DISTRIBUTION OF BELOWGROUND BIOMASS IN A SHORTGRASS PRAIRIE ECOSYSTEM

Sultan Maqsood Khan*

Abstract. *A study was conducted on shortgrass prairie near Fort Collins Colorado to determine the effect of depth, slope and micro-relief (ridges and depressions) on belowground biomass. The underground plant biomass was collected to 40 cm depth. Fifty percent (1004 g/m^2) of the total collected biomass (2008 g/m^2) was found in the 0-10 cm soil section; 24% (482 g/m^2) in the 10-20 cm layer; and 26% (522 g/m^2) in the 20-40 cm depth. The middle slope outproduced (2370 g/m^2) the upper slope (1741 g/m^2) and lower slope (1911 g/m^2) in root biomass. The belowground production of ridges (2064 g/m^2) was not significantly different from that of the depressions (1951 g/m^2). This showed that the bulk of root system in shortgrass prairie ecosystem was close to the ground surface.*

Introduction. A majority of the primary producer components in the shortgrass prairie ecosystem occurs underground (Bartos, 1971). Root systems act as the conducting mechanism between the aerial portions of the primary producer and the soil medium, energy and the nutrient storage organs; and food sources for small herbivores; and are essential in the cycling of nutrients within the ecosystem.

It has been reported for various grassland ecosystems that 80 to 95% of the vegetation biomass occurs underground (Nilsson, 1970 and Ovington, Heitcamp and Lawrence, 1963). Because of the proportion and role of roots in a grassland ecosystem it seemed necessary to study them in more detail.

The objectives of this study were:

1. To determine the total belowground biomass at different soil depths.
2. To determine the effect of depth on production of belowground parts of plants.
3. To evaluate how slope position influenced belowground biomass.
4. To obtain estimates of the variability of belowground biomass production.
5. To document the relationshop between soil depth and belowground biomass.

---

*The author is Range Management Officer in the Pakistan Forest Institute, Peshawar.

Study Area. The study area was located about 8 kilometers southwest of Colorado State University's main campus, along the Tafthill road on a tract of shortgrass prairie. It was situated at about 40½° N Latitude, 105° W Longitude at an elevation of about 1600 metres above msl. The general aspect is northely. The slope was gentle to moderate and was about 80 metres in length.

Located in the semi-arid climatic type described by Thornthwaite (1948), the area was cool and temperate. The 88 year (1887-1975) average temperature and precipitation obtained from the Fort Collins Weather Station, situated about 8 kilometres north-east of the study area, are given in Table 1 (Wirshborn, 1977).

Generally the soil was shallow at the top and the soil depth increased with the distance from the top becoming moderately deep at the bottom. The texture was generally clay loam to sandy loam.

Table 1

Average of temperatures and precipitation of Fort Collins Weather Station (1887-1975)

Month	Maximum temp. (C)	Minimum temp. (C)	Rainfall (mm)	Snowfall (cm)
Janury	4.7	—11.0	9	13.5
February	6.2	—9.2	13	17.8
March	9.9	—5.3	26	24.6
April	15.6	0.1	50	16.3
May	20.3	5.2	71	2.5
June	25.9	9.7	44	0
July	28.9	12.7	39	0
August	28.6	11.8	38	0.8
September	24.1	6.7	33	0.8
October	17.9	0.8	29	7.1
November	10.6	—5.5	13	14.0
December	5.8	—9.4	12	14.5
Total for year			375	111.9

The main species occurring on the study area are listed below:

Shrubs. *Artemisia frigida* (fringed sage), *Atriplex canescens* (fourwing saltbush), *Ceratoides lanata* (winterfat) *Chrysothamnus* spp. (rabbitbrush), *Haplopappus spinosus* (golden weed family), *Opuntia polycarpa* (cactus) and *Yucca glauca* (soapweed).

