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CICLO XXV

SUSTAINABILITY OF DAIRY FARMS IN MOUNTAINOUS AREAS

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“Simply to my father…”

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Elisa

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ABSTRACT

The general aim of this thesis was to analyze the sustainability of dairy cattle farms in mountainous areas. The studies were conducted in the Eastern Italian Alps, a study area representative of the evolution of livestock systems in mountainous areas.

The first contribution classify the dairy systems of Trento Province (Italian Alps) on the base of structural and management characteristics. The productivity, the milk destination, the maintenance of livestock biodiversity, land management and landscape conservation were analyzed on the base of the identified clusters. The study was carried out on a sample of 610 farms. We identified four different farming systems: " Traditional-Original" (lactating cows that are moved to highland pastures during summer; 307 farms), "Traditional Without Summer Pastures" (153 farms), "Traditional with Silages" (36 farms) and "Modern" (114 farms). Modern farms are characterized by recent buildings with loose animals and milking parlor, they also have the largest herd sizes and a high milk production. In contrast, the Traditional farms are characterized by small farms with tie stalls. Among the various classes there were a significant difference nutrition. Focusing on feeding strategies, “Modern” farming systems use mixed rations with silage, while Traditional farming systems mainly use hay. In the Traditional-Original systems there were the highest number of local breeds, on the contrary for Modern systems Holstein Friesian is the main breed. Almost all the farms move the heifers and the dry cows to the highland pastures during summer, whereas the transhumance of lactating cows is typical of the farms of “Traditional-Original” systems and for half of “Traditional with silages” farms. The Traditional practices guarantee a high sustainability in terms of livestock biodiversity, environmental biodiversity (both plants and animals), environmental impact (stocking and manure densities), and landscape protection (re-afforestation and alpine pasture). The GIS analyses of the agricultural surface managed by dairy farms that only Traditional, low-input systems are able to maintain the steep meadows and pastures, with high land fragmentation. This work evidenced also that there was a strong link between Traditional dairy farms and Protected Designation of Origin cheeses in Trento Province. This is essential to reduce the economic handicap experienced by Traditional farms compared to the intensive farming system, transforming some of their technical weaknesses into economical strengths, and contribute to the sustainability of Traditional alpine dairy farms. The second contribution analyzed the sustainability assessing the environmental impact of dairy farms. Specifically the work evaluate the impact of the 4 different farming systems on the soil release of nitrogen, phosphorus and on the air release of methane, by using a sub-sample (565) of dairy farms analyzed in the first contribution. Data on TMR formulation and chemical composition, and on forages production, use and composition were also collected on-farm with a questionnaire. Tabulated data were used when chemical composition of TMR were not available. On farm the N and P excretion per dairy cow (kg/cow/d) was computed following the mass balance methodology as difference between nutrients intake and retention in animal products. Animals moved on highland summer pasture were excluded from the

computation. The farm excretion of N and P was obtained considering the number of cows and heifer reared on farm, the fraction of year of their permanence on farm and the nutrients excreted per head and per day. The estimation of lactating cow methane enteric emissions (kg/cow/d) was made using the following two equations that require quite different inputs. In the study also was analyzed the amount of nitrogen produced by each farm in one year by a function of kernel density estimation in a GIS software. The study showed that the protein content had a large variability, and the Traditional have more less then Modern farms. The average net load of nitrogen in the sample is 187.7 kg/ha of agricultural surface, a value higher than the limit for the vulnerable zones but much lower than the one for the non vulnerable zones. At farm level, the "Modern" cluster has the highest value of nitrogen load, and the farms of "Traditional-Original" cluster had the lowest value of N load per ha. When the nitrogen excretion was measured per functional units (tons of milk), the trend was the opposite, with higher values for farms of Traditional clusters than the ones of Modern group. For the phosphorous we observed the same trend. The estimation of methane production of lactating cows expressed per ha of agricultural surface gave higher values of enteric methane production for the "Modern" cluster compared to the Traditional ones. When the emission was expressed per kg of produced milk, the cluster "Modern" shown the lowest methane production among the analyzed clusters, as expected from the literature. The results showed that the farms of the Modern group, specialized and production oriented, seem able limit the methane production per kg of milk; however, for the evaluation of environmental sustainability of livestock farms in mountainous areas, the link between animal husbandry and local forages must be correctly considered. The Traditional farms, using feeding strategies based on meadows and highland pastures, limit the use of external inputs, reduce the geographical shift of nutrients typical of the intensive systems and at the mean time guarantee positive externalities for the preservation of mountainous areas. These aspects should be considered for the planning of strategies aimed at promote the environmental sustainability of livestock systems in mountainous areas. In the last chapter the interaction between livestock and wildlife was investigated in terms of forage competition. We studied the quantitative and qualitative loss of forages due to the impact of red deer (*Cervus elaphus*) population on the meadows in a sample of four organic farms of the Belluno Province (Italian PreAlps), located in Cansiglio Natural Park. The damages were estimated with the use of exclusion cages, positioned on the meadows during summer 2008 and 2010. Night counts with spotlights were conducted to index deer use of meadows plots. Dry matter production inside the cages was fairly good for the elevation of the area (about 1000 m a.s.l.), and the production outside the cages was significantly lower (both in the first and second cut in 2008 and 2010). Therefore, the magnitude of losses was of 15-20% at the first and 25-40% at the second cut. Dry matter losses in the different meadow plots were positively correlated with index of deer use, which in some plots was as high as 7-8 heads/ha. Deer grazing reduced also crude protein content of forage, with losses being greater where protein content was higher, due to the selective grazing behavior of red deer. This study demonstrates that high densities of grazing deer may seriously impact on forage production and quality, with relevant damages for organic dairy farms.

RIASSUNTO

L'obiettivo generale è di questa tesi di dottorato è lo studio della sostenibilità delle aziende di bovini da latte in ambito montano. I lavori presentati sono stati condotti nelle Alpi italiane orientali, che rappresentano un modello dell'evoluzione dei sistemi di allevamento nelle aree montane.

Il primo contributo è relativo alla classificazione delle aziende di bovini da latte della Provincia Autonoma di Trento. Sono analizzati parametri quali produttività, destinazione del latte, mantenimento della biodiversità zootecnica, gestione del suolo e conservazione del paesaggio. Le analisi sono state effettuate su un campione di 610 allevamenti, dai quali sono state raccolte informazioni sulle caratteristiche strutturali e di gestione delle aziende agricole; inoltre tramite software GIS è stato possibile analizzare le aree agricole utilizzate da ogni singola azienda. Dalle analisi sono stati individuati quattro diversi sistemi di allevamento: " tradizionale-Originale" (vacche in lattazione che vengono monticati nelle malghe durante l'estate; 307 aziende), "Tradizionale senza l'utilizzo delle malghe per le vacche da latte" (153 aziende), "Tradizionale con insilati" (36 aziende), e "Moderno"(114 aziende). Il cluster "Moderno" è caratterizzato da aziende più recenti con animali a stabulazione libera e con sala di mungitura, inoltre le dimensioni dell'allevamento sono le più grandi con una produzione di latte mediamente elevata. Viceversa le aziende tradizionali sono caratterizzate da allevamenti di piccole dimensioni con stabulazione fissa. Per quanto riguarda l'alimentazione è emersa una grossa differenza tra i vari gruppi: infatti, le aziende Moderne utilizzano razioni miste con insilati mentre le aziende tradizionali non utilizzano insilati (ad eccezione del piccolo gruppo di aziende tradizionali con insilati) ma utilizzano prevalentemente fieni di origine locale. Nelle aziende Tradizionali-Originali vi è il maggior numero di razze locali, mentre per le aziende Moderne la Frisona è la razza dominante. Quasi tutte le aziende coinvolte nell'indagine utilizzano il pascolo estivo per la rimonta, mentre la monticazione delle vacche da latte è un caratteristica del cluster "Tradizionale-Originale" che viene tuttavia praticata anche da molte aziende del gruppo "Tradizionale con Insilati". Questa pratica garantisce una elevata sostenibilità in termini di biodiversità animale ed ambientale (piante e animali), di impatto ambientale (stoccaggio e densità di letame), e di tutela del paesaggio (rimboschimento e di alpeggio). Le analisi cartografiche hanno poi evidenziato che solamente le aziende tradizionali sono in grado di mantenere prati ripidi e pascoli alpini. Quindi, anche se i livelli produttivi delle aziende tradizionali sono inferiori di quelli delle aziende più specializzate, sono proprio i sistemi di allevamento tradizionali che possono garantire un maggior legame con il territorio e quindi una maggiore sostenibilità ambientale. Il lavoro dimostra inoltre che vi è un forte legame tra aziende lattiero-casearie tradizionali e la Denominazione di Origine dei formaggi provenienti dalla Provincia di Trento. Questo è fondamentale per ridurre l'handicap economico vissuto dalle aziende tradizionali rispetto ai sistemi di allevamento intensivo, trasformando alcuni dei loro punti deboli in punti di forza

tecnico-economici, in modo tale da poter contribuire alla sostenibilità delle aziende tradizionali con vacche da latte in zone svantaggiate come quelle di montagna.

Il secondo contributo ha analizzato la sostenibilità valutando l'impatto ambientale dei sistemi di allevamento di vacche da latte. Per capire quale sia quello che ha un maggior impatto ambientale, è stato utilizzato un sotto-campione (565) di aziende analizzate nel primo contributo. Lo scopo del lavoro era confrontare 4 diversi sistemi di allevamento, sul rilascio al suolo di azoto, fosforo e metano in atmosfera. Attraverso un questionario sono stati raccolte molteplici informazioni sugli alimenti, per i foraggi è stato raccolto il dato di produzione e la composizione chimica mentre le aziende con unifeed è stata fornita la formulazione della dieta. Dove non è stato possibile reperire le informazioni sulle analisi chimiche dell'unifeed, sono stati utilizzati dei valori tabulati. L'escrezione di Ne P, in azienda, per vacca da latte (kg / capo / d) è stata calcolata secondo la metodologia del bilancio di massa come differenza tra l'assunzione di nutrienti e la conservazione dei prodotti di origine animale. Per l'escrezione di N e P , quindi, sono stati considerati: il numero di vacche e manze allevate in azienda, la frazione di anno della loro permanenza in azienda (Il periodo in cui gli animali sono portati al pascolo alpino estivo sono stati esclusi dal conteggio) e le sostanze nutrienti escrete pro-capite al giorno. La stima delle emissioni di metano nelle vacche in lattazione (kg / capo / d) è stata effettuata utilizzando due equazioni che richiedono input completamente diversi. Nello studio è stata analizzata anche la quantità di azoto prodotto in un anno da ciascuna azienda, attraverso il software GIS con una funzione di stima denominata "kernel density". Il contenuto in proteina grezza è risultato molto variabile tra i gruppi, dove le aziende tradizionali hanno un contenuto inferiore rispetto a quelle Moderne. Il carico medio netto di azoto nel campione è 187,7 kg / ha superficie agricola, un valore superiore al limite per le zone vulnerabili, ma molto più basso di quello per le zone non vulnerabili. A livello aziendale, il cluster " Moderno" ha il più alto valore del carico di azoto, al contrario, le aziende del cluster "Tradizionale-Originale" hanno il valore più basso del carico di azoto per ettaro di SAU. I risultati per il fosforo hanno evidenziato la stessa tendenza osservata per l'azoto. La produzione di metano delle vacche in lattazione, sempre espressa per ettaro di SAU, ha rilevato i valori più alti nel cluster " Moderno" rispetto a quelli tradizionali. Il cluster " Moderno" ha però dimostrato la minor emissione tra i gruppi analizzati se viene espresso per kg di latte prodotto. Dai risultati emerge che dal punto di vista dell'efficienza di utilizzo dei nutrienti le aziende del cluster " Moderno", più specializzate e produttive, sembrano in grado di limitare le emissioni per unità funzionale. Tuttavia, nella valutazione della sostenibilità ambientale delle aziende zootecniche montane è particolarmente rilevante il diverso legame con il territorio e le risorse foraggere locali. Gli allevamenti tradizionali, che basano l'alimentazione dei bovini sull'utilizzo dei prati e pascoli aziendali, con la movimentazione in malga durante l'estate, ricorrono in modo limitato a risorse esterne all'allevamento, riducendo lo shift geografico di nutrienti dalle zone di produzione a quelle di utilizzo e allo stesso tempo limitando riducendo l'impatto complessivo dovuto alle attività connesse agli allevamenti intensivi. L'ultimo contributo è relativo alle relazioni tra allevamenti e fauna selvatica nelle zone di montagna. Questo aspetto assume particolare importanza a fronte dell'incremento della fauna selvatica e del ritorno di alcuni predatori nelle zone montane che si sono registrati negli ultimi anni. Emergono alcune criticità, legate a competizione per le risorse, problemi di

predazione, danni all’agricoltura e possibili interazioni sanitarie. Il lavoro si pone l’obiettivo di studiare l’effetto degli ungulati selvatici sulle aziende di vacche da latte in termini di concorrenza per l’accesso alle risorse foraggiere. Abbiamo studiato la perdita quantitativa e qualitativa dei foraggi a causa dell'impatto di una popolazione di cervi (*Cervus elaphus*) sui prati in un campione di quattro aziende agricole biologiche della Provincia di Belluno (Prealpi italiane), localizzate nel Parco Naturale del Cansiglio. La quantificazione dei danni è stata stimata con il metodo delle gabbie ad esclusione, posizionate sui prati nel corso delle stagioni vegetative 2008 e 2010. Inoltre per indicizzare la presenza dei cervi e quindi avere una stima della numerosità, sono stati effettuati dei censimenti notturni con il faro. Dallo studio è emerso che la produzione di sostanza secca all'interno delle gabbie era abbastanza buona per l’altitudine della zona (circa 1000 m s.l.m.), mentre la produzione all’esterno delle gabbie ad esclusione era significativamente inferiore (sia nel primo che nel secondo taglio, nei due anni: 2008 e 2010). L'entità delle perdite era del 15-20% al primo e al 25-40% nel secondo taglio. Le perdite nei vari appezzamenti sono risultate correlate positivamente con l'indice di utilizzo dei prati da parte dei cervi, che in alcuni appezzamenti è risultata di ben 7-8 capi / ha. Il pascolo dei cervi ha ridotto anche la qualità del foraggio in termini di proteina grezza, con perdite maggiori dove il contenuto proteico dei foraggi era superiore, in virtù del comportamento selettivo dei cervi. Quest’ultimo studio ha dimostrato che alte densità di cervi al pascolo possono causare un serio impatto sulla produzione e sulla qualità del foraggio, con danni particolarmente rilevanti per gli allevamenti biologici.

General Introduction

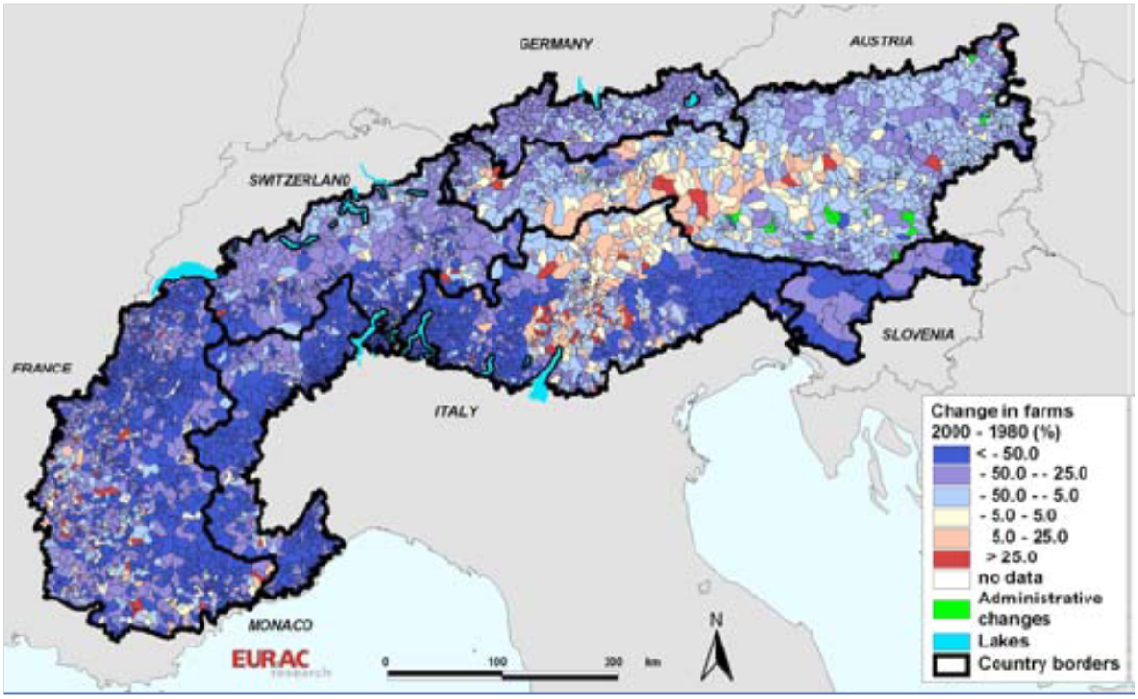
The evolution of livestock sector in Italy in the last decades caused a strong reduction in the number of active farms and a specialization and intensification process in the most favorable areas. The polarization of the livestock production systems in the lowland caused a marginalization (or even the abandonment) of animal husbandry in mountainous areas. However, more than 70% of the utilized agricultural area (UAA) in Italy is classified as hills or mountains, and the presence of livestock farms in these areas guarantee several positive externalities. The sector contraction, as evidenced by Stefanon (2000), and taken up by Sturaro (2010) is presented in two ways. The closing of the farms that are no longer economically viable is accompanied by an increase in herd size of the remaining farms. There is therefore an increase in the density of animals per unit area, but this is due to the decrease in the areas of lawn stable and not to the increase of animals (Sturaro, 2010), also because intensive farms are still limited in number (Stefanon, 2000).

The farms decrease is also accompanied by a reduction of cultivated land. The ISTAT census (2007) on agriculture at the national level, has revealed a general decline of hectares of agricultural activity by 15%. The trend is extended to all types of cultivation (arable, orchards, grassland).

Streifeneder et al. (2005a; 2005b), have summarized (Table 1) the variation of farms and livestock units between 1980 and 2000 in the Alps. In this work Streifeneder observed a reduction of 40% of the farms and livestock. In regions that are disadvantaged by the natural-site conditions, such as Südtiroler Berggebiet and Innsbruck Land in Austria, nearly 37% of land has been dismissed. Likewise, in Carnia region (Italy) about 67% of cultivated areas have been abandoned too (Tasser et al., 2007). The modifications that have been experienced in agriculture resulted moderated in Austria and Germany, and conversely rather strong in Italy, France and Slovenia. In particular, due to a general tendency of increasing the number of animals per farm, most of the smallest farms have ceased.

About the use of permanent grassland in Alpine border regions of Germany, Slovenia and eastern Austria, husbandry is characterized by a high intensity (Table 1) (Streifeneder et al. 2005a; 2005b). On the opposite, France and Italy have mountainous regions with extremely low livestock density. In general, livestock density does not increase as a result of additional livestock, but in relation to a decline in areas of permanent grassland (Streifeneder et al., 2005a and 2005b). In many alpine summer pastures stocking rates are handled at sub-optimal levels, so they are only in part constrained by pasture productivity (Mrad et al., 2009).

Figure 1. Variation of farms between 1980 and 2000



Source: Streifeneder et al., 2005

Changes occurred in animal husbandry exhibit different trend at provincial level (Figure 1). The same country may be characterized by both marginal areas with farm abandonment and zones maintaining a sustainable livestock systems. Eastern Italian Alps provide an example of this situation. The total surface covered by the three bordering provinces of Belluno, Trento and Bolzano is about 17,000 km^2, classified as a completely mountain area. Table 2 reported the changes of livestock indicators in years 1980-2000 (ISTAT 1982 and 2002 official censuses). Bolzano province experimented a slight loss of dairy farms, but also an increase in average herd size. However, the distinctive trait of Bolzano dairy sector is the maintenance of a great amount of small familiar farms. Moreover, small ruminants experienced a great increment, in particular the number of goats in 2000 was doubled with respect the 1980. The maintenance of sustainable farms allowed to maintain also grassland and pastures surface. The situation is different in Trento and Belluno. Both the provinces suffered a dramatic abandonment of small dairy farms, reaching in only 20 years a percentage of ceased farms of about 80%. In 2000 both a reduced number of farm and and increased herd size were observed (11.2 cows/farm in Belluno and 16.8 in Trento, almost the double with respect to Bolzano). A large percentage of sheep and goats farms closed, with a consequent increasing of herd size in the remaining ones. The most evident consequence of this trend on landscape is the loss of open areas, resulted moderate in Trento but relevant in Belluno (-8 and -25%, respectively).

