Analyzing and Modeling the Use of Common Property Pastures in Grindelwald, Switzerland

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Meinen Eltern

SUMMARY

Problem. More than ever, some of the biggest challenges to society involve the governance of natural resources. From large-scale resource systems, such as the rain forest and oceans, to small-scale systems, such as lakes or alpine pastures, cooperative efforts are required to ensure sustainable and yet productive use of natural resources. In Switzerland, the management of alpine pastures has for centuries been predominantly organized by local governance institutions, avoiding an overuse of the scarce resources. During the past decade, the use and maintenance of common property pastures (CPPs) is declining, leading to land abandonment and forest regrowth. However, CPPs provide significant services to the mountain regions, such as additional grazing grounds; assets for the tourism industry; protection from soil erosion, water runoff and landslides; and high biodiversity. These services are currently threatened by reduced use and maintenance of CPPs.

Research Aims. The research presented herein aims for a better understanding of social-ecological interactions driving the use of CPPs to provide policy recommendations for the sustainable governance of CPPs.

Methods. To achieve a holistic understanding of the variables driving CPP use, this research used multiple methods to investigate CPP use in Grindelwald, Switzerland as a social-ecological system (SES). The research was structured in four modules. First, qualitative methods were applied to analyze institutional change in the governance of CPP. Second, regression models were built from survey data to better understand farmers' land use decisions. Third, an analysis of the ecological system was conducted based on land cover statistics. Forth, a systems dynamics model of the local SES was built and combined with a formative scenario analysis to investigate potential future developments of CPP use.

Results. The outcomes of the different modules suggest the following: First, local governance systems originally designed to prevent overuse of CPPs are able to adapt to problems of declining use and maintenance of CPPs by altering a set of rules. Second, farmers' use of CPPs depends on personal attributes, including farm size, norms and dependence on the resource. Furthermore, the analysis suggests that high local demand and prices for alpine cheese are a central factor in the sustainable use of CPPs. Third, the land cover analysis showed that afforestation occurs in Grindelwald at a relatively moderate pace and defined the area most prone to afforestation and bush encroachment. Fourth, the simulation model allows for the display of complex social-ecological interactions, showing that afforestation tendencies are likely to continue, although at a different pace depending on the scenario setting.

Conclusion. This research provided a better understanding of CPP use through the analysis of the subsystem characterizing the SES. It showed how the general framework for analyzing SESs can be operationalized using a broad set of methods. It thereby contributed and advanced central themes within the study of the commons, such as institutional analysis, users' behavior in cooperative dilemmas and modeling of SESs. The integration of the findings from different modules into a simulation provided insights about the effects of different policies on the sustainability of the SES and thereby demonstrated why particular policy blueprints will accelerate rather than counteract the problem of CPP abandonment.

ZUSAMMENFASSUNG

Problem. Die Gesellschaft ist zunehmend herausgefordert, den Umgang mit natürlichen Ressourcen nachhaltig zu gestalten. Kooperative Anstrengungen sind nötig, um eine nachhaltige und produktive Nutzung groß- und kleinflächiger Ressourcensysteme wie Regenwälder, Ozeane und Alpen (Almen) zu gewährleisten. In der Schweiz ist die Alpung seit Jahrhunderten überwiegend kommunal organisiert, mit dem Ziel, die Übernutzung der Weiden zu verhindern. Während der letzten Jahrzehnte ist die Alpung jedoch rückläufig, was zur Auflassung von Weiden und Wiederbewaldung führt. Da die kontinuierliche Weidenutzung und -pflege bedeutende Leistungen für die Bergregion hervorbringen wie Offenhaltung der Futterflächen, ein gepflegtes Landschaftsbild für den Tourismus und diverse Ökosystemdienstleistungen, ist der Rückgang der Alpwirtschaft ein bedeutendes Problem in vielen Bergregionen.

Forschungsziel. Die vorliegende Arbeit soll zu einem besseren Verständnis der Wechselwirkungen zwischen Mensch und Umwelt beitragen, welche die nachhaltige Nutzung der Alpen beeinflussen, um daraus Handlungsempfehlungen abzuleiten.

Methoden. Um ein ganzheitliches Verständnis der Determinanten einer nachhaltigen Alpwirtschaft zu generieren, stützt sich diese Arbeit auf verschiedene Methoden. Dabei dient die Gemeinde Grindelwald in der Schweiz als Fallbeispiel für die sozial-ökologische Analyse, die in 4 Module unterteilt ist: Im ersten Modul wird mittels qualitativer Methoden untersucht, ob die lokalen Körperschaften ihre institutionellen Regime anpassen, um dem Problem der Unternutzung entgegenzuwirken. Im Zweiten werden die Landnutzungsentscheidungen der Landwirte mittels Regressionsmodellen basierend auf Umfragedaten erklärt. Im Dritten wird eine räumliche Analyse des ökologischen Teilsystems basierend auf der Arealstatistik durchgeführt. Im Vierten wird das sozial-ökologische System modelliert und durch Szenario-Analyse mögliche Entwicklungen der Alpwirtschaft von Grindelwald simuliert.

Resultate. Die Ergebnisse zeigen erstens, dass die lokalen Körperschaften auf die rückgängige Nutzung reagieren, indem sie diverse Nutzungsregeln anpassen. Zweitens, dass die Landnutzungsentscheidungen der Landwirte von Betriebsgröße, Normen, und von deren Abhängigkeit von landwirtschaftlichem Einkommen determiniert sind. Drittens, zeigt die Analyse des Ressourcensystems, dass in Grindelwald der Prozess der Wiederbewaldung in moderatem Tempo erfolgt und welche Standorte davon betroffen sind. Viertens, zeigt das Simulationsmodell die sozial-ökologischen Wechselwirkungen auf, welche zum Rückgang der Alpwirtschaft führen. Die Simulation verschiedener Szenarien zeigt zudem, welche exogenen Veränderungen die Wiederbewaldung in Zukunft begünstigen respektive abschwächen.

Fazit. Durch sozial-ökologische Systemanalyse zeigt diese Forschung auf, welche Mensch-Umwelt-Interaktionen die nachhaltige Nutzung der Alpen beeinflussen. In den einzelnen Modulen werden verschiedene Methoden kombiniert, um das Framework zur Analyse sozialökologischer Systeme zu operationalisieren. Damit leistet die Studie Beiträge zu den zentralen Themen der Allmend-Forschung wie Institutionenanalyse, Verhaltensökonomie und computergestützte Simulation sozial-ökologischer Systeme. Die Integration der Ergebnisse aus verschiedenen Modulen bietet schließlich einen Überblick über die Auswirkungen politischer Maßnahmen auf die Nachhaltigkeit der Alpwirtschaft und zeigt auf, weshalb bestimmte Patentrezepte den Rückgang der Alpwirtschaft eher begünstigen als aufhalten.

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PART ONE: SYNOPSIS

1 Introduction

Promoting a more sustainable use of natural resources like pastures, forests, irrigation systems, fisheries, or fresh water and more recently, clean air, global climate, and biodiversity is a major challenge to societies. Science has undertaken tremendous efforts to investigate the social and ecological conditions that facilitate or hinder sustainable governance of natural resources. Herein, property rights are considered key. No matter whether a resource is held in private, state, or common property, particular forms of ownership alone do not guarantee sustainability. Instead different forms of property rights and the characteristics of the resource affect the incentive structures for potential resource users. Institutions such as markets, state quota, or use rights help balance the levels of exploitation with the resources capacity to renew and recover in order to maintain sustainability. This dissertation addresses the current challenges and solutions for maintaining balanced resource use for the case of common property pastures (CPP) in the Swiss Alps.

1.1 Common Pool Resource Governance

Common pool resources (CPRs) are jointly managed resources, for which individuals' appropriation diminishes the resource stock and potential beneficiaries of which are difficult to exclude (Berkes et al. 1989). CPRs can be natural or man-made resources to which a large number of people have access. This situation poses a social dilemma: If one limits his use of the resource while others do not, then the resource will degrade and the individual that restrained himself has no benefit at all. To avoid being in this position, individuals extract as much as possible from the resource before there is nothing left. This dilemma was said to be impossible to overcome, leading to the "tragedy of the commons".

The debate started with the seminal articles of Gordon on fisheries and Hardin on pastures (Gordon 1954; Hardin 1968). Both pictured resources overexploited by self-seeking individuals maximizing their use of the freely available resource that is the property of all, but valued by no one. As a consequence, common property was regarded as an inferior stage of property rights development that needed to be overcome through privatization or state control as the sole means to prevent the tragedy of the commons.

Since then, scholars have shown repeatedly that CPR governance is possible through self-organization of users. Ostrom provided a synthesis of examples for successful community-based CPR-management efforts ranging from communal tenure of pastures and forests in the Swiss Alps, to irrigations systems in the Philippines and Spain, and to fisheries in Turkey (Ostrom 1990). There are many more case studies on collectively governed resources of fisheries (Acheson 2003), irrigation systems (Wade 1989), alpine pastures (Netting 1981), and forests (Agrawal and Chhatre 2006). The main interest of these studies has been to understand how cooperation evolves and which factors facilitate collective governance of natural resources in order to avoid their over-use. The factors that were found to facilitate or hinder sustainable governance, however, vary across space and time, and social and natural sciences put different emphasis on the explanatory variables and methodological approaches. In order to provide ground for multidisciplinary efforts for the analyses of social-ecological systems (SES), Ostrom provided a framework that synthesizes all potential relevant social and ecological variables that explain success of common pool resource governance (Ostrom 2007; Ostrom 2009). This thesis applies the framework in order to analyze the sustainability of CPPs in the Swiss Alps.

1.2 Common Property Pastures in the Alps

Since Nettings' study in Törbel (Netting 1981), common property pastures (CPPs) in the European Alps have become a classic example for the study of collectively governed resources. Several scholars have described organizational principles and the rules applied to govern pasture use in order to avoid overuse (Casari 2007; Ostrom 1990; Stevenson 2005; Stoeckle 2009).

However, as a result of social developments in the past decade, many alpine pastures in Europe have become less intensely used and maintained. Increasing labor productivity in the industrial and service-oriented sectors has steadily moved labor forces away from the agricultural sector. In terms of expanding agricultural land use, alpine agriculture appears to have reached its peak at the beginning of the 19th century (Stöcklin et al. 2007). Since then, agriculture has steadily relinquished from using the least productive areas, which has been identified as a major driver for forest regrowth (Keenleyside, Tucker, and McConville 2010; MacDonald et al. 2000).

In Switzerland, about 12% of the national area consists of alpine pastures (Lauber et al. 2008), approximately 80% of which are kept in communal tenure (Baur, Müller, and Herzog 2007). As a result, CPPs form an important part of the national surface area and provide various social and environmental services and public goods. As these services crucially depend on the cultivation of marginal pastures which are often common property, the cultivation of which under current conditions often does not cover costs, the sustainable use of CPPs nowadays does not simply depend on the ability of collective organizations to avoid overuse: more importantly, it depends on governance efforts to ensure the continuous use and maintenance of CPPs in order to secure the environmental and social services streaming from sustainable CPP use.

1.3 Services Streaming from Sustainable Common Property Pasture Management

Research has identified several services that are potentially threatened by the abandonment of marginal alpine pastures. Among the ecological services figures are:

1.3.1 Ecosystem Services

- Provision of high-value grass for livestock feed and thus an additional income source for farmers;
- Biodiversity (Burel and Baudry 1995; Giupponi et al. 2006; Stöcklin et al. 2007), such as the biological diversity of vascular plant species in alpine pastures, which is twice as high as in forests (Korner and Spehn 2002);
- Protection against soil erosion, water run-off, and landslides (Tasser, Mader, and Tappeiner 2003);
- Protection from natural hazards (Tasser, Mader, and Tappeiner 2003).

1.3.2 Cultural Services

Among the social services are:

- Provisioning of specialties and alpine products;
- Landscape beauty and diversity for recreational activities (Hunziker 1995; Hunziker et al. 2008);
- Identification with the landscape (Bignal and McCracken 2000; Plieninger, Höchtl, and Spek 2006).

For Switzerland, several researchers have investigated the development of these services in the Swiss Alps. The main contribution toward an integrative social and ecological analysis was given by the NFP 48, in which the focus was on landscape development and habitat. The main results of the NFP 48 are summarized in five synthesis books dealing with (i) processes of perception (Backhaus, Reichler, and Stremlow 2008); (ii) processes of change (Stöcklin et al. 2007); (iii) designing goals in landscape evolution (Simmen and Walter 2007); (iv) land use and adding values (Simmen, Walter, and Marti 2006). Key recommendations relating to further research in the Swiss Alps are:

- Alpine research should study development paths of specific regions and compare the driving factors affecting different types of developments (Lehmann and Messerli 2007).
- Grassland and pastures are important elements in the landscape of the Swiss Alps, mostly with respect to biodiversity. Land abandonment and alpine fallows are important issues to be further analyzed (Lehmann and Messerli 2007).
- Current local institutions governing the commons have been stable and effective in dealing with potential resource overuse. However, it was found that these exact institutions might hinder innovative and sustainable development paths. Thus, one open question is how and whether these institutions will be able to adapt to the new demands and support sustainable management in future (Knoepfel and Gerber 2008).
- Participation in research projects in the Alps is recommended given the high diversity of stakeholders and interest groups, ranging from tourism to ecologists and farmers (Simmen and Walter 2007) and thus requiring inter- and transdisciplinary approaches to understand past and future developments of CPP use (Lehmann and Messerli 2007).

2 Research Problems and Questions

Given the services and research recommendations associated with the sustainable management of CPPs in Switzerland, there is a need for research to provide in-depth understanding of the distinctive configurations of variables describing CPP use. As social-ecological (or human-environmental) systems consist of unique configurations, success factors leading to sustainable outcomes in one setting will not necessarily have the same effect in other settings. This is holds even more for the analysis of CPP use, as governance efforts need to deal with the problem of resource underuse, which is usually not considered in CPR research.

Therefore integrative research is needed, which acknowledges the complex relationships between farmers' decision-making, institutional structures, and the ecological system to diagnose sustainability of CPPs. Accordingly, this research aims at providing the following knowledge:

a. Solid understanding of the role of local governance systems in the context of reducing CPP use;
b. Insights on variables driving farmers' use of CPPs;
c. Analysis of the impact of CPP use on land cover;
d. Integrative model of the local social-ecological systems for policy testing.

With respect to these research aims, the following chapters (2.1-2.4) will review previous research and current methods, and identify the gaps and research questions to be answered.

2.1 Institutions for Common Pool Resources Governance

One of the most central questions in the study of the commons is which local governance characteristics allow for the long-term sustainable management of CPR. Several synthesis of case studies exist that highlight ecological and social factors that facilitate self-governance (Agrawal 2001; Baland and Platteau 1996; Ostrom 1990). Herein, the eight design principles of Ostrom have become the most accepted (Cox, Arnold, and Tomás 2010). Accordingly, successful local governance builds on:

1. Clearly defined groups and territorial boundaries;
2. Congruence between appropriation and provision rules and local needs and conditions;
3. Collective-choice arrangements that guarantee access to rule-making for those most affected by the rules;
4. Monitoring systems;
5. Graduated sanctions for rule violations;
6. Availability of low-cost means for dispute resolution;
7. Minimum recognition of rights to self-organize;
8. Nested enterprise.

These design principles illuminate the properties of the governance system that are likely to lead to long-term successful self-governance of CPRs by enforcing institutions as mechanisms for reducing uncertainty in complex environments as a base for collective action. Nevertheless, while design principles may provide a generalized checklist for good-governance principles, they do not allow for predicting whether a local governance system is able to deal with external change such as market developments (Southworth and Tucker 2001;

Tucker, Randolph, and Castellanos 2007) or whether a governance system enforces institutions that fit the changing conditions of the biophysical world (Young 2002). Therefore a simple check for design principles or static institutional analysis will not provide insights about whether and how local governance systems adapt institutions to cope with external change.

Gap 1: *Whilst studies on self-governed CPRs provide useful snapshots about properties and rules applied at a particular point in time, no study exists that traces the evolution of the governance system over longer periods and its adaptations to internal and external changes in the SES.*

Doubtlessly, the local governance system in the Swiss Alps has been stable and effective in dealing with potential resource overuse. However, it is questionable whether these institutions are similarly effective in dealing with resource underuse because the main functions of the local governance system (i) excludes outsiders and (ii) limits the extraction levels of users. Thus, one open question is how and whether local governance systems in the Swiss Alps adapt institutions to the new demands to support the sustainable management of CPPs (Kissling-Näf, Volken, and Bisang 2002; Knoepfel and Gerber 2008). Accordingly, the first research question aims to clarify the role of local governance in the context of reducing resource use:

Research question 1: *Do local governance systems in the Swiss Alps change institutions in order to adapt to the socio-economic changes to avoid reduced use and maintenance of CPPs?*

2.2 Individuals' Behavior in Common Pool Resources Dilemmas

The use of CPRs involves cooperative dilemmas, which actors need to solve in order to manage resources sustainably. The first dilemma results from the fact that CPRs are subtractable. That is, appropriation of resources units of one user imposes externalities on other resource users as the resource stock diminishes. Therefore, users face incentives to maximize appropriation for their own benefit, as the cost of their activities (reduced availability of the resource) is turned over onto other resource users (Gardner, Ostrom, and Walker 1990). Furthermore, the availability of resource units is dependent on provision activities and the upkeep of the resource system as well as the physical infrastructure needed to secure and enhance the resource unit flow (Anderies, Janssen, and Ostrom 2004). For example, CPPs require maintenance clearance from shrub, bush and rock fall and investments into infrastructure such as barns, storage facilities and drinking troughs. Clearly, the individual is interested in shifting these burdens for maintaining the resource system to joint-users. Therefore, appropriation and provision activities involve social dilemmas, as the users' self-interest in maximizing appropriation and free-riding on the provision activities of others is juxtaposed to the interest of the group in ensuring a fair and equitable distribution of the benefits and burdens associated with the use of CPRs (Gardner, Ostrom, and Walker 1990).

Experimental research has extensively studied individuals' behavior in these dilemmas using game theory. For both appropriation and provision situations, experiments exist that replicate appropriation and provision situations through common pool resource and public good games, thus asking under which conditions sustainable levels of cooperation can be sustained. The

focus thereby lies on the effect of rules and institutional constraints, such as payoff functions (Janssen and Ahn 2006), communication (Ahn, Ostrom, and Walker 2010; Janssen et al. 2010), or monitoring and sanctioning (Fehr and Fischbacher 2004; Fehr and Gächter 2000) mechanisms in ensuring the cooperative behavior of players. While such experiments provide important insights into the effect of institutional constraints on overall levels of cooperation, they do not illuminate motivational or material drivers on an individual level. However, it is important to investigate these drivers to explain why some resource users apply cooperative behavior while others do not, within a shared institutional setting. For this endeavor experiments alone are not sufficient as the material constraints, preferences, and motives as they appear in the field, might differ substantially from those in the laboratory for the following reasons:

a. Game theory mostly assumes that self-seeking players behave strictly rational in order to maximize payoffs. This assumption does not necessarily reflect reality (Smith 2010);
b. The behavior of individuals in experimental settings is detached from personal characteristics such as economic endowment or opportunity costs (Anderies et al. 2011; Levitt and List 2007);
c. Subjects in laboratory experiments are usually western students whose personality traits might differ from those of CPR users (Henrich, Heine, and Norenzayan 2010).

***Gap 2**: Although experiments provide important information about the institutional settings that facilitate cooperation, they offer only limited explanations for difference in the behavior of real common pool resource users.*

With respect to the use of CPP in the Swiss Alps, its sustainable use depends crucially on social-ecological interactions, namely appropriation (grazing intensity) and provision (maintenance of the ecological system and the respective infrastructure). Since both under- and overgrazing have adverse effects on the resource system, for example by reducing biodiversity or pasture productivity, total appropriation should remain within a sustainable yield. Furthermore, provision activities are needed to maintain or enhance the productivity of the resource system. This leads to the second research question:

***Research question 2:** Which individual attributes explain differences in the behavior of real CPR users in the field with regard to factor endowment, appropriation, and provision activities?*

2.3 Resource System Analysis: Land Use and Associated Land-Cover Changes

Research on the use of CPR resources is largely based on social and economic approaches. Thus, in the study of the commons the ecological systems is mostly treated marginally with a focuses on the ecological properties that facilitate or hinder sustainable governance of the natural resources rather than on the concrete ecological interactions and the way they are altered through human activities (Epstein et al. 2013; Tucker, Randolph, and Castellanos 2007) Thus, ecological consequences of human-environmental interactions are not given the highest priorities in the study of the commons or the SES framework respectively, as emphasis is put on social processes instead (Binder et al. 2013). Within the natural sciences, studies focusing on changes in the ecosystem processes and land cover often do not illuminate

the social drivers such as users' behavior or the institutional structure. Nevertheless some efforts exist that try to link to land use and the resulting land-cover changes to social process (Anderies, Janssen, and Walker 2002; Janssen, Anderies, and Walker 2004; Janssen et al. 2000; Perrings and Walker 2004; Walker and Janssen 2002). Unfortunately, these studies are conducted for the analysis of vast rangelands and are thus quite different from the ecosystem properties in the Swiss Alps and the way they have been manipulated by land use practices.

For centuries in the Swiss Alps, the main method of increasing the agricultural area for grazing, in particular, has been through the deforestation of marginal areas. However, during the past decade, an opposing trend has been observed: The abandonment of CPPs has led to shrub encroachment and expanding forest areas. Several explanations exist for these trends, which have been observed on a national level, such as structural changes and resulting labor scarcity leading to the abandonment of marginal areas (Baur et al. 2006) or increasing summering costs (Mack, Walter, and Flury 2008). However, the degree to which these tendencies were observed varies regionally. In the Southern Alps, an almost complete abandonment of remote summer pastures, particularly in the canton of Ticino, has been observed (Stöcklin et al. 2007), whereas other regions face moderate to no land use and land-cover change. Therefore, studies on a regional level are needed, which elucidate the development paths of specific regions and compare the driving factors, which account for different regional developments of the land use and land-cover change (Lehmann and Messerli 2007).

Gap 3: *Factors and degree of land-use change and their impact on land cover in CPP areas varies regionally. Therefore research needs to identify the spatial patterns of land use and land-cover change and link them to social drivers of land use.*

With respect to the study region, the current land-cover status must first be established and recent developments identified. Furthermore, the observed land-cover changes must be explained in terms of land-use change or other explanatory factors, such as the development of provision activities or climate change. In addition, changes in land use practices need to be linked to changes in the social system of the SES. Therefore, the third research question is as follows:

Research question 3: *What land use and land-cover change can be observed in the case study region and what are the particular drivers behind these changes?*

2.4 Simulation Models of Social-Ecological System

Recent research is trying to acknowledge the full complexity of social-ecological systems, which form the basis for all natural resource use. Several frameworks were developed for the analysis of social-ecological systems with respect to CPRs (Anderies, Janssen, and Ostrom 2004; Ostrom 2007, 2009). Most research focuses on the interaction of certain subsystems, describing only particular aspects of the social-ecological system; fully integrated simulation models of social-ecological systems are rare. The few models of CPPs are mostly based on case studies in developing countries (Castella, Trung, and Boissau 2005; Janssen and Ostrom 2006; Jin, Xu, and Yang 2009; Stave 2003). Other simulation models, which focus on land dynamics, show how changes in socio-economic factors can impact the vegetation quality and help to determine an optimal stocking density for sustainable land use (Anderies, Janssen, and

Walker 2002; Janssen, Anderies, and Walker 2004; Janssen et al. 2000; Parker et al. 2003; Walker and Janssen 2002). These simulation models are built to represent very different natural environments and social conditions from those in the Swiss Alps. Furthermore, institutional change and farmers' decision-making follow very different paths, which restricts the application of these models to the case of common property management in the case study region. Nevertheless, simulation models are the key for understanding social-ecological interactions, the feedbacks governing social-ecological systems, and for testing policy options for the sustainable governance of social-ecological systems (Janssen and Ostrom 2006; Poteete, Janssen, and Ostrom 2010).

Gap 4: *Simulation models, which acknowledge the interactions between institutional change, farmers' decisions, and the resulting social and ecological impacts, are rare and existing models are far from representing the reality of the case study region. In order to better understand the complex interactions that characterize the social-ecological system of the study region, a simulation model is needed, which allows for policy testing.*

With respect to the study region, the findings regarding the function governance system, farmers behavioral patterns, together with insights on land-use and land-cover change, need to be integrated into a simulation model to provide a better understanding of the specific feedback mechanisms, non-linear relationships, and thresholds, which characterize the local SES and drive the system behavior in response to different policies. This leads to the fourth research question:

Research questions 4: *How can the findings from the analysis of the subsystems be integrated into a simulation model to represent the specific characteristics of the local SES and to test effects of different policy options on the future sustainability of the SES?*

3 Study Area & Conceptual Framework

This chapter describes the specific characteristics of the case study region (3.1), why it was chosen, and introduces the framework used for this analysis (3.2), and described the way it was adapted to the particular case of CPP (3.3).

3.1 The case study region

Grindelwald is a municipality located in the heart of the Alps in the canton of Bern in Switzerland (E 8°01′48″/ N46°37′30). The municipality covers 171 km^2 with the highest peak reaching 4,100 meters above sea level and the village located 1,000 meters above sea level (Figure 1). Due to its natural beauty and snow-sport facilities, Grindelwald is an internationally known tourism resort that attracts visitors year-round. Consequently, tourism is the most important source of income and offers diverse employment opportunities. Unlike other rural regions, the local population remains stable with about 3,800 inhabitants.

Figure 1. The study region (Source: Own figure, adapted from Swisstopo)

Agriculture, in particular dairy farming, manages to coexist with tourism, even if the number of farmers is steadily diminishing as a result of structural change in the agricultural sector towards fewer, but larger-sized farms. Since 1980, the number of farmers in Grindelwald has roughly halved from 242 to 123 in 2010. As a consequence, the average farm size has nearly doubled in terms of livestock and land holdings from about 5-6 to nearly 12 livestock units and hectares per agricultural holding.

In addition to private land holdings, CPPs provide an important source of animal feed. In the summer months, when farmers produce hay on their private lands for wintertime, the livestock grazes on CPPs, looked after by herdsmen who produce artisan cheese from the milk. The herdsman is either the owner of the alp's huts himself or a seasonal employee. The fees farmers pay to the corporation for the care of the animals provides the herdsman's income. At the end of the season, the cheese stock is redistributed to the cattle owner according to the cows' milk yield.

3.1.1 Property arrangements in the study region

The pastures of Grindelwald became communal tenure at the beginning of the 15th century. Before then, the alpine pastures of Grindelwald belonged to the monastery of Interlaken, which supported a loose system of use rights that were leased to farmers in the region.

The first official claim on common property dates back to 1404. In order to prevent the pastures from being overused, six of the currently seven corporations agreed on a statutory regulation ("Taleinungsbrief") to govern the use of alpine pastures. The following two regulations constituted the main building blocks for the protection of the pastures from overuse:

1. Only animals that were fed from feed grown in the valley during wintertime were allowed to be summered on the CPP;
2. Every parcel in the valley was assigned a certain amount of use rights ("Kuhrecht"), according to which the farmer is allowed to subtract his share.

These regulations were an early attempt to solve the problems of exclusion and subtractability associated with CPR management. The statutory regulation was renewed several times (1538, 1867, 1923, and 2002). Since 1538 – with the entry of the corporation Bussalp – the property rights have been stipulated in the law, defining the corporation's territory as can been seen in (Figure 2). In accordance to this, each corporation has its territory separated into private parcels inside the red dotted lines, with everything outside the red dotted lines being defined as CPP area.

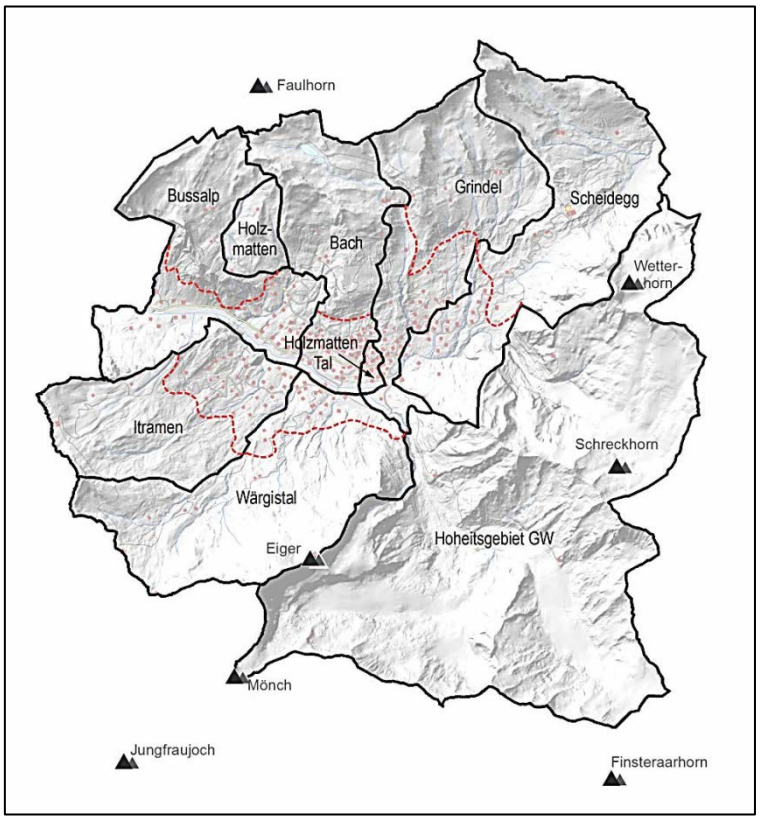

Figure 2. The seven corporations of Grindelwald (Source: Own figure, adapted from Swisstopo)

About 13% of the area is settlement area or agricultural area held as private property, 25% is commonly owned meadows (pastures), and 68% of the area is unused land. Unique to the case

of Grindelwald is the fact that seven spatially defined corporations ("Bergschaft") are embedded in a cooperative ("Taleinung"). The cooperative assigns the territory to the 7 corporations. The small alp "Pfingstegg" is the only alp that is privately owned. The alp Holzmatten (HM) is a special case. Since it is common property, it is not connected to the private property area in the valley(Naegeli-Oertle 1986; Tiefenbach and Mordasini 2006).

As mentioned above, the rights to use CPP depended on ownership or leasehold of private parcels in the valley. Therefore, the number and size of parcels in the valley grounds allows the farmers to use CPPs in the corresponding corporations. The individuals who make use of CPP in turn have to contribute to the upkeep of the resource system with 8-10 provision activities related to their appropriation levels (Table 1). For a long time, the corporations were also the dominant political units in the valley, fulfilling many welfare functions and providing public infrastructure such as schools, paths, and roads. Today, the influence of the corporations is limited to the agricultural sector and the governance of CPP pastures. Each corporation has its unique natural characteristics and different production structures, as indicated in Table 1.

Table 1.Characteristics of the 7 corporations

Corporation	Usage rights (LU)	Maximum sustainable yield (NST)	Alp-enterprises	Sections of Alp-enterprises	Common property pasture area	Provision hours per appropriated unit
Grindel	476	251	5	2	790	8
Scheidegg	365	234	7	4	830	8
Wärgistal	193	167	5	4	750	8
Itramen	347	217	8	3	685	8
Bussalp	432	256	7	3	496	10
Bach	263	149	4	2	630	8
Holzmatten	99	74	2	3	154	8
Total	2175	1348	38	21	4335	—

3.1.2 Motivation for choice of study region

With seven corporations self-governing the use of CPPs, Grindelwald offers a natural lab-like setting for the study of CPR use for several reasons:

- The long endurance of local governance in combination with good documentation of regulations applied to govern the use of CPPs provided an ideal setting for studying the evolution of the governance system and associated institutional change over longer periods of time;
- The fact that the 7 corporations operate under a binding agreement provides a good setting for cross-case comparison of the influence of ecological and social variables on the sustainable governance of CPPs;
- The rules to regulate appropriation and provision activities, which structure the central human environmental interaction, are transparent and structured similarly to those used in laboratory experiments such as CPR games and public good games;
- Work conducted in the early eighties in the regions provided a detailed analysis of the agricultural sector (Naegeli-Oertle 1986) , and its interlinks with tourism (Wiesmann 1983, 2001) which allowed tracking changes of the sector during the past thirty years in order to build a well-parameterized and calibrated model of the developments in the case study region.

3.2 The General Framework for Analyzing Social-Ecological Systems

For the analysis of coupled social-ecological (or human-environmental) systems, several interdisciplinary frameworks exist that provide different perspectives and emphases on the characteristics of the SES, such as:

- Resilience (Gunderson and Holling 2002; Walker et al. 2004);
- Transitions (Fischer-Kowalski and Rotmans 2009; Haxeltine et al. 2008; Pahl-Wostl et al. 2010);
- Land-use change (Redman, Grove, and Kuby 2004; Turner and Robbins 2008; Turner, Lambin, and Reenberg 2007);
- Social-ecological feedbacks (Liu et al. 2007);
- Robustness (Anderies, Janssen, and Ostrom 2004; Janssen and Anderies 2007);
- Self-organization (Ostrom 2007, 2009).

The latter SES framework was chosen because of its implicit focus on institutional analysis (McGinnis and Ostrom 2010), and its proposition of a set of concrete variables. An additional advantage for this study was also the fact that Ostrom's SES framework allows for the analysis of different degrees of specificity due to its nested conceptualization in different tiers (Binder et al. 2013). On the highest level of analysis, any SES consists of 4 subsystems embedded in a broader social, economic, and political setting. As displayed in Figure 3, the system's social compartment consists of the Governance System (GS) and the Actors (A). The ecological compartment entails the Resource System (RS) and the Resource Units (RU). These subsystems interact (I) at various spatial and temporal scales to produce outcomes (O). The functioning of the SES affects adjacent ecosystems (ECO), for example, through externalities or by provision of spatially overlapping ecosystem services.

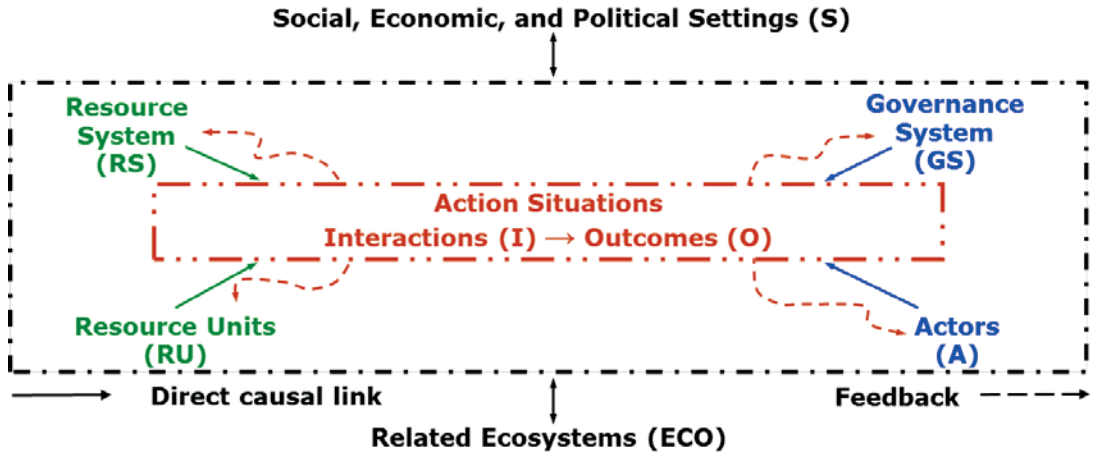

Figure 3. Framework for analyzing sustainability of social-ecological systems on the first tier (Adopted from Ostrom 2007)

Each subsystem can be divided into further tiers. The second tier consists of a set of variables potentially associated with successful self-organization (Table 2).

Table 2. Variables describing social-ecological systems in the second tier.

Social, economic, and political settings (S)

S1 Economic development. S2 Demographic trends. S3 Political stability.
S4 Government resource policies. S5 Market incentives. S6 Media organization.

Resource systems (RS)

RS1 Sector (e.g., water, forests, pasture, fish)
RS2 Clarity of system boundaries
RS3 Size of resource system*
RS4 Human-constructed facilities
RS5 Productivity of system
RS 6 Equilibrium properties
RS7 Predictability of system dynamics*
RS8 Storage characteristics
RS9 Location

Governance systems (GS)

GS1 Government organizations
GS2 Nongovernmental organizations
GS3 Network structure
GS4 Property rights systems
GS5 Operational rules
GS6 Collective choice rules*
GS7 Constitutional rules
GS8 Monitoring and sanctioning processes

Resource units (RU)

RU1 Resource unit mobility*
RU2 Growth or replacement rate
RU3 Interaction among resource units
RU4 Economic value*
RU5 Number of units
RU6 Distinctive markings
RU7 Spatial and temporal distribution

Users (U)

U1 Number of users*
U2 Socioeconomic attributes of users
U3 History of use
U4 Location
U5 Leadership/entrepreneurship*
U6 Norms/social capital*
U7 Knowledge of SES/mental models*
U8 Importance of resource*
U9 Technology used

Interactions (I)→Outcomes (O)

I1 Harvesting levels of diverse users
I2 Information sharing among users
I3 Deliberation processes
I4 Conflicts among users
I5 Investment activities
I6 Lobbying activities
I7 Self-organizing activities
I8 Networking activities

O1 Social performance measures (e.g., efficiency, equity, accountability, sustainability)
O2 Ecological performance measures (e.g., overharvested, resilience, bio- diversity, sustainability)
O3 Externalities to other SESs

Related ecosystems (ECO)

ECO1 Climate patterns. ECO2 Pollution patterns. ECO3 Flows into and out of focal SES.

*Variables found to be positively associated with self-organization (Ostrom 2009)

Recent framework developments

During this dissertation the original framework as presented in Table 2, has been amended with regard several aspects. Users were changed into Actors in order to have a more general category including Third parties and stakeholders that do not make direct use of the resource (McGinnis and Ostrom 2014). This dissertation refers mostly to actors instead of users except where a clear differentiation between direct users of CPP (farmers) and non-farmers with use rights was necessary. Other amendments of the framework included renaming or adding of variables into the framework (Basurto, Gelcich, and Ostrom 2013; Epstein et al. 2013; Ostrom and Cox 2010). These changes could not be considered in the conceptual phases of this dissertation but are taken up in the discussion section. Another major step in the development of the framework has been the explicit integration of the Institutional analysis and development (IAD) into the SES framework (McGinnis and Ostrom 2010) which was considered for answering the first research question. For a general overview about frameworks evolution see McGinnis and Ostrom (2014).

3.3 Applying the SES Framework to the Case Study Region

The use of the common property pasture (CPP) in Grindelwald is analyzed based on the general framework for analyzing social ecological systems. In the framework in Figure 4, that characterizes the CPP management system, includes farmers as the main actors, their interaction with the resource system and units, and the local governance system. The SES and its functioning are influenced by external societal and environmental factors such as agricultural policies or climate change. As farmers heavily rely on subsidies paid by the federal government, farmers land use decisions are substantially influenced by the policy setting. Farmers interact with the common property resource system through appropriation and provision activities. With regard to appropriation, farmers need to decide on the number of livestock they would like to send to the alp. With regard to provision, farmers need to decide how many labor and monetary resources they will dedicate to the upkeep of the resource system and its ability to provide resource units.

The local governance system determines the social-ecological interactions through appropriation and provision rules. Appropriation rules assign the right of usage (“Kuhrechte”) to local individuals based on their land holdings. Thus, appropriation rules serve first to limit the number of actors using the CPPs, and second to regulate the appropriation level to implicitly define a maximum appropriation level. Provision rules aim to ensure the upkeep of the resource system. Dependent on the actors’ appropriation level, the governance system requires provision activities from the actors (see Table 1) and monitors and sanctions non-compliance.

The rules of the governance system can be changed by the farmers through collective choice processes in order to balance or change the incentive structure for the use and maintenance of the CPP. The rule-making process can thus be determined and adapted to the external setting, which includes agricultural policy incentives, federal legislation, tourism development and environmental developments such as climate change.

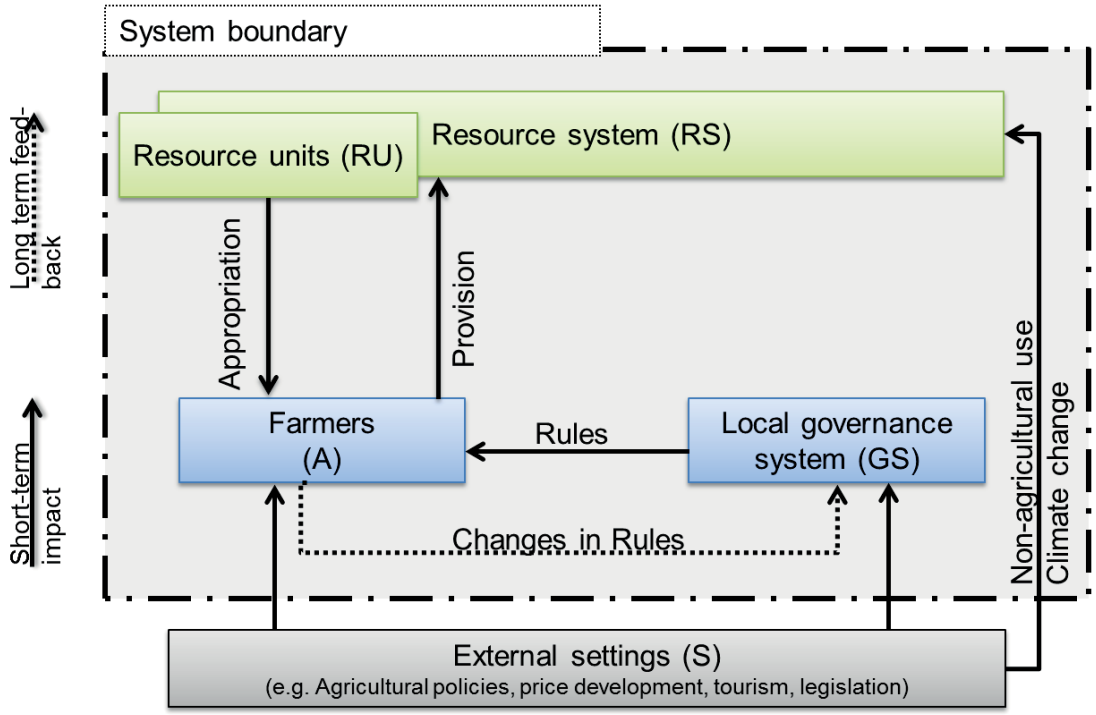

Figure 4. Conceptual framework for analyzing the use of common property pastures (CPPs) (Source: Own figure).

As mentioned above, the state of the environmental system depends on appropriation and provision levels. Furthermore, external societal and environmental factors such as climate change could impact the environmental system by altering the timber line or the provision of resource units (feedstock). Furthermore, the state of the resource system might also depend on the touristic demand for land use and the respective infrastructure, which potentially impacts land use and land cover, possibly also through non-agricultural activities.

4 Procedure & Methods Applied

The research reported herein consists of specific qualitative and quantitative methods tailored to the different research questions and goals of the modules as displayed in Table 3.

Table 3.Overview of procedure & methods applied

Module	Goal	Key subsystems and interactions (in brackets)	Empirical bases	Methods applied	Output
Module 1	Analyze institutional adaptations of the local governance system	Governance System (GS ↔ S) (GS ↔ A)	Statues and Interviews	Coding through "ADICO"	Essay 1
Module 2	Analyze farmers' land-use decisions	Actor System (A ↔ RS) (A ↔ RU)	Survey data	Logit regressions	Essay 2
Module 3	Link farmers' land-use decisions to changes in the resource system	Resource System (RU ↔ RS) (A ↔ RS)	Land cover and land-use statistics	Qualitative assessment of spatial data	Essay 3
Module 4	Integration of knowledge from modules 1-3 into a simulation model	SES (social-ecological feedbacks)	Modules 1-3	System dynamics	Essay 4

4.1 Module 1: Analysis of the Local Governance System

Module 1 analyzed the rules and their adaptations to external and internal socio-economic developments based on qualitative methods such as interviews and the coding statutes using the "ADICO" syntax-scheme.

Several volumes of statutes were collected from the cooperative as well as from the corporation Scheidegg, covering the period of 1967 to 2003. The statutes provided a detailed account of the governance system's organizational principles and the rules applied for the governance of the CPPs. The statutes were then coded for institutional change following the ADICO syntax. According to Crawford and Ostrom (1995), institutional statements are

> "*... shared linguistic constraint or opportunity that prescribes, permits, or advises actions or outcomes for actors."*

Furthermore, institutional statements consist of a minimum of 3 and a maximum of 5 of the following components:

- Attribute (A), which describes for which subject the statement applies;
- Deontic (D) is a verb that describes whether the particular action is required (e.g., must), permitted (may), or forbidden (must not);
- aIm (I) describes the action;

- Condition (C) defines where, when, and possibly to what extent the statements applies;
- Or else (O) defines the type of sanction to be applied for non-compliance;
- And can form a shared strategy (ADI), a norm (ADIC), or a rule (ADICO).

After coding, the resulting institutional framework was validated and contextualized as adaptations to socio-economic changes through a series of interviews with farmers, the monitors of the corporations, and the president of the cooperative.

4.2 Module 2: Analysis of the Actors System

Module 2 aimed to assess the explanatory factors for farmers' land-use decisions within the given institutional constraints. Data was collected through a standardized survey, which was conducted during three weeks in June 2011 in Grindelwald.

The SES framework was used to design the survey question with the aim to investigate how actors' attributes affect the individuals' behavior with regard to three focal land-use decisions:

- Change in livestock endowment;
- Appropriation behavior;
- Provision behavior.

The survey referred to the past ten years for change in livestock endowment and to the past season for appropriation and provision behavior. A total of 95 questionnaires were collected from 125 registered local farmers, mostly at their homes. Data gathering was conducted in 3 teams with a graduate student posing the questions and an undergraduate filling in the farmers' answers. The sample included mostly males (93.7%), with an average age of approximately 52 years. The statistical analysis was based on maximum likelihood (ML) estimations to build separated models for the three land-use decisions that link behavior to individual attributes.

In order to investigate how contextual variables describing the SES affect the behavior, a Q-Method approach was adopted. Eleven local farmers, who were deemed to have in-depth knowledge of the functioning of the SES, were selected for the procedure. Farmers had to put a total of 34 statements (variables) in rank order on a Likert-scale scheme (q-sorting scheme) according to their contribution to the sustainable use and maintenance of the CPP.

The collected samples were analyzed with the standard PQ Method software, Version 2.31. Mean z-scores were calculated for each statement and the corresponding rank to represent the aggregate view. Data was then analyzed according to the standard q-approach (Fairweather and R. Swaffield 2001; Paula 2006). This included the calculation of mean z-scores for the variables, principal component analysis, and a varimax rotation in order to achieve insights on the different views about the role of contextual factors (e.g. agricultural policies) in promoting sustainable use of CPP.

4.3 Module 3: Analysis of the Resource System

Module 3 focused on land use and land-cover change. In a first step, land cover data from areal statistics was analyzed for different time periods from 1979/85, 1992/97, and 2004/09((FSO) 1979-2009). In a second step, the observed land-use changes were assessed qualitatively with farmers, followed by a semi-quantitative questionnaire which was

conducted with the seven monitors. The themes covered in the questionnaires and interviews were:

1. The current use of the summering area. Monitors mapped which part of CPP was used when and with what type of animals;
2. Pasture quality and its determinants. Monitors had to indicate qualitatively the areas with better and worse quality and determine the reason that make particular areas more favorable;
3. Process of pasture selection. Monitors were asked according to which criteria they select pastures that are subject to land-use change such as abandonment;
4. Determining the role of communal work for maintaining the resource systems and pasture quality. Monitors indicated where maintenance efforts are particularly needed and whether current amount of provision work is sufficient to maintain current status of CPP;
5. Monitors were asked basic questions about the future development of the corporations such as how many farms will abandon their farm, or about the development of provisions activities or defections on it, respectively.
6. Definition of land-use scenarios. Monitors had to define which part of the corporations CPP area is most prone to abandonment and whether and when approximately this will take place.

Based on this qualitative data parameters for a GIS-based cost–distance model were derived to model pastures' use. The model allowed generating a spatially explicit land-use model for the analysis of current and potential future land use and land-cover changes. The model aimed to assess the productivity and accessibility of particular CPP areas based on a surface grid involving variables such as topography and enabling or accelerating factors like slope, distance from barn, paths, bridges, and physical barriers, such as dense forests or rivers.

4.4 Module 4: Modeling the Local Social-Ecological System

Module 4 aimed to integrate the insights from modules 1-3 by building an empirically-based simulation model of the SES. The model was built following a system dynamics approach (Ford 1999; Sterman 2001) to match the historical development of the SES. Formative scenario analysis was used to define a potential and consistent set of changes in the external setting of the SES to simulate its potential future states(Wiek, Binder, and Scholz 2006). As such, the model should then serve as a tool for the assessment of the impact of different policy options on the sustainability of the SES.

The aim of the model was to achieve a better understanding of the dynamics behind the empirical observations from earlier modules. Previous observations have shown that findings were highly context-dependent, so that no theoretical model will adequately represent empirical findings of modules 1-3 without overgeneralizing facts. Therefore, modeling approaches based on stylized facts, laboratory or field experiments, or role games would not account for the specific properties of the SES in Grindelwald. Accordingly, a simulation model representing the SES of Grindelwald as realistically as feasible was needed to account for the specific components and interactions of the local SES.

4.4.1 Purpose of the model

The purpose of the model is to understand the social-ecological drivers in the use maintenance of CPP pastures through application of the SES framework. Given the tendencies of abandonment of CPPs in Switzerland, the model needs to address, unlike most models of CPR

use, not just the dynamics leading to overexploitation of natural resources, but also the dynamics and consequences of underuse. By simulating changes in the external setting, the model should help to separate the processes and policy options, under which the SES approaches or maintains sustainability, from those that shift the SES away toward less sustainable states of over- or underuse. Furthermore, simulation results should then uncover the different sustainability trade-offs associated with particular policy options (Janssen and Anderies 2007) as a base for scenario assessment.

4.4.2 System dynamics

The system dynamics approach was developed in the 1950s in economics and from there has been applied to various disciplines that seek an understanding of developments in complex systems. System dynamics modeling is particularly recognized for its ability to deal with internal feedback loops, non-linear relationships, and time delays that affect the behavior of a system.

As the SES framework was developed with certain system theoretic considerations, such as decomposability, feedback between subsystems, and non-linear relationships between variables, system dynamics provides an appropriate tool for applying the framework to the case study. While alternative methods such as agent-based modeling (ABM) also allow for the implementation of the same system properties, they had some disadvantages for our purpose. Firstly, due to the different programming surfaces (stock and flow versus codes), we assumed that farmers or experts may more readily understand structural aspects when feedback structures were clearly visible as relationships between stock and flows. Secondly, our aim was to develop a model of the SES at an aggregate level that displays the interactions between different subsystems rather than interactions. Since modules 1-3 did nod focus on actor-actor interactions, the main motivation for agent-based modeling was eliminated by the previous research questions. Thirdly, system dynamics can rely on well-established procedures for model testing and validation (Barlas 1989; Oliva 2003) which is still an open issue in the younger field of ABM (Rahmandad and Sterman 2008). Fourthly, ABM is more resource intensive, requiring more time and attention from both modelers and decision-makers. As the modeling of all SES components encompasses a rather large system boundary, an ABM of the whole social-ecological system would have limited the scope of the model and constraint sensitivity (Ford 2000)

4.4.3 Formative scenario analysis

In order to define a consistent set of scenarios for simulating the potential trajectories of development of the SES, formative scenario analysis was used (Wiek, Binder, and Scholz 2006; Scholz and Tietje 2002). The aim of running the model under different scenario assumptions is to predict how different policy options will affect the SES and particular outcomes. I hereby concentrated on developments in the external setting (S), and 8 variables of the external setting and the respective potential values of variables were identified based on literature review and previous work conducted in the study region. The variable set and hypothetical values were then validated in expert interviews and refined afterwards. Based on the validated impact factors and potential future levels, the impact matrix was developed. The impact matrix was completed four times in total, with a total of 10 experts including agronomists, farmers, and tourist officials. Each expert only filled in parts of the matrix according to his field of expertise. The completed matrices were then computed using KD software provided by Syst^{aim}. Consistency indicators for scenario selection included (i) additive consistency, which is the sum of all coefficients, (ii) the multiplicative consistency, which is the average rate of additive consistency, (iii) the number of inconsistencies in a scenario, (iv) and the minimum number of consistency (Tietje 2005). Finally, the procedure

provided a ranking of a hypothetical combination of parameter developments, which were internally most consistent and at the same time covered the widest possible developments of trajectories in external developments.

5 Results

This section summarizes the most relevant findings of this thesis, organized according to research questions (Chapter 2) and the 4 modules (Chapter 4). Further details can be found in the respective publications (see *Section B – Manuscripts*).

5.1 Institutional Adaptations of the Local Governance System

The first question needed to resolve whether local governance systems originally designed to avoid overuse of scarce resources have become a dysfunctional trait of the SES by contributing to its underuse. Therefore, the first research question was: *Do local governance systems in the Swiss Alps change institutions in order to adapt to the socio-economic changes to avoid reduced use and maintenance of CPPs?*

The observed institutional adaptations as summarized in Table 4 show that governance systems originally designed to avoid overuse of scarce resources can change their properties through institutional changes mainly to relax exclusion and subtractability. However, the drivers behind these adaptations are not just a decreasing use of CPP, but rather a wider set of socio-economic changes such as governmental resource policies (S5), the regulations that come with federal efforts to foster the use of CPPs, or a decreasing number of right holders who do not make use of their rights (A1). It must be pointed out that previously listed adaptations result from particular problems and thus cannot be considered as general adaptations patterns. Nevertheless, the study indicates that some general governance principles, which facilitate adaptive governance, can be highlighted:

- Constitutional flexibility: allows the governance system to adapt its structure to problems such as the decreasing bargaining power of those most interested in the productivity of the resource system.
- Multiple nested assemblies: allows the identification of competencies among different assemblies to ensure that issues are dealt with in the right assembly.
- Polycentric design: ensures vertical integration and control between user groups concerning the rules they are crafting, and at the same time ensures the flow of information regarding the performance of rule configurations.
- Subsidiary design: allows the change of rule configuration by the people who are best informed about the state of the system.

