agrometeoros
REVISTA DA SOCIEDADE BRASILEIRA DE AGROMETEOROLOGIA

ISSN 2526-7043 www.sbagro.org.br

Vegetation indices variability in the Pampa grasslands in Brazil and Uruguay

Ana Paula Luz Wagner[1], Marcelo Wallau[1], Denise Cybis Fontana[2(*)], Paulo César de Faccio Carvalho[2] and Clyde Fraisse[1]

[1]University of Florida - Institute of Food and Agricultural Sciences, P.O. Box 110810, Gainesville, FL 32611, USA.
E-mails: anaplw@gmail.com, mwallau@ufl.edu and cfraisse@ufl.edu
[2]Universidade Federal do Rio Grande do Sul - Faculdade de Agronomia. Avenida Bento Gonçalves 7712, Caixa Postal 15096, CEP 91501.970. Porto Alegre, RS, Brazil. E-mails: dfontana@ufrgs.br and paulocfc@ufrgs.br
[(*)]Corresponding author.

ARTICLE INFO

Article history:
Received 30 May 2018
Accepted 20 December 2018

Index terms:
EVI
NDVI
MODIS

ABSTRACT

The Pampa Biome is one of the largest and richest grasslands in the world, with a vast diversity of species and an unique coexistence of several C3 and C4 plants in time and space. The object of this study was to characterize the annual and seasonal variability of NDVI and EVI vegetation indices over grassland types and to identify the possible difference between ecological regions. The study area focuses on 13 ecological regions into the Pampa Biome in Brazil (Rio Grande do Sul State), and Uruguay. The temporal and spatial variability of the vegetation vigor was analyzed through NDVI and EVI vegetation indices for a period from 2000 to 2011. The results showed that NDVI and EVI temporal average patterns are similar and reflect, for each region, the vegetation vigor associated to the soil type, and the rainfall. For both vegetation indices, the high values occur during summer and lower values in winter. However, the intra-annual variability of the vegetation indices are higher during summer, when EVI shows more potential to detect changes in vegetation vigor.

Introduction

The Pampa Biome, which includes the southern part of Brazil, northeastern of Argentina and whole Uruguay (Allen et al., 2011), is one of the largest and richest grasslands in the world, with a vast diversity of species and an unique coexistence of several C3 and C4 plants in time and space (Boldrini, 2009). The Campos (Bioma Pampa grasslands) are characterized by a strong dominance of C4 (summer) perennial grasses, with reminiscent of C3 winter species, in varying proportions in the distinct 13 ecological regions that make up this Biome. Perennial grasses, in general, compose 70 to 80% of the total dry matter accumulated, while legumes range from 3 to 8 % (Pallarés et al., 2005). On average, over 60% of the production is concentrated in spring and summer months. Spring is also the most stable season concerning productivity over the years, and summer the most variable one (Nabinger et al., 2000; Berretta, 2001). Variation within and between years is extensively reported in the literature and is associated with low levels of production and degradation of the grasslands when overstocked (Berretta, 2001; Pallarés et al., 2005).

There are markedly phytogeography differences within the Campos ecological region characterized by distinct combinations of soil, landscape and climate patterns (Boldrini, 2009). There is extreme variability in the vegetation structure of the Campos in response to a range of factors, such as climate, soil, and management practices. Also, from another perspective, grazing influences the biogeochemical and physical properties of the soils, inducing changes in root distribution and biomass that alter water and carbon dynamics (Milchunas e Lauenroth, 1992). Trampling often increases soil bulk density, therefore reducing infiltration and soil water holding capacity. In those complex systems, modeling the biosphere-atmosphere interface needs to be able to simulate vegetation activity, i.e., cycles of dormancy, active growth and reproduction, referred to as the phenology cycle. Therefore, a better understanding of spatial and seasonal variation in plant communities is needed to improve representation of phenology in vegetation models, such as the case of the Campos. Furthermore, the understanding of the average conditions and annual dynamics throughout the Pampa Biome is essential to support studies that assess trends in vegetation changes due to the anthropogenic and/or climatic causes, which can be performed with vegetation indices.

Several approaches using vegetation indices have been applied to identify large-scale variations in phenology and its relationship to potential drivers, based on earth observation time series (Bradely e Gerard, 2011). The Normalized Difference Vegetation Index (NDVI) is used extensively in ecosystem monitoring (Rosemback et al., 2010; JONG et al., 2011). Enhanced Vegetation Index (EVI) from Moderate Resolution Imaging Spectroradiometer (MODIS) has improved those observations and results because it corrects distortions in the reflected light caused by particles in the air as well as ground cover below the target vegetation. The EVI also does not become saturated as easy as the NDVI when viewing rainforests and other densely vegetated areas. The EVI can also be directly related to the photosynthetic production of plants and indirectly to the green biomass (Huete et al., 2002), as well as to be applied to phenology studies (Kuplich et al., 2013).

Currently, a few studies were conducted at Pampa Biome focusing on the spatial/temporal patterns and variability of vegetation from MODIS, and therefore, the object of this study was to characterize seasonal and intra-annual of NDVI and EVI over thirteen ecological regions and to identify the possible difference between those.

