Effects of a flexible first mowing date on the biodiversity of extensively managed meadows - a case study from canton Bern, Switzerland

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Summary

The main Swiss agri-environment schemes aiming at supporting farmland wildlife are the so-called biodiversity promotion areas (BPA). One of the management constraints for extensively and less intensively managed meadows, which are by far the most abundant BPA types, specifies the cutting regime. In lowland regions, the date of the earliest possible cut according to the federal regulations is 15 June. However, since 2010 in the canton of Bern, farmers can freely choose the date of the first cut under an alternative cutting regime. This flexible cutting regime aims to increase the spatio-temporal heterogeneity of the first mowing date at the landscape scale to promote grassland species. In contrast, there is scientific evidence that delaying the date of the first cut has positive effects on plant- and animal species richness. In this controversial context, there is little knowledge to what extent the flexible cutting regime is applied at farm and landscape scale and how it affects biodiversity.

This study investigated how the flexible cutting regime is distributed in the landscape and how this eventually affects biodiversity. Data from the cantonal agricultural information system and a detailed online survey on the management of 778 extensively and less intensively managed BPA meadows from 236 farmers were analyzed. Results showed that meadows with flexible cutting regimes were mown on average 5-13 days before the official cutting date. Their spatial distributions appeared random within the landscape (no clustering of mowing regimes above a distance of 100 to 300 m, depending on the agricultural zone). In the lowland, 37.3% of the BPA meadows were managed with a standard cut in 2020 (first cut not before 15 June), and 46.3% were managed according to the flexible cutting regime. Lowland meadows did not differ in terms of ecological quality (based on indicator plant species). In contrast, a larger relative area with higher ecological quality in meadows with standard cut compared to meadows with flexible cut was found in mountain regions. Finally, the main reasons farmers cut earlier are to take advantage of a good weather period and obtain better fodder quality. More exhaustive vegetation and invertebrate surveys are required to fully assess the impact of the flexible cutting regime on the plant and invertebrate communities.

1 Introduction

In response to the loss of farmland biodiversity caused by agricultural intensification (e.g., Donald et al. 2001), agri-environment schemes (AES) were introduced and implemented in 1992 across all EU member states and in 1993 also in Switzerland (Kleijn and Sutherland 2003). These schemes financially support farmers for losses caused by implementing measures addressing biodiversity conservation, water management, and soil protection issues (Henle et al. 2008). In Switzerland, to receive direct payments, farmers have to meet specific ecological standards. Among others, at least 7% of the farmed area must be managed as biodiversity promotion areas (BPA, or *Biodiversitätsförderflächen* in German), representing the main Swiss AES dedicated to biodiversity. Specifically, BPAs are wildlife-friendly managed farmland habitats, such as extensively managed meadows or pastures, wildflower strips, orchards, and hedgerows. In 2020, 418 million Swiss francs were spent to support BPAs (BLW 2020a).

In this study, we focused on extensively and less intensively managed BPA meadows. Contribution for these types of BPA is rewarded with a predefined payment of 500–1'100 Swiss francs per ha per year (Appendix 1). According to the management requirements, farmers are not allowed to cut BPA meadows before 15 June in the lowland, and 1 and 15 July in the mountain zones I+II and II+IV, respectively. The later cutting date in the mountain zones is adapted to the delayed phenology at higher altitudes (BLW 2013). In addition to this input-based scheme and associated quality 1 (Q1) payment, an output-based (or results-based) scheme rewards higher botanical diversity with an additional quality 2 (Q2) payment (see subsection 2.1 and Appendix 1). The meadows' ecological (or botanical) quality is assessed based on the occurrence of indicator plant species.

Because of the predefined date of the first cut, most of the meadows are cut within a few days (the 15th of June is also referred to as the "federal hay-day"), causing homogenous landscapes, temporally depauperate of resources for grasslands invertebrates. An alternative cutting regime, allowing the farmers to choose the date of the first cut flexibly, has been implemented as a bottom-up initiative by farmers and experts since 2010 in several Swiss cantons, particularly in the canton of Bern. Accordingly, farmers are allowed to cut their BPA meadow before the official (federal) date if at least 10% of the meadow is left as an uncut refuge and the interval between the first and second cut is at least eight weeks. For farmers, more flexibility in choosing the date of the first cut bears the possibility to better adapt the mowing period to the weather conditions and prevent the hay from rotting (LANAT 2012). Furthermore, the earlier cut can help manage inedible or toxic weeds for livestock and increase the hay's nutritional value (Kirkham and Tallowin 1995, Blažek and Lepš 2015). The flexible cutting regime, therefore, offers an attractive alternative to the standard management.

From an ecological perspective, a flexible cut might prevent a region-wide homogenization of the first cut on BPA meadows and increase landscape heterogeneity (Diacon-Bolli et al. 2012). It can provide a simultaneous patchwork of mown and unmown meadow habitats and thus shelter and food resources for different species (Cizek et al. 2012, Humbert et al. 2012a). Although the positive effect of landscape heterogeneity in terms of different habitats has been widely reported in the scientific literature (Deutschewitz et al. 2003, Diacon-Bolli et al. 2012, Massaloux et al. 2020), no study has so far investigated the effects of heterogeneity in the first cutting date on regional grassland biodiversity. Likewise, no studies assessed the spatio-temporal distribution of the cutting dates of Swiss BPA meadows at the landscape scale.

In contrast to the potentially beneficial effects of a heterogeneous distribution of cutting dates, it has been discussed that a flexible cutting regime could cause an earlier date of the first cut (Walter et al. 2007). Such a shift to an earlier date causes possible harmful effects on some animal species as a mowing event directly harms less mobile species and destroys a substantial part of the meadow habitat, providing vegetation, resources, and refuges (Humbert et al. 2010, Cizek et al. 2012). Based on the thorough literature review, Humbert et al. (2012) concluded that delaying the first cut from spring (May-June) to summer (July-September) has positive or neutral effects on plant- and invertebrate species richness. Corollary, cutting the meadow earlier than 15 June would have negative or neutral effects. Especially nonclonal, late-flowering plant species can be interrupted in their life-cycle when meadows are cut before seed dispersal (Smith et al. 2002, Boob et al. 2019). Insect species with vegetation-dwelling larvae and late phenology are also likely to suffer from an earlier cut (van Klink et al. 2019).

Extensively managed meadows represent by far the primary BPA type in Switzerland, together with less intensively managed meadows, they represent 58% of the BPA area, corresponding to 78'174 ha in 2019 (BLW 2020b). To further improve the effectiveness of these BPA meadows and support species conservation, it is essential to assess how farmers implement cutting regimes and study how this affects biodiversity. We also need to know the main reasoning behind farmers' management actions to understand the possible consequences of changes in agricultural policies.

This study was initiated by and conducted in collaboration with the office of agriculture and nature of Bern (LANAT for "*Amt für Landwirtschaft und Natur*" in German). It aimed to assess management implementations on extensively managed and less intensively managed BPA meadows in the canton of Bern. More specifically, it investigated the date of the first cut under both cutting regimes and whether the flexible cut increases landscape heterogeneity. In addition, this study aimed to assess any evidence of any harmful effects of the flexible cut on biodiversity. The study was conducted in 2020 using spatially referenced agricultural information from the canton of Bern complemented with an online survey that was sent to a representative subgroup of farmers.

2 Methods

2.1 Meadow management and quality attestation

The meadows' management must follow the official nationwide regulations for biodiversity promotion areas (BPA) meadows. The meadow is cut at least once a year, and cuttings must be removed. Fertilizer application is allowed only on less intensively managed meadows and only in the form of organic manure or compost (maximum 30 kg N per ha and year). In addition to the national constraints, the canton of Bern specifies more detailed management guidelines for meadows in the framework of a networking project. During a project period, one of the official cutting regimes must be set on every BPA meadow (Appendix 2). These foresee that at least 10% of the meadow BPA is left as an uncut refuge and allow grazing from 1 September to 30 November. The standard cutting regime prescribes the earliest possible date of the first cut (15 June in lowland zones, 1 July in mountain zones I+II, and 15 July in mountain zones III+IV). In contrast, the flexible cutting regime does not restrict the first cutting date. As an additional constraint linked to the flexible cutting regime, a minimum interval of eight weeks is required between two cuts. If the nationwide conditions are met, and the meadows' cutting management follows Bern's official guidelines, by default, the meadow is registered with quality level 1 (Q1). Suppose six or more indicator plant species are present on a meadow division (within a 3 m radius representative area). In that case, this part of the meadow is attested additionally with quality level 2 (Q2) according to the assessment guidelines provided by the Federal Office of Agriculture (BLW 2013).

2.2 Data acquisition

GELAN data

The agricultural information system GELAN has been used in the cantons of Bern, Fribourg, and Solothurn since 1999. It stores and manages agricultural data in a geographical information system (GIS) and supports direct payment processing. Agricultural data on extensively (EXWI for *"Extensiv genutzte Wiese"* in German) and less intensively managed meadows (WIGW for *"Wenig intensiv genutzte Wiese"* in German) in the canton of Bern were used in this study. Both types of meadows will be referred to as BPA meadows hereafter. The used datasets contained detailed information on BPA meadows from 2012, 2018, 2019, and 2020, such as:

- BPA type: extensively managed meadows (EXWI) or less intensively managed meadows (WIGW)
- BPA area in hectare [ha]
- BPA area with ecological quality (Q2) in hectare [ha]
- Cutting regime: standard cut, staggered cut, flexible cut, single cut, spring pasture use, species-specific management (**Fehler! Verweisquelle konnte nicht gefunden werden.**2)
- Agricultural zone: plain-, hilly- and mountain zones I-IV

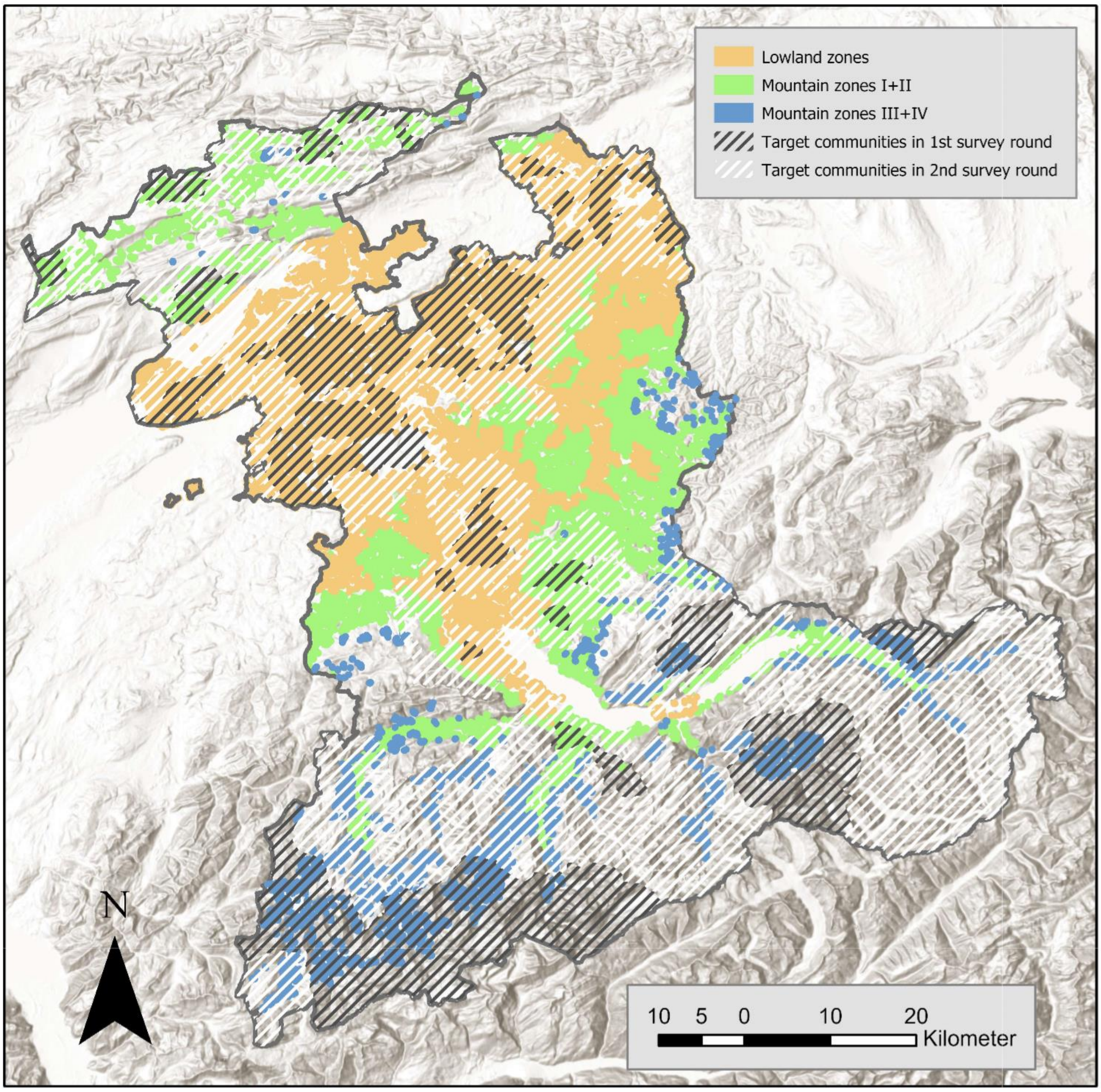
Limits of meadow parcels in the form of an ESRI shapefile were derived from the Swiss portal for geoinformation (www.geodienste.ch, December 2020).

