Cactus Forage Productivity Modelling Using PHYGROW Software in a Semiarid Environment

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Abstract
Plant growth modeling has been shown an increasing strategy to cope with the high demand for food supply, mainly in climate vulnerable areas, providing them to be used in agriculture worldwide. Concerning semiarid regions, the PHYGROW software has been promising to model plant growth, as cactus forage ('Opuntia stricta' cv. "Mexican elephant ear") which was used in this study. Production data from 2017 and 2018 in Petrolina, Permambuco state, Brazil, with 12 replicates each year were considered. This region shows a very hot and dry climate and has an erratic and seasonal rainfall, which varies a lot in quantity, frequency and intensity from one year to another. After the PHYGROW software parameterization, we performed the generation of the synthetic series and, afterwards, we add the field data to calibration and validation. The results showed a high prediction capacity of PHYGROW software, even in such an erratic climate as Brazilian Semiarid, considering the model performed as calibrated. In 2017 and 2018, the observed cactus forage biomass were 1745 ± 505.83 and 2016 ± 584.58 kg DM ha^{-1} and the estimated data were 1795 and 2314 kg DM ha^{-1}, respectively. This relatively high deviation suggests an opportunity to add more data, in order to get the model more accurate. Although there was a high difference in precipitation from 2017 to 2018 (166 and 301 mm, respectively), cactus forage was capable to offset this fluctuation, which makes it a strategic resource to reduces the biomass variation and stockpiling necessity on the farm level. This study also demonstrated the importance of modelling to help the farmer to cope with the weather and feed variation in climate vulnerable areas, allowing them to anticipate and adopt strategies to cope with drought more efficiently.

Introduction
Plant growth modelling has become an important strategy to cope with high feed demand, mainly in climate vulnerable areas, thus contributing to support feed demand around the world. In semiarid areas, the climate variability is a critical factor to plant biomass production, mainly in exclusively rainfed systems. By means of modelling and computational tools, it is possible to estimate under a confidence level, the plant yield, providing to producers more security to invest in agriculture. Among the software's used to plant growth modelling, the PHYGROW (STUTH et al., 2003) has been promising to be used in semiarid regions, as it is a simulation model that works on a daily basis, using climate, plant, soil and livestock parameters to estimate plant growth, forage intake and hydrological processes. On the other hand, among the forage resources available to use in dry areas, cactus forage has been proved a very strategic feed, because of its high-water stress tolerance, thus becoming an important feed and water source to livestock along the most critical periods during drought. In this context, to evaluate the cactus forage biomass prediction capacity by using the PHYGROW software, in a semiarid environment, this study was carried out.

Methods and Study Site

The data to do the simulations were obtained from a field study conducted at the Biossalin Agriculture Prospection and Research field of Embrapa Semiarid, with the following coordinates: - 09º 04′ 16,4″ of latitude and - 40º 19′ 5,37″ of longitude, being 379 meters above sea level. The climate is characterized as a BSwh″ type (KÖPPEN 1936). The soil is classified as Plinthic Abrupt Eutrophic Yellow Argisol (SOLOS 2013), with plain relief and middle texture. The cultivar "Orelha de Elefante" of cactus forage [*Opuntia stricta* (Haw.) Haw.], was sowed in April 2015, in a 1,6 x 0,4 m spacing, performing 15,625 plants/ha. Two data set were used each one with 12 replicates to model its growth. The first data set was obtained from Harvest sis months after uniformizing mowing (named year 2017) and the second 12 months after the first harvest (named year 2018). Afterwards, the cactus forage growth was parametrized in PHYGROW, by inserting plant, climate and soil data specific from the study area. The last step after the model has been calibrated consisted of evaluation of the model capacity to predict the plant growth by statistical criteria, that is, the *Determination Coefficient* "R^2", the *Absolute Mean Error*, (average absolute difference between the simulated and observed values), the *Prediction Mean Error* (estimation bias that reflects the normalized difference between the simulation model output and the observed data) and the *concordance index* "*d*" (values close to 1 indicating perfect agreement between the simulation output and the observed data).

Results

The cactus forage growth simulation model used two data set, one for 2017 year and the other for 2018 year, when the model was calibrated (Fig 1). The cactus forage biomass observed in the field was 1745 ± 505.83 and 2016 ± 584.58 kg MS ha^{-1}, in Years 2017 and 2018, respectively, whereas the mean biomass estimated by PHYGROW was 1795 and 2314 kg MS ha^{-1}, respectively (Tab 1).

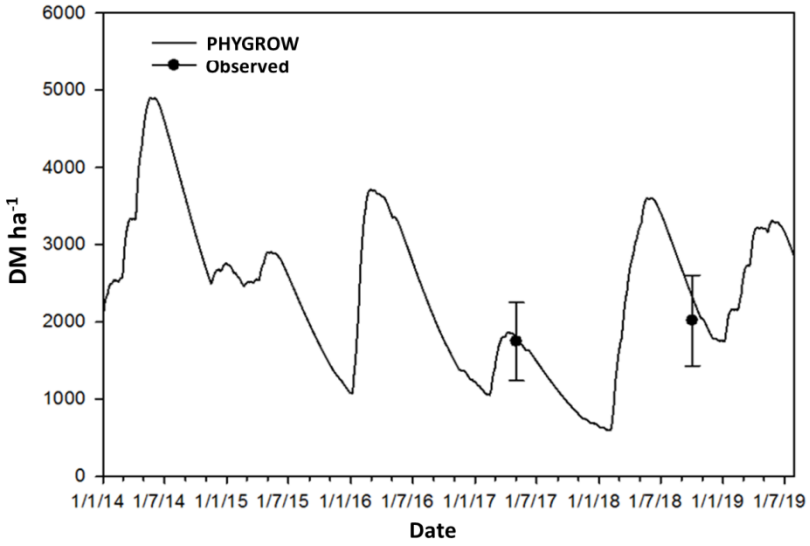

Fig 1 – Cactus forage biomass (kg DM ha^{-1}) predicted by PHYGROW model in Petrolina, Pernambuco, Brazil.

Tab 1 – Statistics to evaluate the PHYGROW model capacity to simulate cactus forage growth in Petrolina, Pernambuco, Brazil

Statitics	2017 Observed x Estimated	2018 Observed x Estimated
Observed means (kg DM ha^{-1})	1745	2016
Estimated means (kg DM ha^{-1})	1795	2314
Standard error (kg DM ha^{-1})	505.83	584.58
Absolute mean error (kg DM ha^{-1})	49.89	297.58
Prediction mean error (%)	2.85	14.75
r^2	0.67	0.17
D	0.99	0.97
N	12	12

Note: r^2 (determination coefficient); *d* (concordance index); *n* (samples number).

Discussion [Conclusions/Implications]

By means of statistical analysis, it is possible to verify a slight overestimation of the model to year 2018, being necessary a new data set to validate the model. Despite this, an overestimation is acceptable, being a result of human error by time of sample harvest. As a rule, the linear regression showed a reasonable correspondence between simulated and observed data, being checked by determination coefficient and concordance index (Tab 1).

Although a big difference in precipitation in Years 2017 and 2018 was observed (166 and 301 mm, respectively), the cactus forage was capable of compensate this fluctuation, being characterized as a strategic forage resource to reduce biomass variation and demand for stockpiling on a farm level. This study also demonstrated the importance of modelling to help the farmer to cope with climate and feed fluctuations in climate vulnerable areas, giving them the opportunity to anticipate the scenarios and adopt strategies to cope with drought more efficiently.

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