Material and Methods

The study area focuses on 13 ecological regions into the Pampa Biome in Rio Grande do Sul, Brazil, and Uruguay, which shows high variability in vegetation structure as response to a range of factors, such as climate, soil, and management practices. Based on the grassland mask developed by Hasenack et al. (2010) (Figure 1), EVI and NDVI values were extracted from the corresponded area, with the further calculation of the mean EVI/NDVI values for the 13 ecological regions. This study analyzed a 12-years' time series of NDVI and EVI images, from Feb-2000 to Jul-2011. The time series were obtained from MODIS/Terra, product MOD13Q1, with temporal and spatial resolution of 16 days and 250 m respectively; and ranges from -0.2 to 1.0. Initially, the images were processed using ENVI software 4.2 + IDL (EXELIS®, McLean, Virginia, USA) to create the mosaics, to project and resize them. Further studies related to spatial analysis were done using the model Earth Trends Modeler (ETM) from Idrisi Taiga software (Clark Lab®, Worcester, Massachusetts, USA), and R language (R Core Team (2013)).

Data from 16-days composites were grouped in a monthly base, where the average and coefficient of variation (CV) were calculated for each index (EVI and NDVI). Maps were built using ArcMap 10. The significant differences between NDVI and EVI values did not allow to compare the two sets of time series directly. Therefore, the dispersion was analyzed in relative terms to its average value, using the Pearson coefficient of variation.

The 12-years mean/median and intra-annual variability in the vegetation were represented as the mean and CV of NDVI/EVI. The monthly images were calculated based on the 12-years average mean values of NDVImean,t (or EVImean,t). The CV was also calculated for the 12-years and for both indices. Those coefficients are expressed in the same units (percentage values) and, therefore, allowed the comparison of the vegetation indices series that had originally different value ranges.

The average images are represented with absolute values divided into 7 classes, from 0 to 1, but with difference in the class intervals adopted. This was done to facilitate the visual comparison between the indices once the absolute values of the EVI are lower than the NDVI,

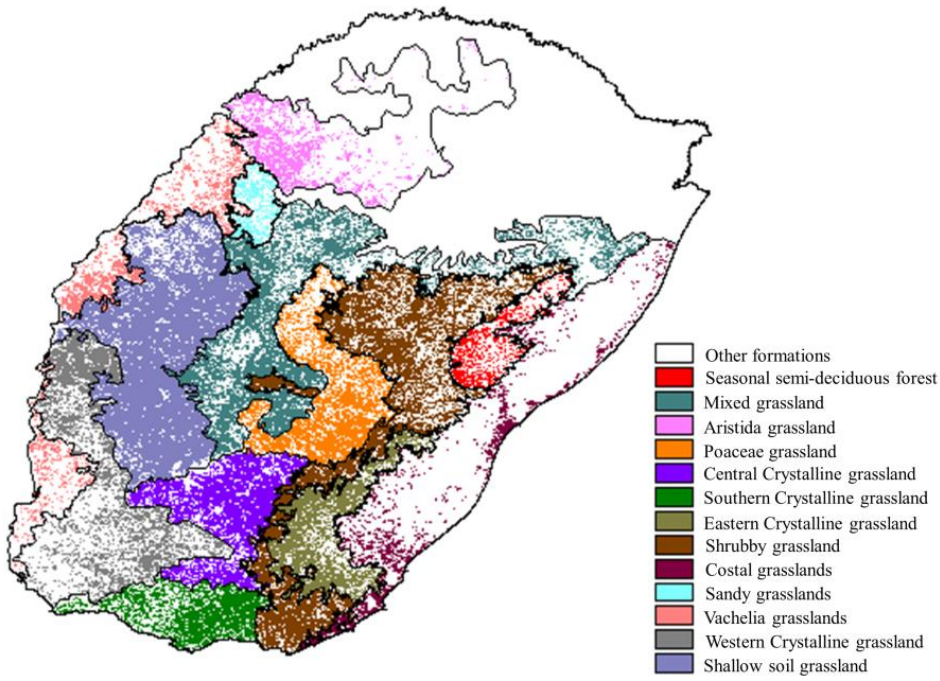


Figure 1. Pampa Bioma ecological regions in Brazil, and Uruguay (adapted from Hasenack et al., 2010).

which could result in impairment of spatial variability. Considering that the CV is calculated with the data obtained from the average, lower values indicated higher homogeneity. These values were grouped into 6 classes with the same intervals.

The averages and CV from NDVI and EVI data were extracted from the values of the 13 ecological regions defined by Hasenack et. al (2010). Average and standard deviation of both vegetations indices for the 16 days cycle data were extracted to calculate the descriptive statistics, such as annual and multiannual mean profile for each of the 13 regions and CV calculation. The monthly averages and variabilities were represented using boxplot.

Results and discussion

The mean values and standard deviation from NDVI and EVI extracted from all ecological regions during the whole study period are presented in Figure 2. The profiles for both indices indicated a similar pattern variation between the regions throughout the year and between the years. Similar results were founded by Silveira et al. (2013), Junges et al. (2016) and Fontana et al. (2018) in parts of the study region.

The extracted NDVI and EVI average values for each individual ecological region are presented as the monthly variability by percentage of variation (grouped by month; Figure 3), and also separated by each grassland type (Figure 4). In general, there are two peaks on the indices in the fall and spring. The increased biomass production in the spring, when cold season species are more productive, seems to be related to EVI, which showed more distinction between regions, except for Coastal grassland and Shallow soil grassland. On the other hand, the NDVI presented higher values than EVI in the early fall growth, when there was a large production of C4 grasses in this region. It suggests that the NDVI could be more associated with C4 grasses and vegetation condition. After the peak in fall, there was a fast drop on both indices, and the lowest values for both EVI and NDVI were observed in the winter, especially around July. After that, there was a fast increase in biomass production, as well as on the indices values towards spring, reaching the maximum on October.

