

**Grass yield forecast from metadata of *Brachiaria brizantha* experiments**

Clayson Correia de Sousa<sup>1</sup> e Glauco de Souza Rolim<sup>2</sup>

<sup>1</sup>Filiação. E-mail: claysoncorreia@posgrad.unesp.br

<sup>2</sup>Filiação. E-mail: rolim@fcav.unesp.br

**Abstract:** Forecast and estimation are distinct concepts within crop modeling and it is precisely in the forecast there is a lack of knowledge. Estimation is the prediction of current conditions based on current data, while forecast is a future event prevision. Grass is the basis of the productive systems of the Brazilian livestock and among the cultivated species, *Brachiaria* sp forage genus is the most important. Among the many factors related to the cattle feeding, the adjustment of supply to forage intake is one of the key objectives for the livestock farming planning. The productive potential modeling of forages represents a technological leap as the application of management procedures of livestock production, reasons for decision-making in livestock systems on pasture in the tropics which happens to be made from statistical models and not only producer's empirical or practical knowledge. The purpose of this paper was adjusting forecast models of *Brachiaria brizantha* yield related to soil and climatic explanatory variables from experiments conducted in eight different regions. The best variables were related to water supply, temperature and fertilizing. The best adjusted model was  $Y^{0.5} = 0.13K2O + 5.77T9 + 0.14EXC8 - 105.94$  (9, 8 subscripts means September and august respectively) whose can be used to forecast yield data with a year in advance.

**Keywords:** meta-analysis, modeling, pastures.

---

Os autores deste trabalho são os únicos responsáveis por seu conteúdo e são os detentores dos direitos autorais e de reprodução. Este trabalho não reflete necessariamente o posicionamento oficial da Sociedade Brasileira de Biometeorologia (SB Biomet).

The authors of this paper are solely responsible for its content and are the owners of its copyright. This paper does not necessarily reflect the official position of the Brazilian Society of Biometeorology (SB Biomet).

---

## Introduction

The grasslands are the basis of the productive systems of the national livestock due to: the low cost, large capacity and ease of establishment (TONATO *et al.* 2010; RODRIGUES 2004). Among the cultivated species of forage *Brachiaria* sp genus is the most important in the national livestock which represent about 80% of the area cultivated with grasslands in the country (TONATO *et al.* 2010; RODRIGUES 2004). The forage yield modeling is an important tool in the estimation of production systems in livestock (TONATO *et al.* 2010). The environmental variables fluctuations can explain the forage yield seasonality. A mathematical modeling is a simple description of real systems from the relationship between different areas of knowledge in order to summarize, describe and evaluate different characteristics of agricultural yield, including the production and the interactions between crops and the environment, thus allowing the prediction of performance of plant community and description opportunities for improvement in handling used (MUNIZ *et al.* 2007). However, as these authors stated when the analysis of correlation among climate variables indicate that there were autocorrelations the variables should be eliminated from the models, because there were not gains with models of greater complexity (TONATO *et al.* 2010). Assuming that the grass yield is influenced by climatic and soil elements, the purpose of this paper is adjust forecast models of *Brachiaria brizantha* yield based on meta-analysis from experiments carried on 8 important Brazilian regions.

## Material and Methods

The *Brachiaria brizantha* yield data due to climatic variables, including experiments conducted in various locations in South-Central region of Brazil between 2000 and 2015 were compiled from papers whose works were carried out in the localities of Piracicaba (SP) Nova Odessa (SP) Jaboticabal (SP) Araçatuba (SP), Janaúba (MG), Londrina (PR), Uberaba (MG), Ilha Solteira (SP) (Figure 1).

