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Towards Adaptive Governance of Common-Pool Mountainous Agropastoral Systems

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Received: 18 March 2010; in revised form: 27 April 2010 / Accepted: 11 May 2010 /

Published: 26 May 2010

Abstract: The paper deals with analyses and propositions for adaptive governance of an alpine (A) and an Ethiopian (B) agropastoral system with common-pool pastures. Sustainability can be enhanced by augmenting (i) the ecological and social capitals in relation to costs and (ii) the resilience or adaptive capacity. In (A), a multifunctional agriculture appears to maintain the ecological capital providing many ecosystem services. In (B), the ecological capital can be increased by reversing the trend towards land degradation. In (A), there are several opportunities for reducing the high costs of the social capital. In (B), the institutions should be revised and rules should restrain competitive behavior. (A) and (B) exhibit a high degree of transformability. Many drivers appear to be responsible for the cycling of the agropastoral and higher level systems vulnerable to multiple stressors. Measures are proposed to escape from possible rigidity (A) and poverty (B) traps.

Keywords: sustainability; adaptive governance; ecosystem services; ecological and social capital; bioeconomic models; panarchy

1. Introduction

Grasslands are among the largest ecosystems in the world, contribute to the livelihoods of many people worldwide and yield ecosystem services (also called environmental services or nature's services), *i.e.*, benefits to humans, that contribute to making human life both possible and worth living [1]. Ecosystem services can broadly be classified into production, regulation and cultural services [2]. Specifically, grasslands provide food and forage, energy, wildlife habitat, storage of carbon and water, and protection of watersheds [3]. Grasslands are also important for *in situ* conservation of genetic resources of forage species, have high species richness and an aesthetic role and a recreational function as far as they provide public access that other agricultural uses do not allow and provide cultural services by contributing to a region's cultural heritage [3]. Permanent grassland comprises both permanent meadows and permanent pastures [4] that are often jointly managed by pastoralists as common-pool resources in that (a) the exclusion or the control of access of potential users is difficult and (b) each user is capable of subtracting from the welfare of others [5-7]. Some grassland belongs to long enduring sustainable agricultural systems that are characterized by common design principles [8]. To study common pool pasture management, a comparative approach has been found useful [9,10].

Like other natural resource management systems, agropastoral farms exploiting common-pool pastures can be qualified and managed with respect to sustainability or the capacity to endure [11]. While it is widely accepted that "sustainable development" is development that meets the needs of the present without compromising the ability of future generations to meet their own needs, the term "sustainability" has defied many attempts to provide a generally accepted definition. Hence, it is recommended to abandon the search for a singular, consensual definition and to try to make progress in the absence of a consensus [12].

Important progress has been made by recognizing the ecological, economic and social dimensions of sustainability in that the respective ecological, economic and social capitals can be defined [13]. In this context, sustainable development is the realization of potentialities for enhancing the capitals [14,15]. The ecological capital is the stock of ecosystems including biological diversity that yields a flow of services supporting human existence and enhancing human well-being [2,16,17]. The ecosystems are managed by an actor community characterized by social capital [18,19]. In absence of a generally agreed definition, the social capital may consist of shared norms or values that promote social cooperation instantiated in actual social relationships and precondition successful development [20,21]. Importantly, a strong rule of law and basic political institutions are necessary to build social capital [20,21]. The social capital has several components including the institutional and motivational capitals [9,22]. Economic capital refers to factors of production, including land, labor and capital goods (e.g., machinery), used to create goods or services, and is linked to both ecological and social sustainability [13]. In this context, sustainability is related to ecological, economic and social capitals and the costs involved in maintenance and growth. It can be enhanced by reducing maintenance costs and obtaining growth through mobilization of internal renewable resources rather than external inputs [23]. Ecological sustainability is a necessary prerequisite to global sustainability [13,24]. To achieve sustainable development, balanced sustainability enhancement in ecological, economic and social dimensions is indispensable [23].

Increasingly, ecological and social structures are combined into ecosocial (ecological-social) systems, in which the actors operate from within rather than from the outside [25]. This approach is seen as a shift in paradigm [26,27] and holds the promise to overcome the limitations of approaches seeking to optimize system components in isolation of others [28,29]. In general, ecosocial systems are hierarchically organized and their complex adaptive qualities lead to uncertainties and surprise in predicting the outcome of management [14,30,31]. In an ecosocial system context, sustainability is the capacity to create, test, and maintain the adaptive capability or resilience of the ecosocial system, and sustainable development can be achieved by fostering adaptive capabilities [28]. General resilience theory describes a conceptual model for socio-ecological resilience based on three system characteristics [32]: (a) the amount of disturbance a system can absorb and still retain the same structure and function, (b) the degree to which the system is capable of self-organization, and (c) the degree to which the system can build and increase the capacity for learning and adaptation. Ecosocial systems change in time and space under the influence of drivers, *i.e.*, natural or human-induced factors with direct or indirect effects [33]. During periods of steady progress, ecosocial systems move forward in roughly continuous ways, while at other times, change is abrupt, disorganized or turbulent [30]. The ecological vulnerability considers the projected changes in ecosystem services as exemplified by climate change compared with the current situation [34]. Social vulnerability to climate change and other types of change is loosely defined as an inability to cope with external pressures, leading to the potential for an adverse outcome [35]. In describing and analyzing evolving ecosocial systems, many scientists refer to the panarchy framework, in that panarchy is defined as the structure in which systems, including those of nature (ecosystems) and of humans (social systems), as well as combined human-natural systems (ecosocial systems), are interlinked in continual adaptive cycles of exploitation, conservation or consolidation, collapse or release, and reorganization [28]. Each level of the panarchy operates at its own pace, protected from above by slower, larger levels but invigorated from below by faster, smaller cycles of innovations [36].

