Sensory properties of cheese from different grazing systems on upland pastures compared to hay-diet

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Contribution of mountain pastures
to agriculture and environment

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In memory of Professor Janina Fatyga (1929-2011), an outstanding scientist, specialist in mountain issues: soil erosion, grassland management and valorization of agricultural space. She authored more than 130 scientific and general public papers. Many year's standing worker of Institute for Land Reclamation and Grassland Farming (now Institute of Technology and Life Sciences), she was an active member of FAO/CIHEAM Mountain Pastures Network.

FOREWORD

Welcome to the 16th Meeting of the FAO-CIHEAM Mountain Pastures Sub-Network in Krakow.

This proceeding must be regarded as a working document. Its edition has been carried out in a short time thanks to the scientific committee and to the local organisers. English isn't the native language of almost all authors and reviewers of the network. In spite of the variability of their syntax, the texts listed here have the merit to update knowledge and methodologies. The geographical extent of the participants is broad, covering regions from all Europe and even from Tunisia, Israel and Kyrgyzstan. Such a multiplicity of study areas illustrates the richness of the network. The 17th meeting will set up an actual inventory of researches done at the field scale to better manage and preserve grasslands. Methods will be shared and common protocols established in a way to reinforce the scientific evidence of the mountain pastures contribution to agriculture and environment.

Primary contribution of mountain pastures, such as fodder and biodiversity, is clearly conditioned by natural conditions. Climate, soil, topography and altitude exert their effects on the yield and the botanical composition of grasslands. Grazing management also influences their biodiversity and moreover consists in the only way of preserving it. Mountain stockbreeders maintain a rare and unique territory. This singularity allows them to escape globalisation. Original animal products issued from permanent pastures are fully in accordance with a sustainable development. The link between bio diverse grasslands and meat or dairy products quality has been a key issue of previous meetings. In 2008 and 2010 an ambitious collaborative research project has been submitted to COST Office, but, unfortunately, was rejected. Today, the network still aims at reinforcing exchange between researchers concerned by authenticity of the mountainous products.

Secondary contribution covers a wide range of function and services. Mountain landscapes are well appreciated as recreation and sport areas. Wildlife symbolizes freedom and is used as marketing image. Spring water is considered as gold. These resources couldn't be preserved without agriculture. Nevertheless, farming, and especially animal production, is often considered as polluting by a major part of consumers. Research conducted on mountain pastures contributes to better practice and to a recognition of the pastures values. As a consequence, it should drive to stabilize population in marginal regions.

Both sessions of the seminar will draw up a large panel of research activities done on mountain grasslands. Pastures themselves include several vegetation types requiring a differentiated management. During the excursion on the second day, organic farms will be visited illustrating the natural potential of their environment. A workshop aiming at demonstrating tools used to assess the vegetation and the animal production will be organised.

On behalf of the organizers, we wish you a fruitful meeting and lot of pleasure in exchanging knowledge on fascinating topics around mountain and hill farming.

Eric Mosimann, Coordinator of Mountain Pastures Sub-Network, 10th May 2011.

Table of content

SESSION 1 Climate change and grazing impacts on vegetation

An Assessment of the Water Requirements of a Mountain Pasture Sward in the Polish Western Carpathians

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Abstract

The water requirement of pasture swards using the Penman-Monteith method-(FAO-56), which is seldom applied in Poland, was assessed. The reference crop evapotranspiration *(ETo)* from a hypothetical grass with an assumed height of 0.12 m, a fixed surface resistance of 70 s m^{-1} and an albedo of 0.23, was used. These assumptions are similar under conditions of ruminant grazing. *ETo* was computed by using meteorological data from 43 weather stations including the Jaworki station. The crop evapotranspiration *ETc* is the product of *ETo*, and single crop coefficient (Kc). The differences between precipitation and *ETo* and *ETc* (climatic water balances) were determined for mountain pastures. The results were summarised in the form of a table and of maps of isohyets and isolines elaborated by applying the Geographic Information System techniques (Arc View 9) with the data interpolated by the geostatic method (Kriging).

Keywords: pasture sward, crop evapotranspiration, water requirements, Carpathian Mountains

Introduction

Various methods have been used in the Polish Carpathians to determine the amount of water requirements of agricultural crops and natural vegetation. The main methods are: lysimeter experiments, field experimental plots and soil moisture studies. Recording from small lysimeters is known not to be accurate. Water consumption or evapotranspitation is the sum of two terms; (1) transpiration, which is water entering plant roots and used to build plant tissue or being passed through leaves of the plant into the atmosphere, and (2) evaporation, which is water evaporating from adjacent soil, water surfaces, or from the surfaces of leaves of the plant. The potential evapotranspiration, introduced by Penman (1948) and Thorntwaite (1948), is defined as “the amount of water transpired in unit time by a short green crop, completely shading the ground, of uniform height under no water shortage”.

The Penman theory contributed greatly towards a better understanding of the process of evaporation. However, the use of the Penman equation (and its modifications) was limited to calculation of evapotranspiration of well-watered short grass. Therefore the FAO Expert Consultation on Revision of FAO Methodologies for Crop Water (May 1990) recommended the adoption of the Penman-Monteith combination method as new standard and advised on procedures for calculation of the various parameters. The reference crop was defined as a hypothetical crop with an assumed height of 0.12 m having a surface resistance of 70 s m^{-1} and an albedo of 0.23.

The objective of this paper was to determine water requirements and climatic water balance of pasture swards in the Polish Carpathians by applying the FAO Penman-Monteith method -FAO-56- (Allen et al.1998) . This objective was achieved through:

- estimation of reference evapotranspiration (*ETo*) and climatic water balance (*P - ETo*);
- elaboration of spatial distribution (maps) of *ETo* and *P - ETo*;
- determination of crop evapotranspiration *(ETc)* for pastures in the Polish Carpathians.

Material and methods

The FAO Penman-Monteith method (FAO-56) (Allen et al. 1994, 1998, 2005, 2006; Łabędzki, 1999; Kuźniar, 1994, 2010; Smith, 1992) was used to assess the evapotranspiration. The reference surface can be unambiguously determined and provides consistent ETo values in all regions and climates. Grass is a well-studied crop regarding its aerodynamic and surface characteristics and is worldwide accepted as reference. The reference evapotranspiratiom ETo (grass) was calculated by means of the following equation:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \dfrac{900}{T + 273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

where : ET_o = reference evapotranspiration [mm day^{-1}], R_n = net radiation at the grass surface (measured or estimated) [MJ m^{-2} day^{-1}], G = soil heat flux density [MJ m^{-2} day^{-1}], T = mean daily air temperature at 2 m height [°C], u_2 = wind speed at 2 m height [m s^{-1}], e_s = saturation vapour pressure [kPa], e_a = actual vapour pressure [kPa], e_s - e_a = saturation vapour pressure deficit [kPa], Δ = slope vapour pressure curve [kPa °C^{-1}], γ = psychrometric constant [kPa °C^{-1}].

The monthly data was extracted from 43 meteorological stations of the Institute of Meteorology and Water Management in Poland and included: maximum and minimum air temperatures, actual vapour pressure,wind speed at 2 m above the ground level and actual duration of sunshine.The climatic stations cover an area of 22,830 km^2 - the Carpathians within the Upper Vistula River basin. The obtained results of agricultural - climatic water balance (reference and potential crop evapotranspiration on a monthly basis) were synthesised in form of tables and maps of mean seasonal values (May-October) from the period 1990-2005. Maps of isohyets and isolines were elaborated by applying the Geographic Information System techniques (Arc View 9) with interpolated data by the geostatic method (Kriging).

Results and discussion

Figures 1 and 2 illustrate the result of this work. The obtained maps allow us to characterise the reference and the potential crop evapotranspiration in the Polish Carpathians. The spatial distribution of mean reference evapotranspiration *(ETo*) in the summer season (Fig.1) shows that it increased from a minimum of 433 mm at Zakopane (Tatra Mts) to reaching maximum of 538 mm at Bielsko-Biała (Beskid Zachodni Mts). Lower values of *ETo* were observed in the Beskid Śląski Mts (440 mm) and in the Beskid Sądecki Mts (460 mm). In the Bieszczady Mts *ETo* ranged between 460 and 480 mm during the season. Crop evapotranspiration of pastures *(ETc*) shows lower values and varies from 325 mm (Zakopane) to 404 mm (Bielsko B.). The lower values of *ETc* were obtained in cases when the Kc coefficients for pastures (reduction factor < 1.) were applied. Seasonal (May-October) climatic water balances (*P-ETo*) are characterized by great spatial differences; they are in a range from 6 to 343 mm and they did not reach negative (deficit) values in the Polish Carpathians. The highest precipitation surpluses (*P-ETo*) occur in the peak areas of the Beskid Żywiecki Mts. and in Polish Tatras (Zakopane 342 mm). In the Beskid Wyspowy Mts. precipitation surpluses amounted from 100 to 250 mm and near the Sieniawska Gate above 200 mm.

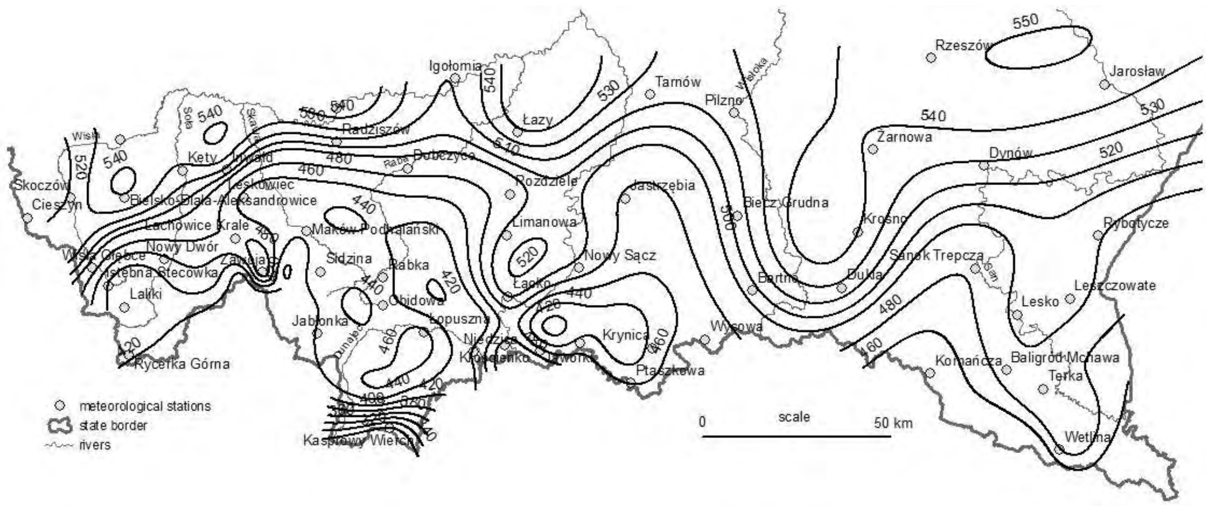

Fig.1. Map of the Polish Carpathians showing isolines of average reference evapotranspiration (*ETo*, mm), according to the FAO-56 Penman-Monteith method during the period May–October from 1990 to 2005.

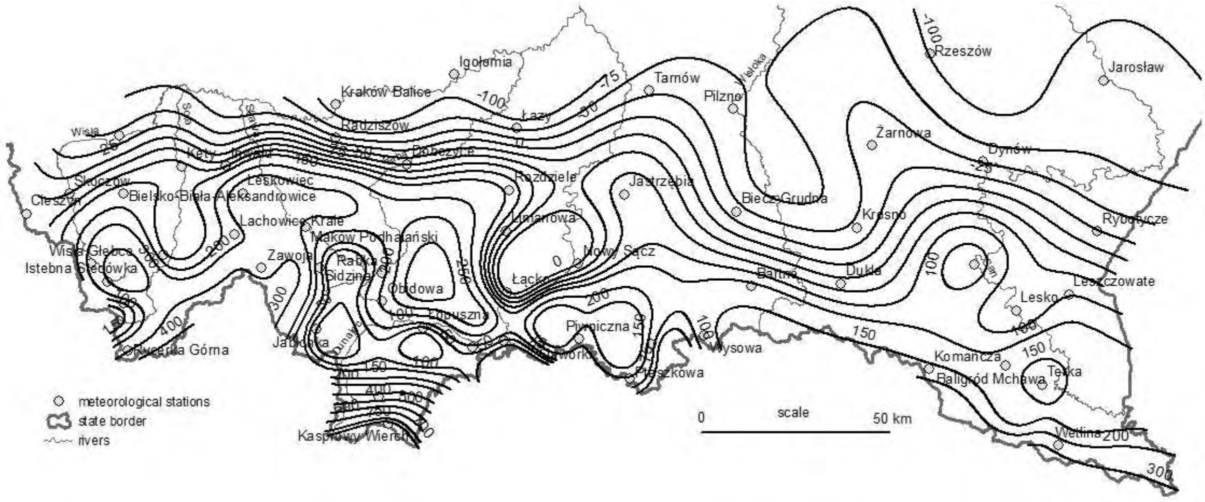

Fig. 2. Map of the Polish Carpathian showing isolines of average climatic water balance (*P-ETo*, mm) - water surplus and deficit - during the period May–October from 1990 to 2005.

Considerable water surpluses are also found in the valleys: e.g. the Sądecka Valley (150–200 mm). In the Bieszczady Mts., the climatic water balance in summer ranged from 150 to 300 mm. The equilibrium isoline between precipitation and reference evapotranspitation *(P=ETo*) runs along the border between the Carpathians and the Valleys. Therefore, it can be concluded that the Carpathian Mountains, as compared with lower parts of Poland, are very favourable for the grassland production. Analyses of spatial distribution of *ETo* and *P*, as well as of (*P – ETo*) in summer showed a good relationship with elevation above sea level (h). For example, the climatic water balance correlated with elevation h gave following regression.

$(P – ET_o) = 0.63h – 216.19$ with $R^2 = 0.732$

Until now, the FAO-56 Penmana-Monteith method has not been applied in the Polish Carpathians for evaluation of evapotranspiration of grasslands and pasture. Furthermore, in relation to the previous calculation formulae, which were applied in the study area, the method makes up a successive stage in gathering data of the components of climatic water balance. An advantage of this method is the possibility of calculating the reference evapotranspiration using standard measurements originating from a meteorological station.

Conclusions

Studies have shown that the FAO-56 Penman-Monteith method which was applied in the Polish Carpathians facilitated computation in a reliable way reference (*ETo*) and potential crop evapotranspiration for grasslands (*ETc*) using readily available computer programs FAO-PM

The maps of isohyets and isolines which were calculated can be used for an evaluation of the water balance of pasture swards, particularly in situations when there is a lack of direct measurements. Linear regression between elevation above sea level and analysed climatic water balance components (May-October) were significant (R^2 > 0.7). This relation can be applied for assessment of mean values in the Carpathians when there is a lack of weather observations. It also can be cartographied for climates classification.

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The effects of climate fluctuations and soil heterogeneity on the floristic composition of sown Mediterranean annual pastures

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Abstract

Sown Biodiverse Permanent Pastures Rich in Legumes (SBPPRL) is a pasture system for Mediterranean climatic areas mixing a large number of pastures species and cultivars, with a predominance of *Trifolium subterraneum*. Since the nineties, it rapidly expanded in Portugal due to its high dry matter yields (DM) and C sequestration rates in soil organic matter. Although without clear experimental evidence, it is currently admitted that SBPPRL are able to adjust soil spatial heterogeneity and to reflect interannual climate fluctuations.

The study was realised on a SBPPRL sown in 2001on a mixed farm located in “Serra da Estrela”, the main agricultural mountain system of Portugal. The effects of two explanatory variables – “Year-climate” (moderately dry in 2007-2008 and humid in 2009-2010) and “Slope” (three positions: hill shoulder, backslope and footslope) – on the floristic composition were explored. Three botanical levels of analysis were used: all species, sown species and *T. subterraneum* cultivar levels. The statistical significance and the influence of the two explanatory variables on the plant composition varied between these three levels. The distribution of *T. subterraneum* cultivars along the microtopographical gradient was congruent with their life cycle duration: short-cycle cultivars had higher relative cover in uphill plots while longer cycle cultivars tended to dominate down the slope. Diversifying the sown species/cultivar colonists’ pool in seed pasture mixtures appears to favour microtopographic gradients and interannual climatic fluctuation tracking. Sown species diversity and *T. subterraneum* cultivar diversity are complementary in this process; they promote, respectively, interannual climatic and microtopographic gradients fluctuation tracking.

Keywords: subterranean clover, pasture legumes, pasture ecology

Introduction

In the seventies, the Portuguese agronomist David Crespo devised a new pasture system – the Sown Biodiverse Permanent Pastures Rich in Legumes (SBPPRL) – mixing a large number of improved pasture plants with a Mediterranean optimum. The SBPPRL can involve up to twenty different pasture plant species and cultivars, the majority of them self-regenerating winter annuals (only grasses are perennial), *Trifolium subterraneum* being the preponderant species.

FERTIPRADO (2011), the main pasture seed provider in Portugal, blends its SBPPRL mixtures according to three criteria: soil texture, soil pH and mean annual precipitation. In these mixtures, to a variable group of pasture species with different ecological requirements are added several cultivars of *T. subterraneum* covering a considerable life cycle length spectrum. *T. subterraneum* cultivar selection in agronomic practice depends on the date at which moisture stress can be expected to occur and the time of flowering required to allow the maturation of adequate seed before this occurs (SMETHAM, 2003). Pasture improvers and seed sellers currently determine these two factors by mean annual precipitation and the date of the cultivars’ first flowers. *T. subterraneum* is a cleistogamic species, its natural populations being constituted by pure lines (KATZNELSON, 1974). Consequently, morphologically consistent cultivars should be recognized several years after pasture sowing.

Several reasons explain SBPPRL rapid expansion in Portugal. The foremost cause is that they are more productive than semi-natural dry-pastures. In a five year study in Southern Portugal, CARNEIRO *et al*. (2005) found that SBPPRL had an average stocking rate 145% superior to contiguous semi-natural pastures (0.86 vrs. 0.35 $LU.yr^{-1}$, p=0.03, paired t-test). In the DM yields summarised in table 2 for the year 2007-2008 in Quinta da França, Portugal, the SBPPRL total DM production was 347% higher that its nearby semi-natural pasture (6.15 t $DM.ha^{-1}$ *vrs*. 1.77 t $DM.ha^{-1}$). All the available empirical evidences points to superior productive characteristics of SBPPRL when compared to semi-natural pastures, even under similar chemical fertilization schedules (TEIXEIRA, 2010). In Mediterranean Portugal areas, CRESPO (2011) reported on SBPPRL yields of 4 - 8 t $DM.ha^{-1}.yr^{-1}$, with more than 50% of legumes, and with production costs of about 15-20% of the compound feed costs. SBPPRL's have other advantages. In Mediterranean territories with large semi-natural hay-meadow areas (e.g. sub-humid to humid supramediterranean mountains), the SBPPRL DM production peak coincides with the period when hay-meadows are closed to herbivores to allow hay growth. So, the integration of hay-meadows and SBPPRL can optimize fodder production at the farm-level, and have a favourable impact on the conservation status of an important Natura 2000 habitat, fully dependent on agricultural management (HALAD *et al*., 2011). In soils with a low soil organic matter (SOM) content, a general consequence of a millenary cereal and fallow rotation used in the Mediterranean basin, the SBPPRLs exhibited a remarkable carbon sequestration in SOM performance achieving 5 $t.ha^{-1}year^{-1}$ CO_2e (TEIXEIRA *et al*., 2011). The Portuguese government is now paying carbon sequestration on an area of up to 42'000 ha of SBPPRL, that could reach 0.91×10^6 t of CO_2e from 2010 to 2012. Finally, it is also important to state the easy conversion of former agricultural soils to SBPPRL, their persistence in time (there are functional SBPPRL of more than 25 years old) and their simple and low cost maintenance.

The SBPPRL address a classical subject in community ecology: the effects of species diversity on ecosystem function. Pasture plants and communities have been a favourite experimental subject in these studies, with much scientific evidence produced (BALVANERA *et al*., 2006). Empirical evidence accumulated during the past decades shows that pastures sown with species diverse seed mixtures are more productive (CLARK, 2001). Diverse pastures are also expected to be less permeable to spontaneous species of low palatability and feed value (FRANKOW-LINDBERG *et al*., 2009), to track environmental heterogeneity (SANDERSON *et al*., 2004) and to withstand extreme climate fluctuations (TILMAN & DOWNING, 1994). In spite of its obvious agronomic relevance, the majority of the published results on pasture diversity effects on ecosystem functions, were carried out on a small scale with strictly controlled experimental conditions (SYMSTAD *et al*., 2003), involving a small number of species (SPEHN *et al*., 2005), in homogeneous soil conditions (WACKER *et al*., 2008) and during short time spans (CARDINALE *et al*., 2007). Furthermore, these studies rarely brought the analysis to the cultivar level (intraspecific diversity).

At the microtopographical scale (local relief) slope influences key environmental factors important in plants - soil relationship (SWANSON *et al*., 1988). GÓMEZ *et al*. (1978) proposed the slope system as the most appropriate model for the study of Mediterranean herbaceous communities subjected to grazing. Later authors have explored microtopographic gradient effects in herbaceous Mediterranean community attributes (e.g. species richness) on small spatial scales (e.g. OSSEM *et al*., 2002; PECO *et al*., 2006). Besides slope, the floristic structure of Mediterranean annual pastures is also remarkably sensitive to annual rainfall fluctuations, as ORTEGA & FERNÁNDEZ ALÉS (1987) or FIGUEROA & DAVID (1991) demonstrated in southern Spain.

It is expectable that species diversity in pastures will have a stronger effect on productivity in habitats with patchy resources that fluctuate over time. This putative positive effect is probably amplified in Mediterranean therophytic plant communities (and in sown SBPPRL) where plant recruitment restarts with the first rains each autumn. This fundamental question hasn't been properly addressed, and the published bibliography about it is scanty and not always straightforward (WACKER *et al*., 2008).

Due to their species-genotypes diversity, SBPPRL are then expected to be able to track and tune to the spatial and temporal heterogeneity of Mediterranean soils. Three hypotheses will be tested is this paper. 1) Do SBPPRL track slope system microenvironments array? 2) Does the same happen with interannual climate fluctuations? 3) Do the SBPPRL responses to these microenvironments spatial arrays and climatic fluctuations occur at the sown species and *T. subterraneum* cultivars levels? If SBPPRL are an agronomic solution these hypotheses should be tested by observational studies under farm conditions at the plant community scale.

Materials and methods

A stabilized SBPPRL was selected on a private farm – Quinta da França (Covilhã, Portugal), 40º 16' N 7º 30' W, ca. 425 m MSL – located on the lower east-facing slope of the highest continental Portugal mountain, the Serra da Estrela. This sward was sown in arable land in 2001 with a commercial SBPPRL. Since then it was intensely grazed with cattle and sheep and annually fertilized with 27 kg P_2O_5 ha^{-1}.

The studied SBPPRL is located on a gentle slope of a granite hill with 20 m elevation and 380 m length. Three clear microtopographic positions according to the simplified slope form model of RUHE & WALKER (1969, cit. BIRKLAND, 1999) were identified: hill shoulder, backslope and footslope. In 2007-2008 and 2009-2010, four sampling squares (stratified random sampling) were randomly located on each position. In the third week of May of 2008 and 2010, species cover was evaluated by use of the point-quadrat method, with a frame of 70x70 cm with 49 points. Plant species were identified to the species level or to the cultivar level in the case of *T. subterraneum*. Each of the quadrats was protected with an exclosure cage during the previous three weeks (the period of higher DM accumulation). DM yields were evaluated in 2007-2008 in exclosure cages that rotated around the quadrats. Soil samples were collected nearby the quadrats of 2009-2010.
The 2009 spring was exceptionally dry and the SBPPRL was impossible to sample. 2007-2008 and 2009-2010 agricultural years were, respectively, moderately dry (589 mm) and moderately wet (1023 mm) (annual rainfall mean of 781 mm). Temperature integrals of the two growing seasons were close to the mean.
In order to identify the *T. subterraneum* cultivars sown in Quinta da França, and to evaluate their life cycle length, a seed collection of the same *T. subterraneum* cultivars was sown in the autumn of 2007 in a greenhouse. To simulate herbivory, plants were manually clipped when reaching 5 cm. The collection was visited two times a week; the date of the first flowers was registered and used to order the cultivar's life cycle length. Of the five cultivars originally sown in Quinta da França it was possible to discriminate morphologically 'Campeda' + 'Woogenellup', 'Denmark', 'Gosse' and 'Losa'. 'Campeda' and 'Woogenellup' were difficult to separate. *T. subterraneum* 'Gosse' is a selection of subsp. *oxaloides* (= subsp. *yanninicum*); the remaining cultivars belong to subsp. *subterraneum*.
All the sampled *T. subterraneum* plants in Quinta da França were similar to one of the four sown cultivars or cultivar groups. Nevertheless, a biunivocal correspondence between them involves some uncertainty because the ingress of autochthonous lines with similar morphology to the sown cultivars in the SBPPRLs cannot be excluded. However, autochthonous *T. subterraneum* genotypes are probably less competitive in nutrient equilibrated soils than improved genotypes. On the other hand *T. subterraneum* is rather uncommon in the semi-natural pastures of Quinta da França, and appears to come from the sown populations.
The floristic data was explored at the community level with the multivariate ordination algorithms available in the CANOCO program (TER BRAAK & ŠMILAUER, 2002). The floristic data – number of pin contacts per species or *T. subterraneum* cultivars – was standardized by the norm to enhance the effect of species/cultivars relative cover on the ordinations. A Detrended Correspondence Analysis (DCA) showed that the species turnover was low and that linear ordination methods use is recommendable (PCA [principal component analysis] or RDA [redundancy analysis]) (LEPŠ & ŠMILAUER, 2003). Two explanatory variables were considered: "Year-climate" (dummy variable, expressed in the ordination diagrams – figs. 1 and 2 – with the 2009 and 2011 values) and "Slope" (semi-quantitative variable with three levels: hill shoulder, backslope and footslope; arrows in the diagrams point to uphill positions).
RDA models and Monte Carlo permutation tests were used to partition variation and to test the effects of each explanatory variable *per se*. "Year-climate" and "Slope" were used alternatively as explanatory variables or co-variables. They could be considered as crossed environmental factors and their effects on species variation partitioned with RDA models for two reasons: (1) each year, with the first autumn rains, there is a restart of the SBPPRL and of the semi-natural pastures flora; (2) the quadrats moved freely inside each slope position between years. A split-plot design with restricted random permutations within each year or each slope position ("design-based" random permutations) was adopted (for theory see LEPŠ & ŠMILAUER, 2003). This test is much more restrictive than free permutations. Point quadrat pin contacts were previously log transformed due to their huge variation between samples. Three botanical levels of analysis were explored in variation partition: all species level, sown species level, and *T. subterraneum* cultivar level. After confirming residuals normality and variance homogeneity (Shapiro-Wilk and Levene's tests, data not presented) one-way or two-way ANOVA were applied to soil fertility, DM production and *T. subterraneum* cultivars relative cover.

Results and discussion

From the original sown mixture, five species were still detected in the studied SBPPRL: *Astragalus* (*Biserrula*) *pelecinus*, *Trifolium subterraneum*, *T. michelianum*, *T. resupinatum* and *Dactylis glomerata*.

The *T. subterraneum* cultivars sown in Quinta da França sward were distinguished based on the following characters: 'Losa' – hirsute twigs; 'Denmark' – glabrous petioles and stipules; 'Gosse' – sparsely villous petioles, glabrous stipules; 'Campeda' + 'Woogenellup' – villous petioles and stipules. The order of the timing of flowering was: 'Losa' (an early season cultivar); < 'Goss', 'Campeda' and 'Woogenellup' (middle season cultivars) with a few days of difference between them, almost two weeks after 'Losa'; < 'Denmark' (late season cultivar), one week after middle season cultivars. To avoid flowering time redundancies and eventual identification errors, middle season cultivars were merged into one group.
Soil fertility parameters and DM production are spatially variable across the studied SBPPRL (tables 1 and 2). P - trend along the slope system is difficult to interpret. SOM was smaller in the hill shoulder; although without a statistical confirmation, the same occurs with K_2O.

Table 1. Soil fertility data from the studied SBPPRL (mean values, Quinta da França, Portugal). Analytical methods: soil organic matter – Walkley-Black; P_2O_5 and K_2O – Egner-Riehm. One-way ANOVA. Significant values (P < 0.05) are highlighted in bold. Different letters indicates significant differences between explanatory variables levels (P<0.05, Tukey's HSD test).

	P_2O_5 ($mg.kg^{-1}$)	K_2O ($mg.kg^{-1}$)	Soil organic matter (%)	pH H_20
Hill shoulder	94	120	1.3**b**	5.2**a**
Backslope	115**a**	128	3.6**a**	4.9**b**
Footslope	63**b**	159	3.4**a**	5.8
Mean	90	136	2.8	5.3
d.f.	2	2	2	2
p-value	0.039	0.179	<0.001	0.051

Table 2. Mean DM production (total and per fraction) in 2007-2008 along the slope gradient in the studied SBPPRL (Quinta da França, Portugal). One-way ANOVA.

	Legumes ($DM\ kg.ha^{-1}$)	(%)	Grasses ($DM\ kg.ha^{-1}$)	(%)	Other plants ($DM\ kg.ha^{-1}$)	(%)	Total ($DM\ kg.ha^{-1}$)
Hill shoulder	2521	51.0%	928	18.8%	1490	30.2%	4939
Backslope	3358	51.0%	1344	20.4%	1883	28.6%	6585
Footslope	3215	46.4%	1640	23.7%	2074	29.9%	6929
d.f.	2		2		2		2
p-value	0.4		0.28		0.202		0.117

A PCA was performed with all sown and autochthonous species monitored in spring 2008 and 2010. The first three axes explained 55.3 % of species data variability; the eigenvalue of the fourth axe was already very low [λ_1=0.297, λ_2=0.143, λ_3=0.120, λ_4=0.069]. The first axe was mostly correlated with "Year-climate" (r= -0.95). Not surprisingly "Year-climate" significantly (p=0.02) explained 27.3% of the community variation. The PCA eigenvalues of axes 2 and 3 were alike (λ_2=0.143, λ_3=0.120). The second axe is difficult to interpret; probably reflects the effect of soil compaction – a soil physical parameter hard to evaluate in mineral Mediterranean soils – in community composition. The "Slope" variable was correlated with the third axe (r=-0.54), explaining 6.9% (p = 0.03) of the species variation partition. The marginal effects in a RDA with a forward selection of environmental variables confirmed that the species variability explained by the explanatory variables decreases in the order "Year-climate" > "Slope" and that soil fertility variables exerted a smaller effect on the flora structure of the sward (data not presented).

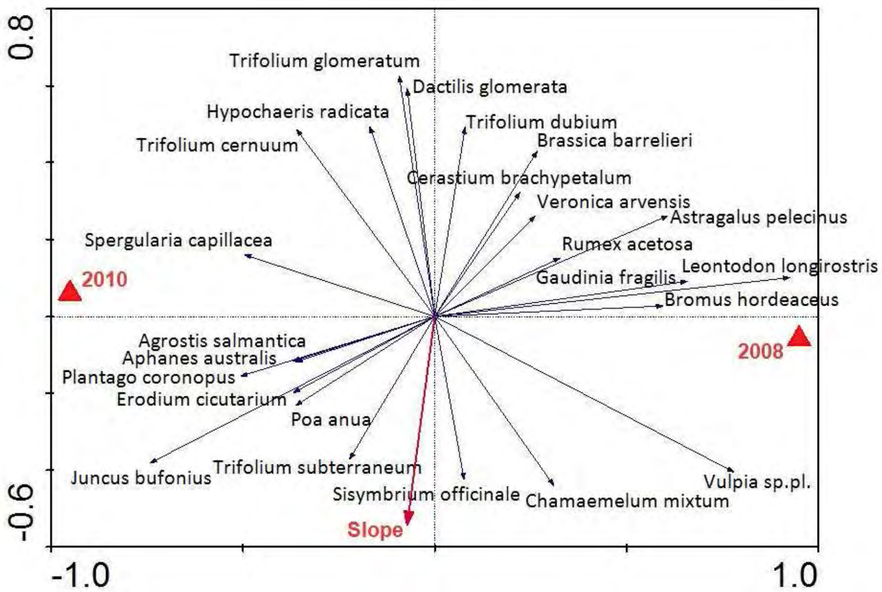

Figure 1. PCA triplot – 1rst and 3rd axes. Data gathered in a SBPPRL of Quinta da França (Portugal). Variables are passively projected. In the figure are represented twenty one species with the highest fit with the 2nd and 3rd PCA axes.

Species of temporary wet soils like *Spergularia capillacea* (*Caryophyllaceae*), *Trifolium cernuum* (*Fabaceae*), *Juncus bufonius* (*Juncaceae*) and *Agrostis salmantica* (*Poaceae*) were promoted by wet condition in 2009-2010 (fig. 1). The opposite happened in 2007-2008, a dry year. Downslope positions favored perennial mesophyllous species (e.g. *Dactylis glomerata*, *Poaceae* and *Hypochaeris radicata*, *Asteraceae*) (fig. 1). Annual species gained dominance at the hill shoulder. *Trifolium subterraneum* relative cover – but not legume biomass (table 2) – was higher uphill because temporary wet soils species response in 2009-2010 was higher in downslope positions. The grass component in DM was also higher downslope than in the hill shoulder, at least in 2007-2008 (table 2). The short cycle and ubiquist grasses of the genus *Vulpia* are abundant in all kinds of Mediterranean grazed pastures, and gain relative cover in dry years (fig. 1). Their short cycle releases them from the effects of dry springs, like in 2008. The same happens with other species like *Leontodon longirostris* (*Asteraceae*).

“Year-climate” retained a significant effect on botanical composition at the sown species level (table 3). Sown species relative cover fluctuated slightly between years, except for *Astragalus pelecinus*, which was higher in 2008 (data not presented). In fact the removal of *A. pelecinus* from the DCA model shattered the significance of the “Year-climate” variable. In the SBPPRL of Quinta da França aerial seeding clover species never surpassed a relative cover of 1% and the dominance of *T. subterraneum* in the legume fraction was absolute because grazing was intense and continuous throughout the year. SBPPRLs with higher covers of aerial seeding clovers probably respond more to annual rain fluctuations then its intensively grazed counterparts. In fact there was an abnormal increase in aerial seeding clovers cover in the wet spring of 2010, throughout moderately grazed SBPPRL in Portugal.

“Year-climate” didn’t had a significant effect in *T. subterraneum* cultivars relative cover at the community scale (table 3). Nevertheless an individualistic approach (table 4) showed that middle season cultivars retreated in the wet year. Apparently, the early season cultivar (‘Losa’) relative cover followed the same trend, and the long season cultivar (‘Denmark’) the inverse. Table 3 and fig. 2 reveal instead that “Slope” had a strong and highly significant effect in the spatial distribution of *T. subterraneum* cultivars at the community scale: uphill position were mainly colonized by the early season ‘Losa’; backslope is the preferred microhabitat of the middle season cultivar samples; and late season cv. Denmark largely surpassed the other cultivars in the footslope. Univariate statistics (table 4) confirm that *T. subterraneum* cultivars are spatially segregated according to the life cycle length, although this effect is only statistically significant with the short season ‘Losa’.

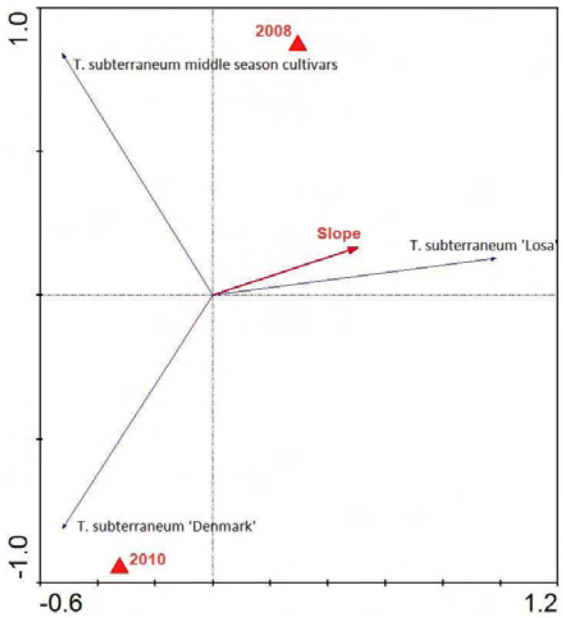

Figure 2. Biplot from a Principal Component Analysis – axes 1 and 2 – with the data gathered in the SBPPRL of Quinta da França (Portugal) for *T. subterraneum* cultivars. All variables passively projected.

Table 3. Variation partitioning of sown species or *T. subterraneum* cultivars composition. Significant values ($P < 0.05$) are highlighted in bold.

Botanical level of analysis Explanatory variable	Explained variability (%)	Significance
Sown species level		
Year-climate	14.7	0.05
Slope	2.9	0.65
T. subterraneum cultivars level		
Year-climate	10.8	0.08
Slope	18.0	0.004

Table 4. *T. subterraneum* cultivars mean relative cover (%) variation between years and along the slope gradient in the SBPPRL of Quinta da França. Two-way ANOVA. Significant values ($P < 0.05$) are highlighted in bold. Different letters indicate significant differences between slope positions in the same pasture type (Tukey's HSD test).

	'Losa' (early season cv.)	'Gosse', 'Campeda' and 'Woogenellup' (middle season cv.'s)	'Denmark' (late season cv.)
Year-climate			
2007-2008	10.4	17.0	20.2
2009-2010	7.5	7.1	27.6
d.f.	1	1	1
p-value	0.503	0.015	0.270
Slope			
Hill shoulder	21.3a	12.6	19.5
Backslope	3.1b	16.5	26.6
Footslope	2.4b	7.0	25.7
d.f.	2	2	2
p-value	0.002	0.125	0.627
Slope x Year-climate			
p-value	0.695	0.445	0.482

Conclusions

The statistical significance and the influence of the explanatory variables "Year-climate" (a proxy interannual climatic fluctuations) and "Slope" (a proxy of soil resources and soil proprieties spatial variability) on the plant composition of the studied SBPPRL varied between the three botanical levels of analysis: all species level, sown species level, and *T. subterraneum* cultivar levels. "Year-climate" and "Slope" explained species variability reached a maximum, respectively, at the all species and *T. subterraneum* cultivar levels. The sown species pool in the studied SBPPRL was impoverished by intensive grazing, hampering a deep exploration of sown flora dynamics at the community scale. Anyway, "Year-climate" exercised a stronger and significant control in sown species assembling then "Slope"; the inverse occurred at the *T. subterraneum* cultivar level. *T. subterraneum* cultivars spatial segregation was related to their life cycle length: early season 'Losa' reached higher relative covers in uphill positions; middle season cultivars were more common in backslope positions; and the late season cv. Denmark surpassed the other cultivars on the footslope.

Diversifying the sown species/cultivar colonists' pool in seed pasture mixtures appears to favour interannual climatic and microtopographic gradients fluctuation tracking. Sown species diversity and *T. subterraneum* cultivar diversity are complementary in this process; they promote, respectively, interannual climatic and microtopographic gradients fluctuation tracking. Our data is merely phenomenological: it corroborates the three hypotheses presented at the end of the introduction section but doesn't prove them.

The gathered information is also too scanty to help a discussion about the underlying mechanisms of sown species and *T. subterraneum* cultivars spatial and temporal accommodation in the SBPPRL's ecological gradients. However, it was found that the three slope positions were heterogeneous enough to permit the reseeding of different cycle length *T. subterraneum* cultivars. The reseeding probability and intensity certainly is not similar for each cultivar in each slope position, and culminates in a spatial distribution pattern of *T. subterraneum* cultivars that persists between years.

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Potential impacts of climatic changes on forage and pasture production in Northern Tunisia

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Abstract

In northern Tunisia, livestock is an important component of the agricultural systems. It depends greatly on forage and pasture productions that continue to be deficient. This deficiency is due mainly to the reduction in forage and pasture productivities which have been attributed to a decrease in rainfalls and consequently an increase in drought frequencies. Under climate change, characterized by high temperature and low precipitation, forage systems will remain dominated by the oats and barley cultivation in pure stand in the rainfed of the humid, sub-humid and superior semi-arid agro-climatic zones with production varying from one year to another. Other adapted genetic resources would play an important role in providing feed for livestock, reducing soil erosion and desertification in this part of the country. In fact, being the centre of diversity of forage species, lots of efforts are needed to exploit the available genetic diversity in developing improved cultivars. Furthermore, a perennial crop, such as *Festuca arundinacea* Schreb., is the best adapted species to water logging areas in spite of its reduced ecological adaptation area while *Dactylis glomerata* L. will occupy the marginal lands and glade forest. On the other hand, in the semi-arid zone, *Orysopsis miliacea* in mixture with annual legumes such as medics species having high hardness seed population will constitute a sustainable pasture system. Based on selected meteorological and forage production data, impacts of climate changes in the targeted region is discussed.

Keywords: livestock, forage production, pasture, climate change, northern Tunisia

Introduction

In northern Tunisia, livestock is an important component of the agricultural systems. Indeed, the number of cattle, sheep and goat expressed as female unit, representing respectively 72, 38 and 24%.
It provides meat and milk necessary for livelihoods - improved nutrition, employment and cash income. In addition, it plays a significant role in improving crop production through the use of manure for soil fertility maintenance. However, it depends greatly on forage and pasture productions that continue to be deficient. This deficiency is due mainly to the reduction in pasture and forage productivity. This is certainly attributed to a decrease in rainfall and consequently an increase in the frequency of drought. In a normal year, feed resource needs are covered mainly by pastures (35%), fodder (20%), agricultural by-products (16%), bran (9%) and concentrates (20%). In a drier year, a reduction in pastures and fodder will have a significant impact on the availability and/or price of concentrates.
There is a need to increase the amount and quality of available feed resources in order to improve food security, diversity household income, and reduce the grazing pressure on the rangelands. Since irrigated arable land is mainly used for food crops, the additional production of forage crops would come from increasing the area grown on rainfed land and from using adapted higher yielding varieties of pasture and forage crops taking into account the effects of climatic changes.
According to Nasr et al. (2009), climate change projections for Tunisia, predict, in horizons years 2020 and 2050, firstly, decreasing rainfall, around 5 to 10% from north to south on the horizon 2020 and more pronounced reductions, 10 to 30% on the horizon 2050; secondly, a decreases of the averages of the very humid and very dry years are expected as well as decreases for springs and very humid and very dry falls; thirdly, a global increasing of dry years as well as of their successive occurrence two and three in the central and southern part of the country; and finally a higher disparities between seasons and geographical regions of the country especially on the horizon 2050.
In Tunisia, potential impacts of climatic changes have been reported on only wheat (Lhomme et al., 2009; Mougou et al., 2011). This study is undertaken to report if correlation existed between forage production and rainfall in Northern Tunisia.

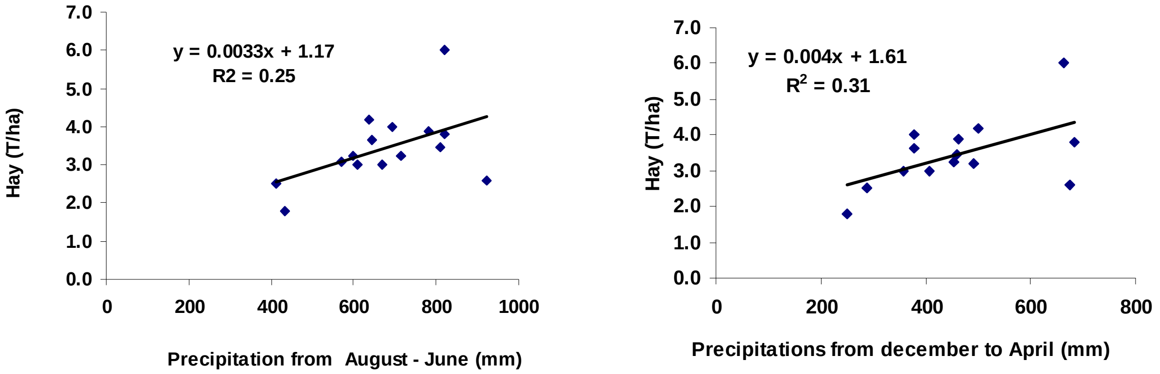
Forage production

In Tunisia, fodder production is characterized by its close association with the climatic conditions which would results in a forage production varying from one year to another. Meanwhile, forage systems are low diversified and dominated by the oat and barley cultivation, in pure stands or in mixture with forage legumes.

To develop the relationship between precipitations, green forage and hay production from fodder crops (i.e. oats, barley etc.), data from the Forage and Legume Crops Service (FLCS) under the General Directorate of Crops (Ministry of Agriculture and Environment, February 2011) were used.

These data include the governorate of Jendouba, Béjà and Bizerte representing the Khroumirie and Mogods (North West Tell of Tunisia). They are continuous for the last seven years except 2007 and 2008. Precipitation data was obtained from the Tunisian National Institute of Meteorology. Hay and green forage production and their relationship with precipitations were investigated by simple correlation analysis using two scenarios: precipitations from August to June and precipitations from December to April representing the full growing season and the vegetated growth season, respectively. Furthermore, the correlations are modulated by linear equation.

As a result, hay production was correlated with precipitations (Figure 1) while green forage was slightly correlated (Figure 2). Accumulation of excessive moisture, particularly during winter and spring (fig 1.b.) appears to increase hay production. Consequently, the favorable production year is the one with high precipitations from December to April. This indicates that timing i.e. the season is also an important factor.



a b

Fig 1. Relationship between hay production and precipitations. Total precipitations from August to June (a) and from December to April (b)

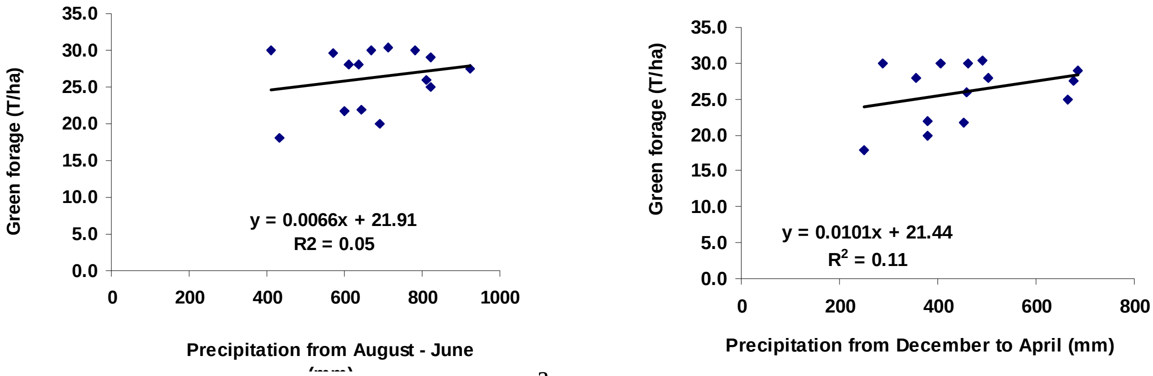


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Fig 2. Relationship between green forage production and precipitations. Total precipitations from August to June (a) and from December to April (b).

Concerning green forage production (fig 2.), data show two groups: one stationary around 30 t/ha and the other showed an increasing trend with precipitation. These can be explained by the fact that when a forage reach the appropriate development stage (Zadocks 31), it is either grazed or cut and carried to livestock. The low correlation is related to the fact that the sown area is almost the same every year or the forage produced is grown earlier in the growing season, when conditions are favorable (stand establishment with high humidity)

How to deal with climate changes for the forage and pasture sectors?

Changes in climate are estimated by many models. Estimations of future precipitations in North Tunisia (Jendouba and Beja governarates) were studied by (Lhomme et al., 2009, Zitouan – Chebbi et al., 2010). These authors estimate future rainfall through simulations obtained by the Météo-France atmospheric model ARPEGE/Climate which resolution is around 50 km over the North Africa and Mediterranean region and using the greenhouses gas and aerosol concentrations scenario A1B given by the IPCC (International Panel on Climate Change). The anomaly method is used to estimate the future (2071-2100) climate. The monthly changes compared to the present climate (1960-1990) are shown in table1.

Table 1. Monthly mean anomalies between future (2071-2100) and reference (1960-1990) scenarios.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Beja	0.65	0.76	0.69	0.63	0.85	0.62	0.9	0.9	1.06	1.21	0.96	0.79
Jendouba	0.59	0.62	0.67	0.56	0.93	0.7	1.02	1.05	1.1	1.12	0.98	0.72

The decrease of precipitations between December and April is significant for both governorates. The decrease of rainfall in this important period for forage production could have negative impacts on national production.

Reaction of farmers to climatic change would be through supplementary irrigation at the appropriate stages of the crop development. This would be difficult to realize because of several reasons: crop competition (wheat, legumes, vegetables, orchards etc.), financial constraints to purchase irrigation materials, etc.

Other solutions would be to implement innovative agronomic practices such as early sowing; indeed, it is possible to have more available water in September and October (table1), and also to adopt newly developed and adapted varieties.

Tunisia is considered as a centre of diversity for forage species, and pasture and forage genetic resources are less vulnerable to poor seasons than other crops. However, for several years, the observations made by the collectors indicate the occurrence of considerable genetic erosion. This is mainly due to overgrazing, cropping and poor soil conservation practices. There is a need to preserve the genetic variability through collection, evaluation and conservation of these genetic resources.

Efforts have been made to exploit the available genetic diversity in developing improved cultivars. Since the last decade, new varieties with appreciable traits were developed and cultural practices were experimented.

For the future and based on monthly mean anomalies between future and reference scenarios (table 1), and in the Khroumirie and Mogods representing the North West Tell of Tunisia, we anticipate perennial crop, such as *Festuca arundinacea* Schreb., is the best adapted species to water logging areas in spite of its reduced ecological adaptation area while *Dactylis glomerata* L. will occupy the marginal lands and glade forest. On the other hand, in the semi-arid zone, *Orysopsis miliacea* in mixture with annual legumes such as medics species having high hardness seed population will constitute a sustainable pasture system.

Pastoral legumes are highly desirable component of the pasture systems; species such as vetch, grass pea and medics could have considerable potential for their tolerance to dry conditions and their adaptability to unfavourable environments such as marginal areas of northern Tunisia. However, good rain is needed during the establishment phase which is in accordance with the anticipated scenario.

The most commonly grown forage crops are forage cereals: oats and barley. Other potentially suitable forage crops include triticale, lupine, sulla, fodder pea, alfalfa as cover crop, etc. They are used in small scale and need to be developed.

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Do typical alpine forage plants have the potential to mitigate methane production by ruminants?

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Abstract

A collection of 17 different alpine forage plants (2 grasses, 8 non-leguminous herbs, 3 leguminous herbs and 4 tree species) were investigated with an *in vitro* fermentation assay for their ruminal methane production potential. All samples were harvested twice in early July of the years 2009 and 2010 from sites in the eastern Swiss Alps in the canton of Grisons. Samples were analyzed for nutrient contents and phenolic compounds. In each year, samples were incubated in four replicates for 24 h with the Hohenheim Gas Test system using bovine rumen fluid. Total gas production and gas composition were measured immediately after incubation. The results showed that almost all alpine plants investigated had lower *in vitro* ruminal methane emission potential compared to hay standard. Except for *Castanea sativa*, methane emission potential of the investigated plants varied less than expected. However, several plants proved to concomitantly express a comparably low methane emission potential and high nutritional value like *Alchemilla xantochlora* and *Sambucus nigra*.

Keywords: alpine plants, methane, nutrient, phenol, rumen

Introduction

Vegetation in the Alps is an important feed resource for livestock production in the respective regions during the summer period. Rapid growth of biomass at the beginning of summer, followed by a period of clearly decreased growth rates and forage quality, are among the main characteristics of the vegetation (Brühlmann & Thomet, 1991). Studies on the influence of alpine vegetation on productivity and product quality (e.g. Leiber *et al*., 2004 and 2005) of ruminants have been previously conducted. However, no studies so far have attempted to assess the methane (CH_4) production potential of the plants after being ingested by ruminants. This is an important issue since the CH_4 accumulation in the atmosphere has gained more attention in recent years. Plant secondary compounds in the alpine vegetation are assumed to modulate rumen processes with significance for the product quality (Leiber *et al*., 2005). The same factors could also influence ruminal CH_4 production. Therefore, the present study aimed at investigating in an *in vitro* ruminal environment the CH_4 production potential of a variety of typical plant species growing on the Alps.

Material and methods

Samples from 17 plant species were collected in early July 2009 and 2010 from three mountainous sites in the South-Eastern Alps of Switzerland (canton of Grisons), i.e. Misox valley, Rhine forest (Sufers) and Albula valley at altitudes of 800, 1400 and 1800-2300 m a.s.l., respectively. The plants consisted of 2 grasses, 8 non-leguminous herbs, 3 leguminous herbs and 4 tree species (leaves and flowers). The herbs and grasses were all common pasture plants of the respective region; the trees were species which have been commonly fed to ruminants in traditional alpine agricultural systems (Machatschek, 2002). After collection, all plant samples were stored at 4^{o}C overnight, oven dried at 60^{o}C for 24 h and ground to pass a 1 mm sieve. Analysis of plant chemical composition included proximate, detergent and phenolic compound determinations. Plant samples were incubated with buffered rumen fluid *in vitro* (in four replicates each year) using the Hohenheim Gas Test (HGT) apparatus (Menke and Steingass, 1988), conducted for the harvests of 2009 and 2010. Hay and concentrate standards (obtained from the Institute of Animal Science, University of Hohenheim, Germany) were also incubated. Rumen fluid was obtained from a fistulated Brown Swiss cow before the morning feeding. After 24 h of incubation, the gas produced during fermentation was recorded and sampled for gas composition determination, including CH_4 using a gas chromatograph. Ammonia and short-chain fatty acids (SCFA) in the fermentation fluid were determined. All analytical methods are described in detail in Jayanegara et al. (2011). *In vitro* organic matter digestibility (IVOMD) and metabolizable energy (ME) were calculated using standard equations. Data were subjected to analysis of variance (mixed model), followed by Tukey's test for multiple comparisons among plants using SAS software version 9.2. Different harvest years and incubation runs were considered as random effects.

Results and discussion

Incubation of hay and concentrate standards resulted in CH_4/total gas values of 161 (±25.3) and 182 (±25.1) ml/l, respectively. These data, especially from the hay standard, are important reference values for determining the CH_4 mitigating potential of each plant. The values are similar to CH_4/total gas of the control substrate (90% hay) in other studies, i.e. 174 ml/l (Bodas *et al*., 2008). Within the grass species, *Poa alpina* produced less CH_4/total gas than *Nardus stricta* (P<0.05; Table 1). Further, *Poa alpina* produced 14.3% less CH_4/total gas compared to the hay standard while *Nardus stricta* produced 9.3% more. This might be explained by the lower NDF content of *Poa alpina* compared to *Nardus stricta*. Dietary cell-wall constituents and ruminal CH_4 emission are considered to be positively correlated since fiber degradation results in large amounts of hydrogen which is utilized by the methanogens for CH_4 formation (Machmüller *et al*., 2003). Further, *Poa alpina* was superior to *Nardus stricta* due to higher values of total gas production, IVOMD, ME and total SCFA (P<0.05). The poor quality of *Nardus stricta* was in agreement with the low *in vivo* digestibility of alpine swards dominated by *Nardus stricta* (Berry *et al*., 2002). Therefore, this grass is hardly accepted by grazing livestock (Fischer & Wipf, 2002).

