ASSESSMENT OF SUITABLE OBSERVATION CONDITIONS FOR A MONTHLY OPERATIONAL REMOTE SENSING BASED CROP MONITORING SYSTEM

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ABSTRACT

Cloud cover is the main issue to consider when remote sensing images are used to identify, map and monitor croplands, especially over the summer season (October to March in Brazi). This paper aims at evaluating clear sky conditions over four Brazilian states (São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul) to assess suitable observation conditions for a monthly basis operational crop monitoring system. Cloudiness was analyzed using MODIS Cloud Mask product (MOD35), which presents four labels for cloud cover status: *cloudy*, *uncertainty*, *probably clear* and *confident clear*. R software was used to compute average values of clear sky with a confidence interval of 95% for each month between July 1st, 2000 and June 30th, 2013. Results showed significant differences within and between the four tested states. Moreover, the period from November to March presented 50% less clear sky areas when compared to April to October.

Index Terms— Cloud cover, Brazilian agriculture, MODIS, acreage estimation

1. INTRODUCTION

Brazil plays an important role in the agricultural production worldwide. Cropped area of soybean, corn, and sugarcane, was about 27.7, 15.9, and 8.7 million hectares in crop season 2012/2013 [1]. Approximately 40% of their area is in the states of São Paulo (SP), Paraná (PR), Santa Catarina (SC) and Rio Grande do Sul (RS) [1]. Because of the wide area and the small period of crop vegetation, remote sensing technologies present great potential to be used for operational crop monitoring systems.

Indeed, Landsat-like images have been shown capability for crop acreage estimation over large areas [2, 3], but cloud-free images acquired during key periods within the crop calendar is required. Provision of cloud free image makes satellite-based agriculture monitoring at regional to national scale a big challenge [3, 4, 5].

To develop a consistent, systematic and continuous acreage estimation system using remote sensing it is necessary to assess suitable observation conditions to quantify clear sky trend through space and time. Several studies claim that cloud cover is an important issue in the use of satellite images [3, 4, 5], but few ones quantified their clear

sky areas [4]. The aim of this study is to evaluate monthly clear sky (i.e., cloud free) area available in the States of SP, PR, SC, and RS over the last 13 years (2000 to 2013) based on almost-daily coverage images from MODIS sensor.

2. MATERIAL AND METHODS

The study area is located between latitudes South 19º 42' and 33º 48' and longitudes West 44º and 57º 41' and comprises four Brazilian states: SP, PR, SC, and RS. These states are divided into 38 mesoregions delimited by: a) social process determinant; b) natural resources as conditionant and social; and c) physical network, by the Brazilian Institute of Geography and Statistics (IBGE) [6].

The MODIS Cloud Mask product is at the level two (L2) of processing in the Earth Observation System program (EOS), and two files are necessary for its: one containing the values of cloud cover (MOD35) and one containing geolocation fields for each cloud cover image (MOD03) [7]. The MOD35 is produced by probabilistic algorithms that use 22 out of the 36 MODIS wavebands to define cloud presence at pixel level [7], in 1 km of spatial resolution. This MODIS product has four labels representing distinct cloud cover conditions registered: *cloudy* (<60% confidence interval), *uncertain* (60 to 95%), *probably clear* (>95 to 99%) and *confident clear* (>99%) [7]. The MOD35 product are composed by five bytes were bits 1 and 2 of byte 0 show the value of cloud cover for each MODIS pixel [7]. We acquired 15,321 images (parts of region of interest) for each MODIS product to compose 4,748 daily images of the Cloud Mask product (MOD35) available from July 1st 2000 to June 31th 2013 (13 crop seasons).

The first step of data processing was to extract the images from HDF to GEOTIFF format using Reprojection MODIS Swath Tool. In the next step, the R software was used [8] (mainly packages *modiscloud* [9] and *raster* [10]) to extract first and second bits of each daily image we analyzed. This process uses the function *get_bitgrid_2bits* in *modiscloud* package, which returns the two chosen bits [9]. A mosaic with cloud-cover labels was created using the *mosaic* function of the *raster* package [10] by mosaicking all daily images portions available for each day. The process to compute values of clear sky was performed using the *aggregate* function of *raster* package to obtain the values for the four classes of cloud mask product present in each date for each state or mesoregion. The four original classes defined in the cloud mask product were regrouped in two new classes: *clear sky* (*confident clear*) and *cloud (probably clear + uncertain + cloudy)*. The *clear sky* calculation was performed by the proportion of classes regarding either state or mesoregion level. In order to identify space as well as temporal variation

of clear sky conditions we calculated the percentage of *clear sky* for each state and mesoregion at daily basis. Using these values we aggregated clear sky values considering two periods: global (over all 13 crop seasons), and monthly (by grouping every month along all the 13 crop seasons). In both cases, we calculated the average and confidence interval (CI) with 5% of significance, for each state and mesoregion. The data analysis at the two different scales (state and mesoregion) was chosen because for an agricultural monitoring system it is necessary to evaluate the differences inter (states) and intra (mesoregions) states.

