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GIS system and livestock field survey as tools to manage the potential reducing of fuel load for fire prevention

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ABSTRACT

This study would mark the potential role of grazing by Podolian cattle for reducing fuel load of fire prevention and propagation. The interconnection of Geographic Information System (GIS) and livestock field survey allowed to monitor different grazing and no-grazing areas in Basilicata region.
Fifteen grazing areas were monitored for five years during the summer pasture, when the Podolian cattle graze on green grazing areas. These areas were monitored by using GIS system and GPS application. The potential impact of Podolian cattle was monitored for the same time period. The cattle consistency allowed to calculate different parameters: livestock unit, dry matter intake and stocking estimation of potential amount of dry matter intake to understand the removal biomass in order to reduce the fuel load for fire prevention.
The spatial analysis (GIS) showed that there were only four grazing areas burned during the time sampling, compared to the surrounding areas used as control (no-grazing area). Therefore an efficient management of grazing by Podolian cattle could be an important tool to prevent the fire propagation.

1. Introduction

Forest, shrubland biomass and grassland, which are formerly consumed by livestock and harvested by people for a variety of purposes, are increasing with the cease of traditional land use practices due to rural abandonment (Bland and Auclair, 1996; Moreira et al., 2001; Azevedo et al., 2010).

Livestock grazing influences factors that are related to both herbaceous and woody fuel characteristics: amount of herbaceous biomass live/dead fuel mix and continuity of fuel at a patch and landscape scale (Strand et al., 2014). Biomass removal by grazing animals is likely to be one of the most important factors for pasture ecosystem management (Leonard et al., 2010). This is particularly

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true for autochthonous breed, since the animals are well adapted to the environment and highly capable to exploit the available resources, especially in marginal areas.

Podolian cattle is an autochthonous breed reared in South of Italy and adapted to the difficulty of the surrounding environment, such as the poor quality forages available in southern Italian pastures (Musto, 2003; Matassino and Ciani, 2009; Freschi et al., 2013;Musto et al., 2013). This breed is well appreciated not only for these capabilities, but also for meat and milk production. Podolian cattle is the most common breed kept in the hinterlands of Basilicata region (South of Italy), where the animals are generally reared under extensive or semi-extensive conditions (Freschi et al., 2015). This allows the animals to utilize different vegetation layers: forest layer <3 m, shrubland and grassland for all the year (Bianchetto et al., 2009). By prescribed grazing, Podolian cattle may play an important role for a sustainable and ecological management of the available resources, by reducing grass and shrub biomass (Pittroff et al., 2006; Fuhlendorf and Engle 2001). The husbandry of these cattle shows a number of positive environmental effects, such as increased climate stability, improved soil functionality, water quality and footprint and preservation from fires (Freschi el at., 2015).

In this context, Podolian cattle may be used to reduce fuel load, creating a firebreak area (Taylor 2006) (fuel-vegetation break). In fact, as suggested by Davison (1996), browsing and trampling by livestock can impact large fuels range (0.51-2.54 cm diameter).

In the present study, the occurrences of fire in different pasture of Basilicata region were monitored from 2010 to 2014. During the same period, the number of Podolian cattle kept on the same pastures areas was recorded to estimate livestock unit (LU) and their feed intake needs. These data were analyzed by means of Geographic Information System (GIS). This technique allows to locate and analyze objects and events that occur on the earth. There are various software technologies used based on GIS, as well as experiences within forestry sciences based on the management of digital territorial data, in order to process, store, analyze and integrate spatial data to produce information for the government and management of the territory (Masoni et al., 2005). Among the different GIS techniques, grid sampling is useful in survey planning. In this study case, the grid sampling was used to detect and record the fire occurrence in grazing and no-grazing areas, and the potential effect of grazing by Podolian cattle.

