International Proceedings of Chemical, Biological and Environmental Engineering, V0l. 93 (2016)
DOI: 10.7763/IPCBEE. 2016. V93. 20

Diurnal Variations of Alpine Wetland Ecosystem Gross Ecosystem Productivity in Qinghai Lake

Guangzhao Han [1,2], Shengkui Cao [1,2 +], Guangchao Cao [1,2], Jing Zhang [1,2], Yangyang Lin [1,2], Fangtao Wu [1,2] and Shuyan Cheng [1,2]

[1] College of Life and Geographical Science, Qinghai Normal University, Xining 810008, China

[2] Qinghai Province Key Laboratory of Physical Geography and Environmental Process, Qinghai Normal University, Xining 810008, China

Abstract. Based on the measurements by the open eddy covariance system, this paper researched into the daily characteristics of alpine wetland ecosystem gross ecosystem productivity (GEP) in Qinghai Lake under the different weather conditions and growth stages. The results showed that the daily variations of alpine wetland ecosystem GEP in Qinghai Lake manifested as single-peak curves in sunny days. When it went cloudy or rainy days, the daily variations of the GEP showed double-peak and multiple curves. In different weather conditions, both the GEP peak and average values in summer appeared maximum, with the peak values of 0.71~ 0.88 mg $CO_2/(m^2\ s)$, and the average values of 0.37~0.45 mg $CO_2/(m^2\ s)$. In different growth stages, the daily GEP variations showed single-peak curves, and the time of diurnal variations was accordingly extended and shortened with changes from plant germinating, growing, withering to dormancy. The values of diurnal GEP variations in growing stage were maximum, and then the second was in the withering stage; the minimum was in the non-growing stage, which its values were 0.38 mg $CO_2/(m^2\ s)$, 0.25 mg $CO_2/(m^2\ s)$ and 0.05 mg $CO_2/(m^2\ s)$, respectively.

Keywords: alpine wetland ecosystem, gross ecosystem productivity (GEP), diurnal variations, Qinghai Lake

1. Introduction

The gross ecosystem productivity is one important indicator of carbon budget, and the ecosystems have different carbon storage function. Wetlands are unique ecosystems which are formed by the interaction between terrestrial and aquatic ecosystems on earth, because of its high productivity, and it plays a very important role in the global carbon storage [1], [2]. In recent years, many scholars have studied the characteristics of carbon fluxes in different wetland ecosystems with the development of the eddy covariance technique, such as Sanjiang plain, Yellow River Delta [3], [4]. The study on carbon fluxes in the Qinghai-Tibet Plateau have mainly been concentrated in a few sites, such as Nagchu [5], Haibei [6], Shule river [7], etc. There is less research about alpine wetland ecosystem carbon fluxes in Qinghai Lake. In this paper, diurnal variations of alpine wetland ecosystem gross ecosystem productivity in Qinghai Lake under different weather conditions and growing stages were studied using data measured by the eddy covariance system so as to provide theoretical references and basic data for deeply understanding alpine wetland carbon cycle on the Qinghai-Tibet plateau.

2. Study Area and Methods

This paper selected Xiaobohu wetland on the east shore of Qinghai Lake as a study object. The observing tower with the height of 2.5 m was built at the fixed sample plot (36°42′15.93″N, 100°47′03.59″E,

+ Corresponding author. Shengkui Cao Tel.: +86-971-6307616; fax: +86-971-6307616.
E-mail address: caoshengkui@163.com.

3214 m asl) forming the alpine swamp near the Xiaobohu wetland. The open eddy covariance system (Li-7500A, Li-Cor Inc., USA) was installed at the 1.94 m height of observing tower, with the datalogger of LI-7550. The sampling frequency was 10 Hz, and the data was collected at the ghg format and saved the average 30 min data.

There selected the raw data measured by the open eddy covariance system and corresponding meteorological and environmental data from July 18 2011 to June 30 2013 in this paper. The eddy covariance raw data were handled using the EddyPro 5.0 soft (Li-Cor, USA) and computed the ecosystem CO_2 fluxes. The missing and deleted CO_2 fluxes were interpolated combing with multiple methods to obtain complete and continuous fluxes data [8]-[12]. The raw CO_2 flux data provided the ecosystem net CO_2 exchange(NEE) amount, which represents the difference between ecosystem photosynthetic absorption or gross primary productivity(GPP) and ecosystem respiration (Re) [13], [14]. The NEE data could be partitioned GPP and Re parts. On the ecosystem scale, the GPP is equal to the gross ecosystem productivity (GEP).

