Agriculture, Ecosystems and Environment 144 (2011) 159–166

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

The short term agronomic impact of raising canal water levels in grassland areas: A case study in the Belgian polders

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ARTICLE INFO

Article history:
Received 12 January 2011
Received in revised form 17 June 2011
Accepted 21 June 2011
Available online 20 September 2011

Keywords:
Lowland grassland
Forage yield
Feed quality
Penetration resistance
Botanical composition
Lysimeter

ABSTRACT

This study tested the hypothesis that raising canal water levels with 30 cm beyond the growing season in intensively managed lowland grassland (2.4–3.7 m above sea level) in Belgium decreases the agronomic value of pastures The study ran 3 years before and 3 years after the water elevation. Using five pairs of plots inside and outside the wetted perimeter, it was not possible to demonstrate significant impacts of the elevated water level on dry matter yield, forage quality, botanical composition, and penetration resistance of the top soil layer of the grassland. In an *ex situ* lysimeter experiment, simulating the effect of a water level in canals up to 50 cm beneath the surface of the pastures indicated a significant decrease of the penetration resistance of the top soil layer.

Results are discussed and confronted with the difficulties of field research addressing the elevation of water levels.

1. Introduction

For centuries, one of the most commonly used practices to upgrade marginal (peat-)land was drainage. This lowering of the groundwater level generally increases productivity and lengthens the period in which the land is accessible for cattle and machinery. On the other hand, it causes desiccation of soils and peat, emissions of greenhouse gasses (Best and Jacobs, 1997; Dobbie and Smith, 2006), soil degradation (Zeitz and Velty, 2002), vegetation changes (Best et al., 1995; Oomes et al., 1996, 1997) and mineralization of nutrients like nitrate and phosphorus (Berendse et al., 1994; Tiemeyer et al., 2007). To counteract these effects, the European Union stimulates a whole spectrum of agro-environmental schemes (e.g. Kleijn et al., 2004) to re-establish higher groundwater levels on former peat and/or wetland areas (Klimkowska et al., 2007).

Elevating groundwater levels can directly influence the productivity and management of grasslands. First, nutrient availability may change due to decreased mineralization rates when oxygen becomes limiting in the decomposition process or when the elevation is realized with nutrient-rich water (Berendse et al., 1994; Oomes et al., 1997; Van Dijk et al., 2004; Lucassen et al., 2005). These processes can result in positive or negative effects on the yield and quality of grasslands. Second, an elevated groundwater level can lower the physical carrying capacity of the grassland (Wells and Treesuwan, 1978; Clary, 1995). When the carrying capacity of grassland drops below a certain threshold level (generally 60 N/cm^2), the sward will be damaged when it is accessed by cattle or heavy machinery (Anonymous, 2000; Di et al., 2001; De Frenne, 2007). Third, a rise in groundwater level can alter the botanical composition of the grassland (Gilbert et al., 2003; Leyer, 2005). As some species are more productive and/or more nutritive for cattle, a shift in botanical composition changes the productivity both in terms of grass quality and in terms of quantity. For instance, it is known that the presence of the highly productive *Lolium perenne* L., decreases compared to species as *Holcus lanatus* L., as groundwater levels increase (Beddows, 1967; Watt and Hagar, 1980). *Glyceria fluitans* R.Br., on the other hand, is a species promoted by increasing ground water levels (Oomes et al., 1997).

From an environmental point-of-view, several advantages are coupled with elevated groundwater levels. Since grassland and peatland soils contain huge amounts of carbon stocks (De Deyn et al., 2008) and the amount of sequestered carbon potentially increases when soils get wetter, wetter grassland may become an important instrument for carbon sequestration within the scope of climate change. Raising water level may also provide a buffer against prolonged dry periods, which are already occurring and are expected to increase in the near future in western Europe (IPCC,

Abbreviations: a.s.l., above sea level; DM, dry matter; NEL, nett energy content available for dairy cows; *I*%, importance percentage; I_a%, importance percentage of grasses with high agronomic value; IN, inside the rewetted area; OUT, outside the rewetted area.

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doi:10.1016/j.agee.2011.06.026

Table 1
Precipitation (mm) registered in the meteorological station in Koksijde (ca. 12 km away from the field study in Lampernisse). *Norm* is the mean rainfall of the most recent 30 years.

	2002	2003	2004	2005	2006	2007	*Norm*
January	56	61	105	41	22	70	51
February	121	17	47	47	63	81	42
March	44	24	30	33	33	47	70
April	31	36	37	56	39	0	50
May	47	76	34	87	115	71	59
June	76	48	46	5	45	129	65
July	96	46	102	13	23	147	72
August	78	39	90	7	292	117	74
September	71	22	19	46	61	82	69
October	79	77	37	57	74	36	72
November	110	69	40	109	77	49	64
December	162	84	63	53	90	88	59
Sum	971	599	650	554	934	917	697

2007). Moreover, restoring wet features in lowland grassland is crucial for the maintenance of the typical fauna and flora of wetlands, like breeding water bird populations (Englington et al., 2008) or wetland plant species (Toogood and Joyce, 2009).

