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# Dynamics of gross productivity and respiration of grasslands in south-eastern Crimea under altered precipitation

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The influence of altered precipitation on gross productivity and respiration of grasslands in south-eastern Crimea (Karadag Nature Reserve) in 2012–2013 was investigated. The positive correlation between wetting and productivity was found; soil humidity has proven to be a better indicator of wetting influence on productivity than average monthly precipitation. Linear regression analysis has shown a significant relationship between gross productivity and air temperature, relative air humidity, soil humidity (15 and 60 cm depth), and luminance. These factors together were able to predict 57% of productivity variation. As variation of month levels, so amount of productivity peaks within a vegetation period were dependent on precipitation levels and water infiltration on the different soil depths.

**Key words:** *gross ecosystem productivity, ecosystem respiration, grasslands, altered precipitation, climate change.*

# Особливості динаміки валової продуктивності та дихання трав’яних угруповань південно-східного Криму під впливом змін кількості опадів

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У роботі представлене дослідження впливу змін кількості опадів на динаміку валової продуктивності та дихання трав’яних угруповань південно-східного Криму, що проводилось на експериментальному стаціонарі на території Карадазького природного заповіднику у 2012–2013 рр. Було підтверджено позитивний вплив зволоження на динаміку продуктивності трав’яних угруповань; вологість ґрунту виявилась кращим показником впливу рівня зволоженості на продуктивність, ніж середньомісячна кількість опадів. Лінійний регресійний аналіз показав достовірну залежність валової продуктивності від температури повітря, відносної вологості повітря, вологості ґрунту на глибинах 15 та 60 см і освітленості, які пояснюють мінливість продуктивності на 57%. Як ступінь варіації місячних значень, так і кількість піків продуктивності протягом вегетаційного періоду залежали від кількості місячних опадів та перерозподілу вологості у різних шарах ґрунту.

**Ключові слова:** *валова продуктивність, дихання екосистеми, зміни клімату, опади, степові фітоценози.*

# Особенности динамики валовой продуктивности и дыхания травяных сообществ юго-восточного Крыма под влиянием изменения количества осадков

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В работе представлено экспериментальное исследование влияния изменения количества осадков на динамику валовой продуктивности и дыхания травяных сообществ юго-восточного Крыма (Карадагский природный заповедник) в 2012–2013 гг. Было подтверждено позитивное влияние увлажнения на динамику продуктивности экосистемы; влажность грунта оказалась лучшим показателем влияния уровня увлажнения на продуктивность по сравнению с среднемесячным количеством осадков. Линейный регрессионный анализ показал достоверную зависимость продуктивности от температуры и относительной влажности воздуха, влажности грунта (15 и 60 см) и освещенности, которые объясняют изменчивость продуктивности на 57%. Как степень вариации месячных значений, так и количество пиков продуктивности на протяжении вегетационного периода зависели от среднемесячного количества осадков и перераспределения влажности в разных слоях грунта.

**Ключевые слова:** *валовая продуктивность, дыхание экосистемы, осадки, изменения климата, степные фитоценозы.*

## Introduction

Global climate change is linked to simultaneous increase of air and soil temperature influencing on hydrological cycling and regional precipitation regimes (IPCC 2007). In its turn, ecosystem carbon fluxes are linked with precipitation regimes through precipitation amount, infiltration depth, soil microorganisms' structure, and also different response time on altered precipitation (Huxman et al., 2004).

Considering climatic trends of south-eastern part of Ukrainian grassland zone, a cyclic variability of the main climatic parameters can be mentioned with certain increase and redistribution of precipitation for 1954/55–2007/08 years (Nesterets et al., 2010). It was observed 0.7°C air temperature increase for Karadag nature reserve (the territory of our research) together with precipitation increase for the last 80 years (Parubets, 2009).

Thus, experimental modification of natural precipitation amounts above grasslands can be an actual and perspective long-term research for Ukraine, taking into account regional climatic trends. Also grassland is a suitable ecosystem for climate change research as grasses react rapidly to altered precipitation and are highly adaptive to extreme climatic conditions with continuous changes (Tkachenko, 2007). That is why it is possible to expect any significant results even after first few years of such experiment.

The aim of this work is to analyze specific features of ecosystem carbon fluxes on grasslands under altered precipitation and to estimate influence of climatic factors on gross ecosystem productivity on the experimental site in south-eastern Crimea.

