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Constructing understory foliar biomass equations for use with standard inventory data in western Montana

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CONSTRUCTING UNDERSTORY FOLIAR BIOMASS EQUATIONS FOR USE WITH STANDARD INVENTORY DATA IN WESTERN MONTANA

By

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The intent of this study was to test the hypothesis that percent cover, canopy length/height and overstory density characteristics have a predictive relationship to understory foliar biomass per unit area. Thus, allowing for the generation of accurate predictors of understory biomass across a range of sites. Data was collected in dry to moderate Douglas-fir habitat types throughout Western Montana. Four understory biomass models were compared for best of fit: log-log, semi-log, linear and non-linear. Furnival's Index was used to compare the four models and indicated that the log transformation (log-log) produced the highest r^2 and the lowest Mallow's Cp and MSE. The significance of plant percent cover, canopy length, and site overstory density is displayed for cover/biomass equations of understory vegetation. Few models of biomass have included the dynamics of the overstory. It was found that reliable predictions could be made for not only individual species, but also aggregated groups of species, or life forms. The equations provide a means to estimate understory foliar biomass per unit area from existing standard inventory data over a wide range of sites.

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Chapter 1: INTRODUCTION

Forest managers are concerned with growing trees. Whether for timber, wildlife, forest health, productivity or water objectives. To do so managers require data on the characteristics of understory vegetation. Biomass of understory species is a critical component of forest ecosystem management prescriptions. Analysis of forage and browse conditions, nutrient cycling, biodiversity, or responses to vegetation manipulation require biomass estimates. Although not well researched, stand understory biomass can comprise up to 27% of the total above-ground biomass in a forest (Cannell 1982). If estimates of biomass could be developed from data collected in operational inventories, managers could respond more efficiently to the new demands without substantial investments in new data.

Estimating biomass equations for many shrub and herbaceous species are individual plant based and require many detailed and time consuming measurements. For operational inventories, collecting plant specific measurements of the understory would be too costly. Biomass equations are needed that can use the ocular estimates of percent cover, and perhaps height categories, that are feasible to collect (and in many cases already collected). Cover based equations also need to capture the overstory effect since cover/biomass relationships for many species have been shown to be sensitive to overstory density (Alaback 1986). Site conditions and overstory characteristics are two variables that significantly influence understory biomass (Telfer 1972). Finally, costs would be reduced if cover observations could be collected, not by species alone, but instead, by groups of life forms (i.e. grasses, forbs, low and high shrubs). These groups are readily identified in the field by inventory foresters. The goal of this study is to investigate the feasibility of constructing foliar biomass equations that satisfy these requirements.

Most biomass equations in the literature are based on single plant, species specific data, often collected from a single stand. Generally, a biomass component (leaf, stem, root, or total plant) is predicted from dimensions of one or more plant parts, i.e. stem diameter, height, crown length, volume, etc..

This approach has been used by many researchers, including: Whittaker and Woodwell (1964) for species in the Northeast; Gholz et al (1979) for Pacific Northwest tree, shrub, and herb species; Ross and Walstad (1986) for shrubs in southcentral Oregon; Brown (1976) and Moeur (1981) for coniferous species in Montana and Idaho; Wakimoto (1977) for Chaparral species in California; Gower et al (1987) for conifers in central Washington; Harniss and Murray have quantified biomass of big sagebrush in Idaho (1976); and Alaback (1986) for understory species in coastal Alaska.

Overstory variables are not included as predictors in these individual plant biomass equations. Use of these equations in forest management requires a significant investment in inventory costs in order to count and measure sufficient individuals of each species.

Although understory biomass production is strongly related to overstory density (Alaback 1982; Long and Turner 1975; Tapia et al 1990), both size and biomass will trend in the same direction in response to overstory density and thus the size/biomass relationship becomes somewhat independent of the overstory density effect. However, Gower et al (1987) and Alaback (1986) note that care must be taken in applying the equations outside the study area because of changes in stand and site conditions, and Moeur (1981) found for conifers, that relative diameter (tree diameter in relation to average stand diameter) and trees per acre were significant predictors of foliage biomass, in addition to stem size.

Cover/biomass relationships for shrubs offer little evidence of independence from overstory effects. Canopy is typically defined as the horizontal projection of crown extent, rather than of leaf area. Since foliage density varies with light levels, a given percent cover may contain varying amounts of leaf area. In addition, specific leaf area (foliar biomass (g)/leaf area (m^2)) tends to fall as light levels drop (Blackman and Rutter, 1948). For a given leaf area, biomass will be less under an overstory than in the open. Therefore, a given percent cover can contain a range of foliage biomass values, depending on the overstory density. This variability can be seen in a plot of *Gaultheria shallon* equations (Gholz 1979) derived from data in old growth vs. young clearcut environments in the Pacific Northwest (Figure 1). For a given percent cover, foliar biomass is much higher in the clearcut than in the old growth stand.

Alaback (1982) found similar results for woody shrubs in southeast Alaska. He noted the vertical dimension and variable structure of such species were responsible for the imprecise relationship between cover and biomass. Presumably these are the characteristics that can be influenced by overstory density and site quality. Under sparse canopies, the depth of crown will be greater than that under dense overstories.

Cover/biomass relationships have been developed for life forms that do not lend themselves to individual measurements, such as grasses (Brown and Marsden, 1976; Payne, 1973) and some herbs (Gholz et al 1979; Alaback 1986). Alaback (1986) found relatively precise relationships between cover and biomass for herbaceous species. It appears that for life forms with a horizontal architecture, overstory on the cover/biomass relationship may be less important than for plants with a strong vertical component.

Gholz (1979) pointed out that equations for species of similar life form were quite similar. This implies that life form/species groups could be specified that would simplify inventory data collection procedures, but still provide for adequate precision.

Equations for estimating biomass from existing inventory data would greatly enhance the use of growth and yield modelling by mensurationists and quantitative inventory personnel in the forestry field.

OBJECTIVES

1) Construct above ground foliar biomass equations for understory species as a function of percent cover, canopy length and overstory canopy density.

2) Compute biomass equations for aggregated groups of life form types (grasses, forbs, low and high shrubs).

HYPOTHESES

1) Ho: Percent cover, canopy length and overstory density do not have a predictive relationship with understory foliar biomass per unit area for individual species.

   Ha: Percent cover, canopy length and overstory density have a predictive relationship with understory foliar biomass per unit area for individual species.

2) Ho: Percent cover, canopy length and overstory density do not have a predictive relationship with understory foliar biomass per unit area for aggregated groups of species, life forms.

Ha: Percent cover, canopy length and overstory density have a predictive relationship with understory foliar biomass per unit area for aggregated groups of species, life forms.

CHAPTER 2: METHODS

SITE SELECTION

Five sites were subjectively chosen throughout Western Montana for destructive sampling. Site location ranged from Libby in northwestern Montana, south to Missoula. Sites were selected in the following Douglas-fir habitat types; PSEMEN/ARCUVA, CALRUB, LINBOR, PHYMAL, VACCAE and VACGLO (Pfister et al 1977). This promoted a sample of similar species (Table 1). The canopy coverage data presented by Pfister for these habitat types indicate significant overlap in the species likely to be found (Pfister et al 1977).

Sites were selected that had not been disturbed for five years or more to ensure equilibrium between understory morphology and stand density. At each site plots were located so as to fill the cells of a sampling matrix defined by level of overstory density and aspect. Thirty-two plots were located across the five sites. Site variables were; elevation, aspect and slope.

MAIN PLOT MEASUREMENTS

A variable plot size was established at each location. (Appendix A). Plot centers were located subjectively beneath the desired levels of overstory density. Beginning at plot center, plot size increased at fixed intervals until it was judged that the mosaic of overstory and understory clumpiness was represented within the plot.

All trees greater than breast height were measured for species, diameter at breast height, crown ratio, height and height to base of live crown. Overstory density was estimated using a calculated crown competition factor (Wykoff, Crookston and Stage, 1982).