Table 4. Institutional adaptations of the local governance system

GS- Variable	Institutional Change	Adaptation to
GS4- Property rights systems	With regard to the exclusion principle, use rights do no longer exclusively define access to CPPs. Since 2005, the cooperative may allow corporations to appropriate cattle of non-right holders. With regard to the assignment of appropriation levels, use rights have lost their relevance, as they are abundant compared to livestock in the valley.	RU5- Number of resource units: Decreasing number of livestock on the alps
	Provision activities are no longer assigned based on the use rights of the individual.	A1- Number of Actors: Increasing number of people holding use rights do not appropriate from the commons.
	The total amount of use rights no longer serves to define Maximum Sustainable Yield (MSY).	S4- Government resource policies: Summering payments are conditioned upon prescribed cantonal MSY. Thus, monetary incentives urge corporations to respect cantonal MSY.
GS5- Operational rules	Division between the position of the appropriator and the right holder. Provision rules became tied to these two positions. Appropriator needs to conduct provision activities based on his appropriation levels (formerly based on use rights).	A1- Increasing number of people holding use rights do not appropriate from the commons.
	Hours of communal work conducted with light private machinery (e.g., a jigsaw) are counted double. Hours of communal work conducted with heavy private machinery (e.g., small transporter) are counted four-fold.	A9- Technology used: Modernization of farmers' machinery fixture
	A newly added rule state that the infrastructure particularly huts and barns on the alp, must not be used for purposes other than agricultural use, and that they cannot be sold to non-right holders.	S1- Economic development: Increasing demand in the tourism sector for recreational infrastructure
GS6- Collective choice rules	Voting within the association was conducted according to individual rights. Currently, all collective choices at all levels are made according to majority rule (50% +1).	S*- Federal law: alignment with the voting procedures for corporations and cooperatives as defined in civil law. At present, every actor holding property rights is assigned one vote.
GS7- Constitutional rules	Corporations became split into a right holders' association and a users' association.	A1- An increasing number of people holding use rights do not appropriate from the commons.
	Payoff rules can now be autonomously set by the users' association mainly through the setting of fees for over- and under-provision of communal work.	No specific adaptation process identified, but important steps are considered toward decentralization and subsidiarity with regard to rule design.

S* the Variable is part of the external settings but can be attributed to a particular third-tier variable

5.2 Farmers' Land-Use Decisions

As farmers in the study region followed different strategies with regard to changes in livestock endowment, appropriation, and provision behavior, the second question aimed to explore the causes for behavioral deviations in CPP use by asking: *Which individual attributes explain differences in the behavior of real CPR users in the field with regard to factor endowment, appropriation, and provision activities?*

As displayed in Table 5, livestock endowment can be well explained by the socio-economic attributes of users as indicated by the high Nagelkerke R-squared. Age (*U2a*), marital status (*U2b*), and area (*U2c*) explained farmers' changes in livestock endowment. The role of age and marital status is best explained by their effect on work organization, as youth and partnership allow the handling of larger endowments. Furthermore, the variable area suggests that farm size itself is the strongest predictor of endowment growth. Furthermore, the negative association of area *(U2b)* with appropriation and provision behavior in particular suggests that farmers with larger-sized farms concentrate labor on private property with reduced use of common property.

Appropriation behavior was shown to have the strongest association with norms (U6a), measured as farmers' aversion against defection on provision, which points to self-interest as a motivational driver. As individuals who make more use of CPPs are also more concerned about the productivity of the resources, they consequently hold stronger norms regarding provision fulfilment. Self-interest might equally explain the association of payoff (*U5b*) and the importance of resource with full provision behavior. Hence, the greater the willingness of individuals to maintain a common pool resource, the more individuals rely on the resource for their livelihood and the higher the generated payoffs.

*Table 5. Direction of significant effects of individuals' attributes on livestock endowment, appropriation, and provision behavior calculated by binary logistic regression (99%***, 95%**, 90%*).*

Method	Regression Models		
Variables	Livestock endowment	Appropriation	Provision
U2a- Age	(−)***		
U2b- Marital status	(+)**	(+)*	
U2c- Area	(+)***	(−)*	(−)**
U5a- Leadership		(−)*	
U5b- Payoff			(+)**
U6a- Norms	(−)**	(+)***	
U8- Importance of resource			(+)*
N	94	93	86
Pseudo R^2 (NK)	0.514	0.220	0.248
−2LL	82.6	109.0	34.6
BIC	105.2	131.6	52.4

As behavior in these situations must be considered context-specific (Anderies et al. 2011; Poteete, Janssen, and Ostrom 2010), findings may not be valid in other social-ecological settings. Thus, context might vary, particularly for settings where users' aggregate behavior leads to over-exploitation rather than underuse. Therefore, the impact of contextual variables on behavior had to be investigated separately, which was done by q-method approach.

The impact of the contextual variable on the use of common property pastures

Among the subsystems that were considered to contribute positively to the use and maintenance of CPPs were the resource units (*RU*) and to a lesser extent group attributes (*A*). The subsystem challenging sustainability included external settings (*S*), the resource system (*RS*), and interactions (*I*). The role of the governance system (*GS*) was considered neutral.

In particular, the value of resource units (RU4) was considered to have the most positive impact on the sustainability of CPPs. As the economic value affects an individual's payoff ability, a close positive relationship exists between the value of resource units' appropriation activities and the fulfilment of provision activities. With regard to actors' attributes, farmers considered the number of users (U1) and their leadership and entrepreneurial skills (U5) positively.

With regard to the external setting (S), farmers associated most negative effects on CPP use with agricultural policies. Both government resource polices (*S5*) and market incentives (*S6*), which are both heavily regulated by the federal government, achieve negative scores. The most problematic issues include dependence on direct payments, regulations for obtaining them, and the milk price. More positively evaluated was the role of tourism in promoting the use of the Alps, mainly due to the fact that farmers acknowledge the positive effect of tourism in strengthening local demand and the economic value of resource units, and thus payoffs. Furthermore, tourism allows for livelihoods with balanced agricultural and off-farm activities, reducing the need to increase farm size, which farmers assumed would lead to reduced use and maintenance of common property pastures. As a result, tourism can be seen to enable rather than compete with farming livelihoods, although it does result in increasing demand for building sites and reduces available productive agricultural land in the resource system (*RS*).

5.3 Land-Use and Land-Cover Change on CPPs in Grindelwald

After identifying the main social dynamics with regard to the institutional structure of farmers' use of CPPs, the third research question sought to link social processes to observable changes in the ecological system. Therefore, we focused on land-use and land-cover change by asking: *What land-use and land-cover change can be observed in the case study region and what are the particular drivers behind these changes?*

5.3.1 Land use

The monitors of the seven corporations highlighted the following factors as major drivers for land-use patterns in terms of attributes, which make plots productive and thus less likely to be abandoned.

- Short distance to barn
- Gentle slope
- Plant composition (high feed value)
- Water availability

Factors, which may lead to abandonment or disregard of potential pasture, were mostly site-specific and included such variables as natural hazards (e.g., rockfall potential), swampy, humid soils, areas interspersed with rocks, and poisonous plant composition.

Farmers stated that recent land-use change took place in some marginal areas that had one or more of the previously listed attributes. Monitors explained these land-use changes with the following social process:

- Increasing workload on agricultural holding, leading to reduced use of CPP (as confirmed and suggested in Module 2);
- Number and type of livestock summered. The slight decrease in summered livestock was considered to have a marginal effect on grazing patterns, while the type of livestock summered was considered more important. With regard to dairy cows, even though their number has remained stable, their feed requirements and weight have been increased through breeding, making them less mobile and making it necessary for farmers to graze them closer to the barn on gentle slopes. This tendency has been accentuated, as cows from the lowlands have been accepted for grazing on CPPs because these breeds are not well adapted to mountainous conditions
- Increasingly, alp enterprises are run by seasonally hired external laborers, which are less concerned with the maintenance of the resource system pasture and instead emphasize cheese production and cattle herding.

5.3.2 Land-cover change

Grindelwald extends more than 17,000 ha, more than half of which is unproductive land. Almost one-third is agricultural land. When comparing longitudinal land-use statistics ((FSO) 1979-2009), the settlement area has increased by 27.5%, forest stands covering 2,802 ha have increased by 2.6%, while agricultural land has decreased by -3.4% since 1980. However, these statistics do not differentiate between common and private property. Thus, a second source (Alporama 2013) was considered, which allowed for assigning statistically registered land-cover changes with regard to the CPP area. According to this source, CPP pastures have decreased by 3.6% from 3,272 to 3,154 ha between the years 79/85 to 04/09. As there was only a marginal change to the area of overgrown pasture, it must be assumed that 118 ha of a total of 212 ha of forest growth took place in the common property area.

Based on land use criteria identified in the monitors' survey, potential land abandonment was visualized by a GIS-based cost-distance model (Figure 5). It shows that those summer pasture areas are most prone to shrub or forest encroachment by modeling the time that is required to walk from any point (cell) in the study area to the next barn, considering enabling factors such as paths (allowing further walking distances and crossing brooks and forests) and hindering factors such as brooks, impenetrable forests, or steep slopes (slowing down or diverting movement). The more the colors turn to dark red, the more prone the pasture is to abandonment and thus – depending on altitude – to shrub or forest encroachment.

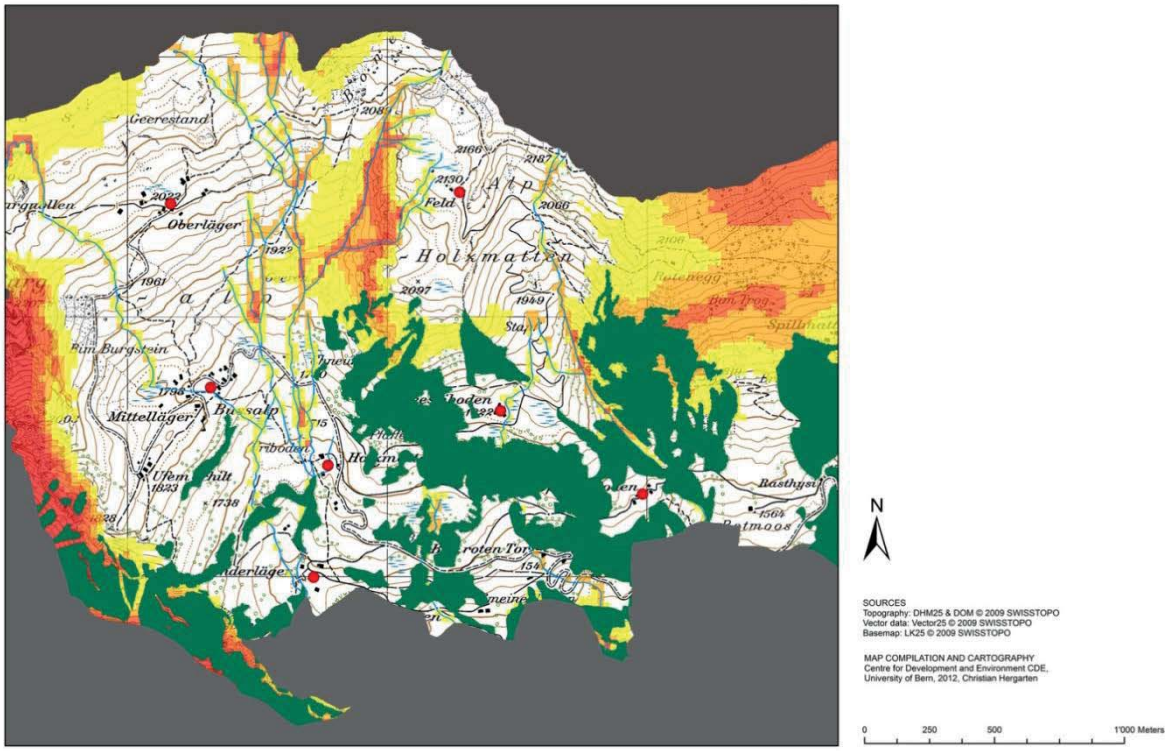

Figure 5. Summer pasture area most prone to gradual abandonment and to subsequent shrub or forest encroachment (zoomed-in detail covering the areas of two Alpine corporations). The more the colors turn to dark red, the more prone the pasture is to abandonment and thus – depending on altitude – to shrub or forest encroachment.

5.4 Modeling the Social-Ecological System

The fourth research questions tried to determine, how previous findings regarding the governance of CPP, actors land-use and the observed land-cover changes can be interlinked to provide a holistic understanding of the SES. Therefore, the fourth research question was: *How can the findings from the analysis of the subsystems be integrated into a simulation model to represent the specific characteristics of the local SES and to test effects of different policy options on the future sustainability of the SES?* To answer this research question, a System Dynamics model of the SES was developed and potential scenarios were identified using formative scenario analysis and simulated.

The baseline simulation of the SES reveals a moderate decrease in the use and maintenance of private plots in the valley as well as CPPs, which led to a slight abandonment of CPPs between 1980 and 2010. As displayed in Table 6, simulated key developments of the SES included:

- In the actors system: process of structural change towards larger but fewer farm holdings and decreasing land use intensity as a result of changes in agricultural polices (market deregulation and increased direct payments), which reduced the number of livestock units in Grindelwald;
- In the resource units: The fewer livestock units present in the valley also impacted on the CPP use with reduced stocking density;
- In the governance system: adaptation to a decreasing number of livestock units lead to changes in operational rules, as corporations start to summer foreign cattle;

- In the resource system: as a consequence of reduced stoking density, the model simulated a reduction of grazing area of 193 ha between 1980 and 2010.

Table 6. Value for selected variables describing past and potential future development of the SES (rounded values).

	Baseline Simulation 1980 -2010		Scenario simulation for 2040			
	Initial values (1980)	Simulated values (2010)	Rising prices	Liberalization and economic growth	Government support	Crisis
Actors System (A)						
Farm households (hh)	242	126	62	50	64	60
Livestock units per household (LU/hh)	6.3	10.8	24.9	25.7	15.9	25
Land use intensity on private parcels	1.13	0.96	1.06	0.88	0.69	1.25
Household income (CHF nominal)	64725	87238	121610	31406	155284	113497
Resource units (RUs)						
Livestock in the valley (LUs)	1525	1358	1347	1271	1022	1497
Stocking density of CPPs (SLUs)	1448	1393	1199	914	996	1204
Foreign cattle summered (SLUs)	0	22	141	283	243	139
Governance System (GS)						
Net provision (hours)	16000	13832	12629	9779	10485	12670
Provision not fulfilled (hours)	0	1260	3034	3490	2408	3436
Resource System (RS)						
CPPs in use (ha)	4375	4182	3444	3175	2754	3513
Average productivity of summer pastures (kg DM/ha/day)	15.00	15.32	16.32	16.65	17.22	16.25
Overgrown common property Pastures (ha)	163	13	519	667	702	482
Forest (ha)	2130	2473	2705	2826	3212	2673

The simulation of the scenarios showed that the use and maintenance of CPPs will further decrease in the near future with subsequent loss of CPP area and forest regrowth. With regard to the use and maintenance of CPPs, scenario 1 (price increase) and scenario 4 (crisis) produce more desirable outcomes than scenarios 2 and 3 (liberalization and government support).

In the rising prices scenario, farmers benefit from a favorable market environment shaping incentives for relatively intensive stocking of private plots as well as of CPPs. As a consequence, the trend of forest regrowth continues, but is not accelerated.

In the liberalization scenario, structural change is accelerated against the baseline trend and household income decreases drastically. Only farmers with strong preferences for agricultural livelihoods remain in the sector. As a result, the number of farmers is reduced because they concentrate their efforts on rather large farms in the valley, rather than on using and maintaining the CPPs. As a consequence, the simulation model predicts the abandonment of about 400 hectares for this scenario.

Surprisingly, the government-support scenario sees the lowest levels of use and maintenance of CPPs. The increase in direct payments slows structural change and impedes farm growth, as farmers conveniently live on land rents. The average holding thus increases to 16 LUs and land use intensity is very low because there is no need to generate income from marketable dairy products. As a consequence, this scenario predicts a process of afforestation.

In contrast to this, CPPs are most intensely used and maintained in the crisis scenario. In this scenario, agriculture becomes a very feasible livelihood because the cost of production and off-farm income decrease, whilst prices for agricultural commodities are comparatively high. This shapes incentives for farmers to use their private plots more intensely than they currently do. However, the crisis scenario pictures a situation where the use and maintenance of CPP is most intense and land abandonment lowest, albeit potentially at the cost to intensely used private parcels due to increased land use intensity in the valley.

However, the simulated changes in the external setting have a delayed impact on land-use and land-cover changes. Since the scenarios are simulated as continuous developments, the actors and governance system will closely follow the patterns produced in the baseline simulation until 2018. Since the changes in the social system affect the ecological system with delays in land-use change and land-cover change, changes in the external setting take about 10 years to become visible in the form of afforested area in the resource system.

6 Discussion

This section discusses first the theoretical and empirical relevance of the study in the context of commons research (6.1), including possibilities for further framework improvement (6.2.). Furthermore, the implications for policy makers are discussed (6.3), as well as the limitations of the present study and recommendations for further research (6.4).

6.1 Relevance of the Findings for the Study of the Commons

This study provides an application of the SES framework (Ostrom 2009) to the example of CPPs in Grindelwald in the Swiss Alps. The analysis was divided into four modules devoted to the particular subsystems. In each module, a different methodological approach (tailored to the research question) was applied. The thesis thereby contributed to the three most important sub-branches within the study of the commons (Janssen and Ostrom 2006; Ostrom 2007):

- Institutional analyses (Module 1);
- Experimental studies on cooperative behavior (Module 2);
- Modeling of social-ecological systems (Module 4).

In addition to the contribution in the three sub-branches, the thesis also showed in Module 3 how a less developed field within the study of the commons – the investigation of the functioning of resource systems – can be approached, which was herein considered as crucial premise for the modeling of SES.

6.1.1 The contribution to institutional analyses

Module 1 provides an empirical analysis of the institutions over a longer time period, applied to govern CPPs. The quality of such institutions is key to sustainable CPR use (Adger et al. 2005; Gibson, Williams, and Ostrom 2005; McCay 2002). Various empirical analyses have focused on institutional design applied to govern CPRs (Acheson 2003). Although various theoretical tools are at hand for studying institutions (Beckmann and Padmanabhan 2009; Ostrom 2005; Scott 1987), they are rarely applied to CPR governance problems. Furthermore, theoretical concepts are mainly designed for static analysis. Thus, systematic studies of institutional change remain a major methodological challenge (Ostrom 2008; Ostrom and Basurto 2011). Module 1 provides an example for how the grammar of institutions (ADICO) can be systematically and empirical applied to study institutional change in CPR governance. Secondly, it shows how institutions and their dynamics can be assessed as process of adaptive governance. Therefore, research on Module 1 might serve as an example of how empirical institutional analysis may be conducted to overcome shortcomings, such as the lack of systematic ordering and classification of institutions, and its static treatment.

The SES framework proves to be a good starting point for this endeavor. However, in-depth institutional analysis needs to be based on the institutional analysis and development framework (IAD), including ADICO, particularly for the analysis of operational rules. Although the SES framework is (implicitly) based on IAD (McGinnis and Ostrom 2010), it would be valuable to expand the rules variables (GS5-8) into a further tier, in particular with regard to operational rules, which turned out to form the core of institutional adaptations.

Findings in Module 1 suggest that institutional adaptations are key to successful long-term governance. Although originally designed to avoid overuse of the CPR, changes in institutions counteract tendencies of underuse. In this study, I found that a change in the organizational structure of corporations allowed for more subsidiarity in decision-making and

thus helped balancing the power between the corporation members who use CPPs, and the members who do not. Subsidiarity was considered an important condition for effective institutional adaptations in particular with regard to operational rules. Effective measures included alteration of appropriation and provision rules that eased the exclusion principle to counteract understocking of CPPs.

6.1.2 The contribution to behavioral research on cooperative dilemmas

Module 2 provides insights on behavioral drivers of individuals in cooperative dilemmas. Cooperative behavior is an extensively researched field, usually by means of experimental methods (Anderies et al. 2011; Cardenas and Ostrom 2004). Laboratory experiments seek to manipulate experimental design to achieve insights on the effects on institutional constraints such as communication (Bochet, Page, and Putterman 2006), sanctioning (Fehr and Fischbacher 2004; van Soest and Vyrastekova 2007) and payoff functions (Janssen and Ahn 2006) on the aggregate levels of cooperation. However, the situation in the lab differs substantially from that encountered by real CPR users. The laboratory does not provide a social-ecological context, and psychological traits and respective behavioral drivers of Western students might be very different from those of Alpine farmers. Thus, the answer to the fundamental question as to why CPR users in the field may differ in their behavior cannot be answered by experiments alone. The analysis in Module 2 showed which individual attributes account for differences in cooperative behavior in CPR dilemmas and therefore aimed to complement the experimental evidence.

We found that the actors' use of CPR resources is explained by two major drivers: Firstly, socio-economic-attributes (U2), particularly landholding, and secondly, self-interest manifested in the variables leadership/entrepreneurship (U5), norms/social capital (U6) and importance of resource (*U8)*. With regard to contextual factors, the value of resource units (RU 4) was deemed most important, as it directly contributes to payoffs. The findings are thus largely congruent with users' attributes identified in the SES framework as promoters of self-organization (Ostrom 2009). Our study, however, provides further insights about the way variables promote pro-social behavior on the individual level. The analysis suggests that the larger the endowment of an actor, the lower his appropriation rate. Furthermore, those with higher appropriation rates hold stronger norms toward the provision fulfillment of joint users. Additionally, the higher an individual's payoff from appropriation, the more likely he is to fulfill his provision duties. Therefore, it can be assumed that within an equitable and well-defined institutional environment, self-interest contributes positively to the sustainable use of resources. Whether this holds independent of context could be investigated in experimental settings that link behavior in appropriation situations (CPR games) to behavior in provision situations (public good games). According to our findings, subjects in the laboratory experiments with higher appropriation levels should make higher investments into the common pool and should be equally more willing to invest in costly monitoring or sanctioning.

6.1.3 The contribution to empirically grounded modeling of social-ecological systems

Module 4 aimed to integrate the findings of previous modules into a simulation model. The separated treatment of subsystems ensured consistency between the framework, empirical observations, the model structure and the ability of the models to replicate real-world behavior. The simulation model of CPP use developed in Module 4 thus stands on solid empirical and theoretical ground, as the functioning of all subsystems was investigated with a focus on its key dynamics, including the main interactions with other subsystems. The research therefore shows how system dynamics modeling allows for the operationalization of the SES framework, although integration required intensive empirical analysis in advance.

System dynamics has proven to be a very suitable approach for the operationalization of the framework for three reasons. Firstly, since system dynamics is explicitly valued for its ability to display behavior resulting from nonlinear relationships and the feedback mechanisms (Ford 2000; Sterman 2000), it perfectly matches the framework assumption's nonlinear relationship between variables and feedback between subsystems (see Figure 3). Secondly, the SES framework provides a top-down rather than a bottom-up perspective on the SES by emphasizing structural components rather than agent interactions. Thus, system dynamics seemed a more appropriate approach for operationalizing the framework than agent-based modeling (ABM), which is considered to be advantageous when heterogeneous agents interact (Bousquet and Le Page 2004). Third, it must be considered that the functioning of the SES in Grindelwald is highly dependent on agricultural subsidies. Thus, the system cannot be considered self-organized but instead is very much driven by the external settings, in particular through agricultural policies, which also calls for a top-down approach such as system dynamics.

The importance of agricultural policies for the functioning of the SES also motivates the scenario definition for external setting, which yielded four scenarios that were then simulated in order to assess how agricultural policies and other changes in external variables would affect the sustainability of the SES in the long run. The scenario simulations showed that the trend of decreased use and maintenance of CPPs continues for all of the four scenarios. The model predicts that certain panaceas, such as liberalization and increased government support for the agricultural sector, will accelerate rather than counteract the trend. Furthermore, it shows that stocking density is the most important system component and that reducing stocking density should be taken as an early warning signal that further afforestation will take place with a delay of between seven and 15 years in the ecological system.

In summary, combining system dynamics with formative scenario analysis allowed for the operationalization of the framework by fruitfully bridging the different methods of the previous modules. This shows that system dynamics is an interesting alternative to ABM, which is currently considered the most promising option in the field (Poteete, Janssen and Ostrom 2010; 171–191), in particular when an SES cannot be considered self-governed, as top-down governance processes, such as federal agricultural policies, are of central importance.

6.1.4 A note on the analysis of resource systems

The development of a simulation model, of course, depended on a proper understanding of the ecological subsystems, which was generated in Module 3. The study of the commons, however, puts emphasis on social process. Therefore, research on the commons, including the SES framework, provides an anthropocentric focus on the resource system, aiming to determine whether its properties facilitate or hinder self-organization (Binder et al. 2013; Epstein et al. 2013). Therefore, the study of the commons can be considered to be in line with traditional approaches in human ecology (Bates 2005) or cultural ecology (Harris 2001; Steward 1968), where behavior and institutions are seen as cultural adaptations to the natural environment. In our Module 3, we followed a different approach for the analysis of the resource system by focusing on the links between land management practices and the state of the ecological system with regard to land cover change. Therefore, our approach was rather aligned with traditional land change science (Turner and Robbins 2008).

For the analysis of SESs, the study of the commons should acknowledge the fact that the impact of humans on the environment has been steadily increasing and is outcompeting natural processes (Crutzen 2006). Thus, social-ecological research should put more emphasis

on the effects of institutions and behavior on ecological processes rather than analyzing the attributes of the resource system toward their contribution to self-organization in SESs. In Module 3, we tried to acknowledge the deterministic role of the social on the ecological by analyzing the ecological system with emphasis on land use and subsequent land cover changes. The analysis showed how land use practices relate to land cover change. I thus consider that an empirical investigation of the ecological system within the study of the commons can be based on land cover data or satellite images in order to show the impact of human activities on the ecological system rather than emphasizing the opposite link.

6.2 Appraisal of the SES Framework

As mentioned above, the framework provided a good starting point for institutional analysis, as it is based on the IAD framework. Recent work (McGinnis 2011; McGinnis and Ostrom 2014) has highlighted that the SES framework is firmly rooted in IAD, which should resolve some ambiguities that might arise when the rules and property rights variables (GS4-8) are analyzed without explicitly considering IAD (including AIDCO). Additionally, findings in Module 1 suggest that the functioning of the governance system is highly influenced by federal governance. Thus, the government resource policies variable is a critical component of the external setting with regard to different aspects, such as subsidies, market incentives (as mostly regulated through agricultural policies) and federal law. Relevant federal law comprises environmental law, which constrains land use practices, and civil law, which impacts the corporations or the cooperative ability to self-organize. I would thus recommend that, in addition to the variable government resource polices (S4), a "federal law" variable be added. This would allow clearly differentiating between the impact of external interventions into markets through taxing or subsidizing of CPR use and external interventions like prohibitions or the prescription through legislative processes. Furthermore, this differentiation would facilitate analyzing possible overlaps and conflicts between diverse legislations enforced by different juridical levels, as emphasized in legal pluralism (Benda-Beckmann 2001; Unruh 2003). The framework should therefore explicitly highlight that rules and property rights (RU4-RU8) may be defined and enforced through different types of governance bodies on local, national and potentially supranational levels.

With regard to the actors' system, our analysis reveals that the economic endowment of actors is central for their (cooperative) behavior. Although the socioeconomic attributes variable (U2) may include economic endowment in the third tier, I consider it fruitful for further analysis to split the variable into sociodemographic attributes, such as gender, age and marital status, and into economic endowment attributes as characterized by the production factors of land, labor and capital. Furthermore, our analysis reveals the key human environmental interactions to be appropriation and provision, both of which are listed among the interactions (I1, I5). I find that the term "infrastructure investment" could be changed to "maintenance" or "provision activities." Infrastructural investments (I5) can be understood as strictly monetary investments into human-constructed facilities (RS4), although this clearly also includes labor dedicated to the upkeep and maintenance of the resource system.

Interactions are essential parts of the framework, which are currently listed without indication of which subsystems or variables they are linking, and strongly emphasize social processes. An important step would therefore be to characterize the interactions as links between or within subsystems to add clarity without unwanted theoretical implications. The process of characterizing interactions as links between or within subsystems would also reveal a bias in the framework toward social processes rather than social-ecological or even ecological processes. Depending on the version of the framework (McGinnis and Ostrom 2014; Ostrom

2007, 2009), the framework lists 8–10 interactions, two of which can be considered social-ecological (I1, I5), and the rest refer to strictly social interactions. This means that environmental interactions are not being considered at all.

As the framework is meant to be a starting point for a multidisciplinary study bridging social and natural sciences, it might be necessary to amend the framework with regard to its characterizations of the ecological subsystem and its interactions to make it more useful for natural scientists. Epstein et al. (2013) have undertaken an effort in this direction and propose inclusion of a seventh subsystem, "ecological rules," to describe ecological processes. Another potential way of making the framework more useful to the natural scientist may be the use of the ecosystem services concept (Carpenter et al. 2009; De Groot et al. 2010; Fisher, Turner, and Morling 2009). Accordingly, provisioning and cultural services might then constitute additional social-ecological interactions, while regulating services describe ecological interactions. With regard to ecological components, one could start with adding physical characteristics, including land cover types and distribution as well as topography, or biological characteristics, such as species pool and geologic setting, as proposed in the LTER framework (Redman, Grove, and Kuby 2004). A second option would incorporate an operationalization of ecological processes through resilience thinking. Rooted in ecology, resilience thinking might allow social scientists to better understand the ecosystem dynamics and the way they are influenced by human activities (Gunderson and Holling 2002).

6.3 Policy Implications

The implications for policy making can be differentiated into two themes: first, the role of local governance systems with regard to the problem of CPP underuse and second, policy options for the federal government for providing a favorable external setting to foster the use and maintenance of CPPs.

Recent concern about the appropriateness (Knoepfel et al. 2005) and persistence (Kissling-Näf, Volken, and Bisang 2002) of a local governance system in light of reducing use of CPPs can be rejected based on our study. Findings from Module 1 suggest that the governance system is able to counteract the problems of underuse through the opening of CPPs to foreign cattle and other institutional adaptations. However, the opening of the governance system may, to a large part, result from the incentives through summering payments by the federal government, which encourage corporations to maintain stocking density close to carrying capacity. However, a shift in operational rules from strict to partial exclusion has just begun, and if the trend continues, as Module 4 suggests, the governance system might put further efforts into acquiring foreign cattle to achieve the desired stocking density. Thus, corporations might slowly develop into more service- than governance-oriented organizations, which offer summering opportunities for lowland cattle against monetary compensation and potentially conduct provision activities themselves or hire labor from the fees paid by externals for summering. As Module 2 suggests, there is a close link between the level of appropriation and provision activities, so that it might well be possible that the willingness to maintain the resource decreases with the increase of foreign cattle on the CPP. Thus, a shift from an exclusion-based access regulation to a market-based approach may not provide better outcomes with regard to the maintenance of the resource system and the prevention of afforestation. To counteract this situation, the upkeep of CPPs might increasingly rely on the availability of voluntary labor or maintenance efforts as part of social service programs. Governance efforts should therefore consider whether and how provision activities on CPPs could be integrated as part of social service schemes.

In order to provide sufficient livestock in the valley, and more importantly to ensure high appropriation levels of local farmers, policies need to target the payoff from appropriation of CPPs. The introduction of appropriation contributions within the new policy framework (2014–2017) is therefore targeting the right point in the system and might be more effective than subsidies made to corporations or alp-enterprises respectively. Other options may include payments for environmental services, which target the upkeep of CPP areas most prone to abandonment. In Module 3, a first step was made to spatially define the plots most prone to abandonment. However, based on the characteristics identified, we are unable to suggest concrete policy measures due to the diversity of site-related factors leading to CPP plot abandonment, as discussed in Module 3. A promising option to foster the use and maintenance of CPPs may include centralized marketing activities efforts on the federal as well as the local level. On the local level, centralized marketing efforts are reported to have a strong positive impact on the overall functioning of the local agricultural sector (Bardsley and Bardsley 2014). In addition, better labeling and better communication of values associated with the consumption of alpine products (through labels declaring mountainous origin, for example) may help raise consumers' awareness of different production methods, feedstock used and the cultural and natural attributes associated with alpine products and thus help strengthen prices and, accordingly, farmers' payoff, which was found to be a key factor in encouraging the use and maintenance of CPPs.

6.4 Limitations and Further research

Although this research follows a case study approach, it offers methodological pluralism. Case studies are considered advantageous for hypothesizing relationships, theory development and the investigation of particular mechanisms (Bates et al. 2000; Lieberman 2005). The weakness of a case study approach is the resulting uncertainty about the generalizability of the findings. This research put emphasis on precision and realism at the cost of generalizability (Costanza et al. 1993). Therefore, the results of different modules need further validation through multiple methods. The insights gained in the different modules suggest the following avenues for further research:

Module 1 provides a step toward a theory of institutional change. Yet, without additional case studies, patterns of institutional evolution cannot be generalized. Therefore, future studies need to further elaborate on the patterns of rule evolvement and relate them to changes in the SES and outcomes. The SES and the IAD framework provide valid tools for doing so. Applied to multiple settings, it will deliver the empirical base for meta-analysis toward a general theory of institutional change, applicable to the governance of CPR.

In Module 2, the findings were based on a rather large number of cases, but the effect of contextual variables limits its value for formulating a general theory of behavior of individuals in commons dilemmas. However, the findings and the hypothesis derived in Module 2 provide an important reality check for experimental research and entail valuable information for formulating future research questions and for designing experiments. First, it should be considered that endowment is a major driver behind behavior and second, that appropriation behavior is closely linked to provision behavior. Whether this holds independent of context could be investigated in experimental settings that link behavior in appropriation situations (CPR games) to behavior in provision situations (public good games). According to our findings, subjects with higher appropriation levels should make higher investments into the common pool and should be equally more willing to invest in costly monitoring or sanctioning. If this could be proven in laboratory experiments, we would have important additional insights about the mechanisms that allow overcoming social dilemmas.

In Module 3, we investigated land cover changes as a consequence of land use change. This is a topic that desires more attention within the study of the commons. Efforts will require better integration of knowledge from the natural sciences, including potential amendments in the SES framework and elaboration on the methods most suitable to analyze a resource system and its dynamics. For our case study, we had some land use statistics available, but it may well be that in developing countries, official land cover data may not be reliable or not available in the desired resolutions. Therefore, it remains conceptually and methodologically challenging to capture the relevant resource system dynamics, in particular as social-ecological modeling depends on previous investigation of ecological and social-ecological interactions.

In Module 4, system dynamics and formative scenario analysis showed to be useful tools for building simulation models of SESs. The method mix constitutes a feasible alternative to agent-based modeling (ABM), in particular when the SES is highly interconnected and dependent on federal policy or regional economic development. The model was simulated on aggregated levels for the whole region. Running the model at the corporation level instead of at the regional level could reveal information about future developments of the single cooperation to identify the properties that make a cooperative more robust or vulnerable to particular types of external changes. That knowledge would then allow theorizing about the social-ecological links, feedbacks and sustainability trade-offs that increase the robustness or vulnerability of the SESs to external perturbations (Anderies, Janssen, and Ostrom 2004; Janssen, Anderies, and Ostrom 2007).

A further step in advancing the model would be its extension toward spatially explicit design. Coupling the system dynamics model with the cost distance model would allow the identification of the areas that are most prone to abandonment and their characteristics. Information about potentially abandoned CPP plots would provide useful information for policy making, allowing the targeting of the specific characteristics of potentially abandoned plots. Unfortunately, Vensim and other system dynamics software currently do not offer the interface for doing so. Therefore, further coupling of findings of Module 3 with the simulation results would rely either on substantial programming efforts or on “soft coupling,” using the generated data from the systems dynamics model as input to for the GIS based cost-distance model to spatially locate the potentially abandoned CPP plots for particular scenarios.

7 Conclusion

Sustainable natural resource use depends on humans' abilities to shape institutions that keep the levels of exploitation, pollution or other externalities in line with the resource system's capacity to recover from these activities. Common property arrangements and the institutions enforced by local communities often provide effective solutions for sustaining resources over centuries. The CPPs in the Swiss Alps provide much empirical proof. However, social-ecological systems are subject to constant change and often fail to maintain sustainability when major changes are at stake. In the Swiss Alps, the situation has changed over the past decades. The CPPs that need protection from overexploitation today depend on governance efforts to foster their use. This dissertation analyzed how the SESs in which CPP use is embedded cope and respond to these new challenges.

Capturing the complexity and different problems driving natural resource use requires multidisciplinary approaches and a combination of different methods. The framework for analyzing sustainability in SESs was developed as a starting point for this endeavor (Ostrom 2009). This thesis demonstrated how the framework can be operationalized through multiple methods to enhance the understanding of complex SESs. In Module 1, it was shown by institutional analyses that the local governance systems, although originally designed to avoid overuse, are able to adapt to problems of underuse. In Module 2, it was investigated how actors' attributes affect individuals' behavior in commons dilemmas. In Module 3, the changes in the resource systems were observed and linked to human land use. In Module 4, the insights from Modules 1–3 were used to formulate a simulation model of the SES. As part of these four modules, the thesis covered and advanced key problems within the study of the commons, provided feedback about the strength and weaknesses of the framework for its further development, and allowed the proposal of governance options to enhance the sustainability of CPP use.

In sum, this thesis showed that analysis of resource use and social-ecological systems requires a mixed-method approach, as the complexity of SESs cannot be captured with only one tool or through the lens of a particular discipline. Multidisciplinary efforts need to acknowledge that SESs are constantly changing, and emphasis must be given to the SES's dynamics rather than its state. Only if the interplay of different components and the resulting dynamics of an SES are understood can policy suggestions move beyond simple blueprints. As humans' interference with the environment steadily enlarges, sound social-ecological research is evermore needed to identify effective governance principles and institutions to promote the resilience of scale social-ecological systems.

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PART TWO: ESSAYS

ESSAY 1:

Baur, Ivo, and Claudia R. Binder. 2013. Adapting to Socioeconomic Developments by Changing Rules in the Governance of Common Property Pastures in the Swiss Alps. *Ecology and Society* 18 (4).

ESSAY 2:

Baur, Ivo, Karina Liechti, and Claudia R. Binder. 2014. Why do individuals behave differently in commons dilemmas? The case of alpine farmers using common property pastures in Grindelwald, Switzerland. *International Journal of the Commons* accepted for publication.

ESSAY 3:

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ESSAY 4:

Baur, Ivo, and Claudia R. Binder. submitted. Modeling and assessing scenarios of common property pastures management in Switzerland. *Ecological Economics*.

Essay 1

Adapting to Socioeconomic Developments by Changing Rules in the Governance of Common Property Pastures in the Swiss Alps

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Research, part of a Special Feature on A Framework for Analyzing, Comparing, and Diagnosing Social-Ecological Systems

Adapting to Socioeconomic Developments by Changing Rules in the Governance of Common Property Pastures in the Swiss Alps

Ivo Baur[1] *and Claudia R. Binder*[1]

ABSTRACT. The common property meadows in the Swiss Alps have been managed by local self-organized governance systems since the Middle Ages, thus preventing their overuse. During the past century, socioeconomic developments, such as industrialization and rapid nonagricultural economic growth, have shifted employment opportunities from the agricultural sector towards the service sector. In the agricultural sector, this has led to less intensive use and maintenance of the meadows in the Alps and consequently to a reduction in biodiversity. We use the example of Grindelwald in the Swiss Alps to analyze how the governance system has adapted to these socioeconomic developments. We based our analysis on the Program in Institutional Analysis of Social-Ecological Systems (PIASES). We coded five statutes ranging in date from 1867 to 2003, and conducted interviews to investigate changes in the governance system. In so doing, we focused on changes in the operational rules that structure the focal interactions between the social system and the ecological system, namely harvesting level and investment activities. Our results show that the governance system has adapted to the socioeconomic changes (1) by creating an additional organizational subunit that allows appropriators to alter operational rules relatively autonomously, and (2) through changing several operational rules. We conclude by outlining the properties of the governance system that have allowed for constant harvesting levels and investment activities over time.

Key Words: *common property pastures; rules; SES; social-ecological systems*

INTRODUCTION

Since the Middle Ages, summer pastures in the Swiss Alps have predominately been held as common property. At present, 80% of the summer pastures located at higher altitudes are managed as common property. Common property resources are natural or human-made resources that are jointly used and managed. In most cases, exclusion is difficult, and joint use of these resources involves subtractability (Berkes et al. 1989). In the Swiss Alps, local authorities such as cooperatives, corporations, and citizens' communes have established institutional arrangements to regulate access to the summer pastures (Picht, *unpublished manuscript*). The members of these organizations jointly own and manage the resources and have successfully avoided the overexploitation of summer pastures for centuries by (1) excluding outsiders, and (2) restricting the harvesting levels of the eligible users (Netting 1981, Ostrom 1990, Stevenson 1991, Tiefenbach and Mordasini 2006).

During the past century, socioeconomic developments have resulted in the decreasing use and maintenance of summer pastures. In particular, industrialization and the shift towards the service-oriented economy increased labor demand in the corresponding sectors. Thus, labor moved from the agricultural sector to the industrial and service sectors (Bergier 1984). When looking at agriculture, one can observe that in the beginning of the 19th century, alpine agriculture reached its peak in terms of land used for agriculture (Stöcklin et al. 2007). In the early 20th century, economic activities in the alpine regions were still mostly agricultural and subsistence-based, and highly dependent on livestock husbandry. The physical infrastructure, such as huts and barns, together with the summer pasture, which we refer to as "alp", were crucial assets of the community. Industrialization and the subsequent rapid expansion of the service sector created new job opportunities in the centers and brought tourism into the valleys. As a result, subsistence farming lost its importance, and the number of farmers on the alps decreased (Volken et al. 2002). The remaining farmers increased their farm size through tenure agreements, and intensified production in the productive areas, while labor-intensive pastures became less intensively used and maintained (Stöcklin et al. 2007).

The changes in land use practices that resulted were twofold: on the one hand, there was regrowth of shrubs and forests in marginal areas. On the other hand, the intensification of productive pastures (in the valley and the alps) reduced their ecological value (Stöcklin et al. 2007, Baur et al. *unpublished manuscript*), as extensively used pastures provide much higher species diversity than intensely used pastures or forests (Freléchoux et al. 2007, Stöcklin et al. 2007). In the 1980s, the Swiss federal government started subsidizing the summering of livestock in the alps, which reduced, but did not overcome, the trend of land abandonment in the higher regions (Baur et al. 2007, Mack et al. 2008). It is apparent that the provision of public goods such as biodiversity and the beauty of maintained landscape and infrastructure are strongly interlinked with continuous use and maintenance of the alps (Lehmann and Messerli 2007).

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Contemporary research on common property resources has predominantly investigated the social and ecological variables that allow for self-organization to avoid overexploitation of the resources (Ostrom 1990, Balland and Platteau 1996, Agrawal 2001, Dietz et al. 2003). Results of these analyses show why some groups build institutions that support them in managing resources sustainably while others do not. Furthermore, institutions and the incentives they shape are considered to be the key for economic welfare (North 1990, Acemoglu and Robinson 2012). Because the importance of institutions for the well-being of humankind is widely acknowledged, methods to analyze institutional structures have been developed in economics and social sciences (Hollingsworth 2000, Gronow 2008). These methods are designed to relate institutional structures to outcomes at one single point in time (Hodgson 1998, Ostrom 2008, Ostrom and Basurto 2011). However, the world is constantly changing and so are social-ecological systems (SESs) (Gunderson and Holling 2002, Dietz et al. 2003, Walker et al. 2004, Olsson et al. 2006, Folke et al. 2007). Accordingly, institutions need to adapt to changes occurring within and around the SES to ensure sustainable outcomes. Therefore, it is of key importance to understand the properties of governance systems and the institutions that allow them to "better cope with, manage or adjust to some changing condition, stress, hazards, risk or opportunity" (Smit and Wandel 2006:282).

We aim to contribute to the analysis of institutional change in governance systems of common property resources. We use the case of Grindelwald in the Swiss Alps to provide an indepth understanding of how the local authorities have adapted their governance system as a reaction to the socioeconomic developments in the region. We address the following questions:

1. Which variables of the social-ecological system were affected by socioeconomic developments?
2. How is the local governance system structured?
3. What changes in the local governance system have occurred over time?
4. How did the governance system adapt to socioeconomic developments?

First, we introduce the study area. Second, we describe the methods applied. Third, we present the results of the analysis as to which variables of the SES framework were affected by socioeconomic developments, including changes in the governance system. In this, we focus on changes in the operational rules that directly affect harvesting levels (number of livestock summered on the alps) and investment activities (maintenance of pastures, huts, and fences). We summarize by discussing the properties of the governance system that allow it to respond adaptively to socioeconomic developments.

The study region

Grindelwald is a Swiss municipality located in the Bernese Alps. The municipality is bounded by the mountains Eiger, Mönch, and Jungfrau, and it covers 171 km^2. About 13% of the area is settlement area or agricultural area held as private property, 25% is commonly owned meadows (pastures), and 62% is unused land. The border between common property pastures (alp) and private property in the valley is shown in Fig. 1. Unique to the case of Grindelwald is the fact that seven spatially defined corporations ("Bergschaft") are embedded in a cooperative ("Taleinung"). The cooperative assigns the territory to the seven corporations. The small alp "Pfingstegg" is the only alp that is privately owned. The alp Holzmatten is a special case because it is common property but is not connected to the private property in the valley (Nägeli-Örtle 1986, Tiefenbach and Mordasini 2006).

Fig. 1. The seven corporations of Grindelwald. Adapted from Tiefenbach and Mordasini (2006). HM = Holzmatten corporation, with common property separated from the private property in the valley. The red dotted line marks the border between common property pastures (alp) and private property in the valley.

METHODS

Theoretical framework

The common property pastures in Grindelwald were analyzed as a social-ecological system (SES). According to the SES framework (Ostrom 2007, 2009), SESs are composed of four nested subsystems embedded in a broader social, economic, and political setting. As displayed in Table 1, the system's social compartment consists of the Governance System (GS) and the Actors (A). The ecological compartment entails the Resource System (RS) and the Resource Units (RU). These

Table 1. Variables of the social-ecological system in Grindelwald affected by societal transitions. Based on Ostrom (2007, 2009), and M. McGinnis and E. Ostrom (*unpublished manuscript*).

Social, Economic, and Political Settings (S)	
†S1 - Economic development; S2 - Demographic trends; S3 - Political stability; †S4 - Government resource policies; †S5- Market incentives; S6 - Media organization	
Resource System (RS)	**Governance System (GS)**
RS1 - Sector (e.g., water, forests, pasture, fish)	GS1 - Government organizations
RS2 - Clarity of system boundaries	GS2 - Nongovernmental organizations
RS3 - Size of resource system	GS3 - Network structure
†RS4 - Human-constructed facilities	‡GS4 - Property rights systems
RS5 - Productivity of system	‡GS5 - Operational rules
†RS6 - Equilibrium properties	‡GS6 - Collective-choice rules
RS7 - Predictability of system dynamics	‡GS7 - Constitutional rules
RS8 - Storage characteristics	‡GS8 - Monitoring and sanctioning rules
RS9 - Location	
Resource Units (RU)	**Actors (A)**
†RU1 - Resource unit mobility	†A1 - Number of actors
RU2 - Growth or replacement rate	†A2 - Socioeconomic attributes of actor
RU3 - Interaction among resource units	A3 - History of use
†RU4 - Economic value	†A4 - Location
RU5 - Number of units	A5 - Leadership/entrepreneurship
RU6 - Distinctive markings	A6 - Norms (trust–reciprocity)
†RU7 - Spatial and temporal distribution	A7 - Knowledge of social-ecological system/mental models
	†A8 - Importance of resource (dependence)
	†A9 - Technology used
Action Situations (Interactions [I] → Outcomes [O])	
§I1 - Harvesting levels	O1 - Social performance measures (e.g., efficiency, equity, accountability, sustainability)
I2 - Information sharing	
I3 - Deliberation processes	O2 - Ecological performance measures (e.g., overharvested, resilience, biodiversity)
I4 - Conflicts	
§I5 - Investment activities	O3 - Externalities to other social-ecological systems
I6 - Lobbying activities	
I7 - Self-organizing activities	
I8 - Networking	
Related Ecosystems (ECO)	
ECO1 - Climate patterns; ECO2 - Pollution patterns; ECO3 - Flows into and out of focal social-ecological system	

†Variables directly affected through socioeconomic developments
‡Governance responses by changing variables
§Focal action situations

subsystems interact (I) at various spatial and temporal scales to produce outcomes (O).

Each subsystem can be divided into its further properties. The GS entails organizations, property rights, and a set of rules that structure interactions among actors and their use of the resource system. The property rights system (GS4) consists of a bundle of rights that regulate access and the degree of command of individual actors or organizations over a resource (Schlager and Ostrom 1992). The rules operate at three hierarchical levels: the operational level (GS5), the collective-choice level (GS6), and the constitutional level (GS7). Hereby, the highest level (constitutional) changes at a slower pace and determines the lower ones (Ostrom 2005). For example, the constitutional level refers to the legal form of a users association as this determines who is a member and is allowed to participate in collective-choice processes. On the collective-choice level, actors are then to agree on the operational rules according to prescribed procedures. The operational rules structure everyday interactions of users with the resources

systems, such as harvesting or investment activities. An example of an operational rule might be a timely restriction of harvesting activities for the preservation of the resource. The resource system, which is the alp, includes the meadow and physical infrastructure, such as huts, barns, and fences. The resource system generates the resource units, which is the grass used as fodder.

The Program in Institutional Analysis of Social-Ecological Systems (PIASES) complements the SES framework by combining it with the Institutional Analysis and Development (IAD) framework (McGinnis 2011, Ostrom 2005). It thereby highlights the importance of seven operational rules that structure focal action situations (McGinnis and Ostrom 2010). In this study, we analyzed the changes in the operational rules for two focal interactions, namely harvesting levels (I1), which we operationalized as the indexed number of livestock grazing on the alps (appropriation), and investment activities (I5), which we operationalized as maintenance of the alps by communal work and the installation of fences (provision). These focal interactions determine the intensity of use and maintenance of the alps, and thus directly affect the ecological state of the resource system.

Data collection and analysis

In a first step, we conducted a workshop with farmers from the seven corporations to analyze the impact of socioeconomic developments on the SES (Table 1). In a second step, to investigate the functioning of the SES, 12 farmers, including the monitor of each corporation, were interviewed using a semistructured questionnaire (Schensul et al. 1999:149–164). Monitors keep track of appropriation and provision levels within a corporation, and lead the users association. That is, they have the best knowledge of the ongoing social and ecological processes in their corporations. In a third step, we conducted structured interviews with three monitors and the president of the cooperative to identify changes in the rules and property rights system (GS4–GS8) devised by the cooperative and corporations for the governance of the alps. Furthermore, the statutes of the cooperative named Taleinung from the years 1867, 1923, and 2002, and the statutes of the corporation "Scheidegg" from 1913 and 2003 were coded for changes in rules following the grammar for analyzing institutional statements (ADICO) (Crawford and Ostrom 1995, Basurto et al. 2009, Schlüter and Theesfeld 2010). The corporation Scheidegg was chosen as an example because of its excellent data availability. The operational rules structuring harvesting activities and infrastructural investment were organized according to the IAD framework (McGinnis and Ostrom 2010). To allow for the fact that rules might exist in form but not in practice and vice versa (Ostrom 2005), the findings were validated through three interviews with elderly farmers.

RESULTS

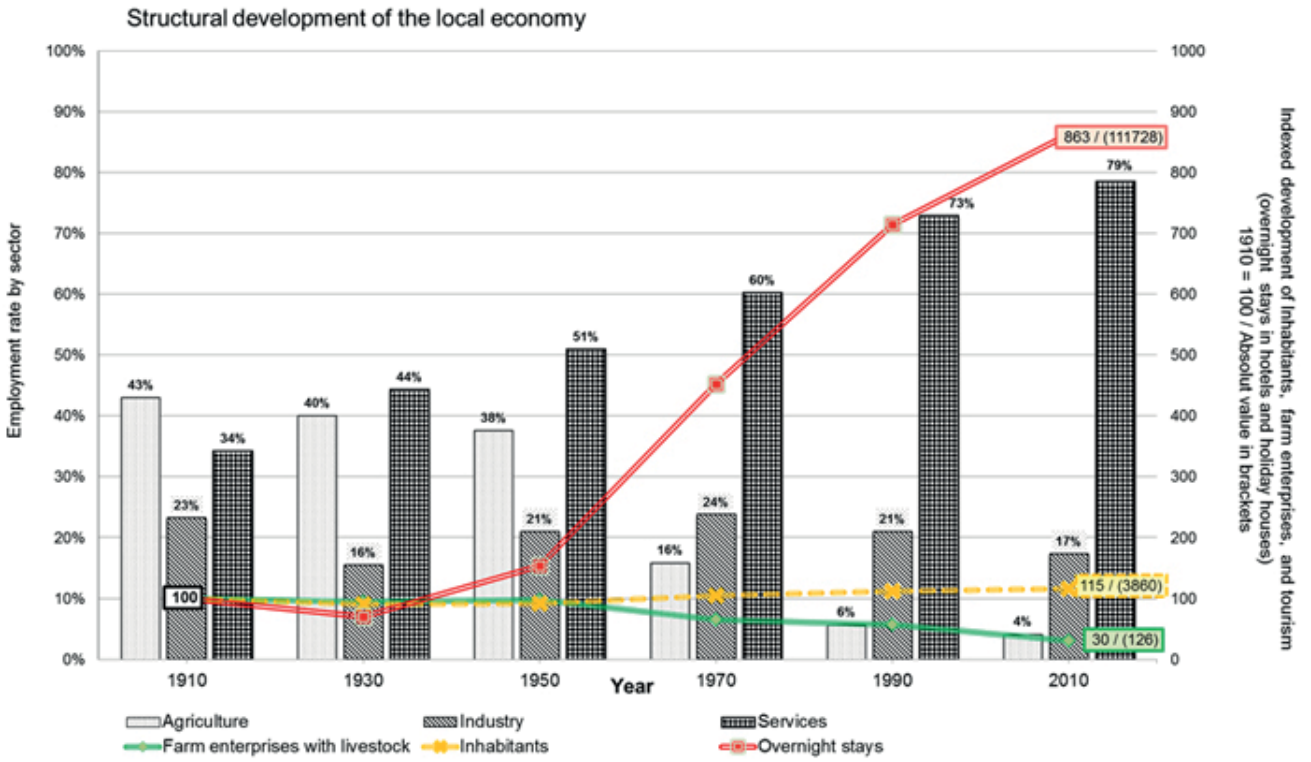
Socioeconomic developments

In the last century, several socioeconomic developments changed the external setting of the local SES. First, economic development (S1) created off-farm income opportunities and increased tourism considerably. This development transformed the local economy from an agriculture-based to a tourism driven economy (Fig. 2), which resulted in competition for land between touristic use (e.g., skiing, biking) and agricultural use in both the productive agricultural areas and the alps. It should be noted that the tourism sector is the main reason why Grindelwald does not suffer from emigration like other regions in the Swiss Alps, and instead has seen modest population growth (Fig. 2). Second, state control of agricultural production has steadily increased. Both production standards (S4) and market incentives (S5) have been increasingly regulated by the state through agricultural policies. Furthermore, state policies have accelerated structural change in the agricultural sector towards fewer but larger farms, and have increased farmers' dependence on direct payments. Thus, without state support, agriculture in Grindelwald is not feasible.

