Biomass Evaluation of a *Chusquea culeau* Crop

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Abstract

Bamboo is a group of woody perennial evergreen plants in the true grass family Poaceae, subfamily Bambusoideae, tribe Bambuseae. *Chusquea* is a genus of bamboo with about 120 species. Most of them are mountain clumping bamboos native from southern Mexico to southern Chile and Argentina. They are sometimes referred to as South American mountain bamboos. Unlike most other bamboos, the stems of these species are solid, not hollow. They are of economic and high cultural significance in East Asia and South East Asia where they are used extensively in gardens, as a building material as well as a food source but the Chilean market gives not account of this reality. Moreover, Chilean bamboo has little scientific or technological studies. One of the scopes without research is related with a crop of *Chusquea culeau*. To solve this we have sown, starting of seeds, with a separation of 1.5 m each plant of *Chusquea culeau* given a total of 375 plants. Six years later was made the decision of to study the evolution of this crop and to evaluate the biomass that was originated.
The biomass was separated in culms with one year old from culms with more than one year old. It was kept up two age groups, greater than one year and less than one year in which were identified some biometric characteristics such as basal diameter, height, mass of leaves and twigs and mass of culms. The data collected were treated statistically to find a relationship between the variables and biomass generated and compared with wild *Chusquea culeau*.

Keywords: *Chusquea culeau*, Biomass evaluation, Crop of bamboo, Colihue, Model regression.

Introduction

There have been several studies on the productivity of *Chusquea* species, such as carried out by Veblen et. al. (1979), in lands of *Chusquea culeou* and *Chusquea tenuiflora* in the Andes, where the vast aerial biomass reflected in the results for *Chusquea culeou*, give enough reasons to study some physical, chemical and morphological properties of this species in order to determine their suitability for industrial use (Rijo et. al., 1987).

In this way, and taking into account that the species of *Chusquea culeou* and *Chusquea quila* concentrate over 80% of species of the genus in Chile, being regarded as industrially useful species (Campos et. al. 2003).

The present study was carried out with material from a farming plot located on "*Los Pinos*", belonging to the *Centro Experimental Forestal* (CEFOR, Experimental Forestry Center) de la *Universidad Austral de Chile*.

This study allows us to establish a comparative analysis between cultivated masses and natural masses, since so far the work related species have been carried out on natural masses, determining the most appropriate morphological variable for the estimation of dry weight by comparing different regression models, with a more appropriate one of the greatest ease of use with a standard error minimum and a maximum ratio determination.

Characteristic of *Chusquea culeou*

Chusquea culeou Desv. is included within the tribe Bambusoides, belonging to the family Gramineae. Get several common names, among which coligüe, colihue, culeú.

C. culeou has unbranched erect culms occurring in dense crowds. Individual culms have a baseline diameter of 4cm and a length of 9m. The long averages of the culms of adult plants reach 3-6m depending on the conditions prevailing on the site (Veblen et. al., 1979). The growth in height and diameter maximum is reached only during the growing season. This rapid growth of the culm is made possible by the accumulation of reserves in the extensive system of rhizomes, which penetrates the soil to a depth of 80cm and extends horizontally until 6m stations in free competition and 1-2m in dense formations scrubland (Veblen et. al., 1979).

Biomass Production. Previous Studies

Veblen et. al. (1979), studied the production of dry matter in two nearly pure stands of the species in San Pablo de Tregua in the Andes, at an altitude of approximately 700m and in an area of about 2Ha. These stands were aged between 20 and 30 years, and originated when a portion of forest was cut and burned. For the quantification of biomass produced by the species distinguished between generated by the leaves and pods and on the other hand the culms, differentiating the latter culms in one year of age and older culms (Table 1).

Also available is information collected for the species *Chusquea culeou* in regions IX, X and XI, where they are concentrated over 80% of the areas covered by gender *Chusquea* in Chile (Campos et. al., 2003). (Table 1).

Garriz and Cepero (1988), conducted a study on a hillside stream Caricu, 1.240m elevation, at department of Aluminé, province of Neuquén, Argentina. Exploring spontaneous undergrowth *Nothofagus* and Araucaria, results of total shoot much lower than those obtained in the work mentioned above, because the latter were carried out mainly on bush open and sunny where *Chusquea culeou* behaved as dominant or codominante (Table 1).

Study	Total Biomass	Culms biomass
Veblem et. al.	161.8 ton/Ha	130,53 ton/Ha
	155.87 ton/Ha	127,35 ton/Ha
Campos et. al.	147 ton/Ha	
Garriz and Cepero	14,3 ton/Ha	10,5 ton/Ha

Table 1 Biomass production of Chusquea Culeou from natural masses

Methodology

Sampling

We carried out a systematic sampling interval with Election Constant, based on the principle of equiprobability, where all individuals of the population have equal chance of being elected and, consequently, all samples of size n also have the same probability to be selected. For the study of morphological variables and biomass production variables, it was selected 30 individuals from which were selected 3 culms.

