MONITORING BIENNIAL BEARING EFFECT ON COFFEE YIELD USING MODIS REMOTE SENSING IMAGERY

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1. INTRODUCTION

Coffee crop is the second most traded commodity in the world, second only to oil production chain. Brazil is the first coffee producer in the world.

Landsat images, due to their spatial and spectral resolutions, are more suitable for mapping coffee fields, however, they can be restricted to a few scenes free of clouds and this condition can obstruct an effective monitoring during crop development [1]. MODIS data, despite not having suitable spatial resolution to correctly identify coffee plantations, it has an appropriate temporal resolution for monitoring agricultural fields.

One of the main characteristics of coffee crop is that it takes two years to complete the entire phenological cycle of fructification. Thus a coffee plot exhibits high and low production in alternated years. Although the biennial bearing effect on coffee yield and its importance in yield modeling are well known [2], up to now there is no effective tool to access this pattern and estimate it in spatial domain.

Considering this predominant yield alternation in coffee crops in consecutive years and the relationship between yield and leaf area, it is possible to expect similar patterns in the alternation of vegetation indices. In this case, correlations could be used as an indicator of yield biennially.

This study aimed to evaluate the potential of using NDVI and EVI indices generated from MODIS product (MOD 13) to detect the biennial coffee yield from 2002 to 2009, in the southern region of Minas Gerais state, Brazil.

2. METHODOLOGY

The selected study area covers the southern region of Minas Gerais state (coordinates 20 ° 00 '23 ° 00' South and 43 ° 50 '47 ° 30' west), where the coffee yield represents more than a half of the state total production.

We used EVI time series [3] and NDVI vegetation indices [4], totaling 23 scenes per year, both indices derived from MODIS sensor, product MOD13. The years from 2002 to 2009 were considered in order to verify the possibility of detection of biennial coffee yield.

The time series corresponding to the selected pixels was filtered using a wavelet based filtering according to [5] and [6].

For each year of the time series, the amplitude of vegetation indices concerning maximum and minimum values for each selected pixel was calculated in order to quantify the magnitude of leaf loss within each crop year (FIGURE 01). Besides the amplitude values, for each selected pixel we also evaluated the sum of vegetation indices [7] and [8], the maximum, minimum and average values for each year, in order to identify which metric could present better correlation with productivity.

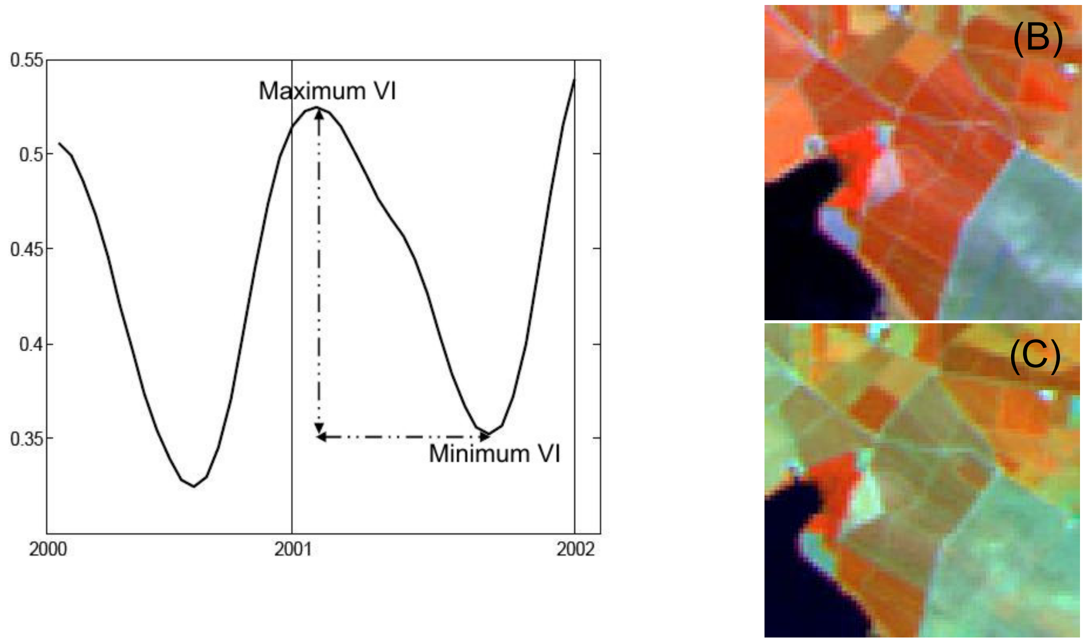

Figure 1: Annual variation of vegetation indices for the selected pixels (A) Standard crop with the maximum vegetation index value for March (B) and minimum vegetation index for August (C) Image TM/Landsat 3B4R5G.

Yield data for Mundo Novo variety (60-kilogram bags of green coffee per hectare), corresponding to the pixels selected from 2002 to 2009 were obtained. This data was collected in interviews with farmers from four locations: Três Pontas, Boa Esperança, São Sebastião do Paraíso e Monte Santo de Minas.

Correlations (Pearson correlation coefficient) were calculated for two different situations: i) correlations between yield and vegetation indices in the same year, assuming that an increase in yield could result in a reduction of vegetation indices and; ii) correlations between vegetation indices and yield the following year, assuming that an increase in vegetation indices could result in an increase of yield the following year.

3. RESULTS

Although the correlation results were smaller than those found in studies with annual crops [9], [10], [11] and [12], the trends suggest leaf area dependence in relation to coffee yield in the same year.

The correlations between yield and foliation were more significant with the minimum values of vegetation indices (minEVI and minNDVI) during the year. The best Pearson coefficients were -0.65 (yield vs minEVI) and -0.66 (yield vs minNDVI) for correlations between the coffee yield and VI's in the same year and 0,74 (yield vs minEVI) and 0,68 (yield vs minNDVI) for correlations between the VI's and yield the following year.

Correlation analysis showed that vegetation indices did not entirely explain yield variation because there are a lot of factors responsible for final yield, but these indices could be associated to agrometeorological models for estimating yield, as well as, be useful as indicators of coffee biennial yield.

In relation to the vegetation indices evaluated, EVI showed better results than those of NDVI in the study for the assessed period. A known limitation of NDVI index is the decrease or the saturation in sensitivity when leaf area index values (LAI) increase [13], such as coffee trees that can reach values of LAI higher than 8. [14] found the NDVI saturation effect when leaf area rates of crops exceed the value 5. On the other hand, EVI has shown to be less prone to saturation effect with higher sensitivity in regions of high biomass [15] and [16] which could make it more appropriate for studies of coffee canopy.

4. CONCLUSIONS

Correlation analysis between minimum values of vegetation indices (NDVI; EVI) and coffee yield data presented better results and, consequently, expressed the combined effect of both seasonal weather variations and mechanical damage from the harvesting process.

EVI vegetation index presented better results in relation to those of NDVI index, probably because it is more capable of detecting variations in regions with high biomass.

Despite the low spatial resolution of MODIS data and the fact that yield is a complex factor because it depends on several conditions, the indices were able to express the relationships between leaf biomass and coffee crop.

The best correlations were observed with vegetation index data obtained from periods in which there are cloud-free higher spatial resolution images, which can produce better results.

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