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IMPACT OF RAINFED ON VEGETATION BIOMASS AND BIOMASS CARBON

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ABSTRACT

Understanding the relationship between terrestrial biomass and climate is necessary to predict the effects of climate changes on carbon stocks. Biomass distribution is affected by geographical and climatic parameters and limits carbon accumulation to soil. This study evaluates biomass, precipitation, and carbon correlations of wheat, lentil and barley left to agricultural rainfall. During 2011 to 2012, total precipitation was 381.3 mm, and biomass was 914.49 grams of dry matter m^{-2} (530.41 g C m^{-2}), during 2012 to 2013, there were 1013.58 grams of dry matter m^{-2} (587.88 g C m^{-2}) that were obtained with 381.3 mm of precipitation. In parallel with a 1 mm increase in precipitation, 2.89 grams of dry matter m^{-2} (1.68 g C m^{-2}) were found during 2011 to 2012 and 2.66 grams of dry matter m^{-2} (1.54 g C m^{-2}) were found in 2012 to 2013. A strong correlation was found between precipitation and biomass ($P<0.001$; $R^2=0.6551$ in wheat, $P<0.001$; $R^2=0.5458$ in lentil and $P<0.001$; $R^2=0.6687$ in barley). In addition, a strong correlation was found between total annual carbon and total annual precipitation ($P<0.001$; $R^2=0.5221$ barley + lentil and $P<0.001$; $R^2=0.6221$ wheat + lentil).

Key words: carbon cycle, agricultural ecosystem, precipitation, annual net plant production, biomass carbon

INTRODUCTION

Annual net plant production has an important place in the carbon cycle and is the main source of carbon dioxide released to the atmosphere from biota. Atmospheric carbon dioxide is turned into glucose by plants with the help of the sun (photosynthesis) (Odum, 1971). Annual net plant production is regarded as a soil organic substance in calculating total carbon in ecosystems. Materials transforming into organic substances consist of dead and alive plants and animal residues. The decomposition of these residues by organisms results in the release of carbon dioxide from the biosphere to the atmosphere. Chemical elements return to soil and atmosphere by the decomposition of organic substances and living activity processing (Ajtay et al., 1979). Therefore, bio-chemical event cycle continues between soil and atmosphere.

The transition of humans to an agricultural life began approximately 10000 years ago (Diamond and Bellwood, 2003) and it expanded to all regions of the world later on. At this time, humans are using or changing 23 to 40 percent of global terrestrial net primary productivity (NPP) (Haberl et al., 2007). Many studies and lots of research on total NPP have been done (Lieth, 1975; Golley, 1972; Bowen, 1966 etc.). Researchers obtained many different results in those studies that they conducted. Whittaker and Likens (1975) conducted one of the most important studies on total terrestrial production, which was found 117.5x1015 grams (53 Pg C $year^{-1}$) of dry matter. Among all of these studies, the highest production of dry matter was calculated as 158.4 Pg by Bazilevich (1974).

Most studies separate the factors affecting annual net plant production into two different categories as environmental and non-environmental. Environmental factors include annual average temperature (Raich et al., 2006), annual rainfall (Sankaran et al., 2005), the proportion of annual rainfall to annual average temperature, the combination of annual rainfall and annual average temperature (Desortova and Puncochar, 2011) and drought (Saatchi et al., 2007). Apart from

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climatic factors, the distribution and amount of useful nutrients in the soil also affect annual net plant production (Kerkhoff and Enquist, 2006). In their study on forestry species, Stegen et al. (2011) indicated that there is not a relationship between forest biomass and annual average temperature.

According to some climate change scenarios, rainfall and its distribution in continental ecosystems change the plant production and the amount of carbon fixed by plants (Weltzin and Tissue, 2003; Schwinning et al., 2004). Rainfall is an important parameter in continental ecosystems. The distribution of rainfall according to geographical gradients may cause ecological and morphological changes (Wang and Gao, 2003a). An increase in rainfall (Sankaran et al., 2005) causes an increase in annual net plant production and accordingly in carbon amount, which decrease together with a decrease in rainfall (Reynolds et al., 2004). However, annual rainfall cannot solely control annual NPP and the amount of carbon (Ogle and Reynolds, 2004); the available nitrogen in the soil and soil temperature are also effective for predicting plant production and the amount of carbon (Muldavin et al., 2008). The regular distribution of rainfall is more important than annual rainfall amount. In addition, water amount in soil, water-holding capacity of soil, nutritional materials and carbon content of the soil are also effective for predicting plant production and the amount of carbon.