CCF is a relative measurement of stand density that is based on tree diameters. Tree values of CCF estimate the percentage of an acre that would be covered by the tree's crown if the tree were open grown. Stand CCF is the summation of individual tree CCF values. A value of 100 indicates that projected crown area will just cover an area in an un-thinned, evenly spaced stand (Krajicek, Brinkman and Gingrich, 1961). CCF per tree was estimated from tree diameter as follows (Wykoff, Crookston and Stage, 1982):

DBH >= 10 in. $CCF = Prob * (a_o + a_1 DBH + a_2 DBH^2)$

DBH < 10 in. $CCF = Prob * B_o DBH^{b1}$

where a_o, a_1, a_2, b_o, b_1, are species dependent constants (Wykoff, Crookston and Stage, 1982)

$Prob = 1/n*a$

n = Number of Sample Plots in Stand
a = Area of sample plot (acres)

MICROPLOT MEASUREMENTS

Microplots were placed at random distances along transects located at the cardinal directions plus NE and SW from plot center. At each microplot, three independent ocular estimates of percent cover were measured: cover of total vegetation, cover of each life form and cover of each species present. Total height and height to the base of the understory canopy were recorded at the species level. Average height was recorded for life forms and for total vegetative cover. One observer recorded percent cover and height in an attempt to minimize variation in observations. Cover was ocularly estimated as the proportion of ground surface covered by the vertical projection of plants maximum canopy width (Appendix B). Plants representing less than 1% cover were grouped into miscellaneous forbs, grasses and shrubs.

Understory vegetation on each microplot was destructively sub-sampled each of the six 1 meter square microplots (Marshall, et al 1990). All plants within the square meter microplot were clipped at ground level (Appendix C). Foliage was separated and bagged in paper sacks by species. The clipped vegetation was kept in coolers to minimize respiration while being transported to the lab for drying and weighing.

LAB PROCEDURES

All samples were oven-dried at 70 deg. C for 48 hours then weighed to the nearest .01 gram. (Telfer, 1972).

ANALYSIS

The statistical software package, SAS was used in the analysis of the data (SAS Institute 1988). Estimates of percent cover, height of understory vegetation and canopy length of understory vegetation were treated as an independent observations for analysis.

The first step in the analysis of the data was to create a variety of graphs and identify any apparent visual trends. Correlations between variables were examined to observe which variables were highly correlated and if this relationship should or should not be expected.

Graphs of percent cover (X) versus foliar biomass (Y) were examined and utilizing the "overlay" command in SAS and CCF values were attached to each observation. The calculated CCF was used in regression analyses, while the CCF codes were used for graphing purposes only.

The data was plotted and examined visually. Interaction terms that might have biological meaning were also investigated. Linear regression was used for screening significant independent variables. The following equations identify the independent variables used in the regression analysis to predict foliar biomass per unit area.

Dependent variable = Foliar biomass per unit area (g/m^2)
Independent variables = % cover, canopy length (cm) and CCF

Several model forms were examined to determine the most appropriate one for the data. This assortment included linear and nonlinear models found in most biomass studies in the literature. The following four equations fit the patterns seen in the data and were used in an attempt to achieve the best possible fit:

Model 1: $\mathrm{Ln}Y = b_o + (b_1\,\mathrm{Ln}X_1) + (b_2\,\mathrm{Ln}X_2) + (b_3\,\mathrm{Ln}X_3)$

Model 2: $Y = b_o + (b_1\,\mathrm{Ln}X_1) + (b_2\,\mathrm{Ln}X_2) + (b_3\,\mathrm{Ln}X_3)$

Model 3: $Y = b_o + (b_1\,X_1) + (b_2\,X_2) + (b_3\,X_3)$

Model 4: $Y = b_o + X_1^{b1} * X_2^{b2} * [1/(\mathrm{EXP}(X_3/100))]^{b3}$.

where X_1 = Percent Cover

X_2 = Canopy Length

X_3 = CCF

In plots that had zero CCF, 0.01 was used for purposes of statistical analysis. It is debateable whether a CCF of zero could exist, since there is usually an effect from the surrounding forest, slope or aspect.

The results of each regression were then reviewed to observe the model behavior. Model behavior was judged biologically reasonable, if it appeared to fit the data and predict reliable estimates outside the bounds of observed data. If the model met this criteria the response surface of each regression was also examined to determine if the simulated response surface was biologically reasonable. (Figure 3). The signs (+/-) on the regression coefficients were then examined for proper biological behavior.

After determination that the model represented the data, the response surface was extrapolated beyond the observed range of data. Appendix E lists the range of percent cover and CCF for each species and life form.

The usual index of fit, the root mean square error, can be used to compare equations that have the same dependent variable but is not suitable when the dependent variables differ. For example, the mean square residual from the combined variable equation, B = a + bC + cH + dD, cannot be compared to the mean square residual from the logarithmic equation of log B = a + b logC + c logH + d logD, where in both equations B is foliar biomass, C is percent cover, H is canopy length and D is overstory density (Furnival, 1961).

Model fit can be compared using Furnival's Index of Fit. This index is a modified likelihood criterion that reflects both the size of the residuals and possible departures from normality and homoscedasticity. It can be used to compare any number of models where the dependent variable Y', represents different transformations on the original Y variable The smallest F.I. indicates the best fit. The index is:

$$FI = [f'(Y)]^{-1} * \text{root MSE}$$

where:

$$[f'(Y)]^{-1} = \exp [\Sigma \ln Y^{i} \backslash n]$$

Therefore, if the dependent variable is not transformed, it is simply the root MSE (Furnival, 1961).

CHAPTER 3: RESULTS AND DISCUSSION

Forty-eight species of plants were collected from the thirty-two plots sampled in this study. Of the forty-eight species sampled, twenty-four were commonly observed (Appendix E - greater than fifteen observations each).

Listed in Table 1 are the species that were commonly observed on the sampled areas:

TABLE 1

SPECIES REPRESENTED IN SAMPLE

(Hitchcock, 1973)

FORBS:	*Achillea millefolium*, Common Yarrow
	Antennaria racemosa, Pussytoes
	Antennaria umbrinella, Pussytoes
	Apocynum androsaemifolium, Dogbane
	Arenaria macrophylla, Sandwort
	Arnica cordifolia, Heartleaf Arnica
	Balsamorhiza sagittata, Arrowleaf Balsamroot
	Centaurea spp., Knapweed
	Clarkia pulcella, Pink Fairies
	Fragaria virginiana, Wild Strawberry
	Hieracium albertinum, Western Hawkweed
	Lupinus argenteus, Lupine
GRASSES:	*Calamagrostis rubescens*, Pine Grass
	Carex geyeri, Elk Sedge
	Festuca idahoensis, Idaho Fescue
SUB-SHRUBS:	*Arctostaphylus uva-ursi*, Kinnick-Kinnick
	Berberis repens, Creeping Oregon Grape
	Chimaphila umbellata, Prince's Pine
	Linnaea borealis, Twinflower
SHRUBS:	*Amalanchier alnifolia*, Serviceberry
	Physocarpus malvaceous, Ninebark
	Rosa spp., Wild Rose
	Symphoricarpos albus, Common Snowberry
	Vaccinium globulare, Blue Huckleberry

Significant regressions were produced for all twenty-four species typical in western Montana (Table 2). Over 90 percent of the linear regression equations presented have an r^2 greater than .70 (range .56 to .97; Table 2).

The species specific equations demonstrate that percent cover proves to be a significant independent variable for all species. Canopy length is a significant independent variable on 75% of the forb species and 44% of the shrub species but it is not significant in any of the species specific equations for grass. The overstory density variable CCF is a significant independent variable in the equations for 40% of the forb species, 33% of the grass species and 66% of the shrub species. CCF is significant for shrubs that display a vertical structure. The effect of CCF on the cover:biomass relationship can be seen in Figure 2. There were apparent patterns or "bands" of CCF levels explaining the variation of the data (Figure 2). As expected, stands with a lower CCF code (Appendix D) appeared to have higher amounts of foliar biomass. Aspect, elevation and slope were among some of the measured variables that were not significant during the screening process. It is possible that this is an artifact of the small data set.

Equations for groups of species (life forms), display somewhat similar results. Percent cover and overstory density are significant independent variables in all groups (Table 3). Average canopy length did not prove to be a contributing factor to the variation at the life form level.

Shrubs were divided into two groups; sub-shrubs (<= 11cm) and med-tall shrubs (> 11cm). This division by height class in the shrubs group appears to be beneficial in obtaining a better fit with Model 1 for sub-shrubs. However, it does not appear to be beneficial for the medium and tall shrubs. The "all shrubs" equation has the best overall fit for this life form group. The root MSE in Table 3, demonstrates that there is an increase in error when life form equations are used over species specific equations.