Table 1. Variation of farms and livestock units between 1980 and 2000 (Source: Modify from Streifeneder et al., 2005)

Country	Agricultural farms, number			Livestock units (LU), total			(LU/permanent grassland, ha)		
	2000	1980	2000-1980 (%)	2000	1980	2000-1980 (%)	2000	1980	2000-1980 (%)
Austria	96,205	119,837	-19.7	1,076,656	1,210,981	-11.1	0.7	0.8	-8.3
Switzerland	26,562	41,363	-35.8	538,066	607,310	-11.4	2.0	2.2	-8.6
Germany	22,511	31,623	-28.8	661,064	705,028	-6.2	2.1	1.7	24.2
France	28,571	52,647	-45.7	384,604	563,752	-31.8	0.7	1.1	-34.6
Liechtenstein	199	494	-59.7	4,608	6,524	-29.4	1.8	2.2	-18.5
Italy	171,038	309,146	-44.7	642,546	900,283	-28.6	0.6	0.7	-14.9
Slovenia	23,149	53,089	-56.4	146,399	181,282	-19.2	1.4	1.2	15.2
Alps total	368,235	608,199	-39.5	3,453,943	4,175,160	-17.3	0.9	1.0	-8.9

Table 2. Evolution of livestock systems in Eastern Italian Alps official censuses, (Source: ISTAT 1982 and 2002)

Variable	Bolzano			Trento			Belluno		
	1980	2000	Variation (%)	1980	2000	Variation(%)	1980	2000	Variation(%)
N of cattle farms	12,792	9,476	-26	6,435	1,678	-74	4,763	1,137	-76
N of cattle	139,708	144,196	3	61,446	45,050	-27	35,830	20,606	-42
N of dairy farms	12,317	8,565	-30	5,749	1,416	-75	4,317	807	-81
N of dairy cows	63,132	75,468	20	28,770	23,812	-17	16,097	9,043	-44
Dairy cows/farm	5.1	8.8	76	5.0	16.8	236	3.7	11.2	203
N of sheep farms	2,080	2,136	3	418	320	-23	740	342	-54
N of sheep	25,796	39,739	54	13,977	20,377	46	5,259	5,615	7
N of goat farms	1,397	1,725	23	820	429	-48	855	244	-71
N of goat	7,930	15,714	98	2,923	5,132	76	2,262	2,318	2
Grassland and pastures (ha)	230,163	240,153	4	120,316	110,196	-8	63,349	47,446	-25
Crops (ha)	7,542	3,780	-50	6,583	1,982	-70	4,892	5,232	7

The abandonment of mountain and marginal areas had various effect. Small businesses had to cease their activities, large companies focusing only on the amount lost the quality of the products. There was also a change in the environment and in the territory, in fact, areas with a high concentration of companies are also characterized by high concentration of pollutants both at ground level that air. For that reason at the end of the last century some measures for the protection of waters against contamination caused by nitrates from agricultural sources were adopted by the EU (European Directive 91/676/EEC, Italy aligned with legislative decree of 11 May 1999. 152 and the Ministerial Decree of 7 May 2006).

The abandonment of these areas leads also to changes in plant and animal biodiversity, and to modifications of suitable habitat for survival. Aiming to leave to future generations a landscape and therefore livestock that are not worse than what we have received from previous generations, we must take into account a new concept of sustainability.

The livestock systems of mountainous areas could be classify according several criteria, and recent studies have demonstrated a large variability of management strategies. We can try to group the farming systems in two main categories: "Intensive" and "Traditional semi-extensive." The first is characterized by modern structures, equipments and management, with the aim to maximize the production. These farms prefer specialized breeds for milk production and leads to a detriment of native breeds, certainly more adapted to the mountainous areas (Stefanon, 2000; Bovolenta et al., 2008). The number of animals per farm in “intensive” model has been increased much more than in traditional breeding, and available resources are no longer the center of the farm, that is now composed by dairy cows, the capital resource and labor availability (Stefanon, 2000).

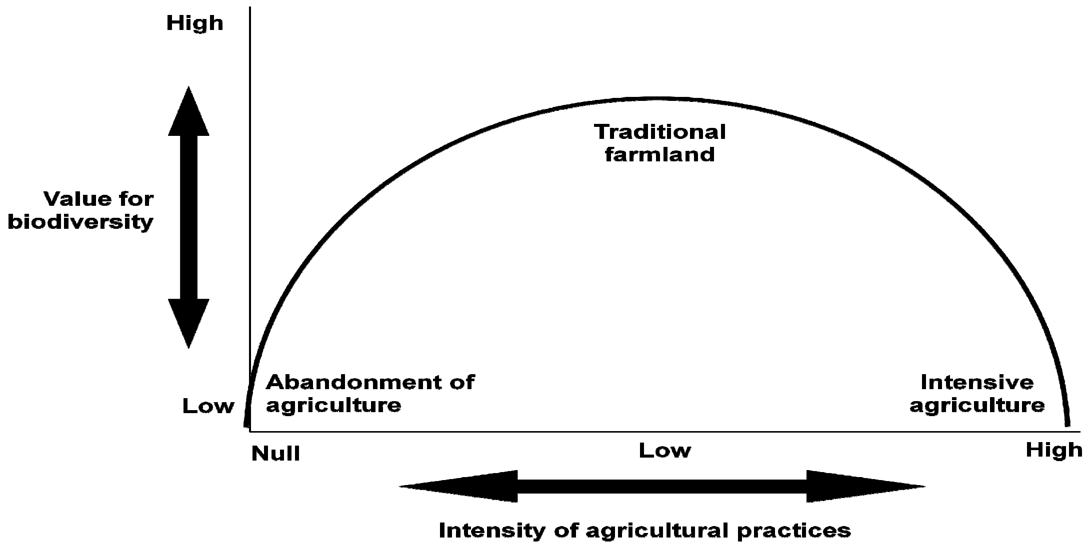
Intensification has changed the way we approach the animal husbandry as it once was in terms of both practical and conceptual. The effects can be observed also in the field of landscaping, with a loss of identity found in various areas (Ramanzin et al., 2009).

In semi-extensive farming system, there is a strict link between the territory and livestock activities, and it favors the use of the use of local forages and resources. The size of the farm and the stocking rate are proportional to the local forage resources, and production (milk, calves) compensates the cost of hay.

The extensive or semi-extensive farming system have a positive role in the mountains to hold the reforestation (Cocca et al., 2012). These systems preserved the agricultural land and stopped the consequent natural forest regrowth in areas not cultivated. It is only for traditional extensive livestock systems that there are unique landscapes and habitats of high aesthetic and ecological value (MacDonald et al., 2000; Gellrich et al., 2007b). Therefore, if disappear this breeding system disappears also the cultural heritage elements, local identity and landscape attractiveness (Hunziker, 1995).

Russo simplified with a scheme (Figure 2) the influence of agriculture polarisation (variation of agriculture in different systems) on biodiversity values. Both intensification and land abandonment lead to a decrease in biological diversity; low-polarised, extensive agriculture of traditional farmlands corresponds to optimal levels of disturbance (minimal disruption of the soil by tillage), and, as a consequence, of heterogeneity, sustaining the highest levels of biodiversity. The higher species richness in extensive agriculture systems may be then explained by their greater heterogeneity and structural diversity (Russo, 2004; Verhulst et al., 2004; Gibon, 2005). However, opportunities offered by land abandonment differ according to species. Although some species are used to spread out within the abandoned area, especially the species with large scale populations, some others contract their areal (open area species), so abandoned lands have adverse effects similar to the effects of intensification on the conservation, for example, of rare and threatened birds (Russo, 2004; Verhulst et al., 2004). However, local extinction and/or reduction in within-species abundance of birds are expected to continue if the process of land abandonment continues (Farina, 1997; Russo, 2004).

Figure 2. Relationship between biodiversity values in agricultural lands and the polarization of agriculture



Source Russo, 2004; Modified after Ostermann (1998)

In the eastern Italian Alps a study by Marini et al. (2009) demonstrated the relationship between the management of meadows and pastures and the richness of species of vascular plants, Orthoptera and Lepidoptera diurnal. The study identified a negative correlation between agricultural intensification and biodiversity of insects (Marini et al., 2009, Reidsma et al., 2006). The increased frequency of soil tillage led to a direct disturbance of Orthoptera, promoted specialization of plant species and reduced the variety of available food resources. The same negative effect has been seen in lepidopteran, which require a large floristic composition for finding of the nectar. The authors therefore suggest a maintenance of traditional farming systems and management of meadows and pastures extensive as possible, in order to be able to limit the impact on the wealth of plant and animal species.

Over the past 15 years the problem of the loss of small farms has been felt, and many initiatives for the reuse of upland areas trying to disincentive the abandonment have been developed, for example by rewarding local products, milk quality, the maintenance of native breeds. This was done because the loss of livestock in mountainous areas would have a “domino effect” on others to supply chains and the environment (flora and fauna) (MacDonald et al., 2000; Strijker, 2005).

As a consequence of the evolution of farming systems, the issues of sustainability and multifunctionality of animal husbandry in mountainous and marginal areas have become key points for the maintenance of the traditional livestock farms.

Sustainability is the ability to meet the needs of the present generation by using natural resources without compromising the possibility of future generations to enjoy such resources (Stefanon, 2000; Francesia et al., 2008; Van Calker et al., 2005). Concerning the livestock sector, sustainability is a topic of considerable importance in recent years, that includes various aspects related to livestock, the production sectors and the environment. In particular, the risks resulting from environmental pollution and degradation, reduction of plant and animal genetic variability, deterioration of food quality, poor animal welfare should be considered (Battaglini et al., 2004; Cozzi e Bizzotto, 2004).

Sustainability can be analyzed from three perspectives that merge and overlap: economic, social and environmental (Francesia et al., 2008, Sturaro et al., 2009; Van Calker et al., 2005; Vecchione, 2010). As regards the livestock sector, these perspectives are the following abilities: to generate income, ensure continuity of the farm and to maintain the mountain area.

Expanding the concept, animal husbandry should be able to provide to the industry (specifically, farmers) a sufficient income for maintaining their activity. The minimum survival is not enough, because of, in order to ensure continuity in the company, it is necessary that it has characteristics of attractiveness for children or for prospective buyer (Francesia et al., 2008).

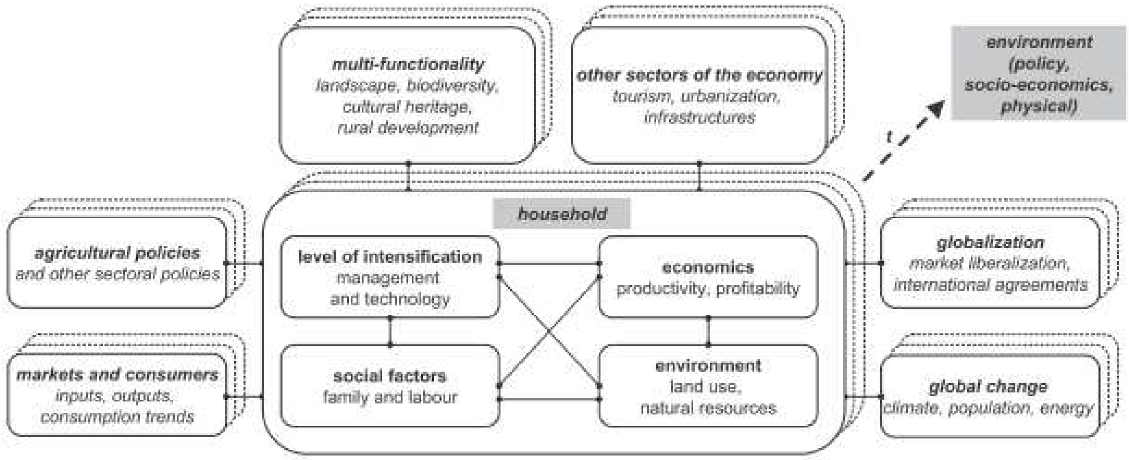
In keeping with these objectives, the valence and the responsibilities of livestock in environmental terms should not be left behind. The relationship between livestock and land is strong, especially in the mountains. Traditionally Alpine livestock represents an example of integration between territorial vocation and product obtainable (Battaglini et al., 2004).

To assess the extent to which a farm is sustainable, a number of sustainability indicators have been studied over years. A good indicator must have three distinct features: solid scientific bases, quality and correctness of the information requested, and usefulness in decision making process (Meul et al., 2009).

A main indicator of sustainability is the autonomy of forage, defined as "the balance between forage production of the farms and forage needs of the herds in the farm at different times of the year" (Francesia et al., 2008). The definition suggests a need to achieve the autonomy in foraging. That is important for the environmental and economic sustainability because it permits to keep care of the land and, at the same time, to have a livestock profitable activity.

Bernués (2011) assesses the sustainability in terms of functional integrity, rather than in terms of resource availability (Thompson and Nardone, 1999). On this concept Bernues proposed a guide (Figure 3) which is shown a conceptual framework for analysing sustainability at the farm level, where technical aspects of the management of animals and grazing resources are considered jointly with environmental implications, household and labor characteristics and economic performance. Moreover the relationships between farm components are multiple and complex, and relationships with the general socio-economic environment are constantly changing (Bernués et al., 2005). Other studies identify sets of indicators, which provide information on the various factors that make a farm sustainable or not.

Figure 3. Conceptual framework for studying the sustainability of agro-ecosystems



Source: Bernués et al., 2011

The first indicator proposed, in chronological terms, is the ISA, or Indicator Synthetic Environment (Stefanon, 2000). This parameter considers five indicators of intensification, giving a distinct score to each one. Concerning cattle, these parameters are: the breed, the ratio between the number of cows and the available manpower, the stocking density per unit area (LU / ha), the milk production per unit area and the milk production per cow. The scores may be evaluated individually or in interaction with each other, and they allow to calculate a reference value, that ranges from zero to 100, that permits to identify different farming systems. Specifically, the range 0-40 includes extensive farming, whereas between 40 and 60 the farms that are compatible with the environment are accounted, and from 60 to 100 farms are considered as intensive. This method to classify farms is easy to use, and can be adopted to detect the presence of an excessive intensification of the system, and to help in the consequent decision-making process, both at managerial and political level.

The question of sustainability and of the indicators intended to define this concept was also addressed by Van Calker et al. (2005), who analyzed four aspects: economic, internal social, external social, and ecological sustainability.

This research, conducted by consulting experts on the different areas, highlighted the economic viability and the working conditions (ability of the dairy farmer to not close his farming business) as descriptors relating to economic and work sustainability (Table 3).

Table 3. Sustainability indicators in the opinion of Van Calker et al. (2005).

Economic sustainability	Corporate sustainability	Externality social	Ecological sustainability
Profitability	Working conditions	Feed quality	Eutrophication
		Animal welfare	Water pollution
		Animal health	Desertification
		Landscape quality	Acidification
		Use of forage	Biodiversity

Source: Van Calker et al., 2005

Internal social sustainability is define relates to working conditions for the farm operator and employees. External social sustainability is the attention of societal about the impact of agriculture on the well being of people and animals. Ecological sustainability is the effects (threats or benefits) to the flora, fauna, water, climate and soil. From the point of view of the ecological sustainability, the issues of main importance are those related to eutrophication, soil degradation, water pollution and biodiversity.

The environmental issue has been addressed in more detail in a survey of 20 Flemish farms (Meul et al., 2009). The indicators chosen in this case were related to nutrient use, energy use, water use and water quality. Each category covered specific aspects, which have been analyzed, and to which a score was assigned. The processing of data collected through the proposed model allows us to understand immediately and visually the strengths and weaknesses of the farm taken into account, and then to act accordingly.

In another study, Vecchione (2010) found 18 different indicators sustainability. He analysed the evolution of the social, economic, and environmental indicators in political term. The study refers to a specific area of Southern Italy, but the applicability of the indicators goes beyond the geographical.

It is evident that to define sustainability through parameters is not simple, and the various methodologies also demonstrate a certain degree of variability in deciding the same. Certainly they are valid in different farms, and they can be a support in the assessment of the sustainability of a farm or a zone. The maintenance of the sustainability may reveals as a key strategy in Alpine and marginal areas conservation.

The research conducted during my PhD studies and presented in this thesis aimed at analyze three aspects that contribute to or detract from sustainability.The studies were conducted in the Eastern Italian Alps, a study area representative of the evolution of livestock systems in mountainous areas. The general aim was to analyze the sustainability of dairy cattle farms in this context. In specific, this thesis is composed by 3 chapters:

In the first chapter 610 dairy farms of Trento Province were surveyed to classify the farming systems. In mountainous areas there is a large variability in the management of livestock farms, and this contribute aim to identify and characterize different systems of production, with a cluster approach. The multifunctionality of the identified clusters were compared on terms of milk production, herd composition (livestock biodiversity) and landscape management. In a second study the environmental impact of dairy farming systems in mountainous area was analyzed in term of nitrogen, phosphorus, and methane release. The ecological footprint of livestock systems if one of the main issue for the research in animal science. Several papers are published on the environmental impact of intensive livestock systems, but the literature on mountainous livestock systems is still limited. In the sector contribute it's presented a research conducted on the same sample of farms of the Trento Province of the first chapter: information on herd composition, productivity, management and diet composition were used to calculate the balances of nitrogen and phosphorous and to estimate the production of methane Traditional livestock systems in mountainous areas are based on the management of grasslands, and this cause several interactions between livestock and wildlife animals. In the last chapter, the relationships between dairy cattle and wildlife is investigated in terms of forage competition. In a sample of organic farms of the Belluno Province, located in Cansiglio Natural Park, we studied the quantitative and qualitative loss of forages due to the impact of red deer (*Cervus elaphus*) population on the meadows.

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Chapter 1

CHARACTERIZATION AND SUSTAINABILITY OF DAIRY SYSTEMS IN MOUNTAINOUS AREAS: FARM ANIMAL BIODIVERSITY, MILK PRODUCTION AND DESTINATION, LAND USE AND LANDSCAPE CONSERVATION

ABSTRACT

This paper aims to classify the dairy systems of the Trento Province (Italy), which serves as an example of Alpine areas, and to analyze the sustainability of the identified dairy systems in terms of productivity, milk destination, the maintenance of livestock biodiversity, land management, and landscape conservation. A sample of 610 dairy farms were surveyed, and data on the structural and management features of the farms were collected. The utilized agricultural areas of each farm were identified and analyzed with GIS software. Four different farming systems were identified with a non-hierarchical cluster approach: “Original Traditional” (lactating cows that are moved to highland pastures during summer), “Traditional without summer pastures”, “Traditional with silages”, and “Modern”. “Modern” farms accounted for about one fifth of the total and were characterized by the presence of recent buildings containing loose animals and milking parlors, larger herd sizes and higher levels of milk production. The feeding strategy on modern farms consisted of total mixed rations based on silage, and Holstein Friesian was the main breed of dairy cow found on modern farms, whereas local and dual-purpose breeds were rare. “Original Traditional” farms were characterized by the presence of old buildings containing tie stalls. These farms tended to have small to medium herds of Brown Swiss and local endangered breeds such as Rendena and Alpine Grey. “Original Traditional” farms used mainly local forages and moved lactating cows to summer alpine pastures. This system guarantees a high sustainability in terms of livestock biodiversity, environmental biodiversity (both plants and animals), environmental impact (stocking and manure densities), and landscape protection (re-afforestation and alpine pasture). The GIS analyses also showed that only traditional, low-input systems are able to maintain the steepest meadows and highland pastures. The main sustainability concerns of traditional dairy farms are low productivity, land fragmentation and agricultural mechanization. This paper shows that the strong link between traditional dairy farms and Protected Designation of Origin cheeses in Trento Province is fundamental to reducing the economic handicap experienced by traditional farms compared with intensive farming systems, transforming some of their technical weaknesses into economical strengths, and contributing to the sustainability of traditional alpine dairy farms.

Key words: dairy cow, farming system, mountain, sustainability

INTRODUCTION

The sustainability of livestock farming systems plays a central role in addressing the policies aimed at sustaining and planning rural development. The World Commission on Environment and Development (WCED, 1987) defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. In livestock science, the concept of sustainability includes environmental protection, animal welfare, biodiversity, food safety and quality, social issues and economic competitiveness (Gamborg and Sandøe, 2005). All these issues should be addressed when considering the diversification of livestock farming systems (e.g., use of resources, degree of intensification, species and orientation of production) at different scales (Gibon et al., 1999; Bernues et al., 2011).

In mountainous regions, where livestock farming has traditionally been of great importance for the vitality of rural economies (Baldock et al., 1996), mutually dependent social, economic, technical and cultural changes are leading to the abandonment of agriculture in marginal areas and to the intensification of farming in the most favorable valleys (MacDonald et al., 2000; Strijker, 2005). Traditional, low-input farms, which played a fundamental role in landscape and ecosystem modeling, are facing abandonment or conversion into more profitable intensive holdings. Both abandonment and intensification lead to a loss of open areas and forest re-growth (Cocca et al., 2012), a loss of biodiversity (Giupponi et al., 2006; Marini et al., 2011), and radical socio-economic changes (Bernues et al., 2005). In mountainous areas, traditional dairy farms provide multifunctional services. In the Italian Alps, several Protected Designation of Origin (PDO) cheeses are produced (Bovolenta et al., 2011) with an added-value chain that helps to maintain a satisfactory income for farmers. These farms use local forages and highland pastures, preserving the landscape from reforestation and contributing to the maintenance of biodiversity (Giupponi et al., 2006; Cocca et al., 2012). These services increase the touristic vocation of mountainous areas, contributing to the economic and social development of rural communities (Scarpa et al., 2010). For these reasons, the maintenance of profitable farms that have adapted to the environmental constraints and are able to guarantee the conservation of traditional land uses is one of the key issues for rural development in mountainous areas (Bernues at al., 2011).

This paper aims to classify the dairy systems of the Trento Province (Italy), an example of Alpine areas. The sustainability of the identified dairy systems was then analyzed in terms of productivity, milk destination, the maintenance of livestock biodiversity, land management, and landscape preservation.

MATERIALS AND METHODS

Data Collection

The survey was carried out in the Autonomous Province of Trento (northern Italy; Figure 1) which covers an area of 6,200 km2 and consists of 217 municipalities, all classified as mountainous for the national statistical database (ISTAT 2010). Land morphology is highly variable, with a minimum altitude of 66 m asl and maximum altitude of 3769 m asl. Utilized Agricultural Area (UAA) covers 1372 km2 and is predominantly characterized by meadows and pastures (81%), followed by orchards and vineyards (17%). Arable crops represent only 2% of land (ISTAT 2010).