The results in Figure 3 and 4 suggest that January was the month with the highest variability (mainly for NDVI) among the grasslands types and within the years, due to a large percentage (50%) of the values on the interval between 0.57 to 0.7 for NDVI. This could be attributed to dry or rainy years during the period (Rosemback et al., 2010). Berretta et al. (2001) and Berlato et al. (2006) already reported that summer was the season with highest variability in the rain (therefore biomass production), whereas the spring had the lowest variance. The effect of the lower biomass production is enhanced in extremely dry years because of the management, where many of the pastures in the region were overstocked, causing a carryover effect for the following seasons (Baethgen e Giménez, 2004).

Although the trends were similar across ecological regions (i.e., the same pattern of variation), there was a difference between them (Figure 4). Seasonal semi-deciduous forest and Shrubby grassland represented types

Figure 2. EVI and NDVI inter-annual average (aver) variability on 13 ecological regions in Pampa Biome. The darker line is the average for all ecological regions along the studied period, and the respective standard deviation (std-aver) for each index is represented by the lighter lines at the bottom.

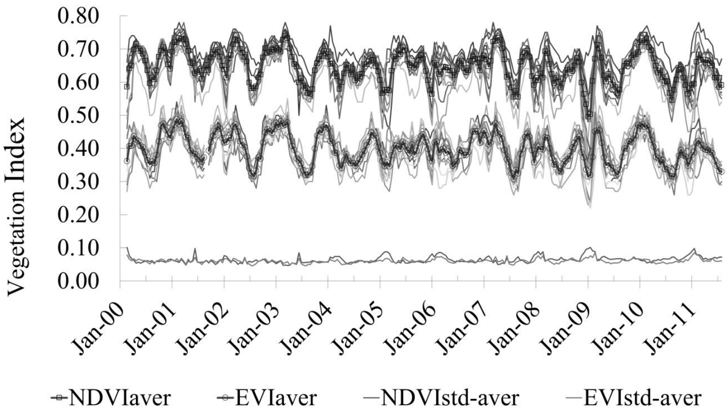
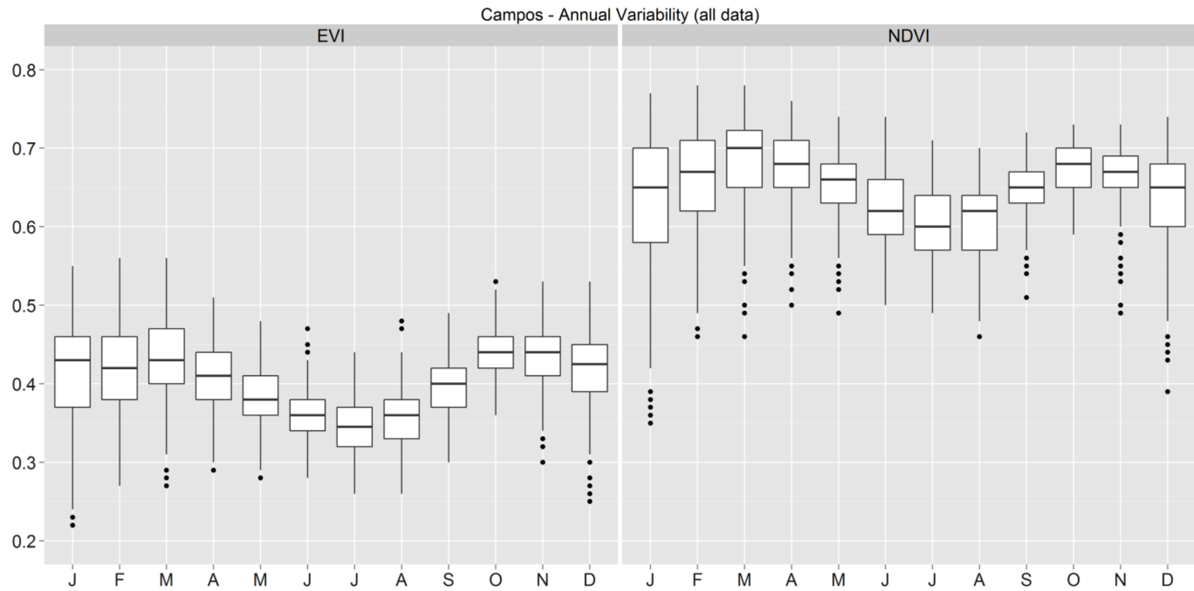


Figure 3. Distribution of EVI (left), and NDVI (right), for average values extracted in the 13 ecological regions in Pampa Biome for the period from Feb/2000 to Aug/2011. The horizontal line inside the boxes represents the 50th percentile (median), the end of the boxes, the 25th and 75th percentiles, the bars, the 10th and 90th percentiles, the filled circles, extreme values.



with the highest biomass, while the lowest values were observed in the Sandy grasslands, which were adapted to hot and dry summers, with almost absence of cooling season growth. The NDVI had a better difference between maximums and minimums values, showing distinguished profiles on extreme values, which were associated with the highest and lowest values on indices related to biomass.

When considering the difference between maximum and minimum values for each of the vegetation index in October, the EVI showed a little more discrimination between the units than the NDVI, except for the Sandy grasslands. Values ranged from 0.41 to 0.47 and 0.65 to 0.69 for EVI and NDVI, respectively. Yet, this is the period with the highest occurrence of C3 species, what suggests that EVI could be better related to them. We speculate that this could have been caused by EVI captures of the blue band which also had a better sensibility to C3 species. C3 plants (mainly cool season grasses in this case) have a lower ratio of Chlorophyll a to Chlorophyll b compared to C4 grasses (2.8 vs. 3.9 respectively; Taiz e Zeiger, 2010). The peak of light absorption by Chlorophyll b is on the blue region (470 nm) while for Chlorophyll a is on the red one (670 nm).

