TECHNICAL PAPER

IDENTIFICATION OF CROPLANDS OF WINTER CEREALS IN RIO GRANDE DO SUL STATE, BRAZIL, THROUGH UNSUPERVISED CLASSIFICATION OF NORMALIZED DIFFERENCE VEGETATION INDEX IMAGES

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ABSTRACT: This study aimed to propose methods to identify croplands cultivated with winter cereals in the northern region of Rio Grande do Sul State, Brazil. Thus, temporal profiles of Normalized Difference Vegetation Index (NDVI) from MODIS sensor, from April to December of the 2000 to 2008, were analyzed. Firstly, crop masks were elaborated by subtracting the minimum NDVI image (April to May) from the maximum NDVI image (June to October). Then, an unsupervised classification of NDVI images was carried out (Isodata), considering the crop mask areas. According to the results, crop masks allowed the identification of pixels with greatest green biomass variation. This variation might be associated or not with winter cereals areas established to grain production. The unsupervised classification generated classes in which NDVI temporal profiles were associated with water bodies, pastures, winter cereals for grain production and for soil cover. Temporal NDVI profiles of the class winter cereals for grain production were in agree with crop patterns in the region (developmental stage, management standard and sowing dates). Therefore, unsupervised classification based on crop masks allows distinguishing and monitoring winter cereal crops, which were similar in terms of morphology and phenology.

KEYWORDS: wheat, black oat, remote sensing, MODIS, NDVI.

IDENTIFICAÇÃO DE ÁREAS AGRÍCOLAS CULTIVADAS COM CEREAIS DE INVERNO NO RIO GRANDE DO SUL POR MEIO DE CLASSIFICAÇÃO NÃO SUPERVISIONADA DE IMAGENS DE ÍNDICE DE VEGETAÇÃO POR DIFERENÇA NORMALIZADA

RESUMO: O objetivo deste trabalho foi propor métodos para identificação de áreas agrícolas cultivadas com cereais de inverno na região norte do Rio Grande do Sul. Para isso, foi analisada a evolução do Índice de Vegetação por Diferença Normalizada (NDVI), proveniente de imagens do sensor MODIS, de abril a dezembro de 2000 a 2008. Foram elaboradas máscaras de cultivo pela subtração de imagens de mínimo NDVI (abril e maio), das de máximo NDVI (junho a outubro). Posteriormente, foi realizada a classificação não supervisionada das imagens (algoritmo Isodata), considerando as áreas pertencentes às máscaras de cultivo. As máscaras de cultivo identificaram pixels com as maiores variações de biomassa verde, associadas ou não à produção de grãos. A classificação não supervisionada gerou classes cujos perfis temporais foram condizentes com corpos d'água, pastagens e cultivos de cereais de inverno para produção de grãos e para cobertura do solo. Os perfis temporais de áreas destinadas à produção de grãos concordaram com os padrões de cultivo dos cereais de inverno na região (ciclo de desenvolvimento, manejo e épocas de semeadura). A classificação não supervisionada de áreas identificadas por máscaras de cultivo permite identificar e monitorar cultivos de cereais de inverno que se assemelham quanto à morfologia e à fenologia.

PALAVRAS-CHAVE: trigo, aveia-preta, sensoriamento remoto, MODIS, NDVI.

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INTRODUCTION

Information collected from surface and orbital remote sensors have emerged as an important and promising data source for agriculture. In order to make this information available to be used to monitor agricultural crops and estimation of cultivated areas and yield, it is necessary to establish the relationship between radiometric parameters contained in remote sensing products, and biophysical parameters of vegetation. In various studies these relationships have been established through vegetation index (EPIPHANIO et al., 1996). One of the most widely used indexes in studies regarding vegetations is the Normalized Difference Vegetation Index, proposed by ROUSE et al. (1973). The frequent use of NDVI is due to the construction of global databases, computational simplicity and sensitivity in detecting changes in vegetation (RIZZI, 2004).

NDVI employ vegetation reflectance at wavelengths of red and near-infrared and is considered an indicator of vegetation growth and biomass accumulation by green plants. NDVI can be calculated from the wavelength bands of orbital or surface sensors. In the case of MODIS sensor (Moderate Resolution Imaging Spectroradiometer), that is the key instrument aboard the Terra and Aqua satellites, vegetation indexes are available in the form of ready product named MOD13Q1, which included NDVI and EVI (Enhanced Vegetation Index) images (MODIS, 2012). NDVI/MODIS images represent compositions of 16 days. It is selected, from among the passages on the period, the pixel with the highest NDVI value and better quality compared to viewing geometry and atmospheric interference to generate these compositions. The NDVI/MODIS images are available free of charge to the end user, with atmospheric and geometric corrections previously performed (RIZZI, 2004), with spatial resolution of 250 meters and time resolution of 16 days, both relevant for monitoring crops at regional scale.

