Evaluation of Vegetation Indices at Livestock Integrated Systems using Remote Sensing Data

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Introduction

Livestock systems' economic importance and a growing demand for production efficiency of Brazilian pastures have been fostering researches about the performance of livestock systems under different types of management. Integrated crop-livestock-forestry systems aim at greater sustainability at the farm, and incorporate agricultural, livestock and/or forestry components within the same area under crop rotation, double cropping or sequential cropping (BALBINO et al., 2011). Thus, in this study we evaluated the effect of different livestock production systems on the Normalized Difference Vegetation Index (NDVI). On one side, the greenness represented by NDVI values correlates with plant production to indicate stronger or weaker production, and also to act as an indicator to distinguish the types of management of livestock systems (ALVARENGA et al., 2015). On the other side, biomass production in pastures correlates with potential for carbon storage in the soil (OLIVEIRA, 2015).

Material and Methods

The study area is located in São Carlos, São Paulo State, Brazil, within the *Mata Atlântica* (Atlantic Forest) biome, a region of humid subtropical climate where the average annual rainfall rate is of 1,362 mm, and the average annual temperature rate is of 21.5 °C. The experimental outline featured the following bovine cattle production systems: (A) crop- livestock-forest integration (iLPF), (B) livestock-forest integration (iPF), (C) crop-livestock integration (iLP); (D) intensive (INT) and (E) low-density extensive (EXT_BL) breeding (Figure 1). The ILPF and iPF systems feature *Eucalyptus urograndis* (GG100) in simple rows spaced by 15 m and trees spaced by 2 m. The pastures feature *Urochloa brizantha*. Currently 1/3 of the area is renovated using *Zea mays* double-cropped with *U. brizantha* (Table 1).

Table 1. Description of the experimental areas and livestock production systems.

Production system	Management type	Dominant grass	N dose at the crop (kg ha^{-1})	N dose at the forest (kg ha^{-1})	N dose at the pasture (kg ha^{-1})	Total N dose (kg ha^{-1})
iLPF	rotation	*Brachiaria brizantha*	130	200*		330
iPF	rotation	*Brachiaria brizantha*	0	200*		200
iLP	rotation	*Brachiaria brizantha*	130	0	200	330
INT	rotation	*Brachiaria brizantha*	0	0	200	200
EXT_BL	continuous	*Brachiaria decumbens*	0	0	0	0

*The N dose applied to the total area is of 200 kg ha^{-1} year^{-1}.

The extraction of NDVI values from temporal series of Landsat 8 OLI/TIRS images was performed using the method described by Conceição et al. (2015). We used 31 images taken from April 2013 to August 2015. The NDVI values extracted for each production system were grouped based on season under 'dry season 2013', 'rainy season 2013/2014', 'dry season 2014', 'rainy season 2014/2015' and 'dry season 2015' and were tested using the Kruskal- Wallis ANOVA method.

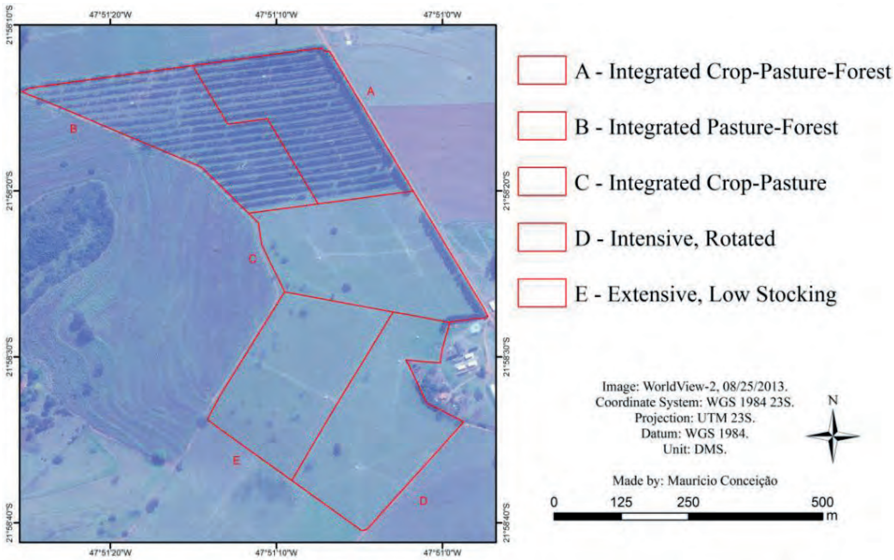

Figure 1. Experimental outline and production systems at the study area.