Due to the structural transformation of the local economy, the number of farmers owning livestock (A1) decreased from 432 to 126 within a century. During the same period, tourism increased with 863 index points, resulting in 111,728 guest-nights in 2010 (Fig. 2). The remaining farmers in Grindelwald have taken advantage of the income opportunities offered by the growing tourism sector, and work on the ski lifts during the winter (A2). The decreasing number of farmers and the inheritance regulations which foresee that land is equally divided among successors, has led to dispersed farm structures in the valley (A4). Farmers who increase their farm size do so mainly through tenancy agreements, and at the cost of dissipating their land holdings. Furthermore, subsidies, off-farm income, and the use of additive fodder (A9) have reduced farmers' dependence on pastures for their livestock and dairy products for their livelihoods (A8). In addition, tourism strengthened local demand for alpine cheese (RU4).

As mentioned, intensification of the productive areas and extensification of marginal areas is also affecting the alps. Productive areas are most often close to the huts, while the marginal areas are characterized by longer walking distances, steepness, and higher altitude. Furthermore, cattle breeds have been increasing in size, and their mobility has declined as a result (RU1), which makes them less suitable for grazing in marginal areas (RU7) since long walks tend to decrease milk yield. This has impacted land cover: marginal meadows have been abandoned, bushes have started colonizing them, and the area is being transformed into forest (fir forest) (RS6). In the intensified areas, closer to huts, over-fertilization due to the high density of cows has taken place, and consequently, the

Fig. 2. Number of overnight stays, farm enterprises and employees, and inhabitants in Grindelwald from 1910 to 2010 (Sources: Nägeli-Örtle 1986, Wiesmann 2001, Federal Statistical Office (FSO) several years).



amount of persistent weeds (such as alpine sorrel or sheep sorrel [*Rumex alpinus*]) has increased.

Nevertheless, farmers in Grindelwald continue with their labor-intensive traditional farming system, which is based on dairy cattle farming and the seasonal cycle of transhumance, with cheese production on the alp during summer. Strategies observed in other regions, such as leisure farming, characterized by a shift from dairy cows to suckler cows or sheep husbandry, have not yet taken place in Grindelwald.

The local governance system

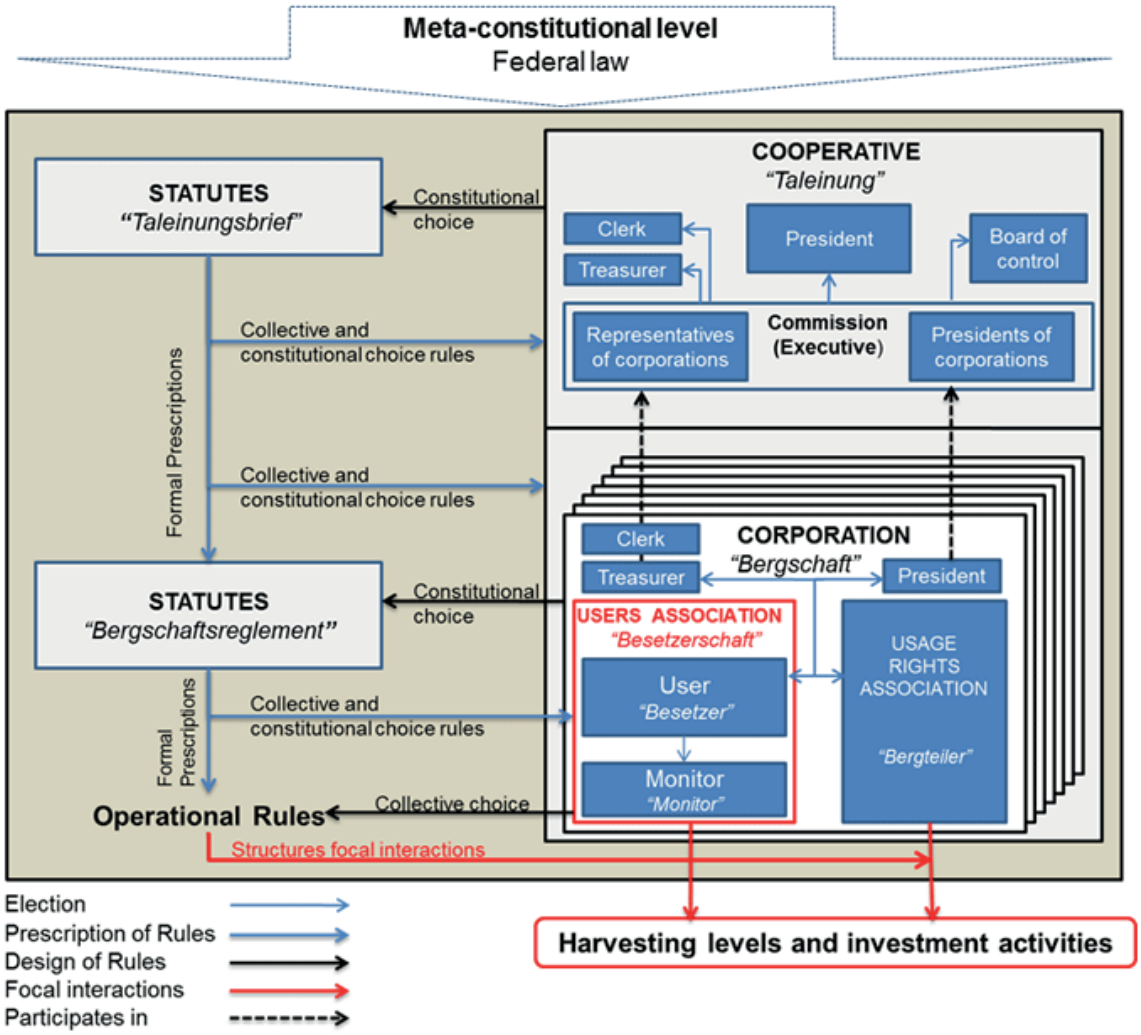
The local governance system in Grindelwald consists of three nested levels with their own assemblies and constitutional design:

1. the cooperative (Taleinung), where every holder of usage rights ("Bergrecht") is a member;
2. the corporations (Bergschaft), where every holder of usage rights of a specific corporation is a member; and
3. the corporations' users association ("Besetzerschaft"), where every holder of usage rights appropriating in the specific corporation becomes a member.

Rules mandatory for all corporations are designed and altered collectively by the cooperative. This ensures vertical control among the corporations by limiting the set of rules that can be crafted autonomously on the corporations' level. Similarly, the cooperative is limited in its constitutional design, since collective-choice rules and organizational principles for cooperatives are determined by cantonal and federal legislation (meta-constitutional level). Nevertheless, at each level, the lower levels still have some autonomy in designing additional rules (Fig. 3).

The cooperative (Taleinung) is an organization that functions as a legislative body in the interest of the corporations ("Bergschaften"). In its statutes ("Taleinungsbrief"), it assigns the territory to the corporations, and sets the constitutional rules, the collective-choice rules, and to some extent, the operational rules for both the corporations and the cooperative itself. The cooperative is headed by a board, which functions as the executive body. The board implements the decisions made in the assembly. The assembly is called whenever the board or a corporation decides to do so, or 100 rights holders demand it.

Fig. 3.The structure of the local governance system in Grindelwald.



The corporation is an operational unit concerned with the management of the alp. Each corporation is obliged to have its own statutes ("Bergschaftsreglement"), which must be in agreement with the rules prescribed in statutes of the cooperative. Formal positions within corporations, such as monitors, are prescribed by the statutes of the cooperative.

Over the last century, the structure of the local governance system has changed considerably as the corporations have split into two associations, one for the users who exercise their rights of usage (Besetzerschaft), and one for the holders of rights of usage ("Bergteiler") who do not make use of their rights to harvest the pastures. The division of the corporation into Besetzerschaft and Bergteiler was first mentioned in the statutes of the cooperative in 1923. At that time, the number of rights holders not engaging in agriculture became the majority in the corporations, and their bargaining power increased to the disadvantage of farmers. Thus, the division was implemented in order to prevent conflicts over the allocation of the corporation's resources. Today, the users association and the usage rights association even have to run separate budgets as stipulated in the statutes of the cooperative from 2002. Within the users association, farmers can make autonomous decisions about the agricultural use of their respective alp. Decisions about the touristic use of the resource system are negotiated within the usage rights association.

The property rights system

The cooperative and the corporation are recognized as legal entities under civil law. The right to own natural resources such as forest, water, and pastures in common is guaranteed by cantonal law (BSG 211.1 Art. 20). The meadows and the

forest are the property of the corporation, or their members, respectively. The cooperative prescribes that the rights of usage are attached to private parcels in the valley and that they are inalienable but leasable. Villagers owning or leasing private property are allowed to access, harvest, and manage the pastures. Formally, every holder of usage rights is allowed to send as many livestock to the alps as they have rights tied to their leasehold or privately owned parcels in the valley. The location of the private parcels determines in which corporation-alp the usage rights are to be appropriated. The sum of usage rights present in the corporation defines the maximum sustainable yield (MSY) of the corporation's alp.

Originally, this property rights system had four functions: first, the exclusion of nonvillagers; second, the assignment of harvesting levels to actors in proportion to their land holdings; third, the assignment of duties to provide infrastructural investments based on the usage rights one holds; and fourth, the definition of the MSY for each corporation. Today, usage rights still serve to exclude outsiders and assign provision duties but do not restrict the individual's harvesting activities and no longer define MSY.

During the 20th century, many private parcels that were once used as private pastures were used as land for vacation homes. Since the property rights remain attached to the plot in the valley, many rights are coupled to land that is no longer in agricultural use. Thus, while the area in the valley that is pasture land and in agricultural use has been decreasing constantly, the usage rights have not. This has resulted in an excess of usage rights, leading to a low lease fee, which in absolute terms barely changed over time. For example, in Scheidegg from 1867 to 2009, the fee for the lease of one single right for one season decreased from CHF 8.80 to CHF 8.50. That is, since the lease of rights is permitted among rights holders, and rights can be leased at very low fees, farmers' appropriation decisions are not restricted by the rights they hold. Because the rights holder is not allowed to lease unexercised rights to nonrights holders, the property rights system continues to serve to exclude outsiders. Furthermore, the opportunity to lease usage rights among local farmers allows appropriation in the corporation of their choice, regardless of the location of their privately owned parcels.

Between the two World Wars, the federal government started to estimate the MSY based on the practices found in the commonly owned pastures. Since the 1980s, the government has based its subsidies on prescribed harvesting levels. Payments related to the summering of livestock are incrementally reduced if total appropriation does not remain within 75–110% of the sustainable yield as defined by the canton (BLW 2010). These subsidy rules offer the corporation strong monetary incentives to keep appropriation within a sustainable range, including a minimum harvesting level. Since summering payments are conditioned on maximum and minimum harvesting levels, state policies determine the MSY for the alps. Because breeding has increased cow size, milk yields, and the cows' fodder needs, the total number of usage rights would no longer reflect the MSY of the alps, and the appropriation of all usage rights would result in serious damage and overharvest of the summer pastures, especially in the easily accessible areas.

Rules

Statutes entail different constitutional rules (GS7) that determine the collective-choice as well as operational rules for the corporations. The statutes of the cooperative thus stipulate that the corporations must keep the rules within the statutes of the cooperative.

Collective-choice rules (GS6) are prescribed for each level in the statutes of the superior level. At present, collective choices are made at all levels according to the majority rule (50% +1). If no majority is obtained, presidents have the deciding vote in the cooperative and in the corporation, and act as monitor in the users association.

Operational rules (GS5) directly regulate appropriation and infrastructural investments, and are defined at various levels. The cooperative defines the boundary rules (ownership of land in the valley) and position rules (e.g., "appropriator" and "rights holder"). The corporation's statutes stipulate that every holder of property rights must invest in infrastructure by installing a defined length of fence on the alps in proportion to the rights they hold. Furthermore, it prescribes that every appropriator has to provide communal work in proportion to their personal harvesting levels. The users assembly defines and changes sensitive operational rules, mainly the payoffs that affect appropriation and investment levels. For example, the users association may set the hours of communal work required per appropriated livestock unit and the monetary fines for underprovision of communal work.

The monitoring (GS8) of the individual's compliance with appropriation and provision rules is a jointly shared task of all farmers. The monitor is to be informed about any unjustified appropriation and has to confiscate the trespassing livestock. Furthermore, they have to control the provision of infrastructural investment and penalize noncompliance through fines. For most of the violations of operational rules, such as underprovision of communal work or failure to install a fence, the catalogue of fines is defined every year by the users association. If a violator has not paid their fine by the start of the following season, they lose their property rights until the fine is paid. In the case of violation of constitutional or collective-choice rules by corporations, a forfeit can be set by the cooperative's board.

Adaptation of rules

As shown in Table 2, we found several changes in the operational rules that directly structure appropriation and provision situations.

Table 2. Rule inventory: displays the level that enforces the operational rule at certain points in time. It shows the seven types of operational rules that directly structure the adjacent action situations appropriation (A) and the provision of infrastructural investment (P). The rule codes are as follows: R = the rule must be complied with; P = the rule may be complied with; P* = the rule may be complied with, but agreement from the cooperative board is required; F = the rule does not have to be complied with; n.r. = no rules exist at this time. MSY = maximum sustainable yield.

	Cooperative (Taleinung)			Corporation (Scheidegg)		User assembly (Scheidegg)
Types of rules	1867	1923	2002	1912	2003	current
Position rules						
AP1: Appropriator (member of the users association)	n.r.	R	R	R	R	R
AP2: Rights holder (holds rights but does not appropriate)	n.r.	R	R	R	R	R
PP1: Provider of infrastructural investments	R	n.r.	n.r.	R	R	R
Boundary rules						
AB1: Appropriator; must be appropriating during current season	n.r.	R	R	R	R	R
AB2: Rights holder; must own land in the valley	R	R	R	n.r.	R	R
BP1: Appropriator; becomes provider of communal work and fencing	R	n. r.	n. r.	R	R	R
BP2: Rights holder; becomes provider of fencing	n.r.	n. r.	R	n.r.	R	R
Choice rules						
AC1: Lease of rights (to or from holder of usage rights)	P	P	P	P	P	P
PC1: Provision levels; pay fine instead of providing communal work	n.r.	n.r.	n.r.	n.r.	P	P
PC2: Fencing; pay fine instead of installing fence	n.r.	n.r.	n.r.	n.r.	R	R
PC3: Delegation of provision activities to proxy	F	n. r.	P	n. r.	P	P
Information rules						
AI1: Standardized measurement for appropriation	R	R	R	n. r.	R	R
AI2: Reporting of illegal appropriation to higher instance	n.r.	R	n.r.	n.r.	R	R
PI1: Reporting of provision levels	R	R	n.r.	R	R	R
PI2: Reporting of fencing levels	n.r.	n.r.	n.r.	n.r.	R	R
Aggregation rules						
AA1: Agreement on the appropriation of external cattle	F	P*	P*	F	P*	R
AA2: Agreement when to drive livestock up and down from the Alps	n.r	n.r	n.r	n.r	n.r	R
AA3: Collective choice rules: proportional to shares	P	F	F	P	F	F
AB1: Defining the levels of provision required	n.r.	n.r.	n.r.	n.r.	R	R
AB2: Reimbursement of additional contribution	n.r.	n.r.	P	n.r.	P	R
Payoff rules						
AP1: Setting the interest for the lease of shares	n.r.	R	n.r.	P*	R	R
AP2: Reimbursement for unused shares	R	R	n.r.	n.r.	n.r	P
AP3: Fixed penalty for unreported appropriation	R	R	n.r.	R	R	R
AP4: Price for appropriating a livestock unit	n.r.	R	n.r.	R	R	R
PP1: Fees for under/overprovision of communal work	R	n.r.	n.r.	R	R	R
PP2: Fees for not fencing	R	n.r.	n.r.	R	R	R
Scope rules						
SA1: Respecting MSY; appropriation must remain within MSY of corporation	n.r.	R	n.r.	R	n.r	R
SP1: Infrastructural investments must serve agricultural purpose	n.r.	R	R	n.r.	R	R

Including constitutional, collective, and operational rules, seven key changes have occurred over the last century, which are worth summarizing:

1. At the constitutional level, since the beginning of the 20th century, the cooperative has prescribed that the corporations must be divided into a users association and a usage rights association.

2. At the collective-choice level, voting procedures prescribed for all levels have been refined. In the statutes of 1923, it was mentioned that voting can be conducted in proportion to the rights one holds, if 20 rights holders or the board demand it at the cooperative level, or the board or 10 rights holders do so at the corporation level. This option was eliminated in the statutes of 2002, since it is not in agreement with the voting procedures for corporations and cooperatives as defined in civil law. At present, every actor holding property rights is assigned one vote.

3. At the operational level, the differentiation between the positions "appropriator" and "rights holder" led to the diversification of rules for the provision of infrastructural activities. The statutes of 1867 prescribe that any holder of rights is obliged to keep their share of the alp in a good state. Accordingly, every rights holder was automatically urged to become a provider of public infrastructure, including fencing and communal work. Infrastructural investments were set in proportion to the usage rights that an actor held, and did not depend on their appropriation, as is the case today. Currently, a rights holder becomes a provider of fencing in proportion to the rights they hold, and the appropriator becomes a provider of communal work in proportion to their harvesting level. A novelty is that the statutes of 2002 allow appropriators to delegate their duties, which has resulted in farmers' spouses engaging in the maintenance of the alps.

4. Appropriation of "foreign" cattle has become permitted pending agreement of the cooperative. Although usage rights were always tied to private property in the valley, the cooperative's statute of 1923 contains the clause that if the livestock population in the valley is significantly reduced "due to forces of nature," the corporations are allowed to admit foreign cattle to the alps, if the cooperative board permits it. At present, questions are raised over whether (foreign) cattle that do not belong to rights holders can be appropriated. The commission has recently allowed the corporation Scheidegg to appropriate foreign cattle, even in the absence of a natural hazard that reduces livestock populations.

5. Over the past century, the rules affecting the payoffs for appropriation and the provision of infrastructural investment came to be totally under the jurisdiction of the corporations. The constitution of the cooperative from 1923 still entailed fixed rental fees for the lease of a right distinguished for the seven corporations. Nowadays, the prices for the lease of a right are defined by the users association and are very low (CHF 8.50 per right in the case of Scheidegg). Similarly, the corporations can now decide whether they will reimburse for unused shares; this was compulsory in the earlier statutes. Most of the payoff rules affecting infrastructural investment are set by the users association. The users association can decide about the hours of communal work they require per appropriated unit. The Scheidegg corporation is currently requesting 8 hours per appropriated unit. Penalties for not providing communal work, and the reimbursement of additional hours of communal work are autonomously set by the corporations. That is, farmers decide whether they contribute in coin or in kind. Furthermore, farmers are offered the opportunity to generate additional income by working more than the required hours. Currently, payments in the Scheidegg corporation for overcompensation are fixed at CHF 20 per hour, while the fee for undercompensation is CHF 25 per hour. If farmers carry out communal work with light private machinery (e.g., a chainsaw) or with heavier private machines, such as smaller carriers for the dispersal of manure, hours are counted double or even fourfold, respectively. However, these fees and payments can always be changed by the users association, and by altering them, the users association guarantees a steady level of provision of communal work within the corporation. Similarly, the cooperative allows the corporations to set the tariffs for failure to fence (one right is equivalent to 15 m). Actors who hold usage rights but do not engage in agricultural activities are charged CHF 1.50 per meter that they do not fence. This has become an additional source of income for the corporation.

6. A newly added rule states that the infrastructure, particularly huts and barns on the alp, must not be used for purposes other than agricultural, and that they cannot be sold to externals. This was allowed in older versions, if the cooperative board agreed. The change in this rule ensures that the huts are not transformed into recreational infrastructure.

7. Since the introduction of summering payments in the 1980s, MSY is ensured through agricultural policy incentives. The total number of usage rights therefore no longer defines the MSY of the alp. The summering payments are conditioned upon a minimum harvesting level in order to increase incentives to use the alps more intensively. Today, these payments are tied to a minimum (75%) and maximum (110%) harvesting level of the state-defined sustainable yield. In 2010, Scheidegg hosted 103% of the MSY (Table 2).

DISCUSSION

We analyzed whether and how local governance systems governing the management of common property meadows in the alps in Grindelwald have adapted to socioeconomic changes. We applied the SES framework to identify the relevant variables within the SES that have changed due to socioeconomic developments, and we used PIASES in order to identify changes in the rules within the governance system. Our study is original in its contribution because it empirically analyzes changes in rule configurations in the governance of common property resources. Additionally, it links the observed changes in rules to changes in the social-ecological context. Therefore, our study supports the development of a general theory of institutional change and a better understanding of the conditions that enhance the capacity of governance systems to change rules successfully.

Socioeconomic changes and their impact on the social-ecological system

In the following, we link the impact of the socioeconomic developments in Grindelwald (industrialization, rapid nonagricultural economic growth, subsidy scheme in agriculture) on the variables of the SES, in particular, the changes in the governance system (Table 3). We focus on the main key reactions of the governance system to these changes.

Changes in the governance system as a response to socioeconomic development

Adapting to a decreasing number of rights holders making use of their rights

Socioeconomic developments have led to a decreasing number of appropriators and an increasing number of rights holders who are not engaging in agriculture (Fig. 3). As a response to this shift in bargaining power, at the level of the cooperative the decision was made to restructure the corporations by dividing them into a rights holders association and a users association. This division ensures that farmers decide relatively autonomously within the users association about the operational rules they apply to govern the agricultural use of the alps. In particular, the ability to alter payoffs for appropriation (e.g., setting the price for the lease of a right) and provision (e.g., setting the fees for under- and overprovision) allows them to balance harvesting and investment activities at the corporation level.

The distinction between the position of an appropriator and a rights holder, furthermore, allowed the provision rules to be adapted, which led to a more flexible labor allocation for investment activities. Initially, communal work and fencing were in proportion to the number of the usage rights one held. Currently, communal work is tied to the appropriation level of an individual, while the duty to install fencing remains proportionate to the usage rights one holds. The actual provision rules allow farmers to plan whether they will pay fines or contribute with labor and machinery work to fulfill their obligations. Additionally, they are free to provide more than the required fences or hours of communal work and to be reimbursed by the corporation or to delegate the provision duties to a proxy. Hence, changes in provision rules increased the flexibility of the single user to contribute with respect to their opportunity costs and machinery assets, which is very likely to increase overall productivity of investment activities in any SES. The fact that provision rules assign different investment activities to different positions is considered key to ensuring high levels of cooperation in the provision of investment activities.

Adapting to declining numbers of cattle and national subsidy schemes

As shown in Fig. 4 for the corporation of Scheidegg, the number of cows in the region has been decreasing. Furthermore, summering subsidies are tied to the number of cows harvesting meadows on the alps and are paid only if the harvesting level is higher than 75% and less than 110% of the MSY. To adapt to this situation, operational rules were changed to allow the possibility to agree upon the appropriation of foreign cattle. It has been observed that some corporations have started hosting livestock that are not owned by local farmers. The result of this adaptation strategy on the MSY in shown in Fig. 4, which depicts the initial MSY, which still exists in form but not in use. The introduction of summering payments had two major effects on the local governance system. First, MSY is now defined through summering payments as they are tied to state defined MSY. Second, the payments shaped stronger incentives for the summering of cattle, which is the reason why the Scheidegg corporation is currently hosting about 40 foreign cows during the summer.

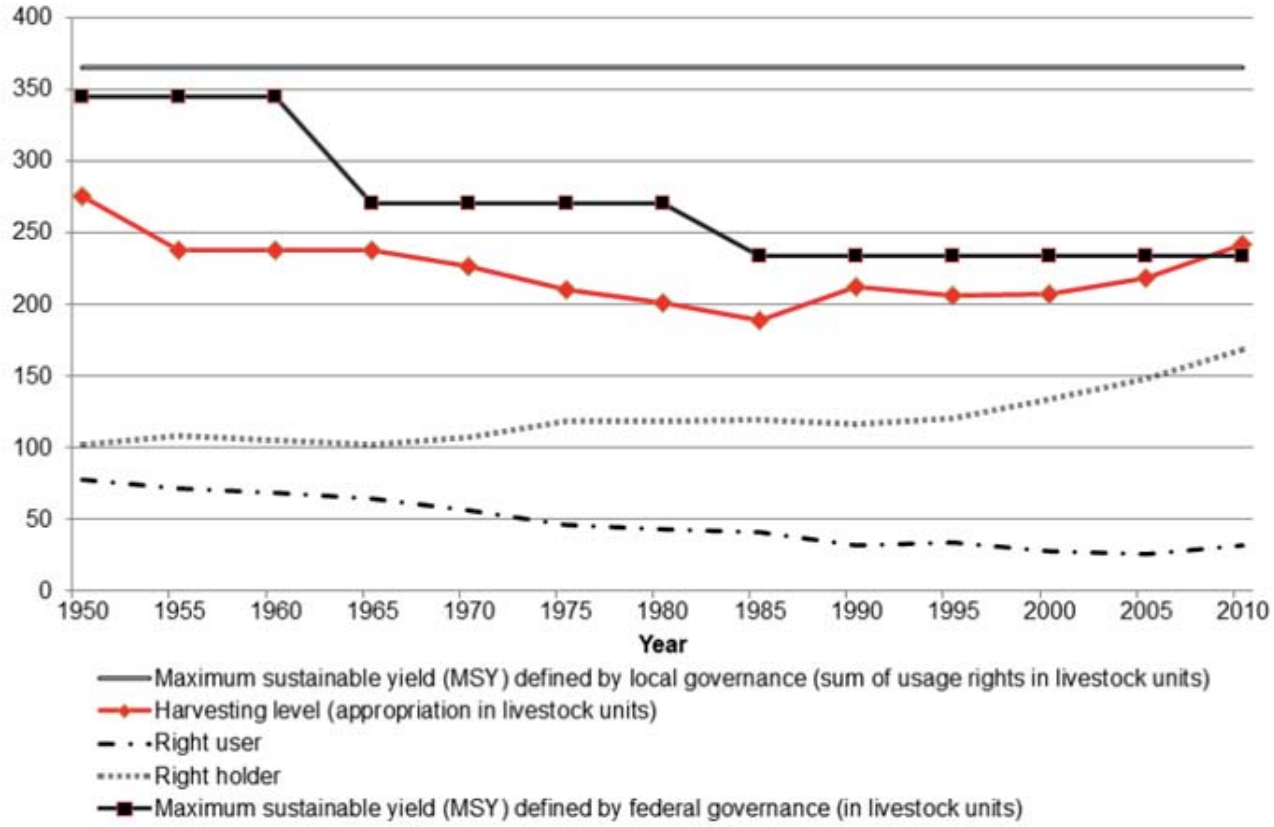
The role of a multileveled governance system for sustainable common property management

Our results show that the local governance system in Grindelwald is a complex system with three levels that have changed its constitutional rules toward a more subsidiary design by creating an additional level. The cooperative (Taleinung) constitutes the highest level and includes seven corporations (Bergschaft). The creation of the additional level, which is the users association, allows farmers to govern the agricultural affairs of the corporation without involvement of tourism entrepreneurs. Furthermore, our findings suggest that these multilayered governance systems enhance the capacity to handle scale-dependent and cross-scale issues (Cash et al. 2006, Berkes 2007, Termeer et al. 2010), and provide a basis for linking local knowledge, action, and the state of the social-ecological system (Lebel et al. 2006). In the case of Grindelwald, the changes in the structure of the local governance system enhanced farmers' capacity to create and alter operational rules within the users association. At this level, farmers are best informed about harvesting and investment activities and have the strongest interest in finding

Table 3. Variables of the social-ecological system framework affected by external socioeconomic developments (industrialization, rapid nonagricultural economic growth, subsidy scheme in agriculture) for the case of Grindelwald.

Variables	Changes that occurred
Resource System (RS)	
RS4 - Human constructed facilities	•Unused alp-huts (mainly cheese storage huts) •Modernized barns (e.g., heating, electricity) •Increased facilities for tourism, such as restaurants, ski lifts, or water reservoirs for artificial snow production, led to reduced grazing area
RS6 - Equilibrium properties	•Decreasing harvest in the marginal areas on the alps has led to observable forest and bush encroachment •Areas covered with forest have increased at the expense of the grazing areas
Resource Units (RU)	
RU1 - Resource unit mobility	•Decreasing mobility of cows due to new breeds •Pastures that are further away from huts/barns are not "harvested"
RU4 - Economic value	•Economic value of milk and milk products has significantly decreased in net value over time •Farm gate prices for milk have decreased from about CHF 1 in the early 1990s to CHF 0.45 at present •Tourism in Grindelwald ensures a high demand for alpine cheese, thereby increasing the relative value of alpine cheese to milk sales
RU7 - Spatial and temporal distribution	•Grazing in marginal areas has been reduced as cows became less mobile
Actors (A)	
A1 - Number of actors	•Slightly increasing number of rights holders •Increasing number of holders of rights not engaging in agriculture
A2 - Socioeconomic attributes	•Income diversification (off-farm income share increased) •Increasing farm sizes (farmers own more livestock and private land than the previous generation)
A4 - Location	•Farm enterprises consist increasingly of dispersed private land holdings in different corporations •Farmers therefore often hold use rights in several corporations, and the location of the farm is no longer the single factor determining the corporation in which the farmer appropriates his cattle
A8 - Importance of resource	•Decreasing importance of meadows as a resource for cow fodder •Increasing importance of meadows for landscape beauty and recreational activities (for tourism)
A9 - Technology used	•Technologies such as modern mowing and transport machineries, or milking technologies have particularly increased productivity on the farm level. On the alps, farmers can use some of their private machinery in order to fulfill their investment requirements.
Governance System (GS)	
GS4 - Property rights systems	•Serves to exclude nonvillagers •No longer required for the assignment of harvesting levels •No longer used to assign the hours of communal work to be fulfilled •The total number of user rights no longer defines the maximum sustainable yield
GS5 - Operational rules	•Division between the position of the appropriator and the rights holder; provision rules tied to these two positions •Hours of communal work conducted with light machinery (e.g., a jigsaw) are counted double •Hours of communal work conducted with heavy machinery (e.g., a small transporter) are counted fourfold
GS6 - Collective-choice rules	•Voting within the association was conducted according to the rights one holds •Currently, all collective choices are made at all levels according to majority rule (50% +1)
GS7 - Constitutional rules	•Corporations were divided into a rights holders association and a users association •In addition, payoff rules can now be autonomously set by the users association, mainly through the setting of fees for over- and underprovision of communal work
GS8 - Monitoring and sanctioning rules	•Sanctions were prescribed at the cooperative level •Currently, most of the penalties for noncompliance regarding the fulfillment of infrastructural investments are set within the users association

Fig. 4.Changes in maximum sustainable yield, constant appropriation, number of rights users, and number of rights holders in the Scheidegg corporation.



adaptive responses to fluctuations in these two focal interactions because they are most affected by the outcomes. The horizontal interplay between the corporations is ensured through the presence of the cooperative and binding statutes. Some operational decisions, such as the appropriation of foreign cattle, can be realized only under the agreement of the cooperative, which allows for checks among corporations. Interlinks with federal law and resource policies have similarly grown stronger as summering payments have become an essential monetary incentive for farmers to keep appropriation within a sustainable range.

Utility of the social-ecological system framework

The SES framework allowed for a systemic analysis of the changes that occurred in the SES, given external socioeconomic developments. As shown in Tables 1–3, the classification along the variables for the SES framework allowed for a structured analysis of the changes in the SES and supports the understanding of how the governance system adapted to changes in other variables of the SES. As the SES framework and the proposed governance variables are rooted in the IAD framework, its key strength lies in the analysis of rules, and the way they structure interactions and outcomes. Furthermore, the framework allows institutional change to be related to changes in the natural resource system because it offers a set of resource-related variables that may affect the governance process. This suggests that the framework is particularly suitable for studies that focus on the social compartment of a SES. Scholars emphasizing the ecological processes within an SES might find frameworks originating in the natural sciences to provide better concepts for their purpose (Redman et al. 2004, Walker et al. 2004, Turner and Robbins 2008). The future integration of these concepts into the present SES framework would be a major step towards a common framework that allows for analysis of equal depth for both the ecological and social compartment of SESs.

Lessons learned

It became evident that analysis of the changes in the structure and rules of the governance system is essential if we want to

look into the dynamics and potential adaptation mechanisms within SESs. As our study has shown, the governance system in Grindelwald adapted to socioeconomic developments by changing rules. Even if the governance system was originally designed to avoid overuse of the resources, it managed to adapt to socioeconomic changes that would have led to reduced use and maintenance of the alps. Although the observed changes in the governance system and its rules are successful adaptations in this case, they might be far from optimal if applied to other contexts. Accordingly, it cannot be assumed that the rule configuration as reported herein serves as a blueprint for effective rule evolvement for the governance of common property resources. However, based on the findings, we suggest four properties of governance systems that facilitate successful adaptation of rules to socioeconomic changes:

- Constitutional flexibility: allows the governance system to adapt its structure to problems such as the decreasing bargaining power of those most interested in the productivity of the resource system
- Multiple nested assemblies: allows competencies among different assemblies to be located, which ensures that an arising issue is processed in the corresponding assembly
- Polycentric design: ensures vertical integration and control between user groups about the rules they are crafting, and at the same time ensures the flow of information about the performance of rule configurations
- Subsidiary design: allows changing the rule configuration by the people best informed about the state of the system

Future research

Future studies that address the dynamics of SESs should focus on further investigating the linkage between changes in the SES and changes in the governance system. We have shown that for the case of Grindelwald, a close relationship can be postulated. These studies need to further elaborate the patterns of rule evolvement, and to relate them to changes in the SES and outcomes. Such research will provide a better understanding of the properties of governance systems that allow for effective rule change, and thus provide the empirical base for the general theory of institutional change, applicable to the governance of common property resources. Furthermore, a simulation model might support the assessment of strategies that support or hinder the sustainable development of the SES given its external and internal dynamics and regulatory structures.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5689

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Essay 2

WHY DO INDIVIDUALS BEHAVE DIFFERENTLY IN COMMONS DILEMMAS? THE CASE OF ALPINE FARMERS USING COMMON PROPERTY PASTURES IN GRINDELWALD, SWITZERLAND.

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Why do individuals behave differently in commons dilemmas? The case of alpine farmers using common property pastures in Grindelwald, Switzerland

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Abstract: The sustainable use of common-pool resources depends on users' behaviour with regards to appropriation and provision. Most knowledge about behaviour in such situations comes from experimental research. As experiments take place in confined environments, motivational drivers and actions in the field might differ. This paper analyses farmers' use of common property pastures in Grindelwald, Switzerland. Binary logistic regression is applied to survey data to explore the effect of farmers' attributes on livestock endowment, appropriation and provision behaviour. Furthermore, Q methodology is used to assess the impact of broader contextual variables on the sustainability of common property pastures. It is shown that the strongest associations exist between (a) socio-economic attributes and change in livestock endowment; (b) norms and appropriation behaviour; and (c) area and pay-off and provision behaviour. Relevant contextual variables are the economic value of the resource units, off-farm income opportunities, and the subsidy structure. We conclude that with increasing farm size farmers reduce the use and maintenance of common property. Additionally, we postulate that readiness to maintain a resource increases with appropriation activities and the net returns generated from appropriation.

Keywords: Appropriation, common-pool resource, contextual factors, provision, Q methodology, social-ecological systems, statistical analyses, user attributes

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1. Introduction

Natural resources like fishing grounds, forests, pastures, and water are often managed as common-pool resources. Common-pool resources are jointly managed resources, for which individuals' appropriation diminishes the resource stock and potential beneficiaries of which are difficult to exclude (Berkes et al. 1989). Additionally, most common-pool resources rely on provision activities for the supply of resource units and the upkeep of the resource system. Appropriation and provision activities comprise social dilemmas, in which users' short-term self-interest stands opposed to the interest of the group, that is to maximise appropriation and minimise provision activities (Gardner et al. 1990).

The behaviour of individuals in commons dilemmas affects the sustainability of all common-pool resources. Game theory provides the means to simulate both appropriation and provision behaviour in laboratory experiments, whereby the appropriation problem equals a common-pool resource game. As such, the appropriation of users diminishes the resource and hence reduces the stock and pay-offs of co-players (Keser and Gardner 1999; Cárdenas and Ostrom 2004; Osés-Eraso and Viladrich-Grau 2007; Ahn et al. 2010; Janssen et al. 2010). The provision problem matches a public good game. Public good experiments require players to invest in a common stock. The stock changes depending on the investments made and with it the individual's return on the investments (Isaac et al. 1994; Ledyard 1994; Fischbacher et al. 2001; Gächter and Thöni 2011). Recent attempts to validate findings from the laboratory with field experiments underline that users are sometimes able to overcome social dilemmas to achieve socially desirable outcomes (Cavalcanti et al. 2010; Rustagi et al. 2010; Prediger et al. 2011).

Whilst experiments provide important information about the factors facilitating cooperation, they offer limited explanations for the behaviour of real common pool resource users, mainly because the material constraints, preferences, and motives as they appear in the field are difficult to control for in experiments. This is due to the following reasons: Firstly, the underlying assumption of game theory that self-seeking players behave strictly rational to maximise pay-offs does not reflect reality (Smith 2010). Secondly, the behaviour of individuals in experimental settings is detached from personal characteristics (Levitt and List 2007; Anderies et al. 2011). Thirdly, subjects in laboratory experiments are usually students from Western

countries, whose personality traits might differ from those of common-pool resource users (Henrich et al. 2010). To complement experimental studies, more information is needed about the variables driving the behaviour of real common-pool resource users (Janssen and Ahn 2006; Poteete et al. 2010; Anderies et al. 2011). That information can then be integrated in experimental design to provide the common ground towards a more general behavioural theory of human actions in the use of common-pool resources beyond models of pay-off maximising individuals.

In doing so, this study analyses the use of common property pastures in Grindelwald, Switzerland. Common property pastures in Switzerland are located at higher altitudes, characterized by mountainous terrain. Therefore, they can only be used to graze cattle during the summer months. These pastures are typically managed and owned by public corporations. The sustainable use of common property pastures depends crucially on social-ecological interactions, namely appropriation (grazing intensity) and provision (maintenance of the ecological system and the respective infrastructure). Since both under- and overgrazing have adverse effects on the resource system, for example by reducing biodiversity or pasture productivity, total appropriation should remain within a sustainable yield. Furthermore, provision activities are needed to maintain or enhance the productivity of the resource system. Therefore, the sustainable use of common property pastures is analogous to common pool and public goods games, dependent upon the following actions of farmers:

- Change in livestock endowment: As livestock provides the means to harvest from common property pastures, farmers' livestock endowment determines potential appropriation and provision levels.
- Appropriation: The decision whether to send animals to the local common property pastures or have them graze in the valley.
- Provision: The work or capital farmers invest to maintain common property pastures and the related infrastructure.

To better understand the drivers behind individual's actions and the role of contextual variables for the use of common-pool resources, the study aims to answer the following questions:

a. What are the overall outcomes for change in livestock endowment, appropriation, and provision situations?
b. What are the individual attributes explaining behavioural differences?
c. How do broader contextual variables relate to the use of common property pastures?
d. What are the implications for the study of the commons and policy makers?

The paper is structured as follows: Firstly, we introduce the case study region and the institutions that influence and structure farmers' actions. Secondly, we describe the conceptual framework, expanding on microsituational and contextual variables, and the methods to study their impact on farmers' actions. Thirdly, we present the

regression models explaining change in livestock endowment, appropriation, and provision. Furthermore, we present the results from Q methodology, which show the impact of contextual variables on the sustainable use of common property pastures. Finally, we discuss the implications of the study for policy makers and further research.

2. The case study region

Grindelwald is a Swiss municipality in the canton of Bern covering 171 km^2, located in the heart of the European Alps (46° 37′ 32.98″ N, 8° 2′ 0.02″ E). With seven corporations self-governing the use of common property pastures, Grindelwald offers a natural lab-like setting for the study of appropriation and provision behaviour analogous to common pool and public good experiments (Table 1). Due to its natural beauty and snow sport facilities, Grindelwald is an internationally known tourism resort that attracts visitors all year round. Consequently, tourism is the most important source of income and offers diverse employment opportunities. Unlike other rural regions, the local population remains stable with about 3800 inhabitants. Besides tourism, agriculture, in particular dairy farming, manages to coexist with tourism, even if the number of farmers is steadily diminishing as a result of structural changes in the agricultural sector towards fewer, but larger sized farms. Since 1980, the number of farmers in Grindelwald has roughly halved from 242 to 123 in 2010. As a consequence, the average farm size has nearly doubled in terms of livestock and land holdings from about 5–6 to nearly 12 livestock units and hectares per household. Correspondingly, land use intensity on private grounds has been relatively stable in terms of livestock units per hectare, but has been significantly intensified in terms of cuts per year.

In addition to private land holdings, common property pastures provide an important source of animal feed. In the summer months, when farmers produce hay on their private lands for wintertime, the livestock grazes on common property pastures, looked after by herdsmen that produce artisan cheese from the milk. The herdsman is either the owner of the alp's huts himself or a seasonal employee. The fees farmers pay to the corporation for the care of the animals provides the

Table 1: Institutions for regulating appropriation and provision activities (Units in brackets; NST = a summered livestock unit).

Corporation Units	Maximum sustainable yield (NST)	Provision requirements (hours/NST)	Penalty for defection on provision (CHF/ hour)	Reimbursement of extra hours of provision (CHF/hour)
Grindel	251	8	25	22
Scheidegg	234	8	24	20
Wärgistal	167	8	25	25
Itramen	217	8	30	29
Bussalp	256	10	25	20
Bach	149	8	25	22
Holzmatten	74	8	25	25

herdsman's income. At the end of the season, the cheese stock is redistributed to the cattle owner according to the cows' milk yield.

2.1. Property arrangements

As Figure 1 shows, the productive area of Grindelwald is divided between 7 corporations ("Bergschaft"). The corporations separate their land into private property in the valley (inside the red dotted line) and common property in higher altitude regions (outside the red dotted line). The small corporation "Holzmatten" is a special case as its private lands are cut off from the common property. The large uninhabitable area to the southeast is the only municipal territory not assigned to a corporation, but instead is under the sovereignty of the canton of Bern.

2.2. Institutional arrangements

The corporations enforce institutions to regulate appropriation and provision activities. Ownership and leasehold of private land allows for appropriation of common property pastures (Naegeli-Oertle 1986; Mordasini and Tiefenbach 2006). All sections of land in the valley have rights attached to them that allow for appropriation in the corresponding corporation. Therefore, the location and the number of private plots formally restrict a farmer's appropriation activities. Since rights can be leased among locals at reasonable rates, appropriation is not restricted for locals, neither by the amount of rights nor by the exact location of private plots.

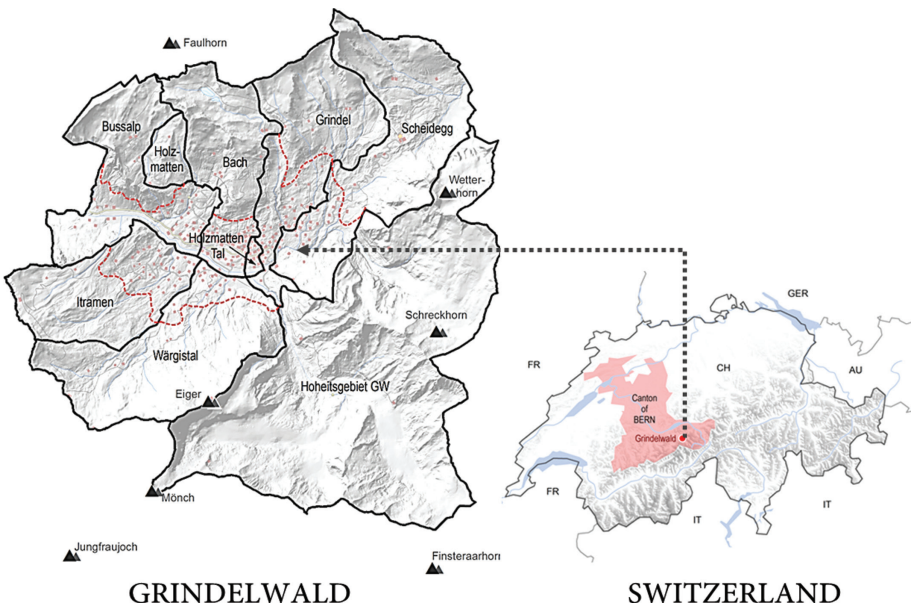

Figure 1: The case study region with the seven corporations (Source: Swisstopo).

In return for the benefits obtained from appropriation, farmers must carry out provision activities or face fines. Provision activities consist of tasks such as the cleaning of pastures from bush, shrubs and stones, the installation of fences and drinking troughs, the distribution of manure, and the maintenance of storage facilities (Mordasini and Tiefenbach 2006). As indicated in Table 1, corporations schedule the hours of provision activities required per appropriated unit, set out penalties for defection and reimburse for additional provision efforts if the budget allows for. Each corporation elects a monitor who sanctions defection on provision activities and organises additional provision activities. If defectors fail to settle fines within a year, they lose the right to appropriate from the common property pasture.

The maximum sustainable yield (MSY) is governed by agricultural policy through summering payments. The federal government subsidises each appropriated unit with CHF 320 per year, paid to the corporation. The subsidy must be reinvested to maintain the resource system and is incrementally reduced, if actual appropriation levels are above 10% or below 25% of the maximum sustainable yield as defined for the corporation. In Switzerland, the sustainable use of common property pastures is currently threatened by under- rather than by overgrazing which results in land abandonment and regrowth of forest and shrubs and consequently reduced bio- and landscape diversity. Summering payments therefore provide incentives for the corporation to keep grazing levels within a sustainable yield, including a lower and upper limit. The maximum sustainable yield is measured in appropriated units (NST). An appropriated unit corresponds to a livestock unit (GVE) summered for a hundred days. A livestock unit reflects an animal's weight and nutritional needs. Accordingly, a dairy cow represents one unit, young cattle of 1–2 years 0.4 units, cattle up to 1 year 0.2 units, sheep 0.25 units, and goat 0.2 units.

3. Methods

3.1. The Framework for analysing behaviour of common-pool resource users

This study uses the framework for analysing behaviour in commons dilemmas (Poteete et al. 2010). The framework build on the social-ecological systems framework proposed by Ostrom (2007, 2009), which compasses three levels of analysis: Firstly, the action situation with the users' behaviour; secondly, the microsituation with the behavioural drivers; thirdly, the broader social-ecological context, where the latter affects the outcome of the microsituation.

Figure 2 displays the framework focus on the action situation. Recent extensions of this framework highlight the adjacency of action situations (McGinnis 2011). As changes in livestock endowment determine potential appropriation and appropriation determines provision, the observed action situations are closely linked. The actions result in an overall intensity of use and maintenance of the common property pasture as the outcome. The microsituation refers to the users' actions driven by personal attributes (*U1*...*U10*). The broader social-ecological context determines the microsituation and consists of the second tier variables, which describe a social-ecological system

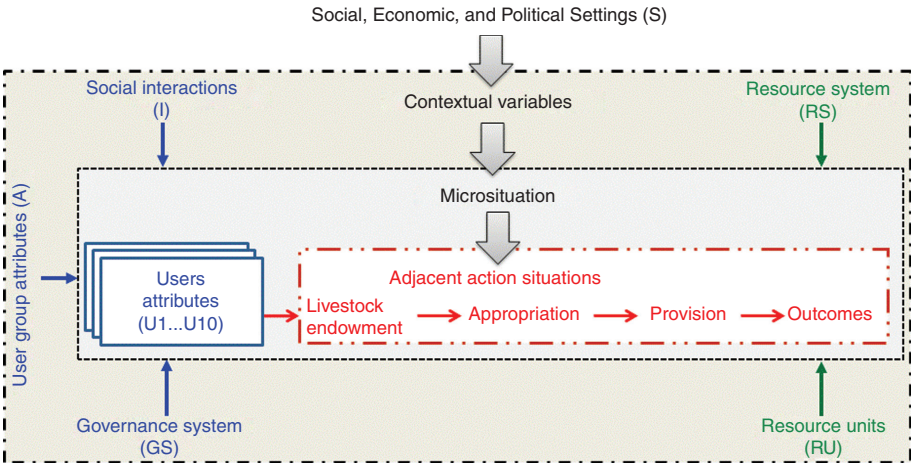

Figure 2: Conceptual model for analysing behaviour in adjacent action situations. Adapted and modified after Poteete et al. (2010, 220–239).

(Ostrom 2007). Consequently, contextual variables include external settings (*S*), the resource system (*RS*), the governance system (*GS*), the resource units (*RU*), users' attributes on the group (*A*) level, and social interactions (*I*) (Ostrom 2007; McGinnis 2011). As user attributes describe both group (*A*) and individual characteristics (*U*), they are part of the microsituation as well as of the broader context as group attributes.

3.2. Analysis of the microsituation

In the microsituation, users' attributes are the explanatory variables and the actions the dependent binary variables. Data was collected in a standardised survey carried out in the course of three weeks in summer 2011. Ninety-five questionnaires were collected from 125 registered local farmers, mostly at their home. The interviews lasted on average 105 minutes and were conducted in teams of two, with a graduate student leading the interview assisted by a bachelor student completing the questionnaire. We interviewed at least 50% of the farmers in each corporation. Only 6 of the interviewed farmers were female.

The dependent variables were cross-checked for reliability with census data and against information collected from the monitors in order to ensure data quality. Livestock endowment was compared as nominal and as binary measure. The survey data for appropriation in absolute numbers were extrapolated to population size and then compared with the census data. The measures for provision behaviour were also extrapolated and compared with the information from a survey conducted with monitors of the corporations (n=7). The main purpose of this survey was to gather data on land use change published in another study. In this survey, the monitors had to state the number of defectors for 2010 in their corporation. For measuring change in livestock endowment we referred to a timespan of ten years

(2000–2010) as it is constrained by fixed factors. As appropriation and provision are seasonal decision, we referred to the behaviour in the past season (2010).

3.2.1. Operationalization of explanatory variables

The explanatory variables consisted of second tier variables describing the users as proposed in the Social-Ecological Systems framework (Ostrom 2007, 2009; Poteete et al. 2010). Moreover, we added variable opportunity costs (U10) and operationalized the variables as follows:

U1- Number of users referred to the number of farmers in the corporation.

U2- Socioeconomic attributes include
- a) Age
- b) Marital status
- c) Successor: whether the farmer expected a family member to continue with the farm enterprise
- d) Area under cultivation
- e) Land use intensity for private plots
- f) Labour productivity of the farm enterprise

U3- History: a change in the farming strategy in the past ten years e.g. a switch in production standards or shift from dairy to mother cows.

U4- Location: geographic location of the farm. Since corporations with exposition North-East (Itramen, Wärgistal) are facing less demand for land from tourism, we expected agriculture to be more prosperous in that area.

U5a- Leadership referred to farmers holding a formal function within the corporation.

U5b- Entrepreneurship was measured as the pay-off per livestock unit resulting from the farmers' appropriation behaviour (equation 1).

$$\frac{\pi_i}{e_i} = x_i(\omega_i - c) + \alpha_i(e_i - x_i) - (MSY_{corp} - x_j)s\frac{x_i}{\sum x_j} \quad (1)$$

Farmers pay-off (π_i) per livestock unit (e_i) depended on their appropriation behaviour. For each livestock unit, the farmer decided to either send it to common property pastures (x_i), or have it graze on private land (e_i–x_i). Each appropriated unit (c) costs a fee of CHF 700 to compensate herdsman for the care and milking of the animal. The revenue of the appropriated unit (ω_i) is the farmer's revenue from cheese sales. The revenue from grazing a livestock unit on private land (α_i) equals the revenue of milk sales during the period. Since the corporation receives a subsidy (s) of CHF 320 per appropriated unit, the difference between maximum sustainable yield of the corporation (MSY_{corp}) and the actual appropriation levels in the corporation (x_j) results in foregone subsidies. We considered the forgone subsidies as costs that a farmer bears according to his share of the total appropriation in the corporation. ($x_i/\sum x_j$).

U6a- Norms measured the farmer's aversion against defection on communal work of joint-users.

U6b- Social capital measured the amount of voluntary labour available to the farmer. This included family and friends who do not live in the same household.

U7- Mental model referred to the identity of the individual regarding his profession. That is, whether the person considered his job title "Farmer" or not.

U8- Importance of resource reflected the household's dependence on agricultural income.

U9- Technology used referred to the production standard. Integrated production (*IP-SUISSE*) is the dominant production standard in the region and refers to a set of production requirements stricter than conventional, but more lenient than for organic farming.

U10- Opportunity costs measured the farmer's relinquished benefit from off-farm income when doing agricultural work (equation 2).

$$Opportunity\ cost = \frac{LA_i}{LO_i} * \frac{IO_i}{IA_i} \tag{2}$$

Whereas (LA_i) is the household's work hours allocated to agricultural activities divided by hours spent doing off-farm activities (LO_i), multiplied by the off-farm income (IO_i) over the agricultural income (IA_i).

3.2.2. Statistical procedure

We calculated binary logistic regression models to predict growth in livestock endowment, appropriation and provision behaviour based on the users' attributes. Binary logistic regression calculates the log of the odds for a dichotomous dependent variable by maximum likelihood (ML) estimation (Hosmer and Lemeshow 2000; Menard 2001) (equation 3):

$$\text{Logit (Y)} = \ln\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_k \tag{3}$$

Where:

P is the probability of the outcome for Y=1 (i.., growth in livestock endowment, full appropriation and provision)

β_0 is the constant in the model

$X_1 \ldots X_k$ represent the explanatory variables

$\beta_1 \ldots \beta_k$ represent the coefficients for the respective explanatory variables

To estimate the parameters of the model, we first calculated full models including all explanatory variables. As we had solely 89 data points for the variable labour

productivity (*A2e*) and 84 data points for the variable opportunity costs (*A10*), we omitted the two variables if not of significant explanatory power when calculating the reduced models. Thirdly, we estimated the parameters for the reduced models by maximum likelihood. The reduced models were selected by Bayesian Information criterion (BIC). Test statistics included for all models a non-significant Pearson Chi-squared, and significant Chi-squared tests. Lastly, we calculated standardised beta weights based on the mean of the predicted probability and the standard deviation of $x_1 \ldots x_k$ (King 2007). The standardised beta transformed the coefficients into "standard deviation units" that allowed for scale-free comparison of binary and nominal variables (Menard 2004). The analysis was performed with the software package SPSS, Version 20.