The same models were regressed for total vegetation (Table 3). The r^2 for Model 3 on total vegetation for the site is 0.67, however the root of the MSE is largest at this level of aggregation. Any biomass prediction based on total ground cover would merely be a very rough estimate with little precision. If precision was not as important as time, this equation would be sufficient.

The residuals of all models were plotted and displayed. They were examined to check for homogeneity of variance (Figure 4). Homogeneity of variance was observed across all groups of residuals, that is, the standard error of the residuals was constant across the range of foliar biomass.

Furnival's Index of Fit indicates that Model 1 presents the best fit in all the life form equations and 80% of the species equations (Table 3). This model is followed in precision by Model 4.

Sources of variation could have occurred due to the timing of the collection of vegetation. Vegetation was collected from mid-May through the end of August. Early in the season, plants were not fully mature but were clipped and weighed based on their percent cover. Foliage on immature plants may have been heavier for a lower percent cover due to the fact that the leaf was not fully extended. This is only one possible source of variation, others would include sampling error, measurement error, inconsistency with ocular estimates, etc...

Both null hypotheses would be rejected. Foliar biomass can be predicted with fairly high precision for individual species and groups of species using percent cover, canopy length and overstory density as independent variables.

TABLE 2

FORBS	TYPE	Bo	B1	B2	B3	N	ROOT MSE	R SQRD.	F.I.
Achillea millefolium	LOG-LOG	-1.4177	0.9496*	0.5258*	-0.0411	26	0.4510	--	0.54
Common Yarrow	LIN-LOG	-0.3559	1.4763*	0.6006*	0.0392	26	0.5607	--	0.56
	LINEAR	-0.0207	0.8556*	0.0266	-0.0056	26	0.5675	0.77	0.57
	NONLINEAR	-0.4256	0.6445*	0.1960*	0.4781	26	0.5374	--	0.54
Antennaria racemosa	LOG-LOG	0.5427	1.1782*	0.2445	-0.0589*	26	0.2575	--	0.32
Pussytoes	LIN-LOG	1.1812	2.2896*	-0.0522	-0.1786*	26	0.7006	--	0.70
	LINEAR	-0.8371	1.2388*	0.1134	-0.0054*	26	0.4432	0.93	0.44
	NONLINEAR	-0.4542	1.0005*	0.1754	0.2493*	26	0.4084	--	0.41
Antennaria umbrinella	LOG-LOG	-0.0666	0.9558*	0.1279*	0.0235*	31	0.5729	--	1.95
Pussytoes	LIN-LOG	-1.4850	3.5856*	1.4421*	0.4212*	31	2.0209	--	2.02
	LINEAR	0.5032	0.9643*	0.0042	0.0176	31	1.8623	0.85	1.86
	NONLINEAR	0.9303	0.9999*	-0.0671	-0.4485*	31	1.7207	--	1.72
Apocynum androsaemifolium	LOG-LOG	-1.1416	0.9335*	0.3799	-0.0253	16	0.4594	--	2.70
Dogbane	LIN-LOG	-14.9671	7.7675*	4.1182	0.1053	16	7.2790	--	7.28
	LINEAR	-2.8283	0.9871*	0.1388*	0.0093	16	2.2931	0.97	2.29
	NONLINEAR	-1.3745	0.8083*	0.2171*	0.0705	16	2.7810	--	2.78
Arenaria macrophylla	LOG-LOG	0.7902	0.7077*	-0.0795	-0.0018	16	0.5043	--	1.46
Sandwort	LIN-LOG	-0.9808	2.1228*	1.1859	-0.0721	16	1.6773	--	1.68
	LINEAR	0.4341	0.7723*	0 .0773	-0.0033	16	1.5899	0.68	1.59
	NONLINEAR	0.8865	0.8340*	0.1362	1.5257	16	1.3667	--	1.37
Arnica cordifolia	LOG-LOG	-0.6678	0.9608*	0.0810*	-0.0630*	78	0.4017	--	1.05
Heartleaf Arnica	LIN-LOG	-0.9229	3.3185*	0.3829*	-0.3025*	78	2.8541	--	2.85
	LINEAR	-0.0978	0.4488*	0.0644*	-0.0058	78	1.6205	0.89	1.62
	NONLINEAR	-0.1154	0.9575*	-0.2669	0.0540	78	1.7449	--	1.74
Balsamorhiza sagittata	LOG-LOG	-1.8227	0.8876*	0.6214*	-0.0251	21	0.5199	--	3.92
Arrowleaf Balsamroot	LIN-LOG	-54.0849	8.7991*	15.7965*	-0.3867	21	13.0100	--	13.01
	LINEAR	-13.4285	0.9529*	0.6095*	-0.0360	21	7.7688	0.85	7.77
	NONLINEAR	-6.6117	0.6915*	0.3945	-0.1526	21	7.7741	--	7.77
Centaurea spp.	LOG-LOG	-0.9287	0.9089*	0.3704*	-0.0246	36	0.4872	--	5.06
Knapweed	LIN-LOG	-12.2074	13.4512*	1.1814	0.2000	36	12.0022	--	12.00
	LINEAR	4.8311	0.8036*	0.1194	-0.1704	36	10.8747	0.78	10.87
	NONLINEAR	0.9116	0.6894*	0.3378*	1.0112	36	10.1892	--	10.19

* SIGNIFICANT AT P=0.05
F.I. = FERNIVAL'S INDEX

LOG-LOG = 'LN(FOLIAR BIOMASS)=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LIN-LOG = 'FOLIAR BIOMASS=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LINEAR = 'FOLIAR BIOMASS=Bo+(B1*%CVR)+(B2*CNPYLNG)+(B3*CCF)
NON-LINEAR = 'FOLIAR BIOMASS = Bo + %CVR ^ B1 * CNPYLNG ^ B2 * [1/(EXP(CCF/100))] ^ B3

%CVR = OCULAR ESTIMATE OF PERCENT COVER
CNPYLNG = MEASUREMENT OF CANOPY LENGTH (FORBS AND GRASSES = HEIGHT)
CCF = CALCULATED CROWN COMPETITION FACTOR OF OVERSTORY TREES
N = OBSERVATIONS

TABLE 2 cont...

FORBS cont...	TYPE	Bo	B1	B2	B3	N	ROOT MSE	R SQRD.	F.I.
Clarkia pulcella	LOG-LOG	-0.9755	0.9650*	0.3075	-0.0683	23	0.2748	--	0.57
Pink Fairies	LIN-LOG	2.6255	2.3412*	-0.2655	-0.2484	23	2.0631	--	2.06
	LINEAR	-1.7811	1.0932*	0.0886*	-0.0008	23	1.6449	0.81	1.64
	NONLINEAR	-1.8649	0.6119*	0.3467*	0.0966	23	1.5905	--	1.59
Fragaria virginiana	LOG-LOG	-1.4968	1.0534*	0.4221*	-0.0929	50	0.4588	--	0.63
Strawberry	LIN-LOG	0.2521	4.0655*	-0.1626	-0.2292	50	2.9423	--	2.94
	LINEAR	-0.4929	0.6186*	0.1292	-0.0092	50	1.6754	0.92	1.68
	NONLINEAR	-1.2541	0.6755*	0.3086*	0.4348	50	1.5361	--	1.54
Hieracium albertinum	LOG-LOG	-1.1820	0.9085*	0.3186	-0.0150	39	0.6356	--	0.58
Western Hawkweed	LIN-LOG	0.4401	2.2669*	0.0678	0.0000	39	1.2772	--	1.28
	LINEAR	0.2000	0.5054*	0.0199*	-0.0030	39	0.6672	0.91	0.67
	NONLINEAR	-0.5240	0.7170*	0.1300*	0.2905	39	0.6167	--	0.62
Lupinus argenteus	LOG-LOG	0.4647	1.0513*	-0.2430	0.0052	18	0.5270	--	1.88
Lupine	LIN-LOG	5.9645	6.2660*	-3.2920	0.3556	18	3.7481	--	3.75
	LINEAR	-0.0050	1.0243*	-0.0581	0.0127	18	2.0238	0.93	2.02
	NONLINEAR	0.4110	1.2483*	-0.2480	-0.0215	18	1.9503	--	1.95

