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Endangered Commons? Modeling the Effects of Demographic Trends Coupled with Admission Rules to Common Property Institutions

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Abstract: This study investigates the long-term effects of demographic trends and admission rules on common properties in the Province of Trento, Italy, which we refer to as historical commons. Historical commons have evolved into socio-ecological systems over the centuries, meaning that communities governed collectively natural resources and lands essential for community survival. Communities and the admission rules that determine their composition are an important constituting element of historical commons because they have developed local ecological knowledge and practices of sustainable use of natural resources. Our study hypothesizes that commons continuity is endangered because of the declining trend of the size of communities being influenced by demographic trends coupled with admission rules. Grounding our research in systems dynamics, we use empirical data including demographic projections and existing admission rules to simulate their effect on the site of the community using the Province of Trento, Italy, as our study region. To achieve that, three types of historical commons are identified: open, semi-open, and closed, each with different admission criteria based on inheritance and/or residency. Results indicate that inheritance-based admission rules can significantly reduce the number of commoners over time, potentially endangering the continuity of these self-governance institutions. The study discusses the results in light of the literature on historical commons' continuity to evaluate different policies affecting the size of the community grounding on different mental models. The study concludes that a simulation approach can promote an anticipatory approach to the co-design of policies to ensure inclusive continuity of historical commons.

Keywords: agile modeling; system dynamics; historical commons; admission rules

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1. Introduction

Commons are institutions through which humans collectively govern natural or cultural resources [1]. Commons that govern forests, pastures, fisheries, and waters are diffused in many parts of the world [2,3] under different forms and names [4]. Their land and natural resources are often located in rural and mountainous areas and show high environmental and biodiversity values [5,6]. Several of these commons are historical, as they have emerged in medieval times [7].

Ostrom' theory [8] demonstrated that commons are a solution to Hardin's theorized "tragedy of commons" issues [9] occurring when finite natural resources are used without exclusion. By implementing a system of principles and rules, commons control resource extraction in a sustainable way and avoid depletion connected with unregulated open access. Sustainability implies maintaining the number of members proportionated to resource availability so as to avoid overuse, misuse, or lack of management [10]. Hence, commons rely on a variety of admission rules, which define who has the right to use lands and resources and at which conditions, and how to participate in the decision-making over them [11]. They thus define the boundaries of the social base of a commons (i.e., the commoners' community). Such rules are aligned with the social-ecological system in place [8] in that they mirror the power relations in place [12] and are adjusted throughout the centuries following socioeconomic changes [7,13–16]; for example, in periods of resource scarcity, commons applied very restrictive admission rules; in moments of socioeconomic and technological development, admission rules were softened to make more space for new commoners who could provide the needed labor force to work on common lands [7].

Historical commons in Europe have played a strategic role in the livelihood of rural communities, their social equilibrium, and cohesion [17–21]. They have catered to the needs of the communities for several centuries, distributing rights for collective enjoyment of resources (e.g., grazing, hunting, and forest harvesting) [22,23] and collective provision of welfare, educational and cultural services. Their guiding principles are, among others, collective provision in resource management activities, sustainable extraction of resource units (e.g., cutting trees), indivisibility of the resource (e.g., of the forest), and resource integrity conservation for future generations to ensure resource preservation in the long term (e.g., Italian Law 168/2017). This has ensured the conservation of the natural heritage for both future generations of commoners and society at large. For this key role as regulators of resource use, historical commons were (and still are) considered a model of sustainable land management [8,24].

Historical commons are confronted with social, economic, and ecological challenges at global scale that have effects at the local scale as well as with internal dysfunctions. Increasing tertiarization of economy [25,26] has led to local communities no longer relying primarily on the extraction of resources for subsistence [27] and to increased connections to global markets to buy and sell the goods. Increasing tertiarization has also had the effects of creating demands, and thus values, for mountain ecosystems in terms of recreation, leisure, and tourism [13,28]. Climate change and biodiversity loss caused by fossil-fuel-based and extractivist human production models call for collective action beyond the local scale [29–33] to manage resources according to a multi-objective and multi-scale perspective [21,28]. Social trends such as aging and depopulation of rural areas [34] due to migration to urban areas and other countries can threaten the continuity of the social base of commons. The literature is increasingly shedding light on the fact that commons are based on rules that mirror the power relations in place and that de facto exclude some groups of society [12,27,35,36] such as women and youths, thus reducing legitimacy and participation in commons assemblies.

The resulting decline of the commons' social base [37] means the loss of local ecological knowledge and practices that have allowed the continuity of social-ecological systems over the centuries [5]. It also implies the disempowerment of communities in collectively deciding over and accessing local resources, thus reducing bonds among community members and community–environment bonds [27].

The literature is rich both in theoretical contributions and case studies on the interconnections between global and local change and commons' adaptive strategies [30,38–41]. Studies concur in highlighting that changing demography in mountain areas coupled with inadequate admission rules may negatively affect commons' long-term persistence, their ability to represent the social composition and the needs of the community members, as well as their ability to contribute to resource management [12,42–46], ultimately jeopardizing the community's ability to contribute to resource maintenance by tackling current social, economic, and ecological needs at different scales. However, the combined effect of declining demography with admission rules and its consequences on the number of commoners has not been modeled yet.

Our study addresses this gap and proposes a simulation approach that focuses on the effects of admission rules and demography on the size of commoners' communities, keeping other social and ecological variables constant. Our ambition is to offer insights and tools that engage communities in understanding the impacts of existing admission rules and the need to adapt them by anticipating demographic changes. Our research questions are: What effect do different admission rules to historical commons coupled with demographic variables have on the dynamics of the community's size? What policies can be derived to ensure the continuity of historical commons, considering that different mental models exist [47]?

The article is structured as follows. In the Materials and Methods section, we illustrate the systems dynamics and agile modeling approaches, the characteristics of the study area and the data collected, and how were they used to build the models. The Results section illustrates the SD models that result from the agile modeling approach. We then discuss the strengths and limitations of the study, as well as the policy implications of the resulting SD models. In Conclusions, we reflect how such an exercise can be used in following studies as well as concretely to support decision-making.