3.3. Analysis of the broader contextual variables

We then applied a Q method approach to analyse the impact of contextual variables on the ecological, economic, and social sustainability of the social-ecological system. Originating in psychology, this method has been applied to a variety of social-ecological problems aiming to develop detailed portraits about people's perspectives on a given problem (Swaffield and Fairweather 1996; Paula 2006; Swedeen 2006; Doody et al. 2009). As the local farmers were deemed to have the best knowledge about the way contextual variables affect the use of common property pastures, Q methodology was chosen to extract that knowledge by means of a five-step procedure.

i. Problem definition: Based on literature review and explorative interviews, we identified 34contextual variables that potentially affect the use of common property pastures. We identified 9 variables describing the external setting (*S*), 10 variables for the local governance system (*GS*), 3 for the resource system, 2 for the resource units (*RU*), 5 for interactions (*I*), and another 5 describing the group attributes of the users (*A*).
ii. Formulation of statements and definition of the sorting scheme: We used contextual variables instead of normative statements and decided that farmers should group the variables on a scale according to their perceived impact on the sustainable use of common property pastures. The scale ranged from +4 to −4, with the most positive impact at +4 and the least positive impact at −4 (Table 2).
iii. Selection of subjects: For our purpose, sampling included the people best informed and most affected by the problem under concern (Rajé 2007). Thus, we selected the seven monitors and four additional farmers for participation.
iv. The sorting procedure (Q sorting): Before sorting, we asked farmers to divide statements into three piles according to their impact on the use of common property pastures; one with variables considered to have a

Table 2: Q sorting scheme.

Q sorting scheme	Least positive impact						Most positive impact		
Statement ranking	−4	−3	−2	−1	0	1	2	3	4
Number of statements	2	3	4	5	6	5	4	3	2

positive impact, one with variables considered to have a negative impact, and one with neutral variables. We simply asked farmers to evaluate whether the variables have a positive or negative or neutral impact on the use of common property pastures instead of mentioning sustainability. This pre-sorting mostly resulted in unequally distributed piles. Farmers then had to rank the statements on the scheme (Q sorting). During sorting, we asked farmers to comment on the reasoning for the placement which was recorded. At the end of sorting, farmers were given the opportunity to reflect on their choices and to reallocate variables. In order to qualitatively understand the impact of the variables on the different sustainability dimensions and on the functioning of the overall social-ecological system, we finally discussed sorting with the farmers. We then photographed the Q sorts and computed them later on.

v. Factor analysis and interpretation of results: We analysed the collected samples using the standard PQ Method software, Version 2.31. We calculated the mean z-scores for each statement and the corresponding rank to represent the aggregate view. Additionally we conducted a principal component analysis that generated 8 factors of which 4 had an Eigenvalue bigger than 1. As all subjects loaded significantly on one of the two factors with the highest Eigenvalues, we considered these two factors for Varimax rotation, which finally displayed the two most contrasting views (Fairweather and Swaffield 2001; Paula 2006).

4. Results

4.1. Descriptive statistics of the microsituation

Table 3 presents the measures for the dependent variables by corporation. Farmers with increasing livestock endowment outweighed farmers with decreasing endowment. The majority of farmers appropriated their entire endowment. Among the farmers with reduced appropriation strategy, nine farmers didn't appropriate at all and were therefore exempt from provision duties. The 86 farmers with provision duties showed strong tendencies towards full accomplishment of provision. On an aggregate level, all corporations achieved sustainable appropriation levels in terms of compliance with the range of state defined sustainable yields (75%–110% of optimal yield). The most intensive appropriation levels were observed in the

Table 3. Descriptive statistics for dependent variables listed per corporation.

Corporation	Livestock endowment		Appropriation		Provision	
	Reduced	Growing	Reduced	Full	Reduced	Full
Grindel	3	9	3	9	2	9
Scheidegg	7	8	7	8	2	12
Wärgistal	3	7	2	8	0	9
Itramen	7	11	10	8	0	18
Bussalp	9	12	10	11	1	19
Bach	6	4	3	7	1	8
Holzmatten	8	1	4	5	0	5
Total	43	52	39	56	6	80
(%)	(45%)	(55%)	(41%)	(59%)	(7%)	(93%)
Cronbachs-α	0.958		0.874		0.723	

corporation Scheidegg with 107% of maximum sustainable yield and lowest for Bach with 82% of maximum sustainable yield. Since no corporation showed a serious amount of defectors, overall provision activities are very close to the institutionally determined maximum. Therefore, both actions can be considered ecologically sustainable.

As indicated by the Cronbach's-α, survey data show very good to satisfying reliability for dependent variables if compared with census or respectively monitors information. Livestock endowment ideally matches census data if coded as binary. However, our sample shows a nominal increase in total livestock endowment by 9%, while the census shows a reduction of 8% from 2000 to 2010. Therefore, farmers with growing livestock endowment are slightly over-represented in the sample. The comparison of appropriation data with the census also shows good reliability with Cronbach's-α at 0.874. The provision data shows lower reliability with Cronbach's-α at 0.723, as monitors indicated 15 defectors, whilst our sample included six. The reason for the deviation is that our sample includes local farmers only while the monitors also referred to 8–10 external farmers, which, according to monitors, are more likely to defect on provision activities.

Table 4 shows the descriptive statistics for farmers' attributes considered in the regression models. Farmers were on average 51.6 years old (*U2a*) with a mean cultivated area (*U2c*) of nearly 12 hectares. Typically, farmers held one livestock unit per hectare (*U2d*). According to the farm size index (SAK), a farm of this size can be managed by one person. The mean value for labour productivity (*U2e*) indicates that it took in fact two persons to run the farm, including the work of partners and voluntary labourers. With regard to family structure, most farmers were married (*U2b*) and often counted on voluntary labour (*U6b*) provided by their own children, grandparents, or neighbours but rarely expected family succession (*U2f*). Importance of resource (*U8*) shows that most farming

Table 4: Descriptive statistics for explanatory variables.

Farmers' attributes	Description	N	Mean	SD
U1- Number of users	Number of farmers in the corporation to which the farmer belongs	94	21.45	4.73
U2- Socioeconomic attributes of users	a) Age of farmer – Nominal (years)	95	51.62	12.28
	b) Marital status – Binary variable. Value 1 if farmer is married	95	0.75	0.44
	c) Area under cultivation – Nominal (ha)	94	11.93	7.84
	d) Land use intensity for private plots – Nominal (GVE/ha)	95	0.98	0.37
	e) Labour productivity – Effective working hours / work time needed according to farm size index (SAK)	89	0.5	0.29
	f) Successor – Binary variable. Value 1 if farmer thinks that there will be a successor in the family willing to continue with the farm business.	95	0.27	0.45
U3- History of use	History – Binary variable. Value 1 if farmer has changed the farming strategy within past 10 years.	95	0.67	0.47
U4- Location	Location – Binary variable. Value 1 if the farmer is located exposition North-East.	94	0.31	0.46
U5- Leadership/ entrepreneurship	a) Leadership – Binary Variable. Value 1 if the farmer has a formal function within the corporation	95	0.32	0.47
	b) Pay-off per GVE during summering season – Nominal variable (CHF)	94	149.1	533.6
U6a- Norms	Norms – Binary variable. Value 1 if the farmer dislikes other farmers avoiding communal work and paying fines instead.	94	0.45	0.5
U6b- Social capital	Social capital – Percentage of voluntary labour available to the farmer when needed (excluding their partners).	95	64.16	56.43
U7- Mental models	Mental model – Binary variable. Value one if the farmer considers his job title to be "Farmer".	94	0.64	0.48
U8- Importance of resource	Importance of resource – Share of agricultural income in proportion to total household income	95	36.78	29.46
U9- Technology used	Technology – Binary variable. Value 1 if the farmer produces according to IP standards.	95	0.68	0.47
U10- Opportunity costs	Opportunity costs – Share of agricultural working hours in relation to total working hours divided by the share of agricultural income in proportion to total income.	84	2.92	3.26

households substantially relied on off-farm income and no household relied solely on agricultural income. With regard to their pay-off (*U5b*), farmers differed widely, as the function allows for negative values. Farmers that appropriated non-milked animals or used a substantial amount of the cheese for their own consumption did not cover the costs of their appropriation decisions. The variable importance of resources shows that farmers in the region have good off-farm income opportunities. On average, their earnings per hour off-farm work triple the earnings from agricultural work. The sample also includes 11 retired farmers that have no opportunity costs (*U10*) for farming activities.

4.2. Regression model for change in livestock endowment

Table 5 lists variables significantly associated with change in livestock endowment. Considering the Bayesian Information Criterion (BIC), the model with 4 variables offers the best fit to the data in relation to the variables included. The β-values reveal positive effects for marital status (*U2b*) and area (*U2c*), and negative effects for age (*U2a*) and norms (*U6a*) on the odds of increasing livestock endowment. The standardised β-values display the actual effect of the variables in the model, irrespective of scale.

As indicated by the standardised β, area is the strongest predictor for change in livestock endowment. With every additional hectare of cultivated area (*U2c*), the odds for livestock growth increased by 17.5%. This suggests that size conditions growth and those farmers with larger sized farms are more likely to attempt to realise economies of scale than colleagues with smaller landholdings.

Age proved to be the second best predictor for change in livestock endowment, as an additional year of life reduced the odds for livestock growth by 7.8%. This relationship might be partly linked to farmers' fitness and partly to policies. As age (*U2a*) is negatively correlated with labour productivity (*U2e*), decreasing physical abilities possibly forced some farmers' to reduce livestock endowment. Additionally, farmers receive substantial direct payments until retirement age. This suggests that farmers' willingness to invest in factors constraining livestock endowment such as barn capacity or land decreases as they approach retirement age. The main reason might be that without direct payments, such investments are likely to become untenable.

*Table 5: Estimated and standardised β-coefficients for binary logistic regression models predicting change in livestock endowment. Standard errors (se) in brackets and significance levels p are indicated by asterisk (99%***, 95%**, 90%*).*

Explanatory Variable	β (se)	β^s
U2a- Age	–0.081	–0.230***
	(0.026)	
U2b- Marital status	1.602	0.163**
	(0.645)	
U2c- Area	0.161	0.288***
	(0.048)	
U6a- Norms	–1.354	–0.158**
	(0.576)	
Constant	2.358	
	(1.339)	
N	94	
Pseudo R^2 (NK)	0.514	
–2LL	82.6	
BIC	105.2	

Growth in livestock endowment was also associated with marital status (*U2b*). For married farmers, the odds for endowment growth increased 4 times. This suggests that partnership facilitates dealing with the extra workload resulting from additional livestock. Rather surprisingly, norms (*U6a*) which display positive attitude towards the fulfilment of provision activities decreased the odds for endowment growth by a factor of 0.24. This suggests that with growth in endowment, the concern for the maintenance of common property decreases.

4.3. Regression model for appropriation behaviour

Table 6 presents the variables significantly associated with appropriation behaviour. The β-values show a positive association of marital status (*U2b*) and norms (*U6a*) and negative association of area (*U2c*) and leadership (*U5a*) with full appropriation. As displayed by the standardised beta weights, norms (*U6a*) are the best predictor for appropriation behaviour followed by leadership (*U5a*), marital status (*U2b*), and area (*U2c*).

We found the strongest association to be between norms (*U6a*) and appropriation behaviour. Hence, farmers with aversion against defection on communal work had 2.4 times higher odds for appropriating all their livestock which points to self-interest. A farmer appropriating all his livestock is likely to be more concerned about the state of the resource and therefore also cares about joint-users fulfilling their provision activities. Leadership attributes (*U5a*) assigned to farmers with formal function in a corporation reduced the odds for full appropriation by a factor of 0.38. As farmers communicated, reduced

*Table 6: Estimated and standardised β-coefficients for binary logistic regression models predicting appropriation. Standard error (se) in brackets, significance levels indicated by asterisk (99%***, 95%**, 90%*)*

Explanatory Variable	β (se)	β^s
U2b- Marital status	0.916	0.096*
	(0.522)	
U2c- Area	–0.038	–0.073*
	(0.032)	
U5a- Leadership	–0.945	–0.106*
	(0.524)	
U6a- Norms	1.253	0.150***
	(0.484)	
Constant	–0.045	
	(0.599)	
N	93	
Pseudo R^2 (NK)	0.220	
–2LL	109.0	
BIC	131.6	

appropriation lessens workload. In this case, mostly younger cattle are kept in the valley to graze unproductive pastures for which mowing is labour intensive. Possible explanations would therefore be that leaders cultivated more marginal pastures or tended to have younger animals.

Socio-economic attributes such as marital status (*U2b*) and area (*U2c*) were also significantly associated with appropriation behaviour. Married farmers were 1.5 times more likely to appropriate their full endowment, while an additional hectare of area leads to a decrease in the odds of full appropriation by 3.7%. The reasoning for both variables again might point to the role of workload. When hay collection and provision duties can be split among couples during peak times, appropriation behaviour of married farmers might be less determined by labour scarcity. The need to reduce workload might also increase with area (*U2c*), leading farmers with larger land holdings to reduce appropriation and concentrate on private lands.

4.4. Regression model for provision behaviour

Table 7 displays the reduced model for provision behaviour. The models entail fewer cases, as farmers without appropriation were exempt from provision activities. The uneven distribution of the dependent variable explains larger standard errors. Stepwise reduction points to area (*U2c*), followed by pay-off (*A5b*), and importance of resource (*A8*) as the most important predictors.

The strongest association existed between area (*U2c*) and provision behaviour. That is an increase in land holding by an additional hectare reduced the odds of full provision by 19.2%. The negative effect of land holding on provision suggests that extra workload resulting from additional plots prevents farmers from accomplishing their provision duties. Regarding the beta coefficient, an

*Table 7: Estimated and standardised β-coefficients for binary logistic regression models predicting provision behaviour. Standard error (se) in brackets, significance levels indicated by asterisk (99%***, 95%**, 90%*)*

Explanatory Variable	β (se)	β^s
A2c- Area	–0.213	–0.127**
	(0.116)	
A5b-Pay-off	0.003	0.108**
	(0.001)	
A8-Importance of resource	0.048	0.103*
	(0.027)	
Constant	3.734	
	(1.223)	
N	86	
Pseudo R^2 (NK)	0.248	
–2LL	34.6	
BIC	52.4	

additional Swiss franc in pay-off (*U5b*) increased the odds of full provision by 0.3%. Although this seems negligible, the standardised coefficient illustrates that with a coarser scale, the effect would have become more pronounced. Moreover, importance of resource shows that an increase in agricultural income of 1% compared to non-agricultural income, increased the odds of full provision by 4.9%. The positive association of pay-off (*U5b*) and importance of resource (*A8*) with full provision suggests a strong positive relationship between the benefits obtained from a resource and farmers' willingness to maintain it.

4.5. The impact of contextual variables on the sustainable use of common property pastures

Table 8 shows the impact of contextual variables on the sustainable use of common property pastures in terms of ecological, economic, and social outcomes. The Mean value represents the overall sample, while Factor A and B represent the most distinguishing views. According to the overall sample, sustainability is promoted in particular through the functioning of the subsystems resource units (*RU*) and to a lesser extent by group attributes (*A*). The subsystem challenging sustainability includes the external settings (*S*), the resource system (*RS*), and interactions (*I*). The role of the governance system (*GS*) is neutral.

The mean value for the external settings reflects discontent with agricultural policies. Both government resource polices (*S5*) and market incentives (*S6*) achieve negative scores. The most problematic issues include dependence on direct payments, regulations for obtaining them and the milk price. In summary, farmers see government support and the relevant regulations as threatening entrepreneurial freedom and would instead appreciate stronger market incentives. Among government policies, only summering payments contribute to sustainability and provide financial resources to the corporation for the maintenance of the resource system. The mean value for income opportunities in the tourism sector shows the importance of off-farm income for farmers' livelihoods. Accordingly, tourism rather enables than competes with farming, even though in the resource system (*RS*) increasing demand for building sites, reduces available productive agricultural land. Within the governance system (*GS*), the local constitutional rules (*GS7*) are considered to have a positive impact, including the recent opening of common property pastures to non-local users. Thus, the presence of foreign cattle is not a desired development, but a necessary response to decreasing local livestock. Furthermore, the agricultural sector faces decreasing standing in municipal politics.

Resource units (*RU*) achieve the highest scores, as their economic value (*RU4*) provides incentives for the use of common property pastures. Particularly the added value in the production of alpine cheese compared to milk sales motivates appropriation. The main reason for the high added value of alpine cheese is sales opportunities resulting from the demand strengthened by the local tourism sector. Besides high scores for the resource units, users' group attributes (*A*) also achieved a slightly positive score. Surprisingly, interviewees consider the group

Table 8: Normalised factor scores for contextual variables on ordinal scale ranging from +4 indicating the most positive impact to −4 indicating the least positive impact of the variables on the sustainable use of common property pasture. The Mean values refer to the overall sample, while Factors A and B display the most distinguishing views. Asterisks mark the variables distinguishing Factors at a significance of 99%. Values for subsystems and second tier variables are calculated by means of the referring statements.

Contextual variables	Normalised scores		
	Mean	Factor A	Factor B
External Settings (S)	**–0.7**	**–0.7**	**–0.1**
S5- Government resource policies	–0.7	–0.2	0
Dependence on agricultural income*	–1	–3	4
Direct payments tied to livestock*	–1	2	–2
Direct payments tied to private land*	0	0	3
Ecological regulations for obtaining direct payments*	–3	0	–4
Rules for the obtainment of summering payments*	–1	–3	1
Summering payments*	2	3	–2
S6- Market incentives	–0.7	–1.7	–0.3
Off-farm income opportunities in the local tourism sector	4	3	2
Dependence upon direct payments*	–4	–4	0
Milk price	–2	–4	–3
Resource System (RS)	**–0.3**	**–0.7**	**–0.7**
RS3- Size of resource system	–0.5	–1	–1.5
Availability of agricultural area in the valley	–2	–1	–2
Area of the corporation	1	–1	–1
RS5- Productivity of system			
Quality of common property pastures	0	0	1
Governance System (GS)	**0**	**0.3**	**0.4**
GS3- Network structure	–0.7	1	1.3
Recognition of agriculture by local politics	–3	–1	–1
Reimbursements of railway operators to the corporations	0	2	2
Solidarity between the corporations	1	2	3
GS4- Property rights system	–0.7	–0.3	–0.7
Flexibility and lease of use rights*	0	–2	1
Amount of use rights in relation to the stock of animals present in the valley	–2	1	0
Attachment of use rights to private parcels in the valley*	0	0	–3
GS5- Operational rules	0.3	–0.3	–0.7
Hours of communal work to be conducted	2	1	1
Opening of the common property pastures for foreign cattle*	3	0	–2
Presence of foreign cattle on the common property pastures	–4	–2	–1
GS7- Constitutional rules			
Rules of the local constitution*	3	2	4
Resource Units (RU)	**3.5**	**4**	**1**
RU4- Economic value	3.5	4	1
Added value of alpine cheese*	4	4	2
Marketing and sales opportunities*	3	4	0

Table 8: Continued

Contextual variables	Normalised scores		
	Mean	Factor A	Factor B
Group attributes of Users (A)	**0.4**	**0.4**	**–1.2**
A1- Number of users	1	1	–1
Number of farmers*	2	1	–1
Share of locally born and raised farmers*	–1	0	–1
A5- Leadership/entrepreneurship	1	2	0
Farmers innovative abilities and entrepreneurship	1	1	0
Leadership within the corporation	1	3	0
A7- Knowledge of SES			
Know-how of the employees on the Alp*	–1	**–3**	–1
Interactions (I)	**–0.4**	**–1**	**0.6**
I3- Deliberation process	0	–2	0
Common values and goals for administering corporations*			
I4- Conflicts among user	–2	–2	3
Negotiability of conflicts on the local level*			
I5- Investment activities	1.5	0	1.5
The amount of resources invested into the infrastructure	2	1	2
Willingness to fulfil provision requirements*	1	–1	1
I7- Self-organizing activities			
Cohesion and solidarity among the farmers*	–3	–1	–3

of farmers to be large enough, although the number of farmers (*A1*) is constantly decreasing. Interactions (*I*) were valued slightly negatively. Farmers complained of solidarity among themselves (*I3*), negotiability of conflicts (*I4*), cohesion (*I7*), and, while infrastructural investments (*I5*) and willingness to fulfil provision activities achieved positive scores.

4.5.1. Disagreement regarding the impact of contextual variables

As indicated by Factors A and B in Table 8, we identified two groups of farmers with different perceptions regarding the role of contextual factors for the sustainable use of common property pastures. Factor A represents a liberal market-oriented view and Factor B represents a traditional view. Their views differ mostly with regard to the functioning of the government's resource policies (*S5*) and interactions (*I*). The liberal viewpoint is closer to the overall sample with an Eigenvalue of 2.89 and seven people loading on it. The traditionalist view achieves an Eigenvalue of 2 with four people loading on it.

The liberal viewpoint displays preferences for market incentives (*S6*) resulting from interrelations with tourism accompanied by scepticism against agricultural policies. Accordingly, the tourism sector supports local demand for alpine products and off-farm income opportunities to reduce dependence on agricultural income and direct payments. Overall, the liberal viewpoint claims that an external setting (*S*), which offers more room for market forces and entrepreneurial freedom enhances

the sustainable use of common property pastures. The estimation of the economic value of resource units (*RS*) as incentives for the sustainable use of common property pastures underlines the market-oriented perspective. According to their perception, higher returns for alpine products determines farmers' willingness to use and maintain the Alps sustainably and was considered the best means to prevent land abandonment. In contrast, increasing governmental regulations cause higher transaction costs with governmental agencies, for example through controls, and furthermore requires unproductive investments to meet the prescribed standards, which are often considered bureaucratic burdens that interfere with sustainable traditional practices. In accordance with preferences for market incentives, the liberals show less concern over the presence of foreign cattle, but more concern over interactions (*I*) among farmers. Particularly common values (*I3*) and goals in negotiating affairs in the corporations and the negotiability of conflicts (*I4*) on the local level achieve negative scores. Such conflicts arise mostly over the organisation of sales activities or the management of the resource system in co-existence with tourism. The latter includes questions such as whether to allow tourist infrastructure such as ponds, artificial snow production or new trails and restaurants.

In contrast to the liberal view, the traditional view shows preferences for a closed agricultural system and livelihood focused on income from agriculture. The traditionalist viewpoint considers a dependence on agricultural income and direct payments tied to private plots to foster the sustainable use of common property pastures. Although the traditionalists are critical about the regulations for obtaining direct payments, they acknowledge that government support secures agricultural livelihoods. According to the traditional view, an external setting (*S*) that relies on heavy government support, enables agricultural livelihoods and thus promotes the sustainable use of common property pastures. Furthermore, traditionalists prefer a closed self-organised system as represented by the strong positive value of constitutional rules (*GS7*) and the possibility of leasing use rights among farmers. In terms of opening the system, traditionalists are concerned about the presence of foreign cattle and the number of farmers and their origin. They are concerned that the opening of the system might endanger the local cohesion and self-organisation.

5. Discussion

The behaviour of individuals in social dilemmas is a central puzzle in the study of the commons (Poteete et al. 2010; Anderies et al. 2011). Since information about behavioural drivers derives mostly from experimental research, this study aims to complement experimental findings with field observations from Grindelwald, Switzerland. In doing so, we estimated regression models from survey data to predict the behaviour of alpine farmers regarding change in livestock endowment, appropriation, and provision. Data showed that a slight majority of farmers (55%) increased endowment and applied full appropriation strategy (59%). Completion of provision activities was remarkably high (93%).

As summarised in Table 9, behaviour depended significantly on diverse user attributes. Socio-economic attributes, in particular age (*U2a*), marital status (*U2b*), and area (*U2c*), explained farmers' changes in livestock endowment. The role of age and marital status is best explained by their effect on work organisation, as youth and partnership allow the handling of larger endowments. Furthermore, the variable area suggests that farm size itself is the strongest predictor for endowment growth. The key role of area and also age in determining farm development is widely confirmed in the literature and indicates structural change towards fewer but larger sized farms (Baur 1999; Weiss 1999; Lauber et al. 2008). Other variables found to be associated with farm development such as presence of a successor (Potter and Lobley 1996; Mann 2003), opportunity costs, and labour productivity (Schmitt 1992), did not have a significant effect upon livestock endowment in the study region. Furthermore, the negative association of area with appropriation and particularly with provision behaviour suggests that farmers with larger sized farms concentrate labour on private property and reduce the use of common property. Likewise, farmers with larger land holdings are more likely to defect. As discussed, reduced appropriation reduces workload in two ways. Firstly, marginal private pastures are grazed by animals instead of labour intensive hay production. Secondly, lower appropriation reduces provision requirements.

Appropriation behaviour showed the strongest association with norms (*U6a*) – measured as farmers' aversion against defection on provision, assuming individuals with a full appropriation strategy are more concerned about the

*Table 9: Direction of significant effects of individuals attributes on behavior in social dilemmas as calculated by binary logistic regression (99%***, 95%**, 90%*). Additionally, the effects of contextual variables on the sustainable use of common property pastures as calculated by Q Method are indicated by arrows (↙moderate negative; ↔neutral; ↗moderate positive; ↑positive)*

Method Variables	Regression Models			Q Method
	Livestock endowment	Appropriation	Provision	Outcomes
U2a- Age	(−)***			
U2b- Marital status	(+)**	(+)*		
U2c- Area	(+)***	(−)*	(−)**	
U5a- Leadership		(−)*		
U5b- Pay-off			(+)**	
U6a- Norms	(−)**	(+)***		
U8- Importance of resource			(+)*	
S- External setting				↙
RS- Resource system				↙
GS- Governance system				↔
RU- Resource units				↑
A- Group attributes of users				↗
I- Interactions				↙

productivity of the resource and consequently hold stronger norms towards provision fulfilment. Self-interest might equally explain the association of pay-off (*U5b*) and the importance of resource with full provision behaviour. Hence, the willingness of individuals to maintain a common-pool resource increases the more an individual relies on the resource for his livelihood and the higher the generated pay-offs.

To assess the impact of contextual variables on the sustainable use of common property pastures, we applied Q methodology. Among the contextual variables, the value of resource units (RU4) was considered to have the most positive impact on the sustainability of common property pastures. As the economic value affects an individual's pay-off ability, we have reason to assume that a close positive relationship exists between the value of resource units and the fulfilment of provision activities. Tourism helps strengthening local demand and the economic value of resource units, and thus pay-offs. Furthermore, tourism allows for livelihoods with balanced agricultural and off-farm activities reducing the need to increase farm size, which is assumed to reduce use and maintenance of common property pastures. With regard to the perception of external settings (*S*), farmers differed significantly in their views. A liberalist viewpoint was identified that favours price incentives over governmental support, while the traditional view assumes that sustainability of common property pastures is promoted by strong governmental support securing agriculture-based livelihoods.

5.1. Implications for policy makers

The study provides further evidence that structural change towards fewer but larger sized farms results in decreasing use and maintenance of common property pastures (Gellrich et al. 2007). As average farm size increases, farmers reduce appropriation levels, resulting in an overall reduction of provision activities. Furthermore, the defection rate is likely to increase as farms grow bigger. To balance the reduced use resulting from structural change, we see three major policy options: (i) within the local governance system (*GS*), a further opening of the pastures and active acquisition of cattle from the lowlands; (ii) regarding external settings (*S*), stronger incentives for summering particularly of younger cattle; and (iii) policies for increasing the value of resource units. The further opening of pastures is likely to have some undesirable consequences. As the monitors stated, external users are more likely to defect on communal work and pay fines instead. This might lead to situations, where appropriators and maintenance providers become two separate groups, with external appropriators paying fees for defection on provision that might be used by the corporation to reimburse local farmers for provision. It is likely that both the quantity and quality of provision activities might then decrease as incentives, for provision are closely linked to appropriation levels. Furthermore, the Q method results for the governance system (*GS*) showed that farmers consider the presence of foreign cattle an undesirable, but necessary, as foreign cattle is less suitable to alpine conditions. Therefore, policies should

target incentives to foster the appropriation of local cattle with focus on younger cattle in particular, which are often left grazing in the valley. Furthermore, the maintenance of common property pastures depends on farmers' pay-offs, which are determined by the economic value of resource units. As a consequence, marketing tools for alpine dairy products should be considered as a policy option. A clear communication of the non-industrial production process and of the added cultural and ecological values potentially secures demand and prices for alpine products which are crucial for the sustainable use of common property pastures.

5.2 Implications for the study of the commons

5.2.1. Variables associates with appropriation and provision behaviour

Ostrom identifies six user attributes (*U1*, *U2*, *U5*, *U6*, *U7*, *U8*) that are potentially important for the sustainability of social-ecological systems (Ostrom 2009; Poteete et al. 2010). Although these variables relate to successful self-organisation of groups, our study expands on how the variables promote sustainable interaction of users with the ecological system. Along the lines of the framework, entrepreneurial attributes (*U5*), norms (*U6*) and importance of resource (*U8*) were central behavioural drivers in our study that relate to Ostrom's findings. According to Ostrom, presence of leaders and entrepreneurship in a group facilitates self-organisation; our study shows that entrepreneurship has a positive impact on fulfilment of provision duties, while leaders (defined as those who hold a formal function in a corporation) are more likely to apply reduced appropriating strategies. The latter is mostly context-specific, as leaders tend to be those with a long regional family tradition who own the ancient "Vorsassen" located on the border to common property; these private plots are generally less productive and difficult to mow and thus particularly suited for grazing younger animals. Furthermore, Ostrom shows that groups with shared moral and ethical norms face lower transaction costs for self-organisation. Our study reveals that with higher appropriation levels, users develop stronger norms for the maintenance of the resource which suggests that they show more commitment to leading self-organising and monitoring activities. Furthermore, users depending on a resource for their livelihood are more willing to invest in the maintenance of the resource, which is shown in the provision model. In contrast to the Ostrom framework, the variables number of users (*U1*) and mental models (*U7*) had no significant impact in our case. This is probably due to the heterogeneous group size of corporations and the fact that the mental model, which measured the farmers' identity, does not significantly affect farmers' actions. We expected that individuals, who define farming as their main occupation, are more likely to run growing enterprises, show higher appropriation and provision levels, which proved not to be the case. Recent studies propose an understanding of mental models as the inner representation of the external world (Jones et al. 2011). Q-methodology is a valid tool to elaborate on individuals' mental models. Unfortunately, our study design does not allow us to draw conclusions on how the perception of the functioning

of the social-ecological system (e.g. liberalist view) relates to actual behaviour. Nevertheless, mental models constitute a central part in the study of social-ecological interactions that can be equally addressed in experimental research (Lynam et al. 2012). Similarly, the variable opportunity costs of farming (*U10*) that we added to the framework did not significantly affect behaviour.

5.2.2. Implications for commonpool and public good experiments

The study provides implications for future experimental research exploring appropriation and provision problems. Most importantly, our findings suggest that appropriation and provision behaviour is closely linked through norms (*U6a*) and pay-offs (*U5b*). People with higher appropriation levels hold stronger norms regarding the provision fulfilment of joint users. Thus, we hypothesise that individuals with higher appropriation levels are more willing to invest in the monitoring and sanctioning of provision defectors in public good experiments. Experiments have shown that sanctioning possibilities increase corporation (Falk et al. 2002; Nikiforakis and Normann 2008), that individuals willingness to invest in sanctioning is best explained through inequality aversion (Fehr and Gächter 2000) and that even externals who do not benefit from public good provision make substantial investment for punishing defectors (Fehr and Fischbacher 2004). Nevertheless sanctioning has not been interpreted as an altruistic act to increase common welfare, but rather rooted in the desire to invoke costs on defectors (Bowles and Gintis 2002). Our results suggest that self-interest might be of central importance for sanctioning behaviour as those with highest appropriation rates hold the strongest norms regarding the corporation of joint users for the provision of public goods. Therefore, future experiments might test if individuals' investment levels are indeed positively associated with higher willingness to punish defectors in public goods games. Furthermore, the study suggests that people with higher pay-offs from appropriation will make higher investments into the public good. This finding relates to public good experiments, where investments increase with marginal returns (Isaac and Walker 1988; Isaac et al. 1994; Janssen and Ostrom 2006) but is contrasted by a study showing that individuals with higher income contribute less (Chan et al. 1996). Therefore, future experiments might consider linking common-pool experiments with public good experiments to test, if individuals with higher appropriation pay-off make larger investments into the public good.

5.2.3. Methodological challenges in linking behaviour to context

As this study observed behaviour for a single period, longitudinal studies are needed to observe the behaviour repeatedly and relate it to actions of joint users. Such studies will allow the inclusion of variables such as reciprocity, which is considered crucial for behaviour in experimental studies (Rustagi et al. 2010; Gächter and Thöni 2011) and whether predicted patterns of strategies towards concentration of either full or cero contribution (Janssen and Ahn 2006) can be equally observed in the field. Furthermore, additional studies on individuals'

behaviours are needed in the context of other common-pool resources to further theorise the interplay of microsituational and contextual variables and the way they determine behaviour. In our study, individuals are guided by robust institutions (Baur and Binder 2013). It might well be that our findings do not apply to a social-ecological context, where incentive structures are entirely different, in particular in settings, where over-exploitation and under-provision are dominant modes of behaviour. Therefore, it remains a methodological challenge to control for the impact of contextual variables on behaviour. Q methodology was used in this study to elaborate on the role of different contextual variables and on the different dimensions of sustainability of the SES. Given the notion of Q methodology that the number of distinct viewpoints on a given topic is limited (Van Exel and de Graaf 2005), we decided to extract knowledge from the people best informed using a rather small sample. The sharp distinction between the two views that we found as confirmed by the individuals' factor loadings increases confidence that the results from Q method best represent the farmers' views.

Unfortunately, the study design does not reveal how differences in the perception of contextual variables link to the observed behaviour on the individual level as this would require a larger sample of the q method to gather more data points for the individuals in order to make reliable predictions. Future studies adopting the same combination of methods would potentially benefit from including not only resource users, but also external experts on the topic from governmental, NGO or science for sampling. Experts might provide different perspectives that would allow distinguishing between farmers and experts opinions more clearly.

6. Conclusion

This study offers explanations about the way personal attributes affect individuals' use of common-pool resources. It thus elaborates on the general framework of studying social-ecological systems and laboratory experiments, which simulate appropriation and provision problems. Our findings suggest that socio-economic attributes (*U2*) determine the endowment of resource users and provision activities. Norms (*U6a*) and pay-off (*U5b*) determined appropriation and provision behaviour. The analysis shows that individuals, who appropriate intensely, hold stronger norms towards maintaining the resource stock and as a result would be probably more willing to invest in the punishment of free-riders. In turn, it was shown that the higher an individual's economic benefit generated from appropriation, the less likely a user is to defect on externally assigned provision duties for maintaining the resource stock and the physical infrastructure. In summary, the study reveals that those individuals who use a resource intensively and benefit most from it also have the biggest interest in maintaining resource productivity in the long run, and thus apply and enforce pro-social behaviour. The analysis of contextual variables suggests that this mechanism is accelerated with increasing value of resource units for

the management of common property pastures. This raises two questions for experimental research that would require linking appropriation to provision situations: (i) Are individuals with higher appropriation rates also more willing to invest in the sanctioning of provision defectors in public good situations in order to sustain or increase their appropriation pay-offs? (ii) Does an increase in an individual's pay-offs from appropriation result in higher investments into the public good? If so, self-interest can be indeed considered a motivational driver leading to pro-social behaviour. Nevertheless, behaviour remains context-specific, which limits the extent to which these findings can be generalised. Behaviour is thus likely to vary with factors such as the quality of institutions, the type, and prices of the resource used, and the overall condition of the social-ecological system; the control for contextual factors and their effect on the associations of personal attributes with behaviour in field studies and experimental research consequently remains a central methodological challenge for the study of the commons.

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Essay 3

Drivers of Land Use Change and Gradual Abandonment of Common Property Alpine Pastures

Drivers of land use change and gradual abandonment of common property Alpine pastures

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ABSTRACT. Open summer pastures in many Alpine regions of Switzerland have diminished over the past decades, as land extensification and gradual land abandonment has led to forest expansion and shrub encroachment. To what extent this has occurred is closely related to the individual characteristics of the human–environment system in any particular area. Taking the example of one case study area, the research presented here shows how drivers related to location and social change are shaping land use and land cover, and how these changes can be assessed from a sustainability perspective. As the trend looks set to continue, ways will need to be found to promote sustainable land use in the summering areas. Defining priority areas in which to prevent encroachment will require a negotiation process that takes into account both external and local interests.

Keywords: Alpine pastures; land use change; forest encroachment; sustainability; common property; Switzerland

1. Introduction

Land use extensification or abandonment and related shrub and forest encroachment in formerly pastured areas is a new phenomenon that is becoming more and more prevalent in industrialized countries (see e.g. Agnoletti 2007; Lasanta et al. 2009; Chételat et al. 2013; Komac et al. 2013). This also applies to mountain regions in Switzerland, where the summering of livestock on Alpine pastures is a widespread practice. Such processes are visible in changing landscape patterns, and give an indication of societal transformations and complex human–environment interlinkages. Since the 7th century AD (Ewald & Klaus 2009: 271), and the start of population expansion into Alpine regions, landscapes have been modified by their users, for example by clearing forest plots for pasture land, which led to the diverse and often small-scale structure of the cultivated landscape of today. Especially in summering areas, this process of land appropriation was often accompanied by the development of common property regimes that frequently still govern pasture use at the regional level. But while deforestation was the main way of gaining agricultural land in times of land shortage, the past decades show a trend in the opposite direction: forest expansion and shrub encroachment have led to a diminishing of open summer pastures in many regions of Switzerland (see e.g. Bebi & Baur 2002; Gellrich 2006; Stöcklin et al. 2007). Statistics confirm that in Swiss mountain regions, forest regrowth between 1993/95 and 2004/2006 has taken place at a total rate of about 9% (Brändli 2007: 50), with the highest regrowth rates attributed to those regions that are used for summering livestock (Baur 2006: 31). Research has also shown that the continuous use of Alpine pastures is strongly interlinked with the provision of public goods such as biodiversity and landscape beauty. With pasture abandonment and related processes of forest encroachment, these values are said to be endangered (Baur et al. 2006: 33; Lehmann & Messerli 2007).

The major drivers behind these developments are related to structural changes in the agricultural sector resulting from adaptation to a liberalized market and rising competition (see e.g. Stöcklin et al. 2007: 85). These changes can be seen, among others, in the decreasing number of farms (change per year between 2000 and 2010 in mountain areas: –1.9%; FOAG 2011: 8, from SFOS), increased size of remaining farms, and a related adaptation of production and land use strategies. In many regions, this has led to a production focus on high-potential, easily accessible areas, and a decreased interest in grazing livestock on marginal Alpine summer pastures. As a result, summer pastures and related, often collective, usage systems face a decrease in both livestock numbers and workforce needed for pasture maintenance and grazing control, and raising costs of summering (see e.g. Mack et al. 2008: 277), which in turn again decreases demand for livestock summering. In some areas, this development has led to a complete abandonment of remote summer pastures (e.g. in some areas of the Swiss canton of Ticino or the southern Grisons) (Stöcklin et al. 2007: 54). Other areas, however, are well maintained, and a breakdown of the system is not expected in the near future. In view of enhancing the sustainable use of natural resources, it is important to obtain a better understanding of the drivers behind such differences; to this end, it is crucial to add localized insights to the analysis of national or larger regional trends.

The research presented here takes a case study approach and aims to provide a broader understanding of a local human–environment system and the driving factors of land use and landscape change in common property Alpine pastures. It visualizes the current land cover status and outlines future trends

of Alpine pasture use. Furthermore, it describes the role of the current governance system in maintaining and reproducing the local landscape, and evaluates the local land use dynamics from a sustainability perspective. The article is structured as follows: We (i) characterize the current status and recent changes in land cover and land use in the study area, (ii) provide insights into the driving forces and challenges of such changes, (iii) outline future perspectives on the use of Alpine pastures, and (iv) discuss the current status and potential future of summer pasture use from a sustainability perspective. By doing this, we aim to contribute to the growing debate on pasture land extensification or abandonment. Contrary to intensification processes and pasture overuse and degradation, the relation between extensification or abandonment of common property and sustainable development has, to our knowledge, not been studied so far.

2. Characteristics of the human–environment system in the study area

The research presented here is based on a case study in Grindelwald, a Swiss Alpine commune popular with tourists. The commune is located at 1050 m asl in the Alpine zone of the Bernese Oberland, and has about 4000 inhabitants. The combination of well-kept agricultural landscape alongside rugged glaciers, rocks, and mountains is an aesthetic contrast that has attracted tourists from all over the world since the 19th century. These days, most of the local income is generated in the tourism sector, mainly by winter sports such as skiing, but also by summer outdoor activities. Agriculture, dominated by livestock husbandry and the production of dairy products, is responsible for the cultivation of meadows and pastures in the different vegetation zones of the commune, which are located between 1000 m and 2400 m asl, depending on the seasonal cycle of transhumance. Village plots and *Vorsassen* (= areas of the lower pasturing area that is partly cut) are located in private, summer pastures in common property (see Figures 1a-c). For a high proportion of the 125 farming households (year 2010) in Grindelwald, agriculture is a side activity, which complements either a higher or lower percentage of off-farm income (Baur et al. unpublished manuscript).

The governance structure of the study area can be characterized as follows:

Internal governance: The whole area of the commune is divided into seven Alpine corporations, legal entities by civil code. Their right to own common natural resources such as pastures and forest is guaranteed (Art. 20 EG ZGB). These corporations are involved in organizing and structuring all collective work related to livestock herding and the use of common property summer pastures (see Tiefenbach & Mordasini 2006). The basic regulations of the Grindelwald corporations (German: *Taleinungsbrief*) date back to the year 1414 and resulted from the growing independence of local farmers and a sustainability crisis (Nägeli 1986: 146). They are, with minor changes, still valid today (*Taleinungsbrief* – most recent version from 2002) (see Commune of Grindelwald 2002; Baur & Binder 2013), and regulate the use of common property summer pastures, such as access or the relation between lowland land tenure and the number of livestock allowed to be summered in the highlands. Furthermore, they are the basis for the statutes of the individual corporations, which contain further regulations such as the maximum stocking rate for the respective Alpine pastures or amount of communal work per summered cow. These regulations have for centuries successfully prevented the overuse of pastures.

External governance: In view of a sustainable and comprehensive use of the summering areas (FOAG 2012a), the summering of livestock has since 1980 been supported by government subsidies. These subsidies are linked to farmers maintaining a stocking range between 75% and 110% of the maximum sustainable yield defined by the canton (Federal Assembly of the Swiss Confederation 2007; see also FOAG 2012b). Observing these conditions is intended to prevent both over- and under-stocking as well as maintain both a biodiverse cultural landscape and well-established land use system that is also of importance for national identity. The official stocking range in Grindelwald is largely based on the Alpine corporations' traditionally-set stocking rate which proved to be sustainable. Depending on size and quality of the pasture area, the corporation with the lowest stocking rate is allowed to summer a range of around 71 livestock units, while the one with the highest may summer around 318.

Agriculture as a nested system: While the Alpine corporations were originally mainly involved in managing the use of common property summer pastures, they became more involved in tourism-related development during the last century, for example by becoming shareholders or owners of infrastructure such as cable cars and hotels. Tourism infrastructure aside, there is a high mutual dependency between the agriculture and tourism sectors regarding their economic and ecological functions: while agriculture provides a well-kept, open, and biodiverse landscape that is key for tourism development, tourism provides the economic base of the commune. And as the majority of the farming households have an (often major) income related to tourism, e.g. in the operation of cable cars, in lodging, or in the construction business, agriculture and tourism can be seen as highly interdependent (Baur et al. unpublished manuscript; Wiesmann 1985/1986).

a) Summering area with the typical cattle breed of the region

b) View encompassing common property Alpine pastures (foreground) and private, partly-cut lower pasturing areas (background)

c) High-Alpine pasture with typical Alpine settlement (at 1983 m asl)

Figures 1a-c: Some impressions of the study area (Photos: Karina Liechti)

3. Materials and methods

The results of the present study are based on a method triangulation (Flick 1998: 282) combining qualitative and spatial data. The qualitative data not only served as a basis to understand the observed land cover changes, but also as model input variables to identify future land use and land cover.

The *qualitative data* were generated based on semi-quantitative questionnaires followed by qualitative semi-structured interviews (Flick et al. 2004) collected from all the Alpine wardens of the seven Alpine corporations in Grindelwald. The Alpine wardens were chosen as they are considered to be the main experts in the fields of summering and its trends. The themes covered in the questionnaires and interviews were 1) the actual use of the summering area (mapping), 2) the perceived quality of pastures and ongoing intensification and extensification processes, 3) the relevant factors for pasture selection, 4) communal work, 5) the perceived future of the corporation and the practice of summering livestock, and 6) land use scenarios. Other qualitative data were derived from semi-structured interviews with internal and external mountain agriculture experts. They covered themes such as general summering tendencies in the region, land cover changes, and future perspectives of Alpine farming. The analysis of the interviews mainly involved categorizing the data according to the thematic lines of current status and recent changes in land cover and land use, driving forces and challenges of such changes, and future perspectives for Alpine pastures use.

The ***spatial data*** comprise 1) land cover data analysis of different time assessments of the Swiss land use statistics from 1979/85, 1992/97, and 2004/09 (SFSO 2009) using GIS for the past land use changes, 2) a land use classification with eCognition®, a software that is designed for object-based image analysis for the current land cover status, and 3) a GIS-based cost–distance model (ESRI 2011) allowing for the analysis of potential future land use and land cover changes. The input parameters for the cost–distance model were based on the results of the qualitative data as well as digital datasets derived from the Swiss topographic map (map scale 1:25,000) and the DTM AV (Swisstopo 2012). GIS-based cost–distance analysis provides a useful tool for assessing animal movements and accessibility parameters. For the current research, a cost or resistance surface grid was derived from one or more spatially-explicit variables such as topography; enabling or accelerating factors like paths or roads; and physical barriers such as dense forests or rivers. Raster cells were weighted in travel time according to the expected time–cost required by an animal (or herder) when moving across the cost surface, and linear features like roads or rivers were merged with the weighted cost surface (see also Adriaensen et al. 2003). The cost–distance model was not calibrated, but served explorative and illustrative purposes, and was used to stimulate the scenario-focused discussion in a stakeholder workshop.

In order to assess the information extracted from the spatial and qualitative data – above all that related to actual shrub and forest encroachment – five ***transect walks*** were undertaken in the summering area.

4. Results and discussion

4.1 Land cover change of the recent past

The total area of the commune of Grindelwald covers more than 17'000 ha; of this, more than half is considered unproductive (glaciers, rocks etc.), and almost one-third is agricultural land (see Table 1). When comparing the development of settlement areas, agricultural areas, forest stands, and unproductive areas between 1979/85 and 2004/09 (SFSO 2009), the major changes have occurred in the settlement areas (+27.5%): this is a sign of booming tourism in the region. This development is partly at the expense of agricultural land, especially the meadows in the lowlands. Forest stands cover a total area of 2802 ha (about 1/6 of the total area), according to the last assessments in 2004/2009. They increased by 2.6% (70 ha) between 1979/85 and 2004/09. For information on developments that go further back to the past, one has to rely on the available literature: according to an assessment by Stampfli (1983: 30), forest stands rose by another 0.6% (17.7 ha) between 1940 and 1978. In an analysis of topographic maps since 1900, Fürstenberg (2011), showed that the process of forest encroachment already started in earlier decades.

Grindelwald	1979/85 [ha]	1992/97 [ha]	2004/09 [ha]	Change 1979/85-2004/09
Settlement areas	240	270	306	+27.5%
Agricultural land	5121	5039	4947	-3.4%
Forest stands	2732	2799	2802	+2.6%
Unproductive areas	9020	9005	9058	+0.4%
Total	17113	17113	17113	

Table 1: Land cover change in Grindelwald [Source: SFOS 2009: Swiss land use statistics 1979/85, 1992/97, 2004/09]

Regarding shrub coverage, Swiss land use statistics from 2004/09 show that 13% of the pastures in the summering area are shrub covered. An investigation on pasture quality from the beginning of the 1980s shows the same phenomenon and speaks of some underused and partly shrub-covered or reforested areas in Grindelwald (Nägeli-Oertle 1986: 210-217). Also the Alpine Land Register (German: *Alpkataster*) from 1973 (FDEA 1973: 68) considers some pastures prone to continuous shrub encroachment and reforestation. In other areas, shrubs are said to have "always" been there. These

areas were never used as pastures and the vegetation is site specific (e.g. different types of dwarf-shrub heaths) and not a result of a dynamic abandonment process. An analysis of the developments between 1979/85 and 2004/09 shows that there was some change (+4%) from brush pastures to scrubs or forest, and from favorable pastures to brush pastures (see Figure 2). A development in the other direction could not be observed.

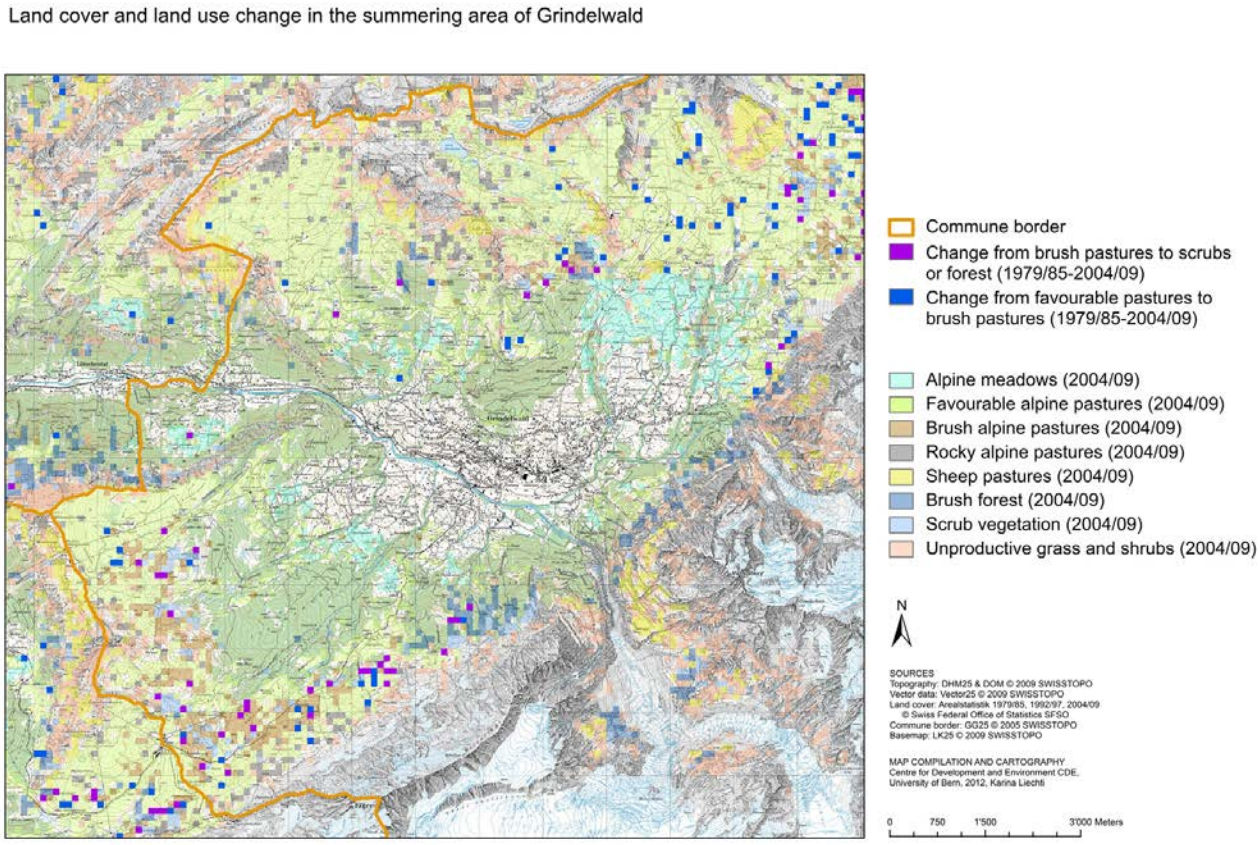

Figure 2: Land cover (selected items) and land cover change (shrub and forest encroachment) in the summering area of Grindelwald

Shrub and forest encroachment is taking place mainly in regions where shrub coverage was already prevalent in 1979/85 (southwestern and northeastern part of the commune; see Figure 2). This result is confirmed by Peter (2006: 680), who investigated the change in botanical composition of Alpine pastures in Grindelwald over the past two decades; he observed that dwarf shrubs had increased especially at sites where shrubs were already abundant in the initial survey and where initial forage quality was poor. Also in an aggregated (national) analysis, Baur et al. (2006: 29) found a high relevance of the explanatory factor “neighbourhood”, which means that in places where shrubs are already prevalent, the process of shrub invasion continues (see also Gellrich et al. 2007: 102). Related

to this factor, shrub and forest encroachment processes are taking place above all in regions with swampy humid soils or on steep slopes, which means in regions that are unfavorable for grazing. These findings correspond to land use scenarios for Grindelwald that were elaborated in the 1970s and 1980s (Messerli et al. 1986: 56f). They suggested a reduction or even an abandonment of steep Alpine pastures (gradient more than 40%) under both a mechanization and minimization scenario.

Visualizing the situation today, Figure 3 shows the land cover of a summering area in the southwestern region of Grindelwald and the potential transition areas where young forest, open forest, shrubs, and brush are prevalent.

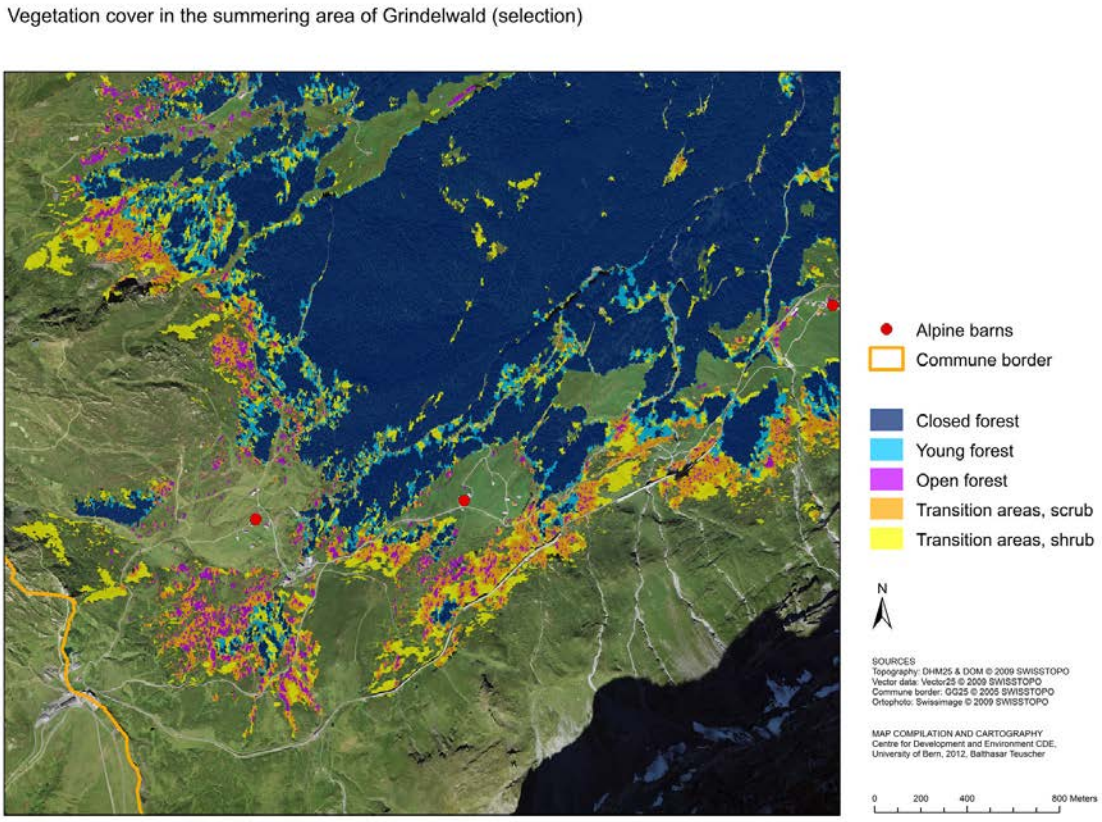

Figure 3: Vegetation cover of a summering area in the southwestern region of Grindelwald in 2009 and the presumed transition areas (zoomed in selection covering areas of two Alpine corporations)

4.2 Spatial drivers: location-related decision making

Location-related drivers for past (and current) land cover changes are to a large extent related to pasture selection criteria. The Alpine wardens view the following factors as the most important ones for assigning grazing areas for cows: distance to the barn, slope, plant composition, and water availability

(see Table 2). Other factors such as natural hazards are considered site specific (e.g. certain pastures below the Eiger north face, which are often wet and prone to rockfall) or of minor importance.

