Estimation of above and below ground biomass and carbon content in the grasslands of Bicakcilar and Kilickaya province in Artvin, Turkey

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Abstract: Above and belowground biomasses of grasslands are important parameters for characterizing regional and global carbon cycles in grassland ecosystems within terrestrial ecosystems. The objective of this study was to determine above and below ground biomass in the grassland areas of Bicakcilar and Kilickaya province in Artvin within Coruh River Basin located northeastern Turkey. Additionally, the amount of carbon contents were also calculated in the study areas in relation to regional distribution patterns of above and below ground biomass and their relationships with environmental factors were also investigated. To implement the study, 55 sampling sites were selected for different altitudes to determine the amounts of above and below ground biomass. For determination of above ground biomass (AGB), 1x1 meters in size wire cages were placed in the selected sample plots before the beginning of the vegetation period. These protected areas/plots (1x1 m^2) were harvested from soil levels at the end of the vegetation period and then dry weighed in laboratory. Root sampling for the below ground biomass (BGB) was also carried out using steel pipe of 6,4 cm in diameter and 30 cm in length. According to the obtained results, the amounts of AGB and BGB were ranged from 1 ton/ha to 3,8 ton/ha and from 3 ton/ha to 6,3 ton/ha in the Bicakcilar, respectively. As for the study areas of Kilickaya, the amounts of AGB and BGB were ranged from 0,8 ton/ha to 4 ton/ha and from 2,4 ton/ha to 5,2 ton/ha, respectively. The average carbon contents in the grassland of Bicakcilar and Kilickaya were estimated as 3,4 ton/ha and 3 ton/ha, respectively. At the same time, it was found that the amount of AGB increased to a certain altitude and then decreased, while the amount of BGB increased or decreased contrarily. Additionally, statistical analysis indicated that precipitation was the key determining factor for the amount of AGB and BGB in respect to the altitudinal change.
Keywords: Aboveground biomass (AGB), Belowground Biomass (BGB), Carbon, Grasslands

1. Introduction

Grasslands are potential carbon sinks to reduce unprecedented increase in atmospheric CO_2. Accurate estimation of above and below ground biomass carbon storage has gained more and more attention in the context of deepening research on the global climate change. Biomass is one of the most important grassland properties used to determine grazing capacities and their yield. Grassland biomass is under the influence of artificial and natural factors, and it shows temporal and spatial changes. Global climate change may affect ecosystem functioning by increasing temperature and changing precipitation amounts and patterns (Fiala et al., 2009), and climate is the major factor influencing carbon fluxes in grasslands (Paruelo et al., 2010). Precipitation and temperature are the main factors affecting grassland biomass (Hielkema et al., 1986; Nicholson et all., 1990; Tucker et al.,

1991; Clenton et al., 1999; DuPlessis, 1999; Wang et al., 2001). These two factors affect the biologic and physiological activities of plants such as photosynthesis, inhalation and sweating, affecting either positively or negatively amount of biomass production in the grassland ecosystems. Also, soil and climatic characteristics affect above ground biomass production as well.

Grasslands are one of the world's most common vegetation types, covering a wide area in both tropical and temperate regions. 15% of all global organic carbon in the world stored in the grasslands (Körner, 2002). Over the world, grasslands cover an area of 3.4 billion hectares and store approximately 343 billion tons of carbon. The amount of carbon stored in pasture areas is about 50% higher than the amount of carbon stored in forests (FAO, 2010a). It has been reported that there is a significant decrease in carbon accumulation due to the deterioration of grassland as a result of overgrazing in the pasturelands (Stypinski et al., 2006). In the global scale, to improve practices on grassland lands or rehabilitation of degraded grasslands that is as important as forest and agricultural areas. The coefficient used to convert the amount of biomass to carbon content in the grassland was found to be 50% (Lales et al., 2001).

In grassland ecosystems, resource allocation between above and below-ground layers, as well as root vertical exploration, are the main determinants of carbon (C) distribution (Sims and Singh 1978). About two-thirds of terrestrial C is located below-ground and this pool generally has much slower turnover rates than aboveground C (Schlesinger, 1997). Approximately 70–75% of root biomass in grassland is concentrated in the upper 15 cm of the soil horizon (Gleixner et al., 2005). The root biomass increases with age of grassland. An analysis of many published research works showed that, in grasslands below ground biomass averaged 1400 gr/m^2 and that 83% of roots occur in the top 30 cm depth (Jackson et al., 1996). In these ecosystems, the below to above ground biomass ratio reaches a value of 3.7 (Jackson et al., 1996).