Grasses. *Agropyron smithii* (western wheat-grass), *Aristida longiseta* (red three-awn), *Bouteloua curtipendula* (side oats grama), *Bouteloua gracilis* (blue grama), *Bromus japonicus* (japanese chess), *Stipa comata* (needle and thread grass), *Buchloe dactyloides* (buffalowgrass), *Oryzopsis hymenoides* (Indian rice-grass), *Stipa robusta* (robust stipa) and *Stipa viridula* (needlegrass).

Forbs. *Aster* spp. (aster), *Astragalus* spp. (locos), *Eriogonum alatum*, *Eriogonum effusum* (bushy eriogonum), *Helianthus* spp. (sun flower) and *Salsola kali* (russian thistle).

Materials and Methods. In September, 1978 eight equidistant parellel transects were laid out along the slope of the study area, 4 along the ridges and 4 along depressions. Each transect was 30 m long. Ten .1 m^2 quadrats (20 by 50 cm) were placed at 3 m intervals along each transect for recording aboveground vegetation characteristics. Three quadrats were randomly selected, one from the upper slope, one from the middle slope and one from the lower sope for sampling belowground biomass.

In the centre of each quadrat, one 5 cm dia. corer was driven with the help of a motor driven pneumatic hammer. Soil cores of 40 cm were extracted with the help of handy-man jack. Reports in the literature indicated that at least 85% of belowground biomass would occur in the upper 40 cm of the soil profile, hence we restricted ourselves to the 40 cm depth because of time constraints. (Shantz 1911, in particular, indicated that shortgrass root system was limited to the upper 45 cm of soil). The core was divided into three sections, 0-10 cm, 10-20 cm and 20-40 cm. The sectioned core samples were placed in paper sacks, transported to the laboratory, and air-dried for one week at room temperature.

The soil cores were then manually washed through soil sieves of Mesh size 40 of the soil. They were placed in small pots, water added to them, stirred and decanted off till they looked clean. When the soil was gone, the remaining root masses were rinsed in clear water. The washed roots were then oven-dried at 60°C and weighed. Weights of belowground material were expressed on oven-dry basis and converted to grams per square meter.

The following variables were examined in the study:

Depth. There were three depths of soil profile for which the belowground biomass was determined separately namely 0-10 cm, 10-20 cm and 20-40 cm. For each one of these depths 24 observations were recorded.

Slope. There were three slope positions i.e., upper slope, middle slope and the lower slope. For each of these 8 observations were recorded.

Location. There were two locations namely ridges and depressions. For each of these 12 observations were recorded.

Replication. There were 8 transects or replications of a group of 3 observations each.

The two-way analysis of variance was carried out to determine whether different depths and slopes had significantly different effect on the belowground biomass production.

Results. The analysis of variance is reporduced in table 2 below.

Table 2

Two-day ANOVA

Source of variation	Sum of equares	DF	Mean square	F	Significance of F
Main Effects	7184978	11	653180	6.620	.001
Slope	564923	2	282462	2.863	.074
Depth	4049457	2	2024788	20.519	.001
Replication	2570597	7	367228	3,722	.006
2-way interactions	4371892	32	13662	1.385	.193
Slop-depth	388679	4	97170	.985	.432
Slope-replication	1107417	14	79109	.802	.660
Depth-replication	2875796	14	205414	2.082	.048
Explained	11556869	43	268764	2.724	.003
Residual	2762880	28	98674		
Total	14319750	71	201687		

The effect of depth, replication, interaction between depth and replication and the main effects on the production of belowground biomass were significant at 5% level. The effect of slope alone was significant at 7.4% level. The explained variation due to the three variables i.e., slope, depth and replication were highly significant, whereas the effects due to interactions between slope and depth and slope and replication and the total effect due to two-way interactions between these three variables were non-significant.

A multiple classification analysis showed that slope, depth and replication together accounted for 50.2% of the total variation in the belowground biomass data collected. This is a fairly good limit in case of field ecological studies. The slope alone accounted for 20%, depth for 50% and replication for 42% of the total variation. This clearly shows that slope, depth and replication were inter-related and not orthogonal.