Table 1: Chemical composition of plants and *in vitro* fermentation variables (n = 8)

Plant species	CP	EE	NDF	TP	NH_3	Total SCFA	Total gas	CH_4/gas	IVOMD	ME
	g/kg dry matter				mM	mM	ml	ml/l	mg/g	MJ/kg
Grasses										
Nardus stricta	116	6	753	8	10.6^{cde}	69.0^{b}	30.6^{b}	176^{d}	525^{b}	7.30^{b}
Poa alpina	139	18	540	20	9.9^{bcde}	88.0^{cde}	46.6^{fgh}	138^{bc}	698^{ghi}	9.99^{fg}
Non-leguminous herbs										
Achillea millefolium	191	16	370	23	11.0^{e}	87.0^{cde}	38.4^{cd}	140^{bc}	691^{fghi}	9.10^{de}
Alchemilla xanthochlora	156	20	256	54	8.3^{abc}	94.1^{de}	47.9^{gh}	134^{bc}	736^{i}	10.34^{fg}
Carum carvi	140	16	359	21	10.9^{de}	91.2^{de}	44.2^{efgh}	152^{bcd}	709^{hi}	9.57^{ef}
Chrysantemum adustum	91	14	412	20	8.8^{abcde}	88.4^{cde}	42.5^{defg}	141^{bc}	648^{defg}	8.91^{cde}
Crepis aurea	139	33	322	24	11.0^{e}	96.5^{e}	49.9^{h}	148^{bcd}	744^{i}	10.81^{g}
Plantago atrata	110	12	444	26	7.2^{a}	77.2^{bcd}	38.7^{cde}	157^{bcd}	621^{cde}	8.46^{cd}
Rhinanthus alectorolophus	143	22	307	29	8.8^{abcde}	92.0^{de}	46.9^{gh}	146^{bcd}	725^{hi}	10.13^{fg}
Rumex arifolius	122	16	409	38	8.2^{ab}	86.1^{bcde}	40.1^{de}	142^{bc}	637^{def}	8.82^{cde}
Leguninous herbs										
Anthyllis vulneraria	131	14	372	25	8.6^{abcd}	91.6^{de}	40.4^{de}	160^{cd}	674^{efgh}	8.91^{cde}
Hedysarum hedysaroides	223	18	319	69	8.7^{abcd}	77.1^{bcd}	29.5^{b}	160^{cd}	568^{bc}	8.18^{c}
Trifolium badium	146	14	321	43	8.3^{abc}	88.5^{cde}	38.8^{cde}	153^{bcd}	650^{defg}	8.78^{cde}
Trees										
Castanea sativa	141	19	402	112	7.4^{a}	44.4^{a}	6.5^{a}	24^{a}	305^{a}	5.13^{a}
Fraxinus excelsior	160	14	408	22	7.5^{a}	71.7^{bc}	34.4^{bc}	150^{bcd}	606^{cd}	8.27^{cd}
Sambucus nigra[1]	243	35	218	37	14.6^{f}	85.8^{bcde}	39.6^{cde}	142^{bc}	712^{hi}	10.03^{fg}
Sambucus nigra[2]	247	32	260	43	16.5^{f}	95.3^{e}	41.0^{def}	129^{b}	712^{hi}	10.21^{fg}
SEM	11.0	1.9	30.0	5.9	0.32	1.68	0.89	3.3	9.4	0.122
P-value	na	na	na	na	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

CP, crude protein; EE, ether extract; IVOMD, *in vitro* organic matter digestibility; ME, metabolizable energy; na, not applicable; NDF, neutral detergent fiber; SCFA, short-chain fatty acids; SEM, standard error of the mean; TP, total phenols

Mean values in the same column without common superscript are significantly different at P<0.05

[1]leaf; [2]flower

Within the non-leguminous herbs, all plants resulted in lower CH_4/total gas ratios than that of the hay standard. When incubating *Alchemilla xanthochlora*, the CH_4/total gas was lowest (-16.8% vs hay standard). This might be related to the relatively high content of phenolic compounds in the plant, particularly hydrolysable tannins (HT; data not shown). The effect of HT in reducing ruminal CH_4 emission has been previously demonstrated (Bhatta *et al*., 2009). However, no difference occurred for CH_4/total gas across all non-leguminous herbs. Total gas production was highest when incubating *Crepis aurea*, followed by *Alchemilla xanthochlora* and *Rhinanthus alectorolophus*. A similar pattern was also obtained for IVOMD and ME. For the leguminous herbs, CH_4/total gas was similar across all three leguminous herbs and almost similar to that of the hay standard. No significant difference was found between the leguminous herbs in terms of NH_3. Incubation of *Hedysarum hedysaroides* resulted in significantly lower total gas production and IVOMD than the other two plants within this functional group (P<0.05). The low variability of CH_4 emissions from the herbaceous species (both non-leguminous

and leguminous) in the present study was unexpected, since the hypothesis had been that at least the flowering alpine herbs contain higher amounts and and a higher diversity of secondary plant compounds which would differently affect ruminal fermentation, including the production of methane.
Within tree species, *Castanea sativa* leaves resulted in an extremely low CH_4/total gas ration (lower by 85.1% than the hay standard) as well as total gas, IVOMD and ME values compared to all other plants ($P<0.05$). This plant contained the highest TP (mainly hydrolysable tannins; data not shown) across all plants investigated here. Although *Castanea* leaves have been commonly fed to ruminants in historical livestock systems, the fermentation results indicated a strongly limited forage quality. Corresponding to the high CP contents, ruminal NH_3 concentrations were higher after incubation of both *Sambucus nigra* flowers and leaves compared to all other species across the different functional groups ($P<0.05$). This indicates that *Sambucus nigra* has a good nutritional quality and fits into the range of the herbs. With the leaves and flowers of this plant, CH_4/total gas ratio was lower by 11.8% and 19.9%, respectively, compared to the hay standard.

Conclusions

Almost all alpine plants investigated had a lower *in vitro* ruminal CH_4 emission potential compared to the hay standard. However, the emission potential among plants varied less than expected. The nutritive value was highest for *Poa alpina* among the grasses, *Alchemilla xanthochlora* and *Crepis aurea* among the herbaceous plants and *Sambucus nigra* among the trees. Particularly *Alchemilla xanthochlora* met the aim of this study, because in addition to its high quality, it produced the lowest CH_4 amounts among the herbs. This was similar for *Sambucus nigra* among the trees. Although *Castanea sativa* appeared to be a very effective CH_4 inhibitor, the incubation data suggest that this plant is hardly digested and fermented in the rumen, thus indicating a low feeding value when fed in larger proportions.

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The impact of cattle and sheep grazing on grassland in Veľká Fatra National Park

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Abstract

The Veľká Fatra National Park stretches over an area of 40'371 ha and was established in 2002 to protect well-preserved ecosystems. With the highest peak Ostredok (altitude 1592 m), the region is one of the highest mountain territory in Slovakia. Grassland areas above the forest line ("hole" in Slovak) and highland relief are typical for the Veľká Fatra where forests cover 85 % of the area. Large areas of grassland resulted from deforestation many centuries ago. The summit alpine meadows which are rich in rare plant communities cover the area of 2'000 ha. The grassland is dominated by *Deschampsia caespitosa* (L.) P. Beauv. and also by very rapidly expanding *Calamagrostis epigejos* (L.) Roth, *Brachypodium pinnatum* (L.) P. Beauv. and *Cirsium arvense* (L.) Scop. what is indicating a prolonged period of absent utilization and sward abandonment.

Keywords: grazing, alpine grassland, cattle, sheep, botanical composition

Introduction

The transformation of Fatra forests began with the migration of population to mountain areas. In the 17th century, it was brought about by the Wallachian colonisation which refers to the spread of shepherds from Romania across the Carpathian arc to our region. Monarchs granted the right to shepherds to deforest the summit areas of the Veľká Fatra mountain range. By cutting down the trees and burning up the land, shepherds created new mountain pastures for their flocks of sheep and goats. Shepherding in the Veľká Fatra mountain range culminated about 75 years ago when several tens of shepherd farms were located in this area. Besides sheep, heifers and horses pastured on pastures above the forest line, which was typical especially for the areas of Ploská and Minčol. Meadow management blossomed as well. During the first years since the collectivisation, the importance of sheep and shepherding was underestimated. As late as in 1972, following the socialisation of agriculture, one of the largest modern sheep farms in Slovakia was established in Liptovské Revúce.

In the past, grasslands in the Veľká Fatra National Park were regularly cut and grazed. Nowadays, 2'000 ha of mountain subalpine meadows are not cut anymore, due to a low numbers of ruminants in nearby farms, high utilisation costs and roded roads. Grazing with young cattle has been banned and consequently tall grasses expanded, swards thinned as well as avalanche risk increased (40 to 200 avalanches occur each year). Currently, it is allowed to graze young cattle again, but farmers do not exploit this option very much. About 200 heifers and 2'500 sheep graze there, but only at the lowest areas of the mountains and for short periods of time.

The grassland management is reflected by the species composition. By employing optimum intensity and appropriate utilization methods, or by alternating between extensive and intensive grazing and cutting, the species-rich communities, comprising many rare and endangered or threatened species, can be maintained on a long-term basis. Land abandonment or too low utilization intensity lead to spontaneous succession in which woody vegetation or also some expansive grass species re-occupy former farm land (SLÁVIKOVÁ, KRAJČOVIČ, 1998). JANČOVIČ and VOZÁR (2004) include non-utilised grassland into the category defined by colonization with woody plants or single trees and shrubs at various levels, and into the category of non-utilised, often abandoned and neglected grassland at various levels of extensification. The second category covers different semi-natural grassland types of various vegetation levels where gradually, without human intervention, natural succession occurs following the exclusion of cutting or managed grazing (return to forest formation). Changes in the diversity in semi-natural grassland on peat soil following reductions in the intensity or complete absence of utilization were assessed by MLYNARCZYK *et al*. (2002). In his work, they are characterized mainly by the decline in cover of valuable grass and legume species, while percentage cover of marsh plant species increased.

In 2010, a project was initiated with the aims of creating favourable habitat conditions for black grouse and ensure quality and nutritive pasture swards for ungulate game, while improving landscape formation processes.

Material and methods

The Veľká Fatra National Park is located in the north-western part of central Slovakia. It stretches over the regions of Turiec, Liptov and Banská Bystrica, ranking among the greatest and highest mountains in Slovakia.

Typical highland relief is rounded and softly modelled. Above the forest line ("hole" in Slovak), avalanche gullies are botanically the most attractive with a great variety of species and rare plants, such as *Astragalus* species. Also some thermophilic species grow at these altitudes, as *Origanum vulgare* L. or *Digitalis grandiflora* Mill. (KOŠŤÁL, 2010).

In 2010, a monitoring was performed on botanical composition of permanent grassland, herbage qualitative parameters, soil qualitative parameters and the state of permanent grassland utilization. The study area (being the part of National Park) - was divided into three parts according to pastures utilisation: (1) non-utilised; (2) grazed in the past; (3) grazed at present.

The botanical composition of grassland was evaluated by the method of projective dominance by Maloch (1953). The nutritive value of forage was determined by the method of grassland quality evaluation according to NOVÁK (2004), applied on samples collected during the growing season $E_{GQ} = \frac{\sum(D \times FV)}{8}$. It was calculated from the relation where D (in%) is the dominance plant species, expressed as a percentage of forage value (FV) and the feed value of plant species.

Results and discussion

The botanical composition of the non-utilised part of grassland (1) was dominated by grasses and cyperacea (77 %) with *Carex sempervirens* L. (34 %), *Briza media* L. (24 %) and *Lolium perenne* L. (19 %). Herbs covered 22 %, with highest abundance of *Alchemilla vulgaris* L. and *Hypericum montanum* L., 4 % each. The presence of legumes was only 1 % (*Trifolium repens* L.).

Permanent grassland utilised by grazing and folding in the past (2) was characterised by following proportion: grasses (25 %), forbs (52 %) and legumes (22 %). The dominant species in each plant family were: *Briza media* L. (18 %), *Alchemilla vulgaris* L. and *Galium cruciata* L. (8 % each), and *Vicia cracca* L. (22 %).

Permanent grassland actually grazed (3) were characterized by a high grass contribution (85 %), with a dominance of *Deschampsia caespitosa* L (65 %), and the 15 % presence of herbs (*Alchemilla vulgaris* L. 6 %).

Non-utilization of grassland resulted in the spread of *Deschampsia caespitosa* (L.) P. Beauv., *Calamagrostis epigejos* (L.), *Brachypodium pinnatum* (L.) P. Beauv. and *Cirsium eriophorum* (L.) Scop. which can suppress the growth of other high value species mainly stoloniferous short grasses, legumes and medicinal herbs. Their forage value is of poor quality. In 2010, grassland quality evaluation (E_{GQ}) ranged between 15.2 and 38.5 throughout the growing season, corresponding to low to lower value categories. Valuable swards start at the value of E_{GQ} = 70.

In the study area, grassland dominated by *Deschampsia caespitosa* (L.) P. Beauv. was grazed by sheep in early spring. Dried samples collected during this period reached mean values of 104.5 g.kg^{-1} crude protein and 258.8 g.kg^{-1} crude fibre. Following coefficients of the nutritive value were calculated: 62.1 % protein digestible in the intestine (PDI), 65.1 g.kg^{-1} metabolisable energy (ME), 9.4 MJ.kg^{-1} brutto energy (BE), 18.6 MJ.kg^{-1} net energy for lactation (NEL), 5.5 MJ.kg^{-1} net energy for fattening (NEF), and 27,62% digestible organic matter.

In a later period, the sward was grazed selectively; i. e. sheep refused *Deschampsia caespitosa* (L.) P. Beauv., resulting in a DM content of 69.2% and a crude fibre concentration of 269.0 g.kg^{-1} DM. An average digestibility coefficient was approximately 57.5%, 43.2 g.kg^{-1} protein digestible in the intestine (PDI), 9.4 MJ.kg^{-1}metabolisable energy (ME), 18.5 MJ.kg^{-1} brutto energy (BE), 5.5 MJ.kg^{-1} net energy for lactation (NEL), 5.4 MJ.kg^{-1} net energy for fattening (NEF) and 64.4% digestible organic matter.

These results correspond with the values reported by GÁLIK, BÍRO, JURÁČEK, ŠIMKO and ROLINEC (2010). Mean digestibility coefficients of hay ranged between 49.1 and 53.7 %. As for hay, negative correlation was found between nutrient digestibility and DM content. The content of crude protein (311.8

$g.kg^{-1}$ DM) was higher, and at the same time, a lower digestibility coefficient of organic matter (49.1 %) was determined.
Forage nutrient digestibility can be considered a limiting factor of forage quality. It expresses the proportion between nutrient content of feed and its actual utilization by ruminants (PAJTÁŠ *et al*., 2009). When producing grass-based hay, a growing season of dominant grass species should be taken into account in order to determine optimal time to harvest. Intensive lignification usually occurs after flowering and results in low nutrient digestibility (GÁLIK *et al*., 2010). The nutritive value of pasture was determined from dried herbage.
Metabolisable energy (ME) of forage from grassland pastures was 9.41 $MJ.kg^{-1}$; net energy for lactation (NEL) 5.50 $MJ.kg^{-1}$; and net energy for fattening (NEF) 5.28 $MJ.kg^{-1}$.

Table 1: Soil Parameters

Site	Depth (mm)	pH/KCl	Humus $g.kg^{-1}$	N $g.kg^{-1}$	P $mg.kg^{-1}$	K $mg.kg^{-1}$
Non-utilised	0 – 100	6.87	149.68	10.77	4.51	87.79
Utilised by grazing and folding in the past	0 – 100	6.83	176.90	10.66	7.12	110.69
Utilised by grazing at present	0 – 100	4.84	142.43	10.88	4.36	209.92

Non-utilised grassland and grassland utilised by grazing and folding in the past have neutral soil reaction. Grassland utilized by grazing at present has extremely acid soil reaction. Humus content is medium in all swards and this can have a positive impact on the retention capability of grassland. Phosphorus content is very low at all sites. Potassium content is medium in non-utilised grassland and grassland utilised by grazing and folding in the past and good in grassland utilised by grazing at present.
Inappropriate grazing management in the past resulted in the occurrence of *Deschampsia caespitosa* (L.) P. Beauv., which is the dominant species at most sites. *Deschampsia caespitosa* (L.) P. Beauv. is one of the most troublesome weed species in meadows and pastures. It has a very low digestibility coefficient due to its rough-textured leaves and solid stems, and it is usually avoided by grazing animals. Moreover, its dense tussocks make it difficult to cut. *Deschampsia caespitosa* (L.) P. Beauv. is also considered a dangerous forest weed due to its dense tussocks which hinder natural regeneration (REGAL, ŠINDELÁŘOVÁ, 1970).
Also the presence of *Calamagrostis epigejos* (L.) in meadows and pastures is surely evidence of insufficient sward utilization. It is rough, hardly palatable grass species with no value for forage purposes. *Brachypodium pinnatum* (L.) P. Beauv. is an indicator species of calcareous subsoil. Its herbage is rough and coarse with a low digestibility coefficient.
Areas, where farms and sheepfolds were once located, are nowadays monoculture swards of *Rumex alpinus* L. and *Urtica dioica* L. (MICHALEC *et al*., 2010).

Conclusions

Non-utilization or insufficient utilization of permanent grassland in the Veľká Fatra National Park results in fast spread of *Deschampsia caespitose* (L.) P. Beauv., *Calamagrostis epigejos* L., *Brachypodium pinnatum* (L.) P. Beauv. and *Cirsium eriophorum* (L.) Scop. which can suppress the growth of other high value species of short – mainly stoloniferous – grass species, legumes and medicinal herbs. Such swards are of poor quality. Their quality according to the grassland quality evaluation (E_{GQ}), ranging between 15.2 and 38.5, indicates that they fall within the category of low to lower value swards. Crude protein content ranged 104.47 $g.kg^{-1}$ DM, and fibre content 258.78 $g.kg^{-1}$ DM. An average digestibility coefficient was approximately 62.05 %. The soil analyses showed that the content of basic nutrients (N, P) was low and potassium and humus content was medium. Non-utilised grassland and grassland utilised by grazing and penning in the past have neutral soil reaction while grassland utilised by grazing at present has extremely acid soil reaction.
In 2010, at highest altitudes from 1’000 do 1’500 m, grassland was utilised only by grazing with heifers. Sheep grazed in areas of lower altitudes. The reasons for this unfavourable state include low numbers of ruminants in nearby farms, high costs associated with the utilization of these swards, poor access roads and non-professional sporadic conservation interventions concerning the utilization or non-utilization of grassland. It should be the obligation of present generation to maintain sustainable landscape. Success in achieving sustainability is dependent on appropriate management systems which, as a result, can lead to

improved quality of life. Grassland exploitation in the Veľká Fatra Mountain Range must be essentially changed namely on the basis of the latest scientific knowledge.

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An analysis of botanical and functional diversity of mountain grasslands in relation to herbivore production systems

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Abstract

Managed grasslands provide environmental and agronomic services that can be predicted from the botanical and functional composition of the vegetation. In mountain regions such as the Massif Central of France, herbivore production systems are based on permanent grasslands. In this study we aimed to test within a common area, the Rochefort-Montagne's area, to what extent grassland botanical and functional diversity is related to the type of herbivore production system.

From inquiries in 19 farms and floristic functional characteristics of 120 permanent grassland plots, we analysed the intra and inter plot diversity taking into account the type of production system (dairy cattle only, beef cattle only, mixed dairy and beef cattle, mixed dairy cattle and sheep), the management of the plot (cut or grazed) and the altitude. The grasslands were classified in 3 vegetation groups: the 1st includes 75 plots in rich environment, with productive species but a low diversity, the 2nd includes 32 plots in rich environment, with a good agronomic value and a larger diversity in botanic families, and the 3rd includes 13 plots in lower fertility environment and agronomic value, but with higher diversity in grasses and forbs. The diversity of plot types is higher above 1000m, whereas at low altitude the plots are mainly in the first group. Compared to specialized dairy cattle systems, the mixed systems (dairy and beef cattle, dairy cattle and sheep) present a higher diversity of types of grasslands, which can be valorised by the complementary of the animal needs of the different herds and animal categories. The variability of production systems within an area should also favour environmental services related to grassland diversity.

Keywords: semi-natural grasslands, botanical composition, functional diversity, cutting, grazing, herbivore production systems

Introduction

In mountain regions such as the Massif Central of France, herbivore production systems are based on permanent and semi-natural grasslands. The main role of grasslands in these systems is to provide food supply to the animals as cut and grazed forages. However environmental services provided by grasslands are more and more recognized both for environmental safety (e.g. limitation of water pollution, potential carbon sequestration) and for ecological management (e.g. conservation of ordinary and patrimonial biodiversity, pollination services). Thus, in these areas, grassland management is questioned in order to reconcile forage production in quantity and quality at the farm level and ecosystem services related to biodiversity.

The links between vegetation characteristics and ecosystem services were clearly shown in a recent review (De Bello et al, 2010). It was suggested that plant trait clusters can be used to monitor and balance the delivery of multiple services in ecosystem management. Relationships between forage production (quantity and quality) and plant life traits were clearly shown (Duru et al., 2008; Andueza et al., 2010). Cruz et al (2010) proposed to classify grasses co-occurring in grassland into functional types according to a set of functional traits including leaf dry matter content (LDMC), specific leaf area (SLA), leaf life span (LLS) and phenology that characterises plant growth strategy according to fertility level. Links between functional characteristics of vegetation and ecosystem services were also suggested, as for example the relation between carbon sequestration and the relative proportion of legumes and grasses (Soussana and Luscher, 2007), or between pollination services and the proportion of entomophily species (Batary et al., 2010).

Thus, botanical and functional diversity of grasslands are important features to evaluate the production and environmental services provided at the plot (intra plot diversity) and at the farm (inter plots diversity) levels. In this study we aimed to characterize grassland diversity within a common area, the Rochefort-Montagne's area, and to test to what extent grassland botanical and functional diversity is related to the type of herbivore production system.

Material and methods

The Rochefort-Montagne's territory is an upland area with volcanic soils of good fertility and average annual rainfall of 1350 mm. The farms are relatively small (42 ha) with a mean stocking rate of 1.05 LSU/ha. Ninety percent of the area used by herbivore production systems consists in permanent semi-natural grasslands. Nineteen farms, including one INRA-experimental farm, located in Laqueuille territory were chosen to cover the range of production systems present in this area. The sample comprised 7 farms specialized in dairy cattle, 5 farms specialized in beef cattle, 4 mixed dairy and beef cattle farms, and 3 mixed dairy cattle and sheep farms. In each farm, 5 to 8 grasslands were chosen according to the information obtained from the farmers on their use in the forage system (cut or grazed), and the intensity of the utilisation (early or late cut, grazed by lactating animals or by heifers).

Floristic analyses were made on 120 grasslands during May and June of 2009 or 2010 according the method developed by Theau et al (2010). The determination of botanical families and species abundance was performed along the longest diagonal of the grassland plot. On this line 10 observations were made within a 0.4x0.4 m frame. For each observation the proportion in grasses, legumes and forbs were scored on a scale from 1 to 6, and within each family the abundance of dominant species was scored on a scale from 1 to the score of the family. Grass species were then classified into the following functional types (Cruz et al, 2010, Table 1): In addition, the proportion of *Cyperaceae* and *Joncaceae* were quantified to indicate wet zones.

In order to classify the 120 plots a principal component analysis followed by an ascendant hierarchical classification (SPAD software package, 7.0 run time) was performed on the six following variables calculated at the plot level: the proportion of grasses (G), of legumes (L) and of forbs (F), the proportion of *Cyperaceae* and *Joncaceae* (Cyp/Jon), the proportion of grasses from fertile sites ($G_{fertile} = \Sigma$ types A, B, b, E) and the proportion of grasses from poor sites ($G_{poor} = \Sigma$ types C, D). The differences between the groups of plots were then analysed by comparison of the means using Wilcoxon test. Finally the distribution of grasslands according the production system, the plot uses and the altitude was analysed.

Table 1: Main characteristics of functional types of grasses (after Cruz et al., 2010)

Functional types of grasses	Site fertility	Flowering date	Characteristic species
Type-A	High	Early (< 900 °Cd)	Alopecurus Pratensis, Lolium perenne
Type-B	Medium to high	Mid-early (1200 °Cd)	Dactylis glomerata, Poa pratensis
Type-b	Medium	Late (> 1600 °Cd)	Agrostis capillaris, Agropyron repens
Type-C	Low	Mid-early (1300 °Cd)	Fastuca rubra, Festuca ovina
Type-D	Low	Late (1700 °Cd)	Nardus stricta, Poa chaixii
Type-E (annual species)	Medium to high	/	Lolium multiflorum, Bromus spp.

Results and discussion

The first axis of the principal component analysis explained 39.9% of the total variability of the dataset. It corresponds to a fertility axis and discriminates $G_{fertile}$ from G_{poor} and Cyp/Jon plots. The second axis explained 31.0% of the total variability and discriminates G from L and F plots. An ascendant hierarchical classification allowed us to distinguish three classes of grasslands whose characteristics are given in table 2. The first class is the most abundant one and comprises 67% of the plots that are dominated by G and by $G_{fertile}$ with 40% of grasses from type A. The second class represents 27% of the plots with a better balance between G, L and F, where grasses mainly belong to $G_{fertile}$ with closer proportion of functional types A, B and b. The third class represents only 11% of the plots dominated by G, mainly G_{poor} with a high proportion of functional type C. Its proportion of L is lower than in the two other classes, and the proportion of F is intermediate.

Table 2: Botanical and functional composition of the three classes of grasslands (mean % ± SD).

	Class 1 (n=75)	Class 2 (n=32)	Class 3 (n=13)
Botanical families			
Grasses (%)	76 ± 8.4 [a]	49 ± 9.4 [b]	70 ± 6.9 [c]
Legumes (%)	11 ± 6.3 [a]	19 ± 8.2 [b]	7 ± 10.2 [c]
Forbs (%)	12 ± 6.6 [a]	32 ± 12.5 [b]	20 ± 9.0 [c]
Cyp/Jon (%)	1 ± 1.3 [a]	0 ± 0.0 [b]	3 ± 4.8 [a]
Grasses from fertile or poor sites			
$G_{fertile}$ = A+B+b+E (%)	91 ± 10.1 [a]	93 ± 10.9 [a]	33 ± 17.8 [b]
G_{poor} = C+D (%)	9 ± 10.1 [a]	7 ± 10.9 [a]	67 ± 17.8 [b]
Functional types of grasses			
Type-A (%)	40 ± 15.8 [a]	28 ± 15.1 [b]	10 ± 13.0 [c]
Type-B (%)	20 ± 12.1 [a]	24 ± 15.2 [a]	2 ± 3.2 [b]
Type-b (%)	27 ± 11.6 [a]	30 ± 16.5 [ab]	21 ± 8.8 [b]
Type-C (%)	9 ± 9.3 [a]	7 ± 9.6 [a]	55 ± 16.1 [b]
Type-D (%)	1 ± 2.6 [a]	1 ± 2.0 [a]	12 ± 12.0 [b]
Type-E (%)	3 ± 7.4 [a]	12 ± 12.9 [b]	0 ± 0.0 [a]

Means without a common superscript are significantly different ($P < 0.05$).

The plots of the specialized dairy cattle farms were mostly distributed in the class one (79%), whereas the plots of the specialized beef cattle and of the mixed farms were more evenly distributed among the three classes of grasslands (Table 3).

Table 3: Distribution of the 120 plots according to the production system (% within each system)

Production system	Class 1 (n=75)	Class 2 (n=32)	Class 3 (n=13)
Specialized dairy cattle (n=58)	79	12	9
Specialized beef cattle (n=25)	48	32	20
Mixed dairy and beef cattle (n=23)	52	43	4
Mixed dairy cattle and sheep (n=14)	36	50	14

Plot utilisation also influenced the botanical composition of the grasslands and thus the distribution of the plots among the three classes (Table 4). Almost all plots that are cut belong to the first and the second classes. Plots that are grazed by dairy cows belong mostly to the first class of grasslands whereas plots that are grazed by beef cows and heifers are more evenly distributed between the three classes.

Table 4: Distribution of the 120 plots according to the plot utilisation (% within each use)

Plot use	Class 1 (n=75)	Class 2 (n=32)	Class 3 (n=13)
Early cut (n=19)	47	53	0
Late cut (n=30)	67	27	7
Dairy cow grazing (n=30)	83	17	0
Beef cow grazing (n=13)	46	31	23
Heifer grazing (n=25)	52	20	28
Sheep grazing (n=3)	67	0	33

The effects of the production system and of the plot use on the distribution of the grasslands among the three classes were partly confounded with an effect of altitude. Indeed, plots that are below 1000 m are mostly distributed in the first and the second classes of grasslands whereas plots of the third class were mostly located above 1000 m (Table 5).

Table 5: Distribution of the 120 plots according the altitude (% within each class of altitude)

Class of altitude	Class 1 (n=75)	Class 2 (n=32)	Class 3 (n=13)
Less than 800 m (n=31)	81	16	3
Between 800 and 1000 m (n=62)	73	26	2
Higher than 1000 m (n=27)	19	41	41

The first grasslands class comprises low diversified plots located below 1000 m, highly dominated by productive grasses characteristic from fertile environment. This class is present in all production systems and in all plot use and is highly dominant in specialized dairy cattle system especially for plots that are grazed by dairy cows. The second grassland class, mainly located above 800 m, comprises plots of higher functional diversity, rich in forbs and to a lesser extent in legumes. This class characterises fertile environment, and is mainly present in beef cattle systems and in mixed systems. The third class of grassland represents poorer environment located above 1000m and comprises plots of higher functional diversity mainly used for beef cattle, heifers and sheep grazing. Farruggia et al (2006) also observed a decrease in the proportion of functional type A and an increase in the proportions of functional types C and D in relation to more extensive management in beef cattle systems.

Conclusions

In the mountain area we investigated, the functional diversity of semi-natural grassland used by herbivores can be simply classified in three groups. The diversity of plot types is higher above 1000m, whereas plots from lower altitudes have a better forage production. Compared to specialized dairy cattle systems, the mixed systems (dairy and beef cattle, dairy cattle and sheep) and the beef cattle systems present a higher diversity of types of grasslands, which can be valorised by the complementary needs of the different herds and animal categories. The diversity of production systems and of animal types within an area should also favour environmental services related to grassland diversity.

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Characteristics of grasslands in the Polish Sudetes in view of fodder production potential and grassland protection

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Abstract

Mountain region of the Sudetes has a productive potential driving to high quality fodder from grasslands. The main reason is that 94% of grassland area is situated below the elevation of 700 m a.s.l. and 75% of them on slopes of less than 9^{o} inclination. Meadows and pastures of the highest economic importance cover an area larger than 50 000 ha. The analysis of ruminant and horse stock in 2008 revealed that the fodder production potential largely exceeded the demands. Productive use of meadows and pastures loses importance, despite financial support within the Common Agricultural Policy of the EU.

Keywords: the Sudetes, grasslands, fodder production, livestock population

Introduction

The Sudetes have all features of mountain areas, that significantly determine the function of these areas in spatial management. Half part of the total area of the region is covered by agricultural land from which 40% is constituted by grassland. This status has persisted till now despite changing trends in agricultural development during the post-war period characterised by following facts:

- collectivisation of agriculture which directly triggered the depopulation of rural areas,
- organisation of the utilisation of leys for young beef cattle,
- lower profitability of animal production after 1990: the drastic decline in cattle and sheep stock resulted in the shrinking of grassland areas, some of which were abandoned and some turned to a different form of land use.

As a consequence, the environmentally and economically valuable meadow and pasture communities lost the features which had enabled them to fulfil their productive and non-production functions.

The Common Agricultural Policy and the system of areal subsidies and compensations implemented in Poland since 2004 facilitated the restoration of agricultural land use, particularly in the most favourable conditions and grassland abandoning decreased. Today, the area of fallow grasslands of the region has decreased by half and does not exceed 15% out of 80 000 ha of meadows and pastures (The state and changes…, 2007).

The aim of this study was to characterise and assess the fodder production potential of grasslands in relation to the demands of ruminants and horses in the Sudetes.

Material and methods

The study area is situated in the mountain region of the Polish Sudetes and covers 329 064 ha. Its southern range is delineated by the main crests along the Czech Republic border and its north-eastern range is drawn by the 300 m a.s.l. contour line of the Sudetic Marginal Fault . The Sudetes are old mountains, one third of their area is localised in Poland and constitutes about 3% of the country area. The highest peaks in the region are: Śnieżka – 1602 m a.s.l. and Śnieżnik – 1425 m a.s.l.

Analyses were performed by use of a digital database containing: Digital Terrain Model (including hypsometry, inclination and exposure) made of 1:10 000 maps, as well as land cover and soil-type maps in the scale 1 : 5 000. For the purpose of this study, grassland-soil complexes were divided into 3 classes and exposure into 8 directions.

The demand for fodder production was analysed based on ruminant and horse stock acc. to agricultural census of the year 2002 and data of 2008 collected by the Lower Silesian Centre of Agricultural Advisory in Wrocław.

Results and discussion

The distribution of the three grassland classes in relation to elevation is presented in table 1. A large part (94%) is situated beneath 700 m a.s.l. which is the upper range of agricultural utilisation in the Sudetes. Medium grassland complex dominates with about 70% of the total area.

Table 1: Grassland area (ha) according to elevation zones

Grassland's complexes	Altitude m a.s.l.											
	<350		350-500		500-700		700-1000		>1000		Total	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
very good & good	147	0	58	0	0		0		0		205	0
medium	6023	7	30990	37	19020	23	1197	1	0		57229	68
poor & very poor	586	1	7389	9	14485	17	3592	4	127	0	26179	31
Total	6763	8	38474	46	33527	40	4790	6	127	0	83613	100

An analysis of the slope distribution showed that more than 75% of grasslands have an inclination of less than 9^{o} (Table 2). On more steep slopes (>20^{o}) there were 12% of grasslands.
Medium meadows and pastures were mainly localised in the first two classes of slope inclination whereas poor grasslands area goes up with the increase of slope inclination up to 20^{o}. Above 20^{o} inclination grasslands occupied very small areas.

Table 2: Grassland area (ha) according to inclination classes

Grassland's complexes	Inclination classes in degrees											Total	
	<3		3-6		6-9		9-12		12-20		>20		
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
very good & good	163	0	26	0	13	0	2	0	2	0	0	0	205	0
medium	21943	26	16447	20	9853	12	5357	6	3407	4	222	0	57228	68
poor & very poor	3447	4	4972	6	5540	7	5596	7	6144	7	681	1	26379	32
Total	25553	31	21445	26	15406	18	10955	13	9552	11	903	1	83813	100

Studied grasslands were mainly situated on slopes of cool, northern to eastern exposures (N, NE, E, NW) favourable due to a smaller risk of water deficits in the vegetation season (Table 3). Their share on slopes of these exposures reached 52% (43 277 ha) with the domination of northern and north-eastern exposure (15% each).

Table 3: Grassland area (ha) according to exposure

Grassland's complexes	Exposures																			
	N		NE		E		NW		S		SW		W		SE		Flat		Total	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
very good & good	22	0	28	0	18	0	15	0	23	0	24	0	16	0	32	0	27	0	205	0
medium	8408	10	8339	10	7498	9	5493	7	5823	7	6165	7	6313	8	6015	7	3175	4	57228	68
poor & very poor	3806	5	3784	5	3274	4	2593	3	3168	4	3017	4	3077	4	2826	3	835	1	26379	32
Total	12236	15	12150	15	10791	13	8100	10	9014	11	9206	11	9406	11	8873	11	4038	5	83813	100

Medium grasslands are of the most important ones in the region distributed favourably with respect to altitude and slope inclination. They grow on mineral soils, not or periodically flooded, as well as wet and organic mud-peat and muck soils. Due to diverse habitat conditions, they shelter a broad spectrum of species. Flat areas and lower parts of slopes are overgrown by communities with the prevalence of valuable fodder plants including grasses: *Dactylis glomerata* L., *Festuca pratensis* Huds., *Alopecurus pratensis* L., *Poa pratensis* L., legumes: *Trifolium repens* L., *Trifolium pratense* L., *Lotus corniculatus* L., *Vicia craca* L., herbs: *Achillea millefolium L.*, *Taraxacum officinale* F. H. Wigg., *Campanula patula* L. and other . These plant communities yearly yield from 4.0 to 6.0 t DM ha^{-1}. Slopes with higher inclination are covered by grasses of medium to low value e.g.: *Agrostis capilaris* L., *Festuca rubra* L., *Holcus mollis* L. and dicotyledons. These communities have a productive potential from 2.0 to 4.0 t DM ha^{-1}. Soil and thermal conditions worsening in mountain areas with elevation and slope inclination result in decreased efficiency and fodder quality. For this reason, the most productive medium grasslands are situated up to 500 m a.s.l. on flat areas and furnish a relatively stable high quality fodder. Between 500 and 700 m a.s.l. and on slopes of 6 to 9^{o}, the maximum yields reach 4.0 t DM ha^{-1}. The remaining grasslands situated above 700 m a.s.l. on slopes of more than 9^o and those on periodically flooded or wet grounds have higher natural than economic value.

Poor grasslands are present on flooded areas with hampered water outflow, in mid-forest regions and on hardly accessible and poorly developed soils (Fatyga, Nadolna, 2009). They are characterised by variable production and quality of fodder. Main grasses are: *Festuca rubra* L., *Agrostis capilaris* L., *Holcus lanatus* L., *Deschampsia caespitosa* (L.) P. Beauv, *Anthoxantum odoratum* L., *Nordus stricte* L., *Briza media* L., *Cynosurus cristatus* L., *Helictotrichon pubescens* (Huds.) Besser ex Schult. & Schult, and herbs and weeds constitute 30 – 50% of the plant cover. Their biomass production ranges between 2.0 and 3.0 t DM ha^{-1} with the most important areas situated in favourable conditions up to 500 m a.s.l. and on slopes up to 6^o inclination. Low-production grasslands and other grasslands situated on steep slopes (>9^o) were excluded from afforestation programmes in 2007 (Journal of Laws, 2007) to preserve and protect naturally valuable communities. They are represented by communities of high floristic diversity, containing rare and protected species (rich mountain hay meadows, xerothermic communities, mosses and sedges) (Fatyga, Nadolna, 2009).

Good grasslands occupy only 205 ha in the region. They occur on mineral soils of various types providing the best conditions for vegetation growth. Valuable grasses mixed with a large legumes proportion prevail there, yielding up to 8.0 t DM ha^{-1}.

Stocking rates. Nowakowski (2008) demonstrated that, under natural conditions of Sudetes mountain pastures (400 – 600 m a.s.l.), 1 ha of grasslands can provide fodder for 2 LU (500 kg) of animals in the grazing season and for 1 LU in an annual scale.

Ruminant stock in the region in 2008 was low and amounted: 24 573 cattle, 3122 sheep, 925 goats and 2257 horses (Table 4). Moreover, the herd of each animal group decreased as compared with that in 2002 when large stock deficits had been already observed in relation to available food base (Głębocki, 2006). The smallest changes were noted in cattle. Noteworthy was a substantial decrease of dairy cows in the herd. The number of goats and sheep decreased to the largest extent, by 68 and 34%, respectively. The number of horses decreased by 16%.

The stock of cattle – most numerous farm animals in the region – was 29 head per 100 ha of grasslands in the region in the year 2008.

Table 4: The stock of ruminants and horses (in head) in mountain counties of the Sudetes in the years 2002 and 2008

Years	Cattle		Sheep	Horses	Goats
	total	cows			
2002	24596	11837	4720	2703	2858
2008	24573	11505	3122	2257	925
difference	**-23**	**-332**	**-1598**	**-446**	**-1933**

2002 - Agricultural census
2008 - A set of data on selected communes in the Sudetes

Based on presented data, one may find that food demands of ruminants and horses could be fulfilled in the year 2008 by a half of the area of moderately efficient grasslands in the region. Productive role of grasslands still loses importance despite multi-directional support for agriculture in a form of areal subsidies, compensations for LFA including those in foothill (350 – 500 m a.s.l.) and mountain (>500 m a.s.l.) zones and an attractive offer of agro-environmental programm. Withdrawal from agricultural use of grasslands and a lack of alternative ways of biomass utilisation poses a real risk for grassland stabilisation in the Sudetes.

Conclusions

The analysis of distribution of 83 613 ha of grasslands in the Sudetes revealed that over 70% of their area is situated beneath 700 m a.s.l. and almost 75% - on slopes of an inclination < 9^o. The greatest importance for fodder production have medium grasslands whose area exceeds 57 000 ha and those situated beneath 500 m a.s.l. and on slopes inclined less then 6^o constitute 45% of the total area.

Grasslands situated above 700 m a.s.l. – the upper limit of agriculture in the Sudetes – and on slopes inclined by more than 9^o (excluded from afforestation programmes) should be involved in activities aimed at preserving and protecting valuable plant communities.

Ruminant stock in the region in 2008 indicated an insufficient utilisation of fodder potential.

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Pastoral Plans to support mountain farming in SW Alps

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Abstract

Semi-natural grasslands cover a large area in Piedmont mountains (south-western Alps). They are exploited mainly by farms that yearly move about 70,000 heads from the valley-floors or the plain to the summer pastures, playing an important role in nature conservation.

In the framework of the Rural Development Programme 2007-2013, axis II - measure 214 (agri-environmental payments), Piedmont regional offices have implemented measure 214.6 that contains specific actions for the conservation of biodiversity, soil, landscape, and water by extensive grazing. The basic actions (measure 214.6.1) aim at boosting extensive farming systems for their positive environmental effects on marginal areas. The additional measure 214.6.2 has introduced Pastoral Plans as a tool aimed at enhancing farm productivity, system sustainability, and environmental aspects by identifying specific management actions.

In this paper Pastoral Plan contents and the state of the art of measure 214.6.2 after two years are summarised, discussing the measure start-up problems.

Key words: alpine vegetation, extensive farming systems, grazing management, Pastoral Plans, RDP - Rural Development Plan.

Introduction

In Piedmont Alps semi-natural grasslands cover about 370,000 ha (Regione Piemonte - CSI, 2007), 75% of which are located in mountain areas (ISTAT, 2007). During summer, these grasslands are exploited mainly by farms that yearly move from the valley-floors or the plain to the mountain pastures leading transhumances of about 70,000 heads (IPLA, 2008). Therefore, in this areas farming systems play an important role in nature conservation and have a remarkable economic impact on local communities.

Since the '90s, the increasing demand for both high quality mountain dairy products and natural environment for recreation has led the Piedmont Region to gather data finalised to an integrated planning of mountain area utilisation. Detailed inventories of the forest types (Forest Regional Plan, Regional Bylaw n.4/2008), as well as of the pasture types (Cavallero *et al*., 2007), along with a generalised inventory of summer pasture infrastructures (IPLA, 2008), have been carried out in the whole regional territory.

Given the need to maintain mountain farming as a conservation and management tool on widespread marginal areas, regional offices have implemented specific actions to improve grazing management in the framework of the Rural Development Programme (RDP) 2007-2013. In particular, agri-environmental payments (RDP axis II - measure 214) have been proposed to promote the use of extensive grazing for the conservation of biodiversity, soil, landscape, and water (measure 214.6). The basic actions (measure 214.6.1) aim at reversing the trend leading to the concentration of livestock in the lowlands, by boosting instead extensive farming systems for their positive environmental effects. In the mountains, the main farmer commitments are: rotational grazing during summer (for at least 80 days) at stocking-rates between 0.2 and 0.5 livestock units (LU) ha^{-1} $year^{-1}$; use of paddocks equipped with water and mineral supplement dispensers; weed or encroaching woody species control without herbicides; 0 nitrogen and limited P_2O_5/K_2O mineral fertilisation. Five year basic engagements are remunerated with a prize of 40 Euros ha^{-1} $year^{-1}$.

The additional measure 214.6.2 has introduced Pastoral Plans as a tool aimed at enhancing farm productivity, system sustainability, and environmental aspects by identifying specific management actions. Additional engagements for the farmers running Pastoral Plans are rewarded with a further prize of 60 Euros ha^{-1} $year^{-1}$.

After a presentation of the Pastoral Plan contents in agreement with the EC and local rules, this paper will focus on the state of the art of measure 214.6.2 after two years, discussing its start-up problems.

RDP measure 214.6.2: Pastoral Plans

Pastoral plans are technical documents defining the criteria for a rational grazing management of pasturelands. Pasturelands, as defined by Allen *et al*. (2011), are the main land use in the Alps. From the mountain to the alpine belt, they are solely exploited by grazing, whereas cutting is an outdated practice in most areas. The pastureland management includes all the actions carried out by a farmer to achieve a yearly animal production resulting in a satisfactory income. A proper exploitation is essential to preserve pasturelands and improve pastoral ecosystem services.

Drafting Pastoral Plans involves gathering a number of *basic elements* used subsequently during the *planning stage*. Afterwards, management practices are set taking into account the specific objectives of the applicant farm (e.g. increasing animal productivity, extending the grazing season).

The *basic elements* include:

the definition of the area covered by the plan on topographic maps, together with a list of cadastral parcels consistent with the land register data. The farm should own the pastureland or provide a legal agreement for its use;

the description of surface (altitude, slope, aspect), climate (in particular during the growing season), and accessibility of the pastures exploited by animals, aimed at highlighting the elements that could influence management decisions and limit the possibilities of change;

a detailed analysis of pasture vegetation. Grasslands are surveyed by applying to a 150 x 150 m grid the vertical point-quadrat method (Daget and Poissonet, 1971; Jonasson, 1988). Relevés are subsequently classified by cluster analysis into ecological groups, vegetation types, and sub-types (*facies*) as proposed by Cavallero *et al*. (2007). The vegetation map resulting from this classification is an essential tool for grazing management planning;

the analysis of past and current farm management including: the state of structures (e.g. buildings, barns, cheesemaking plants), infrastructures (fences, milking areas, drinking draughts), and road network; the production guidelines and processes; the livestock number by species and classes; the management techniques (herd movements, manure management, and other practices concerning pastoral management). Such analysis aims at pointing out advantages and disadvantages of farm management that vegetation may evidence;

the evaluation of pastureland potential in terms of forage allowance and carrying capacity;

the comparison between the current and the potential state of the pastures.

The following records are then included in the *planning stage* taking farm perspectives into account:

indication of management targets for each grazing area (conservation, improvement, recovery, natural evolution), complying with 92/43/EEC directive (Habitat Directive) and its amendments;

localisation of the structures, infrastructures, and facilities to be used or renovated in view of an improving farm management;

grazing management proposals (localisation of paddocks and camps, optimum period for their exploitation and exploitation schedule, stocking-rates and grazing pressure per paddock, localisation of drinking draughts, mineral supplement dispensers, and milking areas);

indication of the priority of interventions;

financial plan with the assessment of the costs of Pastoral Plan implementation.

RDP measure 214.6.2: state of the art

The measure was implemented in June 2009 when a regional act defined the guidelines for Pastoral Plans drafting and the procedures to submit applications and evaluate plans. After two calls a limited number of applications has been submitted as compared with the RDP target (40 out of 500 envisaged applications), whereas 60% of targeted applications have been submitted for measure 214.6.1 that involve a lower level of commitments. Despite the low number of applications, the concerned surface accounts for about 30% of the target one (30,000 ha). The monetary value of the whole measure 214.6 amounts to about 3,800,000 euro, i.e. less than 5% of agro-environmental payments, of which 4.5% for sub-measure 1 (figure 1).

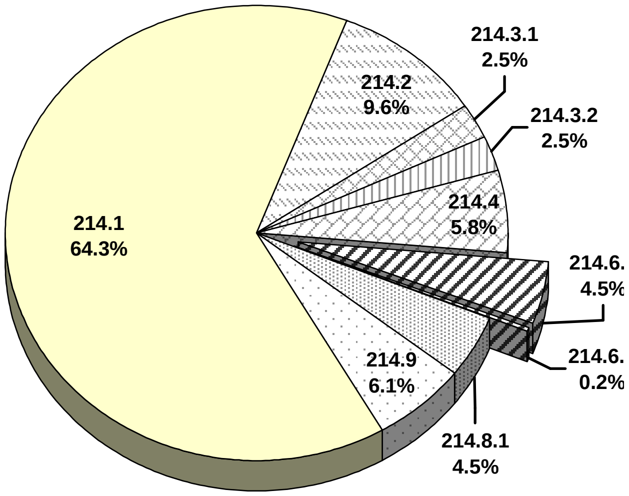

Figure 1: Allocation of agri-environmental payments by sub-measure during years 2009-2011 (total amount of payments: 81,979,494; data from RDP 2007-2013 Monitoring Agency)
Sub-measure codes: 1. Low impact agriculture; 2. Organic farming; 3. Increase of soil organic matter; 4. Conversion of arable lands; 6. Extensive grazing systems; 7. Enhancement of ecosystem environmental and landscape functions; 8. Conservation of local breeds; 9. Enhancement of rice paddy biodiversity. Sub-measures not listed have not been implemented yet.

The start-up of the measure has been probably affected by a remarkable time lag of farmers' union in spreading the news, as it generally operates as contact point between regional offices and farmers. Such a delay could be related either to difficulties to reach agricultural entrepreneurs, who generally are not used to internet communication and often live in inaccessible summer quarters, and to start-up uncertainties. Actually, the submission of Pastoral Plans requires (i) that applicants charge a freelance, whose remuneration has to be paid directly by the farmer, with the draft of the plan; (ii) the collection of all above mentioned basic elements by the freelance, mainly during a short summer period; (iii) the data analysis and the drafting of the management plan; (iv) the delivery of the Pastoral Plan to mountain communities or districts to verify that it is consistent with RDP indicators, appropriate, and applicable; (v) the authorisation to plan start-up at the end of inquest, followed by the check of eligible areas by the regional agency for payments in agriculture (ARPEA), (vi) the payment of the prize by ARPEA, that performs a second check of 5% randomly selected plans.

Several problems have hindered the regular course of submission and inquest stages, starting from identifying the freelance in charge. A limited number of experts in grazing-land management is available; this limit has been partially overcome with specific intensive post-graduate training.

The direct remuneration of freelances could have discouraged several farmers, not willing to spend, on average, the amount of one year measure prize.

Uncertainties dealing with the assessment of advantages, sometimes coupled with uncertainties in the duration of summer quarter lease agreements, have caused a shift in data gathering and plan drafting, reducing the commitment period and, consequently, the number of payments.

Inquests by mountain communities and districts have taken a long time, because of the lack of grazing-management specialists; this limit has been partially overcome by means of specific training. Nevertheless, at the moment few farmers have an official authorisation to start-up, even if since 2009 they have been managing their pastureland according to the Pastoral Plan.

Finally, the need of adjusting some technical parameters dealing with grazing management established by EC and some conflicts between the regional agency for payments and agriculture regional offices, are further delaying the conclusion of procedures and the payment phase.

Conclusions

The attention of farmers towards a more sustainable management of summer pastures, which often results either in labour and production cost reduction and in environmental and landscape ecosystem function improvement, has grown. Even if the measure has suffered several start-up drawbacks, the innovative implementation of Pastoral Plans in the framework of a normative act should be pursued also in the coming Rural Development Programme, so as to give continuity to the development of mountain farming. The actual effects of this public investment on marginal areas will be reached in some years. However, the farms applying the measure have gained a large consensus in the world of mountain livestock breeders, which is a basic condition to enlarge the alpine areas preserved by management under Pastoral Plans.

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The land use changes in the agricultural areas in 1980-2005 with particular attention to permanent grasslands, as per the example of the upper Raba basin

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Abstract

This study has been inspired by dynamic structural changes in Carpathian area, in particular, changes in land use during last 25 years. The aim of this paper is the evaluation of the changes of the areas of pastures and hay meadows, projected over general transformation of the agriculture in selected communities located in mountainous areas of the Raba River drainage basin. Changes in animal husbandry have been described by selected production parameters such as livestock expressed in Livestock Units (LU). Changes in land cultivation have been described as Nitrogen-Phosphorus-Potassium (NPK) load (resulting from fertilizing), NPK balance, and size of the areas cultivated with most important domesticated plants. A determination has been made on relationship between production and structural factors and also, on most important factors influencing structural changes. These analyses have been correlated to associated changes in the quality of the surface waters and to the land use change. Strict relationship between limiting the agricultural production, as well as, the change in the usage of the significant areas from cropland to grassland, to the changes in the magnitude of the biogenic load introduced to the environment has been substantiated. In. There are additional important influencing change factors such as expansion of tourism, urban development, etc. Conclusions of the study will assist in optimal shaping of the functional space of the mountainous regions with preservation of the sustainable development of the area in question.

Key words: agriculture use, permanent grasslands, arable lands, stocking, NPK load.

Introduction

The Carpathian areas have very intensively transformed structurally, mainly in regard to agricultural production, infrastructure transformation, and environmental changes in the structural space. This has in turn influenced the structure of land use, both agricultural areas and their proportion to non-agricultural lands, mainly urban areas and technical infrastructure. These transformations have their roots in the socio-economic changes after 1989, in the Polish accession to European Union in 2004, and several processes of natural and anthropogenic origin (Kopacz 2007; Twardy 2008, 2009).

Since surface waters are abundant in the area in question, these transformations have also an influence on the quality of water environment, which is very sensitive to anthropogenic pressure, and represents specific indicators of spatial and structural changes (Guzik 1995, Simonides 2007).

The aim of this study was to evaluate long term changes in agricultural use with particular emphasis on pastures and meadows. This assessment was projected on the background of transformation in agriculture, which took place in the mountainous Raba River catchment. These changes have been described by some production parameters, such as livestock density, expressed by the Livestock Unit (LU) per ha and the total inflow of biogenic components NPK of agricultural origin in the catchment area (kg NPK/AR).

Material and methods

The structural and performance parameters used in the statistical analysis in most cases were based on the administrative layout. The statistical data used in this study has been obtained for each of the communities situated within the upper Raba River basin and was apportioned to individual parts of the basin using a matrix conversion, which calculated the proportions between common areas of the researched communities and parts of catchment areas.

The studied area was the upper Raba River basin up to section in Dobczyce with total area of 768 square km. Due to its orography, landscape, climate and also hydrography, the research catchment is representative for the entire region of central parts of the Polish Carpathians (Dynowska et al. 1991;

Dynowska 1995). This region includes several geomorphological regions: Brama Sieniawska, Beskid Sadecki, Wyspowy and Zywiec and Pogórze Wiśnickie. The Raba River is a right-bank tributary of the Vistula River. Its sources are located at a height of 785 m above sea level on the slopes of Obidowa. About 86 percent of the Raba River basin is located in the Beskid Mountains, which qualifies this area as typical mountain catchments (Niedbała, Czulak 2000).

Summary of the analyzed catchment areas are presented in Table 1.

Erreur ! Référence de lien hypertexte non valide.

Table 1. **Overview of the analyzed fragments and sections measuring catchment in the upper Raba basin**

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Number of measuring section	River	Area of catchment above measuring section [km^2]	Place of measuring section
1	Raba	27,4	Raba Wyżna
2	Raba	768,0	Dobczyce
3	Trzemeśnianka	29,1	Banowice

Data from the years 1980-2005 on the land use structure and parameters, which are describing the agricultural production, were obtained from the Regional Statistical Office in Krakow. Data were collected from 15 communities located in whole or in part in the upper Raba River basin. The following are the communities in question: Dobczyce, Dobra, Jordanów, Lubień, Mszana Dolna, Myślenice, Niedźwiedź, Nowy Targ (rural part), Pcim, Raba Wyżna, Rabka-Zdroj, Siepraw, Tokarnia, Wieliczka, and Wiśniowa. The numeric values of the parameters for each community or a part of it, have been apportioned to each part of the research catchment as listed in the table 1. The load of biogenic components (NPK load) originating from agricultural sources was calculated using MACROBIL software. The relationships between land use and structural parameters were determined by linear and nonlinear regressions depending on the highest level of statistical significance. (Elandt 1964; Greń 1995).

