No. B-1.3.4 Quantitative Analysis of Carbon Cycling in Pasture

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Abstract An attempt is being made to measure the flow rates of carbon pathways and CO_2 gas fluxes in grazing pastures to clarify the mechanism of carbon cycling.

Production rates of pasture plant roots were higher during the spring. And the decomposition rates were approximated by a function of soil temperature.

CO_2 gas fluxes in grazing pastures were measured directly by eddy correlation method. In the daytime, CO_2 absorption fluxes to grassland (downward) were observed and on the contrary at night CO_2 emission fluxes to atmosphere (upward) were observed.

In 1993, the amount of CO_2 absorbed by grassland were larger than the amount of CO_2 emitted to atmosphere per diem during the measuring period in spite of cool summer and less solar radiation. In 1994, we obtained the reverse carbon budgets especially on very hot days, which resulted from the different fluctuation pattern of the CO_2 gas fluxes. But the amount of CO_2 absorbed by grassland were larger than the amount of CO_2 emitted to atmosphere per diem as observed in 1993 on many days during the year.

Therefore it is suggested that grassland has possibility of being a sink of carbon.

Key Words Pasture, Carbon Budget, Pasture Plant Root, CO_2 Gas Fluxes, Eddy Correlation Method

1.Introduction

Atmospheric concentrations of greenhouse effect gases such as carbon dioxide and methane had been balanced in the global ecosystem. But its balance has been upset by the human activities such as consumption of fossil fuel, felling of forests and farming. Now the atmospheric concentrations of CO_2 and other trace gases that induce climate warming are increasing year by year.

It is said that grassland occupies 41% of terrestrial area except polar regions[1]. And the carbon storage by grassland is considered higher than other ecosystems as reported about introduced deep-rooted grasses in the South American savannas[2].

So it is necessary to clarify the mechanism of carbon cycling in the grassland ecosystem to know whether grassland is a sink or a source of carbon. It is also necessary to evaluate how much the climatic changes will influence the carbon budget of grassland ecosystems.

2.Research Objective

In this study, an attempt is being made to measure the flow rates of carbon pathways in grazing pasture to make a simulation model of carbon cycling. By using this model,the carbon budget of pasture and its contribution to climate warming will be clarified.

Moreover, CO_2 gas fluxes in grazing pastures are directly measured to evaluate the carbon budgets between atmosphere and grassland.

3.Research Method

An outline of the experimental field:

Experiments are continued in grazing pastures at Experimental Field of Grassland Eco-System in Fujinita Hill located in National Grassland Research Institute. Fujinita Hill is about 340m high above sea level. Forests are remained at its northern slopes. *Miscanthus sinensis* and *Pleioblastus Chino* grassland and artificial pastures are on the southern slopes. At this pastures, rotational grazing experiments by using cattle have been executed for about twenty years.

(1)To obtain the data required to analyze the carbon flows of grazing pasture, biomass of herbage, root biomass, amount of litter and amount of herbage intake etc. were measured regularly. And the soil respiration rates were measured by the sponge absorption method$^{3)}$ simultaneously when gas fluxes were measured.

(2)To measure the CO_2 gas fluxes directly in grazing pastures, an ultrasonic anemometer and a CO_2–H_2O fluctuation meter are settled above the vegetation. Fluctuations of wind speed, wind direction, temperature, atmospheric carbon dioxide concentration and water vapor content were measured. Those turbulent fluctuation data were sampled in 10 Hz and gas fluxes were calculated every 10 minutes.

4.Results and Discussion

(1)Measurements of root production rates and root decomposition rates

Carbon cycling in grassland ecosystem is intensively influenced by soil carbon dynamics. It is reported that root biomass are maximized in May and minimized in September and October and gradually increase again in winter$^{4)}$. We took notice of the role of roots as a source of carbon supply to grassland ecosystem and measured root production rates and root decomposition rates.

a. Root production rates

Root production rates are measured once a month at the center of *Festuca arundinacea* stumps and at intervals between stumps. Production rates increased to 2 gDW/m^2/day from April to June and decreased to 0.6 gDW/m^2/day in September (Fig.1).

b. Root decomposition rates

Roots were buried in the ground and dug out every month to measure the loss weight. Root decomposition rates (RDR) were approximated by a function of soil temperature (Fig.2) as follows.

$$RDR=0.00267-0.0005*X \quad (X : \text{soil temperature,℃})$$

(2)Measurements of CO_2 gas fluxes in grazing pasture

Fig.3 shows some observed examples of time variation of CO_2 gas fluxes, air temperature, solar radiation, latent heat and sensible heat in grazing pastures measured directly by eddy correlation method. CO_2 gas fluxes are also corrected by using Webb's equations[5)] for density effects (represented by dotted lines). Each flux indicates positive values when it is transported upward except solar radiation.

a. Observed CO_2 gas flux examples in 1993

We had cool summer and less solar radiation in 1993.