Depth. The belowground biomass distributed in the various depths of the soil is given in Table 3.

Table 3

Distribution of belowground biomass

Depth	Mean belowground biomass g/m^2	% of total collected up to 40 cm depth
0—10 cm	1004	50
10—20 cm	482	24
20—40	522	26
0—20	1486	74
0—40	2008	100

This distribution of belowground biomass in various depths of soil is also given in fig. 1.

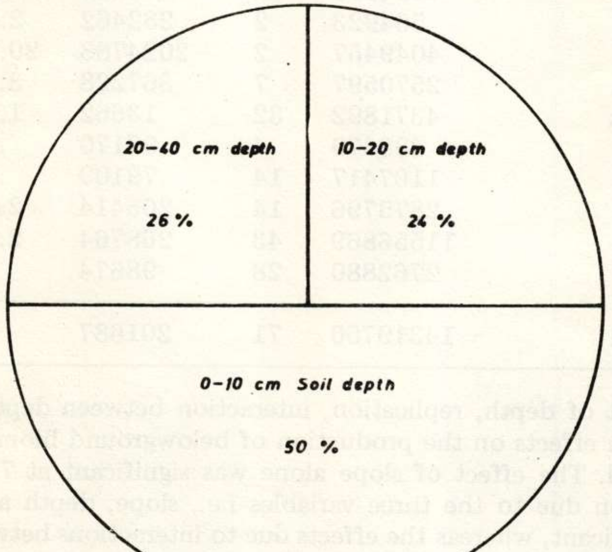

Fig. 1. Percentage of belowground biomass at different Soil depth

The t tests for evaluating the significance of differences in the belowground biomass in different sections of the soil are given in Table 4.

Table 4

t tests for belowground biomass in three depths of soil

depth	Sd	d	t
0—10 cm and 10—20 cm	110	522	4.75**
0—10 cm and 20—40 cm	122	482	3.95**
10—20 cm and 20—40 cm	101	40	.40

**Significant at .01 level.

The belowground biomass in the first section of soil i.e., 0—10 cm differed significantly from those in the second section (10—20 cm) and third section (20—40 cm), while the difference of belowground biomass in the second and third section were not significant. This seems reasonable as the length of the third section was 20 cm as compared with 10 cm length of second section and so the decreasing biomass per unit length was offest by the increase in length.

Slope. The average belowground biomass on the various positions of slope is given in Table 5 and also depicted in fig. 2.

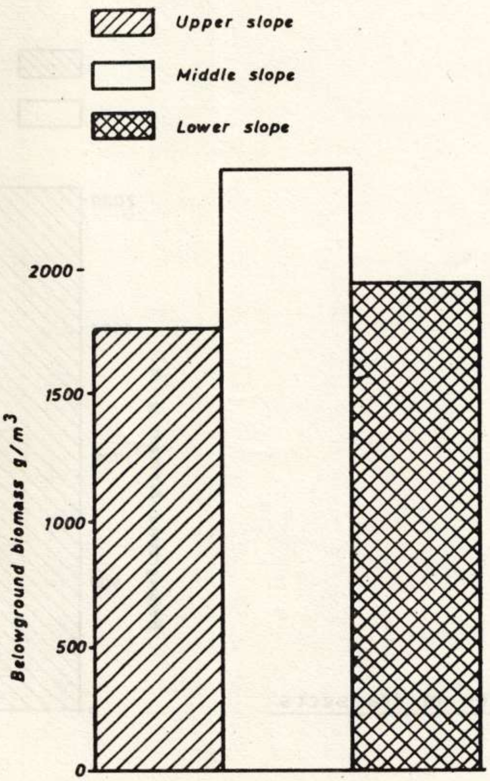

Fig. 2. Slope position

Table 5

Belowground biomass as affected by slope position

Slope position	Belowground biomass g/m^2
upper slope	1741[a1]
middle slope	2370[b]
lower slope	1911[a]

[1] Biomass followed by the same letter were not significantly different while those followed by different letters were significantly different at 0.05 level.