There selected different weather conditions including sunny, cloudy and rainy days in typical months. The daily variations of total solar radiation showed smooth and symmetric single peak curves in sunny days. The curve in cloudy days showed tortuous and multiple peaks. When we selected rainy days, we selected rained more than the half-hour scale and continuous rainfall.

According to the vegetation growth situations in the alpine wetland ecosystem of Qinghai Lake, April and May every year were separated vegetative green up stage; the time from June to July was separated vegetative growing stage; September belonged to vegetative withering stage; October was the withered grass stage; the time from November and March next year was separated vegetative non-growing stage (season).

3. Results and Discussion

3.1 Diurnal Variations of Alpine Wetland Ecosystem GEP in Qinghai Lake in Different Weather Conditions

Diurnal variations of the alpine wetland ecosystem GEP in Qinghai Lake in sunny days were shown in Fig. 1. Results showed that the diurnal GEP variations in March and April showed single peak curves, and its highest values occurred at 16:30, 13:30, but it showed double-peak curve in May, and the peak values occurred at 11:00 and 16:30. The daily GEP values varied from 0.0001 mg $CO_2/(m^2\ s)$ to 0.14 mg $CO_2/(m^2\ s)$, with the average of 0.08 mg $CO_2/(m^2\ s)$ (Fig. 1a). The daily total GEP in March, April and May were 1.65 mg $CO_2/(m^2\ s)$, 1.98 mg $CO_2/(m^2\ s)$ and 2.04 mg $CO_2/(m^2\ s)$, respectively. On the sunny day in summer, the diurnal GEP variations among different months have shown double peak curves. The daily GEP values varied between 0.001 mg $CO_2/(m^2\ s)$ and 0.71 mg $CO_2/(m^2\ s)$, with the average of 0.45 mg $CO_2/(m^2\ s)$(Fig. 1b). The daily total GEP values showed July (13.29 mg $CO_2/(m^2\ s)$) > August (12.68 mg $CO_2/(m^2\ s)$) > June (9.05 mg $CO_2/(m^2\ s)$). Because the plants thrived in July, which resulted that its primary production capacity was the strongest in summer. On the sunny day in autumn, the diurnal variations of the GEP showed single peak curves. The daily GEP values varied from 0.03 mg $CO_2/(m^2\ s)$ to 0.46 mg $CO_2/(m^2\ s)$, with the average of 0.20 mg $CO_2/(m^2\ s)$ (Fig. 1c). The daily GEP amounts showed September (7.42 mg $CO_2/(m^2\ s)$) > October (3.21 mg $CO_2/(m^2\ s)$) > November (1.31 mg $CO_2/(m^2\ s)$). On the sunny day in winter, the diurnal variations of GEP showed single peak curves, and the daily GEP values varied between 0.01 mg $CO_2/(m^2\ s)$ and 0.17 mg $CO_2/(m^2\ s)$, with the average of 0.09 mg $CO_2/(m^2\ s)$ (Fig. 1d). The daily GEP amounts showed February (2.63 mg $CO_2/(m^2\ s)$) > January (1.52 mg $CO_2/(m^2\ s)$) > December (0.75 mg $CO_2/(m^2\ s)$). These results suggested that the daily GEP variations in sunny days also changed with the seasons. The daily GEP values in sunny days were decreased in following order: summer, autumn, winter and spring.