Results and discussion

In the upper Raba basin significant changes in agricultural use have occurred. The largest change refers to the arable lands and grasslands, and especially to meadow areas. Table 2 illustrates the changes in the agricultural use in selected parts of the upper Raba River basin.

Table 2. Changes in agricultural use in the upper Raba River basin in the years 1980-2005 [percent of total area]

Agricultural lands						
Sections/years	1980	1985	1990	1995	2000	2005
Raba - Dobczyce	55,2	54,5	54,1	48,6	47,3	44,2
Raba - Raba W.	58,7	58,7	58,9	58,9	45,7	40,2
Trzemeśnianka	73,0	72,7	71,5	53,2	50,8	46,5
Arable lands						
Raba - Dobczyce	45,1	44,3	42,9	37,8	36,1	26,6
Raba - Raba W.	46,8	46,9	47,0	47,0	29,6	19,7
Trzemeśnianka	56,2	55,5	54,0	38,5	36,7	31,3
Grasslands						
Raba - Dobczyce	8,9	9,2	9,9	9,8	10,3	17,1
Raba - Raba W.	11,5	11,5	11,6	11,6	15,9	20,2
Trzemeśnianka	13,2	14,4	14,1	12,4	12,1	13,5

Although the agricultural lands in upper Raba River catchment have decreased by about 11 percent, the other parts of the catchment have shown greater decrease. The Raba Wyzna section has noted decrease of almost 20 percent. In the catchments of tributaries, the reduction of the agricultural area was even larger. For example: in Bysinka it was about 25 percent, and Trzemeśnianka catchment 30 percent.

Within the agricultural lands the arable lands have suffered the greatest decrease. These areas have decreased from 20 percent to (in some cases) almost 30 percent.

Within the grasslands, an increase of meadow surface occurred, and pastures areas slightly decreased. These changes result from the transformation of some arable lands to permanent grasslands (particularly meadows), as a result of discontinuation of cultivation. These meadows are often either abandoned, or extensively used. Hence, such meadows have converted to wasteland. The phenomenon of "conversion" of the arable lands to grasslands or wasteland is only partial. In the upper Raba River basin, reduction of agricultural lands amounts to about 20 percent. Large parts of arable lands have transformed to non-agricultural areas (eg: habitable areas), or in part have been completely degraded and qualify as wasteland.

These changes resulted from the 1986 northern part of the upper Raba River basin convertion to a retention reservoir in Dobczyce. This reservoir is also classified (by the Statistical Office) as a wasteland. The changes in livestock (–expressed in LU), and NPK load generated by agricultural sources (expressed in the pure Nitrogen, Phosphorus and Potassium components) are illustrated in table 3.

Table 3. Changes of stocking and NPK load in the upper Raba basin

Sections/Years	1980	1985	1990	1995	2000	2005
Stocking [LU per hectare AL]						
Raba - Dobczyce	1,15	1,09	1,03	0,91	0,75	0,39
Raba - Raba W.	1,35	1,26	1,22	1,05	1,06	0,58
Trzemeśnianka	1,01	0,91	0,88	0,78	0,61	0,31
Load NPK [kg NPK per hectare AL]						
Raba - Dobczyce	302,8	285,9	241,8	223,9	189,1	123,2
Raba - Raba W.	335,4	320,4	277,8	254,3	239,0	157,1
Trzemeśnianka	277,7	252,3	214,5	200,0	163,8	115,1

A clear reduction of the herd size was observed. In comparison with the 1980s livestock load, there has been a decrease from 1.0-1.4 to 0.2-0.6 LU/ha. The total load of NPK was also reduced, from an average level of 300 to about 124 kg of NPK per hectare of arable land. Intensity of changes in livestock and NPK load indicate that the greatest reduction of livestock and load began in the second half of the nineties of the last century.

It is noted that within the examined time span a clear collinear relationship exists between the livestock decrease and the reduction in arable land. Concurrently, significant increase in grassland was noted. Changes relationships of arable land and grasslands in relation to the entered load of NPK are illustrated in table 4.

The table 4 regression equations represent the relationship between changes in the volume of catchment NPK load rate and changes in the area of arable lands and grasslands. They can be used to determine the estimated relationship between changes in agricultural use of the different parts of the catchment and the size of the load rate.

Table 4. The regression functions in the upper Raba catchment between load NPK (value Y) and the area of arable lands and grasslands (value X)

Section	Arable lands		Grasslands	
	Formula	R^2	Formula	R^2
Raba Dobczyce	$y = 36{,}24e^{0{,}046x}$	0,90	$y = 5041{,}2x^{-1{,}34}$	0,74
Raba - Raba Wyżna	$y = 28{,}088x^{0{,}6}$	0,71	$y = 3333x^{-1{,}0001}$	0,76
Trzemeśnianka	$y = 4{,}63x - 10{,}23$	0,82	-	-

Increase of grassland area in all sections of the Raba River catchment, decrease of NPK load and simultaneous decrease of livestock seem illogical. Although it proves that the transformation of arable lands into meadows or wasteland, due to its extensive use or disuse (Pietrzak 2002), is a result of the European Union policy and its direct payments to the farmers. Cultivation of the land and livestock breeding has become uneconomical except to cover farmer’s own use, due to numerous agricultural production limits, and the sole stimulus holding the field is direct payment from EU.

Conclusions

The following conclusions can be drawn:

1. There was significant structural and spatial transformation in the upper Raba River catchment in the years 1980-2005. The most dynamic changes happened in the second half of 1990s and first years of the twenty-first century.
2. The greatest decrease concerned arable lands, and increase concerned mainly the meadows.
3. In the studied period a serious reduction of animal and plant production has been observed. It resulted with a reduction of agricultural lands, particularly arable lands.
4. Despite of the decrease in livestock the grasslands and wastelands have increased. This demonstrates the secondary ecological plant succession and it proves the extensive character of grasslands, often maintained only for obtaining some direct payments from EU.

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Evaluation of faecal near-infrared spectrometry as tool for pasture and beef cattle management in herbaceous Mid-Eastern highlands

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Abstract

Rapid assessment of the nutritional quality of diets ingested at pasture is pivotal for successful cow-calf management in Mid-Eastern herbaceous pastures that are subjected to phases of unpredictable rainfall and hot-spells. Composition of pasture samples has little significance, as cows graze selectively in heterogeneous pastures. In contrast, faeces are easily sampled and their near-infrared (NIR) spectra encompass information about nutrients and the use made of them. We calibrated prediction equations based on 125 pairs of individual dietary attributes and the NIR spectral characteristics of associated faeces. Diets were composed of a wide array of grasses and forbs at various phenological states, with or without supplements. Calibrations for *in vitro* DM digestibility, NDF, CP, and ash, were enough precise (R^2 values *ca* 0.90) and accurate (SE of calibrations, 2.8, 3.5, 1.0, and 1.6%, respectively) to be used in a two-year monthly consulting frame with two commercial cow-calf operations grazing on the Golan heights. Faecal NIRS was useful to elicit a dialog on when to start or interrupt supplementation, or when to turn cows to new plots but the time gap between sample collection and delivering of results by e-mail was too long (8 days), and reliable recommendations could be formulated only after assessing cow and pasture condition, i.e., considerable input of skilled manpower.

Key words: beef cattle, nutrition, NIRS, monitoring, decision-making

Introduction

The 40,000 head beef cattle industry in Israel is small, but makes important contributions to preserving natural landscapes and bio-diversity, particularly in the scenic woodlands and grasslands of Northern Israel. Nutritional value of herbage has an important role on cattle productivity (Holloway *et al*., 1979) and is an important consideration in the design and implementation of grazing systems (Briske *et al*., 2008). Diet quality and herbage availability directly affect selection of feeding areas (Ganskopp and Bohnert, 2009) and animal condition.

In Northern Israel, the rainy season starts in October and ends in late March, with rainfall ranging between 400 and 900 mm. Grass primary production extends from January to April. It may be high in Mediterranean ecosystems, but it encompasses mainly short-lived annuals characterized by high seasonality (Sternberg *et al*., 2000). This implies that free grazing beef cattle may face a reduction in the nutritional quality of forage through its chemical ingredients, digestibility and metabolized energy during the hot and dry season (Brosh *et al*., 2004). In particular, fall-calving cows will face a shortage in food during pregnancy and nursing and need supplementation. Accurate assessment of dietary quality allows monitoring temporal stocking density, supplementing cattle adequately, hence, improving the probability of a high calf crop. Poultry litter (PL) feeding is the most widespread supplement in cow-calf operations but PL in excess is a health hazard (Silanikove and Tiomkin, 1992) and evaluating its proportion in freely consumed diets is a tough task.

Elucidation of nutrient intake in free-ranging animals has long been a challenge: estimation of the pasture components which disappear during the grazing process is flawed because clipped samples are seldom representative of animals‘ diets. Oesophageal-fistulated animals have been extensively used in the past to determine diets ingested at pasture, but their use has decreased because extrusa samples collected from fistulated animals may not reflect the selectivity exhibited by non-fistulated resident animals (Coates *et al*., 1987) and because of animal welfare regulations. Microhistological analysis of plant epidermal fragments in faecal samples is considered an accurate technique for estimating botanical composition (Alipayo *et al*., 1992), but evaluations must be corrected for differential digestibility, which makes the method irrelevant for heterogeneous pastures. Plants species can be discriminated within a mixture by using n-alkanes contained in the waxy cuticle of their surfaces as plant "finger-prints”. By using differential corrections for faecal recovery, they can be used as tracers of botanical composition, provided that their concentration in dietary components is well individualized and the number of n-alkanes exceeds the number of species in the diet (Dove and Mayes, 1991). However, alkanes need to be saponified and extracted with heptane before gas-chromatography, *e.g*. a time-consuming procedure that involves the use of hazardous chemicals. Also, Brosh *et al*. (2003) reported unexpected recoveries and large analytical errors at low alkane concentrations. Most importantly, the microhistological and n-alkanes approaches cannot be used as routine farm procedures as their cost is too high.

A technology for easier elucidation of diet quality termed "faecal NIRS" (FNIRS) was pioneered by researchers at the Texas A&M University (Lyons and Stuth, 1992), based on the finding that the chemical information encompassed in faecal spectra in the near-infrared range (1100 to 2500 nm) is closely related to many dietary attributes. Lyons and Stuth (1992) and Coates (1999, 2004) successfully established FNIRS calibration equations for percentages of dietary crude protein (CP), dry matter and organic matter digestibility *in vitro* or *in vivo* in cattle. Boval *et al*. (2004) have also established FNIRS calibrations for fiber attributes. These calibrations were established with cattle grazing herbaceous pastures or fed cut pasture in confinement. Samples for reference values have been obtained with oesophageally-fistulated animals (Lyons and Stuth,1992), with confined animals fed hays or mown pasture (Boval et al. 2004), or a combination of these procedures. Most calibrations have been developed for diets consisting entirely of forage, but Gibbs *et al.* (2002) demonstrated that it is also possible to develop calibrations to measure crude protein and DM digestibility of forage diets supplemented with protein meals and cereal grains. FNIRS is applied semi-commercially, i.e., cost is supported as least partly by governments and NGO’s in the US (Ganlab, Texas A&M, College Station, TX; http://cnrit.tamu.edu/ganlab/GANlab_webpage.htm), Australia (CSIRO, Northern Australia), and FNIRS predictions exist in Israel for goats (Landau *et al*., 2005) and beef cattle.

The aim of this study was to assess the usefulness of FNIRS in assessing nutritional attributes of grazing cattle in the Golan Heights grasslands.

Material and methods

Development of FNIRS calibration equations to predict dietary attributes requires a dataset of diet-faecal pairs consisting of NIRS spectra of faeces and knowledge of the attributes of diets from which these faeces originated. The latter, obtained by conventional procedures such as "wet chemistry" are termed the "reference values" (Landau *et al*., 2006).

We built a database encompassing 134 diet-faecal pairs, including 48 complete mixed diets (wheat silage, wheat straw, corn grain, and urea in varying proportions), 71 diets made of mowed pasture in the Northern Negev area (barley, wheat, garden pea, and safflower at various phenological states, with or without a supplementation of poultry litter and barley grain), and 15 diets that consisted of harvested mature natural pasture in the Upper Jordan Valley, with or without poultry litter and barley grain.

Cows were kept in individual enclosures. After an adaptation period of one week, diets and residues were weighed and dried for 48 h at 70^{o}C in an aerated oven. Feeds and residues were analyzed for *in vitro* dry matter digestibility (IVDMD; Tilley and Terry, 1962), crude protein (CP) concentration, and dietary fiber attributes (Neutral Detergent Fiber- NDF; Acid Detergent Fiber – ADF; Acid Detergent Lignin – ADL; Goering and Van Soeste, 1970).

Fecal samples were packed into sample cells with a near-infrared transparent quartz cover glass and scanned between 1104-2492 nm in 2 nm increments using a Foss NIRSystems 5000 NIR reflectance monochromator spectrometer (Foss Tecator, Hoganas, Sweden) in order to collect NIR spectra as log (1/R) where R = reflectance. Before development of calibration equations, raw spectral data was transformed with the Standard Normal Variance (SNV) and detrend procedures to remove non-linearity that results from light scattering (Barnes et al., 1989). Mathematical treatments used to enhance spectral differences where "1, 4, 4, 1" or "2, 6, 6, 2", where the numbers represent the derivative, gap width over which the derivative is calculated, the number of points in a moving average, i.e., first smoothing procedure, and the number of nm over which the second smoothing is applied, respectively (ISI, 1999). Calibration equations were developed on the treated spectral data, using the Modified Partial Least-Squares routine of the WinISI II software (ISI, 1999). Before final calibration equations were calculated, outlier passes were made to remove observations with T>2.5 (ISI, 1999). The quality of prediction by equations was evaluated by the coefficient of determination (R^2), i.e., the proportion of variability in the reference data accounted for by the regression equation and the standard error of calibration (SEC) that represents the variability in the difference between predicted values and reference values. The accuracy of calibrations was evaluated by aid of cross-validation (with SECV as estimate of quality). Calibration performance is shown in Table 1.

The FNIRS equations were validated with external data from grazing cows in the Northern Negev of Israel, and were found to be sensitive to seasonal changes, supplementation, and stocking density (not shown).

The application of FNIRS equations was carried out with two commercial flocks grazing on the Golan Heights close to Yonatan (Mevo Hama, 600-700 m in elevation; $32^{o}\,56^{'}\,23^{''}$ N, $32^{o}\,56^{'}\,23^{''}$) and Afik (Thierry, 300-400 m in elevation; $32^{o}\,47^{'}\,06^{''}$ N, $35^{o}\,41^{'}\,40^{''}$), with 1000 and 140 adult cows, respectively. The small flock was splitted between two sites (Afik and Metsar). Supplementation policies differ between the two flocks: in the larger flock, poultry litter (PL) and agricultural residues are offered from Mid-May to end of November whereas the smaller herd grazes on wheat aftermath from July to October and PL and hay are offered from October to January. Here we report results spanning from October 08 to February 2011 and from January 2010 to February 2011, for the first and second flock, respectively. Every month, we visited the flocks and collected 5 dung samples from every stocked plot of grassland, we sampled bite-like biomass and we sampled supplements, where adequate. All samples were dried in an aerated oven at for 48 h at 70^{o}C and scanned as explained above. Our results rely on 462 and 135 dung samples from the Mevo and Thierry flocks, respectively.

Within the 134 pairs of diets-faeces included in FNIRS calibration, some were discarded in order to fit the distribution of spectral variation in the calibration to that of the predicted data, using a Mahalanobis distance of 3 SD as cutting criterion (ISI, 1999); as we had no data for very young pasture – difficult to harvest and feed to cows - we assumed that in early spring, when all vegetation has similar nutritional value, cows are less selective, and we used the average chemical values of bite-like clipped pasture in each field as reference value in the first year. In order to make for easier dialogue with farmers, IVDMD values were transformed into Metabolizable Energy (ME) as follows: Gross energy (GE) was assumed to be 4.2 Mcal/kg DM. ME was calculated as GE * IVDMD *0.82. Therefore, the new calibration encompassed 117, 121, 123, and 125 pairs of faeces and diets for ME, ash, CP, and NDF, respectively (Table 1).

Table 1. Calibration performance of the FNIRS equations used in this study: 134 pairs of diets and feces but some outliers were removed: SD represents the standard deviation of nutritional attributes, SEC and SECV are the standard errors of calibration and cross-validation, RSQcal and RSQcval represent linearities of calibration and cross-validation, respectively.

Constituent	N	Mean	SD	SEC	RSQcal	SECV	RSQcval
IVDMD	117	64.9	9.5	2.7	0.92	3.3	0.88
ash (%)	121	10.0	4.3	1.8	0.83	2.0	0.79
CP (%)	123	10.5	3.5	1.1	0.90	1.4	0.85
NDF (%)	125	49.9	10.5	4.9	0.78	5.2	0.75

Table 2. Calibration performance of the equations for faecal composition used in this study: SD represents the standard deviation of nutritional attributes, SEC and SECV are the standard errors of calibration and cross-validation, RSQcal and RSQcval represent linearities of calibration and cross-validation, respectively

Constituent	N	Mean	SD	SEC	RSQcal	SECV	RSQcval
Ash%	159	22.3	5.2	1.2	0.94	1.3	0.94
NDF%	117	52.5	6.8	2.1	0.91	2.7	0.84
ADF%	111	33.9	3.9	1.4	0.87	1.8	0.79
ADL%	159	7.8	1.5	0.6	0.81	0.9	0.70
CP %	132	12.1	2.6	0.5	0.96	0.6	0.95

Our dialogue with the farmers relied on the results of two appraisal systems. First, we assessed dietary composition by using FNIRS equations (Table 1) and second, we established a NIRS-aided calibration of faecal composition based on samples collected during the first year at Yonatan (Table 2). The results of faecal composition were used to back the conclusions drawn from FNIRS: for example, if dietary CP or dietary energy in FNIRS prediction, we expected to see increased faecal CP. This is because most faecal N is of microbial source, and the ruminal flora responds to both dietary energy and protein by increased CP production; and if FNIRS predicted an increase in dietary NDF concentration during the dry season, we also expected increased faecal NDF. We established a scale of recommendations based on NRC (1996) for beef cattle (Fig. 1).

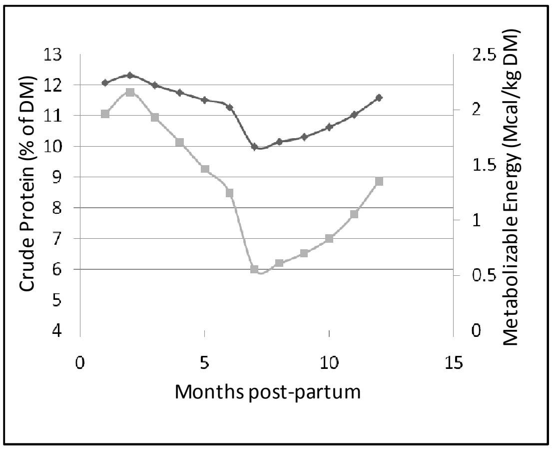
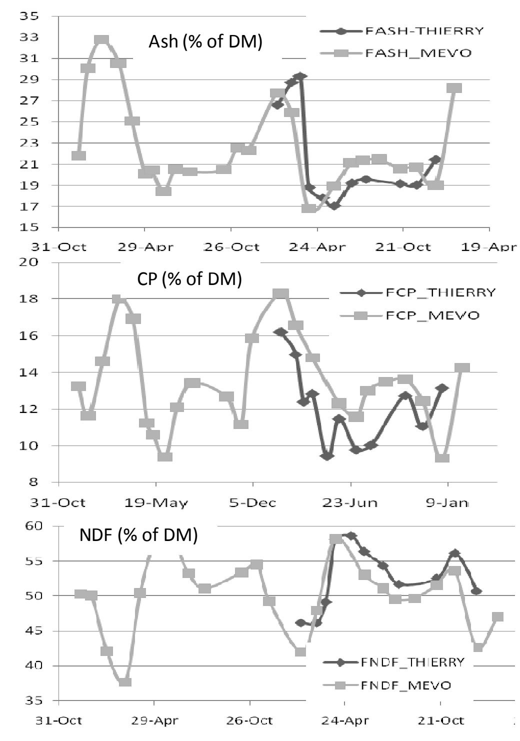


Fig. 1: The NRC (1996) recommendations for Crude Protein (in grey) and Metabolizable Energy (in black) for cows weighing 630 kg and producing 14 kg of milk that served as basis for assessing dietary accuracy during this study

As the minimal CP concentration for cattle is 6%, and given the accuracy of FNIRS equation (SECV, 1.4%), we recommended CP supplementation or moving cows to a new plot any time predicted dietary CP was under 7.5%; at the difference of CP, a temporary deficit in ME can be buffered by using body fat depots similarly, therefore we alerted at ME values lower than 1.7 Mcal/kg DM. We also signaled when PL in diets exceeded 40% (not shown).

Results and discussion



As found also by Coates (2000, 2004) in Australia, FNIRS was instrumental in elucidating seasonal changes in nutrition. Faecal composition (Fig.2) illustrates the highly seasonal character of cattle nutrition in Mediterranean ecosystems. Ash contents peak at the end of January, decreases till April and abruptly increases from October-November to January. NDF nadirs are found in January-March, with peaks in April, and faecal CP graphs also show well-organized series of peaks and nadirs with amplitude probably related to climatic events.

Fig. 2: Faecal contents of ash, Crude Protein (CP, % of DM) and Neutral Detergent Fiber (NDF, % of DM) monitored in two farms (Thierry, n=135, ♦; and Mevo, n=462, ■).

The diets ingested by cows at pasture (Fig. 3) varied extremely in concentrations of ME (from 2.8 to 1.4 Mcal/kg DM), CP (from 25 to 6% of DM), and NDF (from 37 to 73% of DM). Our predictions were always responsive to supplementation: the decrease in dietary ME and CP in late spring was always stopped by supplementation and diagnosed correctly. The farmers were at times surprised by the adequacy of our diagnosis: we discovered that feed had not been trucked to a group of cows, a mistake that farmers were not aware of; we delayed supplementation on May 2009 because it seemed a waste of money, given the state of pasture, which eventually proved to be a good decision as 84% of the group were successfully mated. By comparing the dietary NDF contents in the two farms that we surveyed, it appeared that dietary NDF was well explained by supplementation: unsupplemented cows had higher faecal and dietary NDF. It seems that they had to consume coarser parts of plants than supplemented counterparts. Therefore, FNIRS predictions of NDF can contribute to estimating stocking density in a nutritional scope.

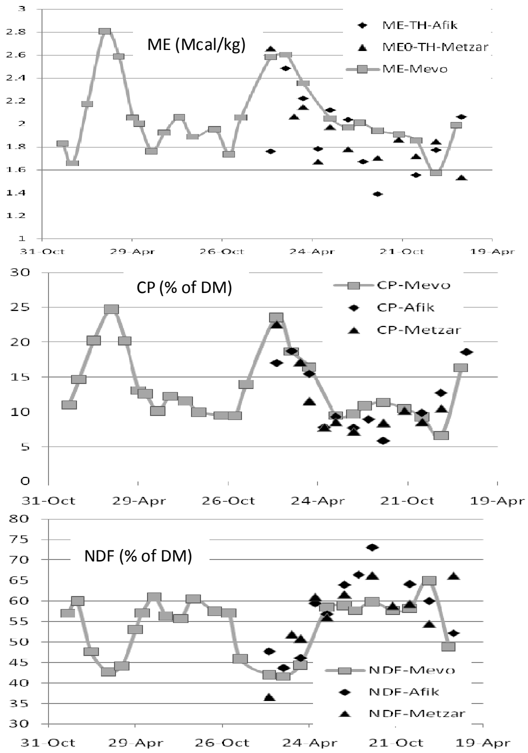


Fig.3: Dietary concentrations of Metabolizable Energy (ME, Mcal/kg DM), Crude Protein (CP, % of DM), and Neutral Detergent Fiber (NDF, % of DM). Periods of supplementation are indicated in grey (Mevo) and black (Thierry). Thierry's flock was grazed on two sites, Afif and Metzar.

At many occasions, we claimed that the diets were not adequate and the farmers had already acted accordingly before the recommendation reached them; only one time, we claimed that diets were too poor and the farmer did not agree to our diagnosis but complied to our recommendation. During the summer of 2010, we claimed that ME and CP contents at Afik and Meitar went dangerously low. The farmer agreed with us but the owner of the wheat aftermath fields did not allow him to supplement the cows. Farmers were surprised that dry, dead plants were consumed, as evidenced by CP and NDF, until late in the green period. Maybe cows are not able to harvest grass at low heights, but more probably they select diets such as to keep nutrients steady as much as can be done, as shown for goats before (Kababya et al., 1998).

Three man-days were needed monthly for each collection, NIRS scanning, data processing and evaluating, and response dispatch to farmers. The span of time from collection to completion of analyses was 7.9±4.2 days. The time needed to compile, verify, and classify the results (diets adequate or not, supplemented needed or not, how to supplement) was approximately 1 day. In other words, the farmers received the information to their cows' diets 9 days after collection, or 11 days after the diets were consumed. It is too much time to be operational under Mediterranean conditions, as changes occur abruply (see a decrease in 8% CP in Afik within one month in 2010). Potential solutions could be quicker drying procedures for faeces or the establishment of calibrations with portable diode-array spectrometers.
As noted in surveys at Ganlab, FNIRS programs increase awareness of farmers to pasture quality. This happened also in Israel. We are looking forward to ensuring that joining FNIRS program results performance improvements and higher benefit.

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Influence of predicted climatic changes on grassland management and productivity in south-eastern Carpathians

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Abstract

According with the last climatic predictions on 2070 year, the annual medium temperatures in East Europe will rise with 3^0C. As consequence, in mountain zone of Romania, particularly South-Eastern Carpathians will take place profound changes referring to the distribution of the actual primary vegetation (woods), secondary (grasslands) and its productivity. So, the maxim actual level of spreading on altitude of spruce will increase from 1600-1800 m to 2200-2400 m (2500 m) and of beech from 1200-1400 m to 1800-2000 m, upper with 600 m, respectively.

Also, the actual productivity of woods and grasslands situated at 1000-1200 m altitude after global warming will be obtained at 1600-1800 m a. s. l. where there are better climatic characteristics. The soil changes will be produced slower than those climatic, influencing negatively the vegetation production. The grasslands from the base of the mountains will suffer a desertification deeply obliging the breeders to practice more the shepherding. In the context of global warming, the correct management of mountain grasslands situated into a more favourable climate can be a rescue solution of livestock rearing in the Carpathian space.

Keywords: climatic change, arid zones, grassland productivity

Introduction

The latest projections of climate evolution in the world, the phenomenon of general warming due to human activities (deforestation, industrialization, transport etc.) with increasing carbon dioxide emissions, melting ice caps and mountain glaciers, increase ocean levels, flooding and arid period, desertification, enhancing extreme phenomena (hurricanes, typhoons, tornadoes, cyclones etc.) will have a major impact on all humanity with unpredictable negative consequences (Gore, 2007, Marusca et al. 2010, Seres, 2010).

Forecasts for global warming climate will affect our country's pastoral land. Average air temperature increase of 3^0C, which is forecast in the years 2070, will determinate a higher arid period and desertification of the plains and hills with major negative implications on crop production and livestock produced on natural grasslands.

The average air temperature increase of 3 ^{0}C in Romania is forecasting that Dobruja, south of Moldavia, western Transylvania, Banat, south of Oltenia and much of southern Romanian Plain, so over than 30 % of the country will undergo a process of desertification and the remaining about 38 % will suffer a sharp arid process, which will include further all our plains, up to 85 % of the hills and almost 20 % of the lower altitude mountains of the country.

Forecast changes in bioclimatic

Predicted climate change will have a major impact on the current redistribution of vegetation on areas and altitude vegetation layers influencing the habitats and economic performance. According to forecasts for the years 2070 an increase of 3^0 C average air temperature in mountainous areas where altitudinal gradients (-0.5^0C / 100 m alt.) are expected to increase by about 600 m of the current altitudinal repartition of primary vegetation. For the mountain zone the bioclimatic changes for the year 2070 are presented in Table 1.

Table 1: Changes of bioclimatic and altitudinal vegetation levels for an increase of the average air temperature with 3^0C (for year 2070)

Current altitudinal vegetation belt	Altitude (m)	Annual average temperature (^{0}C)		Annual rainfall (mm)		Possible altitude of the vegetation belt after hundreds years
		Current value	2070	Current value	2070	
Alpine	2200- 2400	- 1	2	1500	1250	Spruce
Mountain pine	2000-2200	0	3	1450	1150	Spruce
Mountain pine	1800-2000	1	4	1350	1050	Spruce + Beech
Spruce	1600-1800	2	5	1250	950	Beech
Spruce	1400-1600	3	6	1150	850	Beech
Spruce + Beech	1200-1400	4	7	1050	800	Holm oak
Beech	1000-1200	5	8	950	700	Oak
Beech	800-1000	6	9	850	600	Forest steppe
Holm oak	600-800	7	10	800	500	Steppe
(Oak) (Forest steppe) (Steppe)	GRADIENTS for 100 m alt.	- 0,5 ^{0}C	- 0,5 ^{0}C	+ 45 mm	+ 45 mm	(Sub humid areas –dry) (Quasi arid) (Arid - deserts)

From these data results that in high mountain area will disappear the alpine and sub alpine levels (the Mountain Pine) and it will be replaced by spruce and beech forest layer.
The steppe area will replace the upper altitudinal belt of the oak forest and forest steppe will replace the lower level of the beech forests. These major changes in the altitudinal distribution of the woody vegetation in the mountain area will reduce 40 - 70% of current forest area and will produce dramatic consequences on water balance and precipitation.

Forecast changes in mountain soils

Climate change will alter the physical - chemical features of the soil (Table 2).

Table 2: Change of soil conditions at a increase of average air temperature with 3^0C (for year 2070)

Current altitudinal vegetation belt	Altitude (m)	Soil layer depth (cm)		Horizons A			
		2000	Distant future	pH in water		V %	
				2000	2070	2000	2070
Alpine	2200- 2400	20	Very low growth (about 1 cm. per 100 years)	3,6	4,5	6	24
Mountain pine	2000-2200	35		3,9	4,8	12	30
Mountain pine	1800-2000	50		4,2	5,1	18	36
Spruce	1600-1800	65		4,5	5,4	24	42
Spruce	1400-1600	80		4,8	5,7	30	48
Spruce + Beech	1200-1400	95		5,1	6,0	36	54
Beech	1000-1200	110		5,4	6,3	42	60
Beech	800-1000	125		5,7	6,6	48	66
Holm oak	600-800	140		6,0	6,9	54	72
(Oak) (Forest steppe) (Steppe)	GRADIENTS for 100 m alt.	- 7,5 mm		- 0,15	- 0,15	- 3 %	- 3 %

Thus, depth of soil over the next 60 to 70 years will be about the same because 1 cm soil in the temperate zone is formed in about 100 years. However, some features may suffer agrochemical changes due to an undefined time period to achieve a balance determined by the specific temperatures and rainfall forecast for the year 2070. Level of production in return will be lower than the current ones due to a diminishing with about 45 cm of the soil layer depth and higher acidity with 0.9 units.
Soil reaction (pH) and the soil base saturation (V %) will be changed with the altitude corresponding with the more increasing active bioclimatic indicators for vegetation.

The much slower changes at the ground level will make the productivity of the natural vegetation and crops to be quite low because in the future will be more favourable conditions of temperature at higher altitudes.

Predicted **productivity of mountain grasslands and length of grazing period**
As a result of climate change and the physical - chemical features of the soil, the highland grasslands productivity will change in order to achieve a maximum values between 1600 - 1800 m in comparison with current altitude of 1000 -1200 m , above 600 m respectively (Table 3).

Table 3: Predicted **productivity of mountain grasslands and length of grazing period** for an annual average fertilisation of N_{100} P_{50} K_{50} kg/ha (P_2O_5; K_2O)

Altitude (m)	DM yield, (t/ha)				Grazing period (number of days)		
	2000	2070	Dif + -	%	2000	2070	Dif + -
2200- 2400	1,2	3,8	+ 2,6	316	40	100	+ 60
2000-2200	2,4	5,0	+ 2,6	208	55	115	+ 60
1800-2000	3,6	6,2	+ 2,6	172	70	130	+ 60
1600-1800	4,8	7,4	+ 2,6	154	85	145	+ 60
1400-1600	6,0	6,8	+ 0,8	113	100	160	+ 60
1200-1400	7,2	6,2	- 1,0	86	115	175	+ 60
1000-1200	7,4	5,6	- 1,8	76	130	160	+ 30
800-1000	6,8	5,0	- 1,8	73	145	130	- 15
600-800	6,2	4,4	- 1,8	70	160	100	- 60
Gradients per 100 m altitude							
1800-2400	- 0,6	- 0,6	*	*	- 7,5	- 7,5	*
1200-1800	- 0,6	+ 0,3	*	*	- 7,5	- 7,5	*
600-1200	+ 0,3	+ 0,3	*	*	- 7,5	+ 15,0	*

At an average level of fertilization of 100 kg/ha N and 50 kg/ha P_2O_5 and K_2O, the grassland current yield of 7.4 t/ha DM, realized at 1000-1200 m altitude, in the future will be obtained at 1600-1800 m.
The altitudinal production levels of grasslands is strongly influenced by rainfall that grow from the base to the top and the air temperature drops from the base to the top. Duration of grazing season of these pastures currently decreases with 7.5 days per 100 m altitude, being equal to the length of the average air temperatures greater than or equal to 10 ^{0}C. After the rising of the average annual temperature with 3 ^{0}C in 2070, the length of grazing season at 600-800 m altitude decreases by 60 days compared with present, then increasing with 15 days for each of 100 m altitude to 1200-1400 m and decreasing again with 7.5 days per 100 m altitude. Future management of pastures will have to take account of these radical changes through the improvement of infrastructure (roads, water supply, shelters *etc*.) to exploit better the potential of grasslands.
At the base of the mountain area between 600 - 1000 m altitude, where it will be a climate of steppe and forest steppe, it will be an urgent need to install an agro - forestry pastoral system for diminishing the aridity effects. Planting 20-100 trees per hectare, native *Querqus* and *Fagus* or *Robinia* or *Pinus* and other species resistant to drought for several years is one of the main ways in the management of grasslands from the base of the Carpathians.

Conclusions

Soil and climatic conditions in mountainous areas and unfavourable altitude for traditional crops, requires the development of ruminant livestock on natural grassland and best practice more widely to rural tourism, like the Alpine countries.
With global warming projected by climatologists, the highest mountains can be considered as a refuge and salvation for human existence in condition of arid periods and desertification of plains and hills from the lower altitude.

To prevent the negative effects of future climate in our country it is necessary to decide the proper practice regarding the current system of agriculture as it is in the countries already affected by arid periods and desertification. Besides irrigation, the introduction and expansion of the Mediterranean agro - forestry pastoral system and better management of the Carpathian mountain region are preventive and curative measures to protect us against global warming in the future.

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Virtual water: the case study of Lucerne cultivation in Greece

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Abstract

The scarcity of available water, at global and at national level as well, in relation to the expected climate change, forces scientists and policymakers to re-examine and probably to exclude the cultivation of water demanding crops from areas with water deficits. The revision of CAP urges the farmers to produce crops taking into account the protection of environment and the water resources. In this study paper the concepts of virtual, green, blue and grey water, as well as the ones of ecological and water footprint is discussed. Regarding the lucerne cultivation in Greece the water requirements range between 12,000-24,000 m^3/year/ha. Due to the big amounts of needed water this cultivation should be reconsidered especially in locations with water shortages.

Key words: virtual-green-blue-grey water, ecological-water footprint, lucerne meadows, decision making, Greece.

Introduction

The world population is expected to be doubled between 2000 and 2050 reaching about 12 billion inhabitants. Therefore, the need for protein consumption by humans as well as for feeding the domestic animals will be dramatically increased. As the production of plant origin proteins has a worldwide interest, the solution to this problem is expected to be given mainly by the cultivation of legumes (Papakosta-Tasopoulou, 2005). Plants such as vetch, pea, lucerne and trefoil are considered to be highly protein important. These legumes, apart from their nutritional value, have also the ability to fix the atmospheric nitrogen. They contribute to the economy of nitrogenous fertilizers by protecting the underground water from nitrate leaching. However, legumes need water for their growth coming either from precipitation or from irrigation. In semi-arid areas such as Greece, the amount of precipitation is not enough and irrigation is necessary to increase crop yields (Papakosta-Tasopoulou, 2005). On the other hand, it is very important to know that "managing water is highly capital-intensive, and capital is also scarce" while "there are environmental consequences to almost any intervention in the water cycle whilst the economy depends upon the environment"(Green, 2003).

The aim of this study paper is to present a concise introduction to the concepts of virtual, green, blue and grey water as well as the concepts of ecological and water footprint. Moreover, the water needs for irrigation of lucerne cultivation in Greece have been estimated.

Discussion

Theory of games and asymmetric information

In our everyday life, the benefit and the cost of any choice are not fixed. Also, they are not random since in most cases they depend on at least two directly or indirectly interested parties. This is the subject of the theory of games which examines all these cases where various parties interact and behave strategically (Kakridis, 2005). One party may compete with the other; such is the case of farmers and governmental authorities, farmers and environmentalists etc. However, the cost of a probable conflict between each other should not be ignored (Schelling, 1960).

On the other side, the so-called "asymmetries of information" may create many problems or as characteristically mentioned "the unequal allocation of information may affect the market". Examples of such information can occur between employees and employer, creditor and debtor, farmers and the Ministry in-charge (Stiglitz, 2003). These problems are mainly related to the adverse effects on the under-utilisation of the natural resources. They are connected with the reactions of farmers in the case that the agencies in-charge decide to enforce changes on their cultivation habits.

The virtual water

Virtual water is the water which is consumed but also embedded in a product during its production process (Allan, 1998). Virtual water is considered as a term that links water, food, and trade. Regarding the latter, there is a virtual flow of water from the exporting towards the importing countries. Countries which possess big supplies of water are able to produce water-intensive goods. On the contrary, countries with water deficits should import the above products and dispose their water to other uses. Therefore, the trading of the virtual water among regions of a country, among countries or continents may lead to a more effective use of water and restrict the problems in the water scarce areas.

For the production of various goods it is significant not only the amount of water that is consumed but also the specific source which the water is coming from. This knowledge is important for efficient and sustainable water management (Seyam and Hoekstra, 2000). The virtual water consists of three components: green, blue and grey water (Zoumides et al., 2009). Green water comes from precipitation or it is contained in the soil as moisture. Both categories (precipitation and moisture) may be used directly by the growing plants and do not have alternative uses. Blue water is collected by man through costly constructions (dams, desalinated water, transportation networks, etc.) as well as in the form of groundwater. Apart from the agricultural use, blue water has several alternative usages and probably a higher socio-economic and environmental efficiency. Grey water is the volume of water required to dilute the loads of pollutants accrued during the production process based on the existing standards for the water quality. Apart from the big amounts of water required to produce goods, an amount of grey water is also needed for the restoration of the environment. Obviously, products coming from systems that do not overcharge the environment, such as the ones of organic farming, have a small percentage use of grey water due to the exclusion of pesticides.

Ecological and water footprint

From 1980 it seems that the human demand for goods and services has over passed the regenerative capacity of biosphere (Wackernagel et al., 2002). The ecological footprint counts the human demand for goods originating from the nature. It also compares the consumption of natural resources with the ecological capacity or bio-capacity of the land to reproduce these resources (WWF International, 2006; Kitzes et al., 2007). The ecological footprint and the bio-capacity are measured in global hectares (gh). The gh is a common unit that encompasses the average productivity of all the biologically productive land and sea area in the world in a given year. Biologically productive areas include cropland, grazing land, forest, fishing grounds, built up area and land for carbon absorption; deserts, glaciers and the open ocean are not included. In year 2003 the world ecological footprint has estimated at 11.2 billion gh while in that same year the humanity needs in products and services were 14.1 billion gh. Apparently, if this overpass continues, the various ecosystems will constantly deteriorate and probably collapse. This ecological overshoot refers to the level of demanded products and services from an ecosystem that exceeds its ecological carrying capacity (Wackernagel et al., 2004). By definition, the ecological overshoot leads to an eventual exhaustion of resources and to an accumulation of wastes. The process of measuring the ecological footprint besides specific products (meat, milk, tea, potato, cotton, wheat, etc.) may also concern a business, a city, a state (Gerbens-Leenes and Hoekstra, 2008).

The above mentioned concept of virtual water is also related to the concept of the water footprint. The latter is defined as the total volume of fresh water that is used to produce the product. It is an index which provides information about the water that is consumed within a country and originated not only from local sources but also from abroad (Hoekstra and Hung, 2002; Chapagain and Hoekstra, 2004).

The revised CAP

Based on the international trends, the new CAP (2004) suggested that lands cultivated with cotton are released and could be used for the establishment of meadows and livestock farms; moreover, for the establishment of manufacturing units in the sector of livestock husbandry or different combinations between them. The subsidies will not depend on the volume of the production while the producers should take care of the environment and the public health as well (Race and Curtis, 1997; Christodoulou et al., 1998; Christodoulou, 2003).

Lucerne cultivation in Greece

Meadows in Greece are established in public or private lands and they are distinguished into rainfed and irrigated ones. These areas amount about to 150,000 ha, from which 111,000 ha are lucerne meadows with an annual hay production of 1.2 million tons (N.S.S.G., 1999).

In the case of lucerne meadows in arable lands, irrigation is the indisputable factor of annual yield. The amount of used water depends on soil type, climate conditions, age of cultivation and season of growth (Kontsiotou, 2005). Depending on the soil texture, the required amount of water per irrigation is 1,000, 1,200 and 1,800 m^3/ha for the sandy, sandyloam and loamy soils, respectively. The cultivation of lucerne requires at least 5 irrigations per year, namely 1-2 irrigations in the spring and 2-3 irrigations in the summer for meadows cut 5-7 times between May and September (Papakosta-Tasopoulou, 2005). Usually, for 6 cuttings/year the requirements of lucerne meadows for water range between 12,000-24,000 m^3 /year/ha.

Although big amounts of water are needed for the cultivation of lucerne, the origin of this water -green or blue- as well as their proportion have not been investigated yet. The proportion of green and blue water depends on the specific area, the altitude and the seasonal distribution of precipitation during the year.

Based on this proportion the following basic questions should be asked: is irrigated water offered to farmers at a low price due to governmental subsidies? If so, these low prices do not reflect the scarcity cost of the source or the respective externalities from a possible over-pumping of water. Moreover, has the opportunity cost of this water been determined and, consequently, is it the best alternative solution? These three economic factors (scarcity cost, externalities and opportunity cost) constitute important tools for the decision makers and policy agencies. Such decisions should be related to the reorganization of feed crops, saving of water resources and protection of the environment.

Conclusions

The virtual, green and blue water concepts should be used as important tools for the efficient use of water resources by decision makers. This could be done by considering two points of view:

If blue water (irrigation water) constitutes an important fraction in lucerne production, especially in areas with water deficits, such cultivation should be reconsidered.

If changes in lucerne cultivation are necessary, then farmers should be encouraged and supported by authorities' in-charge to adopt the innovation.

Further research is needed for the assessment of virtual water content in lucerne production in different locations of Greece.

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Relationships between grassland management, soil and pasture characteristics in piedmont Mediterranean grazing systems

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Abstract

Fourteen pastures of six livestock farms of the piedmont landscape of NE Sardinia were surveyed in 2009-10 from agronomy and pedology perspectives. All sampling sites were located in an area characterised by the same Potential Natural Vegetation (*Violo denhardtii-Quercetum suberis* association) under a Mediterranean climate and acid soils. The pastures, mainly composed by annual species, were grazed by dairy sheep, dairy cattle and beef cattle. They were characterized by three different types of leys establishment, in relation to the time elapsed since the land had last been tilled and sowed (>20 years; 5-10; 2).

The three types of leys establishment didn't affect herbage mass production and the main soil fertility indicators. On the other hand, the seasonal herbage production was influenced by the livestock category, where dairy cattle farm pastures showed in spring higher production than those grazed by dairy sheep and beef cattle. The latter had the lowest forage production in autumn, winter and late spring. The soils of dairy cattle farm showed the highest pH, organic matter, total nitrogen, assimilable phosphorus and calcium content. This result was interpreted as the consequence of the long term effects of the extensive use of organic fertilisation (manure) in the dairy cattle farm.

Key words: cattle, herbage mass, sheep, soil fertility

Introduction

Oak tree sylvoarable systems represent a dominant landscape of the Mediterranean region. These systems consist of widely spaced trees inter-cropped with annual or perennial crops (Eichorn et al. 2006). Sylvopastoral are considered as extensive form of sylvoarable systems where the widespread vegetation is mainly represented by scattered oak trees, shrubs and annuals herbaceous species. Fodder (forage or winter cereal) are the only grown crops (Eichorn et al. 2006) and the land use corresponds to an extensive agro-pastoral activity. Nevertheless, the variety of land tenure and land management has led to a diversity of agro-sylvopastoral systems (Joffre et al. 1991). In Sardinia, large scale grazing systems represent the dominant land use and sheep and cattle are the most frequent livestock (Caballero et al., 2009). Rainfed dairy sheep farming is the most common in the island and pastures represent the main feed source. Low temperature and radiation constraint pasture production in winter, when energy requirements of the dairy sheep are highest, while in late spring and summer drought limit grass yield potential. Farmers adapt to these conditions growing cereals and annual forage crops in the arable land and using mineral nitrogen and phosphorus fertilisation to increase pasture productivity and quality (Caredda et al., 1993). Agro-pastoral activity can influence the availability of pasture herbage depending on stocking and agronomic techniques (Osman et. al., 1991; Salis et.al, 2010). Fertilisation may substantially increase forage production and change pasture floristic composition and soil mineral fertility (Salis and Vargiu, 2008). Different animal categories show specific grazing and feeding behaviours. They exploit a given habitat depending on the rearing system that can result in changes of pasture characteristics (Jouven et al. 2010).
The aim of this study was to analyse the influence of grazing system and grassland management on vegetation and soil characteristics in a sylvopastoral system of NE Sardinia.

Material and methods

The study was carried out in autumn, winter and spring 2009-10, in the rural area of Berchidda and Monti municipalities, in NE Sardinia. The area belongs to the Meso-Mediterranean phytoclimatic belt. The Potential Natural Vegetation was represented by *Violo dehnhardtii-Quercetum suberis* association (Bacchetta et al. 2004) on granitic substrate with low to moderate slope in piedmont pastures. Six livestock farms belonging to three Mediterranean extensive grazing systems were selected: dairy sheep (DS), organic dairy cattle (DC) and beef cattle farms (BC). All farms relied on grazing pastures all year round. For each farm, we focused on three different types of leys establishment, in relation to the time elapsed since the land had last been tilled for the forage crop establishment (tillage, fertilisation, seeding): long rotation, more than 20 years (A); medium rotation, 5 to 10 years (B); short rotation, 2 years (C). The experiment was conducted according to a completely randomized unbalanced design. Overall fourteen pastures, on fields ranging from 2 to 20 hectares in size, were studied at the six farms. In each pasture, a 1 m deep soil profile was carried out, and each diagnostic horizon sampled for chemical and physical analyses that were performed following Pagliai (2001). In the autumn–winter 2009-10, the herbage cover was sampled on 0.5 m^2 randomized area inside three 5x5m^2 fences of each field, located out of the trees crown area, to measure the herbage mass in ungrazed conditions (H_m). At the end of winter the whole of herbage mass was cut and removed from the fences to stimulate the following spring forage production. In May 2010 the specific contribution was assessed for each plant species within each fence (Daget & Poissonet, 1971). Forage DM production and soil fertility parameters were performed with one-way analysis of variance (ANOVA). The means separation was performed with a Fisher's protected LSD test (Steel and Torrie, 1980).

Results and discussion

During the surveyed period (from September 2009 to May 2010), rainfall was 846 mm, about 60% higher than long term means, and temperatures were slightly lower than average seasonal values, in a range of monthly means between 20°C in September to 7°C in January (data ARPA, Dipartimento Specialistico Regionale Idroclimatico). All farmers adopted similar agro-techniques to establish forage crops, i.e. shallow ploughing (20-30 cm in depth), harrowing and low level of mineral fertilisation (roughly 40 kg ha^{-1} of N and P). The DC farm applied systematically some 50 t $ha^{-1}y^{-1}$ of manure. Herbicides were occasionally applied in DS farms to control tall weeds in the pasture through rope wick applicators.

The soil analyses did not reveal any significant difference between the three types of leys establishment (table 1) both in terms of chemical and physical fertility parameters. These results were interpreted as the consequence of the adoption of shallow tillage and relatively low fertilisers rate for the forage crop establishment.

The different grazing systems had a significant impact on soil fertility, the DC farm soils showing the highest pH, soil organic matter, nitrogen, phosphorus and calcium content, which was interpreted as the consequence of the supply of animal manure and litter.

The pastures were dominated (67%) by annual species among which the most abundant were: Trifolium subterraneum, Anthemis arvensis, Avena barbata, Vulpia ligustica, Hordeum leporinum and Lolium rigidum.

The highest grass H_m production of the pastures was roughly 2.3 t ha^{-1} measured in May, (figure 1) whereas H_m total production was roughly 3.5 t ha^{-1}. The different leys establishment didn't affect herbage mass production, while significant differences were observed between grazing systems. The BC pastures showed a significant lower forage production in autumn, winter and late spring when compared to dairy cattle or sheep systems. Pastures of the dairy cattle system showed the highest forage production in early spring, when the relatively high soil fertility allowed an earlier re-growth (figure 2).

Table 1: Soil characteristics of the A horizon for the three types of grassland management and grazing systems

	pH	Organic matter	Total N	Assim. P	Exchan. K	Ca	Mg	Bulk density	Structural stability
Leys establishment		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	g cm^{-3}	%
>20 years	5.4	29.5	1.8	15.4	268.8	594	185	1.50	62.2
5-10 years	5.3	24.1	1.3	9.6	116.8	481	96	1.58	46.8
2 years	5.5	28.1	1.8	25.9	106.5	775	142	1.43	68.8
P	ns	ns	ns	ns	ns	ns	ns	ns	ns
Grazing systems									
Beef Cattle	5.3b	18.3b	1.1b	7.8b	107.3	466b	143	1.57	58.6
Dairy Cattle	5.9a	44.2a	2.6a	43.7a	313.7	1086a	296	1.47	68.0
Dairy Sheep	5.3b	25.0b	1.5b	9.5b	146.2	480b	74	1.48	52.2
P	0.02	0.03	0.03	0.04	ns	0.05	ns	ns	ns

Means followed by the same letter in the same column are not different (LSD test); ns= not significant

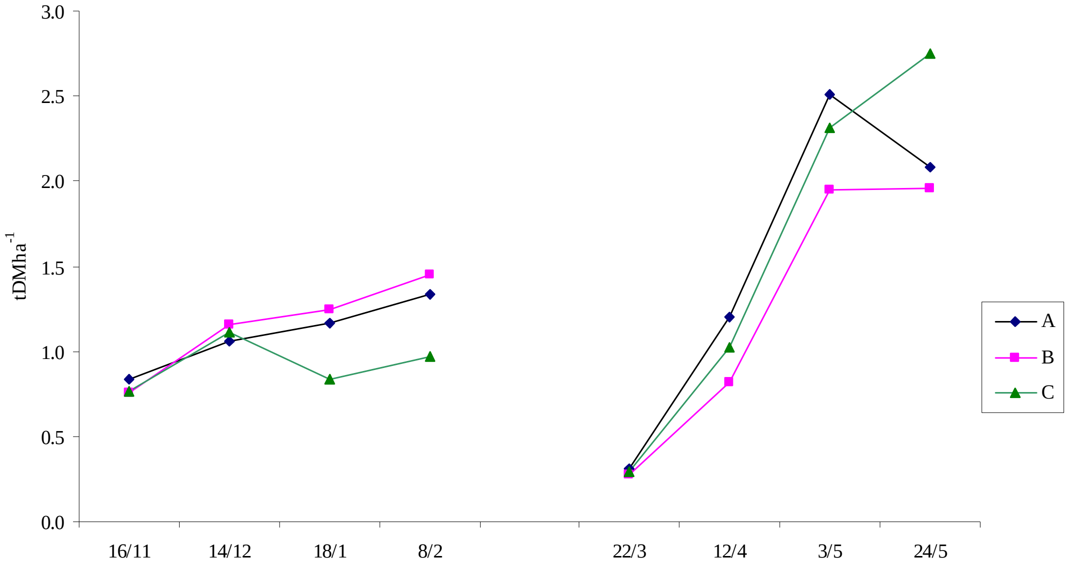

Figure 1: Herbage mass production (H_m) in relation to the three types of leys establishment. 22/03/2010: Clearing cut at the end of the winter

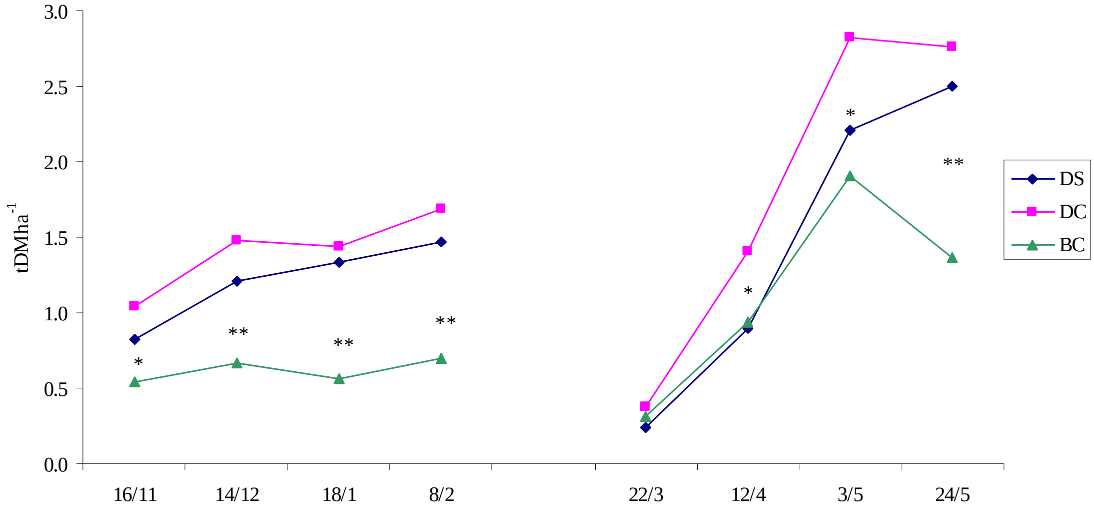

Figure 2: Herbage mass production (H_m) in the three types of grazing systems in autumn 2009, winter and spring 2010. DS=dairy sheep; DC=Dairy cattle; BC=Beef cattle. ** and *= means differ significantly respectively at $p<0.01$ and $p<0.05$. 22/03/2010: Clearing cut at the end of the winter

Conclusions

The results clearly show that the time elapsed since the land had last been tilled for the forage crop establishment did not influence soil and pasture characteristics of the open grasslands of the piedmont sylvopastoral systems considered in this study. The dominance of annual plant species and the rich seed bank that characterize these Mediterranean pastures (Franca et al., 2008) make them resilient to agronomic extensive practices, allowing a rapid recover of spontaneous species the year after crops cultivation. Grazing systems associated to the different livestock species showed a significant impact on soil fertility and pasture production, which were associated to the farm intensification level. The complex relationships between grassland management, soil characteristics, pasture production and natural biodiversity are worth to be further studied to support the identification of environmental friendly Mediterranean grazing systems.