The maximum production of belowground biomass was on the middle slope, followed by the lower slope and the upper slope. There was no significant difference in the production of belowground biomass between the upper and lower slopes.

Location. The average belowground biomass on the ridges was 2064 g/m^2 and that in the depresssions 1951 g/m^2 (fig. 3). Though the production on these two locations did not differ significatly, the production on the ridges was generally higher than that in the depressions.

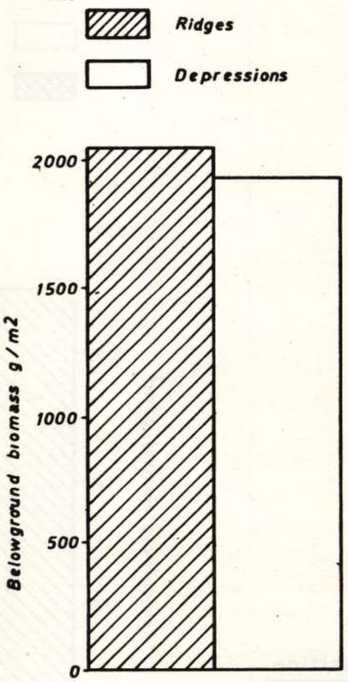

Fig. 3. Location of transects

Discussion. The concentration of the shortgrass roots near the ground surface, as indicated by this and other studies is confirmed and explained by various studies as follows:

Most roots occur in the upper levels of the soil profile (Weaver, 1958 and Nilsson, 1970) and decrease rapidly with depth (Dahlman and Kucera, 1965). Nilsson (1970) stated that grass roots were concentrated in the upper soil layers because grasses are shallow-rooted and have thicker proximal parts. Concentration of shortgrass roots in the upper layers of the soil might be attributed to frequent small and shallow-penetrating rain showers (Bartos and Sims, 1974). Shortgrass prairies have a shallow root system maintained by low and erratic precipitation (Stoddart and Smith, 1955). Weaver (1958) suggested that blue grama and buffalograss had shallow rooting systems in order to drive maximum benefit from soil waer furnished by light showers. Weaver and Albertson (1943) indicated that root depth corresponded to the most frequent depth of penetration of soil water under the ambient rainfall regime. Markle (1917) suggested that a superficial root system was due to low soil water content and Weaver and Crist (1922) suggested that the main factor was available water.

The average total belowground biomass in October at the end of the growing season was found to be 2008 g/m^2. This compared well with values given in the literature (Table 6).

Table 6

Peak belowground biomass estimates obtained for mixed grass prairie

Belowground biomass g/m^2	Reference
2008	Present study
1360	Cruz, 1977
1636	Bartos and Sims, 1974
2068	Bartos, 1971

The 0—10 cm horizon supported 1004 g/m^2 of belowground biomass. These results agree with those reported by Bartos and Sims (1974) who found 900 g/m^2, Nilsson (1970) who reported 900—1700 g/m^2, Dahlman and Kucera (1965) who obtained 1263 g/m^2, Cruz (1977) who found 680 g/m^2 in the 0—10 cm soil layer.

Fifty percent of the total belowground biomass was in the 0—10 cm layer and 74% in 0—20 cm section. These values were lower than values given for shortgrass prairie in the literature. According to Cruz (1977), 0—10 cm layer contained 50% of the total biomass as in this study and 0—20 cm layer had 94%

of the total belowground biomass. Dahlman and Kucera (1965) reported 68%, Nilsson (1970) 77-82%, Persson (1975) 97-98% belowground biomass in the 0—10 cm section. In the Pawnee National Grasslands, Bartos (1971) found 60% of the root weight in the 0—10 cm section and 73% in the 0—20 cm of the soil profile, while Bartos and Sims (1974) working also in the Pawnee shortgrass prairie reported 55% of the root weight in the 0—10 cm layer and 69% in the upper 20 cm of the soil horizon.