CO_2 gas fluxes are dependent mainly on solar radiation, air temperature and wind speed. We observed the typical time variations in both days.

In March, it was a fine day and CO_2 gas fluxes were transferred downward in the daytime, which means that CO_2 gas was absorbed and fixed to vegetation vigorously. On the contrary at night, CO_2 gas fluxes were transferred upward to atmosphere by plant respiration and soil respiration. Fluctuation of CO_2 gas fluxes in the daytime was larger than ones at night. In this period, mean CO_2 absorption fluxes to grassland in the daytime was 0.21 $mg/m^2/s$ and mean CO_2 emission fluxes to atmosphere was 0.06 $mg/m^2/s$.

In June, fluctuation of CO_2 gas fluxes was smaller than ones in March because it was a cloudy day, but time variation of fluxes shows a similar tendency. In this period, mean CO_2 absorption fluxes to grassland in the daytime was 0.03 $mg/m^2/s$ and mean CO_2 emission fluxes to atmosphere was 0.04 $mg/m^2/s$.

b. Observed CO_2 gas flux examples in 1994

We had record-breaking hot summer in 1994, which is in marked contrast to the previous year.

In June, fine days continued during the measurement period. Each fluxes indicated typical time variation. At night, CO_2 gas fluxes were transferred upward to atmosphere by plant respiration and soil respiration. In the daytime, CO_2 gas fluxes were transferred downward, which means that CO_2 gas was absorbed and fixed to vegetation as is the same cases above. In this day, mean CO_2 absorption fluxes to grassland in the daytime was 0.16 $mg/m^2/s$ and mean CO_2 emission fluxes to atmosphere was 0.14 $mg/m^2/s$.

In July, the measurements day was fine and very hot and we observed the different fluctuation pattern of fluxes. In the daytime, the value of CO_2 gas fluxes showed slightly negative, but CO_2 gas transfer downward were not large. At the same time, air temperature was extraordinary high and latent heat fluxes were low, which means that photosynthesis of vegetation was not active then. On the contrary CO_2 gas transfer upward were very large because of increase of soil respiration rates. In this day, mean CO_2 absorption fluxes to grassland in the daytime was 0.05 $mg/m^2/s$ and mean CO_2 emission fluxes to atmosphere was 0.06 $mg/m^2/s$.

Analysis of the values of CO_2 gas fluxes are shown in Fig.4. In the daytime, CO_2 absorption fluxes to grassland (downward) were observed and at night CO_2 emission fluxes to atmosphere (upward) were observed at every measurement period.

In 1993, fluctuation of CO_2 gas fluxes was largest in August. Both of the absorption and emission fluxes were smaller from April to June. It is considered that activity of vegetation was not vigorous because of cool weather and less solar radiation.

In 1994, CO_2 absorption fluxes in the daytime was larger from the late in April to June and was smaller in the summer, which shows the contrast with the pattern in 1993. CO_2 emission fluxes and air temperature at night correlates so adequately that the amount of soil respiration ratio to the amount of CO_2 emission was inferred to be large.

(3)CO_2 budgets between atmosphere and pasture

Fig.5 shows the seasonal variation of soil respiration rates measured simultaneously with gas fluxes in grazing pasture. Soil respiration rates were higher in summer when soil temperature became high.

Fig.6 shows the seasonal variation of primary net production rates of vegetation (aPn). aPn is estimated by using the value of CO_2 gas fluxes ($|F|$), soil respiration rates (SR) and root respiration rates (Rr) as follows. Root respiration rates were approximated by an exponential function of soil temperature and CO_2 emission rates from litter were approximated by a function of air temperature and water content.

$$aPn[day] = |F|[day]+SR[day]-Rr[day]$$

aPn increased in spring and decreased in July and increased again in the middle of August. The latter peak was higher than the former peak.