There is a strong correlation between ground surface, underground NPP, and annual rainfall (Huxman et al., 2004b). The strong correlation between the average annual NPP and annual precipitation was proved through correlation analysis (R^2=0.66). Places with annual rainfall under 220 mm have a low NPP amount (Wehrden and Wesche, 2007). Also, annual biomass is high in areas with high rainfall and soil moisture (Robertson et al., 2009). Carbon penetration into the soil decreases in places with low NPP and increases in places with high NPP. According to Muldavin et al. (2008), the increase in NPP and carbon depends on the water holding capacity of the soil. The presence of water in the soil enables the plants nutritional elements to be transported to the roots of plants through decomposition. When the plants intake decomposed nutritional elements, it causes increases in both annual net plant production and carbon penetration to soil (Renzhong and Qiong, 2003).

This study aimed to determine the correlation between annual rainfall, ground surface biomass, and the carbon values of biomass in areas left to agricultural rainfall in arid and semi-arid climates.

MATERIAL AND METHODS

The study area was located in Harran Plain, which is 40 km south of the Şanlıurfa Province. Harran Plain is located at 36º47' and 39º15' eastern longitude and 37º41' northern latitude (Anonymous, 2006). The altitude of the plain ranges from 340 to 500 meters and it has an even topography. The plain has argillaceous soil and a50 to 60 clay content 1.32 to 1.74 organic materials and 1.03-1.60 dS m^{-1} EC. The soil reaction of the study area soils ranges from (pH) 7.01 to 8.0.

The regions have a semi-arid climate; which is dry and hot in the summer and cold and rainy in the winters. The average minimum temperature was 4.9°C, which was measured in January and average maximum temperature is 31.3°C, which was measured in July. Rainfall and evaporation amount in January were 347.5 mm and 1849 mm, respectively. Summer season had almost no rainfall (GDRS, 2012, 2013).

The study was conducted at the testing ground of Talat Demirören Research Station of SAP (Southeastern Anatolian Project) Agricultural Research Institution. After the soil was prepared, wheat, lentil and barley, which are commonly used in the region, were planted and left to natural rainfalls. In the experiment, randomised blocks experimental design with 3 repetitions was used. Plot width was determined as 2 meters, and length as 3 meters and plot area was 6 m^2. Edge effect was accepted as 50 cm in plot edges and harvested plot was 1 meter by 3 meters in the middle.

The period from planting to harvest (November - June) was 8 months and the rainfall amount (mm) was determined through ground surface NPP amount in 1 m^2 planted areas. Surface biomass from 1 m^2 (1 m × 1 m) in sampling areas was removed from the ground and weighed and then put into paper bags and labelled. The obtained samples were washed in fine and sensitive sieves. All samples were dried at 65ºC for 72 hours until reaching a constant weight, and then their dry weights were measured. The relationship between dry biomass in 1 m^2 and rainfall was determined for each crop.

Samples were taken from 0 to 30 cm soil depth and in three repetitions in order to conduct some physical and chemical analyses of the study sample soils, which is Vertisol soil (Soil Survey Staff, 2010). Soil samples were sieved in 2 mm meshes. In the soil samples, the amount of organic material was determined through Walkley-Black method (Nelson and Sommers, 1982), texture was determined through particle distribution method (Bouyoucus, 1951), the amount of lime was determined through carbonate method (Allison and Moodie, 1965), soil reaction was determined by a pH meter (Horneck et al., 1989), and electric conductivity (EC) was determined by an EC meter in soil extraction method (Janzen, 1993). SPSS (SPSS Science Inc., 1989) statistics program was used in statistics analysis in order to compare all data.