2. Materials and Methods

The human mind is an excellent processor of linear causal relationships, but it has difficulties in making evaluations that include feedback loops, and it is even less able to mentally simulate and distinguish elements that accumulate and the effects of changes in rates over time [48,49]. The modeling approach used in this article is inspired by Forrester's [50] lessons on system dynamics ("when faced with a new problem, I start by identifying the stocks and how they are changing"). System dynamics (SD) is an interdisciplinary applied field that encompasses a variety of tools and approaches to understanding the dynamic behavior of complex systems over time. Systems modeling consists of drawing conceptual models and developing simulation models to analyze the feedback loops, delays, and other dynamic interactions within a system [51]. A basic dynamic model includes "stocks" (i.e., anything that we can count or measure accumulating over time, and whose quantity we are interested in) and "flows" that change such stocks, i.e., inflows and outflows (Figure 1). This is also referred to as the "bathtub" model, in which the stock variable (e.g., the level of water) changes through opening or closing the tap and the drain (i.e., changes in the rates of inflows and outflows). In real systems, the model may consist of several interconnected bathtubs.

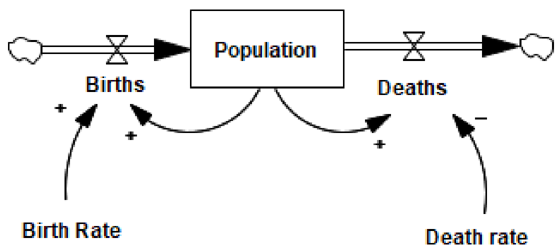

Figure 1. A basic stock-flows model of a population: population is the "stock" variable that changes according to "flow" variables, births and deaths per year, in this case.

There are many approaches to SD modeling [51,52] that are more or less demanding in terms of the amount of data. The approach we used in this article is inspired by Warren's [53] proposal for an agile system dynamics modeling. In the next section, we explain how we designed and applied the modeling methodology.

2.1. Agile Modeling Approach

The agile systems modeling generally starts from the simplest stock-flows model of the quantity of interest and proceeds by continuous improvement of it by adding feedback loops, stocks, flows, and time delays to capture the complexity of the systems involved. Feedback loops can be reinforcing or balancing. Reinforcing loops, also known as positive feedback loops, amplify changes in a system, leading to exponential growth or decline. They occur when an increase in one element of the system causes further increases in that element. In contrast, balancing loops, or negative feedback loops, work to stabilize a system by counteracting changes. They help in maintaining equilibrium by pushing the system back towards a desired state whenever deviations occur. Together, these loops and their interactions guide the dynamics and behaviors of complex systems.

Agile modeling involves multiple iterations as follows. The SD model is developed by framing the problem, explicating key system structures and elements (i.e., stock and flow variables) and causal relationships between them, comparing the simulated dynamics with the hypothesized ones, and correcting the model or the expectations. Thus, along the process of developing increasingly sophisticated models, a better and shared understanding of the complexity of the SD models and of the modeled systems emerges.

2.2. The Study Area

The Province of Trento, a mountainous region in Northeastern Italian Alps, has 76% of the total area and 55% of the utilized agricultural area under a collective type of property [54]. This is the highest share in Italy. Historical commons have been embedded in the social structure of the region for centuries and are now formally recognized as collective property institutions (CPIs) for governing agricultural lands, forested lands, and pasturelands by both a provincial and a national law (L.P. 6/2005 and L. 168/2017). This legal framework allows CPIs (in the paper, we use the term commons and CPI interchangeably) to self-define rules of admission in their own statute. There is a high diversity of CPI in the area according to the different admission rules. This makes the Province of Trento a good case study to explore the outcomes of different admission rules on the size of the community. Using commons' literature [55–57], expert knowledge and the screening of the content of commons' statutes, we identify three categories of CPIs and display their location in Figure 2:

- Open CPIs: admission to the commons' community is residence-based, and admission rights are recognized either to the individual community member or to the household represented by a head (often the male); there is a waiting period, (i.e., a minimum number of years of residence before acquisition of rights), which varies according to statutory rules of the commons from 1 to 10 years. In the study region, over 120 CPIs (i.e., the *Amministrazioni Separate dei Beni di Uso Civico*) belong to this category, and they are spread throughout the entire Province of Trento.
- Semi-open CPIs: admission to the community is based on a long waiting period after residence (i.e., 10–25 years) starting upon subscription to the commons' registry or it is acquired by inheritance of rights from the household once the adult age is reached; in this type of commons, it is always the household as a unit that is the full right holder, not the individual household member. The household is represented by a delegate with decision-making rights. Institutions belonging to this category are called *Regole*, located in *Valli Giudicarie*, and *Magnifica Comunità* located in *Val di Fiemme*.
- Close CPIs: admission to the community is based on inheritance only. As in semi-open CPIs, the household holds full rights, and it is represented by a delegate. This category comprises institutions such as *Consortele* in *Val di Sole* and *Feudo Rucadin* in *Val di Fiemme*.

The mountainous Province of Trento has a population of 538,000 inhabitants [58], distributed in more than 200 municipalities located at an altitude ranging from 70 m to 1400 m. Over the past century, this population has undergone significant fluctuations [59]. At the beginning of the 20th century, the region faced a decline, attributed to the aftermath of war and emigration in pursuit of better living conditions abroad. During the economic boom, a substantial population increase occurred, fueled by prosperity, high fertility rates, and low mortality. However, in the 1980s, growth slowed considerably. Notably, there has been a shift in population distribution from higher altitudes to lower valleys, reflecting an outmigration trend from mountain rural areas to industrial and service-oriented areas, resulting in decreased settlement in municipalities located above 500 m above sea level.