3. RESULTS AND DISCUSSION

The state analysis showed that averaged *clear sky* values for all states were less than 40% with CI of approximately ± 1% (Fig.1). The monthly analyses showed a seasonality of *clear sky* for SP and PR (Fig. 1). In these states, the value of *clear sky* is lower than in RS and SC from November to February, which is a key periods to identify soybean and corn. For PR our result was similar to that reported by Sugawara *et al*. [3], who analyzed Landsat images over seven crop seasons. This jeopardizes the mapping or acreage estimation based on remote sensing images, using traditional remote sensing techniques (i. e. visual interpretation of wide regions like a state).

On the other hand, the average values of *clear sky* in SC and RS were similar along time. In general, the CI and variance were similar for all months for all states (around ±4%) (Fig. 1). However, the low values of *clear sky* in images are probably insufficient to map the entire state area in a two month interval (Fig. 1).

The mesoregion analysis showed similar trend when compared to the state scale for SP and PR. In mesoregion level the seasonality of *clear sky* is concentrated in April to September (Fig. 2). This period is crucial to map sugarcane, which is the main crop in SP and in the north portion of PR. On other hand, the same mesoregions show small values of clear sky over the summer crops period (September to March) (Fig. 2). Between November and January, the clear sky values are less than 20% for important mesoregions in SP state, like Assis, which has great producer of soybean and corn in SP state (Fig. 2).

For the same region, mapping summer crops such as soybean and corn requires images acquired during January and March, when clear sky values are small for all crop season [3, 4] (Fig. 2). The mesoregion analysis showed that along the coast *clear sky* values are similar throughout year. For SC and RS, the average value of clear sky is larger than PR and SP, but not greater than 55%, for example, in Litoral Sul Paulista and Metropolitana de Curitiba (Fig. 2).
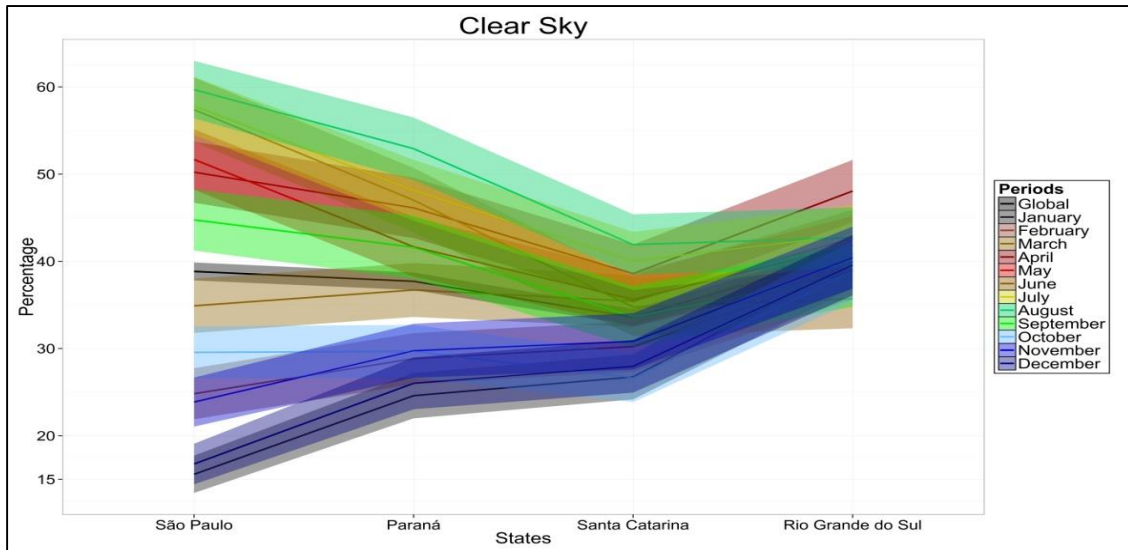
Fig. 1. Average and CI values of *clear sky* for SP, PR, SC and RS states.

