NET ECOSYSTEM EXCHANGE AND SOIL RESPIRATION IN A SHRUBLAND OF THE ARID MEDITERRANEAN REGION OF CHILE

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INTRODUCTION

Studies concerning the role of grasslands in the global carbon balance are relatively recent (Schuman *et al.*, 2002). Grasslands are estimated to represent as much as 20% or more of total terrestrial production and may already be an annual carbon sink of 0.5 Pg (Scurlock and Hall 1998).

Arid and semiarid regions make up for 41 % of the continental territory of Chile covering 31.3 M ha (Benites *et al.*, 1994). In the specific case of the Coquimbo Region, under an arid Mediterranean climate, 25% of the territory is covered by natural shrublands (INE 1998), whereas in large areas this natural shrubland has been largely degraded by over - grazing due to intensive goat husbandry, leading to soil erosion.

No previous study has reported ecosystem carbon balance from natural shrublands in Chile. Long - term observation at a single tower location is the most common approach used today to measure surface energy, water vapor and trace gas fluxes over terrestrial ecosystems.

OBJECTIVES

The objective of this study was to measure the instantaneous carbon flux at the ecosystem level and the soil respiration on a shrubland of the arid Mediterranean region of Chile, calculating the daily and seasonal carbon balances.

MATERIAL AND METHODS

Site Description

The study area is located in the Coquimbo Region of Chile (30º15'S; 71º17'W), 45 km south of La Serena, in the central depression between the Coastal Ranges and the Andes. The climate is arid Mediterranean, with an average annual precipitation of 120 mm, concentrated between June and September. The proximity to the Pacific Ocean creates template conditions, with average temperatures always lower than 26 ^{0}C in January and never lower than 5 ^{0}C in July. The sampling site (60 ha) was located within the Las Cardas Experimental Station, of the University of Chile.

The dominant vegetation is an open and low statured (1.2 m) shrubland, part of the ecotone of two large floristic units of 'pichanilla' (*Gutierrezia resinosa* S.F. Blacke) and 'incienso' (*Flourensia thurifera* [Mol.] DC.), peppered with sporadic tree elements, mainly 'espino' (*Acacia caven*) and 'litre' (*Litharea caustica*) and suculents, and a grass stratum temporally active dominated by terofites (Lailhacar and Aylwin 1988).

Flux instrumentation and measurements

A modified Bowen ratio energy balance system (BREB model 023/CO2, Campbell Scientific Inc. [CSI], Logan, USA) was used to monitor CO_2 flux at the ecosystem level (net ecosystem excange, NEE) and micrometeorological variables, from Julian day (DOY) 31 2008 to DOY 96 2009. Data were averaged and stored in the datalogger (Model CR21X, CSI) every 20 minutes. Details of the operation and maintenance of the BREB system are described elsewhere (CSI 1998).

Soil respiration (Rs) was measured using an Automated Soil CO_2 Flux System (LI - 8100, LI - COR, Lincoln, USA) and the 20 - cm - diameter accesory chamber (LI - 8100 - 103) over five PVC collars, which were distributed close to the BREB system according to the vegetation and bare ground cover. Field campaigns consisted on measuring eight times on each collar during one day on DOY 28, 57, 91, 126, 156, 275 in 2008 and DOY 9 and 42 in 2009. Measurements were made as short as possible (3 - 7 min) in order to keep conditions inside the chamber unchanged.

Data processing

Quality control of BREB data was done using a statistical protocol proposed by Perez - Quezada *et al.*, 2007), based on the use of multivariate distance, multiple linear regression and time series analysis. We modified the multiple linear regression by reducing the number of predictor variables to air temperature, water vapor pressure, wind speed, PAR and soil water content. Quality control of Rs data was done during the measurements on the base of the coefficient of variation of the flux estimation; measurements were repeated if CV was higher than 5%.

Positive values of net ecosystem exchange (NEE) indicate CO_2 uptake by the ecosystem, whereas negative values denote CO_2 efflux (respiration). When respiration is analyzed by itself, it is represented with positive sign. Daily and seasonal cummulative fluxes were obtained by integrating the area under the curve, using the trapezoidal rule, which implies that daily values for days with no data are obtained by interpolating available daily values. For the annual estimations, the period considered was between DOY 32 - 2008 and DOY 31 - 2009.

RESULTS AND DISCUSSION

The year 2007 (previous to the study period) was very dry, with a total annual precipitation of 32 mm. This made climatic conditions at the beginning of the study period very arid. This situation changed with the beginning of precipitations around DOY 140, totalizing 180 mm during 2008, which made it a wet year. Average daily air temperature at the beginning of the study (DOY 32 2008) was around 20 ºC and decreased to 8.5 ºC when precipitations started.