Although multiple studies have evaluated the impact of raising the groundwater level in semi-natural grassland for conservation purposes (Oomes et al., 1996; Van Dijk et al., 2007; Klimkowska et al., 2007; Toogood and Joyce, 2009), few studies have studied the agronomic impact on the productivity, quality, carrying capacity and botanical composition of intensively managed grasslands. Available studies focus mainly on plant diversity and the conclusion is very often that a raised water level has no or only small effects on plant species diversity (Van Dijk et al., 2007; Klimkowska et al., 2007; Toogood and Joyce, 2009).

In the present study, we evaluated the impacts of raising water levels in the drainage canals on the agronomic value of grassland by combining a field experiment and a lysimeter experiment. The field experiment was performed in a lowland grassland area where the water level in the drainage canals was raised by 30 cm during the winter months. A higher water level in the canals is expected to result in a higher groundwater level below the pastures, which in turn may affect agronomic properties (Armstrong, 2000; Gavin, 2003). Aboveground yield, forage quality, botanical composition and carrying capacity were studied in the area. The study ran 3 years before and 3 years after the elevation of the canal water level.

As in field experiments extra variance is created by uncontrollable factors like soil heterogeneity, weather variability and pests (Gomez and Gomez, 1987), we also established an experiment in lysimeters subject to different controlled groundwater level regimes. There, we also evaluated yield, forage quality and carrying capacity of the experimental grasslands over 4 years.

Our research hypotheses were that raised water levels in the drainage canals of a grassland area decreases the agronomic value of the grasslands in terms of productivity, forage quality, botanical composition and carrying capacity (Hypothesis 1), and that the highest water groundwater levels in the lysimeters provoke the largest decrease in agronomic value (Hypothesis 2).

2. Methods

2.1. Field experiment (in situ)

2.1.1. Studied area

The *in situ* study was conducted in the 'Kom van Lampernisse', a grassland area of ca. 500 ha in the western part of Belgium (51.02°N, 2.51°E), in a region called the "Polders". Mean annual temperature is 9.4 °C and mean annual precipitation amounts to 697 mm. Rainfall data, registered during the experimental period in the meteorological station of Koksijde, 12 km away from the experimental area, are given in Table 1. Soils are peaty, covered by a 0.3–1 m layer of clay or clay loam. In the past, the former peatland was transformed into grassland through drainage by using a system of canals and ditches. The whole area is surrounded and crossed by canals that are connected with a grid of ditches with smaller dimensions than the canals. The grassland is grazed in a system of continuous grazing, predominantly by beef cattle and dairy heifers. Occasionally the first growth is silaged. Annual nitrogen fertilization is approximately 250 kg N/ha. Individual fields are irregular in form and surface area but no point is further away than 100 m from any canal or ditch. This causes changes in the water level in the canals and ditches to be reflected into a corresponding change in groundwater levels (Armstrong, 2000).

The altitude of the area varies from 0.5 to 5 m above sea level (a.s.l.), with a mean altitude of 3 m.

Before 2004, the level in the canals was maintained at 2.1 m a.s.l. during the growing season (further indicated as summer). From mid October to mid March (further indicated as winter) the water level was lowered to 1.8 m a.s.l. in order to allow the removal of the animals in the autumn, to limit flooding during winter months and to fertilize, mow and stock the grassland during spring. In line with the rewetting strategy of the Flemish Land Agency, a year-round water level of 2.1 m a.s.l. was installed in the some of the canals from winter 2004 onwards, affecting an area of about 340 ha. Only upon specific request of the farmers the water level occasionally was lowered to 1.8 m a.s.l. for 2 weeks during spring, allowing fertilization and/or mowing.

Water levels in the canals were registered automatically on a daily basis, while the measurement in the ditches occurred less frequently.

We studied the area during three growing seasons before (2002–2004) and three growing seasons after (2005–2007) the elevation of the water level in the canals.

2.1.2. Experimental design

Five pairs of pastures along a microtopographical altitudinal gradient were selected: one pasture of each pair was situated either inside or outside the wetted area (further referred to as IN and OUT, respectively). The IN and OUT components of a pair were as closely as possible related with regard to their soil type and altitude (Table 2), management and initial botanical composition. Precise altitudes were available from detailed laser altimetric maps. The centers of the pastures within pairs 1 and 2 were less than 200 m away from a canal; the other pastures were further away from a canal. This allowed us to detect a potentially higher influence of the larger canals. Within each pasture, plots of 150 m^2 were fenced to exclude grazing animals. The centers of these plots were never further than 20 m away from a ditch, simulating the maximum effect in a pasture of an increase of the water level. Within