Survey

The agricultural data from GELAN does not contain any details on the yearly management of BPA meadows, like the cutting dates, number of cuts, or whether grazing occurred. This information was collected in two online surveys using SurveyMonkey. The surveys were distributed via email. Appendix 3 summarizes the content of the two surveys.

A first survey round was conducted in June and July 2020 by LANAT. It targeted 57 Bernese communities, selected randomly from eleven networking projects and all agricultural zones (Figure 1). In the selected 57 communities, all 1’008 farmers with at least one BPA meadow registered with a flexible cut were addressed. The survey asked the farmers about the dates of the first cut in 2018, 2019, and 2020 of the farmer’s BPA meadows.

The second survey designed explicitly for this MSc study was conducted between November 2020 and January 2021. The survey addressed the remaining 989 farmers in the communities selected in the first survey and all 1’005 farmers from selected adjoining communities. In the second survey, farmers were asked about the dates of the first cut in 2018, 2019, and 2020. Additionally, they were asked about the number of uses (cutting and grazing) per year and why they chose the flexible cutting regime on their BPA meadows.



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Date of cut: Survey data Jan. 2021, Shapefiles: Amt für Geoinformationen des Kantons Bern Dec. 2020, Networking project perimeter: Geoportal des Kantons Bern Feb. 2021

Figure 1. Map of the canton of Bern with the different agricultural zones in orange (lowland zones), green (mountain zones I+II), and blue (mountain zones III+IV) and communities selected for the surveys shaded in black (first and second surveys) and in white (second survey only).

2.3 Statistical analysis

GELAN data, survey data, and geoinformation of the meadows were merged by joining the meadow parcel number (GEOID). Administratively, the area of a meadow reaching Q1 is equal to the meadow parcel size. For the analysis, the meadow area with Q1 but not Q2 is referred to as “Q1 area” and is calculated as: area reaching Q1 – (minus) area reaching Q2. Therefore, the total meadow size was Q1 area + Q2 area.

The data sets were analyzed using RStudio (Version 1.1.383) and ArcGIS pro 2.4.0. Meadows were grouped based on the official date of the first cut in the respective agricultural zone (Figure 1). The resulting three zones are called the lowland zones (the plain zone and the hilly zone), mountain zones I+II, and mountain zones III+IV. Analyses were performed separately for each of the three zones.

Spatial arrangement of cutting regimes

Spatial arrangement analyses focused on standard and flexible cutting regimes only. The distances at which the cutting regimes were spatially autocorrelated were estimated by fitting an exponential model using the 'gstat' package in R (Pebesma and Graeler 2021). Hereby, cut variants were transformed into numerical values; 1 = standard cut variant and 2 = flexible cut. A semivariogram was computed with a lag size of 10 m and a maximal distance of 1'000 m between two meadow centers: for the semivariogram calculation, the meadow polygon features were converted into point features with one point per meadow located in its center.

Ecological quality under different cutting regimes

The Q1 and Q2 area of the BPA meadows were analyzed in more detail. Extensively and less intensively managed meadows were analyzed separately to reveal differences between these two types. For this purpose, the total meadow area attested with increased ecological quality in 2020 was calculated. In addition, the attestation of the ecological quality area between 2012 and 2020 was compared as follows: BPA meadows, registered in 2012 as 100% Q1 area, were selected. Within these selected meadows, the fraction of standard cut meadow area on which Q2 area was registered by 2020, was compared with the fraction of flexible cut meadow area on which Q2 area was registered by 2020.

Survey-based management implementations

The differences (in number of days) between the date of the first cut (as stated by the farmer in the survey) and the official cutting date in the respective agricultural zones were calculated. For example, if a meadow in the lowland zone was cut on 5 June, the deviation from the official cutting date (15 June) was -10 days. Cutting dates and mean deviation (across 2018–2020) were compared between standard cut BPA and flexible cut BPA using a student's t-test.

The farmers could indicate how many times they cut their meadow in a specific year in the survey. This number will be referred to as the number of uses. When autumn grazing occurred, it was counted as one additional use. The mean number of uses over the years 2018–2020 was calculated. A binomial regression for proportion data was used to fit the effect of both the number of uses and the first cutting date's effect on the area with quality (Crawley 2007 chap. 16 Proportion data).

Effect of the number of uses:

glm (Proportion of area with quality ~ mean (Number of uses), family = “binomial”)

Effect of the first cutting date:

glm (Proportion of area with quality ~ mean (deviation from official cutting date), family = “binomial”)

Implementations of the first cutting dates were compared between farms only applying either the standard or only the flexible cutting regime and those farms that applied both cutting regimes. The farm-scale variation of the first cutting dates was calculated as the timespan between the date on which the earliest and the latest first mowing cut took place. Farms that managed only one parcel were excluded from the analysis.

Finally, farmers’ responses from the second survey were analyzed descriptively to assess a farmer’s most important factors in choosing a cut variant.

3 Results

In 2020, 39'663 meadows were registered as biodiversity promotion area (BPA) in the canton of Bern. From all BPA meadows 19'678 were situated in the lowland zones (total area = 5'851 ha, mean size = 0.38 ha), 12'595 in the mountain zones I+II (total area = 3'619 ha, mean size = 0.38 ha) and 7'390 in the mountain zones III+IV (total area = 2'065 ha, mean size = 0.55 ha).

3.1 Spatial arrangement of PBA meadows

Most BPA meadows were managed with either the flexible cut or the standard cut. Other cutting regimes contributed to a smaller part, especially in the lowland zones (Appendix 9). In the lowland zones, a range value of 94.4 m was estimated with an exponential model, 177.1 m in the mountain zones I+II, and 268.7 m in the mountain zones III+IV. Range values, the distances at which semivariance reaches 95% of the maximum value, represent the distance between two points at which registered cutting regimes are no longer spatially autocorrelated (Figure 3). Estimated semivariogram parameters for corresponding models can be found in Appendix 4. Figure 4 shows two examples of a map section of BPA meadows’ arrangement in the different agricultural zones.

Results

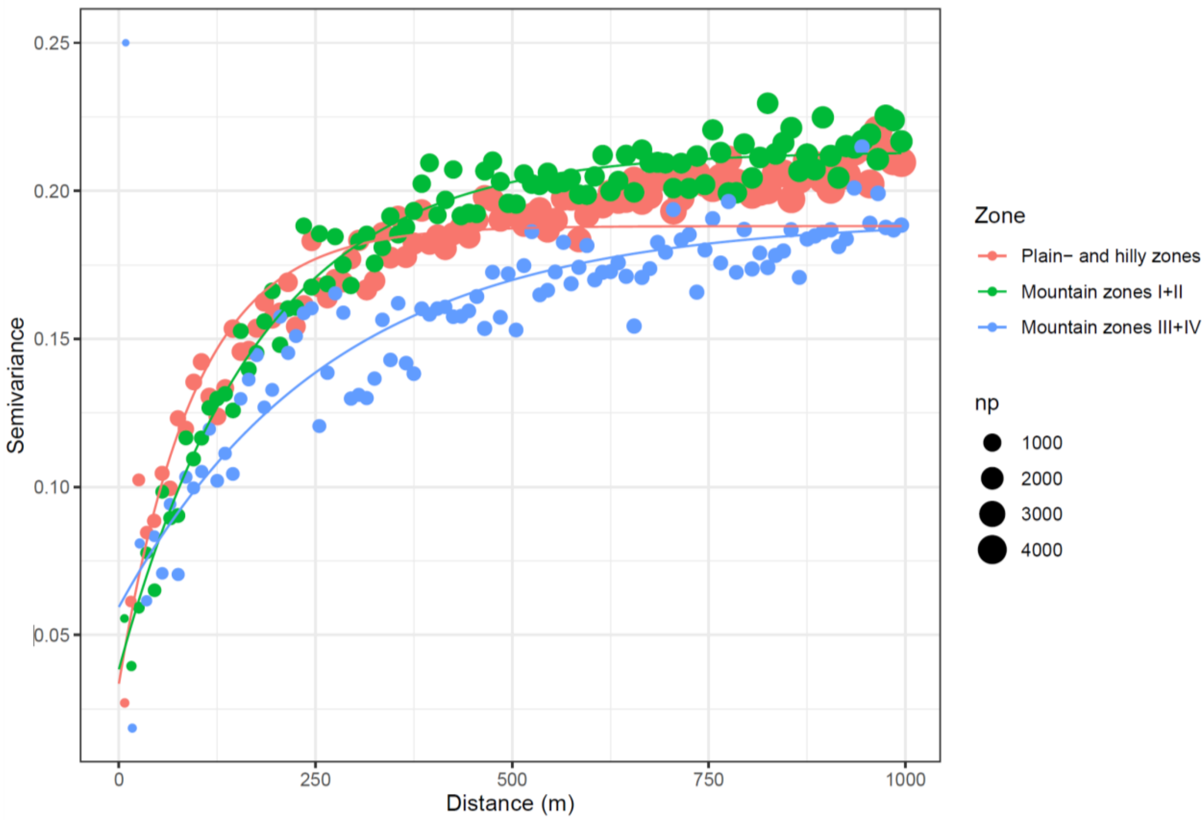
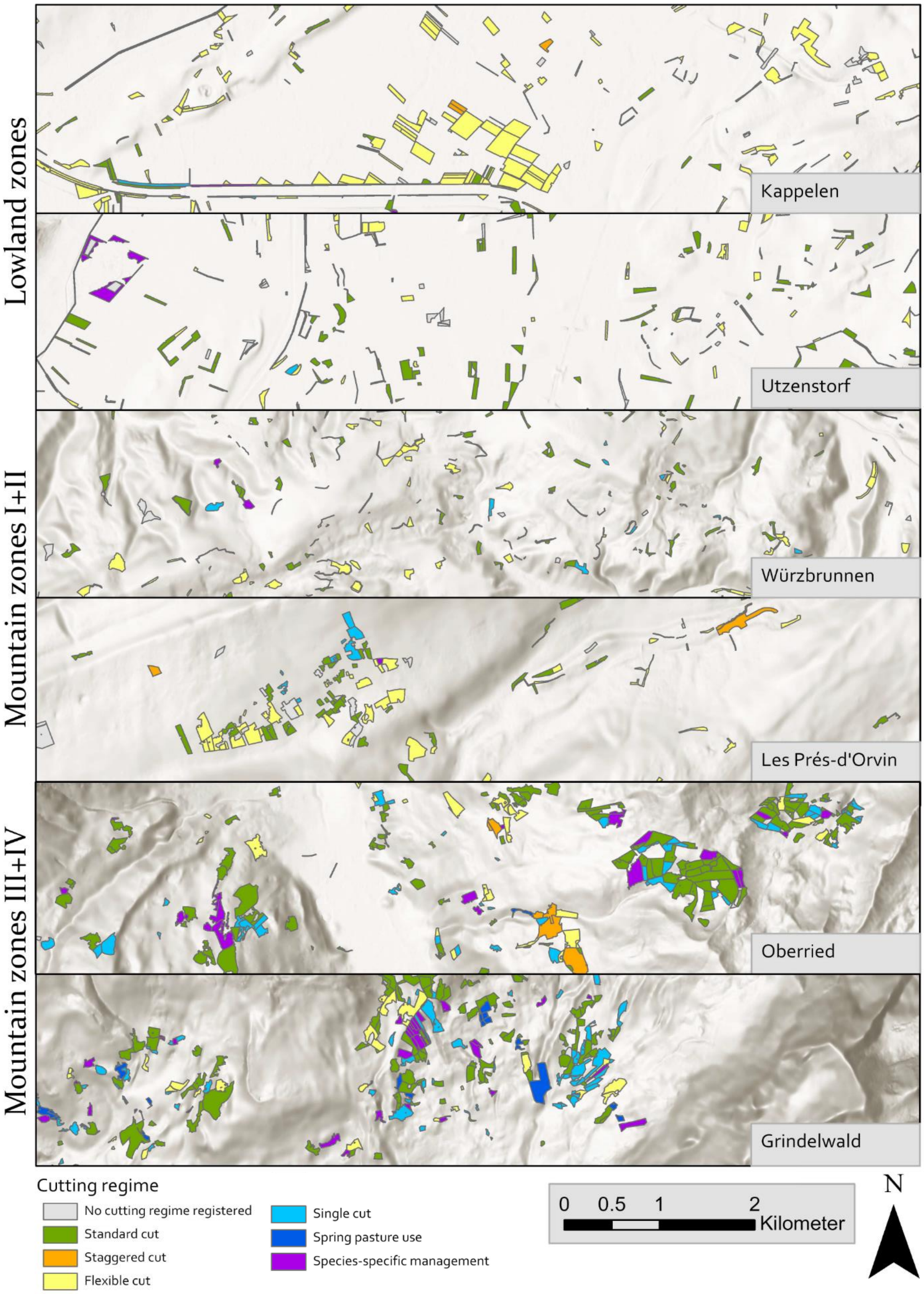


