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Adapting Governance Incentives to Avoid Common Pool Resource Underuse: The Case of Swiss Summer Pastures

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Abstract: The use of summer pastures in the European Alps provides much evidence against Hardin's prediction of the tragedy of the commons. For centuries, farmers have kept summer pastures in communal tenure and avoided its overuse with self-designed regulations. During the past decades, however, summer pastures have become less intensely used, which has reduced its agronomic value and the by-production of public goods. However, very little is known about how the various governance incentives affect farmers' use of summer pasture to result in below-sustainable activity. In this study, we develop an empirically informed game theoretical model of farmers' land use decisions, which we validate with survey data from a case study in Switzerland. Our results reveal that farmers weigh the benefit of resource use against the costs of maintaining it and that all major sectoral developments, such as increasing livestock endowment, increasing opportunity costs, and decreasing land use intensity on private plots, result in the reduced use of summer pastures. Based on these insights, we suggest adapting the incentive structure at the local and federal governance levels to increase incentives for stocking at the margin. Our study shows how game theory combines with field validation to identify the contextual behavioral drivers in common pool resource dilemmas for informed and improved policy making.

Keywords: agricultural policies; appropriation; common pool resources; provision; summer pasture; underuse

1. Introduction

Common pool resource (CPR) management problems are generally associated with overuse, resulting in commons tragedies, such as depletion or pollution of the resource [1]. In this case, mismanagement is characterized by over-appropriation; that is, excessive extraction levels do not allow the resource to regenerate. As many CPRs are not purely natural, but embedded in human-made or enhanced resource systems, infrastructural investments are often required for the system to function sustainably. Therefore, a second problem that relates to CPR systems is under-provision, which means that investment levels toward improving the state of the resources are too low. Jointly, these two factors make CPR use unsustainable [2–4].

Another, less well-known problem associated with CPRs is underuse. In this case, appropriation and provision activities both drop to levels which have potentially negative effects on ecosystem services or infrastructure, also resulting in a decline of resource availability. In contrast to overuse, underuse of CPRs is rarely addressed in a scientific context, possibly because temporary underuse when following spells of overuse is widely considered to be resulting in the regeneration of the resource towards its natural state, which might be seen as desirable. However, the reduced use or abandonment of certain resources—if becoming their new state—may not be desirable in the long run [5,6]. For example, alpine countries in Europe subsidize the use of mountainous pastures, which are often common property, to prevent abandonment, maintain an open landscape, and ensure the provision of ecosystem services [7–9]. Similarly, government efforts are made in Japan to prevent the underuse of rural areas and communal semi-natural grasslands in particular [5,6,10]. Although it is highly context-dependent whether CPR underuse is considered problematic, research should address this topic to better understand the dynamics that lead to CPR underuse.

An example of where a CPR is currently in transition towards underuse and of societal concern are summer pastures in Europe [7,11,12]. For centuries, local government systems have successfully designed and enforced rules preventing overgrazing, organizing the provision of grazing grounds, and providing the necessary infrastructure for animal husbandry [13–16]. Consequently, new landscapes and habitats have been created in the form of summer pastures, which, on the one hand, provided direct economic benefits for livestock farmers, and, on the other hand, co-produced a variety of highly valued ecological services for society, including increased biodiversity [17,18], and protection from soil-erosion, water run-off, and natural hazards [19]. Furthermore, summer pastures produced cultural services fostering recreational activities [20] and identification with the landscape [21,22]. On the other hand, studies showed that preferences for landscape are highly diverse, and that many prefer wilderness and afforested landscapes over cultivated pastoral areas. In addition, it is highly questionable from an economic efficiency viewpoint whether economic activities that would not be feasible otherwise, should be subsidized—unless it is for the provision of public goods.

During the past decades, however, new challenges for summer pastures governance have emerged in the form of abandonment [7,23,24] and reduced stocking [12], which have become widespread phenomena across the European Alps, but also elsewhere in Europe [25] and Japan [10,26]. Consequently, undesired landscape changes with large-scale afforestation can be observed [24,27,28], resulting in a loss of productive agricultural land [11], reduced biodiversity [29], and reduced landscape diversity [24]. Thus, Alpine summer pastures provide a modern example of the problem of commons underuse, often associated with the past [30,31] or with anti-commons [32,33].

Common property pastures (CPP) are the dominant property management model for summer pastures in the European Alps [16,34,35]. In Switzerland, for example, approximately 80% of summer pastures are collectively owned [8]. Like most other humanly enhanced common-pool resource systems (CPRSs), sustainable communal grazing not only requires the restriction of resource appropriation, but also relies on provision activities to sustain the resource [3,4]. Provision hereby refers to activities such as the cleaning of grazing areas of shrubs and stones, or the installation and maintenance of the respective infrastructure, such as fences or drinking troughs. While some man-enhanced CPRs such as grazing or irrigation systems ultimately depend on provision efforts, other natural types of CPRs, such as fisheries, may not require provision activities to foster sustainability.

Nevertheless, appropriation and provision are social dilemma situations, as the self-interest of individuals is to maximize appropriation and minimize provision, and thus to freeride on others [36]. Empirical and theoretical studies highlight that the successful governance of local commons typically relies on institutional arrangements that establish a congruence between appropriation and provision activities by enforcing a linkage of the two [4,37,38]: balancing costs and benefits, individual users trade off expected benefits from more intense appropriation against higher costs of provision which more intense appropriation institutionally incurs. As a result, users may reduce appropriation to avoid provision costs.

Appropriation and provision decisions are usually strategically linked through institutions. The first model connecting appropriation and provision in the context of grazing commons was formed by de Janvry and McCarthy [39], and shows that the quality of provision depends on the quality of appropriation and vice versa. More recently, experimental work has also begun to study the two situations in conjunction, and current evidence suggests that (i) the provision problem can be more efficiently solved than the appropriation problem [2,40,41]; and that (ii) asymmetries tend to be exploited by users increasing their appropriation levels, but also tend to be compensated through higher provision investments [42–44]. These theoretical and experimental investigations of the joint appropriation-provision decision have focused on the issue of joint over-appropriation and under-provision.

In this study, by contrast, we consider the scenario of joint under-appropriation and under-provision. In order to study these two decisions conjointly, an interactive (hence, game-theoretic) framework is in order. By defining such a model, in particular, we aim to identify the behavioral determinants and the role of governance incentives that cause CPR underuse. We shall focus on the Swiss case and argue that the local governance institutions that are in place today were designed to avoid the original problem of overuse. The complex incentive structure that has resulted from such local government regimes, and from federal agricultural policies, no longer provides the right policy mix to address the current problem of underuse.