Data used in this study were from 610 dairy farms that represent 55% of the dairy farms in the Trento Province and were surveyed during the years 2009-2010. This sample included 19,531 dairy cows (32 dairy cows/farm on average), which corresponds to 78% of the total number of cows in the Province (Table 1). The geographical distribution of the sampled farms is shown in Figure 1. Was conducted a preliminary analysis documented in Appendix I Data on the structural and management features of the farms were collected by an on-farm survey and include: type of stalling (tie vs. free), use of TMR, use of silages and transhumance of lactating cows to highland summer pastures. These data were used to classify the farms into different dairy systems. Data on herd size and composition and milk production were obtained by merging and editing different databases (Table 1). Data on the main destination of produced milk were obtained by the Consortium of Cooperative Dairies of the Trento Province (CONCAST). The farms associated with the cooperative dairies that mainly produce ripened cheeses according to traditional techniques and under the Protected Designation of Origin framework of the European Union legislation were classified as “producers of milk for PDO cheese”. The yearly average price of milk paid by each dairy during the years 2006-2011 and the classification of dairies according to their “PDO cheese producer” status were also obtained from CONCAST. The number of cattle reared by each farm, classified according to breed (Brown Swiss, Holstein Friesian, Simmental, Rendena, Alpine Grey, and others), was acquired from the national cattle population register and divided into dairy cows and replacement cattle. Herd size was expressed as Livestock Units (LUs), following EU livestock schemes where cattle > 2 years = 1 LU, cattle 6 months to 2 years = 0.6 LU and cattle < 6 months = 0.4 LU. CONCAST also provided data on the bulk milk yield (kg × day-1) and quality (fat and caseins percentages, and somatic cells score) for each herd.

GIS Analyses

All analyses were conducted using the GIS software ArcGis 10® (ESRI, 2010). Data on the UAA were extracted from the georeferenced cadastral map database of the Autonomous Province of Trento, for a total of 83,343 parcels (Table 1). Land use was provided by the Provincial Agency for Payments in Agriculture (APPAG). Land cover categories were: arable crops, lowland meadows and pastures (grasslands), highland summer pastures, orchards, vineyards and woodlands.

Using these data, the total UAA managed by each farm, the arable surface and grasslands (expressed as total surface and as ha × LU-1), and the stocking rate (LU × ha-1) has been calculated. The highland pastures used during summer transhumance (and the woodlands) were not included in the UAA, and the calculation of the stocking rate excluded the LUs moved to summer farms (LU -SP), weighted for the length of summering (SL, d):

$$\text{Stocking rate (LU} \times \text{ha-1)} = (\text{LU} - (\text{LU SP} \times \text{SL} / 365\text{ d})) \times \text{UAA-1}$$

All adjoining cadastral parcels managed by the same farmer were merged to obtain land management units (LMUs). The following landscape metrics were calculated using the Spatial Analysis extension (ESRI, 2010): the number of LMUs per farm; the number of LMUs per hectare and the number of LUs for each farm; and the average LMU surface. These metrics are common indicators of land fragmentation (Del Corral et al., 2011), which is one of the main problems for mountainous dairy farms. We also calculated the shape of the LMUs, expressed as the perimeter/surface ratio and the shape index (SI). The SI is the ratio perimeter/surface normalized against the area of a circle. Ideally, SI equals 1.00 for a circle and 1.13 for a square and increases with increasing landscape shape irregularity (McGarigal and Marks, 1995).

$$SI = \text{perimeter}/(2 \times \sqrt{\pi \times \text{area}})$$

Using a digital terrain model (DTM) with 10x10 m spatial resolution (Provincia Autonoma di Trento, 2005) we calculated the elevation of the farms (we considered the geographic coordinates of the farm building) and subdivided the UAA into three classes of slope that can be considered proxies of mechanizability (Cocca et al., 2012): slope class 1, expressed as the percentage of farm surface that included areas with a slope < 35%, which is assumed to be mechanizable with normal tractors; slope class 2, expressed as the percentage of farm surface that included areas with a slope between 35 and 60%, which is mechanizable with four wheels tractors; and slope class 3, expressed as the percentage of farm surface that included areas with a slope > 60%, which are assumed to be non-mechanizable. This classification has been used because it describes how the morphology of the UAA can influence its use by farmers better than using the average slope.

Statistical analyses

Dairy systems were identified using the SAS FASTCLUS procedure (SAS, 2008) to group farms on the basis of their structural and management features as described by the following variables: type of stalling (tie vs. free), use of silages, use of TMR, and use of highland summer pasture transhumance for lactating cows. The characteristics related to the “size” of the farm, land use, cow breeds and productivity were not used to group farms but have been analyzed according to the structure and management based grouping described above. The optimal number of clusters was chosen on the basis of the cubic clustering criterion (CCC) statistic. To characterize and compare the identified clusters, the main descriptive statistics were calculated for each of them. Data on herd size and composition, milk production, quality and destination, land use and landscape metrics were analyzed by one-way ANOVA, using identified dairy systems as the source of variation (SAS, 2008). The average price of milk paid by 18 cooperative dairies during the years 2006-2011 was analyzed by two-way ANOVA, including the main destination of milk (“PDO cheese producers” or not), the calendar year and their interaction in the model. The Bonferroni t-test was used for mean comparisons, and the level of significance (α) was set at 0.05. Before statistical analysis, data were examined for normality and variance equality. In cases of unequal variance, the transformed (logarithmic) data were analyzed to confirm the conclusions. A non-parametric Kruskal Wallis (Statistica, 2010) test was performed to analyze the differences between dairy systems for the following variables: herd breed composition (percentage of Holstein Friesian, Brown Swiss, Simmental, Alpine Grey, Rendena, and others), farm total surface (ha), farm grassland surface (meadows and pastures, ha), farm arable surface (ha), grassland availability (ha × LU-1), arable land availability (ha × LU-1), and slope class (1, 2 and 3). For these variables, it was impossible to obtain a normal distribution. The post-hoc Dunn test was used for mean comparisons, and the level of significance (α) was set at 0.05.

RESULTS

Dairy Systems Identified by Cluster Analysis

In 2008, 1111 dairy farms were active, with a total of 38,124 cattle heads, of which 24,943 were dairy cows, for an average herd size of 22.5 cows/farm (Table 1).

The 610 dairy farms sampled for this study were grouped into 4 dairy systems based on the FASTCLUS procedure (Table 2) applied only to structural (type of stalls) and management characteristics (feedstuff distribution, use of silages, use of summer pasture transhumance for cows) of the farms and not to the size of the farm, land use, cow breeds or productivity. Clusters 1 and 2 accounted for 50% (307 farms) and 25% (153 farms) of the units sampled, respectively. They were both characterized by tie stalls and traditional feeding (mainly hay and concentrates, no TMR); silages were used only in cluster 2 by a small proportion (19%) of farms. The main difference between these two groups was that all the farms in cluster 1 moved the lactating cows to highland pastures during the summer, whereas none of the farms in cluster 2 maintained this practice. The dairy system identified by cluster 1 was classified as "Original Traditional", and the dairy system identified by cluster 2 was classified as "Traditional without summer pastures". Cluster 4 included 114 farms with typical features of intensive systems: free stalls and a milking parlor, use of TMR in two thirds of the cases, relevant use of silages and no cows were moved to highland pastures during the summer. This dairy system was defined as "Modern". Cluster 3 was the smallest, with 36 farms. They were characterized by tie stall usage, 28 of them used the TMR techniques, all used silages, and half of this group moved lactating cows to the highland summer pastures. Farms included in this dairy system were defined as "Traditional with silages", having traditional buildings and modern feed management.

Herd Size

Herd size was significantly influenced by the different mountainous dairy systems identified with cluster analysis (Table 3). The average herd size of "Modern" and "Traditional with silages" farms was approximately three times and more than twice that of the other two groups of "Traditional" farms, respectively. Even more differentiated were the number of dairy cattle and replacement heifers reared. Coefficients of determination for these three variables were approximately 30%, indicating a relevant effect of the dairy system. The number of female replacements reared for every 100 cows is an indirect indicator of the longevity of the cows and was characterized by a high variability. It was, on average, lower than 50% in the "Traditional" farms, and 53% and 56% for

“Traditional with silages” and “Modern” farms, respectively. The effect of dairy systems on the percentage of replacement females, although statistically significant, explained a very low fraction of the total variation.

Milk Yield, Quality and Destination

The average milk yield was strongly influenced by the dairy system (r2 = 28%), being highest for “Modern” farms, intermediate for the “Traditional with silages” group, and lowest for the other “Traditional” dairy systems (Table 4). On the contrary, the differences in terms of milk quality, even though significant in the cases of caseins and fat percentages, were negligible, with a very low coefficient of determination.

The percentage of farms that are associated with cooperative dairies that mainly produce PDO Trentingrana cheese and other ripened, traditional cheeses varied from a minimum of 8% in the “Traditional with silages” dairy system to a maximum of 64% in the Original Traditional dairy system (Table 4). The differences were statistically significant ($\chi 2=32.62$; d.f.=3; $P<0.001$).

The price paid by the cooperative dairies that were considered “PDO cheese producers” (Figure 2) for milk during the years 2006-2011was, on average, 26% higher than the price paid by cooperative dairies that mainly produced fluid milk, yogurt and fresh cheeses (52.3 vs. 41.4 €cent /kg, respectively; $P<0.0001$). Additionally, the year of production had a highly significant effect on price (+68% from 2006 to 2011, $P<0.0001$), while the interaction between the final destination of the milk and the year of production was not significant.

Breed Composition of Herds

The differences in productivity levels among the dairy systems were consistent with the differences in breed composition of the herds (Table 5). The “Modern” dairy systems were characterized by a high percentage of cows from dairy breeds, with Holstein Friesian being represented more than the traditional Brown Swiss cattle, whereas dual-purpose and local breeds were almost absent. On the contrary, the “Original Traditional” dairy system, which moved the cows onto alpine pastures during the summer, kept animals belonging to autochthonous, Alpine breeds almost exclusively, especially the Brown Swiss, the dual-purpose Simmental, and the local dual-purpose Alpine Grey and Rendena breeds. In these farms, the Holstein Friesian cows were rare and were generally represented by a few heads reared together with cows of the traditional breeds. The traditional farms of cluster 2, which have abandoned the practice of summer transhumance to Alpine pastures, were characterized by a higher proportion of Holstein Friesian cows that mainly replaced cows of the local breeds. The breed composition of the herds included in dairy system “Traditional with silages” was intermediate between those of the traditional and modern dairy systems, but with the lowest incidence of Brown Swiss. In all the dairy systems, “other” breeds and crossbred cows had an equally low representation (less than 10%). Single-breed farms (i.e., farms with more than 90% of cows belonging to only one breed) represented only 31% of the total herd sample analyzed (190 out of 610). The distribution was heterogeneous among dairy systems, with 37, 24, 14, and 31% of single-breed farms in “Original Traditional”, “Traditional without summer pastures", "Traditional with silages" and "Modern" dairy systems, respectively (Table 3). The differences were statistically significant ($\chi 2$ = 14.28; d.f. = 3; P = 0.003).

Land Use

To analyze the relationships between the dairy systems and the territory, several land use parameters were compared among the identified mountainous dairy systems (Table 6). The elevation of the permanent farm (that of summer alpine pastures has not been considered) was higher in "Original Traditional" dairy system than the other three systems. Within these, the "Traditional without summer pastures" farms were located at higher elevations than the "Traditional with silages". The "Modern" farms had an intermediate elevation.

The surface of the UAA and that of grasslands and arable land were significantly different among the dairy systems. "Traditional" farms managed a much smaller agricultural surface than the other dairy systems, both as grasslands (summer pastures excluded) and especially as arable land. One of the main differences was that the two "Traditional" dairy systems maintained a surface of grassland per LU that was larger than those of the "Modern" and "Traditional with silages" groups, and, as a consequence, the stocking rate per Ha of grassland of "Traditional" farms, with and without summer pastures, was significantly lower than on other farms (from 2.0 to 3.8 cows /Ha grassland). The availability of arable land, which here is mainly used to cultivate maize to be harvested as silage, was negligible for traditional farms (this land cover category was present only in 22% and 40% of farms with and without summer pastures for cows, with average surfaces accounting for 6% and 13% of total UAA, respectively), while it was frequently present in "Modern" (45%) and especially in "Traditional with silages" farms (81%), with average surfaces accounting for 27% and 40% of total UAA, respectively.

Landscape Metrics

The geographical data of each farm were implemented in a GIS analysis, and landscape metrics were calculated for the land managed units (LMUs, with the exclusion of summer pastures). The results of the statistical analysis of landscape metrics are shown in Table 7. The "Modern" and "Traditional with silages" dairy systems managed significantly larger numbers of LMUs than the farms of the other two "Traditional" dairy systems; the average surface was lower for the "Original Traditional" farms than for the others. When the number of LMUs was considered in relation to the farm surface or to the herd size, as indices of fragmentation from the geographic and economic points of view, (N° of LMU/ha and N° of LMU/LU, respectively), the "Traditional" dairy systems showed a higher fragmentation in terms of both surface and LU. The average milk yield per LMU was, on average, double the amount for "Traditional with silages" and "Modern" dairy systems than for the other Traditional farms. No differences were found between dairy systems in terms of the shapes of the LMUs; only the differences in the perimeter/surface ratio were significant, but these differences were negligible. Finally, the farms of the "Modern" and "Traditional with silages" dairy systems used LMUs with gentler slopes than the farms of the very "Traditional" dairy systems. In addition, the "Original Traditional" dairy systems managed steeper LMUs than the "Traditional without summer pastures".

DISCUSSION

This study showed that the dairy farming systems of the Alps (Trento Province) are quite heterogeneous, with 4 different groups of farms identified by cluster analysis. This is in agreement with previous results obtained in other areas of the Eastern Italian Alps (Sturaro et al., 2009). The processes of intensification and modernization of structures and management have been more evident in specific areas (the most favorable valleys, at lower elevations, with lower land fragmentation and gentler slopes). Nevertheless, traditional farming practices, such as the summer transhumance of lactating cows to Alpine high pastures, have been maintained in a large number of farms because of specific subsidies by local governments. The relationships between Alpine dairy systems and farm animal biodiversity, milk production and destination, land use and landscape conservation will be discussed.

Farm Animal Biodiversity

One of the specific aims of the present research was to analyze the sustainability of dairy farms in terms of the maintenance of livestock biodiversity. It is interesting to compare the situation found in 2010 with that of officially recorded dairy farms in 1980 (Official Milk Recording Bullettin, 1980 and 2010, Figure 3). Thirty years ago, the main breed reared in the province was Brown Swiss, an Alpine breed that accounted for 80% of recorded heads. At that time, this breed was genetically close to the original dual-purpose Braunvieh cattle native to Switzerland, but a massive importation of bulls and semen from the USA contributed to almost completely replacing the original Alpine breed with the heavily selected dairy strain from America. Therefore, the Brown Swiss cows farmed now are much more specialized for milk production than those farmed a few decades ago. The other 20% of cows farmed in 1980 were mainly from the autochthonous, medium-framed, dual-purpose Alpine Grey and Rendena breeds (Bittante 2011). Dual-purpose Simmental and Holstein Frisian cows were present only in a few farms.

In 2010, the genetic landscape of the Alpine province is very different. Holstein Friesian has become the most numerous breed in the Trento Province, and the dual-purpose Italian Simmental (mainly improved by German and Austrian Fleckvieh and by French Montbeliarde) has gained importance. The substitution of the original dual-purpose strain with the dairy specialized one did not preserve the Brown Swiss breed from paying a heavy tribute to the tendency toward more intensive dairy systems (the incidence of this breed was halved in 30 years). Nevertheless, Brown Swiss still represents the most important breed in the very “Traditional” dairy systems and is the second most populous breed reared in “Traditional with silages” and “Modern” dairy systems. The recent evolution of the breed and of its role in the different Alpine dairy systems suggests that the future of the Brown Swiss (and also of large part of mountainous territories) will depend more on its selection for fertility and longevity (Dal Zotto et al., 2005 and 2007a; Rossoni et al., 2007; Tiezzi et al., 2011), milkability (Santus and Bagnato, 1998; Povinelli et al., 2003), milk quality (Cecchinato et al., 2009 and 2012; De Marchi et al., 2009 and 2011; Cipolat-Gotet et al., 2012), and harsh environment adaptation (Bovolenta et al., 2009), than on further improvements in productivity.

Beef production favors the maintenance of this breed in mountainous areas. Despite the fact that the value of Brown Swiss calves destined for veal production is similar to that of Holstein Friesian calves (Dal Zotto et al., 2009), the price paid for these calves is characterized by a moderate genetic variability (Penasa et al., 2012). Moreover, the longevity of this breed in a mountainous environment favors the practice of mating any cows in excess of replacement needs with beef bulls, mainly double muscled Belgian Blue bulls. The total value of Belgian Blue crossbred calves compared with Brown Swiss purebreds is high and greater than the value of other dairy and dual-purpose breeds reared in the region (Dal Zotto et al., 2009).

In the Trento Province, the dairy system able to maintain the highest value of livestock biodiversity is represented by the farms of the “Original Traditional” cluster. In contrast with “Modern” intensive or “Traditional with silages” dairy systems, traditional dairy farms that move lactating cows to Alpine high pastures during the summer are still using local breeds adapted to the difficult conditions of mountainous areas, such as Rendena, Alpine Grey, and Simmental. Local Rendena and Alpine Grey breeds maintain constant numbers over the years due to subsidies devoted to endangered breeds and to the high value of purebred and crossbred calves when used for beef production (Dal Zotto et al., 2007b and 2009). As evidenced by Hoffman (2011), local breeds are mostly found in grassland-based pastoral and small-scale, mixed crop–livestock systems with low to medium use of external inputs. The maintenance of local breeds in mountainous areas is particularly important for several reasons: conservation of livestock biodiversity, non-productive services such as the maintenance of marginal open areas and ecosystems with high natural values (Hoffman, 2011), and cultural value (Gandini and Villa, 2003). In these terms, traditional systems are more sustainable than the other dairy systems. Moreover, “Traditional” dairy systems also contribute to off-farm biodiversity, mainly because they maintain an environment more suitable to the life of wild animals (Giupponi et al., 2006; Ramanzin et al., 2009), even though the traditional farms also suffer more food competition between domestic and wild animals (Cocca et al., 2007; Marchiori et al., 2012).

Milk Production and Destination

Dairy farming plays a key role in the Trento Province, and it is strongly connected with cooperative dairies and the production of typical, traditional and PDO cheeses. Approximately 90% of all milk produced in the Province is processed by local cooperative dairies, connected by CONCAST, the Consortium of Cooperative Dairies of the Trento Province (Merz, 2011). The majority of these dairies are small traditional plants devoted to the production of typical cheeses, while some larger dairies produce fluid milk, yogurt and fresh cheeses.

During the years 2006-2011, the price of milk paid by the cooperative dairies of the Trento Province has always been higher than the price paid in the same years in Lombardy, with the exception of 2 of the 18 local dairies in 2008 (www.clal.it). On average, the price of milk paid by Trento dairies was 32% higher than that paid in the same years in Lombardy. Lombardy is the most important region for dairy production in Italy, characterized mainly by very large, high-yielding, Holstein Friesian herds reared on the plain to produce milk for both PDO cheeses (mainly Grana Padano) and other dairy products.

The most important PDO cheese of the Trento Province is the Trentingrana, or Grana del Trentino, which represents approximately 50% of the total milk produced in the Province (Merz, 2011). Trentingrana is a geographic specification of the PDO Grana Padano cheese, even though the production procedure of the Trentingrana is more similar to that of Parmigiano Reggiano cheese than to Grana Padano cheese. In fact, cows that produce milk for PDO cheese are not allowed to be fed from silages (Formigoni and Fustini, 2011) and lysozyme is not used in PDO cheese production (Franciosi et al., 2011; Endrizzi et al. 2012). Moreover, genetically modified organisms are not allowed in the feeding the cows or heifers that produce milk for PDO cheese, and Trentingrana cheese undergoes a strict quality control at the end of ripening (Bittante et al., 2011a, b). Other PDO or typical, traditional cheeses of the Trento Province are Spressa delle Giudicarie, Puzzone di Moena, Vezzena di Lavarone, Casolet Val di Sole, Fontal di Cavalese, Tosela di Primiero, Cuor di Fassa, Affogato di Sabbionara, and Asiago.

The choice of more ‘production oriented’ styles (the “Modern” and “Traditional with silages” dairy systems) is associated with larger herds, often fed using silages and TMR. These farming systems increase productivity, with an apparent economic benefit. However, the use of silages excludes the milk produced by many of these farms from the PDO chain. In 2011, the cooperative dairies of the PDO chain paid, on average, 63.0 €cent per kg of milk (from 50.1 to 71.1 €cent/kg), a price that was 41% higher than that (44.8 €cent/kg) paid by the local cooperative dairies producing other dairy products. In the same year, the milk produced on the intensive farms of the plains of Lombardy to be used for both PDO and non-PDO products was priced, on average, 39.6 €cent/kg. The production of high quality PDO cheeses according to traditional guidelines, without the use of modern technologies and additives, requires a very high quality of milk to maintain the first quality classification and sensory characteristics of produced cheese wheels (Bittante et al. 2011a, b). At the farm level, the breed of the cow seems more important than production conditions, with the important exception of the possible contamination of milk with bacterial spores that are responsible for the late inflation of ripened cheese wheels. The Brown Swiss breed produces milk characterized by a higher content of fat and protein than the Holstein Friesian breed. Furthermore, the cheese yield of the Brown Swiss breed exceeded the yield of the Holstein Friesian breed for the production of typical PDO cheeses more than the expected difference based on nutrient content (De Marchi et al., 2008). Milk produced by Brown Swiss cows has been demonstrated to have a better coagulation time, curd firming rate and curd firmness than the product of Holstein Friesian cows (Mariani et al., 1984; Malacarne et al., 2006; Cecchinato et al., 2011). Milk produced in the Trento Province by dual-purpose cows belonging to the Simmental and local Rendena and Alpine Grey breeds is characterized by better coagulation properties than the milk yielded by Holstein Friesian cows (De Marchi et al., 2007; Bittante et al., 2012).

