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1 **From religion to conservation: unfolding 300 years of collective**
2 **action in a Greek sacred forest**

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12 **Keywords**

13 Adaptive policies; Common Pool Resources; Forest commons; Ostrom framework;
14 Sacred Natural Sites; Socio-ecological systems.

15 1.1. Abstract

16 2. Sacred Natural Sites are integrated-coupled systems with mutual social and natural
17 interactions, and they exist within a variety of local cultures and regions of the world. In
18 Europe and especially in the Mediterranean basin, changing land use patterns and
19 population decline since World War II have had a dramatic impact on the socio-
20 ecological structure and management practices of many of such sites. At the same time,
21 old beliefs and taboos are often neglected due to modernization, rural depopulation, and
22 change in community's structure, norms, and codes. Understanding how social,
23 ecological, and policy processes changed through time becomes thus relevant to identify
24 the main criteria for effective collective action and sustainability of the studied systems.
25 In this paper, we applied Ostrom's social-ecological systems framework to model the
26 main socio-ecological processes acting upon a sacred forest in Epirus (Greece) over a 300
27 years' period. The multidisciplinary approach included collection of archival and
28 ecological data and ethnographic research (semi-structured interviews). Results indicate

29 that significant changes have occurred in social, economic, political, and institutional
30 terms since the creation of the settlement (17th century). However, the sacred forest has
31 been of major importance to the adjacent local community that acts as its custodian
32 guardian even nowadays. Collective action for the preservation of the forest has been
33 achieved under various governance regimes that transformed through time traditional
34 religious taboos into modern conservation approaches. This analysis revealed that local
35 traditional management practices of commons can serve as successful socio-ecological
36 conservation examples.

37 1. Introduction

38 Socio-Ecological Systems (SESs) are outcomes of long-term relationships between humans
39 and natural processes. They can be defined as integrated-coupled human and natural systems
40 (CHANS) in which “people and nature interact reciprocally and form complex feedback
41 loops” (Liu et al., 2007). They are connected systems with multiple interactions and
42 feedbacks at various spatial and temporal levels and scales (Berkes and Folke, 1998). SESs
43 exist within a variety of local cultures and regions of the world, vestiges of the historical
44 interactions which link human societies to their surrounding natural environment (Dudley et
45 al., 2005; Lansing, 1991; McKean, 1992; Mwangi, 2005; Netting, 1976). Many of such sites
46 are nowadays inscribed in the UNESCO World Heritage List, in an effort to preserve their
47 biological, cultural, historical, and spiritual diversity (Mitchell et al., 2009).

48 Sacred Natural Sites (SNS) are outstanding SES examples as areas of spiritual significance
49 for people and/or communities since they represent places of worship and memory. These
50 sites are not static in time or space and can be either created or transformed in the context of
51 changing socio-economic and/or environmental conditions (e.g. demographic crises,
52 protection of scarce natural resources, etc.) (Oviedo et al., 2005; Verschuuren et al., 2010).
53 Mapping SNS governance structure can thus become a complex task, requiring
54 multidisciplinary approaches apt to capture the multiplicity of relations between actors,
55 resource flows, socio-economic backgrounds, and institutions (Ostrom, 1990).

56 Sacred forests and groves constitute a common case of SNS. These spiritual sites are often
57 governed by taboos, rules and bans, which regulate site access and resources exploitation
58 (Dudley et al., 2005). Prohibitions are set by a variety of institutions (i.e. the custodians),
59 which can be either an identifiable group of people with well-defined structures of power and
60 leadership; or in other cases, multiple groups, scattered and diffused (Wild and McLeod,
61 2008). The reasons for establishing and regulating such forests can be both devotional (e.g.
62 dedication to saints) and functional (e.g. managing the ecosystems for conservation purposes)
63 (Byers et al., 2001). For the above-mentioned reasons, sacred forests and groves can be
64 considered Common-Pool Resources (CPRs), as natural and human-made resource systems,
65 whose access is restricted and regulated (Rutte, 2011).

66 In the case of Epirus, a mountainous region in northwestern Greece, sacred forests have been
67 preserved either for the stability of slopes above settlements, and as natural reserves that hold
68 important natural resources for times of need (e.g. water aquifers and feed for animal herds)
69 serving at the same time cultural and aesthetic purposes. In these areas, sacred forests
70 function as strictly controlled management systems. Following a common pattern, their
71 retention is based on taboos, which are mostly related to trees' cutting. Activities such as
72 grazing, collection of dry fallen branches, as well as non-wood forest products (mushrooms,
73 hunting, etc.) are usually allowed. More infrequent are cases of absolute protection, including
74 the prohibition of any provisioning behavior, such as grazing and harvesting of fruits or dead
75 wood (Stara et al., 2016).

76 Changing land use patterns and population decline since World War II have had a dramatic
77 effect on the social structure, management practices, and cultural landscapes of the region.
78 Depopulation waves due to wars and subsequent rural exodus have impacted the socio-
79 economic structure of mountainous rural areas, where many scattered small villages were left
80 with few remaining permanent residents. The effects of these processes can be immediately
81 observed in the landscape where sacred forests are located, formerly rich of agropastoral
82 areas, now left abandoned with substantial forest expansion (Blondel et al., 2010).
83 Simultaneously, old beliefs and taboos are gradually vanishing as many residents have moved

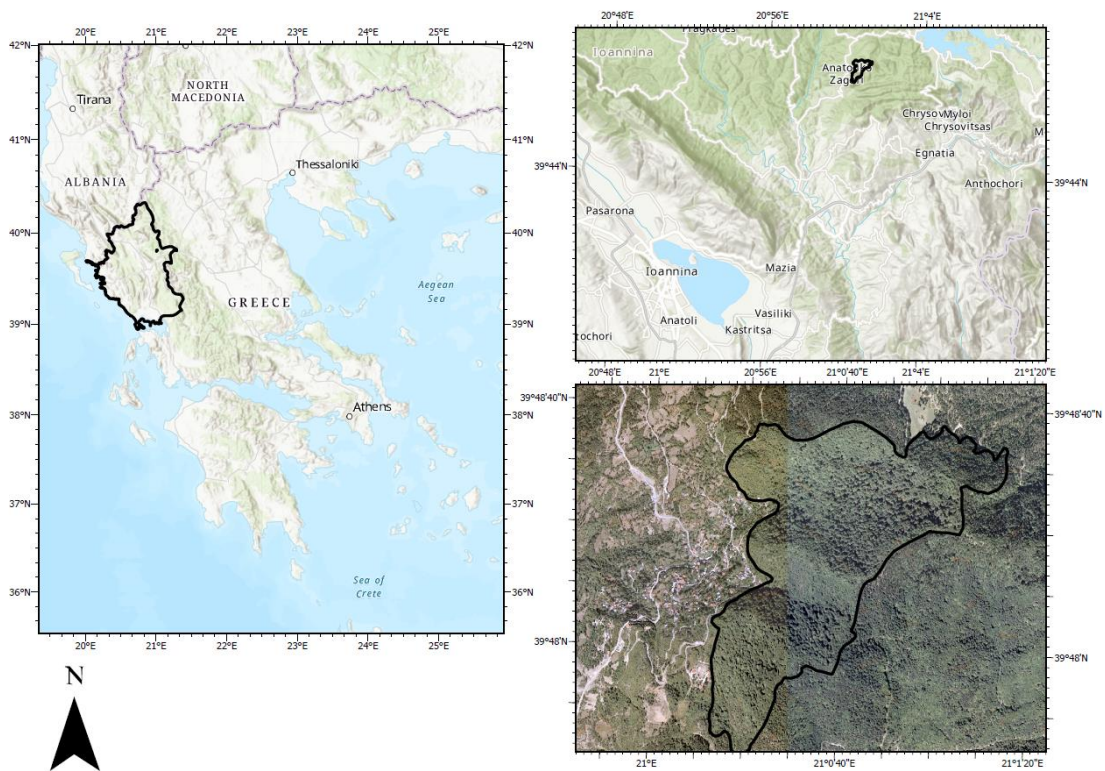
84 away from rural areas favoring larger urban agglomerates. Nonetheless, traditions linked to
85 sacred natural areas remain alive for certain local communities, playing an important role in
86 forging their cultural identity (Stara et al., 2016). It becomes thus relevant understanding how
87 internal governance practices in sacred forests have responded to tumultuous socio-economic
88 changes, to assist practitioners in defining efficient policy tools apt to maximize the potential
89 of sacred forests' role in natural and cultural heritage preservation and modern rural
90 economies.