In each culm, it was extracted a small subsample from the two groups established materials, which were placed in aluminium trays and introduced in an oven at a temperature of 103 ± 2 degrees Celsius to reach constant weight. Then weigh it and it was extrapolated the values obtained. In this way it was determined the dry weight for leaves, pods and twigs and the total dry weight for the whole culm.

Statistic

First, it was conducted a descriptive analysis of morphological variables: diameter at one metre from the base (D_{1m}), diameter at two meters from the base (D_{2m}) and total length of culm (T_l.), as well as the variables for biomass production, weight culm (W_c), weight of leaves, twigs and pods (W_{ltp}) and total weight (W_t), variable resulting from the sum of W_c and W_{ltp}.

Subsequently, it was conducted a study of the frequency distribution of each of the variables, in order to normalize it, when the normal distribution is not followed.

Variable	Mean	Standard Desv.
Culms < 1 year old (n = 27 ; α = 95%)		
D_{1m} (mm)	15,70	3,86
D_{2m} (mm)	12,33	4,86
T_l (m)	3,47	0,95
Culms > 1 year old(n = 59 ; α = 95%)		
D_{1m} (mm)	14,20	4,10
D_{2m} (mm)	10,81	5,40
T_l (m)	3,73	1,00
Culms all ages (n = 86 ; α = 95%)		
D_{1m} (mm)	14,67	4,07
D_{2m} (mm)	11,29	5,26
T_l (m)	3,65	0,99

Table 2 Morphological Variables studied

Variable	Mean	Standard Desv.
Culms number (n = 30 ; α = 95%)		
Culms number < 1	4,73	1,90
Culms number> 1	59,10	23,30
Total Culms	64,00	25,72
Culms < 1 year old (n = 27 ; α = 95%)		
W_c (g)	103,69	67,77
W_{ltp}* (g)	7,26	1,80
W_t (g)	112,23	71,17
Culms > 1 year old (n= 59 ; α = 95%)		
W_c* (g)	208,86	1,96
W_{ltp}* (g)	71,07	1,67
W_t* (g)	288,48	1,74
Culms all ages (n = 86 ; α = 95%)		
W_c* (g)	154,79	2,22
W_{ltp}* (g)	57,95	(1)
W_t* (g)	201,53	2,21

Table 3 Biomass variables studied

Models regression

Once analysed each variable in a separated way, we studied the possible relationship between the variables of morphological and biomass production, in order to establish the regression models most suitable for the estimation of different weights dried (W_c, W_{ltp} and W_t), through the measurement of any of the morphological variables (D_{1m}, D_{2m}, T_l.). It is understood as the most appropriate regression model, that model that presents a maximum coefficient of determination (r^2) and a minimum standard error of estimate (SEE).

We tested different regression models simple linear, square root of the dependent variable, square root of the independent variable, double reciprocal, mutually dependent variable and independent, and exponential multiplier.

We prioritized the linear regression models over other models studied, because of their ease understanding and use, in addition to employ a single morphological variable to estimate weight, which means greater ease of implementation.

Discussion

As set out in section devoted to statistical analysis methodology (Table 2 and Table 3) estimates of population parameters mean and standard deviation for each age group and for the three morphological analysis.

Age	**n**	**Regression model** **Y (g) ; D_{1m} (mm)**	**S.E.E**	**Coefficient of Determination**
Total Weight (Y)				
Culms < 1 year old	26	$LnY = -2{,}44766 + 2{,}5417xLnD_{1m}$	1,38	77
Culms > 1year old	53	$LnY = 1{,}48383 + 1{,}62258xLnD_{1m}$	1,21	87
culm weight (Y)				
Culms < 1 year old	26	$LnY = -2{,}59622 + 2{,}56378xLnD_{1m}$	1,42	74
Culms > 1year old	59	$LnY = -0{,}321548 + 2{,}16203xLnD_{1m}$	1,25	89
Weight of leaves, twigs and pods (Y)				
Culms < 1 year old	23	$LnY = -5{,}05283 + 2{,}56315xLnD_{1m}$	1,21	90
Culms > 1year old	55	$LnY = 3{,}0093 + 0{,}507858xLnD_{1m}$	1,54	11

Table 4 Regression models proposed.

The morphological variables are in agreed with the required assumptions of normality distribution established in advance, regardless of the age group under study.

If we compare the size of the culms less than one year-old with those oldest culms, we see that they reach the maximum size at only one growing season, already known feature of the species and that makes it so interesting for biomass production.

For the total length, Veblen. et. al. (1979), estimated that the average the culms is reached 3 to 6m according to seasonal conditions, being the average value found in the study area from 3 to 4m, approximately.

As for diameters, Campos et. al. (2003), shown that *Chusquea culeou* develops erect culm of 1 to 2.5 cm in diameter, being observed values for our population of about 1.5 cm to one meter diameter and 1cm diameter at two metres from the base.

It may be recalled at this point, on which the plot was not carried out any maintenance treatment or improved, and according to Campos et. al (2003) forest management suitable for this type of training can generate positive responses by rhizomes, resulting in culms larger in diameter and in height.