Thus, the literature suggests that adaptive governance aiming at sustainability enhancement may be based on (a) the assessment of the actual capitals and their costs in ecological, economic and social dimensions, and (b) the recognition that the object is an evolving ecosocial system characterized by resilience. To take into account uncertainties and surprise [14,30,31], system management should rely on adaptive procedures focusing on change rather than on predefined objectives [28,30]. In adaptive management, the state of the system is periodically evaluated for the dual purpose of improving insight into the dynamics and for supporting the decisions for system navigation [37] or for shooting the rapids according to illustrative metaphor [38]. Governance is referred to when expanding the focus from adaptive management of ecosystems to address the broader social context of ecosystem management [30,39] and generally defined as the exercising of authority for planning and implementing actions or the creation of conditions for ordered rule and collective action or institutions of social organization [40]. Governance becomes adaptive when operationalized through adaptive management that emphasizes the role of social capital [30]. Hence, adaptive governance becomes a form of social coordination with self-organizing and -enforcing capabilities and relies on networks that connect individuals, agencies and institutions at multiple organizational levels [38,41]. Societies can improve adaptive governance through the continuous improvement of structures and processes by which they share power to shape individual and collective actions [41]. Adaptive governance may

respond to the need of undertaking gradual or radically different changes. The latter case requires that the ecosocial system is transformable, *i.e.*, has the capacity to create a fundamentally new system when ecological, economic, or social (including political) conditions make the existing system untenable [42].

This paper makes use of the advantages of comparative analyses [9,10] and deals with a Swiss Alpine and an Ethiopian mountainous agropastoral system, also referred to as site, with common-pool pastures as integral components. The Grisons (Switzerland) and the Gurage (Ethiopia) agropastoral system are selected because of our experience and interest in conducting additional analyses for making decisions [43-45]. The work assumes that the navigation of the two systems towards enhanced sustainability would benefit from adaptive governance [30,37]. As an entry point into adaptive governance, a qualitative analysis of readily available information may allow an evaluation of the state of the system and an identification of opportunities for enhancing (a) the actual ecological and social capitals in relation to the respective costs [23] and (b) the resilience or adaptive capacity [28]. The work on capitals and their respective costs on one hand focus on ecosystem service provision [1] and on the implementation of design principles of sustainable agricultural systems [8]. The work on resilience on the other hand assesses first the potential for transforming the systems into a new configuration [42] and evaluates subsequently the vulnerability and adaptive capacity through an analysis of long term adaptive cycles [28].

2. Methodology

2.1. Agropastoral Systems under Study

2.1.1. Alpine pasture systems in the Grisons

The Canton of the Grisons is located in southeastern Switzerland, where its 187,920 inhabitants (2006) enjoy a high standard of living. It covers 7,105 km² of almost entirely mountainous areas. The economy is based on tourism and agriculture where cattle husbandry contributes to the income of SFr 95 (\$90, March 15, 2010) per day for each of the about 3,000 farming families. Traditionally, alpine pastures were managed according to the Rhaeto-Romansh farming system, which is designed to battle against loss of fertile soils in the erosion-prone mountains. It is based on an agro-pastoral transhumance pattern with vertical seasonal shifting of farm activities, including hay production, focusing on the short growing and grazing season from spring to early fall [46]. The alpine pastures, which are equipped with buildings, roads and dairy processing, are managed by corporations and cooperatives who are represented by an elected master, respect maximum stocking rates and define the day of the beginning and end of the grazing period [47]. The cattle of a community are assigned to herds that are managed by a crew. The herds are allowed to graze around 100 days on alpine pastures while farmers back at their farms produce and stock hay for use in the winter. In the past decades, the traditional small-scale agricultural systems were replaced by a few centralized dairying and meat producing enterprises and the population dwindled more than 50% in the post World War II era through labor migration in search of better wage-paying opportunities [46].

The readily available literature provides important information on historical developments at the local (Grisons), regional and world levels [48-54]. Pasture exploitation in the Grisons dates back to the

Bronze Age and may have reached a high level in Roman times. Thereafter, socioeconomic conditions deteriorated in Europe and alpine pasture management may have suffered from drawbacks. In fact, the world was thrown in disarray and Europe entered a period of turmoil and cultural stagnation referred to as the Dark Ages [54]. This was not the case in Western Europe where the Gothic culture flourished and highly developed farming systems existed [53]. At the end of the fifth to the middle of the 10th century, the area of today's Grisons (Churrhaetia) pasture management reached another high level [52]. Contracts referring to stocking rates, conflict resolution mechanisms and access to pastures indicate that alpine pasture management was further developed until the end of the 15th century. However, from the 14th century onwards, the living conditions deteriorated and settlements in the Alps, maybe pastures as well, had to be given up and the people suffered from the multiple effects of climate change, inundations, Bubonic plague outbreaks, warfare and famine [53].

The period from the end of the 15th century to mid 19th century was a time of empire building and angst, new benefits and unconscionable cruelty [54]. Alpine pasture management in today's Grisons (Rhaetia) became difficult and a general decline occurred in the 18th century under the influence of multiple stressors. Nevertheless, there was a tendency to concretize and write management rules, confirm the ownership by communities and to define the responsibilities of farmer corporations. In 1803, Rhaetia was integrated as Canton of the Grisons into the Swiss Confederation. In the 19th century, after a series of flooding damaging the infrastructure, forests and agricultural land, cantonal institutions were charged with torrent control, forest protection and watershed management [48]. These measures and the construction of roads created more favorable conditions resulting in a shift from subsistence to commercial agriculture and in benefits from tourism and wage labor opportunities.

In the 20th century, favorable conditions existed and efforts were made to re-organize corporations and cooperatives and rationalize pasture management with financial and logistic support of the communities, the Canton and the Swiss Confederation [47]. Insurance schemes were set up to protect farmers from livestock losses, public investments into the infrastructure (roads, buildings, equipment) were made and regulations were introduced to establish an environment friendly agriculture. New functions arose, new users and new institutional layers emerged and the focus of management was no longer only a matter of producing fodder, but also of a more general concern for landscape and hydrogeological stability maintenance [55].