91 In order to assess how governance practices in sacred forests change across time, we used the
92 Ostrom's framework for SES to model the main social, ecological and institutional processes
93 acting upon a sacred forest in Epirus (Ostrom, 2009). The Ostrom framework is a common
94 and flexible analytical tool that helps scholars to identify the most important variables and
95 their interactions, diagnosing the system outcomes at various levels and scales (Ostrom and
96 Cox, 2010). Focusing on a large well-preserved sacred forest, we explore local stakeholders'
97 perceptions concerning the resource (the sacred forest) and the related management practices
98 (e.g. ban on tree cutting and grazing restrictions) responsible for its sustainability since the
99 creation of the settlement (year 1668). Our research aims to investigate the social, economic,
100 and ecological factors, which contributed to the formation and conservation of the sacred
101 forest, and to detect any changes in the system's interactions and their outcomes across time.
102 This analysis is relevant because it provides insights on how human-nature relationships are
103 changing in rural areas. This is especially useful for national policy makers and conservation
104 managers of SNS as it points out the extent to which faiths and traditional management
105 practices can support natural conservation approaches (Dudley et al., 2009), and properly
106 manage scenarios in which religious practices fall into disuse (Anyinam and Kalipeni, 1999).
107 Furthermore, this analysis provides a novel adaptation of the E. Ostrom's SES framework to
108 Sacred Natural Sites.

109 2. Methodology

110 *2.1 Site selection*

111 The study area of this research is the sacred protective forest belonging to the village of
112 Greveniti, northwestern Greece. Greveniti village is part of the Municipality of Zagori,
113 located in the Epirus Administrative Region (Figure 1). According to the latest census
114 (2011), Greveniti has a population of 193 people mainly dedicated to woodcutting and
115 forestry activities. In 2005, the village area has been declared peripheral zone of Northern
116 Pindos National Park. The area is in the proximity of the mountainous valley of Valia Calda,
117 protected as a national forest since 1966.



118

119 **Figure 1:** Location of the Epirus region in Greece and (inset) location of the sacred protective
120 forest of Greveniti. Source: ESRI, 2020 and Google Earth.

121 The sacred protective forest (geographic coordinates: $39^{\circ}48'21.6''N$, $21^{\circ}00'13.6''E$), covers
122 an area of approximately 120 ha, with moderate slope. The working boundaries of the forest
123 have been determined with the use of aerial photographs from 1945 (Tsiakiris et al., 2013).
124 The forest's altitude is 1030 meters above sea level in its lower part, reaching up to 1505
125 meters in its top edge (Forestry Service of Metsovo, 2012). It is predominantly constituted by

126 beech trees (*Fagus sylvatica*). Patches of different vegetation types can be found around its
127 edges, with black pine (*Pinus nigra*) in the NE and a mixed *Carpinus-Acer* stand around the
128 W edges proximal to the village. The sacred forest is located at the fringes of the local
129 community forest, where villagers have granted the right from the forestry service to extract
130 timber resources. The site was selected for this analysis because it is one of the biggest and
131 most well-preserved sacred forests among those studied so far in Epirus.

132 Greveniti sacred protective forest forms part of a local network of sites established through
133 different ritual praxes, spanning from Saints dedication, community agreements, or
134 excommunication regimes (Stara et al., 2016). In Greece, trees in the vicinity of churches or
135 belonging to sacred forests are conceptualized as sacred and they are associated with cutting
136 taboos. These are socio-religious norms, which associate the tree cutting with supernatural
137 punishments ranging from warnings, little accidents or even death to the wrongdoers. Such
138 beliefs are based on pre-Christian ideas, according to which mature trees have souls and thus
139 can damage those who try to harm them (Stara et al., 2015).

140 Greveniti forest is located right above the settlement and plays an important role in protecting
141 it from natural disasters, such as floods or landslides. To ensure the protection and longevity
142 of the forest area, the local community had developed a religious practice, *aphorism* or
143 *excommunication*, which historically threatened any potential trespasser or someone doing
144 damage to the forest with direct exclusion from the Church and social stigmatization. These
145 excommunication regimes differ, to a certain extent, to many worldwide examples of sacred
146 forests which were protected for specific religious reasons, as the existence of shrines, homes
147 of gods or spirits, or ceremonial places. Excommunication constitutes the heaviest sentence
148 that can be imposed to Christians. In Greece, during the Ottoman Occupation (1479-1913), it
149 was a practice often used for the resolution of private issues in areas — like Zagori — where
150 the Church found herself in the special position to substitute political power, administration,
151 and judicature (Mihailaris, 2004). In this context, excommunication was used in the Zagori
152 area as an abstract threat and mechanism of production of fear, to protect the forest from

153 anthropogenic interferences. Testimonies report that excommunication rituals were
154 characterized by certain degrees of officiality; in sacred forests it was practiced in situ.
155 Participants used to execute the ritual through singing imprecatory psalms of David (e.g. Ps
156 59), bells ringing, and/or holding black candles. The symbolic number of priests that
157 announced the excommunication was also of great importance (Mihailaris, 2004 Stara, 2012).
158 As the forest's access and use is restricted and regulated, Greveniti sacred forest is considered
159 an ideal CPRs case study to model with the Ostrom SES framework.

160 ***2.2 Analytical framework***

161 The SES framework developed by Ostrom, provides a common set of variables that can be
162 used to analyze forms of interactions in complex systems. The multi-level design of the
163 framework, subdividing the system under study into a define set of explanatory variables and
164 sub-variables, allows scholars to address the issues of self-organization and sustainability of
165 governance institutions in the management of CPRs in a standardized manner (Ostrom, 2009).
166 Ostrom SES framework challenges the supposition of simple and linear models of SESs,
167 acknowledging the diversity of research methods used by different disciplines to describe
168 SESs (Ostrom, 2007). This dynamic utility of the multi-level SES framework has been
169 successfully applied to answer various questions about self-organization and sustainability of
170 community institutions in forest ecosystems (Fleischman et al., 2010; Oberlack et al., 2015),
171 irrigation systems (Cox, 2014; Meinzen-Dick, 2007), fisheries (Basurto et al., 2013; Guevara
172 et al., 2016; Leslie et al., 2015; Partelow and Boda, 2015), lakes (Nagendra and Ostrom,
173 2014), marine settings (Schlüter and Madrigal, 2012) and protected areas (Palomo and
174 Hernández-Flores, 2019; Williams and Tai, 2016).

175 So far, the Ostrom framework has never been applied to empirically study SNS. Nonetheless,
176 the governance model of sacred forests can be assimilated to the one of early protected areas,
177 established as "complementary measures" to promote the sustainability of ecosystem services
178 in response to growing man-made pressures to natural ecosystems (Naughton-Treves et al.,

179 2005). Sacred forests can thus be conceptualized as CPRs, which can be threatened by
180 exploitation (and/or abandonment) leading to congestion or even destruction of the resource
181 itself and other related SESs (Rutte, 2011). The SES framework provides, therefore, a suitable
182 approach for assessing the governance dynamics and their sustainability for sacred forests
183 conservation in northwestern Greece.

184 Following McGinnis and Ostrom's (2014) modifications, the basic components or 1st tier
185 variables of a SES are the Resource System (RS) which is the broader system under study,
186 (i.e. the sacred protective forest of Greveniti in this case-study) and its sub-variables that
187 summarize its characteristics. Resource Units (RU) are described both by the overall forest
188 vegetation dynamics, and the specific characteristics of the individual tree species present in
189 the forest. Actor groups (A) include the responsible people-stakeholders related to the forest's
190 use (such as the community). Governance System (GS) components describe the governance
191 framework in which A and RS mutually interact. These variables are also influenced by, and
192 create feedback to, the external social, political, and economic environment (henceforth
193 Settings: S) and Related Ecosystems (ECO). The framework also maps the Interactions (I)
194 among the components, and their results as Outcomes (O) of the system (McGinnis and
195 Ostrom, 2014; Ostrom, 2007). According to the proposed framework, these variables can be
196 further unpacked in sub-variables of second, third etc. levels or tiers for a more
197 comprehensive analysis of the action-situation as in Vogt et al., (2015). To capture the
198 complexity of SNS (e.g. non-interaction as a form of management), the SES framework was
199 duly redefined. The official framework published by E. Ostrom (2009) was thus adapted
200 according to the latest additions of variables of Epstein and Kreitmair (2013), Vogt et al.,
201 (2015), modifications from Delgado-Serrano and Ramos (2015) and McGinnis and Ostrom
202 (2014).

203 Taking into consideration that Greveniti sacred forest serves as a CPR for the community, the
204 analysis is of vital importance because it maps governance changes in a broad temporal scale,
205 proving that the collective action of local communities can serve to safeguard their common

206 resources. In addition, this research is one of few studies assessing the evolution of a specific
207 CPR in time, as to determine the possible variations in the outcomes within consecutive
208 periods (along with e.g. Basurto et al., 2013). This is a relevant comparative application of the
209 Ostrom framework, which allows researchers to identify how variables and their related
210 outcomes change as time passes.