Our analysis consists of three steps. First, we formulate a game-theoretic model. The model is parametrized to represent farmers' decisions in the context of the use of summer pastures by farmers in Grindelwald, Switzerland. We solve for equilibrium of the model and obtain comparative statics predictions. Second, we test these predictions against empirical data from the same region. Third, based on our findings regarding which factors would theoretically and empirically mitigate under-appropriation and under-usage, we formulate policy alternatives for local and federal governance in our example, which we discuss more generally in our conclusion.

2. Governance of Common Property Pastures

2.1. Federal Subsidies to Avoid Underuse

To ensure the continuous use of summer pastures, the federal government of Switzerland started paying "summering payments" in the 1980s. These premiums are paid to summer farms or cooperative organizations for meeting an externally defined stocking target and must be reinvested to make infrastructural improvements [45]. The stocking target expresses the maximum sustainable yield (MSY) as defined by local (cantonal) authorities. The sum of the premiums reflects the stocking target if actual stocking remains within 75% and 110% of MSY. If stocking falls out of range, payments are reduced, more substantially so for exceeding, less so for falling short: over-appropriation in the range of 110–115% leads to a payment reduction of 25%, and everything above 115% results in payments being completely withheld. If stocking falls short, payments are reduced only after reaching a 75% threshold; in this case, payments are based on actual stocking rather than the target [9,46]. Over the past years, these payments have gradually increased to a level of 400 CHF per summered livestock unit (SLU).

Despite a continuous increase in summering payments since the 1980s, these payments alone have not provided sufficient incentives to prevent a substantial decline of summering activities, which exceeded 10% between the years 2000 and 2013 alone (see Figure 1a). Therefore, the federal government introduced an additional subsidy in 2014. This "appropriation contribution" is a subsidy of 370 CHF/SLU paid directly to the livestock owner to incentivize appropriation [45]. Together, the two subsidies amounted to over 233 Mio. CHF in 2014 (Figure 1a). Since 2014, the number of summered animals has increased by 9% (see Figure 1a).

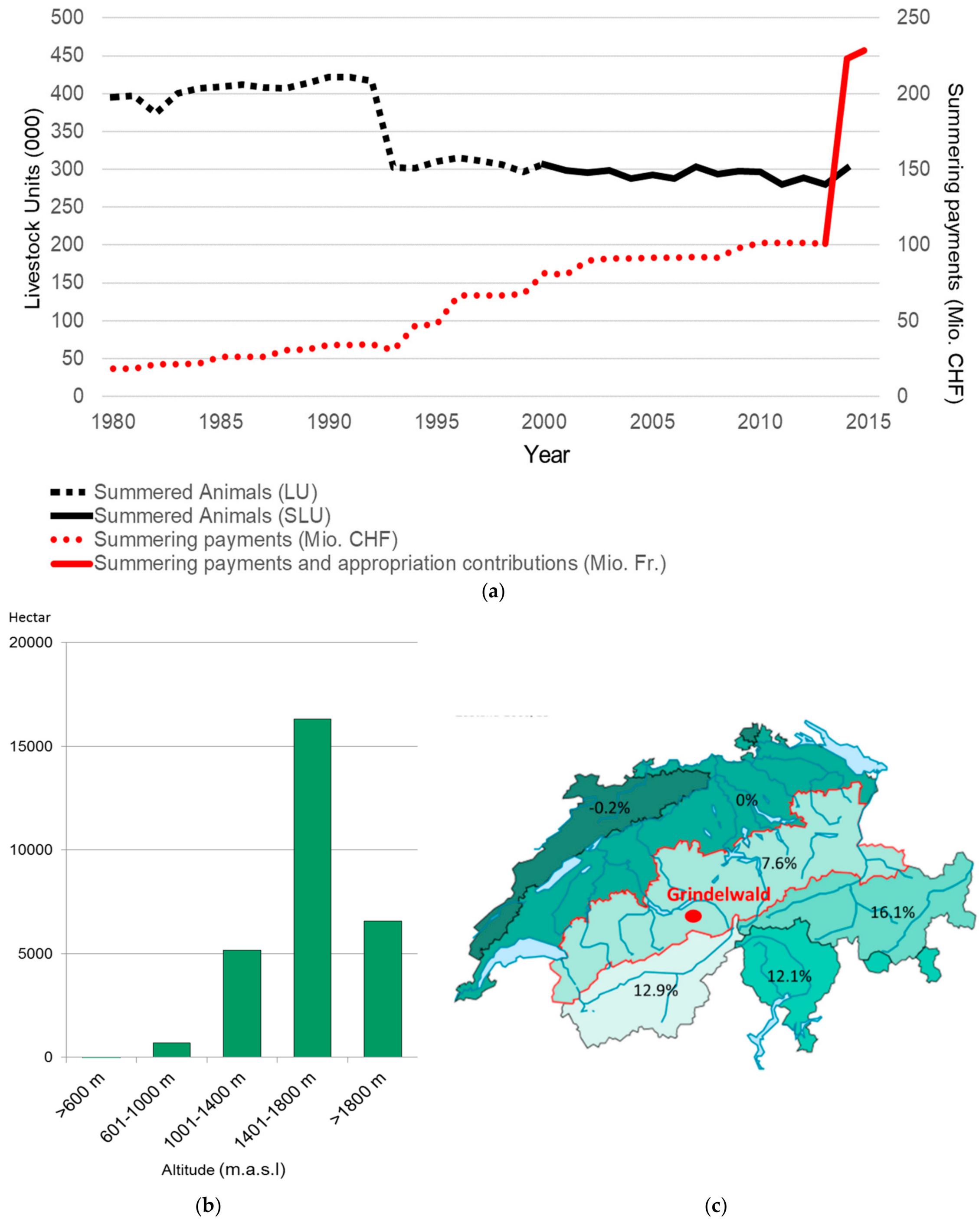

Figure 1. (**a**): Decreasing appropriation levels despite increasing expenditures on subsidies targeting the use of summer pastures in Switzerland (data from 1980–2002 provided by Felix Herzog [8], data from 2003 onwards based on official statistics available from the Federal Office for Agriculture [45]). (**b**): Topographical distribution of afforestation, suggesting that most of the afforestation is due to land use change occurring below the timber line (below 1800 m.a.s.l.), while only a minor share of forest regrowth may be associated with the rising tree line, as indicated by the category >1800 m.a.s.l [47]. (**c**): Afforestation ratios from 93/95-09/13 in different regions of Switzerland with a significant increase in mountainous regions [47].

Despite increased subsidy payments aimed at supporting grazing and open landscapes in mountainous regions, there has been forest regrowth of between 8% and 16% in the past 20 years (see Figure 1b). As displayed in Figure 1c, most of the forest regrowth has taken place in an altitude between 1400–1800 m above sea level, which is where summer pastures are typically located (Figure 1c). These land cover changes indicate that Switzerland faces major challenges to avoid the underuse of CPPs [8] and to maintain the diverse set of ecosystem services associated with sustainably used summer pastures [48].