Biomass Production

Taking the average values of culm and the number of different weights measured, we can get for each age group and for each group of material, biomass production at the place of study. Taking into account the context of planting, 1.5 x 1.5 m, we can express the average production of biomass in tons per Ha (Table 5).

Culm age	Origen of data	Culms (ton/Ha)	Leaves, twigs and pods (ton/Ha)	Total Biomass (ton/Ha)
< 1 year	weight extrapolation	2,18	0,15	2,36
	Regression models	1,82	0,16	1,99
> 1 year	weight extrapolation	54,86	18,67	75,77
	Regression models	59,03	26,77	85,80
All	weight extrapolation	57,04	18,82	78,13
	Regression models	60,85	26,94	87,79

Table 5 Biomass production from statistical data and models proposed.

When was compared the results for biomass production with previous studies conducted on natural stands, we note that the results of our study are lower. As to the number of culm generated, Veblen. et. al. (1979), established a production number of culm per square metre culms of about 1.76 of one year of age and 20 for culms over one year. Being our results of 2 and 26 respectively. As far as this variable have slightly higher values. On the other hand, in that same work, were estimated total biomass production of 161.68 tons / ha, spread over 5.76 tons / ha for culms under one year and 155.95 tons / ha for culm older than one year. These estimates were made using regression equations obtained for conducting such a study.

Campos et. al. (2003), felt that in situations of dominance Type I and II, and for the regions IX, X and XI of Chile, production reached average 147Tn/Ha. This estimate was made on a large scale and with figures from the Land Registry and Forest Resources Assessment native of Chile developed by CONAF-Conama in 1997.

Differences in biomass production found between the place of cultivation and natural stands may be due to several reasons.

The seasonal conditions would be a major factor to take into account.

Veblen et. al. (1979) studied plots of San Pablo de Tregua, in the Andes, where the annual rainfall exceeded 4.000mm and located at an altitude of approximately 700m. The plot of study is at an altitude of approximately 40m, and annual precipitation is about 2.000mm, half that of in San Pablo de Tregua.

On the other hand, must also mention the age of the specimens analyzed. In San Pablo de Tregua, the copies were surveyed aged between 20 and 30 years compared with 6 years of exemplary object of this study. This implies the presence of rhizomes with a higher capacity to generate larger culm. Campos et. al. (2003) made estimates on a large scale, for different seasonal conditions and for different ages of colihue, with a proposed value to be an average point of production of biomass at large. The values recorded by Garriz and Cepero (1988), are approximately 1.5 tons / ha, much lower because they studied the production of colihue in undergrowth spontaneous formations dominated by *Nothofagus* and Araucaria.

Lastly, we mention again the importance that would have to apply a proper forestry management, in order to motivate greater biomass production and achieve production levels of the natural masses in a lowest time.

In addition, it is considered important to make new plantings with different frameworks planting, with the aim of contrasting results and obtain an optimal density value for future crops.

Regression Model

A comparison of the various regression models have as a result that the linear models reach the settings with highest ratios of determination and lowest standard errors, except for estimating the weight of leaves, pods and twigs for the culms with over a year age. The logarithmic transformations of the variables improved the correlation coefficients, and hence, the coefficients of determination.

If we compare the results with the equations proposed by Veblen et. al. (1979), there are similar results. These paper identified that the diameter at one meter as the best variable for the estimation of different weights because it provides adjustments with a maximum coefficient of determination and a minimum standard error. Another advantage of the use of one meter diameter at the base as a predictor variable, and also mentioned by Veblen. al. (1979), is that it is easier its measuring that the diameter of two meters from the base or total lengths.

Given that the proposals equations finally overcame successfully tests of goodness to which they were subjected we believe the proper use of the proposed models for estimating biomass from colihue, as long as, average values of one meter diameter at the base, located within the range of application of the models adjusted.

Conclusions

It has been characterized morphologically and quantified the biomass present in a plot for growing *Chusquea culeou* Desv, from which is extracted a total of 86 culms of 30 plants selected at random. For each of the culms was identified a total of six variables, three morphological variables and three variables of biomass production. The morphological variables were: one meter diameter at the base, two meters in diameter at the base and total length.

Biomass production was tested by the weight of culm, Weight of leaves, pods and twigs, and total weight, the latter obtained by the sum of the previous two. In this way, and through statistical inference through the establishment of confidence intervals, was characterized morphologically samples of the population were measured and biomass production. Subsequently, we examined the relationships between morphological variables and the variables of weight, in order to establish equations for estimating weights.

It contrasted different regression models, choosing satisfactory as those who submitted a maximum coefficient of determination and a minimum standard error. Thus, it was proposed a total of five equations for estimating biomass generated in air masses colihue under conditions similar to the mass studied.

It has succeeded with this work to deliver a background of the development of *Chusquea culeou* under growing conditions, besides establishing a first comparative analysis between masses and natural plantings. It is also considered a useful tool to contrast the effect of future interventions on the plot cultivation studied, as well as a document with which to compare new crops colihue where, for example, employ different frameworks planting.

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