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Review

Swiss alpine summer farming: current status and future development under climate change

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Abstract. High altitude grazing is widespread around the globe and also has a long tradition in European mountain regions. One-third of the Swiss farmland consists of summer pastures: seasonally used marginal pastures without permanent settlements, which extend between the grasslands and forests of permanent mountain settlements and unproductive mountain tops. Farmers' main motivations for using those pastures have been and still are forage provision and health benefits for grazing animals, benefits for labour distribution between home farm and summer farm, and cultural ecosystem services such as the maintenance of a tradition and the associated lifestyle. Yet, remote pastures are being abandoned and are prone to reforestation, while more productive and accessible pastures are intensified. Those processes are related to changes in management practices, to scarcity of labour and – to a lesser extent – to climate change. We summarise the agronomic and ecological status of Swiss summer pastures, in particular with respect to livestock keeping, biodiversity and climate change, and speculate on future trends of summer farming.

Additional keywords: biodiversity, farmers' perception, marginal grassland, rangeland, rough grazing, seasonal grazing, transhumance.

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Introduction

High altitude grasslands in mountain regions are often grazed only seasonally. Herders move up to these regions with their animals during the favourable season – usually the summer – to use the forage that is available for a short period of the year. Such so-called vertical transhumance systems are common across all major mountain regions in the world (Suttie and Reynolds 2003; Bunce *et al*. 2004). In western, central, southern and northern Europe, more than four million hectares of grasslands are used through transhumance (Herzog *et al*. 2005). These are mostly located across the Alpine Arc and the Massif Central, the Carpathians, the Apennines, the Balkan and Greek mountains and the Pyrenees. In the boreal zones, such as in Norway, transhumance also occurs in mountains with lower elevation (Austad *et al*. 2004).

Transhumance links lowland and highland habitats. Together, they form two components of an integral system. Seasonally grazed mountain grasslands are among Europe's most prominent High Nature Value farming systems (Oppermann *et al*. 2012). Like many High Nature Value farming systems, however, seasonal mountain grazing is torn between abandonment and intensification. In the Atlantic mountains of the British Isles, for example, the tradition of seasonal grazing with migrating herds ceased 150 years ago (Jones and Wmffre 2004). Extensive mountain farming systems – like many rangeland systems – are threatened because they are relatively labour intensive but otherwise low input and low yielding, compared with other farming systems. Industrialisation of agriculture and globalisation require large quantities of standardised agricultural products, while seasonal summer farming yields smaller quantities of products with differing properties (e.g. cheeses of different types, consistency, taste, etc.). Still, they are often high-quality traditional specialties, linked to their geographical origin with, for example, a PDO (Product of Designated Origin) label. Also, many summer farming regions are, at the same time, attractive tourist destinations (Herzog and Schüepp 2013).

In Switzerland, the contrast between an industrialised society with a modern farming sector and the traditional summer mountain grazing practices is particularly striking. From most Swiss lowland cities, it takes less than 2 h to reach the summer farming region, where traditional, extensive herding is still practiced. In fact, 11% of the Swiss national territory (and one-third of its farmland) consists of summer pastures in the Alps and the Jura mountains. Despite their importance at the national scale for the farming sector, for mountain landscapes and related ecosystem services (e.g. biodiversity, soil protection), up-to date information on summer farming practices is limited. Research

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and land use statistics of the last decade reveal that the abandonment of summer pastures is ongoing (Baur *et al*. 2007). At the same time, grassland utilisation tends to be intensified at locations, even within the mountain zone, where the natural conditions are favourable, and which farmers can easily reach with their herds (Kampmann *et al*. 2008). The most recent national evaluation was collated by Werthemann and Imboden (1982), based mainly on inventory data recorded from the 1950s onwards. There was thus uncertainty about the current situation of summer farming in Switzerland, and there were conflicting visions about its future development and the attitudes of stakeholders and policymakers towards it. We therefore initiated a national research program entitled, 'AlpFUTUR – The future of Swiss summer pastures' (Baur *et al*. 2007; Seidl *et al*. 2015; www.alpfutur.ch). In all, 80 researchers conducted 22 individual projects, which addressed agronomic, environmental, socioeconomic and technical issues related to summer farming (Lauber *et al*. 2013). This article summarises the agronomic and ecological findings of the AlpFUTUR program, whereas Seidl and Böni (I. Seidl, R. Böni, unpubl.) look at societal implications of summer farming and Schulz *et al*. (2018) present the implications for economic viability and government support.