Diurnal variations of the alpine wetland ecosystem GEP in Qinghai Lake in cloudy days were shown in Fig. 2. The diurnal GEP variations obviously fluctuated and showed double-peak and multiple curves in cloudy days. On the cloudy days in spring, the GEP values varied from 0.002 mg $CO_2/(m^2\ s)$ to 0.20 mg $CO_2/(m^2\ s)$, with the average of 0.10 mg $CO_2/(m^2\ s)$ (Fig. 2a). On the cloudy days in summer, the GEP values varied between 0.006 mg $CO_2/(m^2\ s)$ and 0.88 mg $CO_2/(m^2\ s)$, with the average of 0.42 mg $CO_2/(m^2\ s)$

(Fig. 2b). There appeared the largest daily GEP amounts on the cloudy day in July with the value of for 13.87 mg CO_2/(m^2 s). On the cloudy days in autumn, the GEP values changed between 0.005 mg CO_2/(m^2 s) and 0.28 mg CO_2/(m^2 s), with the average of 0.09 mg CO_2/(m^2 s) (Fig. 2c). On the cloudy days in winter, the GEP values varied from 0.004 mg CO_2/(m^2 s) to 0.12 mg CO_2/(m^2 s), with the average of 0.05 mg CO_2/(m^2 s) (Fig. 2d). These results suggested that the daily GEP variations in the cloudy days were more obvious fluctuation in summer and autumn than spring and winter, and daily GEP values in cloudy days decreased in following order: summer, autumn, winter and spring.

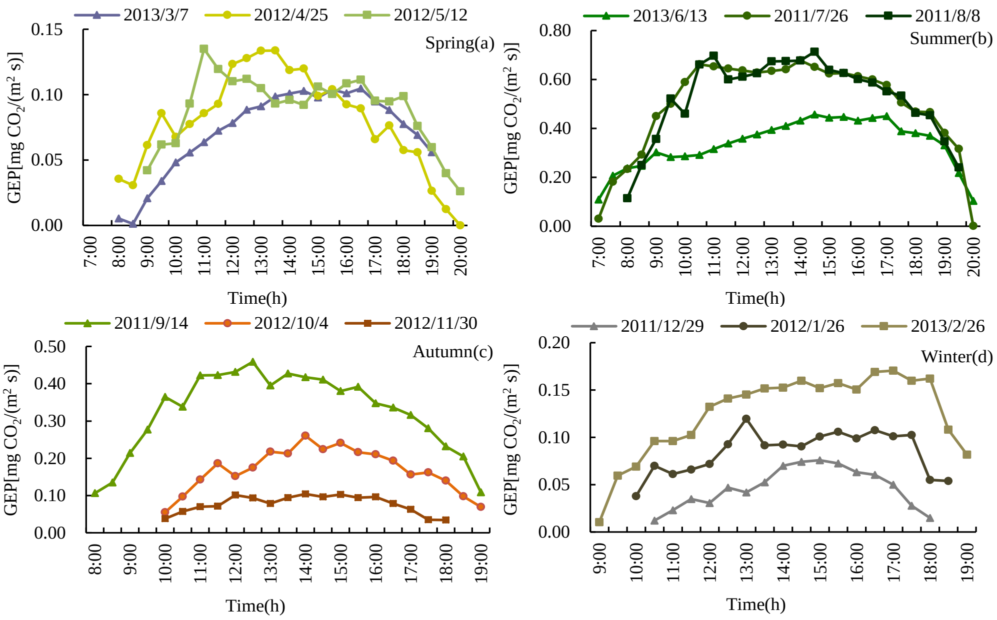

Fig. 1: Diurnal variations of alpine wetland ecosystem GEP in Qinghai Lake in sunny days

