"Estimation of the Primary Net Production above Ground through Remote Sensing in a Pastoral System of the Colombian Altillanura."

R. A. Díaz
Colombian Corporation for Agricultural Research, Colombia

M. Álvarez
Colombian Corporation for Agricultural Research, Colombia

O. Pérez
Colombian Corporation for Agricultural Research, Colombia

J. Bernal
Colombian Corporation for Agricultural Research, Colombia

M. Arango
Colombian Corporation for Agricultural Research, Colombia

The XXIV International Grassland Congress / XI International Rangeland Congress (Sustainable Use of Grassland and Rangeland Resources for Improved Livelihoods) takes place virtually from October 25 through October 29, 2021.

Proceedings edited by the National Organizing Committee of 2021 IGC/IRC Congress

Published by the Kenya Agricultural and Livestock Research Organization

“Estimation of the primary net production above ground through remote sensing in a pastoral system of the Colombian Altillanura."

Díaz, R. A[1]; Álvarez, M[2]; Pérez, O[1]; Bernal, J[2]; Arango, M[2]

[1]Colombian Corporation for Agricultural Research – Agrosavia, Livestock and Small Species Network, C.I La Libertad, Villavicencio, Meta, Colombia. Email: rdiazg@agrosavia.co

[2]Colombian Corporation for Agricultural Research – Agrosavia, Transitory Crops Network, C.I La Libertad, Villavicencio, Meta, Colombia.

Abstract

The primary net production above ground (ANPP) represents the main forage resource that supports the bovine production systems and its valuation is essential to help in the decision making on the management of the pastures. The ANPP has been estimated by periodic biomass courtesy, but with the use of the remote sensor integrated into the efficiency model formulated by Monteih (1972), it has been possible to estimate this biophysical parameter more efficiently at different scales and at low cost. The objective of this study was to estimate the PPNA based on a model of efficiency in the use of light for pastoral coverage in the Colombian Altillanura. The work is in the Carimagua Research Center of the Colombian Agricultural Research Corporation –AGROSAVIA– located in the municipality of Puerto Gaitán - Meta, Colombia. The pasture was monitored through forage supply gaps, in 14 paddocks with an approximate area of 2.6 ha each, established with *Urochloa humidicola* CIAT 6133 c.v Llanero under grazing of cattle with rest periods of 28 to 30 days. The spectral information was obtained from the on-board Sentinel 2 sensor and the global radiation data was obtained from a field weather station. A PPNA observed in the field and estimated by the efficiency model of 603.79 ±189kgDM/ha ± 188 and de 589.22 ±104 kgDM/ha was found, with a coefficient of determination R^2 (0.79) and a significant correlation p <0.01 of 0.89. This methodology would quantify the supply of fodder on a larger scale under the same type of pastures.

Key words: Above ground biomass; pasture; Remote sensing; Vegetation Photosynthesis Model.

Introduction

The ANPP represents the amount of dry matter (DM) accumulated by the plants through the photosynthesis process, expressed in units of space and time corresponding for livestock systems in the amount of biomass available for animal consumption; therefore, estimating this parameter becomes a key aspect for the sustainable management of pastures (Yan et al. 2018). Methods based on direct estimates of the ANPP from biomass cuts have been successfully implemented for observations at the pasture level, however, they present limitations to be used at a regional scale (Pezzani et al., 2017).

The vegetation photosynthesis model (VPM) is based on the efficiency of radiation use (Monteith, 1972), which allows the use of information provided by satellite platforms to study different aspects of pastures at a regional scale. Among them, the PPNA (Madugundu et al. 2017). This model uses vegetation indices (IV) and is based on the active photosynthetic radiation absorbed (APAR) by the green tissues of plants and the radiation use efficiency (RUE) with which energy is transformed into MS (Paruelo et al. 2011), where this one presents some regulatory parameters such as *Tesc* and *Wesc* that correspond to temperature and water, respectively (Xiao et al. 2004a). The objectives of this study is to estimate the PPNA from a VPM model in a pasture of Urochloa humidícola CIAT 6133 cv Llanero, and to compare the model VPM = $PPNA_{VPM}$ with the forage offer evaluated in the field = $PPNA_{OBS}$.

Methods and Study Site

Location

The work was developed at the Research Center C.I. Carimagua of the Colombian Agricultural Research Corporation - AGROSAVIA, georeferenced at coordinates 4 ° 34'25.90 " N and 71 ° 20'16.71 " W at 167 meters above sea level. It is in the flat lands called Altillanura in the municipality of Puerto Gaitán in the department of Meta, Eastern Plains of Colombia. The average annual rainfall is 2,345 mm, the average temperature is 26 ° C, the maximum of 33 ° C and the minimum of 22 ° C; with a well-defined dry season between the months of December to March and the average annual relative humidity is 76%.