If the role of Brown Swiss and Alpine dual-purpose breeds in the chain of production of high priced traditional PDO cheeses is clear, the effect of the dairy system, within breeds, is less clear. There is no doubt regarding the validity of “Traditional” dairy systems for supplying milk suitable for PDO cheese production, and there is no doubt that the use of silages makes the milk of

“Traditional with silages” dairy system unsuitable for PDO cheese production, but the situation is different for “Modern” dairy systems. About half of modern farms, in fact, do not use silages (60%) and can supply their milk to cooperative dairies producing mainly PDO cheeses (41%). More research is needed on this topic.

Land Use and Landscape Conservation

Another sustainability problem connected with the “Modern” and “Traditional with silages” dairy systems is their high livestock density. This is due to the higher quantity of concentrates (almost all imported from other areas) needed to sustain more productive breeds and higher production levels. This results in an increase in manure production per hectare and an increased risk of pollution (Xiccato et al., 2005). Moreover, although the farmland of the Trento Province is not included in the Nitrates Vulnerable Zones (EU, 1991), a high stocking rate might penalize the access to E.U. subsidies. In addition, these farms have often dismissed the use of summer transhumance to summer pastures for dairy cows, which results in an increase in both the stocking rate and milk production per unit of managed land in the lower valleys, which will also likely result in a larger environmental impact (Penati et al., 2011). The GIS analyses showed that “Original Traditional” farms are located at higher elevations, use larger surfaces of grasslands per LU, have a higher slope and more land fragmentation than “Modern” and “Traditional with silages” dairy systems. From the farm management and production points of view, these results should indeed be interpreted as disadvantages because elevation and slope depress forage productivity and increase mechanization and labor costs, and the high costs due to land remoteness and steep slope are recognized as one of the drivers of farm abandonment in mountainous areas (MacDonald et al., 2000; Cocca et al., 2012). In addition, Del Corral et al. (2011) demonstrated that land fragmentation is a strong limitation for the profitability of dairy farms, especially in a situation where milk prices are expected to remain low in the future. On the contrary, from the environmental sustainability point of view, the structural and management features of “Original Traditional” dairy farms show several advantages. In the last decades, the Alpine regions have been subjected to a remarkable process of re-afforestation following agricultural abandonment (Mac Donald et al., 2000; Cocca et al., 2012). In this context, the maintenance of permanent grasslands managed with extensive practices is regarded as a priority for the conservation of landscape attractiveness (Höchtl et al., 2005) and the biodiversity of plants and animals (Niiedrist et al., 2009; Sergio and Pedrini, 2007). This is especially true in lowlands, where the alternatives are arable crops or (in the Trento Province) vine and fruit crops that have a very low biodiversity value (Zimmermann et al., 2010), and in steeper areas (Marini et al., 2009), where the alternative is afforestation (Cocca et al., 2012). Traditional farming systems are still well represented in the dairy sector of the Trento Province but are declining (Marini et al., 2011). In other regions that are less favored from an economic point of view, these systems have experienced massive declines (Cocca et al., 2012). Therefore, it is necessary that grassland management, which is already sustained by the rural development measures of the CAP by the E.U., will be further promoted with the “greening” evolution of the CAP after 2013 (Keley and Baldock, 2011).

The results of the present study show that the maintenance of highland summer pastures plays an important role in the sustainability of the traditional Alpine livestock production systems. The transhumance of dairy cattle onto highland pastures (“Alpage” in French, “Alm” in German, “Malga” in Italian) is a traditional practice connected to several positive externalities: an adequate stocking rate maintains the landscape and the biodiversity; the most suitable cattle are Brown Swiss and dual-purpose breeds, with high-quality milk used for PDO and other typical cheeses; and in many cases, the income generated from the direct selling of products or agro-touristic services on summer farms strongly contribute to the economic sustainability of dairy farms.

CONCLUSIONS

The clustering of dairy farms in the Trento Province revealed that half of the farms still belong to a very traditional, original, dairy farming system. This system allows some very positive externalities regarding livestock biodiversity (local endangered breeds), environmental biodiversity (both plants and animals), environmental impact (stocking and manure densities), and landscape protection (re-afforestation and alpine pasture). But, this dairy system is also characterized by very small farm sizes, low productivity, land fragmentation, difficulty of mechanization, and, as a consequence, higher production costs. These last drawbacks are the main causes of the continuous decrease in the number of traditional dairy farms in all alpine areas, and the main drivers behind the decrease are the abandonment of dairying or the move toward more intensified dairy farm systems.

The abandonment of the summer transhumance of cows to alpine pastures simplifies herd and farm management, reducing the need for a seasonal organization of reproduction and for dual farm management. But, the traditional dairy system without summer pastures, represented by about one fourth of the dairy farms of the Trento Province, are based on farms with a size and productivity similar to the more traditional system.

Moving toward more modern models, the farms of the “Traditional with silages” dairy system, represented by about one fifteenth of farms, are larger than the previously examined ones and still use traditional buildings with tied animals, but these farms introduced the use of silages, mainly maize silage, and TMR. These farmers increased the number of Holstein Friesian cows, the productivity of the cows and the use of external inputs.

The highest herd size and productivity are reached by the farms of the “Modern” dairy system, about one fifth of the total, that are characterized by a larger number of animals reared, a high presence of both dairy breeds, a higher percentage of replacement animals, and more recent buildings with loose animals and milking parlors. From a feed management point of view, only some of the farms use TMR and silages, but all of the farms use much higher external inputs. However, this dairy system was revealed to be the worst in terms of livestock biodiversity, environmental impact and landscape preservation.

An important feature that characterized the dairy farming of the Trento Province is the very important role played by the network of cooperative dairies and their production system, mainly based on PDO and other traditional, typical, ripened, high-value cheeses. PDO cheese production requires a very high quality of milk with certain technological properties and the absence of silages in the diet of the cows but allows the farmers to charge a significantly higher price. This price premium, coupled with the value obtained from beef production (value of cull cows and of beef crossbred calves) and the lower external inputs required, contribute to reduce the economic handicap of traditional dairy farms, transforming some of their technical weaknesses into economical strengths, and toward maintaining their positive externalities regarding biodiversity, environmental impact and landscape protection.

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Table 1. Main sources of information collected and analyzed

	Complete databases		Sampled dairy farms	
	Total	Average/farm	Total	Average/farm
National cattle register:				
Dairy farms (n)	1,111	-	610	-
Cattle reared (heads)	38,124	34.3	29,645	48.6
Dairy cows reared (heads)	24,943	22.5	19,472	31.9
CONCAST[1] database:				
Dairies		-	18	-
Associated farms		-	321/610	-
APPAG[2] database:				
Agricultural parcels recorded (n)	281,980	25[3]	83,343	137
Surface of agricultural parcels (ha)	251,865	22.0	23,085	37.8

[1] Consortium of cooperative dairies of the Province of Trento
[2] Provincial Agency for Payment in Agriculture
[3] on 11,434 agricultural farms

Table 2. Profiles of dairy systems identified with cluster analysis

	Total sample	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Farms, No	610	307	153	36	114
Variable (% within cluster):					
Tie stall	73	86	100	78	0
Use of TMR	19	1	5	78	69
Use of Silages	18	0	19	100	40
Highland summer pastures[1]	55	100	0	51	8
Definition of dairy systems	-	Traditional (original)	Traditional without summer pastures	Traditional with silages	Modern

[1]The majority of lactating cows are subjected to seasonal migration “transhumance” from valley farms to summer alpine pastures.

Table 3. Herd size of the mountainous dairy systems (least square means)

Item	All farms (mean)	Traditional dairy systems			Modern dairy system	R^2	RMSE
		original	without summer pastures	with silages			
Herd size[1], LU/farm	42.0	19.0[a]	23.0[a]	57.2[b]	72.4[b]	30.5	0.81
Dairy cows[1], heads/farm	31.9	14.0[a]	17.7[b]	42.8[c]	55.5[c]	30.3	0.83
Replacement cattle[1], heads/farm	16.7	7.2[a]	7.7[a]	19.7[b]	30.0[c]	28.6	0.88
Replacement cattle, % of cows	52.3	50.2[ab]	46.2[a]	52.8[ab]	56.4[b]	1.5	27.32

Means with different superscripts within row differ significantly: [a,b,c]=P<0.05
[1] = log transformed least square means

Table 4. Milk yield, quality and destination according to the mountainous dairy systems

Item	All farms	Traditional dairy system			Modern dairy system	R^2	RMSE
		original	without summer pastures	with silages			
Milk yield, (kg/d)	20.4	18.8[a]	19.2[a]	22.3[b]	25.7[c]	27.6	4.33
Casein, %	2.71	2.69[a]	2.72[ab]	2.73[ab]	2.75[b]	2.3	0.14
Fat, %	3.94	3.90[a]	3.97[b]	4.01[b]	3.98[b]	2.6	0.23
Somatic cell score	3.22	3.22	3.22	3.42	3.15	0.5	0.78
PDO cheese producers[1], %	53	64	48	8	41	-	-

Means with different superscripts within row differ significantly: [a,b,c]=P<0.05
[1] Percentage of farms associated to cooperative dairies producing mainly traditional ripened PDO cheeses.

Table 5. Breed of the cows (%) reared in the mountainous dairy systems

Item	All farms	Traditional dairy systems			Modern dairy system
		Original	without summer pastures	with silages	
Holstein Friesian	21	8[a]	22[b]	42[c]	50[c]
Brown Swiss	46	50[b]	50[b]	28[a]	36[a]
Simmental	10	12[b]	11[b]	12[b]	4[a]
Alpine Grey	7	10[b]	4[a]	4[b]	1[a]
Rendena	7	11[b]	4[a]	5[ab]	2[a]
Other/crossbred	8	8[b]	9[b]	9[b]	6[a]
Single-breed farms (%)	31	37	24	14	31

Means with different superscripts within row differ significantly: [a,b,c]=P<0.05

Table 6. Land use in the mountainous dairy systems

Item	All farms	Traditional dairy systems			Modern dairy system
		Original	without summer pastures	with silages	
Elevation (m asl)	812	895[c]	768[b]	620[a]	712[ab]
Total surface (ha UAA)	16.7	12.3[a]	14.6[b]	24.6[c]	31.0[c]
Grassland (meadows and pastures, ha)	13.2	10.5[a]	11.6[a]	14.5[ab]	22.0[b]
Arable land (farms with/all farms)	209/610	68/307	61/153	29/36	51/114
Arable land, (ha)	2.9	0.7[a]	1.9[b]	9.6[c]	8.0[b]
Grassland available Ha /LU	0.45	0.51[b]	0.47[b]	0.26[a]	0.31[a]
Arable land available, Ha /LU	0.05	0.03[a]	0.06[b]	0.14[c]	0.07[b]
Stocking rate (LU/ha)	2.46	2.21[a]	2.41[ab]	2.86[bc]	3.10[c]
Land productivity (Kg milk/m^2 UAA)	1.34	1.16[a]	1.19[a]	1.55[b]	1.93[b]

Means with different superscripts within row differ significantly: [a,b,c]=P<0.05

Table 7. Landscape metrics calculated for land management units (LMUs) of the mountainous dairy systems

Variable	All farms	Traditional dairy systems			Modern dairy system
		Original	without summer pastures	with silages	
Land management units (LMU):					
Availability (LMU, N/farm)	44	33[b]	38[b]	60[a]	75[a]
Geographic fragmentation (LMU, N/ha)	4.26	4.51[a]	4.00[a]	3.23[b]	3.57[b]
Economic fragmentation (LMU, N/LU)	1.54	1.73[a]	1.63[a]	1.06[b]	1.04[b]
Average surface (Ha × LMU^{-1})	0.31	0.29[a]	0.32[b]	0.36[b]	0.33[b]
Perimeter/surface ratio	0.15	0.16[a]	0.15[b]	0.14[b]	0.15[b]
Shape index	1.58	1.57	1.57	1.60	1.61
Mechanization index:					
Slope class 1 (<35%), %	84	79[a]	86[b]	93[c]	92[c]
Slope class 2 (35-60%), %	14	18[b]	12[a]	6[a]	7[a]
Slope class 3 (>60%), %	2	3[b]	2[a]	1[a]	1[a]

Means with different superscripts within row differ significantly: [a,b,c]=P<0.05

Figure 1. Study area: white dots indicate the sampled dairy farms

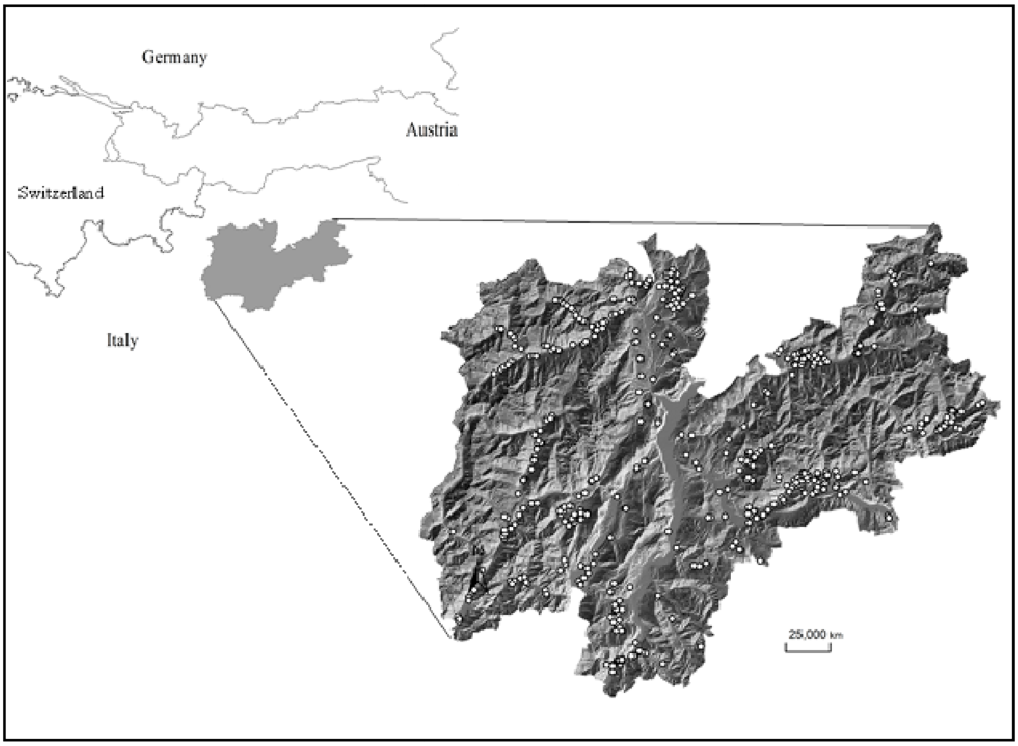
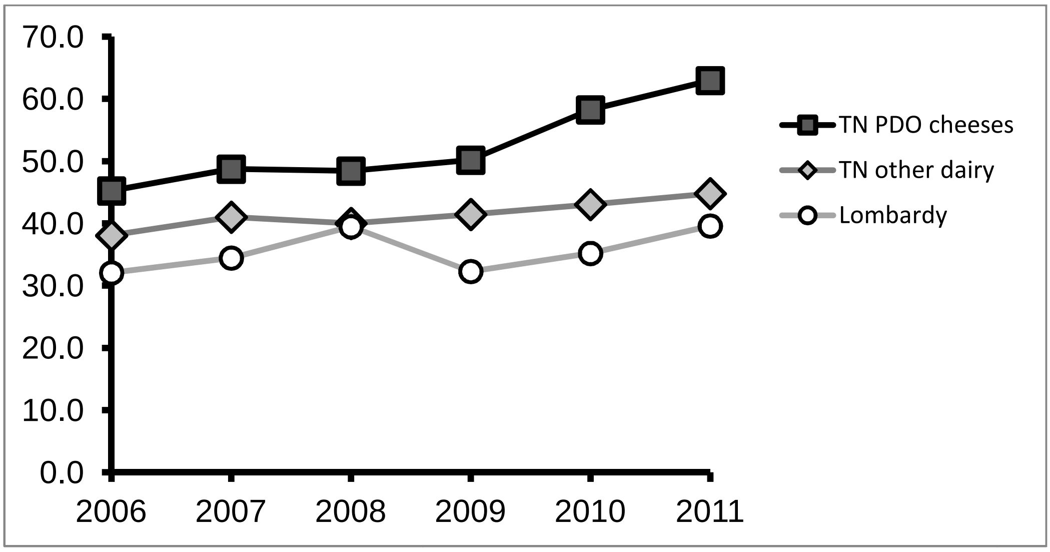
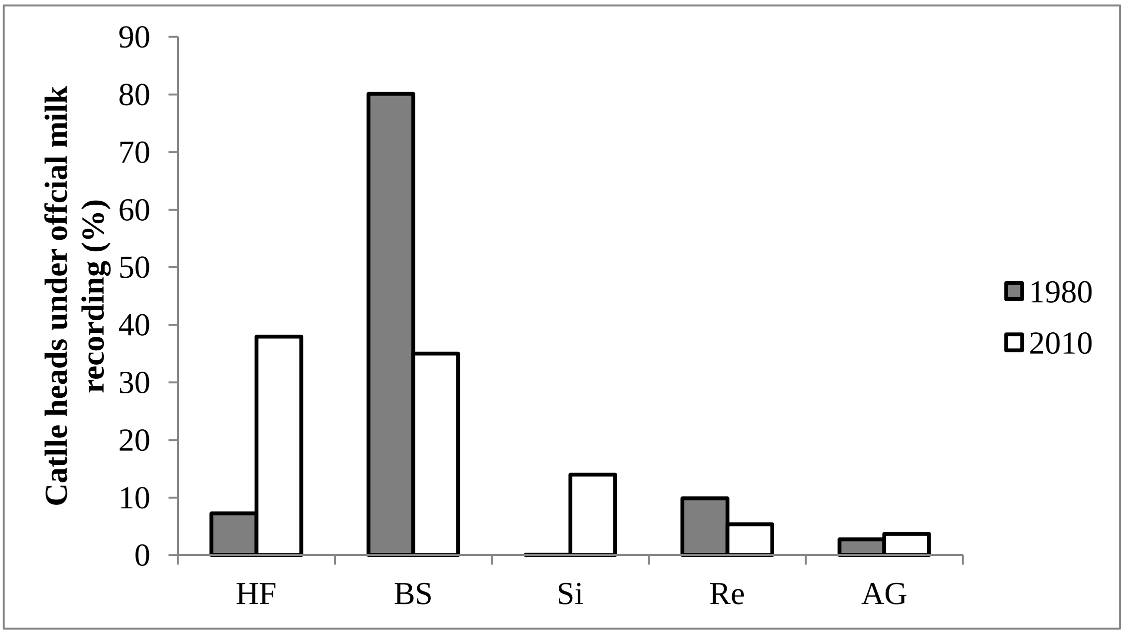


Figure 2. Average price (Euro cent/kg milk) paid by Cooperative Dairies of the Trento Province to their associates according to the main destination of the processed milk and the average price of milk in Lombardy.



"TN PDO cheeses": Cooperative dairies producing mainly PDO Trentingrana cheese and other PDO and traditional ripened cheeses.
"TN other dairy": Cooperative dairies producing mainly fluid milk, yogurt and fresh cheeses.
"Lombardy": average price of milk produced in the Lombardy region of Italy.

Figure 3. Evolution of cattle breeds in Trento Province (AIA- Italian Animal Breeders Association; HF=Holstein Frisian, BS=Brown Swiss, Si=Simmental, Re=Rendena, AG=Alpine Grey)



Chapter 2

ENVIRONMENTAL IMPACT OF DAIRY FARMS IN MOUNTAINOUS AREA IN TERMS OF NITROGEN, PHOSPHORUS, AND METHANE RELEASE

ABSTRACT

Emission of contaminants from livestock has large effects on superficial and subterranean waters and on climate change with strong effect on biodiversity reduction, and this have aroused strong interest in recent years. This paper aims to estimate the environment release of potential contaminant by dairy farms in Alpine areas, using as case study a sample of 565 farms of the Trento province. Specifically the work evaluates the impact of 4 different farming systems, that widely represent the dairy production in alpine area of Italy, on the release of nitrogen, phosphorus and methane. Structural, productive and management features of each farm were collected and the utilized agricultural areas of each farm were identified in the previous chapter. On average the chemical composition of diets in mountain area reflected the lower milk production of dairy cows of these farms in comparison to those reared on plain area of north Italy. Also diets of mountainous farm were characterized by a high starch and protein content, while NDF content was about 34% of DM. The more traditional clusters showed NDF and ADF diet concentrations significantly higher than the “Modern” and “Traditional with silages” clusters. The CP content had a large variability, and the Traditional showed lower contents than modern farms. The average net load of nitrogen in the sample was 187.7 kg/ha UAA, a value higher than the limit for the vulnerable zones but much lower than the one for the non vulnerable zones. At farm level, the “Modern” cluster had the highest value of nitrogen load; on the opposite, the farm of “Traditional-original” cluster had the lowest value of N load per ha of UAA. The balance calculated for phosphorous showed the same trend observed for nitrogen. The production of methane of lactating cows was estimated using two predictive models. When the emission was expressed per ha of UAA both the procedures estimated higher values of enteric methane production for the “Modern” cluster compared to the “Traditional” ones. The “Modern” dairy system showed the lowest emissions among the analyzed clusters per kg of milk produced. The results support the hypothesis that the traditional system allow to reduce the environment impact in the atmosphere of dairy sector in terms of nitrogen, phosphorous and methane release. This trend was obtained considering the efficiency in the use of nutrients and the link with local meadows and pastures for forage self-supply.