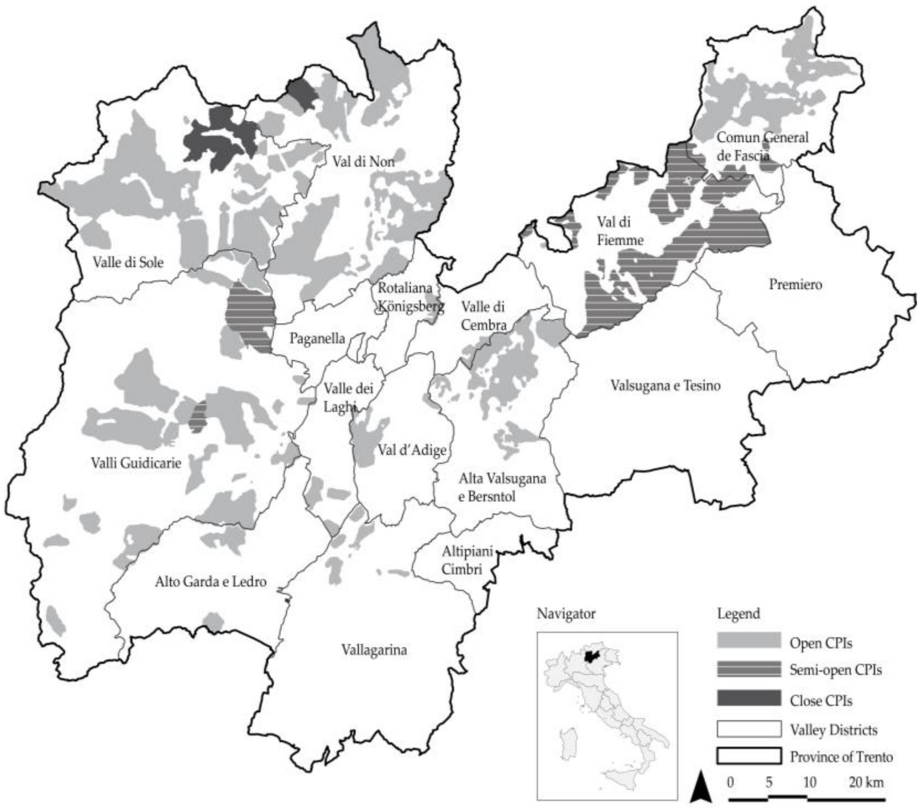

Figure 2. Location of the Province of Trento in Italy and map of the CPIs in Province of Trento according to the typology (adapted from [57]).

Projections at national level elaborated by the national institute of statistics (i.e., ISTAT) indicate a decrease of approximately 23% of the Italian population over the next 60 years [58]. Notably, this decline varies significantly between regions, with those in the South experiencing the most substantial decrease, while those in the North are either slightly decreasing or remaining stable. Figure 3 illustrates ISTAT's projections for the period of 2024–2080 for the population in the Province of Trento.

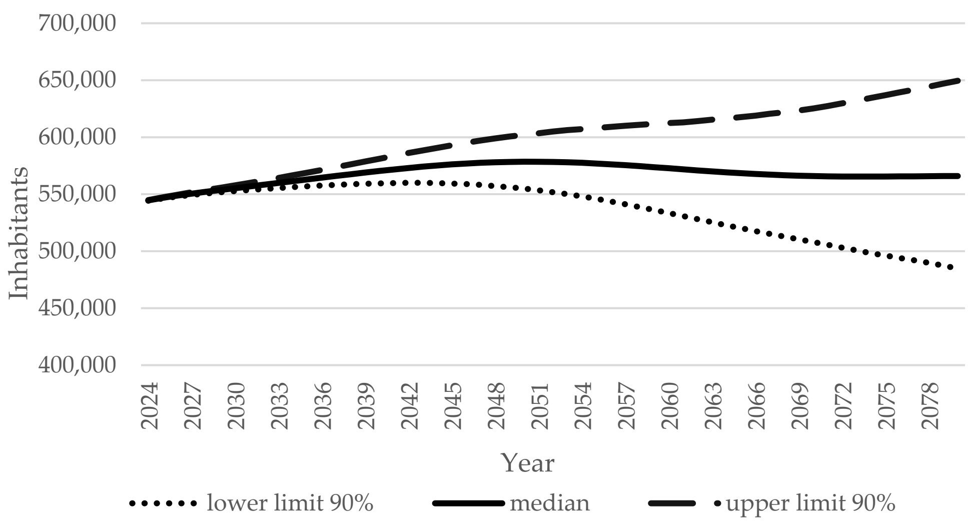

Figure 3. Demographic projections for 2022–2080 (considering median, upper, and lower values) for the Province of Trento (own elaboration on data from [58]).

Despite the relatively stable or slightly declining population of the Province of Trento, the anticipated 23% decrease in the overall Italian population necessitates consideration of the lower limit values as plausible, highlighting its significance for anticipatory governance.

Demographic trends are coupled with the shift of the economy of the Province of Trento towards services and knowledge economy, with an impact on the internal perception of commoners with respect to the role of historical commons and their long-term perspective. As Gretter et al. [60] analyzed, older generations and male population perceive a general loss of interest by community members in participating in the commons' activities, while female and youth participation in the decision-making processes of the commons is perceived as being hindered. These trends and changes together challenge the continuity of historical commons in the next decades.

2.3. Data

For the models, we used demographic data at the regional level and rules of admission to acquire rights in a CPI derived from CPI statutes. Demographic data for the period of 2003–2023 were derived from the projections produced by ISTAT [58] for the following variables:

- Mortality rate: units of deaths per 1000 individuals per year;
- Birth Rate: total number of alive births per 1000 individuals per year;
- Net migration rate: the difference between the number of immigrants and the number of emigrants divided by the population per 1000 individuals per year;
- Household size: the average number of members per household, calculated by dividing the total number of residents in the household by the number of households.

As shown in Figure 3, datasets include confidence intervals for the upper and lower limit values. We used this dataset at the scale of the Province of Trento to base our projections for the period of 2024–2080.

Information on the rules of admission to the commons was retrieved from the statutes of CPIs in the Province of Trento that are available online, as well as from expert knowledge and previous research [55–57,60] on the statutes. As our intention was to represent the variety of admission rules to historical commons, we used the criteria of variety in our search. In the statutes, one or more articles are dedicated to explaining the conditions to acquire rights in a CPI and who has the right to vote for the commons' assembly. As the formulations of these articles are in some cases very articulate and full of exceptions, we simplified and approximated them in the form of "conditions" to be simulated in the SD models, as illustrated in the next paragraph.