On the other hand, aPn estimated by the summation method at the same pasture becomes maximum in late spring, which is reflected by springflush of temperate grasses. In spite of high CO_2 absorption fluxes from spring to early summer as shown in Fig.4, aPn estimated from the above formula became maximum in August. It is because of higher soil temperature and smaller biomass of roots in summer than in spring. Especially, soil respiration rates vary so widely that we should evaluate them carefully.

CO_2 budgets between atmosphere and pasture per diem are shown in Fig.7.

In 1993, the amount of CO_2 absorbed by pasture were larger than the amount of CO_2 emitted to atmosphere except one case (6/2). CO_2 intake to pasture were higher in autumn and its maximum was about 7.10 $g/m^2/day$ (11/17).

In 1994, the amount of CO_2 absorbed by pasture were smaller than the amount of CO_2 emitted to atmosphere on some summer days. In summer, CO_2 budgets per diem tended to make small CO_2 intake to pasture on cloudy days rather than on fine days.

So it is inferred that when the air temperature was extraordinary high, transpiration of vegetation were restrained, so that photosynthetic capacity became lower and as soil temperature increased, decomposition rates of soil organic matter and litter became higher. Thus we got the reverse CO_2 budgets on those hot days.

But the amount of CO_2 absorbed by pasture were larger than the amount of CO_2 emitted to atmosphere per diem as observed in 1993 except on those hot days. Especially, CO_2 intakes in spring were very large and the maximum amount of CO_2 intake to pasture was about 9.91 $g/m^2/day$ (4/30).

Therefore it is suggested that grassland has possibility of being a sink of carbon during the year.

References

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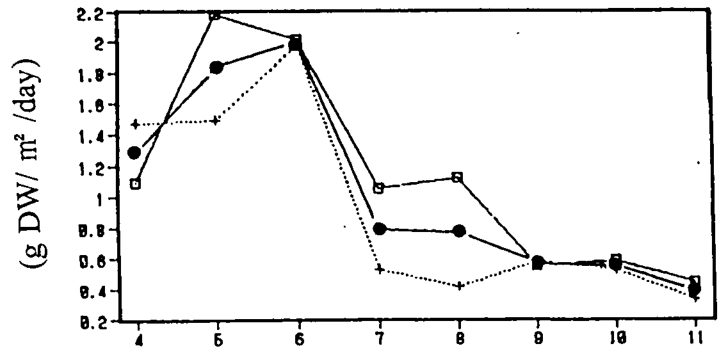

