5.12 ENERGY AND CO_2 EXCHANGES OF A MEDITERRANEAN SHRUBLAND ECOSYSTEM

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1. INTRODUCTION

Net ecosystem exchanges (NEE) of ecosystems and biomass are controlled and modulated by environmental variables, which affect energy and carbon fluxes on daily, seasonal, annual, and interannual temporal scales (Law et al., 1999). Ecosystem carbon fluxes respond differently to environmental forcing variables according to physiological characteristics of the ecosystem vegetation (Baldocchi, 2004; Haszpra et al., 2005; Kosugi et al., 2005).

Most long term carbon flux researches are conducted on temperate conifers and broad-leaved deciduous and evergreen forests, tropical and boreal forests. Few studies concerned over shrubland ecosystems such as Mediterranean maquis, even though maquis represents an important natural biome in temperate areas for its ecological role and biodiversity. In addition, Mediterranean ecosystems are extremely vulnerable because of their small extent, drought, and anthropogenic disturbance.

More information is needed on micrometeorological and ecophysiological control on the carbon balance of a maquis ecosystem in the Mediterranean basin. The main features are that the CO_2 uptake by the vegetation occurs predominantly in the spring and fall depending on rainfall. During the summer drought, latent heat (LE) and photosynthetic fluxes are suppressed. The water use by the vegetation is low all year and the energy balance is dominated by upward sensible heat flux.

The main objectives of this paper are to (i) describe the diurnal and seasonal variation in the energy fluxes of a Mediterranean shrubland ecosystem, (ii) assess the dynamics of CO_2 fluxes, and (iii) investigate the relationship between NEE and environmental variables.

2. MATERIALS AND METHODS

Field observations were taken near west coast of Sardinia, Italy (latitude: 40º 36' N; longitude: 8º 9' E; elevation: 50 m), over shrub vegetation for several periods during 1998-2005. Vegetation included sclerophyll species and some scattered shrubs of a maximum height of 2.0 m. The climate is semi-arid with a significant water deficit from May through September. The long-term (1961-1990) mean annual temperature and the mean annual precipitation values from a nearby weather station are reported in Table 1.

Fluxes of momentum, sensible heat, latent heat, and CO_2 were measured using an eddy covariance system consisted of a 3D sonic anemometer and a closed-path (1998-1999) and an open-path IRGA (2004-2005) mounted over the vegetation at 3.5 m from soil. Fetch was about 0.8 km to the northwest towards the nearby sea. All flux and meteorological data were quality-controlled. Gaps in the data were filled following the procedures reported by Falge et al. (2001) and Reichstein et al. (2005). In addition, net radiation (Rn) and soil heat flux density (G) were measured with a net radiometer and soil heat flux plates. Soil temperature was measured with thermocouples above the heat flux plates to correct G for heat storage above the plates. Air temperature and relative humidity data were collected with a shielded platinum resistance thermometer and a capacitance based humidity sensor. Rainfall was recorded with a tipping bucket rain gauge and volumetric soil water content was measured at 0.2 m depth using a time domain reflectometry (TDR) probes.

LAI values, estimated using LI-2000 under diffuse light conditions, showed small seasonal fluctuations. It was about 2.5 in 1999 and ranging from 2.7 in winter and 3.0 in summer during 2004-2005 period.

Tab. 1. Climate data from a nearby weather station and mean annual air temperature (T air), total annual amount of rainfall (P) and solar radiation (Rg) observed during the experimental period.

	climate	1998	1999	2004	2005
T air (°C)	15.9	15.7	15.9	16.6	15.8
P (mm)	588	578	495	556	562
Rg (MJ)		6521	5376	5663	5740

3. RESULTS AND DISCUSSION

Meteorological data locally measured at the flux tower are reported in Table 1. Figure 1 shows the daily solar radiation, daily mean temperature, daily total rainfall and the daily volumetric water content. There were no significant differences in temperature all over the years, except for the 2004 where mean T air was quite higher than climate, and in solar radiation among years 1999-2004-2005. The year 1998 showed higher values of Rg in summer.