2.4. Developing the SD Models

SD models are developed based on the characterizing features of the three CPI types (i.e., open, semi-open, closed). These features are presented in Table 1. For each CPI type, we illustrate CPI Agents eligible to acquire rights (i.e., individuals or households), Waiting period (i.e., the period before obtaining the commoner rights), Target of admission rules, and Admission rule conditions.

We used the admission rules conditions and demographic variables to integrate the basic stock-flow population model (Figure 1) with specific parameters (Table 2) to simulate how different conditions characterizing CPI types influence the dynamics of community size.

The models are calibrated to represent the situation of a small municipality of 1000 inhabitants in the mountainous areas of the province of Trento, with the presence of a CPI managing the collective lands.

Table 1. Features of the types of CPI considered for the model simulation.

CPI Type	CPI Agents	Waiting Period	Target of Admission Rule	Admission Rule Conditions
Open	Individual	1–4 years	Individuals (new residents)	Once individuals acquire residency, they have to wait a certain period (e.g., 1 to 4 years) before obtaining the full benefits of common property.
		Maturity (legal age, 18 y)	Commoners' child	The children of commoners automatically join the community of commoners, with full rights, upon reaching the age of 18.
	Households	>4 years	Households (new residents)	Households (including one-person households) that acquire residency must wait a certain period before obtaining the commoner rights. The holder of the benefit is the head of the household.
		Maturity and forming household	Commoners' child	Children of commoners inherit the commoner status upon separating from the household to form a new household. If they marry, the new household is represented by a delegate.
Semi-open	Households	10–25 years	Households (new residents)	Families who move and wish to access the commons must register in the commoners list. After a defined waiting period, which begins at the time of registration, they can access the commons.
		Maturity and forming household	Commoners' child	Children of commoners inherit the commoner status upon separating from the household to form a new household. If they marry, the new household is represented by a delegate.
Close	Households	Maturity and forming household	Commoners' child	Children of commoners, upon separation from the household, inherit commoner status. If they marry, the newly formed household is represented by a delegate.

Table 2. Variables selected as specific parameters of the SD models and simulations.

Parameters	Definitions	Source
Waiting rule (influencing "admission" flow variable in Model 2)	Commoners-as-individuals after a waiting period: a resident becomes a commoner with a full bundle of rights after a determined period of continuous residency (ranging from 1 to 10 years). Waiting varies from 0 (i.e., no new residents enter into the commoners' community, as in the case of close CPIs) to 1 (i.e., all new residents become instantly commoners).	CPI statute
Maturity rule (influencing "maturity" flow variable in Model 2)	Commoners-as-individuals by inheritance: commoners acquire rights as individuals through inheritance from commoners' parents.	CPI statute

Table 2. *Cont.*

Parameters	Definitions	Source
Social capital (influencing "Com. emigrants" flow variable in Model 2)	Used to simulate the effect of social capital (the networks of relationships among people who live and work in a community) hindering the emigrations of commoners (it is set to 1 when emigration rate equals that of the province, 0 when no commoners emigrate)	Our hypotheses on demography statistics
Household disappearing rate (influencing "disappearing" flow variable in Model 3)	Used to simulate the possibility that a household may cease to exist, e.g., due to old age and natural death of its members. This variable is influenced by the average household size and the mortality of commoners.	Our hypotheses on demography statistics
Household founding rate (influencing "founding" flow variable in Model 3)	Used to simulate the possibility of a household splitting into two or more household units, with children forming their own household with the same rights as commoners. This variable is influenced by the variable "independence rate" (not present here but shown in the full model in the appendix), i.e., the percentage of children who become adults and form their own household (with autonomous residence).	Our hypotheses on demography statistics

To test the models, a variety of simulations were conducted, using different combinations of parameters:

- Base Median scenario: represents the population and commoners' community dynamics according to the median values for 2022–2080 demographic projections.
- Base Worst scenario: represents the decline of population and commoners' dynamics according to the highest values of death rate and migration rate and the lowest birth rate projections.
- Base Best scenario: represents the relatively stable population and commoners' dynamics according to the lowest death rate and migration rate and the highest birth rate projections.
- Waiting 1, 4, 10 years: represents the CPI in which individual commoners increase through maturity of their children and by the new commoners from local residents with a residency of 1, 4, or 10 years.
- Waiting 10, 25 years: represents the CPI in which commoners as households increase through formation of a new household and by the new households after 10 or 25 years of living in the municipality.
- Only inheritance: represents the CPI in which commoners increase only through the maturity of their children.
- Social capital: represents the community of commoners as above with reduced emigration of commoners (due to the effect of a significant presence of benefits linked to being commoner hindering emigration).

In Table S1, we simulated different scenarios by combining the parameters as well as the other demographic variables considered. For the numeric simulations, we used the web application Silico, as explained in the Supplementary Materials.

3. Results

The modeling process resulted in the design of three SD models that simulate the dynamics where demographics are coupled with admission rules to CPIs. In the following paragraphs, the functioning of the resulting SD models is illustrated in terms of stocks, flows, and feedback loops and then compared according to the emerging dynamics happening in the models over time.

3.1. Baseline Model

The baseline model or Model 1 (Figure 4) represents the typical demographic dynamics of a settlement, where births, determined by a birth rate, represent the in-flow variables in the stock of the population. Deaths, determined by a death rate, and emigrants, determined by a net migration rate, represent the out-flow variables from the stock of the population. In the model, there are three feedback loops, respectively, based on birth (reinforcing), death (balancing), and outmigration (balancing) rates.

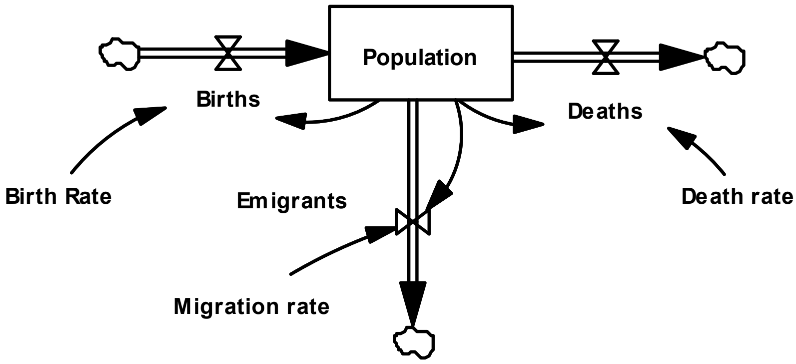

Figure 4. Model 1.

