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ABSTRACT - The research aimed to evaluate the performance (in terms of energy) of livestock farms located in a Mediterranean mountain area and characterized by different stocking rates. Farm data were collected from in-person interviews of farmers of 58 farms representative of the livestock farms of the Madonie and Nebrodi mountains area (Sicily, Italy), including several parameters related to farm characteristics, animal, crop and pasture management. The farm parameters were used to calculate input and output energy values from which agroecosystem performance indicators were derived. Increasing stocking rate corresponded to a more than proportional increase in total inputs per unit area because of a greater farm dependence on external energy sources derived from agriculture (mainly for concentrate feed) and to a lower energy use efficiency. The indicator of dependence on non-renewable energy sources was, on average, very low irrespective of stocking rate. As stocking rate increased the farm autonomy indicator fell and the immediate removal indicator increased. Overall, the best agroecosystem performance in terms of energy was found on farms with lower stocking rates, higher proportions of permanent pastures to total farm area, and longer periods of exclusive grazing.

Key words: Energy efficiency, Agroecosystem performance indicators.

Introduction - In agriculture, the use of non-renewable energy increases the negative impact on the environment as it contributes to the increase in greenhouse gases (GHGs). A reduction of GHG emissions can be achieved by increasing the use of renewable energy sources and/or by increasing energy use efficiency (Corré *et al.*, 2003; Meul *et al.*, 2007). Data acquisition on energy use in different agroecosystems is the necessary base to assess the impact of human activity upon the environment (Giampietro *et al.*, 1994) and to design more environment-friendly farming practices. To reach these goals, it is necessary to have appropriate indicators that, synthesizing the system characteristics, allow the comparison in time and space of different cultivation and farming systems and the evaluation of the sustainability level of a farm's activity, thereby allowing the identification of strategies and techniques with low environment impact. This research aimed to evaluate the performance (in terms of energy) of livestock farms located in a Mediterranean mountain area and characterized by different levels of intensification as expressed by stocking rate. For this purpose, we used the agroecosystem performance indicators (APIs) proposed by Tellarini and Caporali (2000), which represent an instrument for studying agroecosystem functioning and performance according to an input/output approach.

Material and methods - The study was performed in 2005 in the area of the Madonie and Nebrodi mountains (Sicily, Italy), which is situated between 37°47′ N and 38°00′ N and 14°09′ E and 14°28′ E. The climate of the area is sub-humid Mediterranean, characterized by a four-month dry period (June–Sept.), with an annual mean precipitation of 800 mm and an annual mean temperature of 14°C. Agriculture is characterized by natural pasture-based extensive farming. Based on information obtained from local advisors, 58 farms (located between 250 and 1300 m a.s.l.) were selected. These farms were considered representative of the livestock farms of the area and consisted mainly of half-breed suckler cows (Modicana, Limousine, and Charolais) and calves born on the farm and bred for 8–16 months. Farm data were collected from in-person interviews of farmers and included the following: farm characteristics (altitude, farm area, machines, equipment, buildings, water supply, etc.); animal management (livestock type and number, live weight for each animal category, grazing length in days and housing, and hay and concentrate feed supplements); and crop and pasture management. The farm parameters recorded at each farm were used to calculate direct (fuels, electricity, and natural gas) and indirect (fertilizers, seeds, pesticides, concentrates, forages, machines, etc.) farm input and output (milk, meat, forage, grain, etc.) for energy use analysis. The energy values of inputs and outputs were based on scientific literature. Energy use efficiency was estimated by means of some APIs, following the methodology of Tellarini and Caporali (2000): 1) total farm input indicator (Gj obtained from the production process per Gj, from any source, introduced into the system); 2) total internal input (ratio of total output to internal input); 3) total external input (ratio of total output to external input); 4) Dependence on non-renewable energy sources (ratio of input produced by non-renewable sources to total input); 5) farm autonomy (ratio of input produced on the farm to total input); 6) immediate removal (ratio of output destined for final consumption to total output). The farms were grouped according to stocking rate as follows: L<0.75 LU ha^{-1}, M 0.75–1.50 LU ha^{-1}, and H>1.50 LU ha^{-1} (LU, 1 Livestock Unit=500 kg live weight). The results were tested for significance using the PROC GLM procedure (SAS, 1996).

Results and conclusions - The main characteristics of the three groups of farms are described in Table 1. The M and H farms had similar total farm areas (on average 37 ha), and the most extensive farm type (L) was the largest. The land use was markedly different in relation to farm stocking rate: as stocking rate increased the incidence of permanent pastures decreased and the incidence of forage crops increased . The farm area of winter cereals (mainly durum wheat and barley) increased from the L to H farm type; these crops are used on cattle farms to produce straw (for feed and litter) as well as grain. Woodland covered 11% of the L farm areas and was absent in the H farms.