Factors considered when selecting grazing areas for dairy cows		
Factors of major importance (all Alpine wardens agree)	Variable factors (depending on the location of the Alpine corporation)	Factors of minor importance (not or rarely selected or mentioned)
Short distance to barn (+)	Natural hazards (e.g. rockfall) (-)	Shrub coverage (-)
Gentle slope (+)	Swampy, humid soils (-)	Long distance to road / path (-)
Plant composition (high feed value) (+)	Plant composition (poisonous plants) (-)	Unpalatable plant cover (-)
Water availability (+)	Rock coverage (-)	Touristic locations (e.g. hiking paths) (-)

Table 2: Factors considered when selecting grazing areas for dairy cows ((+) = enabling factor; (-) = obstacle)

The results on the drivers of vegetation change on Alpine pastures, in particular, "location with respect to barns", "slope", and a combination of both, are to a large extent congruent with previous scientific research in the region. Peter (2006), after an in-depth study in Grindelwald, showed that there is some evidence for directional changes that could be explained by alterations in grazing management. *"At sites far from cattle sheds, swards of initially intermediate forage quality showed evidence of nutrient enrichment, whereas poor quality swards tended to become encroached by shrub vegetation. These trends suggest a shift in grazing pressure towards more favourable areas"* (Peter 2006: 679). Far from cattle sheds, increasing N-values on sites with gentle slopes and increasing dwarf-shrub cover on sites with steep slopes were observed (Peter 2006). The finding that slopes represent a key factor in land abandonment decisions is also confirmed by research results from other mountainous regions in Switzerland (see e.g. Gellrich et al. 2008: 134; Schneider et al. 2013: 225).

In addition, there are vegetation indicators that suggest an intensive use and a related nutrient enrichment of close-to-barn or other favorable pastures with gentle slopes (see also Peter 2006, above). However, one sign of high nutrient presence or over-fertilization close to barns – the presence of Alpine sorrel (*rumex alpinus*) – is said to have been prevalent for generations. Therefore, it cannot be considered to be the result of a recent process (see Figure 4c).



Figures 4a-c: Two processes: shrub and forest encroachment on marginal pastures and/or on steep slopes (a/b) and intensive use with related over-fertilization close to barns (c) (Photos: Karina Liechti)

4.3 Social drivers: current challenges of pasture use

The drivers within the agricultural system that are contributing to these processes are manifold and highly interrelated. Our investigation showed the following to be crucial:

Workload of farming households and related communal work: The number of farms in Grindelwald has continuously decreased in the last decades. At the same time, there has been only a slight reduction in the cultivated area and the number of livestock. As a result of this, the size of individual farms (defined by the amount of arable land and number of livestock) has constantly risen, which implies that the workload of the individual farming households has increased. Consequently, farmers with large farms are not always able to fulfill all their communal work duties on the summer pastures (20 summered cows would add up to about 200 hours of communal work). Also farmers with small farm sizes and high percentages of off-farm income face this problem. Unable to carry out the communal work, both groups tend to take the option of paying a fee instead. Or as one Alpine warden (July 2011) puts it: *"The workforce is missing. We have to maintain the same number of cows with fewer workers. The work in the lowlands has increased. Of course certain works could be rationalized. But in the mountain areas, there is a limit somewhere."* For the maintenance of the summer pastures, this means that priority is given to the most urgent tasks such as fencing or water provision, while other tasks such as cutting shrubs become second priority. Related to the above-mentioned workload issues is also the decreasing engagement of farmers in local government und thus decline in political influence (we return to this point later).

Type of livestock that is summered: Related to the total number of livestock in the valley, the stocking rate on the summer pastures showed only a slight decrease in the case study region. Some corporations even managed to increase the stocking rate by summering external cattle (LANAT 2011; Baur & Binder 2013). More crucial for pasture quality is the *type* of livestock that is summered: with regard to dairy cows, even though their number has remained more or less stable, their fodder needs and weight have risen through breeding. This means they are less mobile and farmers are reluctant to graze them far from the barn or on steep slopes. This tendency is accentuated when cows from the lowlands are taken to Grindelwald: often, these breeds are not well adapted to mountain conditions. Also, there is a decrease in the number of young cattle traditionally suited to grazing marginal or steep pastures in the summering area. This is because they reach earlier reproduction maturity and are held as dairy cows,

and because meat production is not considered as profitable as producing Alpine cheese. These days, the younger cattle are also more frequently kept in the lowlands to graze the private land holdings that cannot be mowed by machine. This is also the case for other livestock that would be suited to mountain areas – goats and sheep. Despite a decrease in total numbers, they are sometimes even summered outside the region. Also, keeping suckling cows is currently of minor importance in Grindelwald, compared to other regions in Switzerland. This situation might however change in future. If animals that are less labour intensive are sought and cow milk prices continue to decrease, niche production (e.g. "natura" beef) might become an option for some farmers.

High turnover of external herders: In Grindelwald, as in the whole of Switzerland, there is a tendency for herding duties to be taken over by external herders rather than by local farmers. The external herders have a high, sometimes annual, turnover rate, and while their cheese making and other cattle-related work abilities are considered good, they are less concerned with pasture quality and pasture improvement works. These works are long-term issues and thus of more interest to herders who work in the same place for several summers or for local farmers, who have an interest in maintaining the quality of all traditionally-used pastures.

Besides the above-mentioned changes in agriculture, *tourism-related developments* such as new infrastructure for winter sports (e.g. storage lakes for the production of artificial snow) can be considered further challenges to Alpine pasture use. This shift in priorities is the result of a decreasing number of farmers, a growing influence of people related to tourism in the Alpine corporations, and the dependence of farmers on an additional income from tourism. Finally, *climate change* with the related rise of forest and dwarf-shrub line (Straehl, in preparation) might also be contributing to a higher forest and shrub invasion pressure. This observation was also made by one of the Alpine wardens (July 2011): *"Twenty years ago, it was never necessary to cut small fir trees above the restaurant. And nowadays we have to cut like crazy up to 2000 meters asl in order to prevent pastures from becoming overgrown. Some people say the reason might be climate change."*

Despite these obstacles, there are also developments that to a certain extent can balance or improve current trends. These are mainly related to *grazing management*: better education in the last decades has led to an increase in knowledge about vegetation, pasture issues and grazing. As a result, pasture management has become more sophisticated, as seen in improved grazing rotation as well as higher focus on adequate fencing and animal separation (e.g. dairy cows and young cattle are grazed separately). This has led to a more sustainable use of Alpine pastures in several areas. Similarly, weed control has gained importance in farmers' concerns. "*Farmer vocational training has clearly improved the quality of pasturing. This, and learning by imitation"* (vegetation expert, January 2012). Furthermore, *social cohesion* within the Alpine corporation is still relatively high and communal work is therefore not only seen as a duty but also as a social event.

4.4 Future Alpine pasture use and land cover changes

The Alpine wardens and experts consulted believe the processes described above that contribute to extensification and intensification of pastures are likely to continue. The following figure on the future

of Alpine pasture use as seen by Alpine wardens, among others, shows that farmers will face a significant increase in workload (Figure 5). Given the decrease in the number of farmers, it will become even more difficult to provide communal work (e.g. pasture cleaning) requiring a big workforce.

Considering the future use of summer pastures, the most probable scenario entails a stable number of dairy cows, a rising proportion of external cows that are not well adapted to mountainous pastures, and a slightly decreasing number of young cattle. This implies continuing forest and shrub encroachment on distant and steep pastures below the tree- or dwarf-shrub line and intensification on close-to-barn pastures.

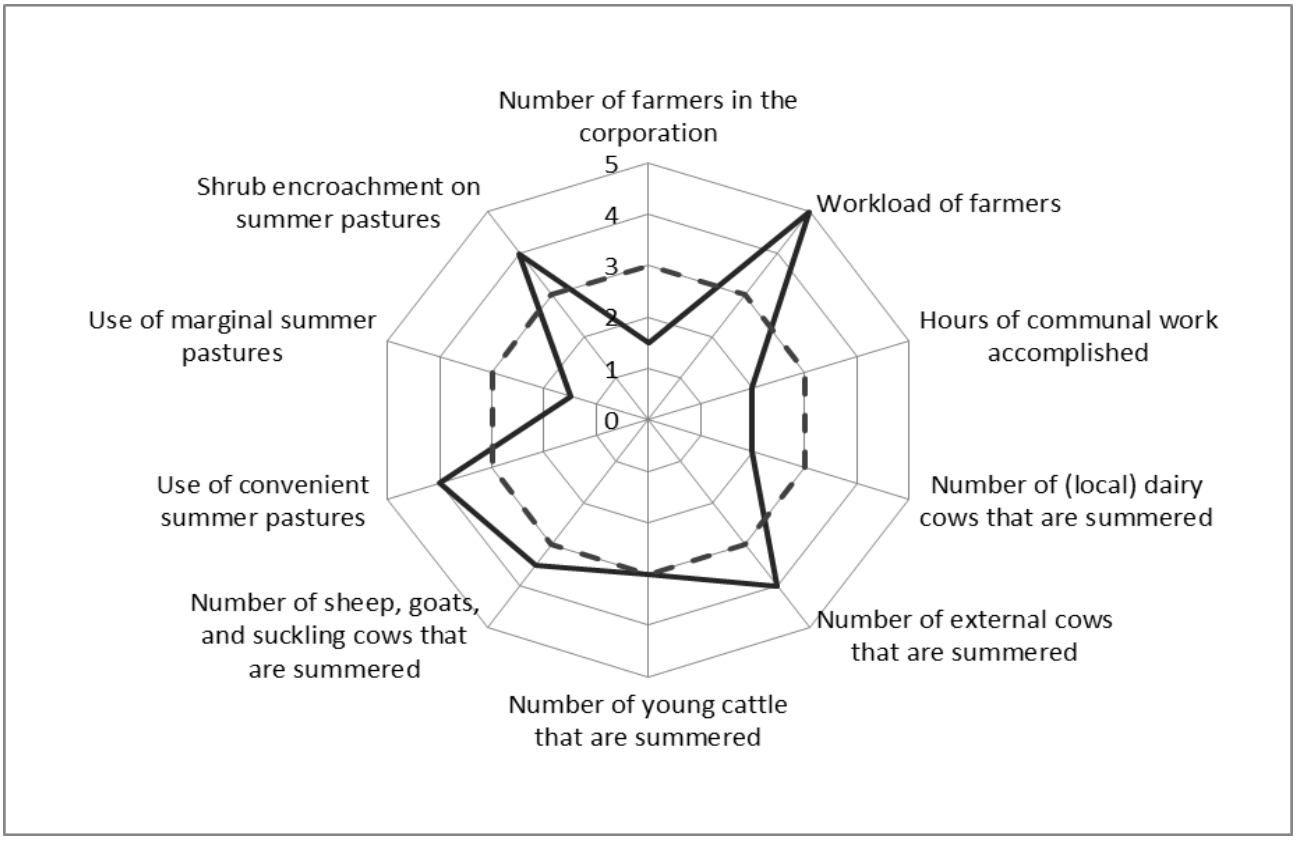

Figure 5: Future of Alpine pasture use as seen by Alpine wardens (legend (solid line): 1=will decrease significantly; 2=will decrease slightly; 3=will remain stable (dashed line as a reference); 4=will raise slightly; 5=will raise significantly).

One possibility of visualizing these scenario conditions is a GIS-based cost–distance model (Figure 6). It shows those summer pasture areas that are most prone to shrub or forest encroachment by modeling the time that is required to walk from any point (cell) in the study area to the next barn, considering enabling factors such as paths (allowing further walking distances and crossing brooks and forests) and

hindering factors such as brooks, impenetrable forests, or steep slopes (slowing down or diverting movements). The more the colors turn to dark red, the more prone the pasture is to abandonment and thus – depending on altitude – to shrub or forest encroachment.

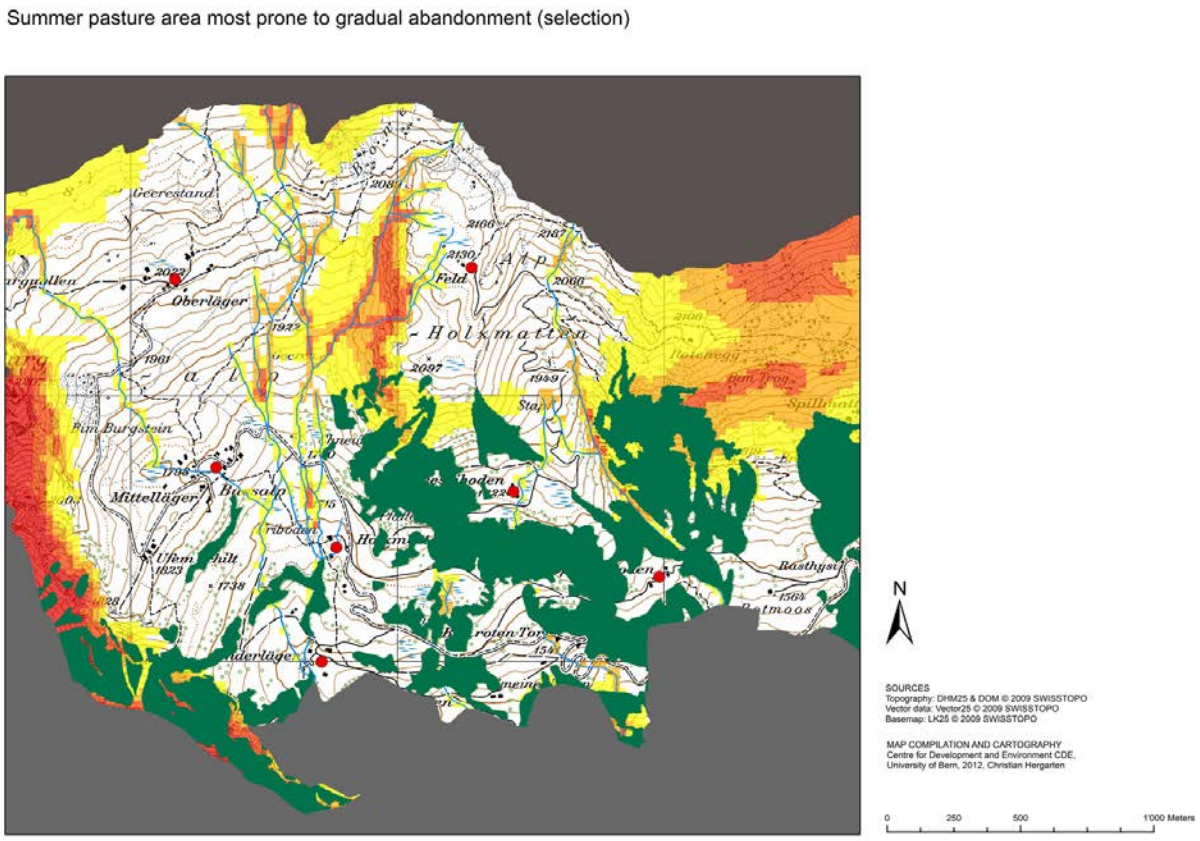

Figure 6: Summer pasture area most prone to gradual abandonment and thus to shrub or forest encroachment (zoomed in selection covering the areas of two Alpine corporations). The more the colours turn to dark red, the more prone the pasture is to abandonment and thus – depending on altitude – to shrub or forest encroachment.

5. Conclusion and Outlook: Land use change from a sustainability perspective

The results of the research show that pasture extensification processes are taking place in the study region. However, the processes are less pronounced than in other regions in Switzerland. This current trend is likely to continue, along with current challenges related to structural changes in the agricultural sector: fewer farmers, a higher workload, and a changing composition of herds. An assessment of these

land use change processes from a sustainability perspective has to take into account that sustainability, as a normative concept, is always gradual and value-based, and that negotiating it is therefore a complex endeavor. Negotiating sustainability has to address economic, ecological, and socio-cultural dimensions (see e.g. Wiesmann 1998: 84) and include both scientific results (external knowledge) and local knowledge derived from the interviews with the Alpine wardens:

Economic dimension: Regarding *fodder availability*, the current land use pattern is considered adequate. The grazing of cows at the current locations provides them with adequate fodder, both in quality and quantity. One exception is the weed coverage close to barns due to intensive use and lack of weed control, as those weeds cover areas that would be most suitable for grazing. From the economic perspective, *revenue and expense* are better balanced if grazing patterns and maintenance work are focussed on certain areas and not all the marginal pastures are maintained. The abandonment of certain pastures is thus a provident decision, common to other regions in Switzerland, where other studies have shown that forest regrowth took place where the cultivation costs were high and yield potential was low (Gellrich et al. 2007: 105).

Ecological dimension: With regards to ecology, and above all, *biodiversity*, we have a different situation. In the Swiss context, it has been shown that provision of public goods such as biodiversity and the beauty of a maintained landscape are strongly interlinked with continuous use of the Alpine pastures (Lehmann & Messerli 2007). Pasture abandonment and related processes of forest encroachment can therefore cause the loss of valuable biodiverse areas (Baur et al. 2006: 33; see also Zoller & Bischof 1980; Maurer et al. 2006). The number of plant species is high on very extensively used plots (Mack et al. 2008: 279), but it only takes a small reduction in the number of summered animals to cause a proportionately greater loss of extensively used pastures (Mack et al. 2008: 290). In Grindelwald, a positive correlation between areas worthy of conservation and the traditional agricultural utilization pattern has been shown (Wiesmann 1987: 161).

In terms of *natural hazards*, the abandonment of certain areas (e.g. below the Eiger north face, or in brook gullies) is a positive development, especially for animal health. Rockfall-prone areas and steep slopes that caused injuries in the past were among the first to be abandoned. Another benefit is that shrub or forest regrowth in these areas might reduce velocity of falling rocks (Perret et al. 2004). Regarding the presumed ecological instability of Alpine regions in general, agricultural use, restoration, and maintenance work are however all considered stabilizing factors (Bätzing 2003: 91ff). Thus, fallow areas are also prone to non-influenceable labile processes (see e.g. Newesely et al. 2000).

Socio-cultural dimension: The high *interlinkage between tourism and agriculture*, which provides the one sector with a well-kept environment and the other with additional income, has led to the fact that still a comparatively high number of members in the Alpine corporations are farmers. Influence in decision making, favorable work conditions for part-time farmers, and thus comparatively well maintained and used summer pastures were a result of this. However, recent developments such as a decline in the number of farming households as well as farmers' decreasing political influence and social recognition suggest that the link between the agricultural and tourism sectors has weakened in the last years. For this reason, agriculture-related works may in future be assessed more from a tourism-utility perspective than by their usefulness for farming. This change might also lead to less secure

employment conditions for part-time farmers, because they are dependent on a certain flexibility of their employer, e.g. when communal works are due.

In terms of *identity*, it is primarily the local farmers who are negatively affected if the pastures that were maintained by their forefathers are abandoned and overgrown (see e.g. Tiefenbach 2006). Up to now, reference to the past and the wish to uphold tradition was one important motivation for farmers to contribute to communal work. With fewer farmers and a growing focus on farming work in the valley, the significance of identity aspects will most probably diminish.

From a *landscape aesthetics* point of view, the current processes will not significantly alter the visual appearance of the landscape. This is because some of the potentially abandoned areas are above the tree line. Also, most visitors to the area are unlikely to notice a low extent of shrub or forest regrowth in marginal areas. Studies from other areas confirm that forest encroachment is considered problematic only once it surpasses a certain level (see e.g. Soliva et al. 2010). This level has not yet been reached in Grindelwald.

In order to promote sustainable land use in the summering areas, the above-mentioned dimensions have to be negotiated. Such a process has to include both external and local knowledge and values on the issue of pasture extensification or abandonment, and has to result in a setting of priority areas where encroachment processes should be prevented. In these areas, the level of losses (e.g. biodiversity, aesthetics) are higher than the level of gains (e.g. reduced labour input).

As the scenarios developed above are mainly based on a continuation of current trends, negotiations and further research also have to include alternative scenarios for such areas. Measures such as the introduction of new types of livestock (sheep, goats, suckling cows) could be discussed as an alternative to prevent average intensive (suckling cows) or marginal pastures (sheep and goats) from shrub or forest encroachment. Improved pasture care also implies improved grazing systems (which have already been tested in many areas) and a fortification of communal work. In order to support the current system, the hiring of additional workers (which for those Alpine corporations that are well-off should be feasible), or the introduction of new actors such as volunteer workers could be tested.

Whatever path will be taken in Grindelwald, measures that are favorable to both nature and society must be adequately rewarded. For this, it is crucial for livestock summering to enjoy both government support that includes pasture-area-related quality criteria, as well as support from the tourist sector, which enjoys an unique selling point due to agriculture. Decisive in these endeavors are the governance aspects that are related to livestock herding in Grindelwald. The Alpine corporations and their regulations have proven to be a strong factor in the cohesion of society up to now and should continue to shape the use of Alpine common lands. However, a relatively sustainable and stable use of Alpine pastures can only be maintained if farmers' influence within the corporations remains stable and approved, and a balance between tourism and agriculture is found. The challenge for further research is to address viable pathways on how cooperative governance systems and the related agricultural actors can be supported and strengthened, and to support negotiations on what new roles corporations can take in future to enhance sustainable land use. In order to do so, comparison and collaborations with other regions facing pasture extensification processes are crucial.

Acknowledgements

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Essay 4

Modeling and Assessing Scenarios of Common Property Pastures Management in Switzerland

Modeling and assessing scenarios of common property pastures management in Switzerland

Ivo Baur[1] and Claudia R. Binder[1]

Abstract. Common property pastures (CPPs) in the Alps provide examples of enduring, sustainable, and self-organized resource use. During the past few decades, the situation has changed, and abandonment of marginal pastures with subsequent forest regrowth has been widely observed. To better understand current drivers, challenges, and policy impacts on the sustainable governance of common property pastures, we present an application of Ostroms' general framework for analyzing social-ecological systems (SESs). We use system dynamics (SD) modeling to operationalize the SES framework for the case study region of Grindelwald, Switzerland. Based on formative scenario analysis, we identify four consistent simulation scenarios. The simulation results show that increasing loss of common property pastures and resulting afforestation can be expected. Scenario assessment shows that policy blueprints such as liberalization or increased government support do not halt but instead accelerate abandonment of common property pastures. Furthermore, the simulation results show the sustainability trade-offs associated with changes in the external setting. We conclude by discussing options for sustainably governing CPPs.

Keywords:

System dynamics model

Common pool resources

Social-ecological systems

Formative scenario analysis

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1 Introduction

Natural resources use is embedded in complex social-ecological systems (SESs; Ostrom 2009). Understanding resources use patterns in SESs requires analyses of the feedback mechanisms (Liu et al., 2007), non-linear relationships (Folke, 2006), and thresholds (Walker and Meyers, 2004) that link actors, institutions, and resources. Dissection of the SES complexities is the base for developing effective policies, particularly under rapidly changing external conditions (Dietz et al., 2003), while disregard of complexities has often led to the implementation of simple policy blueprints with unintended consequences (Ostrom et al., 2007).

In European alpine regions, governance of alpine pastures currently faces the challenge of adapting to the problems of underuse and land abandonment (Baur and Binder, 2013; Kissling-Näf et al., 2002; Knoepfel et al., 2005). For centuries, alpine pastures needed protection from overgrazing, which was often achieved through common property arrangements (Casari, 2007; Netting, 1981; Ostrom, 1990; Stevenson, 1991). During the past few decades, the situation has rapidly changed, and many alpine pastures have been abandoned (Keenleyside et al., 2010; MacDonald et al., 2000). In Switzerland, alpine pastures make up approximately 12% of the national area (Lauber et al., 2008), of which almost 80% are communal (Baur et al., 2007) Since the sustainable use of common property pastures (CPPs) provides not only forage but also public goods, such as species and landscape diversity (Burel and Baudry, 1995; Giupponi et al., 2006; Stöcklin et al., 2007), and cultural values (Bignal and McCracken, 2000; Plieninger et al., 2006), governing CPPs is a major policy challenge for mountainous regions.

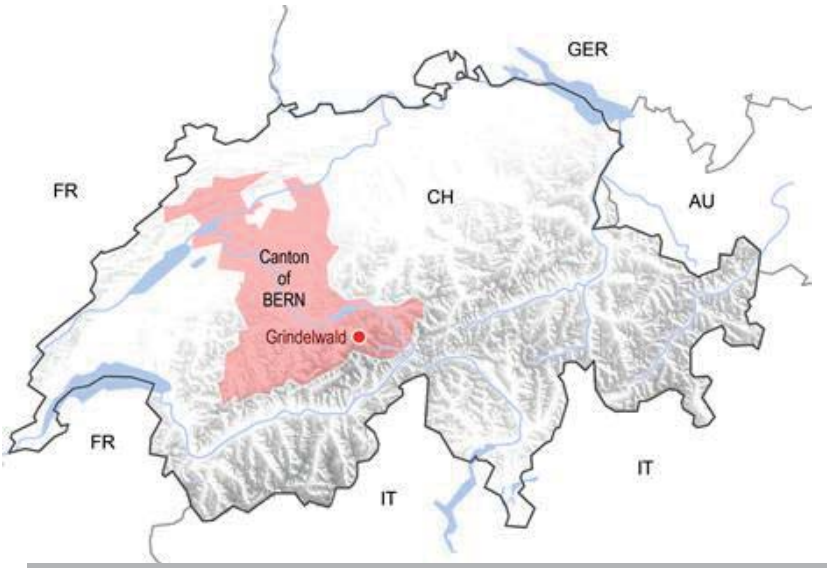
Researchers have identified several drivers of land abandonment, including structural change in the agricultural sector and the resulting labor scarcity (Gellrich et al., 2007), intensification of more productive areas at the cost of less productive areas (Lauber, 2006), dwindling livestock numbers in mountainous regions (Mack et al., 2008), low policy incentives for grazing marginal land, and political barriers that hinder payments for environmental services (Huber et al., 2013). Integrating the different aspects that drive resources use into a simulation model provides a highly valuable tool for assessing different strategies for regulating resource use (Costanza et al., 1993). Essentially, the SES models depend on the incorporation of knowledge across disciplinary boundaries and a holistic account of the properties that characterize the SES (Kelly et al., 2013; Schlüter et al., 2012). However, integrated SES simulation models for CPP use do not exist. Accordingly, this work aims at promoting sustainability of CPP by addressing the following questions:

a. How can we capture the dynamic interactions within an SES and consecutive patterns of CPP use?
b. How does the SES respond to changes in the external setting, and what are the sustainability trade-offs associated with different policy options?

To answer the first question, we operationalize the general framework for analyzing the sustainability of SESs (Ostrom, 2009) with a system dynamics (SD) approach for the case study region of Grindelwald, Switzerland. To answer the second question, we simulate four consistent scenarios developed with formative scenario analysis to investigate the SES reaction to external change. Based on the scenario simulation, we assess the sustainability trade-offs associated with each scenario and discuss different policy options for governing sustainable CPP use.

2 Case Study Region

Grindelwald is a municipality located in the heart of the Alps in the canton of Bern in Switzerland (E 8°01′48″/ N46°37′30). The municipality covers 171 km2 with the highest peak reaching 4,100 meters above sea level and the village located 1,000 meters above sea level (Fig. 1). As a result of the impressive mountainous scenery and winter sports facilities, over the last century Grindelwald has become an internationally recognized tourist resort. The local population of 3,800 inhabitants hosts an increasing number of visitors. In 2010, the village counted 111,078 overnight stays. Consequently, tourism is the main economic driver in the region, and gastronomy, the hotel business, the building sector, ski lifts, and public transportation provide a vital local labor market.



Grindelwald	
Area	171.1 km^2
Altitude	720 – 4107 meters a.s.l.
Surface of private agricultural land	1422 ha located in the valley
Common Property Pastures	4106 ha located on hillsides
Carrying capacity	1342 livestock units per 100 days
Inhabitants	3796 persons
Demographic development	- 6.1% (2000-2010)
Number of farms	123
Number of managing authorities of CPP	1 cooperative & 7 corporations
Rights of usage for CPP	Tied to private parcels in the valley
Maintenance of CPP	Tied to farmers appropriation levels

Fig. 1. The case study region of Grindelwald, Switzerland, and its basic social and ecological characteristics. Sources: author's own map; data source: (Baur and Binder, 2013; Baur et al., 2014)

In the local agricultural sector, farmers profit from off-farm income opportunities and typically generate a larger share of their household income through off-farm work, although they spend more time farming. As a result of structural changes in the agricultural sector, the number of farm households has decreased from 242 in 1980 to 123 in 2010. During that period, farm holdings have grown to an average of about 10 hectares and livestock units (Baur et al., 2014). Agricultural activities are based on livestock production. In the summer, farmers use their private parcels in the valley to produce hay for wintertime, while cattle graze on the CPPs. The CPPs in Grindelwald are located on the hillsides surrounding the valley and start from roughly 1,200 to

1,400 meters above sea level and extend up to 2,500 meters above sea level. A total of 34 alpine enterprises, most of which are privately owned, look after the livestock in the summer and produce artisan cheese, which is redistributed among the livestock owners according to their animals' milk yield. Management of the CPP is organized in seven corporations ("Bergschaften"), which are embedded in a cooperative ("Taleignung"), which functions as an umbrella organization to protect the common interest of the corporations (Baur and Binder, 2013).

3 Model Description

3.1 Model Purpose

The purpose of the model is to understand the effect of social-ecological drivers on the use and maintenance of CPPs. Given the tendency in Switzerland to abandon CPPs, the model needs to address, unlike most models of CPR use, not just the dynamics leading to overexploitation of natural resources but also the dynamics and consequences of underuse. By simulating changes in the external setting, the model should help to separate processes and policy options, under which the SES approaches or maintains sustainability, from those that shift the SES away toward less sustainable states of over- or underuse. Furthermore, simulation results should then uncover the different sustainability trade-offs associated with particular policy options (Janssen and Anderies, 2007) as the base for assessing scenarios.

3.2 Theoretical Framework

The model is based on Ostroms' general framework for analyzing SESs (Ostrom, 2007, 2009). Accordingly, the SES consists of four subsystems, which are embedded in an external setting (E). The social subsystems characterizing the SES include the actors system (A) and the governance system (GS). The social entities are the farmers (A) and the corporations (GS). The ecological subsystems consist of the resource system (RS) that produces the resource units (RUs). The ecological entities consist of the common property area with pasture and forest stands (RS), while the resource units consist of the livestock that graze the CPP and the grass used as fodder. These subsystems describe the SES at its highest level, but can be divided into attributes and subtypes that interact at common spatial and temporal scales to produce outcomes. The dynamic behavior of the SES therefore derives not simply from external inputs but results equally from the complex interactions between and within the subsystems.

3.3 Empirical Basis and Data Sources

The data used to build the model included qualitative data for the structural design of the model, and quantitative data for the numerical formulation of the SD model. Qualitative data was derived from a workshop, during which we discussed key challenges for CPP management with representatives of the seven corporations. We also conducted 10 interviews and four field excursions guided by farmers and experts to gain a detailed understanding of how the SES functions in order to conceptualize the model's structure.

For the numerical formulation of the model, we relied partially on our own data and on secondary quantitative data. The different data sources provided values for the period 1980–2010, upon which the model was validated and calibrated to match historical behavior. The initial values for

1980 derive mostly from the Man and Biosphere project conducted in the eighties in the study region (Nägeli-Örtle, 1986; Wiesmann, 1983). Time series describing the developments in the SES during the past decade were derived mostly from official statistical sources: Developments in the external setting were modeled using several price indices provided by the Federal Office for Statistics ((FSO), 1980-2010). Data that describes the use of the ecological system in terms of CPP stocking density was derived from a livestock census provided by a regional agency ((LANAT), 1980-1990, 2000-2010). Data on land cover changes stems from the areal statistics for 1979–1985, 1992–1997, 2004–2009 ((FSO), 1979-2009), and from an additional online source that describes the natural characteristics of the seven corporations (Alporama, 2013). Finally, our quantitative data from a 2010 representative household survey (n = 95) provided the values that describe the current state of the actors system and the social-ecological interactions (Baur et al., 2014).

3.4 Model Structure

3.4.1 Subsystems and interactions

Operationalization of the SES framework included five subsystems linked through six key interactions. The subsystem external settings (S) included the following eight components:

S1: National direct payments: Includes all payments related to land or animals, which constitute the main source of agricultural income and land use incentives and thus feed into the actors system.

S2: National summering payments: This includes summering payments that are paid to the corporation, which feed into the governance system and the recently introduced appropriation contribution, which is paid to the livestock owner.

S3: Prices for dairy products: This includes the milk and cheese prices, which affect the market returns of the farmers' agricultural activities.

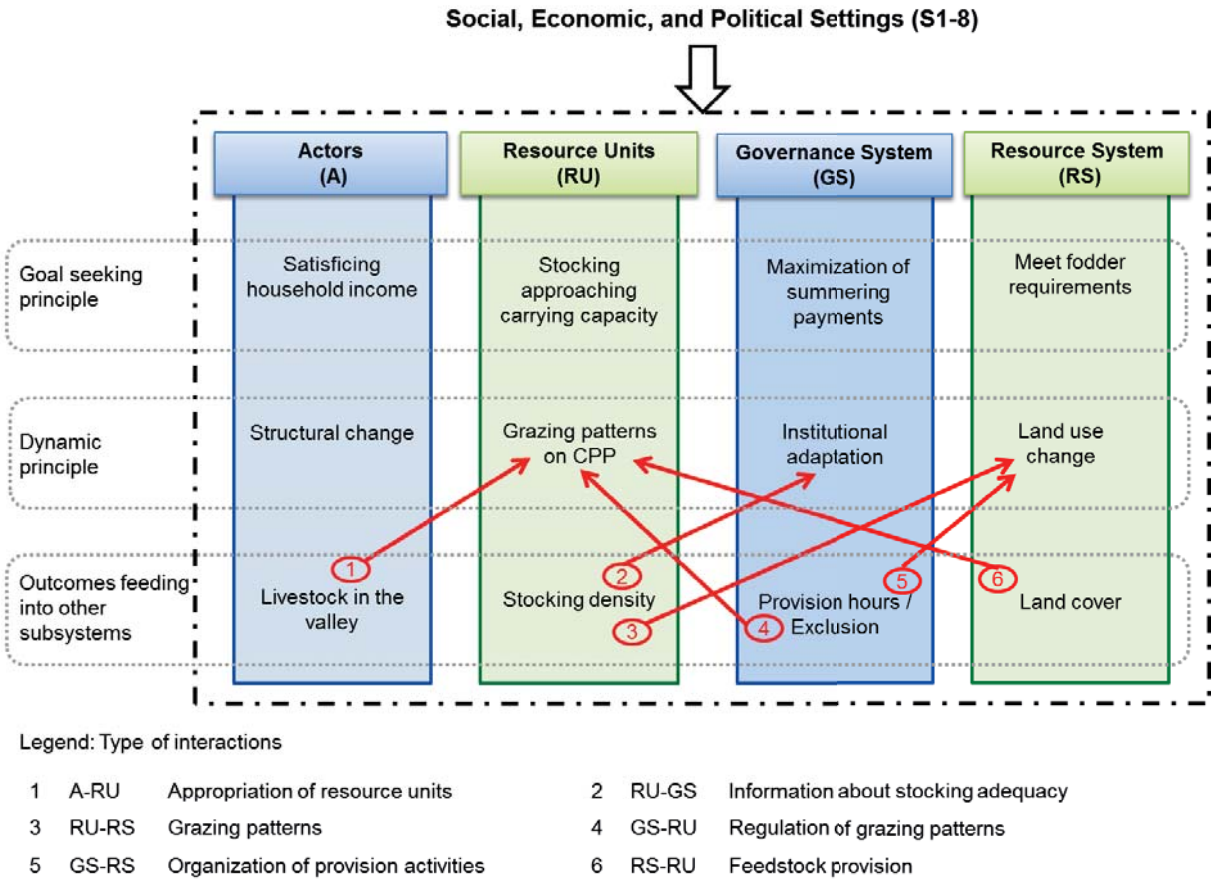
S4: Off-farm income opportunities: Represented through the average wage, which farmers could achieve in the region when they work outside the agricultural sector.

S5: Direct costs include the variable costs of keeping a livestock unit such as labor costs, costs of animal feed, veterinary costs, and infrastructural investments.

S6: Tourism development represents the indexed overnight stays, which affect prices for dairy products and off-farm income opportunities.

S7: Climate change affects the growing season and therefore the annual grass production of pastures.

S8: The wood price affects off-farm income opportunities.



Legend: Type of interactions

1	A-RU	Appropriation of resource units	2	RU-GS	Information about stocking adequacy
3	RU-RS	Grazing patterns	4	GS-RU	Regulation of grazing patterns
5	GS-RS	Organization of provision activities	6	RS-RU	Feedstock provision

Fig. 2. Conceptual framework of the SES model, including the external setting and the four subsystems, their goal-seeking principles, the regulating dynamics, and the key interactions among the subsystems.

The actors system shows how the average farmer in Grindelwald reacts to external incentives (S1–S5). By reallocating production factors such as labor, land, and livestock, the farm households aim to achieve a satisfying household income. Instead of maximizing household income, farmers prefer agricultural activities over off-farm activities and try to generate satisfactory household income by increasing farm size. Regarding agricultural holdings, farmers react to land use incentives shaped by the external setting adapt herd size to maximize agricultural income. The extent to which the average farm household achieves its income goal determines the process of structural change at the macro level. If the household income goal is just achieved, then structural change occurs according to the regular pattern with a generational life cycle of thirty years ending with the farmer's retirement at the age of 65, and a 1 in 3 chance that farm holding continues to exist by succession and a 2 in 3 chance that the farm is abandoned and the land reallocated by the market. At the macro level, the abandonment and succession rates vary with the economic situation of the average farm household. If the income goal is not achieved, succession decreases and abandonment increases, and vice versa if the income goal is exceeded. Accordingly, the process of structural change regulates the number of farm households and their economic endowments such as livestock, which are important links to the resource units since they determine the potential for appropriation and thus affect grazing patterns (Fig. 2, I1).

In the governance system, corporations attempt to maximize income from summering payments paid by the federal government (S2). Since payments are provided per stocked unit and incrementally reduced, if the CPP stocking density is above 110% or below 75% of the government-defined carrying capacity, the summering payments are maximized, when the defined carrying capacity is utilized with a factor of 1.1. To approach the optimal stocking density, the local governance system adapts rules that exclude outsiders (Fig. 2, I2) in order to steer stocking density close to the carrying capacity (Fig. 2, I4). In addition to regulating appropriation activities, the governance system also forces institutions to organize provision activities to maintain the resource system (Fig. 2, I5). These activities include defining the provision hours to be fulfilled, setting fines for non-compliance, and monitoring and sanctioning non-compliance. The amount of provision activities fulfilled in turn affects land cover and the state of the resource system, since provision activities include tasks that enhance the productivity of the resource system, such as cleaning of overgrown CPP areas.

In the ecological system, the interaction of resource units is closely linked to the governance system's goal of maximizing summering payments. In doing so, the grazing patterns are regulated through exclusion in order to get stocking density in line with the carrying capacity. The stocking density produces a certain demand for forage, which affects the resource system (Fig. 2, I3). The extent to which demand is met by the resource systems forage production determines the process for changing use of the land. If the forage needs are not met, overgrown CPPs can be reclaimed through provision activities, and if forage production exceeds the need, land is abandoned. How quickly land use adapts to current requirements depends on the fulfilled provision hours. As a consequence of the changes in the land use, the land cover changes (for example, the CPP area ready for grazing), which in turn changes the forage provision and the resulting grazing patterns (Fig. 2, I6).

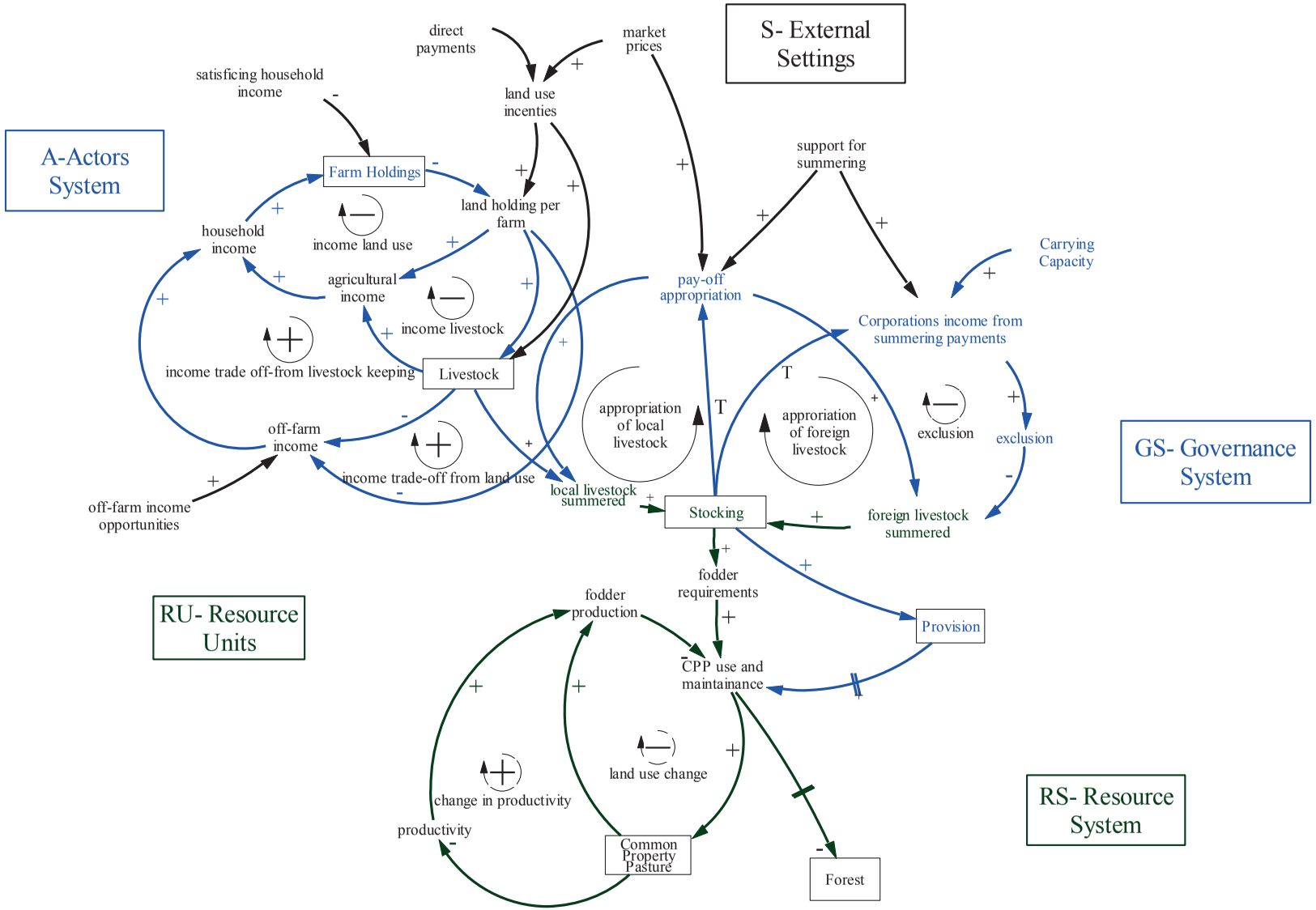


Fig. 3. Causal loop diagram illustrating central feedback loops. The positive links show that the variables develop in the same direction, while the negative links indicate developments in the opposite direction. Arrows marked with T indicate that the direction of the effect depends on a threshold value. The causal chains form feedback loops—positive and negative. Positive feedback loops reinforce the system's behavior and accelerate growth or decay. Negative feedback loops preserve or balance the system state.

3.4.2 Feedback loops and threshold values

We identified nine feedback loops that drive SES behavior. In the actors system, two types of loops were important for factor allocation. First, the two balancing agricultural income loops indicate that farmers try to achieve a satisfactory household income by increasing their land and livestock holdings, and thus search for the optimal land use intensity to maximize agricultural income. Second, dependent on labor productivity, larger farms require more labor input, which cannot be allocated to off-farm activities, as indicated by the two reinforcing loops.

The actors system and the resource units are linked through the farmers' appropriation decision as indicated by the two appropriation loops in Fig. 3. From the appropriation of livestock, farmers generate pay-offs in the form of cheese that can be sold. The pay-off per livestock unit is largest when stocking density is close to the carrying capacity, since overstock decreases the cheese production while understock increases the costs of summering. Furthermore, the pay-off also depends on market prices and policy measures that support summering. Appropriations levels in turn increase with pay-offs and thus affect the CPP stocking. This feedback mechanism applies to local and foreign summered livestock as indicated by the appropriation loops in Fig. 3.

The governance system regulates the appropriation of foreign livestock through operational rules. To maximize income from summering payments, corporations attempt to keep the stocking density as close to the carrying capacity as possible. By excluding non-local users, the governance system might or might not allow non-locals to summer livestock in order to increase stocking density when it is below the carrying capacity, as indicated by the balancing exclusion loop.

For the ecological system, the stocking density is the central link between the social processes and consecutive land use and land cover change for two reasons. First, since the stocking density determines provision and forage requirements, it is the major driver behind pasture use and maintenance. As indicated by the land use change loop, the CPP area is adapted to meet the animals forage requirements. Accordingly, plots of CPPs are abandoned if forage production exceeds needs or reopened if the needs exceed production. Second, as indicated by the change in the productivity loop, land use always affects the least productive plots and leads to changes in average plot productivity. The average plot productivity therefore increases when the CPP area is reduced or decreases when CPP area is increased, as indicated by the reinforcing "change in productivity" loop. The changes in land use also affect the forest stands, since the abandoned CPP plots are transformed into forest over time.

3.5 System Dynamics Integration

The system dynamics model was programmed with Vensim Professional software and consists of five views that display the external setting (S), the actors system (A), the governance system (GS), and the resource units of the resource system (RS). In total, the model includes 173 variables: eight levels, 16 look-ups, 102 auxiliaries, and 62 constants. The model's initial values refer to 1980, while the current values refer to 2010. The model was calibrated using the historical data available for this time period and runs at 1-year increments in discrete time steps to 2040. A detailed description of the model was produced using the System Dynamics Documentation and Assessment (SDM) tool (Martinez-Moyano, 2012), which is detailed in Appendix A. The key elements of the model are level variables regulated through inflows and outflows, formalized as integral and equations (Sterman, 2001):

$$Level\ (t) = \int_{t_0}^{t} [Inflow(s) - Outflow(s)]ds + Level\ (t_0) \quad (1)$$

3.6 Model tests and improvement

To uncover structural flaws and to increase confidence in the validity and parameter values in the model, we applied several tests that can be divided into structural, sensitivity, and behavioral tests (Barlas, 1989).

Structural tests examined whether the system structure was consistent with the observed physical reality and included a four-step procedure:

- Dimensional consistency was used to ensure that all variables have units with real-world meaning.
- Integration error testing was conducted to ensure that the model behavior does not depend on the choice of time steps or the integration method.
- Reality check equations were introduced to prove that the model behaves realistically and is free of illogical relationships between the variables.
- Extreme condition tests were introduced to investigate whether the model behaves realistically when the parameters take extreme values.

Sensitivity tests showed how the model behavior is affected by parameters for which we had no exact data sources available. We used a Monte Carlo simulation with uniform distributions to assess how random changes in the following four parameters affected the model behavior.

- Satisfactory household income was randomized with the lower limit set at CHF 55,000 and the upper limit set at CHF 100,000.
- Initial pasture productivity was randomized with the lower limit of 10 and an upper limit of 25 kg DM/day/ha.
- Availability of cattle in the lowlands was randomized with a lower limit of 0.1 and an upper limit of 1.
- Forage decay fraction was set with a lower limit of 1 and an upper limit of 4.

Based on the Monte Carlo simulation parameters, the parameter values were then adapted in order to achieve the best possible historical fit of key stocks that refer to available longitudinal data. For a more detailed description of the tests applied, see Appendix B.

Behavioral tests provide insights into the model's capacity to replicate the dynamics of the real-world system by assessing the fit between the model and the observed data (Bennett et al., 2013; Oliva, 2003). We tested the values of the key stocks in the model against the information from census data and real statistics for farm households, stocking density on CPP, and livestock in the valley, CPPs, and forest stands. We calculated the correlation coefficient (R), absolute relative error (ARE), and mean absolute relative error (MARE) for level variables. Where n is the number of data, x_d represents the observed and x_m the model data. Standard deviations are depicted by s_d and s_m.

$$R = \frac{1}{n}\sum \frac{(x_d - \overline{x}_d)(x_m - \overline{x}_m)}{s_d s_m} \quad (2)$$

$$ARE = \left|\frac{x_d - x_m}{x_d}\right| * 100 \quad (3)$$

$$MARE = \frac{1}{n}\sum \left|\frac{x_d - x_m}{x_d}\right| * 100 \quad (4)$$

The model showed good fit with the historical data. The simulated number of farm households was correlated at 0.96 with the historical data and achieved a mean absolute error of 4.51% for 2000–2010 (Fig. 4a). Predictions for livestock in the valley achieved the lowest R value with 0.22 and consequently a larger mean absolute error with 7%, because livestock in the valley suddenly decreases in census data by 74 livestock units between 2007 and 2008. This decrease does not reflect a serious decrease in the livestock present, but instead results from a change in the weighting system for livestock units. For 2008–2010, the total livestock in the valley from census data had an R value of 0.92 and a MARE of 3%, which shows that livestock in the valley is adequately replicated by the model and that the largest part of the deviation between the model and census data is explained by change in the weighting of the livestock units. Stocking density of CPP had an R value of 0.4 and showed a very moderate deviation from the census data with a MARE of 3% (Fig. 4a).

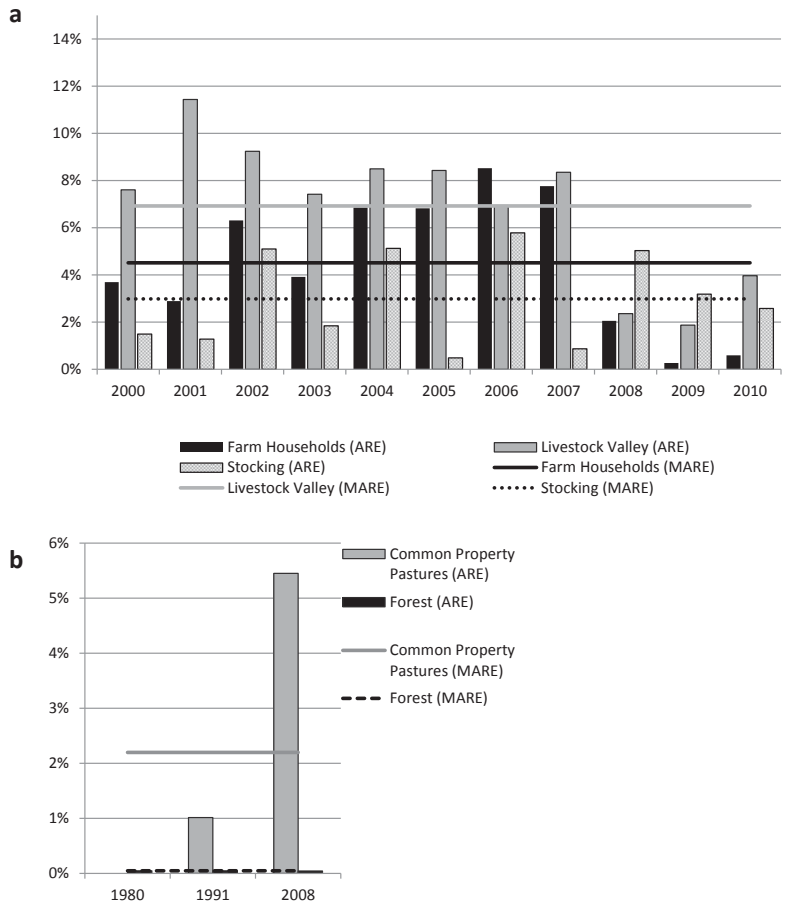


Fig. 4. Absolute relative error (ARE) and mean absolute relative error (MARE) for assessing the historical fit of the model's key level values. (a) The deviations between actual and simulated

development for the number of farm households, the livestock in the valley, and the stocking level on CPP. (b) The deviations between actual and simulated development of common property pastures and forest area.

As indicated in Fig. 4b, the historical fit for the CPP and forest area is satisfactory, although only three data points were available, one of which was used to initialize the model. Therefore, historical fit refers only to two data points (1991 and 2008), but was very high with R values above 0.98 and a MARE of 3.2% for CPPs and 0.04% for the forest area. Although the historical fit of the model is very high, validation of ecological processes relied only on three time points which limits its information value that were available from areal statistics. Furthermore, the areal statistics does not differentiate between common and private lands, and we thus relied on additional data sources (Alporama, 2013) for calculating land cover change. Combining the data sources, we calculated a 0.8% decrease of common property area from 1980 to 1991 and a further 6% decrease from 1991 to 2008. During the same time, the forested area increased in each period by roughly 2%. Since the loss of CPP area does not immediately result in increased forest growth, we assume that the loss is first added to overgrown CPPs and is later converted into forest stands.

3.7 Scenario Analysis

We used formative scenario analysis to identify a consistent set of scenarios for simulating future development of the SES. Formative scenario analysis aims at assessing a hypothetical, but consistent, combination of events that affects the future state of a system (Scholz and Tietje, 2002; Wiek et al., 2006). Therefore, we concentrated on developments in the external setting (S), which served as input values for the simulation. The parameters were defined with an expert assessment as part of a master thesis (Zumstein, 2013). The procedure included the following six steps (Scholz and Tietje, 2002; Tietje, 2005) for further details, see Appendix B):

1 Define the spatial and temporal scales of the scenario parameters.
2 Define the variables and potential parameter values that describe the external setting.
3 Have experts validating the chosen variables and values.
4 Develop an impact matrix.
5 Complete the impact matrix with experts.
6 Conduct a consistency analysis of the completed matrices.