2.2. Local Governance Institutions to Regulate Appropriation and Provision

Historically, summer pasture management in Switzerland has served as one of the most-cited examples for successful resource governance preventing overuse [13,14,49]. A key function of local self-governance is to assign rights of use that define who is to access the resource, as well as to limit the appropriation activities of eligible users. In return for their rights to benefit from the resource, individuals are expected to contribute to the maintenance of the pastures and the respective infrastructure through provision activities which are typically conditional on the appropriation level or the actual amount of use rights held [50,51]. As shown in Figure 2a, some institutional policies link provision obligations with appropriation levels in a linear manner.

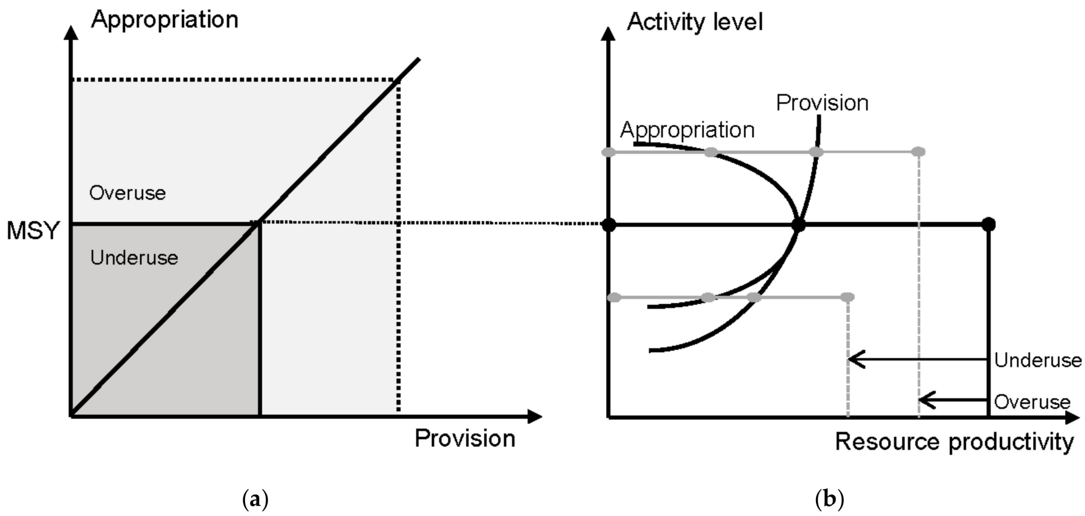

Figure 2. Stylized example of a CPR institution linking appropriation to provision activities in a linear manner (**a**), and its effects on resource system productivity above and below the maximum sustainable yield (**b**).

Accordingly, the system can be considered to be at its optimum when net appropriation equals MSY. This level of activity not only results in the highest possible resource productivity in terms of yields (milk or cheese produced) per appropriated unit, but very likely also co-produces the highest level of public goods possible. In Figure 2b, the hump-shaped appropriation curve shows that activity above and below MSY reduces grazeable biomass production and species diversity. The adverse effects from over-appropriation are caused by increased weed growth or reduced grass growth, while the adverse effects from under-appropriation result from shrub encroachment, and also reduced grass growth. Here, our model contrasts with general models of CPR use, which suggest that every appropriated unit imposes a negative externality on the joint user. In our model, however, any deviation from MSY—in either direction—results in negative externalities as productivity is reducing. On the other hand, every additional provision activity unit—although with diminishing marginal utility—improves pasture quality or infrastructure. Provision activities such as weed control, manure distribution, and cleaning of shrubs and stones have a positive impact on biodiversity and/or biomass production, while the installation of fences and drinking troughs or the renovation of storage huts and barns improves the available infrastructure.

As indicated in Figure 2b, however, the linear link between appropriation and provision is more suited to preventing overuse than underuse: As appropriation moves upwards away from MSY, the degenerative effects of over-appropriation (e.g., weeds and reduced biomass for feedstock) can be partially mitigated through the increase in provision (e.g., through the additional labor available for the distribution of dung or weed control). On the other hand, when appropriation drops below MSY, the negative effects from reduced grazing (e.g., shrub encroachment) are accompanied by negative effects of reduced provision (e.g., reduced labor availability for cleaning encroaching areas or for maintaining infrastructure), which further reinforce the overall negative impact of under-appropriation.

In the study region, the actual provision obligations for an appropriated unit (the slope in Figure 2a) are defined by the corporation. There are seven corporations in Grindelwald which function as operational units. Six of the seven corporations require eight hours of communal work per SLU, while one corporation specifies ten hours per SLU. Similarly, corporations set a fine for provision defection, which ranges between 24–30 CHF/h. Furthermore, there is a variation in the size and productivity of the resource system across the different corporations, as reflected by the differences in the maximum sustainable yield, which ranges from 74 to 256 SLU.

3. Methods

3.1. Model Development

We abstracted from the case of Grindelwald and built a game theoretical model for the appropriation and provision decisions of farmers using CPP. The model includes parameters describing farmers' attributes, federal subsidies, and local institutions. Accordingly, the model reflects the incentive structure so that individuals' appropriation and provision decisions lead to payoffs that mirror the actual setting in the study area. We thus included the two federal government subsidies in our payoff equations (as described in Section 2.1), and linked appropriation and provision decisions through the existing appropriation-provision institution, including the respective fines for provision defections (as described in Section 2.2).

We assume farmers play a subgame-perfect Nash equilibrium of the resulting interaction and derive predictions regarding individual appropriation and provision decisions based on an analysis of the equilibrium's comparative statics, i.e., we evaluated whether higher/lower appropriation and provision levels would result from marginal changes in the relevant game parameters, including individual characteristics such as farm income, local institutional parameters, and federal subsidies. Modeling the relevant interaction "close-to-reality" and thus linking the appropriation and provision decisions is the key novelty of our formal analysis. In particular, we modelled the appropriation and provision decisions as a two-stage game. Firstly, farmers individually decide on appropriation. Determined by local institutions, individual and total appropriation decisions result in a system of subsidies and financial penalties, including provision obligations that depend on individual appropriation decisions. Secondly, farmers decide how much to provide and how much to abate by paying fines. Our game-theoretic analysis will solve the subgame-perfect Nash equilibria of this game.

3.2. Model Testing

3.2.1. Data

Our predictions resulting from the game theoretical model form our testable hypothesis. To test our hypothesis, we relied on data for the study region of Grindelwald, Switzerland, from the year 2011. The sample included 95 (76%) of the 125 local farmers. The questionnaire included information about the individual farmer with regards to demographic and economic composition of the farm household, their land-use decision of private and common property, and their income situations. Part of this data has already been used for previous analysis [52]. As farmers in Grindelwald are divided into seven corporations, each with a certain autonomy in rule design, individuals are organized into groups (corporations), with local governance parameters varying across groups.