2. Materials and methods

2.1. Study site

The study site is Basilicata region (Figure 1), between 40° 30' 00" N latitude and 16° 30' 00" E longitude. The elevation ranges from 0 to 2248 m above sea level. Basilicata receives an average of 799 mm of rainfall per year. The region is characterized by different forest type: deciduous oaks (Quercus cerris L., Quercus Pubescens Willd.), beech forests (Fagus Sylvatica L.), Mediterranean shrubland and other minor species. with an area of 355.409 ha (Costantini et al., 2006).

A part of these forest areas are used by famers as summer pasture for Podolian cattle reared under extensive and semi-extensive system (Freschi et al., 2015).

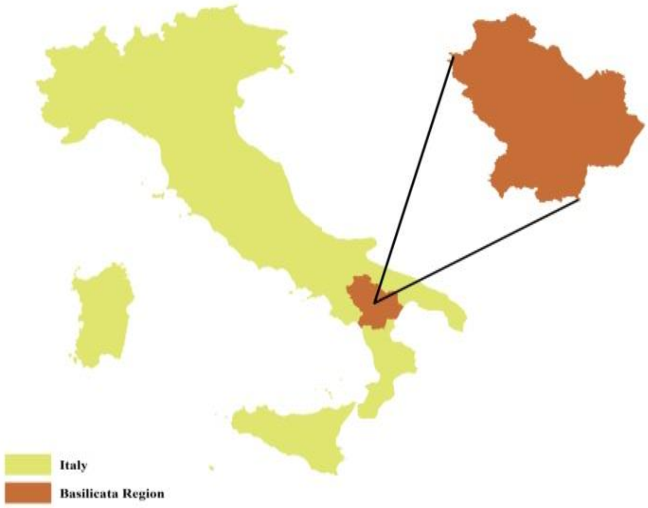

Figure 1. Basilicata Region localization

2.2. Burned areas identification

Fifteen grazing areas, located in 14 different municipalities of Basilicata (Table 2), were chosen using the criterion that the only animals allowed to graze belonged to Podolian breed. These areas were drawn by using open source GIS software. In these areas, the occurrences of fire was monitored for 5 years (2010-2014). The burned areas were recorded by using GPS (Garmin Montana 60T), mapped and classified in two classes: wooded burned area (WBA) and no-wood burned area (NWBA), with the aid of Forest Rangers of Basilicata region government to reach the burned area. The grazing areas and burned areas were analyzed by GIS technique. The extension (ha) of fire damage was measured within and in the surroundings of each grazing areas (no-grazing area) by overlay.

2.3. Livestock production systems and pasture utilization of Podolian cattle

Data (consistency and live weight) on Podolian cattle kept on each grazing area (Figure 2) were obtained in personal interviews with 15 farm operators. The number of animals was used to calculate the number of Livestock Unit, which, according to the European official regulation (Commission Regulation - EC n. 1200/2009), it is defined as follows: 0,0 LU for calves younger than 6 months, 0,6 LU for cattle between 6 months and 2 years, and 1,0 LU for cattle older than 2 years. The Stocking Density (SD) for each area was calculate by dividing the number of LU of each area by the extension (ha) of the same area.

The potential feed intake of Podolian cattle in each area was estimated according to Grenet et al. (1987). Grenet stated that dry matter intake for adult cattle is 14 g DM/kg LW (DM dry matter, LW live weight). While the live average weight (605 kg) was estimated analyzing the weight data reported on farm registers.

The removal of potential biomass by Podolian cattle was estimated by multiplying the feed intake calculated in each area for 120, which is the period (summer season) characterized by highest incidence of fire, as well as the peak of the dry and hot temperatures combined with the lowest rainfall.

Figure 2. Podolian cattle during summer grazing

2.4. Sampling method

A grid 100 m×100 m (1 ha) was constructed (Fishnet tool) and overlaid on the grazing area to identify and record the fire frequency from the fire map. The grids were used as basic sampling unit to detect the fire frequencies, recording the presence/absence (1/0). This grid was also used for surrounding grazing areas, and a buffer area of 300 m (3 ha) was created to quantify the fire presence inside of no-grazing areas. Within each buffer area, no livestock were found during the monitoring time.