Key words: dairy cow, mountain, nitrogen, phosphorus, greenhouse gasses

INTRODUCTION

The soil contamination by minerals and greenhouse gas (GHG) emissions have become an increasingly important topic worldwide due to their effects on superficial and subterranean waters and on climate change with strong effect on biodiversity reduction. In the last decades global consumption of livestock products is growing rapidly and this tendency will continue in the next future, and the livestock systems contribute for a significant proportion to both minerals and GHG emissions.

Steinfeld et al. (2006) using a methodology that considers the entire commodity chain, has estimated that livestock is responsible of 1/3 of total load of nitrogen and phosphorus in the freshwater resources and for 18 %of greenhouse gas emissions. However, the report says, the livestock sector's potential contribution to solving environmental problems is equally large, and major improvements could be achieved at reasonable cost. The dairy farms contribute both to minerals (mainly nitrogen and phosphorus) and gases release in the environment: Nitrogen pollution from dairy farms affects water, by nitrate leaching, which contributes to eutrophication, and also air, through the emissions of gaseous N compounds such as NH_3 and N_2O and NO (Tamminga, 1992). In the same way, the common practice of codify the phosphorus requirements of dairy cows with mineral compounds without consider the consistent contribute of feeds leads to a low efficiency of mineral retention and a large excretion of this mineral in the environment. Methane is the second largest anthropogenic GHG, which contributes 14.3% of total anthropogenic GHG emissions estimated in 2004 (IPCC, 2007). Agricultural emissions of CH_4 account for about 60% of the total CH_4 from anthropogenic sources, of which 25% arises from enteric fermentation in livestock (Olivier et al., 2005). Globally, livestock produces about 80 million tonnes of enteric CH_4 annually.

In mountain areas, where dairy farms are characterized by extensive systems, there is a intensification of milk production similar to lowland. Many dairy farms in the mountains, to maintain their profitability, switch from local to specialized dairy breeds (particularly Holstein Friesian) and raise feed purchase (such as concentrates) to sustain higher milk production. Dairy cow rations shift towards an increase in the use of concentrates and maize silage. Dairy production, in Alpine mountain areas, is even now an important economic activity and it is strictly connected to the production of traditional cheese varieties (Casasùs et al., 2007).

There are not many studies on the environmental impact of dairy system in mountain areas. Recently, Penati et al, Penati et al. (2011) studied the impact of abandoning highland grazing of dairy herds in the central Italian Alps comparing some environmental (nitrogen and phosphorus surplus) and economic (labor income of the farm family) indicators of farms that transfer the dairy cows during the summer period in the highland pasture (12 farms) and those that don’t adopt this practice (16 farms). In this study the Authors evidenced a lower risk of release of nutrients of farms that use greasing pasture compared to those that reared dairy cows on farm during the entire year. Moreover, they suggest that the progressive increase of milk production per ha of farm land will increase the environmental impact of farms. These results suggest that the progressive intensification of farm activity drawn by the improvement of economic income of farms, will increase the environment impact of dairy system in mountain area.

This paper aims to give a pictures of the environment risk of nutrients release by dairy farms in Alpine areas, using as case study a sample of 565 farms of the Trento province. Specifically the work evaluate the impact in terms of nitrogen, phosphorus and methane release of 4 different farming systems, that widely represent the dairy production in alpine area of Italy.

MATERIALS AND METHODS

Data Collection

The survey was carried out in the Autonomous Province of Trento (northern Italy) which covers an area of 6,200 km^2 and consists of 217 municipalities, all classified as mountainous for the national statistical database (ISTAT 2010). In a total of 8365 farms in the Province of Trento, 1529 farms keep dairy cows, of these a sample of 610 farms was extracted and the structural, technical and productive information were achieved from the breeding information system of the Province of Trento. In the first contribution the same sample of farms was used to evaluate the role of dairy systems in mountainous areas in terms of animal biodiversity, milk production and destination, land use and landscape conservation. The sample of farms is well distributed throughout the territory, and can be considered broadly representative of the production farms of the province of Trento as previously described in the first chapter. In this wok, supplementary information were collected on farm to evaluate the nitrogen, phosphorus excretion and methane production and 55 farms were discarded because of missing or not reliable information were available. The final sample of 565 farms included about 18,476 dairy cows (32.7 dairy cows/farm on average), which corresponds to 74% of the total number of cows in the Province.

Data on the structural and management features of the farms were collected by an on-farm survey and include: type of stalling (tie *vs.* free), use of **TMR**, use of silages and transhumance of lactating cows to highland summer pastures. These data were used to classify the farms into different dairy systems. Moreover, data on TMR formulation and chemical composition, and on forages production, use and composition were also collected on-farm. Where chemical composition of TMR were not available, tabulated data (Sauvant et al., 2004) were used to estimate the chemical composition of TMR for the following parameters: starch, crude protein (CP), fat, neutral detergent fiber (NDF), acid detergent fiber (ADF), crude fiber (CF), phosphorus (P). Organic matter digestibility (OMd, % DM), digestible energy (DE, MJ/kg DM) and metabolizable energy (ME, MJ/kg DM) of TMR were computed from chemical composition of TMR according to Sauvant et al. (2004). Data on herd size and composition, cows breed, and milk production (MP) were obtained by merging and editing different databases. Data on the main destination of produced milk were obtained by the Consortium of Cooperative Dairies of the Trento Province (**CONCAST**). The farms associated with the cooperative dairies that mainly produce ripened cheeses according to traditional techniques and under the Protected Designation of Origin framework of the European Union legislation were classified as “producers of milk for PDO cheese”. The yearly average price of milk paid by each dairy during the years 2006-2011 and the classification of dairies according to their “PDO cheese producer” status were also obtained from CONCAST. The number of cattle reared by each farm, classified according to breed (Brown Swiss, Holstein Friesian, Simmental, Rendena, Alpine Grey, and others), was acquired from the national cattle population register and divided into dairy cows and replacement cattle. CONCAST also provided data on the bulk milk yield (kg/d) and quality (protein percentage) for each herd.

Computation of dairy cows nutrients balance (nitrogen and phosphorus).

The on farm nitrogen (N) and phosphorus (P) excretion per dairy cow (kg/cow/d) was computed following the mass balance methodology proposed by ERM (2001) as difference between nutrients intake and retention in animal products. Only on farm information were considered while animal moved on highland summer pasture were excluded from the computation.

Nutrients intake of dairy cows (kg/cow/d) was computed from the feed intake and the N or P content of diets. Feed intake (DM_intake) was estimated using the equation proposed by ADAS (2007) from live weight (LW) and MP for lactating cows (DM_intake_milk= $0.052 \times LW^{0.75} + 0.5 \times MP$, kg/cow/d) and for dry cows (DM_intake_dry= $0.052 \times LW^{0.75}$, kg/cow/d). The mean LW of cows was estimated according to the proportions of each breeds reared in each farm assuming a weight of 620 kg for large size breeds (Holstein Friesian, Brown Swiss and Simmental) and 500 kg for small size breeds (Rendena, Alpine Grey and Cross-breeds) (ERM, 2001; ADAS, 2007). The average DM intake per cow, including the dry period, was computed assuming a fraction of year spent in lactation of 82%.

The nutrients content of diets (% DM) were estimated from TMR formulation using tabulated data for concentrated, and by products (Sauvant et al., 2004), values reported on labels for commercial feedstuff, and fixed values obtained from a large chemical analysis database (1606 analysis) of forages collected in Trento Province from 2009 to 2012, at different altitudes (from 50 to 1,800 m asl), cuts, seasons and dried with different techniques (Pecile, personal communication). The CP and P percentage of dry cows diets was assumed equal to 11% and 0.40% (on DM basis), as reported by Italian normative (DGR 2439, August 7th, 2007; appendix D).

The nutrients retention (kg/cow/d) was computed as sum of the contribute of MP retention and of cows and veal tissues retention. For nitrogen balance, MP contribute was computed considering the mean milk production and N content of milk, and a contribute of cows growth and veal growth of 1.0 and 1.9 kg/year, respectively as proposed by ERM (2001). Similarly, P retention was computed assuming a fixed milk P content of 0.105% and a contribute of cows growth and veal growth of 0.5 and 0.35 kg/year as proposed by ERM (2001).

Assessment of enteric methane production

The estimation of lactating cow methane enteric emissions (kg/cow/d) was made using the following two equations proposed respectively by Kirchgessner (1995) and by Mills (2003) that require quite different inputs:

1) ***Kirchgessner (1995):***

$$CH_4 = 63 + 79 \times CF + 26 \times CP - 212 \times EE + 10 \times NFE$$

Where:

CF = crude fiber (kg/cow/d); CP= crude protein (kg/cow/d); EE= ether extract (kg/cow/d)

NFE = nitrogen-free extract (DM intake – CF – CP – EE) (kg/cow/d)

2) ***Mills (2003):***

$$CH_4 \text{ (kg/cow/day)} = (Emax - Emax \times \exp(-c \times MEI)) / Met$$

Where:

c = –0.0011 × (Starch/ADF) + 0.0045; Starch (kg/d); ADF (kg/d)

MEI = Metabolizable Energy Intake (MJ/d)

Emax = 45.98 (Maximum value of CH_4 production, MJ/cow/d)

Met = 55.5 (energy value of a kg of methane, MJ/kg)

Because of the restricted information on chemical composition of diets of dry cows and heifers, the contribute on methane production of these cattle categories was not estimated.

Computation of farm net N, and P excretion and of farm load

The nutrients balance (kg/farm/year) was computed on farm level excluding from the computation the highland pastures and the animals moved on the summer highland pastures for the fraction of year of permanence of animals on the pasture. Therefore, the farm excretion of N and P was obtained considering the number of cows and heifer reared on farm, the fraction of year of their permanence on farm and the nutrients excreted per head and per day.

The N volatilization losses during removal and manure storage were calculated assuming a coefficient of volatilization of 28% of the excreted N as required by Italian National Legislation (MIPAF, 2006) and the “net N production” was computed as difference between excreted and volatilized N.

The nutrients balances for heifer were not computed because of the low variability on feeding and management strategies between different farms in the territory of investigation, and tabulated values were fixed both for “net N production” (27 and 36 kg/head/year respectively for small and large size breeds) and for P excretion (6.4 and 8.5 kg/head/year respectively for small and large size breeds).

Therefore total farm net N (N_farm_prod, kg/farm/year) were obtained as sum of the contribute of each cow (N_cow_net, kg/cow/d) and heifer (N_heifer_net, kg/heifer/d) reared in a farm, for the number of cow and heifer reared (Cow_n and Heifer_n, n/farm) weighted for the large and small size breeds, and corrected for the fraction of year of permanence of cows and heifers in the highland summer pasture (SP_cow and SP_heifer, d) using the following equation:

$$N\_farm\_prod = N\_cow\_net \times Cow\_n \times (365 - SP\_cow) + N\_heifer\_net \times Heifer\_n \times (365 - SP\_heifer)$$

The same equation was used also to compute the total farm P production (P_farm_prod, kg/farm/year). As described in the first chapter, data on the Utilized Agricultural Area (UAA) were extracted from the georeferenced cadastral map database of the Autonomous Province of Trento, using the GIS software ArcGis 10® (ESRI, 2010). Land use was provided by the Provincial Agency for Payments in Agriculture (**APPAG**). Land cover categories were: arable crops, lowland meadows and pastures (grasslands), highland summer pastures, orchards, vineyards and woodlands. Using these data, the total UAA managed by each farm, the arable surface and grasslands (ha/farm), and nutrients load (N and P, kg/ha) has been calculated. The highland pastures used during summer transhumance (and the woodlands) were not included in the UAA.

Statistical analyses

Dairy systems were classified, as described in previous chapter,on the basis of their structural and management features using the following variables: type of stalling (tie *vs.* free), use of silages, use of TMR, and use of highland summer pasture transhumance for lactating cows. The characteristics related to the “size” of the farm (n. of cows and of replacements cattle, UAA), cow breeds (proportions of local breeds, % cows), milk productivity (kg/d/cow in milk) and period of alpine pasture (d) and nutrients balance parameters were not used to group farms but have been analyzed according to the structure and management based grouping described above. To characterize and compare the identified clusters, the main descriptive statistics were calculated for each of them. Data on herd size and composition, milk production and nutrients balance parameters were analyzed by one-way ANOVA, using identified dairy systems as the source of variation (SAS, 2008). The Bonferroni t-test was used for mean comparisons, and the level of significance (*P*-value) was set at 0.05. Before statistical analysis, data were examined for normality and variance equality. In cases of unequal variance, the transformed (logarithmic) data were analyzed to confirm the conclusions. A non-parametric Kruskal Wallis (Statistica, 2010) test was performed to analyze the differences between dairy systems for the following variables: total farm surface (ha) and total farm nutrients balance (kg/farm/year). For these variables, it was impossible to obtain a normal distribution. The post-hoc Dunn test was used for mean comparisons, and the level of significance (α) was set at 0.05.

Cartographic analysis: Kernel Density Estimation of nitrogen emission

The spatial distribution of the amount of nitrogen produced by each farm in one year was analyzed by a function of kernel density estimation in a GIS software (ArcMap 10.1). The information on how the manure was managed at the farm level were not known, it was estimated the degree of distribution with a weighing function which characterizes the decrease in the concentration of nitrogen (in kg / ha) depending on the increase of distance from farm. It was assumed that the storage of manure in field decreases with distance from the farm (more away from the farms less the amount of nitrogen found in the area). Through the density function, it was assumed that the amount of nitrogen loses meaning for areas outside the area analyzed. For the analysis of the radius of investigation has been chosen equal to 5 km. This value has been attributed on the analysis of the cost of spreading manure which was considered equal to twice the price of chemical nitrogen used for fertilization (0.7 € / kg) within this search radius. These hypothesis have been made assuming that the cost for the spreading of manure is equal to about 1.5 € / t considering a distance equal to 3-5 km (Provolo, 2000).

RESULTS AND DISCUSSION

Nitrogen and phosphorus balance

The formulations of rations for lactating cows in the four farming systems are shown in Table 3. As general description, the farms of Trento province use a high forage/concentrate ratio, and the rations are based mainly on grass hay. However, the results show a large variability between clusters: the “Modern” and the “Traditional with silages” farms use a very low percentage of grass hay with respect to the other farms, and they use the soybean feed as source of protein. In particular, the “Traditional with silages” farms use high percentage of maize and hay silages that represent about 1/3 of the total diet (36.5% DM). In general, the average percentage of leguminous hay is low, with higher values for “Modern” farms (11% DM) than traditional ones (5% DM). On average the TMR formulation of “Traditional with silages” farm in Trento Province is similar to that used by dairy farm in low land area of north Italy (Dal Maso et al., 2009) where silages are about 1/3 of TMR and feed compounds, forages and protein feed cover about 15, 23, 11% of TDM respectively. On average the diets of “modern farm” on mountain area are quite different from those used on plain area mainly for the la large use of grass and alfalfa forages that all together represent about 44% of rations. Moreover, the feeding techniques in mountain area appears strongly more variable compared to those recently surveyed on dairy farms of plain area.

A summary of the chemical composition of diets is shown in Table 4. The average composition is characterized by a high percentage of fiber (NDF and ADF), a low content of starch and a percentage of Crude Protein of 14.2%, with a large variability among farming systems. On average the chemical composition of diets in mountain area reflect the lower milk production of dairy cows of these farms in comparison to those reared on plain area of north Italy (20.5 vs. 29.1 kg/cow/d, respectively)(Xiccato, 2004). The diets of lowland farms are characterized by a high starch and protein content that reach about 24.1% and 15.4% of DM, respectively, while NDF content is about 34% of DM (Xiccato, 2004). The cluster Traditional (with and without alpine pastures) demonstrates NDF and ADF diet concentrations significantly higher ($P<0.05$) than the “Modern” and “Traditional with silages” clusters. As expected, the level of starch showed the opposite term, with higher values for the farms of clusters using silages (“Traditional with silages” and “Modern”) than the others. Also the CP content had a large variability, ranging from a minimum of 13.8% in “Traditional original” to a maximum of 15.4% in “Modern” farms.

The variability of feed parameters (OMd, DE and ME) among the analyzed clusters show a direct proportion among themselves. The cluster “Traditional - Original” has shown the lowest contents of Omd, DE and ME among the analyzed clusters ($P<0.05$). The cluster “Traditional without summer pasture” does not show statistically significant differences in comparison to the “Traditional – original” and “Traditional with silages” groups, regarding the OMd, DE and ME contents in the diets ($P<0.05$). The cluster “Modern” has the highest contents of OMd, DE and ME among the analyzed clusters ($P<0.05$).

According to studies carried out on intensive dairy farms in the Po Valley (Crovetto and Sandrucci,

2010), farms of “Modern” cluster, characterized by herds with a high percentage of Holstein Friesian breed, show high values of average DM individual daily intake. The table 5 summarizes the nitrogen and phosphorus balance in the analyzed clusters. Because the consumed nitrogen is highly related to the dry matter ingestion and its average CP content in the animal diets, the variability between clusters follow the same trend. The 4 clusters are significantly different regarding the nitrogen consume in the diets, what leads for the net nitrogen being different among all the clusters. From the values of table 7 and as expected from literature (Bittante et al., 1993), the animals from large dimension, intensive farming and with TMR diet have greater capacity of intake (21.4 kg DM cow / day) than the animals of the other farms.

The major feed input in farms of the “Modern” cluster can make the intensive farming more impactful (88.5 kg of net N / head / year), compared to managerial types where the production is lower, as a result of greater nitrogen amounts involved in the nutrients balance. In the clusters “Traditional original” and “Traditional without summer farms”, the average of net nitrogen excretion reach the minimum values of 72.4 and 75.8 kg of net N/head/year, respectively. In general, the excretion levels in the “Modern” dairy farms of Trento province are comparable to those obtained from the nitrogen balance of the Veneto Region (Xiccato et al., 2005), which calculates the excretion of nitrogen according to the size of cows, level of production and the average crude protein content. The noted difference in traditional farms can be explained by the reduced dry matter intake and the slightly lower CP content of diets compared to modern farm (on average 10% DM intake and 7% of diet CP less), resulting in lower nitrogen intakes. At individual level, the net excretion values of all dairy cows (considering, although with variations related to farm`s type, remains always below the ministerial value of 83 kg N/head (Ministerial Decree n. 152, 7/4/06), with exception for the cluster ”Modern” (88.5 kg/cow/year). The highest values of net N excreted / cow, were recorded in large dimension intensive farms (clusters “Modern” and “Traditional with silages”), where the production levels and feed inputs are considered very high. Similar studies for dairy farms in the Po Valley, reported net values of N excreted / cow equal to 83.5 kg / head / year (Bittante et al., 2004), in line with the table values dictated by the legislation. For the balance of phosphorous, the trend is similar for the one of nitrogen, with higher consumes and extraction for intensive farms than the traditional. If we consider the excretion of nitrogen and phosphorus as kg of nutrient per ton of produced milk, we see that the farms with large herd size, using total mixed rations and with high productive levels are able to maximize the efficiency in the use of nitrogen and phosphorous and as a consequence to reduce the excretion per ton of milk. As well known, (ERM, 2001; Ondersteijn et al., 2003; Rotz, 2004) the increase in production capacity of dairy cows represents a useful strategy to reduce the excretion of N. Therefore, on average the efficiencies of nitrogen (26.5%) and phosphorus (32.1%) utilization in mountain area appear sensibly lower than those recently estimated in Veneto Region (30 and 37%, respectively) where the milk production reach on average 30 kg/head/d (Xiccato et al., 2005). In general, it is observable a more efficient nutrients use in those kinds of farming practice that use TMR diet (clusters “Modern” and “Traditional with silages”), where the correct protein intake of the ration allows to maximize the retention capacity of the cows and therefore to minimize the nutrients losses in the excretions (Kohn et al., 1997; Tamminga, 1996; NRC, 2001). However, to evaluate the environment impact of nutrients excreted in mountain area it is important to consider the different self-supply of feedstuff among farm clusters that adopts different feeding systems. The large amount of concentrates and forages purchase for the formulation of diets in “Traditional with silages” and “Modern” farms cause a geographic shift of nutrients from the area of production and the area of usage. On the base of this consideration, the traditional farms using self produced roughages, although less efficient than the intensive ones, seems able to maintain an equilibrium in the nitrogen and phosphorous chain.

This conclusion is confirmed by the results presented in Table 6, where the balances of nitrogen and phosphorous are presented per farm. The average net load of nitrogen in the sample is 187.7 kg/ha UAA, a value higher than the limit for the vulnerable zones (170 kg N/ha; EU, 1991) but much lower than the one for the non vulnerable zones (340 kg N/ha). The variability is large, both among clusters and geographic areas. At farm level, the “Modern” cluster has the highest value of nitrogen load, with 267.5 kg N/ha; on the opposite, the farm of “Traditional-original” cluster had the lowest value of N load per ha of UAA (154.6 kg/N), confirming the strong link between herd management and grassland maintenance. Among the modern cluster about 13% of farms exceeded the limit of 340 kg/N, with evident problems of nitrogen surplus while in the others clusters only 6% of farms exceed this threshold.

The balance calculated for phosphorous showed the same trend observed for nitrogen; although the law limits are established only for nitrogen, phosphorous represent a potentially important source of pollution, particularly for the eutrophication (Steinfeld et al., 2006), and its monitoring is strongly recommended in an area as the Province of Trento.

Moving from a farm level to a territorial approach, in Figure 1 is showed the distribution of load of nitrogen in the Province of Trento. The load of nitrogen is expressed as total of kg of net nitrogen produced by each dairy farm. The red areas have a higher level of nitrogen and the blue areas are characterized by a lower load. The highest concentration of nutrients is located in the "Giudicarie" and in the "Val di Non", where there are more intensive farms. However, the cartography expresses trends only to the province of Trento, and the farms that exceed 340 kg N/ha are very few,c onfirming that the dairy cattle systems in Trento generally does not present significant problems related to excessive nitrogen load.