Therefore, the EVI might have a different response than NDVI in case there is absorption increase of blue light (BL). According to Taiz e Zeiger (2010), stomatal responses to BL are rapid and reversible, and are located just in the guard cells, related to stomatal movements throughout the life cycle of the plant. The increase in biomass and temperature towards mid and late spring will increase transpiration (which is higher per unit of biomass in C3 plants), that is mediated by the stomatal opening. In this case, there will be more BL being absorbed by the guard cells, increasing EVI values. This could be an explanation for the steeper incline of the EVI slope in comparison to NDVI from the winter towards spring.

The maps for monthly averages and coefficients of

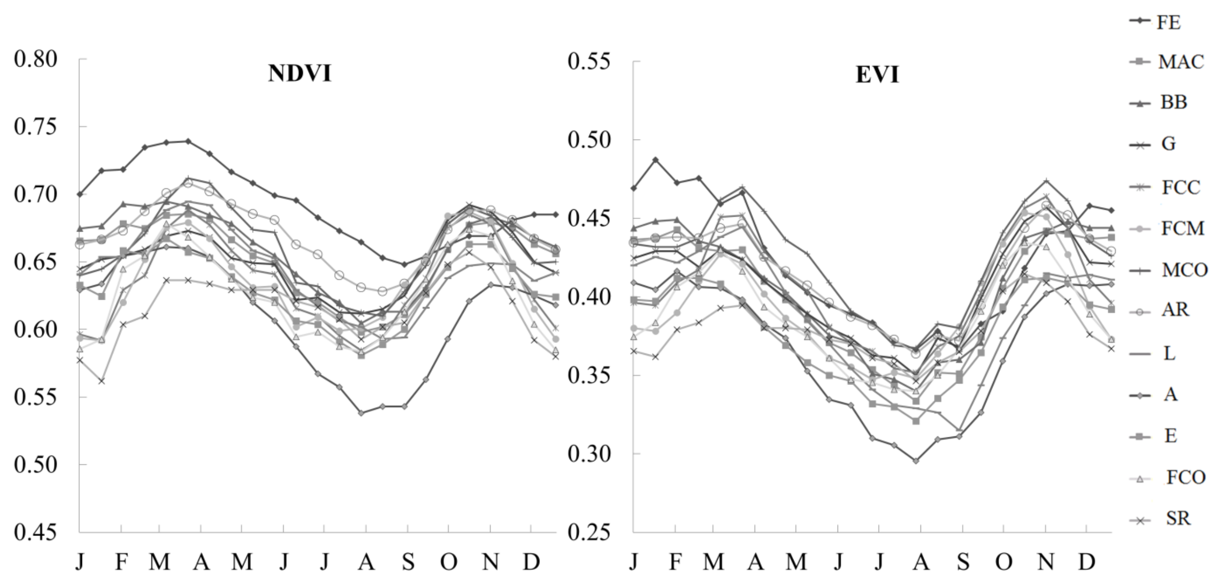


Figure 4. EVI and NDVI annual average variability on grasslands types in Pampa Biome. Types: A: Sandy grasslands; AR: Shrubby grassland; BB: Aristida grassland; E: Vachelia grasslands; FCC: Central Crystalline grassland; FCM: Southern Crystalline grassland; FCO: Western Crystalline grassland; FE: Seasonal semi-deciduous forest; G: Poaceae grassland; L: Costal grasslands; MAC: Mixed grassland; MCO: Eastern Crystalline grassland; SR: Shallow soil grassland.

variation for EVI and NDVI on the whole study region were presented in Figures 5 to 8. The average value maps for both indices showed a peak on March and October, and a dip on July (Figures 5 and 6). The Campos's separation was higher in summer for the two indices, although in the winter-spring (July-November) the EVI performed better, once the last period had the highest occurrence of C3 species. The EVI in winter months was more sensitive than NDVI for differentiating ecological regions, mainly the Shallow soil grassland and Crystalline grassland. Although, NDVI was better for places with higher biomass, such as the Seasonal semi-deciduous forest and the Shrubby grassland. Summer was the season with the highest spatial variability between the vegetation index averages, and the coefficients of variation for both indices were higher on January (Figures 7 and 8).

The use of the CV as a parameter to evaluate the results was useful because it was a value independent of the unit where the measurements were taken. Therefore, it permits the comparison between data sets that had widely different means, e.g., it allowed the comparison of EVI and NDVI performance distinguishing the variability in the vegetation. The maps for CV showed higher variability or lower homogeneity in vegetation during the summer

Figure 5. Spatial distribution of monthly average variability throughout the year for EVI in grasslands in Pampa Biome for the period 2000-2011.