3.2.2. Statistical Procedure

We tested our predictions with regression models. For both appropriation and provision, we estimated two models each: a simple regression model including solely parameters describing the individual, and a mixed effects model to account for variation in local governance parameters and other group-specific effects.

Appropriation was measured as the ratio of animals a farmer sent to graze the CPP to his total livestock; we therefore performed OLS for the individual-level model, and logit estimates for the group-level model. We only included those farmers receiving support through direct payments, which are conditional on farm size and farmer's age (<65 years), which was a total of 85 cases. A particular feature of our statistical analysis is that some of our key theory predictions concern peer effects with respect to others' appropriation decisions, the estimation of which brings with it potential identification problems [53], which we attempt to mitigate.

For the provision models, we proceeded in a similar manner, estimating multilevel models. Since provision was measured on an ordinal scale ranging from one to five, we performed ordered logistic regressions for the individual-level models, and mixed effects ordered logistic regressions for the group-level model. As one farmer considered in the appropriation model did not appropriate at all, they were exempted from provision duties, leaving a total of 85 individuals to be considered in the provision model.

Again, we tested for social effects, i.e., for how farmers' behavior affects others. At the individual level, both appropriation and provision are decisions that are being made while observing others making the same decisions, and these individual decisions are likely to influence each other. In fact, theory will generate predictions regarding these effects. However, the inclusion of appropriation and provision decisions on both sides of the regression formulae has the potential to cause reflection problems, and the social effects that we are after may therefore turn out to be unidentifiable [53]. We have taken several steps to mitigate this problem given the strategic nature of our application. First, the appropriation decisions temporarily precede the provision decisions, hence appropriation can be included amongst the explanatory variables without reflection problems in the regressions related to provision. Conversely, provision cannot be included in the explanatory variables in appropriation regressions. Second, as regards reflection within the appropriation decisions and within the provision decisions, we separate the analyses of individuals who hold official local governance roles ('leaders') from others ('non-leaders'), assuming that non-leaders are influenced by leaders, but not vice versa.

4. The Formal Model

4.1. The Payoff Function for Summer Pasture Use

Decision-makers and decisions: Society consists of a population N of n farmers N = [1,2, ..., n]. Farmers $i \in N$ are characterized by different livestock endowments $W_i > 0$ and by heterogeneous opportunity costs O_i that determine their non-farm incomes. Each farmer's income can be divided into a component based on the use of the CPR and a component that is purely private. The latter component is independent of decisions made by others. The former component is an interactive decision, and his commons-related income is a function of the farmer's appropriation-provision decision and decisions made by others. Based on this, farmer i's appropriation decision is to appropriate between zero LU and all his LU, $a_i \in 0, 1, \ldots, W_i$, and the total appropriation of all farmers is $a = \sum_{i \in N} a_i \in [0, \sum_{i \in N} W_i]$. Similarly, farmer i's provision decision is to spend between none to all of his time (normalized to one), that is, $p_i \in [0, 1]$, on provision activities, and $p = \sum_{i \in N} p_i \in [0, n]$ is the total provision activity by all farmers. For the total of others' decisions, we write $a_{-i} = a - a_i$, and $p_{-i} = p - p_i$, respectively.

Payoffs and costs: A farmer's overall utility depends on a two-component structure as defined by payoffs from their appropriation decisions minus the costs of associated provision obligations. The payoff side consists of three sub-components: The first sub-component is the non-appropriation farming payoff. This income increases with the number of cows not appropriated to the commons and with the proportion of non-provision farming activity, as expressed by $(1 - p_i) * (W_i - a_i)$. Importantly, this part does not depend on decisions made by others.

The second payoff subcomponent is the payoff from appropriation subsidies. As mentioned before, there are two subsidies: one that farmers receive directly for their appropriation (sub_1) and one that is related to the total appropriation and relative to the optimum (sub_2). This is illustrated as follows: $a_i * a * sub_1 + \left(a_i * MSY_c - (MSY_c - a)^2\right) * sub_2$. Note that the part of the expression leading to sub_2 contains a squared component, $(MSY_c - a)^2$, which negatively affects the individual's payoff as total appropriation deviates from the optimum. It should also be noted that both subcomponents, for sub_1 and for sub_2, depend on appropriation decisions by farmers themselves, as well as on the decisions of others.

Finally, the third payoff subcomponent is the appropriation farming payoff, which increases with farmers' appropriation, with provision, and with the quality of the resource (relative to the optimum, depending on total provision)—hence, the formula $(a_i * MSY_c - (MSY_c - a)^2 + a_i * p)$.

In addition to payoffs, we also model the costs incurred by farmers' appropriation and provision decisions. Accordingly, costs have two sub-components:

First, the costs that result from non-fulfillment of provision obligations (as a function of a farmer's individual appropriation and the respective institutional requirements) denoted by $((a_i * inst_c - p_i) * F_c)$. Under the provision regime currently in place, each unit of appropriation incurs a fixed hourly provision obligation, which must be fulfilled or abated by a monetary fee. The following formula summarizes this institution: $inst_c : p_i = af_i * c$.

Secondly, we include opportunity cost, i.e., foregone income which increases with time spent on provision activities. We can think of this cost as representing the income that a farmer would receive in theory from non-farming activities, to which he allocates less time as a result of his provision activities. We use the formula $O_i * p_i^2$ to capture this cost, including a squared term on the provision activity to account for the increasing nature of the foregone income (spending one hour less on non-provision activities may not have a very large marginal effect, but spending almost all available time on provision activities will have a very significant effect on the margin).

Finally, we can combine our list of payoff components (payoffs P1–P3) and cost components (costs C1 and C2) to arrive at the following payoff function:

$$\begin{aligned} u_i = \Big[&(1 - p_i) * (W_i - a_i) + a_i * a * sub_1 + \left(a_i * MSY_c - (MSY_c - a)^2\right) * sub_2 \\ &+ (a_i * MSY_c - (MSY_c - a)^2 + a_i * p)\Big] - \left[O_i * p_i^2 + ((a_i * inst_c - p_i) * F_c)\right] \end{aligned} \tag{1}$$

4.2. Optimal Decision Making

By the nature of the game played by farmers, the timing of the game is such that the farmer first decides on appropriation, and then on provision. First, farmers collectively move their livestock up to the summer pastures at the beginning of summer. Second, each farmer has a designated quota of hours he is meant to work on the pasture (or pay for if he falls short) that depends on the number of cows he moved up. Given the natural sequence of the two, we can deduce the optimal decisions using backward induction: given appropriation, we first solve for the optimal provision decision, and then evaluate the optimal appropriation. This way, we assume play of the subgame perfect Nash equilibrium of the appropriation-provision game we have specified.