3. Results and Discussions

3.1. Fire frequency

The results from GIS analysis showed that only 4 areas (Area 1, 8, 12 and 15) were affected by fire (Table 1 and Figure 3, 4 and 5). In the Area 1 (Abriola/Pignola municipalities), the burned area had an extension of 120 ha in 2011, and 3,35 ha in 2012. In particular, in the grazing area (2011), 25 ha of WBA and 24 ha of NWBA were recorded, with a percentage incidence on the total grazing area of 4,7% and 4,4%, respectively. In the no-grazing area, there were 35 ha of WBA and 41 ha of NWBA, with a percentage incidence on the total no-grazing area (buffer area) 7,5% and 8,8%, respectively. Moreover, in the 2012, 3,35 ha of NWBA were recorded in the grazing area (0,6% of grazing area). In the Area 8 (Ferrandina municipality), in 2012, there were only 5 ha of WBA in the grazing area (1,5% of total area). In the same year, in the Area 12 (Pescopagano municipality), the burned area had an extension of 2 ha of NWBA (0,3% of total of no-grazing area). During 2011, in the Area 15, there were 1 ha of WBA (0,1 % of total grazing area),7 ha of WBA and 3,5 of NWBA (1,8 and 0,9% of total of no-grazing area, respectively). Figures 3, 4 and 5 show the different conditions for all grazing areas that are a support for the spatial analysis reported in the table 1 and 2.

These results show that in the grazing areas, the incidence of fire propagation was very low. The potential effect of removal biomass by Podolian cattle may be useful as a tool to prevent the fire propagation In fact, these breed showed, during the time, a number of positive environmental effects, such as increased climate stability, improved soil functionality, water quality and footprint and preservation from fires (Freschi et al., 2015).

Table 1. GIS spatial analysis of fire monitoring in grazing areas

		2010				2011				2012				2013				2014			
		Grazing area				Grazing area				Grazing area				Grazing area				Grazing area			
Grazing area	Superface (ha)	WBA	%	NWBA	%	WBA	%	NWBA	%	WBA	%	NWBA	%	WBA	%	NWBA	%	WBA	%	NWBA	%
1	539	0	0	0	0	**25**	**4,7**	**24**	**4,4**	0	0	**3,35**	**0,6**	0	0	0	0	0	0	0	0
2	267	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	292	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	274	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	496	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	276	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	135	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	490	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	417	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	680	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	333	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	281	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	337	0	0	0	0	**1**	**0,3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. GIS spatial analysis of fire monitoring in no-grazing areas

		2010				2011				2012				2013				2014			
		No-Grazing area				No-Grazing area				No-Grazing area				No-Grazing area				No-Grazing area			
Grazing area	Surface (ha)	WBA	%	NWBA	%	WBA	%	NWBA	%	WBA	%	NWBA	%	WBA	%	NWBA	%	WBA	%	NWBA	%
1	463	0	0	0	0	**35**	**7,5**	**41**	**8,8**	0	0	0	0	0	0	0	0	0	0	0	0
2	318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	254	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	290	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	276	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	163	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	332	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	328	0	0	0	0	0	0	0	0	**5**	**1,5**	0	0	0	0	0	0	0	0	0	0
9	171	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	532	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	343	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	758	0	0	0	0	0	0	0	0	0	0	**2**	**0,3**	0	0	0	0	0	0	0	0
13	318	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	277	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	394	0	0	0	0	**7**	**1,8**	**3,5**	**0,9**	0	0	0	0	0	0	0	0	0	0	0	0