GRASSES	TYPE	Bo	B1	B2	B3	N	ROOT MSE	R SQRD.	F.I.
Calamagrostis rubescens	LOG-LOG	0.7025	0.8341*	-0.1787	-0.0994*	72	0.4213	--	5.47
Pinegrass	LIN-LOG	-21.2315	9.4088*	3.4731	-1.3882*	72	11.3942	--	11.39
	LINEAR	4.3845	0.4312*	0.1492	-0.0859*	72	10.1632	0.56	10.16
	NONLINEAR	1.1242	0.8486*	0.0579	0.6351*	72	10.0864	--	10.09
Carex geyeri	LOG-LOG	-0.7578	0.8813*	0.3154	0.0066	74	0.4459	--	6.97
Elk Sedge	LIN-LOG	-30.0795	15.4830*	4.6116	0.0632	74	17.5688	--	17.57
	LINEAR	-1.6660	1.0516*	0.0951	-0.0414	74	11.0640	0.84	11.06
	NONLINEAR	-2.2234	0.9621*	0.0786	0.0788	74	11.0900	--	11.09
Festuca idahoensis	LOG-LOG	0.9528	0.8729*	-0.1993	-0.0297	24	0.3557	--	2.55
Idaho Fescue	LIN-LOG	-3.8638	6.2417*	0.4526	-0.1077	24	1.8699	--	1.87
	LINEAR	3.6754	0.5958*	0.0221	-0.0067	24	2.1675	0.81	2.17
	NONLINEAR	1.9974	0.7115*	0.1602	-0.1952	24	1.9485	--	1.95

* SIGNIFICANT AT P=0.05
F.I. = FERNIVAL'S INDEX

LOG-LOG = 'LN(FOLIAR BIOMASS)=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LIN-LOG = 'FOLIAR BIOMASS=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LINEAR = 'FOLIAR BIOMASS=Bo+(B1*%CVR)+(B2*CNPYLNG)+(B3*CCF)
NONLINEAR = 'FOLIAR BIOMASS = Bo + %CVR ^ B1 * CNPYLNG ^ B2 * [1/(EXP(CCF/100))] ^ B3

%CVR = OCULAR ESTIMATE OF PERCENT COVER
CNPYLNG = MEASUREMENT OF CANOPY LENGTH (FORBS AND GRASSES = HEIGHT)
CCF = CALCULATED CROWN COMPETITION FACTOR OF OVERSTORY TREES
N = OBSERVATIONS

TABLE 2 cont...

SHRUBS	TYPE	Bo	B1	B2	B3	N	ROOT MSE	R SQRD.	F.I.
Amalanchier alnifolia	LOG-LOG	-0.9758	0.8486*	0.3374*	-0.0610*	110	0.4238	--	1.94
Serviceberry	LIN-LOG	-13.3663	4.2407*	5.3712*	-0.4015*	110	6.0339	--	6.03
	LINEAR	-1.1699	0.5112*	0.2592*	-0.0263*	110	3.9137	0.84	3.91
	NONLINEAR	-1.3749	0.6629*	0.2921*	0.3964*	110	3.5690	--	3.57
Arctostaphylus uva-ursi	LOG-LOG	0.7070	1.0085*	0.1808	-0.0410	38	0.6091	--	9.64
Kinnick-kinnick	LIN-LOG	-17.0650	21.6533*	4.4011	-2.3746*	38	12.0097	--	12.01
	LINEAR	11.1576	2.4708*	-0.1987	-0.1004*	38	14.2496	0.75	14.25
	NONLINEAR	6.9804	0.8940*	0.7101*	1.2528*	38	13.3381	--	13.34
Berberis repens	LOG-LOG	-0.7837	1.0862*	0.3631*	-0.0192	41	0.3687	--	0.82
Oregon Grape	LIN-LOG	0.4299	3.0497*	0.2172	-0.0678	41	1.3959	--	1.40
	LINEAR	-0.1976	1.1992*	0.0171	-0.0033	41	0.9566	0.88	0.96
	NONLINEAR	0.1352	1.1267*	-0.0360	0.1195	41	0.9251	--	0.93
Chimaphila umbellata	LOG-LOG	0.2788	0.8939*	0.3350	-0.1211	15	0.3279	--	1.34
Prince's Pine	LIN-LOG	-4.0917	5.7890*	3.7334	-0.6870	15	4.0403	--	4.04
	LINEAR	-1.7503	1.2533*	0.3410	-0.0109	15	1.9159	0.96	1.92
	NONLINEAR	0.3032	0.9468*	0.3980	0.5912	15	1.9063		1.91
Linnaea borealis	LOG-LOG	1.2254	0.8865*	-0.4293	-0.0606*	27	0.3770	--	2.47
Twinflower	LIN-LOG	7.9562	6.4999*	-6.3196	-0.6071	27	5.3271	--	5.33
	LINEAR	7.0167	1.5899*	-1.3992	-0.0390*	27	3.3562	0.86	3.36
	NONLINEAR	3.5174	1.3329*	-0.4193	0.5343*	27	2.8950	--	2.90
Physocarpus malvaceous	LOG-LOG	-0.5105	0.9126*	0.2365	-0.0594	17	0.4498	--	3.03
Ninebark	LIN-LOG	7.0872	15.0535*	-4.7407	-1.2745	17	14.2532	--	14.25
	LINEAR	3.6735	0.9329*	-0.0349	-0.0606	17	8.4474	0.90	8.45
	NONLINEAR	3.1018	0.9346*	0.1281	3.3466	17	7.4613	--	7.46
Rosa spp.	LOG-LOG	-0.3961	0.8847*	0.0458	-0.0805*	38	0.4241	--	0.73
Wild Rose	LIN-LOG	1.2804	2.6295*	-0.3157	-0.2205*	38	1.8575	--	1.86
	LINEAR	1.3772	0.6019*	-0.0077	-0.0148*	38	1.2893	0.86	1.29
	NONLINEAR	0.3656	0.8920*	-0.0193	0.9142*	38	1.0295	--	1.03

* SIGNIFICANT AT P=0.05
F.I. = FURNIVAL'S INDEX

LOG-LOG = 'LN(FOLIAR BIOMASS)=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LIN-LOG = 'FOLIAR BIOMASS=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LINEAR = 'FOLIAR BIOMASS=Bo+(B1*%CVR)+(B2*CNPYLNG)+(B3*CCF)
NON-LINEAR = 'FOLIAR BIOMASS = Bo + %CVR^B1 * CNPYLNG^B2 * [1/(EXP(CCF/100))]^B3

%CVR = OCULAR ESTIMATE OF PERCENT COVER
CNPYLNG = MEASUREMENT OF CANOPY LENGTH (FORBS AND GRASSES = HEIGHT)
CCF = CALCULATED CROWN COMPETITION FACTOR OF OVERSTORY TREES
N = OBSERVATIONS

TABLE 2 cont...

SHRUBS cont...	TYPE	Bo	B1	B2	B3	N	ROOT MSE	R SQRD.	F.I.
Symphoricarpos albus	LOG-LOG	-1.5808	0.8851*	0.6077*	-0.0649*	37	0.2931	--	2.16
Common Snowberry	LIN-LOG	-13.8626	9.8765*	1.9627	-0.9159*	37	6.3672	--	6.37
	LINEAR	-0.9269	0.8017*	0.2116	-0.0330*	37	4.2015	0.89	4.20
	NONLINEAR	-2.6809	0.7897*	0.2693*	0.3296*	37	3.1704	--	3.17
Vaccinium globulare	LOG-LOG	-0.3234	0.7667*	0.2423	-0.0887*	18	0.4634	--	2.54
Blue Huckleberry	LIN-LOG	-0.5996	4.3189*	2.1715	-1.6862*	18	6.9273	--	6.93
	LINEAR	3.8016	0.5341*	0.0554	-0.0467*	18	3.8580	0.91	3.86
	NONLINEAR	2.0618	0.7069*	0.2509	1.0843*	18	2.5024	--	2.50

* SIGNIFICANT AT P=0.05
F.I. = FURNIVAL'S INDEX

LOG-LOG = 'LN(FOLIAR BIOMASS)=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LIN-LOG = 'FOLIAR BIOMASS=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LINEAR = 'FOLIAR BIOMASS=Bo+(B1*%CVR)+(B2*CNPYLNG)+(B3*CCF)
NON-LINEAR = 'FOLIAR BIOMASS = Bo + %CVR^B1 * CNPYLNG^B2 * [1/(EXP(CCF/100))]^B3