Status of summer farming in Switzerland

About 7100 summer farmers manage 465 000 ha, grazed by 700 000 animals (mostly cattle and sheep), which correspond to 290 000 livestock units. In most locations, the summer grazing season lasts on average for ~100 days between mid-June and end of August. Summer pastures are an only seasonally used belt of marginal pastures without permanent settlements, extending between the grasslands and forests managed from permanent mountain settlements and the mountain tops consisting of mostly rock and ice (Figs 1 and 2). Since the Middle Ages, significant amounts of forest have been cleared and converted to rangelands and, as a consequence, in many regions the actual tree line is several hundred meters below the potential upper limit of forest growth (Szerencsits 2012).

Farmers started to use the summer pastures because the additional forage they provide allowed armers to increase the size of their herds. This is still their most important motivation today, together with observed positive effects on animal health such as fertility and general fitness (Fig. 3). The third most important argument concerns the organisation of labour during the summer season. When employed herders or family members take care of the animals on the summer farms, the workload on the home farm is reduced and labour is freed for making hay and silage. Farmers also value the pleasure that they gain from staying and working in the alpine environment and the tradition of summer farming as such. Additional arguments (not shown in Fig. 3) are concerned with the profitability (including subsidies) and the actual products obtained during the summering season (see Schulz *et al*. 2018).

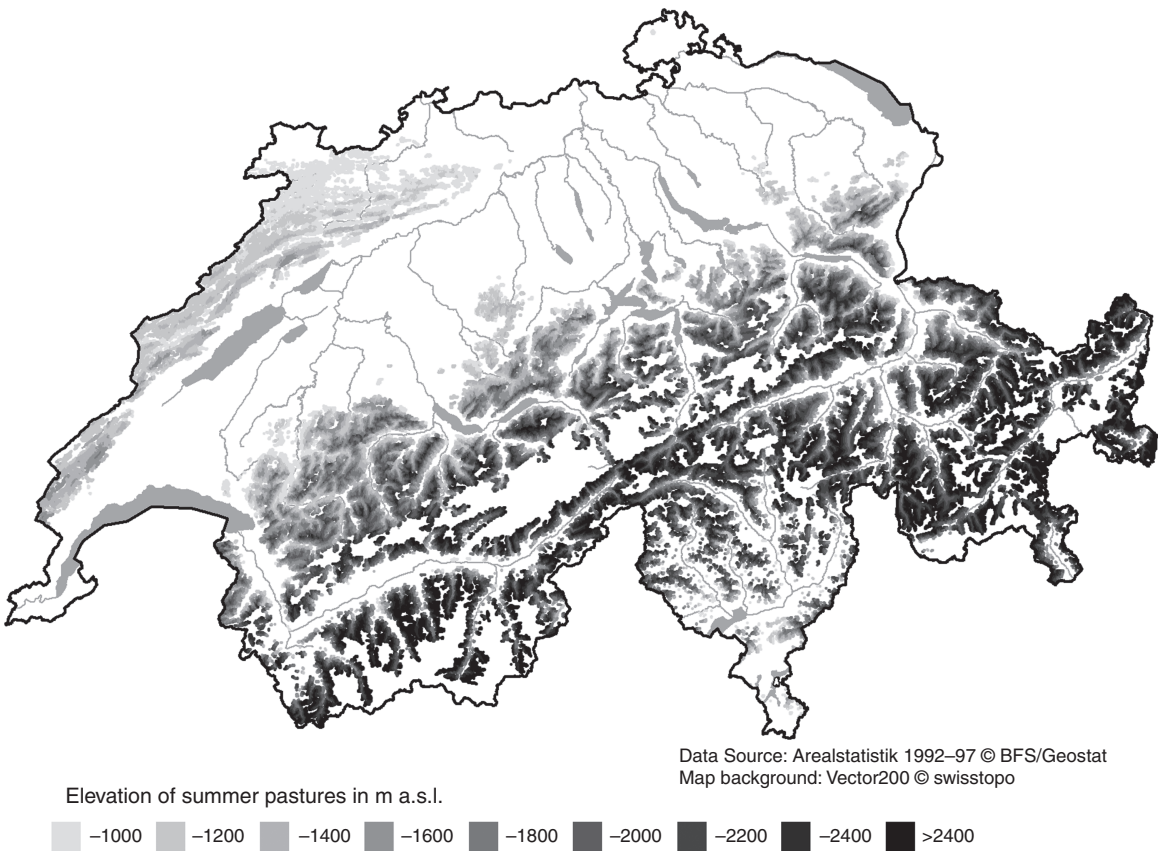

Fig. 1. Summer pastures in the Swiss Jura Mountains and Alps according to altitude. Ninety-five per cent of the summer pastures are located between 1000 and 2500 m a.s.l.