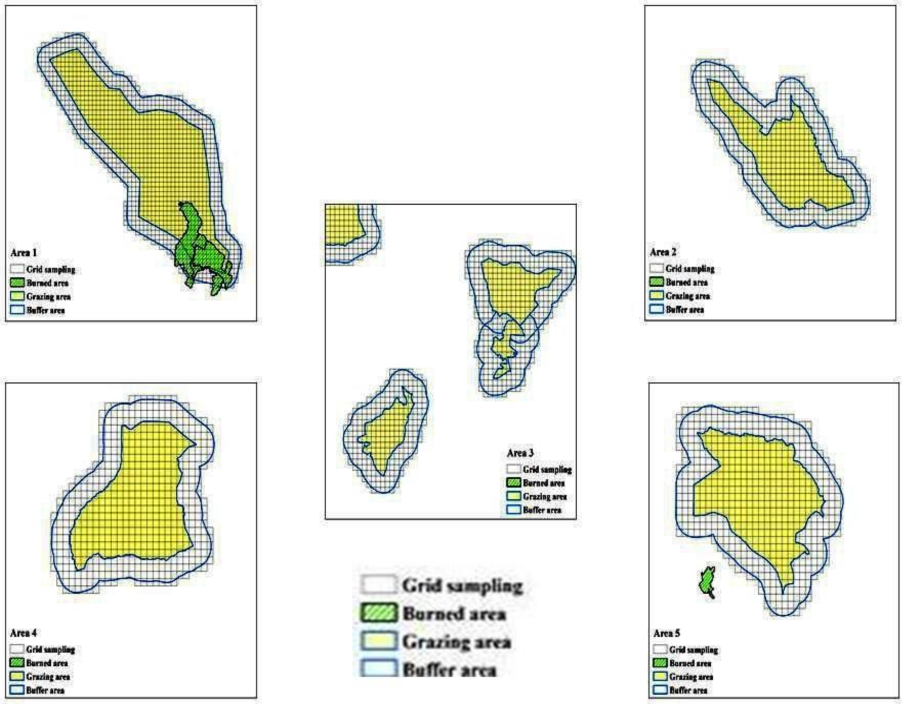

Figure 3. Grid sampling mapping, areas 1 to 5

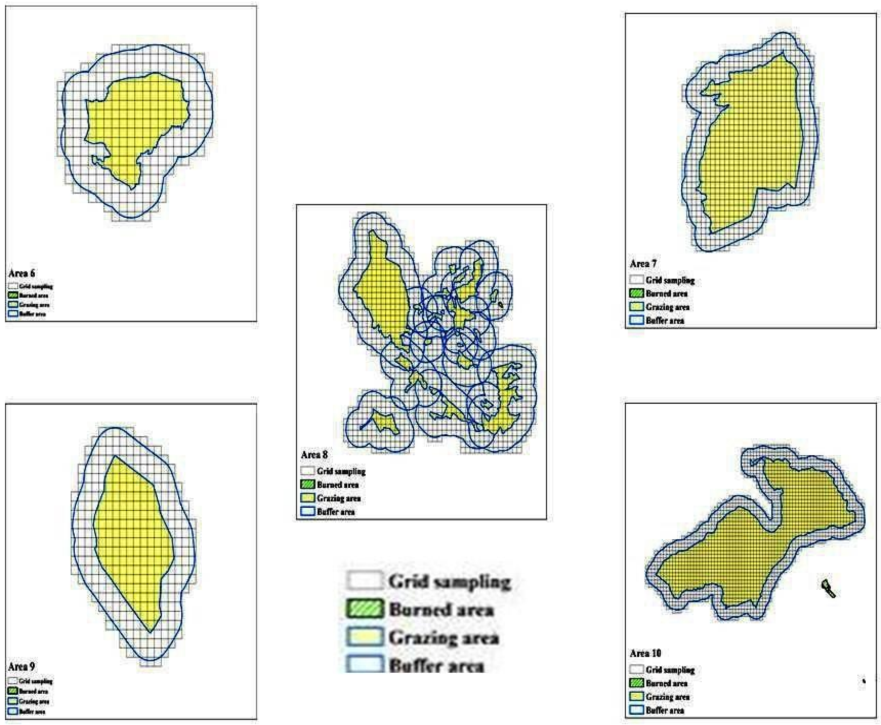

Figure 4. Grid sampling mapping, areas 6 to 10

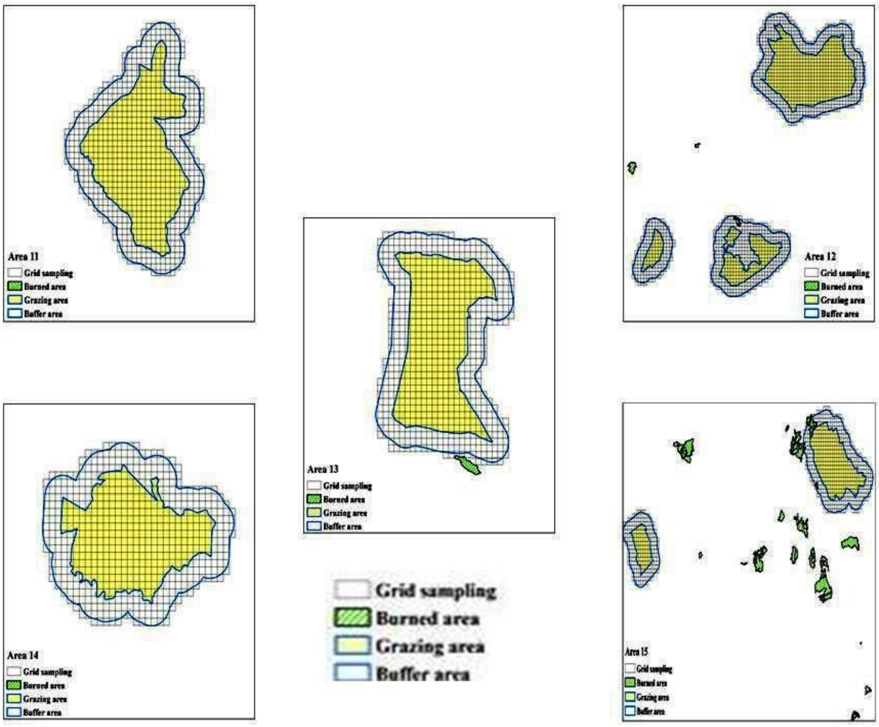

Figure 5. Grid sampling mapping. areas 11 to 15

3.2. Feed intake estimation of Podolian cattle

In Table 3 and 4 are reported the main characteristics of Podolian cattle reared in the areas. Concerning stocking density (SD), in two grazing areas (Area 6 and 9) the parameter was more higher than in the other grazing areas. This was due to both small grazing surface and high consistency of Podolian cattle. SD resulted to be below the threshold values laid down in Nitrates Directive (91/676/CEE). However, it is recommended to keep a low livestock intensity in order to not create overgrazing, which in turn may lead to soil compaction by trampling, reduction of water infiltration, and increased surface run-off and erosion (Freschi et al., 2015)

Moreover, the value of dry matter intake for grazing time (DM) was the highest in 2013 due to substantial cattle turnover. This estimation allowed to understand how the Podolian cattle browsing may