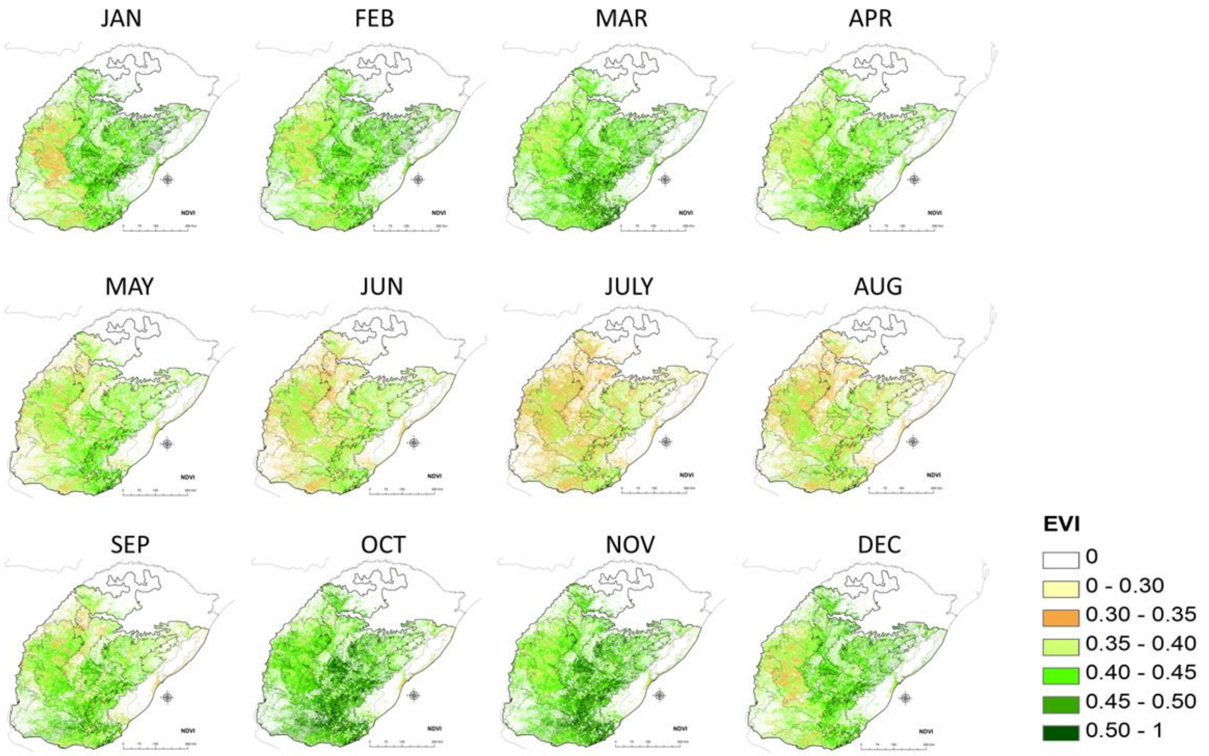


Figure 6. Spatial distribution of monthly average variability throughout the year for NDVI in grasslands in Pampa Biome for the period 2000-2011.

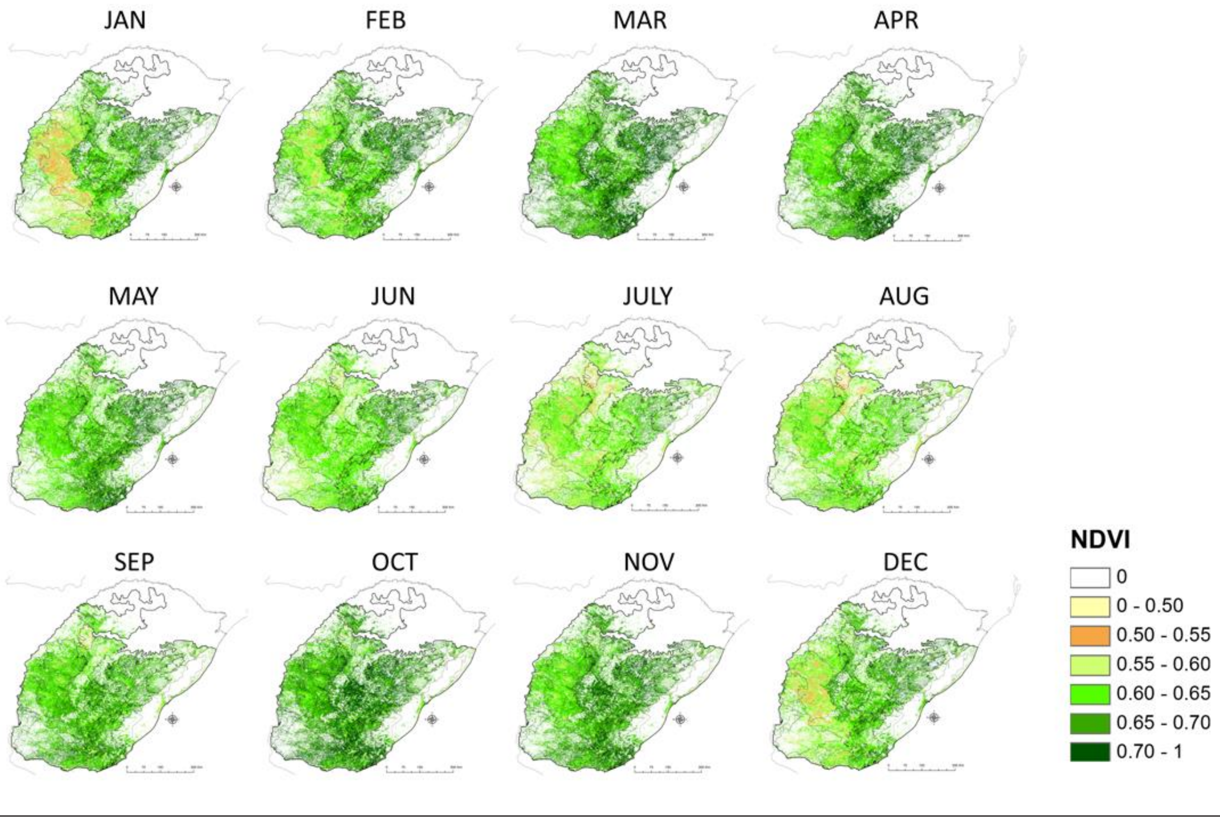


Figure 7. Spatial distribution of monthly coefficient of variation throughout the year for EVI in grasslands in Pampa Biome for the period 2000- 2011.