2.1.2. Tropical highland pastures in Gurage

Gurage is a Zone in the Ethiopian Southern Nations, Nationalities and Peoples Region (SNNPR) with an estimated total population of 1,557,074 (1997) on 5,932 square kilometers [56]. The semi-mountainous zone extends to the Awash River in the north, the Gibe River in the southwest and to Lake Zway in the east. 92,421 hectares (ha) are pastureland, while crops are grown on 359,715 ha [56]. The economy of the Gurage is largely based on subsistence farming and offers few opportunities for income generation and an increasing population lives in absolute poverty. 18% of the Gurage zone is exposed to malaria and 38% to tsetse transmitted trypanosomiasis diseases of cattle [56]. Gurage people grow enset (*Ensete ventricosum*), cereals and vegetables. Animal husbandry is practiced mainly for milk production and secondary for dung as fertilizer for enset [57]. The society operates on systems of rules dealing with how people should relate to each other [57]. The traditional

institutions include the Yeroka (Council of Elders, charged with administrative and juridical matters and authorized to settle external conflicts with other Yerokas), the Idir and the Mahber (both providing social assistance) and the Iqup (banking system). In addition, the farmers and their families are integrated into the political, administrative and juridical system of modern Ethiopia. There are community project committees (CPSs) providing various services to the farmers participating in development projects. Most of the livestock owners combine the animals into herds and practice rotational herding without reference to particular rules. In general, the land is owned by the government that is free to make pastureland available for other purposes. Until then, communities can use it on the basis of traditional/cultural understandings without written rules or agreements.

The readily available literature provides important information on historical developments at the local (Gurage), regional and world levels [54,56-61]. Ancient Ethiopia flourished through the Roman and Byzantine Empires before becoming isolated with long term negative effects on socio-economic development. The situation improved at unknown times, when Ethiopian rulers set up administrative structures during the establishment of Christianity. After suffering from setbacks, the living conditions were favorable again in the 16th century, as documented by the Portuguese Jesuit Francisco Alvarez who wrote in 1520: "It seems to me in all the world there is not so populous a country, and so abundant in corn, and herds of innumerable cattle" [57]. His fellow Jesuit Jerome Lobo noted in 1626 that "the climate is so temperate that at the same time I saw in some places ploughing and sowing, and in others the wheat already sprouting, while in others it was full-grown and mature, in others reaping, threshing, gathering, and again sowing, the land never tiring of continual production of fruits or failing in his readiness to produce them" [57].

Thereafter, until the late 19th century, the livelihood of the people suffered from multiple stresses including wars, disease outbreaks, famines, and from the lack of a formal political structure. The origins of the traditional institutions are unknown, but the Yeroka were solely responsible for judicial and administrative matters at that time [58]. Basically, Gurage was a subsistence economy, and cattle raiding was common. Richard Pankhurst, the renowned historian of Ethiopia, traced the incidence of one famine on average every decade after the 15th century [60].

The situation changed in the late 19th economy century with the beginning of urbanization, migrations into towns, the incorporation of Gurage into modern Ethiopia and the establishment of a subsistence/cash economy [59]. A feudal system, temporarily replaced by the rules of the Italian colonizers, existed until 1974, when the Emperor was deposed and Ethiopia proclaimed a Socialist state. By 1991, decline and state intervention in the agricultural economy culminated into a new upheaval, this time a rural response which changed, if only temporarily, the urban basis of governance [57]. Until today, warfare, droughts and famine continue to negatively affect Ethiopia's development.

2.1.3. Transformation

In the 1990s, the Swiss federal and the Grisons' cantonal authorities designed and implemented a series of programs to establish a multifunctional agriculture jointly producing commodities and non-commodities [62]. As a shift in agricultural policy, they were ready to finance ecological performances of farms. To evaluate the transformability of the ecosocial system, we focus on the well

documented program on the conservation of privately owned pastures and meadows with conspicuous flowers as indicators [45]. The so called “flower conservation program” heavily relied on the work of locally recruited facilitators who assisted the cantonal authorities in establishing an inventory and ensured that the interested farmers were meeting the requirements [45].

In 1995, an animal health improvement project was initiated in Gurage. In the Luke village, people suffer from many constraints including nutritionally unbalanced food, malaria and poor health of livestock. Nevertheless, the people gave priority to cattle health improvement through management of tsetse and tsetse transmitted trypanosomiasis [43,44]. Briefly, to manage tsetse and control the disease, odor baited monitoring and control traps were deployed and antitrypanosome drugs were administered to infested cattle. This was done by relying on a facilitation extension model where facilitators assisted the community to reach the objective of improved animal health [63,64]. The actions were undertaken in an adaptive management framework where the spatial distribution of tsetse was continuously monitored, the data subjected to geostatistical analyses, and control traps deployed accordingly [65]. During a 10 year period, ecological, economic and social indicators were monitored [43,44].

2.2. Analytical Framework

2.2.1. Ecological sustainability

As previously stated, ecological sustainability can be enhanced by augmenting the ecological capital and reducing the costs related to growth and maintenance [23]. The recent discussion on ecosystem services [1,2,17] and work on Himalayan pastures [66] is used for the development of the framework presented in Table 1. For supporting governance in enhancing ecological sustainability, we focus on production, regulation and conservation services rather than on production, regulation and cultural services [2]. Inspired by [67], we differentiate, for the same reason, between an intermediate service category and the here relevant final category that is linked to the benefit to people at the two sites. The level of service provision is used as an indicator for the amount of ecological capital, and the input into the system as an indicator for costs. The assessment of these indicators shows opportunities for better ecosystem service provision, and for ecological capital enhancement as well as for cost reductions to enhance the ecological sustainability.