Figure 2. Omnidirectional semivariogram of cutting regimes standard cut and flexible cut per agricultural zone. Lines show fitted exponential semivariogram models and size of the points represent the number of meadow pairs at the respective distance.



Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Parcel features; Amt für Geoinformation des Kantons Bern 2020, Parcel data; GELAN 2020

Figure 3. Map sections showing BPA meadows and their registered cutting regime in 2020.

3.2 Ecological quality of flexible and standard cutting regime

The majority of BPA meadows in 2020 were registered as extensively managed meadows (95.9% in lowland zones, 69.3% in mountain zones I+II, and 67.8% in mountain zones III+IV). BPA registered as less intensively managed meadows were less common The proportion of area with ecological quality Q2 was larger on standard cut meadows compared to flexible cut meadows in the mountain zones I+II (42.0% vs. 28.6%, Chi-square test: X-squared = 50.156, df = 2, p-value < 0.001) and mountain zones III+IV (70.6% vs. 53.6%, X-squared = 30.791, df = 2, p-value = < 0.001), but not in the lowland zones (Figure 5). Total Q2 area in less intensively managed meadows with the standard cut was not significantly different from the flexible cut. Details on BPA managed with standard and flexible cut and one of the remaining four cutting regimes in 2020 are summarized in Appendix 5 with corresponding plots in Appendix 8.

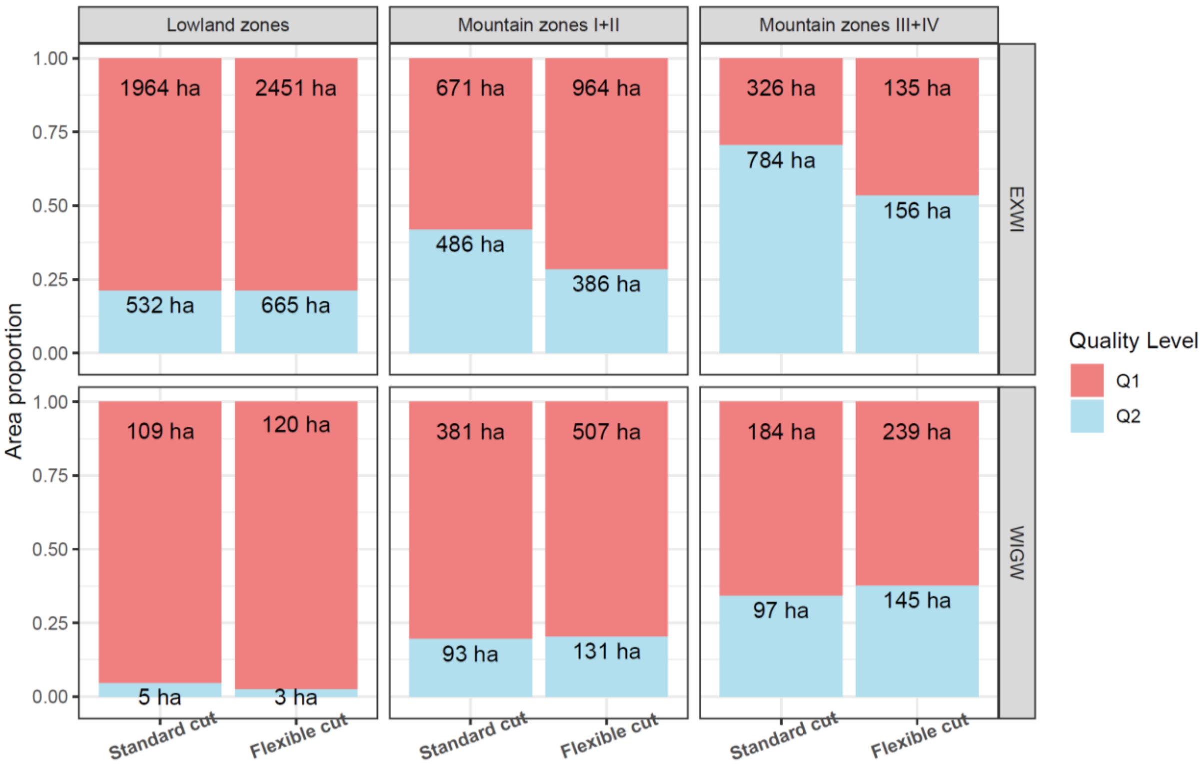


Figure 4. Relative proportion and total area in hectares (ha) of Q1 and Q2 in extensively managed (EXWI) and less intensively managed (WIGW) meadows per cutting regime. 100% corresponds to the respective total meadow BPA area per agricultural zone.

3.3 Changes in quality between 2012 and 2020

In 2012, 13’607 ha were registered as BPA meadows. Of this area, 3’177 ha did not reach ecological quality level 2 in 2012 and were still registered with the same cutting regime in 2020. 1’845 ha were managed with the standard and 1’331 with the flexible cutting regime. From the total area of BPA meadows managed with the standard cut and with no Q2 area in 2012, 10.2% (lowland zones), 20.1% (mountain zones I+II), and 48.6% (mountain zones III+IV) of the area reached Q2 by 2020. In contrast, on BPA meadows with the flexible cut, Q2 level was attested on 10.1% (Lowland zones), 7.3% (mountain zones I+II), and 19.9% (mountain zones III+IV) of the total meadow area by 2020. The BPA meadow area registered with a standard cut switching to Q2 was significantly larger in mountain zones I+II compared to area with the flexible cut (Chi-square test: X-squared = 35.607, p-value = < 0.001; Figure 6), but this difference was not significant in lowland zones (Chi-square test: X-squared = 0.81452, p-value = 0.666) and in in mountain zones III+IV (Chi-square test: X-squared = 4.6807, p-value = 0.096).

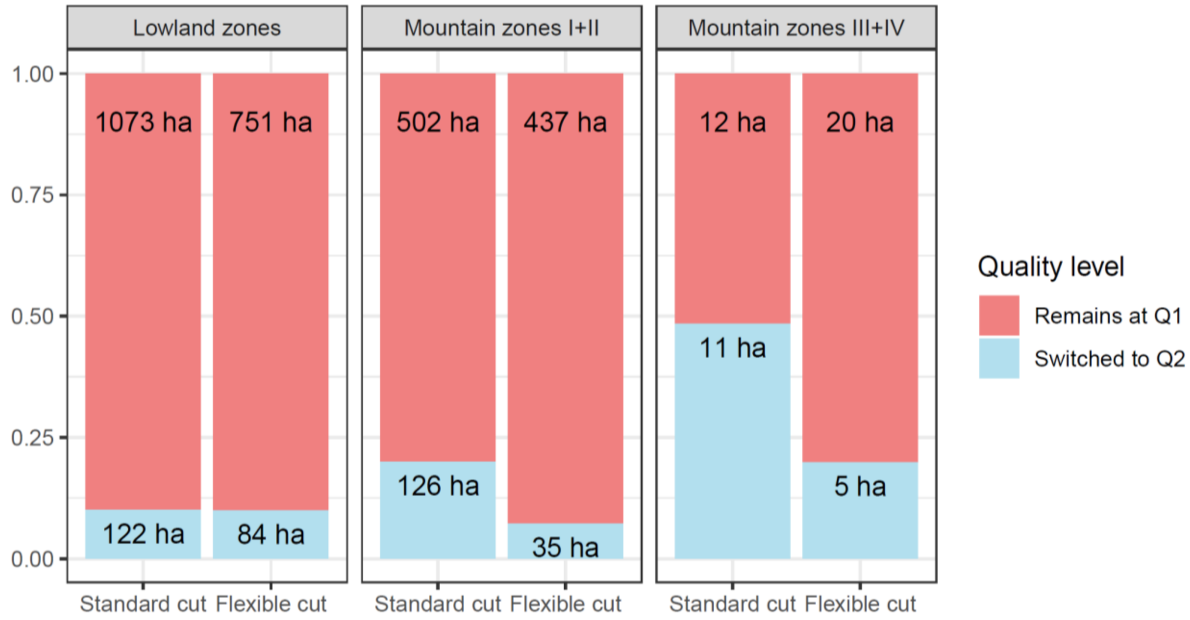


Figure 5. Area of BPA meadows (extensively and less intensively used meadows pooled) that were Q1 in 2012 and still Q1 in 2020 (red) versus the area that switched from Q1 in 2012 to Q2 by 2020 (blue). Data are presented per cutting regime and agricultural zones.

3.4 Management implementation

The survey included 997 entries of cutting dates of BPA meadows. From these entries, 778 (419 from the first survey, 359 from the second survey) could be linked to a registered BPA meadow. Most of the meadows were managed with the standard (n = 280) or flexible (n = 409) cutting regime.

Details on the number of uses and date of the first cut are summarized in Tables 1 and 2. There were no significant differences in the number of uses between BPA with standard and flexible cut, except for meadows in the mountain zones I+II in 2018 and 2020 (when flexible cut meadows were used more often).

Table 1. Mean number of uses per cutting regime and agricultural zone. Corresponding box-plots can be found in Appendix 10, and n = number of fields.

		Lowland zones			Mountain zones I+II			Mountain zones II+IV		
		2018	**2019**	**2020**	**2018**	**2019**	**2020**	**2018**	**2019**	**2020**
Standard cut	Mean number of uses	2.59	2.59	2.59	2.00	2.12	2.06	1.88	1.88	1.88
	Sample size n	177	179	184	16	16	16	8	8	8
Flexible cut	Mean number of uses	2.69	2.67	2.63	2.50	2.25	2.62	-	-	-
	Sample size n	93	95	95	8	8	8	-	-	-

Flexible cut meadows were cut significantly earlier than standard cut meadows in every agricultural zone and year (Table 2). More specifically, on flexible cut meadows, the first cut occurred on average 5.8 days before the official cutting date in the lowland zones, 13.9 days earlier in the mountain zones I+II, and 7.9 days earlier in the mountain zones III+IV. In the lowland zones, 98.6% of standard cut meadows and 57.0% of the flexible cut meadows were cut after the official cutting date on 15 June. In comparison, the respective proportions amount to 96.4% vs. 22.7% in the mountain zones I+II and 100% vs. 30% in the mountain zones III+IV. Map sections showing the implementation of the first cut can be found in Appendix 13.

Table 2. Mean deviation (number of days) of the first cut from the official date per agricultural zone, i.e. 15 June for the lowland zone, 1 July for the mountain zones I+II, and 15 July for the mountain zones III+IV. Corresponding boxplots can be found in Appendix 11.