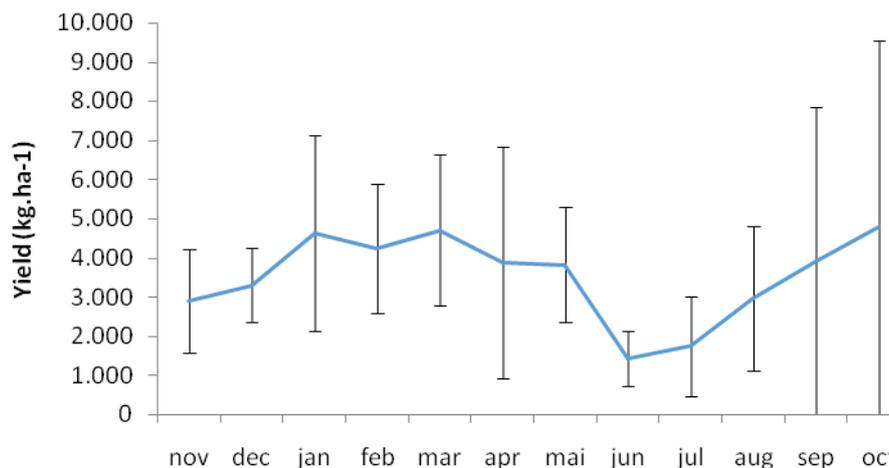


Figure 1. *Brachiaria brizantha* yield in the central-south region of Brazil between 2000 and 2015. Source: Metadata from this search. Mean values of Yield and the bars indicate standard deviations.

Climatic data of the various authors of local experiments were obtained on a daily scale from automatic weather stations (EMA) for monitoring the Agronomic Institute system (APTA-IAC) and the National Institute of Meteorology System (INMET). There were used daily rainfall data (P) and minimum temperature (TMIN), medium (T) and maximum (TMAX) air, organized in monthly scale for the period 2000-2013 for the potential evapotranspiration calculation (PET) by the equation of Camargo (1971) (equations 2, 3,4,5 and 6). From the monthly data P and PET is calculated water balance (BH) proposed by Thornthwaite and Mather (1955) with available water capacity of 100 mm for all locations. Variables with best correlations were selected for the agrometeorological construction models aiming to pasture yield forecast for the regions. In this construction were used multiple linear regression method (Equation) as proposed by GUJARATI and PORTER (2011).

In the construction of the models, especially with many independent variables, the biggest problem is the selection / combination of the most important variables. For the selection of variables, it was used the 'stepwise' process with 'backwards' approach, following the accuracy improvement criteria (Mean Error Percentage Absolute, MAPE) (MORETO and ROLIM 2015). Only models with 0.05 of significance were selected. Preference was given to selection of variables that enable greater yield in anticipation of forecast.

After this stage, were selected about 6 models that best adapt to the statistical requirements and anticipation for each location. These 6 models were applied to accuracy analysis by MAPE, precision by adjusted coefficient of determination ( $R^2$ ) (Equations 9 and 10). We used 70% of data for calibration models (2000 to 2011) and 30% for testing (validation).

$$MAPE(\%) = \frac{\sum_{i=1}^N \left( \left| \frac{Y_{esti} - Y_{obsi}}{Y_{obsi}} \right| \times 100 \right)}{N} \quad (8)$$

$$R^2_{adjusted} = \left[ 1 - \frac{(1 - R^2) \times (N - 1)}{N - k - 1} \right] \quad (9)$$

The basic statistics (including position and dispersion measures, box plot graphic, histogram, confidence interval and normality test Anderson-Darling) were presented as statistical summary in accordance with the procedures described by Minitab Inc (2007).

### Results and Discussion

The yield values ( $Y$ ) presented asymmetry by the Anderson-Darling test (AD) ( $p$ -value  $< 0.05$ ), then the respective values were transformed in  $Y^{0.5}$  (Figure 2) (COTTRELL and LUCCHETTI 2013). The average yield of *Brachiaria brizantha* was of 3,589.3 kg.ha<sup>-1</sup> (Figures 1 and 2) and the data showed high standard deviation and variance what reflects differences of management, soil, genetics, climates whose is discussed in sequence. But with the transformation of the data (Figure 2) this problems were solved. The yield of September and October had the highest standard deviations and this can be explained by the year whose dry season is more severe can extend from May to November or even August or September in the rainiest year. This pattern of distribution of forage production is 85% concentrated in the summer spring seasons and 15% in the autumn-winter according to the literature (FAGUNDES *et al.* 2005).