The energy budget closure from half-hour eddy covariance data was acceptable with an average (H+LE)/(Rn–G) ratio approximately equal to 0.86 for the 1998-1999 measurements and 0.92 for the 2004-2005 period. The energy partitioning exhibited distinct seasonal pattern with Bowen ratio values clearly decreasing during the drought season (Table 2).

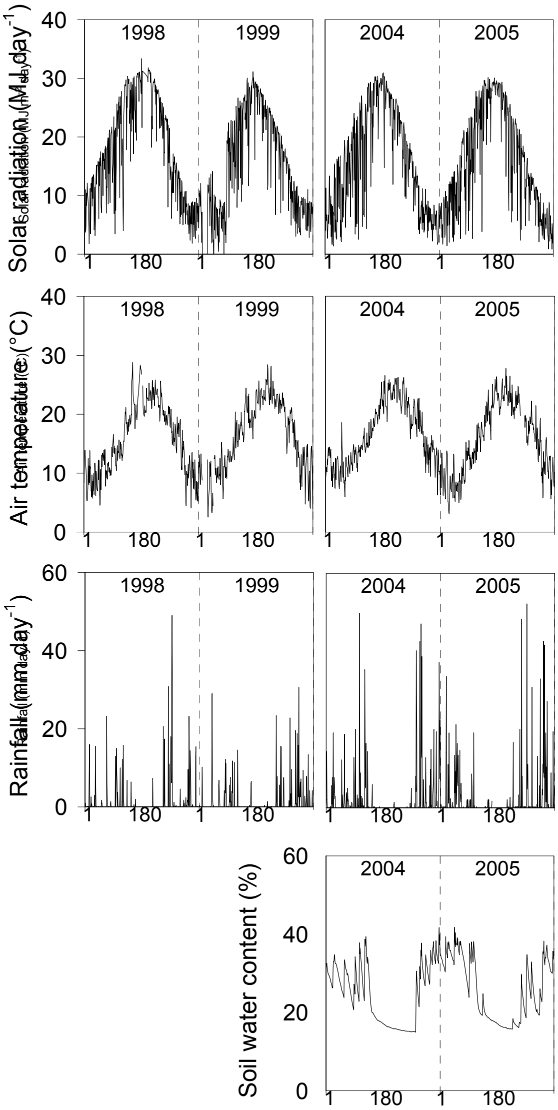

Fig. 1. Daily solar radiation, daily mean temperature, daily total rainfall and the volumetric water content measured in the experimental site.

Figure 2 shows the temporal variation of daily net carbon exchange (NEE) between the ecosystem and the atmosphere. The typical daily net exchange was -1.2 g C m^{-2} but it reached –3.0/-4.5 g C m^{-2} in some days. Peak daily CO_2 uptake occurred during spring (about 2.5 g C m^{-2}) showing a clear decrease in summer and fall (0.8 g C m^{-2}). In general, the sign of NEE remained negative (uptake) for about 160 days in each year and changed back to positive (source) during the rest of the year.

The ecosystem was generally a source of carbon in fall (Table 3) while the C uptake mainly occurred in spring. However, NEE was mainly negative in winter and summer in dependence on the rainfall distribution and the temperature regime.

Tab. 2. Variation in monthly Bowen ratio (β) values.

	Bowen ratio (H/LE)			
	1998	1999	2004	2005
J		-2.67		0.00
F		0.40		0.20
M		1.27		1.71
A	2.19	2.12	1.24	1.39
M	1.77	2.68	1.49	2.24
J	3.90	3.61	3.20	3.49
J	7.15	4.87	4.70	6.88
A	5.90	6.02	8.90	4.23
S	2.21	1.79	7.15	2.68
O	0.27	1.27	1.73	0.93
N	-0.50	-1.76	-0.26	-0.18
D	-0.76	-2.06		-0.59

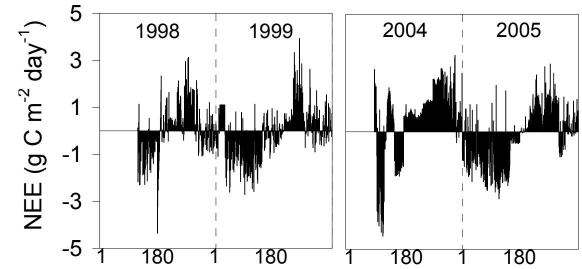

Fig. 2. Daily net ecosystem exchange (NEE) for the 4-years measurement period.