		Lowland zones			**Mountain zones I+II**			**Mountain zones III+IV**		
		2018	**2019**	**2020**	**2018**	**2019**	**2020**	**2018**	**2019**	**2020**
Standard cut	Mean days of deviation	4.4	4.9	8.0	8.9	3.9	7.2	9.1	11.5	4.0
	Standard deviation	6.6	7.2	5.2	12.4	6.2	14.2	8.5	14.3	4.1
	Sample size n	210	212	233	18	18	19	21	20	14
Flexible cut	Mean days of deviation	-3.9	-1.6	-10.3	-10.4	-7.0	-20.7	-11.2	-8.1	-6.5
	Standard deviation	13.6	13.4	17.0	18.6	19.9	19.9	10.8	10.5	9.5
	Sample size n	315	323	340	44	45	43	21	20	14

Figures 7-9 illustrate the distribution of the first cutting dates of the standard and flexible cut meadows in the respective agricultural zone. In the example of the meadows in the lowland zones in 2020 illustrated in Figure 7, the distributions of meadows cut in the period 2-3 weeks before the official cutting date on 15 June matches the period between 24 May and 3 June when little to no rainfall was recorded in Bern/Zollikofen (*Klimabulletin Juni* 2020, *Klimabulletin Mai* 2020).

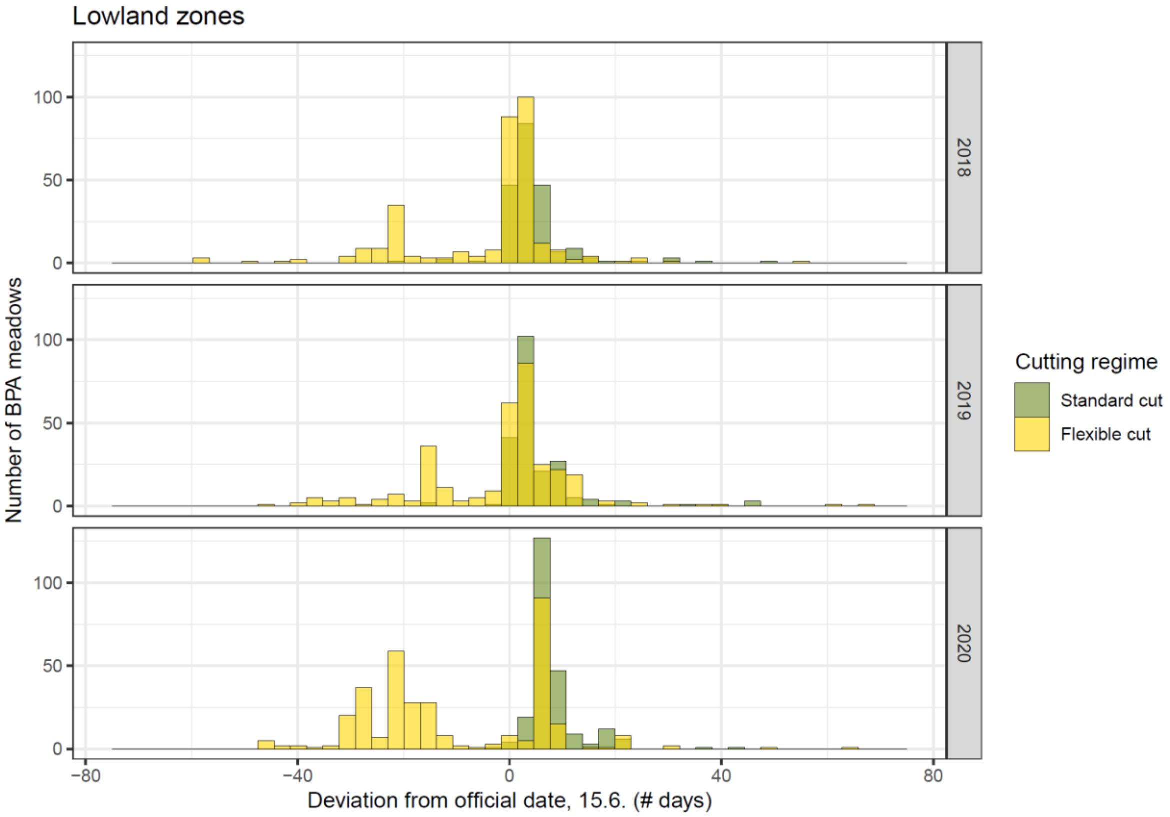


Figure 6. Dates BPA meadows were first cut in 2018–2020 in the lowland zones. X-axis shows the deviation from the official date for the first possible cut under standard cutting regime, i.e. 15 June.

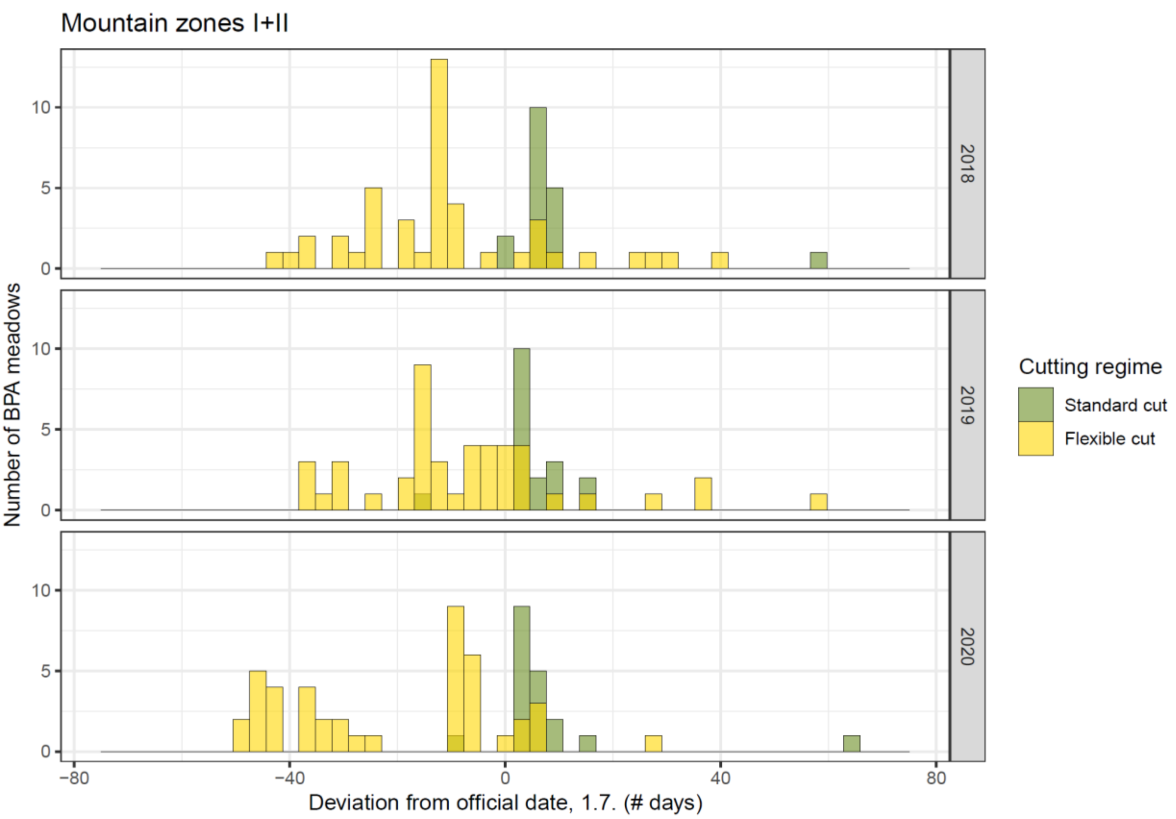


Figure 7. Dates BPA meadows were first cut in 2018–2020 in the mountain zones I+II. X-axis shows the deviation from the official date for the first possible cut under standard cutting regime, i.e. 1 July.

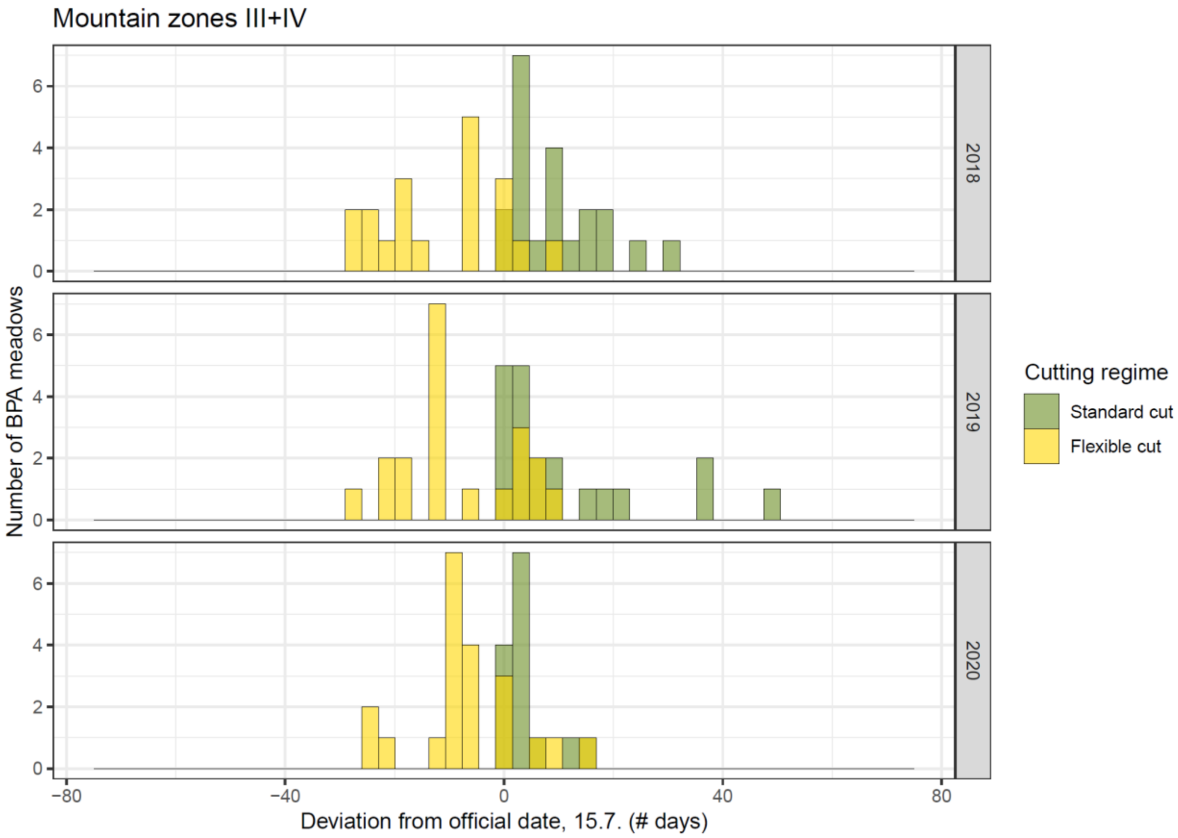


Figure 8. Dates BPA meadows were first cut in 2018–2020 in the mountain zones III+IV. The X-axis shows the deviation from the official date for the first possible cut under the standard cutting regime, i.e., 15 July.

3.5 Farm-scale management

According to the GELAN information, in 2020, farmers managed on average 3.7 BPA meadows in the lowland zones, 2.9 BPA meadows in the mountain Zones I+II and 3.1 BPA meadows in the mountain zones III+IV. A greater fraction of farmers managed more than one meadow, with 80.1% of the farmers in the lowland zones, 68.5% in the mountain zones I+II, and 68.0% in the mountain zones III+IV. The majority of the farmers managed either only standard or only flexible cut meadows. Merely 16.3% in the lowland zones, 22.3% in the mountain zones I+II, and 30.8% in the mountain zones III+IV had mixed cutting regimes (both standard and flexible).

According to the farmers' responses in the survey, the average timespan between the first cuts on different BPA meadows was largest on farms where both cutting regimes were applied (Figure 10). Farmers with only standard cut BPA meadows had all meadows cut on average within 2 to 3.7 days (depending on the year) in the lowland, while the farmers with only flexible cut BPA meadows cut their meadows within 6.9 to 8.5 days. Farmers with mixed regimes (of both standard cut and flexible cut) mowed their BPA meadows on average within the longest period of 13.6 to 20.5 days (Appendix 12).