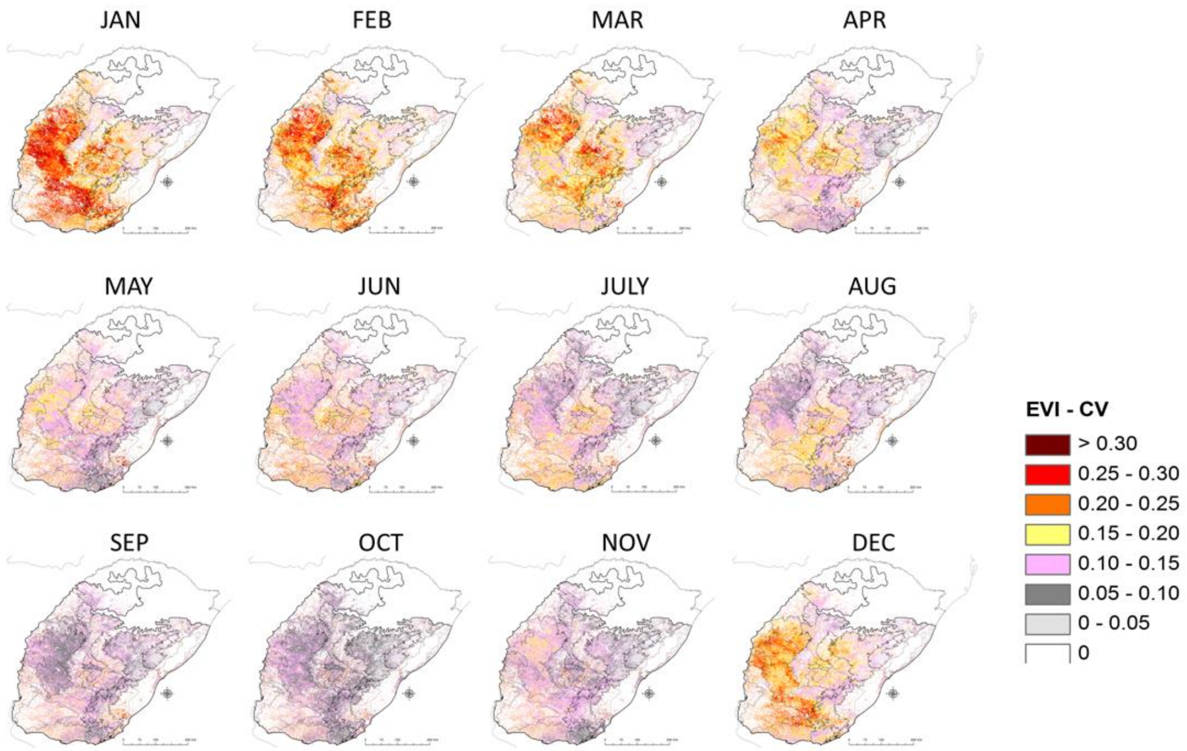
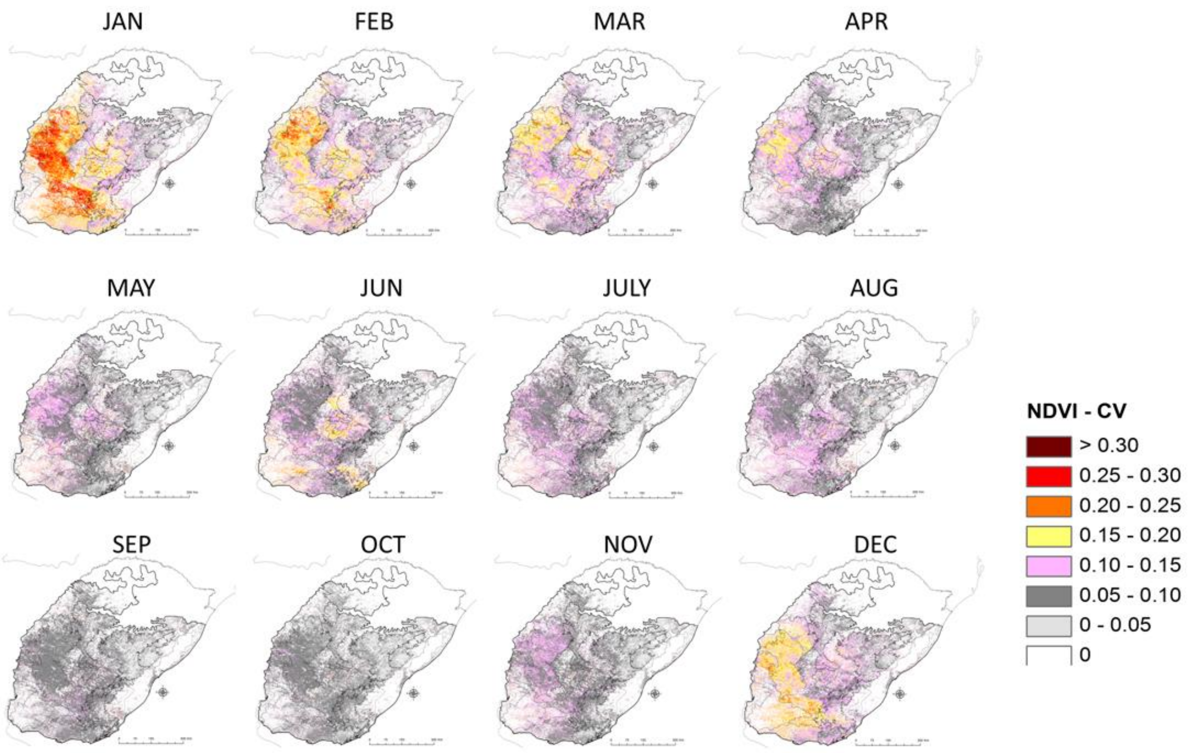


Figure 8. Spatial distribution of monthly coefficient of variation throughout the year for NDVI in grasslands in Pampa Biome for the period 2000-2011.



season, especially on January and February special at Uruguayan Campos. This variability decreased in the winter. Likewise, the EVI presented the highest CV values compared to NDVI for all months (Figure 7), which result suggests that EVI was more capable of detecting annual variability in grasslands.