Gross primary production (GPP) and total ecosystem respiration (R_{eco}) were determined using the soil temperature dependent respiration function. Figure 3 shows the monthly values of carbon GPP, NEE, and R_{eco} for the years during the measurement period. The differences among years are important features of the variables, which can be partially explained by meteorological conditions. The monthly fluctuations showed a wider range in GPP and R_{eco} during the 2004-2005 experimental period.
The forcing factors on ecosystem processes were analysed at seasonal scale. Relationships were found between rainfall amount and GPP in spring and fall (Fig. 4). No clear effect of air temperature on GPP and R_{eco} was found. The GPP/R_{eco} ratio varied between -0.475 (2004) and -0.797 in fall (1998) and -1.3 in spring (all years).

4. CONCLUSIONS

The first results show that the maquis ecosystem can assimilate (spring) and release (fall) carbon at the same average rate with a total seasonal C uptake or release of about ±0.95 Mg C ha^{-1}. The mean net ecosystem production during the four years was about 0.5 Mg C ha^{-1} yr^{-1}. In general, NEE was relatively low compared to other forest ecosystems.

Tab. 3. Net ecosystem exchange (NEE), gross primary production (GPP) and total ecosystem respiration (R_{eco}) at the experimental site.

		NEE	R_{eco}	GPP
	SEASON	(g C m^{-2} month^{-1})		
1998	W			
1998	S	-38.56*	108.59*	-147.15*
1998	S	-17.41	150.43	-167.83
1998	F	67.60	333.37	-265.77
1999	W	-36.30	97.09	-133.38
1999	S	-102.50	292.17	-397.02
1999	S	5.77	197.84	-192.08
1999	F	73.20	286.99	-213.79
2004	W			
2004	S	-98.18*	323.08*	-424.63*
2004	S	-4.16	587.54	-591.85
2004	F	152.38	300.00	-142.54
2005	W	-6.03	226.30	-232.46
2005	S	-148.97	585.84	-739.83
2005	S	37.11	353.14	-314.96
2005	F	84.36	279.88	-192.69

*(data for March were not available)

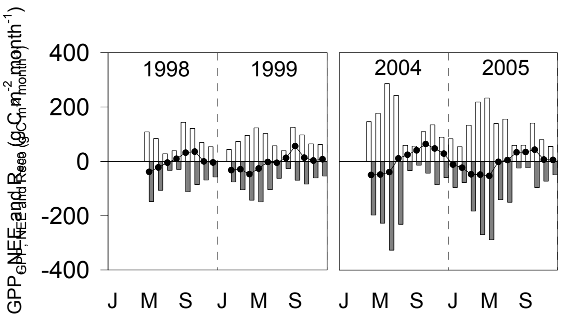

Fig. 3. Monthly values of GPP, NEE and R_{eco} for the experimental period.

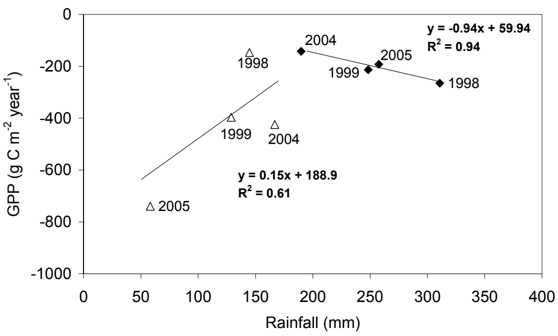

Fig. 4. Relationship between GPP and rainfall in spring (empty triangle) and fall (filled diamond).

5. REFERENCES

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