4 Results

4.1 Simulation of the Historical Development of the SES

The baseline simulation of the SES reveals a moderate decrease in the use and maintenance of CPPs that led to a slight abandonment of CPP from 1980 to 2010. In the external setting, the shift in agricultural policies from market prices support to direct payments caused a significant decrease in the milk price (Table 1). As a result, farmers' land rents and their dependence on direct payments steadily increased, while revenues from keeping livestock stagnated.

Table 1. Baseline simulation for selected variables that describe the past development of the social ecological system (rounded values).

	1980	1990	2000	2010
External Setting (S)				
Payments tied to land (CHF/ha)	1040.00	1480.00	1840.00	2000.00
Payments tied to animals (CHF/LU)	504.00	717.80	892.00	970.00
Summering payments (CHF/SLU[1])	156.00	222.00	276.00	300.00
Direct costs of animals (CHF/LU)	1040.00	1480.00	1840.00	2000.00
Milk price (CHF/kg)	0.92	0.78	0.54	0.51
Cheese price (CHF/kg)	14.42	16.91	17.07	18.00
Potential off-farm income (CHF/year)	41712.00	50876.00	59503.00	63200.00
Wood price (CHF/FMb)	27.50	33.00	34.92	55.00
Tourism index (dmnl)	80.00	87.00	95.00	100.00
Climate change (increase in degrees Celsius)	0.00	0.20	0.40	0.60
Actors System (A)				
Farm households (hh)	242.00	197.00	158.00	126.00
Livestock per household (LU/hh)	6.30	7.70	8.70	10.80
Land holding per household (ha)	5.60	6.90	8.60	11.30
Workload (Sw[3])	0.91	0.98	1.05	1.24
Household income (CHF)	64725.00	75953.00	84234.00	87238.00
Agricultural income (CHF)	19283.00	24363.00	28125.00	39185.00
Resource units (RUs)				
Livestock in the valley (LUs)	1525.00	1514.00	1368.00	1358.00
Stocking density of CPP (SLUs)	1448.00	1474.00	1366.00	1393.00
Foreign cattle summered (SLUs)	0.00	0.00	0.00	22.00
Forage requirements (Mio. kg DM[4])	5.86	6.36	6.41	6.83
Duration of season (days/year)	95.00	97.40	99.80	102.00
Governance System (GS)				
Net provision (hours)	16000.00	14828.00	14272.00	13832.00
Provision not fulfilled (hours)	0.00	0.00	0.00	1260.00
Corporations income from fines (CHF)	0.00	0.00	0.00	31500.00
Provisions bought (hours)	0.00	0.00	0.00	1370.00
Foregone summering payments (CHF)	1373.00	118.00	26127.00	26806.00
Appropriation rules (dmnl)	0.00	0.00	0.00	0.84
Resource System (RS)				
Common Property Pastures (ha)	4375.00	4294.00	4289.00	4182.00
Average productivity of summer pastures (kg DM/ha/day)	15.00	15.14	15.18	15.32
Overgrown Common Property Pastures (ha)	163.00	23.00	14.48	13.00
Forest (ha)	2130.00	2373.00	2374.00	2481.00
Abandoned Common Property Pastures (ha)	142.60	0.00	32.40	0.00
Cleaning of Common Property Pastures (ha)	0.00	6.90	0.00	6.40

[1] SLU = summered livestock unit; 2 FM = solid cubic meter; 3 Sw = standardized workforce; 4 DM = dry matter.

In the actors system, farmers adapted to the changes in the external setting by using the land less intensely and doubling the size of their holdings. Since labor productivity did not keep pace with farm growth, labor demand on farms has increased. At the macro level, this resulted in structural changes toward fewer but larger farms and reduced the number of farm households from 242 to 126. Regarding the income situation, due to the farm growth, agricultural income increased in nominal and real values. Since farm growth requires more labor input that cannot be allocated to off-farm activities, the nominal household income increased only moderately. In fact, the average farm household in Grindelwald increased its holdings at the cost of a nominal 5% decrease in household income from 2000 to 2010 (Table 1).

Due to the decreased land use incentives, the livestock present in the valley decreased by 11%, which directly affected the stocking density. Since stocking density decreased during the 1990s in particular, the corporations' loss of summering payments increased. In response, the corporations changed their appropriation rules in 2005 (when the missed summering payments reached the threshold value) and opened the corporations' pastures to foreign cattle. With the change in appropriation rules that reflect the degree or the share of corporations that allow for foreign cattle, the stocking density was stabilized after 2005 with an additional 22 summered livestock units (SLUs) from non-local farmers.

The governance system shows a net decrease in provision activities, which is mostly a consequence of reduced stocking density. Furthermore, provision duties not fulfilled increased between 2000 and 2010 for two reasons: First, the increasing labor demand on the average farm compelled farmers to pay the fine instead of fulfilling their provision duties. Second, external users had lower provision fulfillment rates. Since provision defections are fined, corporations use these fines to buy additional provision hours from users or even employ full-time laborers.

In the resource system, reduced use and maintenance of CPPs affected land cover through the net abandonment of 2% of the overall CPP area. Even though stocking has been steadily decreasing, feed requirements increased as a result of advances in the breeding, leading to increased animal weight and forage needs. Since the resource system also increased feedstock provision, mainly because of the longer growing seasons, the interplay of forage requirements and forage production resulted in periods of CPP abandonment and periods of CPP reclaim: From 1980 to 1983 and again from 1999 to 2005, the model indicates land abandonment phases, while from 1983 to 1998 and 2006 to 2010, the model simulates phases of cleaning of overgrown pastures by provision activities. Overall, the model shows a decrease of 193 ha in CPP that resulted from the first decade of the simulation. Between 1990 and 2010, the overgrown pastures, which are a surplus area not needed to meet forage demand, ranged between 23 and 13 ha. This indicates that the forage needs and requirements were well balanced for the last period of the simulation, and very little change in land use occurred.

4.2 Scenario Definition

The formative scenario analyses yielded four scenarios as defined by the changes in the following parameter values from 2010 to 2040 (Table 2). The scenarios integrate development on different spatial scales ranging from global developments (climate) to the regional (e.g., tourism) that can be described as follows:

Table 2. The four scenarios describing the potential developments in the external setting between 2010 and 2040.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Rising prices	Liberalization and economic growth	Increased Government support	Crisis
Direct payments	Normal	−50%	50%	−50%
Summering payments	Normal	50%	50%	Normal
Dairy prices	30%	−20%	−20%	30%
Direct cost	40%	−10%	40%	−10%
Off-farm income opportunities	Normal	Normal	−25%	−25%
Tourism development	25%	Normal	−25%	−25%
Climate	1 °C	Normal	1 °C	1 °C
Wood price	100%	50%	200%	200%

Scenario 1: Rising prices: This scenario is characterized by a global scarcity of energy sources and a price increase in raw and energy materials. As a result, the cost of agricultural production increases, which also results in higher food prices, and wood becoming an important energy source. At the national level, the economy remains stable, and the federal government continues its level of agricultural support. The local labor market offers sufficient off-farm income opportunities, and tourism further increases, since ski resorts at higher altitudes such as Grindelwald gain additional international attention for consistent snow levels.

Scenario 2: Trade liberalization and economic growth: The global economy grows steadily and becomes increasingly interconnected. As a result of liberalization, direct payments are largely cut, and agricultural policies remunerate particular environmental services, such as the use of summer pastures. Liberalization also causes national prices in the agricultural sector to approach the global price level. At the local level, tourism and off-farm income opportunities show normal growth patterns with a slight increase in wood prices.

Scenario 3: Increased government support: The global economy suffers from the adverse effects of climate change and faces a shortage of raw materials and energy sources. As a result, the costs of agricultural production rise, and consumers substitute dairy products with cheaper foods. The agricultural sector suffers from market developments and government support increases to secure the survival of the agricultural sector and to prevent unemployment and depopulation of the alpine regions. In Grindelwald, the local economy suffers from global recession and climate change, and the tourist sector and thus off-farm income opportunities decrease drastically.

Scenario 4: Crisis: European economies stagnate and agricultural production struggles to meet demand as adaptation to climate change largely fails. World market prices rise, while purchasing power decreases all over Europe, including Switzerland. The federal government budget decreases and ever-increasing amounts are spent on social security, leaving less for the support for the agricultural sector. The agricultural sector, however, profits from lower production and

increasing demand leading to higher prices, while the costs of agricultural production decrease. At the same time, tourism and off-farm income opportunities decrease in the absence of international visitors and investments in tourism infrastructure. As a result, agriculture becomes a more attractive option for making a living in the region.

4.3 Scenario Simulation

The simulation of the scenarios showed that the use and maintenance of CPPs will further decrease in the near future with subsequent loss of CPP area and forest regrowth. Surprisingly, this trend was strongest under the government support scenario, while the use and maintenance of CPPs is most intense in the crisis scenario. However, changes in the external setting impact land use and land cover changes over time. Since the scenarios are simulated as continuous developments, the actors and governance system closely follow the patterns produced in the baseline simulation until 2018. Since the changes in the social system affect the ecological system with delays in land use change and land cover change, changes in the external setting take about 10 years to become visible in the resource system.

In the actor system (A), the trend of structural change toward fewer but larger farm holdings persists for all scenarios (Fig. 5a). Under government support, structural change slowed down, as the high level of direct payments keeps labor in the sector. In contrast, the liberalization and economic growth scenario accelerates structural change with labor leaving the sector in response to decreased direct payments and producer prices accompanied by attractive off-farm income opportunities. As government support slows the process of structural change, it also impedes farm growth in particular regarding livestock keeping. Accordingly, the average holding increases to only 16 LUs, and since farmers can survive on the direct payments, there is no need to focus production on generating market revenues from livestock keeping (Fig. 5c). This development is most contrasted by scenario 4, in which the economic crisis favors agricultural production, since the costs of production are low and the prices for dairy products are comparably high. Farmers respond to these changes by using land more intensively. In 2040, the average farm household in the region keeps 31 LUs, which is about twice the number of animals kept under the government support scenario. Thus, land use intensity in the valley will reach 1.35 LU/ha, which is more than 35% above the current land use intensity.

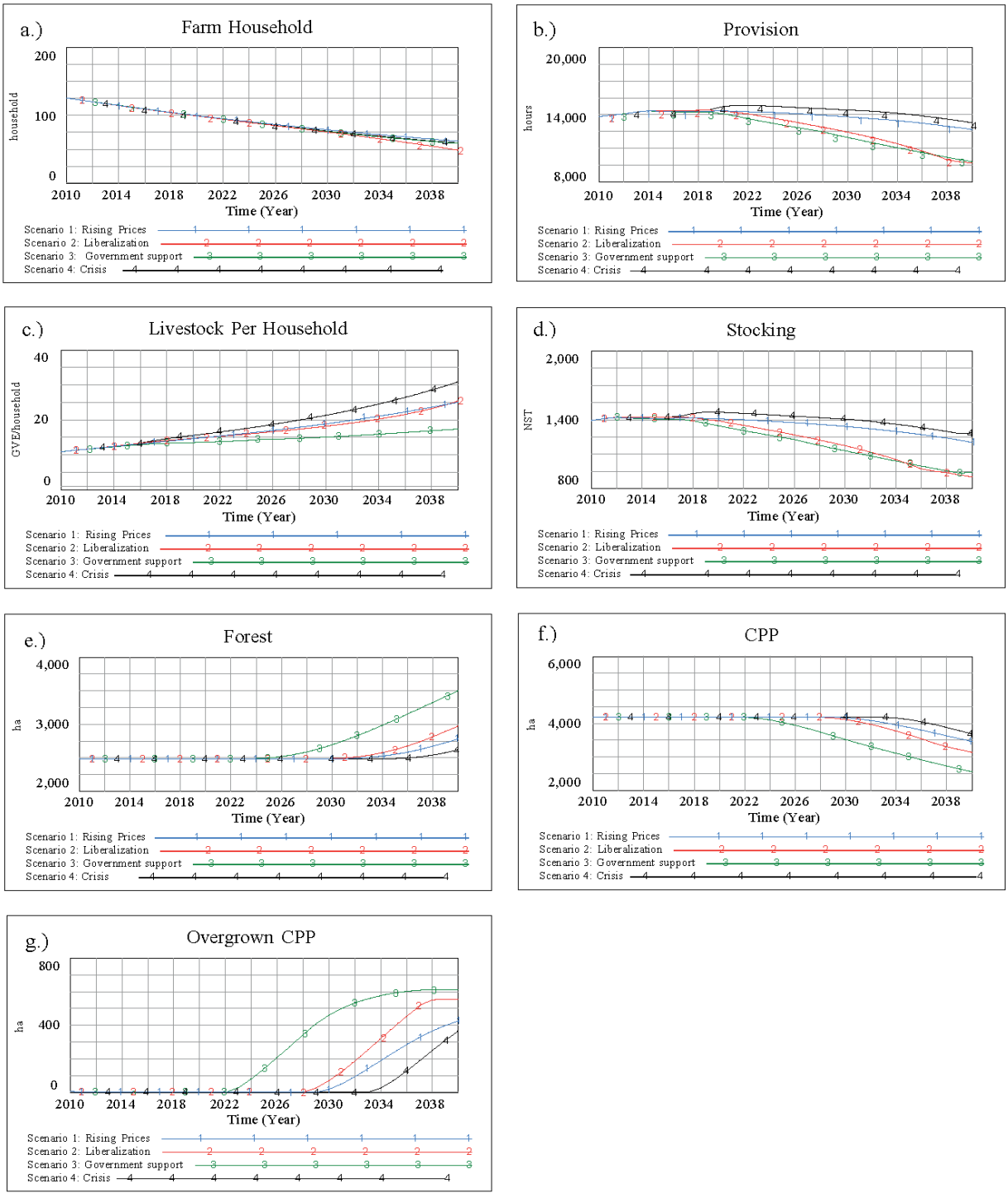


Fig. 5. Scenario simulation of key variables describing the SES between 2010 and 2040.

Regarding the actual use and maintenance of CPPs, provision activities remain closely linked to stocking density on CPP (Fig. 5b and d). As a result of strong land use incentives in the crisis scenario, the stocking levels outnumber current levels between 2020 and 2030. Similarly, scenario 1 (rising prices) will lead to stable use and maintenance of CPPs, while the trade

liberalization and government support scenarios will lead to a significant decrease in the use and maintenance of CPPs. Although the rising prices and trade liberalization scenarios lead to very similar developments in the actors system, they result in different stocking and provision levels. This is due to differences in producer prices which provide better pay-offs for using CPPs under the raising prices scenario compared to the liberalization scenario. In the liberalization scenario, even summering payments are not sufficiently increased to compensate for the price decrease in dairy products.

In the ecological system, the decreasing use and maintenance of the CPPs result in afforestation for all scenarios. The simulation shows that the system is particularly vulnerable to underuse, since stocking is linked to provision. In the case of increased stocking, the negative effects of land use intensity below the optimum can potentially be harnessed, as provision hours increase. In the case of reduced stocking density, the ecological system will be affected in two ways: by lower grazing intensity and the associated lower provision levels. This subtle process of lowered use and maintenance of CPPs causes a backlog of surplus CPP area that manifests with a delay of about 7–15 years in decreasing the CPP area that first is overgrown and later released as forest regrowth (Fig. 5e–g). Since the national law forbids activities that reduce forest areas (Forest Act; Chapter 1; Article 4), once the lost CPP area is transformed into forest stands, it becomes permanent. Therefore, the potential decrease in stocking and provision levels suggested by the simulation results for the near future will have irreversible effects on land cover in terms of forest regrowth.

4.4 Scenario Assessment

The simulation results suggest that regarding the stable use and maintenance of CPP use, scenario 1 (price increase) and scenario 4 (crisis) produce more desirable outcomes than scenarios 2 and 3 (liberalization and governmental support), respectively. Nevertheless, SES adaptation to external changes often involves trade-offs in different systems functions, which can lead to new vulnerabilities (Janssen and Anderies, 2007; Janssen et al., 2007). Therefore, different aspects of sustainability must be considered for the evaluation of scenarios (Table 3).

The SES in Grindelwald is robust against structural change. Structural change and the resulting labor scarcity are a major cause of afforestation (Gellrich et al., 2007). Our results suggest that this is not necessarily the case and that the deviations from the current trend of structural change might accelerate rather than mitigate the problem of CPP abandonment.

A key challenge for avoiding major abandonment of CPPs is to ensure a stable number of local livestock as a premise for stable stocking and provision levels. In the crisis scenario, land use intensity even increases and ensures the largest number of local livestock in the valley, but potentially at the cost of overexploited private plots with adverse ecological effects. Scenarios 1 and 2 would be preferable for keeping land use intensity in the valley within its current range.

The model suggests that the average farm in Grindelwald will increasingly rely on hired labor to cope with larger farm holdings. Only if government support is significantly increased and farm growth is slowed can farming remain a pure family business as in the government support scenario. Additionally, the government support scenario allows for sustainable agricultural livelihoods, while under the liberalization scenario, only farmers with strong preferences for agricultural activities continue farming and need to generate off-farm income to subsidize the farm business and finance respective employees.

Table 3. Indexed indicators for scenario assessment for 2040 (2010 = 100).

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
	Rising prices	Liberalization and economic growth	Government support	Crisis
Number of farm holdings	49.3	39.3	51.1	47.5
Land use intensity in the valley	110.7	91.7	72.7	130.8
Hired labor (in absolute numbers of Sw)	27.8	60.4	0.0	58.2
Total household income	139.4	36.0	178.0	130.1
Agricultural income	350.7	167.9	305.4	382.0
Defection on provision hours	240.8	277.0	191.1	272.7
Provision	91.3	70.7	75.8	91.6
Stocking of CPP	86.1	65.6	71.5	86.4
Foreign livestock on CPP	641.4	1287.9	1102.6	631.1
Afforestation	110.8	115.8	131.6	110.5

In the governance system, additional responses to decreasing local livestock and subsequent stocking levels by opening the pastures to foreign cattle are inevitable, except under the crisis scenario. A continuous shift in governance principles in the use of maintenance of CPPs from closed communal organizations to market principles is therefore likely to continue or increase. In this case, ever-larger shares of non-local farmers pay for summering services and provision activities provided by corporations or local farmers, respectively. This situation, in which the group of beneficiaries of the resource is not congruent with the group that maintains and governs the resource, might be a potential source of conflict. Furthermore, demand from external users for summering, organization, and provision activities involves uncertainties and is difficult to predict. In our model, reduced local livestock and appropriation in scenarios 1–3 are not fully absorbed by the governance system adaptation, as incentives for external users and the corporations are not strong enough to provide a full substitution to match the carrying capacity.

The use and maintenance of CPPs is most stable when agriculture remains an economically feasible activity compared to off-farm opportunities, as in the crisis scenario. Consequently, crises might not result in overall welfare gains, but achieve the best outcomes in terms of halting CPP abandonment (potentially at the cost of overused private plots). Although the rising prices scenario results in larger CPP abandonment compared to the crisis scenario, it will not do so at the cost of intensified agriculture in the valley. However, both scenarios have better outcomes than liberalization or increasing government support for continuous use and maintenance of CPPs.

5 Discussion

Unlike most other common pool resource settings, the current challenge in the Alps is to ensure continuous use and maintenance of the resource rather than preventing it from being overexploited. It is now widely accepted that such problems of natural resource use are embedded in a complex social-ecological system that cannot be steered with simple policy blueprints (Ostrom, 2009). This paper attempts to illustrate the current challenges and policy options for governing common property pastures (CPPs) through integrated modeling of social-ecological systems (SESs). In doing so, we used the SES framework to develop an empirically based Systems Dynamics model of CPP use for Grindelwald, Switzerland. The scenario simulations showed that the trend of decreased use and maintenance of CPPs continues for all of the four scenarios. Nevertheless, the degree and pace at which the CPP plots are abandoned and subsequent forest regrowth takes place vary substantially according to the scenario setting. Simulation results show that policy blueprints such as trade liberalization or increasing government support largely fail to prevent further CPP abandonment. Instead, CPP use remains most stable when the agricultural sector benefits from an economic crisis or when commodity prices increase. However, scenario assessment revealed no optimal solutions, since the different development patterns of the SES involves trade-offs in sustainability and robustness (Janssen and Anderies, 2007). In the crisis scenario, for example, CPP use and maintenance is most sustainable, although potentially at the cost of overexploited private parcels in the valley. In the government support scenario, in contrast, land use in the valley and agricultural livelihoods remain sustainable, albeit at the cost of seriously underused CPPs. However, acknowledging the trade-offs and uncertainties associated with the different scenarios provides the base for effective policies for governing CPPs.

5.1 Policy Implications for the Sustainable Governance of Common Property Pastures

Governing CPPs against the trend of underuse remains challenging. Policies should target and react to stocking density for two reasons. First, stocking is the major driver for the provision and grazed CPP area. As the stocking decreases, the provisions and the grazed area also decrease, and the problem of underuse accelerates. These contrasts with overuse, because when stocking exceeds the carrying capacity, the adverse effects of overgrazing are eased and not accelerated by the consequent increase in provision activities. Second, as the simulation results suggest, decreasing use and maintenance of CPPs becomes visible in the resource system as the afforested area with a delay of about 6 to 10 years that cannot be transformed back to pasture under current federal legislation. Thus, if major forest regrowth is observed, the feedback mechanism of underuse is already in play, which shifts the system further away from its sustainable state. Therefore, if stocking density decreases further in the near future, as predicted in the government support and liberalization scenarios, counteracting interventions must be put in place to prevent serious forest regrowth in the long run.

Such interventions might be most effective when they target two system components: land use incentives for private plots in mountainous regions and farmers' pay-offs from summering. Land use incentives need to balance direct payments with market prices in order to ensure the sustainable use of private plots and at the same time sufficient local stocking potential, which has been reported to be a problem in some mountainous regions (Mack et al., 2008). In contrast to other study regions (Gellrich et al., 2007),structural change in Grindelwald is not a major driver of CPP abandonment. As our simulation results show, deviations from current patterns of

structural change accelerate rather than mitigate the problem of underuse. Instead of slowing or accelerating structural change through increased or decreased government support, policies should target farmers' pay-off from appropriation. Such policies may include national as well as local governance measures. On the national level, polices might include a further increase in summering support as recommended (Baur et al., 2006), particularly through appropriation contribution or with payments for environmental services (Huber et al., 2013), which specifically target the upkeep of CPPs. However, increased marketing activities for alpine dairy products might be an effective tool for shaping price incentives for appropriation, which can be organized on national and local levels. On the local level, such a focus on centralized marketing activities in corporations are reported to have a strong positive impact on the overall functioning of the local agricultural sector (Bardsley and Bardsley, 2014). In addition, better labeling and a better communication of values associated with consumption of alpine products on the national level might raise prices for alpine products and promote incentives for keeping livestock in mountainous regions as well as using and maintaining CPPs.

5.2 Options for Model Improvements and Future Research

The model presented simulates CPP use at the local level. However, this model does not explicitly predict which parts of the CPP plots may potentially be abandoned. Coupling the SD model with geographic information systems would identify the areas that are most prone to abandonment and their characteristics. Information about the biological value and characteristics of these sites might help determine effective payments for environmental services. In addition, the model could be improved by refining the interactions of the resource units. Since different types of species and breeds might have very different mobility traits and grazing preference, land use patterns might vary with the breed types summered, which cannot be simulated with the model.

In addition to the limitation, the model might serve other purposes such as investigating the short-term impacts of changes in the federal agricultural policy framework on CPP use or the simulation of the future development of single corporations. Since agricultural policies are often designed to target the sustainability problems on a national level, and may focus on agricultural holdings in the lowlands, the model might provide insights into the effects of federal policies on marginal regions and respective CPP use. Furthermore, running the model at the corporation level instead of at the regional level could reveal information about future developments of the single cooperation. This could help identify the corporations and their very specific characteristics, which account for vulnerability to understocking and land abandonment. Since two scenarios predict decrease in stocking density of about 500 units by 2040, such a decrease in stocking might concentrate in certain corporations and potentially leads to their collapse, rather than affect all corporations equally. Identifying the characteristics that make corporations more vulnerable or more robust to underuse could be an important step for adaptation in the local governance system. Potential actions might then include financial transfers between corporations, merging of corporations and the respective alpine enterprises, or a change in operational rules to ensure that livestock is allocated consistently between corporations in the case of serious understocking. In addition, simulations at the corporation level would add empirical evidence for identifying social-ecological links and feedbacks that increase the robustness or vulnerability of the SESs to particular external perturbations (Anderies et al., 2004; Janssen et al., 2007).

6 Conclusion

This work provides an example of an integrative analysis of common pool resource use from a social-ecological systems perspective. A system dynamics model has been developed to diagnose social-ecological interactions and outcomes for the use of common property pastures in the Swiss Alps. Using a combination of system dynamics modeling and formative scenario analysis, we simulated developments of the SES for several future external settings. However, the simulation results are not a precise forecast of future developments of the SES but a tool for assessing the SES characteristics and its capacity to deal with upcoming internal and external disturbances. Scenario simulation reveals that the sustainability of CPP is threatened by underuse rather than overuse and that the process of CPP abandonment is expected to continue. Furthermore, simulation results suggest that a panacea such as trade liberalization or an increase in government support will accelerate rather than counteract the problem. Since the different scenario settings changed the state of the SES and associated robustness and sustainability trade-offs, no single best policy setting was identified, but uncertainty in policy design is decreased. Accordingly, effective policies for counteracting CPP abandonment must target stocking density of CPP by changing the incentive structure for farmers' appropriation decisions. This can be achieved with federal and local governance measures. Promising options include subsidies for appropriation paid to farmers, marketing activities such as labels, and a further ease of the exclusion principle by the local governance system.

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PART THREE: APPENDIX

Glossary

Common Pool Resources (CPRs)	Common pool resources (CPRs) are jointly managed resources, for which individuals' appropriation diminishes the resource stock and potential beneficiaries of which are difficult to exclude (Berkes et al. 1989).
Common Property Pastures (CPPs)	Common property pastures (also called "Alp") is collectively managed and used for grazing animals typically located on the hillsides of valleys. Due to their location in higher altitude they are generally less productive than the private plots and only used during summer. The pastures are generally managed in by legal corporate bodies of collective ownership.
Social-ecological systems (SES)	According to Redman et al.2004, a Social-Ecological system are interlinked systems of people and nature, characterized by: 1. a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner; 2. a system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked; 3. a set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems; and 4. a perpetually dynamic, complex system with continuous adaptation.
Institutions	Humanly devised constraints that structure human interactions. They are made up of formal constraints (rules, laws, constitutions), informal constraints (norms of behavior, conventions and self-imposed codes of conduct), and their enforcement characteristics (North 1993)
System Dynamics (SD)	System Dynamics deals with interaction of various elements of a system in time and captures the dynamic aspect by incorporating concepts such as stock, flows, feedback and delays, and thereby provides an insight into the dynamic behavior of system over time (Tang and Vijay 2001)
Constitution of the local governance system ("Taleinungsbrief")	The "Taleinungsbrief" is a local constitution in which the seven corporations of Grindelwald write down their binding agreements about rules and process applied in the governance of their respective common property area. It was last amended in 2002.

Cooperative ("Taleinung")	The "Taleinung" of Grindelwald is a legal body and functions as an umbrella organization in the interest of the corporations, with legislative tasks on the local level.
Corporation ("Bergschaft")	The "Bergschaft" is an operational unit that organizes the agricultural use of their respective resource system.
Use right ("Kuhrecht")	Use rights (or usage rights) define the number of livestock units that a farmer is allowed to send to the CPP. Furthermore, use rights define membership in the specific corporation. The rights cannot be sold and are tied to private plots in the valley.

Supporting Material for Module 2

Survey

Umfrage zur Sömmerung in Grindelwald

Befragungsverlauf

Befragungstermin				**Besuchsdauer**		**Alternativtermin**
Tag		Monat	Jahr	Beginn	Ende	Datum: |_|_| |_|_| |2|0|1|1|
1	|_|_|	|_|_|	|2|0|1|1|	|_|_|:|_|_|	|_|_|:|_|_|	Zeit: |_|_|:|_|_|
2	|_|_|	|_|_|	|2|0|1|1|	|_|_|:|_|_|	|_|_|:|_|_|	Datum: |_|_| |_|_| |2|0|1|1|
3	|_|_|	|_|_|	|2|0|1|1|	|_|_|:|_|_|	|_|_|:|_|_|	Zeit: |_|_|:|_|_|
Interviewer		_____				
Protokollführer		_____				

Resultat der 1. Visite	**Resultat der 2. Visite**	**Resultat der 3. Visite**
Vollständig ☐ 1	Vollständig ☐ 1	Vollständig ☐ 1
Unvollständig ☐ 2	Unvollständig ☐ 2	Unvollständig ☐ 2
Nicht da ☐ 3	Nicht da ☐ 3	Nicht da ☐ 3
Keine Zeit ☐ 4	Keine Zeit ☐ 4	Keine Zeit ☐ 4
Anderer Termin ☐ 5	Anderer Termin ☐ 5	Anderer Termin ☐ 5

Name, Vorname (Betriebsleiter) _____	Geschlecht ☐ M ☐ W
Anschrift _____	
PID –Nummer |_|_|_|_|_|_|_|_|	

1. Betriebsidentifikation

101	Sind Sie persönlich der Betriebsleiter / die Betriebsleiterin	Ja ☐ 1 Nein ☐ 2
102	In welchem Jahr wurden Sie Betriebsleiter / Betriebsleiterin dieses Betriebes	|_|_|_|_|
103	In welchem Jahr sind Sie geboren?	19|_|_|
104	Sind sie verheiratet?	Ja ☐ 1 Nein ☐ 2
103	Bewirtschaftungsform ☐ Bio (Bio-Zertifizierung) ☐ IP-Suisse ☐ÖLN (ökologischer Leistungsnachweis)	
104	Sind sie Mitglied in einer Zuchtgenossenschaft/Verein? Ja ☐ 1 → **welcher** _____ Nein ☐ 2	
105	Haben Sie ihren rechtlichen Wohnsitz in der Gemeinde Grindelwald?	Ja ☐ 1 Nein ☐ 2
106	Sind Sie in Grindelwald aufgewachsen? (mehr als die Hälfte der Lebensjahre 0-16 in Grindelwald wohnhaft)	Ja ☐ 1 Nein ☐ 2
107	Zu welcher Bergschaft fühlen Sie sich am ehesten zugehörig? ☐ Keiner ☐Grindel ☐ Itramen ☐ Bach ☐Bussalp ☐Wärgistal ☐Scheidegg ☐ Holzmatten	
108	Haben Sie derzeit ein Amt inne in dieser Bergschaft? Ja ☐ **1 → welches** _____ Nein ☐ 2	

2. Haushaltsstruktur

201	Wie viele Personen gehören zum Haushalt, respektive wohnen unter obiger Anschrift?	|_|_|Personen → **davon Familienmitglieder?** |_|_|Personen
202	Wie viele davon (Sie eingeschlossen) sind?	Zu wie viel Prozent arbeiten diese auf dem Betrieb mit?
	a. Männer älter als 65 Jahre |_|_| →	|_|_|_|%
	b. Männer zwischen 40 und 64 Jahren |_|_| →	|_|_|_|%
	c. Männer zwischen 20 und 39 Jahren |_|_| →	|_|_|_|%
	d. Knaben und Männer jünger als 19 Jahre |_|_| →	|_|_|_|%
	e. Frauen älter als 65 Jahre |_|_| →	|_|_|_|%
	f. Frauen zwischen 40 und 64 Jahren |_|_| →	|_|_|_|%
	g. Frauen zwischen 20 und 39 Jahren |_|_| →	|_|_|_|%
	h. Mädchen und Frauen jünger als 19 Jahre |_|_| →	|_|_|_|%
203	Haben Sie in der Familie einen potentiellen Nachfolger für den Betrieb?	Ja ☐ 1 Wahrscheinlich Ja ☐ 2 Weiss nicht ☐ 3 Eher Nein ☐ 4 Nein ☐ 5

3. Erwerbssituation

301	Gehen Sie neben der Landwirtschaft noch einem weiteren Beruf nach und verdienen dabei mehr als 2300 Sfr. im Jahr? Nein ☐ 1 Ja, ganzjährlich ☐ 2→ **Zu wie vielen Stellenprozent?** |_|_|_|% Ja, im Winter ☐ 3→ **Zu wie vielen Stellenprozent?** |_|_|_|% Ja, im Sommer ☐ 4→ **Zu wie vielen Stellenprozent?** |_|_|_|%
302	Welches ist Ihre wichtigste außerlandwirtschaftliche Erwerbsquelle? _____
303	Verbringen Sie insgesamt mehr Zeit in der Landwirtschaft als in Ihren außerlandwirtschaftlichen Beruf(en)? Ja ☐ 1 Nein ☐ 2
304	Hat sich in den letzten 5 Jahren das außerlandwirtschaftliche Arbeitspensum des Betriebsleiters /der Betriebsleiterin verändert? ☐ 1 Nein, ist sich gleichgeblieben→**gehe zu 311** ☐ 2 Ja, zugenommen ☐ 3 Ja, reduziert ☐ 4 Aufgegeben
305	Was erachten Sie als die wichtigsten Gründe für die Veränderung des Nebenerwerbs? 1._____ 2._____ 3._____
306	Ist der wichtigste ausserlandwirtschaftliche Arbeitsplatz des/r Betriebsleiters/in Grindelwald? Ja ☐ 1 Nein ☐ 2→ **wo?**_____
307	Würden Sie Landwirt als ihre Berufsbezeichnung angeben? ☐ Ja ☐ Nein
308	Führen Sie den Betrieb zusammen mit einem /einer (Ehe-)Partner*In*? Ja ☐ 1 Nein ☐ 2 →**gehe zu 400**

Erwerbssituation (Ehe-) PartnerIn	
309	Geht der (Ehe) Partner einem außerlandwirtschaftlichen Beruf nach und verdient dabei mehr als 3000 Sfr.? (siehe oben) Nein ☐ 1 Ja, ganzjährlich ☐ 2→ **Zu wie vielen Stellenprozent?** |_|_|_|% Ja, im Winter ☐ 3→ **Zu wie vielen Stellenprozent?** |_|_|_|% Ja, im Sommer ☐ 4→ **Zu wie vielen Stellenprozent?** |_|_|_|%
310	Hat sich in den letzten 5 Jahren das außerlandwirtschaftliche Arbeitspensum des Ehepartners verändert? ☐ 1 Nein, ist sich gleichgeblieben ☐ 2 Ja, zugenommen ☐ 3 Ja, reduziert ☐ 4 Aufgegeben
311	Was erachten Sie als die wichtigsten Gründe dafür, dass sich das außerlandwirtschaftliche Arbeitspensum des/der (Ehe) Partner*In* verändert hat? 1._____ 2._____ 3._____
312	Ist der wichtigste außerlandwirtschaftliche Arbeitsplatz des/der (Ehe) Partner*In* in Grindelwald? Ja ☐ 1 Nein ☐ 2→ **wo?**_____
313	Worin besteht der wichtigste Nebenerwerb? (siehe oben) _____

4. Arbeitsbelastung

401	Wie viele Arbeitsstunden pro Tag wenden Sie durchschnittlich für die Landwirtschaft auf?	Sommer |_|_|Std./T Winter |_|_|Std./T
402	Wie viele zusätzliche Arbeitsstunden werden noch von anderen Familienmitgliedern und Helfern verrichtet?	Sommer |_|_|Std./T Winter |_|_|Std./T
403	Wie viele Tage pro Woche arbeiten Sie für den Betrieb?	Sommer |_|_| T/W Winter |_|_| T/W
404	Was würden Sie sagen, wie viele Stunden Arbeit im Sommer wären insgesamt nötig um die folgende Anzahl GVE zu bestelle?	
	1 GVE 5 GVE 10 GVE 15 GVE 20 GVE 25 GVE 30 GVE	→|_|_| Stunden/Tag →|_|_| Stunden/Tag →|_|_| Stunden/Tag →|_|_| Stunden/Tag →|_|_| Stunden/Tag →|_|_| Stunden/Tag →|_|_| Stunden/Tag

5. Viehbestand

501	Schafe	|_|_|→	|_|_|
502	Welche Rinderrassen halten Sie? ☐ Keine ☐ 1 Simmentaler ☐ 2 Red-Holstein ☐ 3 Holstein ☐ 4 Braunvieh ☐ 5 Jersey ☐6 andere _____		
503	Wie hat sich Ihr Viehbestand (in GVE) in den letzten 10 Jahren entwickelt? (respektive seitdem Sie den Betrieb übernommen haben, falls weniger als 10 Jahre Betriebsleiter)	☐ Verkleinert → -|_|_| GVE ☐ Ist sich etwa gleichgeblieben ☐ Vergrössert→ +|_|_| GVE	
504	Haben Sie in der Vergangenheit eine Umstellung in der Betriebsstrategie vorgenommen? (z.B. Milch- auf Mutterkuh / Rindvieh auf Schafhaltung) ☐ Nein ☐ Ja → **welche (von was auf was)?** _____ _____ _____		
505	Planen Sie für die Zukunft eine Umstellung in der Betriebsstrategie vorzunehmen (z.B. Milch- auf Mutterkuh / Rindvieh auf Schafhaltung/ Bio/ Betriebsgemeinschaft)? ☐ Nein ☐ Ja → **welche (von was auf was)?** _____ _____ _____		

506	Wie planen Sie die Entwicklung ihres Viehbestandes, prozentual in GVE, für die nächsten 10 Jahre?	☐ Verkleinern→ -|_|_| GVE ☐ Konstant halten ☐ Vergrössern → +|_|_| GVE
507	Was sind der Reihe nach die wichtigsten Faktoren, an die Sie Ihren Viehbestand anpassen? 1. _____ 2. _____ 3. _____	
508	Was ist die der maximal Viehbestand (in GVE), der für Sie derzeit zu bewältigen ist?	|_|_| GVE

Motive für Viehbestand

	Bitte bewerten Sie folgende Aussagen	**Trifft zu**	**Trifft eher zu**	**Weder noch**	**Trifft eher nicht zu**	**Trifft nicht zu**
521	Für mich sind die Ausrichtungen der Direktzahlungen zentral bei der Bestimmung der Viehbestand.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
522	Mit der Stallleistung (durchschnittliche Milchleistung pro Stallplatz) steigt auch die Anerkennung unter den Bauern.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
523	Ohne Rindviehhaltung hätte ich keine Freude an der Landwirtschaft.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
524	Je mehr Kühe ein Bauer besitzt, desto mehr Gewicht hat sein Wort in der Bergschaft.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
525	Für mich ist die Rentabilität des Betriebs zentral bei der Bestimmung der Viehbestand.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
526	Für mich ist die Stallkapazität entscheidend für die Bestimmung des Viehbestandes.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
527	Für mich ist die Arbeitsbelastung entscheidend für die Bestimmung der Viehbestand.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
528	Für mich sind die verfügbaren Arbeitskräfte entscheidend für die Bestimmung der Viehbestand.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
529	Mir gibt die Nutzfläche des Betriebes den Viehbestand vor.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
530	Ich passe meinen Viehbestand dem erzielten Preis für Alpkäse an.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
531	Ich passe meinen Viehbestand dem Milchpreis an	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
532	Ich passe meinen Viehbestand der Höhe der Tierbeiträge an	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

6. Flächenverfügbarkeit

				Aktuell	Vor 10 Jahren (resp. seit Betriebsübernahme)	In 10 Jahren
601	Wie viel Landwirtschaftliche Nutzflächen gehören zum Hof? (Pacht und Besitz)			___ ha	___ ha	___ ha
602	Davon **Pachtland**			___ ha	___ ha	___ ha
603	Davon aus **Familienbesitz** übernommen (Erbschaft/Auszahlung)			___ ha	___ ha	___ ha
604	Wie viel ha **zugekauftes Land** besitzen Sie aktuell (nicht aus Familienbesitz)			___ ha	___ ha	___ ha
Hatten folgende Aspekte einen Einfluss auf die Flächenentwicklung?		**Trifft zu**	**Trifft eher zu**	**Weder noch**	**Trifft eher nicht zu**	**Trifft nicht zu**
605	Berufliche Veränderungen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
606	Entwicklung der Direktzahlungen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
607	Entwicklung der Preise für Pachtland	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
608	Familiäre Situation	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
609	Körperliche Verfassung	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
610	Verfügbare unbezahlte Arbeitskräfte	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
611	Verfügbare finanzielle Mittel	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
612	Arbeitsbelastung	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
613	Verfügbarkeit von Pachtland	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
614	Verfügbarkeit von Land zum Kauf	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
615	Entwicklung der Marktpreise (Milch, etc.)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
616	Angenommen ein Teil der landwirtschaftlichen Nutzfläche in ihrem Besitz wird Bauzone, tendieren Sie dazu, diese Flächen zu verkaufen?	**ja** ☐ 1	**Eher ja** ☐ 2	**Weiß nicht** ☐ 3	**Eher Nein** ☐ 4	**Nein** ☐ 5
617	Wie viele Parzellen besitzen Sie, die nicht aneinander angrenzen?			___→	vor 10 Jahren ___	
618	Wie viele Parzellen grenzen nicht direkt an den Betrieb?			___→	vor 10 Jahren ___	

7. Motivation Landwirtschaft

701	Welches sind die drei wichtigsten Gründe, weshalb Sie Landwirt wurden? (Gewichtung) 1. _____ 2. _____ 3. _____	Bitte rangieren Sie die Gründe ☐ ☐ ☐
702	Haben sie schon einmal über den Ausstieg aus der Landwirtschaft nachgedacht?	Nein, niemals ☐ 1 →**Überspringe703** Kam auch schon vor ☐ 2 Manchmal ☐ 3 Immer häufiger ☐ 4 Ist beschlossene Sache ☐ 5
703	Welches sind die vier wichtigsten Gründe weshalb Sie über einen Ausstieg nachgedacht haben? 1. _____ 2. _____ 3. _____ 4. _____	Bitte rangieren Sie die Gründe ☐ ☐ ☐ ☐

	Nicht ökonomische Motive Landwirtschaft	Trifft zu	Trifft eher zu	Weder noch	Trifft eher nicht zu	Trifft nicht zu
704	Die Haltung von Kleinvieh (Schafen/Ziegen) wäre eine gute Alternative zur Haltung von Milchkühen.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
705	Die Haltung von Mutterkühen wäre eine gute Alternative zur Haltung von Milchkühen.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
706	Mit dem Erfolg auf Schauen steigt die Anerkennung unter den Landwirt	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
707	Für mich ist die Freude an der Kuh der wichtigste Grund um Landwirt zu sein/ zu bleiben	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
708	Durch den Tourismus finden wir einfach Arbeit und können so mit der auf Milchproduktion auf Viehwirtschaft weiter fahren	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
709	Die Nachfrage nach Bauland aus dem Tourismussektor führt zum Untergang der Landwirtschaft in Grindelwald	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
710	Mit dem Erfolg auf Schauen steigt die Anerkennung unter den Bauern	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
711	Als Landwirt wird man in der Gemeinde Grindelwald geschätzt und genießt ein hohes Ansehen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
712	Die Viehwirtschaft gehört schon immer zum Leben im Berggebiet, deshalb möchte ich die Tradition weiterführen.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
713	Ich bin mit der Landwirtschaft im Berggebiet aufgewachsen, für mich kam deshalb nie etwas anderes in Frage	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
714	Ich fühle mich voll und ganz als Landwirt	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

8. Sömmerungsentscheid

Viehbestand		**[Anzahl GVE]**	**Wie viele davon wurden letztes Jahr gesömmert? [Anzahl GVE]**
801	Wie viele Tiere (in GVE) besitzen Sie insgesamt	|_|_|	|_|_|

	In welcher Bergschaft besitzen Sie Bergrechte und wie viel Kuhrechte haben Sie?	Anzahl Kuhrechte			Mit wie vielen Tieren haben sie letztes Jahr Bergschaft besetzt?				
		Kuhr.	**Fuss**	**Klauen**	**Kühe**	**Rinder**	**Kälber**	**Schafe**	**Ziegen**
802	**Scheidegg** ☐ **1→**	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐
803	**Grindel** ☐ **2→**	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐
804	**Wärgistal** ☐ **3→**	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐
805	**Holzmatten** ☐ **4→**	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐
806	**Itramen** ☐ **5→**	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐
807	**Bussalp** ☐ **6→**	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐
808	**Bach** ☐ **7→**	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐	☐☐

809 Sömmern sie grundsätzlich Ihren ganzen Viehbestand in Grindelwald?

☐ Ja → **Überspringe 809**

☐ Nein → **Wie viele GVE haben sie nicht in Grindelwald gesömmert?** |_|_|GVE

810 Welches sind die drei wichtigsten Gründe weshalb Sie nicht ihren ganzen Viehbestand in Grindelwald gesömmert haben?

1 _____

2 _____

3 _____

811 Haben Sie jemals die Bergschaft gewechselt?

Ja ☐ 1

Nein ☐ 2 →**Überspringe811**

812	Was waren die drei wichtigsten Gründe für den Wechsel (rangieren)? 1. _____ 2. _____ 3. _____	Bitte rangieren Sie die Gründe ☐ ☐ ☐
813	Können Sie sich vorstellen, die Bergschaft jemals zu wechseln?	Ja ☐ 1 Eher Ja ☐ 2 Eher Nein ☐ 3→**Überspringe 813** Nein ☐ 4→**Überspringe 813**
814	Welches sind die drei wichtigsten Gründe weshalb Sie über einen Wechsel der Bergschaft nachgedacht haben? 1. _____ _____ 2. _____ _____ 3. _____	Bitte rangieren Sie die Gründe ☐ ☐ ☐
815	Angenommen Sie müssten/sich eine Bergschaftaussuchen in der Sie ihr Vieh sömmern, welche der 7 Bergschaften würden Sie der Reihe nach bevorzugen? Scheidegg ☐ Grindel ☐ Wärgistal ☐ Holzmatten ☐ Itramen ☐ Bussalp ☐ Bach ☐	

Welche Einfluss haben folgende Faktoren darauf, dass sie diese Bergschaft bevorzugen würden?		Sehr großen Einfluss	Großen Einfluss	Mässiger Einfluss	Geringer Einfluss	Kein Einfluss
815	Weidequalität	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
816	Leistung Alppersonal	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
817	Produktequalität (Verkäsung)	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
818	Erreichbarkeit	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
819	Nähe zum Betrieb	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
820	Kosten der Sömmerung	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
821	Sozialer Zusammenhalt innerhalb der Bergschaft	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
822	Qualität der Infrastruktur	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
823	Weniger Tagwann zu leisten und tiefere Bussen zu bezahlen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
824	Persönliche Kontakte zum Senntum	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
825	Art des gesömmerten Vieh passt besser in andere Bergschaft	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
826	Das Bergschaftsbudget und Einkommen aus dem Tourismus	☐ 1	☐ 1	☐ 3	☐ 4	☐ 5
827	Die Bergschaft ist nicht ausgelastet und freut sich über mein Vieh	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
830	Falls es hin und wieder Meinungsverschiedenheiten innerhalb der Besetzerschaft gibt, was sind die wichtigsten Streitpunkte? 1. _____ 2. _____ 3. _____					
831	Falls es hin und wieder Meinungsverschiedenheiten innerhalb der Bergschaft gibt, was sind die dreiwichtigsten Streitpunkte? 1. _____ 2. _____ 3. _____					

9. Gemeinwerk

901	Wie viele Tagwannstunden leisten sie normalerweise?	☐ 1	Viel mehr als ich eigentlich müsste→ Überspringe 904 und 905
		☐ 2	Eher mehr als ich müsste→ Überspringe 904 und 905
		☐ 3	Genau so viel wie ich muss→ Überspringe 904und 905
		☐ 4	Eher weniger als ich muss →**gehe zu 904**
		☐ 5	Viel weniger als muss→**gehe zu904**

902	Weshalb leisten Sie mehr oder zumindest die geforderten Tagwannstunden?	**Sehr großen Einfluss**	**Großen Einfluss**	**Mäßiger Einfluss**	**Geringer Einfluss**	**Keinen Einfluss**
A	Ich habe ausreichend Zeit.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
B	Es ist ein willkommener Nebenverdienst.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
C	Der Gruppenzusammenhalt ist gut. Zudem macht es Freude und verbindet.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
D	Wir sind darauf angewiesen, dass der Futterertrag der Alpweiden hoch ist.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
E	Weil es besondere Ereignisse fast immer erfordern.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
F	Einer muss es ja machen.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
G	Weil es mir wichtig ist, dass wir die Alpen weiterhin in ordentlichem Zustand halten, damit sie auch schön anzusehen sind.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
H	Weil es gern gesehen ist innerhalb der Besetzerschaft.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I	Weil für mich die Alp wie eine Verlängerung des Betriebes ist.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
J	Wenn die anderen mitmachen, sollte ich auch mitmachen.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
K	Ich kann meine privaten Maschinen einbringen, dadurch kann ich viele Stunden schreiben.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
L	Weil ich keine Busse bezahlen möchte.	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
M	Wenn die anderen sehen, dass ich mitmache werden Sie auch eher mitmachen	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

903	Wie tief müsste die Busse für nicht verrichtete Tagwannstunden sein, damit sie diese bezahlen und nicht würden?		☐ Ich würde die Tagwann auch verrichten wenn es keine Bussen gäbe. |_|_| CHF/Stunde			
904	Weshalb leisten Sie weniger Tagwannstunden als vorgeschrieben?	**Sehr großen Einfluss**	**Großen Einfluss**	**Mäßiger Einfluss**	**Geringer Einfluss**	**Keinen Einfluss**
A	Ich habe im Frühjahr und Sommer keine Zeit	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
B	Ich arbeite etwas anders während dieser Zeit	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
C	Für mich ist die Alpwirtschaft nicht so wichtig	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
D	Der Gruppenzusammenhalt in der Besetzerschaft ist eher schwach	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
E	Weil oft spezielle Ereignisse dies verhindern	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
F	Die Busse ist so gering	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
G	Dass sollen die machen, die viele Kühe haben	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
H	Es gibt immer mehr Leute, die ab und zu fehlen, also mache ich das auch	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
I	Für die zu leistende Arbeit braucht es nicht so viele Leute	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
905	Wie hoch müsste die Busse sein, damit Sie alle Tagwannstunden erledigen würden?			|_|_| CHF/Stunde		
906	Leisten Sie heute eher mehr oder weniger der verlangten Tagwannstunden im Vergleich zu früher? ☐ 1 Ich leistete früher klar mehr Tagwannstunden ☐ 2 Ich leistete früher eher mehr Tagwannstunden ☐ 3 Ist sich in etwa gleichbleibend ☐ 4 Ich habe früher eher weniger Tagwannstunden geleistet ☐ 5 Ich habe früher deutlich weniger Tagwannstunden geleistet					
907	Stört es Sie wenn jemand regelmäßig keine oder weniger Tagwann verrichtet als er eigentlich sollte und stattdessen bezahlt? ☐ 1 Nein, das ist jedem selbst überlassen ☐ 2Ja, das stört mich ein wenig ☐ 3 Ja, das stört mich sogar ziemlich					

10. Entwicklung der Bergschaft

1001	Was glauben Sie, wird es in den folgenden 10 Jahren in der Bergschaft zu der Sie gehören, resp. In der Sie am meisten Vieh sömmern zu Betriebsaufgaben kommen?	☐ Ja → **wie viele?** Ca. |_|_| ☐ Nein ☐ Weiss nicht
1002	Was glauben Sie, wie wird sich die Bestossung in der Bergschaft zu der Sie gehören, resp. In der Sie am meisten Vieh sömmern, verändern?	☐ Zunehmen→ **wie viel %?** +|_|_|% NST ☐ Abnehmen→ **wie viel %?** - |_|_|% NST ☐ Weiß nicht
1003	Sind sie dafür, dass fremdes Vieh auf Grindelwalds Alpen gesömmert wird?	☐ Nein ☐ Ja, die Möglichkeit sollte uneingeschränkt bestehen ☐ Ja, aber nur wenn das Vieh im Tal knapp ist ☐ Ja, aber nur Schafe und Ziegen ☐ Nur wenn Naturereignisse es erfordern
1004	Was glauben Sie, machen Besetzer aus dem Unterland auch bei der Tagwann mit?	☐ Nein, sicher nicht ☐ Nein, eher nicht ☐ Ja, soviel sie müssen ☐ Ja, die kommen sogar gerne
1005	Was glauben Sie, sind die Kühe aus dem Unterland genauso geeignet für die Sömmerung in Grindelwald wie einheimisches Vieh? ☐ Ja ☐ Nein → **weshalb?** ☐ Zu schwer ☐ Verlassen den Läger kaum ☐ sind nicht genug mobil ☐ weitere Gründe_____ _____	
1006	Haben Sie innerhalb der Bergschaft Mühe, Leute zu finden die gewisse Ämter und Positionen ausfüllen wollen?	☐ Ja, es wird immer schwieriger Leute zu finden ☐ Nein, das ist kein Problem
1007	Was glauben Sie was wäre die optimale Größe (Anzahl Leute) für die (Ihre) Besetzerschaft?	|_|_| Personen
1008	Was glauben Sie wäre die optimale Anzahl zu verrichtender Tagwannstunden pro Normalstoss?	|_|_|Std./NST

11. Produktion/Einkommen

1101	Wie viel Kilogramm Käse hat die Sömmerung Ihrer Tiere letztes Jahr ergeben?	Alpkäse |_|_|_|_| kg Schafkäse |_|_|_|_| kg Ziegenkäse |_|_|_|_| kg	
1102	Falls Sie Alpkäse verkaufen, wer sind ihre wichtigsten Abnehmer? (mehrere Antworten möglich)	**Kilopreis**	**Abgesetzte Menge**
	☐ Tages- und Wochentouristen	|_|_|.|_|_| CHF	|_|_|_|_| kg
	☐ Chaletbesitzer	|_|_|.|_|_| CHF	|_|_|_|_| kg
	☐ Hotellerie	|_|_|.|_|_| CHF	|_|_|_|_| kg
	☐ Dorfladen	|_|_|.|_|_| CHF	|_|_|_|_| kg
	☐ Grossabnehmer (z.B. Emmi, Migros, Coop (?))	|_|_|.|_|_| CHF	|_|_|_|_| kg
	☐ Bekannte in Grindelwald	|_|_|.|_|_| CHF	|_|_|_|_| kg
	☐ Bekannte ausserhalb von Grindelwald	|_|_|.|_|_| CHF	|_|_|_|_| kg
1103	Wie viele Tonnen Milch haben Sie letztes Jahr ungefähr produziert?	|_|_|_|_|_|_| Tonnen	
1104	Welchen Preis haben Sie letztes Jahr im Durchschnitt für einen Liter Milch erhalten?	|0|0|.|_|_| CHF/kg	
1105	Wenn Sie Ihr Bruttohaushaltseinkommen betrachten, wie viel Prozent entfällt auf landwirtschaftliche Tätigkeit?	|_|_|%	
1106	Wenn Sie Ihr Einkommen aus der landwirtschaftlichen Tätigkeit betrachten, wie viel Prozent entfällt auf Verkauf von Alpkäse |_|_|% Verkauf von Verkehrsmilch |_|_|% Direktzahlungen |_|_|% Andere landwirtschaftliche Tätigkeiten |_|_|%→**welche?** etc. _____		
1107	Wie viel Prozent des gesamten Futterbedarfs deckt die eigene Produktion von Heu und Silage in einem durchschnittlichen Jahr?	|_|_|%	

12. Fragen zur Person

1203	Was ist ihre höchste abgeschlossene Ausbildungsstufe?	☐ Keine abgeschlossene Ausbildung ☐ Obligatorische Schulzeit ☐ Berufslehre →**welche?** _____ ☐ Maturitätsschule ☐ Lehrerseminar ☐ Höhere Fach- und Berufsausbildung ☐ Höhere Fachschule ☐ Fachhochschule HTL ☐ Universität, ETH ☐ Keine Angabe
1204	Haben Sie jemals eine Zweitausbildung absolviert?	Nein ☐ 1 Ja ☐ 2 →**welche?** _____
1205	Was ist die höchste abgeschlossene Ausbildungsstufe ihres/ihrer Ehe (Partner)?	☐ Keine abgeschlossene Ausbildung ☐ Obligatorische Schulzeit ☐ Berufslehre →**welche?** _____ ☐ Maturitätsschule ☐ Lehrerseminar ☐ Höhere Fach- und Berufsausbildung ☐ Höhere Fachschule ☐ Fachhochschule HTL ☐ Universität, ETH ☐ Keine Angabe
1206	Hat ihr (Ehe-) Partner jemals eine Zweitausbildung absolviert?	Nein ☐ 1 Ja ☐ 2 →**welche**_____
1207	Wie hoch ist ihr aktuelles Bruttohaushaltseinkommen? (Das Einkommen von allen Personen die in Ihrem Haushalt wohnen, vor den Sozialabgaben wie AHV und IV.)	CHF I_I_I_I_I_I_I→**keine Angabe evtl. Angabe in Kategorien** ☐ Weniger als 50‘000 CHF ☐ 50-99‘999 CHF ☐ 100‘000-149‘000 CHF ☐ Mehr als 150‘000 CHF
1300	Möchten Sie Informationen über die Resultate der Umfrage in Form eines Berichtes?	☐ Ja ☐ Nein

- **DANK AUSSPRECHEN**

Q-Method Protocol

				21				
			31	25	28			
		34	1	18	7	19		
	9	5	8	27	32	23	13	
20	12	10	26	2	17	30	11	14
33	22	15	6	24	4	29	3	16
Negativer Einfluss				Eher kein Einfluss				Positiver Einfluss
Name….....								