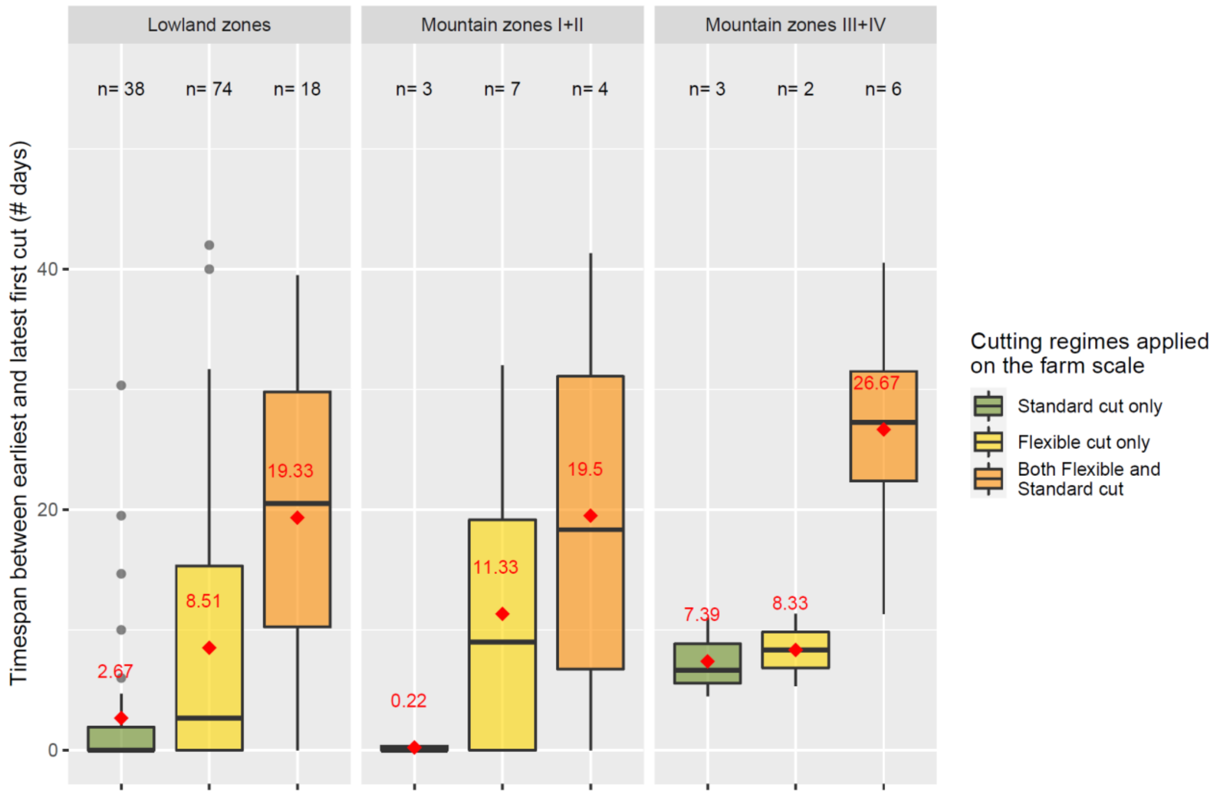


Figure 9 Mean farm-scale variation in the first cutting date in 2018-2020 based on the cutting regime/s applied on the farms' BPA meadows: farmers managing meadows either with standard (green) or flexible (yellow) cut or both cutting regimes (orange). Red numbers are the mean values, and n = number of farmers.

The mean variation of the first cutting date in 2018-2020 was significantly different among the three farm types ($F(2,127) = 11.75$, $p < 0.001$). A Tukey post-hoc analysis revealed significant differences between all the farm types in the lowland zones (table 3). Sample sizes were too small in the mountain zones.

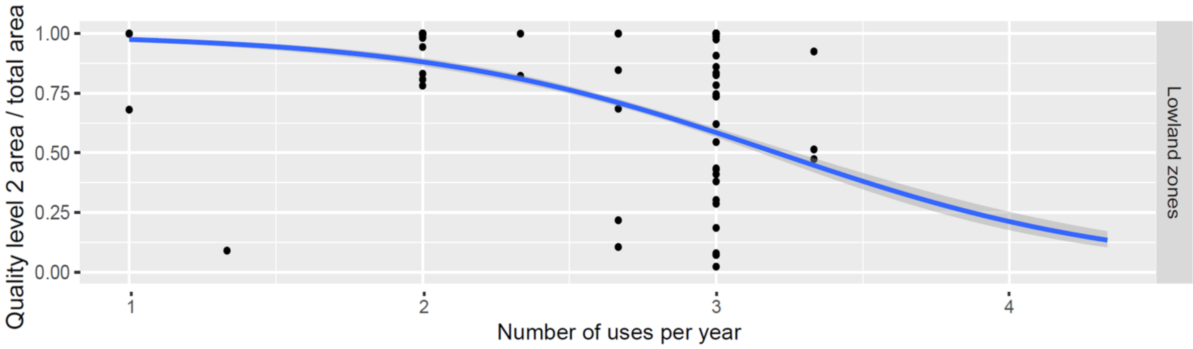
Table 3 Results of Tukey HSD post-hoc analysis of ANOVA testing the differences in the farm-scale variation of the first cutting date in 2018-–2020 in the lowland zones, comparing the variation based on the cutting regime(s) applied on the farms' BPA meadows.

Comparison			Confidence interval		
Farm type	**Farm type**	**Difference (in days)**	**Lower bound**	**Upper bound**	**Significance**
Both cutting regimes	Only standard cut	17.06	8.55	25.57	**< 0.001**
	Only flexible cut	9.49	1.67	17.30	**0.013**
Only flexible cut	Only standard cut	7.57	1.64	13.51	**0.008**

3.6 Linking management implementations with ecological quality

Because information on the number of uses (number of cuts plus autumn pasture) was only included in the second survey responses, the sample size was limited, especially in the mountain zones. Therefore, the effect of the number of uses on the proportion of meadow area with increased quality could neither be estimated reliably in the mountain zones I+II (n = 10) nor the mountain zones III+IV (N = 8). In the lowland zones, the relationship between the proportion of meadow area with quality (Q2 / total area) and the yearly mean number of uses in 2018–2020 was significant (Figure 11).

Figure 10. Logistic regression between the proportion of meadow area with Q2 and the number of uses per year in the lowland zones (n = 72, corresponding model estimates are shown in Appendix 6.



The regression model analyzing the effect of the mean (across 2018-2020) first cutting date on the proportion of meadow area with Q2 indicated that a later date of the first cut has a significant positive on this proportion in the lowland zones and the mountain zones III+IV, but not in mountain zones I+II (Figure 12). Summary outputs can be found in Appendices 4 and 5.

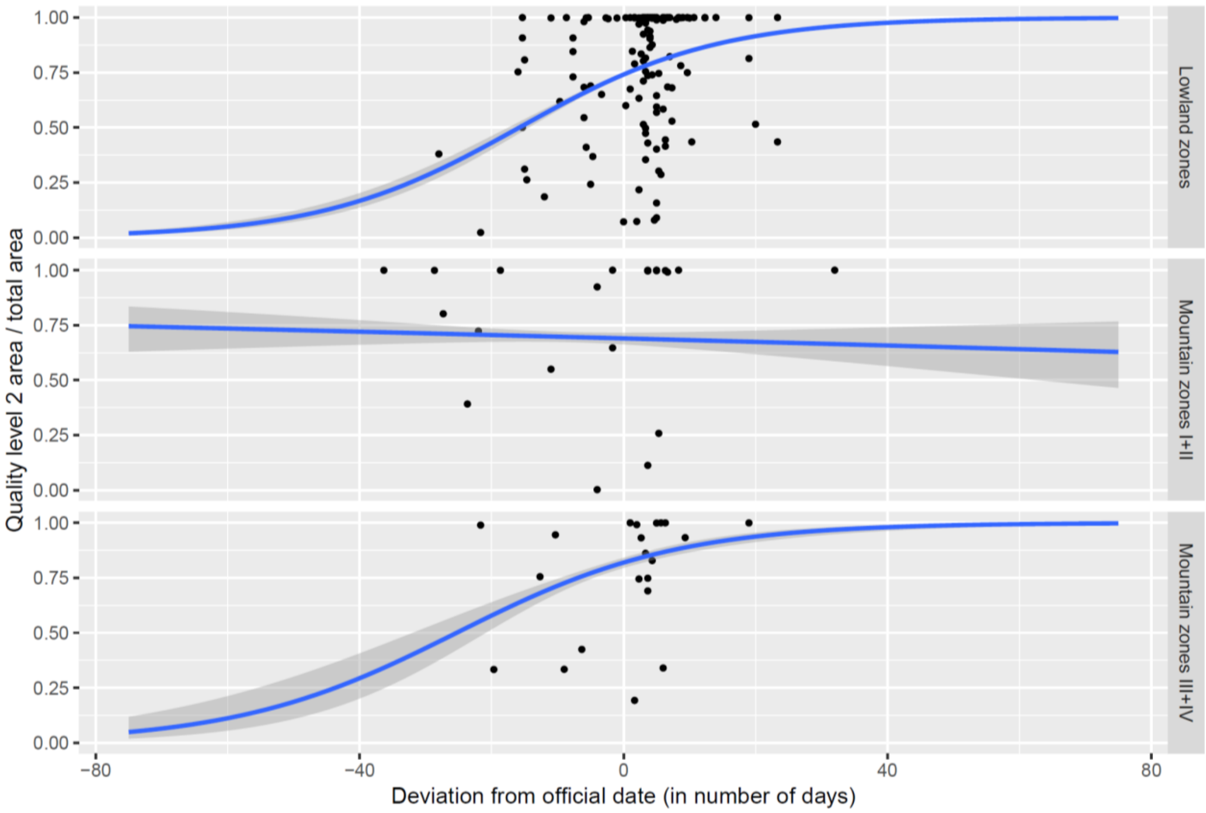


Figure 11. Logistic regression between the proportion of meadow area with Q2 and the mean first cutting date across 2018–2020 in the lowland zones (n = 135), mountain zones I+II (n = 23), and mountain zones III+IV (n = 21). Outliers of more than 75 days of deviation from 0 were removed. Corresponding model estimates are contained in Appendix 7.

3.7 Reasons behind choosing a flexible cutting regime

166 of the 349 farmers participating in the second survey stated one or multiple reasons for choosing a flexible cutting regime. 45.4% of the farmers stated “Taking advantage of a good weather period” as a main reason for choosing the flexible cutting regime. 32.1% chose "Avoiding rotting hay", 26.1% "Improvement of fodder quality", 27.1% "Promote plant diversity", 17.0% "Provide good conditions for wild animals" and 3.7% "Better availability of agricultural machines". 18.3% of the respondents indicated other reasons, such as reducing workload peaks, more flexibility, and the ability to control plants of the *Crepis* and *Erigeron* genus.

4 Discussion

Since 2010, farmers of the canton of Bern can register their BPA (biodiversity promotion area) meadows under a cutting regime where they can freely choose the date of the first cut. The main aim of this study was to evaluate this flexible cutting regime. In particular, it was compared to the standard cutting regime with a restricted first cut, not before 15 June, 1 July, or 15 July in the lowland zones, mountain zones I+II or mountain zones III+IV, respectively. Standard and flexible cut meadows were randomly distributed in the landscapes above distances of more than 94 m in the lowland zones. In general, BPA meadows under the flexible cutting regime were cut earlier than standard BPA meadows and increased the timespan between cutting events if both cutting regimes are considered. The shift towards earlier cutting in BPA meadows managed under the flexible regime may influence grassland biodiversity. This influence, caused by an earlier cut, provides a possible explanation for the differences in the ecological quality between standard cut and flexible cut meadows in the mountain zones in this study. Although the general shift of the first cutting date could be observed in every agricultural zone, there was no indication for a difference in the ecological quality in the lowland zones. These findings spark debate on whether a flexible cutting regime should be further regulated and might be consulted to formulate management recommendations on BPA meadows.