Results and Conclusions

Figure 2 shows average NDVI values in each experimental area for each OLI/Landsat-8 image. As expected, the iLPF system showed higher vegetation indices along all seasons (Table 2). The permanent presence of the forest conveys stability to the vegetation indices' values and a stronger greenness. Nevertheless, the NDVI values of the iPF system were lower than those of the iLPF system, despite the equal presence of trees in both of them (Table 2). This difference might be associated with the stronger fertilization applied to the iLPF system, since a maize crop was part of the rotation, and the system may have benefited from the residual effect of the nutrients in the soil.

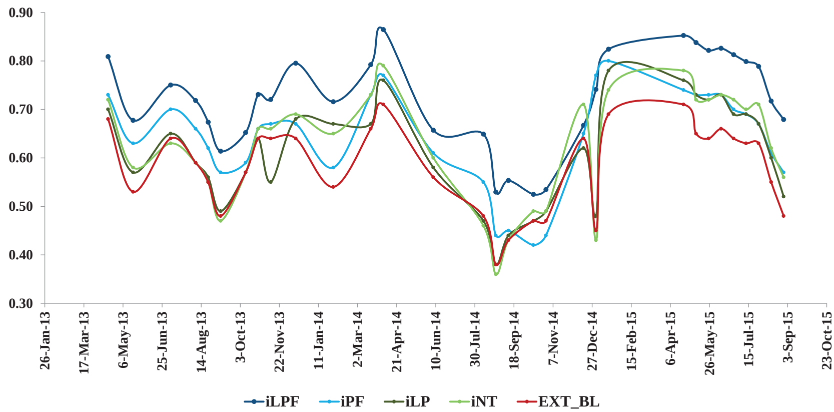

Figure 2. Livestock production systems' NDVI values from April 2013 to August 2015.

During dry periods, the pastures' NDVI values for iLP systems did not differ from those of the iPF and INT systems. The EXT_BL system's NDVI values are equal to those of the iLP system only for the rainy season of 2013/2014, and equal to INT's indices for the dry seasons of 2013 and 2014 (Table 2).

Table 2. Average NDVI values for each production system and season.

Production system	DRY SEASON 2013 (6)*	RAINY SEASON 2013/2014 (6)*	DRY SEASON 2014 (5)*	DRY SEASON 2014 (5)*	DRY SEASON 2015 (9)*	AVERAGE 2013-2015 (30)*
iLPF	0.71[a**]	0.73[a]	0.65[a]	0.66[a]	0.79[a]	**0.71**
iPF	0.65[b]	0.65[b]	0.56[b]	0.62[b]	0.68[b]	**0.63**
iLP	0.59[bc]	0.63[c]	0.52[b]	0.57[c]	0.68[b]	**0.60**
INT	0.59[cd]	0.66[b]	0.53[bc]	0.57[c]	0.70[b]	**0.61**
EXT_BL	0.58[d]	0.61[c]	0.51[c]	0.54[d]	0.62[c]	**0.57**

*Number of Landsat images. **Averages with the same letters did not differ between production systems ($p<0.05$).

The evaluation of the effect of production systems on the NDVI values along time has potential for discriminating livestock systems according to their intensification level. Although it is not advisable to compare vegetation indices obtained for different types of land cover, as we do here, our results show similar greenness between the iPF integrated system and iLP and INT systems, which signals that other discrimination methods may be coupled for a better understanding of NDVI standards in livestock systems. Under homogeneous land cover situations we were able to separate the most productive (iLP and INT) from the least productive (EXT_BL) systems most of the times. Vegetation indices show good potential for use in the monitoring of pasture greenness. Well-managed pastures favor carbon accumulation in the soil and contribute to mitigate the concentration of greenhouse gases in the atmosphere.

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