15 Stresses in Pasture Areas in South-Central Apennines, Italy, and Evolution at Landscape Level

A. Fatica, L. Circelli, E. Di Iorio, C. Colombo, T. W. Crawford, Jr. and E. Salimei

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15.1 SOUTH-CENTRAL APENNINES OF ITALY: MOLISE REGION AND ITS PASTURES

The Molise region is located in the central Apennines of southern Italy, occupies an area of 443,758 ha, and has a range of elevations from sea level at the Adriatic Sea to 2,050 m a.s.l. The Molise region's borders are with Abruzzo region to the north, Lazio region to the west, Campania region to the southwest, Puglia region to the southeast, and the Adriatic Sea to the east (Figure 15.1a).

The population of the region is about 310,499 inhabitants, divided into 136 municipalities, with a density of about 70 inhabitants/km^2. The main regional town, Campobasso City, has 49,168 inhabitants and is located at the center of the region at about 700 m a.s.l. Another province of Molise is represented by Isernia, a town with 21,685 inhabitants that is located at 423 m a.s.l.

The territory in the Molise region is predominantly mountainous, and forest, pasture, and natural meadows represent the most important land use of this territory, which needs to be protected from erosion and other hydrogeological phenomena such as flooding and landslides. In addition, the most important river of the Molise region is the Biferno, which has a torrential regime that is closely related to the intensity and duration of precipitation.

The presence of natural pastures in Molise has undergone a significant decrease over the past 27 years, from around 50,000 ha in 1990 (De Renzis et al. 1992a) to 36,627 ha in 2005 (INEA 2008) and to 37,690 ha in 2007 (ISTAT 2010). Considering the geographic and morphological characteristics

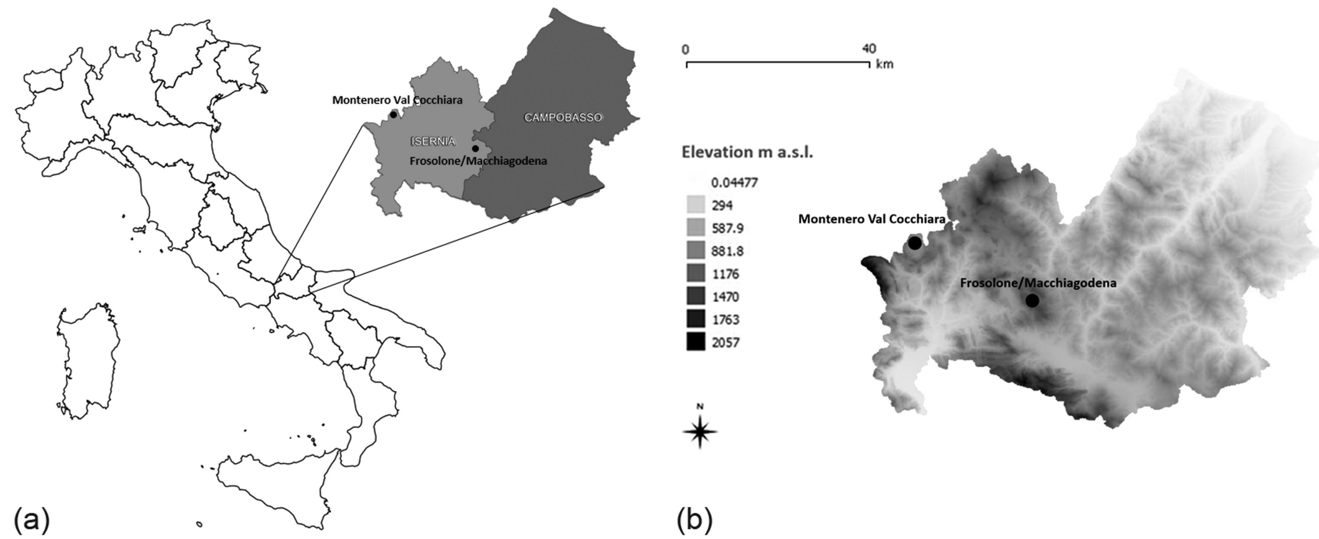

FIGURE 15.1 (a) Map of Molise region in Italy with the position of the two sample areas; (b) digital elevation model of Molise region.

of the Molise region, the need to manage the most fragile mountain areas exposed to erosive phenomena is evident.

This chapter focuses on one of the most important ecosystems of the region: natural pastures, which have always been used as a source of feed for animal husbandry, given Molise's long history of livestock production. However, the best practices to manage grazing can only be applied to livestock production if all the abiotic and biotic factors that stress production of forage are known in detail. These stresses are principally climatic (temperature and rainfall), edaphic, and biotic (competing vegetation in the pasture and stresses due to the presence of the animals).

To describe the best practices of sustainable management of the pastures of the central and southern Apennines, we first present a detailed description of the principal abiotic and biotic stress factors, and then, we report a case study carried out in two municipalities of the Molise region. The study areas are located in Isernia province near the municipalities of Montenero Val Cocchiara (41°43′N, 14°04′E) and Frosolone (41°36′N, 14°27′E), including the municipality of Macchiagodena (Figure 15.1a).

15.1.1 Geography

The Molise territory is nearly all mountainous (55% of the surface area) or hilly, with limited flat ground in the lower valleys and along the Adriatic coast (Figure 15.1b). The Apennines divide Molise into isolated mountains and a chaotic array of hills, which stretch to within a few kilometers of the coast, making communications difficult and creating a state of isolation. The highest mountains are located in part of the "Samnite Apennines" (the northern and eastern parts of the Campano Apennines, separate from the Abruzzese Apennines). The Samnite Apennines include the southern extreme of the Meta Mountains, culminating at 2185 m a.s.l., the northern slope of the calcareous Matese massif (Mt. Miletto, 2,050 m a.s.l.), and the Mount Mutria group. In addition, the Molise border passes the Apennines watershed, including the upper valley of the Volturno River, between the Mainarde and Matese.

Toward the Adriatic, the mountainous landscape of the Apennines consists of a sequence of hills characterized by steeper slopes. Here, the land becomes increasingly lower as it approaches the Adriatic coastline. The Biferno river is entirely in the regional territory of Molise, while the Trigno and Fortore rivers cross the Abruzzo and Campania regions, respectively, and flow into the Adriatic Sea. These rivers, crossing the transverse valleys to the Apennines, lie semi-parallel to each other, flowing for a long distance at the limits of the regional territory onto the Tyrrhenian slope of the Volturno and the Tammaro rivers. Only the upper parts of the basins of these rivers lie in Molise. All the waterways are greatly affected by seasonal variations in precipitation and consequently, are torrential when precipitation is intense.

The studied area is characterized by human settlements that are organized into many sparsely urbanized small municipalities and rural areas. The latter, especially in the valleys, are devoted to marginal agriculture that takes advantage of the presence of water.

15.1.2 Climate

As a result of geographic and topographic differences between the coastline and the inland mountains, at varying distances from the sea, the climate of Molise has a wide range of characteristics that range from the typically maritime characteristics (modest variations in temperature, mild weather in all seasons, low precipitation in summer) to the continental cold-humid characteristics of the mountainous interior (Ludovico et al. 2018) (Figure 15.2).

The temperature shows marked differences in contrasting seasons and between day and night. Heavy precipitation, including snow, occurs up to over 2500 mm/year above 1000 m

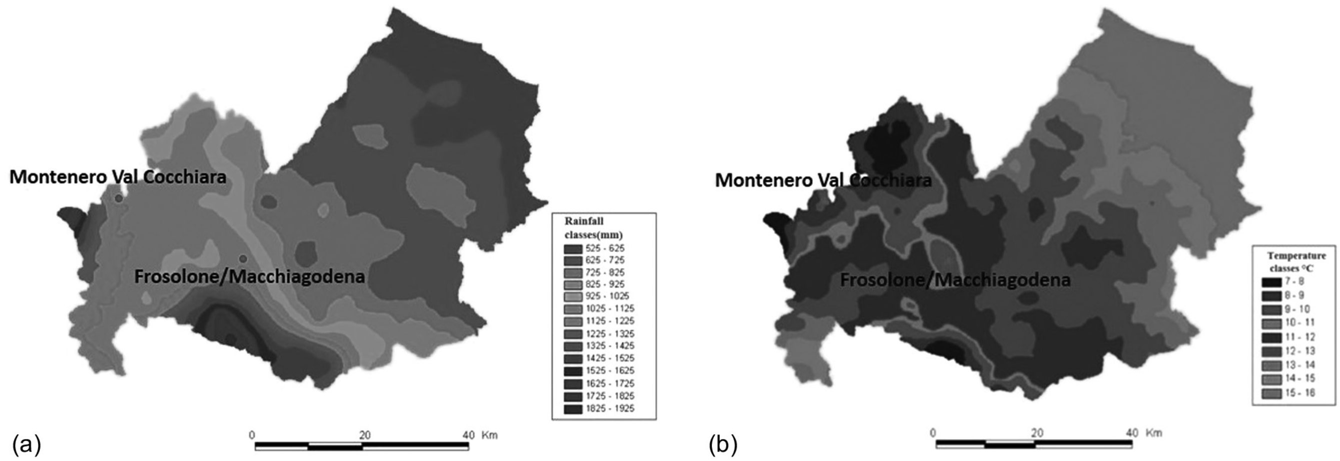

FIGURE 15.2 Maps of climatic conditions in Molise region: rainfall classes on the left, temperature classes on the right.

a.s.l. Rainfall, although of short duration, is most frequently intense in autumn and spring, but rainfall lasts longer in winter, with peak levels in November. The lowest rainfall is in July.

The Montenero Val Cocchiara valley, an intermountain basin located at 950 m a.s.l. in the southern Apennines, was originally the bottom of an ancient lake. Currently, the valley is approximately 3 km long and 1 km wide and is partially covered by a peat bog. The local climate is characterized by cold-humid winters and hot-dry summers, as occurs in typical Mediterranean regions (Figure 15.3a).

The total mean annual rainfall in the Montenero Val Cocchiara valley is around 1000 mm, with an increasing trend during the 31 year period from 1987 to 2017 (Figure 15.3b). The annual rainfall, with a maximum in autumn and a minimum in summer, is usually enough to allow normal natural pasture vegetation. Although precipitation is most intense in autumn (more than 500 mm), droughts during the dry summers present stress, which favors the survival of drought-tolerant vegetation. The average temperature in this valley ranges from 4 °C in January to 21 °C in July, and the average annual temperature is about 12 °C, also in this case with an increasing trend in the same 31 year period (Figure 15.3c). During the winter, freezing temperatures occur, the temperature can drop to −8 °C, and when there is precipitation, it can snow.

In Frosolone/Macchiagodena, at 850 m a.s.l., the average temperature ranges from 8 °C in January to 20 °C in July and August (Figure 15.4a).

During winter and early spring in Frosolone, snowfall is frequent and plentiful, while in summer, the extreme high temperature does not exceed 35 °C. The variation of mean total annual precipitation is more pronounced than the variation of temperature, but with different trends (Figure 15.4b and c). During the period from 1987 to 2017, trend lines that estimate annual precipitation and annual temperature show that annual rainfall at Frosolone has tended to decrease (Figure 15.4b), whereas average temperature has tended to increase (Figure 15.4c). The variation of annual rainfall from year to year at Frosolone indicates that drought stress occurs in the area in some years (Figure 15.4b).