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Coefficient of selectivity of young bulls grazing a Mediterranean natural pasture.

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Abstract

The aim of the study was the definition of selectivity coefficient of Sarda young bulls grazing a Mediterranean mountain natural pasture (850 m. a.s.l.). Three sub-plots were identified after topographical investigation: Low Hill (LH), Upper Hill (UH) and Brushwood (BW). For each subplot the botanical composition, dry matter herbage on offer (HO) were determined. Hand plucked samples of herbage, mimicking animal behavior, were also collected to estimate the herbage selected by the animals (HS). The chemical composition of HO and HS was determined (CP, EE, NDF, ADF, ADL). Coefficients of selectivity based on the most representative chemical parameters were then calculated as ratio between their proportion in HS and HO. Animal body weight was recorded. The foraging selective behaviour of cattle grazing in a Mediterranean natural pasture confirms to be in agreement with a quality level. The coefficient of selectivity for crude protein was 1.34 and for NDF and ADF resulted 0.91. The obtained results suggest that a diet based on pasture would be a valid chance for Sardinian cattle livestock system.

Key words: mountain pasture, botanical composition, herbage quality, Sarda breed cattle.

Introduction

The sustainable development of rural areas and the increasing demand for environmental services are strongly linked with agricultural production methods compatible with the environment protection and, at the same time, with a less dependence on external resources. In this context, beef fed at pasture represents a low-cost and renewable production system (Scotti et al., 2005). Unfortunately, pasture-based systems are usually limited in herbage availability and accessibility which has been considered as a major factor impacting animal productivity (Soder et al., 2009). In addition, few studies have been done on selective foraging behaviour of cattle grazing natural pastures. Much of the experiments have been based on a choice between few herbage species and show that beef cattle preference is related to the crude protein level (Hirata et al., 2008). Moreover the evaluation of spatial and selective feeding behavior of different ruminant species is important to develop strategies for either conservation or goal-oriented development of the ecosystem (Leiber et al., 2009). A trail was carried out to better understand the role and the potentiality of natural pasture for meat farming in a mountain area of Sardinia. It aimed at comparing the performances and the meat quality of Sarda young bulls grazing a natural pasture with those stall-fed. This paper focuses on selectivity coefficients of Sarda young bulls grazing a Mediterranean mountain natural pasture.

Materials and methods

The study, was carried out during spring 2010 (19/4 – 16/6) at the experimental farm of the Department of Animal Production (AGRIS Sardegna) (40°25'N, 8°55'E, 850 m a.s.l.). The Mediterranean climate of the area averages 905 mm annual precipitation , and temperature between 1.7 °C (January) and 28.0 °C (July).

The pasture (8 ha) is a wavy top of a low hill with large *Quercus pubescens* and several *Pyrus spp*, especially in more steep areas. Three subplots were identified after topographical investigation: Low Hill (LH), Upper Hill (UH) and Underwood (UW). All the experimental area was continuously grazed by 9 Sarda young bulls (11.6±0.3 months old and 289±9 kg live weight, means±s.e.) that had a free access to the different subplots. The animals continuously stayed at pasture and did not receive any supplementation.

For each subplot the botanical composition, a census of all plant species, dry matter herbage biomass offered (HO) and fodder quality were determined. HO was determined at the beginning and at the end of the experimental period by clipping at ground level 6 samples (1m × 0.5m) in each subplot. The HO biomass was manually divided into plant species. Each plant family was weighted and dried at 60 °C till constant weight and analyzed for chemical composition (CP, ether extract (EE), NDF, ADF, ADL). To estimate the animal herbage selection (HS) hand plucked samples of pasture, mimicking animal behavior, (Estermann *et al*. 2001) were also collected in three occasions during last week of the experimental period. The HS floristic composition was performed in this occasion by listing all plant species present. Coefficients of selectivity of the most representative chemical parameters were then calculated as ratio between their proportion in HS and HO (Estermann *et al*. 2001). Data of botanical and chemical composition of herbage on offer were analyzed with GLM procedure of SAS using subplot, period and their interaction as fixed effect.

Results and discussion

During the trial, the air temperature ranged between 6,6°C and 18,3°C and the total rainfall was 203 mm. A total of 143 plant species belonging to 35 families were recorded inside the experimental pasture. The most represented families were *Fabaceae* (19.6%), *Asteraceae* (16%) and *Poaceae* (12.6%).
Annual plants were more abundant (53%) than perennials, which were mainly represented by Hemicryptophytes (31%). The three subplots were characterized by different species composition (Tab.1). In particular *Liliaceae* and *Fagaceae* were detected only in UW, *Asteraceae* in UW and UH, *Caryophyllaceae* only in UH. *Fabaceae* and *Poaceae* represented more than 90% of HO in LH. The HO and its quality at the beginning and at the end of the experimental period are reported in table 2. Overall the pasture was characterized by high HO biomass and medium quality. During the experimental period, the average daily gains of Sarda young bulls were comparable to those of stall-fed ones (Acciaro *et al*., 2011).
At the beginning of the grazing period, HO was not different between the three subplots. The quality was higher in UW (higher CP and EE) than in LH and UH. At the end of experimental period the HO resulted higher in LH and UH whereas decreased in UW. A sharp decline of the quality on offer was observed in UH. Both LH and UW still offered a medium quality pasture with about 10% of CP .

Table 1: Botanical composition (% of HO biomass) of the three subplots (LH = lower hill; UW= underwood; UH = upper hill)

	Fabaceae	*Poaceae*	*Asteraceae*	*Liliaceae*	*Caryophyllaceae*	*Plantaginaceae*	*Fagaceae*	Other species
LH (%)	49.5	45.1	0.8 b	0.0 b	0.0 b	1.1 ab	0.0 b	3.5
UW (%)	23.8	47.8	7.3 ab	9.6 a	0.3 b	0.0 b	4.0 a	7.2
UH (%)	25.9	34.0	21.3 a	0.0 b	4.8 a	4.1 a	0.0 b	9.9
P<0.05	ns	ns	*	0.07	*	*	*	ns

Different letters following numbers in the same column indicate significant differences between means

Table 2: Herbage on offer (HO, t DM ha^{-1}) and its nutrient content (g per kg DM) at the beginning (April) and at the end (June) of the grazing period. (means ± standard error)

	LH		UW		UH				
	April	June	April	June	April	June	Subplot	Time	SxT
HO (t DM ha^{-1})	4.37±0.34b	7.60±0.63a	4.87±0.40b	3.64±0.63b	5.09±0.40b	7.03±0.63a	**	**	***
DM, (g.kg^{-1} wet weight)	215.7±8 ab	241.8±15 a	202.6±9 b	227.6±15ab	199.2±9 b	244.2±15 a	ns	**	ns
E.E. (g)	22.7±0.5 a	18.2±0.9 bc	20.5±0.6b	23.2±0.9a	23.7±0.6a	16.1± 0.9c	ns	***	***
CP (g)	101.0±4.9b	112.8±9.0ab	117.5±5.9a	93.5±9.0 bc	108.1±5.5ab	69.8± 9.0c	*	**	**
NDF (g)	543.2±8 c	605.6±15 b	540.8±10 c	564.1±15bc	541.1±9 c	659.5±15 a	*	***	**
ADF (g)	331.2±3.6c	384.0±6.6b	322.0±4.4c	366.1±6.6b	333.5±4.1c	428.2±6.6a	***	***	***
ADL (g)	43.2±3.0b	70.5±5.5a	44.9±3.6b	61.1±5.5a	48.3±3.4b	59.8±5.5a	ns	***	ns

Different letters following numbers in the same row indicate significant differences between means (P<0.05)

The comparison between chemical composition of HS and HO shows that animals choose a higher quality diet than that offered. This is further highlighted by the coefficient of selectivity which shows that animals selected a diet with higher dry matter, CP and EE and less fiber component, except for ADL (Tab. 3).

Table 3: Nutrient content (g per kg DM) of herbage on offer (HO) and of herbage selected by the animals (HS) and calculated coefficient of selectivity of principal chemical parameters (means ± standard error)

	HO	HS	Coefficient of selectivity
Dry matter (DM, g. kg^{-1} wet weight)	238±13	272±13	1.14
Crude protein (CP, g)	$92±6_b$	$126±7_a$	1.36
E.E. (g)	$19±1_b$	$36±1_a$	1.89
NDF (g)	$609±13_a$	$554±15_b$	0.91
ADF (g)	$393±8_a$	$361±9_b$	0.91
ADL (g)	64±3	72±3	1.12

Different letters following numbers in the same row indicate significant differences between means (P<0.05)

Animals selected in their diet 34 different species (24% of the total census species) of 14 families, among which *Fabaceae* (35.3%), *Asteraceae* (11.8%), *Poaceae, Umbelliferae* and *Rosaceae* (8.8% each) were the most represented. Although the main contribution to the total biomass is offered by *Poaceae*, animal selected legumes, probably because of their higher quality (10.6 vs 8.2 CP; 60.3 vs 67.8 NDF, for legumes and grasses respectively), and, as a consequence of the higher ADL content of legumes respect to grasses (7.8 vs 5.2 %), the coefficient of selectivity for ADL resulted higher than 1.
The HO reduction observed in UW together with the decrease in CP content and the moderate increase in NDF and ADF during the grazing period suggest that the animal spent more time grazing under the tree than in other subplots, demonstrating their ability to select between different portions of pasture. (Ganskopp and Bohnert, 2006).

Conclusions

The foraging selective behaviour of cattle grazing species diversified Mediterranean natural pasture confirmed to be in agreement with a quality level. This resulted in coefficient of selectivity higher than 1 for CP and lower than 1 for NDF and ADF. However, feeding preferences couldn't be established only on the basis of plant protein contents. Topographic and botanical features of different areas of the pasture were also playing an important role. In spring, the young bull spent most of their time grazing under the trees, showing a preference for the underwood area. These results suggest that a diet based on pasture would be a valid chance for Sardinian cattle livestock system, also from an economic point of view, matching the needs of environmental protection.

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Effects of sheep and cattle grazing on the habitats of ungulate game (*Artiodactyla*) and black grouse (*Tetrao tetrix*)

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Abstract

The populations of ungulate game (*Artiodactyla*) and black grouse (*Tetrao tetrix*) show different development trends in Slovakia. While the numbers of ungulates are rising, the black grouse population is decreasing. In the 1970s, the red deer (*Cervus elaphus*) population was about 25’500 head, but it increased to 46’000 head in 2009. The roe deer (*Capreolus capreolus*) numbers increased from 72’000 to 96’600 head. The population of black grouse has decreased from 2’200 – 2’300 to the current 1’000 – 1’300 head, respectively. The identical population trends are found within the area of mount Krížna (altitude 1574m; the Veľká Fatra mountain range) with the current approximate numbers of 200 heads red dear, 100 heads roe deer and 50 heads black grouse.

Cattle and sheep grazing showed positive effects on botanical composition of grassland and, as a result, on the quality of herbage available to ungulate game and black grouse. The sward was dominated by low-value *Deschampsia caespitosa* (L.) P. Beauv., but comprised also valuable forage grasses (*Agrostis capillaris* L., *Briza media* L. and *Dactylis glomerata* L.). There were also other forbs with low or high forage value (*Alchemilla vulgaris* L., *Carum carvi* L. and *Galium cruciata* L.). Chemical analyses of dry matter (DM) in herbage were carried out to determine the following parameters of nutritive and energy value in forage: net energy for fattening (NEV), digestible organic matter (DOM) and protein digested in the intestine (PDI).

Keywords: grassland, nutritive value, black grouse (*Tetrao tetrix*), grassland quality, ungulate game (*Artiodactyla*), red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*)

Introduction

The transformation of Fatra forests began with the migration of population to mountain areas. In the 17th century, it was brought about by the Wallachian colonisation which refers to the spread of shepherds from Romania across the Carpathian arc to Slovakia. Monarchs later granted the right to the shepherds to deforest summit areas in the Veľká Fatra mountain range. By cutting down the trees and burning up the land, shepherds created new summit pastures for their flocks of sheep and goats. Shepherding in the Veľká Fatra mountain range culminated about 75 years ago when several shepherd farms were to be found in this area. Typical for the area of Ploská and Minčola, heifers and horses grazed on barren pastures, in addition to sheep. Meadow management blossomed as well. During the first years since the collectivisation, the importance of sheep was underestimated and shepherding (on the basis of cooperatives) has been on rise again over the past few years. For instance, as late as in 1972, following the socialisation of agriculture, a modern sheep farm – one of the largest in Slovakia – was established in Liptovské Revúce. Nowadays, 2,500 ha of mountain meadows in summit areas are not mowed at all. Farmers choose to use grazing only minimally. Heifer grazing is concentrated in two locations – below Borišov and near Kráľova studňa. Grazing of small flocks of sheep is concentrated in the areas at lower altitudes.

Material and methods

The monitoring of the impact of grassland management practices on utilisation of restored permanent grassland by ungulate game and black grouse and on their population is conducted throughout the years by direct observation as well as by detection and recording signs of animal resting places such as tracks, bedding areas, diggings or excrements. When applying direct observation, observers occupy survey positions with perfect view and record the distance and azimuth of an observed animal or a herd of

ungulate game or a flock of black grouse. Measurements of the geographical position of each sign of animal resting places are made by GPS equipment at transects going across selected locations.
Botanical composition of the monitored grassland was evaluated by the method of projective dominance by Maloch (1953). Agri-botanical groups of grasses, legumes, forbs and bare ground were determined. Out of each agri-botanical group, all species present in swards were determined.

Results and discussion

During the growing season, the cover of grass species did not differ considerably. Grass species present in the sward had the highest percentage occurrence out of all observed agri-botanical groups. Predominant species were *Agrostis capillaris* L. (6 – 22 %), *Dactylis glomerata* L. (9 – 16 %) and *Briza media* L. (3 – 16 %). Dominant species was *Deschampsia caespitosa* (L.) P. Beauv. Its cover ranged between 26 and 46 % during the growing season. As for the botanical group of meadow forbs, *Alchemilla vulgaris* L., *Carum carvi* L., *Galium cruciata* L. *Carlina acaulis* L., *Cirsium eriophorum* (L.) Scop. and *Hypericum vulgaris* Lam. were dominant. The presence of legumes was the lowest during the observation period (0 – 2 %).
In 2010, during the black grouse spring and autumn lekking activity which under the conditions of the area of Mount Krížna occurs in the second half of April and during May, the occurrence and population of a black grouse were monitored in selected locations intended for the restoration of alpine meadows. Within the area of Kráľova skala (48°53´01,36´´, 19°02´53,43´´) 4 black grouse males were counted, and 3 within the area of Malá Krížna – Úplaz (48°51´58,87´´, 19°03´15,61´´). There was no evidence of black grouse in the area of Kráľova Studňa Hotel (48°52´47,82´´, 19°02´20,62´´). In all cases, however, there was no record of black grouse females, although this does not necessarily indicate that they do not occur in monitored locations. It is highly probable that they may have escaped our attention thanks to their protective colouring of the feather.

Conclusions

The monitoring of the occurrence of black grouse and the impact of grassland management practices on their population in the model area will also be performed in spring this year. A series of monitoring conducted so far have shown that the highest numbers of black grouse males were found in locations with utilised grasslands. In this case, they were used for livestock – heifers – grazing. Grassland utilisation has a positive impact on the quality of herbage available to black grouse and ungulate game at their habitats.

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The role of grasslands in the formation of structural and spatial order of rural areas

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Abstract

This paper presents structural changes in Poland resulting from recent social and economic transformation. In relation to 1970’ and 1980’, agricultural lands significantly decreased (to 16.15 million ha in 2008). Arable lands were reduced in favour of grasslands and other lands including barren lands which are markedly noticed in Carpathian areas. Actual use of grasslands exceeds 40 % of the whole area, especially above 700 m a.s.l. with more than 65%. However, grassland yields also decreased.

Keywords: Carpathian areas, grasslands, non-productive function, spatial transformation, structural transformation

Introduction

Polish land use structure didn’t changed much in the last years. Till the end of the 1980’, agricultural lands were treated almost exclusively as productive grounds, particularly by an increasing mineral fertilisation. Mineral fertilisers were relatively cheap and strongly promoted by the state authorities. The main aim was to achieve as much plant and animal production as possible regardless of circumstances and consequences. On the other hand, organic fertilisers, mainly those from animal production, were considered as useless and troublesome by-products. Such an approach, often worsened by organizational errors and enforced collectivization, resulted in gradual impoverishment and degradation of rural areas. Any agricultural productive activity, regardless of its costs, was overestimated in those days compared with other aspects, particularly with hardly parameterized environmental values. This in turn brought about specific disturbance of the desired equilibrium between natural environment and human needs (Guzik 1995; Twardy 1993).

Today, many of such areas undergo a characteristic structural and spatial reform aiming at restoring basic functions implemented by the principles of sustainable development. This evolution is accompanied by the combination of moderately intensive economic activity with environmental protection, mainly pertaining to water and soil habitats. In general, this process occurs differently in lowland areas and in the south country uplands.

Independently from the physico-geographic regions, grasslands played an important role in the formation of new structural, spatial and productive conditions. Their importance was recognized, regardless of the way and intensity of their management, and positive properties were observed even if the sward was not used at all. Under conditions of sustainable development and implementation of environmental friendly economy, the same attention is paid to biomass production and to stabilisation and protection of soil profile.

Spatial transformation in Poland

Significant changes in the land use structure took place in the last decade of the 20th century due to a deep social and economic transformation. The changes largely concerned agricultural lands whose area markedly decreased. The reduction of 2.8 million ha of the total Polish agricultural lands in the study period (1974-2008) corresponds to a mean annual decrease of 82’000 ha, with a peak of 120’000 ha y^{-1} after the 1990’. At the same time the share of other land use forms (residential areas, transport areas, wasteland etc.) gradually increased. Between 1974 and 2008, the forest area increased from 27.4% to 29.6% in the country (Poland) and that of other grounds including barren lands from 11.0% to 18.7%. A large part of agricultural lands has been built and consequently moved to the category “other grounds”.

The population density of the country gradually increased, but structural changes were more responsible for the decrease of agricultural area than population growth. There was 0.92 ha of the country area and 0.58 ha of agricultural lands per 1 Polish citizen in 1974. In 2008 the respective figures were 0.82 and

0.48.In the case of agricultural lands, the so-called “per capita feeding area” is slightly smaller and equals 0.43 ha (Rolnictwo…, 2005). The recent reduction of this ratio has been moderated by zero or even negative population growth rate. Moreover, some inconsistencies in given surface areas result from migrations of Polish citizens over Europe. Therefore, one may only approximately assume that the changes have been insignificant with respect to both agricultural lands and total surface area since the 1990’.

Despite a substantial general reduction, proportions between different types of agriculture lands remained nearly the same. Since the 1970’ and even earlier, the structure of agricultural lands was static with respect to all forms of agricultural land use in the country. Arable lands dominated in this structures occupying 74.9–77.4% of lands, followed by meadows 12.7–15.2%, pastures 4.5–8.5% and orchards 1.4–2.0%. Large areas of barren lands exceeding 500’000 ha have recently been noted.

Structural transformation of the Carpathian areas

Mountain areas occupy c. 27’000 km^2 in Poland i.e. more than 8.7% of the country area. They are composed of three separate ranges: the Carpathians, the Sudetes and the Holy Cross Mountains. The Carpathians are largest and form a 300 km long and 60 – 70 km wide belt along the southern border of our country. Polish Carpathians cover a surface of 19’600 km2 (Jagła et al., 1981). Their height increases southward from the lowest Carpathian Uplands through the Beskidy and Bieszczady of medium height to alpine range of the Podhale and Tatras. A characteristic feature of these areas, particularly those at higher elevation, is a large share of permanent, both grassy and forest, plant cover. Permanent grasslands are the main food base for ruminants, mainly cattle and sheep locally bred.

The Carpathians were formed by various geological factors decisive for their structure, orography and relief and by natural, including climatic, factors. Their economic use, however, clearly depends on the altitude a.s.l. Climatic and soil characteristics change with altitude which has a direct effect on habitat conditions. Combined, these factors determine the way of land use for agricultural and forestry purposes. Other climatic factors like solar insolation, cloudiness, evaporation, wind speed, duration and thickness of snow cover change respectively. Under such conditions plant cover displays a bioclimatic zonation (Obrębska-Starklowa et al., 1995) and soil quality determines the possibility of growing crops.

Described relationships manifest themselves in quantitative changes of plant biomass produced in a given habitat conditions and in qualitative changes associated mainly with floristic diversity. Climatic conditions translate also to the length of the vegetation period which shortens by 8 to 10 days per every 100 m of the altitude a.s.l. (Kostuch, 1976).

Grasslands are less affected by the variability of habitat factors than other crop plants. Moreover, grasses form a permanent sward layer and thus provide protection and stabilisation of the soil profile even at high inclinations of mountain slopes. The use of grasslands and forest ecosystems for structural and habitat stabilisation of a given area is of primary importance for spatial management. Human activity decides upon the place, way and intensity of land use. It may protect the territory against degrading exploitation or, on the contrary, may excessively and wastefully exploit it.

System transformation combining market agricultural economy and more friendly approach to highlands was followed by immense structural changes in the Carpathian areas (Głębocki 2006; Twardy 2009). Their range in the years 1988–2004 is presented in tab. 1. Arable lands markedly decrease their share with increasing altitude a.s.l. in favour of grasslands. One should, however, keep in mind that barren mountain lands include large areas covered with sward considered as extensively used pastures. With such correction, the total share of grasslands above 700 m increases to 80–85%.

Of course, grasslands, understood here as areas permanently overgrown by grass vegetation, may also play non-productive functions. Variability of their yielding in analysed years and in relation to altitude is presented in fig. 1. Results are comparatively summarised from earlier studies carried out in the described period of time (Twardy 1993; 2006; 2008; 2009). They were recalculated for hay irrespective of the way of grassland utilisation and yield variability was related to the yield obtained at the foot of the Carpathians (altitude 250–300 m a.s.l.).

Table 1. Changes in the structure of agricultural lands of the Carpathian areas (in%)

Altitude m a.s.l.	Percentage share of area					
	Arable lands		Grasslands		Other (including barren lands)	
	1988-1991	2002-2004	1988-1991	2002-2004	1988-1991	2002-2004
300-500	68.6	47.4	18.5	30.2	12.9	22.4
500-700	52.3	30.3	30.6	50.2	17.1	19.5
700-900	48.5	16.3	38.6	65.4	12.9	18.3
900-1100	22.7	5.6	55.7	68.7	21.6	25.7
> 1100	-	-	43.0	44.6	57.0	55.4
Total	62.3	37.4	23.1	40.1	14.6	22.5

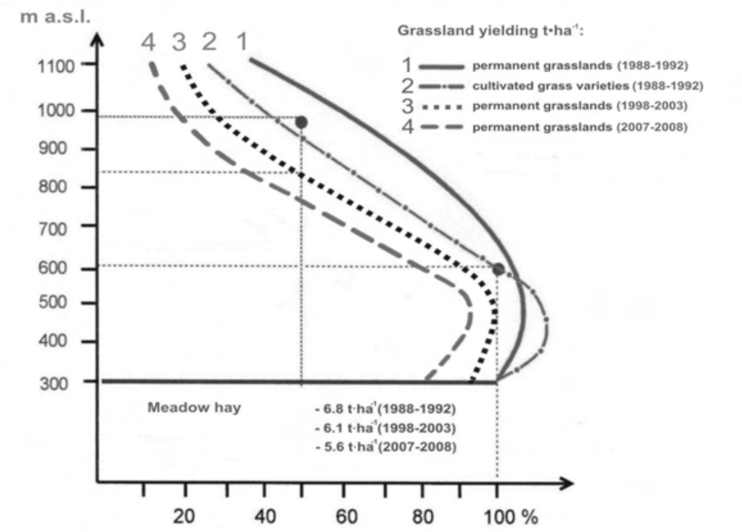

Fig. 1. Variability of grassland yielding in relation to altitude a.s.l. (percentage of the potential hay yield); 1, 3, 4 – permanent grasslands; 2 - cultivated grass varieties

Presented curves of the variability in biomass production demonstrate that the highest yields (1) were obtained in the period when the main focus was on achieving maximum productive effects (till the beginning of the 1990'). In those days mean hay yield obtained at the foot of the Carpathians was 6.9 t·ha^{-1} and that at an elevation of 400–500 m a.s.l. was even higher – 7.0 t·ha^{-1}. Similar yields were noted in leys sown with varieties (2). At higher elevations, however, these crops suffered 10–15% losses compared with the yields obtained from permanent grasslands. The losses were usually caused by neglecting agro-technical regimes and mainly by insufficient fertilisation and delayed mowing and harvesting. In subsequent years (1998-2003) the yielding of permanent grasslands in the Polish Carpathians was markedly lower (3) both at the lowest elevations (6,1 t·ha-1) and at all higher altitudes. The reason was in definitely smaller interest of farmers in fodder production due to parallel reduction of livestock, mainly ruminants (Głębocki 2006). Fodder quality also decreased. This situation persisted until now and is illustrated by curve (4) which refers to the years 2007-2008.

The reduction of yielding in the years 1988–2008 which affected all zones of Carpathian agricultural lands between 300 and 1100 m a.s.l. resulted from gradual limitation or complete abandonment of grassland management. This in turn was an effect of general economic situation with respect to plant crops and animal production which discouraged farmers-highlanders from developing agricultural production.

Trend analysis suggests that structural changes of agricultural lands and forests with respect to elevation a.s.l. can be described with mathematical formulae considering the status recorded in the first half of the first decade of the 21st centry (Twardy 2009). Observations showed that the changes of land use structure were less dynamic later on. Therefore, one may conclude of favourable spatial and structural stabilisation. In general, it consists in substantial increase of sward and forest cover with elevation a.s.l. and in marked decrease of the share of arable lands which in upper zones are usually present as small vegetable gardens.

Non-productive importance of Carpathian grasslands

Agricultural management in the Carpathian areas is difficult and unreasonable from the economic point of view. At the same time, there is a strong social demand for low-cost agricultural activity which is associated not only with the protection of soil and aquatic habitats but also with the protection of plants and animals biodiversity. There is also need for protecting soils, surface and ground waters and the whole habitats as an unique landscape.

Universal, broadly understood protective functions are attributed to grasslands which successfully protect poor mountain soils from water and wind erosion. The both processes intensify with elevation and slope inclination. They are also stimulated by exposure (mainly westward) and arable crops (crop erosion) particularly if performed improperly with respect to slope lines (Jucherski, 2008).
Plant cover, especially that forming dense sward, may largely mitigate the negative effects of natural factors like rainfall and wind power. Hence, the grasslands should dominate in addition to forests in the Carpathian areas - meadows in the lower sites and pastures at higher elevations.
Grasslands play also an aesthetic function in the mountains. They make the landscape more attractive and improve local colour, especially when grazed by large herds of farm animals. There are also various cultural aspects transferred almost unchanged – as it is the case with common pasturage of mountain sheep – from Mediaeval ages to the present days. This is undoubtedly a unique phenomenon in the European scale. The Polish Carpathians are a refuge of biodiversity for plants and animals and for non-living natural values, for spatial systems of agriculture and forestry and for cultural landscapes.
Therefore, the mountains are considered as a specific area of unique environmental properties. These natural values were highly estimated in the *Framework Convention of the protection and sustainable development of the Carpathians*.

Conclusions

Recent structural changes taking place in the Carpathian areas were deeper than in other regions of the country. Agricultural and spatial restructuring of these areas is favourable and corresponds with sustainable and multi-functional development of rural areas. The efficiency of agricultural production in the mountains is an output of many natural and economic factors. Therefore, the optimum and target solution is a low-cost way of utilisation of meadows and pastures there. Described areas are the spring grounds for many Carpathian rivers. The quality of their waters may be protected by the elimination of arable grounds in river valleys and their replacement by twice or thrice mown meadows. Now, it is indispensable to optimise the relationships between agricultural and forest areas and the grounds under rural settlements and technical infrastructure to plan further directions of their development with the consideration of their sustainable and permanent use.

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An assessment of the natural value of meadow-pasture communities in the Middle Sudetes region

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Abstract

The paper presents an assessment of the natural values of grassland communities situated in the region of the Middle Sudetes. The study was carried out in the years 2009-2010 on utilised meadows and pastures. 207 relevés were made with the Braun-Blanquet method in a way to estimate phytosociological affiliation of grassland communities, species richness and index of floristic diversity. Protected species were recorded and their risk categories were estimated.
The studies showed that grassland communities belonged to the class *Molinio-Arrenatheretea*. Five phytosociological units in the rank of association or community with the dominating species were distinguished within this class: *Arrhenatheretum elatioris*, the community *Poa pratensis-Festuca rubra*, the community with *Agrostis capillaris*, mountain hay meadows (*Trisetetum flavescentis*) from the alliance *Polygono-Trisetion* and the community with *Alopecurus pratensis*. The communities represented a broad spectrum of habitat conditions from communities characteristic for poor and acidic habitats through typical forms to communities of very rich habitats. They were characterised by relatively high species richness (from 35 in the community *Poa pratensis-Festuca rubra* to 94 plant species in the association *Trisetetum flavescentis*) and by medium values of floristic diversity index (*H'* = 2.3 in the community with *Agrostis capillaris* to *H*' = 3.6 in the association *Trisetetum flavescentis*). In part of analysed grasslands there were 10 strictly or partly protected species. Six of them belonged to the species endangered in Lower Silesia. Moreover, communities of the associations *Arrhenatheretum elatiori*s, *Poa pratensis-Festuca rubra* and *Trisetum flavescens* are identifiers of protected habitats. Obtained results indicate that the studied grassland communities are characterised by a high natural value.

Keywords: the Sudetes, grasslands communities, natural value, rare and protected plant species

Introduction

Natural values of mountain grasslands are highly estimated (Biała *et al.*, 2002). The grasslands are characterised by a high species richness and diversity and often host rare plant species. They are more diverse than lowland grasslands (Trzaskoś, 1998). Moreover, they occupy large parts of mountain landscape providing its mosaic character which is important for both aesthetic and protective reasons (Fatyga and Nadolna, 2009). Meadows and pastures play an important role in the land use structure in the Polish Sudetes. After the system transformation, due to the decline of profitability of animal production (Fatyga and Paszkiewicz-Jasińska, 2009), the region experienced unfavourable changes in the utilisation of agricultural lands. Large grassland areas were abandoned, forested or ploughed (Nadolna, 2006). The changes resulted in transformation of grass communities, which led to the decrease of their natural value or even to the disappearance of many valuable grasslands (Nadolna *et al.*, 2008; Endangered vascular plants…, 2003). Recent support in a form of direct subsidies, LFA and agro-environmental programmes has slowed down unfavourable processes, improved species composition and grassland diversity but still in insufficient extent (Fatyga *et al*., 2009). That is why recognizing natural values of grasslands and the ways of their protection is so important.
The aim of this study was to assess the natural value of selected meadow and pasture communities situated in the Middle Sudetes.

Material and methods

According to the physico-geographic division by Kondracki (2000) the study area is located in the Middle Sudetes region and encompasses three meso-regions: the Sowie, Kamienne and Wałbrzyskie Mts. Natural value was assessed based on the results from field studies carried out in 2009-2010 on utilised meadows and pastures. During this period of time 270 phytosociological relevés, 25 m^2 each were made with the

Braun-Blanquet method, in the 15 grassland complexes. Collected material served for estimating phytosociological affiliation of grassland communities based on the quantitative proportion of species. Syntaxonomic groups and their characteristic species were adopted after Matuszkiewicz (2001). Moreover, species richness and the Shannon-Wiener diversity index *H'* (Kryszak, 2001) were calculated. Strictly and partly protected species were recorded and their risk category estimated after Kącki (Endangered vascular plants…, 2003). Moreover, communities – identifiers of protected habitats and other forms of nature protection were also indicated in the study area. Names of communities were adopted after Matuszkiewicz (2001) and botanical nomenclature – after Mirek *et al.* (2002).

Results and discussion

Five phytosociological units in the rank of association or community with the dominating species were distinguished upon the analysis of grassland communities (Table 1). The association *Arrhenatheretum elatioris* was found in most (i.e. in 6 sites) and the community *Poa pratensis-Festuca rubra* in only 2 sites. Other communities were recorded in 3 sites each. Most phytosociological relevés were made on grasslands of the *Arrhenatheretum elatioris* association (78) and on the mountain hay meadow (75).In two of analysed units showed relatively strong transformation of communities manifested by a lack of species characteristic for alliances or associations.

Table 1. Five phytosociological units identified in the study area

Class Molinio-Arrenatheretea	
Order Arrhenateratalia	Order Molinietalia
1. Association Arrhenatheretum elatioris	5. Community with Alopecurus pratensis
2. Community Poa pratenis-Festuca rubra	
3. Community with Agrostis capillaris	
4. Mountain hay meadows (*Trisetetum flavescentis*)	

A great species diversity was noted within the **association *Arrhenatheretum elatioris***. Species typical for rich habitats were represented by *Arrhenaterum elatius* L. P. Beauv. ex J. Presl & C. Presl, *Dactylis glomerata* L., *Phleum pratense* L., or *Festuca pratensis* Huds. These grasses have a high economic value. Species indicating habitat acidification (*Agrostis capillaris* L., *Hypericum maculatum* Crantz.) were also represented in this community.

Low grasses *Poa pratensis* L., *Festuca rubra* L. s. str., *Agrostis capillaris* L. and *Cynosurus cristatus* L. and *Holcus mollis* L. dominated in the species composition of the **communities *Poa pratensis-Festuca rubra*** and of the **community with *Agrostis capillaris***. Apart from the mentioned species numerously represented were: *Anthoxantum odoratum* L., *Campanula patula* L. s. str., *Tragopogon pratensis* L. Both communities occupied relatively poor habitats characterised by species of the class *Nardetalia* (and for lower units): *Polygala vulgaris* L., *Hypericum maculatum* Crantz and *Luzula campestris* L. DC. Besides, there were many species preferring sunny sites (*Trifolium campestre* Schreb., *Thymus pulegioides* L., *Campanula persicifolia* L. and *Carlina acaulis* L.) in the community with *Agrostis capillaris*.

The **mountain hay meadows (*Trisetetum flavescentis*)** occupied richer habitats. Species structure was dominated by *Trisetum flavescens* L. P. Beauv. and *Alchemilla monticola* Opiz. Differentiated contribution of tall grasses showed that part of these grasslands was used as meadows and other part – as pastures. Mown communities were composed of *Dactylis glomerata* L. subsp. glomerata, *Phleum pratense* L., *Festuca pratensis* Huds. and *Alopecurus pratensis* L. while grazed communities – of *Poa pratensis* L., *Festuca rubra* L. s. str., *Agrostis capillaris* L., *Anthoxantum odoratum* L. The species indicating locally high habitat moisture included: *Deschampsia caespitosa* L. P. Beauv, *Trifolium hybridum* L. and *Vicia sepium* L. – a species characteristic for warm and moist margin vegetation. In the communities of mountain hay meadows, particularly in those used as pastures, the species characteristic for poorer and acidic habitats were: *Agrostis capillaris* L., *Hypericum maculatum* Crantz and in drier and insolated places - *Dianthus deltoides* L. and *Anthoxantum odoratum* L. The community with *Alopecurus pratensis* grew on most wet sites. Species characteristic for the alliance *Calthion* (*Cirsium rivulare* (Jacq.) All., *Juncus conglomeratus* L. emend. Leers, *Myosotis palustris* (L). L. emend. Rchb., *Scirpus sylvaticus* L.) and for the order *Molinietalia* (*Deschampsia caespitosa* L. P. Beauv, *Lychnis flos-cuculi* L.) had a great share in the species composition. *Filipendula ulmaria* L. Maxim. of the alliance *Filipendulion* was also abundant. *Festuca pratensis* Huds., *Poa pratensis* L., *Lathyrus pratensis* L. and *Phleum pratense* L., among others, represented meadow species.

Table 2. Species richness and the index o floristic diversity

Phytosociological unit	The number of species in community		The index of floristic diversity *H'* in community		
	from	to	from	to	mean
1. Arrhenateretum elatioris	45	80	2.8	2.9	2.9
2. comm. Poa pratensis-Festuca rubra	35	56	2.8	3.2	3.0
3. comm. with Agrostis capillaris	52	90	2.3	2.9	2.6
4. Trisetetum flavescentis	56	94	2.9	3.6	3.2
5. comm. with Alopecurus pratensis	38	59	2.9	3.0	3.0

As shown in table 2, the greatest number of species was noted in phytosociological units 3 and 4, whereas the least species were noted in unit 2. The index of floristic diversity reached medium values from *H'* = 2.3 to *H'* = 3.6. The most diverse communities were the mountain hay meadows and the poorest was the community with *Agrostis capillaris*.

The following strictly or partly protected species were found in studied grasslands: *Platanthera bifolia* (L.) Rich, *Dactylorhiza majalis* (Rchb.) P. F. Hunt & Summerh., *Dactylorhiza maculata* (L.) Soó, *Gymnadenia conopsea* (L.) R. Br. and *Carlina acaulis* L., *Trollius europaeus* L. s. str., *Primula veris* L., *Iris sibirica* L., *Colchicum autumnale* L., *Lilium martagon* L. The presence of protected species in grasslands increases their natural value.

Species from the list of endangered species of vascular flora in Lower Silesia of various risk categories (endangered and rare) were noted in grassland communities. From among vulnerable species were *Trollius europaeus* L. s. str., *Gymnadenia conopsea* L. R. Br. and *Dactylorhiza maculata* L. Soó. Near threatened species included *Dactylorhiza majalis* (Rchb.) P. F. Hunt & Summerh. and *Eriophorum vaginatum* L. Species of least concern included: *Colchicum autumnalis* L. and *Platanthera biforia* (L.) Rich.

Grassland communities were also analysed in view of valuable habitats within the scope of European interest. Among studied communities the identifiers of valuable habitats were the association *Arrhenatheretum elatioris* and the community *Poa pratensis-Festuca rubra* for lowland habitats and extensively used mountain meadows and mountain hay meadows (*Trisetetum flavescentis*) for the habitats of mountain meadows of the alliance *Polygono-Trisetion*. Location of the studied grassland communities within the borders of protected areas (of the Landscape Park of the Wałbrzyskie Sudetes, the Natura 2000 area of the Kamienne Mountains, the Bat Reserve of the Sowie Mountains) has an additional natural value.

Obtained results showed that communities of the studied grasslands belonged to the class *Molinio-Arrhenatheretea* and occupied a broad spectrum of habitat conditions from rich and wet to poor and dry. The communities are characterised by high natural values evidenced by species richness and by diversity index. Similar results for grassland communities were obtained by Trąba *et al.* (2006) in the San river valley and by Kucharski (1999) in Central Poland. Lower values of the described indices were obtained, Kryszak (2001) in Wielkopolska and Żyszkowska and Paszkiewicz-Jasińska (2010) on Złotoryja Foothills. Many such species were found in the studied grasslands i.e. several species of orchids. The importance of these species for natural values was underlined by Wolański and Trąba (2007). In these authors' opinion, protected species may survive if the whole communities and habitats are protected in a system of protected areas NATURA 2000, landscape parks or other higher forms of nature protection.

Conclusions

Meadow and pasture communities are characterised by a high natural value. Belonging to the *Molinio-Arrhenatheretea* class, they represent broad spectrum of habitat conditions from very poor and acidic to rich and wet.

Their relatively high species richness ranged from 35 to 90 species and mean values of floristic diversity index *H'* between 2.3 and 3.6.

High natural values are confirmed by the presence of 10 protected species 6 of which varying in the risk category are listed in the red book of vascular plants of Lower Silesia

Due to a tendency of replacing productive role of grasslands by non-productive functions, it is important to estimate their natural values and to implement appropriate protection programmes for mountain areas.

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Organic farming in northeast of Portugal: effects of soil fertility management on DM yield and nutrients composition of pastures

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Abstract

The aim of this work was to evaluate the effect of six types of soil fertility management: no fertiliser (NF), lime inputs (Ca), mineral fertilisation combined with liming (CaP (lime and phosphorous), CaPB (lime, phosphorous and boron), manure (M), and manure+lime+mineral fertilisation (MCaPB), and two types of pasture (unsown and sown) on DM yield, botanical composition and nutrients content of pasture during two years of study. DM yield was significantly increased when plots were fertilised with manure (M and MCaPB), which also improved the proportion of legumes, mainly in the sown pasture.

Keywords: pasture, organic and mineral fertilisation, grasses, legumes

Introduction

The use of lime and fertilisers is one of the more extensively used agronomic practices to increase pasture productivity and to improve its nutritive value (Martiniello and Berardo, 2007). Both, lime and fertilisation introduce changes in the soil properties (pH, organic matter, available nutrients) that usually cause changes of pasture composition in a short period of time. The aim of this experiment was to study the effect of organic lime and manure fertilisation, combined or not with mineral fertilisation on DM yield, botanical composition and nutrients content.

Material and methods

The experiment was carried out in Vila Meã, (NE Portugal; 860 m a.s.l.) on an acidic soil with an initial soil water pH around 4.5 (1:2.5). The experimental design was a hierarchical split-plot, where pasture type was the main plot and the soil fertility management treatments were the sub-plots. Two types of pasture were studied: spontaneous vegetation (unsown), and sown pasture (sown) with a mixture (kg ha^{-1}): *Trifolium subterraneum* (2.6), *Trifolium vesiculosum* (1.3); *Trifolium michelianum* (0.6), *Trifolium incarnatum* (1.3), *Ornithopus sativus* (1.3); *Ornithopus compressus* (0.6); *Trifolium resupinatum* (0.6), *Biserrula pelecinus* (0.6)), *Trifolium repens* (0.6), *Trifolium fragiferum* (0.3), *Lolium perenne* (3.8), *Lolium multiflorum* (2.5), *Dactylis glomerata* (0.4), *Ph. Aquatica* (0.6), and *Cichorium intybus* (0.6). Soil fertility management treatments included: no fertiliser (NF), lime inputs (Ca), mineral fertilisation combined with liming (CaP (lime and phosphorous (P)), CaPB (lime, phosphorous and boron (B)), manure (M), and manure+lime+mineral fertilisation (MCaPB). Manure and lime treatments implied inputs of 30 and 1.5 Mg ha^{-1}, respectively. The inputs of phosphorous (P_2O_5; rock phosphate 26%) and boron (B; borax 15.2%) were of 100 and 1 kg ha^{-1}, respectively. Finally, a control treatment without inputs was established (NF). In spring 2005 and 2007, three pasture samples were harvested inside exclosure cages on an area of 0.25 m^2 within each sub-plot. In spring 2006, no grazing was allowed in order to favour natural reseeding in sown and unsown pastures. The species were hand separated to determine botanical composition (grasses + other species (G+Ot) and legumes (Leg)). The samples were dried to constant weight (at 60 ºC for 48 h) in order to determine dry matter content and pasture production and to perform chemical analyses. Total N and P were determined after a microKjeldahl digestion by colorimetry using TRAACS 800+ (Castro et al.,1990) and total Ca, Na, K and Mg were analysed with a VARIAN 220FS spectrophotometer using atomic absorption (VARIAN, 1989). Results were analysed by principal component analysis (PCA) based on a correlation matrix for the dependent variables, followed by ANOVA(s) on the PCA scores and original variables and mean separation (Tukey's HSD test).

Results and Discussion

PCA was significant (P <0.000 – Bartlett's test of sphericity) in the explanation of dependent variables G+Ot and Leg, DM yield and nutrients composition of pastures (Figure 1). The first three PCA-axes explained 73% of the variation and were significantly influenced by pasture type and soil management treatment (P<0.05 - ANOVA(s) on the PCA scores). PCA1 was positively related to legumes percentage (Leg), DM yield and N, Ca and Mg levels, and negatively to G+Ot percentage, and CaPB soil fertility management treatments. PCA2 showed a positive relation with K, P and Mg levels, and negative with MCaPB treatment. Finally, PCA-3 was positively related to Na pasture levels and lime inputs (Ca), and negatively to M and MCaPB treatments and P pasture levels.

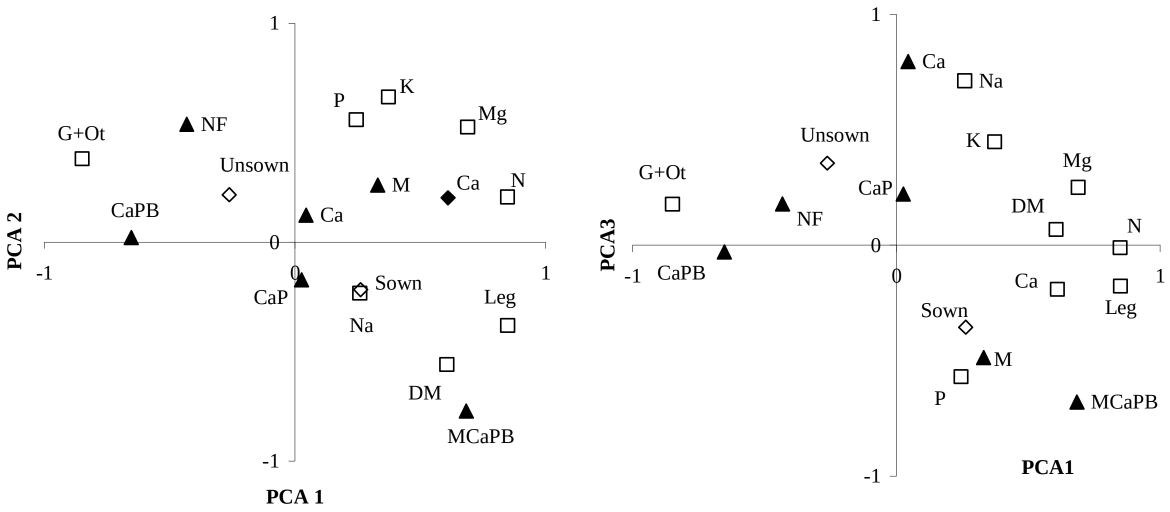

Figure 1. Loadings and scores of the first three PCAs, where: □: loadings of dependent variables (G+Ot: percentage of grasses and other species; Leg: percentage of legumes; DM: DM yield; nutrients levels: N, P, Ca, Na, K, and Mg).◊: scores for pasture type (unsown and sown); ▲: scores for soil fertility management treatments (no fertiliser (NF), lime (Ca), manure (M), lime+phosphorous (CaP), lime+phosphorous+boron (CaPB), and manure+lime+mineral fertiliser (MCaPB)).

DM yield increased significantly during the second year (68% more in 2007 as compared to 2005) and on sown plots (24%) compared to unsown plots (p<0.001). It is known that grasses respond strongly to farmyard manure application and quickly invades areas with animal manure. However, when manure+lime+mineral fertilisation (MCaPB) was applied we observed a significant increase of DM yield and of the percentage of legumes (Figure 2). The same response was observed in 2007 when lime (Ca) or lime+phosphorous (CaP) were applied on sown plots. Brau-Nogue (1996) found that lime inputs quickly increases soil pH and soil nutrient availability, favouring a higher proportion of legumes (Spiegelberger *et al.* 2010) whose growth can be also enhanced by soil P fertilisation (Snyman, 2002).

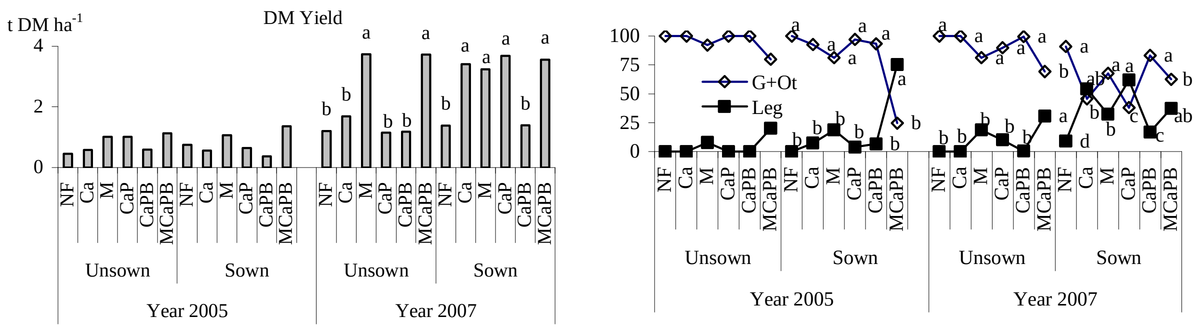

Figure 2. DM yield (t DM ha^{-1}), percentage of grasses + other species (G+Ot) and legumes (Leg) in the two years of study (2005 and 2007), on the two types of pasture (unsown and sown) and in the six soil

fertility management treatments. Different letters indicate significant differences between soil fertility management treatments in the same pasture type and in the same year (p<0.01).

The N, Mg and Ca content of the pasture tended to be higher in the MCaPB treatment (Table 1). This effect can be explained by the higher percentage of legumes, species that have higher concentrations of these nutrients than grasses (Thompson and Troeh, 1988). The percentage of P increased significantly in the treatments with manure (M and MCaPB) during the first year. Zhao *et al.* (2009) found that farmyard manure combined with mineral fertiliser increases soil available P compared to mineral fertiliser alone. Higher K content was obtained in Ca treatment compared to M, CaPB and MCaPB treatments. Finally, the levels of Na tended to be higher in the Ca treatment of unsown pasture. The obtained percentages of N, P, K, and Ca overcame cattle maintenance requirements; while those of Na and Mg were lower (NRC, 2000).

Table 1. Minerals contents for the two types of pasture (unsown and sown), and in the six soil fertility managements in the two years of the study (2005 and 2007). Different letters indicate significant differences between soil fertility management treatments in the same pasture type and in the same year (p<0.01).

		Unsown						Sown					
		NF	Ca	M	CaP	CaPB	MCaPB	NF	Ca	M	CaP	CaPB	MCaPB
Year 2005	% N	1.04	1.13	1.09	1.00	1.20	1.29	1.03	1.11	1.21	1.13	0.98	1.68
	% P	0.12 **b**	0.13 **b**	0.27 **a**	0.14 **b**	0.14 **b**	0.22 **a**	0.24	0.20	0.25	0.19	0.20	0.23
	% K	1.38	1.34	1.14	1.06	1.15	1.19	0.96	0.81	1.16	0.68	0.72	0.91
	% Na	0.03	0.05	0.01	0.02	0.02	0.01	0.02	0.02	0.00	0.04	0.03	0.04
	% Mg	0.17	0.09	0.14	0.12	0.12	0.15	0.08	0.07	0.11	0.05	0.13	0.17
	% Ca	0.32	0.25	0.49	0.43	0.33	0.55	0.68	0.26	0.62	0.23	0.11	0.54
Year 2007	% N	0.86	0.87	1.28	1.06	1.03	1.20	1.33	1.62	1.19	1.59	1.07	1.09
	% P	0.17	0.16	0.17	0.20	0.18	0.15	0.17	0.16	0.17	0.16	0.19	0.14
	% K	0.93	0.95	1.00	1.09	1.15	0.65	1.08 **ab**	1.56 **a**	0.89 **b**	1.18 **ab**	0.82 **b**	0.68 **b**
	% Na	0.02	0.07	0.04	0.03	0.04	0.03	0.03	0.04	0.04	0.06	0.02	0.03
	% Mg	0.11	0.14	0.09	0.18	0.13	0.14	0.16	0.16	0.13	0.07	0.09	0.08
	% Ca	0.27	0.44	0.80	0.66	0.52	0.49	0.66	0.67	0.39	0.45	0.28	0.67

Conclusions

Treatments with manure (M) or manure combined with lime and mineral fertilisation (MCaPB) showed the highest DM yields and legume percentage, mainly in sown pasture. Beyond the significant effect of manure+lime+mineral fertilisation (MCaPB) on DM yield and legume percentage, this treatment tended to have also higher N, P, Ca and Mg pasture levels.

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Effects of shrub and tree encroachment on plant biodiversity, pastoral value and yield of *Bromus erectus*-dominated grasslands

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Abstract

The change of management and the abandonment showed to have strong effects on the conservation of grasslands and shrublands. The paper aims to assess the impact of increasing levels of shrub and tree encroachment on plant biodiversity, pastoral value and yield of *Bromus erectus*-dominated grasslands in a study area characterised by extensive management practices in the Monti Sibillini National Park (900-1350 m a.s.l.; Central Apennines, Italy). According both to phytosociological and point-intercept methods, vegetation surveys were performed during summer 2007 and the results were used to calculate agro-environmental and agronomic indicators. The grasslands characterised by intermediate stage of tree/shrub encroachment showed the lowest values of total number of species and of the endemic components. The decreasing pastoral values associated to vegetations characterised by higher index of maturity and of endemic species with low forage value, suggest to promote a more efficient management of the grasslands. This could prevent undesired vegetation dynamics and, at the same time, could allow to search for practices aiming to reduce the sward litter in order to promote the increase of species richness.

Keywords: biodiversity, pastoral value, DM yield, shrubs, *Bromus erectus*, grassland.

Introduction

Over the last decades, most of the territories of Central Apennines were affected by strong changes of the historical conditions of settlement and management (D'Ottavio *et al.*, 2008). Changes of management and abandonment showed to have strong effects on the conservation of grasslands and shrublands of Community interest (Directive 92/43/EC, i.e. Habitats 6210 and 5130) (Caballero *et al.*, 2010). At the same time, a reduction in herbage production and in nutritive value was found to be the result of shrub encroachment in grasslands (Zarovali *et al.*, 2007). The paper aims to assess the effects of different levels of shrub and tree encroachment on biodiversity, pastoral value and yield of *Bromus erectus*-dominated grasslands in a study area characterised by extensive management, by applying indicators of agro-ecosystem quality and productivity commonly used to define the management of grazinglands.

Materials and methods

The research was carried out in 2007 in 'Campolungo' (Fermo province, 42°58'N, 13°17'E) on grasslands of about 800 ha (900-1350 m a.s.l.) located in the Monti Sibillini National Park (Central Apennines, Italy). The study area is characterised by a prevalent E-NE exposure and calcareous bedrock. The mean annual temperature is 11°C and the precipitation is 1238 mm with two peaks in November-December and at the beginning of spring and a minimum during July and August. Grasslands of Campolungo were continuously stocked by 950 sheep from middle June to end October 2007 with a stocking rate of 0.18 Standard Livestock Units (SLU) ha^{-1} during about 120 grazing days. The pastures belong to the association *Asperulo purpureae-Brometum erecti* Biondi & Ballelli ex Biondi, Ballelli, Allegrezza & Zuccarello 1995, with *Brachypodium genuense*, *Bromus erectus* and *Festuca circummediterranea* as dominant species.