211 *2.3. Data collection*

212

213 In-depth interviews were performed to collect stakeholders' view on the structure of the
214 sacred protective forest, governance, management practices, and forest-stakeholders'
215 interactions. An interview guideline was developed with mainly semi-structured questions
216 based on the different components of the Ostrom SES framework. Pilot interviews were used
217 to shorten and refine the interview guideline. 24 semi-structured questions were finally used
218 during the interviews (Appendix A). Variables not inferred from interviews (i.e. S and ECO)
219 were directly retrieved from bibliography and secondary sources. Beside identifying the
220 variable occurrence, we also enquired about any perceived changes in time, if applicable, as
221 to map how the system interactions and their outcomes evolved as time passed.

222 Field research was undertaken during August 2017, in parallel to the annual local celebration
223 of the village dedicated to the Virgin Dormition (15th of August), which gathers both villagers
224 and former residents now permanently residing in larger urban centers. A "snowball chain"
225 method was used to draw the final list of key informants to interview, including elders, local
226 policy makers, foresters, and rangers of the area (Nichols, 1991). 47 people (26 men and 21
227 women) participated in the study, 24% of the official census village population, and 78% of
228 the actual permanent residents (ELSTAT, 2011)¹. 17 informants were further excluded from
229 the sample as they were merely aware of the protective role of the forest without having the

¹ The official population data from the census should be treated carefully as often official Greek statistics do not match the real population living in villages, especially in rural areas. Official statistics are thus inflated by non-permanent residents there registered but living elsewhere in Greece. Retrieving the real population of rural villages in Greece requires complex ethnographic historical reconstructions (Green, 2016).

230 possibility of providing further details, while five informants refused to participate in the
231 study. 25 face-to-face interviews (18 men, 7 women) were finally conducted, of which 22
232 were audio recorded, with the interviewee's permission, and therefore analyzed. Each
233 interview lasted 45 minutes in average. Additional tools such as local tree names, photos of
234 village locations and buildings, as well as maps of the region's sites, were used to facilitate the
235 discussion with informants.

236 **2.4. Data analysis**

237

238 All semi-structured interviews recorded were transcribed with the help of the program
239 Speechnotes (WellSource, 2017), and then analyzed using R's RQDA qualitative analysis
240 package (R Core Team, 2017). The basic method of analysis was the assignment-linkage of
241 each variable-code with each transcript of the informants to which they refer. The codes used
242 in RQDA were the first and second tiers of Ostrom variables. None, one or more codes, could
243 be assigned to each of the transcribed sentences, depending on the content and the judgment
244 of the researcher. Additional codes were added, to capture emerging information relevant for
245 the research, relating to temporal information, i.e. local toponyms, tree names and species,
246 local values, non-interventional activities, as well as property-rights regime as proposed by
247 Delgado-Serrano and Ramos (2015). During the analysis additional changes were made,
248 removing variables for which no data were found (RS6b Frequency-Duration of Disturbances,
249 RS6c Extent of disturbances and RS10c Human interventions), or which were found to have
250 no effect on the system under-study (RU4ii Value of units, RU6ii Distinctive characteristics,
251 I5 Investment activities, I6 Lobbying activities). The final variables selection includes 9 first
252 tier variables 55 second tier variables, and 12 third tier variables (Full selection in Appendix
253 B).

254 The information gathered was used to reconstruct relevant socio-economic and political
255 events recorded in the local village's history. These events allowed identifying the main time
256 periods of the SES, which were later used to assess eventual temporal changes of the SES

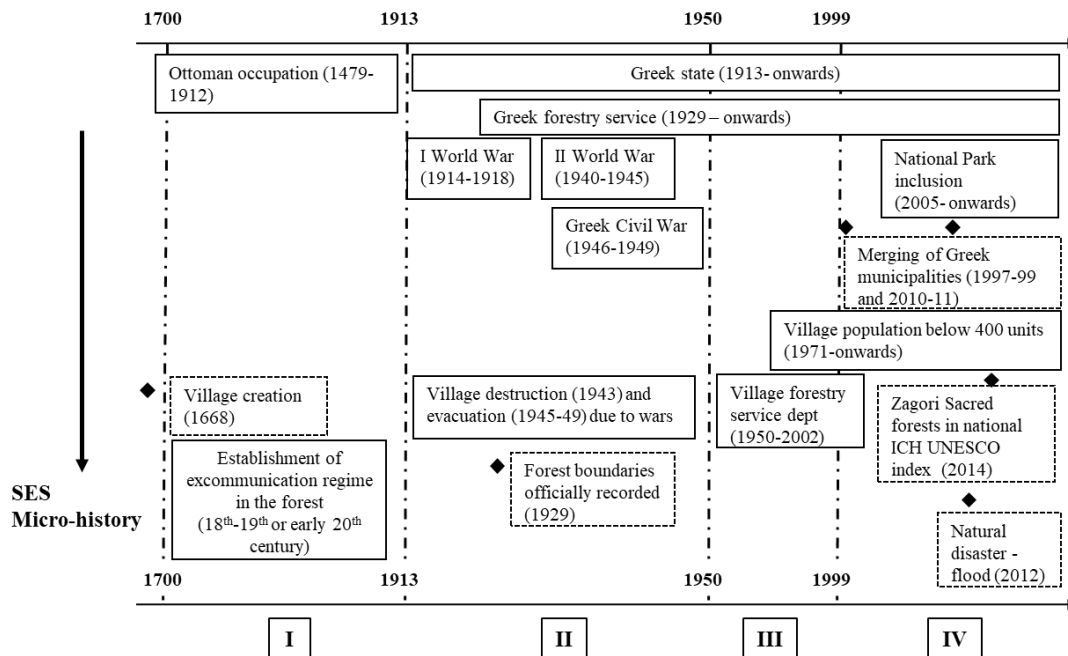
257 first-tier variables and their sub-components. Direct statements from the interviews (reported
 258 in italics and with the corresponding alphanumeric identifier of the interviewee) are also
 259 provided to support the findings.

260 3. Results

261

262 The collected data allowed the identification of the major local, historical, and environmental
 263 historical landmarks, which helped to conceptualize the SES under study in four consecutive
 264 time periods (Figure 2): (i) 1668-1913 (from the creation of settlement up until the end of the
 265 Ottoman occupation): (ii) 1913-1949 (from the annexation of Epirus region to the Greek state
 266 until the end of the Greek Civil War); (iii) 1950-1999 (Post-wars development period); (iv)
 267 2000 onwards (current times, characterized by an increasing trend of population abandonment
 268 in rural areas). These four main demarcation periods are used in the following chapters to
 269 assess temporal changes in the SES under-study.

270



271

272 **Figure 2:** Timeline of the main events relevant to the history of the Greveniti Sacred Forest.

273 Events are subdivided into national (SES Macro-history) and local (SES Micro-history). Latin

274 numbers indicate the four main demarcation periods selected for the analysis of the SES (I:
 275 1700-1913, II: 1913-1949, III: 1950-1999, IV: 2000 onwards). Dashed-line boxes and black
 276 diamonds indicate punctual events; solid-line boxes indicate processes occurring across years.

277 Table 1 identifies the main occurring changes across the first-tier variables of the SES Ostrom
 278 framework applied to the sacred forest of Greveniti (years 1668-2017) according to the four
 279 intervals formerly introduced. In the following chapters, we highlight the main temporal
 280 changes and key aspects determining the successful collective organization and system's
 281 sustainability during each period elaborating on the main components of the SES framework.

282

283 **Table 1:** Comparison of key SES variables for the four distinct time periods (I-IV) in
 284 Greveniti village, Greece. The categorization of variables is mainly qualitative and indicates
 285 their occurrence in the SES under study (present, absent, na= not available) or their variability
 286 (high, moderate, low, very low, decreasing, na). Plus (+) and minus (-) indicate
 287 positive/negative developments for the SES. Data retrieved by ethnographic research for
 288 which supporting literature was not found is indicated with an asterisk (*).