Therefore, tropical and subtropical grasslands usually have a root: shoot ratio (R:S) higher than 4 (Mokany et al., 2006), while, in comparison, forest ecosystems have an R: S ratio below 1 (Cairns et all., 1997; Castro et all., 1998). This highlights the importance of below-ground biomass in grassland ecosystems. Although the amount of carbon in the above ground biomass in the grassland is small compared to the forest, but grassland is very important in terms of the carbon storage. Grazing can affect the stock and flow of C between above and below ground vegetation layers (Pineiro et al., 2009).

Grasslands have a rich and complex below-ground structure, with fine and coarse roots and a variety of below-ground organs, such as rhizomes, bulbs, corms and xylopodia, as well as a rich micro-flora and fauna (Stanton, 1988). A great deal of competition among the plants is taking place under the soil. Studies on C storage suggested that most of the C in grasslands originates from below ground biomass (Hungate et al., 1997; Jackson et al., 2002), primarily roots (Adair et al., 2009). Larger roots may be more important compared to small roots to enhance C pools (Rasmussen et al., 2010). Plants on the above ground compete for light and water and nearly twenty basic food stuffs in the below ground (roots) (Casper et al., 1997). Harris (1973), stated that in relation to root studies, "Although the importance of roots as structural repositories and physiologically active organs is well known, due to the difficulties in work it has been neglected in ecosystem studies" (Santantonio et al., 1977, 1979). Although significant research has been done on roots from 1970's to 2000, the difficulty of root work remains the most important problem. The methods used to determine the amount of below ground biomass are generally ignored because they are boring, time consuming and difficult.

In this study, we investigate the above and below ground dynamics of both biomass and carbon stocks of catchments in Coruh River Basin: Bicakcilar micro-catchments (40^0 51^I 27^{II} S, 41^0 12^I 58^{II} W), and Kilickaya micro-catchments (40^0 36^I 12^{II} S, 41^0 20^I 27^{II} W) located in Northeastern Turkey (Figure 1). Local annual precipitation of Bicakcilar and Kilickaya micro-catchments were 1274 mm and 918 mm, with the mean temperatures of 7 ^{0}C and 6,5 ^{0}C, respectively. The climate characteristics of the micro-catchments change in general, from the temperate climate features to the continental climate as you go from the Black Sea coast to inner parts of the Black Sea. Average elevations of the micro-catchments are 2287 m for Bicakcilar and 1547 m for Kilickaya above msl.