These climatic conditions indicate that the ecosystem was a net source of carbon during the period DOY 32 - 140 2008, starting with values of NEE around - 30 mmol CO_2 m - 2 d - 1 and approaching to zero right before precipitations started. Thereafter, the herbaceous stratum began growing, followed by the re - sprouting of the woody species progressively turning the ecosystem carbon balance positive (becoming a net sink), reaching 40 mmol CO_2 m - 2 d - 1 around DOY 36 2009, this is the following summer.

The herbaceous stratum senesced around DOY 290, which implies that the maximum positive values of NEE reached later were due to the activity of the shrub stratum. The dominant shrub species, *F. thurifera*, is a summer - deciduous (i.e. it drops its leaves during stressful dry periods). The senescence of *F. thurifera* occurred around DOY 15 2009 therefore the peak in NEE was due to the activity of the two other dominant species, *G. resinosa* and *Heliotropium stenophyllum*, which are perennial. Both species kept green leaves until the end of the study period, thereby sustaining positive NEE values.

Rs showed a pattern consistent with the NEE values, with very low values at the beggining of the study period, due also to the environmental dryness, which made the soil also to be very dry. Observed daily Rs (mmol CO_2 m - 2 d - 1) was 8.8 on DOY 28, 6.9 on DOY 57, 4.6 on DOY 91 and 4.5 on DOY 126 2008. The Rs values increased dramatically after the occurrence of precipitations, reaching values of 44.6 and 40.6 mmol CO_2 m - 2 d - 1 on DOY 156 and 275, respectively. After this wet period, conditions started getting dryer, and Rs decreased during the summer of 2009 down to 17.1 mmol CO_2 m - 2 d - 1 on DOY 9, 15.1 on DOY 31 and 14.1 on DOY 42. This shows that, after a wet year, Rs flux was about double compared to the same period after a dry year.

Cummulative flux computations were done using the trapezoidal rule. In the case of Rs, the 10 measured days were interpolated to obtain a yearly sum. Failures of the BREB system caused that only 308 out of 430 potential daily NEE values were obtained, for the whole study period. The seasonal carbon balance for the shrubland was estimated at - 279 g CO_2 m - 2 year - 1, meaning that the system was a net source of carbon. The seasonal Rs was estimated at 422 g CO_2 m - 2 year - 1, with about 90% emitted after the precipitations started.

CONCLUSION

Continuous measurements of NEE and about monthly measurements of Rs allowed estimating daily values, seasonal patterns and cummulative fluxes of these two carbon flux components in a shrubland of the arid Mediterranean region of Chile. Daily NEE showed that ecosystem moved from being a source of - 40 mmol CO_2 m - 2 d - 1, to be a net sink of 30 mmol CO_2 m - 2 d - 1 during the study period (430 days). Daily Rs varied between 4.5 and 44.6 mmol CO_2 m - 2 d - 1 during the same period; this is a 10 - fold increase during the same year. Both NEE and Rs showed a great change after precipitation events occurred during the winter of 2008. Cummulative NEE was - 279 g CO_2 m - 2 year - 1, which means that the ecosystem was a net sink, even in a wet year.

Modeling of daytime ecosystem respiration (Re) will allow the estimation of daily Re, the calculation of gross primary production (GPP) since GPP=NEE + Re, and the separation of Re into its components Rs and aboveground respiration.

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REFERENCES

Benites, J., D. Saintraint, & Y. K. Morimoto. 1994. Degradación de tierras y producción agrícola en Argentina, Bolivia, Brasil, Chile y Paraguay. Erosión de suelos en América Latina. Santiago, Chile: FAO. p. 83 - 116.

CSI. 1998. 023/CO2 Bowen Ratio system with CO2 flux. Instruction manual. Revision 4/98. Logan, Utah, USA.: Campbell Scientific, Inc. p. 52.

INE. 1998. VI Censo nacional agropecuario: total nacional, año 1997. Santiago, Chile.: Instituto Nacional de Estadísticas.

Lailhacar, S., & M. Aylwin. 1988. Efecto de tres especies leñosas en algunas variables del suelo y del estrato herbáceo en la pradera de clima mediterráneo árido. Simiente 58:51 - 61.

Perez - Quezada, J. F., N. Z. Saliendra, W. E. Emmerich, & E. A. Laca. 2007. Evaluation of statistical protocols for quality control of ecosystem carbon dioxide fluxes. J. R. Statist. Soc. A. Part 1, 170:213 - 230.

Schuman, G. E., H. H. Janzen, & J. E. Herrick. 2002. Soil carbon dynamics and potential carbon sequestration by rangelands. Environmental Pollution 116:391 - 396.

Scurlock, J. M. O., & D. O. Hall. 1998. The global carbon sink: a grassland perspective. Global Change Biology 4:229 - 233.