289

Variable	I: 1700-1913	II: 1913-1949	III: 1950-1999	IV: 2000-onwards
Settings (S)				
Economic development (S1)	High	Moderate	Moderate	Low
Demographic trends (S2)	High	Decreasing	Decreasing	Very low
Political stability (S3) ¹	Unstable	Unstable	Unstable	Stable
Government resource policies (S4)	Ottoman rule/community autonomy ²	Greek State	Greek State	Greek State
Resource System (RS)				
Sector (RS1)	Excommunicated	Excommunicated	Excommunicated-protective	Mostly protective
Boundaries (RS2)	na	Stable	Stable	Stable
Predictability of system dynamics (RS7)	High*	Present	Present	High
Human use and disturbance history (RS10c)	Limited *	War shelter	Fringe disturbances; paths; fields; hunting;	Fringe disturbances; hunting; clearing water channels

			clearing water channels	
Actors (A)				
Number of relevant Actors (A1)	Community	Community & others	Community & others	Community & others (+)
Socioeconomic attributes (A2)	Farmers, merchants	Farmers, merchants	Farmers, woodcutters	Retired persons, woodcutters
Location (A4)	Settlement & further	Settlement & further	Settlement & further	Mainly further
Leadership (A5)	Community	Forestry service & community	Forestry service & community	Forestry service & community
Norms/social capital (A6)	na	na	Moderate	Moderate
Knowledge of SES (A7)	High*	High	High	High
Importance of resource (A8)	High	High	High	High
Governance System (GS)				
Government organizations (GS1)	Community*	Forestry service	Forestry service	Forestry service and national park
Property-rights (GS4a)	Community	Community	Community	Municipality
Access (GS4b)	No restrictions	No restrictions	No restrictions	No restrictions
Subtractability (GS4c)	Forbidden*	Forbidden	Forbidden (-)	Forbidden (-)
Operational rules (GS5a)	Excommunication	Excommunication	Grazing & dead branches collection permission; forestry service rules	Forestry service rules
Collective rules (GS5b)	Present*	Present	Present	Present
Constitutional rules (GS5c)	Present	Present	Present	Present (+)
Repertoire of norms and trends (GS6)	Excommunication	Excommunication	Excommunication & law	Excommunication (-) & law
Monitoring and sanctioning rules (GS7)	High*	High	High	High
Interactions (I)				
Harvesting (I1)	Absent*	Absent	Firewood collection only	Firewood collection only (-)
Self-organizing activities (I7)	Present	Present	Present (+)	Present
Monitoring activities (I9)	High*	High*	High	High
Outcomes (O)				
Social performance measures (O1)	High*	High	High	High

Ecological performance measures (O2)	High*	High	High	High
Externalities to other SESs (O3)	na	na	Absent	Present

¹The S3 variable measures only stability.
² During the Ottoman rule, the mountainous communities of Northern Pindos, as it is Zagori, enjoyed a considerable degree of autonomy .

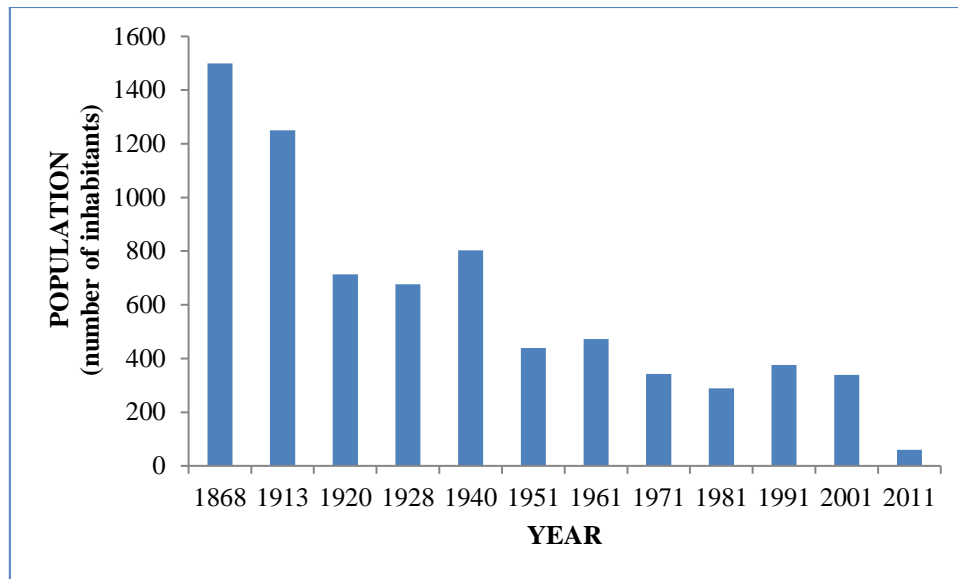
290

291 **3.1. Socio-economic and political settings (S)**

292 The socio-economic and political background of Greece, including Greveniti village,
293 underwent major changes during the previous centuries, (as depicted in Fig.2). Since the 15th
294 century, many parts of the Hellenic area were under the Ottoman rule, which lasted until the
295 beginning of the 20th century (1913 in Zagori) (**S4**). However, the mountainous communities
296 of Northern Pindos, as it is Zagori, enjoyed a considerable degree of autonomy including,
297 among others, absolute religious freedom, and the right of self-governance (**S3**) (Damianakos
298 et al., 1997). During the 17th -18th centuries, the settlement of Greveniti consists of
299 approximately 1500 people (**S2**). Agropastoralism was initially the basis of the local
300 economy; Dasoulas (2009) reported the absence of an extended livestock farming sector, as in
301 neighboring communities due to limited pastures. From the 17th century, village's men
302 worked as carriers or migrated and worked elsewhere in cities and trade centers in
303 Macedonia, Constantinople, Asia Minor, but mostly in Bucharest and other cities in
304 Moldovlachia. During this period only elders, women, and children (boys until the age of 12-
305 15) resided in the village maintaining the agropastoral activities, satisfying only 1/3 of the
306 village population necessities. Remittances from the family members abroad greatly
307 supported the village income, covering the construction of luxury private houses and
308 community buildings. This brought cosmopolitan cultural and architectural styles in a rather
309 rural and isolated settlement, which contributed to its educational and intellectual
310 flourishing during the 18th and 19th centuries (Damianakos et al., 1997).

311 After the incorporation of Epirus region in the Modern Greek State (1913), agropastoral
312 activities along with seasonal migration remained the basic economic activities, and the
313 products from the village's fields were traded abroad with a great demand (S1) (Rogkotis,

314 1998). In 1922 temporary migrations of men ended and were slowly replaced by a permanent
315 exodus to extra-European countries (e.g. U.S.A., Canada, Argentina, Egypt, Congo, and
316 Ethiopia). An increasing political instability, peaking into the Second World War (1940-
317 1945), and the subsequent civil war (1946-1949) led to an incessant decrease in the village
318 population (Fig.3). During WWII, Greveniti was burnt to the ground several times, with all
319 private houses (297) and community buildings destroyed, except of the village church. Losses
320 in human lives were the second largest among all Zagori villages. During the civil war (1946-
321 1949) the village was mandatory evacuated, and all villagers moved to the town of Ioannina.
322 After the wars, most of village residents permanently flee to larger urban areas (Damianakos
323 et al., 1997) (S3). Only 450 people came back to the village after the end of the civil war,
324 compared to more than 1200 inhabitants recorded at the beginning of the 20th century (S2;
325 Figure 3). In 1950, those who returned had to face a village with all houses destroyed and
326 fields abandoned. This destruction was turned into an economic opportunity by shifting the
327 local economic activity to logging of the community forest, located in the proximity of the
328 sacred protective forest. About 30 foresters organized themselves in two forest cooperatives
329 and this formed the basis of the local economy and social life during the post-war period and
330 became the main occupation in the area until current days. (Damianakos et al., 1997) (S1) By
331 1991, only 376 people were recorded to reside in the village. Depopulation was worsened by
332 modern public management changes (1999) which shifted most services from villages to
333 larger towns (S2).



334

335 **Figure 3.** Real Population data of the Greveniti village (1868-2015). The definition of
 336 ELSTAT for real population means the number of people present at the census day in each
 337 prefecture, district, municipality/community, and independent settlement. This differs from
 338 official census data (Sources: Damianakos et al., 1997; ELSTAT 1913-2011).

339 **3.2. Resource System (RS)**

340

341 Most RS variables appear to be stable enough since the beginning of the 20th century (Table
 342 1). The sacred forest boundaries were officially recorded in 1929 and their official
 343 formalization by the Forestry Service (1938) remains almost the same up until today. “No,
 344 nothing has changed. The boundaries, as it is said, have been set a few hundred years ago.
 345 (III)” (RS2). Even if the RS boundaries are perceived as stable, the ethnographic research
 346 shows that the abandonment of grazing has caused the infilling of vegetation in former open
 347 areas in its west boundaries and neighboring open areas, probably linked to the abandonment
 348 of local management and the reduction in population flows. (Additional information on RU is
 349 reported in Appendix C). This was confirmed by field observations on the forest structure
 350 (Marini Govigli et al., 2020). The key feature of the RS’ dynamics is natural gap regeneration
 351 processes (Cullen, 2015) (RS6; Appendix C). Informants confirm that this phenomenon
 352 occurs periodically every winter as trees fall due to age or weather events such as wind and
 353 snow.

354 Ethnographic research also identified that the forest contained certain plain areas, which
355 villagers cultivated as fields until the '70s. (RS10c) Additional activities which are commonly
356 performed in the wider area and within the sacred forest are hunting and the cleaning of water
357 channels and tanks. No major human constructions were allowed and indeed none was
358 recorded except for paths and a couple of water tanks to supply the village demand (RS4).
359 This limited interference with the forest was probably linked to its protective function,
360 sheltering the village from floods or landslides, and preserving water aquifers (RS7). *“This*
361 *forest of ours will grow more and stronger over the years. And it will always protect the*
362 *village, as long as the village lives.” (I15).*

363 Additionally, no major anthropogenic disturbances (e.g. timber harvesting) were identified by
364 our research as occurring in the RS during the past century. Only few anthropogenic cuts and
365 pollarded trees were detected, mainly clustered around the periphery of the sacred forest, the
366 areas with the highest level of interfering as in the proximity of the village poorest families.
367 (RS10). Similarly, no evidence of natural disasters was recorded in the forest until 2012,
368 when an unprecedented flood occurred (ECO1).