As the farm stocking rate increased, a shorter period of exclusive grazing and a greater feed offer (hay and concentrates) was recorded. Increasing the stocking rate resulted in a more than proportional increase in total inputs per unit area (Figure 1) because of a greater farm dependence on external energy sources derived from agriculture (mainly for concentrate feed). In addition, outputs increased as the stocking rate increased whereas the relevant proportion of internal

Table 1. Main structural and livestock management parameters for the three groups of farms.

		Stocking rate (LU ha^{-1})			P level of significance[1]		
		< 0.75	0.75–1.50	> 1.50			
		L	M	H	L *vs* M	L *vs* H	M *vs* H
Farms	no.	32	19	7			
LU ha^{-1}		0.53	0.99	2.36	< 0.001	< 0.001	< 0.001
Total farm area	ha	172.0	40.2	34.4	< 0.001	0.018	ns
Permanent pastures	%	77.7	60.8	29.4	0.016	< 0.001	0.004
Forage crops	%	7.6	22.9	48.2	< 0.001	< 0.001	< 0.001
Cereals	%	4.1	11.7	22.4	ns	0.002	ns
Woodland	%	10.6	4.6	0.0	ns	0.044	ns
Only grazing	d year^{-1}	257.7	199.2	44.7	0.004	< 0.001	< 0.001
Stalling	d year^{-1}	54.6	95.5	192.4	0.012	< 0.001	< 0.001
Hay	kg LU^{-1} d^{-1}	1.40	3.07	5.20	0.003	< 0.001	0.014
Concentrate feed	kg LU^{-1} d^{-1}	0.84	1.76	5.51	0.037	< 0.001	< 0.001

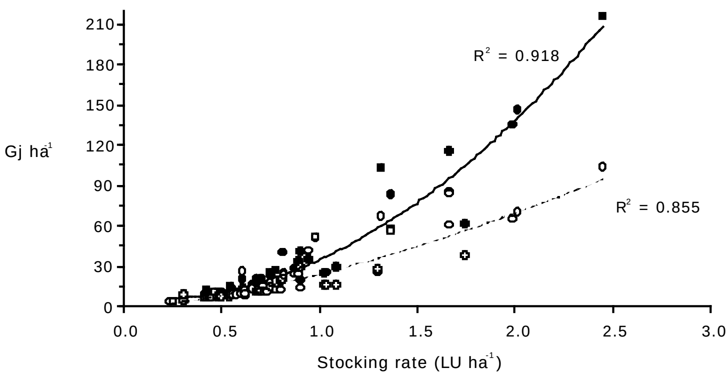
[1]*ns: P>0.05.*

Table 2. Main structural and functional indicators (Gj Gj^{-1}) for the three groups of farms.

	Stocking rate (LU ha^{-1})			P level of significance[1]		
	<0.75 L	0.75–1.50 M	>1.50 H	L *vs* M	L *vs* H	M *vs* H
Total farm input	0.83	0.75	0.57	ns	<0.001	0.022
Total internal input	1.42	1.57	2.14	ns	0.004	0.032
Total external input	2.02	1.67	0.82	ns	ns	ns
DoNES[2]	0.04	0.07	0.04	ns	ns	ns
Farm autonomy	0.60	0.50	0.32	0.021	<0.001	0.005
Immediate removal	0.28	0.33	0.42	ns	0.009	ns

[1]*ns: P>0.05;* [2]*Dependence on non-renewable energy sources.*

Figure 1. Relation between total energy inputs (solid circle and solid line), total outputs (open circle and dotted line), and stocking rate.



transfer decreased. The total farm input indicator was, on average, 0.72, which is similar to the findings of other studies (Ferrière *et al.*, 1997; Risoud and Chopinet, 1999). The group of farms with the higher stocking rate showed a significantly lower efficiency compared with the other two groups (Table 2).

The indicator of dependence on non-renewable energy sources was, on average, very low and the differences between the farm groups were not significant. With the increase in stocking rate, the farm autonomy indicator fell and the immediate removal indicator increased. In other words, the global indicator of voluntary re-use was significantly higher for L farms (60% reuse) than H farms (32%). Thus, energy efficiency can be increased by increasing the level of internal transfer. Furthermore, the autonomy indicator was positively related to the efficiency of performance of external input, showing that external inputs decrease as the efficiency with which they are used increase. Overall, the best agroecosystem performance in terms of energy was found in farms with a lower stocking rate, a higher proportion of permanent pastures in relation to the total farm area, and a longer period of exclusive grazing.

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