Fig.1 Seasonal variation of root production rates

☐ centere of stump + intereval between stumps

● average

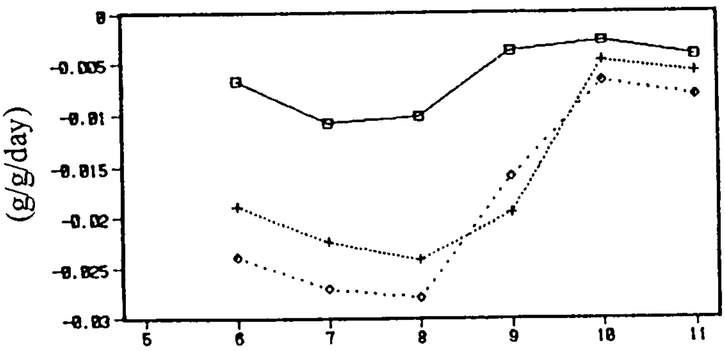

Fig.2 Seasonal variation of decomposition rates of roots

☐ decomposition rates of roots buried in the ground

\+ that of litter buried in the ground

◇ that of litter put on the ground

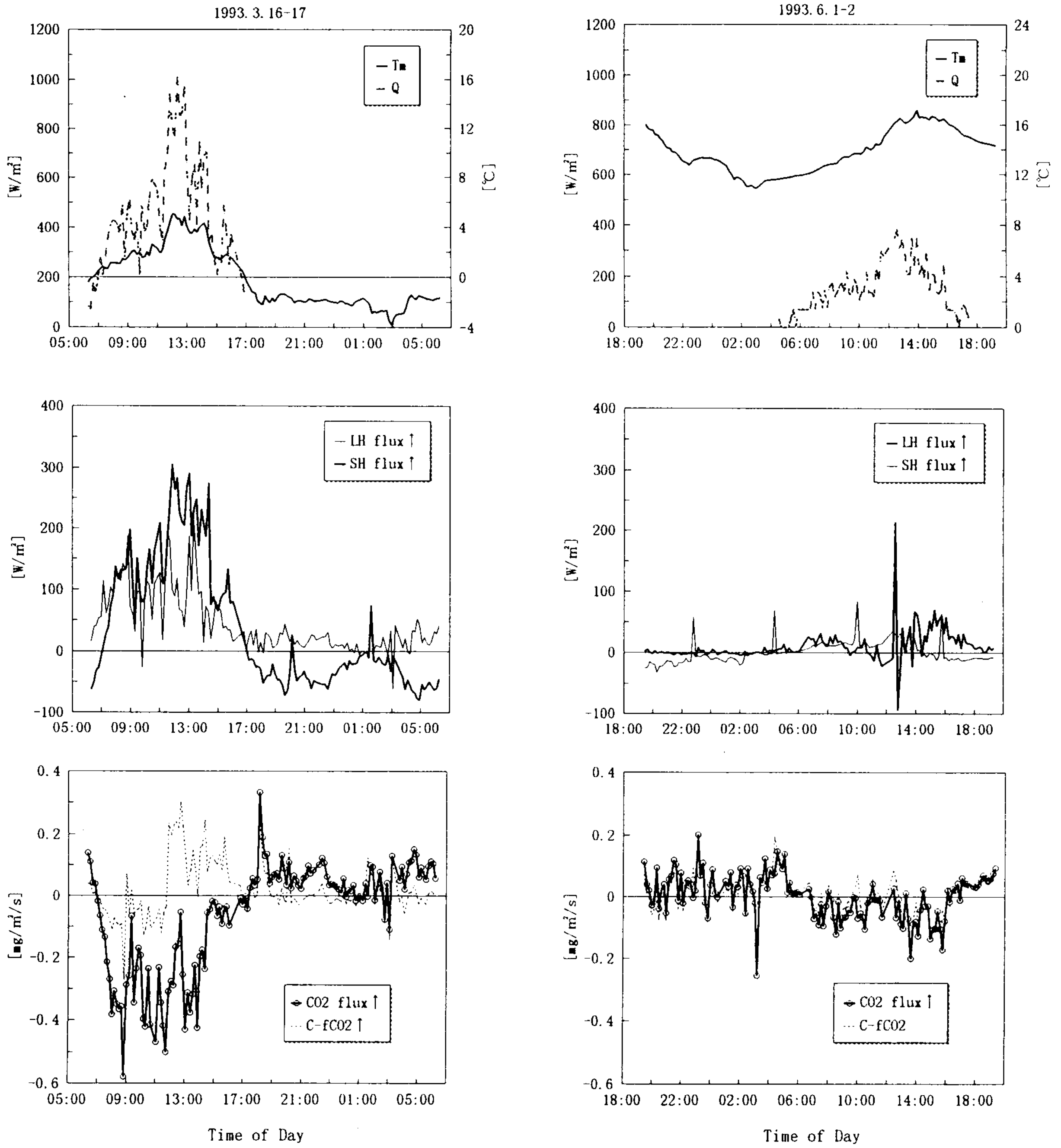

Fig. 3a Time variation of vertical fluxes of solar radiation(Q), air temperature(Tm), latent heat(LH), sensible heat(SH) and carbon dioxide over grazing pasture (Measurements in March and June, 1993)

