

Statement of Problem

The biomass of ecosystems and the individual plants that constitute those systems are a major piece of information for researchers. However, the data is often difficult to collect, as the data collection process is both time-consuming and destructive to the ecosystem in study, requiring an alternative method of determining mass.

Introduction

The biomass of a plant and of an ecosystem is crucial to many ecological and environmental studies. In particular, great difficulties have been encountered in the measurement of change in biomass over time for shrubbery and related families of plants. The knowledge of the biomass is in particular a major data in calculating productivity and changes in constitution of an ecosystem.

However, the collection of this data is a time-consuming process that hinders the research done, and has a great impact on the environment in study. Although the overall mass of a plant is highly variable on the time of day, season, and specific qualities of the specimen in study, it was hypothesized that the dry mass of the plant would be a consistent that was not subject to the variations in climate.



Encelia californica, a species of shrubbery used in the study

Furthermore, unlike for deciduous plants, whose density is regular and shape consistent within the species, shrubs have differing densities and shapes, making the prediction of canopy mass difficult without causing damage through restrictive sampling.

In the past, plants have been analyzed and categorized in different categories by its differing qualities to develop possible relationships of mass and other characteristics within these categories. These plants were most commonly divided by shape in an effort to develop models for each categorization of plants. Other possible characteristics that were studied include elevation, height, and environment that might influence its overall biomass.

Hypothesis

The mass of a plant would be closely related with its volume, which could be calculated using modified versions of the typical volume formula for standard Euclidean objects of cylinder and cone. In particular, the dry mass would show the highest correlation and be the most accurate predictor of the canopy mass of the plant, as it is less variable to climate conditions and time of day. Furthermore, it would be reasonable to assume that the linear regression model would differ between species, even with similar correlation, as the plant biomass density are inconsistent within separate species of plants. The plants may also require different models depending on the shape, location, or season, as they may affect plant density or volume within each variation.

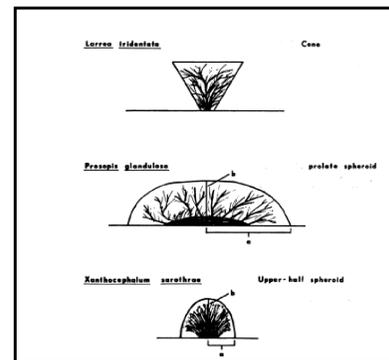
Predicting the Canopy Mass of a Plant Using Measured Characteristics

Methods and Materials

The plants used in the study were all found in the Forrestral Reserve in the Palos Verdes Peninsula. Each sample of plant data was taken, measured, and their specific location within Forrestral Reserve was recorded. The specific Canopy Type was evaluated by shape, and were categorized into PS (Prolate Spheroid), S (Half Spheroid) and C (Conic). The other measured characteristics of the plant consisted of height, circumference, and diameter of the shrub at different points of the shrub. The plants were then removed from Forrestral Reserve and where each sample's fresh weight was calculated. The samples were then dried to calculate dry mass of the specific portions of the plant, including leaf, wood, and seed. These were then added to calculate the overall dry mass of the plant.



A sample of Erigonum cinereum, one of the species used in the study



Shapes of plants, used by an earlier study on desert shrubs

With the collected data, each observation was used in the study to provide a regressional model that could accurately predict the canopy mass of a plant from the values measured in the study. A regressional model was developed for the two species used in the study after data analysis of the collected observations. The major pieces of data that consisted the regressional model created through the analysis included the circumference, height, and the ratio of circumference to diameter.

Results

Initially, both the data samples showed reasonable correlation between the natural log of circumference, diameter, and height. The shape, as decided and determined in the field, did not seem to have an impact when the data was categorized to the individual shapes. Of the four pieces of data numerically available (height, circumference, diameters measured at the longest and shortest points of the plant) the circumference appeared to have the biggest impact on the dry mass of the plant. To normalize the curve and to diminish the impact of the outliers of dry mass, the natural log was taken; this had the effect of reducing both skewness and increasing correlation of the observations. However, E. cinereum still showed a noticeable skewness in the graph, reducing the accuracy of the model for typical values not near the extremes.

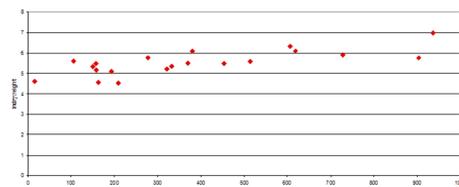
When tested, the diameter had the greatest impact when the arithmetic mean of the data points were taken, and in particular the ratio of the circumference to diameter showed high correlation with dry mass of both E. californica and E. cinereum.

When graphed and measured for correlation, the natural log of dry weight of E. californica showed a very high correlation between the ratio of the circumference and diameter (taken to the fourth power) and height times circumference, with a correlation coefficient of 0.730. However, when the result is used to modify the data for E. cinereum, it would have the approximately same correlation coefficient but be heavily skewed and dependent upon the outlier values of high-mass E. cinereum samples. When the outlier data were removed, however, the correlation dropped dramatically. This was in parallel with its correlation coefficient with other unmodified data, such as circumference, height, and diameter. These observations suggested that E. cinereum has a high variability and is difficult to model reliably for values under 400 grams of dry mass.