%CVR = OCULAR ESTIMATE OF PERCENT COVER
CNPYLNG = MEASUREMENT OF CANOPY LENGTH (FORBS AND GRASSES = HEIGHT)
CCF = CALCULATED CROWN COMPETITION FACTOR OF OVERSTORY TREES
N = OBSERVATIONS

TABLE 3

LIFE FORM	TYPE	Bo	B1	B2	B3	N	ROOT MSE	R SQRD.	F.I.
FORBS	LOG-LOG	-0.8599	1.0223*	0.2067*	-0.0545*	177	0.4866	--	3.41
	LIN-LOG	-27.7861	9.6758*	8.2829*	-0.4225	177	11.4819	--	11.48
	LINEAR	-3.0127	0.8393*	0.3421*	-0.0353*	177	7.5950	0.83	7.60
	NONLINEAR	-2.5254	0.7760*	0.3026*	0.4000*	177	6.8516	--	6.85
GRASSES	LOG-LOG	0.9666	0.8902*	-0.2397	-0.0614*	170	0.5227	--	8.40
	LIN-LOG	-17.1141	15.4210*	-1.3976	-0.6964*	170	16.1249	--	16.12
	LINEAR	4.8772	0.7458*	0.0425	-0.0913*	170	13.5302	0.61	13.53
	NONLINEAR	0.7842	0.9490*	0.0304	0.3871*	170	13.4975	--	13.50
ALL SHRUBS	LOG-LOG	0.2626	0.9806*	-0.0759	-0.0762*	153	0.6146	--	8.13
	LIN-LOG	-1.3958	13.6692*	-3.2325	-1.9510*	153	16.9477	--	16.95
	LINEAR	13.7537	1.0028*	-0.4184*	-0.1431*	153	13.2488	0.70	13.25
	NONLINEAR	5.4660	1.1840*	-0.2305*	0.6977*	153	12.9734	--	12.97
SUB-SHRUBS (<= 11 CM)	LOG-LOG	0.6870	0.9937*	-0.2203	-0.1269*	62	0.7362	--	5.75
	LIN-LOG	10.9418	9.4490*	-4.5366	-2.5759*	62	11.8239	--	11.82
	LINEAR	15.0030	1.0304*	-0.5803*	-0.1434*	62	11.0039	0.60	11.00
	NONLINEAR	2.8724	1.2340*	-0.1343	0.8777*	62	8.8742	--	8.87
MED-TALL SHRUBS (> 11 CM)	LOG-LOG	-0.4757	1.0124*	0.1348	-0.0524*	91	0.5092	--	9.63
	LIN-LOG	-12.4966	17.5474*	-3.4161	-1.4565*	91	19.0117	--	19.01
	LINEAR	12.3540	1.0077*	-0.3599	-0.1465*	91	14.8058	0.69	14.81
	NONLINEAR	4.9325	1.1256*	-0.1572	0.5989*	91	14.8092	--	14.81
TOTAL VEGETATION	LOG-LOG	-0.0685	1.0300*	-0.0263	-0.0652*	192	0.4542	--	17.97
	LIN-LOG	-75.8198	34.4425*	1.0860	-2.5947*	192	28.5439	--	28.54
	LINEAR	1.7129	1.0430*	0.4105	-0.2357*	192	22.7260	0.67	22.73
	NONLINEAR	-6.8388	0.8947*	0.2431*	0.4375*	192	21.5468	--	21.55

* SIGNIFICANT AT P = 0.05
F.I. = FERNIVAL'S INDEX

LOG-LOG = 'LN(FOLLIAR BIOMASS)=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LIN-LOG = 'FOLIAR BIOMASS=Bo+(B1*LN%CVR)+(B2*LNCNPYLNG)+(B3*LNCCF)
LINEAR = 'FOLIAR BIOMASS=Bo+(B1*%CVR)+(B2*CNPYLNG)+(B3*CCF)
NONLINEAR = 'FOLIAR BIOMASS=Bo+(CVR) ^ B1 *(CNPYLNG) ^ B2 *[1/(EXP(CCF/100))] ^ B3

%CVR = OCULAR ESTIMATE OF COVER
CNPYLNG = MEASUREMENT OF CANOPY LENGTH (FORBS AND GRASSES = HEIGHT)
CCF = CALCULATED CROWN COMPETITION FACTOR OF OVERSTORY TREES
N = OBSERVATIONS

CHAPTER 4: CONCLUSIONS

The intent of this study was to test the hypothesis that percent cover, canopy length/height and overstory density (CCF) have a predictive relationship to understory foliar biomass per unit area. And, that this predictive relationship exists not only at the species level, but also at the life form level.

The equations developed in Table 2 show a high degree of correlation between foliar biomass per unit area and percent cover for all species. Canopy length/height was most significant for forbs. It appears that overstory density explains more variation at the life form level (Table 3) than in the individual species equations. The forest floor as a whole, will respond to the density of the overstory more than individual species. Individual species experience different levels of overstory density depending on their position on the forest floor and their vertical structure.

Foliar biomass per unit area for species and life forms can be calculated with an acceptable level of precision from the equations developed in this study. These equations provide a relatively quick, simple and nondestructive method for estimating foliar biomass. Although it is not recommended to extrapolate beyond the observed data, the models were acceptable when extrapolated. A major benefit to using regression equations when estimating understory biomass is decreased sampling cost. However, it must be kept in mind that regression introduces equation and prediction error.

The equations developed in this study will work best in dry to moderate Douglas-fir habitat types similar to those of western Montana where data for this study were collected.

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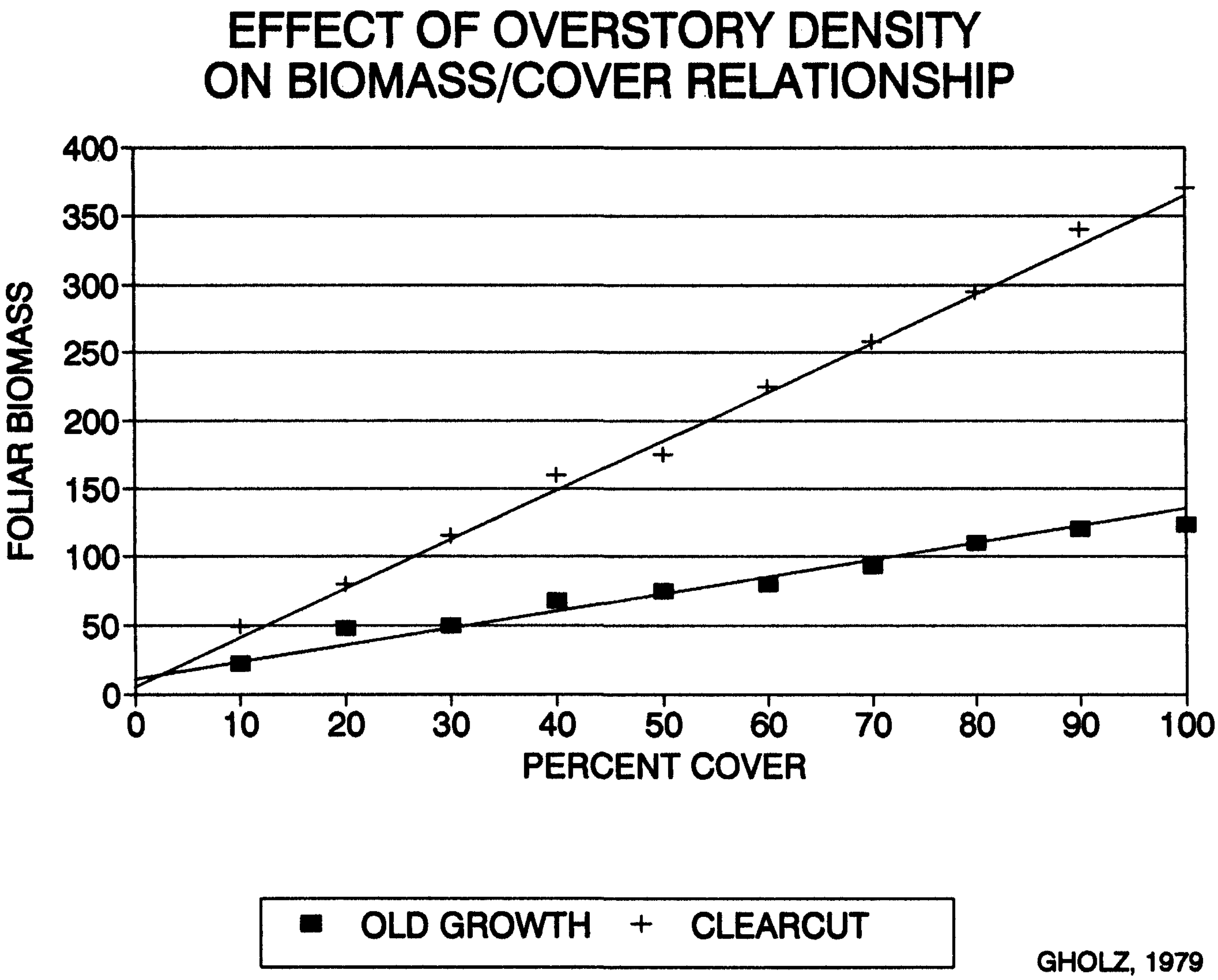
EFFECT OF OVERSTORY DENSITY
ON BIOMASS/COVER RELATIONSHIP
FOLIAR BIOMASS
400
350
300
250
200
150
100
50
0
0
10
20
30
40
50
60
70
80
90
100
PERCENT COVER
OLD GROWTH
CLEARCUT
GHOLZ, 1979