4.1 Timing and spatial distribution of the first cut

The flexible and standard cutting regimes were clustered on distances up to 94 m in lowland zones, 177 m in lower mountain zones, and 269 m in the most elevated mountain zones. Below these distances, two neighboring BPA meadows are likely managed with the same cutting regime. Above these distances, flexible and standard cut meadows are randomly distributed in the landscape. The larger meadow size in the mountain zones can explain the differences in spatial autocorrelation. We found that even if the meadows were managed by the same farmer, there was a variation in the cutting dates when looking at a mixed set of both flexible cut and standard cut BPA meadows. The clustering of regimes on smaller scales could be decreased by introducing additional regulations. For example, a maximum proportion of BPA meadows that can be managed with the flexible cut could be established. Such regulation has already been introduced in some other cantons, where a maximum of 20% of the BPA can be managed with the flexible cut (Canton de vaud 2018, Kanton Zug 2019). It can be assumed that mainly the mobile organisms will profit from the resulting heterogeneity in the distribution of cut and uncut meadows; birds, butterflies, and bees might profit from uncut meadows on a scale of hundreds of meters (Cizek et al. 2012, Kennedy et al. 2013, Johansen et al. 2019). Other literature describing positive aspects of landscape heterogeneity on farmland plant and animal diversity focused on the landscape compositional heterogeneity (with different habitat types) and edge effects rather than the distribution of first mowing dates (Hass et al. 2018, Massaloux et al. 2020). Beneficial effects from uncut areas separated by > 100 m distance on less mobile species groups such as ground beetles, orthopterans, and spiders are yet to be demonstrated. On the other hand, these less mobile and the more mobile groups benefit from uncut refuges left within the meadow (Buri et al. 2014, 2016, Bruppache(Humbert et al. 2018)r et al. 2016). It causes heterogeneity on both the field scale and at the regional scale.

According to the outputs of the surveys sent to the farmers, standard cut meadows were on average cut 6–8 days after the official cutting date, while flexible cut meadows were on average cut 5–13 days before the prescribed date. Obviously, weather conditions are important and probably the main factor when deciding to cut or not the meadow. In fact, using a potentially earlier good weather period was the most frequently indicated reason for choosing a flexible cutting regime (45.4% of the farmers participating in the second survey). Given the increasing spring temperatures, the first cutting date is likely to shift to an earlier date in the future.

Meadows managed with a flexible cutting regime had a greater variance in the date of the first cut (with a standard deviation of 15–20 days), while most of the meadows with the standard cut were cut on the official cutting date or shortly after (with a standard deviation of 7–11 days). A similar pilot study (by Stäheli et al. 2007) also showed more spread-out cutting events on flexible cut meadows. The flexibility in choosing the first cutting date led to fewer meadows being cut on the same day within a year. However, suppose all the meadows are cut during the first period of nice weather. In that case, it could lead to meadows being cut in the same phenological stage each year and, therefore, favor less vulnerable species during this period. In contrast, the first cutting event on the standard cut meadows is more independent from the annual climate. Varying onsets of warm periods after the winter could cause between-year variation of the phenological state at the first cutting date. The standard cutting regime could thus cause a "temporal storage effect", favoring different groups of species in different years. This coexistence mechanism could, in theory, boost species diversity (Chesson and Warner 1981, Allan et al. 2014).

4.2 Relationship between cutting regimes and ecological quality

In this study, the ecological quality of a BPA meadow, or a fraction of the meadow, was classified as without quality, abbreviated Q1, or as with quality Q2, if six or more indicator plant species were present within a 3 m radius. This categorization offers only a limited binary assessment for the botanical diversity of a meadow. Nonetheless, it has been shown to correlate well with the total number of plant species present in the meadow as well as butterfly species richness (Weinrich 2018). A proportion of 27% of the farmers indicated the promotion of greater plant diversity as a main reason for choosing the flexible cut. However, there was no evidence for higher or increased plant diversity on meadows with the flexible cut. On the contrary, in the mountain zones, standard cut meadows harbored a significantly higher proportion of area with quality (Q2) than meadows with a flexible cut. This pattern was also partly reflected in the attestation history between 2012 and 2020 where a greater fraction of standard cut meadow area improved from Q1 to Q2 in some mountain zones. As the flexible cut generally implies an earlier date of the first cut, we also tested if it was correlated with ecological quality. Results show a significant negative correlation between the ecological quality (proportion of area with quality) and the mean first cutting date across 2018–2020 in the lowland and mountain III+IV zones. These findings are in line with the literature showing that delaying the date of the first cut is beneficial for plant diversity, whilst a shift to an earlier date is detrimental (reviewed in

Humbert et al. 2012b). In addition to the forward shift of the first cut, the flexible cutting regime led to more annual uses in some of the mountain zones in 2018 and 2020. More uses have been reviewed by Gaujour et al. in 2012 as detrimental for botanical diversity and thus provide an alternative explanation for the smaller quality area in the mountain zones under the flexible cutting regime. The same relationship was found in the lowland zones, where more frequently used meadows showed a lower proportion of ecological quality. However, the number of uses per year did not differ between flexible and standard cutting regimes in the lowlands zone. Altogether it indicates that the prescribed first cutting dates in the different zones are not equally well adapted to the phenology of the respective zones.

In their one-year pilot study, Stäheli et al. (2007) reported that species-rich meadows were chosen less often to be managed with a flexible cut. Additionally, species-rich meadows were cut later than meadows with lower species richness. Similarly, in the present study, it is possible that meadows with a smaller Q2 fraction and a less valuable plant composition were more often chosen to be cut earlier. The different meadows might vary in soil nutrient content due to different periods since the transition from a fertilized meadow to an extensively managed meadow, different atmospheric nitrogen deposition, or leaching from adjoining fields (Berendse et al. 1992). A meadow's higher soil nutrient content would cause a faster growth of vegetation linked with an earlier and more frequent need for mowing to prevent the hay from rotting, which was also stated a main reason for choosing the flexible cutting regime. Such productive meadows would harbor a decreased plant species diversity (Zechmeister et al. 2003, Stevens et al. 2004, Kleijn et al. 2009). Therefore, different soil nutrient contents, linked to historical management or current environmental conditions would offer an alternative explanation for the correlation between earlier first cuts and decreased measures of ecological quality found in this study.

4.3 Conclusion and further research

At the federal level, regulations regarding the management of BPA meadows specify the first possible mowing date on BPA meadows. However, in the canton of Bern, a relatively new cutting regime allows farmers to choose the date of the first cut flexibly. This represents an attractive alternative to the standard regime and is already widely used. It was shown by Humbert et al. in 2018 that the additional restriction of a minimum interval of eight weeks between two cuts, linked with the flexible cut, does not represent a considerable constraint.

Being implemented on the most abundant BPA type, it is crucial to investigate the effect of this cutting regime on biodiversity. Neighboring BPA meadows are managed more often with the same regime and thus more similarly up to a certain distance. The desired mosaic of cut and uncut meadows is better achieved if cutting regimes are distributed randomly. There was an indication in this study that plant communities at various elevation levels respond differently to the different cutting regimes. We do not know which factors caused the differences in ecological quality on the meadows but saw that an earlier cut was correlated with a smaller relative area of increased quality. So far, there is no reason to assume that the desired positive effect of the increased heterogeneity caused by the flexible cutting regime outweighs the negative impact of an earlier first cut on biodiversity.

Although the mowing regime, particularly the first possible cutting date, is critically important for invertebrates, they were not considered in this work. Therefore, we can only speculate about invertebrate community responses to the shift of the first cut of two weeks in the lowland zones and even more in mountain zones. Especially species whose development depends on the vegetation structure are likely to be disturbed by the earlier mowing event (Humbert et al. 2012b, van Klink et al. 2019). Invertebrate assessments on selected meadows should complement this study to evaluate the relative effect of field and landscape-scale management implications under the flexible cutting regime. Various Arthropod species benefit much from the uncut grass refuge, which is currently part of the flexible and standard cut's management guidelines (Walter et al. 2007, Noordijk et al. 2010).

Consideration should be given to adapting the management guidelines to the meadows' elevation levels as the differences between the cutting regimes were different depending on the considered agricultural zone. The earliest possible date for the first cut in these agricultural zones might be limited to two weeks before the official cutting date. Additionally, the proportion of area which can be managed with a flexible cutting regime should be limited to promote heterogeneity of cutting regimes at the farm level. As a supplementing supporting measure, the proportion of the mandatory uncut grass refuge should be raised on meadows with a flexible first cutting date.

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7 Appendices

Appendix 1. Financial contributions in Swiss francs for BPA (biodiversity promotion areas) meadows according to the Swiss Ordinance on Direct Payments in Agriculture in 2019. Meadows with a higher ecological quality 2 (Q2) receive a bonus payment in addition to the contribution for basic ecological quality (Q1).

	Payment per ha and year for BPA extensively managed meadows (EXWI) in Swiss francs		**Payment per ha and year for BPA less intensively managed meadows (WIGW) in Swiss francs**	
	Q1	**Q2**	**Q1**	**Q2**
Valley zone (Lowland zone)	1’080	1’920	450	1’200
Hilly zone (Lowland zone)	860	1’840	450	1’200
Mountain zones I+II	500	1'700	450	1'200
Mountain zones III+IV	450	1'100	450	1'000

Appendix 2. Bernese Cantonal management regulations for extensively and less intensively managed BPA meadows in the framework of a networking project, valid in 2020 (LANAT 2020, Anforderungen an Biodiversitätsförderflächen in der Vernetzung.).

Official German name of cutting regime	English translation	Earliest cutting date	Additional requirements
Standard	Standard cut	15 June in lowland zones 1 July in mountain zones I + II 15 July in mountain zones III + IV	• 10% of the meadow must be spared as uncut refuge • Grazing is allowed from 1 Sept - 30 Nov
Gestaffelter Schnitt	Staggered cut	Max. 20 days before the standard dates	• 50% of the meadow area must be spared as uncut refuge • Grazing is allowed from 1 Sept - 30 Nov
Flexibler Schnitt	Flexible cut	Freely selectable	• 10% of the meadow must be spared as uncut refuge • At least 8 weeks between two cuts • Grazing allowed from 1 Sept - 30 Nov
Einmaliger Schnitt	Single cut	Freely selectable	• No grazing • No refuge
Aetzheu	Spring pasture use	Careful grazing in springtime (no date indicated)	• Only in mountain regions • Meadow must have Q2 level on at least 50% of the meadow area • At least 8 weeks between two cuts • Second grazing is allowed from 1 Sept - 30 Nov
Artenspezifische Bewirtschaftung	Species-specific management	By arrangement with the department of nature promotion (canton of Bern)	• By arrangement with the department of nature promotion (canton of Bern)

Appendix 3. Summarized content of the surveys launched in June 2020 and November 2020. Reasons for choosing flexible cut are inspired by Stäheli et al., 2007.

	Question	Type of answer/ Possible answers
In both Surveys, launched in June 2020 & November 2020	What is your PID (personal identification number)?	6 digs. number
	How many BPA meadows are you currently managing?	Number
	What is the GeoID (area identification number) of your parcel?	6 digs. number
	What was the date of the first cut in 2020/2019/2018 on this parcel?	Date
	Comments	Text
Only in the survey launched in November 2020	How many times was the meadow cut in the year 2018/2019/2020?	Number (1-4)
	Was the meadow grazed in the year 2018/2019/2020?	Yes/no
	In case you are applying the flexible cut on any of your meadows, what was the main reason for choosing this variant?	Multiple choice: • Improvement of the fodder quality • Take advantage of good weather periods • Improved availability of agricultural machines • Avoid rotting hay • Provide good conditions for wild animals • Promote plant diversity • Other reason (to be indicated)
	What is your email-address?	Email

Appendix 4. Exponential model estimates for the spatial autocorrelation of BPA meadows with the cutting regimes flexible cut and standard cut. Range values represent distances between two meadows at which the cutting regimes are no longer autocorrelated, nugget values represent the calculated variance at zero distance between two meadows.

Region	**Range (m)**	**Nugget (10^{-1})**	**Partial sill (10^{-1})**	**Weighted sum of squared errors**
Lowland zones	94.4	0.034	0.155	0.000884
Mountain zones I+II	177.1	0.038	0.175	0.000213
Mountain zones III+IV	268.7	0.059	0.134	0.001274

Appendix 5. Area of BPA meadows without ecological quality (Q1) and with ecological quality (Q2) in 2020. The data are provided per cutting regime and separately for the three agricultural zones.