## Materials and methods

### *Study site*

The experimental site was set in May 2011 in the Karadag Nature Reserve of Ukraine (Kurortne, Feodosia, AR Crimea) at the foot of the coastal range (N 44° 54,914'; E 50° 12,289'), at a distance of 30 m from the boundary of the reserve protective zone. The site area is 17×30 m (0,051 ha); it is located on a flat, relatively plain plateau at the average elevation of 41 m a.s.l. The vegetation represents typical dry grassland of Festuco-Brometea Br.-Bl. et R.Tx. in Br.-Bl. 1949 class, on brown neutral clayish soil (for more details see Didukh, Kuzmanenko, 2013). Precipitation (PPT) is being modified at 7 levels: (1) CC: control ambient PPT, (2) 20%Pa: added PPT by 20%, (3) 20%Pr: reduced PPT by 20%, (4) 40%Pa: added PPT by 40%, (5) 40%Pr: reduced PPT by 40%, (6) 60%Pa: added PPT by 60%, (7) 60%Pr: reduced PPT by 60%. Each treatment is randomly repeated by 3 times for a total of 21 plots. The rainfall-collection-redistribution (RCR) devices as described by Zhou et al. (2006) and rainout-shelters as described by Yahdjian and Sala (2002) are used. There are a rainout shelter above each plot, which consists of a steel frame and 12 gutters placed at the top of the frame as a "roof". The purpose of the gutters is to allow partial interception of precipitation without significant impact on the process of photosynthesis. Every gutter set, depending on installation mode, enables from 0 to 60% interception of precipitation. The collected rainfall is used for adding the precipitation rate on other experimental plots through the water redistribution system.

### *Data collection*

Soil temperature at the 5 cm depth, air temperature, and air relative humidity were measured together with $CO_2$ fluxes with soil temperature probe (Vernier, USA) and T/humidity sensor (Quibit Inc., USA) at the experimental plots. Light intensity was measured with the digital light meter TES-1330A (China). Soil moisture at three depths (15, 30, & 60 cm) was measured 4–5 times a month and daily for next 5 days after every rainfall event with 24in Analog Soil Moisture Tester (Spectrum Technologies, Inc., USA). Daily basic climatic data (air temperature, precipitation, atmospheric pressure) was also retrieved from meteorological on-line archive (http://rp5.ua/Weather_archive_in_Kurortnoye), which represents the data from the geophysical observatory of Centre of Hydrometeorology in Kurortne (5 km from the experimental site).

$CO_2$ fluxes were measured with CO650 Plant CO2 Analysis Package (Qubit Systems Inc., Canada) based on non-dispersive infrared technology. A home-made acrylic transparent canopy chamber (0.5 x 0.5 x 0.5 $m^2$) was used (for more details see Khalaim, Vyshenska, 2012). During the net ecosystem exchange (NEE) measurements, the canopy chamber connected to infrared gas analyzer was sealed on the plastic frame inserted to the soil (2–3 cm depth). To measure ecosystem respiration (ER), after the chamber ventilation it was covered by opaque cloth to prevent $CO_2$ assimilation due to photosynthesis. Gross ecosystem productivity (GEP) was estimated as the difference between ER and NEE. Negative NEE values indicated prevalence of $CO_2$ assimilation by ecosystem. All $CO_2$ fluxes were measured once a month in clear days (8.00–12.00 am) from May to October in 2012 and 2013.

***Statistical analysis***

Statistical analyses were performed with SPSS ver. 16.0.2 (IBM). Results were considered to be significant at the P≤0.05 level. Stepwise multiple linear regression analysis was used to explore the relationships of ecosystem $CO_2$ fluxes with environmental factors (precipitation (mm), soil temperature (ºC), soil moisture, air temperature (ºC), air humidity (%), and luminance ($Lux^2$)) as independent explanatory variables. Linear correlation analyses were also used. In order to examine the effect of experiment type on ecosystem carbon fluxes, 1-way ANOVA was performed.