Enteric methane emissions estimation

The values of methane production of lactating cows estimated using the approaches proposed by Mills et al. (2003) and Kirchgessner et al. (1995) are reported in Table 7. The two Authors proposed different sets of equations to estimate the rumen production of methane that are based both on the chemical composition of the TMR and the daily feed intake. On average, the values of methane estimated using the approach of Mills et al. (2003) were only slightly lower than those estimated according to Kirchgessner et al. (1995) (433 vs. 484 g/cow/day, respectively). When data were expressed per head, the two methods of methane quantification evidenced differences statistically significant among the clusters but these differences were not relevant from a quantitative point of view. However, when data were expressed per ha of UAA both the procedures estimated higher values of enteric methane production for the "Modern" cluster compared to the traditional ones ($P<0.05$). As previously described, this difference reflects the different head load of these farm systems. On the opposite, the cluster "Modern" showed the lowest enteric methane emissions among the analyzed clusters per kg of milk produced ($P<0.05$) that was on average about 22% and 26% lower compared to the "Traditional" clusters using the Mills et al. (2003) and Kirchgessner et al. (1995) approaches, respectively. These results support the hypothesis that the most sustainable alternative for reducing the environment impact of dairy sector in terms of methane release, appears the maximization of the milk productivity of cows. In this way, the methane, produced in the rumen in an amount that is relatively stable among different feeding and management systems (Janssen, 2010), is diluted in a greater amount of milk (Boadi et al., 2004). Kirchgessner et al. (1995) estimated that increasing milk production of dairy cows from 5000 to 10 000 L of milk annually in the EU, by using high grain rations or by improving the genetic merit of animals, would increase total CH_4 production per animal per year by 23% (i.e., from 110 to 135 kg yr^{-1}). However, CH_4 production per kg of milk produced would be reduced by 40% (i.e., from 0.022 to 0.014 kg of CH_4 kg $milk^{-1}$).

Therefore, total CH4 emissions could be decreased by reducing animal numbers while maintaining milk production. On the basis of these results, intensification seems to be a efficacious strategy for the reduction of methane emission by dairy farms of mountainous areas; nevertheless, as seen for nitrogen and phosphorous emissions, the link with local meadows and pastures for forages self supply is more strict in traditional than modern farms. This relationship limits the geographical shift of nutrients and carbon typical of the livestock systems using a large amount of concentrates and feedstuffs produced from the farm (Steinfeld et al., 2006), and also guarantees the maintenance of grassland and the preservation of mountain ecosystems

CONCLUSIONS

The results showed the same tendency for emissions contaminants N and P in different clusters analyzed. The groups of traditional farms showed the lowest emissions per capita and per hectare of agricultural land. There was also a big difference between the clusters more traditional than most modern farms. The net nitrogen emissions in the analyzed clusters were lower than the values indicated by the National law for dairy cows in large part of the farms except for those of the "Modern" cluster. However, these farms were characterized by greater nutrient supply per ha of utilized agricultural area (UAA) compared to "Traditional with silage" and traditional (original and without summer pasture) farms.

The differences of methane emission, expressed per head, were not quantitatively significant among farm clusters. When data were expressed per ton of milk produced, there was a reduction of 1/3 of the emissions in the "Traditional" farms compared to "Modern" ones. The lowest emissions were estimated for farms with more intensive production trend and with a more rational feeding strategies.

On the basis of these results, the planning of strategies aimed to improve the environmental sustainability of dairy farms in mountainous areas should take into account for the efficiency in the use of nutrients and the link with local meadows and pastures for forage self-supply.

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Table 2. Profiles of dairy systems identified with cluster analysis (% within cluster)

Variable	All farms	Traditional			Modern
		Original	without summer pasture	with silages	
Farms, n.	565	285	138	31	111
Variable, % within cluster:					
- Tie stall	73	86	100	78	0
- Use of Total Mix Ration	19	1	4	81	68
- Use of silages	18	0	21	100	39
- Dairy cow on Highland Summer Pasture (HSP) *	54	100	0	45	7
- Replacement cattle on HSP	86	90	80	71	85

* The majority of cows on milk are subjected to seasonal migration “transhumance” from valley farms to summer alpine pastures

Table 2. Farm parameters used to estimate the nutrients excretion and the methane production

Variable	All farms	Traditional			Modern	R^2	rMSE
		Original	Without summer pasture	with silages			
Cows/farm, n	32.7	20.9[a]	24.9[a]	50.7[b]	67.5[c]	0.31	27.6
Replacement cattle /farm, n	15.1	8.8[a]	10.1[a]	24.1[b]	34.8[c]	0.30	16.0
Milk yield, kg/d/cow in milk	20.5	18.8[a]	19.5[a]	22.0[b]	25.6[c]	0.28	20.5
Local breeds, % cows	25.8	36.3[c]	18.8[b]	24.5[bc]	7.9[a]	0.10	34.3
UAA, ha	17.0	11.8[a]	14.8[b]	25.3[b]	30.9[c]	0.29	11.7
Period on highland summer pasture, d	97.4	98.2	96.6	96.6	94.2	0.01	14.0

[a,b,c,d] Values on the same row with different superscripts differ significantly ($P<0.05$);
rMSE= root mean square error.
UAA= Usable Agricultural Area: arable crops, meadows and pastures on valley floor.
Local breeds = Rendena, Alpine grey, Simmental.

Table 3. Formulation of rations (% DM) for lactating dairy cows.

Variable	All farms	Traditional			Modern	R^2	rMSE
		Original	Without summer pasture	with silages			
Grass hay	55.8	67.1[c]	58.5[b]	23.3[a]	32.6[a]	0.44	17.1
Alfalfa hay	6.2	4.6[a]	5.5[a]	4.1[a]	11.8[b]	0.11	8.0
Maize silage	5.2	0.4[a]	4.1[b]	31.0[d]	11.6[c]	0.38	9.7
Grass silage	1.2	0.2[a]	1.2[a]	5.5[b]	2.4[b]	0.10	4.1
Cereals	8.2	5.6[a]	6.3[a]	9.5[a]	17.0[b]	0.16	10.3
Soybean and/or other protein feed	1.3	0.0[a]	0.1[a]	3.6[b]	5.2[b]	0.26	3.6
Compound feed	21.4	21.7[b]	23.7[b]	21.9[ab]	17.5[a]	0.02	13.4
Mineral-vitamin supplements	0.2	0.0[a]	0.0[a]	0.4[b]	0.7[b]	0.07	1.0
By-products*	0.6	0.4[a]	0.5[a]	0.7[ab]	1.2[b]	0.01	2.9
Forage, %	65.8	72.0[c]	67.2[b]	48.4[a]	53.0[a]	0.32	12.1

[a,b,c,d] = values on the same line with different letters are significantly different (P<0.05);
rMSE= root mean square error.
* Meanly: wheat bran, distillers, sugar beet pulp and molasses, and brewers grains.

Table 4. Chemical composition of diets for lactating dairy cows on farm (% DM)

Variable	All farms	Traditional			Modern	R^2	rMSE
		Original *	without summer pasture	with silages			
CP	14.2	13.8^{A}	14.0^{A}	14.5^{B}	15.4^{C}	0.18	1.3
Starch	15.2	12.2^{A}	14.5^{B}	23.3^{C}	21.6^{C}	0.32	5.8
Fat	3.20	3.08^{a}	3.17^{b}	3.47^{c}	3.41^{c}	0.12	0.39
NDF	47.6	50.5^{C}	48.4^{B}	42.3^{A}	40.7^{A}	0.29	6.2
ADF	28.1	29.8^{C}	28.5^{B}	24.6^{A}	24.1^{A}	0.23	4.2
Phosphorus	0.38	0.37^{a}	0.39^{a}	0.42^{b}	0.38^{a}	0.02	0.1
OMd	69.8	68.8^{a}	69.6^{ab}	70.6^{b}	72.3^{c}	0.10	4.1
DE, MJ/kg DM	12.6	12.4^{a}	12.6^{ab}	12.7^{b}	13.1^{c}	0.10	0.7
ME, MJ/kg DM	10.1	10.0^{a}	10.1^{ab}	10.2^{b}	10.5^{c}	0.10	0.6

^{a,b,c} = values on the same row with different superscripts differ significantly (^{abc} P<0.05, ^{ABC} P<0.01);
rMSE= root mean square error.
OMd=organic matter digestibility estimated from chemical composition of diets (Souvant et al., 2004)
DE= digestible energy estimated from chemical composition of diets (Souvant et al., 2004)
ME= metabolizable energy estimated from chemical composition of diets (Souvant et al., 2004)
* Use of highland alpine pasture during the summer period for dairy cows

Table 5. Nitrogen and phosphorus balance of dairy cows per day on farm*

Variable	All farms	Traditional			Modern	R^2	rMSE
		Original *	without summer pasture	with silages			
Feed intake, kg DM/d	19.3	18.5^{A}	19.1^{B}	19.9^{BC}	21.4^{D}	0.26	1.8
Nitrogen Balance for lactating cow, g/d:							
Consumed	440	410^{A}	430^{B}	460^{C}	530^{D}	0.31	66
Retained	120	110^{A}	110^{A}	130^{B}	150^{C}	0.28	23
Excreted	320	300^{A}	320^{B}	340^{C}	380^{D}	0.27	50
N retention efficiency, %	26.5	26.2^{A}	26.0^{A}	27.0^{AB}	27.7^{B}	0.04	3.3
N Excreted per ton of milk, kg/t	16.3	16.6^{B}	16.7^{B}	15.7^{AB}	15.2^{A}	0.04	3.0
Net N excreted**, kg/head/year	76.8	72.4^{a}	75.8^{b}	79.9^{c}	88.5^{d}	0.26	10.2
Phosphorus balance for lactating cow: g/d							
Consumed	73.8	69.4^{a}	74.3^{b}	83.8^{c}	81.8^{c}	0.08	18.2
Retained	22.5	20.8^{a}	21.5^{a}	24.1^{b}	27.9^{c}	0.28	4.4
Excreted	51.3	48.6^{a}	52.8^{b}	59.7^{c}	53.9^{c}	0.03	16.7
P retention efficiency, %	32.1	31.2^{a}	30.6^{a}	30.4^{a}	36.7^{b}	0.04	11.7
P excretion per ton of milk, kg/t	2.60	2.67^{b}	2.74^{b}	2.78^{b}	2.17^{a}	0.05	1.3
P excreted**, kg/head/year	19.4	17.7^{a}	19.0^{b}	20.9^{c}	19.4^{bc}	0.04	4.8

* The nutrients balance consider only the period of dairy cows permanence on farm and exclude the highland summer pasture.

** Nitrogen and phosphorus balance including the contributes of lactating and dry dairy cows.

^{a,b,c,d} = values on the same row with different superscripts differ significantly (^{abc} $P<0.05$, ^{ABCD} $P<0.01$);

rMSE= root mean square error.

Table 6 – Loads of net nitrogen (N) and phosphorus (P, kg/farm/year) on farm*

Variable	All farms	Traditional			Modern	R^2	rMSE
		Original	without summer pasture	with silages			
Net nitrogen**:							
Produced on farm	2980	1602^{a}	2189^{b}	4682^{c}	7027^{d}	0.36	2857
Produced on farm and on Highland summer pasture	3299	1955^{a}	2326^{a}	5193^{b}	7428^{c}	0.34	3021
Rate of net N produced on summer pasture, % total	12.6	18.8^{c}	5.6^{a}	9.2^{b}	6.0^{a}	0.40	7.9
Farm load, kg net N/ha UAA	187.7	154.6^{a}	187.5^{a}	207.0^{ab}	267.5^{b}	0.04	215.9
Phosphorus:							
Produced on farm	705	411^{A}	548^{B}	1258^{C}	1498^{D}	0.31	659
Produced on farm and summer pasture	782	497^{A}	582^{A}	1390^{B}	1595^{B}	0.29	703
Rate of P produced on summer pasture, %	12.5	18.7^{C}	5.4^{A}	8.7^{B}	6.7^{AB}	0.38	8.0
Farm load, kg P/ha UAA	46	40.1^{a}	47.9^{ab}	58.8^{c}	55.3^{bc}	0.02	52.0

* The nutrients balance consider only the period of dairy cows permanence on farm and exclude the highland summer pasture.

** Net N computed assuming the volatilization of 28% of excreted nitrogen (MIPAF, 2006).

^{a,b,c,d} = values on the same row with different superscripts differ significantly (^{abcd} P<0.05, ^{ABCD} P<0.01);

rMSE= root mean square error

UAA = Usable Agricultural Area

Table 7. Methane production of dairy cows in lactation per day on farm

Variable	All farms	Traditional			Modern	R^2	rMSE
		Original *	without summer pasture	with silages			
Mills 2003:							
g/head/day	433	430^{B}	433^{B}	412^{A}	444^{C}	0.05	30
kg/t milk	22.1	23.7^{B}	22.9^{B}	19.3^{A}	17.8^{A}	0.26	4.0
kg/UAA/year	438	411^{a}	414^{a}	444^{ab}	535^{b}	0.009	438
Kirchkessner 2005:							
kg/head/day	484	492^{C}	485^{BC}	444^{A}	474^{B}	0.04	58
kg/t milk	25.0	27.4^{C}	25.8^{B}	20.8^{A}	19.0^{A}	0.24	5.9
kg/UAA/year	499	471^{a}	465^{a}	520^{ab}	607^{b}	0.009	505

^{a,b,c} = values on the same row with different superscripts differ significantly (^{abc} P<0.05, ^{ABC} P<0.01);

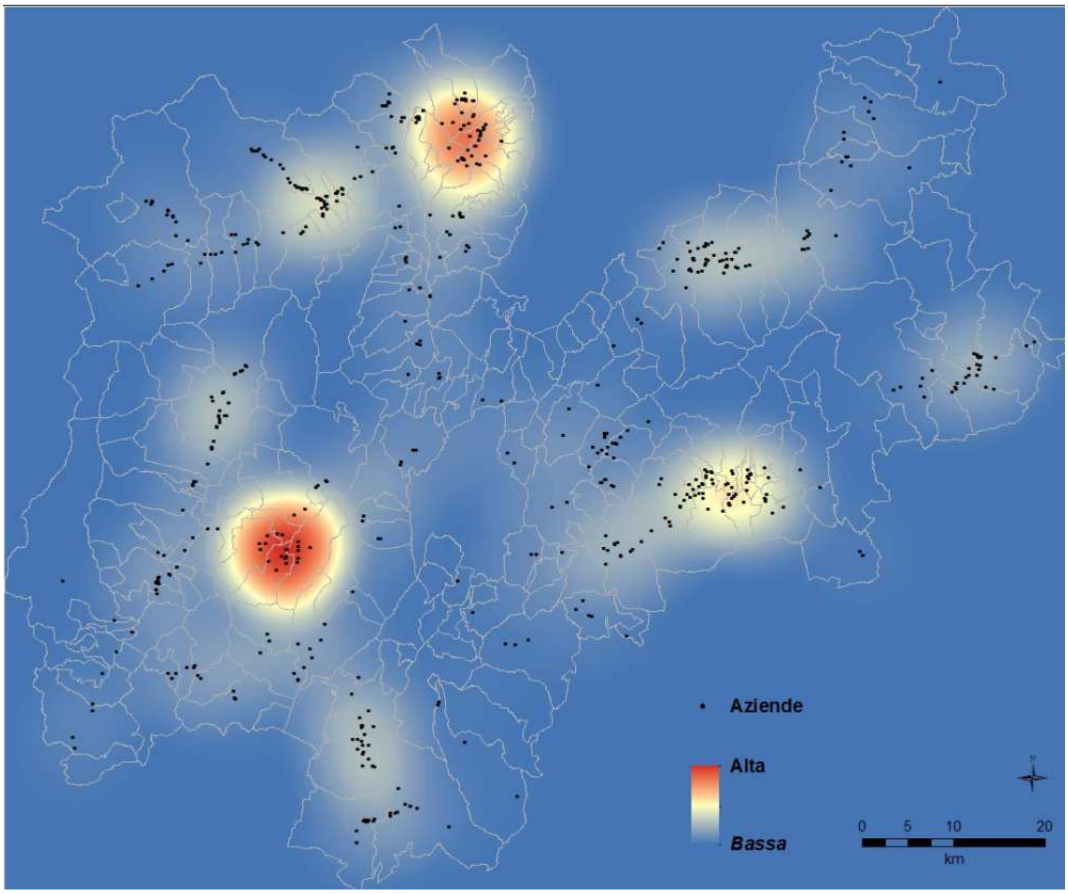
rMSE= root mean square deviation.

[1]Methane production values estimated using the equations proposed by Mills *et al.* (2003)

[2]Methane production values estimated using the equations proposed by Kirchgessner *et al.* (1995)

* Use of highland alpine pasture during the summer period for dairy cows

Figure 1. Geographic distribution of nitrogen produced by the dairy farms of Trento province



Chapter 3

WILD RED DEER (*CERVUS ELAPHUS L.*) GRAZING MAY SERIOUSLY REDUCE FORAGE PRODUCTION IN MOUNTAIN MEADOWS

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ABSTRACT

This study aimed at estimating the impact of red deer grazing on the productivity of meadows located in Pian Cansiglio, north-eastern Italian Pre-Alps. These meadows (185 ha; average elevation 1000 m asl are managed for hay/silage production (1-2 cuts per season) and are included in a protected area that hosts a high density of deer (around 30 heads/100ha). In 2008 and 2010, dry matter (DM) pro-duction and loss due to deer grazing were esti- mated with exclusion cages (1 m 2 ; 48 exclu-sion cages in 2008 and 52 in 2010). Night counts with spotlights were conducted to index deer use of meadows plots. DM production inside the cages was fairly good for the area (first-second cut: 4963-2297 kg DM/ha in 2008, and 4145-2475 kg DM/ha in 2010). DM produc-tion outside the cages was significantly lower (first-second cut in 2008: 4199-1378 kg DM/ha, and in 2010: 3376-2052 Kg DM/ha). Therefore, the magnitude of losses was of 15-20% at the first and 25-40% at the second cut. DM losses in the different meadow plots were positively correlated with index of deer use, which in some plots was as high as 7-8 heads/ha. Deer grazing reduced also crude protein (CP) content of forage (15.6±4.4% DM inside exclusion cages and 13.8±3.5% DM outside), with losses being greater where CP content was higher. This study demonstrates that high densities of grazing deer may seriously impact on forage production and quality.

Key words: Red deer, Dairy farms, Forage production, Wildlife damages, Mountain.

INTRODUCTION

In the last decades, wild red deer (*Cervus elaphus Linnaeus*, 1758) populations have greatly expanded in range and numbers in Europe and in Italy, as a result of a number of factors including land use and climate changes, protection from poaching and imple-mentation of sustainable harvest plans, and reintroduction programmes (Mattioli et al., 2001; Milner et al., 2006; Carnevali et al., 2009). Due to its body size, feed intake, and adaptability to a wide variety of habitats where it may reach high population densities, red deer is considered as a keystone species, i.e. a species that may exert serious impacts on the structure and functioning of agro-forestry ecosystems (Côté et al. 2004; Gordon et al., 2004). These impacts include changes in vegetation structure and composition that influence plant richness and biodiversity (Russell et al., 2001; Schütz et al., 2003; Goetsch et al., 2011), and may result in damages to forest regeneration and productivity (Ammer, 1996; Motta, 1996; Motta et al., 2003; Tremblay et al., 2007). In addition, they may have cascading effects on the communities of birds (Holt et al., 2011; Martin et al., 2011), invertebrates (Rambo and Faeth, 1999; Melis et al., 2005) and other mammals (Smit et al., 2001; Muñoz et al., 2008).

Although it is generally recognised that red deer impacts affect mainly forest ecosystems (Putman and Moore, 1998; Rooney and Waller, 2003), the recent expansion of the species resulted in an increased use of cultivated areas, and claims of damages to agricultural crops are rising. Red deer is an intermediate feeder (Hofmann, 1989), and as such it tends to browse selectively but has also the ability to graze grass swards (Gebert and Verheyden-Tixier, 2001). Therefore, crops damaged may include fruit orchards and woody ornamental plants (Caslick and Decker, 1979; Porter, 1983; Fargione et al., 1991), cereals and oilseed crops (Decalesta and Schwenndeman, 1978; Wilson et al., 2009), but also grasslands (Trdan and Vidrih, 2008; Wilson et al., 2009; Kamei et al., 2010). These damages are linked to the seasonal availability of crops as respect to natural sources of food and to the deer density around and inside crop plots, which in turn is influenced by human interferences as hunting and disturbance, by seasonal displacements, and by the availability of cover (Putman and Moore, 1998; Trdan and Vidrih, 2008;Wilson et al., 2009; Kamei et al., 2010).

This study aimed at assessing the impact of red deer grazing on grass production of meadows located in a protected area of the eastern Italian Pre-Alps. In this area red deer has increased greatly in the last decade, causing significant damages to forest (Caudullo et al., 2003). Recently, an impact on grasslands has also been suggested (Mearns et al., 2007), but a comprehensive assessment is lacking. Therefore, specific objectives were to estimate the extent of the reduction of grass production due to deer grazing, and to verify whether this reduction: i) varied from spring to summer; ii) was related to deer use of meadow plots and to distance from forest edge; iii) resulted in changes of chemical composition of forage.