2.2.2. Social sustainability

As previously stated, social sustainability can be enhanced by augmenting the social capital and reducing the costs related to growth and maintenance [23]. Social capital may consist of shared norms that can be viewed as statements that regulate behavior and act as informal social controls. They are usually based on some degree of consensus and are maintained through social sanctions. Long-surviving sustainable agricultural systems are governed by local rules and robust institutions that can be characterized by eight design principles [8]. To assess the degree of social sustainability, we evaluate the social arrangements, expressed in rules and institutions, implemented at the two sites and, briefly refer to the costs for maintenance and growth.

Table 1. Framework for a qualitative assessment of service provision by mountainous pasture ecosystems in the Grisons (Switzerland) and in semi-mountainous tropical highlands in Gurage (Ethiopia).

Inputs in the Grisons and in Gurage	Intermediate services	Final services	Benefits in the Grisons	Benefits in Gurage
Radiation, precipitation	Production of photosynthates	Forage	Meat, milk, butter, cheese, whey as pig feed	Some meat, milk, butter, traction
Pasture management in the Grisons: defined stocking rates and grazing periods, herd management, dung distribution on pastures, weed control and stone removal	Regulation Nutrient cycling	Soil fertility maintenance	Stable forage supply during grazing period, carbon sequestration	Limited forage supply and carbon sequestration
Pasture management in Gurage: herd management	Water retention	Water regulation and purification	High quality water for drinking, plant growth, irrigation, recreation, hydroelectrical power generation, flood mitigation	Water for drinking and some irrigation
	Soil stabilization	Erosion control	Protection of pastures and of residential and tourist infrastructures	Limited protection of pastures and infrastructures
	Conservation Genetic biodiversity	Conservation of genetic resources (livestock breeds)	Limited preservation of options, cultural benefits	Preservation of options, cultural benefits
	Species biodiversity	Conservation of forage species, rare flowers, wildlife	Preservation of options, productive pastures, hunting and fishing, cultural benefits	Preservation of options, pastures with limited productivity, cultural benefits
	Ecosystem biodiversity	Conservation of landscape beauty, identity, structure and function	Preservation of options, sustainable agriculture, attractive landscape, cultural benefits	Preservation of options

2.2.3. Transformability

The flower conservation program in the Grisons [45] is evaluated on the basis of the area under conservation management, farmer participation and the establishment of a facilitation system.

The ecosocial consequences of technology implementation at Luke (Gurage) were analyzed using a bioeconomic model [43,44,68,69]. Bioeconomic models are developed for better understanding pathways of development and for assessing the impact of alternative policies on the natural resource base and human welfare. Bioeconomic models integrate important biophysical information and ecological processes with economic decision behavior. Therefore, they are capable of addressing the effects of technology changes and trade-offs in sustainability objectives [70]. Here, we briefly refer to a model where the agropastoralists M_3 seek to maximize the present value utility U of individual consumption C from the revenue according to

$$\max_{C,D} \int_0^{\infty} e^{-\xi_{try} t} M_3 U(C) dt$$

The discount factor $e^{-\xi_{try} t}$ reflects the level of risk of trypanosomiasis, t is time, and D and C are the per capita demand and consumption rates, respectively. The maximization by all M_3 is subject to the constraints of the dynamics of cattle ($dM_2/dt = f(.)$) and agropastoralists ($dM_3/dt = f(.)$) populations [43,44]. In this paper, we exclusively summarize the findings of relevance for the evaluation of ecosocial transformability and refer the reader to [43,44] for an analysis of the model and for a discussion of the consequences resulting from risk reduction and conversion of cattle (M_3) into agropastoralists (M_3).

2.2.4. Vulnerability and adaptive capacity

The panarchy framework, allowing the study of a nested set of adaptive cycles at different scales, that exhibits cross-scale interactions, is used to assess the vulnerability and adaptive capacity of the systems [71]. The knowledge of factors that shaped adaptive cycles, and on points at which the systems are capable of accepting positive change and points where they are vulnerable, allows adaptive governance to make use of these leverage points to foster the sustainability and resilience within the ecosocial system [28].

During the past 2,000 years, the regional systems integrating the Grisons and the Gurage agropastoral systems and the rest of the world underwent substantial changes. Here, we tentatively identify drivers that shape long term adaptive cycles at local, regional and world levels and seek to qualify the interactions occurring between the cycles. Secondly, we assess the current state of the two systems for fostering ecosocial sustainability in adaptive governance [28].

3. Results and Discussions

3.1. Ecological Sustainability

Table 1 summarizes the framework for comparing the ecological sustainability of the two sites on the basis of ecosystem service provision, ecological capital and costs. With respect to production (Table 1), the Alpine pastures benefit from better management, but receive less radiation and precipitation and experience lower temperatures than the semi-mountainous tropical highland areas. However, Gurage faces a higher risk of droughts with serious consequences for cattle health and

human livelihoods. Irrespective of disadvantageous pedologic conditions, the annual primary production is higher in Gurage than in the Grisons and grazing is usually possible throughout the year. In the Grisons, the grazing period is restricted to pasture specific periods during the summer months. The annual primary production is around 1.5 t ha^{-1} in the Grisons while reaching about 2.0 t ha^{-1} in Gurage [72,73]. During a grazing period of 100 days [47], a cow in the Grisons produces 10 liters (L) of milk per day, while a Gurage cow only produces between 0.12 and 1.4 L milk per day (Table 3). The number of cows allowed on grazing areas is limited to less than 3 ha^{-1} in the Grisons [47], while Table 3 reports stocking rates between 1 (1995) and 9.7 (2005) in the Luke village of the Gurage zone. The data obtained at Luke are not sufficient to calculate precise stocking rates in Tropical Livestock Units (TLU); however, the stocking rate of 9.7 cows per ha is considerably higher than the recommended 2–5 TLU per ha for the Southern Ethiopian Highlands [74]. The possibilities for increasing the primary production in the Grisons may be limited. In Gurage, however, there is some potential for increasing the primary production and rationalizing animal husbandry [73]. The realization of these potentialities in Gurage may enhance ecosystem services in general (Table 3).