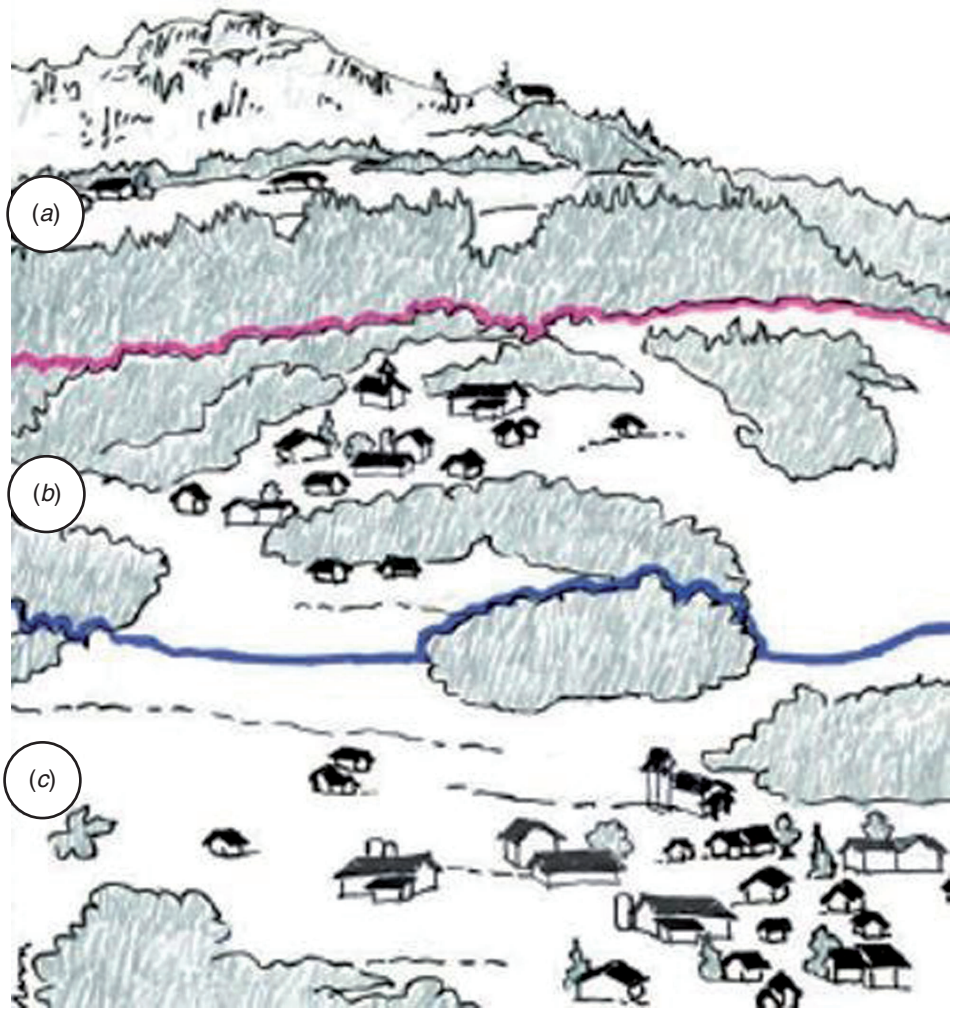

Fig. 2. Seasonally used and inhabited summer grazing belt (*a*) below the high alpine mountain zone. The (*b*) mountain zone and (*c*) the valley zone are permanently inhabited. Herders move up to the summer pastures in late spring and stay there for ~100 days. Source: Lauber *et al*. (2013).

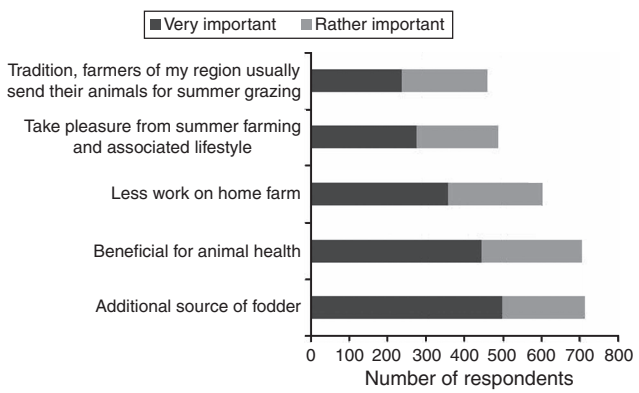

Fig. 3. Importance attached to reasons why farmers send (part of their) animals to summer farms. Results of a representative survey conducted in 2010 with 731 respondents. Source: Lauber *et al*. (2013).

