and the *casèra* (for making and storing cheese, and human accommodation) – surrounded by hay meadows, cultivated fields and small vegetable gardens. Because of their mid-altitude location, the buildings functioned as *summer residences*, in an intermediate spot between the Alpine pastures and the villages. The prevailing law of succession meant that plots of land and buildings were divided equally among the heirs, which over the centuries contributed to their lack of viability. Zimpel (1962) gives an impressively detailed description of the extent of these divisions in the case of Soglio (Grisons). In addition to the unfavourable climatic and topographical conditions in the high mountains, the sub-division of farms and plots into unworkably small units was a major reason for the extensive decline of land use, especially in the Italian Alps (Tappeiner et al. 2008, 216–217).

Due to the end of subsistence farming and the creation of roads leading to the alpine pastures, buildings such as *tabia* and *casèra* and meadows at mid-altitudes were abandoned, and have progressively disappeared or been given new functions. In the case of the ParcoPan, some of these buildings have been restored and allocated to the Vanoi Ecomuseum. Examples of *tabia* and *casèra* can be observed all along the ethnographic trail, especially in the settlement Pradi de Tognola (1,256 m), along the *anello dei prati*.

Cylinders of mobility as a means of visualization

The classic form of visualization for the Alpine system of vertical land use is the mobility diagram, i.e. the visual representation of patterns of movement of people and livestock at different altitudes throughout the year (Arbos 1922 and 1923) (Figure 9). This type of visualization was adopted by Frödin, who conducted research mainly in the French Alps, to describe Alpine pasture farming (Frödin 1940, 336; 1941, 198, 279). It then spread further in the German-language literature (e.g. Zimpel 1962; Groier 1990; Bender 2023).

The mobility diagram was adopted by the Vanoi Ecomuseum and developed in the form of *cylinders of mobility* (*cilindri della mobilità*) (see Figure 10). Since the main focus of the Vanoi Ecomuseum is to preserve and enhance the natural and cultural heritage con-



Figure 5 – Mountain pastures of Malga Miesnotta beneath the peaks of Cima Cece, 2,754 m, in the Lagorai chain. © Oliver Bender



Figure 6 – Valcanza sawmill (1,200 m), reconstructed by ParcoPan. © Oliver Bender



Figure 7 – An example of *tabia* (right) and *casèra* (left) in the ParcoPan, with Cima d'Asta (2,847 m) in the background. © Oliver Bender



Figure 8 – Val Vanoi, a glacial U-shaped valley, seen from the south, with the village of Caoria, 840 m, in the central background, beneath the peaks of the Lagorai chain. © O. Bender

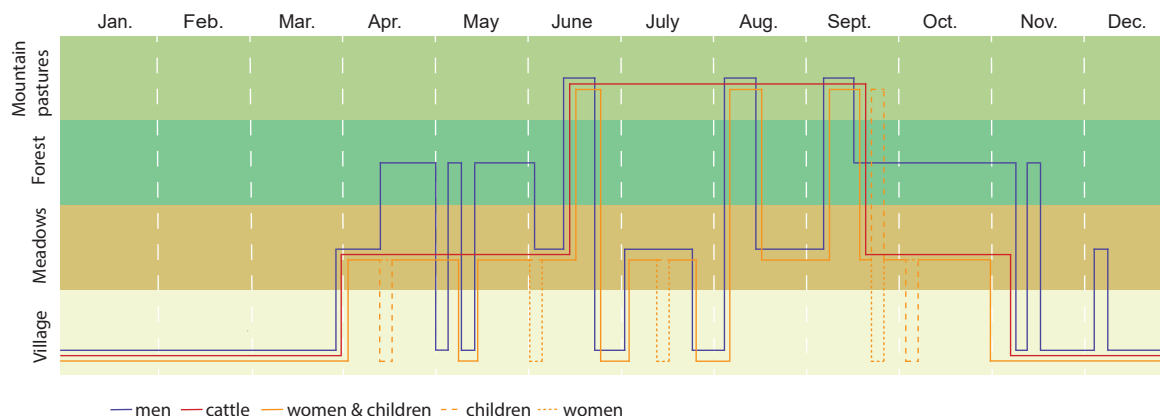


Figure 9 – Vertical circulation mobility diagram of the traditionally agrarian Caoria community (up to mid-20th century), following the scheme of Arbos (1923), with information from Bortolotti (2004). Design: Oliver Bender

nected to the traditional vertical mobility and land use, *mobility signage* (*segnali della mobilità*) is found along the ethnographic trail in the form of information boards, towers and cylinders. Two cylinders are located in significant places: one is at the start of the trail, next to the visitor centre, and introduces visitors to the topic of vertical mobility and land use; the other is located in Pradi de Tognola and shows the daily distribution of work among men, women and children in each season. By rotating the cylinder, visitors can visually follow the seasonal and daily movements of people and livestock: movements are shown using different colours and symbols, depending on the direction of movement and the activity to be carried out.