**Results and discussion**

***Influence of abiotic factors on ecosystem $CO_2$ fluxes***

In order to define the character and the level of abiotic factors' impact which can be potential predictors of ecosystem $CO_2$ fluxes' dynamics, we have done correlation and regression analyses for both research years. GEP in 2012 positively correlated with monthly precipitation ($R^2$=0,27, p<0.0001), soil moisture at the depth 15, 30, and 60 cm ($R^2$=0,36, p<0.0001; $R^2$=0,3, p<0.0001; $R^2$=0,25, p<0.0001, respectively), and air temperature ($R^2$=0,13, p<0.0001). In 2013 correlations were weaker almost twice. Thus, our research has confirmed a widely known (Patrick et al., 2007, Chou et al., 2008, Huxman et al., 2004) positive influence of watering on the productivity dynamics. Here soil moisture has proven to be a better indicator of watering influence on carbon processes than precipitation.

In 2012–2013 ER had a linear correlation with air temperature ($R^2$=0,31, p<0.0001), soil temperature at depths 5 and 10 cm ($R^2$=0,18, p<0.0001; $R^2$=0,16, p<0.0001, respectively), and atmospheric pressure ($R^2$=-0,16, p<0.0001). The common respiration of autotrophs and small heterotrophs in ecosystem has a positive relationship with air and soil temperature, and inverse one with atmospheric pressure, as it has been evaluated from $CO_2$ concentration dynamics in the air of measured soil mass (Ostroumov, Butsenko, 1993).

NEE in 2013 had a negative correlation both with soil humidity at the depth 15, 30, and 60 cm ($R^2$=-0,36, p<0.0001; $R^2$=-0,25, p<0.0001; $R^2$=-0,31, p<0.0001, respectively) and with precipitation ($R^2$=-0,13, p<0.0001). Such negative correlation also means more intensive $CO_2$ assimilation by ecosystem under more watered conditions.

Linear regression analysis has shown a significant relationship between GEP and some climatic factors in 2012-2013. The most effective regression model included as independent variables air temperature, air humidity, soil humidity, and luminance (see table 1).

**Table 1.**

**Coefficients of the linear regression equation which describes relationship between GEP and climatic factors in 2012–2013**

| Variables | Non-standardized coefficients | | Standardized coefficients | t | Significance |
|---|---|---|---|---|---|
| | B | St. error | Beta | | |
| Constant | -1,748 | 0,266 | | -6,572 | 0,000 |
| T air | 0,017 | 0,004 | 0,337 | 4,595 | 0,000 |
| RH air | 0,011 | 0,003 | 0,310 | 4,270 | 0,000 |
| Hsoil 60 | 0,069 | 0,021 | 0,275 | 3,281 | 0,001 |
| Hsoil 15 | 0,031 | 0,014 | 0,193 | 2,243 | 0,026 |
| Light100 | 0,000 | 0,000 | 0,124 | 2,014 | 0,045 |
| Hsoil 15 – soil moisture at the depth 15 cm, T air – air temperature, Hsoil 60 – soil moisture at the depth 60 cm, RH air – air relative humidity, Light100 – luminance. | | | | | |

As it can be seen from the table 1, determination coefficient of this model estimated partial model results' variation at the level of 0.57. It means that 57% of GEP values can be explained by effect of the mentioned climatic factors with the high level of significance (p<0,001).

***GEP and ER dynamics***

GEP varied significantly within both vegetation periods, but character of monthly distribution was different in 2012 and 2013 due to different situations with precipitation (see fig. 1). In 2012 monthly precipitation level was close to average long-term data (for last 80 years, the geophysical observatory of Centre of Hydrometeorology in Kurortne). In 2013 spring was anomaly dry and in summer there was twice as much precipitation as at the same time last year. Such climatic situation influenced GEP dynamics; there were two typical peaks in 2012 at the control plots (May and the beginning of September) and only one high peak in 2013 (the end of June).

GEP in 2012 varied through all experimental plots from 1.84±0.3 to 6.89±1.1 μmol $CO_2$ $m^{-2}s^{-1}$. The most productive there were experimental plots with additional precipitation and control (see fig. 2). In 2013 the same situation can be seen only at the experimental type «+60%» due to anomaly dry spring months. This year GEP varied from 0,26±0,01 to 7,58±2 μmol $CO_2$ $m^{-2}s^{-1}$; the highest GEP values can be seen in June and July after intensive June precipitations (see Fig. 2). Also it needs to be mentioned that bigger variation of precipitation amounts can lead to bigger variation of GEP within a vegetation period.