Grazing areas

The areas under cattle grazing used correspond to pastures of *Urochloa humidicola* CIAT 6133 cv llanero (flat grass) (syn. *Brachiaria humidicola*; previously considered as *Brachiaria dictyoneura*) (Cook and Schultze-Kraft, 2015; Rincón et al. 2019) with rotational management; the observed forage supply ($PPNA_{OBS}$) was evaluated after 30 days of regrowth in 14 paddocks, transects were made with a 50cm x 50cm frame in 20 points for each paddock and cut at 15 cm high, the samples were weighed and dried in a forced air oven at 60ºC for 72 hours; the DM was obtained by the difference in green weight and dry weight.

Sentinel 2 images and vegetation indices

The Sentinel 2 satellite belongs to the Copernicus program of the European Space Agency (ESA), which is composed of the MSI (Multi Spectral Instrument) instrument that captures information from the Earth's surface in 13 spectral bands that cover the visible and near infrared regions. and a half, composed of four bands with a spatial resolution of 10 m, six of 20 m and three of 60 m and one revisit every 10 days.

The study area images were downloaded from the Earth Explorer website (https://earthexplorer.usgs.gov/), a free access portal of the United States Geological Survey-USGS. Three cloud-free images were obtained for the dates December 8, 2015 (*Img1*), January 7 (*Img2*) and November 15 (*Img3*) of 2016, which coincided with eight, three and three field gauges respectively. The DOS1 atmospheric correction toolbox was used in the free software QGIS 2.18.14; the bands used for the study of vegetation corresponded to red (R), near infrared (NIR) and SWIR 1. The IVs generated were the NDVI (Rouse et al. 1973) and the LSWI (Xiao et al. 2004b), equations (1 and 2).

$$NDVI = (NIR - R)/(NIR + R) \quad (1)$$

$$LSWI = (NIR - SWIR1)/(NIR + SWIR1) \quad (2)$$

Where: R: corresponds to the red spectral band, NIR: corresponds to the near infrared band and the SWIR1 band: corresponds to the Sentinel 2 short wave infrared.

PPNA estimation from the vegetation photosynthesis model – VPM

As described by Gallego et al. (2017) in equation 3, the VPM is used as a function of the photosynthetically active radiation (PAR), the fraction of the photosynthetically active radiation (FPAR) and the RUE, and in a complementary way a conversion coefficient is added to this model carbon *Coef (dm)* to DM (White et al. 2000).

$$PPNA_{(VPM)}\ (kgDM/ha) = APAR\ (PAR * FPAR) * EUR * Coef(dm) \quad (3)$$

The FPAR was calculated from Sentinel 2 reflectance data, using IV NDVI as a linear function according to Alves, (2018) equation 4; PAR was obtained using global radiation (RG) data from the meteorological station located at C.I. Carimagua, equation 5.

$$FPAR = 0.004 + 0.9843 * NDVI \quad (4)$$

$$PAR = RG * 0.5 \quad (5)$$

The maximum efficiency value (Ɛ) used in this work was 0.54 gC/MJ, proposed by Alves, (2018) in pastures of this same genus *Urochloa*, before *Brachiaria* (equation 6), and the down regulation factors *Tesc* (equation 7) and *Wesc* (equation 8) (Madugundu et al. 2017).

$$EUR = \mathcal{E} * Tesc * Wesc \quad (6)$$

$$T_{esc} = \frac{(T - T_{min})\ (T - T_{max})}{[(T - T_{max})(T - T_{max})] - (T - T_{opt})^2} \quad (7)$$

Where the *Tesc* represents the effects of temperature on the photosynthesis of the leaf; *Tmin, Tmax* and *Topt* are the minimum, maximum and optimal temperatures for photosynthetic activities (Xiao et al. 2004a), these parameters vary according to the photosynthetic pathway (C3 or C4), the type of crop, seasonal changes (rain - drought), altitude and diurnal cycle (Madugundu et al. 2017).

$$W_{esc} = \frac{1 + LSWI}{1 + LSWI_{max}} \quad (8)$$

The $LSWI_{max}$ is the maximum value during the growth period of the grassland grass, which depends on the remote sensing data (Xiao et al. 2004a). The *Coef (dm)* used in this work was 0.00066 kgDM for the conversion of carbon to DM (White et al. 2000).