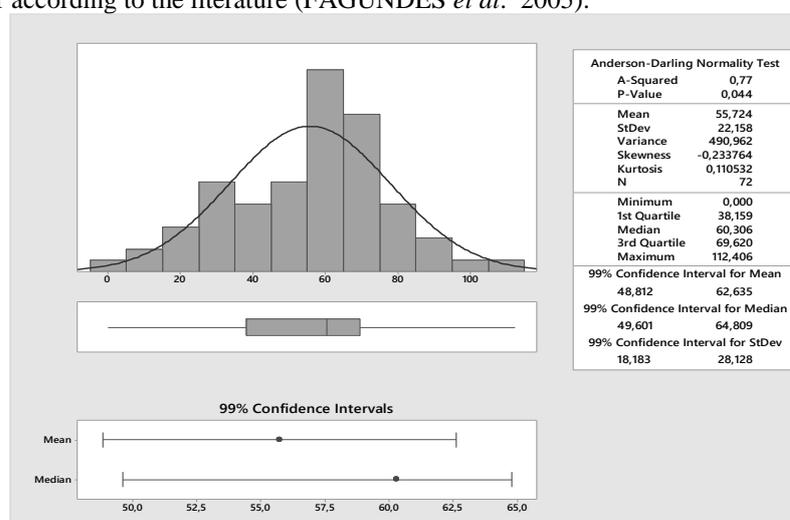


Figure 2. Statistical summary for *Brachiaria brizantha* yield corrected by root transformation ( $Y^{0.5}$ ) of metadata.  $p$ -value  $> 0.01$  = normal distribution.

The climate elements are significant in the establishment of the forage yield, and variables such as temperature, rainfall and light (photoperiod and light quality) influence greatly mass production and seasonality of forage yield (TONATO *et al.* 2010). However, as these authors the correlation analysis between climate variables showed that, for all data sets assessed by them, climatic variables were high and positively correlated, allowing discard models of greater complexity. Therefore, the tests performed gave no regression when using 4 independent variables, since collinear variables ( $r = 0.6$ ) were excluded from the model. However, were found 65,230 models with 3, 2 and 1 variables with no multicollinearity (Figure 3). We selected only the top 6 models, which had the lowest MAPE (high accuracy). The method of APC testing for the independents variables was efficient.

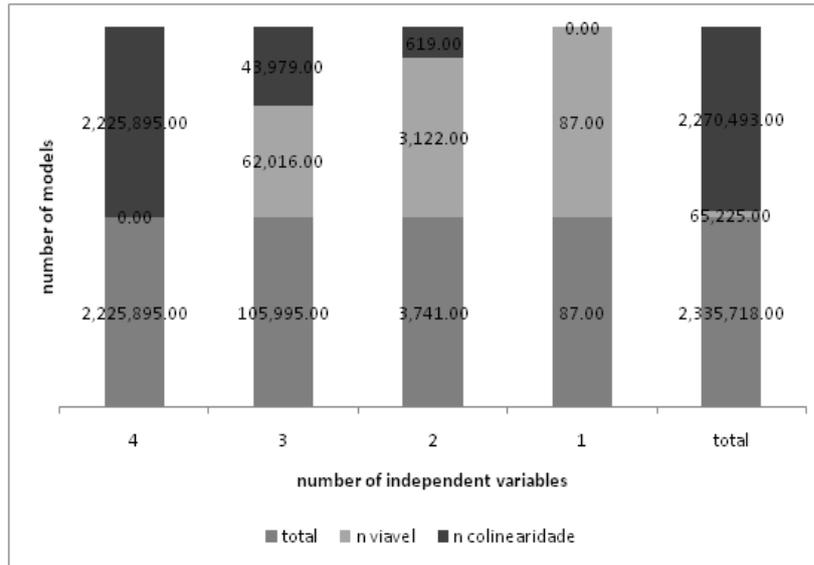


Figure 3 Number of possible viable models with 4, 3, 2 or 1 independent variables for yield forecasting of *Brachiaria brizantha*.