In the state of Rio Grande do Sul, during the autumn-winter-spring, crops of oat, rye, barley, wheat and triticale for grain production are planted. The deployment of winter cereal crops diversified agricultural production, increases income for the farmer and enables the direct seeding system and crop rotation (TIBOLA et al., 2009). During the period, in addition to winter cereals for grain production, plantations with species producing green mass for pasture or soil cover are established. The most cultivated species for covering soil in the Brazilian southern region, preceding crops of corn and soybeans, is the black oat (SILVA et al., 2006). The sowing of black oat is also performed for the establishment of pasture, cropping only or forage mixtures.

Besides being set in the same period last year, black oat and winter cereals to grain production are grasses with phenological and morphological similarities. In satellite images, the morphological similarities between winter cereals hinder the identification and distinction of crops, especially when images of a single date are used (FONSECA et al., 2010).

The temporal variation of NDVI has been used in vegetation mapping due to the possibility of identifying the seasonal changes of vegetation associated with the development cycle (PONZONI & SHIMABUKURO, 2010). According to TOWNSEND & WALSH (2001), multitemporal studies allow information concerning phenological variations are included in the process of image classification, increasing accuracy due to detailing of vegetation characteristics. In multitemporal studies with images obtained during the whole cycle, the differences in sowing dates and management can serve as a basis for distinction of crops. In Rio Grande do Sul, CARESANI (2010) found differences between the temporal profiles obtained from areas cultivated with wheat and ryegrass in the regions of *Campanha* and *Fronteira Oeste*, employing NDVI/MODIS images. In the state, methodologies based on the behavior of spectral-temporal crops have also been proposed for estimating soybean cultivated areas (SANTOS, 2010) and irrigated rice (KLERING, 2007). Multitemporal compositions of NDVI images from the SPOT Vegetation satellite (from French, *Systeme Pour l'Observation de la Terre*), subjected to supervised classification, were considered adequate for mapping crops in the state of Paraná (ARAÚJO et al., 2011).

The aim of this work was to propose methods for discrimination, in NDVI/MODIS images, of agricultural areas cultivated with winter cereals for grain production, in relation to other established areas during the autumn-winter-spring period in the northern region of Rio Grande do Sul state.

MATERIAL AND METHODS

Study area

The study area comprised 270 municipalities located in the northern area of the State of Rio Grande do Sul, including the Caxias do Sul (58 municipalities), Erechim (50), Passo Fundo (70), Ijuí (47) and Santa Rosa (45) regions according to EMATER/RS (Figure 1). The study area, covering a total area of 8,817,583ha (approximately 32% of the state area), was responsible for 86% of the cultivated area and amount of wheat produced in Rio Grande do Sul, in the average of the years 2000 to 2008 (IBGE, 2010).

Agricultural areas established during the autumn-winter-spring were characterized by the temporal evolution of NDVI. Thereunto NDVI images from the MODIS sensor (product MOD13Q) regarding the months from April to December of 2000 to 2008 were used. Seventeen yearly images were used (two images per month, except the month of August, as the NDVI/MODIS match the compositions of 16 days). The use of images from April to December aimed at characterizing the cycle of winter cereals from the period prior to the development of crops to harvest of the grains. In this sense, the sowing of wheat in Rio Grande do Sul is recommended from May to July, starting in the warmest region (west) and ending in colder region (east) of the State (CUNHA et al., 2001). Thus, in the study area, the indicated period of sowing wheat occurs primarily in the Santa Rosa region and, finally, in the Caxias do Sul region.