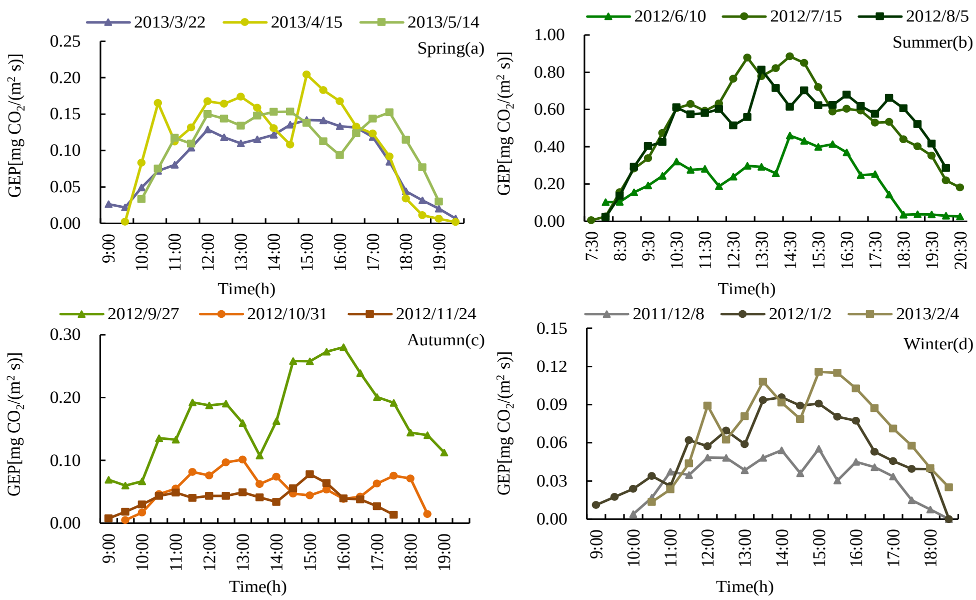

Fig. 2: Diurnal variations of alpine wetland ecosystem GEP in Qinghai Lake in cloudy days

Diurnal variations of the alpine wetland ecosystem GEP in Qinghai Lake in rainy days were shown in Fig. 3. Results showed that the GEP values on the rainy days in different seasons were violently fluctuated. On the rainy days in spring, the GEP value changed between 0.002 mg CO_2/(m^2 s) and 0.11 mg CO_2/(m^2 s), with the average of 0.05 mg CO_2/(m^2 s) (Fig. 3a). On the rainy days in summer, the GEP values varied from 0.01 mg CO_2/(m^2 s) to 0.86 mg CO_2/(m^2 s), with the average of 0.37 mg CO_2/(m^2 s) (Fig. 3b). On the rainy days in autumn, the GEP values varied between 0.002 mg CO_2/(m^2 s) and 0.35 mg CO_2/(m^2 s), with the average of 0.09 mg $CO_2/(m^2\ s)$ (Fig. 3c). On the rainy days in winter, the GEP values varied from 0.0001mg $CO_2/(m^2\ s)$ to 0.12mg $CO_2/(m^2\ s)$ with the average of 0.03 mg $CO_2/(m^2\ s)$ (Fig. 3d). These results suggested that the daily variations of GEP also changed with the seasons. Those changes were more obvious in spring and autumn. In different seasons, the daily variations of GEP from 12:00 to 17:00 were more affected by rainy.

3.2 Daily Variations of Alpine Wetland Ecosystem GEP in Qinghai Lake in Different Stages

Daily variations of the alpine wetland ecosystem GEP in Qinghai Lake in different stages were shown in Fig. 4. Results showed that the diurnal GEP variations manifested as single peak curves. From the non-growing stage to green up stage, the average time of the daily GEP changes was gradually extended; from growing stage to withering stage, the time began to shorten. That was related to plant phenology and duration of daylight changes. The daily GEP average values appeared maximum at the growing stage, which the GEP values ranged between 0.003 mg $CO_2/(m^2\ s)$ to 0.59 mg $CO_2/(m^2\ s)$, with the average of 0.38 mg $CO_2/(m^2\ s)$. And then, at the withering stage, the GEP values varied from 0.001 mg $CO_2/(m^2\ s)$ to 0.39 mg $CO_2/(m^2\ s)$, with the average of 0.25 mg $CO_2/(m^2\ s)$. In the green up stage, the daily GEP values varied from 0.001 mg $CO_2/(m^2\ s)$ to 0.17 mg $CO_2/(m^2\ s)$, with the average of 0.10 mg $CO_2/(m^2\ s)$. In the withered stage, the daily GEP values were between 0.001 mg $CO_2/(m^2\ s)$ and 0.14 mg $CO_2/(m^2\ s)$, with the average of 0.07 mg $CO_2/(m^2\ s)$. In the non-growing season, the daily GEP values varied from 0.0004 mg $CO_2/(m^2\ s)$ to 0.09 mg $CO_2/(m^2\ s)$, with the average of 0.05 mg $CO_2/(m^2\ s)$. Those results showed that the diurnal GEP values were gradually increased with the vegetation germinating and growing, and decreased with the vegetation withering, withered and dormancy. The above results suggested that the alpine wetland ecosystem daily GEP in Qinghai Lake mainly focused on the growing and withering stages.

