Adapting functional trait-based mechanistic model for subtropical climates

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Introduction

Simulation models are important tools for studying and predicting effects of variable environmental conditions and disturbances in ecosystems. However, many grassland models are highly demanding in terms of parametrization, limiting their use across sites and species. Recent studies suggest that plant functional traits may be a useful approach to simplify and generalize grassland models, creating a robust tool that can be easily transferred across species and environments. In an attempt to study the herbage production dynamics of complex (Figure 1) grasslands, we adapt a mechanistic vegetation model (ModVege; Jouven et al., 2006) to subtropical, C4 dominated conditions, creating **PampaGraze** .

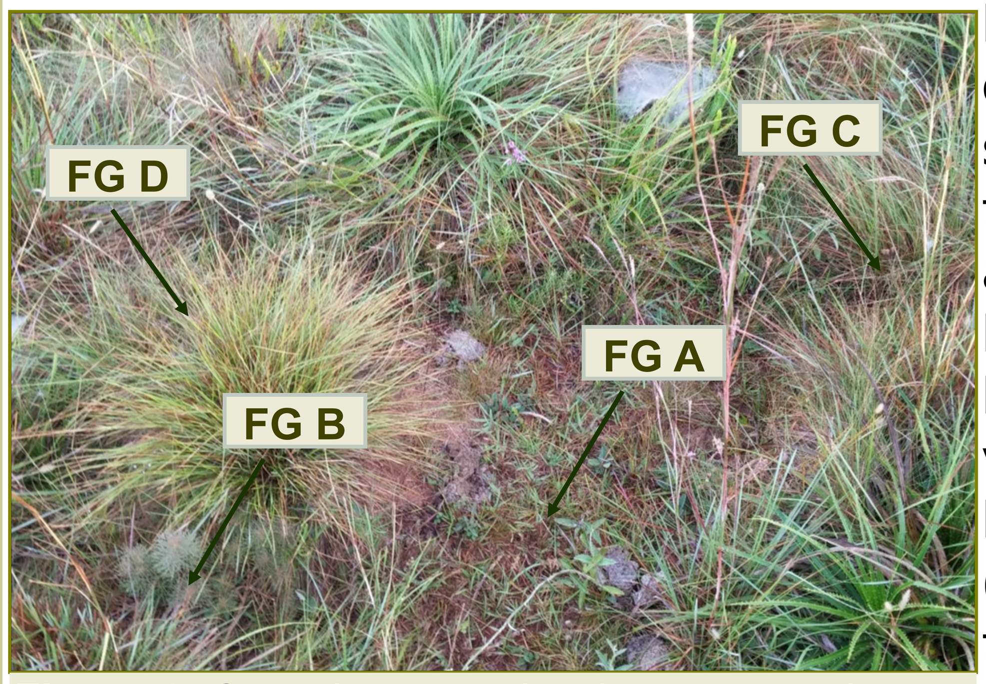

Figure 1: Complex grassland structure showing four functional groups (FG) of grasses.

Material and Methods

The mechanisms of the model are based on four main assumptions: 1) functioning of permanent grassland is given by functional attributes of grass groups (FG); 2) canopy heterogeneity given by relative abundance of structural components (and functional composition); 3) growth regulated by season; and 4) growth, senescence, and decay are continuous flows

For validation, we utilized data on herbage accumulation rate [HAR; kg dry matter (DM) ha^{-1} d^{-1}] of native grasses from a long-term grazing experiment on the Campos Grasslands in the Central Depression region of Rio Grande do Sul, Brazil (30°05'S; 51° 40'W). Local weather data was used to run simulations and parameters were collected from literature for local species (Table 1). Validation was checked using random mean square error (RMSE), modeling efficiency (Yang et al., 2014), and graphical analysis. Model was developed using JAVA and analysis performed on R.

Table 1: Range of values for weather variables and plant parameters used on original (Jouven et al., 2006) and new adapted mnodel (PampaGraze).

Variable or parameter	Original range	New adapted range
Range of mean temperature (°C)	1 – 15	15 – 25
Annual precipitation (mm)	1200	1500
Altitude (m)	1100	60
Specific Leaf Area (m^2 g^{-1})	0.033 – 0.019	0.024 – 0.006
Leaf Life Span (°C)	500 – 1400	400 – 1000
Basal temperature (°C)	4	9
Optimal temperature (°C)	10 – 20	25 – 35
Radiation use efficiency (g DM MJ^{-1})	3	1.8 – 4.1

Results and Discussion

First attempts using original equations (Jouven et al., 2006) and new parameters resulted in extremely high senescence rates (up to 1600 kg DM ha^{-1} d^{-1}), water and temperature stress, and low growth. Original model was not adapted to subtropical climates and C4 grasses, resulting in high sum of temperatures and strong environmental limitation. This required not only change in parameters, but on the mechanisms of the equations.