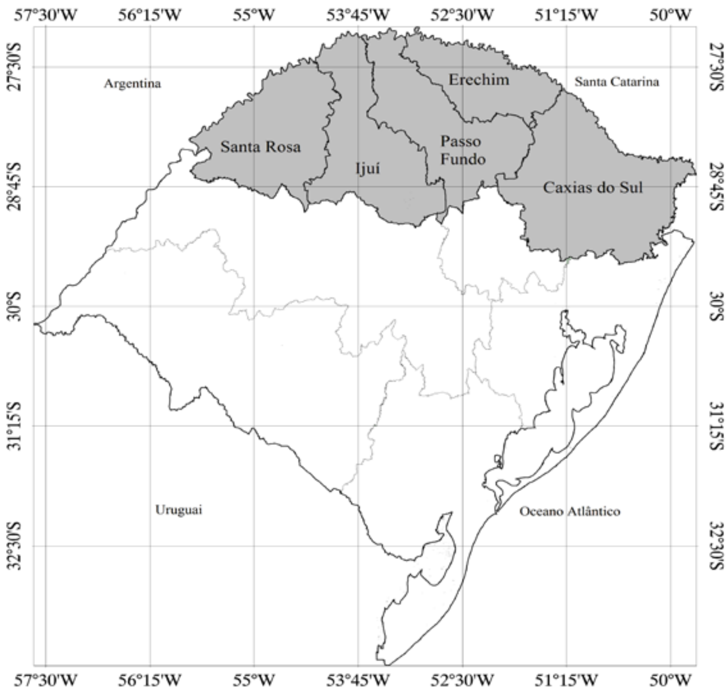

FIGURE 1. Location of the study region in Rio Grande do Sul State, Brazil (Caxias do Sul, Erechim, Passo Fundo, Ijuí and Santa Rosa regions in accordance with EMATER/RS).

Crop masks

The agricultural areas were identified in NDVI/MODIS images using the methodology of crop masks, already employed in the study of temporal profiles of NDVI/MODIS of areas of winter cereals in Rio Grande do Sul (JUNGES & FONTANA, 2009). The assumption of this methodology is that the areas that make up the crop mask are those in which there is the greatest variation of NDVI in the period, which is possibly associated with agricultural use.

The crop masks were obtained from the subtraction of NDVI minimum of maximum NDVI images, which generated difference images for each region and year. The compositions of minimum and maximum NDVI were elaborated using the images of the first half of April to the second half of

May (minimum NDVI) and the second half of June to the first of October (maximum NDVI). Thresholds were tested in the difference images. It was chosen the threshold that generates, for each region and year, crop mask with area (ha) similar to the cultivated area in the spring-summer period (sum of official areas of corn and soybeans, according to the survey *Levantamento Sistemático da Produção Agrícola* - LSPA/IBGE). The generation of crop masks based on the cultivated areas of corn and soybeans was adopted due to the lower interannual variability, in the area cultivated with these crops, in relation to the area cultivated with winter cereals.

Subsequently, the average values of NDVI pixels belonging to the crop mask were collected, then NDVI/MODIS temporal profiles were created for the analyzed years and for the biweekly average of the period ranging from 2000 to 2008.

Unsupervised classification

Considering only the areas within the crop masks, an unsupervised classification of NDVI/MODIS images carried out, using the algorithm Isodata and taking as a grouping criterion the temporal attribute of similarity in relation to the evolution of vegetation index during the period from April to December. Classes resulting from unsupervised classification process were transformed into vectors, which were superimposed on the NDVI/MODIS images in order to create temporal profiles. The profiles of the classes were related to sowing date and the agricultural calendar of wheat (Table 1), since this crop cycle is accompanied by EMATER/RS biweekly, and that, in terms of cultivated area, wheat is the main crop production grain established during autumn-winter-spring in the regional analysis.

The class that adjusted better to the expected evolution of agricultural areas cultivated for grain production was named "winter cereal-grain". The area occupied by the "winter cereal-grain" class, in each region and year, was compared to the official area planted with winter cereals (sum of the areas of oat, rye, barley, wheat and triticale).

The accuracy verification of the classification was performed with control points, obtained using GPS (Global Positioning System), of 72 wheat crops established in 2006 and four crops established in 2010 in the region of Passo Fundo, according to EMATER/RS. The correlation between the temporal profiles of NDVI/MODIS of control points and those from the winter cereal class were verified.

TABLE 1. Fortnights in which the wheat crops were during flowering, grain filling, physiologic maturation and harvest time, in the majority of the cultivated areas of the regions of Caxias do Sul, Erechim, Passo Fundo, Ijuí and Santa Rosa; averages ranging from the period of 1999 to 2009. Data source: EMATER/RS (2010).