15.1.3 Soil

The geological substrate in the central south Apennines is formed by Tertiary arenaceous, silty, marly sediment, namely, Miocene "Flysch" (Vezzani et al. 2010). The mountains are formed by hard calcareous rocks that result in a karstic landscape, while hilly and locally terraced morphology is dominated by marly limestone bedrock (Patacca and Scandone 2007). Based on mean annual precipitation (900–1400 mm), the soil moisture regime is udic and locally ustic in the valleys. The soil temperature regime is mesic and thermic. On flat land, soils are more developed, with pedogenic structure in depth. According to Food and Agriculture Organization World Reference Base (FAO-WRB) classification (FAO 2006), the weakly differentiated profiles are Eutric and Calcaric Cambisols (Eutrochrepts as reported by the United States Department of Agriculture [USDA] Soil Taxonomy; Soil Survey Staff 2010), soils with clay accumulation (Haplic and Gleyic Luvisols), and acid soils with organic matter accumulation (Humic Umbrisols). During spring and autumn, the soils are affected by intense erosion by water, resulting in the deposition of alluvial parent material, which results in soils (Eutric and Calcaric Regosols and Lithic Leptosols). In the sloping land along the steep sides of the hills, more intense erosion by water occurs at altitude 800–600 m a.s.l. on slopes >30%. This soil erosion results in changes associated with slope, stoniness, rockiness, and locally, changing morphology.

The Montenero Val Cocchiara area (289 ha; Figure 15.5) is located mainly on an alluvial plain of the Zittola river (Oligocene age), which is characterized by peaty layers with local outcropping. The boundary slopes of the plain consist of well-stratified limestone and alternating marly layers (Oligocene–Miocene age). The presence of a deep layer of peat (4 m) is due to ancient filling up and swamping of the plain. This area is subject to some environmental protection programs, such as the Sites of Community Importance

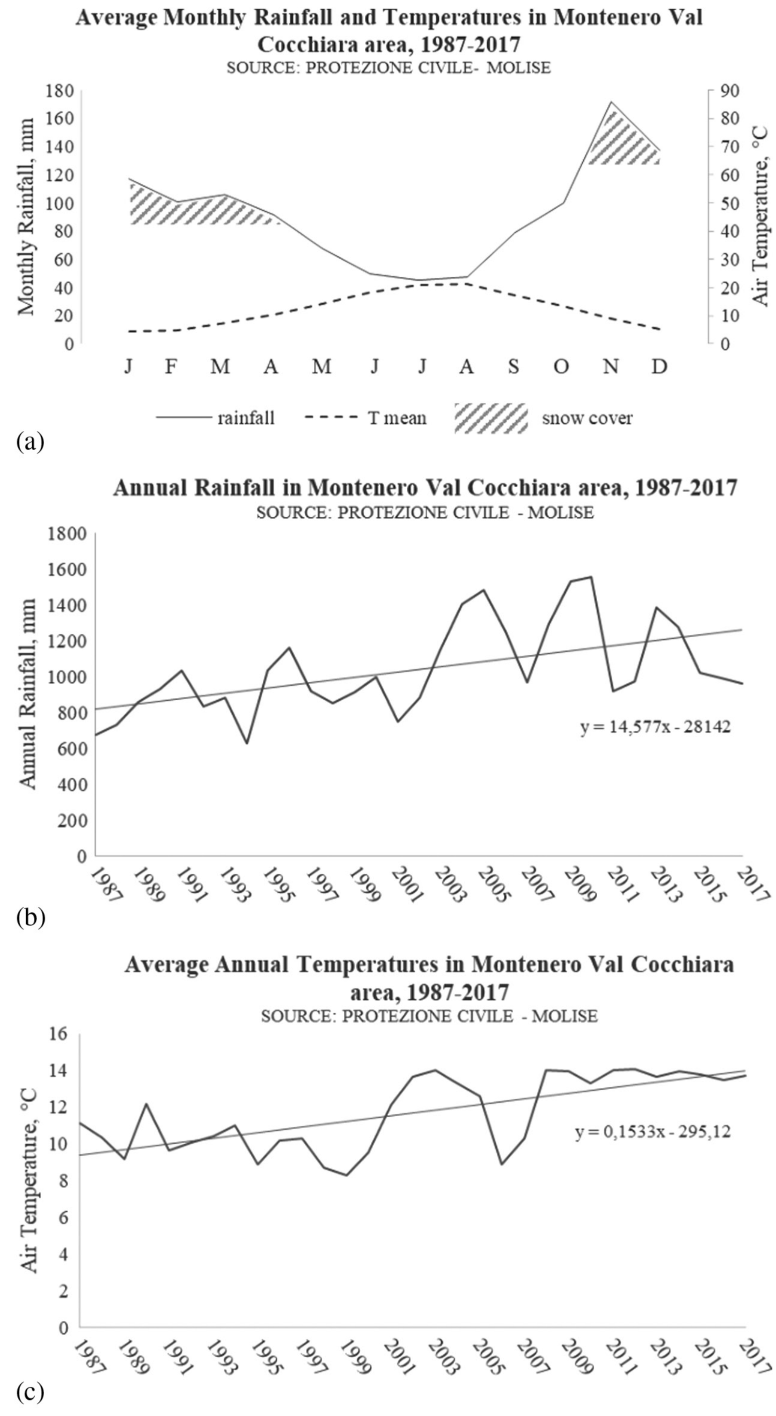

FIGURE 15.3 Climatic characterization of Montenero Val Cocchiara area: (a) average monthly rainfall and temperatures, (b) annual rainfall, (c) average annual temperatures.

(SIC) Program, set up by the European Union to safeguard the habitats and autochthonous animal and plant species. The soils sampled along the plain at locations highlighted in Figure 15.5 are very different in texture and profile development, but gley features, due to seasonal submersion, characterized them all. These soils, classified according to USDA Soil Taxonomy (Soil Survey Staff 2010) as Eutrochrepts, are characterized by the presence of gley features in B and C horizons (Montenero V.C. 3 and Montenero V.C. 4; Figure 15.6); their depth is adequate for root growth of pasture vegetation.

The Montenero soils sampled have clay–silty texture and are skeleton-free and calcareous, with a weakly to moderately alkaline reaction. They have very slow permeability and high available water holding capacity. The content of organic matter varies little throughout the profile sampled. Peaty horizons may be present below the depth of 1 m. The water table is

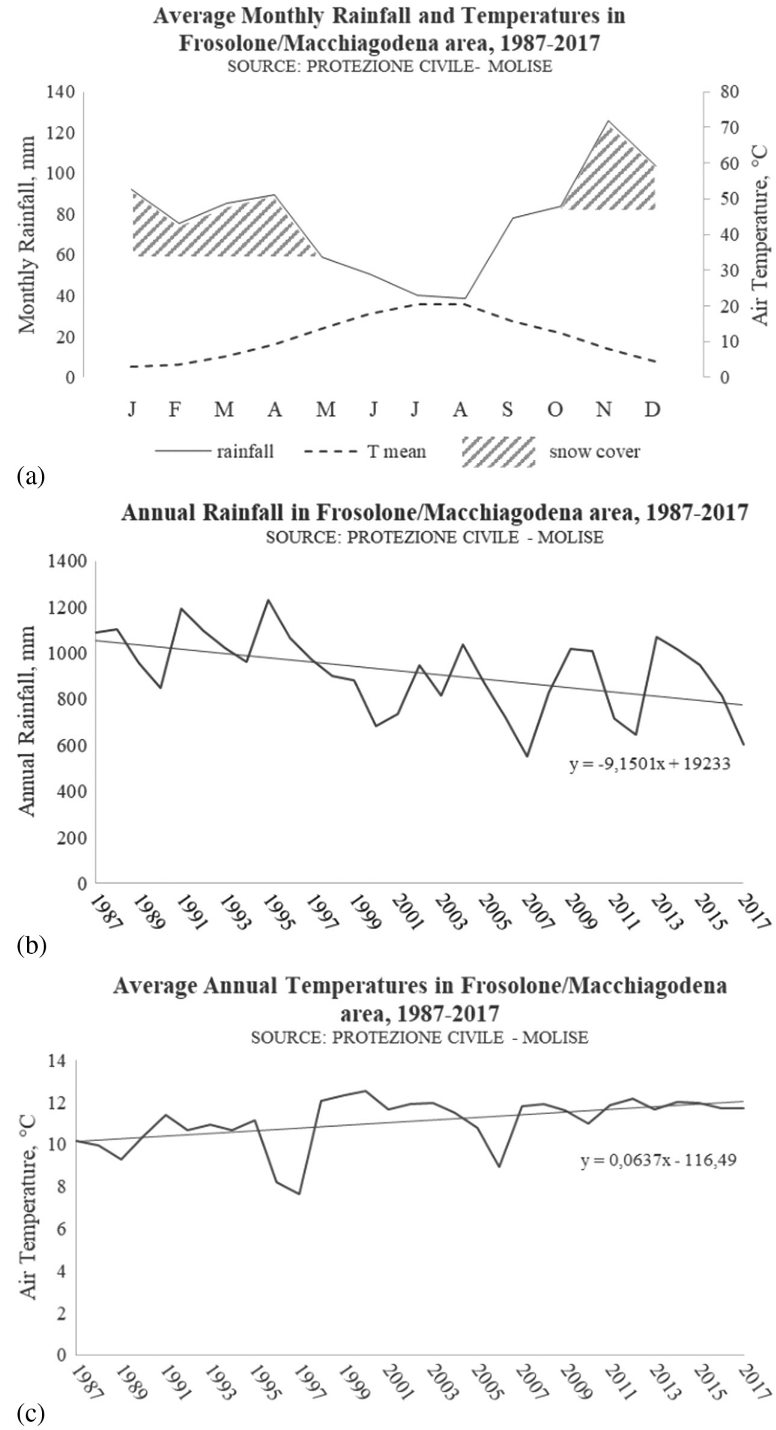

FIGURE 15.4 Climatic characterization of Frosolone/Macchiagodena area: (a) average monthly rainfall and temperatures, (b) annual rainfall, (c) average annual temperatures.

present for significant periods, starting from a depth of 20 cm from the surface during the wet season but present within 100 cm of depth at other times during the year.