RESULTS AND DISCUSSION

Annual net plant production was differentiated in three different types of agricultural plants. From 2011 to 2012, total NPP was 1131.05 grams of wheat, 893.21 grams of lentil and 470.22 grams of dry matter m^{-2} in barley, from 2012 to 2013 it was 1378.74 grams of wheat, 1088.81 grams of lentil and 573.19 grams dry matter m^{-2}, respectively (Table 1). Biomass production depends on rainfall and the amount of present water in soil. Therefore, from 2012 to 2013, biomass amount was to be higher than the other period. An increase in annual rainfall causes an increase in annual biomass until the generative period and then stays stable. Sakin (2012) conducted a study in the Southern Anatolian Region and determined 791.49 grams of dry matter m^{-2} in wheat, 325.15 grams in barley and 199.24 grams in lentil. The study concluded that low amounts of biomass were created because of the drought from 2010 to 2011.

Table 1. NPP amounts between 2011-2012 and 2012-2013 seasons

Year	Rainfall	Wheat NPP (g m^{-2})	Lentil NPP (g $m^{-2)}$	Barley NPP (g m^{-2})	Year	Rainfall	Wheat NPP (g m^{-2})	Lentil NPP (g m^{-2})	Barley NPP (g m^{-2})
2011-2012	21.20	0	0	0	2012-2013	47.40	0	0	0
	78.80	21.98	20.09	38,50		143.80	40.11	36.66	70.26
	117.00	70.32	23.23	71,98		221.20	132.95	43.92	136.08
	218.30	253.95	85.51	158,59		270.50	314.68	105.95	196.52
	281.60	379.29	175.60	136,08		317.90	428.19	198.23	153.62
	288.90	1027.88	707.10	473,97		320.30	1139.60	783.95	525.48
	299.00	1232.66	971.35	513,21		332.10	1369.12	1078.88	570.03
	312.80	1235.05	993.21	515,22		381.30	1378.74	1088.81	573.19

Many studies indicated that several different factors affect annual net plant production. These factors include annual average temperature (Raich et al., 2006), annual rainfall (Sankaran et al., 2005), the proportion of annual rainfall to annual average temperature, the combination of annual rainfall and annual average temperature (Desortova and Puncochar, 2011) and drought rainfall (Saatchi et al., 2007). Apart from the climatic factors, the distribution and amount of useful nutritional materials in the soil also affect the amount of biomass (Kerkhoff and Enquist, 2006). Stegen et al. (2011) indicated that there is not a relationship between forest biomass and annual average temperature.

Places with an annual rainfall amount under 220 mm have low NPP. However, annual biomass is high in periods with high precipitation and soil moisture (Robertson et al., 2009). Accordingly, if there is an increase or decrease in biomass, then in turn carbon penetration to soil increases or decreases, respectively. According to Muldavin et al. (2008), the increase in NPP and carbon depends on the water holding capacity of soil. The presence of water in soil enables plant nutritional materials to be transported to the roots of plants through decomposition. When the plants intake decomposed nutritional materials it causes increases in both annual net plant production and carbon penetration to soil (Renzhong and Qiong, 2003).

A strong correlation was found between annual rainfall and annual total biomass in each of the three NPP types. These correlations were found in wheat ($P<0.001$; $R^2=0.6551$), lentil ($P<0.001$; $R^2=0.5458$) and barley ($P<0.001$; $R^2=0.6687$). An increase in annual rainfall caused an increase in annual biomass until the generative period and then it stayed stable (Figure 1).

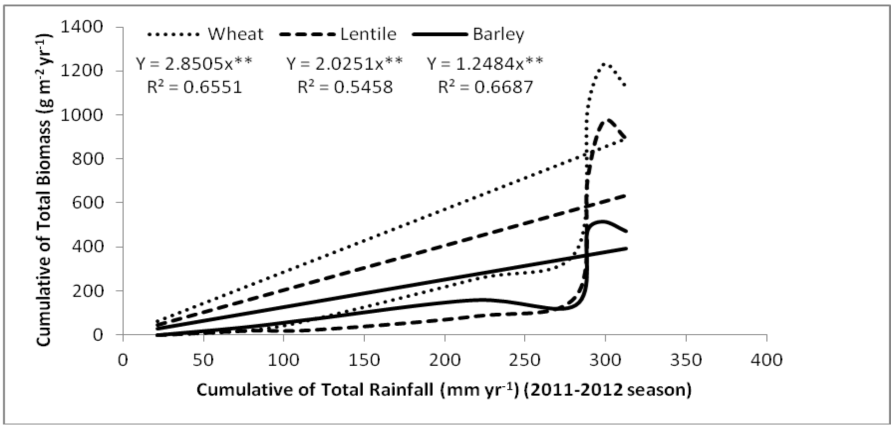

Figure 1. Relationships between cumulative total biomass and cumulative rainfall of 2011-2012 seasons (*P<0.05, **P<0.01)