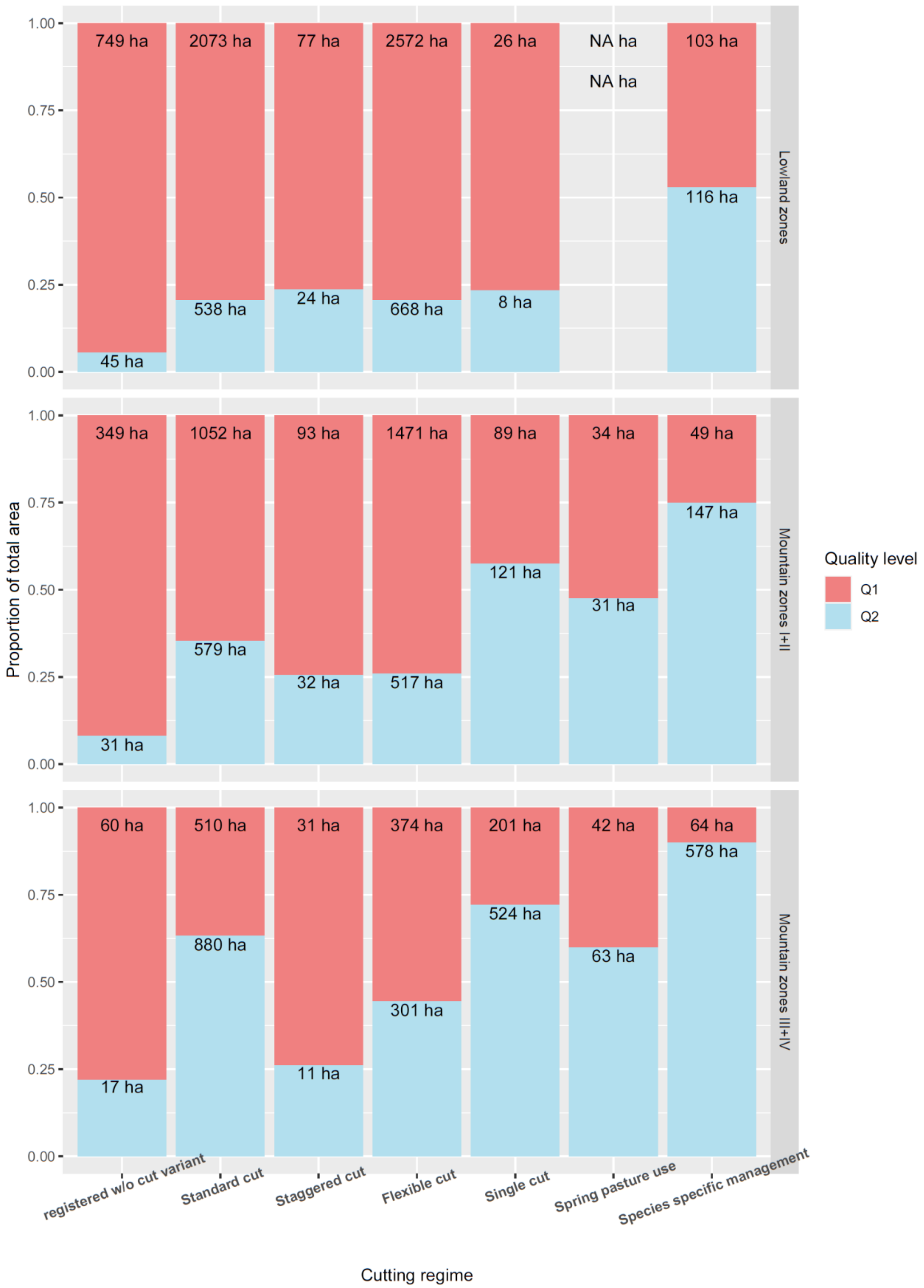
	Lowland zones			**Mountain zones I+II**			**Mountain zones III+IV**		
Cutting regime	**Area Q1 (ha)**	**Area Q2 (ha)**	**Prop. with Q2**	**Area Q1 (ha)**	**Area Q2 (ha)**	**Prop. with Q2**	**Area Q1 (ha)**	**Area Q2 (ha)**	**Prop. with Q2**
Standard cut	2'073	538	20.6%	1'052	579	35.5%	510	880	63.3%
Staggered cut	77	24	23.7%	93	32	26.0%	31	11	26.4%
Flexible cut	2'572	668	20.6%	1'471	517	26.0%	374	301	44.5%
Single cut	26	8	22.6%	89	121	57.6%	201	524	72.2%
Spring pasture use	-	-	-	34	31	48.2%	42	63	60.0%
Species-specific manage-ment	103	116	52.8%	49	147	74.8%	64	578	90.1%
No cutting regime registered	749	45	5.6%	349	31	8.1%	60	17	22.5%

Appendix 6. Summary outputs of the binomial regressions on the proportion of area with quality (Q2/Total area) according to the mean number of uses per year (average across 2018–2020).

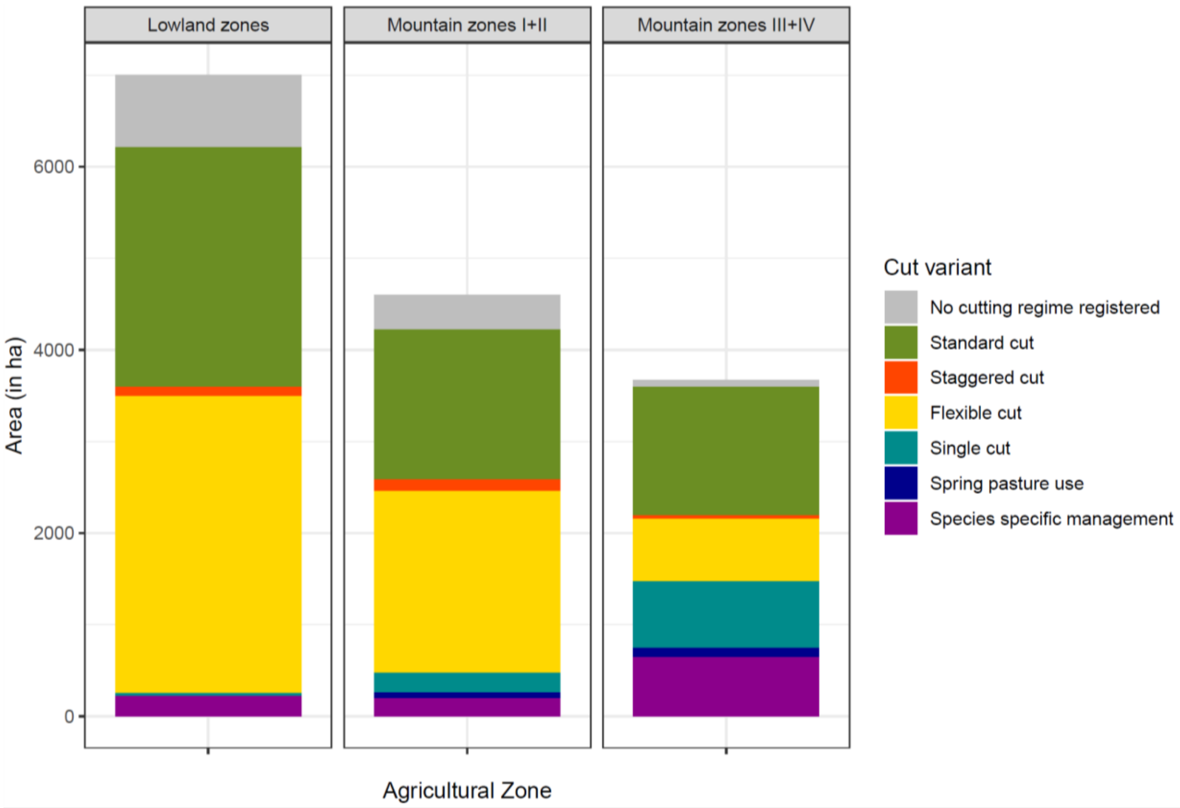
	Estimate	**SE**	***z***	***P***
Lowland zones				
Intercept	5.315	0.266	19.97	**<0.001**
Number of uses	-1.658	0.094	-17.68	**<0.001**

Appendix 7. Summary outputs of the binomial regressions on the proportion of area with quality (Q2/Total area) according to the deviation from the official date (average across 2018–2020), separated by the three different agricultural zones; lowland zones, mountain zones I+II and mountain zones III+IV.

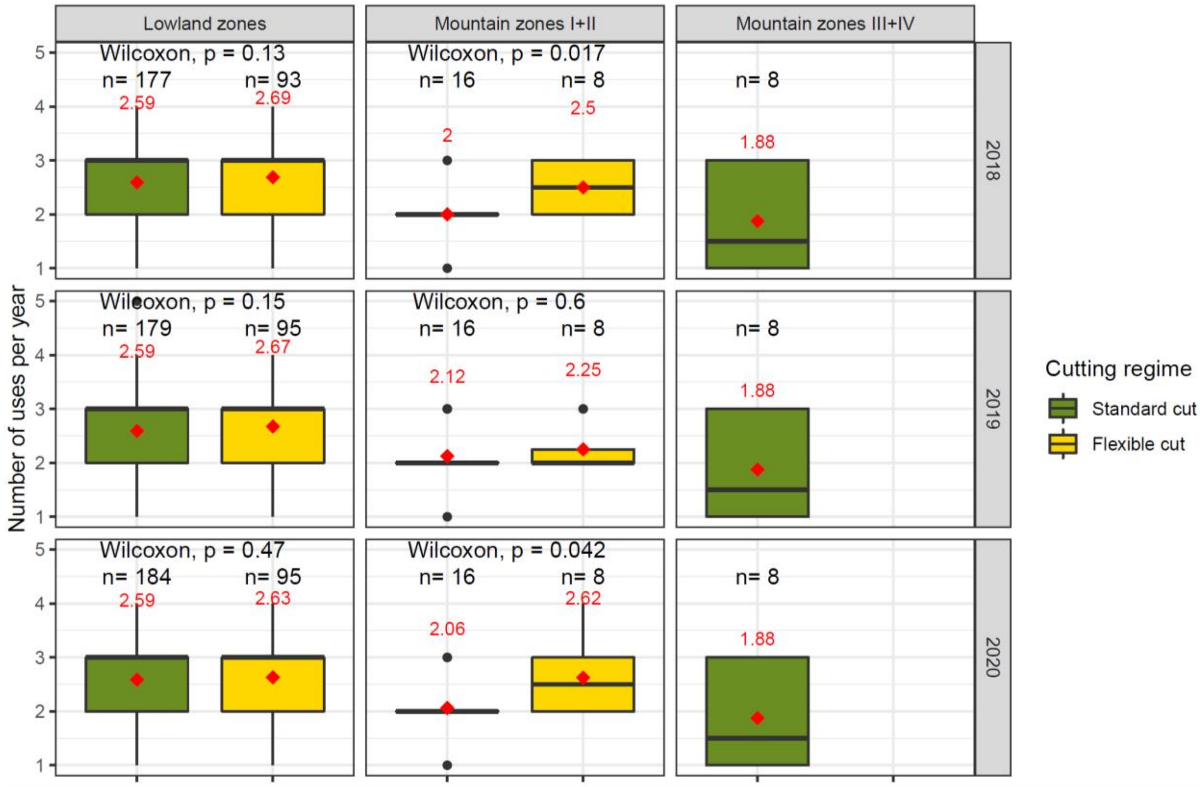
	Estimate	**SE**	***z***	***P***
Lowland zones				
Intercept	1.042	0.025	41.65	**<0.001**
Date of first cut	0.047	0.003	17.15	**<0.001**
Mountain zones I+II				
Intercept	0.800	0.063	12.668	**<0.001**
Date of first cut	-0.004	0.004	-0.907	0.365
Mountain zones III+IV				
Intercept	1.512	0.079	19.211	**<0.001**
Date of first cut	0.060	0.007	8.707	**<0.001**