Within the studied grasslands, 5 sample areas characterised by homogeneous environmental conditions and differentiated by increasing cover of trees and shrubs (L1: 0-5%, L2: 40% and L3: 75% with 3, 1 and 1 sample areas, respectively) were identified. From the beginning to the middle of June 2007, the sward specific contribution in each sample areas was determined by the point-intercept method (Daget and Poissonet, 1971) along two 25 m-transects where 50 points were distributed at 50 cm intervals. Moreover, a phytosociological survey according to Braun-Blanquet (1932) was performed in each sample areas on

surface of 100 m^2, in order to acquire data concerning presence and cover values of all the present species.
The vegetation data obtained by applying the point-intercept method were used to calculate the following indicators to assess the environmental quality of agro-ecosystems according to Taffetani and Rismondo (2009): Index of Maturity (IM: 0-9) measuring the actual stage of maturity of a vegetal community in relation to the presence and abundance of the species; Index of Floristic Biodiversity (IFB) as the total number of the identified species in each vegetation survey; Index (% total species abundance) of the therophytic (IT), hemicryptophytic (IH) and perennial non-hemicryptophytic (IF) components tacking into account the abundance of the therophytic, hemicryptophytic and non-hemicryptophytic species, respectively; Index (% total species abundance) of the endemic (IL) and exotic (IE) components providing information on presence and abundance of endemic and exotic flora.
The vegetation data were used to calculate the Pastoral Value (PV: 0-100) of the grasslands according to Daget and Poissonet (1971), D'Ottavio *et al.* (2009) and by using the Specific Indexes (SI) reported by Roggero *et al.* (2002). PV was corrected by considering the reduction due to the shrub/tree and the herbage vegetation cover (CPV) and calculated only for the herbage vegetation (H CPV) by considering the reduction due to the herbage vegetation cover.
Within each sample area, on five 0.25 m^2-sub-areas (0.50 x 0.50 m) characterised by homogeneous environmental conditions, dry matter (DM) yield of total above-ground biomass was determined. Biomass was divided into green (Green DM) and senescent/dead tissues (Dead DM). Moreover, within each sub-area, five 0.0625 m^2-sub-sub-areas (0.25 x 0.25 m) were used to assess the dry matter yield of the litter (Litter DM). Data were analysed by ANOVA procedure using SAS (1985). Means comparison was performed by the protected Fisher's LSD test. Among all variables the Pearson's correlation coefficients were calculated.

Results and discussion

According to Taffetani and Rismondo (2009), the grasslands showed a mean IM of 5.05, but not significant differences among the increasing levels of tree/shrub cover were found (Tab. 1). This is because significant changes in species composition inside mature grasslands can affect the IM only over a longer period. In this case the mean value of the IM denoted a good conservation status of the coenoses, with a dominant presence of herbaceous vegetation of the class *Festuco-Brometea*. Moreover, the vegetation data assessed by applying the point-intercept method and used to calculate IM did not adequately took into account the increasing presence and abundance of tree and shrub species of the areas L2 and L3. This was the main reason why L3 grassland did not showed higher IM.
Significant differences were observed in terms of total number of species (IFB) among the grasslands with different levels of tree/shrub encroachment. L1 and L3 showed an higher IFB than L2. The higher IFB observed in L3 grassland seem to be in contrast with the most relevant literature (Mazzoleni *et al.*, 2004), but according to Dorroug *et al.* (2004) optimal conditions for biodiversity are likely to occur when biomass and heterogeneity are high.
The different tree and shrubs cover did not significantly influence the abundance of therophytic (IT), hemicryptophytic (IH) and perennial non-hemicryptophytic (IF) species. The indices showed anyway a small increase in perennial non-hemicryptophytic (IF) species in L2 and L3, with a consequent decrease of the abundance of hemicryptophytic (IH) species. These changes are the result of the dynamic evolution of vegetation communities under abandonment conditions. On the contrary, the three types of grasslands showed significant differences in terms of presence and abundance of endemic (IL) and exotic (IE) flora. For the endemic species, L1 (above all *Carex macrolepis*, *Avenula praetutiana* and *Phleum ambiguum*) and L3 (above all *C. macrolepis* and *Sesleria nitida*) had higher values than L2. Concerning the exotic species (above all *Onobrychis viciifolia*), higher values were recorded for the grasslands with the higher levels of encroachment (L2 and L3).
As expected, the CPV showed the lowest values in the L3 grasslands due to the reduction determined by the its high shrub/tree cover. On the contrary, no differences were recorded in terms of H CPV among the grasslands with different levels of tree/shrub encroachment.
With regards to above-ground biomass DM fractions, only for Green DM were observed significant differences among the grasslands with increasing levels of tree/shrub cover. Higher values were recorded in the L3 grassland compared to L1 and L2.
The litter DM yield showed high mean values as the consequence of the understocking conditions (Bonanomi *et al.*, 2006 and 2009), irrespectively of the tree/shrub cover.

Table 1. Agro-environmental and agronomic indicators of the grasslands with different levels of tree/shrub cover.

Tree/shrub cover	L1	L2	L3	Mean
IM	5.06	5.01	5.06	5.05
IFB	19.83 [a]	16.00 [b]	22.50 [a]	19.6
IT (%)	0.24	0.00	0.33	0.21
IH (%)	93.20	93.19	92.53	93.06
IF (%)	6.56	6.81	7.13	6.73
IL (%)	11.61 [a]	1.24 [b]	13.64 [a]	9.9
IE (%)	1.08 [b]	3.33 [ab]	4.05 [a]	2.1
CPV	22.92 [a]	17.64 [ab]	7.26 [b]	18.7
H CPV	23.67	29.41	29.05	25.89
Green DM (t ha^{-1})	3.14 [b]	2.54 [b]	3.73 [a]	3.14
Dead DM (t ha^{-1})	1.99	2.04	1.76	1.95
Total DM (t ha^{-1})	5.13	4.58	5.49	5.09
Litter DM (t ha^{-1})	3.19	3.12	3.94	3.33

Within rows, means with different letters differ significantly at the 0.05 level.

The relationships among the indicators of agro-environmental quality and those commonly used to define management of grazinglands, highlighted a significant negative correlation between H CPV and both IM and IL (Tab. 2). The first correlation suggest that H CPV decreased with the increasing abundance of species of low forage value (above all *C. macrolepis* and *S. nitida*) recorded in the L1 and L3 grasslands. The second correlation seems strictly connected to the previous result. Among the endemic species, in fact, the high presence and abundance of species of null or scarce forage value (above all *C. macrolepis*) contributed to the reduction H CPV.

On the other hand, high values of Litter DM were significantly associated to a low presence of endemic species. This was particularly observed for *A. praetutiana* and *C. macrolepis*, suggesting that litter could be a limiting factor for their establishment and growth, although at least for *A. praetutiana* litter removal did not produce any increase in species cover after 3 years-application treatment (Bonanomi *et al.*, 2009). The negative correlation between H CPV and IL, explained by the scarce forage value of the endemic species, seems to be in contradiction with the above correlation (Litter DM vs. IL) that could be considered symptomatic of under-stocking conditions. However, it is important to point out that, under the low stocking rates of the study area, presumably the litter accumulation in the grasslands is always high independently from their botanical composition and therefore from the their pastoral value.

Table 2. Correlation coefficients (R) among agro-environmental and agronomic indicators.

	IM	IFB	IT (%)	IH (%)	IF (%)	IL (%)	IE (%)
CPV	-0.38	-0.29	-0.22	0.25	-0.24	-0.45	-0.52
H CPV	-0.79**	-0.09	-0.25	0.16	-0.13	-0.80**	0.58
Green DM (t ha^{-1})	0.66	0.10	-0.01	-0.39	0.41	0.00	-0.45
Dead DM (t ha^{-1})	0.10	-0.14	-0.25	-0.38	0.42	0.14	0.52
Total DM (t ha^{-1})	0.79	0.04	-0.13	-0.62	0.66	0.06	-0.27
Litter DM (t ha^{-1})	-0.53	0.03	0.28	-0.07	0.05	-0.98**	0.04

Significant correlations: ** = $p<0.01$.

Conclusions

The grasslands characterised by intermediate stage of tree/shrub encroachment showed the lowest values of total number of species and of index of the endemic components compared to those with the lowest and the highest cover. Considering the large diffusion of these grasslands in the study area, their management aiming to biodiversity conservation should be addressed to prevent undesired vegetation dynamics.

On the other hand, the increasing encroachment of large areas of *Bromus erectus*-dominated grasslands in the study area, mostly to be associated to reduced stocking rates and to the abandonment (D'Ottavio *et al.*, 2008), is causing a strong decrease of grazing surfaces and of their pastoral value. The decreasing pastoral values associated to vegetations characterised by higher index of maturity and of endemic species with low forage value, suggest to promote a more efficient management of these grasslands. This could prevent undesired vegetation dynamics and, at the same time, could allow to search for practices aiming to reduce the sward litter in order to promote the increase of species richness (Bonanomi *et al.*, 2006 and 2009).

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The Forest-Grassland Land Use Method as the Alleviating Factor of Water Erosion in the Carpathian Mountains

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Abstract

Soil erosion by water is an important issue because erosion strongly degrades the environment. This phenomenon occurs in the Carpathian areas, and it is caused chiefly by inappropriate land use. During the last quarter of the century, in whole region, significant structural changes took place i.e. an increase of the grassland area. Research was undertaken in the water year 2009/2010 in the Biała Woda catchment area (10.91 km^2), of the Carpathian Mt. The study area is characterized by a low share of arable lands and a high contribution of the permanent grasslands. In this paper the mass of eroded materials (soil losses) was determined by application of the universal soil losses equation – USLE (Wischeier and Smith, 1978). The principal factors which were considered have an impact on shaping the catchment area: geological structure, terrain relief, soils, land use and slopes. The main attention was focused on agricultural land use (grasslands), hydrographics and the road network. Sometimes the field roads become streams (gullies), which create favourable conditions for linear erosion e.g. for transporting eroded material during, heavy rainfall. Therefore, the structural–spatial changes which now are taking place sometimes intensify the erosion process.

Keywords: grasslands, land use, erosion, soil losses equation,

Introduction

The Carpathian mountain regions are characterized by high precipitation as well as by considerable inclination of the hillsides (Dynowska and Maciejewski, 1991). In this regard, and with a combination of other factors, the region is particularly threatened by the erosion process, mainly by water erosion. The principal elements which contribute to erosion are: geological structure, the soils, precipitation, land use, relief and land slopes. Agricultural land use e.g. plough cultivation methods, favour water erosion, mainly surface. In turn, a dense hydrographical network and the road net, in the period of intensive rains, are transformed into streams, which accelerate drainage of the eroded materials from the field surfaces (Prochal *et al.,* 2000). Soil erosion by water is also an important economical problem, because it strongly degrades the environment. This phenomenon occurs on about 60% of the Carpathian area, and is caused, in considerable degree, by unsuitable land use as well as by the inappropriate distribution pattern of the arable lands. In the last quarter of the century significant structural changes took place i.e. an increase of grasslands; hence they gather peculiar production and protective value (Jagła, 1965,Twardy,1993). At present, determination of the amount of soil losses gains significance, because the management conditions in the mountain areas are changing as well as the share of forest-grassland cover has increased. The aim of research was to determine the mass of soil losses in the Biała Woda catchment area in the water year 2009/2010 (November, 1st – October 31st). This year was characterised by a very high precipitation, which was 55.7 % higher than the 50 year, long term average.

Material and methods

In order to define the water erosion process it is necessary to determine the quantity of surface runoff and the soil loss after each rainfall. Estimation of the displaced soil within a catchment area can be made using the Universal Soil Loss Equation –USLE (Stone and Hilborn 2000).

The method is based on an analogy between amount of erosion which occurs in a standard plot of length 22.1 m, which is located on a slope with the gradient of 9 %, to the amount of soil loss from the area under consideration (Banasik and Górski.,1991; Nearing *et al*.1989). For a purpose of soil erosion analysis the model elaborated by Wischeier and Smith (1978) was applied. It shows average soil losses, whereas applied parameters in universal soil loss equation are mean values for separated catchments and areas. The USL equation has the following form:

$$A = R\ K\ L\ S\ C\ P \qquad (1)$$

where:

***A* –** represents the potential long term average annual soil loss in tons $\cdot km^{-2} \cdot year^{-1}$.
The respective elements (coefficients) in the above equation are described below:
***R* –** mean annual erosive factor of rainfall and runoff (expressed in Je·year $^{-1}$; Je=soil erosive unit)
K – susceptibility of the soil to erosion, which depends on granulometry (the size distribution in a collection of grains). The value of K coefficient can be estimated from appropriate diagram modified by Schwertman (quoted by Banasik and Górski, 1991)

L – characterizes the features of hillside slope and it is the ratio of eroded soil from the plot of considered length to the amount of eroded soil from the standard plot, when the remaining conditions, which have the impact on an intensity of this process, are identical. .

S – is characteristic of the hillside slope, being the ratio of eroded soil from the plot at given gradient to the amount of soil loss from standard plot with steepness of 9 % , when remaining conditions which influence the intensity of the process are identical.
C – is the crop/vegetation and management factor. It is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil losses
P – is the support practice factor. It reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The P factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip-cropping.
In order to estimate the mass of eroded soil from the unit area, USLE programme was used. Depending on the amounts of soil losses from the unit area- the degree of soil erosion, can be determined based on the Zachar's (1982) classification.

Results and discussion

The analysis and calculations made by applying the Universal Soil Loss Equation, by using the USLE programme (Wischeier and Smith,1978) allowed for estimation of the eroded soil from the unit area of the Biała Woda catchment. It has a large share of permanent grasslands and forest and some spatial elements which were used in calculations are shown in table 1 (below) :

Table 1. Soil losses against a background of the Biała Woda catchment characteristics

Area [km^2]	10.91
Average gradient of the catchment [%]	4.43
Density of stream network [km·km^2]	3.15
Length of the stream [km]	7.93
Precipitation totals - the water year (Nov-Oct)- 2009/2010 [mm]	1,602
50- year average annual precipitation [mm]	886
Soil losses [kg·ha^{-1}· $year^{-1}$]	874

The results of studies according to Zachar's (1982) classification, categorised the terrain under consideration to the second (II) degree, described as a weak. The studies confirmed that the land use method had the principal impact on occurrence and the intensity of water erosion. Research at Szymbark (the Beskid Mts) proved that annual soil loss from hillside field amounted to respectively: potatoes cultivation, 74, 241 kg·$ha^{-1,}$, cereals fields 108 kg·ha^{-1} , grasslands 51 kg·ha^{-1} , and from forest only 0.2 kg·ha^{-1} [Starkel *et al*,1978]. And similar studies in the Sudety Mts, showed that permanent grasslands were susceptible to the erosion process in the lowest degree. (Fatyga, 1978).

However, the results obtained in the Biała Woda catchment area in the analysed water year of 2009/2010 (table 1) showed that soil losses from the areas with permanent grassland and forest were higher as compared to the data quoted by the above authors. One of the most probable reasons of this disparity in soil loss assessment from grasslands was the very high annual precipitation, which was about 56 % higher than the long term averages.

Conclusions

Studies showed that the Universal Soil Loss Equation was suitable for soil loss assessment of a catchment area with a large share of grassland and forest. Research based on the USLE procedures confirmed that the land use pattern in the Carpathian area had a significant impact on the occurrence and intensity of water erosion. Forest-grassland land use methods are the best soil conservation means against soil loss under conditions of high precipitation and its concentration in a short period of time.

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Estimating aerial biomass and degradability of some tannin-rich species in the National Park of Zaghouan Mountains (NE Tunisia)

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Abstract

This study aims at determining the main groups of vegetation in the National Park of the Zaghouan mountains (Northeastern Tunisia) and evaluate their aerial biomass. We also studied the *in sacco* dry matter degradability at 48 h (D48) of leaves and stems of the most dominant species in the park as an index of their digestibility by ruminants. The studied area occupies 1881 ha. Species were distributed in 12 groups with 3 to 11 species per group. Two samples per group were collected during spring 2008 (between March and May) using the plot method. The total biomass of the park was estimated to be *ca.* 6664 tons (*ca.* 3.54 tons ha^{-1}). The group of *Quercus ilex* and *Pistacia lentiscus* was the most abundant and occupied 804 ha. The second dominant group, present in over 515 ha, was that of *Olea europea, Pistacia lentiscus* and *Ceratonia siliqua*. The most heterogeneous group, in terms of the wide variety of species included was the most productive (5.93 tons ha^{-1}) although it occupied only 5 ha. Whilst, the least productive group (1.83 tons ha^{-1}) was that of *Callycotum villosa, Prinus prostrata* and *Crataegus azarolus.*

With respect to D48, studied species revealed a large variability. Leaves of *O. europea* followed by those of *C. villosa* (0.63 and 0.59, respectively); while stems of *Erica multiflora* were the least (0.25).

Keywords: Tunisia, shrubs, biomass, *In sacco* degradability.

Introduction

Rangelands in Tunisia represent one-third (5.5 million hectares) of the total land area. They are widespread mainly in the semi-arid and arid regions. For decades these rangelands have been considered as a generous and non-exhaustive resource for ruminant feeding. Nevertheless excessive browsing has resulted in the degradation of the ecosystem. Many development actions were undertaken in collaboration with different partners to establish a conservation policy of the natural heritage. In the case of the National Park of Zaghouan Mountains, a typical example for degenerated ecosystem, a preliminary study was carried out by classifying the area in different plant communities (groups). Examples of the ecological value of the Park include the communities of *Pistacea lentiscus, Phyllerea angustifolia, Ceratonia siliqua and Ampleodesma mauritanicus*. Biomass production and abundance of these species are closely related to the conservation status of the Mediterranean vegetation. Determination of the forage biomass of bushes is a basic tool in the analysis of the carrying capacity of semi-arid Mediterranean ecosystems and consequently to avoid the risk of its degeneration.

Our objective in this present study consists in the identification of the different plant groups and the description of their distribution and abundance in the National Park of Djbel Zaghouan. We also aimed at quantifying the forage biomass production and at determining the *in sacco* dry matter degradation, of the most abundant bushes.

Material and methods

All the plants were sampled in the protected area of the Natural Park of Djebel Zaghouan (East central Tunisia). The altitude is 1295 m. The average annual rainfall is 350 mm corresponding to a semi-arid Mediterranean climate (Rivas-Martinez, 1987). The Park area is 1881 ha, it is covered mainly by Mediterranean forests and shrub lands. The soils are calcite characterized by a fragile structure

A total of 21 tree and shrub species, the most abundant in the Park, were sampled twice during Spring 2008 (March and May), using the square plot (20m x 20m) method. Samples were distributed in 12 groups as illustrated in Table 1 according to the species dominance. In each group, a maximum of 6 plots were randomly placed, this gives a total of 43 plots representing the sampled area. In each plot, fresh browsing biomass of trees and shrubs was harvested. This browsing biomass is considered to be the annual productivity and defined as the plant fraction that can be foraged by the animal. It is composed of the current year's stems, leaves, flowers and green fruits.

Estimation of the individual tree biomass (B, ton DM/ha) in the park is obtained using biomass estimation for all plots and the percentage of the area occupied by each group (% Gi) following the formula

$$B = \sum_{i=1}^{i=12} \left[\frac{\text{Biomass production/plot}}{400} * 10000 \right] * \%\,Gi$$

The fresh biomass was oven dried at 60°C for 48 h producing the dry forage matter (DM) which was then weighed on an electronic balance with a precision level of 0.01 g.

For the determination of dry matter degradation a total of 9 species with distribution frequency (cover) in the studied area superior than 3% were submitted to the determination of their *in sacco* dry matter degradation at 48h (D48). Samples of leaves and young stems were ground through a 3-mm sieve and two replicate samples of each, weighing about 3 g, were placed into nylon bags and incubated in the rumen of fistulated heifer. Elapsed the incubation time (48 h), bags were retired and rinsed gently with tap cold water. Then bags were oven dried (60° C, 48 h) and weighed to calculate degradability as the difference between the initial (3 g) and the residual of incubation. Heifer was fed on alfalfa hay (8 kg/d) and concentrate (4 kg/d).

Results and discussion

As highlighted in Table 1, the most dominant tree and shrub species in the park were distributed in 12 different groups (G). The areas occupied by each group varied widely between 2 ha (G11) and 804 ha (G4). The majority of the groups were homogeneous to a large extent since they contained no more than three different species (G1, G2, G3, G4, G5, G9, G11). Only G6 seemed to be heterogeneous as it included 7 different species.

Literature references on biomass production and nutrient content in semi-arid woodlands are scarce compared to tropical rain forests or temperate forests (Lieth, 1975; Montès *et al.*, 2002). However, in these areas where the herbaceous layer is usually sparse (Archibold, 1995), trees play an important ecological role. In the semi-arid mountain ecosystems, often characterised by a vegetation cover decline (Gardner and Fisher, 1996; Barbero *et al.*, 1990), trees represent the main compartment of the ecosystem from a biomass and nutrient content point of view.

P. lentiscus followed by *P. angustifolia*, were the most predominated species in the studied area and represent respectively 15.3 and 10.8% of the total studied species. In a few cases, some species like *O. europea* seemed to be more patchy and dispersed (dominance <1%) than others such as *P. lentiscus* (dominance >15%), even though they had similar productivity. These results are confirmed by other studies (Montès *et al.*, 2002) in other semi-arid Mediterranean areas

Except for *Q. ilex, O. europea* and *P. lentiscus*, individual species biomass production revealed a wide variation (0.6 - 898 kg.ha^{-1}). This result is in agreement with findings of Felker *et al.* (1982) and Sosa and Baez (1985) who attributed such variation to strong relationship existing between biomass and morphological measurements that is specific to each species. However, Villalobos (2007) proved that morphological measurements, like height, are little correlated with biomass and variation between species is attributed mainly to differences among their individual growth forms and to site resource response. Moreover, some species (tree or shrub) such as *M. vulgaris, C. azorolus and P. halepensis* were identified in only one group, whilst others such as *P. lentiscus, P. angustifolia* and *C. siliqua* were dominant in more than four groups (Table 1). The total biomass production of all the studied area was estimated to 6664 t

The biomass recorded in the different groups ranged from 1.83 to 5.93 t DM.ha^{-1} (Table 1) and the highest production was found in the most heterogeneous group (G6). This group included the tallest trees (*P. lentiscus*, *O. europea*, *E. multiflora*, *Q. coccifera*, *C. siliqua* and *P. angustifolia*) which appear to be located in the densest vegetation area, and consequently the most productive one (Montès *et al.*, 2002).

Biomass production of either the total area or of *J. phoenicea*, *Q. ilex*, *T. articulata* reported in this study was widely different from that carried out in the literature (Lieth, 1975; Haloui, 1992; Tsiourlis, 1992) in similar ecosystems. This should be attributed partly to micro-environmental differences in soil permeability and soil composition.

Table 1. Surface (ha) and biomass production of the different identified groups of vegetation

G1		G2		G3		G4		G5		G6	
area (ha)	Biomass t/ha	area (ha)	Biomass t/ha	area (ha)	Biomass t/ha	area (ha)	Biomass t/ha	area (ha)	Biomass t/ha	area (ha)	Biomass t/ha
49 ha	2.15	30	1.83	125	2.58	804	3.15	33	5.07	5	5.93
Callycotum villosa, Pistacea lentiscus, Prunus prostrata		*C. villosa, P. prostrata Crataegus azarolus*		*Ceratonia siliqua, Phyllerea angustifolia P. lentiscus*		*Quercus ilex P. lentiscus*		*Ampleodesmos mauritanicus P. lentiscus, Q. Suber*		*C. siliqua, P. angustifolia, P. lentiscus, Marrubium vulgaris,Olea europea, Erica multiflora, Q. coccifera*	
G7		**G8**		**G9**		**G10**		**G11**		**G12**	
area (ha)	Biomass t/ha	area (ha)	Biomass t/ha	area (ha)	Biomass t/ha	area (ha)	Biomass t/ha	area (ha)	Biomass t/ha	area (ha)	Biomass t/ha
515	4.47	74	4.94	65	2.22	93	4.77	2	2.50	86	2.21
C. siliqua, P. angustifolia, P. lentiscus, O. europea		*E. multiflora, Pinus halepensis Tetraclinis articulata Stipa tenacissma*		*E. multiflora, Rosmarinus officinalis, T. articulata*		*P. angustifolia A. mauritanicus R. officinalis, S. tenacissma*		*A. mauritanicus P. lentiscus, S. tenacissma*		*A. mauritanicus, C. villosa, C. siliqua, P. lentiscus*	

Tree and shrub cover (%) and individual biomass production are illustrated in Table 2.
P. lentiscus followed by *P. angustifolia*, were the most dominant species in the studied area and represent respectively 15.3 and 10.8% of the total studied species (Table 2). In few cases, some species like *Q. suber* seemed to be more patchy and dispersed (abundance <1%) than others such as *P. lentiscus* (abundance >15%), even though they had similar productivity. These results are corroborated by other studies (Montès et al., 2002) in other semi-arid Mediterranean areas where shrubs show great variability in size–biomass relationships. These authors suggested that plant biomass production is affected by light, water, temperature, nitrogen, and herbivore.
Q. ilex was the most productive tree (898.3 kg/ha) followed by *O. europea* (768 kg.ha^{-1}) and *P. lentiscus* (757.5 kg.ha^{-1}); whilst *Q. coccifera* was the least productive species (0.6 kg /ha).
With the exception of *Q. ilex*, *O. europea* and *P. lentiscus*, individual biomass production of the different identified species in the studied area revealed a wide variation (0.6-898 kg ha^{-1}) (Table 2). This result is in agreement with findings of Felker et al. (1982) and Sosa and Baez (1985) who attributed such variation to strong relationship existing between biomass and morphological measurements that should be appropriated to each species.

Table 2. Tree and shrub cover (%) and individual biomass production (kg/ha) in the studied area

Species	A. mauritanicus	C. villosa	C. silqua	C. monspeliensis	Cr. azarolus	E. multiflora	G. alypum
Species cover (%)	9.3	6.2	9.5	2.4	1.9	5.4	2.8
Biomass production (kg/ha)	144.3	14.4	445.2	1.5	7.5	10.1	2.3
Species	M. vulgare L	O. europea	P. angustifolia	P. lentiscus	P. halepensus	P .prostrata	Q. ilex
Species cover (%)	1.2	5.3	10.8	15.3	2.3	3.8	4.5
Biomass production (kg/ha)	1.0	768.2	364.0	757.5	80.2	17.0	898.3
Species	Q. suber	Rhammus alatarnum ssp	R. officinalis	S. tenacissma	T. articulata	J. phoenicea	Q. coccifera
Species cover (%)	0.7	0.4	6.4	5.7	4.3	1.0	0.7
Biomass production (kg/ha)	62.8	2.5	25.8	17.4	74.0	6.5	0.6

Leaves of *G. alypium* were the most degradable at 48 h (79% DM), while stems of *R. officinalis* had the lowest D48 value (19% DM) (Table 3). For the same species, D48 was higher for leaves than stems. This difference was more noticeable in the case of *G. alypium* which could contain high tannin levels.
Forage intake is reduced by low forage biomass according to functional response relationships (Spalinger and Hobbs, 1992), or by low forage quality. There is little information available about the quality and nutritive value of fodder trees in the national Park of Djebel Zaghouan. Researchers and scientists have to depend upon farmers' traditional knowledge to gather such information. The great diversity in D48 of

species studied herein is attributed mainly to large variations in their nutriment contents (protein and cell wall) and anti-nutritional factors such as tannins (Ammar *et al.*, 2008, 2009). Leaves of *G. alypum* revealed the highest D48 (79 %) and *R. officinalis* the lowest (19 %). Composition and structure of the cell wall may affect digestibility to a greater extent than the cell wall content (Ammar et al., 2004). It is noteworthy that the most abundant shrubs in the Park are the least digestible and *vice versa*. A relevant factor in this oppositional ranking may be the presence of anti-nutritional factors such as tannins which can also affect cell wall digestibility to a variable extent.

Table 3. *In sacco* DM degradability at 48 h incubation (D48 h) of leaves and stems of the species.

Species	A. mauritanicus	C. villosa	C. siliqua	C. albidus	O. europea	E. multiflora	G. alypium	P .lentiscus	R. officicnalis
Leaves	26	59	41	46	63	41	79	46	39
Stems		32	35	39	37	25	34	37	19

Negative effects of this secondary compound vary with plant species, animal species, tannin levels and possibly tannin structure (Ammar *et al.*, 2009). This may explain the common practice of feeding a combination of species, which may result in better nutritive value than feeding a single species.

Conclusion

The National Park of Zaghouan Mountains includes a high diversity of shrub and plant species. *P.lentiscus* and *P. angustifolia* were the most dominant species, while *Q. suber*, *Q. coccifera* and *R. alatarnum* were patchy. Q. ilex followed by O. europea were the most productive species Q. coccifera was the less productive one. For an accurate analysis of the carrying capacity of the park under ruminant management, additional research could be performed on the nutritive value (chemical composition, presence of anti-nutritional factors and dry matter digestibility) and palatability to the animal of the different shrubs and browses in different periods of the year.

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Assessing the influence of grassland fertilisation on *Rosa gallica* L. shrub (case study)

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Abstract

The purpose of this work is to show the influence of different fertilisation types on the occurrence of the French rose (*Rosa gallica* L.) in a grassland. Its interrelation with different parameters such as botanical composition, biodiversity and pastoral value were also analysed. The vegetation data were collected using the linear point-quadrate method. The studied permanent grassland has a relatively constant contribution of the species *R. gallica* in the vegetation sward, which is dominated by *Festuca valesiaca* and *Filipendula vulgaris*, other species with important contributions being *Achillea millefolium, Plantago lanceolata* and *R. gallica*. The contribution of French rose was independent from the level of fertilisation.

Keywords: *Rosa gallica* L., grassland, fertilisation, vegetation, floristic composition

Introduction

Rosa gallica L. is a moderate thermophilic low growing (Dúbravková *et al.*, 2010) shrub species commonly found in Europe, Asia Minor and North Africa from lowland to highland. In Romania it is present in very different habitats as pastures and hayfields, cultivated land, shrubland, sunny slopes, forest edge and meadows (Pârvu, 2000). In other countries, as Poland, French rose is a rare and endangered species (Towpasz & Cwener, 2002).

Material and methods

The field experiments were carried out during 2004-2009 on permanent grassland from Grădinari (Caraș-Severin County, Romania). The analysed grassland belongs to the forest steppe type and the plots were harvested biannually.

Nine fertilisation variants and one control (V1) were applied in three replicates. The fertilisation types were the following: organic (20 t/ha manure – V2, 40 t/ha manure – V3, 60 t/ha manure – V4), mixed (20 t/ha manure + P_{50} – V5; 20 t/ha manure + P_{50} + K_{50} – V6; 20 t/ha manure + N_{50} + P_{50} + K_{50} – V7) and chemical (N_{100} + P_{50} + K_{50} – V8; N_{150} + P_{50} + K_{50} – V9; $N_{150+100}$ + P_{50} + K_{50} – V10). The vegetation data were collected using the linear point quadrat method. The analysed vegetation parameters were: species number, specific contribution (SC%), Shannon index (H'), Simpson index (D) and pastoral value (VP) on 0-100 scale. ANOVA, linear regression and correlation were used for statistical analyses.

Results and discussion

The studed grassland was dominated by *Festuca valesiaca*. Other species with important contribution in the sward were *Filipendula vulgaris, Achillea millefolium, Plantago lanceolata, Briza media, Lotus corniculatus, Lathyrus pratensis, Lathyrus nissolia* and *Hieracium pilosella*. *R. gallica* shrub was present on all experimental plots and persisted in the vegetation cover although the biomass was harvested twice a year.

The results show that fertilisation rates didn't influence the contribution of *Rosa gallica* L. (Table 1); this aspect being evidenced by a p value (0.999) greater than the significance level ($p > 0.01$).

The influence of the years of biomass harvesting on the specific contribution of *R. gallica* was also analysed. The single factor ANOVA results are presented in Table 2. The repeated harvesting of the biomass didn't have any effect on the SC% of *R. gallica* in grassland ($p > 0.01$).

Table 1: ANOVA results for the contribution of *R. gallica* at different fertilisation doses.

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between fertilisation variants	1.301	9	0.145	0.107	0.999	2.785
Within fertilisation variants	67.644	50	1.353			
Total	68.945	59				

Table 2: ANOVA results for the contribution of *R. gallica* for different number of years of biomass harvesting.

Source of Variation	*SS*	*df*	*MS*	*F*	*p-value*	*F crit*
Between harvesting years	14.947	5	2.989	2.99	0.019	3.377
Within harvesting years	53.998	54	1.0			
Total	68.945	59				

Figure 1 illustrates the linear regression between *R. gallica* and several vegetation parameters, such as number, respectively specific contribution, of grasses, legumes and other species, H', D and VP. The obtained values show the absence of any interrelation, except with the biodiversity indexes (H' and D) and the number of other species that were expressing a weak relationship, which is possible to be influenced by other factors too.

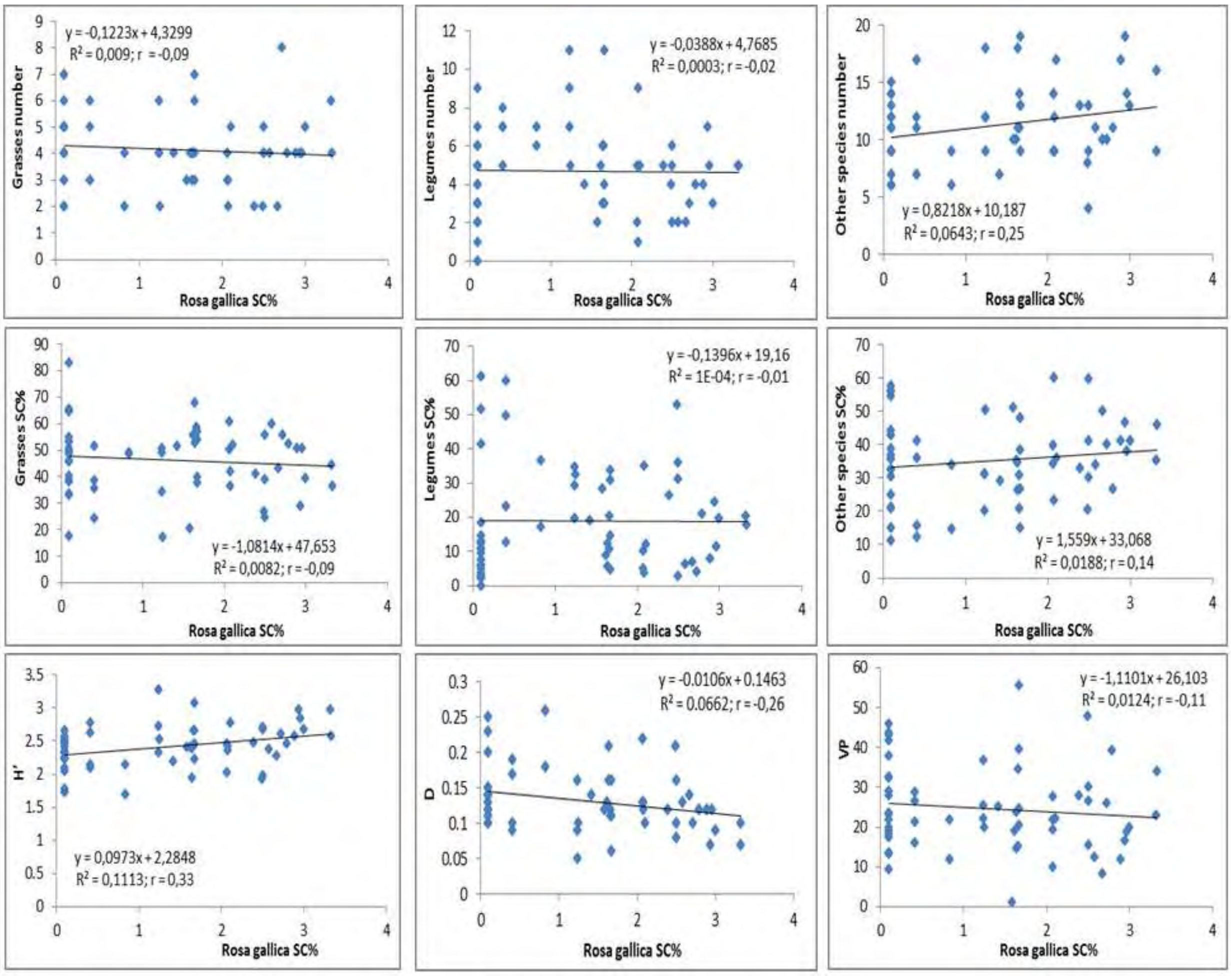

Figure 1: Relationship between *Rosa gallica* L. contribution in sward and vegetation parameters (number of grasses, legumes and other species number, contribution of grasses, legumes and other species, H', D and VP).

The floristic composition of the analysed sward is presented in table 3. Variability of grasses SC% was very high with the lowest value in 2006 in V4 (17.1%) and V3 (17.5%) and the highest in 2005 in V10 (82.9%). Chemical fertilisation exerted a greater effect on grasses than organic ones. Legumes were absent in 2007 in V6 (0%) and the greatest contribution was found in 2003 in V3 (61.2%) and V2 (60.0%). Organic fertilisation generally caused an increase of their contribution in the vegetation cover.

Regarding the contribution of species from other families, the lowest value was determined in 2005 in V10 (11.2%) and the greatest in 2006 in V8 (60.0%) and in 2008 in V5 (59.6%).

Table 3: Evolution of the botanical composition depending on fertilisation variants.

	Species number						Specific contribution (%)					
	Grasses		Legumes		Other families		Grasses		Legumes		Other families	
	2004-06	2007-09	2004-06	2007-09	2004-06	2007-09	2004-06	2007-09	2004-06	2007-09	2004-06	2007-09
V1	3.7	4.3	5.3	8.3	8.3	17.7	50.4	40.8	16.2	23.5	33.3	35.7
V2	3.7	4.0	5.0	8.0	8.3	16.3	41.9	42.4	28.5	26.2	29.6	31.4
V3	4.3	4.0	6.0	5.0	11.0	12.0	41.2	54.7	29.9	14.2	28.9	31.1
V4	3.7	3.7	5.0	5.7	11.3	10.7	30.0	45.2	34.6	19.9	35.4	34.9
V5	4.7	3.3	3.3	5.0	10.7	9.3	54.2	37.8	16.8	18.5	29.0	50.4
V6	3.3	4.0	4.3	4.0	11.3	10.3	46.0	42.1	17.9	18.2	36.1	39.7
V7	4.0	3.7	4.0	4.3	10.0	12.3	42.3	48.1	21.2	17.2	36.4	34.8
V8	5.0	4.0	5.0	5.3	11.7	13.0	46.7	48.1	21.0	15.1	32.4	36.8
V9	5.7	4.7	2.7	3.3	9.7	14.7	53.6	55.4	14.3	6.9	32.1	37.6
V10	4.0	5.7	2.0	2.7	8.3	8.7	47.8	55.6	12.2	7.2	40.0	37.2

Conclusions

French rose is a shrub species that can become a problem by diminishing the useful surface in case of the absence of the grassland use. When the biomass is harvested by cutting, it can maintain itself at a relatively constant low contribution in the vegetation cover independently from fertilisation level. It is recommended to cut unconsumed plants of *R. gallica* after the end of a grazing cycle, in a way to prevent its encroachment.

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Influence of *Prunus spinosa* L. shrub on the grassland vegetation in western Romania

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Abstract

Prunus spinosa L. is a shrub species that is leading the permanent grassland to the shrub-land successional phase. This species has a great occurrence in western Romania and is difficult to control it because it has a great ability of vegetative spreading from roots. The massive presence of this species in some grassland is due mainly to the abandonment and to the diminishing of the livestock. The vegetation was analysed with the linear point-quadrat method. This work has in view to analyse the influence of this species on some vegetation parameters as species richness, number of grasses, legumes and other species, contribution of grasses, legumes and other species, biodiversity indexes (Shannon – H' and Simpson – D) and pastoral value (VP).

Keywords: *Prunus spinosa* L., vegetation, grassland, floristic composition, correlation.

Introduction

Prunus spinosa L. (blackthorn) belongs to *Prunus* genus from the *Rosaceae* family. It grows wildly in various regions (Marakoglu *et al.*, 2005) as Europe, Asia, North Africa and North America from lowland to highland (1000 m) (Pârvu, 2000). It has a great capacity of vegetative spreading, invading the open land areas forming dense and spiny brushwood (Pârvu, 2000).

After Gardiner & Vaughan (2009) after two years of management by hay cutting and shrub (*P. spinosa* and *Rubus fruticosus*) clearance, the floristic species richness doubled. Shrub clearance also prevented *R. fruticosus* and *P. spinosa* from further smothering the grassland flora.

Temperate woodlands and meadows support a variety of thorny shrubs (such as blackthorn *Prunus spinosa* L., *Crataegus* spp. and *Rosa* spp.) that are light-demanding and occur mostly along forest edges (Stortelder *et al.*, 1999 cited by Bakker *et al.*, 2004).

Another good method for the maintenance over the years of a relatively constant coverage of *P. spinosa* in grassland without clearing the land is the grazing with goats (Rahmann, 2004).

Material and methods

The researches presented in this work were carried out during 2003 – 2008 on two permanent grasslands, one steppe type from Cheglevici and one forest steppe type from Surduc (Timiș County, Romania). The coverage index of *P. spinosa* was determined on a permanent quadrate transect of 100 square meters. The herbaceous vegetation data was determined using the linear point-quadrat method. The vegetation parameters analysed were: species richness, number of grasses, legumes and other species number, contribution of grasses, legumes and other species, Shannon index (H'), Simpson index (D) and pastoral value (VP) on 0-100 scale. The statistical method used is Pearson's correlation coefficient.

Results and discussion

Grassland from Cheglevici is dominated by *Cynodon dactylon* and *Bromus hordeaceus*. In the vegetation sward have an important contribution *Achillea millefolium, Polygonum aviculare, Geranium pratense* and *Prunus spinosa* (Table 1). The species number was comprised between 21 and 30, respectively the grasses number was between 3 and 4, legumes between 2 and 4 and species from other botanical families between 15 and 20. The contribution of the grasses is relatively low being comprised between 17.65% and 35.83%. The contribution of legumes was comprised between 0.82% and 6.95%, and the SC% of the species from other botanical families has a high value, being comprised between 62.49% and 75.59%. H' values obtained were characteristic for an average to high biodiversity (2.36 – 2.96), but the values obtained for D were typical for high diversity (0.06 – 0.14). The high values of biodiversity are due to the great number of annual weeds. The values calculated for VP were very low (14.58 – 18.93) highlighting that the species without or with low forager value have the most important contribution in the grassland sward.

Table 1. Synthesis of the taxa from the grasslands from Cheglevici and Surduc (2003 – 2008).

Cheglevici	Surduc
Grasses: *Cynodon dactylon , Bromus hordeaceus, Alopecurus pratensis, Lolium perenne, Poa pratensis, Poa annua*	**Grasses:** *Agrostis tenuis. Festuca rupicola, Holcus lanatus, Festuca pratensis, Anthoxanthum odoratum*
Legumes: *Medicago lupulina, Lotus corniculatus, Lathyrus tuberosus, Trifolium pratense, Ononis arvensis, Vicia angustifolia, Vicia cracca, Vicia grandiflora*	**Legumes:** *Lotus corniculatus, Medicago lupulina*
***Juncaceae* and *Cyperaceae*:** *Carex praecox, Luzula avensis*	***Juncaceae* and *Cyperaceae*:** none
Other species: *Achillea millefolium, Daucus carota, Geranium pratense, Cirsium undulatum, Cichorium intybus, Eryngium campestre, Carlina vulgaris, Polygonum aviculare, Dipsacus fullonum, Xanthium italicum, Agrimonia eupatoria, Scabiosa ochroleuca, Plantago lanceolata, Symphythum officinale, Pastinaca sativa, Inula helenium, Verbascum phlomoides, Linaria vulgaris, Convolvulus arvensis, Capsella bursa pastoris, Carduus acanthoides, Chenopodium album, Taraxacum officinale, Lamium purpureum, Silene alba, Myosotis arvensis, Veronica hederifolia, Adonis estivalis*	**Other species:** *Erygeron anuus, Mentha arvensis, Bellis perennis, Hieracium pilosella, Thymus serpyllum, Gallium verum, Euphorbia cyparissias Erygeron canadensis, Daucus carota, Plantago lanceolata, Hypericum maculatum, Rumex acetosella, Pimpinela major, Viola odorata, Potentilla argentea, Ranunculus acris, Eupatorium cannabinum, Rudbeckia laciniata, Cirsium arvense, Veronica chamaedrys, Pimpinela major, Carpesium cernuum, Leontodon autumnalis, Carthamus lanatus*
Shrubs: *Rosa canina, Prunus spinosa*	**Shrubs:** *Prunus spinosa, Rosa canina, Rubus caesius, Crataegus monogyna*

Grassland from Surduc is dominated by *Agrostis tenuis* and *Festuca rupicola*, there being present in an important amount *Holcus lanatus, Plantago lanceolata* and *Daucus carota* (Table 1). The species richness was comprised between 21 and 25, respectively the grasses number was between 3 and 5, legumes between 1 and 2 and species from other botanical families between 15 and 21. The contribution of the grasses is high being comprised between 50.62% and 70%. The contribution of the legumes was comprised between 0.4% and 5.42% and the SC% of the species from other botanical families was between 29.6% and 52.48%. H' values obtained were characteristic for an average biodiversity (2.04 – 2.53), but the values obtained for D were typical for high diversity (0.12 – 0.21). The values calculated for VP were low to medium (26.94 – 41.04).
In Figure 1 is presented the evolution of *P. spinosa* coverage index along the time during the study. The values registered in Surduc (9.63% – 31.56%) were lower than in Cheglevici (3.75% - 15.27%).

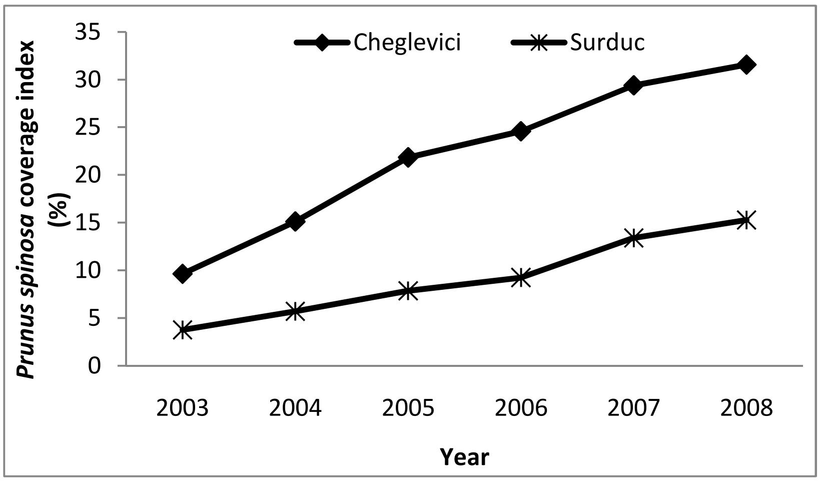

Figure 1: Evolution in time of *P. spinosa* coverage index

The analysis of the influence of the *P. spinosa* coverage index on the vegetation of both grasslands was realised with the help of the correlation coefficients (*r*) and determination coefficients (R^2) among *P. spinosa* coverage index and species richness, number of grasses, legumes and other species, contribution of grasses, legumes and other species, H', D and VP (Table 2).

Table 2: *r* and R^2 among *P. spinosa* coverage index and species richness, number of grasses, legumes and other species, contribution of grasses, legumes and other species, H', D and VP (α = 0.05; one-tailed test; *df* = 5; ^{ns} p > 0.05, * p < 0.05, ** p < 0.025, *** p < 0.01)

Specification		Species richness	Number of grasses	legumes	others	SC% grasses	legumes	others	H'	D	VP
Cheglecivi	*r*	0.29^{ns}	0.02^{ns}	0.43^{ns}	0.18^{ns}	-0.42^{ns}	0.31^{ns}	0.43^{ns}	0.26^{ns}	-0.11^{ns}	0.12^{ns}
	R^2	0.09	0.00	0.19	0.03	0.18	0.10	0.17	0.07	0.01	0.01
Surduc	*r*	-0.83***	0.10^{ns}	-0.14^{ns}	-0.66*	-0.66*	-0.32^{ns}	0.81**	0.41^{ns}	-0.61^{ns}	-0.68*
	R^2	0.69	0.01	0.02	0.43	0.44	0.10	0.63	0.16	0.38	0.46

The obtained correlation coefficients were different between the analysed grasslands. In the case of grassland from Cheglevici there wasn't any correlation between the analysed variables, even it has a greater coverage index of *P. spinosa*. The correlation coefficients obtained for the grassland from Surduc were the following: strong negative relationship with species richness (*r* = –0.83), medium strength positive relationship with the contribution of the species from other families (*r* = 0.81), and weak negative relationship with the number of the species from other families (*r* = –0.66), grasses contribution (*r* = –0.66) and pastoral value (*r* = –0.68).

Other researches from literature have shown that the effects of shrub encroachment on plant diversity are ambiguous (Pihlgren, 2007). Some studies have demonstrated negative effect of shrubs on plant diversity (Lindborg & Eriksson, 2004 cited by Pihlgren, 2007) and other correlation analyses showed that increasing proportion of the pasture area covered by shrubs had a positive effect on species richness on most taxa (Söderström *et al*., 2001).

Conclusions

The encroachment of *P. spinosa* in grasslands has different influence on the vegetation sward, from the point of view of the coverage index of the shrub and the management intensity. At lower coverage indexes *P. spinosa* can determinate the decrease of the species richness, the contribution of the species from other families increasing instead of the decrease of their number of taxa. Also, the increase of the contribution of the taxa from other families is determining a lower pastoral value. Other values of the coverage index aren't determining significant changes on the vegetation cover.

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A typology to characterize grasslands in uplands dairy farms

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Abstract

In upland areas, semi-natural grasslands assure a link between products and territory. They provide specific qualities for animal products, supply environmental services and open landscapes. Rules on PDO cheeses of Massif central set grassland at a key point of the forage system for farms involved in the labelling process. Local stakeholders are also interested in the characterization of the services provided by grasslands: forage production, biodiversity, other environmental services and organoleptic and nutritional properties of cheeses.
The multidisciplinary project "Prairies AOP" built a typology-tool to characterize grasslands. It is based on a network of 75 plots in which botanic composition and agronomic measurements were realised. A multidisciplinary expertise was used to characterize services like biodiversity, C-Storage, cheese quality. Twenty vegetation types (VT) were identified by combining descriptive and functional data. Agro-ecological conditions, vegetation characteristics and services, included quality of animal products, typify each VT. The tool includes an identification key and the index cards of each VT. This typology shows the multifunctional aspects of grasslands and constitutes therefore a useful tool for stakeholders to think the future of livestock farming in upland areas.
Keywords: PDO cheese sector, multifunctionality, ecosystem services, multidisciplinarity, dairy production, permanent grasslands

Introduction

In uplands dairy farms in Massif central, grasslands represent the major part of the cultivated area. They exhibit a great diversity resulting from soil and climate variability and management diversity. Those factors influence botanical composition and agricultural or environmental performances of the grasslands. Breeders and advisers have difficulty to deal with this great diversity and want to get simple tools describing vegetation and giving its potentials. Moreover, rules on PDO cheeses production of the Massif central set grasslands as a key point of the forage system (cutting and grazing). Studies in PDO farms have shown that grasslands are under-used and that their management could be improved with better knowledge of their potential and with coherent practices regarding the functioning of vegetation (Theau *et al.*, 2009). The stake is to promote and improve the use of grasslands to guarantee the economic durability of farms, the biodiversity of grasslands and the quality of cheeses. To achieve this goal, a typology-tool to characterize grasslands was designed, as a part of the research-development program "Prairies AOP"[1] involving 14 research, extension and education partners (Carrère *et al.*, 2008).

Material and methods

To characterize at the same time the vegetation, the production potentials and their evolution, the management and environmental conditions and the quality of cheeses, we combined a botanical and an agronomic approach. The data came from a network of 75 plots from 15 dairy farms chosen to cover a wide range of environmental and management conditions. Surveys identifying farmer practices, agronomic and phytosociologic measurements were carried out. The agronomic samples were realised in

[1] http://www.prairies-aoc.net/

the dominant vegetation community of each plot four times during the grazing season. The phytosociologic samples were realised in all communities and then organized using phytosociology taxonomy (Braun-Blanquet, 1932). These data allow us to describe the vegetation from an ecological point of view. The combination of these agronomic and phytosociologic data with multidisciplinary expertises designed the typology.

Results and discussion

The twenty vegetation types (VT) identified were organized considering agro-ecological characteristics (altitude, moisture, management, fertility). The table 1 shows an example for highland VT (between 1000 and 1300 m a.s.l.). The same organization was done for lowland (less than 1000 m a.s.l.) and mountain (more than 1300 m a.s.l.) VT.

Table 1: Organization of the eight highland VT considering agro-ecological characteristics
In this table, the class of moisture is from 1 (dry) to 5 (very damp) and the class of fertility from 1 (poor) to 5 (very fertile) (classes defined by a group of experts). The characteristic species help the user to confirm the type of vegetation but are not always dominant species.

VT code	Class of altitude	Dominant practice	Class of moisture	Class of fertility	Number of phytosociologic data	Number of agronomic data	Number of plots	Characteristic species
1	High	Mowing (late)	2	4	7	33	5	*Knautia arvernensis* and *Trisetum flavescens*
2	High	Mowing	2	5	3	13	2	*Apiaceae*
3	High	Mowing	3	4	4	7	1	*Sanguisorba officinalis*
4	High	Mowing (early) or pasture	2-3	5	7	12	2	*Rumex* spp., *Bromus mollis* and *Phleum pratense*
5	High	Pasture	2	1-2	15	16	3	2 types: with *Festuca* gr. *ovina* and/or *Brachypodium pinnatum* OR with *Nardus stricta*
6	High	Pasture	2-3	3	4	6	2	*Alchemilla xanthochlora* and *Viola lutea*
7	High	Pasture	2-3	4	10	30	5	*Alchemilla xanthochlora* without *Viola lutea*
8	High	Pasture	2-3	5	2	6	1	*Cynosurus cristatus* and *Lolium perenne*

A hierarchical approach considering altitude, practice, moisture and fertility was used to organize the twenty VT (identification key). The several data available for the twenty VT were used to describe each type and were synthesized in index cards. These cards present seven main parts (table 2): (i) code, name and photo of the type, (ii) agro-ecological conditions, (iii) vegetation composition, (iv) agricultural and environmental potentials, (v) agricultural and environmental services and quality of cheeses, (vi) dynamics of VT under perturbations and (vii) a synthesis with strengths and weaknesses. The typology includes also attached documents describing the calculation methodology, supplying additional data and instructions for use.

Conclusions

We created a simple tool although it results from a large analysis work of all the partners. The typology shows the impact of environment and management conditions on vegetation composition and on the dynamics of herbage biomass and quality during the season. This typology ensures a link between agricultural and environmental potentials but also with quality of cheeses. To turn the presented prototype into a real tool we have to validate it during this spring (2011) and train the future users. To conclude, this typology shows the multifunctional aspects of grasslands and constitutes therefore one of the tools available for stakeholders to think the future issues of livestock farming in upland areas.