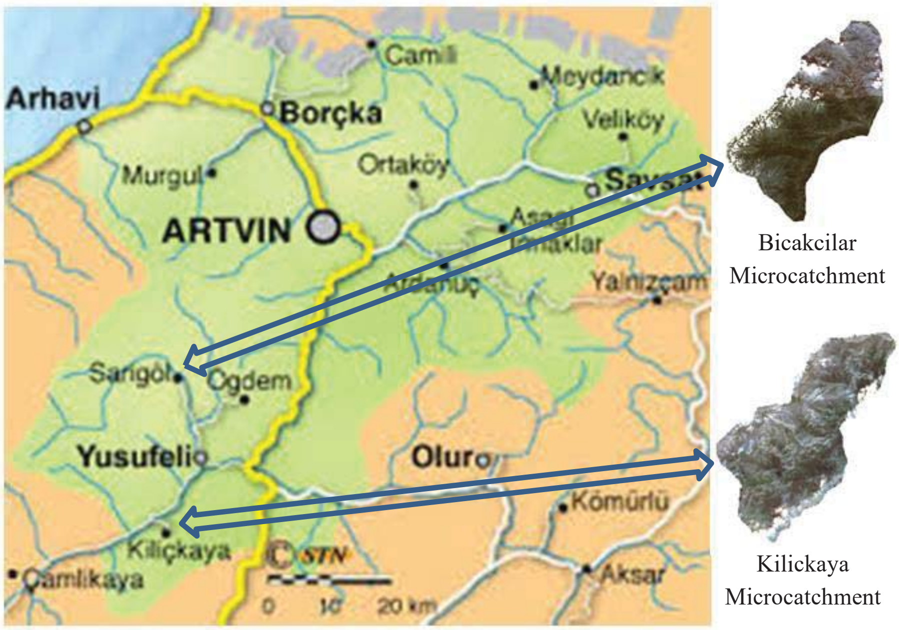

Figure 1- Micro-catchments within the study area

In terms of the land use types, Kilickaya has % 33 (8090 ha) and Bicakcilar has %42 (10998 ha) grassland area of total area. In general, the study area consists of various volcanic and metamorphic rocks and quaternary mineral deposits. The most common soil types in the study area are basaltic soil, brown forest soil, brown soil, chestnut soil and high mountain grassland soil. Most of the soils, with moderate to low productivity, have moderate to high erosion levels, especially on steep slopes (URL-1). Micro-catchments are also located in the flora region of Siberia in Europe. The Euro-Siberian (Euxine-Colchis) flora area contains all the northern parts of Turkey (Black Sea and Inner parts) and extends to a large part of the Caucasus to the Crimea and Dobrudja mountains to the east. With increasing elevation, the number of trees increases (pine, spruce, fir and mixed forest) in this region. The forests extend especially along the northern slopes, which receive more precipitation (URL-2).

2.2. Field data

In order to determine the above ground biomass in the grassland, wire cage assemblies of 1x1 meter size have been established at selected sampling points/plots (Todd ve ark. 1998) in Bicakcilar and Kilickaya (Figure 2).

(a) (b)

Figure 2- 1x1 m size cage established for determining the above ground biomass (a) before the vegetation period (b) and end of the vegetation period.

Three different elevation zones (1000-1500m, 1500-2000 m and 2000-2500m) and two different classes of aspects (shaded and sunny) were taken into account in order to estimate the amount of above ground biomass most accurately in the sampling plots. These plots were harvested from soil levels at the end of the vegetation period and placed in polyethylene bags and brought to the Artvin Coruh University Soil Science and Ecology Laboratory.

To determine the below ground biomass in the grassland, 55 sampling location were selected randomly and 220 root samples were taken randomly (4 samples were taken from each sampling location). In the study area, steel pipes with a diameter of 6,4 cm and a length of 30 cm were used for the sampling of the root (Figure 3).

Figure 3- View from root sample in the study areas

Each cylinder sample was transferred to a polyethylene bag and labeled and closed at the mouth and brought to Artvin Coruh University, Department of Soil Science and Ecology. According to the researches, the depth of 0-30 cm can represent 70-85% of the existing root mass (Eissenstat et al., 1997; Tüfekçioğlu et al., 2002).

2.3. Sampling processing and climate data

End of the vegetation period, vegetative parts was cut with scissors on the ground level to determine the above ground biomass. The dry matter weight of all sampling points was determined by sensitive scales by flushing at 80ºC for 2 days (Todd et al., 1998). The necessary transformations were made to determine the root amount in hectare (Figure 4a).

To determine the below ground biomass, all samples taken from the study area transferred to plastic bottles and added a little water, then left overnight to separate the soil from the roots. Below- ground biomass was water-washed in order to remove most of the soil attached to roots and other organs until free from all soil parts and filtration through 0,2 mm sieves. The roots that were cleaned from the soil were put into the water in white cups, and the pieces of dead cover, foreign matter and earthy soil were removed with the help of tweezers (Figure 4b).


Figure 4 (a)- Drying of the above-ground biomass samples (b)- Extraction of root samples from soil

Then, again with the help of tweezers, the roots were divided into three groups: capillary (0-2 mm), fine (2-5 mm) and coarse root (5-10 mm) and dried at 80 ° C for 24 hours and weighed at a sensitivity of 0.001 grams. The necessary transformations were made to determine the root amount in the hectare.

Meteorological data were used (rainfall and temperature) for the study area for the 30 previous years, recorded at Meteorology Station located in the research area.

3. Result and discussion

The average above and below ground biomasses and carbon amounts were presented in Table 1. When the amounts of total biomass in hectare were evaluated, it was determined that the highest value (6,38 ton/ha) was found in Bicakcilar and smallest value (4,96 ton/ha) was found in the study areas of Kilickaya.