The concordance between the data observed and estimated by the VPM model was analyzed using the R2, *Pearson's* correlation coefficient and the *student's T*-test.

Results

In Figure 1, the results obtained for the three images in each of the 14 evaluated paddocks (PDK) are presented, the average values for the $PPNA_{OBS}$ and $PPNA_{VPM}$ were 603.79 ± 189 kgDM / ha and 589.22 ± 104 kgDM/ha respectively.

Figure 1. Airborne net primary production of the evaluated areas.

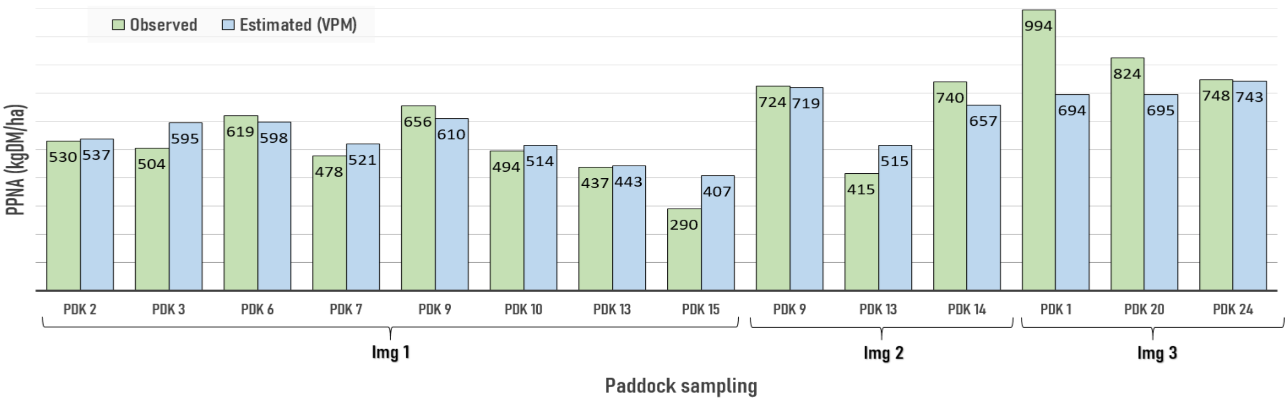

Table 1: PPN, PAR and Precipitation values for each of the points evaluated.

Image	$PPNA_{(OBS)}$	$PPNA_{(VPM)}$	*PAR (MJ/m^2)	*Precipitation (mm)
Img 1	501	528	240	2.2
Img 2	626	630	277	3.1
Img 3	855	711	259	7.7

*** 30-day accumulated values**

The $PPNA_{VPM}$ model presented a linear relationship that estimates the forage supply with an R2 of 0.79 [PPNAOBS y = 1.6188 X ($PPNA_{VPM}$) - 350.04]; the correlation coefficient and the *T-student* test between the observed and estimated data was 0.89 (p = ≤0.001) and a *p* value of 0.80 respectively.

Discussion

The average values of PPNA observed and estimated, as well as the precipitation increased gradually throughout the experiment; this behavior was not followed by PAR, which showed a lower radiation value in *Img3* compared to *Img2*, this decrease did not affect forage production, on the contrary, an increase in forage supply was only explained by precipitation. In other words, the increase in PAR under conditions of limited water supply does not *per se* represent an increase in forage production.

The VPM model overestimated the forage offer in 27kgDM/ha and 4kgDM/ha for the gauges that coincided with *Img1* and *Img2*, respectively (Table 1), on the contrary, in Img3 the $PPNA_{OBS}$ presented a difference of 144 kgDM/ha in comparison to $PPNA_{VPM}$, this could be due to the fact that the IV NDVI used in the model to estimate FPAR, presented saturation possibly caused by the increase of green leaves in the pasture due to precipitation. In this sense, Piazza (2006), Grigera (2011), indicated that the main source of the PPNA in pastures is the FPAR, which is conditioned to structural parameters such as the leaf area index and the angle of inclination of the leaf. Even so, the observed and estimated values presented a strong correlation (0.89 and *p* = ≤0.001) and no statistical difference was found from the comparison of means (p = 0.8013).

The VPM model demonstrated the potential to estimate PPNA in pastures from Sentinel-2 images, however, it presents limitations in its operation in the rainy season due to the frequent cloud cover in tropical conditions.

