Agriculture, Ecosystems and Environment 197 (2014) 243–254

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

Semi-natural grasslands of the Non Valley (Eastern Italian Alps): Agronomic and environmental value of traditional and new Alpine hay-meadow types

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ARTICLE INFO

Article history:
Received 18 January 2014
Received in revised form 31 July 2014
Accepted 1 August 2014
Available online 14 September 2014

Keywords:
Botanical composition
Environmental impact
Management intensity
Nutrient balances
Production
Semi-natural grassland types
Soil characteristics

ABSTRACT

Semi-natural Alpine grasslands represent an important Western European ecosystem but recent agricultural intensification has substantially changed their characteristics. The extent to which this ecosystem may have been compromised are quantified using a combination of farm, soil and botanical attributes collected for 48 hay-meadows over 2 years in the Non Valley (Eastern Italian Alps).
Due to the wide range of estimated nutrient balances meadow type diversity is high but the trend is for the creation of productive but species-poor meadows at the expense of low-intensity but species diverse ones. Currently the typical *Arrhenatherum elatius* grasslands are less species-rich and *Bromus erectus* ones, traditionally not fertilized, are now often subject to low fertilisation. Yields can be high (up to 10.5 t d.m. ha^{-1} $year^{-1}$ at about 1000 m a.s.l.) but, due to the generally late first cut and low cutting frequency, these provided reduced forage quality sometimes accompanied by excessively high potassium concentrations. Forage quality is not generally sufficient for highly productive dairy cattle, so that supplementary feeding is required. Reduced cutting frequency and traditional hay-making also limit the efficient removal of nutrient inputs with annual surpluses up to 245, 63 and 293 kg ha^{-1} for N, P and K respectively. The combination of sandy soil texture and sloping ground do not favour nutrient retention therefore increasing the potential risk for the wider environment. Reducing the trend of genetic cattle improvement towards high milk production and replacement of the traditional Brown Swiss breed with Friesian Holstein, more efficient forage harvesting and higher cutting frequency could greatly improve the environmental sustainability of new meadow types. However, biodiversity conservation can only be achieved if enough of the extensive grassland is maintained coupled with appropriate management of intensive meadows.

1. Introduction

The creation and expansion of semi-natural grasslands to produce forage of quality suitable for domestic herbivores has accompanied the whole development of European agriculture since the late Mesolithic (Ellenberg, 1988), with the result that these ecosystems have acquired a basic role in the landscape and biological richness of Western Europe (Bignal and McCracken, 1996). However, during the 20th century, most semi-natural grasslands were lost after the abandonment of areas which were difficult to cultivate or underwent a substantial reduction in their biodiversity as a consequence of intensive management of more favourable surfaces (van Dijk, 1991; MacDonald et al., 2000; Gellrich et al., 2007; Hopkins and Holz, 2006).

In Alpine regions, intensified livestock farming and forage production have also been taking place over the last 60 years (Andrighetto et al., 1993), resulting in profound changes to semi-natural grasslands. Fertilisation and higher cutting frequencies have increased the agronomic value of grasslands by raising the production of nutritional substances (Klapp, 1971) and the protein, mineral and energy concentrations of forage (Buchgraber et al., 1998), thus making yields from semi-natural grasslands suitable for high-production dairy cattle (Jeangros and Scehovic, 1996; Schmid and Thöni, 1990).

Together with its effects on agronomic value, intensified cultivation has profoundly changed the environmental quality of mountain meadows, made even more significant as these crops

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http://dx.doi.org/10.1016/j.agee.2014.08.003
0167-8809/

increasingly play a particular role within cultivated ecosystems (Thiébaud et al., 2001). It has created meadow ecosystems characterised by fertile soils, which represent new types of vegetation (Ellmauer and Mucina, 1993; Dietl, 1995). The number of plant species has decreased (Jeangros, 1993) and with it also the animal species hosted (Haddad et al., 2000). Nutrient contents in soil but also nutrient losses to air and water have increased (Plantureux et al., 1987). Conversely, agronomic value is often compromised by weeds, such as tall nitrophilous herbs or ruderal species of low forage value, which spread over meadows when cutting frequency is not adjusted to fertilisation (Dietl and Lehmann, 2004) or site conditions are not suitable for grasses compatible with intensive management (Dietl, 1982).

These relations among management, meadow types, species richness, amount and quality of produced forage, soil characteristics and nutrient balance have only rarely been examined systematically in the semi-natural mountain hay meadows of an entire geographical area. The present study faces this topic in order to evaluate differences among the types of traditional and recently formed hay meadows, with reference to real management situations, which often differ substantially from experimentally controlled conditions. It also supplies suggestions for improving grassland management, hay harvesting and conservation, aiming at increasing forage quality, reducing environmental impact and maintaining the natural value of semi-natural grasslands.

2. Materials and methods

2.1. Main characteristics of the environment, livestock farming and forage production in the Non Valley

Located in North-East Italy in the provinces of Trento (PAT) and Bolzano (PAB) over a total area of 635 km^2, the N-S-running Non Valley represents the middle and low basins of the Noce stream. The agricultural landscape is dominated by apple orchards up to about 900 m a.s.l. and semi-natural grasslands above that altitude. Rainfall is about 900 mm $year^{-1}$ and has a within-year distribution from equinoctial (southern part) to continental (northern part). At the meteorological station of Romeno (957 m), the mean yearly temperature is 9.1 °C. The lithological substrates are mostly sedimentary (dolomite, marl, chalk, etc.): only in the north-western side do silicate volcanic or metamorphic rocks outcrop. The central part of the area is a wide morainic terrace (Bosellini et al., 1999).