Major agronomic and ecological challenges

Abandonment, intensification and biodiversity

Mountain grasslands worldwide are known to be particularly rich in species (Klötzli *et al*. 2010; Spehn *et al*. 2010). They host specific plants and animals that are adapted to the often harsh environmental conditions; therefore, mountain grasslands are among the biodiversity hotspots of the world (Fischer *et al*. 2008; Peter *et al*. 2009). This is also true for the Swiss summer pastures, on which three-quarters of the country's protected wetlands and dry meadows of national importance are located. Besides hosting 250 vascular plant species for which Switzerland has a specific responsibility, summer pastures host eight of the country's 12 endemic vascular plant species (Lauber *et al*. 2013). At the landscape scale, the different characteristic grassland habitats that are laid out in the variable mountain topography and are interspersed with forest islets, form a

characteristic and attractive landscape, which is a major asset of the national tourist industry.

However, those areas are threatened by both abandonment and intensification. Abandonment of marginal grassland has occurred in most European mountain regions over the last decades (e.g. Pornaro *et al*. 2013). In Switzerland, regional policy and the financial support to agriculture through agri-environmental schemes have slowed this trend and contributed to maintaining traditional farming practices (Kampmann *et al*. 2012). Nevertheless, ~2400 ha of summer pastures are invaded by forest every year (Brändli 2012), amounting to a loss of almost 30 000 ha over the last 25 years (BFS 2013). Based on a spatially explicit model by Rutherford *et al*. (2008), we projected the future trend and evaluated its implications for species diversity (Schüpbach *et al*. 2012). The model predicts that abandonment and afforestation will be highest in the southern and central Alps (Fig. 4). The south-eastern Alps, in particular, have the highest importance for plant and animal species that depend on traditional, extensive summer pasturing (Walter *et al*. 2010).

A detailed analysis of two specific summer pastures, however, revealed that increased habitat heterogeneity because of shrub encroachment increased the number of species and the ecological quality of the pastures (Koch *et al*. 2015). Fig. 5 illustrates that the number of vascular plants is highest on summer pastures that are overgrown by 50% of *Juniperus communis*. Homburger *et al*. (2013) have also found the highest numbers of vascular plants on summer pastures grazed at medium levels of intensity. Those findings support the intermediate disturbance hypothesis (Horn 1975); similar curves have also been observed in European and American mountain grasslands (Cingolani *et al*. 2003; Spiegelberger *et al*. 2006; Olofsson and Shams 2007; see also Stohlgren *et al*. 1999). Higher numbers of species of vascular plants were consistent with higher arthropod diversity (grasshoppers, butterflies; Koch *et al*. 2013*a*). At yet higher levels of shrub