3.2. Commoners-as-Individual Model

In Model 2 (Figure 5), the commoners are the individual (new) residents in the settlement who, after a waiting period, are admitted to the commoners' assembly. This model includes two stocks: commoners-to-be (i.e., teens) and commoners, influenced by the same birth, death, and migration rates. The commoners-to-be reach maturity at a maturity rate and flow into the stock of commoners. In-flow variable from the Population stock to the Commoners stock is regulated by the admission flow variable.

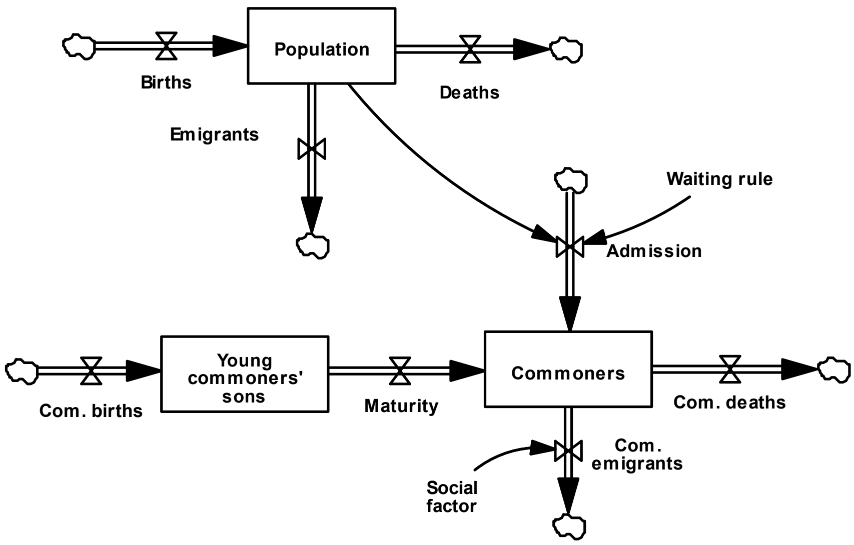

Figure 5. Model 2 (rate variables and feedback shown in Model 1 are omitted here).

3.3. Commoners-as-Household Model

Model 3 (Figure 6) is an extension of commoner-as-individual model, in which commoners-to-be and commoners contribute to found a new household. A new commoner-as-household is determined by maturity of the commoners' children, approximately influenced by the household size. A commoner-as-household may disappear due to death or migration of its members. When the number of deaths and emigrants is equal to the average size of the household, or multiples thereof, one or multiple commoners-as-household is considered to disappear. Model 3 has two variations, depending on whether the CPI is semi-close or close.

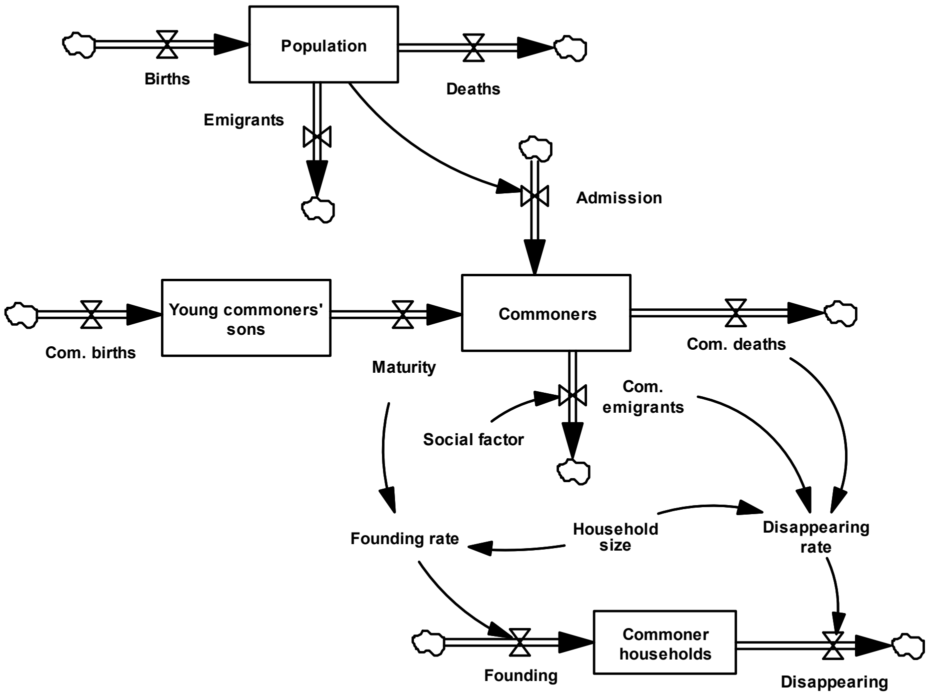

Figure 6. Model 3 (rate variables, feedbacks shown in Model 1 are omitted here).

Semi-close CPI: Commoners-as-household become such after a waiting period. In this variation, relocating households become commoners after a period of waiting after application to the commons (ranging from 10 to 25 years). In such a type of CPI, a percentage of the benefits are shared individually among the households, whether in the form of monetary compensations or subsidies. This makes us assume that there is a binding factor inhibiting emigration from the commoners' household members.

Close CPI: Commoners-as-household become as such by inheritance only, upon formation of the household. There is thus no in-flow from population stock. In close commons, revenues (both material and monetary) are directly distributed among commoners. Therefore, we assume that there is a binding factor due to economic benefits to the commoners, which inhibits emigration. The binding factor is a key variable, varying from one (i.e., no binding, where net-migration from commoners is set to be the same as for non-commoners) to zero (i.e., binding factor determines commoners' emigration to be zero).

3.4. Comparison of the SD Model Simulations

In the following paragraphs, we compare the community dynamics as a result of the demographic projections coupled with admission rules in the three SD models.