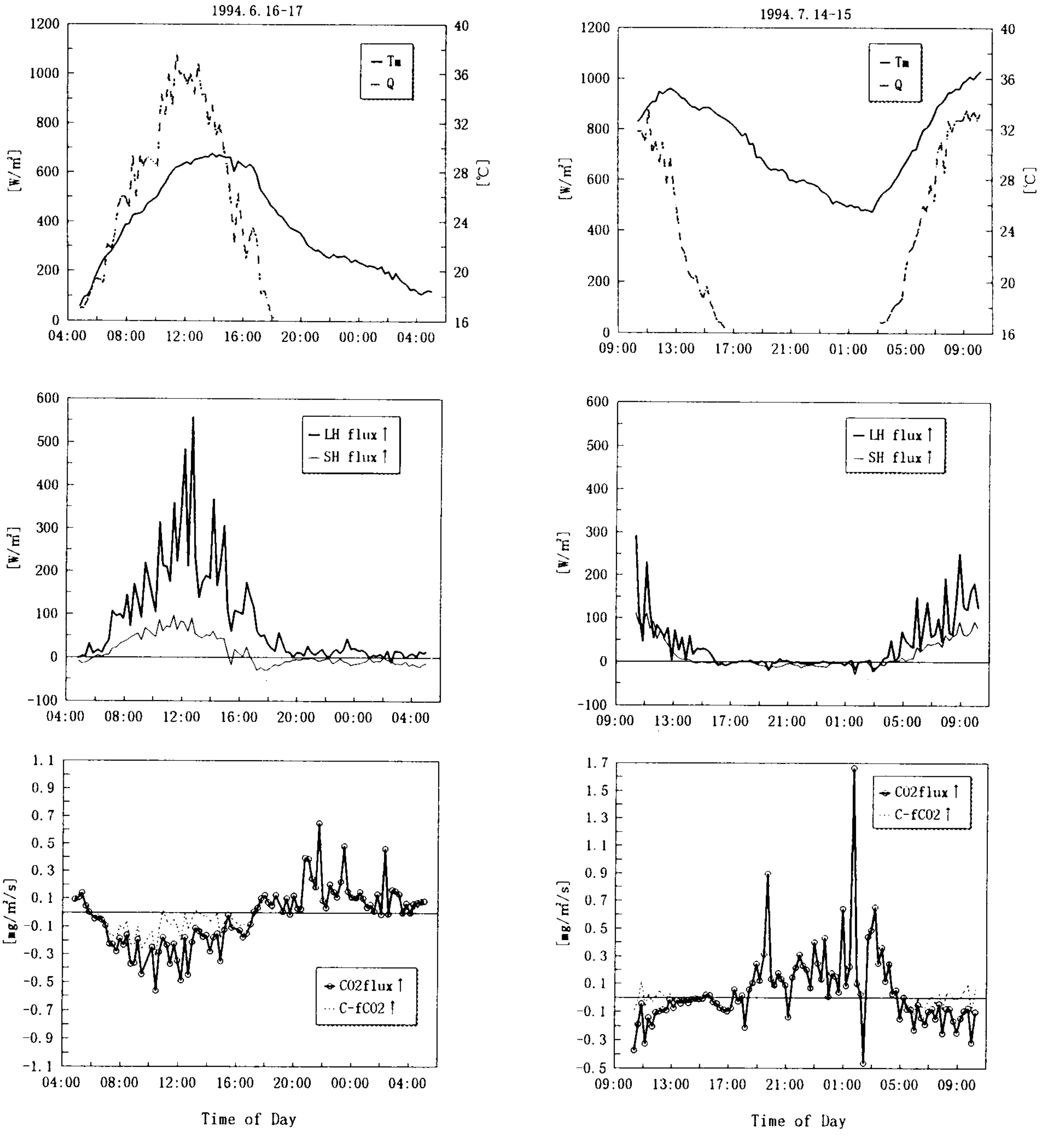

Fig. 3b Time variation of vertical fluxes of solar radiation(Q), air temperature(Tm), latent heat(LH), sensible heat(SH) and carbon dioxide over grazing pasture (Measurements in June and July, 1994)