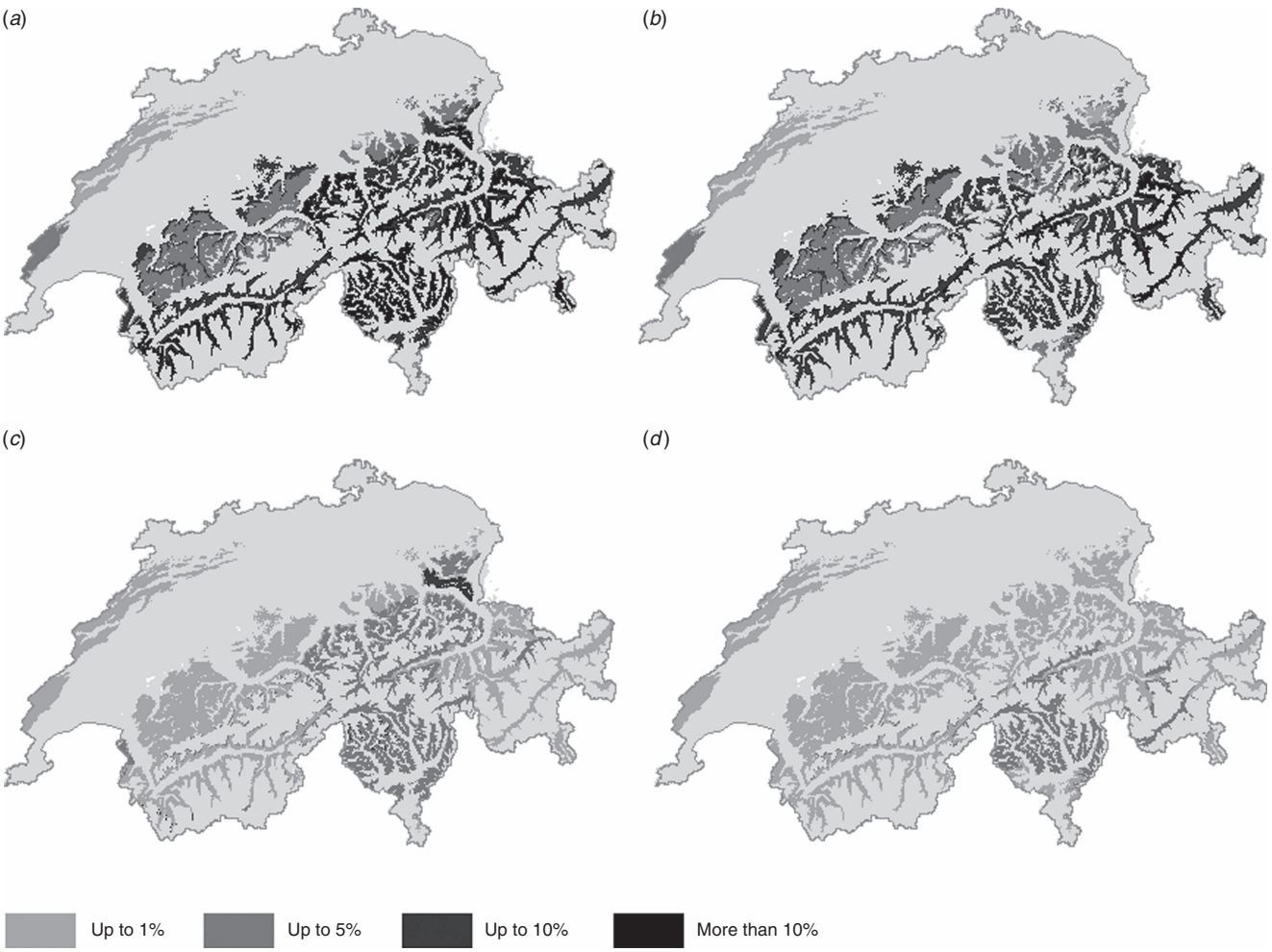

Fig. 4. Projected loss of summer pastures by 2021 due to tree and shrub growth. (*a*) Total reforestation, (*b*) reforestation with closed forest, (*c*) reforestation with shrubs, and (*d*) reforestation with open forest. Source: Schüpbach *et al*. (2012).

cover, however, biodiversity declined, the spectrum of species changed and the species typical of summer pastures disappeared (Koch *et al*. 2015). Keeping the shrub cover low on marginal rangelands has always been a challenge. It requires careful herding management to maintain a certain grazing pressure (see also Babái *et al*. 2014; with an example from the Carpathians). In most cases, manual or mechanical removal of shrubs is also required. Keeping up this active maintenance of summer pastures has become more difficult during the last decades. The main reasons are that, in Switzerland, labour has become more expensive and the structural change in agriculture has led to bigger home farms managed by fewer people: the number of mountain home farms has decreased by 50% since the 1980s (BFS 2016). Both the trend and its origins are observed throughout European mountain regions (see MacDonald *et al*. 2000; and references therein). During summer, farm families are busy working the more fertile farmland and little time is left for maintaining remote, marginal rangelands. Among the summer pastures, farmers tend to intensify – if feasible – the more productive and easily accessible sections. This also entails a decrease in biodiversity. In order to counteract both trends – abandonment and intensification – a result-oriented agri-environmental scheme has recently been introduced. It grants payments for those sections of the summer pastures that maintain a minimum number of target plant species (Bundesrat 2016; see Schulz *et al*. 2018).

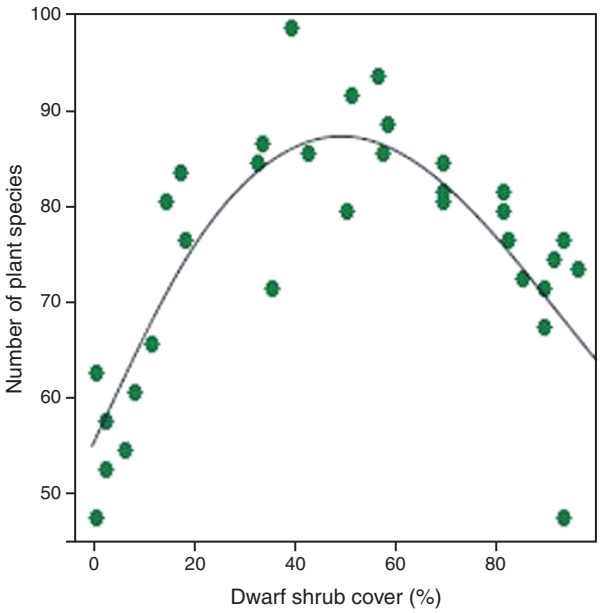

Fig. 5. Number of vascular plant species on 900 m^2 at an increasing share of shrub encroachment by *Juniperus communis* on the summer pasture of the municipality of Sura in the South-Eastern Alps. Source: Hofer *et al*. (2013). Vascular plants were recorded once per season during the height of the vegetation on nine systematically located 1-m^2 plots and the entire 900-m^2 plot was searched during 30 min for additional species.