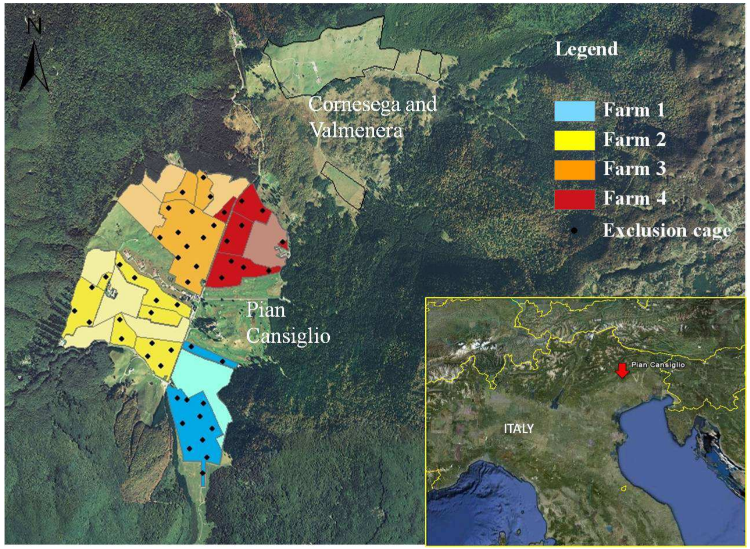
MATERIALS AND METHODS

Study area

The study was conducted in the Cansiglio forest, located in the north-eastern Italian Pre-Alps (Longitude 12°20′-12°29′E; Latitude 46°01’-46°08’N), between the provinces of Belluno, Treviso and Pordenone (Figure 1). The Cansiglio Forest covers approximately 7000 ha and is owned by the Italian Government. It has a characteristic bowlshaped morphology, where a central basin lying at an elevation of about 1000 m asl is surrounded by mountain chains (Monte Pizzoc: 1565 m; Monte Millifret: 1581 m; Monte Croseraz: 1694 m; Monte Cavallo: 2250 m). This morphology and karst phenomena are responsible of a thermal inversion. Average annual temperatures are close to 6.8°C, which is 2-3 degrees less than in other pre-Alpine areas at the same elevation (Caudullo et al., 2003). Annual precipitations are abundant and close to 2000 mm (average±SD=1946±476 mm/year, from 1993 to 2010) with highest values in May and November (ARPAV, 2011).

Vegetation in the Cansiglio Forest is mainly beech (Fagus sylvatica L.) dominated woodland, with minor areas of Norway spruce (Picea abies (L.) Karst) and silver fir (Abies alba Miller). In the central basin, three areas, i. e. Pian Cansiglio, Cornesega and Valmenera (Figure 1), are covered by meadows and pastures for a surface of approximately 383 ha. The whole forest is Site of Community Importance according to directive 92/43/EEC Habitat and Special Protection Area according to directive 79/409/EEC Birds (Natura 2000 identification site code: IT3230077).

Figure 1. Study area with the meadows surveyed for each farm. Black dots indicate location of exclusion cages, and numbers indicate the different plots.



Grassland management

The grasslands in Pian Cansiglio are managed by four dairy farms, three of which are organic. The total surface managed is 305 ha, with an average farm size of 81 ha (SD=11). Meadows are in total 185 ha, with an average size per farm of 46 ha (SD=11), and pastures are 120 ha, with an average size per farm of 30 ha (SD=3). During the study period the four farms had a total of 339 livestock units (LU), with an average herd size of 81 LU (SD=31). The average stocking rate (LU/ha) was 1.03 (SD=0.25).

Meadows are normally cut two times per season, the first between mid and late Juneand the second around mid August. However, some plots are cut only once and then grazed. Grasslands in Valmenera and Cornesega are managed by a single farm (meadows, 15 ha; pasture, 63 ha), with 34 LU and a stocking rate of 0.47. The few hectares of meadows are cut only once, after July 15, due to limitations imposed for the protection of corncrake (Crex crex) nesting. Due to these particularities, this farm was not included in the study.

According to botanical composition estimated on 79 sample sites (Wildi and Orloci, 1996), the meadows in Pian Cansiglio can be assigned to the two groups of high productive meadows. The most represented group cannot be classified as natural according to phytosociological criteria, because it includes mainly few species, as Poa trivialis, Phleum pratense, Festuca pratensis, and Dactylis glomerata, which have a high forage value and result from past actions of re-seeding and high inputs of fertilizers. The second group is less influenced by management practices and can be classified as a transition between Centaureo transalpinae – Trisetum flavescentis (Marshall 1974 corr. Poldini and Oriolo 1994) and Centaureo carniolicae – Arrhenatheretum elatioris (Oberdorfer 1964 corr. Poldini and Oriolo 1994). Small, localised areas are affected by Deschampsia caespitosa.

Red deer population

As a State property since 1871, the Cansiglio Forest is a protected area and hunting is forbidden. Red deer in Cansiglio and in all the surrounding areas became extinct in the mid 1800s. The species reappeared in the forest in the late 1980s, when a few individuals escaped from a fenced area (Mattioli et al., 2001). The population, at that time demographically isolated, increased slowly and in 1997 the estimated number of red deer was of about 200 heads (Stiz, 1997). Since then, also as a result of immigration from the expanding populations of the surrounding areas, the population growth was impressive. In the red deer management unit comprising the forest plus a buffer area for a total of approximately 85 km^2, the population size between 2008 and 2009 has been estimated at around 2800-3000 heads, with a population density higher than

30 heads/km 2 (Bottazzo and Nicoloso, 2010). This density is very high, as compared to that of the species in other Alpine areas (Carnevali et al., 2009), and is favoured by both the protection status and the good habitat suitability of the Cansiglio forest. The seasonal displacements of the population are not known in details. However, population density decreases in winter due to partial migration towards wintering areas at lower elevations, while it increases again in spring and summer, to peak probably during the rutting season between September and October (Bottazzo and Nicoloso, 2010). In the forest there are no large predators, and other wild ungulate species include roe deer (Capreolus capreolus, L. 1758) and fallow deer (Cervus dama, L. 1758). In contrast with red deer, for these species there are no recent standardized counts, but population densities are considered much lower than those of red deer.

Data collection

The study was conducted in the summers of 2008 and 2010 on the meadows of the four farms located in Pian Cansiglio (Figure 1). Pastures were excluded, because of mixed grazing by livestock and deer. Grass production and consumption by deer were estimated using exclusion cages, made of wire mesh, with a size of 1.0x1.0x1.2 (height) m. The cages (48 in 2008 and 52 in 2010) were distributed in order to cover all the meadow plots of each farm, and to sample different distances from the forest edge, as shown in Figure 1. Their location was geo-referenced with a portable GPS to allow re-positioning after each cut and in different years, and implemented into ArcGiS 10 (ESRI 2010) to calculate their distance (m) from the forest edge, using an ortophotograph (year 2006; 1:10.000) of the area. The cages were placed in April, before the resumption of vegetative growth. Immediately before the first cut, the grass grown inside the cages was manually harvested by cutting at an approximate height of 5 cm from the ground. The same procedure was followed for a sample area of 1x1 m chosen randomly at a distance of 1-2 m from the cages. The cages where then removed to allow mowing, and re-positioned with the aid of the GPS immediately after harvest. The sampling procedure was repeated before the second cut.

Samples collected inside and outside each cage were oven dried at 65°C until constant weight, ground, and analysed for residual dry matter (DM) content (AOAC, 1990) in order to estimate the DM produced and that removed by deer. In addition, the contents of crude protein (CP), ash (AOAC, 1990), and neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) (Van Soest et al., 1991) were determined in 130 samples in 2008 (34 cages x 2 positions (inside and outside) at the first cut and 31 cages x 2 positions at the second) and in 138 samples in 2010 (41 cages x

2 positions (inside and outside) at the first cut and 28 cages x 2 positions at the second).

The DM production inside the cages was used as an estimate of meadows productivity, while that outside the cages gave an estimate of the residual production left after deer grazing. The DM loss was calculated as the difference between them. DM productions and losses were expressed as kg/ha. The loss of CP was calculated as the difference between the CP content (% DM) of the samples collected inside and those collected outside the cages.

Index of deer use of meadow plots

During the summer 2008, night counts of deer with spot-lights were conducted from vehicles driving three transects that covered the meadow plots surveyed. The three transects were covered simultaneously by three teams over 1-2 h, starting at least 3 h after sunset. Counts were replicated on 29 May, 19 June, and 24 July. The aim of these counts was to obtain an index of the use of the different meadow plots by red deer, roe deer and fallow deer. To this purpose, the number of deer in each group observed for each species was recorded, and its location was plotted on a map (1:10.000). Based on this location, the deer counted were then assigned to each plot using ArcGIS 10 (ESRI 2010). The index of deer use was expressed for each plot as number of deer/ha. Given the very low numbers of roe deer and fallow deer counted (see results), the index was calculated only for red deer.

Statistical analysis

Forage productions (DM, kg/ha) and chemical composition (% DM) were analysed with the PROC MIXED procedure of SAS (2006), using a mixed linear model with the fixed effects of farm (4 levels), cut (2 levels), year (2 levels), sampling position (2 levels: inside vs outside of the cage) and the interaction between cut, year and sampling position. Cage nested within farm was used as random effect.

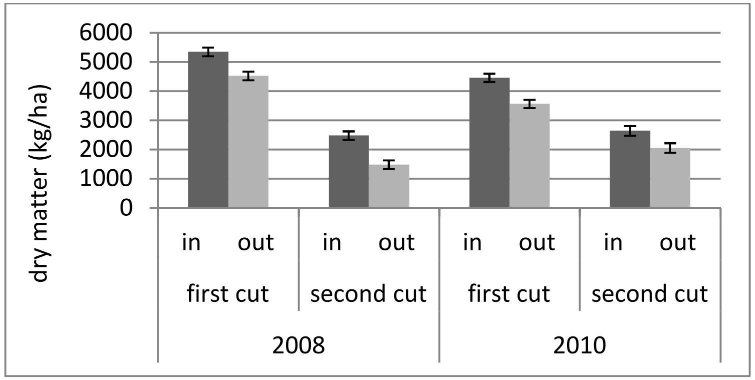
The effect of distance from forest edge on DM losses was tested with a mixed linear model where year was used as fixed effect, distance (m) of the cage from the forest edge as a covariate, and cage as a random effect.

Finally, simple Pearson correlation analyses were used to test whether in the different meadow plots there was any relation between the index of deer use (average of all counts) and the DM losses (sum of losses at the first and second cut), and whether the CP content of grass inside the different cages was related to the CP losses.

RESULTS

The analysis of variance of DM production showed highly significant effects for year (F=7.04; df=1; P<0.01), cut (F=532.60; df=1; P<0.001), sampling position (F=69.85; df=1; P<0.001), farm (F=20.65; df=3; P<0.001), and the interaction between cut, year and sampling position (F=10.99; df=4; P<0.001). The LS means for this interaction are given in Figure 2. The DM production inside the cages at the first and second cut was 4963±139 kg/ha and 2297±136 kg/ha in 2008, and 4145±133 kg/ha and 2475±153 kg/ha in 2010. The residual DM production outside the cages was remarkably lower in both cuts, with 4199±139 kg/ha at the first and 1378±136 kg/ha at the second in 2008, and 3320±133 kg/ha and 1913±153 kg/ha in 2010.

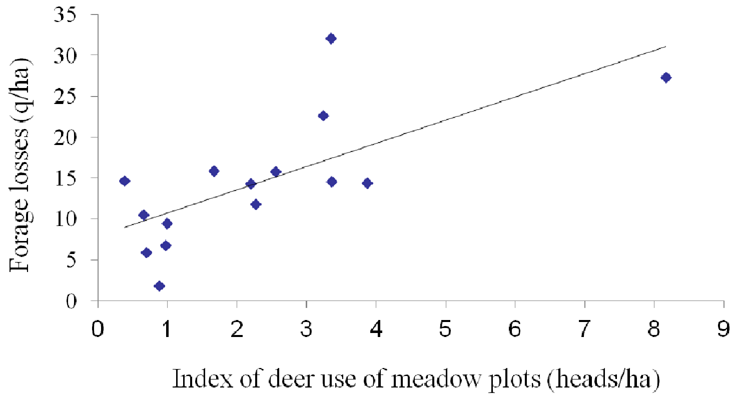
Figure 2. LS means of dry matter production per year, cut and cage side (in = inside; out = outside). Bars indicate SE

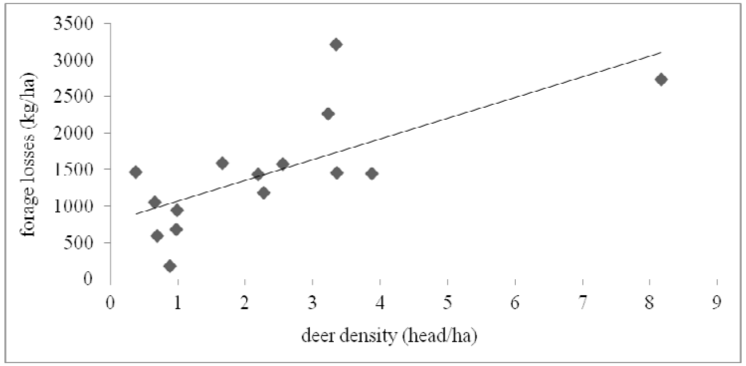


The distance from forest edge significantly affected the DM losses in 2008 (b=-1.69; t=-2.28; SE=0.74; df=42; $P<0.05$), but not in 2010 (b=-0.48; t=-0.65; SE=0.48; df=42; P=0.52). For each m of increasing distance from forest, DM losses decreased of approximately 1.7 kg DM/ha in 2008, while did not change in 2010.

The maximum number of red deer observed during the night counts was 686 heads, while the maximum numbers of roe deer and fallow deer were 3 and 20 heads respectively. The index of meadows use by red deer varied widely between plots, without a clear temporal trend (average 2.1±2.0 heads/ha). There was a significant correlation with total DM losses (n of meadow plots=15; r=0.70; $P<0.01$ Figure 3).

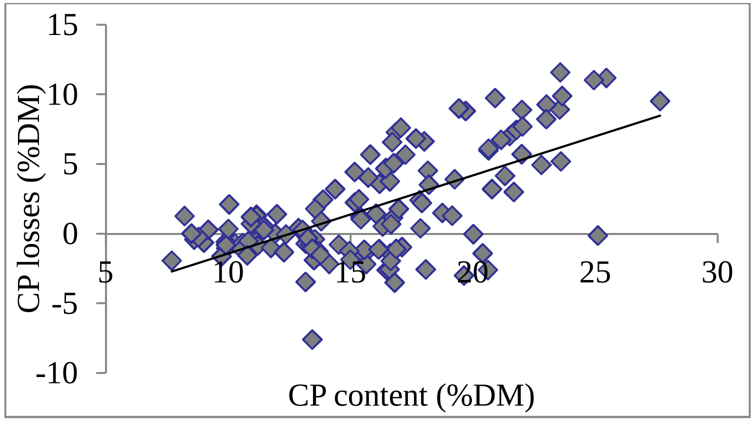
Figure 3. Correlation between index of deer use and total forage dry matter losses in meadow plots.





The chemical composition of forage is given in Table 1. On average, forage quality was good, with CP and NDF contents of 13-15% DM and 56-60% DM at the first cut and 18-19% DM and 51% DM at the second. The statistical analysis showed significant differences for chemical composition. Crude Protein content was affected by cut (F=153; df=1; P<0.001), farm (F=24.76; df=1; P<0.001), sampling position ((F=24.76; df=1; P<0.001), and the three-way interaction between year, cut and sampling position (F=3.25; df=4; P<0.05). In all cuts and year, CP content of forage was 1-3% lower outside than inside the cages. However, CP losses depended on the initial quality of the forage, as indicated by a strong positive correlation between the CP content of the samples inside of the cages and the corresponding CP losses (n=128; r=0.66; P<0.001; Figure 4).

Figure 4. Correlation between crude protein (CP) content (% DM) and losses (in-out, % DM).



Also for ADL, ADF, and Ash contents the three-way interaction was statistically significant, but post-hoc tests showed no significant differences between sampling position. This interaction was not significant for NDF (F=2.02; df=4; P=0.092).

DISCUSSION

Grass production differed slightly between the two years, most probably as a result of climatic variability, and was in line with what expected from these groups of high productive mountain meadows (Ziliotto et al., 2004; Scotton et al., 2005). Also the difference between the first and the second cut was predictable (Gruber et al., 1999; Spanghero et al., 2003). A significant source of difference was the farm. This effect was expected and was included in the model because sward improvements and fertilizers inputs vary between the four farms studied.

The production losses observed in this study were remarkable and fairly constant throughout the study period, varying within a narrow range of around 800-1000 kg DM/ha in both cuts and years. These amounts account for approximately 15-20% of the forage productivity at the first cut, and for 25-40% of that at the second cut. The negligible occurrence of other deer species observed during the night counts, and the positive correlation between the index of deer use and the production lost in the different plots, confirmed that these losses are a direct consequence of red deer grazing. In general, the losses observed confirm preliminary indications obtained in the same area by Mearns et al. (2007), while are higher than those reported by Trdan and Vidrih (2008) and Wilson et al. (2009). There may be many reasons why losses in this study were so remarkable and did not vary between cuts and years. Red deer density in Cansiglio is high because the species, which is very sensitive to hunting disturbance (Pedrotti et al., 2007; Kamei et al., 2010), is attracted by protected areas (Pedrotti et al., 2007). In addition, the absence of risks to be shot while in open areas encouraged deer to use grasslands, as is also suggested by the fact that the distance from forest edge had a limited effect on forage losses. In fact, losses decreased with increasing distance in 2008 but not in 2010, most likely as a result of a progressive habituation by deer to using open areas. This might be an important implication, because other studies, which were conducted in proximity of forest edges, suggested that forage consumption by deer was higher in plots closer to cover (Trdan and Vidrih, 2008; Wilson et al., 2009; Kamei et al., 2010). Another reason for the high losses is the continuous presence of deer throughout summer. In general, in mountain areas red deer use meadows in early spring, at the beginning of grass re-growth, but then, with the advancing of summer, migrate to higher elevations where forage quality is better (Pettorelli et al., 2005; Luccarini et al., 2006; Bocci et al., 2010). However, in Cansiglio the density of deer is constant, or even growing, from late spring to autumn, probably because the second cut of the meadows maintains an offer of good quality forage provided by the grass re-growth (Mearns et al., 2007).

This study demonstrates also that red deer grazing, in addition to reducing the production of forage, might have a negative impact on its quality. The chemical composition of grass, especially for CP content, was slightly better than that observed in previous studies in the same area (Andrighetto and Ramanzin, 1987; Xiccato et al., 1998), but was significantly affected by deer grazing. In fact, there were no differences in CP content between the samples collected inside and outside the cages when CP content inside was around 12-13% DM, but the reduction in CP content outside reached an average of around 5% DM when CP content inside was around 20-25% (Figure 4). This effect most probably reflects a selective feeding of deer on plant species and/or morphological parts that are richer in CP content. To this regard, an increase in the proportion of grasses as respect to that of legumes in the samples collected outside the cages might explain why in these samples CP decreased while NDF did not change, since grasses are poorer in CP than legumes, while are richer in NDF. In this study the botanical and morphological compositions of the samples collected inside and outside the cages were not compared. However, based on the feeding behaviour of other deer species grazing pastures of different quality (Bryant et al., 1981; Weckerly, 1994), it is plausible to hypothesize that red deer in Cansiglio were able to feed more selectively when sward was younger and richer in leaves.

The results obtained in this study have also important management implications. In the most severely damaged plots, the farmers might decide to shift to pasture after the first instead than the second cut, because its labour and mechanisation costs would not be compensated by the low residual production. In addition, the loss in protein content increases the costs of forage supplementation, and might again discourage the farmers from investing in management practices designed to improve forage quality. The losses in quantity and quality of the forage produced on farm are especially negative for the organic farmers, who might be unable to fulfil the share of the forage budget that must be produced on farm as required by organic regulations (EU Regulation N. 834/2007), and, in any case, have to face higher costs when purchasing forage and supplements from the market.

CONCLUSIONS

This study confirms that high densities of red deer seriously impact on forage production by mountain meadows. In addition, demonstrates that this heavy grazing might negatively influence the crude protein content of the residual forage, most likely as a result of selective feeding by deer. These damages increase substantially production costs for the local dairy farms, and might require adjustments in management practices of meadows and in feeding strategies. The magnitude of the effects observed in this study is likely the result of a series of combined circumstances: the study area is protected and therefore attracts high densities of the species, the intensive management to which meadows are subjected maintains an offer of good quality forage throughout summer, and the forest surrounding grasslands provides cover when needed. Therefore, the findings of this study cannot be generalised to other areas where deer density is lower and human disturbance is stronger. However, red deer is rapidly expanding in many European Countries, and this, in combination with the abandoning of agriculture and the depopulation of mountain regions, will increase the presence of the species into rural areas. Hence, the occurrence of conflicts with agriculture will also increase. Finally, the study concentrated on the damages to meadows, but it is also important to stress that this problem must be addressed with an ecosystem and holistic approach. The co-existence of deer and cattle in the same meadows might cause cross-transmission of etiological agents and have sanitary implications (Gortazár et al., 2007). To avoid any actual and potential conflict, meadows could be fenced to exclude deer. However, this practice could be too expensive for large areas, and could not be acceptable in a Nature 2000 site because of potential impacts on other species. In addition, it would concentrate all feeding by deer in the forest, where the impacts on biodiversity are already high. Red deer culling might reduce population density, and provide an additional source of income to the local communities, but it would also reduce the touristic appeal of the area, which is now often visited especially for deer-watching, and would be strongly contrasted by part of the public opinion. In conclusion, this paper is also an example of how, in marginal areas, farming will increasingly need to be integrated into a multi-purpose ecosystem management.

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Table 1. LS means (SE) of chemical composition (% DM) per year, cut and sampling position.