The CI in mesoregion level for all states is similar, with greater values of ± 4% around the average. During the *safrinha* (i.e., second crop within the same crop year), which begins around March in SP and PR, the values of *clear sky* are larger and gradually rise up to September, which increases the possibility of successful crop monitoring in this period (Fig. 2).

Our results emphasize the difficult to map wide regions (state) using satellite images such as Landsat-like. Especially

over summer crop season (November to March) which demands cloud-free images acquired during a short period when clear sky values area low. Thus, to overcome this issue a sample probabilistic method can be apply since it does not require an entire cloud-free image to retrieve the acreage estimation.
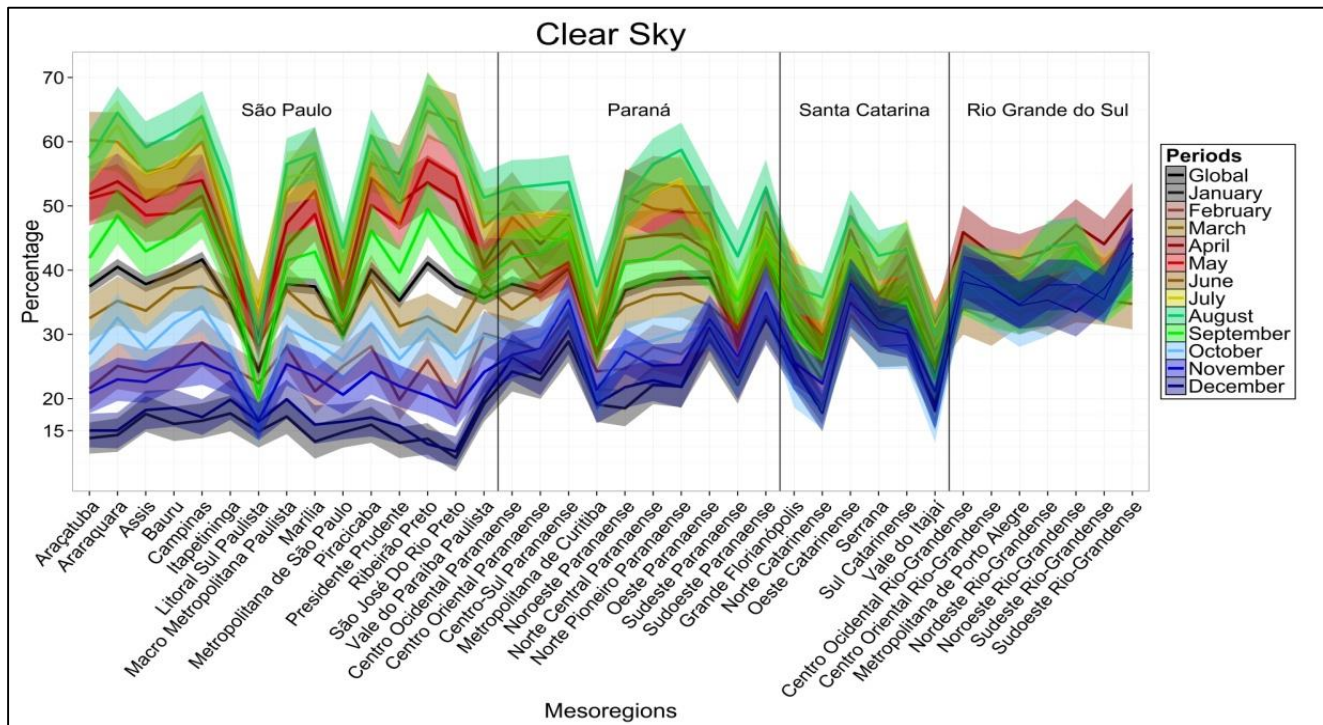

Fig. 2. Average and CI values of *clear sky* for all mesoregions of SP, PR, SC, and RS states.

4. CONCLUSIONS

Our analysis reveals that for the two summer crops analyzed (i.e. soybean and corn in first cropseason) and the beginning of *safrinha* the values of *clear sky* (and so the possibility of mapping this crops for all extension of states) are very small. This cloud coverage jeopardizes acreage estimation for summer crops using traditional remote sensing approaches over wide regions (map all region using Landsat-like images). On the other hand, the mapping of sugarcane should be easier since this crop tends to stay longer in the field, and over the months with higher *clear sky* values (April and September).

Cloud cover may seriously limit an operational program of crop monitoring based on mapping remote sensing images as source of information, especially for monthly acreage estimates of summer crops over large areas.

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