In the Grisons, the variety of goods is higher and a farming family earns about 7,000 USD from pasture management as compared to a Gurage family with an income of 183 USD per year.

With respect to regulation (Table 1), the intermediate ecosystem services provided in the Grisons result in maintaining soil fertility and water quality as well as controlling erosion. As a consequence, residents and tourists alike benefit from superior provision of final ecosystem services than the subsistence farmers in Gurage (Table 1). There, pastures are unable to provide comparable services because overstocking and a rapidly increasing population, land fragmentation, abject poverty and repeated cycles of drought and human tragedies lead to land degradation [75].

With respect to conservation (Table 1), the biodiversity of genetic, species and ecosystem levels appears to be better maintained in the Grisons than in Gurage and may better sustain the life support functions. Biodiversity conservation is important because ecosystem evolution, structure and functioning as well as ecosystem service provision are linked to biodiversity [1,76]. In the Grisons, the final services resulting from conservation efforts lead to a variety of benefits that appear to a limited extent in Gurage (Table 1). Our limited knowledge on life fulfilling or cultural services, depending upon human interpretation of the ecosystem and allowing recreation, cognitive development and spiritual reflection, is a hindrance to evaluate these services and compare the two sites (Table 1).

In general, biological diversity is highest under intermediate management levels [77]. This is apparently the case in the Grisons where, in contrast to Gurage, pastures appear to provide satisfactory services. On one hand, grasslands require periodic defoliation to control succession leading to unwanted plant communities [66]. On the other hand, overstocking and overgrazing lead to biodiversity losses and land degradation [66]. The strict application of rules limiting the stocking rates in the Grisons is a major element of the intermediate management scheme. The better integration of common-pool pasture management into farm management in the Grisons and the aforementioned public efforts to establish a multifunctional agriculture may also contribute to superior intermediate management schemes.

The evaluation and the recommendations show the potential of ecosystem service assessments for evaluating the ecological sustainability. Ecosystem service assessments as done here may be an entry

point into an adaptive governance process where more detailed data and quantitative analyses [78] could create a solid ground for the continuous improvement of system management [28].

From the general levels of service provision, we suspect that the Grisons have a higher ecological capital than Gurage. However, the maintenance of service provision and ecological capital comes at much higher costs. The infrastructure including access roads, milk processing and dairy production equipment, the transport of goods and the operations can only be financed through substantial public support (14 Mio SFr. equal to \$13 Mio, March 15, 2010) per year [47]).

In the Grisons, the tendency to centralize farming leads to the neglect of transhumance patterns and may decrease regulation services including the capacity to control erosion. In Gurage, modest ecosystem services are provided at increasing costs. Moreover, the ecological capital is low and tends to decrease, while the costs are small. In summary, the already low and ever decreasing ecological capital in Gurage and the already high and ever increasing financial costs as well as the neglect of transhumance patterns in the Grisons are major sources of unsustainability. The evaluation of ecosystem service provision provides some opportunities for its enhancement. To fully realize the potentiality of service provision, however, the analysis should be completed with quantitative measurements, analyses and valuation of services [78] and take into account direct use values (e.g., dairy products), indirect use values (e.g., positive externalities by benefits from tourism), option values (e.g., preservation of pastures and livestock breeds for the future) and non-use values (existence value, altruistic value, bequest value resulting from the translation of life fulfilling functions into benefits for residents and tourists) [2,17]. Governance should recognize that the pasture systems have public good aspects and for their services, markets have not been formed [17]. Instead, common pool pastures can be sustained on a wide variety of government created policy approaches based on legal/ethical tools, institutional innovations, command-and-control approaches, and economic incentive approaches [17]. However, excessive subsidization can reduce the capacity to self-organize and increase the vulnerability [9,79].

Governance in the Grisons should aim at strengthening multifunctional agriculture able to maintain the ecological capital and seek the valuation of the broad range of services to reduce the dependency on public financial support. In Gurage, governance should reverse the trend towards land degradation and implement measures aimed at the building-up of ecological capital. The list in Table 1 which includes maximum stocking rates and grazing periods may be helpful for this purpose.

3.2. Social Sustainability

Table 2 summarizes the design principles identified in long-surviving agricultural systems [8] and lists the existing arrangements in terms of institutions and rules. In the Grisons, written rules on maximum stocking rates and grazing periods prevent pasture degradation. Gurage people relate to each other on the basis of unwritten rules that do not prevent overstocking land degradation. Moreover, ownership and land use possibilities are defined in the Grisons but unclear in Gurage.

Table 2. The eight design principles of long-surviving agricultural systems [60] and their consideration in the social arrangements by agropastoralists in the Grisons, Switzerland, and Gurage, Ethiopia.