	2008				2010			
	first cut		second cut		first cut		second cut	
	inside	outside	inside	outside	inside	outside	inside	outside
CP	13.0[a] (0.52)	11.8[b] (0.52)	18.6[a] (0.52)	17.4[b] (0.52)	15.2[a] (0.48)	12.1[b] (0.48)	18.1[a] (0.55)	16.2[b] (0.55)
NDF	60.2 (0.91)	60.1 (0.91)	51.2 (0.91)	50.9 (0.91)	56.4 (0.84)	55.8 (0.84)	50.8 (0.96)	50.3 (0.96)
ADF	34.4 (0.50)	33.9 (0.50)	28.9 (0.50)	28.4 (0.50)	30.5 (0.46)	29.8 (0.46)	28.1 (0.53)	27.6 (0.53)
ADL	3.0 (0.17)	2.7 (0.17)	3.9 (0.17)	3.8 (0.17)	3.7 (0.15)	3.5 (0.15)	3.8 (0.18)	3.7 (0.18)
ASH	6.5 (0.24)	6.3 (0.24)	9.5 (0.24)	9.5 (0.24)	6.3 (0.23)	6.2 (0.23)	7.7 (0.25)	8.1 (0.25)

CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignine; a,b different letters indicate that, within each year and cut, values differ significantly at P<0.05 between inside and outside.

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Appendix I

TRENTINGRANA CHEESE PRODUCTION: ANALYSIS OF DAIRY SYSTEMS

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, **ABSTRACT**

This research aimed to study the relationships between livestock systems and typical products in the Trento Autonomous Province, a mountainous area of the Eastern Italian Alps. A total of 1111 dairy farms were censed in the province; a sample of 678 was surveyed collecting information on herd composition in terms of animal breeding and category, management system and quality of milk. Data were analyzed with a non-hierarchical cluster procedure that clustered farms into 6 types: modern farms with traditional feeding (86 farms); small farms with corn silage (51farms); modern farms with unifeed and corn silage (63 farms); traditional small farms without summer pasture (146 farms); intensive farms (34 farms); traditional small farms (298 farms). The traditional system are able to maintain a greater animal biodiversity than the intensive ones, thanks to the farming of indigenous breeds. This group of farms is largely involved in the Trentingrana cheese production, a traditional long ripened cheese (DOP) of the area, whereas the intensive systems produce milk for large distribution. This study demonstrates that in the province there is a wide variability of livestock farming systems. Traditional systems which have an important role for maintenance of landscape and farmed biodiversity are strongly connected with the typical cheese production, and this association could help in maintaining their economic viability.

Keywords: Farming system, cluster analysis, mountain areas, dairy cattle, Trentingrana cheese

INTRODUCTION

In mountainous areas, physical disadvantage and extreme distances reduce competitiveness of livestock systems, and give rise to serious limits to the technical and structural adjustment. In addition, people of mountain are less adaptable because of entrenched traditions (Walther, 1986; Campagne et al., 1990; Bazin, 1995). In the alpine regions of southern Europe traditional farming systems, with low production and incomes, have therefore experienced a dramatic decline (MacDonald et al., 2000). The case of the province of Trento, in the north-eastern Italian Alps, is an example of this trend. Livestock farming was in the past a fundamental source of income for the population, which had permeated social and cultural traditions and had shaped a typical cultural landscape (MacDonald et al., 2000; Sturaro et al., 2005).

However, during the last 40 years the number of farms and livestock has dropped dramatically (Walther, 1986; MacDonald et al., 2000). In the attempt of maintaining economic viability, the remaining farms have pursued an intensification process, with an increase in the average number of animals farmed/unit and a substitution of indigenous breeds with more productive breeds, such as Holstein Frisian cows (Battaglini et al., 2003). Pasture and meadows which were abandoned with the closure of traditional farms were not reutilized by the new intensive farms, with the result of an extensive spontaneous reforestation and a loss of landscape attractiveness (Gusmeroli and Della Marianna, 2005; Cocca et al., 2007).

In fact, maintenance of traditional farming systems based on grasslands, such as permanent meadows and alpine summer pastures, is seen today as an essential strategy for safeguarding mountain landscape and biodiversity (Mac Donald et al., 2000; Battaglini et al., 2003; Sturaro et al., 2005; Cocca et al., 2007). In addition to local policies for agricultural subsidies supporting extensive farming, also the economic valorization of typical dairy products may help to sustain traditional farming systems. In the Trento province there are several types of cheeses, and Trentingrana represents the most important of them. This product is part of the Grana Padano family (Aprea et al., 2007), but the trademark is different, and it is a DOP product (a recognised quality trademark). Even if the production of Trentingrana is relatively small (about 4000 ton/year; consortia personal communication) when compared with that of the direct competitors (about 125,000 ton/year for Grana Padano; and about 113,000 ton/year for Parmigiano; http://www.granapadano.com, www.crpa.it), it is relevant for the local economy. Trentingrana is produced with partly skimmed, raw cows’ milk acidified with a mixture of Lactobacillus and coagulated by the addition of bovine liquid rennet but, having a more restrictive production protocol, the use of lysozyme is not allowed. The ripening process is divided in two phases: the first lasts nine months and takes place in the dairies, the total period lasts 15 to 20 months and the second phase is done in a Trentingrana storehouse. At the end of both periods the product is thoroughly checked. The rounds whole cheese not fit for sale are discarded.

This paper is part of a larger research project, aimed to monitor the production chain of Grana Trentino. The specific aim of this paper is to examine the management of dairy farms in the province of Trento conferring the milk for Trentingrana cheese production.

MATERIALS AND METHODS

The survey was carried out in Trento that is an autonomous province of northern Italy (figure 1). This province consists of 223 municipalities, all classified as mountainous for the national statistical database (ISTAT 2007), covering an area of 6200 km2 with a minimum altitude of 66 m asl and maximum of 3769 m asl. Vegetation is predominantly characterized by woodland (66%), followed by meadows and pastures (26%). Permanent and arable crops represent respectively 5% and 1% (ISTAT 2002 and 2007). Farms with livestock account for 14% of the total holdings of the province, but with a heterogeneous distribution across the territory (figure 1). In the areas interested by Trentingrana cheese production, livestock farming accounts for 40-50% of farms.

To study the characteristics of dairy systems in Trento, different databases were merged to obtain the final database. A first database, provided by the Provincial Agency for payments (APPAG), contained data on type of farm, with 1111 dairy cow herds out of a total of 2153 farms, and herd composition with information on livestock category and breeds (Brown Swiss, Holstein Friesian, Simmental, Rendena, Alpine Grey or crossbreeds). These data were merged with those of the cattle population register with a number of 1534 farms (both dairy and beef) provided by the veterinarian service of the Province (APSS), which included the farms location (georeferenced on a GIS). Then, main structural characteristics and feeding techniques of farms (see below for details) were collected by personnel of the Federazione Provinciale Allevatori Trento (FPAT) on 719 farms, and included in the database. Finally, the database was completed with the milk recording data (886 holdings; of which 724 with more than 100 controls) produced by the Federation itself using the test-day model. From the final data editing 678 farms with complete information were retained for statistical analysis. Qualitative aspects considered for the milk given to dairies are: fat, protein (and casein), lactose percentage and somatic cells score. These characters refer to bulk milk and are measured with the controls from the CONCAST-Trentingrana. In figure 1 the distribution of sampled farms on the territory are reported.

Farms were grouped by structural and management characteristics by adapting the “Non Hierarchical K-means clustering” (PROC FASTCLUS, SAS 2006). Observations were allocated to the groups based on the smallest Euclidean distance from the initial seeds of the cluster. Cluster centroids were updated as each observation was assigned (Ottavianti et al., 2003; Usai et al., 2006). The method maximizing homogeneity inside a group and diversity within the groups offered different protocols to decide how many groups would have parted from the initial distribution. The variables included in the analysis are: housing (tie vs free stalls), feeding system (Unifeed vs traditional), use of Summer Pasture (yes/no), Corn Silage (yes/no) and Livestock Unit (LU)/Farm. The profiles of each cluster were used to investigate the differences between clusters. Proportion of each breed in the herd, average milk production and milk quality were compared among groups by using a one-way ANOVA (SAS, 2006). To verify whether there was association between farming systems and Trentingrana cheese production, the distribution across identified systems of farms conferring to Trentingana was compared to that of the total farms sample.

RESULTS AND DISCUSSION

Six different farming styles were identified from the non hierarchical cluster analysis of the 678 sampled farms (table 1). The number of clusters was chosen on the base of cubic clustering criteria (F = 431.57, R2 = 0.67 and cubic clustering criteria = 30.55, data not in table). The identified clusters were characterized by very specific features. The first is characterized by modern farms (n=86) with large herds (80 LU/Farm), mainly free housing and traditional feeding technique with no use of corn silage and a frequent use of summer pastures. The second group identifies 51 farms with an average herd size (42 LU/Farm), traditional tie stall housing (96%), use of both traditional and unifeed (41%) feeding technique but in all cases of corn silage (100%), and a low frequency of use of summer pastures (14%). The third cluster grouped 63 farms with a large herd size (99 LU/unit), modern housing (tie stall only 13%) and feeding technique (unifeed 100%), almost no use of summer pasture (10%), and an average frequency (49%) of corn silage use. The fourth group (146 holdings) is characterized by a small herd size (32 LU/farm), traditional housing (90% tie stalling) and feeding practice with no unifeed (3%) and corn silage (0%); summer pastures are also absent (0%). The fifth cluster groups 34 intensive farms similar to those of the most productive lowlands of Italy, with a very large herd size (241 LU/farm), modern housing (100% free) and feeding (91% unifeed) and frequent use for corn silage (65%). The sixth cluster is very similar to the fourth one, differing only for the use of summer pastures (100%).

Clusters are defined as: 1: Modern farms with traditional feeding; 2: Small farms with corn silage; 3: Modern farms with unifeed and corn silage; 4: Traditional small farms without summer pasture; 5: Intensive farms; 6: Traditional small farms.

The differences between the clusters for proportion of different breeds, productivity and milk quality were significant for all variables (table 2). In the Trento province is quite common to have two or more breeds in the same farm, with Brown Swiss and Holstein Friesian accounting for a main proportion in all clusters (the two breeds together accounted for 54 to 93% of LU's according to the cluster), with Holstein Friesian predominating over Brown Swiss in the more intensive systems. Simmental, Rendena and Alpine Grey were almost absent in these systems (clusters 3 and 5: 2 and 11%), while they were present with appreciable proportions in the other, traditional systems (from less than 20% in clusters 1 and 2 to 40% in cluster 6).

Milk production ranges from a minimum of 18 kg/d in traditional farms to a maximum of 26 kg/d in intensive ones (Table 2). Fat and casein content and somatic cell score varied slightly between types of farm, with a general high quality, most probably due to the guidelines for Trentingrana cheese production.

The above results confirm a general dichotomy between traditional farming systems, with small units based on use of grassland, and intensive systems with large farms based on modern feeding techniques and corn silage. Other studies conducted in the province at a farm scale (Marini et al., 2009), in Austria (Schmitzberger et al., 2005) and in the province of Belluno, bordering that of Trento (Giupponi et al.,2006) at a landscape scale, indicate that in mountain areas highly-producing farms support the lowest biodiversity and landscape richness. In addition, it is clear that biodiversity of farmed breeds is also much greater in traditional systems.

Figure 2 shows that the distribution in the six clusters of the 414 farms delivering milk to Trentingrana differed significantly from that of the total sample of 678 sampled farms ($\chi 2$ = 48.43; df = 5; P< 0.001) As respect to what expected from the total sample of 678 farms, traditional farming systems based on grasslands were more frequent and modern, intensive systems with less use of grasslands and more use of corn silage (which is forbidden in the Trentingrana guidelines) were less frequent. This means that the role of small traditional farms is not fundamental for conservation of the landscape and biodiversity, but also for supporting typical products such as Trentingrana.

CONCLUSIONS

The dairy sector of the Trento province is diversified into 6 different farming systems which differ in terms of structures, feeding techniques, farmed breeds and production level. Only milk quality is homogenous, and good, amongst systems. Traditional farms clusters, with feeding techniques based on grazing and on-farm produced forage, maintain local breeds with low productivity and are largely involved in the Trentingrana cheese production. On the opposite, modern and intensive farms which rely mostly on corn silage and maintain highly productive breeds are excluded from the production of this cheese. The association between extensive dairy farming and typical cheese production might increase the economic viability of traditional systems, and as a consequence help in maintaining a sustainable livestock sector in mountain areas. A prospective of this research will be the analysis of the relationship between dairy farms, environmental impact and landscape maintenance in Trento province.

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Table 1: profiles of groups identified by the non hierarchical cluster analysis

Cluster	N	Average LU/Farm (SD)	Tie Stalling %	Unifeed %	Summer Pasture %	Corn Silage %
1[1]	86	79.8 (29.5)	22	10	70	1
2[2]	51	42.1 (25.9)	96	41	14	100
3[3]	63	99.4 (31.2)	13	100	10	49
4[4]	146	31.9 (20.5)	90	3	0	0
5[5]	34	241.1 (81.7)	0	91	21	65
6[6]	298	21.6 (16.9)	98	0	100	0

Table 2: analysis of differences between farming systems in terms of reared breeds, milk production and quality

	1 (SD)	2(SD)	3 (SD)	4 (SD)	5 (SD)	6 (SD)	F	P
Brown Swiss%	54 (35)	36 (32)	35 (29)	47 (34)	24 (31)	46 (40)	5.17	< 0.001
Holstein **Frisian%**	20 (26)	42 (35)	58 (31)	20 (26)	61 (38)	7 (19)	67.64	< 0.001
Simmental %	11 (21)	7 (13)	2 (6)	15 (25)	5 (15)	15 (25)	4.83	< 0.001
Rendena %	8 (26)	7 (21)	-	3 (15)	6 (23)	12 (29)	4.47	< 0.001
Alpine Grey %	-	3 (13)	-	7 (23)	-	13 (29)	7.54	< 0.001
Milk	23.3 (3.6)	18.9 (4.2)	25.8 (4.3)	19.3 (4.4)	27.7 (4.1)	17.7 (3.9)	81.84	< 0.001
Fat	3.92 (0.24)	4.00 (0.23)	4.00 (0.24)	3.95 (0.24)	4.00 (0.32)	3.90 (0.23)	3.57	< 0.01
Casein	2.75 (0.14)	2.68 (0.14)	2.75 (0.13)	2.73 (0.14)	2.76 (0.12)	2.67 (0.14)	8.71	< 0.001
Somatic Cell Score	3.22 (0.63)	3.62 (0.76)	3.24 (0.63)	3.12 (0.86)	3.26 (0.59)	3.21 (0.92)	2.82	< 0.05

Figure 1: The Autonomous Province of Trento (on left) and location of farms in the territory: red points indicate dairy farms conferring to Trentingrana, blue points other dairies.

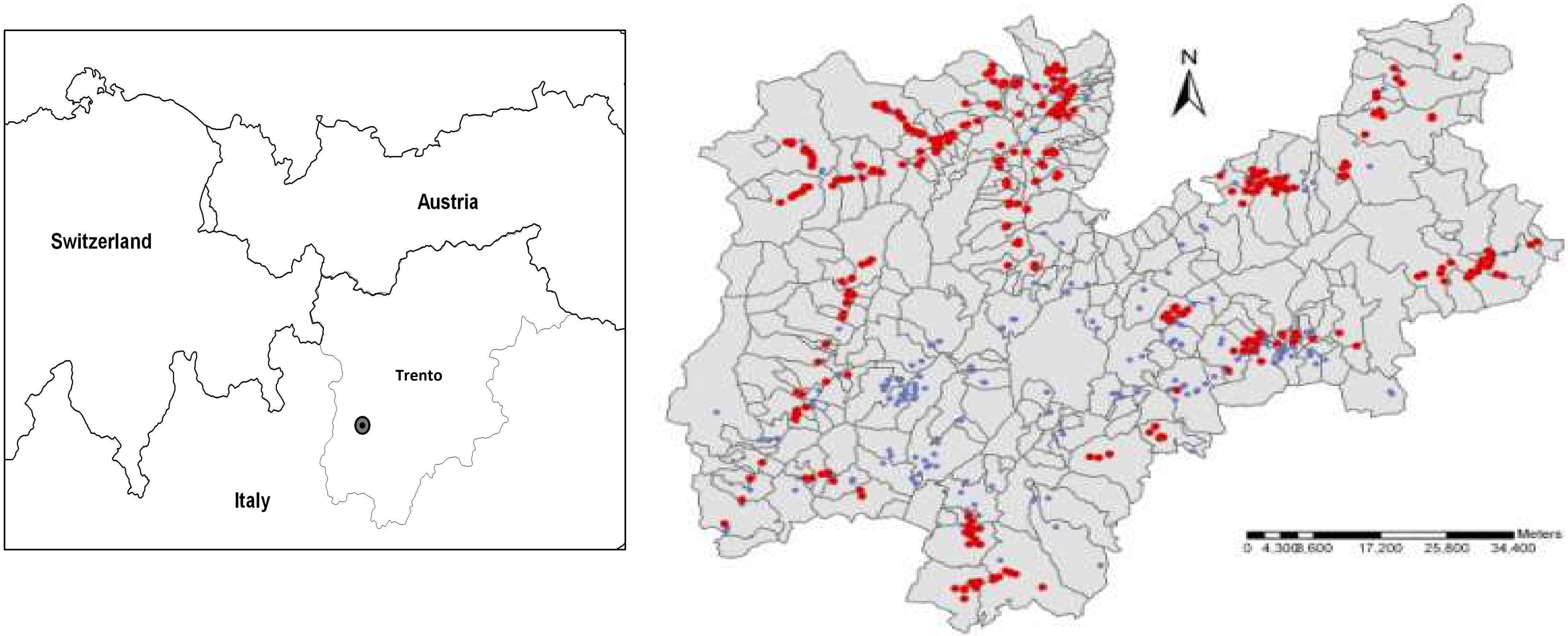
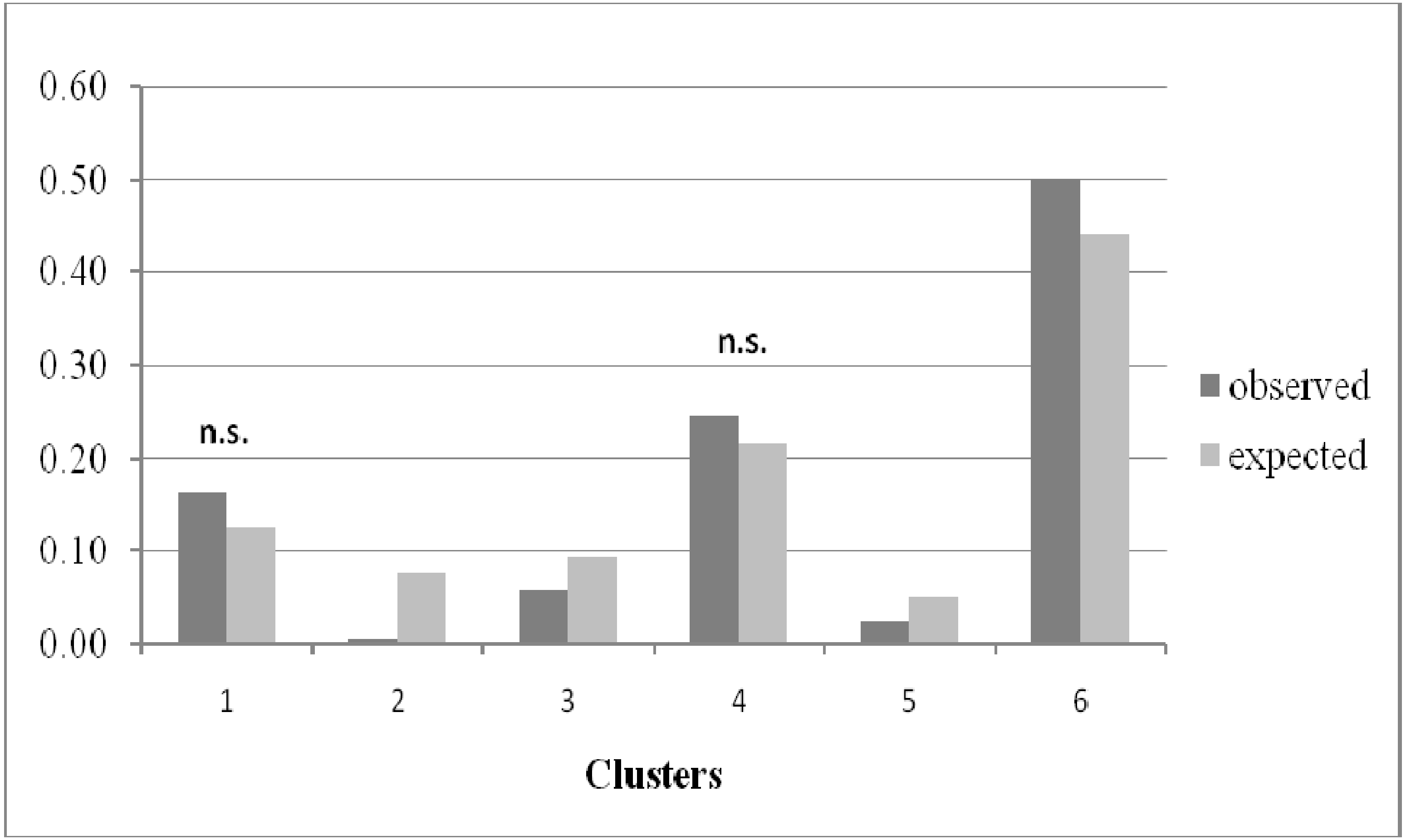


Figure 2: Distribution in the 6 farming systems of farms delivering to Trentingrana (observed) as respect to that expected from the distribution of the total farms (expected)



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