369 **3.3. Actor groups (A)**

370 Some variables of the Actors group have been identified as changing during the four time
371 periods. These are: Number of Actors (A1), Socio-economic characteristics (A2), Location
372 (A4). On the contrary three variables stand out as stable: Leadership (A5), Knowledge of the
373 System (A7), and RS Importance (A8).

374 Concerning the Actors number, the data collected from bibliography shows that from the
375 establishment of the settlement (1668) until the actual organization of the forestry service
376 (1929), the only group responsible for the RS was the community itself (Dasoulas, 2009).

377 After that time, the Actor group enlarged including forest guardians and state foresters. Since
378 1999, the number of relevant groups drastically increased. This now includes: the community
379 council, a logging cooperative (initially two established in the 80s), the village cultural

380 association, the village brotherhood², the municipality of Zagori, forestry service employees,
381 Northern Pindos National Park officers, academic researchers, and tourists (A1, A2). Most of
382 the afore-mentioned Actors are located away from the system, (A4) as currently Greveniti is a
383 depopulated village whose inhabitants are mostly summer and occasional residents. The
384 interviews highlighted that the role of the local community is substantial for the long-term
385 governance of the system (A5). The community has been the direct responsible of the forest
386 through the years. This is a role which persists up until today, despite sharing responsibilities
387 over the forest with official governing bodies (e.g. the forestry service and the national park;
388 Section 3.4). *“But it is us, the woodcutters here who protect it. And when a stranger gets
389 inside, we all notice who he/she is and what he/she is doing in there, you know. We all protect
390 it, because it [the sacred forest] is the protection of the village. (I20)”*.

391 Ethnographic research confirms that no use of the RS was taking place until the 1970s, due to
392 the enforcement of the supernatural fears associated with the religious practice of
393 excommunication (A3). *“What is Eftapapado [efta = seven, papas = priest]: seven priests
394 surrounded the forest with a candle from a church, spelling religious words (meaning curses).
395 It was excommunicated, like cursed, whoever was going to cut down a tree or do something
396 bad, he was excommunicated too. There was no other protection, people believed in religion
397 back then, and it turned out to be very good. Because this forest was protected.” (I25).*
398 Exceptionally, elder informants remember hiding inside this forest from the Nazi German
399 army during the war (1940-1945) (A3). *“When the war began, I was 10 years old. Our homes
400 were burned to the ground. We were hiding in the woods like wild beasts, like animals inside
401 the forest. We were sleeping in the snow. We didn't have anything to eat.” (I9).*

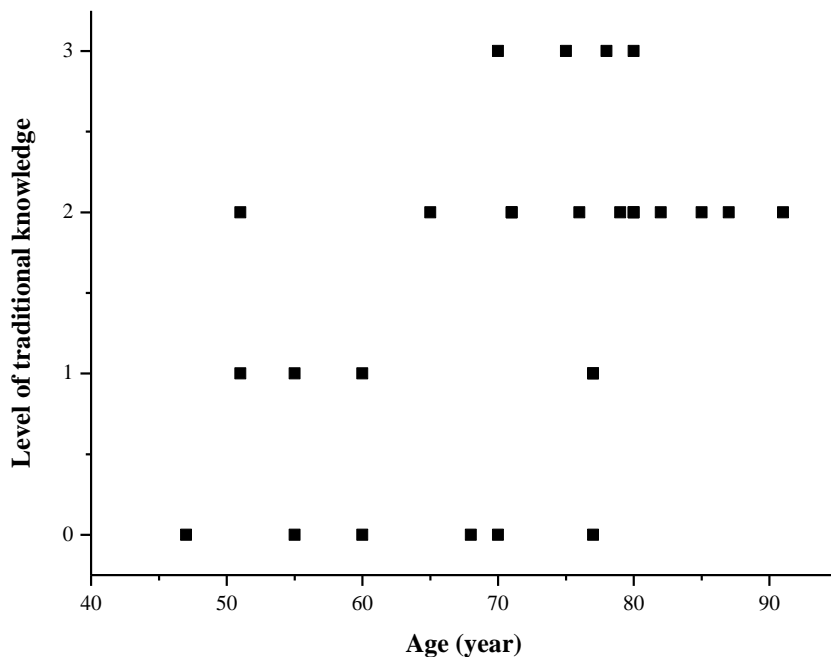
402 Regarding the Actors' social capital (A6), field observations indicate the occurrence of
403 several personal disputes among residents. Only one was identified as relevant to the RS, as it
404 focused on the collection of firewood from the forest. Seven informants believe that this
405 service degrades the RS: *“But what is good is not to be removed (the dead wood) because it*

2 the brotherhood is an assembly from people who descent from Greveniti but reside in Athens.

406 *rots and leaves, how to explain, something like manure, helping the tree to grow. Because if*
407 *you remove it then you leave nothing for the tree so that it can grow” (I18), while few others*
408 *support that it is beneficial for it: “Back then the authorities did not permit the collection of*
409 *dead wood nor anything. Later, they allowed the collection of dead ones fearing of fires.”*
410 *(I5). Some other interviewees support that there is trust and lack of disputes among the*
411 *relevant Actors of the SES.*

412 What is more, the present case study shows that all Actor groups are aware of the existence of
413 the RS (A7): *“Everybody knows about the protective forest, even the younger ones, everyone*
414 *knows it” (I20), yet confirms the differences in mental models of people belonging to*
415 *different generations (Figure 4). Youngest informants are amongst the 68% of the*
416 *interviewees unaware of the excommunication ritual enforced at the time of the sacred*
417 *forests’ establishment. On the contrary, those informants who still believe in the taboos*
418 *associated to religious ritual of the forest correspond almost entirely to the oldest age class.*

419 Concerning the importance of the RS (A8), all the Actors state that the sacred protective
420 forest is indispensable to their village: *“Because the forest protects the village from the floods*
421 *and all this, keeps the rainwater, the snow, so that the village does not flood because of its*
422 *downhill location.” (I7).*



423

424 **Figure 4:** Changes in the level of traditional knowledge concerning Greveniti’s sacred forest
 425 according to the ages of the informants (N = 24). Levels legend: 0: Unaware of the sacred
 426 forest history, 1: Aware of the sacred forest existence, 2: Aware of the sacred forest existence
 427 and of its establishment tradition (excommunication ritual), 3: Aware of the sacred forest
 428 existence, its establishment tradition, and still actively believing in it.

429 **3.4. Governance System (GS)**

430

431 As elaborated in the Settings, during the 15th-19th centuries the community of Greveniti was
 432 granted the right to self-manage its natural resources without the intervention of the Ottoman
 433 rulers by simply paying a tax to the Ottoman authorities (Damianakos et al., 1997). Once the
 434 village was annexed into the Greek state (1913), the management of forest ecosystems is
 435 placed under the responsibility of the forestry service. After 1950, a local forestry department
 436 was created in Greveniti, but its function ceased in 2002 because of national administration

437 changes³: The fact that the village is declared a peripheral zone of Northern Pindos National
438 Park (2005) seems to face positive responses from the community members (GS1) “*Yes, this*
439 *is a good thing; it's an additional protection for the forest. The National Park's Management*
440 *Agency patrols here, in all villages. And they see things, they will detect a fire, anything*”
441 (I20).

442 Another relevant GS change is the ownership status of the RS. Formerly owned by the
443 community, after the progressive merging of Zagori communities into a single municipality
444 that ended in 1999, the municipal council becomes the RS official owner and manager
445 (GS4a). Despite this major change of ownership, RS access (GS4b) and RS subtractability
446 (GS4c) were not generally affected. The forest is still accessible to anyone as it was in the
447 past, and the extraction of the forest's resources was and still is forbidden and remains a
448 community prerogative (GS4c).

449 Since the Greek forestry sector in the area began to be centrally coordinated by the State
450 (1924-1929), protective forests above settlements have been acknowledged and strictly
451 protected by ad hoc legislation (GS5c) (L. 86/1969; PD 11/1928). Thus, any activity that
452 could degrade protective forests such as Greveniti sacred forest (i.e. grazing and wood-
453 cutting) is not allowed *de jure*. Greveniti community is still unanimously in favor of this
454 restrictive legislation (GS5b), except a minor modification requested by the community
455 council in the '70s (GS5a), related to obtaining permission in the collection of firewood and
456 grazing domesticated animals in the forest periphery for the inhabitants residing on its
457 foothills. This request was accepted, and it applies up until today.