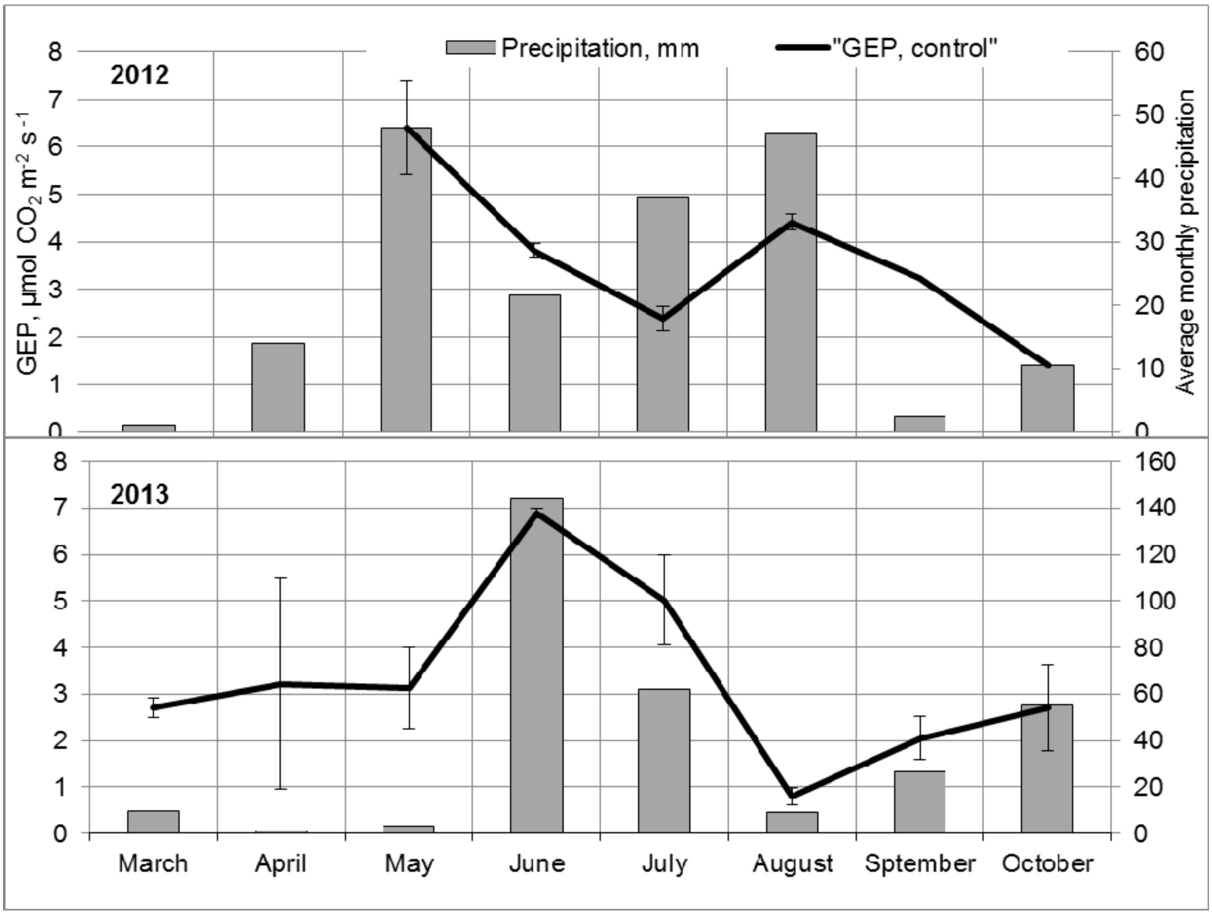


**Fig. 1. GEP (μmol $CO_2$ $m^{-2}s^{-1}$) dynamics on control plots in 2012 (May-October) and 2013 (March-October) together with average monthly precipitation (mm).** "T"-shaped lines represent standard errors for GEP

According to ANOVA results, GEP in 2012–2013 has been influenced significantly by experiment type; analysis of contrasts has shown lack of significant difference between control and experimental modifications, but GEP values of the «-» experimental group (-60%, -40%, -20%) significantly differed from the «+» experimental group. Control GEP significantly differs only from «-60%». In 2012 difference between «+» and «-» experimental groups is bigger.

ER in 2012 has not been significantly influenced by experimental modification of precipitation amounts; grouping of ER values by experimental type was not presented in ANOVA results. In 2013 the significant difference between experimental types has appeared; analysis of contrasts has shown 2 separate groups of ER values according to «+» and «-» experiment types.