The topography of the Frosolone/Macchiagodena area (249 ha; Figure 15.7) is terraced and flat, and the morphology of the soil surface is characterized by the absence of superficial stoniness and rockiness; the typical land use of this area is grazing. The degree of plant cover is always high (>90%), and the vegetative composition of the Frosolone/Macchiagodena area is typical of Mediterranean grassland (Catorci et al. 2011). The vegetative cover diminishes the risk of stress to vegetation due to aridity and decreases the risk of potential erosion and compaction of the soil surface. Variations in the density or seasonality of grazing have significant impacts on plant community composition (Catorci and Gatti 2010). Calcaric Cambisols and Humic Humbrisols are sometimes present as lower soil

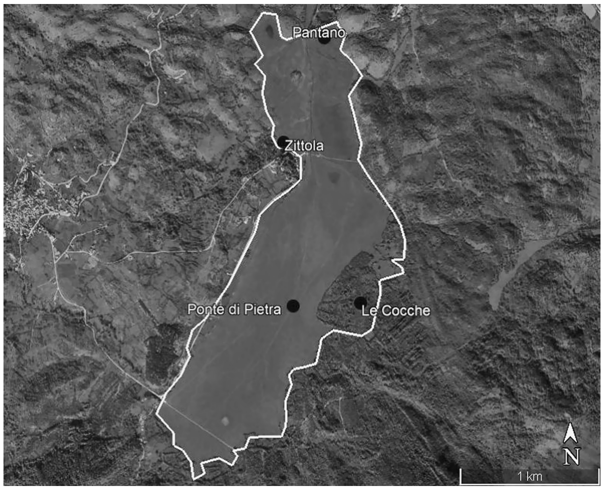

FIGURE 15.5 Aerial photo of Montenero Val Cocchiara area.

horizons. The soils of the Frosolone/Macchiagodena area (Frosolone 1 and Frosolone 5; Figure 15.6) are well drained, without skeleton, very deep, and with good depth for the roots. These soils, classified according to USDA Soil Taxonomy (Soil Survey Staff 2010) as Haplumbrepts and Hapludalfs, are characterized by a low calcium carbonate content, and their reaction is acid in the top soil and weakly acid in the subsoil. They have moderately slow permeability and very high water holding capacity. The soil organic matter content is high in the surface horizon. Based on geomorphic features, Aucelli et al. (2012) estimate spatially averaged water erosion rates for these basins as 0.13–0.23 mm/year, with valley (fluvial) incision rates of 0.46–0.71 mm/year for the same period.

These data suggest 200–400 m of downcutting since the mid-Pleistocene, which has set the boundary condition for hillslopes in the area. Hillslope gradients in the study area range from 10° along the top to more than 35° in the hillier northeast of the study area, with the majority of slopes being 8°.

15.1.4 Vegetation

Pasture is a complex ecosystem whose productivity is influenced by natural factors, such as climate, soil, and vegetative characteristics, and anthropogenic factors, such as the mode and intensity of grazing (Di Rocco et al. 1992a).

Within the pasture ecosystem, the soil plays an important role, influencing the productivity of the vegetation as well as the most suitable management and conservation techniques.

First, the pedological characterization of the pasture areas allows assessment of the nutritional and habitability functions of the soil, which define its capacity to support the development of the herbaceous cover, influencing the productivity of the pasture from both a quantitative and a qualitative point of view.

Some soil parameters that directly influence the productivity of a pasture are

- Water holding capacity: it constitutes the reserve of water that the soil is able to retain for absorption by plants, in particular during the growing season.

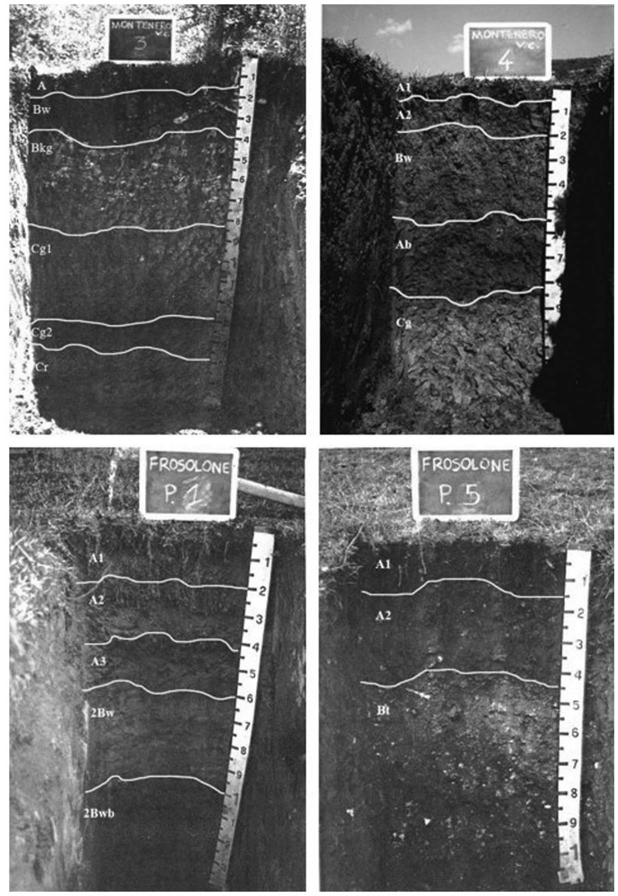

FIGURE 15.6 Soil profiles of the two study areas made in 1991–1993 (Di Rocco et al. 1991b), classified according to USDA Soil Taxonomy Montenero V.C. 3—*Eutrochrepts*: deep, well-drained soil with fine texture in all horizons. The top soil (A horizon), with a thickness of about 15 cm, has a very dark brown color (10YR 2/2) and a granular and subangular blocky structure; the exchange complex is saturated; the organic matter content is average (4.2%). The subsoil is characterized by the presence of a carbonate accumulation horizon (Bkg), with a coarse and very coarse subangular blocky structure toward massive. Montenero V.C. 4—*Eutrochrepts*: deep, well-drained soil with silty-clay texture, without skeleton. The topsoil is calcareous with a neutral reaction and a high content of organic matter (14%). During the wet season, the water table can also be found at a depth of 50 cm, the subsoil being characterized by a rather low permeability. This condition causes the presence of gley features in Cg horizon. Frosolone 1—*Haplumbrepts*: well-drained soil, without a skeleton and limestone, very deep, with high depth useful to the roots. The reaction is moderately acidic in the topsoil (pH 5.1) and weakly acidic in the subsoil (pH 6.1). The available water capacity is as high as the organic matter content (9.2%). In all horizons, there is a developed coarse subangular blocky structure. Frosolone 5—*Hapludalfs*: well-drained soil, very deep, with fine texture and high depth useful to the roots. The skeleton, of medium size, is frequent in the topsoil and abundant in the subsoil. The soil is without limestone, and it has a very strong acidic reaction in the topsoil (pH 4.9) and moderately acidic in the subsoil (pH 5.2). The available water capacity is moderate; the organic matter content is high (10.4%). In Bt horizon, there is a high content of clay (48.5%), and the granular structure is developed. (Soil Survey Staff 2010).

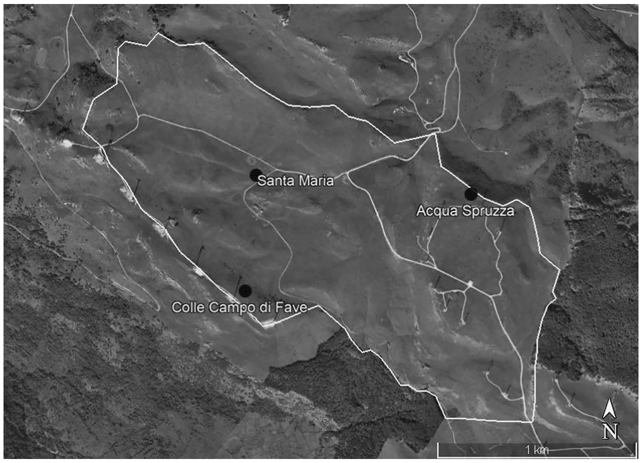

FIGURE 15.7 Aerial photo of Frosolone/Macchiagodena area.

- Nutritional status of the soil: it expresses the average level of both nutrients and organic substances in the soil, including their losses due to surface water erosion and leaching.
- Availability of oxygen for the roots: it is correlated with drainage of the soil. Indeed, limited availability of oxygen for the roots during the growing season influences the quality of forage produced by causing a decrease in the palatability of the forage.

However, as for all other ecosystems, even the pasture ecosystem is continually subjected to biotic and abiotic stress. According to Di Rocco et al. (1991b), the dynamics of degradation that can affect grazing areas are many.

Factors that can affect the soil erosion process are the intensity of the rainfall, the rate of surface water flow, the texture, structure, and permeability of the soil, the slope of the soil surface, and the presence or absence of cover crops. Furthermore, the action of humans on the soil, such as ploughing, deep ripping to improve drainage, installation of tile drains, or removal of vegetation, can strongly influence the intensity of the erosive process. Soil erosion is a process that takes place in two phases: detachment of the particles from the soil mass and transport of the soil particles. In conditions characterized by poor plant cover and soil with low infiltration capacity, the whole area of the slope contributes to generate surface runoff.

The Mediterranean basin is characterized by a climate that promotes the erosion process, with high intensity of rainfall and the alternation of strongly dry periods and very humid periods. The presence of dry periods is stressful to pastures, because the lack of water inhibits regular development of the vegetation and leaves the soil unprotected. Moreover, the topography of the Italian peninsula is very uneven. Two-thirds of the Italian peninsula is mountainous or hilly, and as elevation above sea level increases, the potential energy of the water flowing downhill by the force of gravity can cause erosion of the soil surface. According to Morgan (1986), it is estimated that one-sixth of the national surface (50,000 km^2) of Italy is subject to accelerated erosion and that soil losses range from 0.1 to 1.4 mm per year, with maximum values of 7 mm in particularly erosive years.

Another source of stress on pastures is degradation due to soil compaction caused by the passage of livestock and operating machines. The compaction of the soil involves the destruction of the structural aggregates and the reduction of both macroporosity and microporosity, which causes slower infiltration of the water in the soil. Overall, there is a worsening of the physical properties of the soil and its permeability as regards the movement of air, water, and plant roots of pasture species. Sometimes, reduction of the permeability of pasture soils results in the spread of competitive weed species.

Pasture includes herbaceous plants, bushes, and trees that can be directly used by the animals (Cavallero et al. 2002; Pardini 2005). However, there is a difference between pasture and pasture territory. Pasture territory indicates a vast surface covered by natural vegetation made by herbaceous, arboreal, and shrub species, used exclusively for animal grazing (Vallentine 1990). Pasture territory is not less than hundreds of hectares and excludes the possibility of intensive management.

Pasture presents a greater management intensity and less areal extension (Pardini 2005) of phytocenoses, whose biomass is used partly or wholly by herbivorous animals (Cavallero et al. 2002) that consume it directly.

As a result of stresses due to grazing by animals of different species and categories present on the pasture, the floral composition and the physical structure of the vegetation and the soil undergo modifications (Acciaioli and Esposito 2010).

However, meadows and pastures are not only a source of food for animals; they also have other functions, which are part of the cultural and social heritage of the territories (Cavallero et al. 2002). These functions are regulating the emission of gases in the atmosphere, controlling soil erosion phenomena (Gusmeroli 2004), and contributing to maintenance of the structure of the landscape (Sanderson et al. 2004).

According to the definition of Peeters et al. (2014), grasslands are represented by land devoted to the production of forage for harvest by grazing, cutting, or both, or used for other agricultural purposes such as renewable energy production. The vegetation can include grasses, grass-like plants, legumes, and other forbs. Woody species may also be present. Grasslands can be temporary or permanent, when they are not completely renewed or regenerated after destruction by ploughing or herbicide use, for 10 years or longer.

Two management categories of grasslands can be identified: meadows, i.e., grasslands that have been harvested predominantly by mowing over the last 5 years; and pastures, i.e., grasslands that have been harvested predominantly by grazing over the last 5 years (Peeters et al. 2014).