From 2012 to 2013, strong correlations ($P<0.05$; $P<0.001$) were found between annual rainfall and annual biomass: $R^2=0.5464$ in wheat, $R^2=0.4464$ in lentil, and $R^2=0.5928$ in barley. This increase, as shown in Figure 2, started in October and continued until the generative period and then stayed stable. From 2012 to 2013, during the production period, if there was a 1 mm increase in rainfall, then biomass increased by 4.33 grams of dry matter from wheat, 2.86 grams of dry matter from lentil and 1.5 grams of dry matter from barley. Huxman et al. (2004) also determined a strong correlation between ground surface biomass and annual rainfall ($R^2=0.66$).

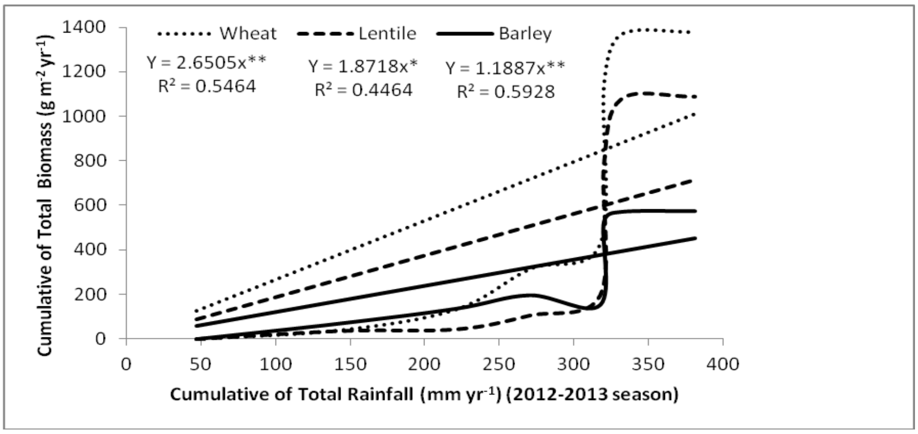

Figure 2. Relationships between cumulative of total biomass and cumulative rainfall of 2012-2013 seasons (*P<0.05, **P<0.01)

From 2011 to 2012, during the production period, if there was an increase of 1 mm in rainfall, then biomass increased to 3.95 dry matter m^{-2} in wheat, 3.09 dry matter m^{-2} in lentil, and 1.65 g dry matter m^{-2} in barley. On average, 2.89 grams of dry matter m^{-2} were collected. If there was 1 mm increase in rainfall, the increase of biomass was found to be 1.5 g m^{-2} by Blaisdell (1958), 1.0 g m^{-2} by Walter (1955), 0.4 to 0.6 g m^{-2} by Pandey and Singh (1992). The total increase was stated as 2.4 grams m^{-2}. Therefore, the results of the present study are consistent with other research studies.

Annual total carbon increases depending on the increase in annual total biomass. A strong correlation was found between annual rainfall and carbon obtained from annual biomass ($P<0.001$, $R^2=0.5221$). From 2011 to 2012, an increase of 28.43 to 587.88 grams C m^{-2} $year^{-1}$ was obtained from three crops (wheat, lentil and barley) (Figure 3).