458 The ethnographic research proves that from 1913 until the '70s no activity was allowed inside
459 the sacred forest and that its actors would entirely comply with it (GS6). The “institution”

³ A major reform in the local administration of Greece was initiated in 1997 (L. 2539/97, the Ioannis Kapodistrias Programme). According to this law, all existing municipalities and communities were obliged to form new enlarged municipalities. With this legislation, decision-making responsibilities of communities' local councils were replaced by a larger municipal council (Lalenis & Liogkas, 2002). Another similar reform occurred in 2010 (L. 3852/2010, the Kallikratis Programme) which additionally reduced the overall number of municipalities.

460 responsible for CPR governance used to be the local community represented by the Church,
461 which substituted political and juridical power through the establishment of religious rituals
462 for the protection of fragile ecosystems during the Ottomans times (Stara et al., 2016). *“If you*
463 *were to do anything illegal for example, there was no one to punish you, you had to believe in*
464 *religion. To the fact that it is excommunicated and somehow indeed the people were more*
465 *religious, they believed back then, they believed it.”* (I5). After the Second World War, many
466 villages replaced their fear on religious bans with the ecosystem service value of the RS (i.e.
467 the fact that the forest shelter the village from extreme weather events and replenish water
468 supplies) *“They protect it, and there is a tradition, we don't intervene in this forest, we don't*
469 *touch it. It is a protective forest, it protects us.”* (I12).

470 Lastly, there is no clear evidence about the existence of monitoring and sanctioning
471 institutions before the 20th century, although the religious excommunication ritual might have
472 acted itself as a tacit sanctioning instrument. (GS7). After 1913, the protection of the forest
473 was under the responsibility of state forest guardians along with the community itself.
474 Nonetheless, after the merging of municipalities in 2010, only few forest guardians were left
475 responsible for the whole area in which Greveniti is located (YPEKA, 2014) in addition to
476 some wardens of the Management Agency of the National Park who do not have the authority
477 to impose penalties to trespassers.

478 **3.5. Interactions (I) and Outcomes (O)**

479

480 No written evidence was found about Interactions (I) with the RS during the Ottoman years.
481 The only available evidence came from the ethnographic research pointing out that all Actors
482 refused to damage trees within the forest during those years, fearing the consequences of the
483 excommunication (I1). Most of the informants argue that this is the main reason why the RS
484 was preserved in the first place. The research shows that except the collection of firewood
485 after 1970s, no other harvesting activity ever took place inside the sacred forest (I1). *“No one*
486 *goes inside it, no one does damage. They wouldn't even go in the past when they needed it*

487 *most” (I16). A documented evidence confirming the findings of the ethnographic research*
488 *was found in a descriptive report of the forest. There it is stated that: “The removal of very old*
489 *beech trees is possible, assuring the lack of negative consequences to the protective effect of*
490 *the system. However, such an intervention was not desirable from the community for moral*
491 *reasons, so it [the sacred forest] is exempted of any management plans” (Forestry Service of*
492 *Metsovo, 1982). After the reconstruction of the village in 1950, new self-organized activities*
493 *of the community with the RS were developed, consisting in forest paths repairing to attend*
494 *the annual feast at the Prophet Elias chapel (July 20th), located in the neighboring, non-*
495 *protective, communal forest area, and marking of new mountain trails (I7). After the*
496 *municipalities’ establishment, control by the State in the area is still undertaken by forest*
497 *guardians from the Metsovo Forestry Service, located 40 km away from the village. The*
498 *community itself, however, carries out additional guard duties concerning its protective forest*
499 *(I9).*

500 The above interactions have resulted in a successful collective performance (O1) and a
501 positive ecological state of the forest, which continues to regenerate naturally (O2), since the
502 creation of Greveniti settlement. However, the lack of care in cleaning water channels and
503 tanks for storing the water coming from the forest since 2000, has contributed to the
504 occurrence of landslide in the settlement of Greveniti (Paschos and Nikolaou, 2010). This also
505 creates certain shortage of water supply in the village, especially in the summer months where
506 water management is rendered necessary (O3).

507 4. Discussion

508 The purpose of this research is to assess the degree to which collective action was successful
509 in preserving the sacred protective forest of Greveniti across time, identifying the main social,
510 economic and ecological factors, which contributed to the forest formation and conservation.
511 Our results overall indicate that changes in the socio-economic context and the wider
512 governance system recorded over time and the different forms of interactions between its

513 actors do not appear to have affected in a negative way the collective management of the
514 system, which has been maintained under different multi-centered governance regimes.

515 The first main finding of this research is that the studied SES was subjected through centuries
516 to dramatic socio-economic, political, and governance changes. These included migration,
517 wars and subsequent destructions, depopulation as well as a changing ownership status of the
518 forest. The latter meaning that the SES regime gradually shifted from a monocentric
519 (community-based) to a polycentric decision-making system (community-municipality-
520 forestry service; state driven). That is to say, the decision-making center has been gradually
521 shifted away from the community itself since 1999.

522 Frequent socio-economic and governance changes are typical of long-term SES (Skulska et
523 al., 2020), and in certain cases deteriorating conditions, such as political instability and an
524 absence of economic development can affect negatively the outcomes of an action situation
525 (Guevara et al., 2016). Moreover, SESs where communities are deprived of their former
526 property rights on CPR have been showing symptoms of collapse (Basurto et al., 2013;
527 Mutekwa and Gambiza, 2017).

528 Nevertheless, in our case study, it appears that such changes have not impacted the success of
529 collective action neither the sustainability of the sacred forest for at least 300 years. Most of
530 the village inhabitants are still aware of the sacred forest's existence and of its protective role,
531 despite the experienced turmoil. This is an outstanding finding, which contrasts other SNS
532 literature where the changes in the social and political background of the country are
533 considered the main factors for the degradation of sacred forests: i.e. China (Zeng and Reuse,
534 2016), India (Osuri et al., 2014), and Africa (Alohou et al., 2016; Mutekwa and Gambiza,
535 2017). We link the success of the collective action in preserving the sacred forest to four main
536 drivers: (i) adaptive governance, (ii) simplicity of the adopted rules, (iii) combined formal and
537 informal institutions, (iv) community role.

538 For 200 years (18th and 19th century) the basic collective rule for the management of the
539 sacred forest of Greveniti was the fear of excommunication. Since the beginning of the 20th

540 century, the fear of excommunication has been gradually supplanted by the ecosystem service
541 value of the resource, *i.e.* the protective role of the forest in replenishing village's aquifers
542 and mitigating flood risks. This shows how the villagers have adopted an alternative vision
543 for the conservation of the forest future; adapting and rationalizing the traditional governance
544 system (preserve the forest via spiritual taboos) to modern governance tools (preserve the
545 regulating and provisioning value of the forest with the support of forestry service activities).
546 However, no matter the method in use, the central role of the sacred-protective forest in
547 community's life remains active. In most sacred forests across the world sacredness is a one-
548 dimensional value, that is to say, local populations believe primarily in the spirituality of the
549 forest itself and not in conservation values, despite major social, economic and political
550 changes (Allendorf et al., 2014; Allendorf and Yang, 2013; Orłowska and Klepeis, 2018;
551 Strauch et al., 2016). Yet, additionally to our case study, community strategies evolution to
552 conserve sacred forests has been also noted in e.g. SNS in India and Sri Lanka (Weerasinghe,
553 2011).

554 In addition, CPR surveys' findings confirm that locally based rules that are easy to
555 understand, to enforce, and to help to resolve conflicts, are more likely to lead to effective
556 governance (Basurto et al., 2013). For this reason, they are also considered a very important
557 variable for collective action (Chhatre and Agrawal, 2008). This is the case for the sacred
558 forest of Greveniti, where a simple rule (prohibition of tree cutting) managed to withstand
559 centuries of social, economic, and political changes in the SES.

560 Moreover, laws established by the Greek state for protective forests have acted as
561 supplementary enforcement for the *de facto* community customary rules. Self-management in
562 the years of Ottoman occupation and Zagori's autonomy, is replaced by the co-management
563 of the community and the Greek state management policies after 1913. These state
564 mechanisms appear to have enhanced the protection of the ecosystem and contributed to the
565 implementation and monitoring of community rules, ensuring the success of collective action
566 until today, as it has happened in the sacred ecclesiastical forests of Ethiopia (Klepeis et al.,

567 2016). This is an extraordinary prerogative of this sacred forest thanks to the active role
568 played by the local community. This finding contrasts other neighboring sacred forests in
569 Zagori, where forests were at logging risk because no agreements were reached between the
570 forestry service and local communities.