Figure 1

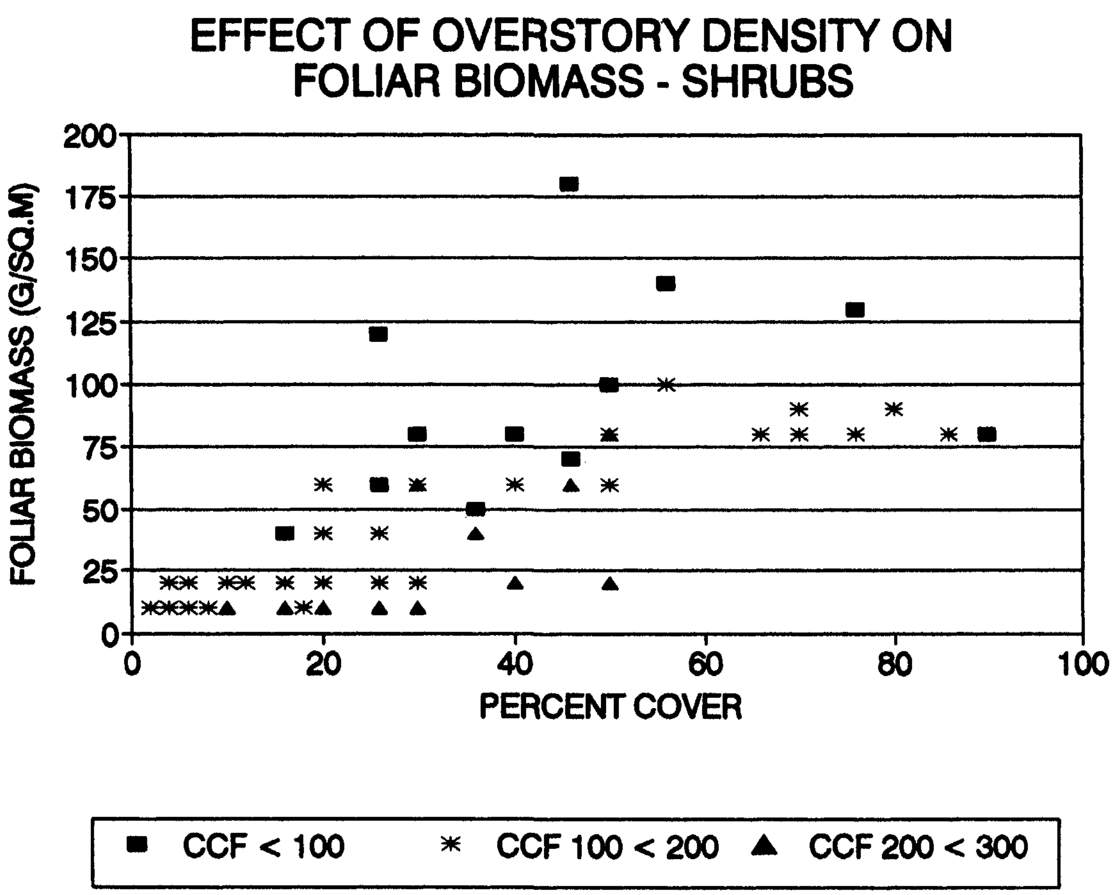
EFFECT OF OVERSTORY DENSITY ON
FOLIAR BIOMASS - SHRUBS
FOLIAR BIOMASS (G/SQ.M)
0
25
50
75
100
125
150
175
200
0
20
40
60
80
100
PERCENT COVER
CCF < 100
CCF 100 < 200
CCF 200 < 300

Figure 2

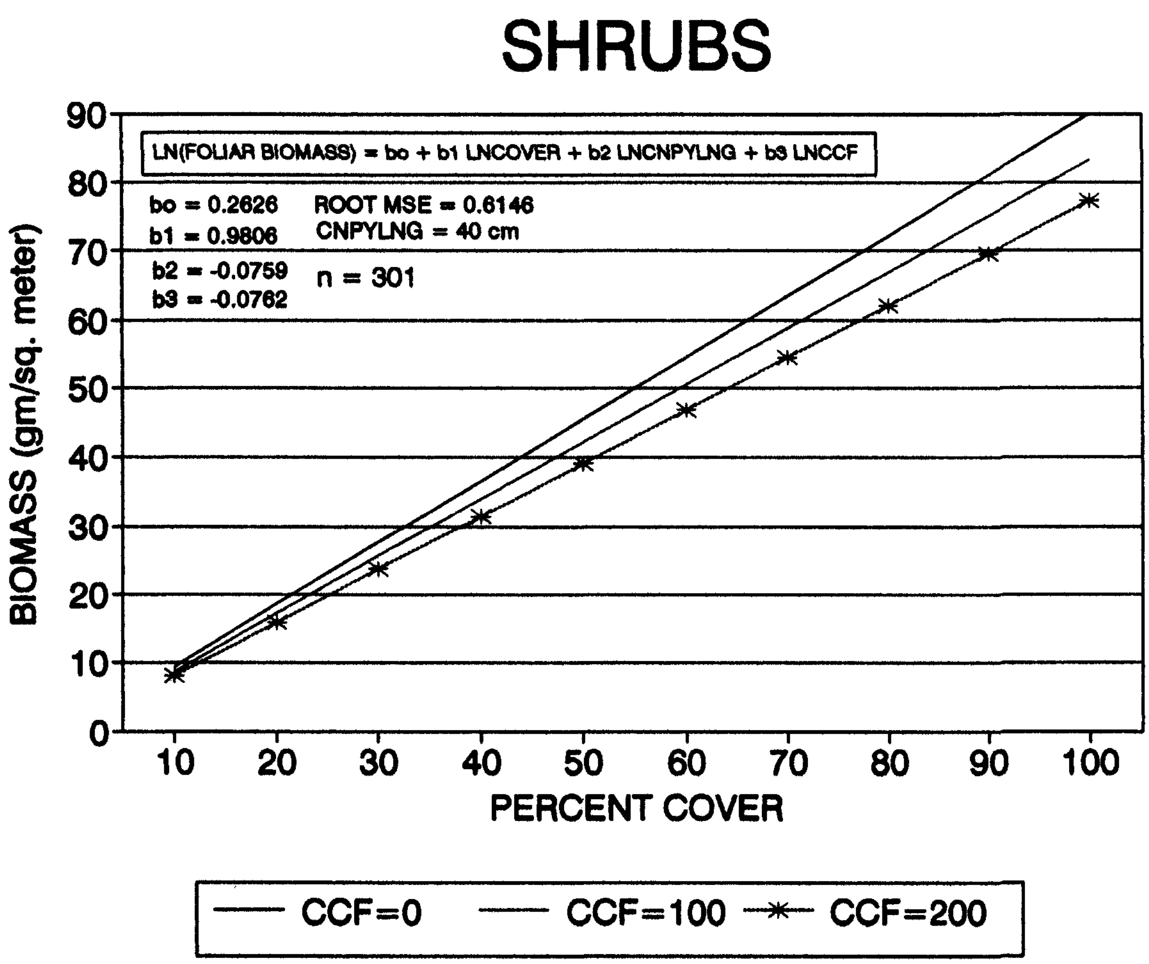
SHRUBS
LN(FOLIAR BIOMASS) = bo + b1 LNCOVER + b2 LNCNPYLNG + b3 LNCCF
bo = 0.2626
b1 = 0.9806
b2 = -0.0759
b3 = -0.0762
ROOT MSE = 0.6146
CNPYLNG = 40 cm
n = 301
BIOMASS (gm/sq. meter)
0
10
20
30
40
50
60
70
80
90
10
20
30
40
50
60
70
80
90
100
PERCENT COVER
CCF=0
CCF=100
CCF=200