The large variation on observed data had a detrimental effect on validation parameters (RMSE 18.1 and 26.7, and modeling efficiency 0.21 and 0.27, for no cut and monthly cut management for FG B, respectively). However, monthly average and variation range of the simulated values were close to the observed (Figure 2). Cutting had a major influence on results, but more related to the mechanical structure of the model rather than physiological response.

When running the 25-year simulations, the general pattern of the results for herbage accumulation rate and total biomass for FG A and B were satisfactory, despite overestimating herbage production. The model was not able to simulate herbage production of slow-growing, tussock forming FG C and D, because of some important unaccounted physiological and morphological processes.

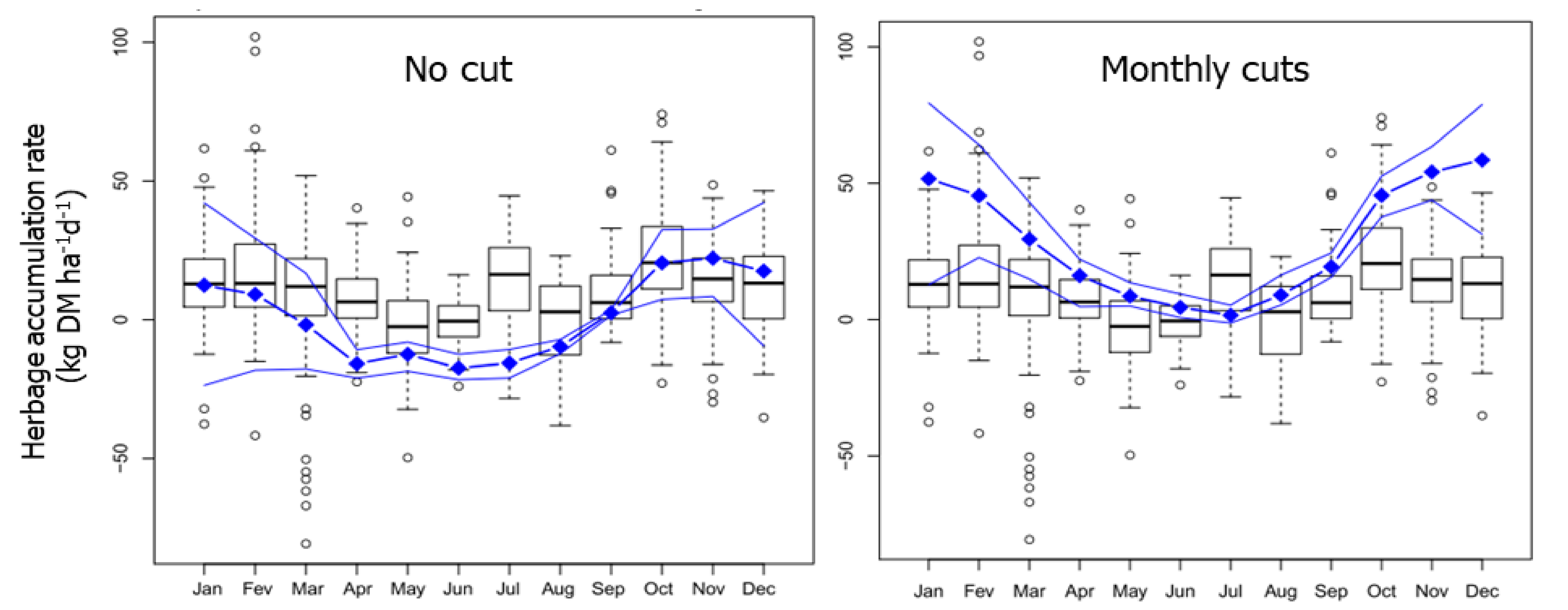

Figure 2: Observed (boxplot) and simulated (lines, upper and lower lines represent 95% confidence interval) herbage accumulation rate (kg DM ha^{-1} d^{-1}) for functional group B under no cut or monthly cut management