571 In the case of Greveniti sacred forest, we believe that the clear ownership status and
572 collective rules originally set up by the community for the community itself, are two vital
573 factors responsible for the sustainability of this ecosystem. Yet, the absence of strong
574 enforcement mechanisms of these rules as well as proper monitoring can lead to a degradation
575 of resources (Ostrom and Nagendra, 2006) or poaching of the RS from outside actors
576 (Basurto et al., 2013; Fleischman et al., 2010). The lack of such mechanism for the sacred
577 forest of Greveniti seems to not have caused any negative consequence yet on the SES
578 governance.

579 The local community emerges as being the main custodian of the Greveniti sacred forest, as
580 in many other SNS (Dudley et al., 2009; Virtanen, 2002; Byers et al., 2001). Although its
581 socio-economic attributes have changed radically compared to previous centuries, the
582 community council maintains the role of the leader for the system preservation. The presence
583 of recognized and collectively elected leaders/representatives from the community is indeed
584 another factor identified as important in achieving collective action among the actors of a
585 CPR system (Guevara et al., 2016; Williams and Tai, 2016; Onyx and Leonard, 2011). The
586 clear identification and small size of the group, their interdependence, the existence of
587 leadership, the existence of a common identity and common social norms, are some of the
588 elements the literature has pointed out as important for successful collective governance. In
589 the studied system, the two most important variables to ensure positive results are, in our
590 opinion, that all stakeholders in the system know about its existence (A7) and that the
591 community's direct dependence on resource is universally accepted (A8). Both variables
592 remain stable at high levels in each time period (Table 1). These variables have been

593 highlighted by other researchers as of paramount importance for preserving a common
594 resource through time (Orlowska and Klepeis, 2018; Basurto et al., 2013).

595 An additional result of the performed analysis is the perceived stability of the sacred forest by
596 the informants, in contrast to its actual ecological dynamics. Even older informants perceive
597 the sacred forest as a static, unaltered system since its creation. A similar result is confirmed
598 by other sacred forest surveys, where fewer than half of the informants perceive observable
599 changes in the sacred forest (Allendorf et al., 2014). However, the analysis shows that tree
600 units have increased inside the sacred forest because of the lack of human intervention.
601 Furthermore, the tree cover seems to be “expanding” towards the village former open
602 neighboring areas because of minimum human-induced pressures during the past 30 years,
603 like grazing. The existence of temporal and spatial variability in vegetation coverage has been
604 also recorded in the sacred church forests of Ethiopia (Cardelús et al., 2017) but Klepeis et al.,
605 (2016) proved that such changes are hard to perceive within the span of one human
606 generation. Further research on the temporal variability of sacred forests boundaries and the
607 way they are perceived by their neighboring communities is currently underway.

608 ***4.1. Conclusions and policy implications***

609 The present research confirms that the studied mountainous communities in Northern Greece,
610 have developed an intimate century-long interaction with their sacred forests and related
611 ecosystem services, framed by collective decision-making and customary forms of protection.
612 This enables us to consider sacred forests in northwestern Greece as complex SESs, being
613 natural systems governed through community rules and religious and social taboos, which
614 have evolved as time passes and through subsequent ecological and societal changes. Our
615 application of the Ostrom’s SES framework showed that socio-ecological, political and
616 governance changes have not affected the sustainability of the resource for more than 300
617 years. Moreover, Actors’ solutions for the collective management of the system proved to be
618 evolving, as time passes. Traditional religious taboos for protecting the resource thus persist,
619 although molded into environmental awareness and heritage preservation reasonings. This

620 finding has multiple implications relevant from a policy perspective. First, it indicates how
621 SNSs require adaptive policy measures, which can comply with local circumstances and their
622 socio-ecological changing context (Schultz et al., 2015; Undaharta and Wee, 2020). In the
623 field of SNS, this can correspond to adaptive policy frameworks that depart from static
624 sacredness to dynamic conservation strategies for the SNS and its socio-ecological values.
625 Secondly, policies on SNSs need to consider the interconnectedness between all element
626 systems and between the micro-scale (each individual site, with its own specificities) and the
627 macro, landscape, scale. This essential modularity of the policy framework dealing with SNS
628 is necessary to allow the various actors and decision-making centers (e.g. communities, local
629 administrations) to operate in a grid, but without hampering each other work (Anderies and
630 Janssen, 2013). Lastly, policies should aim at being diversified and plurals. SESs rely upon
631 multiple actors' interactions. Maintaining alive the plurality of visions in SNSs is extremely
632 important as it increases chances of social confrontations, possibly leading to the emergence
633 of innovative ideas and practices supporting effective management of SNSs in changing
634 socio-economic contexts.

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6. Appendices

Appendix A: English translation of the interview guideline used to support the semi-structured interviews.

RESOURCE SYSTEM (RS)	
<u>Sector:</u> What is the name of your Sacred grove?	
1. Clarity of system boundaries	(What are its boundaries?) Have they changed?
2. Ecologically defined boundaries	Is there some ecological sign to define forest's boundaries? (e.g., watershed, changes in vegetation, rocks) How do they distinguish it from the community forest?
3. User-defined boundaries	Any other signs such as chapels? How would they personally know forest's boundaries? What is their opinion about them?
4. Location	What was there in the past? Have they noted any changes? Is there a path inside the forest? Where does it go? How often it was used in past? How often is it used now and by whom? Have they ever used it personally? When was the last time? Do people make any use of it nowadays and why?
5. Size of resource system	Has the size of the forest changed over time?
8. Ecosystem History	[Which historical/physical events affected its structure and how?] How was it used during the war?
9. Natural disaster history	Did any natural disasters take place? Do people relate them to the forest protection?
10. Human disturbance history	Do they remember any major disturbances caused by humans? When was the pasture-land and grazing abandoned?
Equilibrium properties	Which disturbances exist and how do they affect the system?
11. Frequency/timing of disturbance(s)	How often do they notice disturbances? What are the most usual ones?
24. Predictability of system dynamics	What do they believe about its future development?
ACTOR GROUPS (A)	
6. History or past experiences	Any local or personal stories concerning the forest?
7. Importance of resource (dependence)	How is the sacred forest important for their livelihood? In what way? In the past?
12. Location	Has it ever changed? Any stories about smaller communities that united? Any communities inside the forest?

RESOURCE UNITS (TREE SPECIES) (RUII)	
13. Value	To what tree species do they attribute more value and why? Is it the same they like the most?
14. Distinctive characteristics	Does any tree species have some distinctive characteristics for them?
15. Spatial and temporal distribution	Which species is dominant in the forest today? Is it the dominant sp. in every part of it? What about the community forest and the forests of near villages? Why do they think this is taking place?
16. Growth or replacement rate	Do they notice any change in species? What about canopy tree sp.? Are they the same?
POPULATION OF RESOURCE UNITS (THE FOREST) (RUI)	
17. Growth or replacement rate	Do they believe their grove keeps growing? Do you know the ages of older trees? Comparing to the past ones?
18. Number of units	Do they see more trees in the forest now than the past?
19. Spatial and temporal distribution	Do they believe the composition of the forest has changed compared to previous time periods?
GOVERNANCE SYSTEM (GS)	
20. Government organization	Who owns the forest? Who takes decisions about it? Do they know if it is part of National Park? What would they think of that?
21. Property-rights systems	Who had access to the forest? Does that apply to every member of the community?
23. Repertoire of norms and trends	Do actors comply with them or have a different way of managing things? What was the case before/during the war?
Rules in use	What are the rules and how often are they modified?
22. Monitoring and sanctioning rules	Are there any monitoring rules? Any sanctions in case of illegal activities?

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878 **Appendix B:** First (bold), second and third (*italics*) tier variables selected initially for the current
 879 study. * indicates the existence of more than one tiers. Variables defined according to Epstein &
 880 Kreitmair (2013) and Delgado-Serrano & Ramos (2015). RU is decomposed in two components, with
 881 the aim of including the forest as a single system (RUI) and the units from which it is composed
 882 (RUII). RU4-Economic Value was renamed to Resource Value (Delgado-Serrano & Ramos, 2015)
 883 because the ecosystem is protected and there is no economic exploitation.
 884

**SOCIO-ECONOMICAL AND
 POLITICAL SETTINGS (S)**

- S1 Economic development
- S2 Demographic trends
- S3 Political stability
- S4 Government resource policies
- S7 Technology

- RS6c* Extent of disturbance(s)
- RS7 Predictability of system dynamics*
- RS9 Location
- RS10 Ecosystem History*
- RS10a* Relevant geologic history
- RS10b* Natural disaster history
- RS10c* Human use and disturbance history

RELATED ECOSYSTEMS (ECO)

- ECO1 Climate patterns
- ECO3 Flows in &out of SES

ACTORS (A)

- A1 Number of relevant actors
- A2 Socioeconomic attributes
- A3 History or past experiences
- A4 Location
- A5 Leadership/entrepreneurship
- A6 Norms (trust-reciprocity)/social capital
- A7 Knowledge of SES/mental models
- A8 Importance of resource (dependence)
- A9 Technologies available