In both cases, the grassland types can be characterized by different tree associations. Especially in central Italy, along the Tyrrhenian coast, evergreen trees and shrubs (e.g., *Quercus ilex*, *Q. suber*, and *Q. coccifera*) can be found, while inland, in the hills, forests of deciduous trees (e.g., *Castanea sativa*) prevail, and in the mountains, forests of *Fagus sylvatica* prevail (Porqueddu et al. 2017). Finally, natural meadows are associated with various types of vegetative association (*Brachipodietum* spp., *Brometum* spp., *Arrhenatheretum* spp., *Festucetum* spp., and *Lolietocynosuretum* spp.) in high mountains. In southern Italy, grasslands are associated with thermoxerophytic shrubs along the coasts, together with forest and evergreen sclerophylls (Porqueddu et al. 2017). In the Apennine zone, above 500 m a.s.l., permanent grasslands are found. However, these areas were characterized by a gradual reduction from 1900 to 2000, while from 2000 to 2013, the area of permanent grasslands remained stable (EUROSTAT 2012).

Pastures have positive effects from different points of view (i.e., economic, ecological, managerial, and productive) linked, for example, to the increase of the number of palatable (edible) and not palatable species, the control of weed species, the reduction of soil losses due to erosive phenomena, the maintenance of biodiversity, and the decisions of the Natura 2000 network.

Natura 2000 is the main instrument of the European Union's policy for the conservation of biodiversity. This is an ecological network spread throughout the Union, established under Directive 92/43/EEC "Habitat" to ensure the long-term maintenance of natural habitats and endangered or rare species of flora and fauna at the Community level. The Natura 2000 network is constituted by the Sites of Community Interest (SIC), identified by the Member States as laid down in the Habitats Directive, which were subsequently designated as Special Conservation Areas (ZSC) and include the Area of Special Protection (ZPS) established under Directive 2009/147/EC "Birds" concerning the conservation of wild birds. The purpose of Article 2 of the Habitat Directive is to ensure the protection of nature by keeping and "taking account of economic, social and cultural needs, as well as regional and local particularities" (Directive 92/43/EEC); so, the aim of the directive is to preserve natural and semi-natural habitats (such as areas with traditional agriculture, woods that are used, or pastures).

In Italy, SIC, ZSC, and ZPS cover a total of about 19% of the national land and almost 4% of the marine territory. The Montenero Val Cocchiara area, an important SIC area, encompasses a wetland area of about 900 hectares, which represents one of the last wetlands existing in Europe (Tamburro et al. 2005).

However, the capacity of the pasture to sustain the requirements of the animals is determined by the quantity of biomass produced and the qualitative characteristics of the pasture, expressed as nutritional values.

In the following are reported the most important nutritional values of the pasture biomass collected in 2000–2003 in Montenero Val Cocchiara—Area 1 and Frosolone/Macchigodena—Area 2.

15.1.4.1 Montenero Val Cocchiara—Area 1

This area, included in the "Corine Biotope," "Bioitaly," and "Natura 2000" list (Lucchese 1995), is characterized by very rare plant populations such as *Salix pentandra* and *Dactyloriza incarnata*, and most of the soil is a peat bog residue, which is very uncommon in the Apennine areas (Miraglia et al. 2001). The area is located between 800 and 900 m a.s.l. and is formed by a broad plain surrounded by wooded hills encompassing 2200 ha. The broad plain is used as grazing meadow (586 ha), while the remaining part is used as pasture. The broad plain (about 1000 ha) is divided into two sub-areas for the pasture area and three sub-areas for the grazing-meadow area, in which the animals cannot graze from the middle of April to the end of June (haymaking time).

In the following are reported some data from studies conducted in 2000 and 2001 and aimed at the preservation of the entire area (Miraglia et al. 2003), which is the habitat of the autochthonous Pentro horse (MiPAF 2003) as well as the habitat of the rare plant species already mentioned. The Pentro herd lives wild all year and is not fed using supplementary foods; moreover, cattle, sheep, and goats also graze in the area, resulting in a total of 1500 Adult Bovine Units (UBA, 24-month-old bovine) (Di Rocco et al. 1992a).

In the grazing-meadows system, there are a great number of plant species usually related to the pasturing and belonging to the Poaceae and Fabaceae families (80% of the plant species observed), identified according to Corral and Fenlon (1978). In the sub-areas used only as pasture, there is a different ratio between Gramineae (Poaceae) and Legume (Fabaceae) and a higher percentage of weeds such as *Juncus articulatus* and *Ranunculus acris*.

In their 2 year study of precipitation and temperature, Costantini et al. (2004) found abundant rainfall in fall and spring, while rainfall was scarce from June to September. During this period, when evapotranspiration is at the maximum level, there were differences in the rainfall: 85.2 and 150.4 mm of rain in the first and second year, respectively. In the first and second year of the study, the average temperature was 11.9 °C, and it ranged between 3.6 °C in January and 21.1 °C in July in both years.

Several variables measuring the chemical composition of forage from the grassland did not show differences between the two years; only the dry matter and protein percentage of the forage were different (Table 15.1), according to Costantini et al. (2004). The differences in dry matter and protein content of the forage are probably due to a greater drought stress in the first year, which could have caused a qualitative and quantitative deterioration of the grassland and resulted, at least temporarily, in proportionately more growth of the xerophytic (more drought-tolerant) species, which have a lower protein content.

A simulation model was used to evaluate the availability of forage in the investigated Area 1 (970 ha), assuming a 65% use of the herbaceous resources. In the year 2000, the production of forage in Montenero Val Cocchiara—Area 1 was estimated to have been 2500 t DM (dry matter), while in the second year (2001), it was estimated to have been 2900 t DM.

15.1.4.2 Frosolone/Macchiagodena—Area 2

This area is located between 1200 and 1400 m a.s.l. and is characterized by sloping areas with a slope between 10% and 20%, a high grassy covering, and flat areas destined for

TABLE 15.1
Montenero Val Cocchiara—Area 1: Chemical Composition of Pasture, 2000 and 2001 (Mean ± m.s.e.)

	2000	2001
Dry Matter (DM), %	32.68 ± 2.58	23.23 ± 1.8
Organic Matter, %DM	89.72 ± 0.33	90.22 ± 0.40
Crude Protein (CP), %DM	18.16 ± 0.93	21.45 ± 0.87
NDF, %DM	53.57 ± 0.98	52.37 ± 1.27
ADF, %DM	37.62 ± 1.24	35.17 ± 0.97
ADL, %DM	11.78 ± 0.58	10.63 ± 0.50

ADF: acid detergent fiber; ADL: acid detergent lignin; NDF: neutral detergent fiber.

permanent pastures that are characterized by a very high level of grasses and forbs, covering between 90% and 100% (Di Rocco et al. 1992a).

In the following are reported some data collected during 2002 and 2003 in a study conducted in the grassland managed by the "Comunità Montana Sannio," which was divided into three sub-areas in Frosolone municipality (Isernia) and one sub-area in Macchiagodena municipality (Isernia).

In these areas, the soil is acid, and the soil texture is light loam, with good organic matter content and a balanced C/N ratio. This soil can be used under permanent pasture by heavy animals, such as cattle and horses, without damaging the soil structure (Salimei et al. 2001). This area, used for bovine, equine, ovine, and caprine pasture, is nonetheless degraded, probably due to excessively high stocking rates (De Renzis et al. 1992b). The total cadastral area of the "fida pascolo" contract parcels is 1975 ha (Di Rocco et al. 1992a). Each sub-area has prefabricated structures used as animal shelters and for milk processing and storage of dairy products. These structures can all be reached through the regular road network, which has also promoted rural tourism, which, with the selling of typical products such as "Caciocavallo" and "Pecorino" cheese, represents additional income for the local farmers.

From the management authority, registered data in Area 2 indicate 3644 head at pasture (1800 UBA) in the first year (2002), and the grazing population increased to 4069 head in the following year (1950 UBA), due to an increase in grazing goats. The simulation model, described in Section 15.2.1, was applied to the data of the whole grazing area, permitting the estimation of the total available area, excluding spaces containing such features as streets, trees, buildings, and backwaters, at about 1555 ha, mainly composed by grass. The data of both Area 1 and Area 2 were analyzed similarly.

The grassland composition of Area 2, 52% annual grasses and 10% legumes, is typical of south-central Italy. In the heavily grazed and staging areas, there are ferns (*Pteridium aquilinum*) and species of the Carduaceae family (*Cardus* spp., *Cirsium* spp., and *Carlina acaulis*). There were also a single beech tree, an apple tree, and a pear tree in the grazing area, as well as some shrubs such as *Prunus spinosa* and *Crateagus* spp. In the second year of study, occurrences of rainfall were irregular, including the critical summer time period (July and August), during which biotic stress on pasture vegetation is greatest due to the presence of livestock.

In Area 2, the weather in the years 2002–2003 influenced the quality and quantity of grassland production: based on the experimental outcomes and considering the overlapping of the grazing zones (herbaceous, shrubby, and arboreal), the production of animal feed was estimated for the whole grazing area during the whole grazing time (180 d/year) to be approximately 6120 and 4300 t of dry matter in the first and second year, respectively.

Moreover, as also highlighted for the Montenero Val Cocchiara area (Table 15.1), many differences in the dry matter and chemical composition of pastured vegetables were observed for Frosolone/Macchiagodena (Table 15.2), comparing the two different pasture seasons.

Based on productivity and climatic conditions, pasture grass is generally available to animals from May to September, considering that its growth rate reaches a peak in autumn (15–25% of production) and another in spring (about 70%) (Pardini 2005). This trend is strongly influenced by relatively stable environmental factors, such as soil and altitude, and by changes in the weather (temperature and rainfall), changing seasons, and management practices (Pardini 2005). An important limiting factor of the growth of grass in temperate climates is the low winter temperature, while in tropical climates, variations in rainfall can limit the growth of grasses. In the Mediterranean climate, the principal climatic factors limiting the growth of pasture vegetation are low temperature in winter and high temperature in summer (Cavallero et al. 2002). Cavallero and his colleagues (2002) state that the average productivity of Italian pastures can range from 2–2.5 to 6.5 t dry matter/ha in the most productive pasture of the Apennine areas. However, as also shown by the two reported study cases, the qualitative and quantitative characteristics of forage can be affected by abiotic and biotic stresses.

TABLE 15.2
Frosolone/Macchiagodena—Area 2: Chemical Composition of Pasture, 2002–2003 (Mean ± m.s.e.)

	2002	2003
Dry Matter (DM), %	30.22 ± 1.02	34.10 ± 1.10
Organic Matter, %DM	89.54 ± 0.27	89.81 ± 0.29
Crude Protein (CP), %DM	16.55 ± 0.41	15.87 ± 0.44
NDF, %DM	49.16 ± 0.78	47.36 ± 0.85
ADF, %DM	30.81 ± 0.63	29.36 ± 0.68
ADL, %DM	7.87 ± 0.32	8.23 ± 0.35

ADF: acid detergent fiber; ADL: acid detergent lignin; NDF: neutral detergent fiber.