Step 1. Optimal provision, given appropriation. Taking first-order conditions yields optimal provision, given appropriation, identified by:

$$p_i^* = \frac{F_c - W_i + 2 * a_i}{2 * O_i} \tag{2}$$

Note that the expression governing the optimal provision decision derived this way depends on the fine, on various idiosyncratic parameters, and on the appropriation decision. The following comparative statics predictions can be made from the analysis of p_i^*:

(a) F_c: A higher fine increases the incentive to fulfill provision activities. Hence, we expect that higher fines positively impact provision fulfillment.
(b) W_i: Larger livestock endowment leads to more workload in the valley and thus reduces the time available for provision. We thus expect a negative effect of livestock endowment on provision fulfillment.
(c) a_i: Greater individual appropriation increases income, and thus the willingness to perform provision activities to further increase payoffs. We expect a positive effect of the individual's appropriation on provision.
(d) O_i: A better alternative income option means that paying a fine for provision defections is relatively cheaper, hence we expect a negative effect of opportunity costs on provision.

Step 2: Optimal appropriation. Predicting individual optimal provision, optimal appropriation can then be shown as follows:

$$a_i^* = \frac{-1 - \frac{W_i}{O_i} - a_{-i} * sub_1 + 3 * MSY_c * (sub_2 + 1) - F_c * inst_c + \frac{F_c}{O_i} - 2 * a_{-i} * (sub_2 + 1) + p_{-i}}{2 * \left(1 + sub_2 - sub_1 - \frac{1}{O_i}\right)} \tag{3}$$

Inspection of this formula yields the following comparative statics predictions:

(e) $inst_c$: Increased provision obligations lead to higher provision duties per appropriated unit, hence appropriation is strategically decreased to avoid these duties: negative relationship between provision obligations and appropriation levels.
(f) F_c: Higher monetary fine leads to higher costs for defecting on provision duties, hence those with high alternative options (if O_i high) will avoid these additional costs by lowering appropriation levels, while those with low alternative options (if O_i low) will fulfill their provision duties and appropriate at the same or higher levels: Hence we expect a negative effect for individuals with high O_i, and a positive effect for individuals with low O_i.
(g) a_{-i}: Larger group appropriation improves productivity (for the case of under-appropriation), hence less incentive to mitigate negative effects by oneself. We thus expect a negative relationship between joint users and individuals' appropriation.
(h) MSY_c: The better the resource, the higher the incentive to use it, and the higher the cost of falling short of the optimum. Hence, we expect a positive effect of resource capacity on appropriation.
(i) sub_1: Increasing this subsidy—similar to the effect of a higher resource quality—makes appropriation more attractive: Hence we expect a positive effect on appropriation (denominator effect, dominating numerator effect).
(j) sub_2: Increasing this subsidy makes appropriation and resource quality improvements more attractive. Hence, there is more incentive to appropriate (in case of under-appropriation). Hence, we expect a positive effect on appropriation unless the quality of the resource is very low, in which case the adverse incentive of reducing appropriation in order to reduce individual farmers' provision duty is stronger.
(k) p_{-i}: Higher provision by others increases the yield from the resource, and makes appropriation more attractive: positive effect.

(l) W_i: Owning more livestock makes the non-provision time spent down in the lowlands more valuable, so that provision becomes costlier. Effectively, farming down in the valley becomes the most attractive option. Accordingly, we expect a negative effect of endowment on appropriation.

(m) O_i: Better off-farm income alternatives reduce appropriation for farmers owning few cows, while they increase appropriation for farmers owning many cows. A farmer who owns a large number of livestock with good alternative options chooses to appropriate, expecting to not do his provision work, in order not to have to deal with his farming duties at all: positive effect for farmers owning much livestock, negative effect for farmers owning few livestock.

5. Model Validation

5.1. Descriptive Statistics

Farmers send most of their livestock to the CPP. With seven of the 95 farmers not using CPP, 87% of the local livestock in the valley is still appropriated. Regarding provision duties, very few farmers defect on their obligations. Provision activities are measured on a five-level ordinal scale, with farmers indicating if they (1) did not fulfill their provision duties or much less so than required; (2) a little less than required; (3) to the required degree; (4) a little more than required; or (5) much more than required. The seven farmers not appropriating at all were exempted from provision obligations, and another seven farmers stated that they were not fulfilling all their obligations. The majority of farmers therefore fulfilled their provision duties, and 57% even stated that they carried out more provision activities than required. Considering endowment, farmers owned 11.6 livestock units (LU) on average and earned more than twice as much per hour working off-farm than on-farm (Table 1). Regarding local governance parameters, the seven corporations govern different sized resource systems, as reflected by variances of the MSY, which ranges from 74 to 256 LU. Local governance parameters such as provision rules are set at 8 h per livestock unit among most corporations, with one corporation requiring 10 h. Equally, the monetary value of fines is relatively homogenous, with five corporations at 25 CHF per hour, one being slightly higher at 30 CHF, and one slightly less at 24 CHF.

Table 1. Descriptive statistics for model parameters and the respective effects, as predicted by comparative statics for appropriation and provision.

Term abb.	Description	Mean (SD) or Frequency (%)	Appropriation(a_i)		Provision(p_i)	
			Predicted Effect	Tested	Predicted Effect	Tested
Individual Parameters (i) (n = 85)						
W_i	Farmers' livestock endowment (LU)	11.6 (7.8)	(–)	Yes	(–)	Yes
a_i	Farmers' appropriation ratio. Endowment divided by net appropriation (LU/SLU)	87.3 (25.5)	/	/	(–)	Yes
p_i	Provision fulfillment level (ordinal variable)	Much more 13 (14.9%) A little more 37 (42.4%) Exact fulfillment 30 (34.5%) A little less 4 (4.6%) Much less/none 3 (3.4%) Non-appropriators exempted from provision 7				
O_i	Farmers' opportunity costs. Ratio of hourly wage off-farm vs. on-farm. J	2.2 (2.1)	(+) if W_i large and fee low; (–) if W_i low and fee high	Yes	(–)	Yes
Local governance parameters (c) (7 groups)						
MSY_c	Maximum sustainable yield (SLU)	74, 149, 167, 217, 234, 251, 256	(+)	No [a]		
$inst_c$	Provision rules/requirements (hrs./SLU)	8 (6*), 10	(–)	Yes		
F_c (fine/fee)	Fine for provision defection	24, 25 (5*), 30 20 (2*), 22 (2*), 25 (2*), 29	(–) if O_i high, (+) if O_i low	Yes	(+)	Yes
a_{-i}	Peer appropriation (within group)		(–)	Yes	(–)	Yes
p_{-i}	Peer provision (within group)		(+)	No [c]	(+)	Yes
a_{-i} (leaders)	Leaders' appropriation (within group)		(–)	No [c]	(–)	Yes
p_{-i} (leaders)	Leaders' provision (within group)		(+)	No [c]	(+)	Yes
Federal governance parameters						
sub_1	Subsidy for the appropriation paid to the owner of the animal CHF/SLU	370	(+) if a_{-i} high, (–) if a_{-i} low	No [b]		
sub_2	Subsidy for appropriation paid to the summer farm/cooperative	400	(+) if $MSY_c > a_i > a_{-i}$	No [b]		

[a] Not tested, as strongly correlated with a_{-i}. [b] Not tested due to lack of variance in parameter. [c] Not tested due to lack of identification. Data source: own survey.