In 1998, meadows covered about 3000 ha (4.5% of the whole surface area), of which 2600 ha were permanent. Farmed animals were almost exclusively cattle, totalling 7230 LSU, with a mean stocking rate of 2.42 LSU ha^{-1}. When seasonal transfer of cattle to the summer Alpine pastures is also included, the mean stocking rate in the meadows was 2.25 LSU ha^{-1}. The milk was destined to produce the Trentino Grana cheese, which must be made with milk from animals not fed with silage. Also for this reason, forage was harvested almost exclusively with traditional hay-making.

In the late 20th century, livestock farming and forage production changed profoundly. The number of farms breeding cattle dropped (by 64% between 1984 and 1998). Meadow surface areas also significantly decreased, due to the expansion of apple orchards (low valley) and the abandonment of grassland on the steepest slopes (high valley), although the number of cattle reared remained about the same. As a consequence, stocking rates greatly increased, from 0.9 LSU ha^{-1} in 1967 (Garzena, 1971) to the recent 2.25 LSU ha^{-1}. Milk production amounted to about 3.7 t cow^{-1} $lactation^{-1}$ in the 1970s and 6.2 t in 1998 (sources: PAT Veterinary Service, PAB Agriculture Census and Farm census).

2.2. Study of farms and semi-natural hay meadows

In meadow areas representing the various soil and climatic conditions of the Non Valley, 22 dairy farms with differing numbers of reared animals (range 3–208) were randomly chosen at the end of 2003. Based on a properly constructed questionnaire, information on breeding and meadow management was obtained from each farmer.

For each farm, at least 2 semi-natural hay meadows with different management intensity were chosen, resulting in 48 meadows with altitude ranging between 900 and 1600 m and size between 850 and 40,000 m^2. In the following 2 years, shortly before each cut, the botanical composition and production of each meadow were examined. According to the flora of Italy (Pignatti, 1982), all vascular plants on a 10 m × 10 m sample area were identified and the percentage contribution of each species to the above-ground plant biomass was estimated (percentage abundance: Klapp, 1971). To estimate forage production, 4 meadow strips (0.9 m × 5 m or 0.9 m × 10 m, according to grass height, higher or lower than 70 cm, respectively) were cut with a sickle bar mower at a height of 3–5 cm. The cut grass was immediately weighed and sampled. Samples (1000 g per strip) were dried and analysed in the laboratory according to standard VDLUFA (1988) methods for the following chemical characteristics: content of dry matter (d.m.) in fresh forage, concentration of crude protein (CP, obtained from Dumas nitrogen (N) content multiplied by 6.25), crude fibre (CF, Weende method), ash and minerals (phosphorus, potassium, calcium, magnesium: P, K, Ca, Mg) in the d.m. Protein digestible in the intestine (PDI) and net energy for lactation (NEL) were calculated according to Arrigo et al. (1999).

During the 2-year study, the management practices of each meadow were recorded as regards fertilisation, time and number of cuts, irrigation, forage harvesting, and weed control. Nutrient inputs by fertilization were estimated from the recorded amounts of mineral and organic fertilisers and the corresponding nutrient concentrations. For organic fertilisers, the following values of N, P_2O_5 and K_2O contents were used (Walther et al., 2001): solid manure, 49, 32 and 66 kg in 10 t; manure leachate, 49, 12 and 116 kg in 10 m^3; liquid manure, 43, 18 and 80 kg in 10 m^3. To compare the utilisation intensity of areas at different altitudes, an index was calculated for each meadow by transforming the real cut number into the cut number that the same meadow would have had at the "standard" altitude of 900 m. Under the assumption that shortening of the vegetative period decreases the cut number by one for every 400 m of difference in altitude (Walther et al., 1994), the index was obtained with the following formula: index value = no. of cuts per year + (1*x* (meadow altitude − 900)/400).

For each meadow, the lithological substrate (Bosellini et al., 1999), slope, aspect, distance to farm centre and soil depth (mean of six measurements) were assessed. The following laboratory analyses were carried out on soil samples collected from the 0–20 cm layer, according to official Italian methods of soil analysis (G. U. (Gazzetta Ufficiale dello Stato Italiano), 1997): texture (hydrometer, II.6), pH (in water solution 1:2.5, III.1), content of organic matter (o.m.) (Springer–Klee method, VII.2), total carbonates (treatment with hydrochloric acid, V.1), total nitrogen (N: Kjeldahl, XIV.3), total P and K (crumbling with turpentine oil and ICP measurement), Olsen P (Olsen method, XV.3), exchangeable K and Mg (treatment with ammonium acetate, XIII.4) and cationic exchange capacity (treatment with barium chloride and triethanolamine, XIII.2). As suggested by CEC (2007), gross nutrient balances were calculated for the 48 meadows. Fertilisation, symbiotic N fixation and atmospheric deposition were considered as inputs. The amount of symbiotically fixed N (range 0–32 kg ha^{-1} $year^{-1}$) was estimated under the assumptions that 70% of N in legumes comes from N fixation (Jacot et al., 2000), the N