Design principles	Social arrangements in the Grisons Alpine pasture systems	Social arrangements in the Gurage tropical highland pasture systems
1. clearly defined boundaries for pastures	Existence at least since the Early Middle Ages, land-use defined	Boundaries not well defined and land-use changes possible
2. proportional equivalence between benefits and costs	Benefits vs. salaries of the crew and costs for pasture management activities (e.g., transport of dairy products and feed supplements, dung distribution on pastures) are not equivalent (see Table 1)	Benefits (milk, meat, dung, draught power) vs. costs of livestock production (including animal disease control) are presumably equivalent (see Table 1)
3. collective choice arrangements	Arrangements within farmers' institutions (e.g., corporations, cooperatives) on delimitation of pastures, maximum stocking rates, grazing rules, pasture management activities, dairy product sale, crew supervision) in accordance with political, administrative and juridical institutions at the community, regional and national levels. Pasture management is based on written regulations.	Arrangements between farmers and setting up of CPC's under the jurisdiction and administration of <i>both</i> the Yeroka (Council of Elders) and the political, administrative and juridical institutions at the community, regional and national levels. The social interactions among farmers are based on unwritten rules.
4. monitoring	Milk production per cow, milk and dairy product quality and grazing patterns	Milk production and cattle health
5. graduated sanctions	Overstocking, unsustainable practices (use of synthetic fertilizers and pesticides), inadequate milk and dairy product quality, refusal to accept responsibilities by members of the corporation	Actions in disagreement with rules and regulations may be sanctioned by both the Yeroka and the modern institutions at community, regional and national levels.
6. conflict resolution mechanisms	Discussions within the corporations or cooperatives, enforcement of laws and regulations by corporations, cooperatives, communities, the Canton of the Grisons and the Swiss Confederation	Discussions between farmers under the jurisdiction of both the Yeroka and the modern institutions at community, regional and national levels.
7. minimal recognition of rights to organize	Guaranteed	Accepted
8. nested enterprises	Pastures are a component of an individual farm (economic and social unit with membership in cooperatives or corporations) operating within a hierarchical organization of communities, the Canton and the Swiss Confederation	Pastures are a component of an individual farm (economic and social unit) operating under the jurisdiction and administration of the Yeroka and the modern institutions at community, regional and national levels.

The institutions at the two sites have hierarchal structures arranged on several levels. In the Grisons, agropastoralists operate within well established, nested and defined political, administrative and

juridical institutions. To name some without referring to their legal status, the agropastoralists are organized in cooperatives and corporations and operate within communal, cantonal and national institutions. Apparently, the traditional corporations were successfully integrated into modern institutions. In Gurage, however, the farmers belong to traditional organizations that have not been incorporated as yet into modern institutions giving rise to conflicts of interest. The better defined structures in the Grisons may be better suited to deal with conflict resolution than the Gurage institutions. Moreover, the Grisons farmers benefit from superior logistic and financial public support, have better access to better markets and receive superior professional education. All these advantages may contribute to a higher social capital in the Grisons.

Many rules as well as the corporations and cooperatives of the Grisons and the traditional organizations in Gurage are the result of self-organizing processes which are important elements of long surviving agricultural systems [8]. However, this is not the case for many authoritative rules (regulations) that are imposed by higher level institutions and are not fully understood and hence, not fully supported by the Grisons farmers and their organizations [49]. The imposition of such regulations could even be seen as a severely criticized top-down approach [79] and an attempt to stabilize a set of desirable goods and services that ultimately increase the vulnerability of the system to unexpected change [30,38]. Moreover, it could be viewed as an indicator for imbalanced connectedness between the farm and the cantonal as well as the national layer.

According to the “Tragedy of the Commons” [80], a herdsman will try to keep as many cattle as possible on the commons because he receives all the proceeds from the sale of the additional animal (positive utility) but shares the effects of overgrazing with all other herdsmen (negative utility). However, the “Tragedy of the Commons” is possible but not inevitable [5], since it may be avoided by the maintenance and augmentation of the social capital.

In the Grisons, the maintenance of rules and institutional structures may avoid the tragedy while only their revision may be able to prevent it in Gurage. In the Grisons, the decrease in population density of farming communes and an increasing unwillingness to accept responsibilities are serious hindrances to maintain the ecological and social capital. Inadequate rules, unclear structures and responsibilities as well as a low level of education may be the major obstacles to social capital augmentation in Gurage.

The maintenance of the social capital in the Grisons and its augmentation in Gurage comes at a cost. In the Grisons, the costs are much higher and linked, among others, to sustain institutions and provide various social services including education. The costs could be reduced by various means including the encouragement of self-organization and the substitution of the current advisory by a facilitation extension system, where a facilitator assists the agropastoralists in reaching their objectives [63,64]. In the Grisons, governance may seek to strengthen the subsidiarity, *i.e.*, a particular task should be decentralized to the lowest level of governance with the capacity to conduct it satisfactorily [5,81], limit top-down regulation, and better integration of agropastoralism into rural development aiming at maintaining population densities and institutions in agropastoralist communes. In Gurage, governance should seek a revision of current institutions, increase their diversity and implement rules that restrain competitive behavior and stimulate self-organization [5,8,44].

The evaluation and recommendations show the potential of Table 2 for evaluating the sustainability of institutions. The results are seen as an entry point into an adaptive governance process where more

detailed data and quantitative analyses could create a solid ground for the continuous improvement of system management [28].

Changing motivations in the context of new perspectives, challenges and conflicts of interests lead to ethical questions and reflections on the basis of duty-based (deontological system) and utilitarian (consequential) moral systems [82]. Governance at both sites should take into account the limits of the current predominant utilitarian value system and justify actions and decisions and a broader value system and encourage epistemological pluralism as well as cooperation in ecosocial system governance [82-85].

3.3. Transformability

Under the influence of external drivers (Swiss federal and cantonal authorities), the flower conservation program produced an inventory within four years (1992–1996) of 2,619.9 ha managed by 30% of the 3,000 farms in the Grisons. During this period, 39 facilitators were recruited, trained and integrated into the program [45]. The fast response of the farmers to new opportunities and the acceptance of facilitation as a new extension program by farmers, communes and cantonal authorities alike indicate a high degree of transformability of the ecosocial system. The contraction of the program after 1996 is mainly due to the decreasing logistic support by cantonal authorities. Thus, governance can rely on transformability but should face the challenge of sustaining the programs if the influence of the external driver decreases.

Under the influence of an external driver (the Nairobi-based International Centre of Insect Physiology and Ecology), the Luke ecosocial system underwent profound changes (Table 3). Cattle health, expressed in disease prevalence, and productivity were substantially improved, wide areas are being ploughed, the income increased, and a public school was established. However, the number of cattle increased 4.6 times, while the pastureland decreased by a factor of 1.5 at the expense of arable land. Inevitably, overstocking leads to overgrazing and land degradation. Moreover, the increasing human population augments the demand for food and ecosystem services.