Q-SORT: Example of a completed impact matrix

Q-STATEMENTS to be placed in the matrix

Nummer	Statements
1	Flächenbeiträge sind besonders wichtig für ein vitale Landwirtschaft im Berggebiet
2	RGVE-Beiträge sind besonders wichtig für ein vitale Landwirtschaft im Berggebiet
3	Sömmerungsbeiträge sind besonders wichtig für die Alpwirtschaft
4	Absatzmöglichkeiten über Tourismus erhöhen die attraktivität der Alpwirtschaft
5	Milchpreis ist besonders wichtig für die
6	Abhängigkeit von Direktzahlungen ist schlecht für die Landwirtschaft
7	ÖLN ist wichtig für die vitale Landwirtschaft
8	Erwerbsmöglichkeiten im Tourismus
9	Zahlungen von Bergbahnen an Bergschaften
10	Vorschriften im Rahmen der Sömmerungsbeiträge
11	Anzahl Landwirte
12	Flächenverfügbareit
13	Weidequalität
14	Anteil Grindelwaldner unter den Landwirten
15	Wirtschaftliche Eigeninitiative der Landwirte
16	Führung der Bergschaften
17	Zusammenhalt unter den Landwirten
18	Gemeinsame Werte
19	Wertschöpfung Alpkäse
20	Abhängigkeit vom landwirtschaftlichen Einkommen
21	Fremdes Vieh auf Grindelwalds Alpen
22	Know-how Alppersonal
23	Solidarität zwischen den Kooperativen
24	Die Landwirtschaft hat politisches Gewicht
25	Schlichtung von Konflikten
26	Grösse der Bergschaften
27	Flexibilität der Kuhrechte
28	Die zu verrichtendeTagwann ist angemessen
29	Die Taleinung
30	Die Seyung ist der verfügbaren Futtermenge angepasst
31	Bindung der Kuhrechte an Privatbesitz
32	Öffnung der Alp für fremdes Vieh
33	Investitionen in die Infrastruktur auf den Alpen
34	Bereitschaft Tagwann zu leisten

Q-ANALYZES Protocol

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Correlation Matrix Between Sorts

SORTS	1	2	3	4	5	6	7	8	9	10	11
1 Kaufmann	100	12	9	-19	17	21	-6	-19	-54	-1	14
2 Nebiker	12	100	23	20	56	5	-16	20	-39	47	21
3 Aeschlim	9	23	100	9	4	42	36	9	1	24	31
4 Gertsch	-19	20	9	100	21	28	10	100	-9	9	1
5 Roth	17	56	4	21	100	-5	-5	21	-22	39	11
6 Wahli	21	5	42	28	-5	100	47	28	-31	16	21
7 Schluneg	-6	-16	36	10	-5	47	100	10	18	17	29
8 Egger	-19	20	9	100	21	28	10	100	-9	9	1
9 Michel	-54	-39	1	-9	-22	-31	18	-9	100	-16	-9
10 Steuri D	-1	47	24	9	39	16	17	9	-16	100	39
11 Steuri A	14	21	31	1	11	21	29	1	-9	39	100

Unrotated Factor Matrix

	Factors 1	2	3	4	5	6	7	8
SORTS								
1 Kaufmann	0.2033	-0.6442	0.1136	-0.5438	-0.0404	0.1406	0.3139	0.2660
2 Nebiker	0.6403	-0.3787	-0.3549	0.2641	0.2373	-0.1503	-0.0668	-0.2835
3 Aeschlim	0.4962	0.0355	0.5242	0.0886	0.5686	-0.2601	0.1974	0.1164
4 Gertsch	0.6003	0.6523	-0.3943	-0.1737	-0.0829	-0.0532	0.0992	0.0807
5 Roth	0.5298	-0.3030	-0.4157	0.3013	0.0867	0.4811	0.2374	-0.0589
6 Wahli	0.5671	0.1602	0.4698	-0.4615	0.0646	0.0687	-0.2705	-0.1031
7 Schluneg	0.3107	0.3306	0.6933	0.0721	-0.0794	0.4445	-0.0128	-0.1440
8 Egger	0.6003	0.6523	-0.3943	-0.1737	-0.0829	-0.0532	0.0992	0.0807
9 Michel	-0.4431	0.5171	0.1992	0.5529	0.1152	0.0896	0.2353	0.1233
10 Steuri D	0.6037	-0.2376	0.0713	0.5039	-0.1502	0.0212	-0.4034	0.3657
11 Steuri A	0.4642	-0.1891	0.4330	0.2726	-0.5223	-0.3110	0.3046	-0.1270
Eigenvalues	2.8933	1.9972	1.8313	1.3766	0.7217	0.6546	0.6022	0.3776
% expl.Var.	26	18	17	13	7	6	5	3

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Cumulative Communalities Matrix

	Factors 1 Thru							
SORTS	1	2	3	4	5	6	7	8
1 Kaufmann	0.0413	0.4564	0.4693	0.7650	0.7666	0.7864	0.8849	0.9557
2 Nebiker	0.4100	0.5534	0.6794	0.7492	0.8055	0.8280	0.8325	0.9129
3 Aeschlim	0.2462	0.2475	0.5223	0.5302	0.8535	0.9212	0.9601	0.9737
4 Gertsch	0.3603	0.7859	0.9413	0.9715	0.9784	0.9812	0.9911	0.9976
5 Roth	0.2806	0.3724	0.5453	0.6360	0.6436	0.8750	0.9313	0.9348
6 Wahli	0.3216	0.3473	0.5680	0.7810	0.7852	0.7899	0.8631	0.8737
7 Schluneg	0.0965	0.2058	0.6865	0.6917	0.6980	0.8956	0.8958	0.9165
8 Egger	0.3603	0.7859	0.9413	0.9715	0.9784	0.9812	0.9911	0.9976
9 Michel	0.1964	0.4637	0.5034	0.8091	0.8224	0.8304	0.8858	0.9010
10 Steuri D	0.3645	0.4209	0.4260	0.6799	0.7025	0.7029	0.8656	0.9994
11 Steuri A	0.2155	0.2512	0.4387	0.5131	0.7859	0.8826	0.9754	0.9915
cum% expl.Var.	26	44	61	74	80	86	92	95

Factor Matrix with an X Indicating a Defining Sort

	Loadings	
QSORT	1	2
1 Kaufmann	0.5745X	-0.3554
2 Nebiker	0.7323X	0.1310
3 Aeschlim	0.3528X	0.3508
4 Gertsch	0.0290	0.8860X
5 Roth	0.5991X	0.1162
6 Wahli	0.3251	0.4915X
7 Schluneg	0.0196	0.4532X
8 Egger	0.0290	0.8860X
9 Michel	-0.6732X	0.1025
10 Steuri D	0.6125X	0.2140
11 Steuri A	0.4751X	0.1597

```
 % expl.Var.          23        22
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Free Distribution Data Results

 QSORT            MEAN     ST.DEV.

  1 Kaufmann      0.000     2.202
  2 Nebiker       0.000     2.202
  3 Aeschlim      0.000     2.202
  4 Gertsch       0.000     2.202
  5 Roth          0.000     2.202
  6 Wahli         0.000     2.202
  7 Schluneg      0.000     2.202
  8 Egger         0.000     2.202
  9 Michel        0.000     2.202
 10 Steuri D      0.000     2.202
 11 Steuri A      0.000     2.202

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     Correlations Between Factor Scores

               1       2

    1     1.0000  0.1551

    2     0.1551  1.0000
```

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Factor Scores with Corresponding Ranks

No.	Statement	No.	Factors 1		2	
1	1 Flächenbeitäge sind besonders wichtig für ein vitale	1	0.24	15	1.42	3
2	2 RGVE-Beiträge sind besonders wichtig für ein vitale	2	0.56	7	-1.10	29
3	3 Sömmerungsbeiträge sind besonders wichtig für die Al	3	1.83	3	-0.91	27
4	4 Absatzmöglichkeiten über Tourismus erhöhen die attra	4	1.98	2	0.91	7
5	5 Milchpreis ist besonders wichtig für die	5	-1.89	34	-1.25	30
6	6 Abhängigkeit von Direktzahlungen ist schlecht für di	6	-1.84	33	-0.22	20
7	7 ÖLN ist wichtig für die vitale Landwirtschaft	7	0.07	18	-1.78	33
8	8 Erwerbsmöglichkeiten im Tourismus	8	1.58	4	0.84	8
9	9 Zahlungen von Bergbahnen an Bergschaften	9	0.50	8	0.72	9
10	10 Vorschriften im Rahmen der Sömmerungsbeiträge	10	-1.09	30	0.40	14
11	11 Anzahl Landwirte	11	-0.12	19	-1.88	34
12	12 Flächenverfügbareit	12	-0.37	24	-1.07	28
13	13 Weidequalität	13	0.23	17	0.49	12
14	14 Anteil Grindelwaldner unter den Landwirten	14	0.35	11	-0.44	23
15	15 Wirtschaftliche Eigeninitiative der Landwirte	15	0.33	13	0.10	16
16	16 Führung der Bergschaften	16	0.87	5	0.16	15
17	17 Zusammenhalt unter den Landwirten	17	-0.49	25	-1.41	32
18	18 Gemeinsame Werte	18	-0.98	29	0.09	17
19	19 Wertschöpfung beim Alpkäse ist hoch	19	2.11	1	-0.03	19
20	20 Abhängigkeit vom landwirtschaftlichen Einkommen	20	-1.48	31	1.69	2
21	21 Kein Fremdes Vieh auf Grindelwalds Alpen	21	-0.87	28	-0.64	25
22	22 Know-how Alppersonal	22	-1.50	32	-0.31	21
23	23 Solidarität zwischen den Kooperativen	23	0.77	6	1.34	4
24	24 Die Landwirtschaft hat politisches Gewicht	24	-0.31	22	-0.61	24
25	25 Schlichtung von Konflikten	25	-0.77	27	1.25	5
26	26 Grösse der Bergschaften	26	-0.33	23	-0.31	22
27	27 Flexibilität der Kuhrechte	27	-0.53	26	0.47	13
28	28 Die zu verrichtendeTagwann ist angemessen	28	0.41	10	0.56	11
29	29 Die Taleinung	29	0.42	9	1.86	1
30	30 Die Seyung ist der verfügbaren Futtermenge angepass	30	0.26	14	0.07	18
31	31 Bindung der Kuhrechte an Privatbesitz	31	-0.25	20	-1.35	31
32	32 Die Öffnung der Alp für fremdes Vieh	32	0.24	16	-0.65	26
33	33 Investitionen in die Infrastruktur auf den Alpen	33	0.34	12	1.01	6
34	34 Bereitschaft Tagwann zu leisten	34	-0.26	21	0.59	10

Factor Scores -- For Factor 1

No.	Statement		No.	Z-SCORES
19	19	Wertschöpfung beim Alpkäse ist hoch	19	2.113
4	4	Absatzmöglichkeiten über Tourismus erhöhen die attraktivit	4	1.978
3	3	Sömmerungsbeiträge sind besonders wichtig für die Alpwirts	3	1.828
8	8	Erwerbsmöglichkeiten im Tourismus	8	1.579
16	16	Führung der Bergschaften	16	0.869
23	23	Solidarität zwischen den Kooperativen	23	0.768
2	2	RGVE-Beiträge sind besonders wichtig für ein vitale Landwi	2	0.562
9	9	Zahlungen von Bergbahnen an Bergschaften	9	0.504
29	29	Die Taleinung	29	0.423
28	28	Die zu verrichtendeTagwann ist angemessen	28	0.406
14	14	Anteil Grindelwaldner unter den Landwirten	14	0.354
33	33	Investitionen in die Infrastruktur auf den Alpen	33	0.344
15	15	Wirtschaftliche Eigeninitiative der Landwirte	15	0.328
30	30	Die Seyung ist der verfügbaren Futtermenge angepasst	30	0.256
1	1	Flächenbeitäge sind besonders wichtig für ein vitale Land	1	0.240
32	32	Die Öffnung der Alp für fremdes Vieh	32	0.235
13	13	Weidequalität	13	0.233
7	7	ÖLN ist wichtig für die vitale Landwirtschaft	7	0.065
11	11	Anzahl Landwirte	11	-0.116
31	31	Bindung der Kuhrechte an Privatbesitz	31	-0.252
34	34	Bereitschaft Tagwann zu leisten	34	-0.260
24	24	Die Landwirtschaft hat politisches Gewicht	24	-0.310
26	26	Grösse der Bergschaften	26	-0.327
12	12	Flächenverfügbareit	12	-0.373
17	17	Zusammenhalt unter den Landwirten	17	-0.488
27	27	Flexibilität der Kuhrechte	27	-0.525
25	25	Schlichtung von Konflikten	25	-0.771
21	21	Kein Fremdes Vieh auf Grindelwalds Alpen	21	-0.871
18	18	Gemeinsame Werte	18	-0.983
10	10	Vorschriften im Rahmen der Sömmerungsbeiträge	10	-1.089
20	20	Abhängigkeit vom landwirtschaftlichen Einkommen	20	-1.481
22	22	Know-how Alppersonal	22	-1.504
6	6	Abhängigkeit von Direktzahlungen ist schlecht für die Land	6	-1.841
5	5	Milchpreis ist besonders wichtig für die	5	-1.895

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Factor Scores -- For Factor 2

No.	Statement		No.	Z-SCORES
29	29	Die Taleinung	29	1.856
20	20	Abhängigkeit vom landwirtschaftlichen Einkommen	20	1.688
1	1	Flächenbeitäge sind besonders wichtig für ein vitale Land	1	1.422
23	23	Solidarität zwischen den Kooperativen	23	1.345
25	25	Schlichtung von Konflikten	25	1.250
33	33	Investitionen in die Infrastruktur auf den Alpen	33	1.006
4	4	Absatzmöglichkeiten über Tourismus erhöhen die attraktivit	4	0.907
8	8	Erwerbsmöglichkeiten im Tourismus	8	0.842
9	9	Zahlungen von Bergbahnen an Bergschaften	9	0.717
34	34	Bereitschaft Tagwann zu leisten	34	0.594
28	28	Die zu verrichtendeTagwann ist angemessen	28	0.564
13	13	Weidequalität	13	0.485
27	27	Flexibilität der Kuhrechte	27	0.469
10	10	Vorschriften im Rahmen der Sömmerungsbeiträge	10	0.400
16	16	Führung der Bergschaften	16	0.164
15	15	Wirtschaftliche Eigeninitiative der Landwirte	15	0.099
18	18	Gemeinsame Werte	18	0.091
30	30	Die Seyung ist der verfügbaren Futtermenge angepasst	30	0.069
19	19	Wertschöpfung beim Alpkäse ist hoch	19	-0.026
6	6	Abhängigkeit von Direktzahlungen ist schlecht für die Land	6	-0.225
22	22	Know-how Alppersonal	22	-0.309
26	26	Grösse der Bergschaften	26	-0.313
14	14	Anteil Grindelwaldner unter den Landwirten	14	-0.438
24	24	Die Landwirtschaft hat politisches Gewicht	24	-0.606
21	21	Kein Fremdes Vieh auf Grindelwalds Alpen	21	-0.637
32	32	Die Öffnung der Alp für fremdes Vieh	32	-0.652
3	3	Sömmerungsbeiträge sind besonders wichtig für die Alpwirts	3	-0.911
12	12	Flächenverfügbareit	12	-1.071
2	2	RGVE-Beiträge sind besonders wichtig für ein vitale Landwi	2	-1.101
5	5	Milchpreis ist besonders wichtig für die	5	-1.254
31	31	Bindung der Kuhrechte an Privatbesitz	31	-1.349
17	17	Zusammenhalt unter den Landwirten	17	-1.414
7	7	ÖLN ist wichtig für die vitale Landwirtschaft	7	-1.779
11	11	Anzahl Landwirte	11	-1.882

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Descending Array of Differences Between Factors 1 and 2

No.	Statement	No.	Type 1	Type 2	Difference
3	3 Sömmerungsbeiträge sind besonders wichtig für die Alpwirts	3	1.828	-0.911	2.739
19	19 Wertschöpfung beim Alpkäse ist hoch	19	2.113	-0.026	2.139
7	7 ÖLN ist wichtig für die vitale Landwirtschaft	7	0.065	-1.779	1.844
11	11 Anzahl Landwirte	11	-0.116	-1.882	1.766
2	2 RGVE-Beiträge sind besonders wichtig für ein vitale Landwi	2	0.562	-1.101	1.663
31	31 Bindung der Kuhrechte an Privatbesitz	31	-0.252	-1.349	1.097
4	4 Absatzmöglichkeiten über Tourismus erhöhen die attraktivit	4	1.978	0.907	1.071
17	17 Zusammenhalt unter den Landwirten	17	-0.488	-1.414	0.926
32	32 Die Öffnung der Alp für fremdes Vieh	32	0.235	-0.652	0.887
14	14 Anteil Grindelwaldner unter den Landwirten	14	0.354	-0.438	0.792
8	8 Erwerbsmöglichkeiten im Tourismus	8	1.579	0.842	0.738
16	16 Führung der Bergschaften	16	0.869	0.164	0.705
12	12 Flächenverfügbareit	12	-0.373	-1.071	0.698
24	24 Die Landwirtschaft hat politisches Gewicht	24	-0.310	-0.606	0.296
15	15 Wirtschaftliche Eigeninitiative der Landwirte	15	0.328	0.099	0.229
30	30 Die Seyung ist der verfügbaren Futtermenge angepasst	30	0.256	0.069	0.187
26	26 Grösse der Bergschaften	26	-0.327	-0.313	-0.015
28	28 Die zu verrichtendeTagwann ist angemessen	28	0.406	0.564	-0.157
9	9 Zahlungen von Bergbahnen an Bergschaften	9	0.504	0.717	-0.213
21	21 Kein Fremdes Vieh auf Grindelwalds Alpen	21	-0.871	-0.637	-0.234
13	13 Weidequalität	13	0.233	0.485	-0.252
23	23 Solidarität zwischen den Kooperativen	23	0.768	1.345	-0.577
5	5 Milchpreis ist besonders wichtig für die	5	-1.895	-1.254	-0.641
33	33 Investitionen in die Infrastruktur auf den Alpen	33	0.344	1.006	-0.662
34	34 Bereitschaft Tagwann zu leisten	34	-0.260	0.594	-0.854
27	27 Flexibilität der Kuhrechte	27	-0.525	0.469	-0.994
18	18 Gemeinsame Werte	18	-0.983	0.091	-1.074
1	1 Flächenbeitäge sind besonders wichtig für ein vitale Land	1	0.240	1.422	-1.182
22	22 Know-how Alppersonal	22	-1.504	-0.309	-1.195
29	29 Die Taleinung	29	0.423	1.856	-1.433
10	10 Vorschriften im Rahmen der Sömmerungsbeiträge	10	-1.089	0.400	-1.489
6	6 Abhängigkeit von Direktzahlungen ist schlecht für die Land	6	-1.841	-0.225	-1.617
25	25 Schlichtung von Konflikten	25	-0.771	1.250	-2.020
20	20 Abhängigkeit vom landwirtschaftlichen Einkommen	20	-1.481	1.688	-3.169

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Exact Factor Scores (á la SPSS) in Z-Score and T-Score units

No.	Statement		Factors 1		2	
1	1	Flächenbeitäge sind besonders wichtig für ein vitale	1	0.28	53	1.26	63
2	2	RGVE-Beiträge sind besonders wichtig für ein vitale	2	0.53	55	-1.42	36
3	3	Sömmerungsbeiträge sind besonders wichtig für die Al	3	1.86	69	-1.11	39
4	4	Absatzmöglichkeiten über Tourismus erhöhen die attra	4	1.80	68	0.84	58
5	5	Milchpreis ist besonders wichtig für die	5	-1.68	33	-0.56	44
6	6	Abhängigkeit von Direktzahlungen ist schlecht für di	6	-1.91	31	-0.67	43
7	7	ÖLN ist wichtig für die vitale Landwirtschaft	7	0.35	53	-1.87	31
8	8	Erwerbsmöglichkeiten im Tourismus	8	1.38	64	0.91	59
9	9	Zahlungen von Bergbahnen an Bergschaften	9	0.18	52	0.48	55
10	10	Vorschriften im Rahmen der Sömmerungsbeiträge	10	-1.24	38	0.28	53
11	11	Anzahl Landwirte	11	0.23	52	-1.77	32
12	12	Flächenverfügbareit	12	-0.57	44	-0.92	41
13	13	Weidequalität	13	0.42	54	-0.04	50
14	14	Anteil Grindelwaldner unter den Landwirten	14	0.65	56	-0.38	46
15	15	Wirtschaftliche Eigeninitiative der Landwirte	15	0.34	53	0.63	56
16	16	Führung der Bergschaften	16	0.99	60	-0.01	50
17	17	Zusammenhalt unter den Landwirten	17	-0.38	46	-1.68	33
18	18	Gemeinsame Werte	18	-0.85	42	0.30	53
19	19	Wertschöpfung beim Alpkäse ist hoch	19	2.08	71	-0.20	48
20	20	Abhängigkeit vom landwirtschaftlichen Einkommen	20	-1.84	32	1.77	68
21	21	Kein Fremdes Vieh auf Grindelwalds Alpen	21	-0.99	40	-1.15	38
22	22	Know-how Alppersonal	22	-1.29	37	0.34	53
23	23	Solidarität zwischen den Kooperativen	23	0.55	55	0.86	59
24	24	Die Landwirtschaft hat politisches Gewicht	24	-0.44	46	-1.00	40
25	25	Schlichtung von Konflikten	25	-0.91	41	0.77	58
26	26	Grösse der Bergschaften	26	-0.34	47	0.21	52
27	27	Flexibilität der Kuhrechte	27	-0.60	44	0.40	54
28	28	Die zu verrichtendeTagwann ist angemessen	28	0.39	54	0.59	56
29	29	Die Taleinung	29	0.44	54	1.47	65
30	30	Die Seyung ist der verfügbaren Futtermenge angepass	30	0.31	53	-0.33	47
31	31	Bindung der Kuhrechte an Privatbesitz	31	-0.19	48	-0.93	41
32	32	Die Öffnung der Alp für fremdes Vieh	32	0.53	55	0.14	51
33	33	Investitionen in die Infrastruktur auf den Alpen	33	0.13	51	1.63	66

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 34  34     Bereitschaft Tagwann zu leisten                        34     -0.21  48   1.15  61
PQMethod2.20               Grindelwald                                                    PAGE   10
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Factor Q-Sort Values for Each Statement
Factor Array
No.  Statement     Variance =  4.706  St. Dev. =  2.169
  1  1      Flächenbeitäge sind besonders wichtig für ein vitale Land    1        0      3
  2  2      RGVE-Beiträge sind besonders wichtig für ein vitale Landwi   2        2     -2
  3  3      Sömmerungsbeiträge sind besonders wichtig für die Alpwirts   3        3     -2
  4  4      Absatzmöglichkeiten über Tourismus erhöhen die attraktivit   4        4      2
  5  5      Milchpreis ist besonders wichtig für die                     5       -4     -3
  6  6      Abhängigkeit von Direktzahlungen ist schlecht für die Land   6       -4      0
  7  7      ÖLN ist wichtig für die vitale Landwirtschaft                7        0     -4
  8  8      Erwerbsmöglichkeiten im Tourismus                            8        3      2
  9  9      Zahlungen von Bergbahnen an Bergschaften                     9        2      2
 10  10     Vorschriften im Rahmen der Sömmerungsbeiträge               10       -3      1
 11  11     Anzahl Landwirte                                            11        0     -4
 12  12     Flächenverfügbareit                                         12       -1     -2
 13  13     Weidequalität                                              13        0      1
 14  14     Anteil Grindelwaldner unter den Landwirten                 14        1     -1
 15  15     Wirtschaftliche Eigeninitiative der Landwirte              15        1      0
 16  16     Führung der Bergschaften                                   16        3      0
 17  17     Zusammenhalt unter den Landwirten                          17       -1     -3
 18  18     Gemeinsame Werte                                           18       -2      0
 19  19     Wertschöpfung beim Alpkäse ist hoch                        19        4      0
 20  20     Abhängigkeit vom landwirtschaftlichen Einkommen            20       -3      4
 21  21     Kein Fremdes Vieh auf Grindelwalds Alpen                   21       -2     -1
 22  22     Know-how Alppersonal                                       22       -3     -1
 23  23     Solidarität zwischen den Kooperativen                      23        2      3
 24  24     Die Landwirtschaft hat politisches Gewicht                 24       -1     -1
 25  25     Schlichtung von Konflikten                                 25       -2      3
 26  26     Grösse der Bergschaften                                    26       -1     -1
 27  27     Flexibilität der Kuhrechte                                 27       -2      1
 28  28     Die zu verrichtendeTagwann ist angemessen                  28        1      1
 29  29     Die Taleinung                                              29        2      4
 30  30     Die Seyung ist der verfügbaren Futtermenge angepasst       30        1      0
 31  31     Bindung der Kuhrechte an Privatbesitz                      31        0     -3
 32  32     Die Öffnung der Alp für fremdes Vieh                       32        0     -2
 33  33     Investitionen in die Infrastruktur auf den Alpen           33        1      2
 34  34     Bereitschaft Tagwann zu leisten                            34       -1      1
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Factor Q-Sort Values for Statements sorted by Consensus vs. Disagreement (Variance across Factor Z-Scores)

No.	Statement		Factor Array 1	2
26	26	Grösse der Bergschaften	-1	-1
28	28	Die zu verrichtendeTagwann ist angemessen	1	1
30	30	Die Seyung ist der verfügbaren Futtermenge angepasst	1	0
9	9	Zahlungen von Bergbahnen an Bergschaften	2	2
15	15	Wirtschaftliche Eigeninitiative der Landwirte	1	0
21	21	Kein Fremdes Vieh auf Grindelwalds Alpen	-2	-1
13	13	Weidequalität	0	1
24	24	Die Landwirtschaft hat politisches Gewicht	-1	-1
23	23	Solidarität zwischen den Kooperativen	2	3
5	5	Milchpreis ist besonders wichtig für die	-4	-3
33	33	Investitionen in die Infrastruktur auf den Alpen	1	2
12	12	Flächenverfügbareit	-1	-2
16	16	Führung der Bergschaften	3	0
8	8	Erwerbsmöglichkeiten im Tourismus	3	2
14	14	Anteil Grindelwaldner unter den Landwirten	1	-1
34	34	Bereitschaft Tagwann zu leisten	-1	1
32	32	Die Öffnung der Alp für fremdes Vieh	0	-2
17	17	Zusammenhalt unter den Landwirten	-1	-3
27	27	Flexibilität der Kuhrechte	-2	1
4	4	Absatzmöglichkeiten über Tourismus erhöhen die attraktivit	4	2
18	18	Gemeinsame Werte	-2	0
31	31	Bindung der Kuhrechte an Privatbesitz	0	-3
1	1	Flächenbeitäge sind besonders wichtig für ein vitale Land	0	3
22	22	Know-how Alppersonal	-3	-1
29	29	Die Taleinung	2	4
10	10	Vorschriften im Rahmen der Sömmerungsbeiträge	-3	1
6	6	Abhängigkeit von Direktzahlungen ist schlecht für die Land	-4	0
2	2	RGVE-Beiträge sind besonders wichtig für ein vitale Landwi	2	-2
11	11	Anzahl Landwirte	0	-4
7	7	ÖLN ist wichtig für die vitale Landwirtschaft	0	-4
25	25	Schlichtung von Konflikten	-2	3
19	19	Wertschöpfung beim Alpkäse ist hoch	4	0
3	3	Sömmerungsbeiträge sind besonders wichtig für die Alpwirts	3	-2
20	20	Abhängigkeit vom landwirtschaftlichen Einkommen	-3	4

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Factor Characteristics

	Factors	
	1	2
No. of Defining Variables	7	4
Average Rel. Coef.	0.800	0.800
Composite Reliability	0.966	0.941
S.E. of Factor Z-Scores	0.186	0.243

Standard Errors for Differences in Factor Z-Scores

(Diagonal Entries Are S.E. Within Factors)

Factors	1	2
1	0.263	0.305
2	0.305	0.343

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Distinguishing Statements for Factor 1

(P < .05 ; Asterisk (*) Indicates Significance at P < .01)

Both the Factor Q-Sort Value (Q-SV) and the Z-Score (Z-SCR) are Shown.

			Factors			
				1		2
No.		Statement	No.	Q-SV	Z-SCR	Q-SV	Z-SCR
19	19	Wertschöpfung beim Alpkäse ist hoch	19	4	2.11*	0	-0.03
4	4	Absatzmöglichkeiten über Tourismus erhöhen die attraktivit	4	4	1.98*	2	0.91
3	3	Sömmerungsbeiträge sind besonders wichtig für die Alpwirts	3	3	1.83*	-2	-0.91
8	8	Erwerbsmöglichkeiten im Tourismus	8	3	1.58	2	0.84
16	16	Führung der Bergschaften	16	3	0.87	0	0.16
2	2	RGVE-Beiträge sind besonders wichtig für ein vitale Landwi	2	2	0.56*	-2	-1.10
29	29	Die Taleinung	29	2	0.42*	4	1.86
14	14	Anteil Grindelwaldner unter den Landwirten	14	1	0.35*	-1	-0.44
33	33	Investitionen in die Infrastruktur auf den Alpen	33	1	0.34	2	1.01
1	1	Flächenbeitäge sind besonders wichtig für ein vitale Land	1	0	0.24*	3	1.42
32	32	Die Öffnung der Alp für fremdes Vieh	32	0	0.24*	-2	-0.65
7	7	ÖLN ist wichtig für die vitale Landwirtschaft	7	0	0.07*	-4	-1.78
11	11	Anzahl Landwirte	11	0	-0.12*	-4	-1.88
31	31	Bindung der Kuhrechte an Privatbesitz	31	0	-0.25*	-3	-1.35
34	34	Bereitschaft Tagwann zu leisten	34	-1	-0.26*	1	0.59
12	12	Flächenverfügbareit	12	-1	-0.37	-2	-1.07
17	17	Zusammenhalt unter den Landwirten	17	-1	-0.49*	-3	-1.41
27	27	Flexibilität der Kuhrechte	27	-2	-0.53*	1	0.47
25	25	Schlichtung von Konflikten	25	-2	-0.77*	3	1.25
18	18	Gemeinsame Werte	18	-2	-0.98*	0	0.09
10	10	Vorschriften im Rahmen der Sömmerungsbeiträge	10	-3	-1.09*	1	0.40
20	20	Abhängigkeit vom landwirtschaftlichen Einkommen	20	-3	-1.48*	4	1.69
22	22	Know-how Alppersonal	22	-3	-1.50*	-1	-0.31
6	6	Abhängigkeit von Direktzahlungen ist schlecht für die Land	6	-4	-1.84*	0	-0.22
5	5	Milchpreis ist besonders wichtig für die	5	-4	-1.89	-3	-1.25

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Path and Project Name: c:/pqmethod/projects/Grindelw Mar 12 12

Consensus Statements -- Those That Do Not Distinguish Between ANY Pair of Factors.

All Listed Statements are Non-Significant at P>.01, and Those Flagged With an * are also Non-Significant at P>.05.

			Factors			
			1		2	
No.		Statement	No.	Q-SV	Z-SCR	Q-SV	Z-SCR
5	5	Milchpreis ist besonders wichtig für die	5	-4	-1.89	-3	-1.25
8	8	Erwerbsmöglichkeiten im Tourismus	8	3	1.58	2	0.84
9*	9	Zahlungen von Bergbahnen an Bergschaften	9	2	0.50	2	0.72
12	12	Flächenverfügbareit	12	-1	-0.37	-2	-1.07
13*	13	Weidequalität	13	0	0.23	1	0.49
15*	15	Wirtschaftliche Eigeninitiative der Landwirte	15	1	0.33	0	0.10
16	16	Führung der Bergschaften	16	3	0.87	0	0.16
21*	21	Kein Fremdes Vieh auf Grindelwalds Alpen	21	-2	-0.87	-1	-0.64
23*	23	Solidarität zwischen den Kooperativen	23	2	0.77	3	1.34
24*	24	Die Landwirtschaft hat politisches Gewicht	24	-1	-0.31	-1	-0.61
26*	26	Grösse der Bergschaften	26	-1	-0.33	-1	-0.31
28*	28	Die zu verrichtendeTagwann ist angemessen	28	1	0.41	1	0.56
30*	30	Die Seyung ist der verfügbaren Futtermenge angepasst	30	1	0.26	0	0.07
33	33	Investitionen in die Infrastruktur auf den Alpen	33	1	0.34	2	1.01

Results from Factor-Analysis

Statement N	Framework Variable	Description	Overall			Factor 1		Factor 2		Distinguishing statements				Normalized Factor scores		
			Score overall of the statemen	Rank overall of the statement	Normalized Factor score	F1 Score	F1 Rank	F2 Score	F2 Rank	Variance	Distinguishing Statemens F1	Consenus statements	distinguishing	F1 Normalized Factor scores	F2 Normalized Factor scores	Difference in Factor scores
1	S4	**Direct payments tied to private parcels**	0,09	15	0	0,24	15	1,42	3	-1,18	1		**1,00**	0,00	3,00	3,00
2	S4	**Direct payments tied to livestock**	-0,36	23	-1	0,56	7	-1,10	29	1,66	1		**1,00**	2,00	-2,00	4,00
3	S4	**Summering payments**	1,00	6	2	1,83	3	-0,91	27	2,74	1		**1,00**	3,00	-2,00	5,00
4	RU4	**Marketing and sales opportunities**	1,73	1	4	1,98	2	0,91	7	1,07	1		**1,00**	4,00	2,00	2,00
5	S5	The milk price	-1,18	29	-2	-1,89	34	-1,25	30	-0,64	1	1,00	**0,00**	-4,00	-3,00	1,00
6	S5	**The dependence upon direct payments**	-2,00	34	-4	-1,84	33	-0,22	20	-1,62	1		**1,00**	-4,00	0,00	4,00
7	S4	**Ecological regulations for obtaining direct payments**	-1,64	32	-3	0,07	18	-1,78	33	1,85	1		**1,00**	0,00	-4,00	4,00
8	S5	Off-farm income opportunities in the local tourism sector	1,55	2	4	1,58	4	0,84	8	0,74	1	1,00	**0,00**	3,00	2,00	1,00
9	GS3	Reimbursement of railway operators to the corporations	-0,09	19	0	0,50	8	0,72	9	-0,22	1	1,00	**0,00**	2,00	2,00	0,00
10	S4	**Rules for the obtainment of summering payments**	-0,55	25	-1	-1,09	30	0,40	14	-1,49	1		**1,00**	-3,00	1,00	4,00
11	U1	**The share of locally born and raised farmers**	-0,27	21	-1	-0,12	19	-1,88	34	1,76	1		**1,00**	0,00	-4,00	4,00
12	RS3	Availability of agricultural area	-1,09	28	-2	-0,37	24	-1,07	28	0,70	1	1,00	**0,00**	-1,00	-2,00	1,00
13	RS5	The quality of the CPP	-0,09	20	0	0,23	17	0,49	12	-0,26	0	1,00	**0,00**	0,00	1,00	1,00
14	U1	**The number of farmers**	0,91	7	2	0,35	11	-0,44	23	0,79	1		**1,00**	1,00	-1,00	2,00
15	U5	Farmers innovative abilities and entrepreneurship	0,55	12	1	0,33	13	0,10	16	0,23	0	1,00	**0,00**	1,00	0,00	1,00
16	U5	Leadership within the corporation	0,55	13	1	0,87	5	0,16	15	0,71	1	1,00	**0,00**	3,00	0,00	3,00
17	I7	Cohesion and solidarity among the farmers'	-1,55	31	-3	-0,49	25	-1,41	32	0,92	0		**0,00**	-1,00	-3,00	2,00
18	I3	**Common values and goals**	0,09	16	0	-0,98	29	0,09	17	-1,07	1		**1,00**	-2,00	0,00	2,00
19	RU4	**The added value of alpine cheese**	1,18	5	3	2,11	1	-0,03	19	2,14	1		**1,00**	4,00	0,00	4,00
20	S4	**Dependence upon agricultural income**	-0,27	22	-1	-1,48	31	1,69	2	-3,17	1		**1,00**	-3,00	4,00	7,00
21	GS5	The presence of foreign cattle on the CPP	-1,73	33	-4	-0,87	28	-0,64	25	-0,23	0	1,00	**0,00**	-2,00	-1,00	1,00
22	U7	**The know-how of the employees on the Alp**	-0,36	24	-1	-1,50	32	-0,31	21	-1,19	1		**1,00**	-3,00	-1,00	2,00
23	GS3	Solidarity between the corporations	0,55	14	1	0,77	6	1,34	4	-0,57	0	1,00	**0,00**	2,00	3,00	1,00
24	GS3	Recognition of agriculture by local politics	-1,36	30	-3	-0,31	22	-0,61	24	0,30	0	1,00	**0,00**	-1,00	-1,00	0,00
25	I4	**Negotiabilty of conflicts on the local level**	-0,55	26	-2	-0,77	27	1,25	5	-2,02	1		**1,00**	-2,00	3,00	5,00
26	RS3	The size of the corporations	0,64	10	1	-0,33	23	-0,31	22	-0,02	0	1,00	**0,00**	-1,00	-1,00	0,00
27	GS4	**Flexibility and leasability of use rights**	0,00	17	0	-0,53	26	0,47	13	-1,00	1		**1,00**	-2,00	1,00	3,00
28	GS5	The hours of communal work to be conducted	0,73	9	2	0,41	10	0,56	11	-0,15	0	1,00	**0,00**	1,00	1,00	0,00
29	GS7	**The rules of the local constitution**	1,27	4	3	0,42	9	1,86	1	-1,44	1		**1,00**	2,00	4,00	2,00
30	GS4	The amount of use rights	-0,73	27	-2	0,26	14	0,07	18	0,19	0	1,00	**0,00**	1,00	0,00	1,00
31	GS4	**The attachment of use rights to private ownership in the valley**	0,00	18	0	-0,25	20	-1,35	31	1,10	1		**1,00**	0,00	-3,00	3,00
32	GS5	**The opening of the CPP for foreign cattle**	1,45	3	3	0,24	16	-0,65	26	0,89	1		**1,00**	0,00	-2,00	2,00
33	I5	The amount of resources invested into the infrastructure on the CPP	0,91	8	2	0,34	12	1,01	6	-0,67	1	1,00	**0,00**	1,00	2,00	1,00
34	I5	Willingness to contribute communal work is positively affecting	0,64	11	1	-0,26	21	0,59	10	-0,85	**1**		**0,00**	-1,00	1,00	2,00

Supporting Material for Module 4

Model Tests

Description of the four types of structural tests conducted:

1. **Dimensional consistency:** ensured that all variables have units with real-world meaning; automatically conducted with the Vensim software.
2. **Integration error testing:** This included running the model with different integration methods such as Euler and Runge-Kutta and with different time intervals. When the integration method was changed, the behavior of the model remained unchanged. A change in the time interval had a minor impact on the model behavior, since farmers automatically adapt their livestock more frequently to changing land use incentives. As a result, the ecological system was also affected by the chosen time interval. Simulating the model with a time interval of one year resulted in 2,481 ha of forest, with a time interval of 0.5 in 2,488 ha forest, and with a time interval of 0.0078 in 2,501 ha forest. However, this indicates only that changes in time interval would require changing the parameters incorporating delays such as "time to adjust herd size."
3. **Reality check equations:** We used RC decay functions to force variable values to 0 at a certain time to see whether logical consequences arise in the following relationships:
    - "No farmers no livestock"; CONDITION: Farm households = 0; IMPLICATION: Livestock per household = 0
    - "No farmers no appropriation of local cattle"; CONDITION: Farm households = 0; IMPLICATION: Appropriation of local cattle = 0

- "No monitoring no provision"; CONDITION: Monitoring = 0; IMPLICATION: Provision fulfillment = 0
- "No appropriation no provision"; CONDITION: Stocking = 0; IMPLICATION: Provision = 0
- "Conservation of landmass"; CONDITION: Forest = 0; IMPLICATION: Forest + Overgrown Summer Pastures + Summer Pastures = 6,663.

4. **Extreme condition tests:**
    - "No government support": if direct payments tied to private parcels are set to 0 no matter at which time point, the system collapses within 5 years. Since farming was no longer feasible, farmers completely gave up agriculture, because it no longer generated a satisfying household income.
    - "Increasing costs of agricultural production": if the costs of agricultural production were increased in 2000 by 10% annually, the last farmer would abandon agriculture in 2019.
    - "Increasing productivity of CPP": A sudden doubling of the animal feed yield on CPPs in 2000 as a result of a technological breakthrough would have caused a massive abandonment of CPPs followed by an increase in forest stands of up to 4,800 ha by 2020.

Sensitivity tests for parameter assessment:

Outcomes for sensitivity tests when the following parameters are randomized:

- Satisficing household income was randomized with the lower limit set at CHF 55,000 and the upper limit set at CHF 100,000.
- Initial pasture productivity was randomized with a lower limit of 10 and an upper limit of 25 kg DM/day/ha.

- Availability of cattle in the lowlands was randomized with a lower limit of 0.1 and an upper limit of 1.
- Fodder decay fraction with a lower limit of 1 and an upper limit of 4.

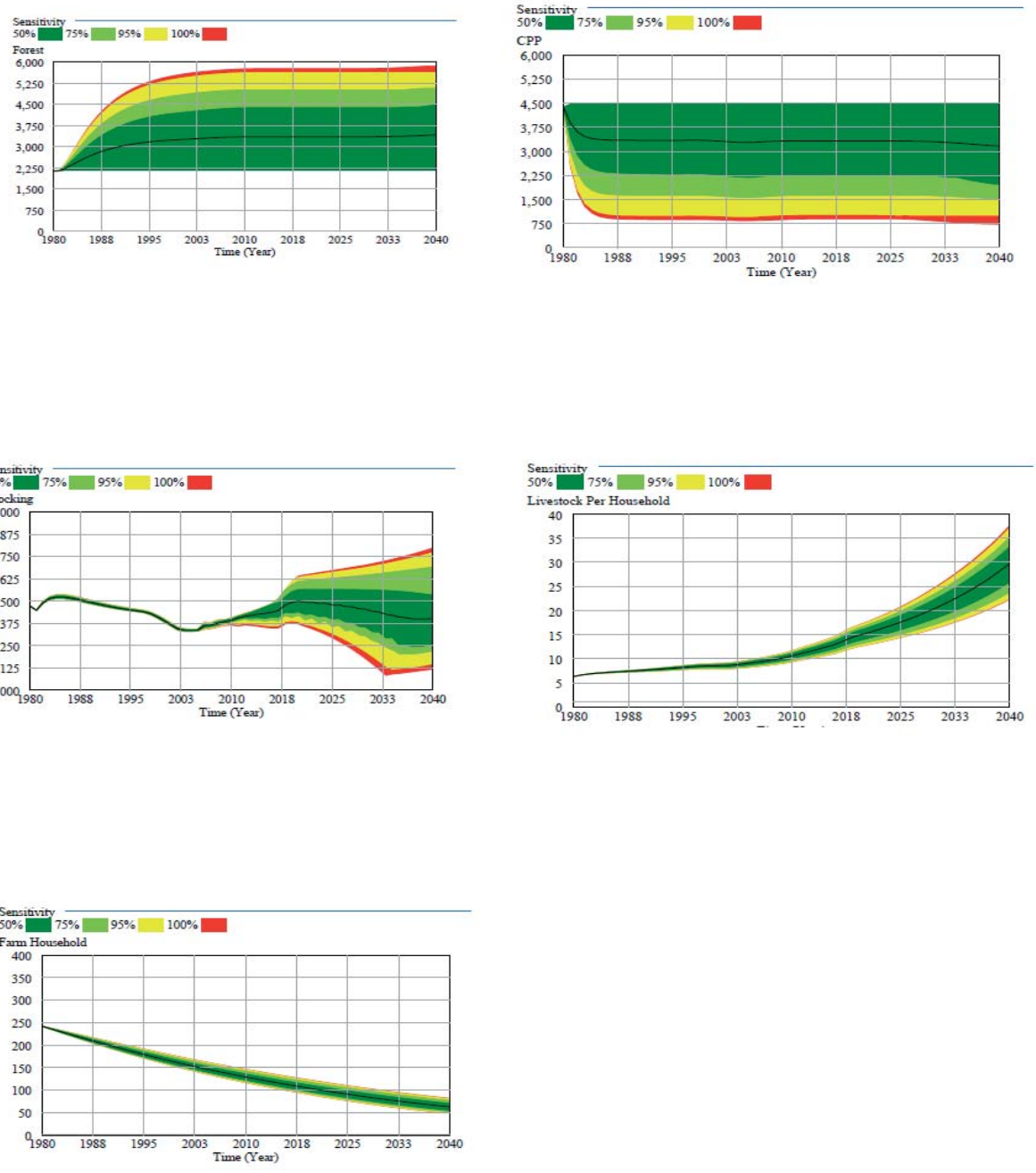


Fig. 1. *Outcomes of sensitivity tests for farm households, stock, common property pasture area, and forest stands by randomizing parameters.*

Model Documentation

Documentation of Full model SES Grindelwald

View the 172 variables sorted by type, module, group, variable name, module/group/name, Level Structure, or in a view summary.

Model Assessment Results

Model Information	Number
Total Number of Variables	172
Total Number of State Variables (Level+Smooth+Delay Variables)	8
Total Number of Stocks (Stocks in Level+Smooth+Delay Variables) †	8
Total Number of Macros	0
Function Sensitivity Parameters	0
Variables with Source Information	0
Data Lookup Tables	0
Time Unit	Year
Initial Time	1980
Final Time	2040
Reported Time Interval	TIME STEP
Time Step	1
Model Is Fully Formulated	Yes
Modeler-Defined Groups	**- No -**
VPM File Available	**- No -**

Warnings	Number
Undocumented Equations	168
Equations with Embedded Data	42
Equations With Unit Errors or Warnings	Unavailable
Variables Not in Any View	0
Incompletely Defined Subscripted Variables	0
Nonmonotonic Lookup Functions	1
Cascading (Chained) Lookup Functions	0
Equations with IF...THEN...ELSE	10
Equations with MIN or MAX	0

Potential Omissions	Number
Unused Variables	4
Supplementary Variables	0
Supplementary Variables Being Used	0
Complex Variable Formulations (Richardson's Rule = 3)	1
Complex Stock Formulations	0

Types:

L : Level (8 / **8**) *	**SM** : Smooth (0 / **0**) *	**DE** : Delay (0 / **0**) * †	**LI** : Level Initial (4)	**I** : Initial (0)
C : Constant (62)	**F** : Flow (15)	**A** : Auxiliary (102)	**Sub**: Subscripts (0)	**D** : Data (0)
G : Game (0)	**T** : Lookup (16 / **16**) ††			

* (state variables / **total stocks**)

† Total stocks do not include fixed delay variables.

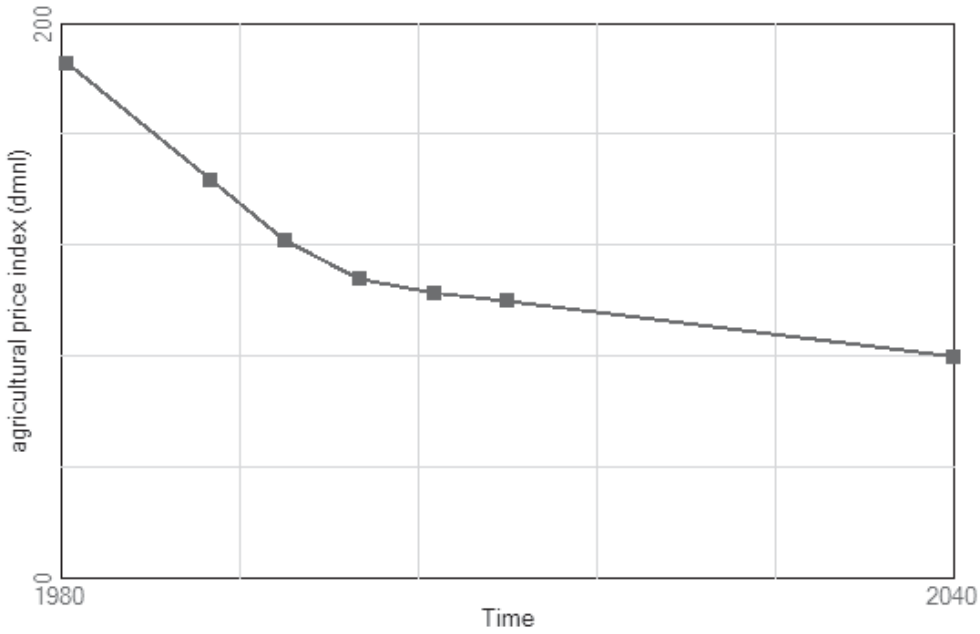
†† (lookup variables / **lookup tables**).