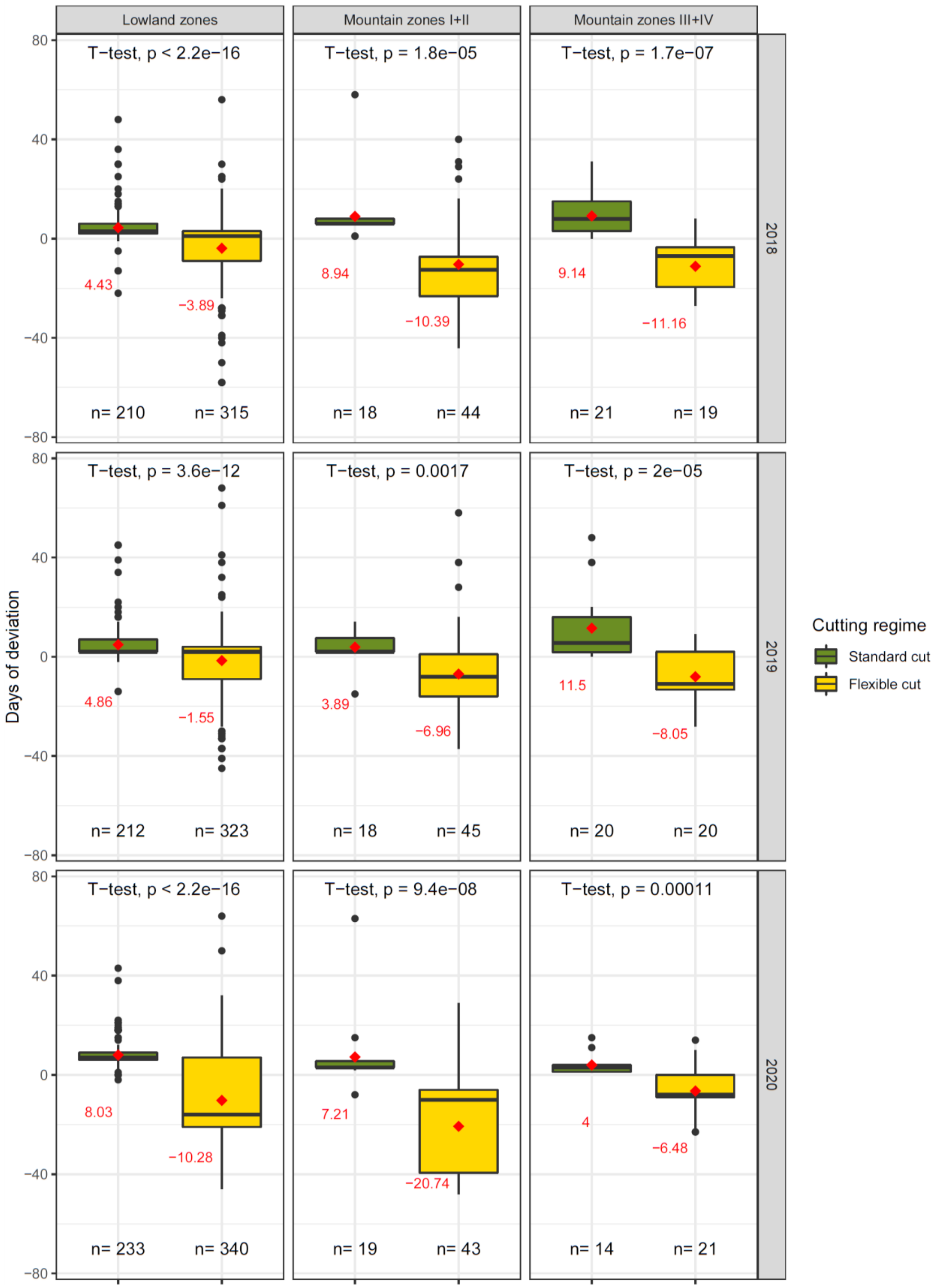
Appendix 8. BPA meadow area (in ha) registered in the canton of Bern in 2020. Data are presented according to the agricultural zones and the cutting regimes. Stacked bars represent the proportion of Q2 and Q1 area, note that there are no BPA meadows with Spring pasture use in lowland zones.



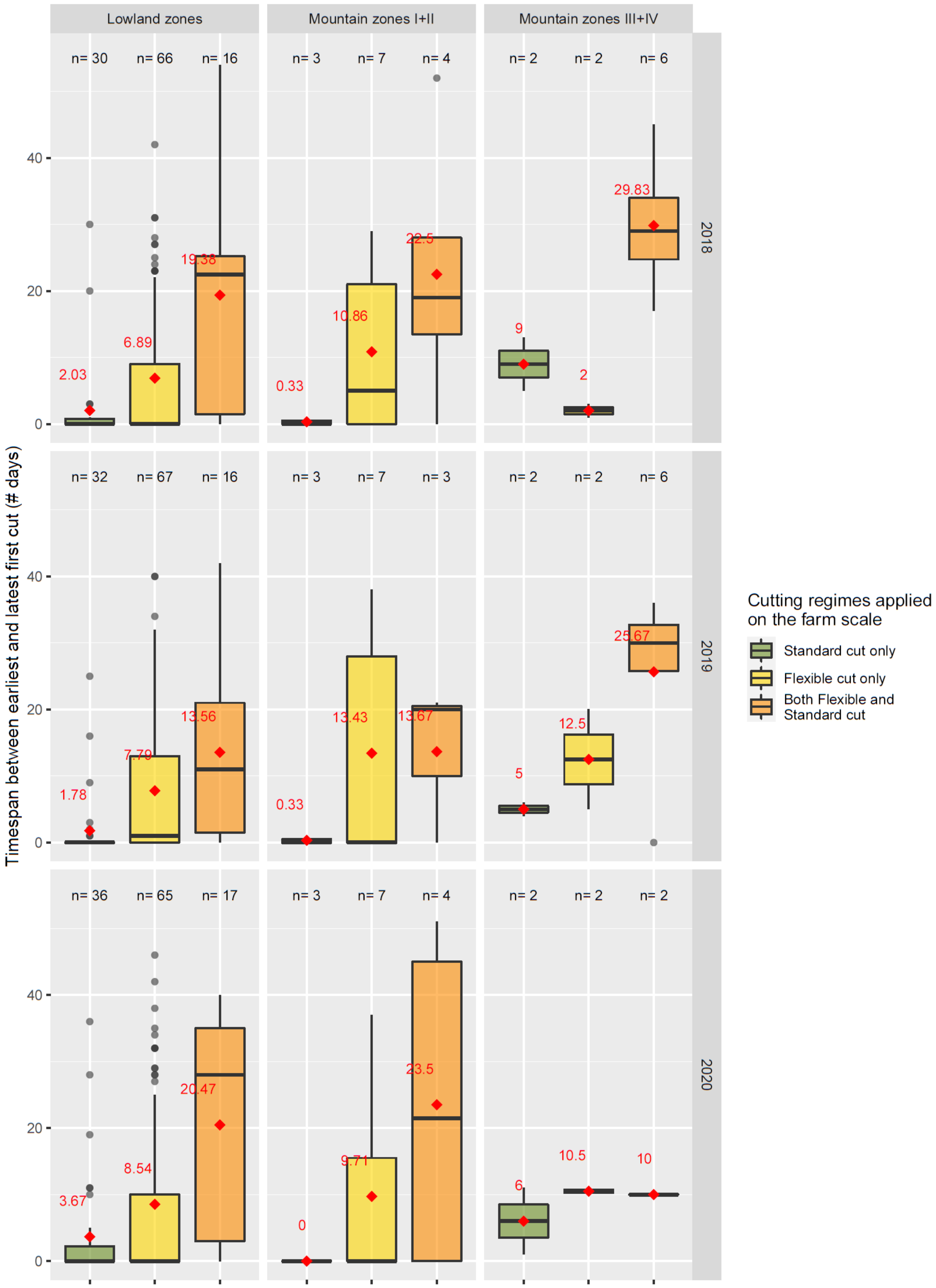
Appendix 9. Total area (in ha) of extensively and less intensively managed meadow per cutting regime and agricultural zones in 2020 in the canton of Bern.



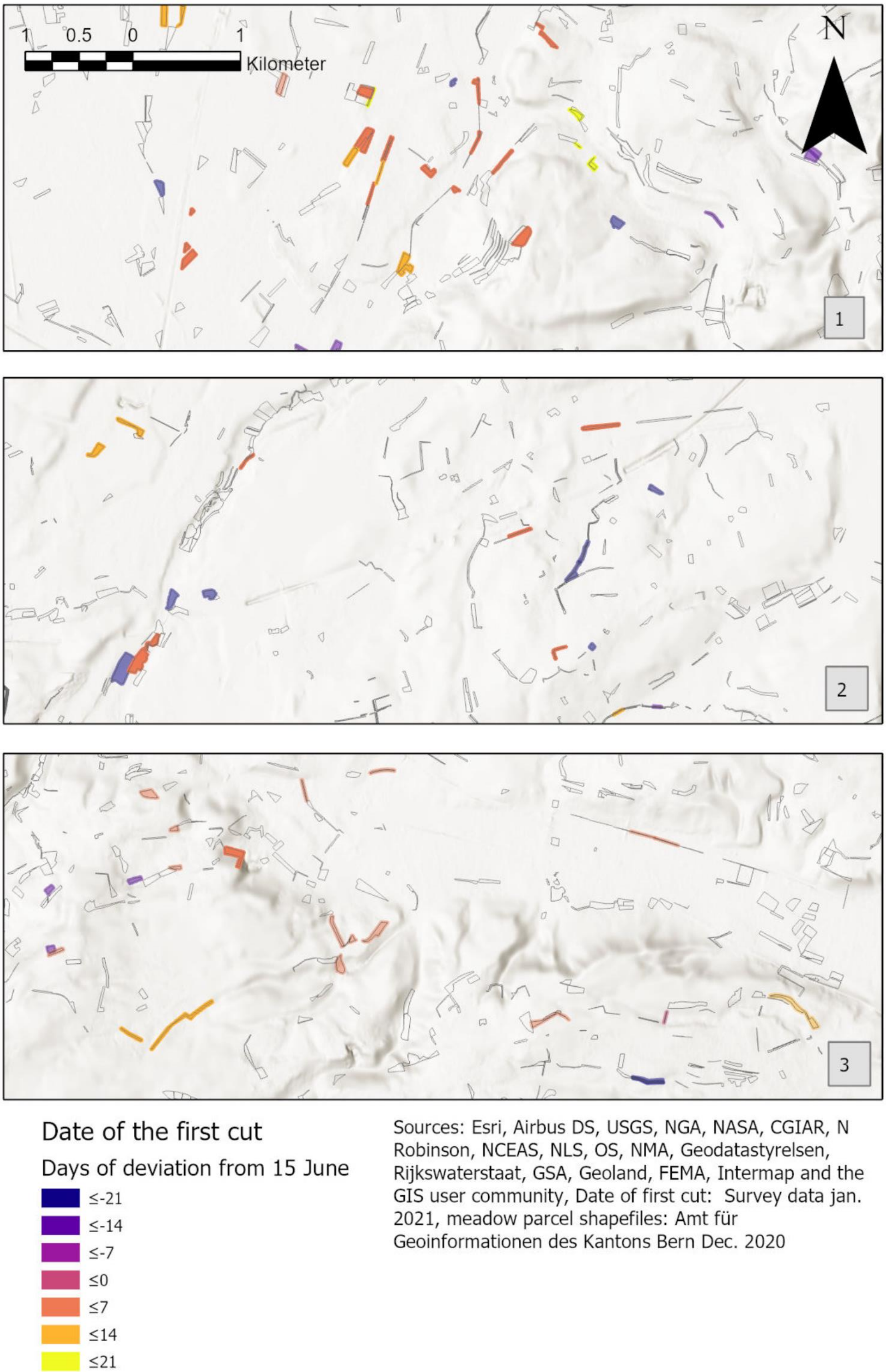
Appendix 10. Mean number of uses (number of cuts plus one if used as pasture in fall) on BPA meadows in all agricultural zones in 2018-2020. Mean values are displayed in red and n = number of meadows.



Appendix 11. Deviations of the first cutting date from the official cutting date in the respective zone (15.6., 1.7. and 15.7.) on BPA meadows in all agricultural zones in 2018–2020. Mean values are displayed in red and n = number of meadows.



Appendix 12 Mean farm-scale variation in the first cutting date based on the cutting regime(s) applied on the farms' BPA meadows: farms managing meadows either with standard (green) or flexible (yellow) cut, or both cutting regimes (orange). Red numbers are the mean values and n = number of farms.



Appendix 13. Map sections on a scale of 1:50'000 showing BPA meadows and how their first cutting date deviated from 15 June in 2020. The three examples are from lowland zones with greatest density of meadows with known first cutting date. Map section 1: Alchensdorf, map section 2: Schüpfen, map section 3: Herzogenbuchsee.