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Table 2: Organization of index cards with descriptive and functional data and their sources

Main parts	2nd level of organization	3rd level	Sources
Code, name and photos of type			
Agro-ecological conditions	Environment conditions		Phytosociologic and agronomic data
	Management conditions		Agronomic data and farms' surveys
Vegetation composition	Proportions of grasses, legumes and forbs and their evolution during spring		Agronomic data
	Dominant species	Functional types composition (Cruz et al., 2010) and its evolution during spring	Agronomic data
	Characteristic species	Species of specific environmental conditions and of specific management conditions	Phytosociologic data
Agricultural and environmental potentials	Quantity	Biomass quantity and its evolution during spring + indicator of phenology	Agronomic data
	Quality	Biomass quality and its evolution during spring	Agronomic data, Baumont et al (2009) and INRA (2007)
	Soil information		Agronomic data
	Indicators of biodiversity		Phytosociologic data
Agricultural and environmental services and quality of cheeses	Agricultural services	Agricultural use value (production patterns and levels, feed value)	Agronomic data and Duru *et al.* (2010)
		Dairy production allowed by pasture or hay	Agronomic data and INRA (2007)
	Environmental services	Carbon storage	group of experts
		Habitats	Natura 2000 and Corine Biotope
		Diversity of flowers' colours Capacity for having pollinators Capacity for having fauna	Phytosociologic data and Orth et al. (2008)
	Services for quality of cheeses	Sensorial compounds Nutritional compounds	group of experts
VT dynamics			group of experts
Synthesis	Strengths Weaknesses		group of experts

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The Protective Significance of Meadows and Pastures for the Natural Environment of the Western Carpathians (as an Example of the Upper Dunajec River Basin)

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Abstract

In the mountain areas of southern Poland, significant structural changes occurred during the years 1995-2007, particularly in the catchment areas of the Upper Dunajec River basin. The share of arable lands decreased in the range of 17.7 – 27.6 % of the total area. Simultaneously the area of permanent grasslands (meadows and pastures) increased from 9.8 to 21.1%. The objective of the work is to evaluate selected quality features of the environment, particularly surface water, under the condition of a large contribution of permanent grassland. This aim was achieved in the Białka catchment region where arable land amounted to 16.2 % and pastures and meadows to 83.7% of the total area.
At several points on the Białka River the concentrations of nutrients e.g. $N\text{-}NH_4$, $N\text{-}NO_3$, and PO_4 was monitored. Studies showed that surface water quality in this catchment area was very good, in the range of 1st class. However, other studies done in the area with a larger share of arable land revealed that nutrient concentrations were of 3rd class quality or lower. Therefore, it has been concluded that mountain grasslands fulfil an important protective role for surface water quality.

Keywords: Western Carpathian, meadows, pastures, environment, nutrients

Introduction

The quality of water flowing from agricultural areas depends on land use and the intensity of agricultural production. The concentration of chemical components, especially $N\text{-}NO_3$ in drainage waters from intensively fertilized arable lands may be about 5 times higher compared to permanent grasslands (Koc et al, 1996). Similar variations of $N\text{-}NO_3$ concentration were found in lysimeter studies comparing crops that required mechanical cultivation and permanent pasture (Smoroń et al. 1996). The quality of surface water also depends on factors associated with human activities and existence (Gałka, Strutyński, 2003; Pawlik-Dobrowolski, 1990; Smoroń, Twardy, 2001).
The aim of this study was to assess ***qualitative characteristic of the environment***, in particular surface water quality under dominance of low intensive permanent grassland mainly fertilised with manure. .

Material and methods

The study was conducted from 2002 to 2007 in the high relief Białka catchment region located in the Western ***Carpathians*** in the South of Poland (Atlas ..., 1985; Niedźwiedź, Obrębska–Starklowa, 1991). The investigated area is characterised by a small share of arable land and a large contribution of permanent grasslands. Forest covers the main part of the whole catchment area (41 %). The structure of agricultural lands is composed of 16.2% arable lands, 83.7% pastures and meadows and only 0.1% orchards.
In the Białka river catchment, five water sampling points were determined: Point No. 1 is an affluent of Brzegi stream situated in an uninhabited region with forests covering 80% and permanent grasslands 20% of the area. Point No. 2 is situated in a lower part of the Brzegi stream, distanced about 2.8 km from point No. 1. This part of the catchment is dominated by grasslands and forests. It undergoes strong human pressure. Over 1000 people live on the neighbourhood, resulting in a high concentration of stables and manure storages. Point No. 3 is a thickly wooded and 95% uninhabited area where the Białka river flows. Point No. 4 corresponds to the area where Białka river approaches the "Czorsztyn-Niedzica" reservoir. Point No. 5 is located on the Kaniowski stream, which waters come from an area covered with 90% of grasslands from a few farms. The territory situated between points 3 and 4 is covered by 55% permanent grasslands and 25% arable lands.
Water samples were collected monthly in order to analyse their concentration in $N\text{-}NO_3$, $N\text{-}NH_4$, PO_4. The results of water monitoring obtained were compared with those issued from the Szreniawa River,

which flows through the Proszowice plateau located to the North of Krakow. In this region, arable lands occupy almost 91.3%, while permanent grassland only 7.6 % of the agricultural area (Smoroń et al., 2009) and root crops, vegetables and industrial crops are intensively cultivated.

Results and discussion

Based on the analysed components, the best quality water was found in the Brzegi stream source area (Point No. 1). The concentrations of PO_4 and $N\text{-}NH_4$ were the lowest of all measurements, with on average 0.03 and 0.06 $mg \cdot dm^{-3}$ respectively. $N\text{-}NO_3$ content reached 0.51 $mg \cdot dm^{-3}$. Compared to the other sampling points, the water in point No. 2 had the worst quality with average concentrations of 0.18, 1.71 and 0.25 $mg \cdot dm^{-3}$ of $N\text{-}NH_4$, $N\text{-}NO_3$, and PO_4, respectively, and maximum values of 0.45, 2.14 and 1.04 $mg \cdot dm^{-3}$, respectively. The water quality of the Bialka river at point No. 3, above the mouth of the Brzegi stream, was slightly worst than at point No. 1. Phosphate concentration was more than two times greater, 0.07 mg $PO_4 \cdot dm^{-3}$ on average. At the Kaniowski stream (point No. 5), with waters flowing from permanent grasslands, average concentrations of $N\text{-}NH_4$, $N\text{-}NO_3$, and PO_4 were similar to those at point No. 3. In the subsequent course of the Białka river, carrying water from the above sub-basin (point No. 4 – the village Trybsz) concentrations reached an average of 0.11, 0.64 and 0,06 $mg \cdot dm^{-3}$ of $N\text{-}NH_4$, $N\text{-}NO_3$, and PO_4, respectively. Flowing water collected from areas with a very high proportion of arable lands in the Szreniawa area, located on the Proszowice plateau, was significantly higher than in the Białka river catchment. The average concentrations of $N\text{-}NH_4$, $N\text{-}NO_3$, and PO_4 amounted 0.73 (SD = 0.46), 4.10 (SD = 0.44) and 0.47 $mg \cdot dm^{-3}$ (SD = 0.15), respectively. Studies conducted allowed us to determine the quality of surface water running off steep mountain areas characterized by very high contribution of forests, permanent grasslands and slight arable lands cover. The human pressure gradient could also be highlighted. The catchment waters quality dominated by grasslands (point No. 5) was maintained at high level, comparable (especially in terms of nitrogen and phosphate contents), to the one from the source waters of the Brzegi stream (point No. 1) and that flowing from forested areas (point No. 3).

Based on the studied components, waters were ranged around the Ist class of surface water quality (Regulation ...., 2004). This indicates clearly that a low-input grassland system, based on natural fertilizers originating from livestock and small amounts of mineral fertilizers, influenced water quality profitably.

The Brzegi stream water quality determined at the mouth of the Białka (point No. 2) was very poor. Concentrations of PO_4 were 8 times greater and for $N\text{-}NO_3$ and $N\text{-}NH_4$ about 3 times greater than in the source of the Brzegi stream. This resulted from strong human pressure exerted by a high number of residents living in a small area, who were unable to take advantage of a sewerage system (Raczak, 2002; Pawlik-Dobrowolski, 1990). According to National Ordinance (Rozporządzenie Ministra Środowiska, 2004), water from point no 2, in terms of PO_4 concentration, was ranged around IInd class quality during the whole research period, and was one class worse in 2005- 2006. For $N\text{-}NO_3$ concentrations, water was of IInd class quality.

To properly define the impact of low productive agricultural activity on the natural environment, especially hydrous balance, it is necessary to take under consideration demographics. This is particularly relevant in areas with strong declivity, especially with regard to maladjustments in the level of infrastructure conditions related to protecting the environment in a way appropriate to the inhabitants needs. (Smoroń, Twardy; 2001). Water quality from the Szreniawa catchment area, with a very high contribution of arable land that has intensive mechanical root crop cultivation, was much poorer. Average annual concentrations of $N\text{-}NH_4$ in relation to the Białka river water flowing from areas dominated by grasslands, were 15 times larger, $N\text{-}NO_3$ and PO_4 about 7 times larger. In the case of annual crop rotation, the agricultural areas are not fully covered by vegetation, conducive to a water erosion process and to nutrient penetration into ground waters.

Conclusions

1. The water quality of the Białka river catchment from the source areas of water courses, which are dominated by woodlands and permanent grasslands, is characterized by low nutrient concentrations, which places them within the border of Ist Class surface water quality.
2. The basic factor significantly deteriorating water quality in some fragments of the analysed region, especially in terms of phosphate, and nitrate nitrogen, was anthropopression caused by a high population density and concentration of livestock buildings located near the watercourses.

3. The quality of water flowing from areas with a large contribution of arable lands was much worse than in comparison to the areas dominated by permanent grasslands.
4. Mountain grasslands have a crucial meaning with regard to the protection of the natural environment, in particular a favourable influence on the qualitative state of water resources.

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Evaluation of sheep production systems in central Greece

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Abstract

Sheep farming is one of the most important sectors of the rural areas in Greece. In this study the production system of sheep was investigated based on questionnaires which were addressed to all the farmers (n=60) of the six districts of the municipal of Koilada, Larissa Prefecture, central Greece, during the summer of 2010. It was found that the existing sheep production system is based on grazing of communal natural grasslands, on temporary pastures (annual winter cereals) and cereal stubble fields after crop harvesting. However, farmers also extensively utilize purchased feedstuffs, especially concentrates, in order to improve animal performance resulting in semi-intensive production system.

Keywords: dairy sheep, farmers' characteristics, rural areas

Introduction

Sheep represent 9 million heads and are considered as the most significant livestock sector in Greece from an economic, cultural and environmental point of view. Most of these animals (85%) are extensively managed in marginal areas and produce milk which is transformed mainly into *feta* cheese. Due to the great significance of the sheep farming, several researches have been carried out regarding the economics and viability of this sector as well as the potential for further improving its competitiveness (Rancourt et al. 2006, Aggelopoulos et al. 2009). However, information concerning the characteristics of the sheep production system and the use of natural resources by grazing animals is relatively limited (Yiakoulaki et al. 2003, Evangelou et al. 2008). The aim of this study was to evaluate the sheep production system in a typical area of central Greece.

Material and methods

The research was conducted in the municipal of Koilada, which is located in the south-western part of the prefecture of Larissa in central Greece, during the summer of 2010. The climate is moderate in winter with high temperature in the summer. Mean annual precipitation is 425 mm and mean air minimum temperature is 8 ^{0}C, indicating a semi arid Mediterranean climate. Topography varies with the flat areas occupied by arable lands and the hills and mountains covered by natural vegetation. The latter is dominated by evergreen shrub lands mainly composed of kermes oak (*Quercus coccifera* L.) interspersed by openings with herbaceous species. The production system of sheep was investigated based on questionnaires that were personally addressed to all the farmers (n=60) of the six districts (Amygdalea, Eleftheres, Koilada, Koutsochero, Loutro and Rachoula) of the municipal of Koilada. All the farmers responded to the questionnaire. The questions concerned the animal capital, the characteristics of the exploitations, the farmers' profile, the utilisation of natural resources (communal natural grasslands, artificial pastures, fields of cereal stubble after harvesting, season of grazing, transhumance, etc), the supplemented feedstuffs (kind, quantity, cost, feeding time), the milk yields and the prolificacy. In addition, population and livestock data were collected for the six municipal districts. Domestic animals were not included in the research.

Results and discussion

Farm characteristics-Farmers' profile

The 2.3% (n=60) of the registered residents of the area were flock owners (Table 1) and they participated in the research. They were generally men (90%) in late middle-age (mean=56 years). More than the half of them (52%) earned their income directly from farming exploitation while the income of the rest came from farming along with agriculture. All of them said that they practice farming traditionally without any kind of training and that they need to learn new ways to manage their farms in order to address environmental concerns. The majority of the farms (67%) were family exploitations, while 30% of them were individual exploitations. Very few (3%) reported that their farms were families' partnerships. In 68% of the exploitations, one to two family members contributed to the total non-paid necessary labour while for the rest of them more than two family members are employed. The majority (71%) employs one shepherd that is not member of the family while 29% employ 2-3 non-family shepherds. The 65% of the holdings are located outside of the residential area and 90% of the building facilities are of low investments as they are old-fashioned. The majority of them (87%) have no milking facilities.

Animal capital

Livestock is composed of 13.298 sheep and 845 goats distributed in 60 exploitations (Table1). The majority of the farmers (78%, n=51) owns sheep flocks and the rest (22%, n= 9) keeps mixed sheep and goat flocks. 60% of the farmers has small size flocks (less than 200 animals) and only the 10% of them keeps more than 500 animals. One quarter of the sheep belongs to the Greek breeds *Karagouniko*, *Chios* and *Skopelou*, a small proportion (2%) is of the *German* breed and the rest are cross-bred of *Karagouniko* with other breeds such as *Lacaune, Chios* and *German*. 65% of the sheep are raised as double-purpose animals (milk and meat) while 35% are raised only for milk.

Table 1: Human population, exploitations, animal number and available forage resources (ha)

Municipal Districts	Registered residents	Livestock Exploitations	Number of animals		Communal Grasslands	Artificial Pastures	Cereal Stubble
			Sheep	Goats			
Amygdalea	343	13	3.063	105	210	19.5	330
Eleftheres	421	4	152	0	90	2.5	30
Koilada	683	6	1.220	0	50	44	215
Koutsohero	320	11	2.570	260	550	45	348
Rachoula	562	6	890	0	75	18.5	212
Loutro	303	20	5.403	480	500	84.5	360
Total	2.632	60	13.298	845	1475	214	1495

Farming system characteristics

The majority of the animals (77%) remains in the study area grazing around the villages, without changing base throughout the year, whereas less than a quarter (23%) moves out during summer, practicing transhumance. They move towards the region of Kalambaka in the prefecture of Trikala (around to 70 km). The animals leave at the end of May and most of them return at the end of October. They are transported by rented trucks which representing a cost ranging from 1.5 to 3 €/animal/route.

Grazing time of sheep on available forage resources is presented in Table 2. The natural grasslands are the most important source of grazing for sheep as they are utilized throughout the year by the majority (65%) of the farmers. 16% and 19% of the respondents said that they don't graze their flocks in grasslands during the summer and winter period, respectively. In addition, the majority of the farmers (73%, n=44) uses alternative resources. These include artificial pastures with annual winter cereals (86%) grown in private (43%) or rented lands (57%), which are used for grazing in late winter-early spring. The use of cereal stubble fields after crop harvesting in order to cover the feed gap during summer is also a common practice for 68% (n=41) of the respondents. Besides, it has been found (Yiakoulaki and Papanastasis, 2003; 2009) that cereal crop residues provide a satisfactory feed for both sheep and goats for this period.

Table 2: Grazing time of sheep on available forage resources and (%) of farmers using feedstuffs

Grassland grazing	Alternative grazing resources	Grazing time ($h\ day^{-1}$) in Grasslands		Grazing time ($h\ day^{-1}$) in artificial pastures		Grazing time ($h\ day^{-1}$) in stubble		Period of feedstuff supply	Farmers using feedstuffs (%)	
All year round	a. Artificial Pastures (December-May)	Winter	3	Winter	2	Winter	-	All year round	Winter	100
		Spring	7	Spring	3	Spring	-		Spring	89.5
	b. Stubble (June-August)	Summer	3	Summer	-	Summer	6		Summer	51.5
		Autumn	6	Autumn		Autumn	-		Autumn	77.4

On the other hand, all farmers extensively utilize complementary purchased feedstuffs for their animals (Table 2), in order to increase milk production. Feedstuffs, mainly roughages and concentrates (corn, wheat, barley, oats, alfalfa hay, wheat straw, cotton seed cake, beet pulp) are used during the entire period of the year, thus making the production system semi-intensive. based to a large extent on EU subsidies.

The farmers received 30.7 € per head of eligible animals. The amount of provided feedstuffs depends on the season, the weather conditions and the physical status of the animals. The provided feedstuffs to the animals throughout the year as well as their cost are presented in Table 3. The overwhelming majority (97%) use supplements (salt and blocks of vitamins A, D, E and trace elements Cl, Na, Ca, P, Fe, Co, Zn, Mn, Se) throughout the year. The supplements are placed by the farmers in the feeders so that the animals have free access to them. The cost of salt varies between 0.15-0.20 €/kg, and the cost of the blocks ranges from 1-1.30 €/kg.

Table 3: Feedstuffs and purchased feedstuffs cost throughout the year

Feedstuffs	Winter		Spring		Summer		Autumn	
	(kg/day/anim)	Cost (€/kg)	(kg/day/anim)	Cost (€/kg)	(kg/day/anim)	Cost (€/kg)	(kg/day/anim)	Cost (€/kg)
Concetrates	1.0	0.20	0.7	0.14	0.4	0.08	0.7	0.14
Alfalfa hay	0.7	0.14	0.4	0.08	0	0	0.6	0.12
Wheat straw	0.3	0.03	0.2	0.02	0	0	0.2	0.02
Total	2.0	0.37	1.3	0.24	0.4	0.08	1.5	0.28

Births-Milk production

Hormonal synchronization and stimulation of oestrus are not used. The ewes are mated in May and June and parturitions occur from October to November. The prolificacy index ranges from 1.3 to 1.6. 2/3 of the lambs is slaughtered after weaning (40days) while 1/3 is kept as store lambs. The carcass weight of lambs ranges from 8-10 kg and the price ranges from 4.5 to 5.5 €/kg. The ewes are usually milked for 6-7 months/year and the mean annual milk production ranges from 120 to 150kg. The milk is sold to dairies, located within the prefecture of Larissa, and it is used for the production of cheese and yogurt. The selling price of milk ranges from 0.93 to 1 €/kg.

Conclusions

The deficient use of the available forage resources by grazing sheep along with the extensive use of purchased feedstuffs constitute considerable weaknesses of the existing sheep production system. Its potential for restructuring should be considered in order to increase the utilisation time of forage resources by grazing through offering a high quality feed to cover the animal needs

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Technical and economic factors affecting the profitability of mountain grassland-based organic farms in the years 2004-2009

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Abstract

Studies performed with the method of steered interview were carried out in 2004–2009 in grassland-based organic farms, in 9 farms in mountain areas and in 32 farms in lowland voivodships. The mean agricultural area (AA) in the studied farms was 46 ha in 2009. It ranged from 3 ha to 306 ha. Technical (yield and livestock numbers) and economic (standard gross margin per ha of AA and per full-time worker) data were related to other environmental, agricultural and economic characteristics.
Analysed factors included the agricultural area (AA), cow stock, milk efficiency, farmers' age and the value of fixed assets. Low to medium levels of investment in fixed assets and relatively low level of direct costs of plant and animal production was noted in studied farms. Incomes from agricultural production in studied mountain farms were 'medium' to 'low'. They were higher from livestock (cattle and sheep) than from crop productions. Gross margin both per ha AA and per person was 'medium' to 'low' compared to all farms of the country. Incomes of organic farmers were strongly supported by Polish and EU subsidies.

Key words: standard gross margin, subsidies, dairy production, herd size, manpower

Introduction

Organic farming is developing rapidly worldwide and particularly in the EU. Products from such farms are supposed to be healthy and organic farming is usually recognized as environmentally friendly. The demand and the offer of organic products increases. The number of organic farms increases. In Poland, in 1993, there were 255 organic farms (3 500 ha AA), in 2007, 11 877 farms (286 000 ha AA) and in 2009, 17 138 farms (?? ha AA) [Rolnictwo, 2009].
Present and future developments of organic farming is closely influenced by its profitability and competitiveness compared to other agricultural systems. The aim of this study was to analyse technical and economic factors affecting the development of mountain and lowland grassland-based organic farms. The selected factors were related to other environmental, agricultural and economic characteristics of these farms.

Material and methods

Studies were carried out with the method of steered interview in the years 2004–2009 in grassland-based organic farms, in 9 farms in mountain voivodships and in 32 farms in lowland voivodships. The total agricultural area (AA) of the studied farms was 1 892 ha in 2009. The AA of individual farms ranged from 3 ha to 306 ha (average of 46 ha) [Źródłowe, 2005, 2006, 2007, 2008, 2009]. In all farms, the livestock production was based (circa 90%) on their own grasslands. These grasslands occupied at least 30% of the AA [Badania, 2005,2006,2007,2008, 2009].
Direct costs were calculated for the whole farm and separately for plant and livestock productions. The costs of fuel, electric energy and hired labour were distinguished from indirect costs. Standard gross margin (SGM) was adopted as the main criterion for economic assessment of a farm. SGM is a three-year mean value of a given agricultural activity (obtained from a farm, from one ha of arable land or from one animal). Comparison of the revenues with direct costs of farms in the years 2007-2009 gave the 'SGM 2008' [Metodyka, 2000].

Economic and agricultural effects

Yields of main plant crops

The yields of cereals and potatoes in both groups of organic farms (mountain and lowland) were assessed in relation to the soil quality index of arable lands. Cereal yields were slightly higher (by 13.4%) in lowland farms (table 1) while the yields of potatoes were higher in mountain farms (by

22.5%) despite lower soil quality index [Jankowska–Huflejt et al., 2004]. Better production technique, for example larger manpower for weed control, contributed mainly to this effect. In general, crop yields are not always correlated with soil quality (measured by the index of soil quality of arable lands).

Table 1. Mean yields of the main crops in relation to the index of soil quality in mountain and lowland farms in the years 2007-2009

Voivodship		Number of farms	Index of soil quality	Yields in t /ha	
				cereals	potatoes
Mountain	małopolskie	5	30.92	2.78	20.92
	podkarpackie	4	47.7	2.27	19.20
	mean	**9**	**38.91**	**2.53**	**20.06**
Lowland	podlaskie	6	39.58	2.28	11.67
	kujawsko–pomorskie	4	52.61	3.06	16.65
	lubuskie	8	45.48	3.11	19.41
	mazowieckie	6	33.63	2.82	18.85
	pomorskie	5	44.95	3.06	15.31
	mean	36	**43.31**	**2.87**	**16.38**
Mean		45	**42.92**	**2.74**	**17.19**

Farm economic efficiency in relation to the AA, the value of fixed assets and employment
Mountain farms were characterised by a smaller AA (mean 22.8 ha) compared to lowland farms (46.4 ha), by a higher value of fixed assets (14 409 euro ha-1 AA compared to 7 300 euro ha-1 AA) and a higher employment per 100 ha AA (14.4 persons compared to 7.7 persons). At the same time, mountain farms achieved lower 'SGM 2008' both ha-1 AA (675.7 euro) and per person (5 520.4 euro) and lower efficiency of fixed assets measured as the value of SGM per 1 euro of fixed assets. Assuming the SGM per ha AA, SGM per person and the efficiency of fixed assets as 100 in mountain farms, the respective indices for lowland farms would be 107, 217 and 217. It thus appears that the economic efficiency of these production factors is by 7% to 117% higher in lowland than in mountain farms (table 2).

Table 2. The efficiency of area, fixed assets and employment in studied farms in the years 2007-2009 measured with the 'SGM 2008' and percentage share of subsidies in relation to the age of farm owners and the number and dairy production of cows

Voivodship		Mean surface area of AA	Fa-rmer's age	Number of cows	Annual dairy production (l/cow)	Fixed assets per ha AA	Employment per 100 ha AA	'SGM 2008' in euro[1)] per		% of subsidies in the SGM	Efficiency of fixed assets[2)]
								ha UR	person		
mountain	małopolskie	16.59	44.6	3.3	3880	20329	20.4	786.1	4340.2	61.5	0.19
	podkarpackie	30.16	45.9	8.7	3612	8372	8.51	537.6	6995.6	55.4	0.27
	mean	**22.81**	**45.9**	**6.0**	**3746**	**14409**	**14.4**	**675.7**	**5520.4**	**58.4**	**0.23**
lowland	podlaskie	20.97	43.4	12.4	2783	9026	9.81	661.9	10966.3	42.1	0.41
	kujawsko–pomorskie	21.86	47.2	13.0	4060	8120	9.19	692.9	9668.4	30.8	0.64
	lubuskie	66.51	44.3	12.5	3250	4170	3.6	884.7	18308.2	20.0	0.39
	mazowieckie	18.93	46.5	11.5	3489	7633	11.97	665.6	7558.0	37.7	0.53
	pomorskie	94.95	44.3	46.5	4155	7880	5.87	707.5	15591.5	39.3	0.50
	mean for	**46.38**	**45.4**	**21.1**	**3206**	**7300**	**7.75**	**722.8**	**11969.4**	**34.0**	**0.50**
Mean		**40.72**	**45.7**	**15.4**	**3593**	**7228**	**8.01**	**645.2**	**10181.4**	**41.0**	**0.44**

1) 1 euro = 3.8 zł; 2) – measured with the standard gross margin per one euro of fixed assets

This is mainly the result of less favourable natural and economic conditions of farms situated in mountain regions (large altitude differences, worse field accessibility, lower air and soil temperatures, shorter vegetation period). It can be considered that both groups of organic farms were characterised by 'medium' to 'low' incomes from agricultural production, especially from crop production. In the years 2007-2009 the incomes were mainly generated by livestock production, mainly by dairy cows. The 'SGM 2008' was 'medium' to 'low' both calculated per ha AA and per person. The mean value of the SGM per ha decreased with the size of farm and increased with the manpower.
The incomes were largely supported by EU subsidies which constituted on average circa 40% of the GM [Jankowska-Huflejt and Prokopowicz, 2011].

Economic results of organic mountain and lowland farms in relation to the age of farm owners and to the number and milk efficiency of cows in a farm

Economic results of organic farms ('SGM 2008') were analysed in relation to the age of farm owners and the number and annual dairy production of cows in a farm. The importance (contribution) of Polish and European subsidies for the SGM of farms (in %) were also considered (table 2).

The owners of studied mountain farms were slightly older (45.9 years) than the owners of lowland farms (45.7 years). Moreover, mountain farms had fewer cows (6.0 on average) than lowland farms (21.10) but had a higher annual dairy production per cow (3 746 l and 3 206 l respectively). Mountain farms obtained lower SGM per ha AA than lowland farms (675.7 euro and 722.8 euro, respectively or 107% in favour of lowland farms). Per capita value of this parameter was 5 520.4 euro in mountain farms and 11 969.4 euro in lowland farms i.e. by 17% more in the latter. The contribution of subsidies to 'SGM 2008' was higher in mountain (58.4%) than in lowland (34.0%) farms. As already mentioned, this effect resulted from more favourable environmental and economic conditions of the latter. Lower subsidy share in the income of lowland farms resulted from better natural and economic conditions (i.a. more favourable index of agricultural area use). Moreover, 'SGM 2008' in mountain farms was also affected by much higher employment in this group of farms.

From other studies [Prokopowicz, Jankowska-Huflejt 2009], it appears that the highest values of GM (both per person and per ha AA) were obtained in farms where the annual dairy production ranged between 4 000 and 5 000 l per cow. Fixed assets and employment had a limited but positive effect on GM calculated per ha AA and a negative effect when calculated per person and the efficiency of fixed assets. Together with increasing value of fixed assets and with increasing employment per ha AA, the value of GM per ha AA increased and the same value per person employed in the farm – decreased. The efficiency of fixed assets decreased similarly and, moreover, was inversely proportional to dairy production per cow. The increase of dairy production per cow in a farm enforces additional investments in one stall for cows (the quality and value of buildings and facilities for feeding, milking and cooling the milk).

Costs of fuel, electric energy and manpower

The analysis of mean costs calculated per ha AA in both groups of studied farms showed (tab. 3) that in mountain farms the costs of fuel and manpower were lower than in lowland farms and that the costs of electric energy were similar in both groups. Assuming the cost in mountain farms as 100, the respective indices for lowland farms were: fuel – 125, electric energy – 97, manpower – 155. These figures reflect higher intensity of agricultural production in lowland farms.

Table 3. Mean cost of fuel, electric energy and hired labour per farms (2007-2009)

Voivodship	Mean cost in euro ha^{-1}								
	fuel			electric energy			hired labour		
	mean	min.	max.	mean	min.	max.	mean	min.	max.
Małopolskie	94	30	146	40	16	73	21	4	56
Podkarpackie	49	24	75	25	12	49	19	4	48
Mean for mountain farms	**72**	**27**	**111**	**33**	**14**	**61**	**20**	**4**	**52**
Podlaskie	72	29	111	33	14	61	20	4	52
Kujawsko–pomorskie	64	64	99	30	13	57	20	4	51
Lubuskie	78	16	198	14	3	43	30	16	52
Mazowieckie	71	36	136	25	10	53	23	8	52
Pomorskie	101	55	154	41	8	77	64	3	279
Mean for lowland farms	**90**	**44**	**157**	**32**	**12**	**66**	**31**	**10**	**101**
Mean for studied farms	**85**	**39**	**144**	**32**	**12**	**65**	**28**	**8**	**87**

Despite a large demand for manpower to control weeds and protect plants, the farms used hired labour to a small extent which means that their own manpower was sufficient.

Other studies [Prokopowicz and Jankowska-Huflejt 2007, 2008, 2009, Jankowska-Huflejt, Prokopowicz 2011] showed that the costs of fuel, electric energy and hired labour increased with increasing dairy production per cow.

Standard gross margins in mountain and lowland farms in the 2005-2008 period

The analysis of SGM per ha AA (table 4) shows a moderately increasing trend. Mean GM from the four study periods was 708.7 euro ha-1 AA and ranged from 487.3 euro in podkarpackie voivodship to 833.6 euro in lubuskie voivodship. In general, the least favourable were the indices for the year ‘2005’ and those for the remaining years were similar to each other [Prokopowicz and Jankowska-Huflejt 2007, 2008, 2009]. Lowland farms obtained slightly higher SGM than mountain ones. It means that agricultural space is utilised more effectively in lowland farms. Assuming 100 as the value of SGM per ha AA in mountain farms, the respective values for lowland farms were: 111 in ‘2005’, 128 in ‘2006’, 137 in ‘2007’ and 114 in ‘2008’ (mean 121). It thus appears that SGM in the study years was higher by 11-37% in lowland than in mountain farms.

Table 4. SGM in mountain and lowland farms in the 2005-2008 period

Voivodship		Standard Gross Margin (SGM), euro per ha AA or per person									
		2005		2006		2007		2008		Average of the whole period	
		ha	person	ha	person	ha	person	ha	person	ha	person
mountain	Małopolskie	843.0	3999.5	800.2	4561.1	732.9	4488.5	786.1	4340.2	740.5	4347.3
	Podkarpackie	378.5	5286.1	519.8	7295.3	513.1	7431.1	537.6	6995.6	487.3	6752.1
	Mean	**525.4**	**4571.3**	**675.6**	**5776.3**	**635.2**	**5796.4**	**675.7**	**5520.4**	**628**	**5416.1**
lowland	Podlaskie	772.0	8858.1	984.9	11364.6	757.1	10936.1	661.9	10966.3	794.0	10531.3
	Kujawsko–pomorskie	475.2	6131.8	658.8	78810.8	7755.9	9186.1	692.9	9668.4	645.7	8217.0
	Lubuskie	424.3	9180.7	943.8	13739.2	1082.5	17243.2	884.7	18308.2	833.6	14617.6
	Mazowieckie	685.1	6375.4	844.9	7609.8	882.8	4533.8	665.6	4558.0	754.6	7269.2
	Pomorskie	573.5	10347.3	780.6	14314.1	881.4	15871.7	707.5	15591.5	735.7	14031.1
	Mean	**582.9**	**8314.2**	**864.4**	**11271.0**	**871.1**	**13076.8**	**772.8**	**12326.1**	**760.3**	**11247.0**
Mean for studied farms		**586.8**	**6178.6**	**800.5**	**8929.0**	**802.3**	**10213.6**	**645.2**	**9907.2**	**708.7**	**8807.1**

1) for all years, 1 euro = 3.8 zł

SGM calculated per full-time employed person in a farm (table 4) showed a moderately increasing trend. Its mean value from the four three-year-long periods was 8007 euro with the range from 4347 euro in małopolskie voivodship to 14618 euro in lubuskie voivodship. In general, the least favourable was the index for 2005 and the indices for the remaining years were similar to each other. Lowland farms obtained better indices of the GM per person compared with mountain farms. If the index for mountain farms were 100 than the respective values for lowland farms were: 182 in 2005, 195 in 2006, 226 in 2007 and 223 in 2008 (mean 208). It means that lowland farms, despite lower subsidies, obtained SGM higher by 82% to 126% compared with mountain farms. Lowland farms used their manpower resources more effectively, mainly because of better environmental and economic conditions and lower employment.

Performed economic analysis showed that not all organic farms had a chance of further development and investment. Acc. to Józwiak [2008] such a chance have farms of an economic size above 10500-13000 euro, which pertains to c. 69% of studied farms [Prokopowicz, Jankowska-Huflejt, 2009], while 31% of smaller farms will not accomplish necessary (acc. to Kodeks … [2002]) investments like individual sewage treatment plants, slurry tanks or silos.

Conclusions

Economic efficiency of the use of land and labour resources in organic grassland-based farms measured with the SGM per ha AA and per full-time employed person was better in lowland than in mountain farms despite higher subsidies in the latter. The efficiency calculated per ha AA decreased while that calculated per person increased with increasing surface area of AA.

The owners of mountain farms were slightly older than the owners of lowland farms, kept fewer cows (6.0 heads) than those in lowland farms (21.1 heads) and obtained higher dairy production per cow (3 746 l versus 3206 l in lowland farms). The ‘SGM 2008 per ha AA was lower in mountain than in lowland farms (675.7 and 722.8 euro, respectively or 107% in favour of lowland farms). The same parameter calculated per person amounted 5 520.4 euro in mountain farms and 11969.4 euro in lowland farms i.e. by 117% more.

The SGM (per ha AA and per person) in most farms of both groups showed a slightly increasing tendency during the study period which means that the efficiency of land use and labour slowly increased.
Subsidies are an important factor affecting the economic efficiency of organic farms. They increased the income of studied farms and, on average, constituted 41.0% of SGM ranging from 43.0% in lowland to 58.4% in mountain farms.

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Comparison of nitrogen, phosphorus and potassium budgets in organic farms of mountain and lowland regions

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Abstract

Despite small differences in the land use structure and animal stock between the study years, nutrient balances, particularly those of nitrogen and potassium, differed largely. In smaller farms from mazowieckie and małopolskie voivodships with larger animal stock (c. 0.8 LU/ha) nitrogen balance was positive or only slightly negative. In organic farms of limited nitrogen sources there are large deficits of this nutrient as seen in farms from podlaskie and podkarpackie voivodships. The latter were characterised by small animal stock (below 0.7 LU/ha) and negative nitrogen balances, even in farms of relatively large, over 30%, share of legume or pulse crops. Hence, the nitrogen budget in organic farming is mainly determined by animal production. Higher deficits of phosphorus were also found in these two groups of farms and in farms of animal stock equal to 0.56 LU/ha (podkarpackie voivodship) the balance of potassium was also negative. Despite some similarities of N and P budgets in podlaskie and podkarpackie voivodships, performed comparison showed that nutrient (mainly N and K) management was better balanced in lowland than in foothill or mountain farms. The negative balance of phosphorus and potassium may be improved by the application of ores or other sources of nutrients (not applied in described farms) and the improvement of nitrogen budget is possible through increasing ruminant stock.

Keywords: grassland organic farms, NPK budgets, “field scale”, animal stock, land use structure

Introduction

Beyond its productive effects, agriculture should play ecological functions. More rational management allows a decrease of nutrient dispersion in a farm.

Permanent grasslands, despite similar share in the structure of agricultural area in the different provinces of Poland (voivodships), are used with different intensity, particularly in organic farms. Nutrient balance at the field scale [Barszczewski et al. 1999; Pietrzak et al. 1997] is helpful in identifying the intensity of management, in optimizing nutrient cycling and in improving current grassland management. The principles of organic farming imply limitation of imported nutrients which often result in a negative budget [Jończyk 2005; Karpiński 2005; Barszczewski et al. 2007]. Nutrient balances, both at the field scale and “at the farm’s gate”, are objective methods to assess the grassland management.

The aim of this study was to compare nitrogen, phosphorus and potassium management in organic farms from four voivodships representing lowland, foothill and mountain regions.

Material and methods

Steered interviews were carried out in the years 2005 – 2007 in selected organic farms with a large (above 30%) contribution of grasslands to the agricultural lands (AL). The surveys were realised in four voivodships: podlaskie (northern part of the country), mazowieckie (Central Poland) as lowland regions and in małopolskie and podkarpackie voivodships representing foothill and mountain areas. Each group was represented by five farms of an area much larger than the country mean (8.0 ha). Mean farm area in małopolskie voivodship was 17.5 ha and remained constant during the study period while the area in podlaskie and podkarpackie voivodships enlarged from 20 to 31 ha. Collected data were used to determine the management of nitrogen, phosphorus and potassium of each farm “at the field scale” with the MACROBIL computer programme [Fotyma et al. 2000]. Outputs consist in the total N, P and K uptakes by plants. Inputs include: mineral fertilisers, animal faeces left on pasture, manure, slurry and liquid manure, straw of leguminous plantleguminous plant, oil plants and cereals, leaves of tuber crops, biological N fixation by legumes and atmospheric deposition.

Mean values from particular groups of voivodships were discussed in relation to the land use, crops and animal stock structures.

Results

Nitrogen balance. Mean nitrogen balances showed marked differentiation both among voivodships and the study years (tab. 1). The greatest differences were noted in 2005 between mazowieckie and podkarpackie voivodships. An important factor affecting the balance of all elements, particularly of nitrogen, was the input from various sources. In the case of nitrogen, the main sources were animal stock in farms, the share of legumes in the botanical composition and the share of leguminous plant.

Table 1. Nitrogen, phosphorus and potassium inputs and balance (in kg·ha^{-1})

Voivodship		Year	Mean farm area in ha	N		P		K	
				input kg·ha^{-1}	balance kg·ha^{-1}	input kg·ha^{-1}	balance kg·ha^{-1}	input kg·ha^{-1}	balance kg·ha^{-1}
Lowland	podlaskie	2005	26.46	75.00	-11.80	8.56	-3.60	66.28	6.40
		2006	26.46	61.48	-12.60	6.48	-3.60	53.12	18.60
		2007	31.08	68.24	-12.60	6.68	-6.20	58.38	23.40
		X	**28.00**	**68.24**	**-12.33**	**7.24**	**-4.47**	**59.26**	**16.13**
	mazowieckie	2005	21.71	77.22	2.40	9.38	-0.80	65.08	9.00
		2006	21.99	79.88	4.80	12.06	2.20	71.72	24.00
		2007	22.12	73.90	-6.60	8.32	-5.80	61.42	-5.00
		X	**21.94**	**77.00**	**0.20**	**9.92**	**-1.47**	**66.07**	**9.33**
	mean		**24.97**	**72.62**	**-6.06**	**8.58**	**-2.97**	**62.66**	**12.73**
Foothill or mountain	małopolskie	2005	17.57	101.66	0.60	11.66	-1.80	89.88	-8,40
		2006	17.57	70.34	-1.60	8.40	-1.40	69.92	34,80
		2007	17.60	88.80	-7.20	10.16	-1.40	86.64	25,40
		X	**17.58**	**86.93**	**-2.73**	**10.07**	**-1.53**	**82.15**	**17.27**
	podkarpackie	2005	21.61	49.50	-57.25	4.88	-9.00	41.85	-44.50
		2006	31.89	64.88	-24.75	7.43	-5.00	54.58	-0.75
		2007	31.80	61.48	-45.50	6.10	-8.25	53.90	-5.25
		X	**28.43**	**58.62**	**-42.50**	**6.13**	**-7.42**	**50.11**	**-16.83**
	mean		**23.00**	**72.77**	**-22.61**	**8.10**	**-4.47**	**66.13**	**0.22**

Table 2. Average animal stock (LU·ha^{-1} AL) from interviewed farms

Voivodship		Year	Cattle	Pigs	Horses	Sheep	Poultry	LU ha^{-1} AL
Lowland	podlaskie	2005	0.54	0.04	0.00	0.10	0.02	0,72
		2006	0,52	0.02	0.00	0.04	0.00	0.58
		2007	0.64	0.00	0.00	0.02	0.00	0.66
		X	**0.57**	**0.02**	**0.00**	**0.05**	**0.01**	**0.65**
	mazowieckie	2005	0.52	0.05	0.14	0.05	0.01	0.80
		2006	0.54	0.04	0.18	0.04	0.00	0.78
		2007	0.50	0.02	0.12	0.06	0.00	0.72
		X	**0.52**	**0.04**	**0.15**	**0.05**	**0.00**	**0.77**
	mean		**0.55**	**0.03**	**0.08**	**0.05**	**0.01**	**0.71**
Foothill and mountain	małopolskie	2005	0.61	0.04	0.00	0.21	0.02	0.96
		2006	0.66	0.02	0.00	0.06	0.02	0.76
		2007	0.80	0.02	0.00	0.16	0.00	0.98
		X	**0.69**	**0.03**	**0.00**	**0.14**	**0.01**	**0.90**
	podkarpackie	2005	0.40	0.01	0.01	0.07	0.00	0.48
		2006	0.45	0.00	0.00	0.15	0.00	0.60
		2007	0.48	0.00	0.00	0.13	0.00	0.60
		X	**0.44**	**0.00**	**0.00**	**0.12**	**0.00**	**0.56**
	mean		**0.57**	**0.02**	**0.00**	**0.13**	**0.01**	**0.73**

Despite large nitrogen input to farms in podlaskie voivodship in consecutive years, its negative balance slightly increased in the years 2006 and 2007 compared with that in 2005. Mean nitrogen balance in farms with a large (c. 60%) share of grasslands was -12.3 kg N ha^{-1}.

Nitrogen input to farms in mazowieckie voivodship was by c. 10 kg N ha^{-1} higher than that in podlaskie voivodship (tab. 1), due to a larger animal (mainly horse) stock (tab. 2) in spite of smaller contribution of grasslands to the agricultural area. Animal production provides proper nitrogen source in these farms characterised by an increasing share of cereals and vegetables, and a decreasing contribution of legumes. Despite small negative nitrogen balance in 2007, the mean value was positive which evidenced proper nutrient management in this group of farms.

In farms situated in foothill and mountain areas of małopolskie voivodship, the mean nitrogen input was much higher than in lowland farms in both 2005 and 2007 (tab. 1). This had a positive effect on nitrogen balance and resulted mainly from relatively large animal stocks – much larger than those in the group of lowland farms. Cattle and sheep dominated in farms of małopolskie voivodship, the share of pigs and poultry was small and horses were not kept at all. Such an animal stock required a high contribution of grasslands to agricultural lands which was c. 65% in particular years (fig. 1). Favourable nitrogen balance was also affected by significant share of papilionaceous plants and leguminous plant which together amounted 20% of the crop structure (fig. 2).

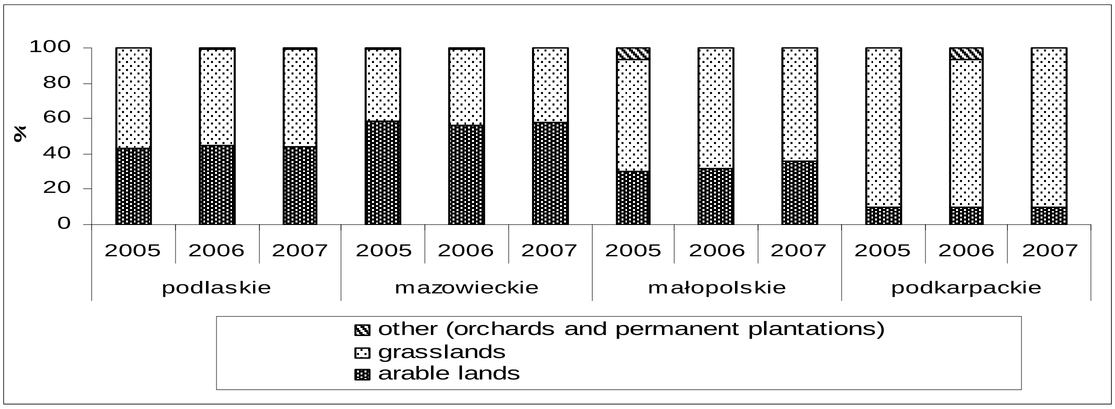

Fig. 1. Land use structure in consecutive years in the studied voivodships – mean from the farms

In the foothill and mountain farms of podkarpackie voivodship the nitrogen input was much smaller than in malopolskie voivodship (tab. 1). Due to small nitrogen inputs, N balance was highly negative, especially in 2005, but improved year after year. An improvement would be possible in these farms with 90% grasslands (fig. 1) by increasing animal stock, mainly cattle and sheep. Mean from three years stock of these animals was only 0.56 $LU \cdot ha^{-1}$. Observed improvement of nitrogen balance was an effect of increasing legumes' share in the crop structure of these farms (fig. 2).

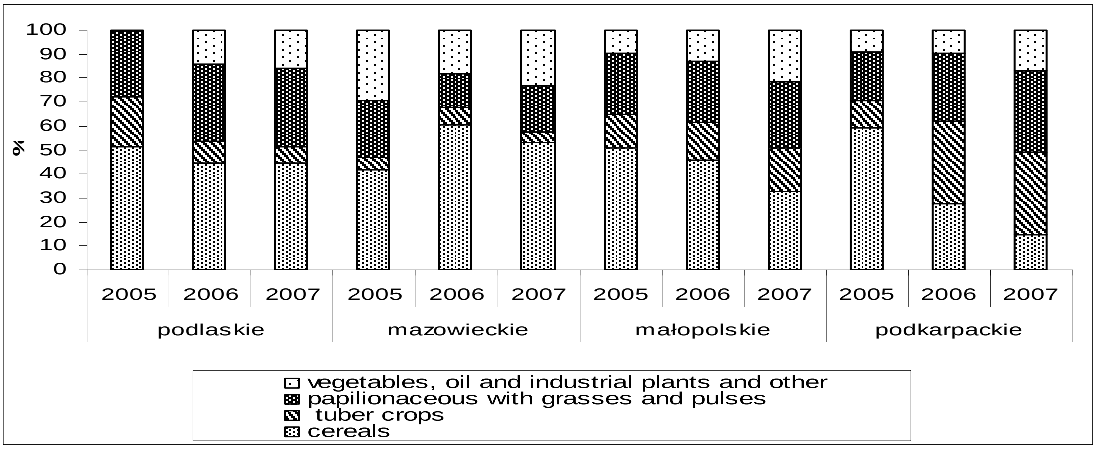

Fig. 2. Mean crop structure in consecutive years in studied voivodships

Phosphorus balance. Phosphorus input to organic farms of podlaskie voivodship was slightly differentiated from year to year (tab. 1). It was higher in mazowieckie voivodship (similarly to N input). The questionnaires revealed that these nutrients mainly originated (as nitrogen and potassium) from organic fertilisers, contributing to a smaller negative P balance. In the foothill and mountain farms of małopolskie voivodship P input was similar resulting from larger animal stock.
The least phosphorus input was noted in podkarpackie voivodship. Consequently, phosphorus balance largely departed from the values recorded in other groups of farms.

Potassium balance. Potassium inputs in the podlaskie farms decreased from 2005 to 2007, while K balance showed substantial increase. In mazowieckie voivodship mean potassium input in the second study year was slightly higher but potassium balance varied considerably from year to year.
Mean potassium inputs to farms from małopolskie voivodship, particularly those in the years 2005 and 2007, were highest from among compared groups of farms. Potassium balance in the first study year was negative. Significantly improved in the second and third study years it was comparable with that in farms

from podlaskie voivodship.
The smallest potassium inputs were found in podkarpackie voivodship. Small potassium input and, consequently, remarkably negative mean balance (-16,9 kg K $\cdot$ ha^{-1}) was an effect of the least amount of applied organic fertilisers, relatively small animal stock and a lack of fertilisation with other forms of this nutrient.

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Effects of grazing exclusion on vegetation and productivity of Kyrgyz pastures

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Introduction

Livestock-breeding is a leading branch of agriculture in Kyrgyzstan. That is why high emphasis is placed on scientific development and improved feed production. Agricultural area makes up 10.6 million ha from which 9.2 million ha or 87% are used as permanent grassland (pastures and meadows for hay).

At present, livestock mostly belongs to small farmers. Almost all animals graze on near village and on spring/autumn pastures. Therefore, the stocking rate has increased up to 5-6 times. As a result, this surfaces have been highly overgrazed. Such a management system leads to total destruction of pastures in the regions where a high density of human population is observed. A loss of floristic diversity can be observed near settlements. Persistent vegetation types dominated by good plant species are replaced by undesirable and poisonous annual plants. It leads to a reduction of pasture productivity up to 2-2.5 times and, in some cases, to its total loss.

The total area of degraded pastures in Kyrgyz Republic (pastures covered with weeds, degraded or eroded at different degrees) accounts for more than 4.5 million ha or 49% of the area of permanent pastures. Lately, 2.4 million ha of pastures were damaged by different degrees of soil erosion and 4.1 million ha were invaded by weed species like *Rosa platyacantha, Caragana sp.* or *Carex spp*. Five million ha are invaded by plant species with a low nutritive value, such as *Artemisia dracunculus, Veratrum lobelianum* and others. At the same time, remote and summer pastures are not fully grazed. As a consequence, large area of these pastures is occupied by undesirable and uneatable plant species.

The aim of this study is to assess the effect of grazing exclusion on the vegetation and productivity of i) near village intensively used pastures and ii) summer pastures which are less intensively used, and to evaluate the potential of degraded pastures to recover when protected from overgrazing. This paper presents some preliminary results after two years of grazing exclusion.

Material and methods

With local community representatives, six pastures have been selected in three pilot regions of Kyrgyzstan, three on near village pastures and three on summer pastures.

The pilot region of Orgochor is situated on the south-east part of Issyk-Kul oblast, on the territory of Jety-Oguz rayon. Near village pastures in Orgochor are situated at 1700 m above sea level and belong to wormwood-ephemeral dry steppes. The demonstration plot is located on the eastern part of Orgochor village. Mean annual rainfall is 300 mm per year. Annual average temperature lies between 6.0 and 7.0 ^{o}C. Summer pastures of Orgochor region are located on the northern mountainside of Terskei Ala-too, in a place called Kaindy, about 12-15 km to the south. Vegetation type here is a grass-forb meadow-steppe. Altitude is 2000 m above sea level and mean annual rainfall is 400 mm per year. Annual average temperature is comprised between 5.0 and 6.0 ^{o}C.

Lahol pilot region is located in the central part of inner Tyan-Shan, in Karakujur valley, on the territory of Naryn rayon and oblast. Altitude is 2700 m above sea level. The demonstration plot on near village pastures is situated in Tura-Suu village. Vegetation is a grass-forbs steppe. Climate is sharply continental with large fluctuations in air and soil temperature. Frosts are typical here even in summer time. Average annual air temperature lies between –0.4 and –0.5 ^{o}C and the mean annual rainfall is comprised between 360 mm (in valley part) and 400 mm (mountainous part). The demonstration plot on summer pastures is situated in Danakan area, near Tura-Suu head river, at an altitude of 2900 m. Vegetation is also a grass-forbs steppe. Climate is more severe than in the valley and weather changes several times a day. Mean annual rainfall reaches 400 mm.

Terek pilot region is situated on south-east part of Kyrgyzstan, in Ak-Tala rayon of Naryn oblast. The near village pasture of Terek is a grass-forbs dry steppe. Climate is sharply continental with large fluctuations in air and soil temperature. Average annual air temperature lies between –5.0 and -6.0 ^{o}C and average annual rainfall in the valley reaches 320 mm. The demonstration plot on summer pasture is located behind Kara-Bulak mountain ridge pass, 45-50 km south from Terek village, in a place called Kara-Tash. The vegetation type of this summer pastures is a grass-forbs steppe. Climate is sharply continental and severe. Average annual air temperature is between –6.0 and -7.0 °C, mean annual rainfall is 360 mm.

Grazing was excluded with fences since 2008 or 2009. Depending on the local situation, the size of each protected area varies between 300 and 900 m^2. The botanical composition have been observed during summer in 2009 and 2010 according to the quick start methodology (Herrick *et al.*, 2005). Plants have been identified according to Golovkova (1962) and Nikitina *et al.* (1959). In 2009 and 2010, four small plots of 1 m^2 were cut monthly from May to September inside the exclusion area and outside next to the fenced area at a height of 2-3 cm (near village pastures) or 4-5 cm (summer pastures) above soil level. The harvested plant material was air dried and weighed to determine the dry matter yield. Observations and main calculations have been conducted according to the experimental methods for meadows and pastures described by Iglovikov (1971) and Imenov and Djoldoshev (2009).

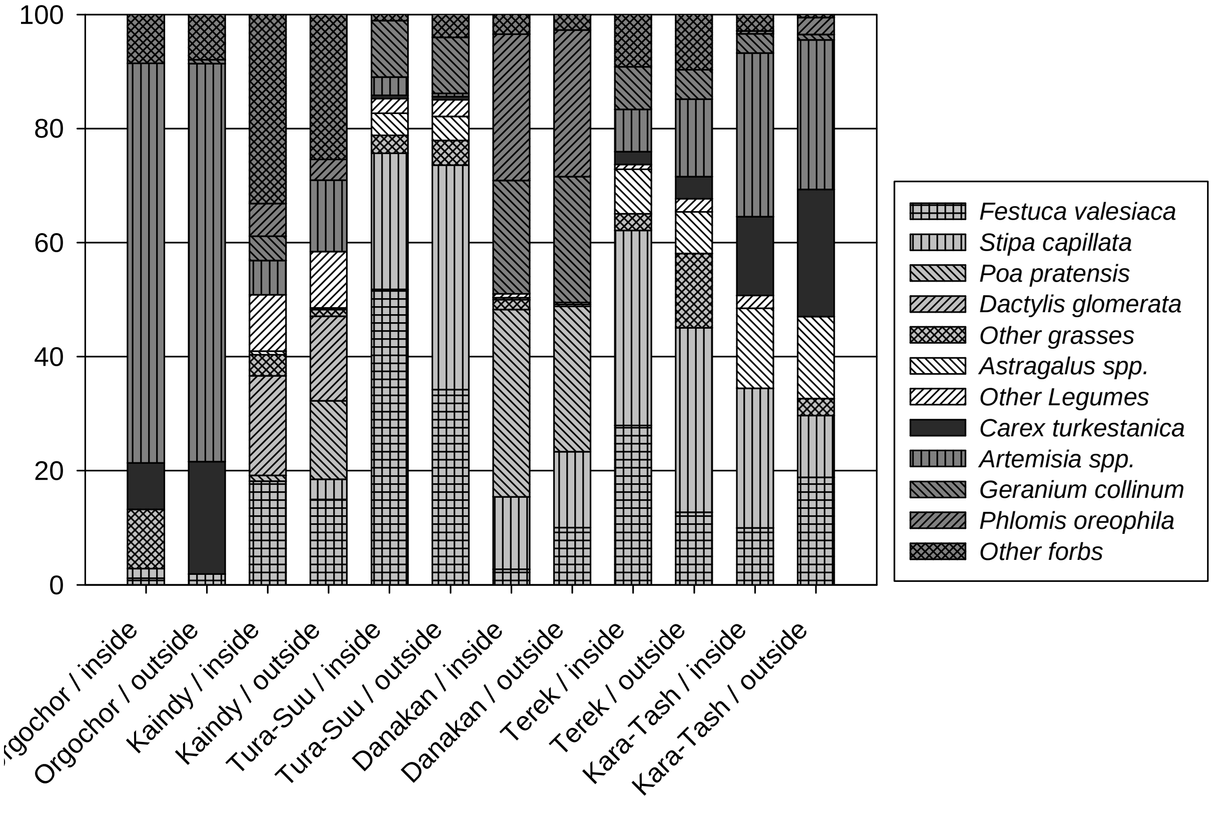

Figure 1. Specific contribution (%) of the main plant species inside and outside the six demonstration plots (Orgochor, Tura-Suu and Terek = near village pastures, Kaindy, Danakan and Kara-Tash = summer pastures; mean of 2009 and 2010).

