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Effects of different irrigation systems on the biodiversity of species-rich hay meadows

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ABSTRACT

The maintenance of traditional management practices is essential for the conservation of the biodiversity of semi-natural grasslands including species-rich hay meadows. In the canton Valais (Switzerland), hay meadows are traditionally irrigated using open water channels. However, since the 1980s, this labour intensive irrigation technique has been increasingly replaced by sprinkler irrigation. This study examined whether the different irrigation techniques (traditional vs. sprinkler) influence the local biodiversity of species-rich hay meadows. In particular, the diversity and composition of plant and gastropod species of eight traditionally irrigated meadows were compared with those of eight sprinkler-irrigated meadows. It was also assessed whether the species of either meadow type differed in functional traits. A high plant species richness was found in the meadows investigated. The study showed that the diversity and composition of plant and gastropod species of hay meadows were not affected by the change in irrigation technique 8–18 years ago. However, a lower grass/forb-ratio was observed in traditionally than in sprinkler-irrigated meadows. Furthermore, irrigation technique affected the leaf distribution and the onset of seed shedding in plants. Thus, the change in the irrigation technique altered only some aspects of biodiversity. Therefore, irrigation system alone does not represent the major factor affecting the biodiversity of hay meadows investigated.

1. Introduction

Semi-natural grasslands including hay meadows belong to the most species-rich habitats in Central Europe and therefore are of high conservation value (Baur et al., 2006; Poschlod and WallisDeVries, 2002). The high biodiversity of these grasslands is a result of traditional management practices such as grazing and mowing, which have been applied since many centuries and allow the coexistence of several species through regular disturbance (Poschlod and WallisDeVries, 2002). Nowadays, these grasslands are considered as refugia for numerous rare species whose primordial habitats were destroyed (Baur et al., 1996). Above all relative changes in costs for labour and fertilizers led to changes in agricultural practices beginning in the mid 20th century (Strijker, 2005). As a consequence, semi-natural grasslands are either used more intensively or were abandoned, resulting both in a decline in the area of these habitats throughout Europe (Strijker, 2005) and a decrease in plant species richness (Homburger and Hofer, 2012; Maurer et al., 2006; Niedrist et al., 2009).

The maintenance of hay meadows and their typical species composition also depends on irrigation, especially in arid regions where meadows are traditionally irrigated using open water channels (Leibundgut, 2004). These water channels are found in several parts of Europe, amongst others on the south-facing slopes of the Valais, Switzerland, where their first occurrence dates back to the 11th century (Leibundgut, 2004). Since the mid 20th century, however, the modernization and rationalization of agricultural practices in the Valais have led increasingly to the replacement of the traditional irrigation technique by sprinkler irrigation systems (Crook and Jones, 1999; Meurer and Müller, 1987).

Traditional and sprinkler irrigation differ substantially in their distribution of the water used, which may have potential effects on the biodiversity of the meadows. In traditional irrigation, the ground is inundated irregularly, depending on the micro-relief, whereas a sprinkler distributes the water over the meadow more homogeneously from above (Meurer and Müller, 1987). Traditional meadow irrigation therefore leads to the coexistence of different microhabitats and hence to a high floristic and faunistic diversity (Werner, 1995). Previous surveys focused on the plant species composition of meadows with either traditional or sprinkler irrigation (Volkart and Godat, 2007; Werner, 1995). However, to the best of our knowledge, no study compared the effects of different irrigation systems on the biodiversity of meadows.

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In the present study, we examined whether changes in irrigation technique influence the local biodiversity of species-rich hay meadows in the Valais. As a proxy for the local biodiversity, the species richness and abundance of vascular plants and terrestrial gastropods were recorded. Owing to the high habitat specificity and low mobility, these organisms are considered as ideal diversity indicators in small-scale grassland habitats (Boschi and Baur, 2008; Gaujour et al., 2012). Beside these taxonomic indicators for biodiversity, functional traits are of interest because they represent another aspect of biodiversity and therefore supplement the results of taxonomy-based analyses. In the analyses of functional traits, species are grouped according to their attributes, which are assumed to respond similarly to an environmental factor such as irrigation technique (Lavorel and Garnier, 2002). The aim of the present study was to identify traits of plants and gastropods responding to the different irrigation techniques.

In particular, the following questions were addressed: (1) Do traditionally and sprinkler-irrigated meadows differ in their diversity and composition of plants and gastropods after 8–18 years since the change in irrigation technique took place? (2) Do different irrigation techniques result in an alteration in the functional traits of vascular plants and gastropods?

2. Methods

Field surveys were conducted in three areas located on the south-facing slope of the Rhone valley in the canton Valais (Switzerland), namely in Ausserberg (46°19′N, 7°51′E; hereafter referred to as AU), Birgisch-Mund (46°19′N, 7°57′E; BM) and Guttet-Erschmatt (46°19′N, 7°40′E; GE; Table 1). The distances among these areas ranged from 8 to 22 km. Mean annual temperature in this region is 8.6 °C and total annual precipitation is 599 mm (MeteoSwiss, 2012).