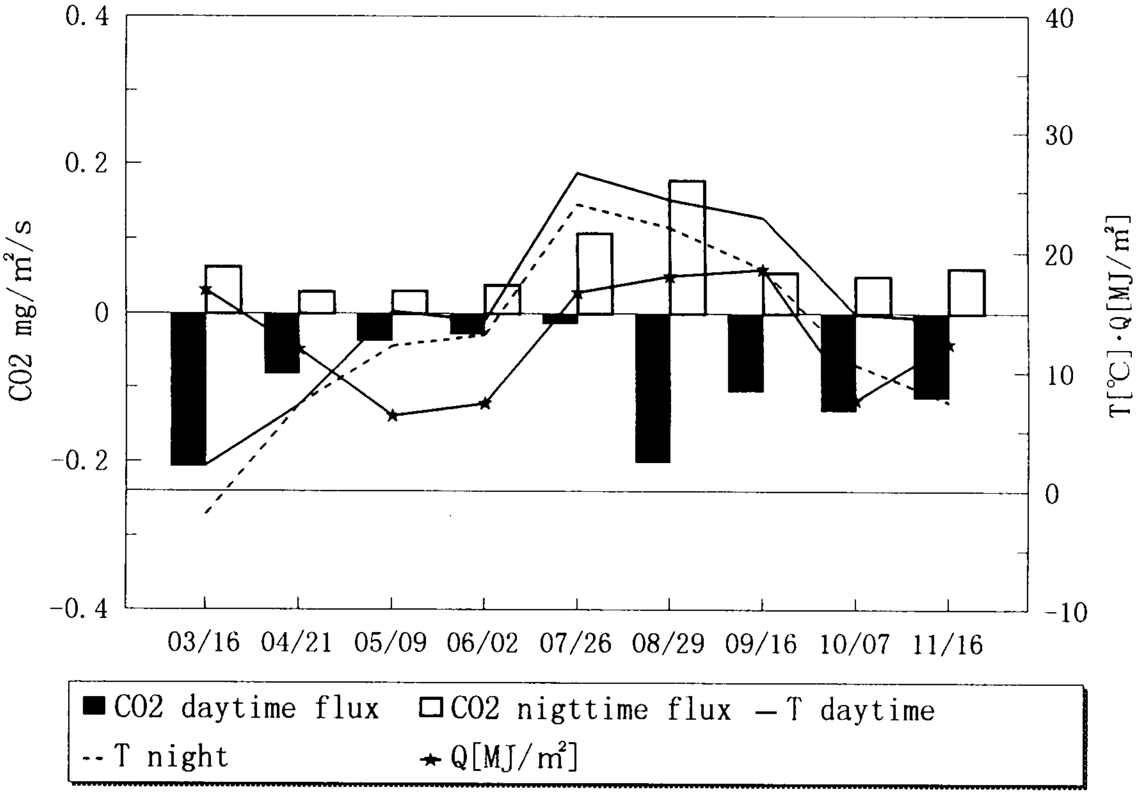

Fig. 4a Seasonal variation of CO2 flux, air temperature and integrated solar radiation over grazing pasture (in 1993)

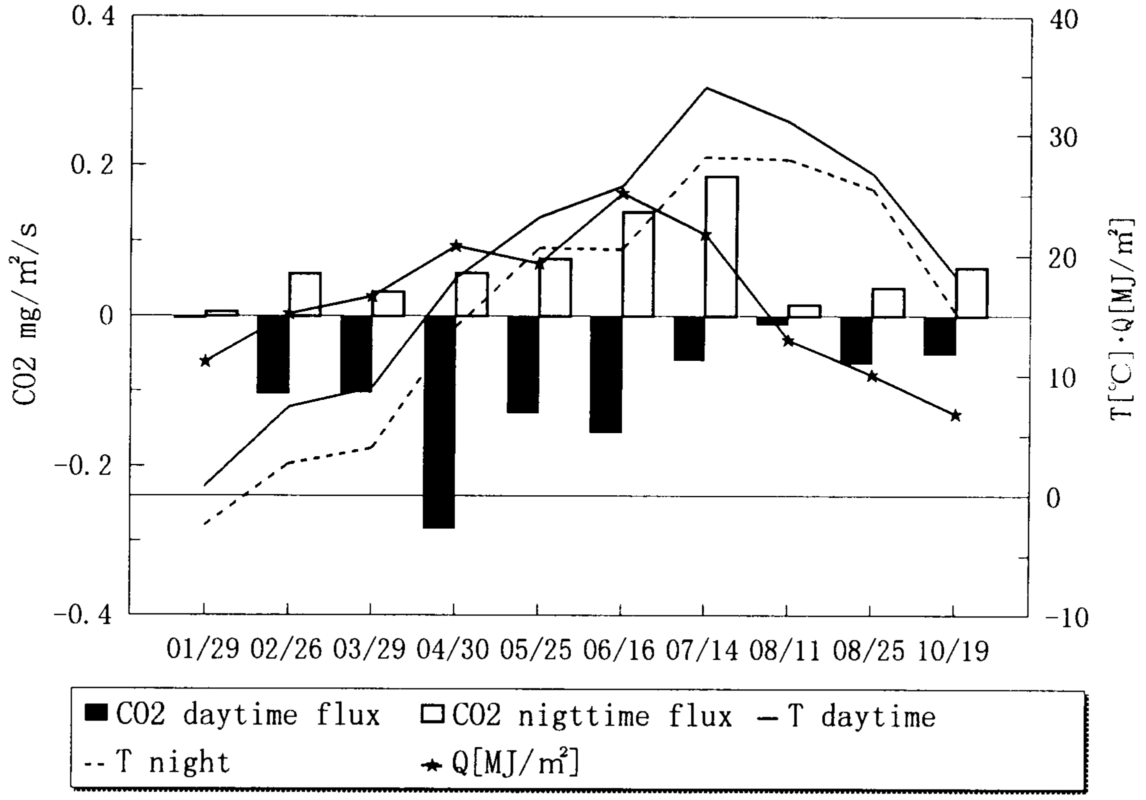

Fig. 4b Seasonal variation of CO2 flux, air temperature and integrated solar radiation over grazing pasture (in 1994)