By combining information about distances, activities and distribution of work within families, cylinders are effective means not only to visualize the vertical nature of economic relations and land use, but also to understand the social and cultural dynamics within the valley's community. As well as learning that every year men used to walk at least 35,000 m in terms of difference in altitude, women at least 11,000 m, young people at least 15,000 m and livestock at least 3,700 m, one can grasp the changing rhythm and liveliness of the landscape at different altitudes and times of the year. In line with the ecomuseum approach (Tuan 1977), the local community and visitors can indeed understand and experience why people settled in this area, their history, way of life and values, as well as their local economy and the shaping of their cultural landscape.

Conclusions

The traditional farming life in the mountains of the Southern European Alps – characterized by mid-altitude centres in the *maggenghi / montagne / monti* zone and by the constant vertical movement of people and livestock – was abandoned in the course of the 20th century, but it is still part of the tangible and intangible heritage of many valleys. Integrating ecomuseums

with nature parks can be a valuable approach to preserve such heritage and enhance the cultural landscape, while developing sustainable adaptations of traditional land use and future trajectories for local communities (Bortolotti 2004).

The Vanoi Ecomuseum plays a key role in managing and enhancing the regional cultural landscape by preserving and partially reconstructing historic artefacts, buildings and paths, and by managing the continuation or partial resumption of traditional land use practices and production methods (e.g. alpine pasture farming with butter production). The ecomuseum also preserves and transmits memory and knowledge connected to the former peasant way of life and the related vertical circulation mobility in the valley, which for centuries were typical of the Southern European Alps. The ethnographic trail allows people to engage with the landscape and walk to places that have been significant to the local community and to the traditional Alpine economy. In particular, visitors get to learn more about the movements of humans, livestock and other resources throughout the year thanks to the *mobility signage* and the *cylinders of mobility*, as effective tools to visualize the verticality of the traditional mountain economy.

It must be acknowledged that the Vanoi Ecomuseum, like any other ecomuseum, does not address all the environmental, social and cultural concerns in the valley; nor does it solve the long-standing tension between conservation and development. However, thanks to close and long-lasting collaboration with several institutional (e.g. the tourism consortium, municipality and Parcopan) and non-institutional actors (e.g. community members, craftspeople, local organizations), it plays a fundamental role in strengthening the territorial network (Reina 2014). While the ecomuseum benefits from the support of the Parcopan, in terms of finance, human resources and knowledge of the territory, synergies between it and the nature park can be observed in the fields of sustainability education, cultural heritage and tourism. In fact, the

nature park can count on the ecomuseum's expertise in fulfilling sustainable tourism goals in accordance with the European Charter for Sustainable Tourism in Protected Areas (EUROPARC Federation), which was formally endorsed by the Parcopan in 2015.

The implementation of the Charter through the Sustainable Development Strategy (approved in December 2022) is based on 5 axes and 20 goals, aiming at strengthening the park's holistic, participative and long-term approach to landscape and resource management, and tackling socio-ecological changes appropriately. The Vanoi Ecomuseum was involved in the identification and implementation of various axes and goals, in particular those related to cultural tourism (axis no. 2). Because of its role as a repository of site-specific knowledge and know-how, it is responsible for projects and activities contributing to the conservation of natural and cultural heritage, introducing visitors to the social and cultural history of the region, and fostering mindful forms of tourism.

Within the local community, the Ecomuseum works as a shared and safe space where community-centred and place-specific trajectories for sustainable local development are envisioned and pursued by the local community and stakeholders. The Vanoi Ecomuseum is actively engaged with networking around the shared aim of using and enhancing existing natural and cultural resources, while promoting participation, co-creativity and social innovation, in the form of shared knowledge and deep learning, which ultimately contribute to sustainability (Borén & Schmitt 2022).