Livestock keeping: intensity and feeding strategy

One reason for the loss of pastureland is the slight but continuous decrease in summering animals over the last decades (Baur *et al*. 2007). In particular, the number of milk cows and heifers has been reduced, and suckler cows have only partly replaced them. Among other factors, this can be explained by the increased performance of modern cow breeds. In fact, high-yielding dairy cows require more energy intake at higher altitudes (Christen 1992; Imfeld-Müller 2013) and therefore suffer on summer farms from an energy deficit, which leads to reduced milk yield at the beginning of the summering season. Attempts to compensate for this deficit with cereal and protein supplements have been only partially successful. On an alpine pasture in Italy (1900 m a.s.l.), Bovolenta *et al*. (2009) supplemented the cow diet with 4.8 kg of organic matter per day, resulting in an increase in milk yield of only 0.9 kg day^{-1}. The supplements actually reduce the intake of grass and the net energy intake is increased only at higher levels of supplementation (Berry 2000). On Swiss alpine pastures, supplements are regulated and limited to 1 kg day^{-1} per milk cow, mainly to limit nutrient imports to elevated mountain grasslands. High-yielding milk cows are less suitable for grazing steep and remote summer pastures, as already observed by Bovolenta *et al*. (1998), and often remain in the valley

Table 1. Overview on major grazing systems practiced on summer farms
Adapted from: Imfeld-Müller (2013)

Grazing type		Advantages	Drawbacks
Free grazing	No management of grazing animals, no fencing but delimitations by natural obstacles. Mostly practiced for sheep grazing (but in decline)	Low labour input	Heterogeneous utilisation of pasture (partly overgrazed, partly under grazed)
Extensively managed large paddock grazing	Grazing animals remain for a long time in one paddock, which is not subdivided. Maximum of three paddocks per summer farm	Animals can select the best fodder, relatively low labour input	Non-equilibrated utilisation of the pasture, important fodder losses (ungrazed parts)
Rotational grazing	Subdivision of the summer pasture in several smaller paddocks, which are then grazed for shorter periods at a time	Vegetation can re-grow between grazing periods; herd is easy to control.	Irregular availability of fodder, relatively high labour input
Continuous herding	Animals are continuously tended by a herder, who manages the herd and chooses the pastures to be grazed	Regular and targeted utilisation of the pasture, continuous surveillance of animals protects them from large predators and other threats	Very high labour input

Table 2. Summarised outcome of five qualitative interviews[A] on effects of climate change and other direct drivers with experienced extension officers and summer farmers across the Swiss summer farm region

Adapted from: Blanke and Herzog (2012)

Region	Central/Western Switzerland (Canton Berne)	Central Switzerland (Canton Obwalden)	South-eastern alps (Canton Grisons)	South-western alps (Canton Wallis)	Jura mountains (Canton Vaud)
Description of summer farming region					
Average elevation of summer pastures [m a.s.l.]	1300–1900	1100–2300	1700–2600	1900–2400	1100–1400
Precipitation (av. 1980–2009) [mm]	1350–1650	1550–2100	800–900	~650	1350–1700
Main animal categories	Milking cows, heifers	Milking cows, heifers	Heifers, milking cows, some goats	Milking cows, heifers, sheep	Milking cows, heifers
Management intensity	Average	Average (low on alps with moist pastures)	Low and declining	Low and declining	High
Interview partners	Extension officer, 40 years of experience	Extension officer, 30 years of experience	Extension officer and three farmers, 40 years of experience	Extension officer, 30 years of experience	Extension officer and three farmers, 50 years of experience
Climate change effects observed					
Beginning and duration of summering period	Tends to start ~5 days earlier: Earlier start of vegetation period and need to use young grass with higher quality	About a week earlier. Earlier start of vegetation period and less risky because the better road system allows to evacuate the cattle in case of late snowfall	Constant, no trend perceived	Slightly longer, mostly because of declining stocking rate. Start date mostly determined by traditions and customs	Earlier and up to 3 weeks longer. Need to use young grass with higher quality for high-yielding milk cows
Fodder quality and availability	Increased quality and quantity due to improved management and fertilisation. Increase of problematic weeds	Increased quality due to improved management and in spite of reduced fertilisation. Increase of problematic weeds	On well managed pastures: increased quantity observed. On underused pastures: increased biomass with low fodder quality	Reduced fodder availability on lower and south exposed pastures due to lack of water in spring. Increase of problematic weeds	Observed trend of reduced fodder quantity and quality due to reduced fertilisation. Increase of problematic weeds
Shrub and forest growth	Constant pressure, but increasingly by deciduous trees. Increased pressure by shrubs above the timber line	Loss of marginal pastures due to lack of management and possibly to longer duration of vegetation period	Faster growth of shrubs and trees even under constant management. Perceived increase of tree line	Increase of tree line, possibly due to warmer temperatures. Loss of pastures due to lack of management and to reduced grazing pressure	In last decades, woody pastures have turned into wood because of forest protection. Recently they have been cleared again