Cycle stage	Fortnight	Regions
Flowering	1st of September	Santa Rosa and Ijuí
	2nd of September	Passo Fundo and Erechim
	1st of October	Caxias do Sul
Grain filling	1st of October	Santa Rosa, Ijuí and Passo Fundo
	2nd of October	Erechim and Caxias do Sul
	1st of November	Caxias do Sul
Physiologic Maturation	2nd of October	Santa Rosa and Ijuí
	1st of November	Passo Fundo and Erechim
	2nd of November	Caxias do Sul
Harvest	1st of November	Santa Rosa and Ijuí
	2nd of November	Passo Fundo and Erechim
	1st of December	Caxias do Sul

RESULTS AND DISCUSSION

Crop masks

The average profiles of NDVI/MODIS, based on the methodology of crop masks, reflected the temporal variation of the expected rate of cultivated agricultural areas during the autumn-winter-spring period in Rio Grande do Sul (Figure 2). The NDVI values were low (0.46 to 0.52) during the development of crops (second half of April and the first one of May) and crescent (0.68 to 0.73) until August (for regions of Erechim, Passo Fundo, Ijuí and Santa Rosa) and September (0.70 for region of Caxias do Sul).

The maximum NDVI values occurred in near fortnights, but previous to the ones, in which the wheat, in most of the cultivated area was flowering (Table 1), indicating that the accumulation of green biomass reached a maximum value at the end of the vegetative growth. This result is consistent with the experiment of MOREIRA et al. (2005), in which the highest correlation coefficients between total dry matter of the aerial part of 20 wheat genotypes and NDVI occurred at flowering and early grain filling.

From August (September to the region of Caxias do Sul) to the second half of November, the NDVI values decreased, which can be attributed to the process of translocation of photoassimilates to the grains and plant senescence, which occurred from flowering and early grain filling. The low NDVI values in November (0.42 to 0.56) were related to physiological maturity and harvest of winter cereals. Increasing values of NDVI from December indicated the establishment and early vegetative growth of crops in spring-summer, especially soybeans (PINTO & FONTANA, 2010).

The methodology of crop masks was satisfactory for enhancing NDVI pixels with temporal variations of the index consistent with the stages of the development cycle of winter cereals obtained by EMATER/RS (Table 1). This result corroborates with the papers that used the methodology of crop masks in highlighting areas and monitoring the soybean crop (SANTOS, 2010), irrigated rice (KLERING, 2007) and winter cereals (JUNGES & FONTANA, 2009) in the states of Rio Grande do Sul and Paraná (DEPPE et al., 2007). However, it is important to note that the temporal evolution of NDVI reflects variations in green biomass, associated to crops for the production of grains and soil cover established in the area shown below.

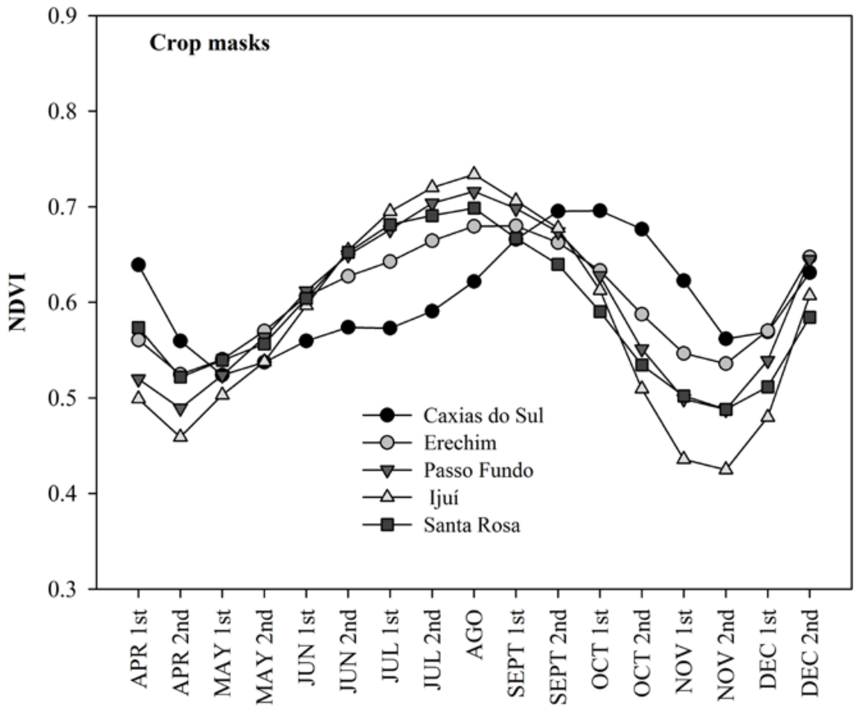

FIGURE 2. NDVI/MODIS average temporal profiles, from April to December, of agricultural areas identified by crop masks, in the regions of Caxias do Sul, Erechim, Passo Fundo, Ijuí and Santa Rosa, averages ranging from 2000 to 2008.