Edaphic aspects refers to fertility attributes and physical soil and the effect of fertilization of pastures on dry matter yield, especially nitrogen fertilization has been thoroughly studied and numerous studies show a linear relationship of the amount of dry matter (DM) due to the increase of nitrogen, (FAGUNDES *et al*; 2006). In the best equations, 1 and 2 (Table 1) the best soil variable was K<sub>2</sub>O (in fertilizing), but the correlation coefficient between K<sub>2</sub>O and N was strong (r = 0.81), so the two variables do not appear together in the calibrated models. The response variables of the calibrated models (table 1) essentially are water, temperature and fertilizing. This corroborates with Tonato et al (2010) whose estimation model uses the temperature as explanatory variable and fertilizing effect, namely nitrogen, is reported in papers of SANTOS *et al.* (2009).

As Tonato et al (2010) the minimum temperature (Tmin) was the one that allowed a highest correlation to grass yield, followed by radiation (RA) and a seasonal variability described by julian days (JD). The estimation models were obtained respectively for TMA (average rate per day of dry matter accumulation, (kg.ha<sup>-1</sup>) of *Brachiaris* respectively for groups 1 (Marandu, Basilisk and Arapoty) and group 2 (Capiporã and Xaraes cultivars): TMA = -94.92 + 8,19T<sub>min</sub> and TMA = -128.07 + 10.66 T<sub>min</sub> (TONATO *et al.*, 2010).

Table 1. Top 6 adjusted models. Precision (R<sup>2</sup>), Tendency (EP reg) and Accuracy (MAPE) measures.

Eq	model	adjusted R <sup>2</sup>	EPreg	MAPE- Calibration	MAPE- Test
1	$Y^{0.5} = 0.13K_2O + 5.77T_9 + 0.14EXC_8 - 105.94$	0,53	14,96	29,29	25,68
2	$Y^{0.5} = 0.07K_2O + 5.76T_9 + 0.14P_9 - 107.73$	0,45	16,22	29,96	25,78
3	$Y^{0.5} = 0.12K_2O + 5.79 T_9 + 0.14 P_8 - 105.25$	0.501	15.46	30,17	25,98
4	$Y^{0.5} = 0.07K_2O + 5.75T_9 + 0.14 P-PET_9 - 107.73$	0.457	16.12	30,34	24,27
5	$Y^{0.5} = 0.12K_2O + 5.88 T_9 + 0.14P-PET_8 - 107.05$	0.498	15.49	30,37	25,33
6	$Y^{0.5} = 0.07K_2O + 5.92T_9 + 0.14EXC_9 - 111.14$	0.461	16.06	30,60	26,35

RP = root productivity(kg ha<sup>-1</sup>)<sup>0.5</sup>. K<sub>2</sub>O = potassium fertilizer (kg/ha). T<sub>9</sub> =temperature of ninth month (°C). EXC<sub>8</sub> = hydric exceeding of eighth month (mm). P<sub>9</sub> = precipitation of ninth month (mm). PET = Potential Evapotranspiration (mm). P-PeT = Precipitation – Potential Evapotranspiration (mm). EPreg = standard error of regres'sion. R<sup>2</sup> = determination coefficient. Eq = Equation number. The models coefficients were significant (p-value < 0.01).

The irrigation effect is reported by RASSINI (2004) and the relatively low R<sup>2</sup> (table 2) whose larger value was of the equation 8320, and the respective differences remaining to 1 can be explained for others soil attributes like chemistry composition, physic aspects, micronutrients fertilizing levels (CAVALLINI *et al.* 2010), management practices like sealing and rotational grazing with supplemental fertilizer nitrogen (SANTOS *et al.* 2009), besides genetic aspects in function of different varietal cultivars used in the

experiments (TONATO *et al.* 2010) and DM production in response variations can occur depending on the season of work and the effect of the year (FAGUNDES *et al.* 2005) (FAGUNDES *et al.* 2006). The variables EXC8, EXC9, P8, P9, P8, P-PET and PET9 are all related to water balance and explain the *B. brizantha* yield (Table 1). As yield data were regressing to climate data of the previous year, these models are used to forecast the yield within a year in advance, making it the month temperature of September and the water availability of the months of August and September determinants of yield in the 12 months following and explain the high standard deviation of grass yield in the October month (Figure 1). In the model 1 (Table 1) for each 1 Celsius rise in temperature, we have 5.77 (kg ha<sup>-1</sup>)0.5 increase in RP (root yield) and for each 1 mm of EXC have 0.14 (kg ha<sup>-1</sup>)0.5 increase in RP.