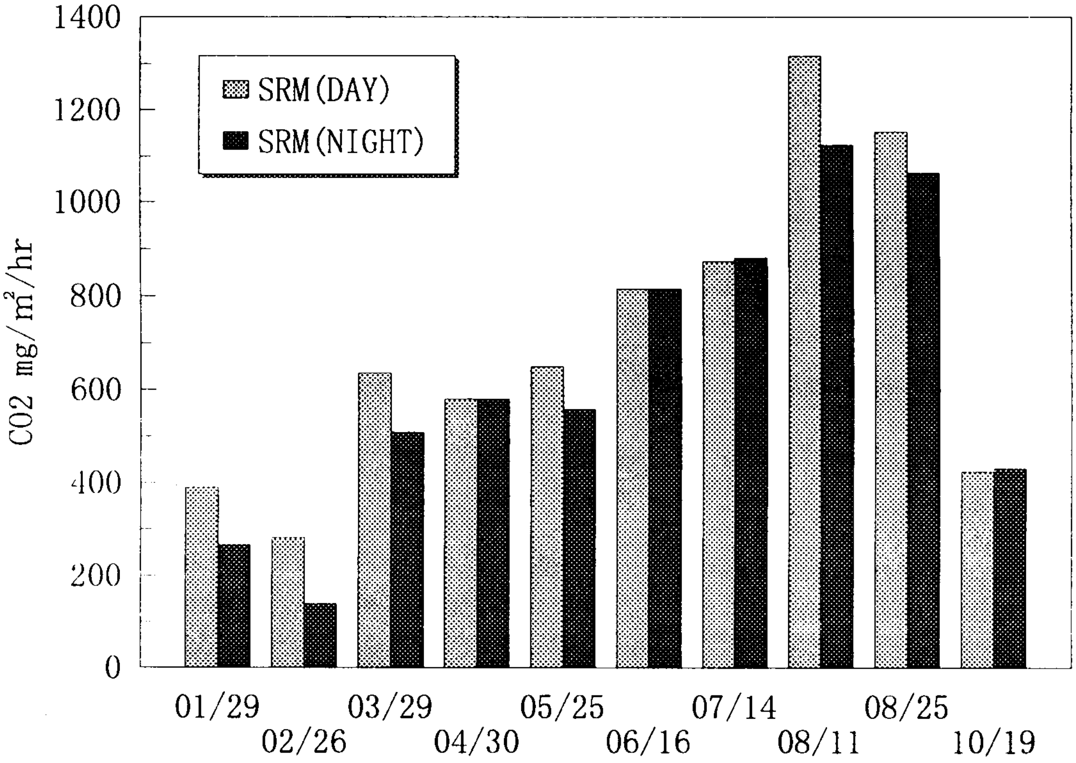

Fig. 5 Seasonal variation of soil respiration rates (SRM) in grazing pasture(in 1994)