be an important tool to reduce the fuel in order to create a horizontal and/or vertical fuel break. In fact, the Podolian cattle may be an interesting tool for fuel reduction, just like goat (Lovreglio et al., 2014). Obviously, this goal should be achieved through appropriate measures, such as the use of metallic or electrified fence in order to maintain an appropriate stocking density, for browsing both the available foliage and twigs from all woody plants and all herbaceous vegetation.

Table 3. Feed intake estimation of Podolian cattle from 2010 to 2012

Potential feed intake of Podolian cattle												
Grazing area	2010				2011				2012			
	CO[1]	LU[2]	DM[3] (kg)	SD[4]	CO[1]	LU[2]	DM[3] (kg)	SD[4]	CO[1]	LU[2]	DM[3] (kg)	SD[4]
1	187	140	141145	0,26	200	150	151227	0,28	167	125	126022	0,23
2	107	80	80654	0,30	133	100	100818	0,37	153	115	115940	0,43
3	253	190	191554	0,65	240	180	181472	0,62	247	185	186513	0,63
4	247	185	186513	0,64	267	200	201635	0,69	260	195	196595	0,67
5	140	105	105859	0,38	160	120	120981	0,44	120	90	90736	0,33
6	140	105	105859	1,05	133	100	100818	1,00	153	115	115940	1,15
7	113	85	85695	0,17	133	100	100818	0,20	167	125	126022	0,25