5.2. Determinants of the Appropriation Decision

Our predictions for appropriation behavior resulting from the formal model regarding individual level parameters by the OLS (predictions l & m) were confirmed (Table 2). Accordingly, farmers with larger endowments have lower appropriation rates, which suggests that it is challenging for individuals owning larger farms to fulfil all provision duties if they appropriate all their livestock. Therefore, owners of larger farms tend to reduce appropriation levels as they cannot or do not want to make time to fulfill their provision duties. Furthermore, farmers who are using their private land more intensely also depend more heavily on the additional fodder sources available from the CPP and thus have higher appropriation levels [52,54]. Farmers achieving a larger share of income from agriculture tend to use the CPP more intensely. As predicted by the formal model, opportunity costs have a negative effect on appropriation levels for farms below the mean size ($W_i < 11.6$ LU) and a positive effect for farms above the average size ($W_i > 11.6$ LU). Other variables which control for livestock composition and social attributes do not significantly affect farmers' appropriation decisions (Table 2).

Table 2. Regression estimates predicting appropriation behavior.

	OLS	Mixed Effects			
	Individual Level Model	**Group Level Model**	**Leaders Only**	**Non-Leaders**	**Non-Leaders, incl. Leader Behavior**
W_i	−1.02 **	−0.93 *	1.52	−1.37 **	−1.33 **
	(0.51)	(0.49)	(1.03)	(0.57)	(0.57)
Land use intensity	18.11 **	16.55 **	9.25	24.60 **	23.52 **
	(7.47)	(7.22)	(9.31)	(10.91)	(10.94)
Agricultural income	0.27 **	0.25 **	−0.44 *	0.36 ***	0.36 ***
	(−0.12)	(0.12)	(0.25)	(0.14)	(0.14)
O_i	−1.66	−1.72	1.51	−3.22 **	−3.99 **
	(1.43)	(1.34)	(2.78)	(1.62)	(1.68)
O_i (small $W_i < \mu$; $n = 44$)	−3.20 *				
	(−1.67)				
O_i (small $W_i > \mu$, $n = 41$)	8.18 *				
...	(−4.75)				
Share of small livestock	−0.15	−0.17	−0.14	−0.24	−0.34
	(−0.22)	(0.2)	(0.32)	(0.25)	(0.25)
Share of young livestock	0.47	0.33	−0.22	−0.73	−0.75
	(−0.70)	(0.67)	(0.72)	(1.73)	(1.73)
Leadership	−5.10	−5.85			
	(−5.53)	(5.23)			
Successor (dummy)	5.42	5.07	4.87	5.58	5.74
	(−5.75)	(5.37)	(9.62)	(6.42)	(6.43)
Years left to retirement	0.32	0.29	0.62	0.64	0.42
	(−0.26)	(0.25)	(0.45)	(0.3)	(0.3)
$Inst_c$		2.61	1.64	0.93	2.07
		(1.16)	(4.28)	(4.67)	(4.36)
F_c		0.27	−3.61 *	1.62	1.64
		(1.16)	(1.94)	(1.69)	(1.49)
a_{-i} $(leaders)$					55.15
					(34.48)
Constant	71.7 ***	44.99	146.6 **	49.8	41.3
Observations	85	85	27	58	58
Number of Groups		7	7	7	7
R-squared	0.174				
Log likelihood		−376.2	−113.1	−256.2	−255.2
chi2		18.53	13.35	21.20	24.81
P		0.070	0.204	0.019	0.009

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Data source: own survey.

Although the random effects model (RE) did not show significant effects regarding group parameters (predictions e–h), the trend of effects is largely in line with predictions. The prediction that higher fines lead to reduced appropriation levels was only true for the leaders' subsample (prediction f). When splitting the sample into leaders and non-leaders, assuming that leaders' behavior influences non-leaders but not vice versa, we find that, for the leaders, increased provision fines F_c reduce appropriation behavior, but the same does not hold for non-leaders, which may be partly rooted in higher opportunity costs for leaders, as our theoretical model suggests. Contrary to theoretical predictions, leaders' behavior has large positive social effects (even though not significant), suggesting that reciprocity norms may be at play here beyond strategic considerations. The only deviation from our prediction concerned the provision obligations ($inst_c$), which did not show the expected negative effect on appropriation behavior (prediction e). Instead, farmers were shown to increase appropriation as provision obligations increase. However, this effect is likely to be coincidental and due to the low variance in the variable ($inst_c$). Unfortunately, the lack of variability in the premiums did not allow us to test our predictions on the suggested effects of subsidies (predictions i and j).

5.3. Determinants of the Provision Decision

Concerning provision, none of the predictions from comparative statics were confirmed with significant effects in the regression analysis, but all the model parameters describing individuals had effects that pointed in the predicted direction. Accordingly, livestock endowment and opportunity costs (predictions b and d) negatively impacted on provision fulfillment, suggesting that the workload from additional livestock reduces the time to fulfill provision obligations. This effect appeared to be significant for leaders, maybe because they have even less time-reserves than non-leaders because of their formal obligations (prediction b). Also, higher opportunity costs slightly negatively affected provision, as paying a fine becomes less of a deterrent against the backdrop of increased opportunity costs. Interestingly, when considering only the non-leaders, these effects are significant (prediction d), suggesting that leaders behave more rationally in this regard. Among the additional controls, we also find that land use intensity on private parcels positively affects provision fulfillment for the case of non-leaders. Regarding our prediction that individuals with higher appropriation levels also show higher provision levels (prediction c), we did not find significant or consistent effects.

Concerning the predicted social effects on leader behavior, we find that our theoretical predictions are significantly confirmed, at least for the non-leaders (Table 3).

Table 3. Log likelihood estimation predicting provision behavior.