The 26% figure for the belowground biomass in the 20—40 cm soil section, as found in this study, was higher than values reported in the literature. Bartos (1971) reported 14% of the total biomass in this horizon, while Bartos and Sims (1974) found 16% in the same soil section. Cruz (1977) reported a very low figures of 6% for all root biomass below 20 cm. Bartos (1971) indicated only 13% and Bartos and Sims (1974) 15% biomass below 40 cm depth. According to Dahlman and Kucera (1965) 93% of the total root biomass existed upto 40 cm while Persson (1975) reported 95% of the root crop in the upper 30 cm of the soil.

These data are also comparable to values of Weaver (1958) who found 79% of the total belowground biomass in the upper 15 cm and Weaver and Zink (1946) who reported 80% in the upper 35 cm of the soil.

The belowground biomass on the middle slope was greater than that on upper slope which was expected as the middle slopes usually contain deeper and more fertile soil that the upper slopes. The root biomass on the lower slope, however, were expected to have been greater than that of the middle slope, contrary to the findings of this study. Similarly the belowground biomass was expected to have been higher in the depressions than on the ridges, due to a more favourable water regime and deeper soils.

Conclusions. In the shortgrass prairie, the greatest root biomass was found nearest the soil surface. Biomass decreased rapidly as depth increased. Depth was the single most important factor influencing the amount of belowground biomass. The middle Slope produced more root biomass than the upper or lower slope while the ridges and depressions did not differ in the quantity of belowground biomass.

Literature Cited

BARTOS, DALE LEE. 1971. Root dynamics of a shortgrass ecosystem. Ph.D. Thesis. C.S.U. Fort Collins. 129 p.

BARTOS, DALE L., and PHILLIP L. SIMS. 1974. Root dynamics of a shorgrass ecosystem. J. Range Manage. 27 (1): 33-36.

CRUZ, ARMANDO A. DE LA. 1977. Energy value, elemental composition, and productivity of belowground biomass of a Juncus Tidal Marsh. Ecology 58: 1165-1170.

DAHLMAN, R.C., and C.L. KUCERA. 1965. Root productivity and turn over in native prairie. Ecology 46: 84-89.

MARKEL, M.S. 1917. Root systems of certain desert plants. Bot. Gaz. 64: 177-205.

NILSSON, J. 1970. Notes on the biomass and productivity of belowground organs of a south-swedish hay-meadow. Bot. notiser. 123: 183-194.

OVINGTON, J.D., D. HEITCAMP. and D.B. LAWRENCE. 1963. Plant biomass and productivity of prairie, savannah, Oakland and maize field ecosystems in Central Minnesota. Ecol. Monogr. 44(1): 52-53.

PERSSON, HANS. 1975. Deciduous woodlands at Andersby, Eastern Sweden: Field layer and belowground production. Borgstrom Tryckeri A B Motala. Sweden. 71 p.

SCHANTZ, H.L. 1911. Natural vegetation as an indicator of the capabilities of land for crop production in the Great Plains area. U.S. Dep. Agr. Bur. Plant Ind. Bull. 201. pp.

STODDART, L.A., and A.D. SMITH. 1955. Range Management. McGrawHill Book Co., Inc., New York. 433 pp.

THORNTHWAITE, C.W. 1948. An approach towards a rational classification of climate. Geog. Rev. 38: 55-94.

WEAVER, J.E. 1958. Summary and interpretation of underground development in natural grassland communities. Ecol. Monogr. 28: 55-78.

WEAVER, J.E., and E. ZINK. 1946. Annual increase of underground materials in the range grasses. Ecology: 27: 115-127.

WEAVER, J.E., and F.W. ALBERTSON. 1943. Resurvey of grasses, forbs and underground plant parts at the end of the great drought. Ecol. Monogr. 13: 63-117.

WEAVER, J.E., and J.W. CRIST. 1922. Relation of hardpan to root penetration in the Great Plains. Ecology. 3: 237-249.

WIRSHBORN, JAMES F. 1977. Weather records, Fort Collins, Colorado. 1889-1975. Mountain States Weather Services, Fort Collins.