Figure 3

SHRUB RESIDUALS

Plot of Residuals * Predicted Biomass

```
    |
  2 +                 P
R   |
e   |       P    PP  P                P
s   |  P         P    PP     P  P  P     P P PP P  P
i   |       P          PP  P PPPPPP PP PPPPP PPP   P P
d 0 +PP-------------P---------PP-PP-PPP-PPPPPPPPPP-PPPP----P----
u   | P     P   P   P    P      PPP PPP  PPPP P  PP
a   |PP     P      P  P P    P      P PPPP PP   PPP         P
l   | P                            P
    |
 -2 +---+----------+----------+----------+----------+----------+
        0          1          2          3          4          5
```

Predicted Value of (LN)Biomass
Symbol used is 'P'

Figure 4

APPENDIX A

CIRCULAR PLOT SIZES

	Radius
1/100 hectare	5.64 meters (18.50 ft.)
1/50 hectare	7.98 meters (26.18 ft.)
1/40 hectare	8.92 meters (29.26 ft.)
1/25 hectare	11.28 meters (37.01 ft.)
1/20 hectare	12.62 meters (41.40 ft.)
1/10 hectare	17.84 meters (58.53 ft.)

APPENDIX B

PERCENT COVER CLASSES

< 1%	=	.05
1%	=	1
2%	=	2
3%	=	3
"		"
9%	=	9
10 - 12.5	=	10
12.5 - 17.5	=	15
17.5 - 22.5	=	20
"		"
97.5 - 100	=	100

APPENDIX C

SPECIES SAMPLED

LF	SPECIES	COMMON	# OBS.	
F	ARNICA CORDIFOLIA	HEARTLEAF ARNICA	78	
F	FRAGARIA VIRGINIANA	STRAWBERRY	50	
F	HIERACIUM ALBERTINUM	WESTERN HAWKWEED	39	
F	CENTAUREA spp.	KNAPWEED	36	
F	ANTENNARIA UMBRINELLA	PUSSYTOES	31	
F	ACHILLEA MILLEFOLIUM	COMMON YARROW	26	
F	ANTENNARIA RACEMOSA	PUSSYTOES	26	
F	CLARKIA PULCELLA	PINK FAIRIES	23	
F	BALSAMORHIZA SAGITTATA	ARROWLEAF BALSAMROOT	21	
F	LUPINUS ARGENTEUS	LUPINE	18	
F	APOCYNUM ANDROSAEMIFOLIUM	DOGBANE	16	
F	ARENARIA MACROPHYLLA	SANDWORT	16	
F	COLLINSIA PARVIFLORA	BLUE EYED MARY	12	
F	PENSTAMEN WILCOXON	WILCOX PENSTAMEN	8	
F	CALOCHORTUS spp.	SEGO LILLY	7	
F	ERYTHRONIUM GRANDIFLORUM	GLACIER LILY	6	
F	LANCIOLATA SEDUM	LASE	6	
F	SALSIFY TRAGOPOGAN	DANDELION	6	
F	THALICTRUM OCCIDENTALE	WESTERN MEADOWRUE	6	
F	HABENARIA UNALASCENSIS	ALASKA REIN ORCHID	5	
F	GALIUMA TRIFLORUM	BEDSTRAW	4	
F	LONICERA CILIOSA	HONEYSUCKLE	4	
F	POTENTILLA GRACILIS	CINQUEFOIL	4	
F	SOLIDAGO MISSOURIENSIS	GOLDENROD	4	
F	CASTILLEJA LINARIAEFOLIA	INDIAN PAINTBRUSH	3	
F	DISPORUM TRACHYCARPUM	FAIRYBELL	2	
F	MITELLA STAUROPETALA	MITREWORT	2	
F	VICIA AMERICANA	AMERICAN VETCH	2	
F	PEDICULARIS RACEMOSA	LEAFY LOUSEWORT	1	FORBS = 462
G	CAREX GEYERI	ELK SEDGE	74	
G	CALAMAGROSTIS RUBESCENS	PINE GRASS	72	
G	FESUCA IDAHOENSIS	IDAHO FESCUE	24	
G	AGROPYRON SPICATUM	BLUEBUNCH WHEATGRASS	14	
G	FESTUCA OCCIDENTALIS	WESTERN FESCUE	13	GRASSES = 197
S	AMELANCHIER ALNIFOLIA	SERVICE BERRY	110	
S	BERBERIS REPENS	OREGON GRAPE	41	
S	ARCTOSTAPHYLOS UVA-URSI	KINNICK KINNICK	40	
S	ROSA spp.	WILD ROSE	38	
S	SYMPHORICARPOS ALBUS	COMMON SNOWBERRY	37	
S	LINNAEA BOREALIS	TWINFLOWER	27	
S	VACCINIUM GLOBULARE	BLUE HUCKLEBERRY	18	
S	PHYSOCARPUS MALVACEUS	NINEBARK	17	
S	CHIMAPHILA UMBELLATA	PRINCE'S PINE	15	
S	VACCINIUM CAESPITOSUM	DWARF HUCKLEBERRY	13	
S	PACHISTIMA MYRSINITES	MYRTLE BOXWOOD	5	
S	SHEPHERDIA CANADENSIS	BUFFALOBERRY	5	
S	MENZIESIA FERRUGINEA	FOOL'S HUCKLEBERRY	1	
S	VACCINIUM MEMBRANACEUM	BIG HUCKLEBERRY	1	SHRUBS = 368
		TOTAL OBSERVATIONS	**1027**	

APPENDIX D

CCF CODES

CALCULATED CCF	CCF CODES
CCF = 0	0
CCF < 50	1
50 <= CCF < 100	2
100 <= CCF < 150	3
150 <= CCF < 200	4
200 <= CCF < 300	5
CCF >= 300	6

APPENDIX E

SPECIES $\geq$ 15 OBSERVATIONS

LF	SPECIES	COMMON	# OBS. (n)	OBS. RANGE OF % COVER	OBS. RANGE OF CCF
F	ARNICA CORDIFOLIA	HEARTLEAF ARNICA	78	1-40%	0-172
F	FRAGARIA VIRGINIANA	STRAWBERRY	50	1-40%	0-172
F	HIERACIUM ALBERTINUM	WESTERN HAWKWEED	39	1-25%	0-108
F	CENTAUREA spp.	KNAPWEED	36	1-90%	0-63
F	ANTENNARIA UMBRINELLA	PUSSYTOES	31	1-20%	0-127
F	ACHILLEA MILLEFOLIUM	COMMON YARROW	26	1-4%	0-158
F	ANTENNARIA RACEMOSA	PUSSYTOES	26	1-6%	0-137
F	CLARKIA PULCELLA	PINK FAIRIES	23	1-9 %	0-158
F	BALSAMORHIZA SAGITTATA	ARROWLEAF BALSAMROO	21	1-50%	0-105
F	LUPINUS ARGENTEUS	LUPINE	18	1-20%	0-105
F	APOCYNUM ANDROSAEMIFOLIUM	DOGBANE	16	1-45%	0-63
F	ARENARIA MACROPHYLLA	SANDWORT	16	1-9%	0-40
G	CAREX GEYERI	ELK SEDGE	74	1-90%	0-172
G	CALAMAGROSTIS RUBESCENS	PINE GRASS	72	1-90%	0-172
G	FESUCA IDAHOENSIS	IDAHO FESCUE	24	2-35 %	0-63
S	AMELANCHIER ALNIFOLIA	SERVICE BERRY	110	1-70%	0-172
S	BERBERIS REPENS	OREGON GRAPE	41	1-9%	0-172
S	ARCTOSTAPHYLOS UVA-URSI	KINNICK KINNICK	40	1-45%	0-127
S	ROSA spp.	WILD ROSE	38	1-20%	0-172
S	SYMPHORICARPOS ALBUS	COMMON SNOWBERRY	37	2-45%	0-172
S	LINNAEA BOREALIS	TWINFLOWER	27	1-20%	0-137
S	VACCINIUM GLOBULARE	BLUE HUCKLEBERRY	18	1-80%	0-137
S	PHYSOCARPUS MALVACEUS	NINEBARK	17	1-80%	0-137
S	CHIMAPHILA UMBELLATA	PRINCE'S PINE	15	1-20%	6-137