15.1.5 Abiotic Stresses of Plants

15.1.5.1 Temperature

The analysis of soil temperature data collected at the Montenero Val Cocchiara area shows that the average annual air temperature increased from 1987 to 2017 by about 2.3 °C. The coefficients of the x term (x = year) of the linear regression equations of the annual temperature values of Figure 15.3c indicate a gradual warming trend of approximately 0.15 °C/year. This warming trend is less evident in the Frosolone/Macchiagodena area, where the linear regression equations of the annual temperature values of Figure 15.4c is approximately 0.06 °C/year. This warming trend indicates that the approximate rate of air temperature increase was greater in Monetenero Val Cocchiara than in Frosolone, for which climate records from 1987 to 2017 indicate a mean annual air temperature increase of 0.95 °C. Extensive studies on the Alpine and Apennine climate show that the average annual air temperature over the Alps has increased in the last 100 years by approximately 1.5 °C (EEA 2009). The long-term climatic data available for the central Apennines indicate that average annual air temperature increased by approximately 0.027°C/year during the period 1950–2014 (Evangelista et al. 2016). In Figure 15.3c and Figure 15.4c, the low values of slope (the coefficient x, the independent variable, time) of the equations describing the trend of increasing temperature over the 31 year period indicate a relatively slow rate of increase in temperature for both the studied areas.

The increasing average annual temperatures recorded from 1987 to 2017 in the studied area may represent gradually increasing stress on the permanent pasture, which might affect the development of the stems and the aging of all the organs of the plant by gradually increasing lignin components and decreasing digestibility. Low temperatures have been shown to cause a decrease in nutritional value due to stunted growth of the aerial part of plants (Giardini 2012). As the temperature increases, there is generally an increase in the respiratory activity of plants, but the stress of very high temperatures has been shown to stop photosynthesis, thus depressing the accumulation of dry matter. In the same way, the stress of very low temperatures can stop the development of the plant by inhibiting its metabolic activities (Giardini 2012).

15.1.5.2 Rainfall

As regards mean annual rainfall series, data collected from 1987 to 2017 in the Montenero Val Cocchiara area show a trend for precipitation to increase at a rate of approximately 15 mm/year (Figure 15.3b). The opposite trend for mean annual rainfall during the same 31 year period was observed for the Frosolone/Macchiagodena area (Figure 15.4b), with an annual rate of decrease of mean annual rainfall of approximately 9 mm/year. Other climatic analyses conducted on other stations in Molise show a general tendency toward an increase in temperature, particularly in the minima (Costantini et al. 2013). However, the situation throughout Molise is by no means uniform, because besides stations that experienced substantial stability in the period examined, such as Frosolone/Macchiagodena, there are others, such as Campobasso (the Region's capital) and Guardiaregia, that show positive trends, even more so than the Montenero Val Cocchiara area, in both mean temperature and annual rainfall. Precipitation trends in Molise are more temporally and spatially variable and can be asymmetric compared with trends in air temperature (Izzo et al. 2004). Climatic warming is predicted to cause changes in the seasonality of precipitation, with an expected increase in intra-annual variability, more intense precipitation extremes, and more potential for flooding and soil erosion by water (Gobiet et al. 2014). Projected changes in precipitation, snow cover patterns, and glacier storage in the Alps will also alter runoff regimes, leading to more droughts in the summer (EEA 2009).

The quantity and frequency of rainfall during the period of vegetative growth and the persistence of the snow cover that serves as thermal insulation are elements that can positively influence the productivity and the quality of grasses and forbs (Cavallero *et al.* 2002).

Rainfall is the main source of water supply of the pastures in the present study. However, plentiful rainfall, frequent and intense, can stress pastures by causing negative phenomena such as waterlogging, surface erosion by water, lack of flowering, or delay in the maturation of the various plants (Giardini 2012). Indeed, climatic warming effects and changes in rainfall seasonality and water availability have been proved to be important for ecosystem productivity in the forests of the Apennine regions, where changes in above-ground net primary productivity in response to a shift in the precipitation regime have been detected (Chelli et al. 2016).

15.1.5.3 Soils

The characteristics of soils, and in particular the pH and the calcium carbonate content, can influence the chemical composition, especially the mineral content, of the grasses and legumes that grow in Apennine pastures. At subalkaline pH, the lack of a microelement in soil often results in limited plant growth and a reduced concentration of the element in plant tissues (McDonald et al. 2011). In addition, micronutrient deficiencies of forage may affect both intake of the forage by animals and forage digestibility (McDonald et al. 2011). Some of the most common mineral nutrient deficiencies that result in stresses to pasture grasses include deficiencies of phosphorus, magnesium, copper, and cobalt. The reaction (pH) of soil is also an important factor that can affect the absorption of many elements; e.g., plants in limestone soils (McDonald et al. 2011) poorly absorb both manganese and cobalt. Stress due to drought caused by reduced precipitation or increased evapotranspiration can override the positive effects of higher temperatures on plant growth in hot, arid climatic zones.

15.1.5.4 Altitude

According to Zilotto et al. (2004), the temperature of the air decreases at an average of 0.6 °C per 100 m height, thus causing a shortening of the vegetative activity by about 5 days and a decrease in forage production by about 5%. In the context of recent changes in annual rainfall and average annual air temperature (Figure 15.3b and c and Figure 15.4b and c), an analysis of vegetative cover estimates that plant cover has increased in Apennine mountain sites (Chelli et al. 2017). For example, a general tendency toward increased forest vegetative cover was also observed on Matese mountain at 1400–1600 m a.s.l. The increase in plant cover over the last 30 years is most likely related to the expansion of the most thermophilic species or to the immigration of species from lower elevations. Indeed, in the case of the studied area, the increasing warming can affect ecosystems by increases in temperature, early snowmelt, and a prolonged growing season. These factors may have reduced climatic stresses on the plant communities studied by Chelli et al. (2017) and may have played a key role in the observed increase in plant cover. In fact, the air temperatures before snowmelt and after the meltdown (i.e., the May/June temperatures) are the main factor affecting plant growth in alpine ecosystems (Carbognani et al. 2014).

15.1.5.5 Solar Radiation

Solar radiation directly influences both the climate and the biological activity of plants and animals, and abundance or lack of solar radiation beyond the normal range of a plant can decrease the plant's growth. The energy necessary for plants to carry out photosynthesis comes from the sun, and the quantity of sun received by the plant can affect the concentration of sugars and the yield of grasses and forbs. In general, on a cloudy day, the soluble carbohydrate content of grass will be lower than on a sunny day (McDonald et al. 2011).

15.1.6 Biotic Stresses of Plants

15.1.6.1 Botanical Composition

The relationship between biotic stress and disturbance intensity not only affects the functional response of plant communities but can also lead to changes in plant community structure. The most common plant species for feeding animals belong to the families of Gramineae and Fabaceae (Acciaioli and Esposito 2010). Plants of the Gramineae are usually preponderant in spring at the beginning of the vegetative growth season and escape drought stress by seed production. Annual plants of the Gramineae family come quickly to maturity, and due to their superficial root system, they cannot withstand the stress of summer drought (Porqueddu et al. 2008). During the flowering phase, lignin begins to accumulate in the supporting tissues so that both the palatability and the digestibility of annual forages diminish: it follows that the ideal use of annual plants for forage is in the early vegetative phases before flowering. From the standpoint of forage quality for livestock, Gramineae have a higher carbohydrate content and energy value than Fabaceae, and Gramineae are richer in phosphorus, but poorer in protein and calcium, compared with Fabaceae (Cesaretti et al. 2009).

Because of their relatively deep root systems, Fabaceae, compared with Gramineae, are more resistant to drought stress, and Fabaceae are more present in the composition of the pastures when the vegetative growth stage season is advanced. In evaluating the composition of a pasture, it is also important to consider the presence of the less appetizing species, or weeds, which can strongly compromise the total value of the forage (Cesaretti et al. 2009). Depending on the geographical location, the composition of plant species of pastures may vary: in the alpine areas, perennial species predominate, while in the central-southern pastures, annual species prevail (Pardini 2005; Dumont et al. 2015).

15.1.6.2 Herbivory

Animals can stress forages in pastures in a number of ways, so proper management of grazing animals is essential to reduce stress on pastures (Colonna and Rosati 2015). The determination of the stocking rate, i.e., the crucial grazing management decision on the appropriate number of animals on a given surface in a certain period, allows the conservation of the forage's natural resources, as it ensures the balance between production and use of resources. Thus, appropriate stocking rates can help to prevent degradation of the forage, which can occur when a higher (overload) or lower (underload) load on the pasture is encountered (Pardini 2005). The stocking rate depends on the carrying capacity of the pasture, i.e., the quantity of forage produced per unit of the surface.

An excessive load (overload) of grazing animals leads to a breakdown of the forage plants due to plants not being able to build their reserves before the next access. Overstocking also causes morphological modifications of plants, which is manifest when they assume a creeping and prostrate habit with the roots arranged more and more superficially (Gusmeroli 2004). In the long term, therefore, excessive grazing pressure on forage plants can change the floristic composition of the pasture with a rapid decrease in palatable species and an increase in non-palatable species. Finally, due to excessive trampling, soil compaction and the formation of paths occur, which can increase erosion (Di Rocco et al. 1992a).

With an undersized load (underload), there is generally greater development of undesirable plant species, usually of poor palatable value, that do not require high fertility of the soil (Di Rocco et al. 1992a). Thus, the animals, having surplus food, concentrate their attention on the best forage, allowing the less appetizing plant species to produce seeds and resulting in a worsening of the floristic quality of the pasture. Finally, at the extreme, the effects of the underload can result in the abandonment of a pasture, which favors the return of forest ecosystems (Potenza and Fedele 2011).

15.1.7 Landscape Evolution in Abandoned Areas

Land degradation is more difficult to quantify in Italy than in other European countries because of widespread differences among Italy's landscapes and pedo-environmental conditions. This means that the application of soil and water conservation systems in Italy needs to be planned with a focus on local conditions. The most important driving forces of land degradation in the south-central Apennines are unfavorable climate conditions, poor soil management, improper land planning, and bad management of agriculture and animal husbandry.

Among the different drivers, poor management of soil in fragile environments (the responsibility of both public administrators and farmers) is the most important cause of soil degradation (Costantini and Lorenzetti 2013).

In the Apennines, significant land cover changes have occurred in the last 50 years, with expansion of forests and re-allocation of the urbanized areas (Borrelli et al. 2014). Changes in rural areas have taken place to promote more effective exploitation of agricultural and livestock areas in the most favorable sites, resulting in a gradual abandonment of hilly and mountainous areas and areas of increased hydrogeological instability to maximize food production and reduce the operational costs. This has led to a general degradation in cropland and livestock grazing quality in high-elevation rural areas (Bracchetti et al. 2012).

Despite rural soils of Molise being covered mainly by forests and permanent meadows, superficial soil erosion and landslides are frequent and are of concern to a large part of the Molise region. Landslides (Magliulo et al. 2008) have affected an area greater than 10% of the total regional surface of Molise (Figure 15.8).