For the sake of brevity and to show the lowest extreme yet possible resulting dynamics, below we present only the resulting dynamics of the worst possible scenarios, except for the inheritance-only SD model (i.e., Model 3), for which we compare median, best, and worst possible dynamics.

Figure 7 shows the effect over the period from 2002 to 2080 of admission rules based on the different numbers of years that a new individual resident must wait before acquiring the status of commoner. In observing the figure on the left side, the following observations can be made. The longer the waiting (i.e., 25-year curve Vs. 1-year waiting curve), the slower the number of commoners reaches a convergence value. The waiting time can have long-term effects as the 25-year waiting rule perceptibly reduces the number of commoners between now and 2080.

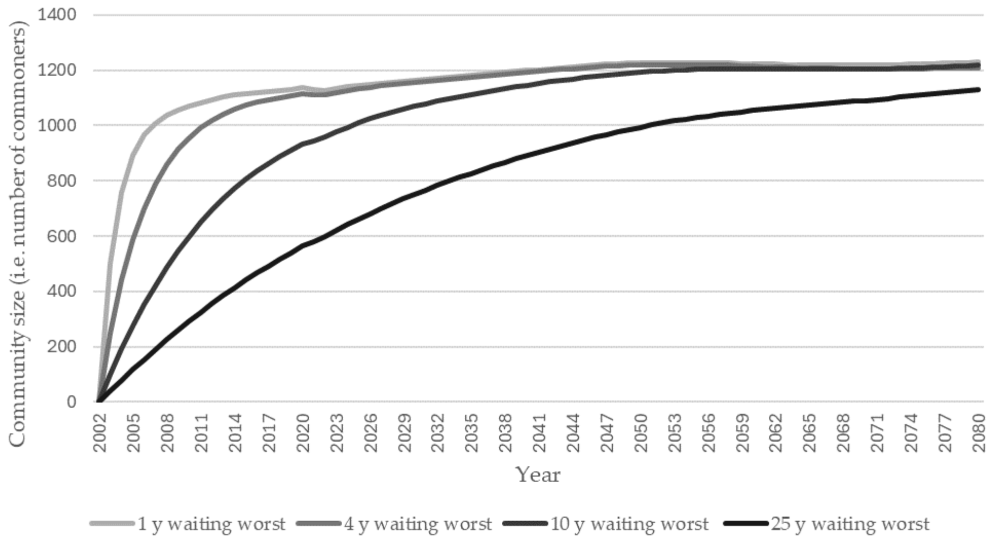

Figure 7. Compared effect of the 1-, 4-, 10-, 25-year waiting rule on the trend of the community size.

As shown in Figure 8, the effect of social capital (SC) on society in limiting the emigration of commoners (i.e., full SC and half SC curves Vs. no SC curve) seems negligible on the dynamics of the community size in the study area, but it could instead be significant in regions with higher emigration rates, typical of Southern Italy.

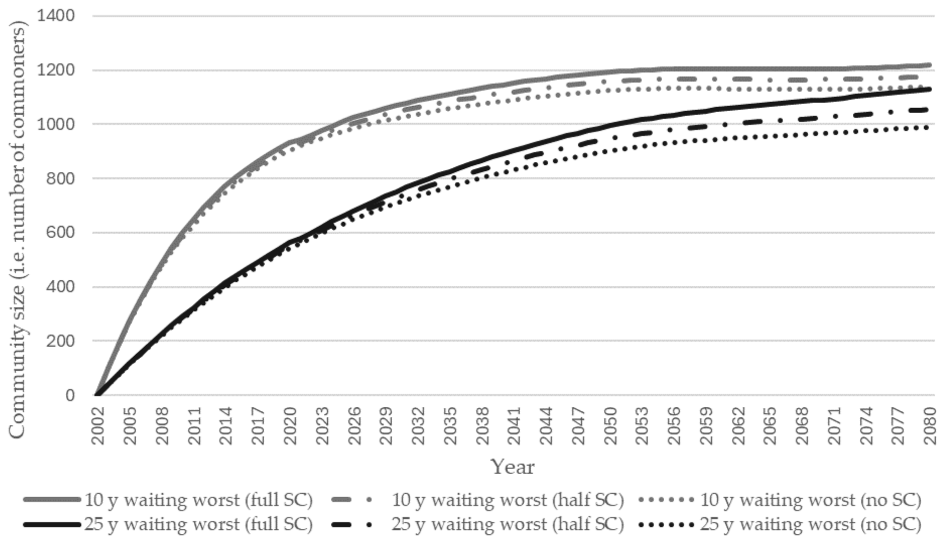

Figure 8. Compared effect of the combined influence of different degrees of social factor (full, half, no SC) and 10-, 25-year waiting rule on the trend of the community size.

Figure 9 shows the possible dynamics of a community of commoners-as-household CPI (with initial number of 1000 commoners, then about 442 households) under the three demographic scenarios with the combined effect of the binding factor and the "only inheritance" rule. The figure shows that with such a rule, commoners-as-household stock steadily declines unless there is a strong social capital.

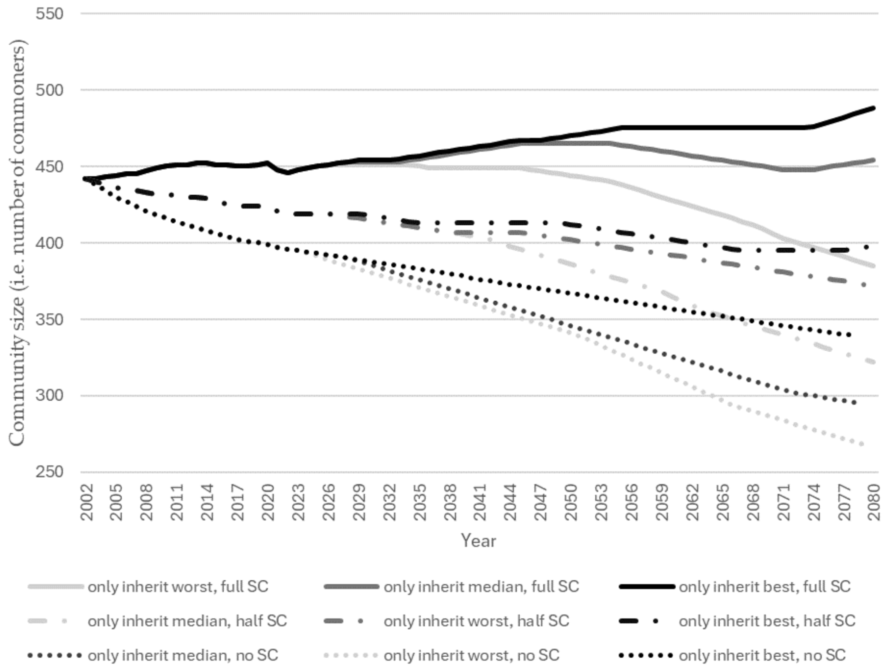

Figure 9. Combined effect of social capital and inheritance rule for best, worst, and median scenarios on the trend of the community size.