	Ologit	**Mixed Effects**			
	Individual Level Model	**Group Level Model**	**Leaders Only, incl. Peer Behavior**	**Non-Leaders, incl. Peer Behavior**	**Non-Leaders, incl. Group-Leader Behavior**
W_i	−0.01	−0.02	−0.13	−0.15 **	−0.16 **
	(0.04)	(0.05)	(0.12)	(0.07)	(0.07)
a_i	0.43	0.00	−0.05	(0.00)	0.01
	(1.14)	(0.01)	(0.03)	(0.01)	(0.01)
Land use intensity	1.2	1.27	−0.05	4.72 ***	4.65 ***
	(0.81)	(0.85)	(0.05)	(1.45)	(1.39)
Agricultural income	−0.01	−0.01	−0.04	0	−0.01
	(0.01)	(0.01)	(1.21)	(0.02)	(0.02)
O_i	−0.14	−0.14	0.38	−0.43 **	−0.43 **
	(0.12)	(0.12)	(0.36)	(0.17)	(0.17)
Leadership	−0.53	−0.49			
	(0.49)	(0.5)			
Successor (dummy)	0.51	0.52	−0.05	1.19	1.09
	(0.52)	(0.52)	(1.16)	(0.78)	(0.76)
Years left to retirement	−0.02	−0.02	−0.05	−0.06	−0.07 *
	(0.02)	(0.02)	(0.06)	(0.04)	(0.03)
$inst_c$		−0.1	0.48	−0.58	0.06
		(0.27)	(0.53)	(0.42)	(0.8)
F_c		−0.03	−0.1	−0.28	−1.23
		(0.1)	(0.37)	(0.17)	(0.63)
			−0.03	0.02	
a_{-i}			(10.3)	(7.57)	
			−9.64	5.25	
p_{-i}			21.06 **	(0.82)	
			−9.34	6.67	
a_{-i} (*leaders*)					−27.61 *
					(15.25)

Table 3. *Cont.*

	Ologit	Mixed Effects			
	Individual Level Model	**Group Level Model**	**Leaders Only, incl. Peer Behavior**	**Non-Leaders, incl. Peer Behavior**	**Non-Leaders, incl. Group-Leader Behavior**
p_{-i} (*leaders*)					15.25 **
					7.53
Observations	84	84	27	56	56
Number of groups		7	7	7	7
Pseudo R-squared	0.0577				
Log likelihood	−96.36	−96.26	−24.13	−51.89	−50.77
chi2	11.36	10.33	11.18	22.15	23.79
P	0.182	0.412	0.428	0.0232	0.0137

Standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Data source: own survey.

Concerning local governance variables, we expected that a more substantial fine would increase provision fulfillment (prediction f), which was not confirmed. Instead, higher fines had a slightly negative effect on provision fulfillment, which again is likely to result from the small variance in fines.

6. Policy Options

6.1. Adapting Local Governance Institutions to Avoid Underuse

We recall at this stage the logic of current local governance institutions linking appropriation and provision proportionally, whereby the overall provision obligation increases in line with appropriation. Defections on those provision obligations are sanctioned with fixed hourly fines. The local institution in question promised success in situations where the resource is prone to over-appropriation as the adverse effects of overuse; that is, where $\sum_{i \in N} a_i > MSY_c$, is mitigated for two reasons. Firstly, the negative effects of overgrazing are (partially) offset by increased provision levels. Secondly, the additional provision obligations incurred by appropriating an additional unit limit activity at the margin. In a setting where underuse of the CPR becomes a problem, the linear link between appropriation and provision in combination with principles of diminishing marginal utility results in a suboptimal incentive structure. As the analysis and data indicate, such an institution creates strategic incentives not to appropriate, as individuals strive to avoid additional provision costs. Hence, in a situation where $\sum_{i \in N} a_i < MSY_c$, such a provision institution reduces incentives for both appropriation and provision and reinforces the adverse effects of underuse.

Consequently, we would suggest reformulating the appropriation-provision link to increase the incentive to appropriate at the margin. This could be done by setting the provision obligation marginally in relation to the total appropriation. In this case, each additional cow would cost marginally less, just like in bulk pricing, where higher quantities cost marginally less than smaller quantities. If $\sum_{i \in N} a_i < MSY_c$, then appropriating an additional unit to graze on the CPP should incur a proportionally lower provision obligation than if $\sum_{i \in N} a_i > MSY_c$. This can be implemented via the following incremental quantity-based provision institution: Denoted by a_i^k, the k-th appropriated unit by farmer i, and by $inst_c\left(a_i^k\right)$, the provision institution for this appropriated unit is therefore, $inst_c\left(a_i^k\right) = inst_c\left(\left(\frac{MSY_c}{n} - k\right)^2\right)$, so that the total provision obligation is

$$inst_c = \sum_{\{k=1,2,\ldots,a_i\}} inst_c\left(a_i^k\right)$$

It is of note here that appropriating the k-th cow so that an individual's contribution to achieving the MSY is exactly met incurs no additional provision obligation. As a result, the negative impact (avoiding provision by reducing appropriation) is eliminated, and everyone has an incentive to appropriate at the margin. Such a reformulated local institution can be expected to help to resolve the problem of underuse. This institution would be more efficient in mitigating both the under-appropriation and under-provision problems targeting farmers with larger endowments in particular. Under the institutions proposed herein, the time constraint that particularly larger farmers face, which leads them to reduce appropriation levels in order to avoid additional provision, is mitigated as every additional appropriated unit is associated with lowered provision costs.

6.2. Redesigning Federal Governance Subsidies

On the federal government level, a policy reform could be implemented by re-designing subsidies. Our model predicted a positive effect for both subsidies, unless the quality of the pasture declined and reduced MSY, in which case sub_2 had a negative impact. However, both sub_1 and sub_2 could be re-designed to mitigate the problem of under-appropriation (and consecutive under-provision) more efficiently when being paid marginally based on livestock units instead of a fixed rate. Currently, this idea is partially realized in the design of Sub2, as payments are reduced if overall appropriation is above 110% or below 75% of MSY. However, the reduction in payments is more drastic for over- than for underuse. The logic behind this design is not to reinforce underuse by further reducing incentives if targets are not met [9].

However, it would be more efficient to have both subsidies designed in accordance with the principles of marginality. Similar to the incremental quantity-based system proposed for re-designing the provision obligations above, federal subsidies should consider incremental direct and communal quantity-based subsidies:

Sub_1: (direct subsidy): $sub_1\left(a_i^k\right) = sub\left(\left(\frac{MSY_c}{n} - k\right)^2\right)$, so that the total direct subsidy received is

$$sub_1 = \sum\nolimits_{\{k=1,2,\ldots,a\}} sub\left(a_i^k\right)$$

Sub_2: (communal subsidy): $sub_2\left(a^k\right) = sub_2\left((MSY_c - k)^2\right)$, so that the total becomes

$$sub_2 = \sum_{\{k=1,2,\ldots,a\}} sub\left(a^k\right)$$

These staggered subsidies which peak around MSY would mitigate the under-appropriation, and in combination with the re-designed local institution, also the under-provision issue. The redesign of the subsidies would also constitute a step away from action-oriented schemes, towards the much-advocated result-oriented agri-environmental schemes, e.g., [55,56], as the amount of payments received would depend more closely on meeting the stocking target. However, adapting the local governance institution as proposed herein would not increase transaction costs, while changing the design of the federal subsidies would certainly require additional documentation from both farmers and the paying agency, which raises transaction costs.