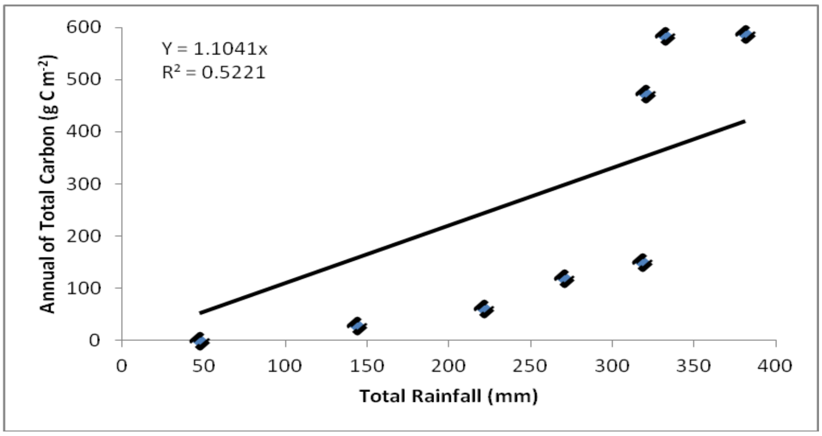

Figure 3. Relationships between carbon and rainfall of 2011-2012 seasons (**P<0.01)

From 2012 to 2013, during production period, a high, strong correlation was found between annual rain fall and annual total carbon amount ($P<0.001$, $R^2=0.6221$). So in effect, an increase in rainfall also increases carbon (Figure 4).

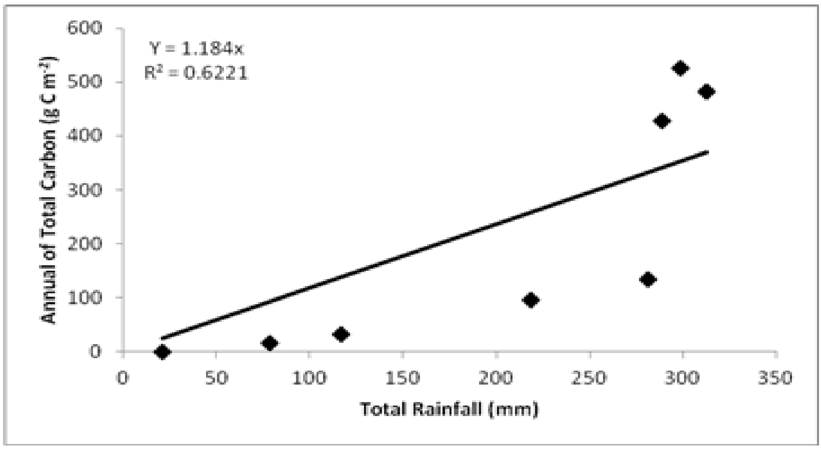

Figure 4. Relationships between carbon and rainfall of 2012-2013 seasons (**P<0.01)

Annual total biomass carbon also increased in parallel with annual rainfall. In other words, carbon amount increased as biomass amount increased. According to the present study, from 2011 to 2012, during production period, if there was a 1 mm increase in rainfall, then biomass increased to 2.29 grams C m^{-2} from wheat biomass, 1.79 grams C m^{-2} from lentil biomass and 0.96 grams C m^{-2} from barley biomass, with an average of 1.68 grams C m^{-2}. From 2012 to 2013, 2.10 grams C m^{-2} was obtained from wheat biomass, 1.66 grams C m^{-2} from lentil biomass and 0.87 grams C m^{-2} from barley biomass, with an average of 1.54 grams C m^{-2}. The average total carbon amount of both years was found to be 1.61 grams C m^{-2}. Previous research showed that if there was a 1 mm increase in rainfall, then biomass in carbon was calculated to increase by 0.68 g C m^{-2} according to Blaisdell (1958), 0.45 grams C m^{-2} according to Walter (1955), and 0.20 grams C m^{-2} according to Pandey and Singh (1992). The total increase was calculated to be 1.09 grams C m^{-2}. The results of the present study are consistent with these other research studies.

According to the changing climate, rainfall and its distribution in continental ecosystems changes plant production and the amount of carbon (Snyder and Tartowski, 2006). Rainfall is one of the most important parameters in continental ecosystems and may cause ecological and morphological changes in plants.

CONCLUSIONS

All biomass types in continental ecosystems should be measured in order to understand the effect of global climate changes on carbon. All parameters affecting biomass should be separately examined and the correlation between them should be determined. The primary purpose of the present study was to determine and examine the correlation between biomass and rainfall, which affects carbon penetration in the soil. This study determined strong correlations between rainfall, biomass and carbon.

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