Thus, governance can rely on transformability but should be aware of the profound ecological, economic and social changes to technology implementation. In fact, the bio-economic model predicts the rapid expansion of animal husbandry with reduced tsetse/trypanosomiasis pressure and resulting adverse effects on the base pastoral resource and an attendant reduced carrying capacity of the land as well as increasing economic capital as a result of lowering the trypanosomiasis risk and increasing the conversion of cattle into pastoralists (Table 3). In addition, the bio-economic model predicts, as observed, increases in human populations with reduced risk from tsetse/trypanosomiasis due to technologies that enhance system productivity. The model predicts, as observed, that increased surplus revenues can be used for economic consumption (e.g., schools, pest management, *etc.*). These investments required not only increased revenues, but also the development of additional social organizations that were not evident in 1995 when the first economic survey was taken. The higher level of school attendance also reflects a preparedness of the Luke population to adapt to change and to invest in the future (*i.e.*, to increase consumption). Of utmost importance is the demonstrated capacity to develop social structures that enable the community to respond to change leading to the development of self-organizing rules of organization [43,44].

Table 3. Response of the Luke (Gurage) ecosocial system to the implementation of tsetse management and trypanosomiasis control technologies. The project aimed at improving cattle health and succeeded in reducing the trypanosomiasis prevalence from 29% (1995) to about 10% (2005).

Sector	Categories	Variable	1995	2005	2006
CATTLE HUSBANDRY	population	total number of cattle	574	2,872	2,634
		number of oxen	3	136	201
	production reproduction	milk [$l\ day^{-1}\ cow^{-1}$]	0.12	1.30	1.40
		calving rate [$year^{-1}\ cow^{-1}$]	0.068	0.56	0.64
LAND USE	area of Luke	total area	1,500	1,500	1,500
	human food	area ploughed [ha]	12	506	546
	cattle food	area of pastures [ha]	440	295	295
SOCIO-ECONOMICS	population	number of households	524	524	544
		number of residents	1,834	2,620	2,645
	education	number of schools	0	1	1
		school children per household	0.03	0.42	0.62
		school attendance	10%	92%	94%
	income	income per household per month	15.6 USD	60 USD	148 USD

Currently, the disregard of the ecological dimension threatens to flip the Gurage ecosocial system into a configuration that is characterized by a domain of attraction causing long-term human suffering. It is unlikely that the ecological system will continue to sustain the progress made in economic and social dimensions. In fact, the bioeconomic model predicts a fast collapse of the system unless governance finds a societal solution for resource exploitation that maximizes the present value utility of individuals in ways that do not contribute to growth (consumption) and yet assures the persistence of the renewable resource over an infinite time horizon.

3.4. Vulnerability and Adaptive Capacity

During the past 2,000 years, the Grisons and Gurage pastoral systems, the regional systems and the world, underwent substantial changes. There are indications for adaptive cycles with periods of exploitation, conservation, collapse and re-organization. The ascertainment of these cycles and their explanation on the basis of different drivers [33], however, goes far beyond the scope of this paper.

On the world level, exploitation and conservation seems to fall into Roman and Modern times, and collapse and re-organization throughout the Middle Ages and the colonization period. With respect to the Grisons, however, there was also a period of exploitation and conservation in the High Middle Ages. At the regional African and the local Gurage levels, exploitation and conservation seems to fall only into two periods, *i.e.*, during Roman times and sometime before the period of colonization, while collapse and re-organization occurred twice, *i.e.*, after the decline of the Roman Empire and, importantly, from the period of colonization until today. As expected the Grisons and the Gurage cycles are closely linked to their respective regional cycles.

The cycling may result from a complex web of interactions between humans and their surroundings as humans seek to satisfy their basic needs and improve their well-being [33]. Among them are most likely climatic drivers characterized by a sequence of irregularly spaced global-scale cooling periods separated by global warming events and periods with relatively warm climates and favourable precipitation [86] as well as technological changes [43]. With respect to the Grisons and the respective regional level, the cooling periods appear to coincide with the phases of collapse and reorganization. At the Ethiopian regional and the Gurage local level, however, the coincidence occurred until the beginning of modern times, while at the world level, only classical and modern times appear to coincide with relatively warm conditions.

Disturbances are relatively discrete events that change the cycling. At all levels and both sites, bubonic plague outbreaks had a strong and long lasting effect and recovery was often slow. Likewise volcanic eruptions were disturbances with world-wide effects, but at least in modern times, the recovery was relatively fast. However, during the 17th century, a series of eruptions was responsible for summer cooling [87]. Unfavorable climatic conditions and disease outbreaks appear to coincide with other stressors including war, famine, and diminishing returns in natural resource acquisition [83]. The systems appear to have a high degree of resilience to deal with one disturbance but are vulnerable to the effect of multiple stressors. Therefore, governance should enhance the adaptive capacity of the systems and design as well as implement measures able to deal with multiple stressors if the need arises [83]. As predicted by the panarchy theory, the re-organization in Gurage and the Grisons, *i.e.*, the setting up of new institutions, the establishment of rules and the configuration of national structures occurred during difficult periods. The history of the Grisons furthermore suggests that local institutions such as the corporations were able to invigorate higher levels by innovations including the creation of political, administrative and legislative structures, while the history of Gurage reveals a limited influence from lower on higher levels with exceptions in the recent past.