Water availability	Enough water, no trend	Enough water, no trend	Trend towards less water for cheese making and conservation. New wells have been dug	Meadows and pastures have traditionally been irrigated, Some new irrigations have been installed	Increasing lack of water for watering livestock, milk processing, personnel due to both, increased requirements and insufficient water capture because of more frequent extreme rainfall
Extreme weather events	Trend towards less snow, more thunderstorms and heavy rainfalls since 1980s. But still enough water available throughout the season	Increased intensity of thunderstorms, rainfalls, heat waves, dry periods (in spring). Earlier start of vegetation period and therefore higher risk of damage due to late frost	Extreme weather events seem to increase. After thunderstorms stronger water flow with stones and gravel, which are partly spread on the pastures	Increase of drought and of heavy rain. More landslides, at higher elevations due to melting of permafrost	Increased intensity of rainfall events. In some years pastures are dry already in spring because snow evaporates without melting. Animals need more drinking water during heat periods in summer
Expected future importance of climate change					
Overall expected importance of climate change	Low	Almost none. Difficult to differentiate from effects of management	Lower importance than management. But extreme events can have strong effects	Low. The high topographic variability of the alps offers enough alternatives (e.g. grazing in higher altitudes during dry periods)	Water may become a limiting factor. Is partly caused by increased requirement

[A]Five interviews were conducted, some with groups of several specialists: Central/Western Switzerland (1 person), Central Switzerland (2), South-eastern alps (3), South-western alps (1), Jura mountains (4).

throughout the year. Farmers who pursue a strategy of intensification and high levels of milk production lose interest in the tradition of summer farming.

Other farmers, however, consider such a strategy as risky, and instead maintain a medium intensity level of production. They also strive for diversification, sometimes with combinations of economic activities from outside the farming sector (e.g. part-time jobs in the tourist, building or forest industry). Usually, such farmers keep medium performing livestock and which are more suitable for summer farming, which has been shown to be beneficial for animal health and to increase cow fertility, such that (un-productive) periods between lactations remain short. Although heifers and fattening stock may gain less weight during the summering season, they exhibit compensatory growth once back in the valley (see also Bohman's 1955; experiment with different qualities of hay). Breeding cattle that had spent a summer period on alpine pastures had a higher milk yield during the first lactation compared with cattle that had remained on the valley farm (Imfeld-Müller 2013). Expected health benefits are among the most important reasons why farmers send their animals to summer pastures (Fig. 3).

Livestock keeping: grazing management strategies

Summer pastures are often rather large rangelands where the animals are free to move during the grazing period. Homburger *et al*. (2014, 2015) have shown that the utilisation of those grasslands can be quite heterogeneous, with some parts being intensively grazed while other parts are almost abandoned. This effect is often particularly observed on summer farms with sheep because sheep tend to aggregate at the upper parts of the summer pasture. These parts are then overgrazed, whereas the lower parts are hardly grazed. Rotational pastures and active herding allow for a better control of the grazing animals and of the quality of the pastureland (Table 1). Those systems, however, are more labour intensive and profitable only for larger herds (Schulz *et al*. 2018).

In recent years, new categories of animals have made their appearance on Swiss summer farms. Suckler cows are the most important of those new animal categories, but also oxen, donkeys, llama, alpaca and even geese are summered. Different animal categories have different effects on the vegetation, on account of their specific grazing behaviour, weight, etc. (Schneider *et al*. 2013). Loucougaray *et al*. (2004) recommend a combination of different animal categories in order to improve the rangeland management and to facilitate the maintenance of forage quality of the sward. In fact, combinations of goats and milk cows as well as of horses and cattle are successfully practised on various summer pastures and are even characteristic for some regions such as the Jura Mountains with free-ranging horses and cattle (Imfeld-Müller 2013). Additional combinations should also be tested in field experiments.

Climate change

Recent predictions for climate change in the Alpine Arc indicate that, by 2050, average temperature will rise by up to 2°C and precipitation will decrease, particularly during the summer months (CH2011 2011; Zubler *et al*. 2014). The magnitude of those effects, however, varies strongly between regions and

Table 3. Conceptual approach to factors that act in favour of either intensification or extensification/abandonment of summer pastures in Switzerland