8	227	170	171390	0,62	240	180	181472	0,65	233	175	176431	0,63
9	180	135	136104	1,00	200	150	151227	1,11	200	150	151227	1,11
10	193	145	146186	0,30	187	140	141145	0,29	173	130	131063	0,27
11	153	115	115940	0,28	160	120	120981	0,29	133	100	100818	0,24
12	160	120	120981	0,18	173	130	131063	0,19	180	135	136104	0,20
13	227	170	171390	0,51	240	180	181472	0,54	213	160	161308	0,48
14	100	75	75613	0,27	107	80	80654	0,28	133	100	100818	0,36
15	253	190	191554	0,56	240	180	181472	0,53	233	175	176431	0,52
Total	**2680**	**2010**	**2026436**		**2813**	**2110**	**2127254**		**2767**	**2075**	**2091967**	

[1]CO= Consistency
[2]LU= Livestock unit
[3]DM= Dry matter intake for grazing time [14 g of DM/LW (dry matter/ live weight)]
[4]SD= Stocking density per hectare

Table 4. Feed intake estimation of Podolian cattle from 2013 to 2014

Grazing area	Potential feed intake of Podolian cattle							
	2013				2014			
	CO[1]	LU[2]	DM[3] (kg)	SD[4]	CO[1]	LU[2]	DM[3] (kg)	SD[4]
1	200	150	151227	0,28	213	160	161308	0,3
2	133	100	100818	0,37	133	100	100818	0,4
3	240	180	181472	0,62	247	185	186513	0,6
4	260	195	196595	0,67	253	190	191554	0,7
5	160	120	120981	0,44	133	100	100818	0,4
6	140	105	105859	1,05	133	100	100818	1,0
7	133	100	100818	0,20	133	100	100818	0,2
8	233	175	176431	0,63	233	175	176431	0,6
9	207	155	156267	1,15	207	155	156267	1,1
10	187	140	141145	0,29	173	130	131063	0,3
11	160	120	120981	0,29	147	110	110899	0,3
12	173	130	131063	0,19	173	130	131063	0,2
13	240	180	181472	0,54	240	180	181472	0,5
14	120	90	90736	0,32	107	80	80654	0,3
15	240	180	181472	0,53	227	170	171390	0,5
Total	**2827**	**2120**	**2137335**		**2753**	**2065**	**2081886**	

[1]CO= Consistency
[2]LU= Livestock unit
[3]DM= Dry matter intake for grazing time [14 g of DM/LW (dry matter/ live weight)]
[4]SD= Stocking density per hectare

4. Conclusions

The GIS spatial analysis could be a tool for the improvement and development of “fireman profession”. In fact, the application of these advanced software systems (GIS tools) may optimize the State Forestry Corps management interventions.

Concerning grazing, the prescribed grazing with Podolian cattle can reduce the fuel load of shrublands, grassland in the short term by partially reducing woody fuels. Moreover, livestock grazing may reduce fire ignition potential and spread by removing live and dead herbaceous vegetation and accelerating litter decay through trampling. However, the stocking density should not excessive in order to manage the pastureland and to reduce the fire propagation.

Grazing can increase the propensity for fire to spread because the herbivores selectively remove green biomass and thereby increase the proportion dead to live biomass. Other limitations of grazing application for firefighting are directly related to weather and orographic conditions. In fact, under extreme burning conditions, (low fuel moisture and relative humidity, high temperature, wind speed and slope conditions), wildland fires are driven by weather conditions rather than by fuel characteristics and the positive effect of grazing on fire propagation may be nullified.

For these reasons, the relationship between GIS system and field livestock survey maybe useful for improving fire protection in Mediterranean areas like those of Basilicata region.

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