Besides other factors, the anthropic influence on soil erosion by misuse of irrigation water and rainfall has been related to i) destruction of forest cover caused by fire, ii) abandonment of traditional hydraulic agrarian arrangements, especially of terracing, iii) diffusion of more intensively cultivated crops, iv) deep ploughing, and v) diffusion of excessive land levelling and slope reshaping during land preparation for specialized tree plantations. The importance of accelerated soil erosion by water in these soil regions is demonstrated by the fact that many agricultural soils have a low or very low organic matter content in the A horizon. In addition to increasing soil loss, the expansion of the aforementioned practices has caused the loss of the traditional landscape constituted by species diversity and in many cases, has damaged the land's capability and suitability for crops. The driving forces of soil degradation act on different levels: national, regional, municipal, and farm. Therefore, the most effective response to combat land degradation will require integrated policy measures carried out in different spatial frames of reference (Colombo et al. 2011). The land degradation process that causes the most damage in Italy is certainly the irreversible loss of land caused by urbanization and other non-agricultural uses, which often affects the most fertile soils of the plains. Landscape that is more sensitive is mainly located in the upland areas of central Italy and to a lesser extent in the plains, where population density is generally higher. Actually, since the 1980s, the population has increased in moderately vulnerable areas, but it has decreased where there is highly vulnerable land affected by soil degradation and landslides (Torta 2005). At present, among the different ecosystem services that are lost with soil degradation, the diminished capability to produce food is particularly relevant, as it increases the gap between the Italian primary sectors and the primary sectors of other developed countries in terms of food self-sufficiency.

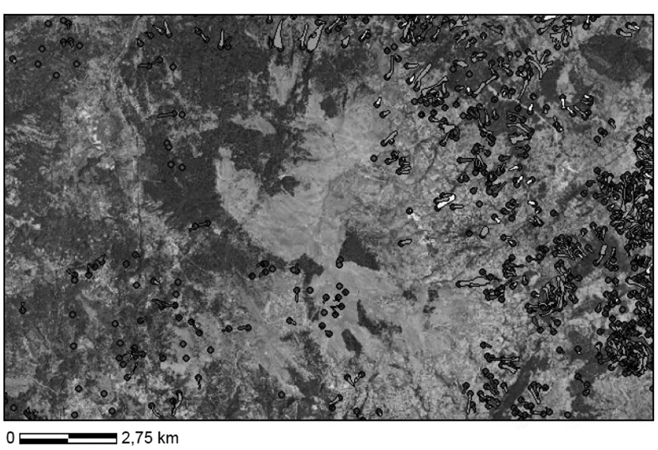

FIGURE 15.8 Map of territories close to Frosolone/Macchiagodena area: different types of landslides, georeferenced by points, are shown in the figure.

15.2 SOUTH-CENTRAL APENNINES STOCKING RATES EVOLUTION

In Europe, the flat land area allocated for cultivation is decreasing as a consequence of providing space for large and constantly expanding cities. The Directorate General of the European Commission recently issued an Annual Activity Report for Agriculture and Rural Development (2016). The report explains that this contraction of the cultivable area is proceeding in proportion to increasing the urban surface, resulting in a real need to intensify the production of primary goods and therefore, food. Furthermore, it is estimated that the demand for food and other agricultural products will increase by 50% between 2012 and 2050 due to factors such as population growth, urbanization, and per capita increases in income (FAO 2017).

In Italy, during the last 30 years, there has been a steady depopulation of the so-called "marginal" mountain areas in favor of the already heavily urbanized flat areas (MacDonald et al. 2000). This process, which led to a contraction of the number of small and medium-sized farms in the area, is also responsible for important economic, environmental, and social consequences. The progressive abandonment of mountain areas leads to a weakening of the entire economic network of the "mountain" (Ievoli et al. 2017) and therefore, of sectors such as agriculture, livestock, recreational activities, and tourism, resulting in an exponential increase in environmental stress. This phenomenon was mainly determined by the difficulties that often characterize agriculture and mountain economic activity because of difficulty in mechanizing agricultural practices, difficulty in finding manpower, difficulties in physically reaching the business centers due to roads often being completely absent, and the inability of small companies to join together to create cooperatives that have a greater resonance in the competitive market compared with small businesses.

Therefore, it is necessary to recover and protect all the "marginal" areas to enhance the touristic and cultural (agritourism) aspects of rural Molise, given the importance of the typical food products of the region (Xosé et al. 2006).

The abandonment of transhumance and pastoralism in the central Apennines, with a consequent reduction in anthropogenic grasslands, took place around the 1950s, with major changes in grazing activities, such as a steep decrease of sheep units of about 30% (Falcucci et al. 2007).

Less Favoured Areas (LFAs), as marginal areas, cover 25% of the European surface, but in the main Euro-Mediterranean countries, namely, Greece, Italy, Portugal, and Spain, there are only 15.2 million ha of permanent grasslands (EUROSTAT 2012). In fact, these four countries show a considerably lower proportion of natural or agriculturally improved grasslands compared with the countries of northern and central Europe (EUROSTAT 2012).

Therefore, given the natural agricultural-livestock vocation of the marginal areas, meadows and natural pastures are increasingly important, because they represent the first source of food supplies for the animals. From the point of view of conservation and environmental protection, the grazing of pastures in mountainous areas of Molise appears to be one of the most effective forms of land use. Efficiently and effectively managing grazing in Molise while minimizing stresses to forages in meadows and pastures can control both degradation and abiotic stresses, such as erosion and hydrogeological instability, and stabilize the equilibrium among humans, their livestock, and their environment (Frattaroli et al. 2014). In fact, both meadows and natural pastures may be able to resist frequent, but moderate, disturbances (i.e., deforestation, fires, and overgrazing) by strategies to ensure sustainable animal production and sustainable ecosystems over several millennia (Plieninger et al. 2010; Zapata and Robledano 2014).

At present, consumers' demand for foodstuffs is mainly for products derived from agro-zootechnical activities whose marketing is directly linked to a positive image associated with the presence of meadows and pastures at high altitudes. On the other hand, as already mentioned, the growing interest in agri-tourism and local and traditional animal products also emphasizes the importance of management of grazing animals to preserve some indigenous plant and animal populations from extinction (Lucchese 1995; Miraglia et al. 2003; Iamarino et al. 2004).

So, pasture is an essential source of food for the welfare of native species and their traditionally obtained products, which offer the consumer unique aromas and dietary components with health-promoting properties (e.g., conjugated linoleic acid isomers). In this regard, different studies have demonstrated that pastures have an influence on the volatile chemical compounds of milk and its derivatives (Bendall 2001; Gaspardo et al. 2009; Coppa et al. 2011). A role of the chemical composition of forage in affecting the fatty acid composition of milk has been demonstrated (Lourenço et al. 2010), suggesting that unsustainable management of grassland not only leads to the onset of degradation of the vegetation and soil, but also contributes to malnutrition and stresses the grazers, with serious repercussions on the production of milk and meat and their compositional peculiarities. Both the nutrient requirements of grazing animals and the sustainability of the pasture are crucial factors in the microeconomics of the fragile LFAs. Different studies have been, and are continuing to be, carried out to assess systems for the evaluation of both pasture productivity and animal needs. According to Morenz et al. (2012), when a model for the prediction of animal feeding behavior, needs, and production is used to determine the stocking rate in a grazing area, it is necessary to verify the adaptation of the model to the characteristics of grazing animals (species and breeds), the climatic conditions of the area, and the type and quantity of plants available to animals. Furthermore, Baudracco et al. (2012) created an animal simulation model, named e-Cow, that predicts herbage intake, milk yield, and live weight in dairy cows grazing temperate pastures with and without supplementary feeding. The use of technology in many agricultural and pastoral practices has made possible increases in the efficiency of production processes while limiting environmental impacts (Zhang and Carter 2018).

In this general framework, it is worth considering that Molise is highly susceptible to landslides and hydrogeological instability due to its complex geological setting, characterized by several different structurally susceptible lithologies. More than 4000 mass movements and incipient erosional processes are known to affect the territory of Molise, despite its limited area, and as consequences of poor landscape management (Pisano et al. 2017). Soil erosion by water and mass movements of soil are still the most widespread forms of soil degradation in many regions of the central Apennines. Landslides and floods, soil organic matter decline, and loss of biodiversity are all linked to erosion by water. Besides reducing soil fertility and stressing plants, erosion by water impairs several other ecosystem services, e.g., quality of cultivable land, value of the landscape, and biodiversity. In this regard, in agreement with Cocca et al. (2012), it should be noted that a loss of cultivable land increases in areas with steeper slope, which are less productive and more difficult to manage but are richer in terms of landscape and biodiversity resources. Therefore, it is crucial to maintain a territorial network of traditional, extensive farms to avoid further landscape deterioration.

The current study aims to evaluate the contribution of pasture management to minimizing the environmental stresses in the two described areas of Molise in the Apennines, i.e., in the municipalities of Montenero Val Cocchiara (Area 1) and Frosolone/Macchiagodena (Area 2). The sustainable stocking rate was assessed and compared with the real stocking rates. The same areas were considered 30 years later to achieve suggestions for the future management of the land. To achieve this purpose, a series of environmental parameters have been used as inputs in a spreadsheet model for the assessment of a sustainable stocking rate with a nutritional approach (Pulina et al. 1999) adapted to the specific conditions of multispecies grazing animals in south-central Italy (Salimei et al. 2001, 2005).

15.2.1 Simulation Model with Nutritional Approach

With this model, considering the different grazing species, the best use of the pasture resource is hypothesized with respect to maintaining or increasing the biodiversity of plants and animals as a basis for supporting organizational decisions at the local level. For the construction of the model (Pulina et al. 1999), stocking rate, expressed as the number of animals per unit of territory and time, is calculated according to the type of animals and their diet, i.e., the dry matter (DM) and energy intake. For sustainable use of the pasture, the maximum availability of forage for each species among grass, shrubs, and trees is considered without compromising the long-term production of the pasture (Tothill and Gillies 1992). Specific areas were defined as portions of the land surface delimited by its intrinsic physical, biological, and socioeconomic characteristics (Sereni 1997), which has a minimum dimension of 100 km^2.

The original model (Pulina et al. 1999) assumes that

- The current state of the pastures is considered in its context through the application of intensity of grazing appropriate to the different vegetative dynamics.
- The feed intake of different animal species must not vary due to the different floristic composition of pastures.
- Feed supplements can be considered as possible inputs within the model.

The resulting stocking rates consider grazing species characteristics such as race, breeding techniques, and production levels (Pulina et al. 1999).

In more detail, the model simulates the livestock stocking rate based on the primary equation, which considers stocking rate (SR) as a function of the surface covered by tree (S_t), shrubs (S_s), and grass (S_g), and it is composed of three modules (Figure 15.9):

1. The forage module, estimating the quantity of forage available for animals
2. The animal module, evaluating the dry matter intake and the nutritive requirements of the animals
3. The stocking rate module, assessing the stocking rate on the basis of data elaborated from the previous two modules (Pulina et al. 1999)

The investigated areas of Molise have been divided into areas (named Grazing Unit Areas—GUAs) homogenous in terms of size, topography, soils, and vegetation cover, as described in the first paragraph of this chapter.