Currently, both systems appear to have a limited adaptive capacity, *i.e.*, limited abilities to adjust to changing internal demands and external circumstances [88]. In the Grisons, the imposition of regulations on agropastoralists is seen as an indicator for unbalanced cross-scale relationships, while the apparently high connectedness and inflexible structures may be linked to an undesirable ecosocial state referred to as a rigidity trap [28,88,89]. The Gurage system on the other hand appears to experience difficulties to enter a re-organization phase, presumably because of being in an undesirable state referred to as poverty trap characterized by low potentials, limited connectedness and low resilience [28,88,89]. To make use of this information for fostering the sustainability and resilience within the ecosocial system [28], governance may consider the adoption of measures to reduce the high and inadequate connectedness and rigid as well as inflexible structures in the Grisons, and enhance the potential with a limited input of external resources and the connectedness in Gurage.

These observations may only scratch the surface of historical developments, but indicate a high potential for exploiting past experiences not only for adaptive governance of the agropastoralist systems discussed here, but even for planetary stewardship [90]. Furthermore, this work is limited to a qualitative assessment of the system's vulnerability. A quantitative analysis holds the promise to improve insight into the dynamics of the systems and to better support governance [91]. The analysis focuses on the transformability and adaptive capacities. As previously indicated, the general resilience theory describes a more comprehensive conceptual model for socio-ecological resilience [32].

Undoubtedly, the consideration of the general resilience theory has the potential to further strengthen the ground on which adaptive government is undertaken.

At this stage adaptive governance may take into account four clusters [31]: (a) learning to live with change and uncertainty, (b) nurturing various types of ecological, social and political diversity, (c) increasing the range of knowledge for learning and problem-solving, (d) creating opportunities for self-organization and building cross-scale linkages as well as problem-solving networks. Although not all clusters are explicitly supported by this analysis, they may nevertheless be useful for the adaptive governance of the two agropastoral systems.

As initially stated, societies can improve adaptive governance through the continuous improvement of structures and processes by which they share power to shape individual and collective actions [40,41]. The analysis of the two agropastoral systems enabled us to sketch out opportunities for more detailed work and make some tentative recommendations on structural and procedural changes for sustainability enhancement. However, only the process of adaptive governance, if adequately conducted at each site, holds the promise to further improve the insight into the dynamics of the two agropastoral systems and enhance the quality of recommendations.

4. Conclusions

The absence of generally accepted rigorous definitions is not a hindrance for improving adaptive governance to enhance sustainability [12]. Also in the case of extremely diverse ecosocial systems, a comparative analysis is useful for obtaining insights into the system's evolution, structure and functioning [9,10]. Adaptive governance aiming at sustainability enhancement benefits from the assessment and the identification of opportunities for enhancement of (a) the actual ecological and social capitals in relation to the respective costs [23] and (b) the resilience or adaptive capacity [30]. Thus, (a) and (b) may be the cornerstones of an emerging conceptual framework for study and adaptive governance of ecosocial systems in light of epistemological debates [85], pluralistic views [84], shifting paradigms [26,27] and diverging value systems [82]. As an entry point into adaptive governance, the framework, supported by qualitative analyses and experiences reported in the literature, can be constructed without reporting technical details of the components.

The work on ecological capitals and their respective costs allows the evaluation of ecosystem service provision [1], while the assessment of design principles of sustainable agricultural systems creates a basis for social capital enhancement with respect to costs [23]. The work on resilience allows the assessment of the potential for transforming the systems into a new configuration and subsequently evaluates the vulnerability and adaptive capacity through an analysis of long term adaptive cycles on the basis of the panarchy theory [28].

Alpine (Canton of the Grisons, Switzerland) Ethiopian (Gurage zone) agropastoral systems with common-pool pastures as integral components provide ecosystem services. In the Grisons governance should aim at strengthening the multifunctional agriculture to maintain the ecological capital and seek the valuation of the broad range of ecosystem services. In Gurage, governance should reverse the trend towards land degradation and implement measures, including limitations on stocking rates that aim at the building-up of ecological capital. In the Grisons, the costs of the social capital are much higher than in Gurage. To reduce costs, governance in the Grisons should encourage self-organization,

substitute the current advisory by a facilitation extension system, strengthen the subsidiarity, limit top-down regulation, and seek better integration of agropastoralism into rural development aiming at maintaining population densities and institutions in agropastoralist communes. In Gurage, governance should seek a revision of current institutions and increase their diversity of institutions and implement rules that restrain competitive behavior and stimulate self-organization.

The agropastoral systems under study exhibit a high degree of transformability [42]. This quality should facilitate adaptive governance aiming at increasing the adaptive capacity of the system and at overcoming the limitations of ecological and social unsustainability.

Several drivers may be responsible for the cycling of ecosocial and higher level systems that appear to be particularly vulnerable to multiple stressors [84]. Among the drivers are technological changes, climate change, volcanic eruptions, disease outbreaks, social unrest, warfare and famine. To escape from the rigidity and poverty traps, adaptive governance should re-configure the connectedness, revise the structures and the procedures for rule design and implementation. Moreover, adaptive governance should take into account the four clusters [31]: (a) learning to live with change and uncertainty, (b) nurturing various types of ecological, social and political diversity, (c) increasing the range of knowledge for learning and problem-solving, (d) creating opportunities for self-organization and building cross-scale linkages as well as problem-solving networks. The process of adaptive governance, if adequately conducted at each site, holds the promise to further improve the insight into the dynamics of the two agropastoral systems and enhance the quality of recommendations [30].

Acknowledgements

We are grateful to R. Kaiser, University of Zurich, for assisting us in the characterization of the Early Middle Ages in Churrhaetia, to Jürg Simonett, Rhaetic Museum, Chur, Switzerland, for discussing the historical development of agro-pastoral systems, to Woudyalew Mulatu (International Livestock Research Institute, Addis Ababa, Ethiopia) for providing important information on the Gurage pastures, and to Jürg Thürer, Landwirtschaftliches Bildungszentrum, Landquart, Switzerland, for making available socio-economic data on the Grisons farms. The useful comments and constructive criticism of unknown reviewers substantially improved the paper.

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