References

Alves, G. 2018. Produtividade primária bruta e biomassa em pastagem no bioma cerrado: uma análisea partir dos modelossebal/casa e mod17 no estado de Goiás. Tesis presentada para obtener el título de Doctor en geografía. Goiás. Disponible en: https://repositorio.bc.ufg.br/tede/handle/tede/8625

Cook, B ans Schultze-Kraft. 2015. Botanical name changes – nuisance or a quest for precision?. Tropical Grasslands – Forrajes Tropicales, 3, 34-40. DOI: 10.17138/TGFT(3)34-40

Grigera, G. 2011. Seguimiento de la productividad forrajera mediante teledetección: desarrollo de una herramienta de manejo para sistemas de producción ganadera. Tesis presentada para optar al grado de doctor en ciencia agropecuarias. Bueno Aires, Argentina: Facultad de Agronomia, Universidad de Buenos Aires. Disponible en: http://ri.agro.uba.ar/files/download/tesis/doctorado/2011grigeragonzalo.pdf.

Madugundu, R., Al-Gaadi, K., Tola, E., Kayand, A and Sekhar, C. 2017. Estimation of gross primary production of irrigated maize using Landsat-8 imagery and Eddy Covariance data. Saudi Journal of Biological Sciences. 24: 410-420. DOI: http://dx.doi.org/10.1016/j.sjbs.2016.10.003.

Monteith, J. 1972. Solar Radiation and Productivity in Tropical Ecosystems. Journal of Applied Ecology, 9 (3): 747-766. doi:10.2307/2401901

Paruelo, J.M., Oyarzabal, M and Oesterheld, M. 2011. El seguimiento de los recursos forrajeros mediante sensores remotos: bases y aplicaciones. En A. Altesor., W, Ayala and J.M. Paruelo (Eds.), *Bases Ecológicas y tecnológicas para el manejo de pastizales.* Instituto Nacional de Investigación Agropecuaria – INIA. Uruguay, pp. 136-145. Disponible en: http://www.inia.uy/Publicaciones/Documentos%20compartidos/18429020511100111.pdf

Piazza, M. V. 2006. Estimación satelital de la productividad primaria neta aérea de la vegetación herbácea del Caldenal. Buenos Aires: Escuela para Graduados Ing. Agr. Alberto Soriano, Facultad de Agronomía – Universidad de Buenos Aires.

Pezzani, F., Lezama, F., Gallego, F., López-Márisco, L., Leoni, E., Costa, B., Parodi, G y Mello, A.L. 2017. El método de corte de biomasa genera mayores diferencias en la estimación de la productividad de pastizales que el tipo de pastizal. Revista Argentina de Producción Animal. 37 (1): 21-32. Disponible en: https://www.researchgate.net/publication/317549460_El_metodo_de_corte_de_biomasa_genera_mayores_diferencias_en_la_estimacion_de_la_productividad_de_pastizales_que_el_tipo_de_pastizal.

Rincón, A., Álvarez, M., Pardo, O., Amaya, M. A y Díaz, R. A. 2019. Estimación de la concentración de clorofila y su relación con la concentración de proteína cruda en tres especies del pasto Urochloa en el Piedemonte Llanero, Colombia. Tropical Grasslands-Forrajes Tropicales. Vol 7. N°5, 533-537. DOI: 10.17138/TGFT(7)533-537.

Rouse, J., R. Haas, J. Schell, y D. 1973. Deering. Monitoring Vegetation Systems in the Great Plains with ERTS. Third ERTS Symposium, NASA: 309-317

White, M. A., Thornton, P. E., Running, S. W., and Nemani, R. R. .2000, Parameterization and Sensitivity Analysis of the BIOME–BGC Terrestrial Ecosystem Model: Net Primary Production Controls, Earth Interactions, 4(3), 1-85. DOI: https://doi.org/10.1175/1087-3562(2000)004<0003:PASAOT>2.0.CO;2.

Xiao, X., Zhang, Q., Hollinger, D., Aber, J., Moore III, B. 2004a. Modeling seasonal dynamics of gross primary production of an evergreen needleleaf forest using MODIS images and climate data. Ecological Applications 15: 954-969.

Xiao, X., Hollinger, D., Aber, J., Goltz, M., Eric, A.D., Zhang, Q., Moore III, B. 2004b. Satellite-based modeling of gross primary production in an evergreen needle leaf forest. Remote Sens. Environ. 89, 519–534.

Yan, Y., Liu, X., Ou, J., Li, X and Wen, Y. 2018. Assimilating multi-source remotely sensed data into a light use efficiency model for net primary productivity estimation. International Journal of Applied Earth Observation and Geoinformation., 72: 11-25. DOI: https://doi.org/10.1016/j.jag.2018.05.013.