The summer months during the evaluated period, mainly after 2006, are associated with drought conditions (Rosemback et al., 2010), and can help to explain the better performance of EVI. Alternative mechanisms that relate EVI to drought stress have been proposed, such as structural changes in the canopy associated to leaf loss and effect of leaf loss in reducing shaded fraction by the tallest trees (Anderson et al., 2011).

The Shallow Soil and most of the Crystalline grasslands are the areas with the highest differences in the vegetation indices. Those areas have also the lowest average annual values and highest CV for almost every month. In the Shallow soil grassland, the lowest areas with deeper soils tend to produce more biomass and to be affected later in case of water deficit (Berretta et al., 2001; Pallarés et al., 2005), while Crystalline grasslands are located in agriculture marginal areas, where dominate the livestock production and most of the high fertility deeper soils used only to annual crops (Boldrini, 2009; Hasenack et al., 2010). Those grasslands are also profoundly influenced by the rainfall regime because soils have low water holding capacity, and botanical composition is even more dependent on the topography, where lower areas tend to be more productive (Pallarés et al., 2005).

Therefore, the results observed on mean and CV values for NDVI and EVI in these grasslands indicated an association between vegetation index variability and grasslands patterns. Those results showed the potential usage for the vegetation indices to spatially and temporally characterize Campos patterns and variability. Considering countries which natural grasslands are viewed as extensive systems, such study can improve the knowledge about vegetation patterns, and generate information and maps that can assist on panel discussions about balancing the production versus the conservation dilemma.

Conclusions

The temporal and spatial variability of the vegetation vigor that occurs at the Pampa Biome in Brazil and Uruguay may be detected through NDVI and EVI vegetation indices.

The EVI and NDVI average temporal pattern is similar, and reflect for ecological region, the vegetation vigor associated to soil type, and the rainfall. The high values occur during summer and lower values during winter. The higher variability of vegetation index is during summer, which EVI shows more potential to detect it.

References

ALLEN, V. G.; BATELLO, C.; BERRETTA, E. J.; HODGSON, J.; KOTHMANN, M.; LI, X.; MCIVOR, J.; MILNE, J.; MORRIS, C.; PEETERS, A.; SANDERSON, M. An international terminology for grazing lands and grazing animals. **Grass and Forage Science, v.** 66, n.1, p. 2–28, 2011.

ANDERSON, L. O.; ARAGÃO, L.E.O.C.; SHIMABUKURO, Y.; ALMEIDA, S.; HUETE, A. Use of fraction images for monitoring intra-annual phenology of different vegetation physiognomies in Amazonia. **International Journal of Remote Sensing**, v. 32, p. 387–408, 2011.

BERLATO, M. A.; FARENZENA, H.; LEIVAS, J. F. Probabilidade da precipitação pluvial decendial ser igual ou superior à evapotranspiração de referência na metade sul do Estado do Rio Grande do Sul. **Pesquisa Agropecuária Gaúcha**, n. 12, p. 7-16, 2006.

BERRETTA, E. J.; RISSO, D. F.; BEMHAJA, M. Tecnologías para la mejora de la producción de forraje en suelos de Basalto. In: Tecnologías forrajeras para sistemas ganaderos de Uruguay. INIA Tacuarembó. **Série** Técnica, n. 76, p. 1-37, 2001.

BAETHGEN, W.; GIMÉNEZ, A. La variabilidad climática, el cambio del clima y el sector agropecuario. **INIA Serie Actividades de Difusión**, n. 1, 2004.

BOLDRINI, I. I. A flora dos campos do Rio Grande do Sul. In: PILLAR, V.D.P.; MÜLLER, S.C.; CASTILHOS, Z.M. de S.; JACQUES, A.V.A. (ed.) Campos sulinos: conservação e uso sustentável da biodiversidade. Brasília, **MMA**. p. 63-77, 2009.

BRADLEY, A.; GERARD, F. Relationships between phenology, radiation and precipitation in the Amazon region. **Global Change Biology**, v. 17, n. 6, p. 2245–2260, 2011.

FONTANA, D.C.; JUNGES, A.H.; BREMM, C. SCHAOARUBU, L.P.; MENGUE, V.P.; WAGNER, A.P.; CARVALHO, P.C.F. NDVI and meteorological data as indicators of the Pampa biome natural grasslands growth. **Bragantia**, Campinas. v. 77, n. 2, p.404-414, 2018.

HASENACK, H.; WEBER, E.; BOLDRINI, I. I.; TREVISAN, R. Mapa de sistemas ecológicos da ecorregião das Savanas Uruguaias em escala 1:500.000 ou superior. **Relatório Técnico**, Produto 4. Projeto IB/CECOL/TNC, 2010.

HUETE, A.; DIDAN, K.; MIURA, T.; RODRIGUEZ, E.P.; GAO, X.; FERREIRA, L.G. Overview of the radiometric and biophysical performance of the MODIS vegetation indices. **Remote Sensing of Environment**, v. 83, p. 195–213, 2002.