7. Discussion and Conclusions

Common pool resource problems are usually associated with overuse. In this analysis, we investigated the problem of CPR underuse through a case study of mountainous common property pastures in Switzerland. Cases in Switzerland have served as examples where the local government has successfully self-organized to avoid overuse. In past decades, however, summer pasture abandonment has become widespread and a major concern for policy makers and researchers in many European alpine countries [7,11]. Nowadays, the grazing of alpine common property pastures can only be maintained through massive targeted subsidies.

To understand the drivers behind reducing summer pasture usage, we explored how individual attributes and local and federal government measures affect farmers' use of CPP with regards to their appropriation and provision behavior. The crucial innovation of our analysis is linking appropriation and provision decisions in a unified game-theoretic model. This is an essential modeling aspect, because local government systems typically enforce rules that link provision obligations to individuals' appropriation activities. In such a constellation, each user will carefully evaluate whether the benefits from appropriation will pay off the costs of associated provision activities. Hence, we studied these two situations in conjunction, and in game-theoretic language, solved these decisions in terms of strategic subgame perfection. Previous game-theoretical experiments studied the two situations together as a CPR and public goods problem, e.g., [40,42], but did not link these two decisions through an institution. But in any CPR setting where such an institution is in place, the two decisions become strategically interlinked. Consequently, the institution may lead a user to refrain from appropriation to save on provision costs, which is a problem when resource systems are adversely affected by underuse.

Furthermore, our empirical analysis is a first attempt at pursuing a serious in-the-field validation of the theoretical results. Overall, our regression analysis validated the model predictions regarding individual parameters for appropriation behavior. Results concerning provision qualitatively validated certain aspects, although these effects were not statistically significant, with the exception of the leaders in the sample. Our attempts to validate the effects of governance or subsidy parameters on appropriation and provision behavior, however, were less successful, because the scope of the regression analysis was plagued by two problems. Firstly, we worked with a rather small sample of farmers. Secondly, the group-specific local governance parameters did not encompass sufficient variance to produce robust effects in the nested models. Furthermore, the suggested effect of the subsidies could also not be tasted as they were constant in the field. Nevertheless, we suggest that with a larger sample and more group stratification, the local governance parameters, such as provision obligation, the monetary value of the fine, or the role of maximum sustainable yield, could be confirmed. Another promising avenue would be to translate this decision setting into a lab experiment that allows for further testing of our predictions regarding local and federal governance parameters.

7.1. Sectoral Developments and Their Expected Effect on Summer Pasture Use

On an individual level, we found that farmers reduce appropriation with increasing endowment. As predicted, we also found that a higher opportunity cost leads farmers with smallholdings to reduce appropriation, while the opposite effect was shown for larger farms. However, the strongest effect was found for land use intensity, as farmers using their private land intensely are more dependent on additional fodder available from CPP. Concerning provision, we expected that herd size and opportunity costs to have a negative effect on provision fulfillment. Although the regression models showed these tendencies, the effects were non-significant.

Considering trends in the agricultural sector with increasing endowment (+16% from 2000–2014), increasing opportunity costs (+5% from 2000–2014), and slightly decreasing land use intensities (−3.7% from 2000–2014) [57,58], all significant parameters on the individual level are currently developing so as to reduce farmers' appropriation behavior. Therefore, the sustainability of CPPs will continue to heavily depend on the incentives shaped by the local and federal government to stimulate appropriation and provision levels.

Regarding federal governance, the theoretical model suggested that farmers increase appropriation if provision obligations are lower, and when fines for non-provision are reduced, especially for farmers with lower opportunity costs. Regarding provision behavior, the formal model suggested that higher fines positively affect provision fulfillment. Although the regression model showed the expected trend for individual parameters, the effects were non-significant. In terms of fines, the regression even suggests that an increase in fines will lead to higher provision defection rates, although this effect may be due to insufficient variance in fines. Therefore, validation of the assumptions on local government policies on provision behavior requires larger datasets with more intergroup variance in local government parameters.

7.2. Accounting for Marginality in Policy Design

Local government parameters showed no significant effects in the regression analysis, but this may again be due to lack of variance. Nevertheless, we demonstrated that local governance systems could adapt their incentive structure to better deal with underuse by making use of the principles of marginality. Instead of requiring a fixed amount of labor hours per appropriated unit, the institutions should be designed to lower the marginal provision obligation as a function of total appropriation. Given that total appropriation is too low, higher individual appropriation should be made "cheaper" by lowering provision obligations for every additional appropriated unit.

Our theoretical model suggested that both subsidies incentivize appropriation. Although we were unable to test the actual effect on farmers' appropriation decisions, it is indisputable that subsidies increase payoff and thereby incentivize appropriation. The question is rather if the two subsidies in place are the most effective in stimulating the use of CPPs. Our analysis suggested that the federal government could improve the efficiency of subsidies by changing their relative monetary value (Sub1 < Sub2), and by once again making use of marginality principles. The design of Sub2 is an initial attempt to implement this, given the reduction in payments when total appropriation deviates too far from MSY. Such efforts to include marginality into the policy design should be extended to Sub1 to increase the efficiency of local government expenditures. A more fundamental debate is also needed to establish whether such government efforts should be pursued at all, as, for example, some favor a return to forests in the case of Swiss pastures [20].

7.3. Limitations

Our findings are limited to common pool settings where appropriation and provision are institutionally linked in a way that is demonstrated by the present-day institutional setting in Switzerland. Although that link is considered key to successful local governance [4,38], many social-ecological systems, particularly natural CPR systems, may function without provision efforts and the respective institutional arrangement or policy linking appropriation and provision. For such settings, the implications of our results are less relevant. However, in our analysis, we have argued that adhering to principles of marginality in designing the appropriation-provision link may provide an option for local authorities to fine-tune policies to better steer appropriation towards optimal use. As there was no variability in the subsidies premium in our field data, and the seven groups were rather homogenous with regard to their governance structure, the validation of the predicted effects in this regard requires further empirical investigation.

Another limitation of our study was the fact that our model of human decisions assumes standard (rational and selfish) economic decision-making. Provided that our model captures the relevant structural parameters of the decision-making process, the residuals in the regression models suggest that other decision factors are at play, including a strong presence of other social motives beyond economic rationales [59]. For example, the experimental literature shows that other factors, including norms [60], inequality aversion [61], reciprocity [62], interdependent preferences [62], and learning [63,64] can influence behavior beyond economic rationality. The first steps have been taken toward integrating norms [65] and attitudes [66] into farmers' decision-making. Future behavioral research, including experimental and applied empirical approaches, will require continuous efforts to integrate a variety of non-pecuniary motives and other factors interfering with rationality, in order to produce more robust empirically-based models of behavioral models of common pool resource use.

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