The GUAs represent sub-areas open to grazing by animals in the whole pasture area (Pulina et al. 1999). The module identifies the percentage of the surface covered by grass, shrubs, or trees and establishes the amount of total dry matter available to the animals. Therefore, grass, shrubs, and trees are divided into different heights according to the different animal feeding behaviors (Van Soest 1994; Papachristou 1997). Thus, sheep explore their feeding areas in two dimensions, grazing on grass and on the smaller bushes, while goats and cows move in a three-dimensional space (Figure 15.10).

The area covered by grass, shrubs, or trees is investigated using aerial photography, and inputs are represented by

- The area covered by vegetation (excluding rocks, bare soil, water sources, buildings, and roads)
- The surface occupied by trees and shrubs
- The grass production per hectare (DM/ha) assuming that the hectare is completely covered by vegetation
- The energy content of forages reported for the investigated years (2000–2003) from literature data (Baumont et al. 2000; Freer and Dove 2002; Martin-Rosset et al. 1994; National Research Council 2001)

To limit the problem of overestimation and/or underestimation of the consistency of the pasture, samples were collected using transects delimiting a precise area (Salimei et al. 2005).

15.2.1.1 Animal Module

The animal module calculates animal feed intake and requirements in terms of energy and DM. According to Van Soest (1994), given the different digestibility of feedstuffs and the different feeding behavior, in herbivorous animals, the use efficiencies of the various feeds can be defined as being constant.

In the animal module, the intake values have been calculated according to data in the literature (Baumont et al. 2000; Freer and Dove 2002; Martin-Rosset et al. 1994; National Research Council 2001). Inputs are represented by body weight (kg) of adult males, females, and young, average milk production (kg/d), and average body weight gain (g/d), as well as additional nutrient requirements in the case of late gestation.

15.2.1.2 Stocking Rate Simulations

All inputs described in the preceding paragraphs have been processed by the simulation model to calculate the stocking rate for 180 days of the grazing season per year (Salimei et al. 2005). In more detail, based on the diet and on dry matter intake detected on these two areas, the grassland use was estimated up to the limit beyond which all the vegetation would be compromised in the long term, considering three different stocking rates (minimum, medium, and maximum) up to the point of exhaustion of one of the three forage sources available, arboreal or shrubby or herbaceous, according to Pulina et al. (1999).

15.2.1.2.1 Montenero Val Cocchiara—Area 1

Based on chemical composition data of the pasture of Montenero Val Cocchiara—Area 1, reported in Section 15.1.4, the estimation of the maximum stocking rate (Table 15.3 B) is 1.14 UBA/ha in 2000 and 1.35 UBA/ha in 2001.

In the first year, the effective stocking rate (1.55 UBA/ha) was higher than the maximum stocking rate simulated by the model. Moreover, considering the estimated maximum stocking rate, a significant deficit of the arboreal and shrubby resources was calculated (Table 15.3 C); it was −1109 kg DM

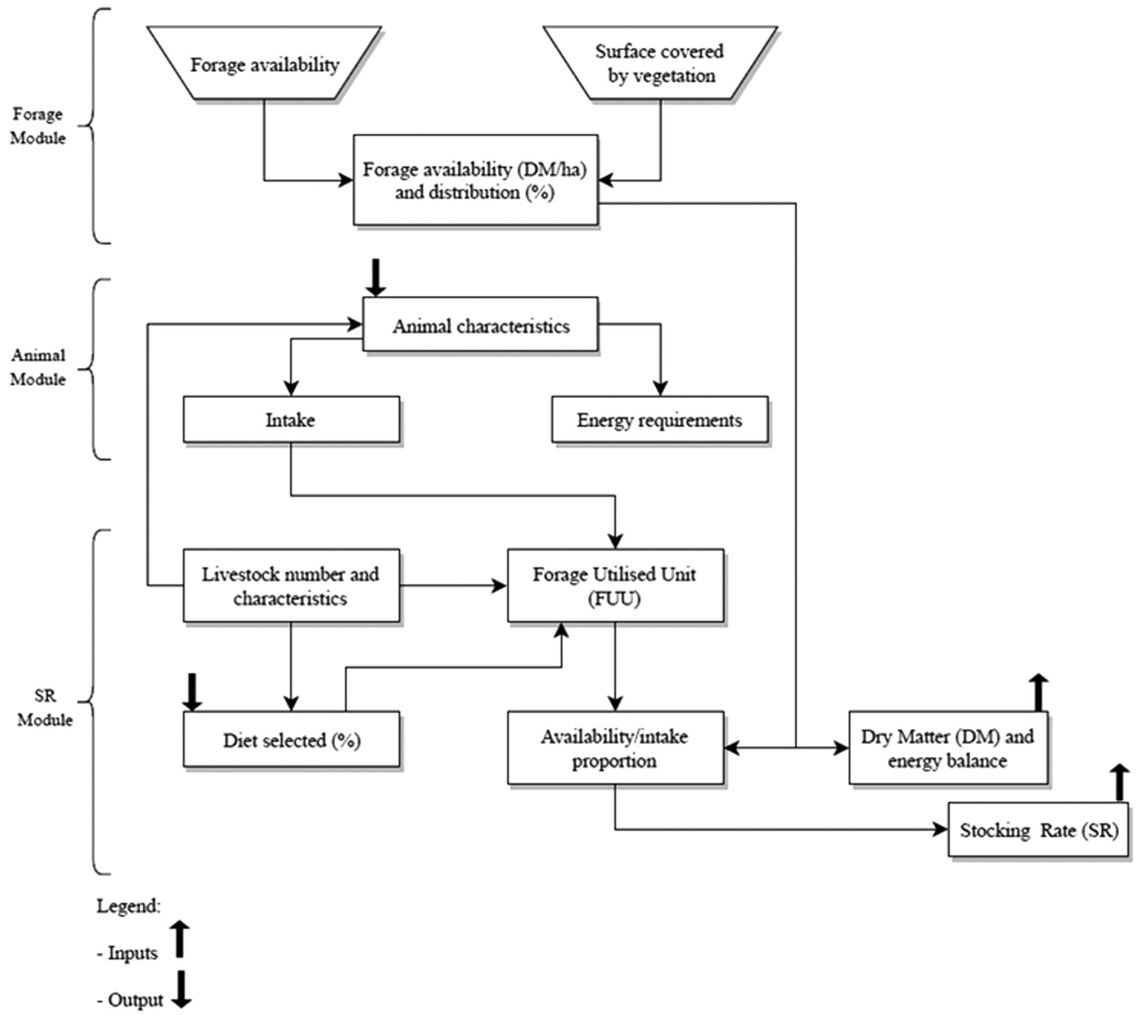

FIGURE 15.9 Flow chart of the three modules. (Adapted from Pulina, G., et al., *Livest. Prod. Sci.*, 61, 287–299, 1999.)

and −1329 kg DM in years 1 and 2, respectively. Due to the significant herbaceous percentage in the grassland (Table 15.3 A), it was not surprising that the minimum stocking rate (Table 15.3 B), estimated considering the complete shrubby (2000) and arboreal depletion (2001), results in an underuse of the herbaceous component (Table 15.3 C).

The simulation model used to evaluate the stocking rate suggests that to reduce stresses to soil and plants due to overgrazing, one must take into account all the management procedures, such as the reduction of stocking rate, the periodic exclusion of the more degraded areas from grazing, and the administration of complementary hay and concentrates.

15.2.1.2.2 Frosolone/Macchiagodena—Area 2

Based on the chemical composition of the pasture of Frosolone/Macchiagodena—Area 2, reported in Section 15.1.4, the estimated stocking rates in 2002 and 2003 (180 days/year) ranged between 0.006 UBA/ha (minimum level) and 1.66 UBA/ha (maximum level, observed in the first year) (Table 15.4 B).

The observed forage availability affected the determination of the maximum estimated stocking rate, 1.66 UBA/ha (Table 15.4 A and B), which was higher than the stocking rate based on measurements (1.16 UBA/ha).

Considering that the data for Area 1 showed an opposite trend in year 1, it is important to highlight not only that overgrazing has negative, stressful effects on soil and grass but also that the reduction of the grazing pressure and the consequent abandonment of the mountain areas can result in dangerous environmental degradation (Nolan et al. 1998). Moreover, considering the maximum stocking rate estimated for the first year, a significant deficit of arboreal and shrubby forage is shown (−1708 kg DM), indicating the need for a careful evaluation and management of the grazing livestock so as not to compromise the arboreal and shrubby resources by excessive grazing stress. Balancing the stresses of foraging animal species on various species of grass, shrubs, and trees can be facilitated by the careful management of both the livestock and the forage vegetation.

In the second year, the arboreal and shrubby resources in Area 2 were scant (−1270 kg DM) (Table 15.4 C). The maximum estimated stocking rate (1.190 UBA/ha; Table 15.4 B), was similar although not identical to the measured one (1.25 UBA/ha).

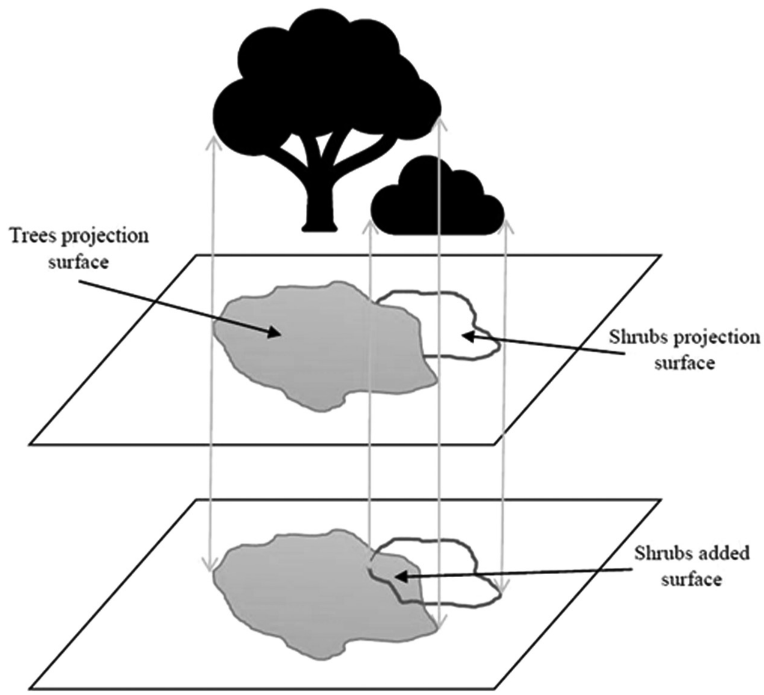

FIGURE 15.10 Volume of forage distribution in area covered by trees and shrubs. (Adapted from Pulina, G., et al., *Livest. Prod. Sci.*, 61, 287299, 1999.)

TABLE 15.3
Area 1: Pasture Stocking Rate and Feedstuffs Deficit Study in the Two Years

	2000			2001		
A	Forage availability:nutritional needs ratio					
	Trees	Shrubs	Grass	Trees	Shrubs	Grass
	0.01	0.01	1.44	0.01	0.01	1.46
B	Stocking rate, UBA/ha					
	max	med	min	max	med	min
	1.14	0.008	0.007	1.35	0.010	0.008
C	Feedstuffs deficit, kg DM					
Trees	−290.5	0.0	0.2	−349.1	-0.5	0.0
Shrubs	−818.5	−0.5	0.0	−980.8	0.0	1.4
Grass	0.0	2472.2	3473.7	0.0	2966.1	2970.4
Total	**−1109.0**	**2471.7**	**3473.9**	**−1329.9**	**2965.6**	**2971.8**

DM: dry matter; UBA: Adult Bovine Unit (24 months).