	Intensification	Extensification/abandonment
Environmental conditions		
Topography and location	Flat areas at lower altitude, close to the summer farm with comparatively fertile soil	Steep pastures, remote and difficult access, poor soil conditions and risk of stone fall and loss of animals
Climate change	Increased productivity of the sward and longer summer farming period	Regionally longer drought periods and more frequent and violent thunderstorms
Agronomic and technological progress		
Husbandry animal breeding	Higher yielding animals require forage of higher quality and protein content	High-yielding animals are not adapted to graze high altitude, remote pastures of low forage quality
Mobile technologies	Mobile phones, GPS trackers, virtual fences, etc. may facilitate herding. This may help to prevent abandonment but should not lead to intensification	
Socioeconomic developments		
Decreasing number of mountain farms, increase in farm size		Scarcity of labour and increased availability of fodder at the home farm
Subsidies	Subsidies aim at maintaining the current status of summerfarming and at increasing the ecological quality of pastures. They aim at preventing both, abandonment and intensification	
Demand for labelled summer farm products	Good marketing opportunities for high quality cheese	

valleys. In order to obtain a more differentiated picture of the consequences of climate change, we interviewed experienced practitioners and agricultural extension agents from major regions in the Alps and the Jura mountains. We opted for a qualitative approach, in contrast to survey techniques (e.g. Nunoo and Akua Asiamah Nunoo 2016). We asked them whether they had perceived climatic trends over the last decades, what the consequences for summer farming were until now and what they possibly expected for the future. Their responses are summarised in Table 2.

It is evident that the results of such qualitative interviews have to be interpreted with caution. The farmers and extension officers themselves underlined that their evaluations may be affected by subjective perceptions. Yet, their responses are fairly consistent and can be summarised as follows:

– Over the last decades, the summer farming season has started earlier in the spring (by about a week). It also tends to last longer, but its duration is limited by the availability of forage.

– The overall productivity of summer pastures has increased, allowing for longer and/or more intensive pasturing. This can be due to both climate change and agronomic measures (fertilisation with organic manure, improved pasture management), and the effects of changing climate and land-use practices cannot be disentangled.

– Shrubs and trees also seem to grow more vigorously and the encroachment of marginal summer pastures by woody species appears to happen more rapidly.

– Water scarcity during the summering period has always been a limiting factor in the Jura Mountains and in the south-western and south-eastern Alps. In those regions, water scarcity has worsened during the last decades. Effects of water scarcity vary strongly at the small scale and depend on local elevation and exposition. This offers the opportunity to move animals from drier pastures to pastures where forage is still growing. Pipelines are being built to transport water to summer farms that regularly suffer from lack of water.

Some of those observations are confirmed by measured time series such as the decrease in snowfall since the 1980s (Laternser and Schneebeli 2003), earlier start of the vegetation period along with higher biomass production (OcCC 2007; Jonas *et al*. 2008; Rammig *et al*. 2010), a trend for the tree line to shift to higher altitudes (Gehrig-Fasel *et al*. 2007) and longer dry periods in the Jura mountains (Buttler *et al*. 2012).

At the large (regional) scale, summer pastures may become more important in years when forage growth is inhibited in the lowlands because of summer dryness. Grazing animals may then be moved to higher altitudes, including summer pastures, where there is still comparatively higher precipitation and more forage available. More flexible stocking strategies are recommended and observed as a strategy to adapt to climate change also in North America and South Africa (e.g. Derner *et al.* 2016; Samuels *et al*. 2016).

Conclusions and recommendations

Table 3 proposes a conceptual approach to factors that favour either intensification or extensification/abandonment of summer farming in Switzerland. Yet, summer farming is a tradition that farmers and policymakers want to maintain, despite its dependence on public support through subsidies. The major justification for those subsidies are the ecosystem services they help maintaining, namely the production of forage, biodiversity, landscape scenery and cultural values. Specific agri-environmental schemes targeting those services have recently been put in place by the government, in line with the recommendation resulting from the AlpFUTUR program (Schulz *et al*. 2018). Payments for summer-pasture biodiversity are result-oriented, which should increase the motivation of summer farmers to maintain species-rich pastures. To this end,

shrub encroachment and reforestation need to be controlled by combinations of manual labour and careful and targeted pasture management, which may also involve combinations of different animal species (Koch *et al*. 2013*b*). Best management practices are illustrated by three short AlpFUTUR films, in which summer farmers explain their herding strategies (Fry 2013; Herzog *et al*. 2016). Deliberate abandonment of remote or particularly steep or exposed sections, possibly even with targeted reforestation, will reduce the workload for summer farmers and may also reduce injuries and losses of grazing animals at sometimes hazardous locations.

Under climate change, forage production even on marginal summer pastures may gain importance. Although they will also be affected by reduced summer precipitation and higher temperatures, effects are expected to be less at high elevations compared with the lowlands. Because the topography is highly variable, many summer farms have pastures with differing exposures, and north-exposed pastures will be less affected by summer drought. This may lead to a renewed reliance of farmers on mountain summer pastures for forage production.

Conflicts of interest

The authors declare no conflicts of interest.

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