Results

Orgochor region

In the near village pasture of Orgochor, *Artemisia spp.* constitute about 70% of the biomass (figure 1). There are few grasses and *Carex turkestanica* is less developed inside than outside the fenced area.Vegetation starts to grow at the beginning of April and reaches its maximum at the end of July, with 640 kg DM ha^{-1} outside the fenced area and 755 kg DM ha^{-1} within the fenced area (table 1).

In Kaindy, *Festuca valesiaca*, *Dactylis glomerata* and *Poa pratensis* dominate among grasses (figure 1). Legumes represent 10% of the biomass. *Artemisia dracunculus* reaches a higher proportion outside than inside the fenced plot. Plant vegetation starts to grow 8-10 days later than on near village pastures (Orgochor). Maximum productivity of the vegetation was obtained at the end of July, with 1980 kg DM ha^{-1} outside the fenced area and 2550 kg DM ha^{-1} inside the fenced area (table 1).

Lahol region

The near village pasture in Tura-Suu is dominated by *Festuca valesiaca* and *Stipa capillata*, the former grass reaching a higher proportion inside the plot, the latter being more developed outside (figure 1). Legumes occupy 7% of the biomass and *Geranium collinum* is the main forbs species. Vegetation here begins to grow at the end of April, i.e. 15-20 days later than in Orgochor and reaches its maximum in August only. At this time, the productivity reaches 405 kg DM ha^{-1} on free grazing area (unfenced) and 505 kg DM ha^{-1} within the fenced area (table 1).

In Danakan (summer pasture of Lahol), *Poa pratensis* is the most important grass species and seems to be favored by grazing exclusion (figure 1). *Geranium collinum* and *Phlomis oreophila* occupy a high proportion in the biomass, the same one inside and outside the fenced plot. The vegetation starts to grow in May. Maximum productivity was reached in August and show higher values than in Tura-Suu: 1095 kg DM ha^{-1} outside the fenced area and 1400 kg DM ha^{-1} inside the plot (table 1).

Table 1. Dry matter yield (kg DM ha^{-1}) produced by the pastures from May to September outside (unfenced) and inside (fenced) the six exclusion area located in the three pilot regions (means 2009-10)

			Dry matter yield (kg DM ha^{-1})				
Pilot region	Pasture type	Plot type	May	June	July	Aug	Sept
Orgochor	Near village pasture (Orgochor)	unfenced	110	345	640	600	555
		fenced	140	415	755	720	675
	Summer pasture (Kaindy)	unfenced	190	900	1980	1625	1530
		fenced	200	1215	2550	2100	1885
Lahol	Near village pasture (Tura-Suu)	unfenced	105	205	310	405	365
		fenced	130	260	395	505	470
	Summer pasture (Danakan)	unfenced	140	500	875	1095	825
		fenced	180	605	1090	1400	1030
Terek	Near village pasture (Terek)	unfenced	85	215	380	505	475
		fenced	100	275	520	670	625
	Summer pasture (Kara-Tash)	unfenced	180	350	320	435	395
		fenced	220	430	370	495	460

Underlined values indicate the maximum value from May to September

Terek region

In Terek (near village pasture), *Festuca valesiaca* and *Stipa capillata* are the dominant grasses (figure 1). *Astragalus spp.* are well developed and legumes represent about 8-9% of the biomass. Outside the fenced area, the proportion of *Artemisia dracunculus* is relatively high (14%). The highest productivity was reached in August, with 505 kg DM ha^{-1} outside the fenced area and 670 kg DM ha^{-1} within the fenced plot (table 1).

In Kara-Tash (summer pasture of Terek), *Festuca valesiaca* and *Stipa capillata* are also the dominant grasses, but they are less developed than on the near village pasture (figure 1). Legumes, mainly *Astragalus schanginianus*, constitute 15% of the biomass. The main weed species are *Artemisia dracunculus* and *Carex turkestanica*, the latter species being much more developed outside than inside the fenced plot as in Orgochor. The productivity reaches its maximum value in August and was low: 435 kg DM ha^{-1} outside and 495 kg DM ha^{-1} inside the fenced area (table 1).

Conclusions

To assess the effects of grazing exclusion, long term observations are required. Nevertheless, two years of observations already reveal first effects of grazing exclusion. On overgrazed near village pastures, grazing exclusion favored the emergence of plant species with a good nutritive value and reduced the proportion of some undesirable species. For this type of pastures, it is necessary to introduce rest periods to avoid pasture degradation. On less overgrazed summer pastures, the positive effects of grazing exclusion are less obvious. Some undesirable plant species may be favored. In such a case, a long rest period is not recommended.

Acknowledgements

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SESSION 2 Mountain meat and milk production systems

Dairy production systems in the Italian alpine area

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Abstract

Dairy livestock is still a leading sector for agricultural economy in the Italian Alps. However, in recent decades it was concerned by dramatic reduction in farms number, strong increase in the number of animals per farm, raise in indoor production systems, growth of specialized non-indigenous cattle breeds, as well as use of extra farm concentrates instead of meadows and pastures for fodder. This trend is likely to standardize alpine dairy products and their market value. The first part of the paper describes the dairy sector in the Italian Alps and analyzes the most important factors characterising the production system which can potentially make typical and recognizable mountain cheeses. The second part describes the strengths and weaknesses of the production chains of some of the most famous Italian products with protected designation of origin.

Keywords: *Italian Alps; milk; cheese; dairy production systems*

Introduction

The Italian Alps are characterized by a great variety of environments and socio-economic situations, which are quite difficult to standardize. This consideration can be applied also to the dairy sector, strongly linked to old traditions and local resources utilization. In the recent past, intensive production systems have gradually replaced the traditional ones, resulting in the increase of farm production and income. At the same time intensification processes caused environmental problems, abandonment of marginal lands and biodiversity losses (Cozzi *et al.*, 2006; Gusmeroli *et al.*, 2006). Today, the competitiveness of alpine production systems cannot be based simply on the ability to reduce production costs. It is necessary to focus on products quality and activities diversification, as well as on the ability to evoke the production area and its environmental, historical and cultural values. Alpine production constraints can be transformed into competitive advantages because consumers show a strong interest on modern issues, such as environmental sustainability, “local identity” products and animal welfare. Alpine farms are well suited to this production approach which allows to realize “positive externalities” and consequently to access to CAP payments. As a matter of fact European Parliament decisions are oriented to remunerate management farm choices related to real benefits for the society.

Dairy sector in Italian Alps

Alpine dairy farms

Dairy livestock is still a leading sector for agricultural economy in the Italian Alps, except for Trentino Alto Adige region where products diversification - especially fruit and wine - reduced its role. As a result of the intensification process, dairy farms radically changed i.e. reduction of farms number, increase of head number per farm, increase of milk yield per farm, animal genetic improvement, extra farm resources utilization (Table 1).

Table 1 – Number of dairy farms (with quotas) and their marketed milk yield in mountain area of Italian alpine regions (Source: *Milk Observatory* on *Agea* data)

	1995/96			2009/10		
	Farm (n.)	Milk yield (,000 t)	Milk yield/farm (t)	Farm (n.)	Milk yield (,000 t)	Milk yield/farm (t)
Region:						
Valle d'Aosta	1,585	46	29	993	44	45
Piemonte	2,234	66	29	897	80	90
Lombardia	3,633	128	35	1,814	164	90
Trentino A.A.	9,122	407	45	6,646	512	77
Veneto	3,896	198	51	1,360	206	151
Friuli V.G.	1,265	40	32	408	61	149
Total:						
Alps (*)	21,735	885	41	12,118	1,067	88
Mountain	41,270	1,643	40	19,042	1,834	96
Italy	97,044	10,403	107	40,199	10,876	271

(*) Ligurian Alps are excluded

In 2009/2010 milk campaign the dairy farms located in the Italian alpine area were 12,118 (63.6% of those in Italian mountains and to 30.1% of the farms in Italy). Marketed milk yield was 1,067 thousand tons (58.2% of Italian mountain production and 9.8% of Italian overall production). In the last decade the average milk yield per farm has doubled, from 41 to 88 tons/year (Pieri, 2010). In the Italian Alps about 220,000 dairy cows are farmed (National Livestock Database, modified) and the average milk yield per cow is 4.9 tons/year.

Dairy farms present different levels of intensification and integration with the territory. In intensive dairy farms, cattle - mainly Holstein and Brown Swiss breeds – are bred in loose housing stables located in valley and fed with hay (also of extra farm origin) supplemented by concentrates. Cattle calving is distributed throughout the year because of industrial dairy plant requirements.

A decreasing number of alpine farms practice the traditional livestock system, characterised by high altitude pasture utilization during summer, milk processing in small farms and dairy products sold in farm shops. A small number of farms use pasture at different altitudes to exploit vegetation gradient and guarantee animal nutrition transition. Traditionally local sheep were farmed together with cattle while goats for meat production. In recent years goats dairy farms are not unusual in alpine valleys and the common breeds are *Saanen* and *Camosciata delle Alpi*.

Dairy plants and products in Italian Alps

Most of alpine milk is processed into dairy products. In the last century dairy plants in alpine area were usually small sized and worked only during winter period. In recent times the number of dairy plants decreased and their average size increased, resulting in safety and hygiene improvement as well as in standardization of milk yield and quality. A large part of alpine dairy products are included in the Italian “Traditional Food Product” (TFP) list (173 totally alpine of 457), while some others obtained Protected Origin Denomination (PDO) label. Italian PDO cheeses are 37, of which 10 are produced only in the alpine area and 11 partially. Most of alpine PDO cheeses are sold exclusively in local markets. A specific initiative to enhance alpine products is the establishment of the Mountain Products (MP) label; it is granted to products whose entire manufacturing process takes place in a mountain area (altitude > 600 m a.s.l.). In addition to TFP and PDO cheeses, recent labels linked to production area (e.g. “Südtirol Quality”) and to single animal breed (e.g. “only Italian Simmental breed”) have spread. Several other dairy products are manufactured in the Italian Alps, mostly sold in local market and produced with mixtures of bovine and goat (or ovine) milk.

Factors affecting the quality of dairy products and the multifunctionality of alpine dairy farm

Dairy products standardization is due to farming practices intensification and to industrialization of dairy manufacturing. The adoption of precise constraints in product specification can maintain (or improve) product-territory relationship, highlighting organoleptic originality and positive externalities of dairy products. Factors affecting quality of alpine dairy products can be classified in five main categories: (i) production area (e.g. environmental value, tourist importance, etc.); (ii) forage component of animal diet (e.g. forage quality and productivity, pasture, etc.); (iii) animal (e.g. species, breed, etc); (iv) farming practices (e.g. pasture management, concentrate supplementation, animal welfare, etc.); (v) milk manufacturing (e.g. technology, storage conditions, etc.). The four first strongly affect also “positive externalities” of alpine farms. In recent years several researches were carried out to provide scientific data on subjects listed above, resulting in a great number of reviews and meetings (Grappin & Coulon, 1996;

Peeters & Frame, 2002; Agabriel *et al.*, 2004; Biala *et al.*, 2005; Coulon *et al.*, 2005; Bovolenta *et al.*, 2006; Noziere *et al.*, 2006; Piano, 2010, Mattiello *et al.*, 2011).

Can PDO cheeses be considered as "local identity" products?

PDO label covers agricultural products which are produced, processed and prepared in a given geographical area complying with a specific product specification. This results in a detailed description of raw material characteristics, production process and chemical-organoleptic quality of product. Then the analysis of product specifications for PDO cheeses allows to verify the use of production features making a product as a "local identity" one, i.e. not reproducible outside the production area and linked to local traditions. In table 2 are shown the main constraints established by product specification for some alpine PDO cheeses.

Table 2 – PDO cheeses in alpine area and main constraints established by product specification

Cheese - Label	Production area	Forage	Animal	Farming practice	Milk manufacturing
Fontina PDO – MP	Valle d'Aosta region	regional hay and herbage, no silage	only *Valdostana* breed	concentrate supplementation: limitation for single food	whole milk of 1 milking, > 90d ripening and 90% humidity
Bitto PDO – MP	high altitude pasture in Sondrio province and neighbouring municipalities	pasture and hay (if necessary)	indigenous cattle and goat breeds	concentrate supplementation: max. 3kg/d	*in loco*, whole milk of 1 milking, goat milk <10%, >70d ripening
Castelmagno PDO – MP *Castelmagno di Alpeggio*	3 municipalities in Cuneo province	forage >30% from PDO area, no silage	several cattle breeds (no Holstein), goat and sheep	no constraints	raw milk max. 4 milking, goat milk <30%, >60d ripening
Grana Padano PDO	34 provinces of NE Italy	forage min. 75% from PDO area	cattle breeds	concentrate supplementation: max 50%	raw milk, 1-2 milking, >9 months ripening
Grana Padano PDO "*Trentino*" *(Trentingrana)*	Trento province and some municipalities of Bolzano province	no silage	id.	id.	no lysozyme
Asiago PDO	Vicenza, Trento, Padova (partially) and Treviso (partially) provinces	no constraints	cattle breeds	no constraints	1-2 milking, >20d ripening
Asiago PDO – MP	mountain area of PDO provinces	no silage	id.	id.	no lysozyme, >30d ripening
Montasio PDO	Friuli Venezia Giulia region and NW Veneto region	no constraints	cattle breeds	no constraints	raw milk max. 4 milking, >60d ripening
Montasio PDO - MP	mountain area of PDO area	id.	id.	id.	id.

Product specification for *Fontina* PDO cheese is the only requiring tight constraints for all factors analyzed, from production area to cheese storage conditions. In particular, it is the only one obliging the use of a specific breed (*Valdostana*). As a consequence the breed was not interested by the strong animal number reduction affecting all alpine breeds.

Instead, other PDO specifications enhance only some of the factors taken into consideration.

Bitto PDO cheese is entirely produced and manufactured on high altitude pastures of the production area. However, the use of specialized cattle breeds (mainly *Brown Swiss*) resulted in concentrate supplementation on pasture, once not used.

Castelmagno PDO cheese is produced both in valley and on high altitude pasture. The origin is specified on different cheese packaging. In both products, the use of Holstein breed is forbidden.

About *Grana Padano*, *Asiago* and *Montasio* PDO cheeses, produced mainly in lowland and in a small Alpine area, the strategies to improve mountain products were different. The first one obtained a specific geographic indication "*Trentino*" for cheese produced in the Trento province (entirely alpine). Both *Asiago* and *Montasio* terms refer to two famous alpine uplands in Veneto and Friuli Venezia Giulia regions, respectively. However cheeses are produced and manufactured largely in lowlands. Therefore the

MP label utilization allowed to recognize mountain from lowland productions.

Conclusions

At present, consumers show a strong interest on innovative subjects i.e. link between products and territory, environmental issues and animal welfare. The challenge is increasing consumers' capacity to recognise in alpine products a set of *terroir* characteristics. The term *terroir* was defined for wine sector by French researches and then extended to other product to identify a production system based on peculiar environmental conditions, animal ability to exploit local resources and sustainable agricultural practices. Although not exhaustive, this analysis revealed that the potentialities linked to *terroir* for Italian alpine dairy products are not exploited enough. The production area and processing techniques are always well defined, as results of product specifications constraints, while fodder, animal characteristics and farming practices are not enhanced enough.

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Effects of NDF content in mountain pastures and cultivated pastures on lamb meat quality

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Abstract

Norwegian lamb meat production is mainly based on free grazing in mountainous pastures during the summer. Prior to slaughter in the autumn, some lambs not big enough for slaughter are finished on e.g. cultivated pastures. This study looked at the feed quality of different forages, and the effect on lamb meat quality. Lambs grazed on mountain pastures at Kvaløya in Northern Norway (69°N) and Sør-Fron in Mid Norway (58°N) in 2007, and a subgroup at each location was finished on cultivated pastures for 6 weeks prior to slaughter in September. The fiber content was significantly higher in the cultivated pasture in Mid Norway compared to the mountain pasture while no differences between pastures in Northern Norway were found. In Mid Norway the content of polyunsaturated fatty acid (18:3) was significantly higher in meat from lambs grazing the mountain pasture compared to lamb grazing the cultivated pasture. For Northern Norway, the opposite pattern was observed. The higher 18:3 content may be attributable to lower fiber content at the mountain pasture. In our study, there appears to be an effect of fiber content on the fatty acid composition in lamb meat.

Keywords: fatty acids, lamb meat, NDF

Introduction

In Norway, most of the sheep meat produced is based on lambs slaughtered directly from unimproved mountain range pastures in the autumn. To reach the recommended carcass weight, lambs below 40 kg live weight (LW) are finished on cultivated lowland pastures. The level of poly-unsaturated fatty acids (PUFA), an in particular the omega-3 PUFA are considered to be positive in the human diet but the nutritional value of fat in lamb meat is discussed amongst nutritionists. However, feeding systems have shown effects on the fatty acid composition in lamb meat and as high levels of the fatty acid (FA) linoleic acid (C18:2*n-6*) is related to concentrate feeding (Aurousseau *et al*., 2007), high levels of α-linolenic acid (C18:3*n-3*) is related to grazing. Green plants contain high levels of the latter FA but factors such as the rate of fattening in the lamb, the age of the lamb and the level of bio-hydrogenation in the rumen, all play a role in the total level of α-linolenic acid found in the meat. Unsaturated FAs ingested by ruminant animals are hydrogenated to their saturated counterparts in the rumen. However, the rate of hydrogenation depends, amongst other things, on the composition of rumen bacteria, and the composition of the rumen bacteria depends on the feed that the animals are fed. The level of neutral detergent fibre (NDF) is important in the bacteria composition in the rumen. In the present study we examined the effects of NDF in pastures on the level of PUFA in lamb meat.

Materials and methods

Two locations, Kvaløya in Northern Norway (69°N 18°E) and Sør-Fron in Mid Norway (61^0N 9^0E), were selected for the study. The experiment was undertaken in 2007. In Northern Norway, the experimental lambs grazed on cultivated pastures for 39 days and in Mid Norway for 42 days before being slaughtered. Lambs from a control group at each location were sent directly to the abattoirs after being gathered from the mountain pastures. The experiment is explained in more details in Lind *et al*. (2009a).

The mountain pastures ranged from 0 to 800 m and 700 to 1000 m above sea level for Northern and Mid Norway, respectively. In the mountain pasture in Northern Norway *Avenella flexuosa, Anthoxanthum odoratum, Nardus stricta, Vaccinium myrtillus, Empetrum nigrum, Salix genus* and ferns were the most dominating species, representing more than 80% of the biomass. In Mid Norway, *A. flexuosa, Agrostis capillaris, Deschampsia cespitosa, A.odoratum* and the herbaceous species of *Geranium sylvaticum, Betulanana* and *V. myrtillus* were the most dominating species, representing approximately 85% of the biomass. The botanical composition and biomass of the mountain pastures were estimated using the point intercept method described in Bråthen *et al*. (2007).

The cultivated pastures were dominated by the grasses *A. capillaris* (39%) and *Elymus repens* (45%) in Northern and Mid Norway, respectively. Other grasses in the pastures were *Poa pratensis, Phleum pratense, Festuca pratensis* and *D. cespitosa.* The grasses represented about 90% of all species. Grass samples from the cultivated pastures were collected throughout the finishing periods. The samples were scanned with a NIR spectrophotometer (Foss NIRSystem model 6500, Silver Spring, MD, USA) to determine the nutritional value (energy-, protein- and fiber content).

Traditionally managed Norwegian Crossbred Sheep were used in the study. In Northern Norway 40 twin lambs with a minimum LW of 32 kg were randomly separated from the flock and brought to the cultivated pasture for the finishing period. Out of these 40 lambs, 35 of both sexes weighing more than 40 kg LW were slaughtered. As a control group, 35 lambs from the main flock grazing in the mountains, with similar LW, litter size, sex and age were selected and sent directly off the mountain pasture to the local abattoir, together with the experimental lambs. After slaughtering, 20 carcasses from each pasture type were selected for determination of fatty acid composition. The same procedure was followed in Mid Norway and included 72 male twin-lambs. Fatty acid composition was tested using one-way ANOVA analysis with pasture as fixed effect and single animals as experimental units.

Results and discussion

We did not find any significant differences in the NDF content between pastures in Northern Norway (Table 1). The NDF content in the cultivated pasture in Mid Norway was significantly higher than the NDF content found on the mountain pasture. Meat from lambs grazing the cultivated pastures at both locations had a higher content of palmitic acid (C16:0) while no differences in the content of stearic (C18:0) and oleic acid (C18:1*n-9*) were found. In Northern Norway, lambs grazing the cultivated pasture had a lower content of linoleic acid and a higher content of α-linolenic acid compared to meat from lambs grazing the mountain pasture. In Mid Norway, lambs grazing the mountain pasture had a higher content of both the PUFAs compared to lambs grazing the cultivated pasture (Table 1).

Table 1. Least square means of fatty acids (% of total fat) in subcutaneous fat in lambs and content of NDF (% of DM) of different pastures in Northern and Mid Norway.

	Northern Norway				Mid Norway			
	Cultivated pasture	Mountain pasture	SEM	P-value	Cultivated pasture	Mountain pasture	SEM	P-value
Palmitic acid	27.2	25.5	0.4	***	28.7	27.7	0.3	**
Stearic acid	21.2	22.1	0.9	NS	18.9	18.9	0.7	NS
Oleic acid	37.5	37.4	0.6	NS	36.7	38.5	0.7	NS
Linoleic acid	1.8	2.6	0.2	***	1.5	2.0	0.1	***
α-linolenic acid	1.9	1.5	0.1	**	1.4	1.6	0.07	**
NDF % of DM	53.9	51.5	1	NS	65.2	53.5	2	***

NS – non significant; ** $P<0.01$; *** $P<0.001$; SEM – Standard Error Mean

A higher level of NDF in the feed to ruminants will cause an increased growth and activity of the rumen bacteria *Butyrivibrio fibrisolvens*, a bacterium that degrades the fiber content in the rumen. It is also found that this bacterium is important in the bio-hydrogenation of PUFA to saturated fatty acids (Chiofalo *et al*., 2010). Our study showed that meat from lambs grazing pastures with a high content of NDF had a lower content of PUFA in the subcutaneous fat. Chiofalo *et al*. (2010) found that sheep grazing ryegrass (*Lolium multiflorum*), white clover (*Trifolium subterraneum*) or a mixture of the species had a higher activity of cellulolytic bacteria for the bio-hydrogenation process. Lambs grazing *L. multiflorum* had a lower level of omega-3 fatty acids than lambs grazing *T. subterraneum* as a consequence of the reduction of the linoleic acid to stearic acid. The level of NDF in *L. multiflorum* was significantly higher than that of *T. subterraneum*. Similar results were found by Fraser *et al*. (2004) where lambs grazing red clover (*Trifolium pratense*) had a higher level of PUFA in the meat than that of lambs grazing perennial ryegrass (*Lolium perenne*). In both studies the ryegrass species had a higher level of NDF than the clover species. In a study performed on lambs finished on ryegrass (*L. multiflorum*) or indoor on concentrate and roughage (Lind *et al*., 2009b), the level of α-linolenic acid was higher in meat from grazing lambs compared to the indoor fed lambs. The level of NDF, however, was higher in the ryegrass than in the total composition of indoor feed. The results might be due to the already high level of α-linolenic acid in the pasture compared to the concentrate diet. Even if more hydrogenation occurred when grazing ryegrass pasture, the ingested level of this FA was high enough to counteract the suggested effect. In the present study, the cultivated pasture had the highest content of NDF compared to the mountain pasture. This could be explained by the fact that the cultivated pasture to a large extent consisted of *E. repens*. This is a species that matures early in the autumn and therefore the high level of NDF was expected. In contrast the mountain pasture had a large variety of species and some, e.g. *A. flexuosa* that is preferred by sheep, develops later in the autumn.

One explanation of the results from Northern Norway could be that the mountain pasture ranged from sea level as the cultivated pasture did and it was observed that the lambs more often grazed at lower altitudes in the autumn than during the summer. In addition, it was found that the species composition in both pastures to a large extent consisted of *A. capillaris*.

Conclusion

Our results suggest that feeds with a high level of NDF can be one of many factors that might influence the level of PUFA in lamb meat, but lambs grazing pastures that contain large amounts of PUFA still have healthier FA composition in meat compared to lambs fed concentrate. Producers of lamb meat should pay attention to the finishing system to aim for a healthy lamb meat.

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Effects of alpine vegetation type and animal breed on fattening performance and meat quality of lambs

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Abstract

Lambs of two Swiss mountain breeds, Engadine Sheep (ES, 27) and Valasian Black Nose Sheep (VS, 27), were fattened for 9 weeks in paddocks allowing *ad libitum* forage intake on the following four vegetation types: control red/white clover-ryegrass ley (C) in the lowlands, and three high alpine pastures, *Crepido-aurea Festucetum* (F), *Geo montani-Nardetum* (G) and *Seslerio-Caricetum sempervirentis* (S). Initially, ES and VS lambs weighed 33 and 31 kg and were 26 and 18 weeks old, respectively. After 9 weeks, the lambs were slaughtered in a commercial slaughterhouse. Subjective grading of the carcasses according to the Swiss classification system CH-TAX favoured ES across all vegetation types for meat conformation. In both breeds meat conformation was scored highest in animals fattened on pasture F. Breed × vegetation type interactions were found for dressing percentage and daily weight gains. There were increased gains for ES on C and for VS on all three alpine pastures. Additional breed differences were found for meat colour, cooking loss and shear force; further vegetation type differences occurred for cooking loss. In conclusion, animal breed, alpine grazing and vegetation type on alpine pastures were shown to influence fattening performance and meat quality of lambs.

Keywords: sheep breed, vegetation type, meat quality, fattening performance, alpine

Introduction

Alpine grasslands are a resource that contributes to the global food supply mainly by serving as feed for ruminant livestock. Food produced in high alpine agricultural systems has been shown to have specific nutritional advantages (Leiber *et al.*, 2005, Ådnøy *et al.*, 2005). Plant species composition and nutritional value clearly varies between lowland and alpine pastures but also within different alpine vegetation types, which may also affect product quality (Falchero et al., 2010). The level of adaptation of ruminant breeds to the specific alpine dietary, climatic and topographic conditions may differ and thus result in different coping abilities and quality of animal-source food products. The aim of the present study was to investigate the effects and interactions of sheep breed and vegetation type on fattening performance and meat quality of lambs.

Material and methods

The breeds selected, Engadine Sheep (ES; 27; castrated males) and Valasian Black Nose Sheep (VS; 27; castrated males and females, 4:3), originated from different mountainous regions of Switzlerland. All lambs first grazed together a lowland (400 m a.s.l.) red/white clover-ryegrass ley for one month adaptation period. The initial live weights were 32.7±3.5 kg and 30.8±3.0 kg and ages were 26±2 and 18±7 weeks for ES and VS, respectively. Afterwards, the lamb were allocated in groups of seven (one ES and one VS group with six only) to the following four pastures consisting of different vegetation types: control lowland pasture (C; located besides the pasture used for adaptation), an alpine *Crepido-aurea Festucetum* pasture at 1950 m a.s.l. (F), an alpine *Geo montani-Nardetum* pasture at 2250 m a.s.l. (G) and an alpine *Seslerio-Caricetum sempervirentis* pasture at 2150 m a.s.l. (S). The lambs on each vegetation type were fattened for 9 weeks in paddocks of $\geq$ 1 ha size (depending on the productivity of the different pastures) allowing *ad libitum* intake and were slaughtered immediately after return from the pastures in a commercial slaughterhouse where subjective grading of the carcasses for conformation (from concave to convex animal profile) and fatness (from no fat cover to over fattened) according to the Swiss classification system CH-TAX was performed. Meat quality analyses were conducted on the *Musculus longissimus dorsi* (LD) after ageing for 25 days at 4°C in sealed bags. Meat colour was analysed with a Minolta photometer (model 300 CR, Dietikon, Switzerland) operated with the L*a*b* principle, giving values for lightness, redness and yellowness of the measured meat pieces. Cooking loss was analysed by weighing meat samples before and after 45 min of cooking in sealed bags in a water bath at 72°C. Shear force was analysed with the Warner Bratzler shear blade mounted on a texture analyser in the cooked LD. Data was subjected to analysis of variance considering breed, vegetation type and the interaction as effects.

Results and discussion

Breed × vegetation type interactions were found for average daily weight gain (P=0.002) and dressing percentage (P=0.028). ES gained more weight on the lowland pasture C than VS while this was opposite on all three alpine pastures (F, G and S), indicating a better adaption of VS to the sparse but more biodiverse mountain pastures and of ES to lowland pastures with high density of well digestible grass. The VS consistently had a lower meat conformation (P<0.001) and fat cover (P<0.001) than ES when applying CH-TAX. Both breeds had the highest meat conformation and fat cover on alpine pasture F followed by the lowland pasture C. Significant breed differences were found for dressing percentage (P<0.001), shear force (P=0.006) and cooking losses (P<0.018). Across all four vegetation types, the VS had a lower dressing percentage (36.6, 37.4, 35.9 and 38.6 %) compared to ES (42.1, 45.9, 41.2 and 42.9 %). Furthermore VS showed continuously lower shear force of the meat (52.5, 59.3, 59.9 and 56.6 N) than ES (60.5, 73.1, 65.4 and 60.8 N) and higher cooking losses (20.9, 21.0, 25.7 and 24.4%) compared to ES (19.6, 19.4, 22.8 and 22.3%) on the vegetation types C, F, G and S, respectively. Thus it appears that lamb meat had higher cooking losses and seemed to be more tender when carcasses had a lower fat cover. Sañudo *et al.*, (2000) also found the highest cooking losses in lamb meat that had either the lowest or highest fatness cover, while moderate fat cover was positively correlated to cooking loss. It seems that evaporative losses may be facilitated due to the lack of protective fat layer. In the present study, sheep breed seems to have a stronger effect on meat tenderness than fat cover and the often reported positive correlations of fat amount/cover and meat tenderness (Babiker *et al.*, 1990, Sañudo *et al*. 2000) were not found. It has to be stated that the observations in the current study described in this context might also have been random breed-specific characteristics. Cooking losses were highest in meat from pasture G for both breeds (22.8 and 25.7 % for ES and VS), and meat of both breeds was most tender when originating from the lowland pasture (19.6 and 20.9 % for ES and VS), indicating that vegetation type and related nutritional characteristics have a clear effect on meat cooking losses (P=0.001) and a trend for vegetation type differences was found for meat tenderness (P=0.079). VS had slightly less tender meat but of comparable texture on the three alpine pastures (59.3, 59.9 and 56.6 N on F, G and S) compared to lowland (52.5 N), while meat of ES showed clear differences in tenderness between the three alpine pastures (73.1, 65.4 and 60.8 N on F, G and S). Meat colour is an important factor influencing the acceptance of meat by consumers. In Switzerland, light red to red lamb meat colour is preferred by consumers (Konsumentenforum 2011). Meat colour was strongly influenced by sheep breed as the meat was lighter (P<0.001), less red (P<0.001) and less yellow (P<0.001) for VS compared to ES throughout all vegetation types. Consumers may therefore favour the light lamb meat from VS more than the reddish meat from ES. This breed difference in colour was also easily observable by simply looking at the meat. Meat colour was further influenced by vegetation type, although to a lesser extent. Lightness and yellowness were highest for both breeds on alpine pasture G.

Conclusions

The breed × vegetation type interaction in average daily weight gains and the breed differences in subjective carcass grading indicate that there is a different level and type of adaptation of the two breeds to mountain pastures. VS appear to be the less efficient but also the less demanding breed coping better with the sparse but more biodiverse alpine pastures. Concerning meat quality, all parameters measured were significantly affected by breed, while vegetation type differences were only significant in case of meat colour redness and cooking losses. Thus, vegetation type selection and breed choice are important factors that influence meat quality and fattening performance and therefore have to be considered during implementation in pasture-based fattening systems.

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Yield and chemical composition of milk from dairy cows fed on roughage and concentrate in various ratios

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Abstract

A survey was conducted to study the effect of diet composition on milk quality production in 12 dairy farmers located in different regions of Sidi Bouzid (Central Tunisia). Two groups of 26 (G1) and 23 (G2) multiparous and homogeneous cows were managed as separate herds for this purpose. The G1 group was fed with a ration (R1) including 60% concentrate and 40% oat hay. The G2 group received a ration (R2) with 40% concentrate, 30% oat hay and 30% cereal straw. Chemical composition of different diets (R1 and R2) in terms of dry matter (DM), crud protein (CP) and crud fibre (CF) contents, energetic value (UFL) and intestinal digested protein (PDI) were studied using the NIR technique. Milk samples were collected separately from all of the dairy cows of both groups from early to mid-lactation. Milk and chemical composition (fat, protein and urea content) was studied using the integrate milk machine. Changes in dietary composition (R1 and R2) had no significant effect on milk yield, protein, urea contents and somatic cell counts. However, when cows were fed on R2, milk fat content was higher ($P<0.05$) than that produced from cows fed on R1.

Key words: dairy cows, ration, concentrate, milk, fat, protein.

Introduction

The problem of milk production in the Mediterranean area can be examined in relation to its contribution to the human food supply and its role as an element of the agricultural economy. The development of milk production from cows in these areas would greatly help the supply of high nutritive value protein. To meet the population demand for dairy products, Tunisia has always given high priority to the development of local dairy production. The bulk of the cattle is local and grade cattle owned by small farmers with little or no land. More than eighty per cent of dairy producers have less than 5 cows and half of them have a farm size less than 5 hectares (Office of Livestock and Pasture, 2008). Like in most developing countries, dairy farming in Tunisia is generally carried out at the smallholder level. Such sector has always been given a high priority to increase the domestic production of milk, raise small holders' income and improve their livelihood while meeting the rising demand of the population for fluid milk and dairy products.

Milk yield and composition traits were found sensitive to management system and production environment (Rekik et al., 2009). With this regard, the objective of this study was to evaluate the effect of concentrate and roughage (hay/straw) ratio on milk yield and composition of dairy cows conducted under landless breeding system.

Material and methods

Data were collected from twelve cow farms located in different sites of Sidi Bouzid (Central Tunisia) during March-April 2005. Farms were chosen mainly for presence of crossed breed (Local x Holstein) and the lactation stage of the cow (pick of lactation: 30-50 days post partum). Herd sizes ranging between 1 and 7 dairy cows and farm size varying between 0 and 2 ha. A structured survey was designed to collect herd data on small scale dairy farms. The survey involved two main parts. The first was addressed to the farmers (age, education, farming experience,..) and farm characteristics (location, size, land tenure, major activity, land use, crops, etc.). The second part dealt with herds (size and management, feeding strategies, milk yield, etc.).

Two groups of 26 (G1) and 23 (G2) multiparous and homogeneous cows were managed as separate herds. The G1 group was fed with a ration (R1) including 60% concentrate and 40% oat hay. The G2 group received a ration (R2) with 40% concentrate, 30% oat hay and 30% cereal straw.

Chemical composition of different diets (R1 and R2) in terms of dry matter (DM), crud protein (CP) and crud fibre (CF) contents, energetic value (UFL) and intestinal digested protein (PDI) were studied using the NIR technique.
Data on 49 cows were collected. Individual milk yield and chemical composition were determined. Milk production was determined according to the method proposed by Ricordeau et al. (1960) using oxytocin. Cows were handily milked twice a day and samples were taken out in plastic flasks containing 1 mg of bicromate in order to avoid any possible fermentation of the milk. Samples were then immediately transported to the laboratory for analysis of fat, protein and urea contents using an integrated milk machine (Combifoss 5300, Foss Electric, Denmark).
Based on the feeding strategy, herds were classified into two groups. The first one receive a total ration concentrate (60%) and oat hay (40%). The second group received concentrate (40%), oat hay (30%) and cereal straw (30%). Effect of concentrate roughage ratio on chemical composition traits (fat, protein, urea and somatic cell counts) and milk yield was studied by one way analysis of variance (Steel and Torrie, 1980). The statistic significance of the differences between means was assessed using the Duncan test.

Results and discussion

Chemical composition of tested feedstuffs is presented in table 1. Cereal straw and oat hay are characterized by low CP and high CF contents. Likewise, both feedstuffs are energy deficient (0.48-0.55 UFL/kg DM). In our present study concentrate was offered between 40 and 60% to balance the ration and meet animal requirements particularly under landless breeding system. Survey results revealed that average flock was comprised between 3 and 7 cows and the farm size was usually less than 2 ha. This would justify the excessive use of concentrate for dairy cows. This called landless breeding system is recently introduced in Tunisia mainly in Sfax and Mahdia where farmers had not milk production tradition. Actually more than 80% of national milk is produced in these costal regions.

Table 1. Chemical composition of experimental diets.

Feedstuff	DM (%)	Crud fiber (%)	CP (%)	UFL/kg DM)	PDIN (g/kg DM)	PDI (g/kg DM)
Concentrate	88	3	18	1.13	123	128
Oat hay	83	40	7	0.55	45	59
Cereal straw	82	42	5	0.48	30	50

Results on milk production and chemical composition are presented in Table 2. With the exception of milk fat content, apparently diet composition had not significant effect neither on milk yield nor on chemical composition. This result is in discrepancy with that reported by Gaafar et al. (2009) who recorded a significant effect of concentrate roughage ratio on both milk yield and chemical composition of dairy buffaloes.
Although it was not statistically significant, cows received R1 (60% concentrate) had higher milk production than group received R2 (40% concentrate). Effects of concentrates increase on milk production are attributed to a quick and phasic degradation of non-structural carbohydrates in the rumen, reducing dramatically the rumen pH and altering the amount and composition of microbial protein synthesis and limiting the degradation of structural carbohydrates (Bocquier and Caja, 2001).

Table 2. Milk production and chemical composition.

Feedstuff	Milk yield (kg/d/cow)	Fat content (%)	Protein content (%)	Urea content (mg/100 ml)	Somatic cells counts (10^5)
R1	22.3	4.2 [b]	2.9	28.7	6.92
R2	20.0	5.4 [a]	3.0	29.2	7.54

[a,b] Values in the same column with different letters differ significantly ($P < 0.05$).

However, the increment of concentrates to 60% in ration was traduced by a decrease of all traits of chemical composition. It seems therefore that a negative correlation is established between milk yield and milk composition (Fuertes et al., 1998).
In accordance with findings of Moujahed et al. (2009), increasing concentrate ratio had a negative and significant effect on milk fat content (Table 2). Such variation observed in milk fat can be attributed to changes in fatty acids produced in rumen fermentation when concentrate in the ration exceeds 40%.
More precisely, the higher the ratio of acetate to propionate in the rumen, the higher the fat content of the milk will be (Snowdon, 1991). These results were not supported by Gaafar et al. (2009) who reported a significant increase of milk yield and fat content of buffaloes when concentrate ratio was increased up to

60%. It appears therefore that other external and/or internal factors are in cause. Manipulation of fat content and its nature in the milk to manufacture better sub-products is an important process asked by consumers. This is more and more important both from a nutritional side (omega-3, CLA) and to achieve some specifications (soft butter to be spread just after being taken from the fridge, raw milk cheese, etc).

Fat content was almost 1.5 times higher than that reported by Awadesh (2009) and in close accordance with those carried out by Dang and Anand (2007). This result confirms that fat is more sensitive to feeding strategies than other components of milk. Increasing concentrate ratio in the R1 diet was traduced by a significant decrease of fat content. For both groups fat content (4.2 and 5.4 %) was higher than the average national value recorded for Holstein cows (3.6%) (Office of Livestock and Pasture, 2008). This can be attributed to the higher concentrate proportion in both diets tested.

Irrespectively of feeding strategy, the values of milk protein content were lightly lower than those recorded for Holstein cows (3.15%) under the National recording system and raised according to conventional production systems (Office of Livestock and Pasture, 2008). This can be partly attributed to the low dietary energetic supply. Indeed, forages in the basal diet have low nutritive value and are not adequately supplemented with concentrate feeds compared to the requirements of the cow. Moreover, it is noteworthy remember that cows during experimental period were at pick of lactation (30-50 days post-partum), a stage when milk is mainly poor in protein. Similar results were reported in the literature either for cows (Dang and Anand, 2007; Awadesh, 2009) or buffaloes (Gaafar et al., 2009).

Milk urea concentration was not affected by concentrate ratio and it was proved to be increased significantly during late lactation stages (Dhali et al., 2006).

With respect to somatic cell counts (SCC), values are maintained higher under both feeding strategies (Dang and Anand, 2007). The manual milking practices and human interference under the rural conditions of the studied breeding explain partly of the higher SCC. The reasons for not following procedures like regular screening of udders or post milking teat dipping were found to be due to low awareness levels and economic reasons (Dang and Anand, 2007). Major concern under rural conditions is that even the minimal values of milk SCC are on the higher side indicating that mammary gland is under stress in these conditions. Additionally, more influx of milk SCC not only disrupts the mammary epithelium but also decreases milk quality (Singh and Dang, 2002) which in turn leads to lower returns. Several of these issues can be addressed if we are able to link milk quality with payment using different milking systems. As prices of concentrate feeds, mostly imported from outside the country are substantially increased and milk price has remained relatively steady, the paid price for milk has become nowadays the major limiting factor for farmers' revenue under landless systems. It appears therefore that improved feeding strategies and management practices will result in a better efficiency and an increased productivity.

Conclusion

The use of proportion of concentrates in diets higher than 40% of dry matter may depress both the milk fat and protein contents during the first months of lactation. Milk quality seems to be affected not only by feeding strategies but also by breeding conditions and mainly by milking procedures.

A balance between practices able to increase milk yield and to increase the milk protein content are urgently required.

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Influence exerted by productivity and quality of different-level pastures on sheep productivity

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Abstract

Sheep breeding represents one of the major economic sectors in the studied areas, and the permanent pastures represent the only forage for these animals. This study took place in Banat's Mountains, in the South-West Romania, on permanent pastures located between the altitude of 236 – 1300 m. The weather conditions are different depending on the altitude: between 236 – 700 m, the rainfall quantity ranges between 400 – 700 mm, and at the levels of 800 – 1300 m, it represents 800 – 1200 mm. The observations were performed during a three-year period, on thirteen sheep farms, located at different altitude levels. The objectives of our study were to evaluate the influence on permanent pastures of the ecologic conditions at the different altitude levels. Productivity and quality of forage, as well as the quality of sheep products were investigated. In this viewpoint, the mean dry matter yield of the pastures diminished by 87 kg/ha for each 100 m altitude increase ($DM = 9*10^{-6}*x^2 - 23*10^{-2}*x + 1.7618$, $R^2 = 0,86$). In the case of the altitude level studied, we observed a great variation of the daily weight gain, between 23.25 – 68.57 g/day. The highest daily weight gains were recorded between the altitude limits of 630 – 720 m, with values ranging 51.04 and 68.57 g/day.

Keywords: permanent pasture, altitude, sheep production

Introduction

Productivity and quality of permanent pastures from hill and mountain regions, located at different altitude levels, are strongly influenced by the abiotic factors, respectively by land topography and climatic factors. This may explain the yield differences and the diversity of floristic composition between different types of pastures, located at similar altitude levels.

In many altitude regions, the pastures represent the most important resource for animal feed, especially for sheep. Animal products from grazing are often the only agricultural incomes to households.

This work presents the results regarding productivity, forage quality and animal-based product quality in the Occidental Carpathians mountains in Romania, to an altitude comprised between 240 and 1300 m.

Material and methods

The researches were carried out on permanent pastures of the Banat's Mountains (Occidental Carpathians), in 13 localities located between the altitude levels of 236-1300 m, in some family farms with sheep farming as the main activity.

In order to determine pasture yields and the floristic composition, between 2005 and 2009, we delimited with a fix fence an area of 200 m², in each farm, in four repetitions. Surface delimitation was made after the uniformity degree of floristic composition.

The determination of forage biomass yield was performed in each farm, by cutting, at the beginning of earring of the dominant gramineae species.

The carrying capacity was determined according to pasture yield, to the duration of the grazing period, and also in concordance with the pastoral value (Vp) and with the specific contribution of each plant.

Determination of animals productivity was performed in every year of study on an effective of 100 sheep, used for both meat and milk; we measured their weight at the beginning and the end of grazing period and milk production was measured daily.

The diversity of species, given by their frequency and specific contribution, was determined with the help of the double meter method, described by Daget and Poissonet (1969).

The chemical content of pasture forage and of each species was determined with specific laboratory analyses, and the specific relative coefficients (that determine each species or each plant group's influence on forage quality) were determined according to the relationship established by Lambert and Peters (1985).

Results and discussion

Permanent pastures' yield is influenced by climatic conditions and also by the floristic structure of the vegetal cover. The latest may explain the differences available in altitudinal regions with very small amplitudes (below 100 m), where the yield and floristic composition are much different.

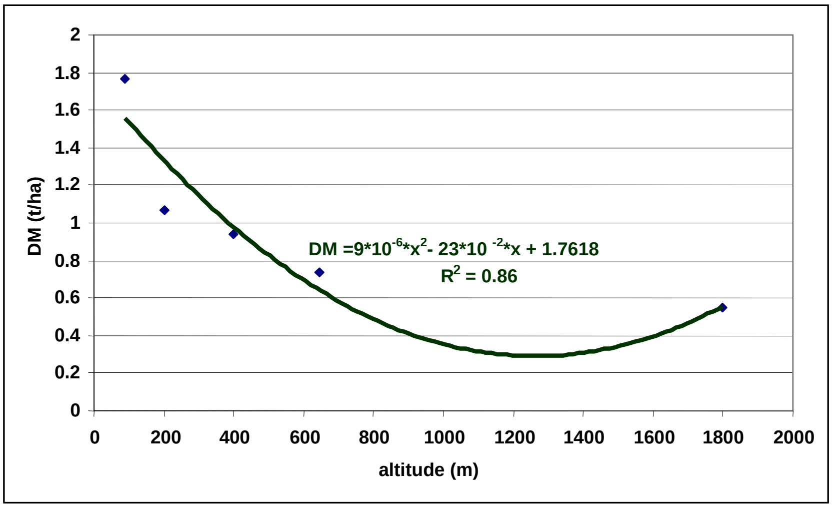
Table 1. The dry matter yield and carrying capacity on altitudinal level 236 – 1300 m

Altitudinal level (m)	DM (t/ha)	Carrying capacity (CCU/ha)[1)]		
		depending on the area of grassland and the number of existing animals	depending on the yield DM and grazing period	depending on the pastoral value
236 – 400	2,29 – 2,49	0,18 – 0,61	1,20 – 1,30	0,49 – 0,85
450 – 650	1,56 – 2,15	0,17 – 0,59	0,93 – 1,29	0,18 – 1,04
700 - 1300	1,21 – 2,31	0,05 – 0,63	1,20 – 1,76	0,12 – 0,92

[1)]CCU- cow calf unit

At the altitude level studied (236 – 1300 m), pasture yield was 1.21-2.49 t/ha dry matter (Table 1). In the case of the pastures located on lower hills (between 236 – 400 m altitude), where we obtained the biggest yields, the yield difference between the extreme limits is only 0.20 t/ha, compared with 0.59 t/ha in the case of the high hills (450 – 650 m) and with 1.10 t/ha DM on the sub-mountain pastures (700-1300 m).
If we consider only the animal livestock existing in the households from the studied region, then the animal load between the altitude levels of 236-1300 m is very reduced, respectively 0.05 – 0.63 CCU/ha. If we consider the potential pasture yield and the duration of the grazing period (ranging between 96-148 days/year), the carrying capacity ranges between 1.20 – 1.76 CCU/ha. Also, the pasture quality (expressed as pastoral value) determines the following carrying capacity classification: 0.49 – 0.85 CCU/ha on lower altitude pastures (236-400 m), between 0.18-1.04 CCU/ha on high hill pastures (450-650 m) and between 0.12-0.92 CCU/ha on sub-mountain pastures (700-1300 m).

Figure 1. Correlation between altitude (m) and DM (t/ha)



The relationship between altitude and pasture yield is given by a significant coefficient of correlation (r = - 0.927 ***).
On the permanent pastures where technological amelioration works are not usually applied (no fertilizers, no oversewing), the climatic resource is the only factor that influences both yield level and forage quality (Table 2).
The unitary dry matter efficiency, expressed as DM quantity obtained with 1 mm rainfall recorded during the vegetation period, ranged between 2.73 and 5.02 kg DM/mm, with a general mean of 3.86 kg DM /mm.

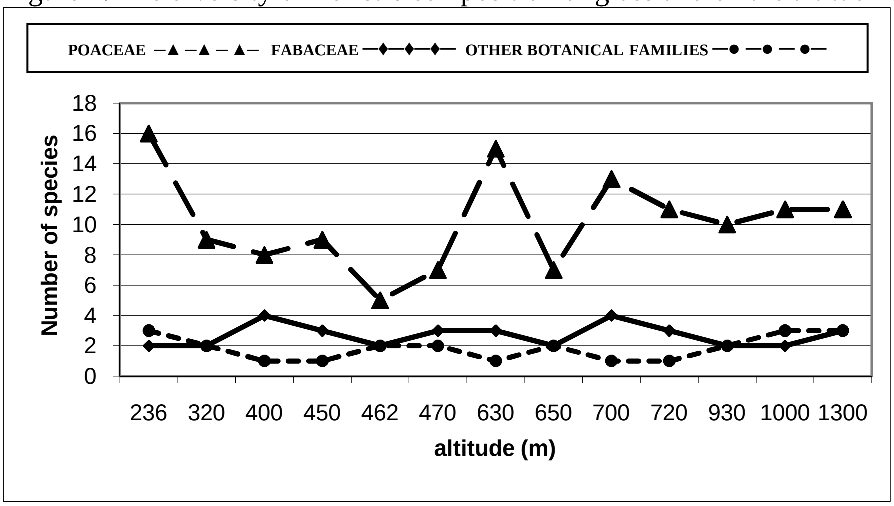
Table 2. Influence of climatic conditions on the unitary dry matter efficiency and specific consumption of permanent grasslands

Altitudinal level (m)	Unit of produced dry matter, per mm rainfall (kg DM/mm)	The water consumption for producing one unit of dry matter (mm/t DM)	Unit of produced dry matter per degree Celsius (kg DM / 1^0C)	The heat constant for producing one unit of dry matter [1)] (^0C/t DM)
236 – 400	4,24 – 5,02	212 – 247	0,73 – 0,79	1280 – 1683
450 – 650	2,84 – 4,04	250 – 373	0,50 – 0,69	1483 – 2037
700 - 1300	2,73 – 4,16	251 - 376	0,50 – 0,73	1385 – 2117
CV %	18,03	19,33	15,58	16,01

[1)] Useful daily average temperatures > 5^0C

The most reduced specific water intake was recorded in the lower altitude regions (236-400 m), comprised between 212-247 mm / t DM, compared with the higher regions (of over 450 m), where the specific intake was 250-376 mm / t DM.
The thermal resource, given by the warmth quantity (with daily mean temperatures >5 ^0C) accumulated during the vegetation period, for the high altitude levels, represents a factor that limits pasture production. So, on the altitude level studied, the unitary warmth efficiency decreases from 0.73-0.79 kg DM/1^0C to 0.50-0.73 kg DM/1^0C, with a general mean, for the entire altitudinal level, of 0.65 kg DM/1^0C.
The useful thermal constancy recorded a dramatic decrease from the pastures located at 236-400 m (with 1280-1683 ^0C/t DM), to the pastures located in higher regions, comprised between 700-1300m, with an index of 1385-2117 ^0C/t DM.

Figure 2. The diversity of floristic composition of grassland on the altitudinal level 236-1300 m



The floristic variability of structure (CV%)

	Poaceae	Fabaceae	Other botanical families
Number of species	28	43	31
Grad of roofing (%)	27	79	26

The number of botanic species within pasture vegetation was much differentiated, respectively between 9 and 21. The biggest number was recorded in the pastures located at altitudes of 236 m (21 species) and 630 m (19 species), and the smallest at the altitudes of 462 m and 650 m (9 species). According to the forage value of the botanic families, the number of species ranged between 2 and 4 per association in the Family *Poaceae*, between 1 and 3 in the Family *Fabaceae* and between 5 and 16 species in the group „other botanic families”. The variability coefficient determinations prove the high-degree variation of the number of species (between 31-43%) and of the covering degree (between 26-79%) (Figure 2).
The results of the chemical analyses performed, regarding the association of botanic species available within the floristic structure of the pastures studied, showed that the chemical composition of the forage from all the 13 pastures is rather balanced, with small differences between the altitudinal regions (Table 3).

Table 3. Chemical composition of the feed from permanent grasslands

Altitudinal level (m)	CP (%)	CF (%)	P (%)	Ca (%)	Ca/P	K (%)
236 – 400	13,49–14,03	21,06-22,55	0,35-0,38	0,44-0,46	1,19-1,31	1,57-1,73
450 – 650	13,92–14,52	20,89-21,73	0,38-0,42	0,46-0,58	1,22-1,38	1,69-1,78
700 - 1300	13,94–15,37	0,41-22,31	0,41-0,47	0,55-0,68	1,28-1,45	1,76-1,86

The nutritive value of the forage from permanent pastures is determined by the chemical content of each species within the floristic structure. Each species' contribution to the achievement of forage quality may be made evident by the determination of specific relative coefficients, for each element or quality index. Compared with the species grouped in the category „other botanic families", the species belonging to the Families *Fabaceae* and *Poaceae*, with their reduced percentage of participation in the floristic structure (below 12%), present a reduced contribution to the achievement of forage quality, although they have a mineral composition that is higher than the one of the other species. According to the data presented in Table 4, we may conclude that the high specific coefficient values of some species belonging to the category „other botanic families", similar with the level recorded by the species belonging to the Family *Fabaceae*, condition the nutritive forage value in the permanent pastures studied. In this viewpoint, we did not observe any significant differences between the 13 pasture types located at different altitude levels (Table 4).

Table 4. Assessing the chemical composition on the feed by specific relative coefficients

Altitudinal level (m)	Floral structure	CP	CF	P	Ca	Ca/P	K
236 - 400	Fabaceae	1,62-1,71	0,76-0,88	1,45-1,91	3,11-5,14	1,98-2,20	1,26-1,46
	Poaceae	0,91-1,06	0,80-1,36	0,70-1,16	0,80-1,18	0,87-1,14	0,82-1,03
	Other botanical families	0,75-2,36	0,54-1,17	0,71-1,51	1,00-3,48	0,87-2,72	0,95-1,63
450 – 650	Fabaceae	1,50-1,69	0,79-0,84	1,34-1,76	2,75-3,63	1,88-2,50	1,25-1,46
	Poaceae	0,92-1,00	0,82-1,42	0,68-1,30	0,61-1,25	0,56-1,05	0,80-1,05
	Other botanical families	0,68-2,23	0,31-1,42	0,62-1,42	0,78-3,48	0,87-4,31	0,76-1,61
700 – 1300	Fabaceae	1,42-1,66	0,77-0,86	1,34-1,47	2,03-3,20	1,78-2,25	1,20-1,33
	Poaceae	0,88-1,11	1,10-1.42	0,55-1,24	0,49-0,96	0,63-1,13	0,76-1,02
	Other botanical families	0,62-1,58	0,68-1,12	0,55-1,31	0,54-2,41	0,58-4,28	0,76-1,60

Sheep breeding represents one the main occupations of the population living in the regions studied, and the permanent pasture represents the only forage resource for these animals.