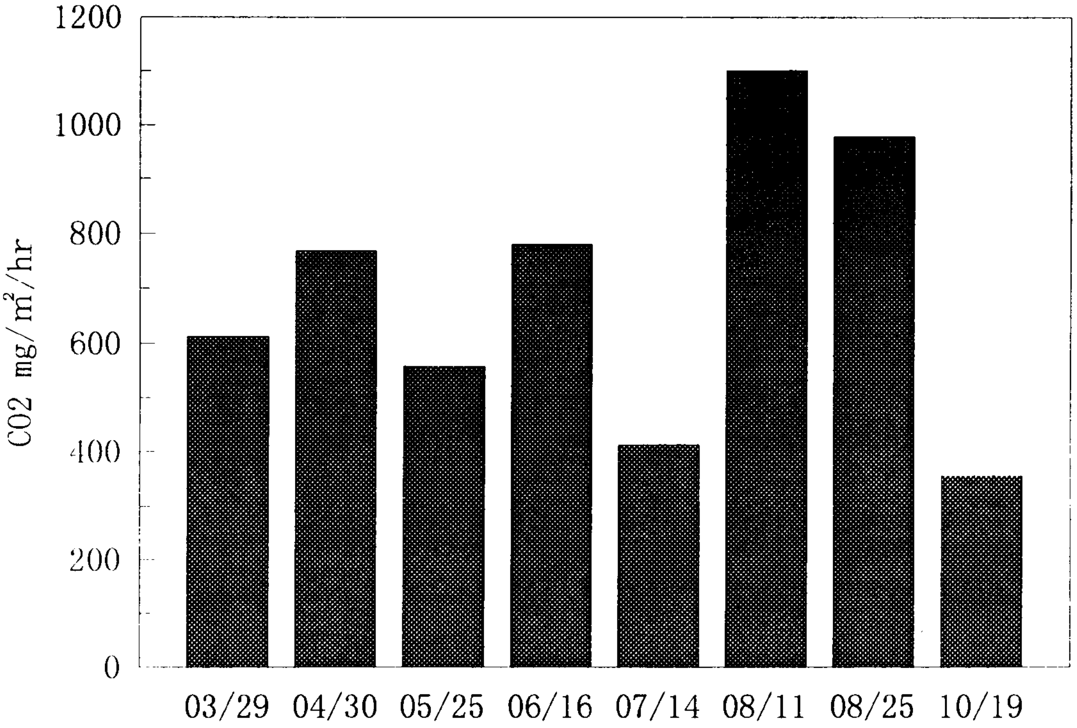

Fig. 6 Seasonal variation of primary net production rates calculated from eddy correlation method(in 1994)

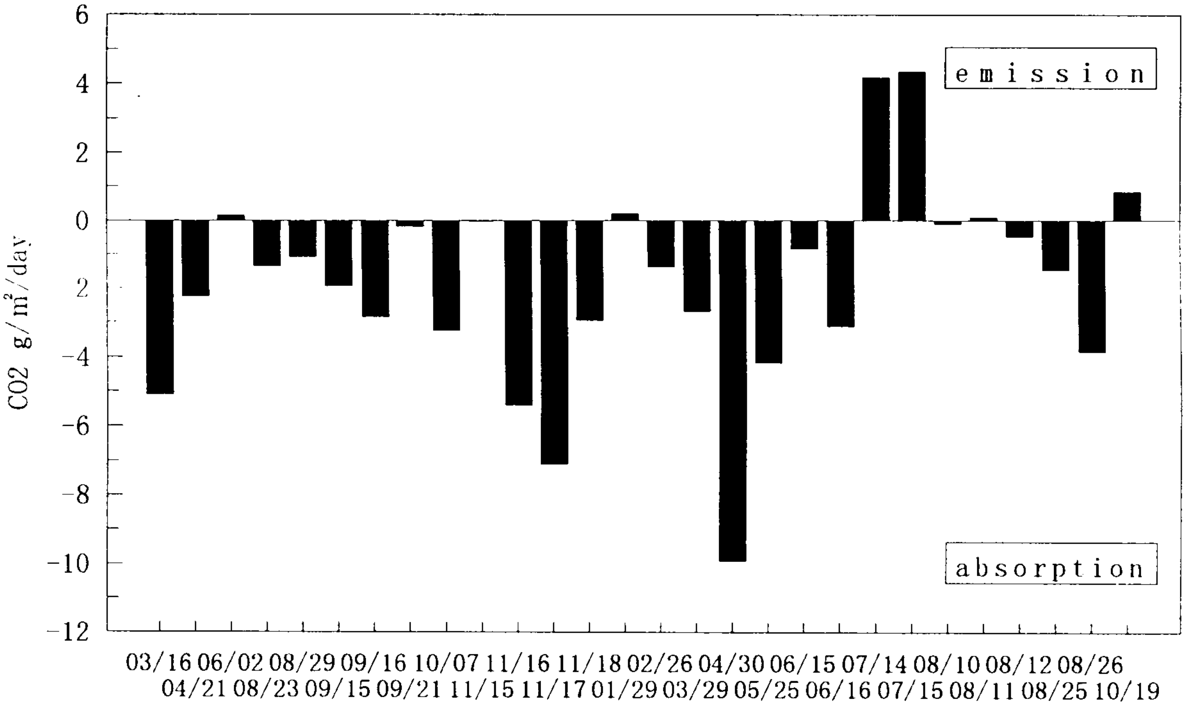

Fig. 7 CO2 budgets in grazing pasture(1993-1994)