Despite the high variance of productivity data (Figure 3) which reflects the different environmental conditions in the compiled experiments in this work and certainly reduced the precision of the calibrated model (R<sup>2</sup> values) (Table 2) the data transformation (Figure 2) provided with the calibrated models presented good accuracy (Table 1). In the national literature lacks forecast articles which would compare the R<sup>2</sup> and MAPE values obtained here, so this work is pioneering serve as the basis for future comparisons.

### Conclusions

The *B. brizantha* yield was a function of temperature, water availability and potassium.

The calibrated models were accurate in forecast *B. brizantha* yield within a year in advance.

The temperature of September and the water availability of August and September months are determinants of yield in the 12 months following.

### References

Cavallini MC, Andreotti M, Oliveira LL, Pariz CM, Carvalho MP (2010) Relationships between yield of *Brachiaria Brizantha* and physical properties of a savannah oxisol. R. Bras. Ci. Solo 34: 1007-1016. <http://dx.doi.org/10.1590/S0100-06832010000400001>

Camargo AP (1971) Balanço hídrico no Estado de São Paulo. Campinas: IAC, 28p. (Boletim Técnico, 116).

Cottrell A, Lucchetti RJ (2013). Gretl Use's Guide. Gnu - Regression, Econometrics and Time-series Library. Wake Forest University/Università Politecnica delle Marche.

Fagundes JL, Fonseca DM, Gomide JÁ, Junior DN, Vitor CMT, Morais RV, Mistura C, Reis GC, Martuscello JA (2005). Biomass of the forage in *Brachiaria decumbens* pastures fertilized with nitrogen. Pesq. Agropec. Bras. 40: 397-403. <http://seer.sct.embrapa.br/index.php/pab/article/view/6970/4018>

Fagundes JL; Fonseca DM, Mistura C, Morais RV, Vitor CMT, Gomide JA, Junior DN, Casagrande DR, Costa LT (2006) Morphogenetical and structural characteristics of the signalgrass in a nitrogen fertilized pasture evaluated over the seasons of the year. Braz. Jour. A. Sci. 35: 30-37. <http://www.scielo.br/pdf/rbz/v35n1/28338.pdf>

Gujarati DN, Porter DC (2011). Econometria básica. 5ª Ed. Editora MC Graw Hill.

Minitab Inc (2007). Minitab Statistical Software, Release 15 for Windows, State College, Pennsylvania.

Moreto VB; Rolim GS (2015) Estimation of annual yield and quality of “Valência” Orange related to monthly water deficiencies. African Jour. Agric. Res. 10: 543 - 553. <http://www.academicjournals.org/journal/AJAR/article-full-text-pdf/21D4C4C50178>

Muniz LC, Viu MAO, Magnabosco CU, Lopes DT (2007) Modelagem e simulação na agropecuária. Pubvet 1: 1982-1263. <http://www.pubvet.com.br/antigos/11>.

Rassini JB (2004). Seasonality period of production in irrigated pastures. Pesq. Agropec. Bras. 39: 821-825. <http://seer.sct.embrapa.br/index.php/pab/article/view/6844/3900>

Rodrigues DC (2004) Forage production of *Brachiaria brizantha* (HOCHST. Ex A. Rich.) Stapf and modeling yield in response to climatic variables. Dissertation. Esalq/USP.

SANTOS MER, Fonseca DM, Balbino EM, Monnerat JPIS, Silva SP (2009). Deferred and fertilized signalgrass: forage production and characteristics. Braz. Jour. A. Sci. 38: 650-656. <http://www.revista.sbz.org.br/artigo/index.php?artigo=8116>

TONATO F, Barioni LG, Pedreira CGS, Dantas OD, Malaquias JV (2010) Development of forage accumulation prediction models in tropical pastures. Pesq. Agropec. Bras. 45: 522-529. <http://seer.sct.embrapa.br/index.php/pab/article/view/2498/5971>