Acknowledgement

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Figure 10 – An example of cylinder of mobility showing the traditional vertical mobility and land use in the Vanoi valley. © Oliver Bender

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AlpsLife

The Alps are a global biodiversity hotspot threatened by climate and land-use change. Additionally, the lack of Alpine-wide coordination reduces the effectiveness of conservation efforts. The main challenge arises from the variety of biodiversity monitoring schemes existing at different levels in different Alpine countries. Coherent ecological indicators are key to defining priority areas and to supporting decision-making processes, enhancing the action of Alpine protected areas. The AlpsLife project promotes science-based strategies for preserving and restoring Alpine biodiversity. Relying on EU-wide relevant indicators, it combines existing biodiversity monitoring schemes and data sources to ensure the interoperability of results at the Alpine level. The outputs are then checked on the ground, adjusting them to the needs of Alpine protected areas and policymakers. This allows for a better understanding of Alpine biodiversity trends and the implementation of appropriate cross-border management measures.

Alparc website: <https://alparc.org/alpslife> Project website: <https://www.alpine-space.eu/project/alpslife/>



LifeAlpsNature

Hotspots for biodiversity, tourism & outdoor activities: how do they go together? A challenge for the Alpine Protected Areas covering 30 % of the Alpine territory. Ecologically fragile alpine sites are exposed to overcrowding and naturebased activities (NBA), which impact species by fragmenting or destroying their habitats and disturbing their reproduction phases. Biodiversity loss from NBA, a trend observed across the Alps, requires region-wide solutions. LiveAlpsNature analyses the impact of NBA on alpine biodiversity, develops innovative biodiversity-friendly solutions for visitor management based on the One-Health approach, and then directly implements and evaluates them in Alpine Protected Areas. Open source data will be made available for dissemination across digital platforms. By involving local stakeholders, LiveAlpsNature addresses the increase in tourism by guiding pro-ecological behavioural changes to reduce impacts on biodiversity and create sustainable nature-based activities. Alparc website: <https://alparc.org/fr/livealpsnature> Project website: <https://www.alpine-space.eu/project/livealpsnature/>



ForumAlpinum 2024

The proceedings of ForumAlpinum 2024 are now available, <https://forumalpinum.org/proceedings/>. They contain the abstracts of the more than 40 contributions presented during the conference. You can also find a small photo gallery of the event on the ForumAlpinum website.

IMC – Innsbruck Mountain Conference 2025

The MC will take place from 14–18 September 2025 in Innsbruck, Austria. IMC builds upon the previous mountain conferences and aims to continue this scientific conference series exclusively targeted towards mountain-research. Hosted in the Alps, IMC provides an excellent opportunity for experts from different disciplines to discuss mountain-related issues in a cross-disciplinary setting with flexible session formats. The key goals of the conference are to synthesize and enhance our understanding of mountain systems, in particular their response and resilience to global change.

More information: <https://imc2025.info/>

UNESCO mission to Bhutan to establish the kingdom's first biosphere reserve

Günter Köck, member of the editorial board of eco.mont and representative of the World Network of Mountain Biosphere Reserves, joined a UNESCO mission to help Bhutan establish its first biosphere reserve (BR). The team included Miguel Clüsener-Godt (former UNESCO Ecology Director) and Sishtri Kumar (UNESCO Delhi). Bhutan's government sought UNESCO's assistance due to its lack of experience in creating BRs. Funded by the UNESCO Earth Network, the mission consulted Bhutanese authorities, private stakeholders, and international representatives, including the Austrian Ambassador in Delhi and the UNESCO Delhi office. Two workshops with the Forestry Department covered zoning options and the process of preparing a BR nomination dossier following MAB guidelines.

During a field visit to the proposed BR site, the Climate Science Literacy Exhibition was launched at Lamperi Visitor Centre. Featuring 27 posters tied to the 17 SDGs, it aims to educate locals and tourists on climate science.

The mission team received very positive feedback and is optimistic the nomination will be ready for submission to UNESCO by September 2025.



Official launch of the Climate Science Literacy Exhibition at the Visitor's Centre in Lamperi. From left to right: Pabi Mongar, Tshering Pem (both Dept. Forestry), Srishti Kumar (UNESCO Team), Günter Köck (UNESCO Team), Sangay Dorji (Dept. Forestry), Miguel Clüsener-Godt (UNESCO Team), Mr. Passang (GBCL). © UNESCO Mission Team