The vegetation types of hay meadows investigated belonged to the *Trisetetum* association (Ellenberg, 1986). On these meadows, traditional irrigation technique was replaced by sprinkler irrigation 8–18 years ago (various farmers, pers. com.; Table 1). Nowadays, 10–30% of the hay meadows in the study areas are still irrigated in the traditional way leading to a small-scale arrangement of either traditionally or sprinkler-irrigated meadows (K. Liechti, pers. com.). Furthermore, the meadows investigated were mown, fertilized and served as pastures in autumn for 1–30 d (various farmers, pers. com; Table 1). Data regarding the amount of fertilizer, stocking rate and forage yield were obtained by personal interviews with farmers. The amount of water applied per irrigation event was calculated based on the duration of a single irrigation event (various farmers, pers. com.) and the specific water need of the areas (2 l/s ha for traditional and 0.7 l/s ha for sprinkler irrigation; Dienststelle für Bodenverbesserung Oberwallis, 1991).

To investigate the effects of the two irrigation techniques on the biodiversity of hay meadows, eight pairs consisting of a traditionally and a sprinkler-irrigated meadow were chosen in the study areas. Two pairs were located in AU and three pairs each in BM and GE. Distances between the meadows of a given pair ranged from 50 to 100 m. The distances among pairs within an area ranged from 0.2 to 2 km in AU and BM and from 0.2 to 1 km in GE. One 10 m × 10 m sampling plot was set up in a homogenous part of each meadow. The sampling plots were installed at a minimum distance of 2 m from the water channels and trails and 3 m from the roads to minimize potential edge effects. Elevation, exposure and inclination were assessed for each of the 16 study plots distributed over the three study areas.

2.1. Plant and gastropod surveys

Plant species richness and abundances of single species were assessed in a 5 m × 5 m subplot established in a randomly chosen

Table 1
Characteristics and land use features of the eight traditionally irrigated (T) and eight sprinkler-irrigated (S) meadows investigated.

Study area[a]	Irrigation type, plot number	Time since change (year)	Elevation (m a.s.l.)	Exposure	Inclination (°)	Irrigation interval (weeks)	Water amount per irrigation (l/ha)	Fertilizing frequency (per year)[b]	Amount of fertilizer (m^3/ha y)	Mowings (per year)	Forage yield (kg/ha)	Grazing regime	Stocking rate (no. of animals/ha d)[e]
AU	S1	15	1192	S	17	3	5040	None	0	2	na	No grazing	0
AU	T1	–	1236	S	26	2	3600	Once	8.6	1	na	Autumn (cattle)	na
AU	S2	18	1212	SE-S	19	2–3	10080	Every 2nd y	8.6[c]	2	6500	Autumn (sheep)	0.8 (8, 30)
AU	T2	–	1237	SE-S	21	3	16200	Every 2nd y	4.3[c]	2	8250	Autumn (cattle)	6.2 (10, 7)
BM	S3	9	1148	SE	11	3	25200	Once	10.1	2	5403	Autumn (cattle)	291.6 (34, 1)
BM	T3	–	1142	SE-S	9	2	14400	Once	33.3	2	na	Autumn (cattle)	1166.7 (35, 2)
BM	S4	8	1128	SE	20	2	12600	Once	6.3	2	3281	Autumn (cattle)	56.3 (12, 1)
BM	T4	–	1135	SE-S	8	3	18000	Once	10.1	2	5057	Autumn (cattle)	258.6 (34, 1)
BM	S5	10	1279	SE	16	3	25200	Once	24.0	2	11000	Spring and autumn (goats)[d]	685.7 (15, 2)
BM	T5	–	1275	SE	16	3	14400	Once	36.0	2	18000	Spring and autumn (goats)[d]	685.7 (15, 2)
GE	S6	8	1317	SE	6	3	30240	Once	33.3	2	23810	Occasionally in autumn (cattle)	190.5 (35, 2)
GE	T6	–	1313	SE-S	13	3	39600	None	0	2	na	Autumn (cattle)	80.0 (35, 2)
GE	S7	8	1373	SE	22	3	30240	Once	33.3	2	5952	Occasionally in autumn (cattle)	95.2 (35, 2)
GE	T7	–	1396	E	16	3	39600	Once	33.3	2	20833	Occasionally in autumn (cattle)	166.7 (35, 2)
GE	S8	8	1310	S-SW	19	3	10080	Every 2nd y	6.0[c]	2	64000	Autumn (horses)	10.0 (10, 10)
GE	T8	–	1291	W	16	3	25200	Every 2nd y	5.8[c]	2	3750	Autumn (horses)	na

na: data were not available.
[a] AU: Ausserberg; BM: Birgisch-Mund; GE: Guttet-Erschmatt.
[b] Manure in all meadows.
[c] Values are per year.
[d] Grazing in spring was applied in 2010 and 2011 only. In the years before, meadows served as a pasture in autumn.
[e] The number of animals and the duration of grazing (in d) are given in brackets.