Table 1- The average above and below ground biomass and carbon amount in the study areas of Kilickaya and Bicakcilar

StudyAreas	Average above ground biomass (ton/ha)	Average above ground carbon (ton/ha)	Average below ground biomass (ton/ha)	Average below ground carbon (ton/ha)	Precipitation (mm)	Temperature (ºC)
Kilickaya	1,57	0,78	3,39	1,70	914	6,5
Bicakcilar	1,87	0,94	4,51	2,25	1274	7

According to this data, the amount of biomass increased linearly with increasing precipitation ($p < 0.05$). Since water is an important source of plant growth, the amount of above ground biomass in the pasture areas is generally expected to decrease under arid conditions, while the judgment that the amount of below ground biomass should, on the other hand, increase under arid conditions has been supported by many investigations and findings (Tilman et al., 1992; Keller et al., 2004; Kahmen et al., 2005).

When the amount of above ground biomass is examined in the study areas of Bicaklcilar and Kilickakaya, the above ground biomass increased with the increased rainfall amounts. The amounts of above ground biomass were estimated 1,57 ton/ha in Kıilickaya (914 mm rainfall) and 1,87 ton/ha in Bicakcilar (1274 mm). Kendir (1999), calculated that the above ground biomass in Ankara grassland was 1,02 ton/ha, where the average annual rainfall was 368 mm. Yavuz et al., (2013) reported that the total above ground biomass in Duzce Esenler grassland was found to be 1,5 ton/ha. The study conducted in Artvin Aydin village grasslands by Bilgin (2010) found that the above ground biomass amount was changed from 1,5 ton/ha to 2,9 ton/ha with the average of 2 ton/ha.

In this study, the ratio of the below ground biomass to above ground biomass were found as 2,16 in the Kilickaya and 2,41 for Bicakcilar. Similar results recorded by Jiangwen et al. (2007) in China found that the ratio of below ground biomass to above ground biomass was estimated as 2.45.

The amount of total carbon (above and below ground carbon) was estimated as 2,48 ton/ha in Kilickaya, and 3,19 ton/ha in Bicakcilar and the average carbon amount was found 2,84 ton/ha (Bicakcilar and Kilickaya). The percentage of below ground carbon was changed between %69 to %76 and the percentage of above ground carbon varied from %24 to % 31 when we compared to total carbon amount in these two study areas. Glatzle (2012), reported that the ratio of below ground carbon was changed between %40 and %80 and the ratio of above ground carbon varied between %20 and %60. Also, he stated that the presence of woody species increases with increased of above ground biomass while below ground biomass decreasing.

Total biomass amounts were calculated from the study areas as 40126 ton for Kilickaya and 70167 ton for Bicakcilar (Tablo 2).

Tablo 2- Above and below ground biomass and carbon amount (ton)

Micro basins	Total above ground biomass (ton)	Total above ground carbon (ton)	Total below ground biomass (ton)	Total below ground carbon (ton)	Total biomass (ton)	Total carbon (ton)
Kilickaya	12701	6351	27425	13713	40126	20063
Bicakcilar	20566	10283	49601	24801	70167	35084

4. Conclussion

When we examine the amount of above ground biomass obtained according to precipitation amounts, the amount of above ground biomass is 1,87 ton/ha (Bicakcilar) which is highest precipitation and 1,57 ton/ha (Kilickaya) which is lowest precipitation amount. The amount of above ground carbon was calculated as 0,94 ton/ha and 0,78 ton/ha, respectively. The total biomass and carbon content depents on precipitation. According to analysis of varience, statistically significant differences were found in terms of above ground biomass and carbon contents between these micro basins ($p<0,05$). Also, the temperature determines the length or the shortness of the vegetation period and these affected to amount of above and below ground biomass.

Grasslands largely contain carbon deposits, which should be included in national carbon accounting. Although grasslands have large areas for carbon storage, more work and knowledge are needed on how changes in their composition affect the amount of carbon they can store. In order to be able to generalize the results obtained in the works done in Turkey, similar studies should be conducted in different climates, lands, aspect and geographical regions of Turkey.

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