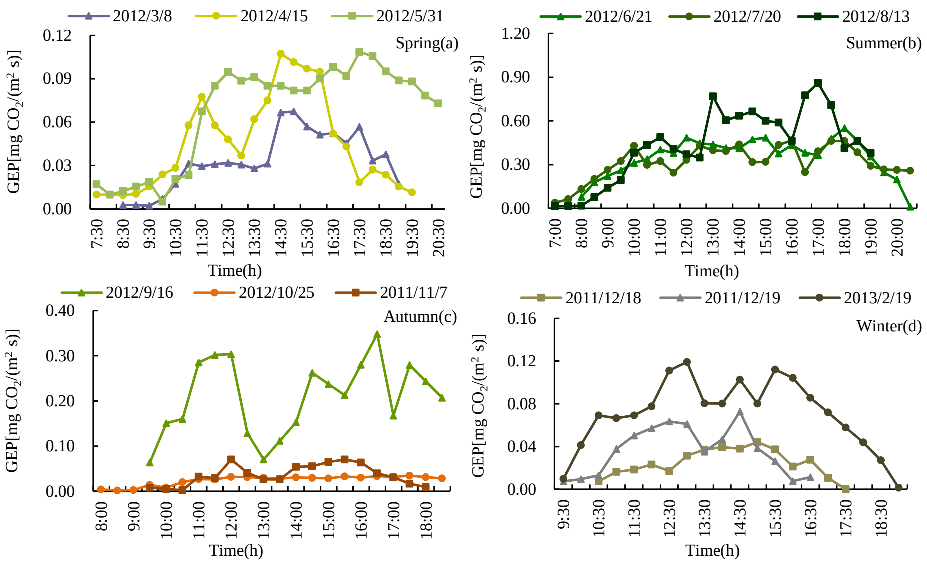

Fig. 3: Diurnal variations of alpine wetland ecosystem GEP in Qinghai Lake in rainy days

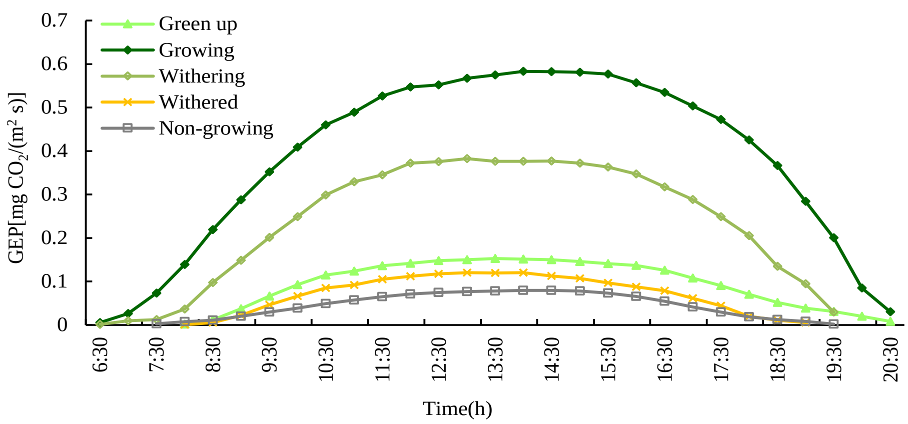

Fig. 4: Daily variations of alpine wetland ecosystem GEP in Qinghai Lake in different stages

4. Conclusions

Diurnal variations of the alpine wetland ecosystem GEP in Qinghai Lake in sunny days totally showed single or double peak curves in sunny days; and fluctuated in cloudy and rainy days. The daily GEP average values under different weather condition were the maximum in summer, the values on the sunny days in spring were minimum, and the daily GEP minimum in the cloudy and rainy days appeared in winter. The diurnal variations of the alpine wetland ecosystem GEP in Qinghai Lake were mainly effect by daily hours and plant growing. The alpine wetland ecosystem primary productivity in Qinghai Lake mainly focused on the growing and withering stages. The variations of daily average GEP at different vegetation developing stages all showed single peak curves. The changes of GEP in different stages showed obvious increasing and decreasing trend. From non-growing, green up to growing stages, the daily values of the alpine wetland ecosystem GEP in Qinghai Lake increased gradually and the peak value appeared in the growing stage; Entering withering and withered stages, the time of daily GEP variations was gradually shortened and the GEP values were decreased.