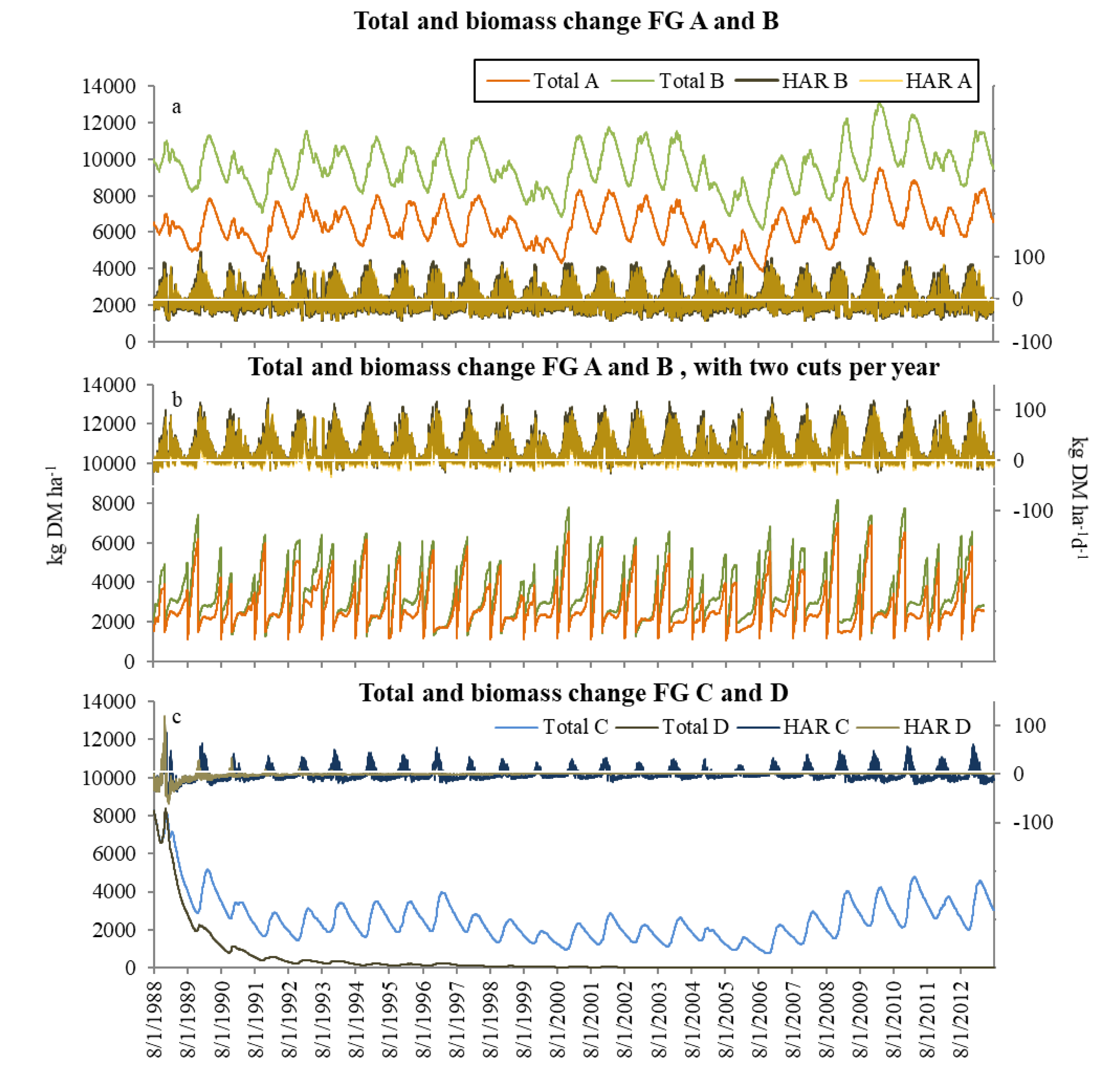

Figure 3: Total biomass and herbage accumulation rate simulated for 25 years (Aug – 1988 to Jul – 2013) for functional groups (FG) A and B, without (a) and with (b) two cuts per year (Oct-31 and Mar -30), and FG C and D (c). Upper lines in chart (a) and bottom lines in charts (b) and (c) represent total biomass at the specific date, while the other set of lines represents herbage accumulation rate. Top, boxed legend is referent to both (a) and (b) charts.

Conclusions

Our results show that adapting a model across environments is not just a process of changing parameters. Although the model has previously been validated for temperate grasslands, further work is required in order to accurately represent herbage production in subtropical grasslands. Important physiological processes in one climate may not necessarily be relevant elsewhere, thus not properly represented in the original structure of the model. Furthermore, plant functional traits which are easily measured are also highly variable, leading to potential errors in the model outputs .

References and Acknowledgements

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