JONG, R.; BRUIN, S.; WIT, A.; SCHAEPMAN, M. E.; DENT, D. L. Analysis of monotonic greening and browning trends from global NDVI time-series. **Remote Sensing of Environment**, v. 115, n. 2, p. 692–702, 2011.

JUNGES, A.H., BREMM, C., FONTANA, D.C., OLIVEIRA, C.A.O., SCHAPARINI, L.P., CARVALHO, P.C.F. Temporal profiles of vegetation indices for characterizing grazing intensity on natural grasslands in Pampa biome. **Scientia Agricícola**. v.73, n.4, p.332-337, 2016.

KUPLICH, T., MOREIRA, A., FONTANA, D.D. Série temporal de índice de vegetação sobre diferentes tipologias vegetais no Rio Grande do Sul. **Revista Brasisleira de Engenhantia Agrícola e Ambiental**, v.17, n.10, p.1116–1123, 2013.

MILCHUNAS, D.G.; LAUENROTH, W.K. Carbon dynamics and estimates of primary production by harvest, C-14 dilution, and C-14 turnover. **Ecology**, v. 73, p. 593-607, 1992.

NABINGER, C.; MORAES A.; MARASNCHIN, G. E. Campos in South Brazil. p. 355–376, 2000. In Lemaire, G., Hodgson, J., Moraes, A. de, Carvalho, P.C. de F., Nabinger, C. (eds.), **Grasland ecophysiology and grazing ecology**. CABI, Wallingford.

PALLARES, O. R.; BERRETTA, E. J.; MARASNCHIN, G. E. The South American Campos Ecosystem. In SUTTIE, J., REYNOLDS, S.G., BATELLO, C. (eds.), **Grasslands of the world**. Rome. p. 171–219, 2005.

ROSEMBACK, R.; FERREIRA, N.J.; SHIMABUKURO, Y.E.; Conforte, J. C.; Análise da dinâmica da cobertura vegetal na região Sul do Brasil a partir de dados MODIS/Terra. **Revista Brasileira de Cartografia**, v.62, n. 2, p.401-416, 2010.

SILVEIRA, A. C. R.; KUPLICH, T. M.; MOREIRA, A.; BARBIERI, D. W.; OVERBECK, G. E.; ABREU, P. M. F. Desempenho de EVI e NDVI para monitorar vegetação campestre através de ondaletas. In: **Anais** *XVI Simpósio Brasileiro de Sensoriamento Remoto*, p. 2770–2777, 2013.

TAIZ, L.; ZEIGER, E. **Plant physiology**. 5th ed. Sunderland, MA, USA, 2010.

CITATION

WAGNER, A.;WALLAU, M.; FONTANA, D. C.; CARVALHO, P. C. F.; FRAISSE, C. Vegetation indices variability in the Pampa grasslands in Brazil and Uruguay. **Agrometeoros**, Passo Fundo, v.26, n.1, p.83-92, 2018.

agrometeoros
REVISTA DA SOCIEDADE BRASILEIRA DE AGROMETEOROLOGIA

ISSN 2526-7043 www.sbagro.org.br

Variabilidade de índices de vegetação em pastagens do bioma Pampa no Brasil e no Uruguai

Ana Paula Luz Wagner[1], Marcelo Wallau[1], Denise Cybis Fontana[2(*)], Paulo César de Faccio Carvalho[2] and Clyde Fraisse[1]

[1]University of Florida - Institute of Food and Agricultural Sciences, P.O. Box 110810, Gainesville, FL 32611, USA. E-mails: anaplw@gmail.com, mwallau@ufl.edu and cfraisse@ufl.edu
[2]Universidade Federal do Rio Grande do Sul - Faculdade de Agronomia. Avenida Bento Gonçalves 7712, Caixa Postal 15096, CEP 91501.970. Porto Alegre, RS. E-mails: mowallau@yahoo.com, dfontana@ufrgs.br and paulocfc@ufrgs.br
[(*)]Autor para correspondência.

INFORMAÇÕES

História do artigo:
Recebido em 30 de maio de 2018
Aceito em 20 de dezembro de 2018

Termos para indexação:
EVI
NDVI
MODIS

RESUMO

Os campos naturais do Bioma Pampa estão entre os maiores e mais ricos do mundo, com uma enorme diversidade de espécies e uma singular coexistência de plantas C3 e C4 no mesmo tempo e espaço. O objetivo deste estudo foi caracterizar a variabilidade anual e sazonal dos índices de vegetação NDVI e EVI dos campos do Bioma Pampa e identificar a possibilidade de distinção entre regiões ecológicas. O estudo teve como foco as 13 regiões ecológicas deste bioma no Brasil (estado do Rio Grande do Sul) e no Uruguai. A variabilidade temporal e espacial do vigor da vegetação foi avaliada utilizando os índices NDVI e EVI para o período de 2000 a 2011. Os resultados mostraram que o NDVI e EVI apresentam um padrão temporal similar e refletem para cada região ecológica, o vigor da vegetação associada ao tipo de solo e precipitação pluvial. Para ambos índices os maiores valores ocorrem durante o verão e os menores valores no inverno. Mas é no verão que se observa a maior variabilidade interanual dos índices de vegetação, sendo que o EVI mostra maior potencial para detecção mudanças no vigor da vegetação.

REFERENCIAÇÃO

WAGNER, A.;WALLAU, M.; FONTANA, D. C.; CARVALHO, P. C. F.; FRAISSE, C. Vegetation indices variability in the Pampa grasslands in Brazil and Uruguay. **Agrometeoros**, Passo Fundo, v.26, n.1, p.83-92, 2018.