RESOURCE SYSTEM (RS)*

- RS1 Sector
- RS2 Clarity of system boundaries*
 - RS2a* Ecological defined boundaries
 - RS2b* User-defined boundaries
- RS3 Size of resource system*
 - RS3a* Different ecosystem types within the RS
- RS4 Human-constructed facilities
- RS6 Equilibrium properties*
 - RS6a* Successional stage/trajjectory
 - RS6b* Frequency/timing of disturbance(s)

**POPULATION OF RESOURCE
 UNIT (THE WHOLE FOREST)
 (RUI)**

- RU2i Growth or replacement rate

RU3i Interaction among resource units

RU4i Resource value

RU5i Number of units

RU7i Spatial and temporal distribution

RESOURCE UNIT (TREE SPECIES) (RUII)

RU2ii Growth or replacement rate

RU4ii Resource value

RU6ii Distinctive characteristics

RU7ii Spatial and temporal distribution

GOVERNANCE SYSTEM (GS)*

GS1 Government organization

GS2 NGOs

GS3 Network structure

GS4 Property-rights systems

GS5 Rules in use*

GS5a Operational-choice rules

GS5b Collective-choice rules

GS5c Constitutional-choice rules

GS6 Repertoire of norms & trends

GS7 Monitoring and sanctioning rules

GS8 Regime type

GS9 Historical continuity

INTERACTIONS (I)

I1 Harvesting

I2 Information sharing

I3 Deliberation processes

I4 Conflicts

I5 Investment activities

I6 Lobbying activities

I7 Self-organizing activities

I8 Networking activities

I9 Monitoring activities

I10 Evaluative activities

OUTCOMES (O)

O1 Social performance measures

O2 Ecological performance measures

O3 Externalities to other SESs

Appendix C: RU data collected for the sacred forest of Greveniti. Sources: (Cullen, 2015; Marini-Govigli et al., 2015; Marini-Govigli et al., 2020; Metsovo Forestry Service, 2012).

I. POPULATION OF RESOURCE UNIT (THE WHOLE FOREST) (RU _i)		
RU2i	Growth/replacement rate	Natural regeneration, gap dynamics
RU2ia	Age of forest	Up to 310 years old
RU3i	Interactions among units	Competition does not appear to affect the growth rate of mature trees., although further research needs to be conducted (Cullen, 2015)
RU4i	Resource value	Aesthetic, recreational, spiritual, conservation, research, utilitarian
RU5i	Number of trees	Increasing (according to informants)
RU7i	Spatio-temporal distribution	Dominant tree species is beech, spreading in an area of approx. 66 ha. The ethnographic research conducted did not detect any changes in the current species distribution.
II. RESOURCE UNITS (INDIVIDUAL TREE UNITS) (RU _{ii})		
RU2ii	Growth/replacement rate	The number of individuals decreases exponentially as size classes increase. Beech trees dominates understory vegetation, with exception to the W side where the regeneration layer is more diversified with other broadleaves
RU2iia	Tree species	Fig. C.1
RU2iib	Tree ages	<i>Fagus sylvatica</i> was found in all size classes (except 100-125years old), <i>Pinus nigra</i> trees correspond only to medium-large sized trees (approx..100-150 years old)
RU7ii	Spatio-temporal distribution	Two distinct beech dominated forests, separated by a belt of lower understory vegetation (<i>F. ornus</i> , <i>F. angustifolia</i> and <i>C. orientalis</i>) (Fig.1). Pine (<i>P. nigra</i>) in the NE and a mixed <i>Carpinus-Acer</i> stand around the W edges proximal to the village of Greveniti (Fig. C.2).

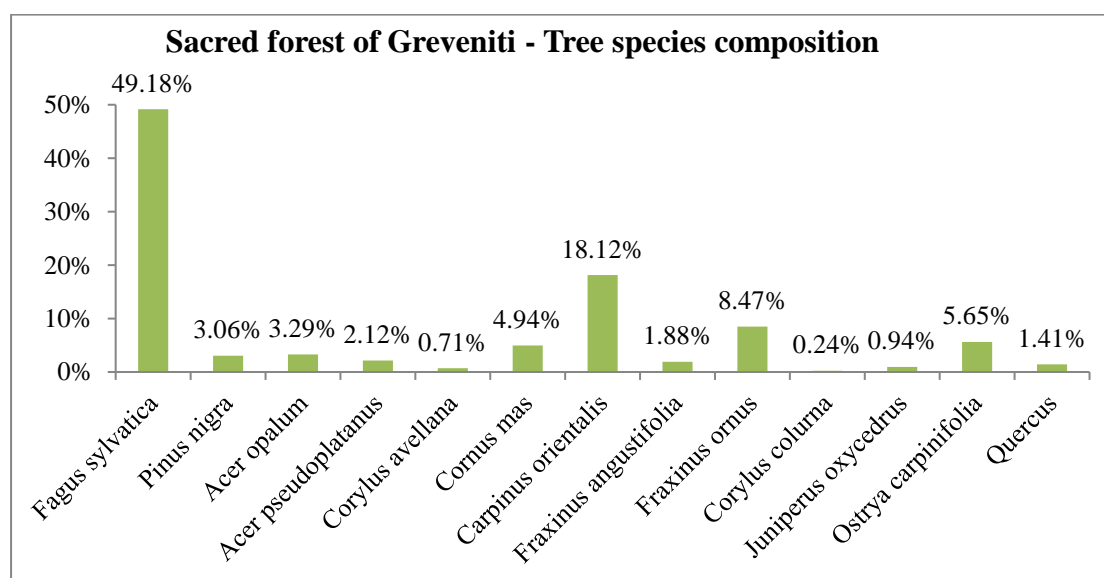


Figure E.1 Tree species composition in Greveniti sacred forest. Values are percentages of the total identified individuals at tree level. (Due to identification issues, juveniles of deciduous oaks were pooled at *Quercus spp* level). Source: Marini-Govigli *et al.*, 2020.

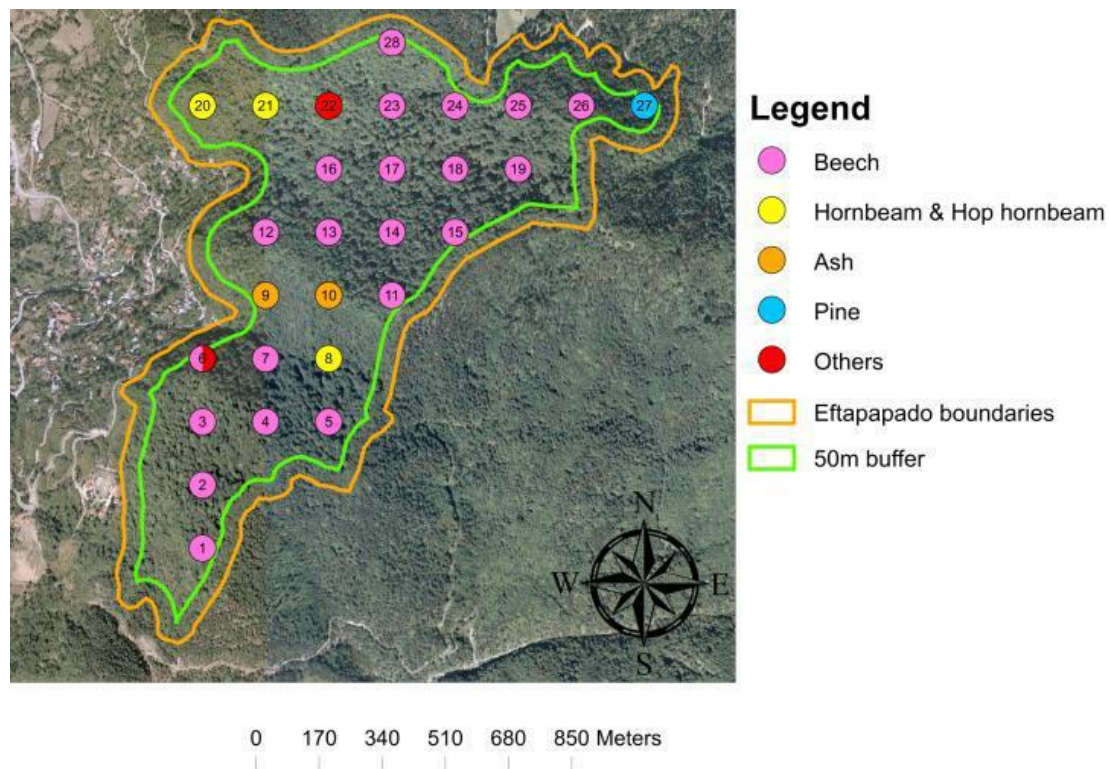


Figure E.2 Dominant tree species by plot stems number. Presence of two colors shows a case of co-dominance. (Source: Marini-Govigli *et al.*, 2015.)

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