APPENDIX F
DATA SUMMARY

SPECIES	VARIABLE	N	MIN.	MAX.	MEAN	STD. DEV.
ACHMIL	CCF	26	0.0000	157.7300	17.9542	37.2320
COMMON YARROW	COVER	26	0.5000	4.0000	1.5577	0.9932
	CNPYLNG	26	5.0000	30.0000	13.3077	5.5769
	BIOMASS	26	0.2800	4.2900	1.5669	1.1103
AMEALN	CCF	110	0.0000	171.8900	53.9652	57.7099
SERVICEBERRY	COVER	110	0.5000	70.0000	13.7182	13.3230
	CNPYLNG	110	5.0000	74.0000	16.1273	9.9918
	BIOMASS	110	0.2100	60.0500	8.6042	9.6470
ANTRAC	CCF	26	0.0000	136.9500	46.1338	50.7668
PUSSYTOES	COVER	26	0.5000	6.0000	1.8269	1.2078
	CNPYLNG	26	3.0000	7.0000	4.8462	1.0842
	BIOMASS	26	0.2800	7.7600	1.7242	1.6272
ANTUMB	CCF	31	0.0000	127.3900	27.6868	30.7662
WOODS PUSSYTOES	COVER	31	0.5000	20.0000	4.5645	4.3622
	CNPYLNG	31	2.0000	27.0000	9.1613	7.2988
	BIOMASS	31	0.2100	17.9500	5.4294	4.5728
APOAND	CCF	16	0.0000	62.9700	7.8713	21.5083
DOGBANE	COVER	16	1.0000	45.0000	10.0625	11.2811
	CNPYLNG	16	10.0000	68.0000	29.2500	18.5347
	BIOMASS	16	0.5400	47.3200	11.2381	12.3644
ARNCOR	CCF	78	0.0000	171.8900	73.4409	57.5768
HEARTLEAF ARNICA	COVER	78	0.5000	40.0000	10.1859	10.0146
	CNPYLNG	78	5.0000	15.0000	9.4359	2.0296
	BIOMASS	78	0.1200	20.8400	4.6556	4.7851
AREMAC	CCF	16	0.0000	40.2100	10.9163	14.8898
SANDWORT	COVER	16	0.5000	9.0000	2.8438	2.5477
	CNPYLNG	16	9.0000	20.0000	14.3125	3.3609
	BIOMASS	16	0.5200	10.7100	3.7001	2.6311
ARCUVA	CCF	38	0.0000	157.7300	32.1021	48.8240
KINNICK-KINNICK	COVER	38	1.0000	45.0000	8.6579	8.9813
	CNPYLNG	38	3.0000	12.0000	6.4474	2.4128
	BIOMASS	38	1.5700	97.6800	28.0445	27.3526
BALSAG	CCF	21	0.0000	105.2600	22.0114	27.8987
ARROWLEAF BALSAMROOT	COVER	21	0.5000	50.0000	14.2619	14.7679
	CNPYLNG	21	11.0000	42.0000	25.6190	6.5458
	BIOMASS	21	0.3600	70.0200	14.9838	18.4558

APPENDIX F cont...

SPECIES	VARIABLE	N	MIN.	MAX.	MEAN	STD. DEV.
BERREP	CCF	41	0.0000	171.8900	68.4968	61.4855
CREEPING OREGON GRAPE	COVER	41	0.5000	9.0000	2.8902	2.0631
	CNPYLNG	41	2.0000	16.0000	8.6122	3.3773
	BIOMASS	41	0.1800	12.6400	3.1910	2.6696
CARGEY	CCF	74	0.0000	171.8900	42.9430	44.9160
ELK SEDGE	COVER	74	0.5000	90.0000	27.4527	22.6241
	CNPYLNG	74	6.0000	74.0000	27.9459	10.9830
	BIOMASS	74	0.5400	99.9000	28.0834	26.7398
CALRUB	CCF	72	0.0000	171.8900	58.5340	60.6799
PINE GRASS	COVER	72	1.0000	90.0000	32.5694	21.6625
	CNPYLNG	72	16.0000	57.0000	31.2639	5.7237
	BIOMASS	72	0.3200	75.7400	18.0633	15.0347
CENTAUREA spp.	CCF	36	0.0000	62.9700	16.9094	20.0764
KNAPWEED	COVER	36	1.0000	90.0000	19.5000	21.5320
	CNPYLNG	36	6.0000	68.0000	35.9440	18.7189
	BIOMASS	36	0.2700	70.6900	21.9114	21.9338
CHIUMB	CCF	15	6.3700	136.9500	86.8260	45.8951
PRINCE'S PINE	COVER	15	0.5000	20.0000	5.0000	6.0445
	CNPYLNG	15	6.0000	15.0000	11.2666	2.4631
	BIOMASS	15	1.0100	27.4000	7.3853	8.2947
CLAPUL	CCF	23	0.0000	157.7300	31.8617	53.7911
PINK FAIRIES	COVER	23	0.2500	9.0000	3.1413	2.5814
	CNPYLNG	23	10.0000	50.0000	23.7391	11.0298
	BIOMASS	23	0.1800	137.7000	3.6661	3.5050
FESIDA	CCF	24	0.0000	62.9700	16.0479	19.3258
IDAHO FESCUE	COVER	24	2.0000	36.0000	7.5417	6.9155
	CNPYLNG	24	6.0000	64.0000	19.0000	13.2172
	BIOMASS	24	0.8300	23.1200	8.4821	4.6909
FRAVIR	CCF	50	0.0000	171.8900	28.7654	50.8802
WILD STRAWBERRY	COVER	50	0.5000	40.0000	6.0800	8.6031
	CNPYLNG	50	2.0000	17.0000	7.5400	3.3455
	BIOMASS	50	0.0800	28.2400	3.9768	5.8383
HIEALB	CCF	39	0.0000	127.3900	33.4990	43.0510
WESTERN HAWKWEED	COVER	39	0.5000	25.0000	2.3462	3.9367
	CNPYLNG	39	2.0000	56.0000	12.0769	11.7907
	BIOMASS	39	0.1400	12.5100	1.5249	2.1471

APPENDIX F cont...

SPECIES	VARIABLE	N	MIN.	MAX.	MEAN	STD. DEV.
LINBOR	CCF	27	0.0000	136.9500	67.3044	51.9405
TWINFLOWER	COVER	27	0.5000	20.0000	5.4630	4.2402
	CNPYLNG	27	2.0000	6.0000	2.6666	1.0000
	BIOMASS	27	0.7500	42.2400	9.3463	8.3952
LUPARG	CCF	18	0.0000	105.2600	35.6717	29.3274
LUPINE	COVER	18	1.0000	20.0000	6.6111	6.3629
	CNPYLNG	18	9.0000	30.0000	16.7778	5.7349
	BIOMASS	18	0.2400	23.6300	6.2456	6.7467
PHYMAL	CCF	17	0.0000	136.9500	24.7471	43.4562
NINEBARK	COVER	17	1.0000	80.0000	17.5882	24.7438
	CNPYLNG	17	12.0000	65.0000	33.8235	17.3250
	BIOMASS	17	0.5300	84.2000	17.4012	24.0723
ROSA spp.	CCF	38	0.0000	17.8900	59.9497	64.5044
WILD ROSE	COVER	38	0.5000	20.0000	4.3421	4.4693
	CNPYLNG	38	3.0000	31.0000	13.1842	7.9690
	BIOMASS	38	0.1600	14.0100	3.0050	3.3577
SYMALB	CCF	37	0.0000	171.8900	71.1110	66.8879
COMMON SNOWBERRY	COVER	37	2.0000	45.0000	15.6757	12.2067
	CNPYLNG	37	3.0000	30.0000	16.2432	7.3839
	BIOMASS	37	0.7500	43.1100	12.7311	12.3645
VACGLO	CCF	18	0.0000	136.9500	73.3239	51.3588
BLUE HUCKLEBERRY	COVER	18	0.5000	80.0000	15.6389	17.9327
	CNPYLNG	18	2.0000	36.0000	12.8333	8.3402
	BIOMASS	18	0.4000	50.9100	9.4383	11.3748