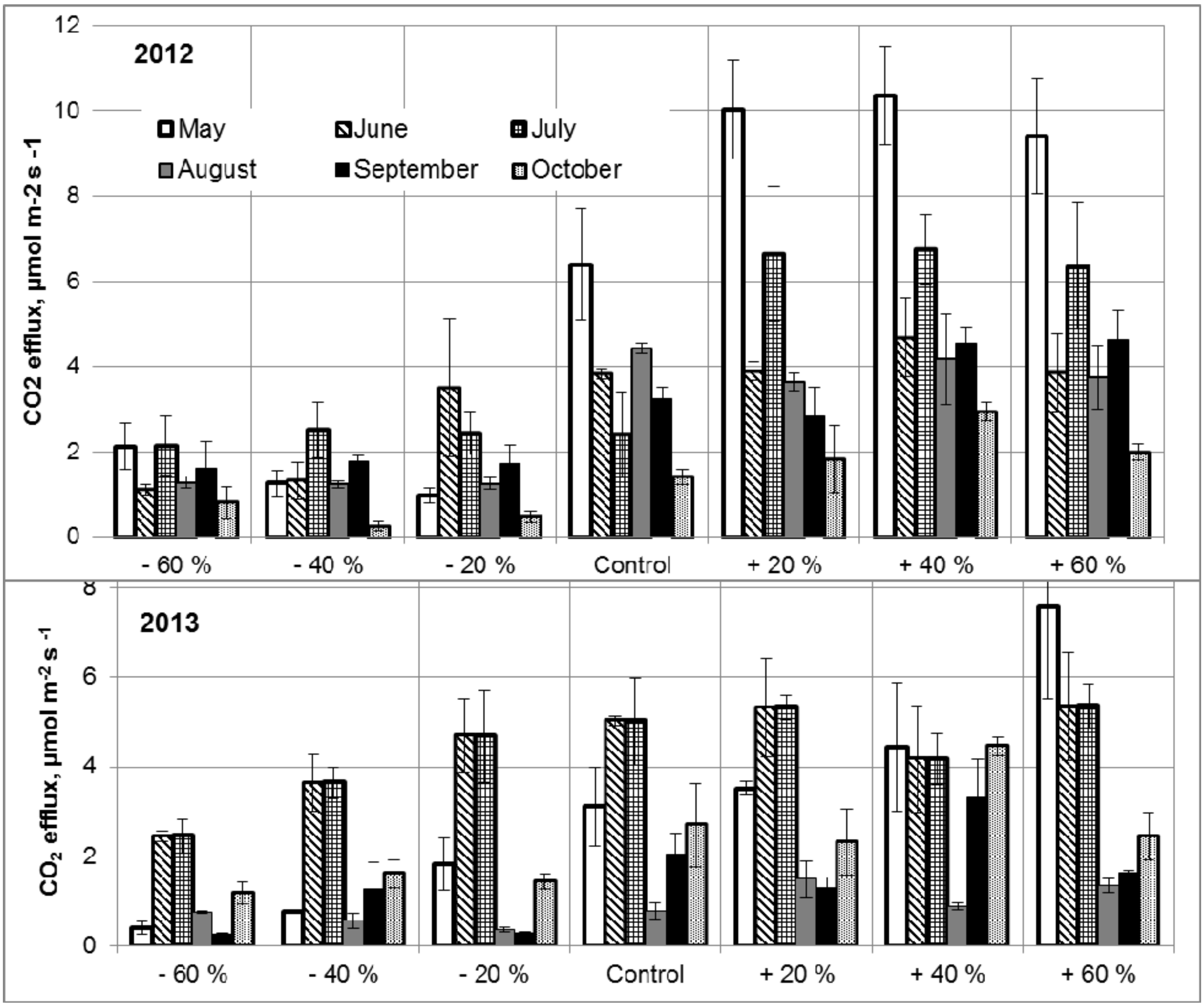


**Fig. 2. Dynamics of monthly average GEP (μmol $CO_2$ $m^{-2}s^{-1}$) in 2012-2013 (May-October) at 6 experimental types and control.** "T"-shaped lines represent standard errors for GEP

Thus, our research has shown a significant positive relationship between level of watering and effectiveness of $CO_2$ assimilation by plants during photosynthesis: both the level of monthly GEP values' variation and the amount of vegetation peaks depended on precipitation quantities and specific redistribution of water in different soil depths.

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