In the future, we will continue to make the research better, and study on the monthly and annual variations.

5. Acknowledgements

This paper is co-sponsored by National Natural Science Foundation of the People's Republic of China (31260130), Western Light Project of Chinese Academy of Sciences (2012179), Key Scientific and Technological Research Project Fund of Ministry of Education of the People's Republic of China and Postdoctoral Science Foundation of the People's Republic of China (2013M542400) and Qinghai Province Key Laboratory of Physical Geography and Environmental Process (2014-Z-Y24, 2015-Z-Y01). The authors thank to them and the anonymous reviewers.

6. References

[1] S. Frolking, NT. Roult, T. Moore, et al. Modeling Northern Peatland decomposition and peat accumulation. *Ecosystems*. 2001, 4: 479-498.

[2] K. Inubushi, Y. Furukawa, A. Hadi, et al. Seasonal changes of CO_2, CH_4 and N_2O fluxes in relation to land use change in tropical peatlands located in coastal area of South Kalimantan. *Chemosphere*. 2003, 52: 603-608.

[3] S. J. Xu, J. H. Liu, and Y. Wang. Variation characteristics analysis of major crop carbon fixation in Sanjiang Plain during 1980-2007. *Journal of Arid Land Resources and Environment*. 2011, **25**(10): 179-183. (in Chinese)

[4] L. Q. Yang, G. X. Han, J. B Yu et al. Net ecosystem CO_2 exchange and its environmental regulation mechanisms in a reed wetland in the Yellow River Delta of China during the growth season. *Chinese Journal of Applied Ecology*. *Sep*. 2013, **24**(9): 2415-2422. (in Chinese)

[5] Z. K. Zhu, Z. Y. Hu, Y. M. Ma, et al. Net Ecosystem Carbon Dioxide Exchange in Alpine Meadow of Nagchu Region over Qinghai-Xizang Plateau. *Plateau meteorology*. 2015, **34**(5): 1217-1223. (in Chinese)

[6] F. W. Zhang, Y. N. Li, G. M. Gao, et al. CO_2 fluxes and their driving factors over alpine meadow grassland ecosystems in the northern shore of Qinghai Lake, China. *Chinese Journal of Plant Ecology*. 2012, **36**(3): 187-198.(in Chinese)

[7] Q. Zhao, W. J. Liu , S.Y. Chen, et al. Soil CO_2 flux characteristics in alpine meadow of permafrost regions in the upper reaches of the Shule River, Qilianshan Mountains. *Journal of Glacioligy and Geocryology*. 2014, **36**(6): 1572-1281.(in Chinese)

[8] H. Xu, Z. Hou, Z. An, et al. Major ion chemistry of waters in Lake Qinghai catchments, NE Qinghai-Tibet plateau, China. *Quat Int*. 2010, **212**(1): 35-43. (in Chinese)

[9] J. Lloyd and J. A. Taylor. On the temperature dependence of soil respiration. *Funct Ecol*. 1994, **8**(3): 315-323.

[10] R. K. Dixon, A. M. Solomon, S. Brown, et al. Carbon pools and flux of global forest ecosystems. *Science*. 1994, **263**(5144): 185-190.

[11] E. Falge, D. Baldocchi, R. Olson, et al. Gap filling strategies for defensible annual sums of net ecosystem exchange. *Agr Forest Meteorol*. 2001, **107**(1): 43-69.

[12] E. Falge, D. Baldocchi, J. Tenhunen, et al. Seasonality of ecosystem respiration and gross primary production as derived from FLUXNET measurements. *Agr Forest Meteorol*. 2002, **113**(1-4): 53-74.

[13] C. Li, H. L. He, M. Liu, et al. The design and application of CO_2 flux data processing system at ChinaFLUX. *Geo-Information Science*. 2008, **10**(5): 557-565. (in Chinese)

[14] M. Reichstein, E. Falge, D. Baldocchi, et al. On the separation of net ecosystem exchange into assimilation and ecosystem respiration: review and improved algorithm. *Global Change Biol*. 2005, **11**(9): 1424-1439.