4. Discussion

The challenges facing historical commons have been widely documented, with many studies noting symptoms of dysfunction that threaten the social foundations of these important resource-governing institutions. A decline in the participation of commoners in managing lands and resources not only jeopardizes these institutions but also risks the loss of local ecological knowledge and practices vital for climate adaptation, ecosystem preservation [2,3,5], and the relational values that connect communities with their environment [22,61]. However, much of the existing research focuses on commoners' communities while overlooking broader demographic trends affecting the entire population within these contexts.

Our study aimed to bridge this gap by connecting the perspectives of commoners' communities with the demographic dynamics of mountain populations. Understanding these dynamics as well as the admission rules governing access to historical commons is essential for evaluating the future of these self-governance systems and the sustainable management of natural resources in mountain regions.

The methodology and SD models developed in this article offer valuable insights and raise new questions about the evolution of commoners' communities in small Alpine regions. These conceptual models provide a framework for understanding the potential impacts of demographic trends and admission policies on the future of commoners. Specifically, the simulation models explored the interplay between demographic scenarios, admission rules, and the binding influence of social capital within the community. The results are presented as patterns of change over time, focusing on the qualitative characteristics of these patterns rather than their specific numerical values. In the following, we discuss the strengths, limitations, and possible developments of the methodology and the implications of the resulting SD models.

4.1. Strengths of the Used Approach

The development of system dynamic models according to the agile modeling approach enabled us to make explicit and share with precision a variety of assumptions and individual mental models of the studied complex reality. To our knowledge, we consider the translation of admission rules into conditions and then equations for simulation models to be an original exercise. Using qualitative and social elements, i.e., the admission rules translated into conditions, together with quantitative variables, i.e., demographic data and projections, represents one of the main advantages of the SD approach [51]. Furthermore, in the iteration during the modeling phase, the resulting simulated dynamics were continuously compared with the expectations following the assumptions. This helped further model refinement. The practical benefits of building simulation models is the development of "boundary objects" [62] or "transactional tools" that operate at different levels [63]: the level of knowledge creation, as a calibration tool between the observer and the observed field, where the model is used to reproduce and simplify reality into a mental model; the level of group learning, where simulations are controlled and replicable experiments that help individuals to improve accuracy of their conversations and to support a collective learning; and the level of content as a thinking tool to understand and deal with the complexity of the long-term persistence of the CPI. A crucial aspect of this process is the concurrent development of both the diagrammatic representation and the working model providing simulations. This parallel evolution offers significant advantages. It enhances transparency and ease of understanding by explicitly showing the consequences in terms of patterns of dynamics emerging from specific assumptions and interdependencies.

The consideration of the mutual influences between demographic factors and admission rules helps to understand the complexity of the social and economic aspects that influence the common goods, at a level that is difficult to reach without the visual support of stock-flow models and simulation graphs [64]. Furthermore, the inclusion of different demographic scenarios (median, best, worst) in the simulations supports the understanding of the potential variability of demographic trends and their impact on the historical commons. This aligns with the need to consider multiple future trajectories, beyond the median or the most probable one, in line with the key principle of futures studies and strategic foresight [65].

The models and simulations rely on data for the Province of Trento, derived from the national institution of statistics and from current admission rules that characterize a variety of CPIs in the same province. However, the approach developed and illustrated in this article can be easily adapted to other contexts.

The study, by investigating causal feedback relationships, could support community-based decision-making about management that promote the well-functioning and conservation of the social-ecological system [39,66].

4.2. Are Commons Endangered?

The results of this study show that admission rules deeply influence the model dynamics. The decline in the number of commoners is accelerated by stricter admission rules ("Inheritance only" rule) or balanced by easier access for new individual residents and households ("Waiting period").

While it has been thoroughly argued that strict rules of admission enable the homogeneity, stability, trust, and communication in case of common pool resource at the local level [7,8,10,14,16], it has been also recognized that in case of a complex and multi-level common pool resource situation, such strict admission rules contribute to make the commons dysfunctional [27,37,42,60] because they hinder active participation in a commons. The results confirm the arguments by Brossette et al. [42] and Dietz et al. [17] about the need to review institutional rules as a "lever" to increase participation and provision in a commons. The literature suggests that opening the commons towards new members with different stakes and competences may foster collaboration at different scales, with other institutions, and with commons in other contexts [3,13,20,28,32,67,68]. We would like to discuss how this second argument holds true both in case of demographic increase and decrease intertwining with admission rules in a commons.

In the case of demographic decline, as exemplified in the study area, strict rules (e.g., "commoner-as-household with 25 years waiting rule" and "only inheritance") determine the gradual but steady reduction in the stock of commoners. As a consequence, we could assume that this leads to reducing the available skills and collective action abilities to contribute to the provision in a commons [34], thus undermining the potential role of commons to be agents of rural sustainable development.

In the case of demographic increase, strict admission rules create a greater difference between commoners and residents-non-commoners, possibly contributing to an increasing feeling of lack of external legitimacy towards commons institutions. Such difference could also determine situations of elite-capture and disparity within the whole stable community of the settlement that comprehends commoners and non-commoners, in the case where the community members whose families have lived for a long time have more rights than those that relocate. This disincentivizes the contribution of newcomers to the local development as they do not have decision-making rights nor provision duties. Furthermore, strict admission rules determine reproduction of gender roles and exclusion of female participation in decision-making processes [61]. This makes the commons dysfunctional in a situation where marginalized and small alpine communities need more and more the collaboration of motivated actors to contribute to face the challenges of a globalizing market economy with its fluctuations and of a changing climate [21].