Groups:

Control (4) Simulation Control Parameters	**Full model SES Grindelwald** (168) (Default)	

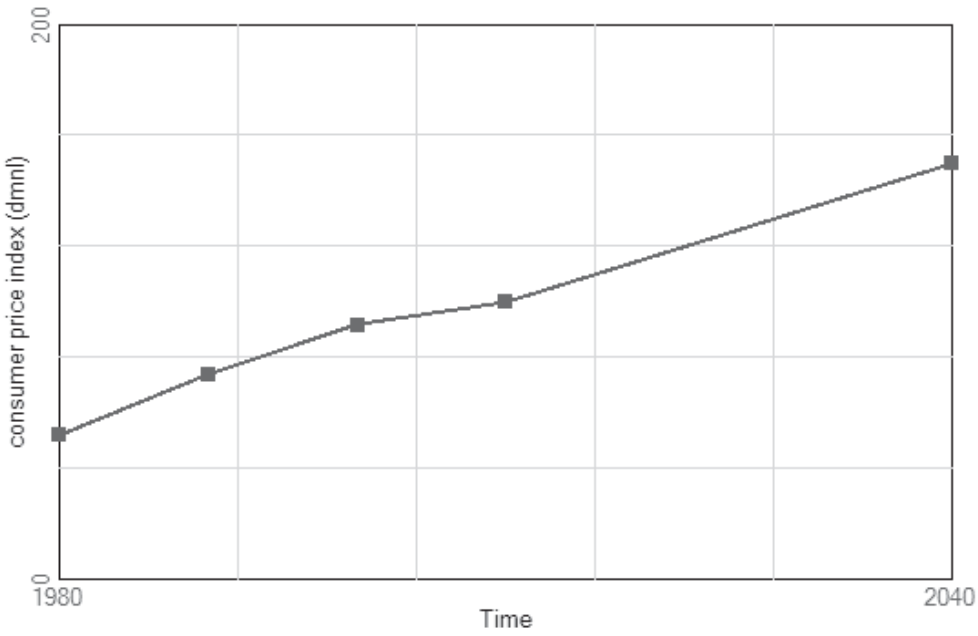
Modules:	Default (172)				
Views:	External Setting (61)	Actor (A) (58)	Governance System (GS) (35)	Resource Units (RU) (44)	Resource System (RS) (24)
	Levels (8)	auxilary (0)	Reality checks (0)	View 9 (0)	View 10 (0)

External Setting (61 variables)

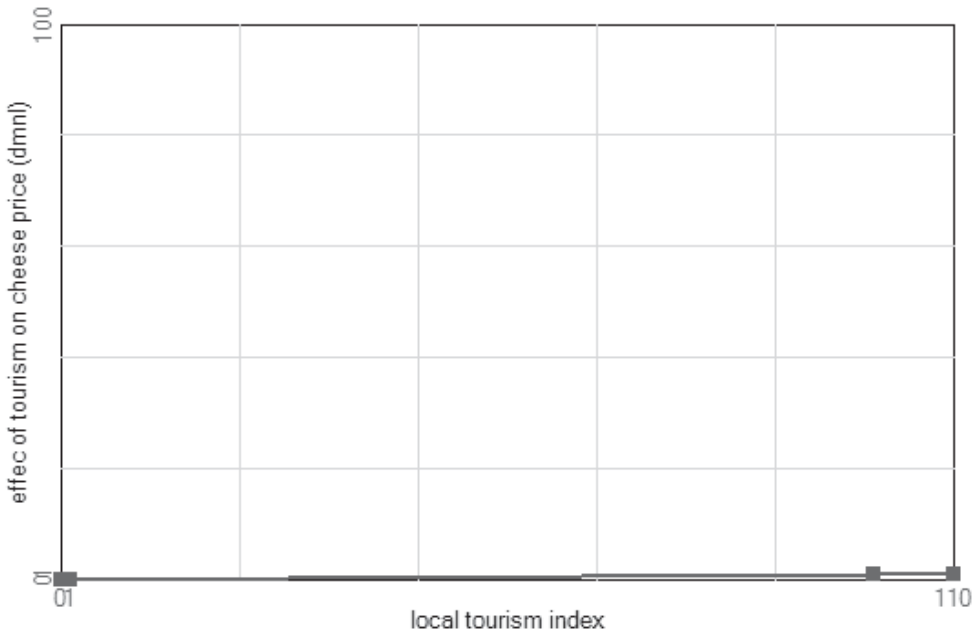
Module	Group	Type	Variable Name and Description
Default	Full model SES Grindelwald (Default)	T,A	**agricultural price index** (dmnl) = WITH LOOKUP (Time,([(1980,0)-(2040,200)],(1980.37,185.965),(1990,144),(1995,122),(2000,108),(2005,103),(2010,100),(2040,80))) **Present in 1 view:** • External Setting **Used by:** • cheese price • milk price 
Default	Full model SES Grindelwald (Default)	A	**appropriation contribution** (CHF/NST) = STEP(current appropriation contribution*(consumer price index/100), 2015)*scenario multiplier summering **Present in 2 views:** • External Setting • Resource Units (RU) **Used by:** • pay-off appropriation
Default	Full model SES Grindelwald (Default)	C	**Change Direct Costs / GVE** (1/Year) = 0.013 **Present in 2 views:** • External Setting • Levels **Used by:** • scenario multiplier costs of agricultural production

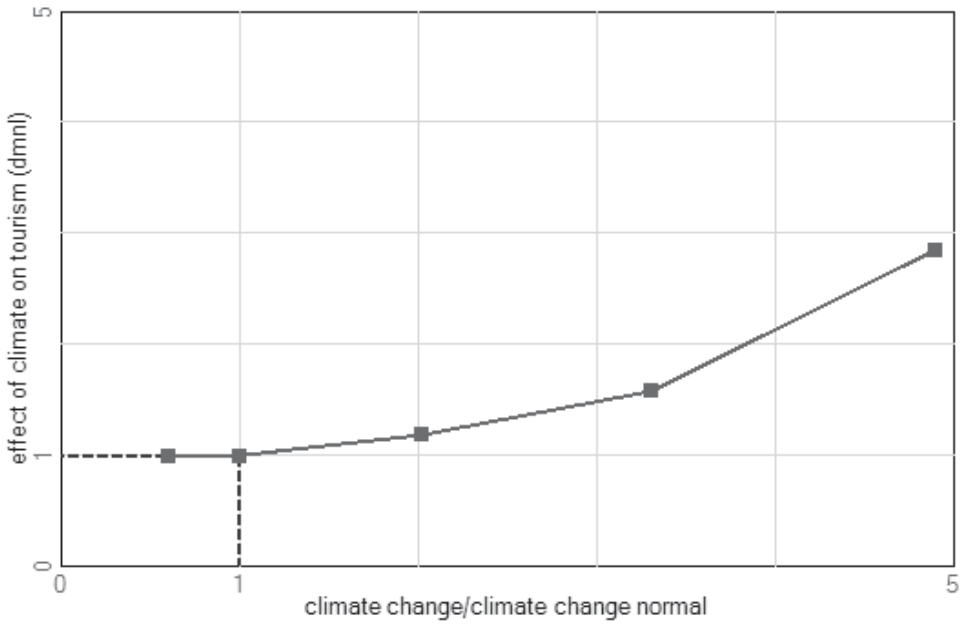
Default	Full model SES Grindelwald (Default)	C VAB	**Change Direct Payments** (1/Year) = 0 **Present in 2 views:** • External Setting • Levels **Used by:** • scenario multiplier direct payments
Default	Full model SES Grindelwald (Default)	C VAB	**Change in climate development** (1/Year) = 0.067 **Present in 2 views:** • External Setting • Levels **Used by:** • scenario multiplier climate
Default	Full model SES Grindelwald (Default)	C VAB	**Change off-farm income opportunities** (1/Year) = 0 **Present in 2 views:** • External Setting • Levels **Used by:** • scenario multiplier off-farm income
Default	Full model SES Grindelwald (Default)	C VAB	**Change Producer Prices** (1/Year) = 0.01 **Present in 2 views:** • External Setting • Levels **Used by:** • scenario multiplier producer prices
Default	Full model SES Grindelwald (Default)	C VAB	**Change Summering payments** (1/Year) = 0 **Present in 2 views:** • External Setting • Levels **Used by:** • scenario multiplier summering
Default	Full model SES Grindelwald (Default)	C VAB	**Change Wood Price** (1/Year) = 0.033 **Present in 2 views:** • External Setting • Levels **Used by:** • scenario multplier wood price
Default	Full model SES Grindelwald (Default)	A VAB	**cheese price** (CHF/kg) = ((((agricultural price index/100)*(consumer price index/100))*current cheese price)*effec of tourism on cheese price)*scenario multiplier producer prices **Present in 2 views:** • External Setting • Resource Units (RU) **Used by:** • pay-off cheese

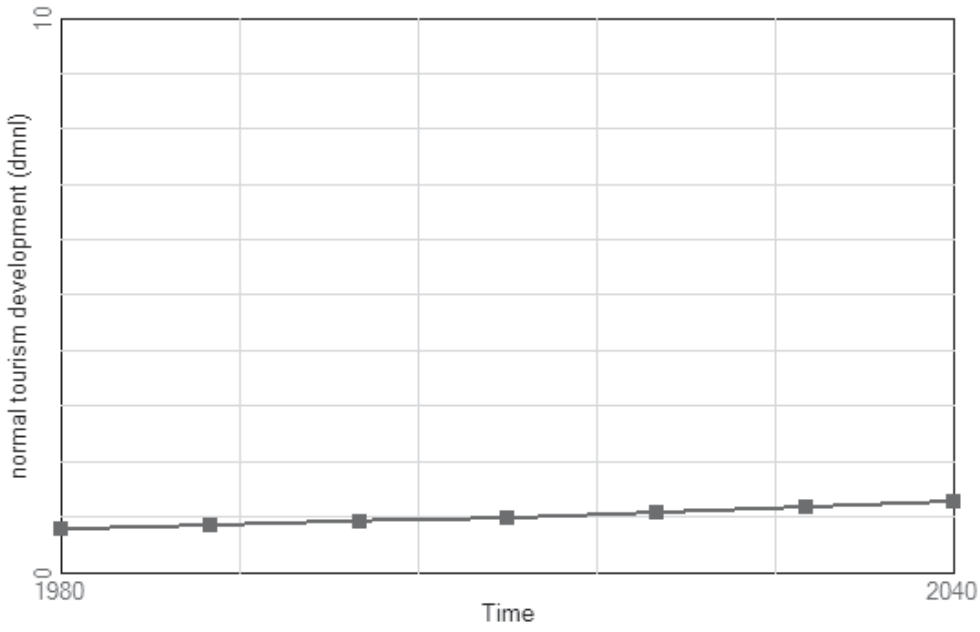
Default	Full model SES Grindelwald (Default)	A	**climate change** (degree/Year) = climate change development*scenario multiplier climate **Present in 1 view:** • External Setting **Used by:** • effect of climate on tourism • growing season
Default	Full model SES Grindelwald (Default)	A	**climate change development** (degree/Year) = RAMP(0.02, 1980, 2040) **Present in 1 view:** • External Setting **Used by:** • climate change
Default	Full model SES Grindelwald (Default)	C	**climate change normal** (degree) = 0.6 **Present in 1 view:** • External Setting **Used by:** • effect of climate on tourism
Default	Full model SES Grindelwald (Default)	T,A	**consumer price index** (dmnl) = WITH LOOKUP (Time,([(1980,0)-(2040,200)],(1980,52),(1990,74),(2000,92),(2010,100),(2040,150))) **Present in 2 views:** • External Setting • Actor (A) **Used by:** • appropriation contribution • cheese price • direct costs/GVE • direct payments/GVE • Direct payments/ha • discrepancy ratio • potenital off-farm income • spendings on labor • summering fee • summering payments

			
Default	Full model SES Grindelwald (Default)	C VAB	**current appropriation contribution** (CHF/NST) = 370 **Present in 1 view:** • External Setting **Used by:** • appropriation contribution
Default	Full model SES Grindelwald (Default)	C VAB	**current cheese price** (CHF/kg) = 18 **Present in 1 view:** • External Setting **Used by:** • cheese price
Default	Full model SES Grindelwald (Default)	C VAB	**current direct costs/GVE** (CHF/GVE) = 2000 **Present in 1 view:** • External Setting **Used by:** • direct costs/GVE
Default	Full model SES Grindelwald (Default)	C VAB	**current direct payments/GVE** (CHF/GVE) = 970 **Present in 1 view:** • External Setting **Used by:** • direct payments/GVE
Default	Full model SES Grindelwald (Default)	C VAB	**current direct payments/ha** (CHF/ha) = 2000 **Present in 1 view:** • External Setting **Used by:** • Direct payments/ha

Default	Full model SES Grindelwald (Default)	C VAB	**current milk price** (CHF/kg) = 0.5 **Present in 1 view:** • External Setting **Used by:** • milk price
Default	Full model SES Grindelwald (Default)	C VAB	**current potential off farm income** (SFr/person) = 63200 **Present in 1 view:** • External Setting **Used by:** • potenital off-farm income
Default	Full model SES Grindelwald (Default)	C VAB	**current summering costs** (CHF/NST) = 700 **Present in 1 view:** • External Setting **Used by:** • summering fee
Default	Full model SES Grindelwald (Default)	C VAB	**current summering payments** (CHF/NST) = 300 **Present in 1 view:** • External Setting **Used by:** • summering payments
Default	Full model SES Grindelwald (Default)	C VAB	**current wood price** (CHF/FM) = 55 **Present in 1 view:** • External Setting **Used by:** • wood price
Default	Full model SES Grindelwald (Default)	A VAB	**direct costs/GVE** (CHF/GVE) = current direct costs/GVE*(consumer price index/100)*scenario multiplier costs of agricultural production **Present in 2 views:** • External Setting • Actor (A) **Used by:** • costs of herd
Default	Full model SES Grindelwald (Default)	A VAB	**direct payments/GVE** (CHF/GVE) = (consumer price index/100)*current direct payments/GVE*scenario multiplier direct payments **Present in 2 views:** • External Setting • Actor (A) **Used by:** • household income direct payments animals • land use incentive direct payments
Default	Full model SES Grindelwald (Default)	A VAB	**Direct payments/ha** (CHF/ha) = ((consumer price index/100)*current direct payments/ha)*scenario multiplier direct payments **Present in 2 views:** • External Setting • Actor (A) **Used by:** • income land use

			• land use incentive direct payments
Default	Full model SES Grindelwald (Default)	T,A	**effec of tourism on cheese price** (dmnl) = WITH LOOKUP (local tourism index,([(0,0)-(110,100)],(0,0),(1,0.1),(100,1),(110,1.1))) **Present in 1 view:** • External Setting **Used by:** • cheese price 
Default	Full model SES Grindelwald (Default)	T,A	**effect of climate on tourism** (dmnl) = WITH LOOKUP (climate change/climate change normal,([(0,0)-(5,5)],(0.6,1),(1,1),(2.01835,1.18421),(3.30275,1.57895),(4.89297,2.85088))) **Present in 1 view:** • External Setting **Used by:** • local tourism index

			
Default	Full model SES Grindelwald (Default)	C VAB	**effect on climate change on growing season** (days/degree) = 12 **Present in 1 view:** • External Setting **Used by:** • growing season
Default	Full model SES Grindelwald (Default)	A VAB	**growing season** (days/Year) = Initial summering season+(effect on climate change on growing season*climate change) **Present in 3 views:** • External Setting • Resource Units (RU) • Resource System (RS) **Used by:** • forgone payoff-milk when summered • local stocking potenital • milk sold per dairy cow • pay-off cheese • plot annual fodder production
Default	Full model SES Grindelwald (Default)	C VAB	**Initial summering season** (days/Year) = 95 **Present in 1 view:** • External Setting **Used by:** • growing season
Default	Full model SES Grindelwald (Default)	A VAB	**land use incentive direct payments** (GVE/ha) = Direct payments/ha/direct payments/GVE **Present in 1 view:** • External Setting
Default	Full model SES Grindelwald (Default)	A VAB	**local tourism index** (dmnl) = ((normal tourism development*100)*scenario multiplier tourism)*effect of climate on tourism **Present in 1 view:** • External Setting **Used by:** • effec of tourism on cheese price

			• potenital off-farm income
Default	Full model SES Grindelwald (Default)	A	**milk price** (CHF/kg) = (agricultural price index/100)*current milk price*scenario multiplier producer prices **Present in 2 views:** • External Setting • Resource Units (RU) **Used by:** • forgone payoff-milk when summered • pay-off milk
Default	Full model SES Grindelwald (Default)	C	**Minimum revenue needed for harvesting** (SFr/FM) = 10 **Present in 1 view:** • External Setting **Used by:** • rentability of wood harvest
Default	Full model SES Grindelwald (Default)	T,A	**normal tourism development** (dmnl) = WITH LOOKUP (Time,([(1980,0)-(2040,10)],(1980,0.8),(1990,0.87),(2000,0.95),(2010,1),(2020,1.1),(2030,1.2),(2040,1.3))) **Present in 1 view:** • External Setting **Used by:** • local tourism index 
Default	Full model SES Grindelwald (Default)	A	**potenital off-farm income** (SFr/person) = (((consumer price index/100)+(local tourism index/100))/2)*current potential off farm income*scenario multiplier off-farm income*rentability of wood harvest **Present in 2 views:** • External Setting • Actor (A) **Used by:** • off farm income

Default	Full model SES Grindelwald (Default)	A VAB	**rentability of wood harvest** (dmnl) = IF THEN ELSE(wood price-wood harvesting cost>Minimum revenue needed for harvesting, wood price/wood harvesting cost, 1) **Present in 1 view:** • External Setting **Used by:** • potenital off-farm income
Default	Full model SES Grindelwald (Default)	A VAB	**scenario multiplier climate** (dmnl) = 1+STEP(RAMP(Change in climate development, 2015, 2040), 2015) **Present in 1 view:** • External Setting **Used by:** • climate change
Default	Full model SES Grindelwald (Default)	A VAB	**scenario multiplier costs of agricultural production** (dmnl) = 1+STEP(RAMP(Change Direct Costs / GVE, 2015, 2040), 2015) **Present in 1 view:** • External Setting **Used by:** • direct costs/GVE • summering fee
Default	Full model SES Grindelwald (Default)	A VAB	**scenario multiplier direct payments** (dmnl) = 1+STEP(RAMP(Change Direct Payments, 2010, 2040), 2010) **Present in 1 view:** • External Setting **Used by:** • direct payments/GVE • Direct payments/ha
Default	Full model SES Grindelwald (Default)	A VAB	**scenario multiplier off-farm income** (dmnl) = 1+STEP(RAMP(Change off-farm income opportunities, 2015, 2040), 2015) **Present in 1 view:** • External Setting **Used by:** • potenital off-farm income
Default	Full model SES Grindelwald (Default)	A VAB	**scenario multiplier producer prices** (dmnl) = 1+STEP(RAMP(Change Producer Prices, 2015, 2040), 2015) **Present in 1 view:** • External Setting **Used by:** • cheese price • milk price
Default	Full model SES Grindelwald (Default)	A VAB	**scenario multiplier summering** (dmnl) = 1+STEP(RAMP(Change Summering payments, 2010, 2040), 2010) **Present in 1 view:** • External Setting **Used by:** • appropriation contribution • summering payments
Default	Full model SES Grindelwald (Default)	A VAB	**scenario multiplier tourism** (dmnl) = 1+STEP(RAMP(Tourism development, 2015, 2040), 2015) **Present in 1 view:** • External Setting **Used by:** • local tourism index

List of 168 Undocumented Variables

Module	Group	Type	Variable (168)
Default	Full model SES Grindelwald	F,A	abandonment (ha/Year)
Default	Full model SES Grindelwald	F,A	afforestation (ha/Year)
Default	Full model SES Grindelwald	A	agricultural income houshold (SFr/household)
Default	Full model SES Grindelwald	T,A	agricultural price index (dmnl)
Default	Full model SES Grindelwald	A	appropriation contribution (CHF/NST)
Default	Full model SES Grindelwald	F,A	appropriation of foreign cattle (NST/Year)
Default	Full model SES Grindelwald	F,A	appropriation of local livestock (NST/Year)
Default	Full model SES Grindelwald	C	availability of cattle in the lowlands (1/Year)
Default	Full model SES Grindelwald	C	average land holding (ha/household)
Default	Full model SES Grindelwald	A	average land holdings per household (ha/household)
Default	Full model SES Grindelwald	A	breeding progress (dmnl)
Default	Full model SES Grindelwald	C	Carrying Capacity (NST)
Default	Full model SES Grindelwald	C	Change Direct Costs / GVE (1/Year)
Default	Full model SES Grindelwald	C	Change Direct Payments (1/Year)
Default	Full model SES Grindelwald	C	Change in climate development (1/Year)
Default	Full model SES Grindelwald	C	change in milk yield when not summered (Year/NST)
Default	Full model SES Grindelwald	C	change in milk yield when summered (Year/NST)
Default	Full model SES Grindelwald	C	Change off-farm income opportunities (1/Year)
Default	Full model SES Grindelwald	C	Change Producer Prices (1/Year)
Default	Full model SES Grindelwald	C	Change Summering payments (1/Year)
Default	Full model SES Grindelwald	C	Change Wood Price (1/Year)
Default	Full model SES Grindelwald	A	cheese price (CHF/kg)
Default	Full model SES Grindelwald	F,A	clearing (ha/Year)
Default	Full model SES Grindelwald	A	climate change (degree/Year)
Default	Full model SES Grindelwald	A	climate change development (degree/Year)
Default	Full model SES Grindelwald	C	climate change normal (degree)
Default	Full model SES Grindelwald	L	Common Property Pastures (ha)
Default	Full model SES Grindelwald	C	compensation for additional provision (SFr/hour)
Default	Full model SES Grindelwald	T,A	consumer price index (dmnl)
Default	Full model SES Grindelwald	C	converter NST (NST/GVE)
Default	Full model SES Grindelwald	C	cost of agricultural workforce (CHF/person)
Default	Full model SES Grindelwald	A	cost of appropriation (CHF/NST)
Default	Full model SES Grindelwald	A	costs of herd (CHF/household)
Default	Full model SES Grindelwald	T,A	cultivated private parcels (ha)
Default	Full model SES Grindelwald	C	current appropriation contribution (CHF/NST)
Default	Full model SES Grindelwald	C	current cheese price (CHF/kg)
Default	Full model SES Grindelwald	C	current direct costs/GVE (CHF/GVE)
Default	Full model SES Grindelwald	C	current direct payments/GVE (CHF/GVE)
Default	Full model SES Grindelwald	C	current direct payments/ha (CHF/ha)
Default	Full model SES Grindelwald	C	current milk price (CHF/kg)
Default	Full model SES Grindelwald	C	current potential off farm income (SFr/person)
Default	Full model SES Grindelwald	C	current summering costs (CHF/NST)
Default	Full model SES Grindelwald	C	current summering payments (CHF/NST)
Default	Full model SES Grindelwald	C	current wood price (CHF/FM)
Default	Full model SES Grindelwald	A	daily fodder need per NST (kg/NST/day)
Default	Full model SES Grindelwald	A	daily milk yield of dairy cow (kg/day)
Default	Full model SES Grindelwald	F,A	defection (hours/Year)
Default	Full model SES Grindelwald	T,A	desired land use intensity (GVE/ha)
Default	Full model SES Grindelwald	A	direct costs/GVE (CHF/GVE)
Default	Full model SES Grindelwald	A	direct payments/GVE (CHF/GVE)
Default	Full model SES Grindelwald	A	Direct payments/ha (CHF/ha)
Default	Full model SES Grindelwald	A	discrepancy ratio (dmnl)
Default	Full model SES Grindelwald	F,A	duty fullfilment (hours/Year)
Default	Full model SES Grindelwald	T,A	effec of tourism on cheese price (dmnl)
Default	Full model SES Grindelwald	T,A	effect of climate on tourism (dmnl)
Default	Full model SES Grindelwald	T,A	effect of discrepancy ratio on farm abandonment (dmnl)
Default	Full model SES Grindelwald	T,A	effect of foregone summering payments on exludability (dmnl)
Default	Full model SES Grindelwald	T,A	effect of land holding on appropriation (dmnl)

Default	Full model SES Grindelwald	T,A	effect of land holding on fullfilment rate (dmnl)
Default	Full model SES Grindelwald	T,A	effect of land holding on herd adjustment (dmnl)
Default	Full model SES Grindelwald	T,A	effect of open pasture on productivity (dmnl)
Default	Full model SES Grindelwald	C	effect on climate change on growing season (days/degree)
Default	Full model SES Grindelwald	F,A	extra provision bought (hours/Year)
Default	Full model SES Grindelwald	F,A	farm abandonment (household/Year)
Default	Full model SES Grindelwald	L	Farm Household (household)
Default	Full model SES Grindelwald	F,A	farm succession (household/Year)
Default	Full model SES Grindelwald	C	fines (SFr/hour)
Default	Full model SES Grindelwald	A	fines payed (SFr)
Default	Full model SES Grindelwald	A	fodder requirements (kg/Year)
Default	Full model SES Grindelwald	C	fooder decay fraction (dmnl)
Default	Full model SES Grindelwald	T,A	foreign cattle allowance (dmnl)
Default	Full model SES Grindelwald	L	Forest (ha)
Default	Full model SES Grindelwald	A	forgone payoff-milk when summered (CHF/NST)
Default	Full model SES Grindelwald	A	forgone summering payments (CHF)
Default	Full model SES Grindelwald	C	fraction dairy cow (Year/GVE)
Default	Full model SES Grindelwald	C	fraction planed (1/Year)
Default	Full model SES Grindelwald	A	fullfilment rate (1/Year)
Default	Full model SES Grindelwald	A	growing season (days/Year)
Default	Full model SES Grindelwald	F,A	herd adjustment (GVE/household/Year)
Default	Full model SES Grindelwald	A	hired labor (person/household)
Default	Full model SES Grindelwald	A	household income (SFr/household)
Default	Full model SES Grindelwald	A	household income direct payments animals (SFr/household)
Default	Full model SES Grindelwald	A	household income livestock (SFr/household)
Default	Full model SES Grindelwald	A	household lifetime (Year)
Default	Full model SES Grindelwald	A	houshold stocking gap (GVE/household)
Default	Full model SES Grindelwald	A	in use ratio (dmnl)
Default	Full model SES Grindelwald	T,A	incentives for summering (dmnl)
Default	Full model SES Grindelwald	A	income land use (SFr/household)
Default	Full model SES Grindelwald	LI,C	INITIAL CPP (ha)
Default	Full model SES Grindelwald	C	INITIAL FODDER NEED per NST (kg/NST/day)
Default	Full model SES Grindelwald	LI,C	INITIAL FORREST (ha)
Default	Full model SES Grindelwald	C	INITIAL MILK YIELD (kg/day)
Default	Full model SES Grindelwald	LI,C	INITIAL OVERGROWN SUMMER PASTURES (ha)
Default	Full model SES Grindelwald	C	INITIAL PRODUCTIVITY (kg/ha/day)
Default	Full model SES Grindelwald	C	INITIAL PROVISION POTENTIAL (hours)
Default	Full model SES Grindelwald	LI,A	INITIAL PROVISION POTENTIAL I (hours)
Default	Full model SES Grindelwald	C	Initial summering season (days/Year)
Default	Full model SES Grindelwald	C	initial time to change land use (Year)
Default	Full model SES Grindelwald	C	labor potenital (person/household)
Default	Full model SES Grindelwald	A	labor productivity (dmnl)
Default	Full model SES Grindelwald	A	labor requirements (person/household)
Default	Full model SES Grindelwald	C	Lactation phase (day/Year)
Default	Full model SES Grindelwald	A	land discrepany (ha)
Default	Full model SES Grindelwald	A	land use incentive direct payments (GVE/ha)
Default	Full model SES Grindelwald	A	land use incentives (dmnl)
Default	Full model SES Grindelwald	L	Livestock Per Household (GVE/household)
Default	Full model SES Grindelwald	A	local stocking potenital (NST)
Default	Full model SES Grindelwald	A	local tourism index (dmnl)
Default	Full model SES Grindelwald	A	milk price (CHF/kg)
Default	Full model SES Grindelwald	A	milk sold per dairy cow (kg/Year)
Default	Full model SES Grindelwald	A	milk to cheese conversion factor (kg/kg)
Default	Full model SES Grindelwald	C	Minimum revenue needed for harvesting (SFr/FM)
Default	Full model SES Grindelwald	C	monitoring (1/Year)
Default	Full model SES Grindelwald	C	mortality rate (1/Year)
Default	Full model SES Grindelwald	C	normal appropriation rate (1/Year)
Default	Full model SES Grindelwald	C	normal household lifetime (Year)
Default	Full model SES Grindelwald	C	normal labor requirements livestock (person/GVE)
Default	Full model SES Grindelwald	C	normal labor requirments area (person/ha)
Default	Full model SES Grindelwald	A	normal land holding (dmnl)
Default	Full model SES Grindelwald	C	normal succession rate (1/fraction [0,1])

Default	Full model SES Grindelwald	T,A	normal tourism development (dmnl)
Default	Full model SES Grindelwald	A	off farm income (SFr/household)
Default	Full model SES Grindelwald	L	Owergrown Common Property Pastures (ha)
Default	Full model SES Grindelwald	A	pasture deficit (ha)
Default	Full model SES Grindelwald	A	pay-off appropriation (CHF/NST)
Default	Full model SES Grindelwald	A	pay-off cheese (CHF/Year)
Default	Full model SES Grindelwald	A	pay-off milk (CHF/Year)
Default	Full model SES Grindelwald	F,A	planed provision (hours/Year)
Default	Full model SES Grindelwald	A	plot annual fodder production (kg/ha/Year)
Default	Full model SES Grindelwald	A	potenital off-farm income (SFr/person)
Default	Full model SES Grindelwald	A	productivity of pastures (kg/ha/day)
Default	Full model SES Grindelwald	A	profit from livestock (SFr/household)
Default	Full model SES Grindelwald	L	Provision (hours)
Default	Full model SES Grindelwald	L	Provision Capacity (hours)
Default	Full model SES Grindelwald	F,A	provision executed (hours/Year)
Default	Full model SES Grindelwald	A	provision level (dmnl)
Default	Full model SES Grindelwald	C	provision requirements (hours/NST)
Default	Full model SES Grindelwald	A	rentability of wood harvest (dmnl)
Default	Full model SES Grindelwald	F,A	reopened (ha/Year)
Default	Full model SES Grindelwald	F,A	return to valley (NST/Year)
Default	Full model SES Grindelwald	C	sanctioning (Year)
Default	Full model SES Grindelwald	C	satysificing household income (SFr/household)
Default	Full model SES Grindelwald	A	scenario multiplier climate (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier costs of agricultural production (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier direct payments (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier off-farm income (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier producer prices (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier summering (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier tourism (dmnl)
Default	Full model SES Grindelwald	A	scenario multplier wood price (dmnl)
Default	Full model SES Grindelwald	A	search for foreign cattle (dmnl)
Default	Full model SES Grindelwald	C	season normal (day/Year)
Default	Full model SES Grindelwald	A	spendings on labor (CHF/household)
Default	Full model SES Grindelwald	L	Stocking (NST)
Default	Full model SES Grindelwald	A	stocking gap (NST)
Default	Full model SES Grindelwald	C	succession time (Year)
Default	Full model SES Grindelwald	A	summering fee (CHF/NST)
Default	Full model SES Grindelwald	A	summering payments (CHF/NST)
Default	Full model SES Grindelwald	A	surplus pasture (ha)
Default	Full model SES Grindelwald	C	time for provision (Year)
Default	Full model SES Grindelwald	C	time to adjust herd size (Year)
Default	Full model SES Grindelwald	A	time to change land use (Year)
Default	Full model SES Grindelwald	A	total livestock in the Valley (GVE)
Default	Full model SES Grindelwald	C	Tourism development (1/Year)
Default	Full model SES Grindelwald	C	wood harvesting cost (SFr/FM)
Default	Full model SES Grindelwald	A	wood price (CHF/FM)
Default	Full model SES Grindelwald	T,A	wood price index (dmnl)
Default	Full model SES Grindelwald	A	workload (dmnl)

List of 1 Non-Monotonic Lookup Function

Module	Group	Type	Variable (1)
Default	Full model SES Grindelwald	T,A	wood price index (dmnl)

List of 10 Variables Using IF...THEN...ELSE Functions

Module	Group	Type	Variable (0)
Default	Full model SES Grindelwald	F,A	abandonment (ha/Year)
Default	Full model SES Grindelwald	F,A	clearing (ha/Year)
Default	Full model SES Grindelwald	A	forgone summering payments (CHF)
Default	Full model SES Grindelwald	A	hired labor (person/household)
Default	Full model SES Grindelwald	A	off farm income (SFr/household)
Default	Full model SES Grindelwald	A	pasture deficit (ha)

Default	Full model SES Grindelwald	A	rentability of wood harvest (dmnl)
Default	Full model SES Grindelwald	F,A	reopened (ha/Year)
Default	Full model SES Grindelwald	A	spendings on labor (CHF/household)
Default	Full model SES Grindelwald	A	surplus pasture (ha)

Formulation Complexity Summary (Violations of Richardson's Rule)

Module	Group	Type	Variable	Complexity Score
Default	Full model SES Grindelwald	L	Common Property Pastures (ha)	4
Default	Full model SES Grindelwald	A	costs of herd (CHF/household)	4
Default	Full model SES Grindelwald	L	Provision Capacity (hours)	4
Default	Full model SES Grindelwald	A	household income livestock (SFr/household)	4
Default	Full model SES Grindelwald	F,A	clearing (ha/Year)	4
Default	Full model SES Grindelwald	F,A	appropriation of foreign cattle (NST/Year)	4
Default	Full model SES Grindelwald	A	fodder requirements (kg/Year)	4
Default	Full model SES Grindelwald	A	forgone payoff-milk when summered (CHF/NST)	4
Default	Full model SES Grindelwald	L	Owergrown Common Property Pastures (ha)	4
Default	Full model SES Grindelwald	A	pay-off cheese (CHF/Year)	4
Default	Full model SES Grindelwald	A	pay-off appropriation (CHF/NST)	4
Default	Full model SES Grindelwald	A	labor requirements (person/household)	5
Default	Full model SES Grindelwald	A	local stocking potenital (NST)	5
Default	Full model SES Grindelwald	A	cheese price (CHF/kg)	5
Default	Full model SES Grindelwald	A	potenital off-farm income (SFr/person)	5

List of 42 Equations with Embedded Data

Module	Group	Type	Variable (42)
Default	Full model SES Grindelwald	A	appropriation contribution (CHF/NST)
Default	Full model SES Grindelwald	A	breeding progress (dmnl)
Default	Full model SES Grindelwald	A	cheese price (CHF/kg)
Default	Full model SES Grindelwald	F,A	clearing (ha/Year)
Default	Full model SES Grindelwald	A	climate change development (degree/Year)
Default	Full model SES Grindelwald	A	costs of herd (CHF/household)
Default	Full model SES Grindelwald	F,A	defection (hours/Year)
Default	Full model SES Grindelwald	A	direct costs/GVE (CHF/GVE)
Default	Full model SES Grindelwald	A	direct payments/GVE (CHF/GVE)
Default	Full model SES Grindelwald	A	Direct payments/ha (CHF/ha)
Default	Full model SES Grindelwald	A	discrepancy ratio (dmnl)
Default	Full model SES Grindelwald	L	Farm Household (household)
Default	Full model SES Grindelwald	A	forgone summering payments (CHF)
Default	Full model SES Grindelwald	A	hired labor (person/household)
Default	Full model SES Grindelwald	LI,A	INITIAL PROVISION POTENTIAL I (hours)
Default	Full model SES Grindelwald	A	labor productivity (dmnl)
Default	Full model SES Grindelwald	L	Livestock Per Household (GVE/household)
Default	Full model SES Grindelwald	A	local tourism index (dmnl)
Default	Full model SES Grindelwald	A	milk price (CHF/kg)
Default	Full model SES Grindelwald	A	milk to cheese conversion factor (kg/kg)
Default	Full model SES Grindelwald	A	off farm income (SFr/household)
Default	Full model SES Grindelwald	A	pasture deficit (ha)
Default	Full model SES Grindelwald	A	potenital off-farm income (SFr/person)
Default	Full model SES Grindelwald	L	Provision (hours)
Default	Full model SES Grindelwald	A	rentability of wood harvest (dmnl)
Default	Full model SES Grindelwald	F,A	reopened (ha/Year)
Default	Full model SES Grindelwald	F,A	return to valley (NST/Year)
Default	Full model SES Grindelwald	A	scenario multiplier climate (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier costs of agricultural production (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier direct payments (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier off-farm income (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier producer prices (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier summering (dmnl)
Default	Full model SES Grindelwald	A	scenario multiplier tourism (dmnl)
Default	Full model SES Grindelwald	A	scenario multplier wood price (dmnl)
Default	Full model SES Grindelwald	A	spendings on labor (CHF/household)

Default	Full model SES Grindelwald	L	Stocking (NST)
Default	Full model SES Grindelwald	A	stocking gap (NST)
Default	Full model SES Grindelwald	A	summering fee (CHF/NST)
Default	Full model SES Grindelwald	A	summering payments (CHF/NST)
Default	Full model SES Grindelwald	A	surplus pasture (ha)
Default	Full model SES Grindelwald	A	wood price (CHF/FM)

List of 8 State Variables

Module	Group	Type	Variable
Default	Full model SES Grindelwald	L	Common Property Pastures (ha)
Default	Full model SES Grindelwald	L	Farm Household (household)
Default	Full model SES Grindelwald	L	Forest (ha)
Default	Full model SES Grindelwald	L	Livestock Per Household (GVE/household)
Default	Full model SES Grindelwald	L	Owergrown Common Property Pastures (ha)
Default	Full model SES Grindelwald	L	Provision (hours)
Default	Full model SES Grindelwald	L	Provision Capacity (hours)
Default	Full model SES Grindelwald	L	Stocking (NST)

List of 4 Unused Variables

Module	Group	Type	Variable (4)
Default	Full model SES Grindelwald	C	INITIAL PROVISION POTENTIAL (hours)
Default	Full model SES Grindelwald	A	land use incentive direct payments (GVE/ha)
Default	Full model SES Grindelwald	A	total livestock in the Valley (GVE)
Default	Full model SES Grindelwald	A	workload (dmnl)

List of 6 Views and Their 173 Variables*

	External Setting	Actor (A)	Governance System (GS)	Resource Units (RU)	Resource System (RS)	Levels	
Total:	**61**	**58**	**35**	**44**	**24**	**8**	**:Total**
abandonment (in 1 view)					X		abandonment (in 1 view)
afforestation (in 1 view)					X		afforestation (in 1 view)
agricultural income houshold (in 1 view)		X					agricultural income houshold (in 1 view)
agricultural price index (in 1 view)	X						agricultural price index (in 1 view)
appropriation contribution (in 2 views)	X			X			appropriation contribution (in 2 views)
appropriation of foreign cattle (in 1 view)				X			appropriation of foreign cattle (in 1 view)
appropriation of local livestock (in 2 views)			X	X			appropriation of local livestock (in 2 views)
availability of cattle in the lowlands (in 1 view)				X			availability of cattle in the lowlands (in 1 view)
average land holding (in 1 view)		X					average land holding (in 1 view)
average land holdings per household (in 1 view)		X					average land holdings per household (in 1 view)
breeding progress (in 1 view)				X			breeding progress (in 1 view)
Carrying Capacity (in 1 view)			X				Carrying Capacity (in 1 view)
Change Direct Costs / GVE (in 2 views)	X					X	Change Direct Costs / GVE (in 2 views)
Change Direct Payments (in 2 views)	X					X	Change Direct Payments (in 2 views)
Change in climate development (in 2 views)	X					X	Change in climate development (in 2 views)
change in milk yield when not summered (in 1 view)				X			change in milk yield when not summered (in 1 view)

change in milk yield when summered (in 1 view)				X			change in milk yield when summered (in 1 view)
Change off-farm income opportunities (in 2 views)	X					X	Change off-farm income opportunities (in 2 views)
Change Producer Prices (in 2 views)	X					X	Change Producer Prices (in 2 views)
Change Summering payments (in 2 views)	X					X	Change Summering payments (in 2 views)
Change Wood Price (in 2 views)	X					X	Change Wood Price (in 2 views)
cheese price (in 2 views)	X			X			cheese price (in 2 views)
clearing (in 1 view)					X		clearing (in 1 view)
climate change (in 1 view)	X						climate change (in 1 view)
climate change development (in 1 view)	X						climate change development (in 1 view)
climate change normal (in 1 view)	X						climate change normal (in 1 view)
Common Property Pastures (in 1 view)					X		Common Property Pastures (in 1 view)
compensation for additional provision (in 1 view)			X				compensation for additional provision (in 1 view)
consumer price index (in 2 views)	X	X					consumer price index (in 2 views)
converter NST (in 2 views)		X		X			converter NST (in 2 views)
cost of agricultural workforce (in 1 view)		X					cost of agricultural workforce (in 1 view)
cost of appropriation (in 2 views)		X		X			cost of appropriation (in 2 views)
costs of herd (in 1 view)		X					costs of herd (in 1 view)
cultivated private parcels (in 1 view)		X					cultivated private parcels (in 1 view)
current appropriation contribution (in 1 view)	X						current appropriation contribution (in 1 view)
current cheese price (in 1 view)	X						current cheese price (in 1 view)
current direct costs/GVE (in 1 view)	X						current direct costs/GVE (in 1 view)
current direct payments/GVE (in 1 view)	X						current direct payments/GVE (in 1 view)
current direct payments/ha (in 1 view)	X						current direct payments/ha (in 1 view)
current milk price (in 1 view)	X						current milk price (in 1 view)
current potential off farm income (in 1 view)	X						current potential off farm income (in 1 view)
current summering costs (in 1 view)	X						current summering costs (in 1 view)
current summering payments (in 1 view)	X						current summering payments (in 1 view)
current wood price (in 1 view)	X						current wood price (in 1 view)
daily fodder need per NST (in 1 view)				X			daily fodder need per NST (in 1 view)
daily milk yield of dairy cow (in 1 view)				X			daily milk yield of dairy cow (in 1 view)
defection (in 1 view)			X				defection (in 1 view)
desired land use intensity (in 1 view)		X					desired land use intensity (in 1 view)
direct costs/GVE (in 2 views)	X	X					direct costs/GVE (in 2 views)
direct payments/GVE (in 2 views)	X	X					direct payments/GVE (in 2 views)

Direct payments/ha (in 2 views)	X	X					Direct payments/ha (in 2 views)
discrepancy ratio (in 1 view)		X					discrepancy ratio (in 1 view)
duty fullfilment (in 1 view)			X				duty fullfilment (in 1 view)
effec of tourism on cheese price (in 1 view)	X						effec of tourism on cheese price (in 1 view)
effect of climate on tourism (in 1 view)	X						effect of climate on tourism (in 1 view)
effect of discrepancy ratio on farm abandonment (in 1 view)		X					effect of discrepancy ratio on farm abandonment (in 1 view)
effect of foregone summering payments on exludability (in 1 view)			X				effect of foregone summering payments on exludability (in 1 view)
effect of land holding on appropriation (in 1 view)				X			effect of land holding on appropriation (in 1 view)
effect of land holding on fullfilment rate (in 1 view)			X				effect of land holding on fullfilment rate (in 1 view)
effect of land holding on herd adjustment (in 1 view)		X					effect of land holding on herd adjustment (in 1 view)
effect of open pasture on productivity (in 1 view)					X		effect of open pasture on productivity (in 1 view)
effect on climate change on growing season (in 1 view)	X						effect on climate change on growing season (in 1 view)
extra provision bought (in 1 view)			X				extra provision bought (in 1 view)
farm abandonment (in 1 view)		X					farm abandonment (in 1 view)
Farm Household (in 2 views)		X		X			Farm Household (in 2 views)
farm succession (in 1 view)		X					farm succession (in 1 view)
FINAL TIME (in 0 views)							FINAL TIME (in 0 views)
fines (in 2 views)			X	X			fines (in 2 views)
fines payed (in 1 view)			X				fines payed (in 1 view)
fodder requirements (in 2 views)				X	X		fodder requirements (in 2 views)
fooder decay fraction (in 1 view)				X			fooder decay fraction (in 1 view)
foreign cattle allowance (in 1 view)			X				foreign cattle allowance (in 1 view)
Forest (in 1 view)					X		Forest (in 1 view)
forgone payoff-milk when summered (in 1 view)				X			forgone payoff-milk when summered (in 1 view)
forgone summering payments (in 1 view)			X				forgone summering payments (in 1 view)
fraction dairy cow (in 1 view)		X					fraction dairy cow (in 1 view)
fraction planed (in 1 view)			X				fraction planed (in 1 view)
fullfilment rate (in 1 view)			X				fullfilment rate (in 1 view)
growing season (in 3 views)	X			X	X		growing season (in 3 views)
herd adjustment (in 1 view)		X					herd adjustment (in 1 view)
hired labor (in 1 view)		X					hired labor (in 1 view)
household income (in 1 view)		X					household income (in 1 view)
household income direct payments animals (in 1 view)		X					household income direct payments animals (in 1 view)

household income livestock (in 1 view)		X					household income livestock (in 1 view)
household lifetime (in 1 view)		X					household lifetime (in 1 view)
houshold stocking gap (in 1 view)		X					houshold stocking gap (in 1 view)
in use ratio (in 1 view)					X		in use ratio (in 1 view)
incentives for summering (in 1 view)				X			incentives for summering (in 1 view)
income land use (in 1 view)		X					income land use (in 1 view)
INITIAL CPP (in 1 view)					X		INITIAL CPP (in 1 view)
INITIAL FODDER NEED per NST (in 1 view)				X			INITIAL FODDER NEED per NST (in 1 view)
INITIAL FORREST (in 1 view)					X		INITIAL FORREST (in 1 view)
INITIAL MILK YIELD (in 1 view)				X			INITIAL MILK YIELD (in 1 view)
INITIAL OVERGROWN SUMMER PASTURES (in 1 view)					X		INITIAL OVERGROWN SUMMER PASTURES (in 1 view)
INITIAL PRODUCTIVITY (in 1 view)					X		INITIAL PRODUCTIVITY (in 1 view)
INITIAL PROVISION POTENTIAL (in 1 view)			X				INITIAL PROVISION POTENTIAL (in 1 view)
INITIAL PROVISION POTENTIAL I (in 1 view)			X				INITIAL PROVISION POTENTIAL I (in 1 view)
Initial summering season (in 1 view)	X						Initial summering season (in 1 view)
INITIAL TIME (in 0 views)							INITIAL TIME (in 0 views)
initial time to change land use (in 1 view)					X		initial time to change land use (in 1 view)
labor potenital (in 1 view)		X					labor potenital (in 1 view)
labor productivity (in 1 view)		X					labor productivity (in 1 view)
labor requirements (in 1 view)		X					labor requirements (in 1 view)
Lactation phase (in 1 view)				X			Lactation phase (in 1 view)
land discrepany (in 1 view)					X		land discrepany (in 1 view)
land use incentive direct payments (in 1 view)	X						land use incentive direct payments (in 1 view)
land use incentives (in 1 view)		X					land use incentives (in 1 view)
Livestock Per Household (in 2 views)		X		X			Livestock Per Household (in 2 views)
local stocking potenital (in 1 view)				X			local stocking potenital (in 1 view)
local tourism index (in 1 view)	X						local tourism index (in 1 view)
milk price (in 2 views)	X			X			milk price (in 2 views)
milk sold per dairy cow (in 1 view)				X			milk sold per dairy cow (in 1 view)
milk to cheese conversion factor (in 1 view)				X			milk to cheese conversion factor (in 1 view)
Minimum revenue needed for harvesting (in 1 view)	X						Minimum revenue needed for harvesting (in 1 view)
monitoring (in 1 view)			X				monitoring (in 1 view)
mortality rate (in 1 view)				X			mortality rate (in 1 view)
normal appropriation rate (in 2 views)		X		X			normal appropriation rate (in 2 views)
normal household lifetime (in 1 view)		X					normal household lifetime (in 1 view)

normal labor requirements livestock (in 1 view)		X					normal labor requirements livestock (in 1 view)
normal labor requirments area (in 1 view)		X					normal labor requirments area (in 1 view)
normal land holding (in 3 views)		X	X	X			normal land holding (in 3 views)
normal succession rate (in 1 view)		X					normal succession rate (in 1 view)
normal tourism development (in 1 view)	X						normal tourism development (in 1 view)
off farm income (in 1 view)		X					off farm income (in 1 view)
Owergrown Common Property Pastures (in 1 view)					X		Owergrown Common Property Pastures (in 1 view)
pasture deficit (in 1 view)					X		pasture deficit (in 1 view)
pay-off appropriation (in 1 view)				X			pay-off appropriation (in 1 view)
pay-off cheese (in 2 views)		X		X			pay-off cheese (in 2 views)
pay-off milk (in 2 views)		X		X			pay-off milk (in 2 views)
planed provision (in 1 view)			X				planed provision (in 1 view)
plot annual fodder production (in 1 view)					X		plot annual fodder production (in 1 view)
potenital off-farm income (in 2 views)	X	X					potenital off-farm income (in 2 views)
productivity of pastures (in 1 view)					X		productivity of pastures (in 1 view)
profit from livestock (in 1 view)		X					profit from livestock (in 1 view)
Provision (in 1 view)			X				Provision (in 1 view)
Provision Capacity (in 1 view)			X				Provision Capacity (in 1 view)
provision executed (in 1 view)			X				provision executed (in 1 view)
provision level (in 2 views)			X		X		provision level (in 2 views)
provision requirements (in 2 views)			X	X			provision requirements (in 2 views)
rentability of wood harvest (in 1 view)	X						rentability of wood harvest (in 1 view)
reopened (in 1 view)					X		reopened (in 1 view)
return to valley (in 1 view)				X			return to valley (in 1 view)
sanctioning (in 1 view)			X				sanctioning (in 1 view)
satysificing household income (in 1 view)		X					satysificing household income (in 1 view)
SAVEPER (in 0 views)							SAVEPER (in 0 views)
scenario multiplier climate (in 1 view)	X						scenario multiplier climate (in 1 view)
scenario multiplier costs of agricultural production (in 1 view)	X						scenario multiplier costs of agricultural production (in 1 view)
scenario multiplier direct payments (in 1 view)	X						scenario multiplier direct payments (in 1 view)
scenario multiplier off-farm income (in 1 view)	X						scenario multiplier off-farm income (in 1 view)
scenario multiplier producer prices (in 1 view)	X						scenario multiplier producer prices (in 1 view)
scenario multiplier summering (in 1 view)	X						scenario multiplier summering (in 1 view)
scenario multiplier tourism (in 1 view)	X						scenario multiplier tourism (in 1 view)
scenario multplier wood price (in 1 view)	X						scenario multplier wood price (in 1 view)
search for foreign cattle (in 2 views)			X	X			search for foreign cattle (in 2 views)

season normal (in 1 view)				X			season normal (in 1 view)
spendings on labor (in 1 view)		X					spendings on labor (in 1 view)
Stocking (in 2 views)			X	X			Stocking (in 2 views)
stocking gap (in 2 views)			X	X			stocking gap (in 2 views)
succession time (in 1 view)					X		succession time (in 1 view)
summering fee (in 3 views)	X	X		X			summering fee (in 3 views)
summering payments (in 2 views)	X		X				summering payments (in 2 views)
surplus pasture (in 1 view)					X		surplus pasture (in 1 view)
Time (in 4 views)	X	X	X	X			Time (in 4 views)
time for provision (in 1 view)			X				time for provision (in 1 view)
TIME STEP (in 1 view)			X				TIME STEP (in 1 view)
time to adjust herd size (in 1 view)		X					time to adjust herd size (in 1 view)
time to change land use (in 1 view)					X		time to change land use (in 1 view)
total livestock in the Valley (in 1 view)		X					total livestock in the Valley (in 1 view)
Tourism development (in 2 views)	X					X	Tourism development (in 2 views)
wood harvesting cost (in 1 view)	X						wood harvesting cost (in 1 view)
wood price (in 1 view)	X						wood price (in 1 view)
wood price index (in 1 view)	X						wood price index (in 1 view)
workload (in 1 view)		X					workload (in 1 view)
Total:	**61**	**58**	**35**	**44**	**24**	**8**	**:Total**
	External Setting	Actor (A)	Governance System (GS)	Resource Units (RU)	Resource System (RS)	Levels	

*** Includes *Time*, if used in a view. Excludes variables not present in any view.**

Level Structure †

Common Property Pastures = ∫clearing+reopened-abandonment *dt* + [INITIAL CPP]
INITIAL CPP = 4375
abandonment = IF THEN ELSE(surplus pasture<Common Property Pastures, surplus pasture/time to change land use, Common Property Pastures/time to change land use)
clearing = IF THEN ELSE(Owergrown Common Property Pastures=0, IF THEN ELSE(pasture deficit<Forest, pasture deficit/time to change land use,Forest/time to change land use), 0)
reopened = IF THEN ELSE(pasture deficit<Owergrown Common Property Pastures:AND:Owergrown Common Property Pastures>0, pasture deficit/time to change land use, Owergrown Common Property Pastures/time to change land use)

Farm Household = ∫farm succession-farm abandonment *dt* + [242]
farm abandonment = Farm Household/household lifetime
farm succession = farm abandonment*(normal succession rate*discrepancy ratio)

Forest = ∫afforestation-clearing *dt* + [INITIAL FORREST]
INITIAL FORREST = 2130
afforestation = (Owergrown Common Property Pastures)/succession time

Livestock Per Household = ∫herd adjustment *dt* + [6.3]
herd adjustment = (houshold stocking gap*effect of land holding on herd adjustment)/time to adjust herd size

Owergrown Common Property Pastures = ∫abandonment-(reopened+afforestation) *dt* + [INITIAL OVERGROWN SUMMER PASTURES]

INITIAL OVERGROWN SUMMER PASTURES = 163

Provision = ∫(duty fullfilment+extra provision bought)-provision executed *dt* + [16000]
duty fullfilment = Provision Capacity*fullfilment rate
extra provision bought = (fines payed/compensation for additional provision)/time for provision
provision executed = Provision/time for provision

Provision Capacity = ∫planed provision-(defection+duty fullfilment) *dt* + [(INITIAL PROVISION POTENTIAL I)]
INITIAL PROVISION POTENTIAL I = (Carrying Capacity*1.1)*provision requirements
defection = Provision Capacity*(1-fullfilment rate)
planed provision = (provision requirements*Stocking)*fraction planed

Stocking = ∫(appropriation of local livestock+appropriation of foreign cattle)-return to valley *dt* + [1474]
appropriation of foreign cattle = stocking gap*(search for foreign cattle*availability of cattle in the lowlands*incentives for summering)
appropriation of local livestock = local stocking potenital*(normal appropriation rate*effect of land holding on appropriation)
return to valley = Stocking*(1-mortality rate)

† ***Level Structure Report*** **still under development.**

Source file: Full model SES Grindelwald.mdl (7/21/14 - 12:04 PM)
SDM-Doc Tool Version 4.9.6
Decision and Information Sciences Division
Argonne National Laboratory

Formative Scenario Analysis

We selected eight variables of the external setting and respective potential values of variables based on the literature review and previous work conducted in the study region (Baur, Liechti, and Binder unpublished manuscript). The variable set and hypothetical values were then validated in expert interviews and refined afterwards. Based on the validated impact factors and potential future levels, we constructed the impact matrix.

		Direct payments			Summering payments			Prices for dairy products		Direct cost		Off-farm income opportunities		Tourism development			Climate		Wood price	
		normal	-50%	50%	25%	50%	-50%	-20%	30%	-10%	40%	normal	-25%	boom +25%	normal	-40%	normal	increase (2°	50%	200%
Direct payments	normal																			
	-50%																			
	50%																			
Summering payments	25%	0	0	0																
	50%	0	-1	0																
	-50%	-1	0	-1																
Prices dairy products	-20%	0	-1	1	0	1	-1													
	30%	0	0	-1	0	-1	0													
Direct cost	-10%	0	0	0	0	0	0	0	0											
	40%	0	0	1	0	0	0	0	0											
Off-farm income opportunities	equal	0	0	0	0	0	-1	0	0	0	1									
	-25%	0	1	0	0	0	0	-1	0	0	-1									
Tourism development	boom +25%	0	0	0	0	0	-1	-1	1	0	0	1	-1							
	normal	0	0	0	0	0	0	0	-1	0	-1	1	-1							
	-40%	0	0	0	0	1	-1	0	-1	0	0	-1	1							
Climate	normal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
	increase (2°Celsius)	0	0	1	0	0	-1	-1	0	1	0	1	0	1	-1	-1				
Wood price	50%	0	0	0	0	0	0	-1	0	0	0	1	0	0	0	0	0	-1		
	200%	0	0	0	0	0	-1	-1	1	-1	0	1	-1	0	0	0	-1	1		

Fig. 8. *Completed consistency matrix with consistency scale from –1 to 2: –1 = Parameter value x does not occur in conjunction with parameter value y; 0 = Parameter value x possibly occurs in conjunction with parameter value y; 1 = Parameter value x supports occurrence of parameter value y; 2 = Parameter value x induces parameter value y.*

The impact matrix was completed four times in total by 10 experts, including agronomists, farmers, and tourist officials. Each expert filled in only the parts of the matrix that corresponded to his or her field of expertise. The completed matrices were then computed using KD software provided by Syst^{aim}. The program is analogously developed to the impact matrix shown in Fig. 8. Computing reduced the set of scenarios to the most consistent but also differentiated the parameter combination to cover a wide range of possible developments. Consistency indicators for scenario selection included (i) additive consistency, which is the sum of all coefficients, (ii) multiplicative consistency, which is the average rate of additive consistency, (iii) the number of inconsistencies in a scenario, (iv) and the minimum number of

of inconsistencies in a scenario, (iv) and the minimum number of consistencies (Tietje 2005). Out of the 864 possible scenarios, we identified 21 scenarios that had a multiplicative consistency between 0 and 9.5, an additive consistency value ranging from 4 to 8, and an inconsistency value ranging from 0 to 3, a minimum number of consistencies of 0. To further decrease the number of the scenarios, we calculated the distance between scenarios that is described by the number of different parameter values characterizing a scenario (Tietje 2005). This last step ensures that the analysis covers the widest possible development of the external setting among the consistent scenarios. Finally, the four most different of the 21 scenarios with the highest consistency were selected for simulation.

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