Data

PlantNo	Canopy Type	Height (m)	Circumference (m)	Dia 1 (m)	Dia 2 (m)	Dia Avg (m)	Total Dry Wt (g)
1	PS	0.53	2.19	0.70	0.58	0.64	173
2	PS	0.71	5.35	1.46	1.24	1.35	1074
3	PS	0.63	3.9	1.17	1.04	1.11	439
4	PS	0.60	3.65	0.84	0.87	0.86	363
5	PS	0.59	3.35	1.04	0.82	0.93	212
6	PS	0.72	3.05	0.97	1.02	1.00	165
7	PS	0.80	3.24	1.16	1.19	1.18	205
8	PS	1.11	3.79	1.10	1.18	1.14	266
9	PS	1.08	4.55	1.50	1.23	1.37	552
10	PS	1.52	4.6	1.52	1.48	1.50	435
11	S	1.18	4.94	1.68	1.12	1.40	319
12	PS	0.81	3.35	0.98	1.05	1.02	183
13	S	1.02	4.15	1.23	1.35	1.29	242
14	PS	0.88	3.42	1.24	1.13	1.19	91
15	S	0.86	3.77	1.41	1.42	1.42	97
16	P	0.83	2.39	0.90	0.70	0.80	243
17	P	0.96	2.56	1.06	0.94	1.00	272
18	P	0.41	1.42	0.70	0.56	0.63	102
19	PS	0.91	5.80	2.45	1.56	2.01	249
20	PS	0.83	2.94	0.82	0.98	0.90	321

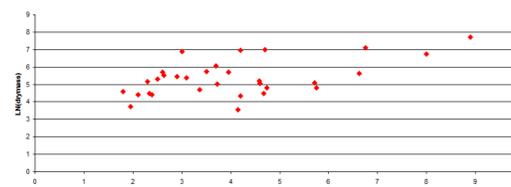
Data for E. californica



Natural log of dry weight versus modified data of E. californica and select elements of E. cinereum

PlantNo	Canopy Type	Height (m)	Circumference (m)	Dia 1 (m)	Dia 2 (m)	Dia Avg (m)	Total Dry Wt (g)
1	PS	0.33	3.10	1.17	0.86	1.02	220
2	PS	0.77	4.67	2.05	1.35	1.70	87
3	PS	1.01	6.83	1.42	1.72	1.57	283
4	PS	0.90	4.58	1.43	1.72	1.58	183
6	C	0.86	2.34	0.95	0.58	0.77	88
7	PS	0.85	5.75	1.97	1.61	1.79	122
8	PS	0.68	2.10	0.88	2.10	1.49	81
9	PS	0.67	2.63	0.82	1.01	0.92	247
10	PS	0.37	3.72	1.35	0.74	1.05	154
11	PS	0.50	2.39	0.69	0.79	0.74	84
12	PS	0.50	1.95	0.80	0.66	0.73	41
15	PS	1.26	4.14	1.36	1.22	1.29	35
16	PS	0.72	4.74	1.76	1.19	1.48	124
17	PS	0.8	4.60	1.47	1.55	1.51	158
18	PS	0.86	5.71	2.08	1.97	2.03	160
20	PS	0.62	3.36	1.68	0.86	1.27	110
21	PS	0.54	3.95	1.24	1.08	1.18	297
22	PS	0.80	4.7	1.38	1.44	1.41	1071
23	PS	0.70	2.3	0.60	0.80	0.70	174
24	PS	0.60	2.5	2.80	0.82	1.81	203
25	PS	0.95	8.0	2.44	2.5	1.35	850
26	PS	0.73	4.2	1.23	1.24	1.24	1051
27	PS	0.63	3.0	0.63	0.93	0.79	978
28	PS	1.0	8.9	2.4	3.05	2.73	2240
29	PS	0.82	6.75	2.53	1.06	1.80	1195
30	PS	0.25	2.6	1.02	0.5	0.76	299
31	PS	0.52	3.5	1.28	1.04	1.16	307
32	PS	0.54	3.7	1.55	1.83	1.69	424
33	PS	0.64	2.9	0.99	0.90	0.95	236
34	PS	0.55	4.2	1.82	0.95	1.39	78
35	PS	0.35	1.8	0.69	0.60	0.65	100

Data for E. cinereum



Circumference of E. cinereum versus the natural log of dry mass

Conclusions

The regression model, as the hypothesis, showed a clear resemblance with the volume formulae. The value of pi, in this case, was calculated to be circumference divided by the diameter; as the plants were irregular in shape, the ratio was not a constant. By exaggerating this value of the ratio, the graph became approximately linear with high correlation. From the fourth power, modifying the power had a parabolic effect in terms of correlation, suggesting that it was the ideal ratio and power to apply in the given situation.

Due to the irregularity of the plant, the circumference provided a much more reliable predictor of the volume and mass than the diameter, as it would be highly variable between different parts of the plant. Since the formula was variable for different species, and had different reliability at differing ranges, it would be necessary to determine the ideal conditions in which the formula is readily applicable. As the variables measured and used in this study did not require the destruction of the plant, nor extensive guesswork as to shape or location, it would be a sound method of calculating dry mass given an adequate number of samples and would aid ecological studies that require the calculation of the biomass.

Further Research

It would aid the reliability of the regression model if tested on many different species beyond two, found in the same climate and ecosystem. Furthermore, it would establish at which ranges and under what conditions the model is a sound predictor of dry mass, which is beneficial to the study. Furthermore, it would aid the research to conduct it under variable conditions at different times of day, to modify the model accordingly as to provide an alternative when the overall mass is desired.