4.3. Feasibility of Change in Rules

Among all possible policies, our study shows the relevance of the admission rule as a significant variable that increases the distance between population of non-commoners and commoners, together with social capital as a binding factor that may hinder emigration. Deciding on the policies to adopt to steer the dynamics in the desired direction is, however, a non-neutral and potentially conflictual operation. This is because the different policies belong to different worldviews and mental models of social and institutional actors at local and regional levels on how to strengthen the social engagement in historical commons [47]. Such worldviews and mental models encompass different spatial and temporal frames [48]. For instance, modifying admission rules can be perceived as a controversial process, although potentially easy to be achieved at the commons level in the short-medium term. Changing rules involves a formal transformation process, and easing the admission to the assembly of the commons may be perceived by the current commoners as exposing commons to the risk of losing the collective control over the system. Conversely, advocating for modernization elements and fostering leadership to counteract out-migration, while well-received by local communities, entails a prolonged process marked by hidden complexities. This is due to the necessity of relying on funding programs that surpass the influencing capacity of individual commons institutions. Consequently, despite being an explicit goal, it runs the risk of becoming an objective that remains on paper due to the challenges in acquiring the necessary funds for implementation.

Thus, the advocated solution is to combine different policies directed at increasing social capital by leveraging on the relational value [69] and entrepreneurial potential of commons and at designing admission rules that enable an inclusive and self-sustaining stock of commoners that actively participate in decision-making and provision activities in a commons. In a multi-objective multi-purpose collective action issue, diversity and redundancy [70] as well as polycentricity [36] are shown to benefit the commons in the long term.

4.4. Limitations of the Study and Future Perspectives

Our study has four main limitations. First, the results are intended as "qualitative" simulations of the plausible dynamics based on the feedback between key variables but not numerically validated or statistically tested for robustness. Second, the data available on the projections from 2022 to 2080 are taken at provincial level, whereas the commons are regimes at the settlement or municipal level, and thus data at sub-municipal scale are needed to approximate reality more precisely. Third, there is also a limitation in setting the initial value to the stock of commoners due to a dependency between the admission rule and the initial stock of commoners as the number of commoners depends on the access rule, and, with a certain delay, the established admission rule is established according to the stock of commoners that need to use the resource in order to preserve the resource quality over time. The fourth limitation relates to the use of applied systems dynamics to treat humans in a social-ecological systems whose relative weight and impact might be either over- or under-represented with respect to the weight of other elements that have not been considered in the model as they may have an impact in the reality that the models seek to represent. These limitations and simplifications of the study might affect the generalizability of our results.

For this reason, the future perspective of the study is linked to the opportunity of group model building [52] or participatory modeling processes [6,71,72] in which to engage and enable the affected communities and other stakeholders in understanding how each part of the interested system interacts and how they can contribute to system behavior. This approach to multiple possible futures could provide local communities and stakeholders with tools for anticipation literacy and anticipatory governance that promote adaptive institutions, decision-making, strategy formation, and social resilience [65,73].

From the ethical point of view, discussing the change of institutional rules as suggested by Brossette et al. [42] requires the involvement of the affected communities because rules are a product of people's interpretation of their collective experience. Thus, any process of change needs the acceptance of the affected to be embedded in the context. Such a process of involvement requires specific attention about the power relations in place in order not to reproduce exclusive power dynamics [29,61,69]. The use of such a methodology and tool with the affected communities thus needs to be refined to enable processes that are inclusive and enabling.

5. Conclusions

Our paper aimed to reply to the question: what are the implications of demographic trends coupled with admission rules on the persistence of historical commons? This article showed that admission rules fitting demography and new resource dependencies are key for commons persistence in the role of self-governance of lands and resources. This article contributed to showing that admission rules are relevant factors in light of the persistence of historical commons. Our study showed that in a situation of negative demographic trends, the stricter the access rules, the fewer the people are in the position of contributing to the common resource management. Furthermore, our study showed that the stricter the admission rules to a commons, the greater the difference between commoners and the rest of residents in a settlement.

The results were discussed placing the issue in the broader context of commons in the changing socioeconomic situation of the world mountains, and especially in the European Alps.

Resources are increasingly competed for not at the local scale, but at multiple scales. Considering the fact that local communities have played a role in stewarding the resources for centuries and are willing to continue doing so—but considering also that the nature of the resource dependency is changing—collective resources are increasingly acquiring a public good characteristic while also playing a collective good characteristic in that they concur to maintain the bonds of the local community to the resource. Lands and resources governed in commons regimes are thus more and more competed for. Such lands and resources are governed in a situation of polycentric governance. Admission rules in a commons thus play a role in who has access to decision-making in such a governance constellation.

It should be further problematized whether strict admission rules to commons governance in a situation of polycentric governance and competing powers over resources are the best strategy to guarantee that the community interest as well as the integrity of resources and lands are well cared for. It should also be investigated whether innovations in community-based resource governance are needed to better consider newly emerging community interests are considered, to care for sustainability and integrity of the resource, and to enable that community-based resource governance contributes to tackle social, economic, and environmental challenges that world mountains are facing. These are questions to be tackled in future studies.

The systemic modeling approach allowed to ask questions among co-authors while modeling in an iterative process of successive approximations (an abductive process typical of transdisciplinary research and critical systems thinking) to avoid a colonial approach to the sensitive issue of intervening in the relationship between a community and the resource it has long cared for.

Further developments could include using this approach in participatory modeling to start the process of making explicit the different stakes mentioned before: that of the community members towards access to collective resources, that of the resource integrity, and that of commons contribution to tackle mountain challenges.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/land13101704/s1, Table S1: Simulations (in row) of the SD models based on parameters (in column). The complete models and the data used are freely accessible, interactively, on the Silico app, via this link: https://silico.app/@rocco_scolozzi/commoners00-80?s=c38lpSBIQgWFBgTm31L53w, accessed on 9 October 2024.

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