On the altitude level of 236-1300 m, we recorded a great variation of the daily mean meat growth, between very wide limits, namely 23.25-68.57 g/day. The biggest daily mean growths were obtained in the pasture region of 450-650 m altitude, with values of 37.38-68.57 g/day. The meat growth obtained during sheep grazing period had values of 3.72-10.97 kg/individual. In this viewpoint, like in the case of the daily mean growth, the biggest values were recorded in the region of high and sub-mountain hills, between the altitude limits of 450-1300 m. Because the entire milk quantity is processed as ewe cheese in each household, we may consider that the value of this index, reported to 100 milk sheep, represents an important economic index of differentiation. From this point of view, the biggest amounts were obtained on the pastures located at smaller altitudes, 236-400 m, where we recorded between 1200-1804 kg cheese/100 sheep, compared with the region of sub-mountain pastures (700-1300 m), where the yield limits were between 908 and 1288 kg cheese (Table 5).

Table 5. The sheep production from grazing altitudinal zone between 236 – 1300 m

Altitudinal level (m)	The daily mean meat (g/day)	The weight gain (kg/individual)	The quantity of cheese at 100 sheeps during the grazing (kg)
236 – 400	35,64 – 36,72	6,06 – 6,61	1200 – 1804
450 – 650	37,28 – 68,57	6,34 – 10,97	609 – 1580
700 - 1300	23,25 – 64,33	3,72 – 10,29	908 – 1288
CV %	29,13	29,50	18,21

Sheep milk quality, given by milk's chemical composition, recorded some variations according to altitude and the nature of indices determined. So, the smallest variations were recorded in the case of the crude fat content, crude protein and lactose, and bigger variations (CV > 9 %) were obtained at the level of some chemical elements from milk (P, K, Ca, Mg, N).

On the whole, we may conclude that, for the altitude level studied (236-1300 m), sheep milk's chemical content belongs to optimal quality categories, with very reduced variations between the three altitude levels.

Table 6. Chemical composition of the sheep milk

Altitudinal level (m)	Crude fat (%)	Crude protein (%)	Lactose (%)	P (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	N (mg/l)
236 – 400	7,79-7,92	5,54-5,69	4,52-4,59	5,44-6,31	0,64-1,25	0,87-1,04	0,17-0,19	0,82-0,89
450 – 650	8,04-8,69	5,46-5,68	4,21-4,33	5,22-6,28	0,51-0,75	0,78-0,92	0,13-0,17	0,63-0,74
700-1300	7,15-8,99	5,57-5,94	3,99-4,21	3,81-5,46	0,56-1,03	0,86-1,04	0,15-0,17	0,63-0,67
CV%	5,97	6,54	4,30	14,91	31,34	9,50	9,27	11,87

Conclusions

The yield of the permanent pastures located at the altitudinal level of 236-1300 m was comprised between 1.21-2.49 t/ha DM and the carrying capacity (according to the pastoral value) was between 0.12-0.92 CCU/ha.

The climatic resource of the region studied determines the achievement of 1 t DM with a consumption of 212-376 mm rainfall water and 1280-2117 ^{0}C warmth.

The nutritive value of the forage from the pastures studied is mainly determined by the chemical composition of the species belonging to the group „other botanic families”.

Sheep productions (meat, milk) record rather big variations between the altitude levels studied.

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Carcass and meat characteristics of lambs Grazing on mountain pastures or reared on feedlot

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Abstract

The objective of this study was to compare the growth and meat quality of feedlot lambs with lambs grazing on mountain pastures. The experiment was undertaken in the region of Tunisian Centre-West with 21 Barbarine lambs divided into three groups. One group (GMP) was conducted on grazing mountain pasture with a dominance of *Artemisia herba-alba* and containing *Rosmarinus officinalis*, sheep received daily 400 g of concentrate per lamb. The two other groups were conducted on feedlot (FL) with oat hay ad-libitum and 800 g of the same concentrate only (FL-C) or control plus 200 g of fresh foliage of aromatic plants (FL-AP) of pasture. At the end of the experiment, all lambs were slaughtered.
Sheep of all groups had an average daily gain of 160 g. All carcasses contained the same quantity of muscle and fat. The average daily fat and muscle gains were 44 and 58 g, respectively. Significant differences between the groups were found only for initial pH with 7.3 for GMP group vs. 6.9 for both FL ones ($p<0.05$). Differences in colour parameters were not significant; although GMP sheep had higher redness value (17.1) than FL sheep (15.6). Similar values were obtained for L (36.3) and b* parameters (7.2). Differences in sensory traits were small and not significant. Generally, the meat lamb was considered tender and juicy. In conclusion, mountain pasture resulted in the same growth in spite of the half quantity of concentrate without difference for quality traits.

Keywords: Sheep; Grazing; Feedlot; Growth, Meat quality; Carcass characteristics

Introduction

In the Mediterranean area, sheep feeding is based on natural resources, range land and stubble. The availability of such resources is uncertain in all years. However, some systems of feeding management were developed in this region; Thus, the fattening operation is based on concentrate. However and particularly in good years, grazing is available in whole parts during a short period (3 to 4 months) in spring. Grazing natural fallow, Barbary lambs reached slaughter age (6 months) with a higher slaughtering weight and less carcass fat than feedlot lambs fed on hay and concentrate (Atti and Abdouli, 2001). Furthermore, meat of lambs grazing on mountain pastures is often considered to be of superior quality (Ådnøy et al., 2005). The objective of this study was to compare the growth and meat quality of feedlot lambs with lambs grazing on mountain pastures (750 m above sea level).

Material and methods

The experiment was carried out at INRA experimental farm of Ouesslatia (region of Tunisian Centre-West). A total of 21 fat tail Barbarine lambs was randomly divided into three groups. One group grazed on mountain pasture (GMP) with a dominance of Artemisia herba-alba and containing *Rosmarinus officinalis*. These sheep received a daily supplement of 400 g of concentrate per lamb. The two other groups were conducted on feedlot (FL) with oat hay ad-libitum and 800 g of the same concentrate only (FL-C) or control plus 200 g of fresh foliage of aromatic plants (FL-AP) of pasture (Artemisia and rosemary). At the beginning and the end of experiment, lambs were weighted and some tail measurements were taken to calculate fat and muscle mass at both stages (Atti and Ben Hamouda, 2004). At the experiment end, all lambs were slaughtered. The pH was determined on Longissimus dorsi (LD) muscle at slaughter and 24h post-mortem with a penetrating electrode connected to a portable pH-meter. Carcasses were dissected and samples of muscle LD were taken for analysis of meat characteristics and sensory tests. Color variables (L* (lightness), a* (redness), b* (yellowness)) were measured using a Minolta CR 400 color meter. For sensory analysis, samples of LD were roasted in aluminum paper in a pre-heated oven at 180ºC and samples of neck were cooked as a Tunisian sauce in boiling pot, and then presented to 7 panelists to evaluated each sample for the tenderness (scale 1-10; 1=extremely tough, 10=extremely tender), juiciness (scale 1-10; 1=extremely dry, 10=extremely juicy) and flavor (scale 1-10; 1=very poor, 10=very good).

Data concerning sheep growth, carcass and meat quality were analyzed using a one-way ANOVA design. Statistical analysis was carried out with the GLM Procedures (SAS, 1987). The following contrasts were used to compare the effects of the different diets:

(GMP) vs. (FL-C + FL-AP): effect of grazing (C1)

(FL-C) vs. (GMP + FL-AP): global effect of aromatic species (C2)

(FL-C) vs. (FL-AP): effect of aromatic species in FL (C3)

Results and discussion

During the whole period, sheep of all groups had a similar weight gain of 11 kg, which equivalent to an average daily gain of 160 g and slaughter BW of 42.7 kg. However, carcass weight and consequently the dressing percentage were higher for GMP group than both FL ones (Table 1). So, with the halve concentrate quantity, grazing sheep had similar growth but higher carcass than FL, which confirmed other findings on better efficiency of grazing system (Atti and Abdouli, 2001; Nuernberg et al., 2005).

Table 1. Body weight (BW) parameters, carcass weight and dressing percent (DP)

Group[£]	FL-C	FL-AP	GMP	p	C1	C2	C3
Initial BW (kg)	30.2	32.3	31.2	ns	ns	ns	ns
Final BW (kg)	42.6	42.5	43.3	ns	ns	ns	ns
Daily gain (g)	176	147	173	ns	ns	ns	ns
Empty BW (kg)	35.7	35.8	38.4	*	**	ns	ns
Carcass (kg)	19.5	19.4	21.1	*	ns	ns	ns
DP (%)	45.8	45.6	47.9	**	*	ns	*

[£:] FL-C: Feed lot group GMP: Grazing group FL-AP: Feed lot group receiving aromatic plant

Carcass composition was similar for all regimens; they had the same proportion of muscle and fat (Table 2). In other researches, the fat proportion has been reduced in grazing lambs compared to FL ones (Atti and Abdouli, 2001; Nuernberg et al., 2005). The average daily muscle gain was 63 g for GMP group and 56 g for both FL ones, without significant difference; but average daily fat gain was 44 g for all groups. Differences in colour parameters were not significant; although GMP sheep had higher redness value (17.1) than FL sheep (15.6) and the contrast 1 was significant. Similar values were obtained for L and b* parameters (Table 2). Ultimate pH was similar for all groups, however, initial pH was significantly higher ($p<0.05$) for GMP groups than both FL ones (Table 2).

Table 2. Meat (longissimus d) characteristics and tissue's proportions in carcass of Barbarine lambs

Group[£]	FL-C	FL-AP	GMP	p	C1	C2	C3
pH1	6.94	6.92	7.23	**	**	**	ns
pH2	6.23	6.06	6.09	ns	ns	ns	ns
L*	36.5	35.2	37.3	ns	ns	ns	ns
a*	15.5	15.8	17.1	ns	*	ns	ns
b*	5.8	7.0	7.7	*	ns	ns	ns
Muscle (%)	49.8	49.7	49.8	ns	ns	ns	ns
Fat (%)	29.1	28.8	30.2	ns	ns	ns	ns

[£:] FL-C: Feed lot group GMP: Grazing group FL-AP: Feed lot group receiving aromatic plant

For both cooking modes, Barbarine lamb's meat was considered tender and juicy. Differences in sensory traits were small and the statistical model not significant (Tables 3 and 4). However, for roasted meat, the presence of aromatic plant (GMP and FL-AP) increased meat tenderness, the contrast 2 was significant.

At reverse, the juiciness was higher for FL groups than GMP one and the contrast 1 was significant (Table 3).

Table 3. Sensory attributes of roasted meat (Longissimus dorsi muscle) for Barbarine lambs

Group[£]	FL-C	FL-AP	GMP	p	C1	C2	C3
Tenderness	6.76	7.20	7.21	ns	ns	*	ns
Juiciness	6.21	6.71	5.58	ns	*	ns	ns
Flavour	7.16	7.06	7.14	ns	ns	ns	ns

[£:] FL-C: Feed lot group GMP: Grazing group FL-AP: Feed lot group receiving aromatic plant

Table 4. Sensory attributes of cooked meat (neck) for Barbarine lambs

Group[£]	FL-C	FL-AP	GMP	p	C1	C2	C3
Tenderness	6.66	7.57	6.33	ns	ns	ns	ns
Juiciness	6.83	6.85	6.66	ns	ns	ns	ns
Flavour	6.66	7.28	7.01	ns	ns	ns	

[£:] FL-C: Feed lot group GMP: Grazing group FL-AP: Feed lot group receiving aromatic plant

Conclusions

In conclusion, grazing mountain pasture system resulted in the same growth rate in spite of the half quantity of concentrate offered in FL system without difference for quality traits.

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Kid's growth curve parameters of goat adjusted by Gompertz model

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Abstract

The Gompertz model was tested to fit the kid's growth curve parameters of indigenous goat, Alpine, Damascus and their F1 and F2 crosses. Data issued from 16 years periodical weighing was used to adjust growth curve. Among tested models, the iterative procedure allowed to identify the Gompertz model as the best to adjust kid's growth evolution. The crossbreeding allows a better growth kinetic with respect to indigenous kids. The best growing performances were obtained for the first generation of crossbreeding due to heterosis effects.

Key words: Caprine genotypes, growth, Gompertz model, Tunisia.

Introduction

Local goat is genetically considered as a population having a wide phenotypic variability and it's essentially raised in pastoral and agropastoral modes. The suckling kid's meat is the main product for this breeding system and it contributes with about 75% in the regional meat production under very low input systems. Under oasian conditions, the goat husbandry plays a key role by its significant various contributions in the farmer's incomes. Goat benefits from an intensified breeding mode under low climatic risks which characterize the arid area (Gaddour and Najari, 2008).

In order to increase the oasian goat herds' production, some high yielding exotic breeds were introduced, since 1980, in the arid region. The objective of this program has been either to produce meat where goats were not milked or to increase dairy yields where milk contributes to the farmer incomes. These goals had to be achieved upgrading local breeds to different levels through crossbreeding as a step to produce new goat genotypes having high performances and adapted to local environment (Mignon and Beaumont, 2000).

The kid's growth model assessment is of particular importance in animal production because of its practical implications in genetic evaluation and herd management. Growth curve parameters change by all factors affecting the weight, especially the genetic potentialities of the breed (Rekik *et al.,* 2003).

During animal lifetime, the essential weight gaining is reached before the maturity stage, and it is well known that animals achieve the target mature size in a well-defined sigmoid or S-shaped curve (Macciotta et *al.,* 2005). This has led to use typical curves to describe animal growth due to the general predictable pattern followed by the growth process. A typical growth curve can be divided into two phases, an early phase where the gain rate is increasing and a later phase where the gain rate is decreasing. The point of inflection is the point where the curve turns from concave to convex. Several non-linear functions have been proposed for various domestic livestock species and breeds to model the growth curve per genetic group (Macciotta et *al.,* 2005).

The present study aims at adjusting the kid's growth curve of local population, introduced breeds and crosses as a step to evaluate the meat production kinetic and potentialities for each genotype. Establishing curves parameters leads to optimise the use of local and introduced genetic animal resources and then, to increase farmers' incomes in the southern Tunisia oases (Najari, 2005).

Materials and methods

During 16 years, the crossing scheme was applied and an individual periodical weighing control was continuously realized from birth till weaning in summer beginning. A total of 1687 kids' data were registered and used as the data base for this study. For each kid the data include genotype and control dates with respective observed weights.

The local goat population is characterised by it is small size with an average hight of 76 cm for the male and 60 cm for the female. To cross local goat, three ameliorative breeds were used: Alpine, Damascus and Murciana breeds were imported respectively from France, Cyprus and Spain (Gaddour and Najari, 2008).

Evaluation criteria used to compare studied models accuracy were computing difficulty and fitting goodness. Computing difficulty was defined as the number of iterations needed to converge. Except for Richards' model, the starting values of parameters are null to allow the same convergence conditions. Goodness of fit was defined as the magnitude of the residual mean squares at convergence (RMS), which provides a measure of the estimation precision. The accuracy is also evaluated by the nonlinear coefficient of determination (CD). Statistical analysis was done by SPSS.

Results & discussion

Kid's growth curve shape and parameters

The kid's growth parameters issued from the curve assessment by the Gompertz functions are presented in table (1). The kid's growth curve adjusted by the Gompertz function is presented in figure (1), including lower and upper limits of weights estimation.

The calculated curve parameters value A, b and c provided the following growth equation:

$P=15.74e^{(-e(-0.03*t+0.31))}$ (1)

where P is the kid's weight (kg), and t is the kid age (days).

The model function allows estimating some crucial growth curve parameters: the asymptote A value represents the adult weights when the age t tend to the infinite; the inflexion point correspond to the point in which the second derivative becomes "zero" and the growth rate is the maximum. The weight and the age at inflexion are consequently calculated as:

Age at inflexion (days) = c/b (2)

Weight at inflexion (kg) = A e (-e(-b*age-c)) (3)

The inflexion point is located at 10 days, at a weight of 5.79 kg; the asymptotic weight is estimated to 15.74 kg (Table 1).

Table 1. Growth curve parameters estimated by the Gompertz model.

	A	b	C	Age at inflexion (days)	Weight at inflexion (kg)
General	15.74	0.03	-0.31	10.33	5.79

A: Asymptotic weight; b and c: Gompertz curve parameter.

The curve asymptote is usually used to estimate the adult weight when the Gompertz model is used to adjust the growth. As shown by equation (1), the A value is about 15.74 and seems to be less than the real goat adult weight estimated in other studies. It's well known that Gompertz model can underestimate the A constant especially when relative late age is used to estimate the curve parameters (Macciotta et *al.*, 2005).

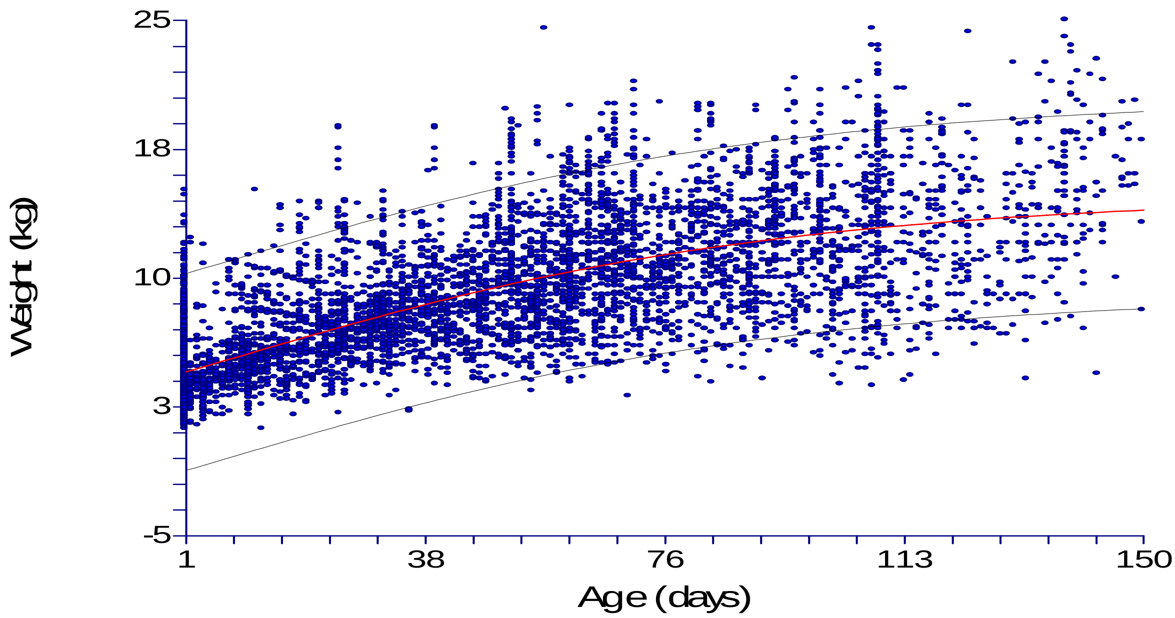

Figure 1: Kid's growth curve adjusted by the Gompertz model, with lower and upper limits.

Conclusions

The shape of the kid's growth curve parameters provides valuable information about the biological and economic efficiency of the studied goats genotypes under oasian conditions. Such results seem useful for genetic improvement and herd monitoring of caprine livestock.

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Curve lactation of goat Genotypes in Southern Tunisia

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Abstract

The Wood model was used to fit lactation curve of goat genotypes under oasian conditions in southern Tunisia. Data of 993 adult dairy milk goats were analyzed to adjust individual milking curves per genetic group. Wood models parameters were estimated by non linear regression iterative procedure. The local goat lactation curve was fitted after 16 iterations with a value of 0.22 as the residual mean squares. Among pure breeds, the Alpine had the highest production at peak with 1.9 $kg.day^{-1}$. The starting production, the milking peak and date, the persistence coefficient illustrated differences between studied genotypes.

Key words: Goat, curve lactation, Wood model, Tunisia.

Introduction

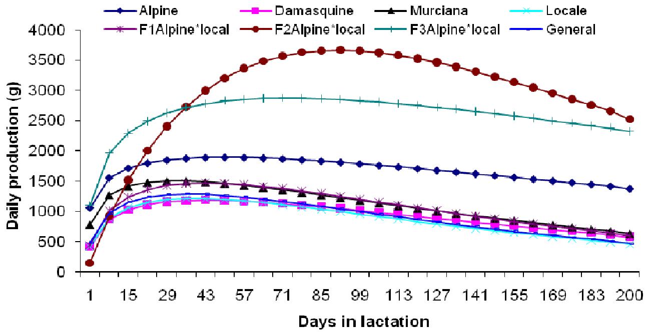
The mathematical models used to assess lactation curves were regular functions y = f(t), defined for positive values of daily milk production (y) and time from parturition (t), used in the dairy livestock for breeding and herd management purposes (Rekik *et al.,* 2003; Macciotta *et al.,* 2005). These models represent an essential research tool for developing and validating mechanistic models, aimed at explaining the main features of the milk production pattern in terms of the known biology of the mammary gland during pregnancy and lactation (Macciotta *et al.,* 2005). Milking kinetic curve after parturition is characterized by a first ascending phase to a peak followed by a decreasing phase (Rekik *et al.,* 2003; Macciotta *et al.,* 2005). Among many mathematical functions performed to describe lactation curve, the common model applied is Wood's Model, which generally uses a logarithmic transformation of an incomplete gamma curve to obtain least squares estimates of constants (Najari, 2005).
The present study aims at estimating the lactation curve parameters of local goat population, introduced breeds and crosses as a step to characterize the milk production potentialities for each genotype and the crossbreeding impacts under oasian conditions.

Materials and Methods

About 1923 individual goat milking data was used to evaluate the dairy potentialities of local goat imported breeds and crossed genotypes. A statistical analysis was applied on estimated dairy performances such as, daily milk average, total production by lactation and milking period.
Evaluation criteria used to compare adjustment convergence accuracy were computing difficulty and fitting goodness. Computing difficulty was defined as the number of iterations needed to converge (Gaddour *et al.,* 2008). Goodness of fit was defined as the magnitude of residual mean squares at convergence (RMS), which provides a measure of the estimation precision (Mignon Grasteau and Beaumont, 2000). The coefficient of determination (CD) is also used to evaluate the parameters estimation accuracy. SPSS and CNSS were the statistical software used.
Lactation curve adjusted by the Gamma function becomes (Rekik *et al.,* 2003): Yt= Atb Exp–ct
Where Yt: Dairy production (kg), t: Days after parturition (days).
The Gamma curve parameters (A, b and c) allow the estimation of dairy parameters such as:
Initial dairy production (Y0) = A, Date of peak (days) = b/c,
Production of peak (kg) = $(A^*(b/c)^b)^*\text{Exp} -b$, Coefficient of persistence (%) = 100- (-b+1) Ln c .
To compare milking parameters of studied genotypes, a Student Newman Keuls test (α = 5%) was applied. The local goat population (Lo) is characterised by it is small size with an average hight of 76 cm for the male and 60 cm for the female. To cross local goat (Lo), three ameliorative breeds were used: Alpine (A), Damascus (D) and Murciana (M) breeds were imported respectively from France, Cyprus and Spain (Gaddour *et al.,* 2008).

Results and Discussion

The model Gamma was adopted for adjustment of the lactation curve and estimates the performance of introduced goat breeds and crosses. In addition, Najari (2005) used this model to adjust the lactation curve of local goat population. The converging behaviour of the lactation curve fitting seems to be dependent on the data corresponding to dairy production which varies with the genotype. The lowest iteration number corresponded to the Murciana (Figure 1), in this case, only 10 iterations were sufficient to reach the convergence criterion (10^{-8}). While the estimation of the F1 and F2 Alpine*local crosses needed about 30 iterations. The F3 Alpine*local had the highest and the worst residual means squares where the value was 1.43; the reduced observation number can explain such result. All curve's parameters were positive, so, all lactation curves could be considered regular (Rekik et al., 2003).



The gamma function and parameters allowed establishing the lactation curve shape (Figure 1). These parameters were analyzed as genetic group's performances. In addition, other settings for selected lactating genotypes were considered (Figure 1).

Figure 1: Lactation curve adjusted by the Gamma function, for local goat population, pure breeds and crossed groups.

The lactation curve parameters illustrate a specific milking behaviour for the studied genotypes. It seems that some groups are able to produce an additive daily production than others. After parturition, the highest initial production was observed for F3 Alpine*local crossed goats. This production represents more than 200% of the local goat performance at the same lactation phase. Damascus performances were similar to those of the local goat. The peak parameters illustrate that the earliest peak date corresponds to the F2 Alpine*local crossed goats. Also these goats had the highest production at the curve point.
Among studied genotype curves, the lactation curves of the Alpine breed and crosses (Figure 1) looked much better with a production peak quite high and of good persistence. During the first lactation phase, the performances of local goat population and Damascus breed were quite comparable in shape and magnitude, however, after the peak phase, the Damascus dairy performances became increasingly higher than the local goat population. For Murciana, the low rates of persistence gradually lead to the production similar to Damascus goats (Figure 1). Such aspects help to optimize the genotypes management and provide scientific tools to optimise crossbreeding plans to improve caprine milk production under oasian breeding mode.

Conclusions

The shape of the lactation curve and milking parameters provide valuable information about the biological and economic efficiency of the studied goats genotypes under oasian conditions. Such results seem useful for genetic improvement and herd monitoring of caprine livestock. In fact genotypic milking merits, highlighted by Gamma model assessment, help to optimize the crossbreeding of local goat in the aim to produce a new genotype both productive and adapted to the natural conditions of the oasian area.

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Sensory properties of Cantal cheese from different feeding systems and ripening times

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Abstract

Sensory properties of Cantal cheese from three equivalent groups of 12 Montbéliarde cows fed hay (H) and grazing on a high species-rich upland pasture under continuous stocking (C) and on an old lower species-rich hay grassland under rotational stocking (R) were compared after 12 and 24 weeks ripening. Cheesemaking were done on three consecutive days in July. A panel test was performed by 10 trained panelist. The H cheeses had more intense rind colour, more pronounced spot salience, less intense paste colour, less intense odour and aroma, higher butter odour, and less persistent taste than pasture-derived cheeses. They had also firmer, less elastic and less creamy texture, in relation to their higher polyunsaturated fatty acids (FAs) content and *cis*9-C18:1/C16:0 ratio. Panelists were unable to distinguish between 12-weeks ripened C and R cheeses in a triangular test. Sensory differences became perceptible after 24 weeks ripening when C cheese had more intense odour, more intense and persistent aroma, sourer, more pungent and saltier taste than R cheese. The weakness of the sensory differences between R and C cheeses could be due to interactions of pasture species-richness and herbage phenology with stocking method and diet cow selection.

Keywords: cheese sensory properties, milk fatty acids, upland pasture, stocking method.

Introduction

Changes in cheese characteristics are frequently reported by cheese-makers as related to the type of forage supplied to dairy cows. On this basis, several studies have been conducted to highlight the effects of animal feeding on cheese sensory properties. Differences between pasture- and preserved forage-derived cheeses are well known (Martin *et al.*, 2005). Pasture provides less firm, creamier, more elastic, and yellower cheeses, with a less sour and less intense odour and a more intense sour and bitter taste (Martin *et al.*, 2005). A broad variability in pasture-derived cheese sensory properties has been reported in on-farm studies, according to grazing management, botanical composition and plants (or herbage) phenological stage (Bugaud *et al.*, 2002). However, in experimental conditions, little is known about the effect of the stocking method and of pasture species-richness on cheese sensory properties.
The aim of this work was to compare, in controlled conditions, the sensory properties of cheeses derived from two different stocking methods in an upland area: continuous on a high species-rich pasture and rotational on lower species-rich hay grassland. The sensory properties were evaluated at two different ripening times.

Material and methods

The experiment was carried out at INRA experimental farm of Marcenat (mountain area of central France) where three equivalent groups of Montbeliarde dairy cows of which: the first (H) was kept indoor and fed with a concentrate and hay-based diet; the second (C) grazed, by continuous stocking at low density (0.96 LU/ha), an heterogeneous high species-rich pasture (74 species) of 12.5 ha; the third (R) grazed by rotational stocking at higher density (1.56 LU/ha) an old and lower species-rich hay grassland (31 species) of 7.7 ha. Milk of 2 consecutive milkings was collected and cheese manufactured (9 cheeses overall) during 3 consecutive days in early July 2009. Small size Cantal type cheeses (10 kg) were produced with raw milk. The milk fat-to-protein ratio was standardized at 1.10. A panel of 10 trained panelists analysed the cheeses after 3 and 6 months ripening for a precise description of the cheese sensory profile. The intensity of 32 attributes was scored on a structured scale from 0 to 10. A triangle sensory analysis was performed between the C and R cheeses. The analyses of milk and cheese are described in Martin *et al.* (2009). The data were treated by analysis of variance to assess the differences among feeding systems, ripening time and their interaction.

Results and discussion

Results of cheese sensory properties are reported in Table 1. The H cheeses had a more pronounced spot salience, many more spots, less intense paste colour than pasture-fed cow cheeses. The differences between cheese from hay-fed and grazing cows were described by Coppa *et al.* (2011) as might be related to milk FA profile. The lower melting point of pasture cheese fat could cause a loss of butter-oil in the curd during pressing. This could be deposited on the rind, creating an environment less favourable to the development of the inoculated mould and bacteria involved in spot development and coloration. Texture was firmer, less elastic and less creamy for H than for C and R cheeses, confirming literature results (Martin *et al.*, 2005). These differences may be mostly explained by the higher cis9-C18:1/C16:0 ratio and poly-unsaturated fatty acid content recorded for pasture-based milk (Bugaud *et al.*, 2002; Coppa *et al.*, 2011).

The C cheeses had a more intense odour and a more intense and persistent aroma than H cheeses. They also had less butter odour and tended to taste sourer and more pungent than the R and H cheeses. The sensory differences found between H and pasture-derived cheeses are in accordance with Martin *et al.* (2005).

At 3 months ripening, only 35.5% of the assessors (22 correct answers out of 62) were able to distinguish R from C cheese ($P > 0.05$) by triangular test. The weakness of cheese sensory differences between the two stocking methods is surprising, considering the effect of botanical composition on cheese sensory properties reported by Martin *et al.* (2005) and may be explained by: (i) the strict-hygiene procedure and the simultaneous milking and cheesemaking in the same environment for C and R groups, that may minimize the effects of upstream environmental factors on raw milk microflora (Verdier-Metz *et al.*, 2009); (ii) the uncooked hard Cantal cheese model, in which the milk endogenous protease plasmin plays a minor role on proteolysis, with consequent minor changes in flavour and texture of cooked or semi-cooked cheeses from different pastures (Bugaud *et al.*, 2002); (iii) the continuous stocking enables cows to select more species with high palatability and quality, mainly vegetative grasses, making botanical composition and phenology of herbage ingested by C cows similar to R ones. The rotational stocking, was in fact devised to offer cows mainly leafy edible grasses throughout the season (Coppa *et al.*, 2011). Thus differences in between C and R may be less important than expected. Lastly, (iv) the first sensory evaluation, which did not reveal any difference between C and R, was achieved only after 3 months ripening of cheeses. This ripening time seems to be too short to highlight diet effects on sensory properties of Cantal cheese (Cornu *et al.*, 2009). In fact, 44.6 % of the panelists (25 correct answers out of 56) correctly identified C and R cheeses at 6 months ($P = 0.02$) by triangular test. C cheeses were characterized by stronger notes confirming the long-term evolution during ripening in cheese from high species-rich mountain pastures already described by Bosset *et al.* (1999).

The 6 months ripened cheeses had a less intense butter odour and cooked paste odour and aroma, but they had more intense, more stable and more persistent aromas than the 3 months ripened cheeses. They tasted also more salty, sour and pungent. These differences, regardless the treatment, were consistent with the ripening time-related increases in pH, dry matter, and proteolysis indicators (Martin *et al.*, 2009).

Conclusions

In our trial, carried out in controlled conditions, the effect of pasture species-richness on cheese sensory properties proved surprisingly weak, suggesting that other factors, such as herbage phenology, cow species selection and stocking method may be involved in determining cheese sensory properties. The differences between the stocking methods became perceptible only after long-time ripening.

Table 1. Effect of feeding system and ripening time on cheese sensory properties.

Item	Treatment			Ripening		SEM	Effects and significance		
	H	R	C	3 months	6 months		Treatment	Ripening	Treatment×Ripening
Appearance									
Rind colour	4,8	4,1	4,1	3,6	5,2	0.14	†	***	ns
Spot colour	6,4^{a}	6,1^{ab}	5,5^{b}	5,1	7,0	0.11	***	***	***
Spot salience	5,9^{a}	4,9^{b}	4,5^{b}	4,1	6,2	0.14	***	***	***
Spot quantity	6,7^{a}	5,7^{b}	5,4^{b}	5,2	6,6	0.13	***	***	***
Paste colour	3,7^{b}	6,6^{a}	6,3^{a}	5,5	5,7	0.13	***	ns	ns
Paste cracks	4,4^{b}	4,9^{a}	5,0^{a}	4,4	5,2	0.11	*	ns	**
Texture									
Firm	7.2^{a}	5.5^{b}	5.6^{b}	5.7	6.6	0.11	***	***	ns
Elastic	3.4^{b}	4.5^{a}	4.2^{a}	4.3	3.7	0.13	*	**	ns
Creamy	3.0^{b}	3.8^{a}	4.0^{a}	3.8	3.4	0.13	**	**	ns
Odour									
Intense	5.0^{b}	5.2^{ab}	5.6^{a}	5.1	5.5	0.10	**	ns	ns
Butter	0.9^{a}	0.7^{a}	0.4^{b}	0.9	0.3	0.09	*	***	ns
Cooked paste	1.0	1.0	1.2	1.2	1.0	0.09	ns	*	ns
Aroma									
Intense	5.0^{b}	5.4^{ab}	5.6^{a}	5.1	5.6	0.09	*	†	ns
Cooked paste	0.9	0.6	0.7	0.8	0.7	0.07	ns	*	ns
Stable	0.2	0.2	0.1	0.1	0.3	0.05	ns	*	ns
Persistent	5.0	5.3	5.5	5.1	5.4	0.10	†	†	ns
Taste									
Salty	5.3	5.2	5.3	5.1	5.4	0.05	ns	**	ns
Sour	1.4	1.4	1.8	1.2	1.8	0.11	†	**	ns
Pungent	1.3	1.2	1.6	1.0	1.7	0.11	†	***	ns

Significance: ***, P<0.001; **, P<0.01; * P<0.5

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Are there any differences in bone metabolism of lactating sheep and goats kept on high altitude and lowland pastures

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Abstract

The purpose of this study was to investigate the impact of increased movement on different landscapes of lactating ewes and goats on bone metabolism.
A group of five adult lactating ewes and goats was kept on pasture at 2000 to 2600 m a.s.l. (alpine) and 400 m a.s.l. (lowland), respectively. Two ewes and goats were equipped with a GPS receiver in order to calculate daily tracks on the alpine landscape. The daily milk yield was quantified and the metatarsus was measured three times with peripheral computed tomography (pQCT).
The ewes walked on average longer distances and covered larger altitude differences. They remained mainly on grass-covered landscapes, whereas the goats stayed in bush-dominated areas. The sheep from both groups revealed an increase in cortical thickness, bone mineral density (BMD) and bone mineral content (BMC). The goats from the lowland group revealed a decrease in BMD, whereas in the goats from the alpine group a decrease in cortical thickness and an increase in BMC was detectable. The goats produced significantly more milk than the sheep. In sheep, there was no lactation induced bone loss detectable compared to the goats which could be partially reduced by increased high impact movements.

Keywords: small ruminants, bone metabolism, exercise, lactation, high altitude

Introduction

During lactation, maternal mineral and bone metabolism is altered due to milk production. To meet the high calcium requirements, a reversible demineralisation of bone takes place. Bone loss due to lactation is described in animals (Zeni *et al.*, 1999; Gonen *et al.*, 2005; Liesegang *et al*., 2006) and in humans (Hayslip *et al.*, 1989; Polatti *et al*., 1999; Laskey *et al*., 2010). In humans and in rats the BMD at the end of lactation was significant lower compared to non lactating control groups. A study from Lovelady *et al*. (2009) suggests that exercise may slow bone loss during lactation due to the well known fact that exercise induces an increase in bone size, cortical thickness, cortical bone area, bone mineral content (BMC) and/or bone mineral density (BMD) (Raub *et al*., 1989; Hiney *et al.*, 2004; Firth *et al.*, 2010). BMD and BMC can be determined by peripheral quantitative computed tomography (pQCT). The content of this study was to investigate the impact of increased movement on different landscapes of lactating ewes and goats on bone metabolism.

Material and methods

A group of five adult lactating ewes (East Frisian milk sheep) and five adult lactating goats (Saanen dairy goat) was kept on pasture at the ETH research station Alp Weissenstein, Albula, Grissons at 2000 to 2600 m a.s.l (sheep alpine group = SA; goats alpine group = GA). The lowland group, also five adult lactating ewes and goats, was kept on pasture at the ETH research station Chamau, Central Switzerland, 400 m a.s.l. (sheep lowland group = SL; goats lowland group = GL). At the beginning of the experiment, SA were in lactation 98.4± 1.96 d, SL 94.4 ± 5.41 d, GA 72.4 ± 6.75 d and GL 93.4 ± 2.66 d. They were milked twice daily and the milk yield was measured. During daytime, they had access to the pasture for 10 hours. At night, they stayed either in the barn or at the pasture, depending on weather conditions, but always treated the same way on high altitude and in the lowlands. Two ewes and two goats from the alpine-group were equipped with a GPS receiver (Wintec, G-Rays WBT-201, Taiwan) in order to calculate daily tracks and the movement pattern of the animals. The left metatarsus of each animal was measured with pQCT (Stratec XCT 960A, Stratec Medizinaltechnik GmbH, Pforzheim, Deutschland) at the beginning of the experiment and at the end of the experiment at week 12 and 6 weeks afterwards at week 18.

The experiment is divided in the experimental period (week 1 to week 12) and the post experimental period (week 12 to week 18). In the experimental period, the animals were kept either at the alpine or the lowland pasture. In week 12, they were brought back to the home barn and both groups where kept under the same conditions until week 18, when the final sampling was performed.

Results and discussion

The SA walked on average longer distances and covered larger altitude differences than GA. From the beginning of the experiment, the SA and the GA significantly increased the distances until week 6 and week 5, respectively (Figure 1). In the second half of the experimental period the SA covered significant shorter distances, the distances covered by the GA did not change significantly in the second half of the experimental period. The SA remained mainly on grass-covered landscapes, whereas the GA stayed in areas where bushes dominated.

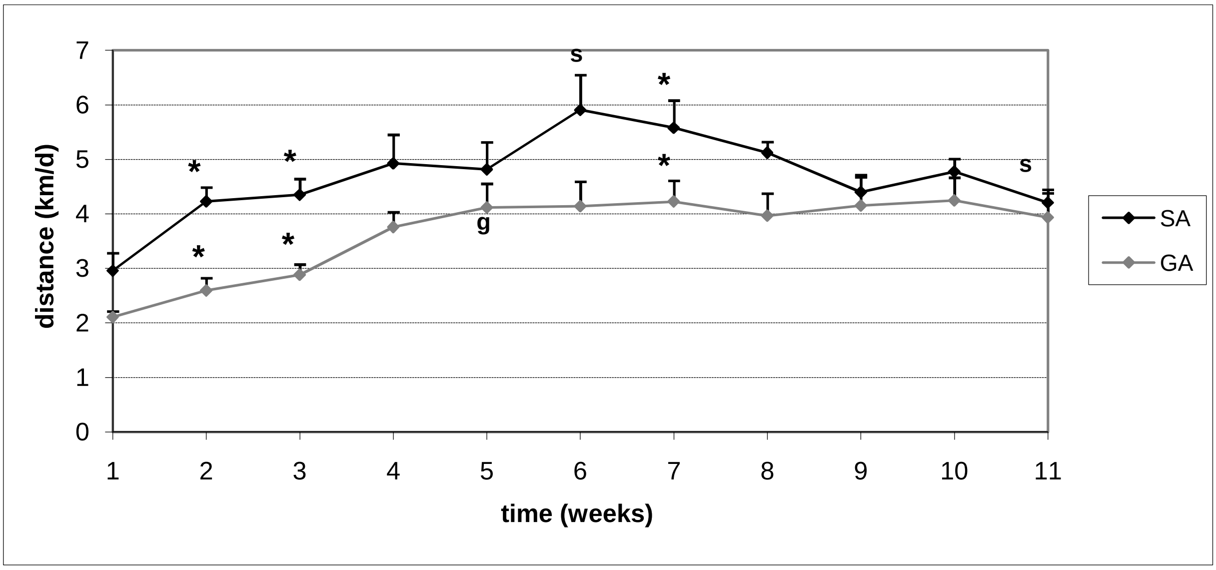

Figure 1: distance travelled by the SA and GA. s = significant difference between timepoints in SA; z = significant difference between timepoints in GA; * = significant group difference (SA versus GA).

The daily movement of the SL and GL can only be guessed. Due to the fact that the pasture of the SL and GL groups was smaller than the pasture of the alpine groups and the landscape includes no hills, these groups had lower high impact movements.
The goats compared to the ewes showed a significantly higher milk production of 2.15 l/day compared to 0.73 l/day, respectively during the experimental period.

Table 1: results pQCT. Crt_thk = cortical thickness (mm); BMD_D = bone mineral density diaphysis (mg/cm^3); BMC_D = bone mineral content diaphysis (mg/cm); BMD_E = bone mineral density epiphysis (mg/cm^3); BMC_E = bone mineral content epiphysis (mg/cm); w = week; * = significant group difference within species groups; Values with different letters indicate significant differences ($p<0.05$) between time points within one group

	SA			SL			GA			GL		
	w0	w12	w18	w0	w12	w18	w0	w12	w18	w0	w12	w18
crt_thk	3.32^{a}	3.48^{ab}	3.58^{b}	3.11^{a}	3.35^{b}	3.49^{b}	2.90^{a}	2.63^{ab}	2.58^{b}	2.96	2.92	2.72
BMD_D	940 * ^{a}	924^{ab}	990^{b}	865 * ^{a}	886^{ab}	938^{b}	826	750	722	811	817	737
BMC_D	198^{a}	225^{b}	219^{b}	200^{a}	230^{b}	224^{b}	175	171 *	171	185	187 *	186
BMD_E	560	551	561	532^{a}	566^{ab}	612^{b}	532	512	516	625^{a}	534^{ab}	465^{a}
BMC_E	190	217	289	203^{a}	220^{a}	309^{b}	164^{a}	169^{a}	238^{b}	160	181	176

The effect on bone in sheep was according to the above mentioned studies on the effect of exercise on bone. No effect of lactation was detectable, probably because the milk production in sheep was low. Goats showed different results in bone metabolism compared to sheep. The calcium concentration in sheep milk (1.93mg/g) is higher than in the goat milk (1.34mg/g) (Park *et al*., 2007), still the goats lost more calcium through the milk, because they produced significantly more milk than the sheep. In addition, within the group, the GA had higher milk yield compared to GL, probably due to the fact that they were on average in lactation for a shorter time than GL. The loss of BMD in the epiphysis in the GL is corresponding to the studies from Zeni *et al.* (1999) and Laskey *et al.* (2011), where a bone loss is described due to lactation located mainly in areas with high trabecular bone. In the GA group, no loss in BMD or BMC in diaphysis or epiphysis was detectable. In contrast, the BMC of the epiphysis was increased significantly. This fact is probably due to increased movement straights on the alpine pasture. On the other hand, the cortical thickness decreased significantly. The reason for this decrease in cortical thickness might be the high milk production, although this would be in contrast to the above mentioned studies, where lactation induced bone loss was observed mainly in trabecular bone. Interestingly, findings of Liesegang *et al*. (2006, 2007) supported the results of the present study since decreased cortical thickness during lactation in goats was also shown in their studies. In the goats, a significant difference between GA and GL in the BMC in diaphysis was observed at week 12. The BMC was significantly smaller in GA compared to GL. The reason for this might be the higher milk production of GA compared to GL.

In conclusion, there was no lactation induced bone loss detectable in sheep. In goats, lactation induced bone loss could be partially reduced by increased movement straights.

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Effect of PEG addition on milk composition of goats browsing a tanniferous fodder tree

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Abstract

In this present study we aimed to investigate the effect of the administration of a tannin-neutralising agent (polyethylene glycol, PEG) to lactating local breed goats browsing a tanniferous fodder tree (*Acacia cyanophylla*) on the milk chemical composition and the average daily gain (ADG) of the suckling kids. Fifty four native goats (live weight 35.1 kg) and sixty nine kids (average birth weight 2.0 kg) were used. The experiment was conducted until day 90 post-partum. Just before kidding, goats were allocated into two equal experimental groups: a treated group where animals were orally drenched with PEG 4000 (20 g/d), and a control group (C), not treated with PEG. Milk chemical composition was studied at different post-partum weeks: 3, 6, 7, 10 and 12 weeks. Daily weight gain (DWG) of kids was determined at two stages: 0-30 d (DWG1) and 30-90 d (DWG2). PEG had not effect on any milk component at any lactation week. Highest protein (3.49 %), fat (6.31 %) and urea (130.5 mg/100 ml) contents are observed at week 10th postpartum, remaining stable afterwards. The lowest values were observed at week 3rd (Urea, 95.2 mg/100 ml), 6th (fat, 4.59%) and 7th (protein, 2.86%) postpartum and differences were statistically significant ($P<0.05$). Addition of PEG to the diet of goats had not significant effects on kid performance. In conclusion, the administration of PEG to lactating goats browsing the tanniferous *Acacia cyanophylla* fodder tree had no effects ($P>0.05$) either on goat milk composition or on the suckling kids growth rates.

Key words: goat milk, protein, fat, lactation stage, tannin, PEG

Introduction

It is estimated that over 80% of the world's goat population is located in Asia and Africa (Morand-Fehr et al., 2004). Goat milk production is a dynamic and growing industry that is fundamental to the wellbeing of hundreds of millions of people worldwide and is an important part of the economy in many countries (Silanikove et al., 2010). Goat milk contains a high proportion of medium-chain fatty acids that can be absorbed rapidly from the intestine, and are known to have a potential antimicrobial activity and reduce cholesterol deposits (Shingfield et al., 2008). In Tunisia, fodder trees are very important sources of food for local goats, particularly under harsh conditions. However, most browse species are dicotyledons that contain large amounts (up to 50% of the dry matter) of polyphenols, many of them tanniferous compounds (Silanikove et al., 2004). Polyethylene glycol (PEG), a polymer that binds tannins irreversibly over a wide range of pH and reduces the formation of tannin-protein complexes in the rumen (Jones & Mangan, 1977), has been administered to grazing goats to deal better with tanniferous plants on the pasture. The main objective of the present study was to assess effect of PEG on goat milk composition at different stages of lactation and the daily weight gain of kids.

Material and methods

The trial was conducted in a farm located in Nadhour, a delegation of Zaghouan (north-east of Tunisia, 36°24' North, 10°9' East, at an altitude of 800 m), where goats are hand-milked once a day and kidding is concentrated during January and February. Kids are weaned at 90 days of age. Fifty-four pregnant local goats were allocated into two equal experimental groups (Control and PEG) 15 days before parturition and measurements were recorded from the first post-partum day. Both groups grazed on *Acacia cyanophylla* pastures for 5 h daily (from 11:00 to 16:00) and confined during the night. Animals of both groups were fed 300 g of alfalfa hay and 300 g of concentrate offered in two equal meals. Goats in the PEG group were drenched with 20 g PEG (molecular weight 4,000) dissolved in 40 ml water. Goats in the control group did not receive any PEG. PEG was administered before kids suckled goats (in the morning before grazing). PEG administration started before kidding and was extended until weaning (90 days age). Kids were weighed at birth, and when they were 30 and 90 d old. Daily weight gain (DWG) was calculated by difference during periods 0-30 days (DWG1) and 30-90 days (DWG2).

At five post-parturition times (3, 6, 7, 10 and 12 weeks), milk production was recorded following the method proposed by Ricordeau et al. (1960) using oxytocin. Goats were hand-milked and samples were taken out in plastic flasks containing 1 mg of dichromate in order to avoid any possible fermentation of the milk. Samples were then immediately transported to the laboratory for analysis (fat, protein and urea contents) using an integrated milk machine (Combifoss 5300, Foss Electric, Denmark).

Offered diets (*Acacia*, hay and concentrate) were analysed for their chemical composition. Dry matter (DM, method ID 934.01), ash (method ID 942.05) and crude protein (CP, method ID 984.13) contents of leaves and young twigs of *A. cyanophylla*, alfalfa hay and concentrate were determined following the methods of AOAC (1999). Neutral detergent fibre (NDF) and acid detergent fibre (ADF) contents were determined with the ANKOM fibre analyzer using the reagents described by Van Soest et al. (1991). Total tannins (as tannic acid equivalent) and condensed tannins (as leucocyanidin equivalent) were determined in *Acacia* fodder following the methods described by Makkar (2003). All chemical analyses of browse samples were conducted at the University of León (Spain).

Statistical differences between experimental groups (control vs. PEG) and lactation stage in fat, protein, and urea contents of milk were evaluated by analysis of variance (Steel & Torrie, 1980).

Results and discussion

Chemical composition of *A. cyanophylla* (leaves and young twigs), hay and concentrate is shown in Table 1. Cell wall components were higher in hay and stems of *A. cyanophylla* than in leaves and in concentrate, whereas an opposite trend was observed for CP content. Leguminous shrubs and trees have been used as feedstuffs for livestock in many regions of the world, mainly because of their high protein contents throughout the year (Ammar et al., 2004) that can be attributed to the ability of these plants to fix atmospheric nitrogen. However, as many other browse species, *A. cyanophylla* is characterized by its high tannin contents (72 g/kg DM in stems).

Table 1- Chemical composition (g/kg dry matter) of different components of the ration

Feed	Dry matter (g/kg)	Ash	Crude protein	NDF	ADF	Total tannin	Condensed tannins
A. cyanophylla leaves	360	125	144	252	193	32	58
A. cyanophylla stems	420	58	69	576	421	44	72
Hay	960	111	78	698	416	-----	-----
Concentrate	880	99	152	282	173	-----	-----

In this study, PEG was added to the diet of dairy goats to explore any effect on the chemical composition of milk and results are presented in Table 2. It seems that tannin contents in the foliage of *A. cyanophylla* had not effects on milk chemical composition and administration of PEG did not cause changes in milk components (P>0.05). Even though, a numerical general slight increase of protein was observed for the treated group.

Table 2. Effect of PEG administration on chemical composition of goat milk

	Control	PEG	sed	P
Protein	3.07	3.16	0.092	0.365
Fat	5.39	5.16	0.170	0.193
Urea	117.1	112.2	3.51	0.163

These results can be mainly attributed to the fact that local goat breeds of the Mediterranean basin are well adapted to the Mediterranean scrubland, consisting mostly of high-tannin containing plants (Silanikove et al., 2004). These goats are assumed to be able to consume as much as 10 g/day of hydrolysable tannins and 100–150 g/day of condensed tannins without evidence of toxicity (Silanikove et al., 1996). In our study, condensed tannin contents even in stems (72 g/kg DM) did not exceed the threshold limit. Theoretically, large amounts of hydrolysable and condensed tannin-derived phenols as well as other types of phenolic compounds may be absorbed from the intestine in browsing goats (Silanikove et al., 2010). Detoxification of tannins by goats is based on enzymatic hydrolysis and depolymerization of the ingested tannins (Silanikove et al., 2004).

Studies reported by Vasta et al, (2008) revealed that effects of tanniferous feeds on milk fat and protein composition vary markedly with the concentration of tannins present in the feeds. In this context, Gilboa et al, (2000) noted that supplementation with 10 g/day of PEG had a significant effect on milk fat, protein and lactose in goats. However, goats treated with 50 g of PEG (Decandia et al., 2000) showed a significant increase in both milk yield and urea content, but there was not a significant effect on milk fat and protein percentages.

When lactation stages (3, 6, 7, 10 and 12 weeks) were considered (Table 3), effect of PEG on milk composition was not significant (P>0.05). Milk fat and urea contents were numerically smaller at the beginning of lactation (3, 6 and 7 weeks).

Table 3. Effect of PEG on goat milk composition at different lactation stages

Stage of lactation (weeks)		3	6	7	10	12
Protein	Control	3.23	3.01	2.84	3.23	3.06
	PEG	3.20	2.89	2.89	3.75	3.05
	Esd	0.218	0.204	0.075	0.388	0.076
	Pr>F	0.9140	0.5694	0.5284	0.1859	0.9190
Fat	Control	5.79	4.60	5.34	5.11	5.00
	PEG	4.88	4.57	5.11	6.45	4.80
	Esd	0.475	0.415	0.210	0.580	0.139
	Pr>F	0.0611	0.9266	0.279	0.6532	0.1523
Urea	Control	102.55	105.09	120.58	127.54	126.54
	PEG	87.78	98.34	114.66	133.41	129.80
	Esd	7.929	7.542	2.956	15.279	2.570
	Pr>F	0.0687	0.3755	0.0502	0.7032	0.2102

Lactation stage had a significant effect (P<0.001) on the chemical composition of milk (Table 4). Generally, highest values of protein (3.49 %), fat (6.31 %) and urea (130.5 mg/100 ml) were observed at week 10th postpartum and maintained constant till the end of experimental period (12 weeks). However the lowest values of these parameters are detected at weeks 3rd (urea, 95.2 mg/100 ml), 6th (fat, 4.59%) and 7th (protein, 2.86%) postpartum. Similar lactational trends in milk protein (Chornobai et al., 1999; Bhonsale et al., 2009) and fat (Bhonsale et al., 2009) contents have been recently reported.

Table 4. Effect of lactation stage on the chemical composition of goat milk

Lactation stage (weeks)	3	6	7	10	12	sed	P	Diet x lactation stage P
Protein	3.22 ^{ab}	2.95 ^{b}	2.86 ^{b}	3.49 ^{a}	3.06 ^{ab}	0.152	<0.001	0.260
Fat	5.34 ^{b}	4.59 ^{c}	5.22 ^{ab}	6.31 ^{a}	4.90 ^{ab}	0.280	<0.001	0.302
Urea	95.2 ^{c}	101.7 ^{bc}	117.6 ^{ab}	130.5 ^{a}	128.2 ^{a}	5.78	<0.001	0.511

^{a,b,c} Values in the same line with different letters differ significantly (P <0.001).

Regarding kid performances (DWG), there were no differences in kid birth weights and DWG between control and PEG groups (Table 5). Our results are in agreement with those reported by Infascelli et al. (2008), whereas Gilboa et al. (2000) found birth weights and DWG significantly greater for kids whose does received 10 g/day of PEG in their diet. In this latter case, the tanniferous species grazed was *Pistacia lentiscus* ,which has a high condensed tannin content, so the influence of PEG should have been more evident due to the higher intake of tannins in the control group.

Table 5.kid body weight (kg) and average daily gains (g/day)

	Control	PEG
Birth weight (kg)	2.45±0.731	2.49±0.524
Weight at 30 days old (kg)	6.75±1.123	6.97±1.393
Weight at 90 days old (kg)	13.85 ±1.041	14.15±0.956
DWG1 (0-30d, g/d)	143.33±1.134	149.33±0.187
DWG2 (30-90, g/d)	118.33±0.154	119.66±0.117

Conclusion

Results of this study revealed that PEG does affect neither goat milk composition nor suckling kid performances. Milk composition varied significantly during lactation with peaks in fat, protein and urea contents at week 10th postpartum. Further research on the effects of tannins on milk composition would be timely, since potential effects of these anti-nutritional compounds would depend upon the browse species consumed and the type and amount of tannins ingested.

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