In times of climate change, the opportunity to have "real time" estimations of forage availability, consistent with the different animal feeding behaviors and adaptations, is of increasing importance for sustainable grassland management.

In conclusion, the stocking rate simulations, based on the field results of two case areas in south-central Italy, highlight the great importance of managing foraging stresses on arboreal and shrubby vegetation to sustainably maintain the forage resources. Climatic data on rainfall and temperature (Figure 15.3 and Figure 15.4) between 1987 and 2017 show a trend for temperature to increase in both Montenero Val Cocchiara—Area 1 and Frosolone/Macchiagodena—Area 2. On the other hand, during the same period, annual rainfall tended to increase in Montenero Val Cocchiara—Area 1 but tended to decrease in Frosolone/Macchiagodena—Area 2. If these trends continue, forage plant species composition and growth in the two areas may differ, requiring differences in management of grazing livestock and the forage trees, shrubs, and grasses in the two areas. An estimation of the arboreal, shrubby, and herbaceous forage availability, together with knowledge of animal feeding behavior, can contribute to better management of grassland in the control of the negative

TABLE 15.4
Area 2: Pasture Stocking Rate and Feedstuffs Deficit Study in the Two Years

	2002			2003		
A	**Forage availability: nutritional needs ratio**					
	Trees	**Shrubs**	**Grass**	**Trees**	**Shrubs**	**Grass**
	0.01	0.01	1.43	0.01	0.01	1.46
B	**Stocking rate, UBA/ha**					
	max	**med**	**min**	**max**	**med**	**min**
	1.66	0.01	0.006	1.190	0.007	0.006
C	**Feedstuffs deficit, kg DM**					
Trees	–429.5	–0.4	0.0	–318.5	–0.1	0.0
Shrubs	–1278.5	0.0	1.1	–951.5	0.0	0.4
Grass	0.0	3899.9	3903.2	0.0	2741.6	2742.8
Total	**–1708.0**	**3899.5**	**3904.3**	**–1270**	**2741.5**	**2743.2**

effects of under- and overgrazing, enabling the preservation of biodiversity and edaphic resources, and vegetation while improving local microeconomies.

15.2.2 Strategies of Land Protection

The environment, climate, and intensity of land use can influence the floristic composition of permanent pasture (Pini et al. 2017). For example, a decrease in the presence of high-quality forage can result in the reduction of the nutritional value of the grassland, its palatability, and useful biomass production. These phenomena can result from alteration of the concentrations of nutrients within the soil that influence the development of one plant species rather than another.

Botanical degradation of the pastures in Molise can be associated mainly with the extensive presence of weeds which cause a decline in the forage quality of the grassland. The botanical degradation of pastures is determined by assessing the proportions of coverage of forage species and weed species. The problem of weeds is greater on permanent meadows and pastures where no rotation is practiced. There are two stages of the development of weeds: in the first phase, therophytes, or annual weeds, develop, while over the years, during a second phase, plants typical of set-aside lands proliferate, tending to reach a balance with the surrounding environment (Di Rocco et al. 1991a). In fact, in such environments, the dynamism is very limited because of the limited human interventions within the system. However, it is essential to clarify the term *weeds*, as a plant can be considered a weed in an annual pasture but not in a perennial one. Therefore, for a perennial pasture, it can be understood that weeds are all those plants that are poor-quality forage, that are not useful for livestock, or at worst, are toxic (Cantele et al. 1980).

Stress on forage can result from unbalanced distribution of a herd of cattle among different areas of a pasture due to factors related to traditional breeding activities or because of infrastructural problems associated with administrative and legal constraints. Due to these and other factors, some pastures can go from being underused and abandoned areas to overgrazed areas. In both cases, the soil is not efficient in terms of production and environmental protection.

A significant problem in reducing biotic stress on forages is the challenge of managing grazing well, based on precise technical-agronomic requirements. The achievement of this aim depends upon moving from poorly controlled and indiscriminate exploitation of resources to unified, qualitative improvement of production to achieve productive and sustainable use of the potentialities of the same landscape (Malandra et al. 2018).

These problems can be overcome thanks to the adoption of a regional plan to enhance the rural resource, which includes a set of regulatory, organizational, technical, and training activities. The objectives of rural resource management plans will differ depending on whether the objective of the plan is to improve public or private pastures (Argenti et al. 2017). In either case, the priority will be to increase the productivity of the pastures both in primary (forage production) and in secondary terms (production of meat, milk, and wool) (Di Rocco et al. 1991c).

In addition, permanent pasture may have an important stabilization effect on soil on steep slopes. Cultivated areas have generally negative effects on slope stability. In the south-central Apennines, natural pasture areas, which are not cultivated, are less prone to landslides when compared with other cover types. Well-managed pastures can help conserve and efficiently utilize soil and water resources on slopes.

The objectives of a grazing management plan to provide economically sustainable livestock production while minimizing stresses on the forage resources may include

- Diffusion of income-management techniques through the application of agronomic techniques, including partial mechanization of cultivation operations, mowing of the pasture, and sizing of the grazing load
- Design of pasture management able to guarantee the stabilization of forage production during the pasturing season

- Forecasting of recovery of high-value areas and risk of degradation
- Monitoring of the rural resource on a regional scale

Another important strategy of permanent pasture protection is the creation of an inventory of the grazing resources through the study of the climatic, geomorphological, pedological, vegetational, agronomic, and socioeconomic aspects that characterize different types of pasture. Based on the data of such an inventory, one can proceed to the classification of areas of study, with the aim of presenting an inventory for quick consultation that highlights the potential, management, and type of conservation area. The purpose of this tool is to evaluate the management of the pasture, to be understood as productive activity, in qualitative and quantitative terms, sustainable over time, and contributing to the effective control of any irreversible degradation processes that occur in specific territories (Dibari et al. 2015).

Considering the characteristics of pastures that influence the qualitative and quantitative values of production (Martin-Rosset 2015; National Research Council 2007), management techniques should guarantee the achievement of the expected production results by meeting the requirements of economic profit, technical feasibility, and ecological sustainability. The management of livestock and forage should also reduce and, if necessary, reverse degradation processes of the resource by implementing specific conservation practices appropriate to the qualities of the territory examined (FAO 1977).

The qualities of LFAs are linked to:

- Climate, expressed in reference to the seasonal risk of drought responsible for the lack of development of the grass in the pastures
- Degree of deepening of the roots and therefore, the soil's ability to support forage plant species
- Vegetation, intended as productivity class and therefore, estimated on the basis of the floristic-vegetational surveys
- Fodder value (palatability) of the forage production, the expression of the extent to which fodder is appealing in the green state
- Management, possibly using mechanization
- Land conservation to counter widespread water erosion risks (rearrangement of surface horizons implies the degradation of the nutritional status of the soil)
- Landslide risks (i.e., pastures in the clayey hills characterized by limited productivity)

In conclusion, to preserve the characteristics of LFAs in marginal mountainous areas, a distinction can be made between ordinary interventions, such as works repeated annually to improve soil fertility, and those of an extraordinary nature, concerning works whose usefulness has a multi-year character.

Examples of ordinary improvements include:

1. Agronomic interventions, such as annual fertilization, weeding, spring mowing, spring rotary tillage, and seeding
2. Zootechnical interventions, such as correct proportioning of the livestock load based on the analysis of the quantitative elements (productivity of the pasture, surface, animals' feed needs, grazing time), qualitative elements (palatability, food value), climate (temperature and precipitation as rain and snow), use (animal species, grazing methods, availability of stocks, distribution of water points and admissions), and physical characteristics of areas being managed (e.g., slope, exposure, degree of coverage)

In contrast, examples of extraordinary improvements include:

1. Creation of production and service facilities (land improvement), such as shelters, drinking troughs, fences, and various infrastructure
2. Improvement of the ecosystem services that were decreased by land degradation; in particular, the capability to produce food, in terms of food self-sufficiency
3. Improvements of soil, such as drainage channels, and stone removal

An important factor for environmental protection and particularly for the protection of mountain pastures is the choice of livestock load on a given pasture.

Knowing the sustainable number of animals that can visit a grazing area enables the establishment of a balance between the productive potential of the forage and its use by the animals, guaranteeing protection against erosion. Therefore, to quantify the load of livestock, we must take into account the many functions that the forage performs.

It is widely demonstrated that in the long term, stresses of different types can cause negative effects on forage and grazing animals in the case of both grazing overload and underload (Di Rocco et al. 1991b). In the first case, there will be a direct negative effect on the animals, which will fail to satisfy their dietary needs, as well as on soil, because it will manifest rapid degradation of the forage and the appearance of erosive phenomena. In this situation, the plants are subject to the stress of high-use regimes that cause a decrease in total production and impede the development of a stable production system. With this is associated the innate feeding behavior of animals, which, when possible, prefer plants that are more palatable, leading to a drastic reduction of the more palatable plants, reducing competitive stress on infesting species of lower nutritional quality, and enabling them to thrive. Other floristic changes tend to occur in overgrazed pastures (e.g., ammonia flora increase: *Pteridium* spp. and Urticaceae family). Another result of overgrazing is the establishment of paths of compacted, denuded soil where grazing animals have created waterlogging of the soil that prevents plant growth (Di Rocco et al. 1991a).

In the second case, however, the negative effects of underload are more associated with the progressive deterioration of the floristic composition of the grasses and forbs. The excessive presence of available forage implies freedom of choice for grazers, resulting in disproportionate stress on high-quality forage and leading to almost exclusive consumption of plants with higher nutritional value. Such selective grazing behavior, resulting in higher stress on more palatable forage, will result in a qualitative decline of the pasture. Selective grazing of high-quality forage in underused pastures can become increasingly frequent if livestock are rotated between highly grazed areas and others infrequently used by livestock.

15.3 CONCLUSIONS

In conclusion, the balanced use of pastures to minimize stress on the forage, while achieving economically profitable and environmentally sustainable animal production, can be achieved by managing the grazing animals to ensure the optimal livestock load. Data on temperature and rainfall at Montenero Val Cocchiara and Frosolone in the south-central Apennines from 1987 to 2017 indicate a gradually increasing average annual air temperature for the two sub-montane grasslands. Gradually increasing rainfall at Montenero Val Cocchiara and gradually decreasing rainfall at Frosolone during the same period suggest that the species composition of forage grown in these two areas may require changes in management in the future. The modeling of stocking rates in the two areas of the present study indicates the importance of managing the stocking rates of cattle, horses, sheep, and goats to sustainably maintain the grasses, forbs, shrubs, and trees of pastures in the south-central Apennines. Our study provides in-depth knowledge that can be useful to manage the abiotic and biotic stresses of grazing under conditions of two gradually changing climatic variables, temperature and rainfall. Best management practices of managing pastures for sustainable production can result in both sustainable economic activity and sustainable ecosystems in Mediterranean regions such as the south-central Apennines.

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