The differences between official and crop mask areas were in all cases (years and regions) lower than 10%. On average of the analyzed years, the difference ranged from 6,539 ha (2.2% of the official area) in Caxias do Sul region and 23,546ha (2.8% of the official area) in the Santa Rosa region (Table 2). The thresholds chosen were different for each region and year. In this work it was not possible to adopt a single threshold that generates, regardless of the year, a crop mask with an area equal to the area cultivated with corn and soybeans. The threshold values had coefficients of variation of 23% (Passo Fundo), 25% (Ijuí), 27% (Erechim), 28% (Santa Rosa) and 33% (Caxias do Sul) (Table 2). JUNGES & FONTANA (2009) also used different thresholds to generate masks cultivation of agricultural areas established during the period of autumn-winter-spring in the region covered by the Cotrijal Cooperative (13 municipalities within Passo Fundo region). In turn, FONTANA et al. (2007) and KLERING (2007) showed the existence of a single and stable threshold over the years to generate wheat crop masks in Australia and irrigated rice in Rio Grande do Sul, respectively.

TABLE 2. Thresholds employed in the generation of crop masks in the regions of Caxias do Sul, Erechim, Passo Fundo, Ijuí and Santa Rosa; area with corn and soybean crops (LSPA/IBGE) and difference between areas (official and delimited by thresholds), average, standard deviation and coefficient of variation from 2000 to 2008.

Region	Threshold			Area (ha) corn and soybeans (1)	Difference (2) (ha, %)
	Statistics	N°	Area (ha)		
Caxias do Sul	Average	0.16	306,682	300,143	6,539 (2.2)
	Deviation	0.05	42,992	45,863	-
	CV (%)	33.2	14.0	15.3	-
Erechim	Average	0.12	510,375	502,493	7,882 (1.6)
	Deviation	0.03	7,921	10,383	-
	CV (%)	26.8	1.6	2.1	-
Passo Fundo	Average	0.17	1,010,856	984,461	19,447 (2.0)
	Deviation	0.04	34,525	21,815	-
	CV (%)	22.9	3.4	2.2	-
Ijuí	Average	0.21	1,091,722	1,077,767	13,955 (1.0)
	Deviation	0.05	11,950	14,751	-
	CV (%)	25.34	1.09	1.37	-
Santa Rosa	Average	0.11	869,965	846,420	23,546 (2.8)
	Deviation	0.03	13,270	8,404	-
	CV (%)	28.01	1.53	0.99	-

(1) Corn and soybeans cultivated area , in accordance with the survey *Levantamento Sistemático da Produção Agrícola* (LSPA/IBGE), averages ranging from the years of 2000 to 2008. (2) Difference = area delimited by thresholds – corn and soybeans cultivated areas in hectares (ha) and percentage of the official area (LSPAIBGE), averages ranging from the years of 2000 to 2008.

Unsupervised classification

The unsupervised classification of NDVI/MODIS images based on temporal variation from April to December, considering the areas delimited by the crop masks, indicated five classes in each one of the regions (Figure 3).

The Class 1 NDVI/MODIS temporal profile, for all regions but Caxias do Sul, showed low NDVI values in the period from April to December. Biweekly average values ranged between 0.10 and 0.20 in Erechim, Passo Fundo and Santa Rosa regions, and between 0.03 and 0.13 in Ijuí region. In Caxias do Sul region, none of the classes presented temporal profile of NDVI/MODIS similar to the described profile. The small temporal variation of NDVI, coupled with the spatial location next to water bodies indicated that areas of Class 1 did not correspond to areas for crops. The average for the analyzed class 1 occupied 12,073ha in the Erechim region (equivalent to 2.4% of the average crop masks), 8,080ha in Passo Fundo region (0.8%), 13,860ha in the Ijuí region (1 3%) and 9,120ha in the Santa Rosa region (1.0%). In the Caxias do Sul region, the temporal profile of NDVI/MODIS of class 1 matched the profile of NDVI obtained by JACÓBSEN et al. (2003) for fields and dirty fields, which were characterized by increments of NDVI starting in August (regrowth in early spring).

The areas classified as belonging to class 2 were the ones which presented, in all regions, a temporal profile of NDVI more consistent with the expected evolution of the index of areas cultivated with winter cereals for grain production. For most of the municipalities of Erechim, Passo Fundo, Ijuí and Santa Rosa regions, the recommended period for the beginning of sowing of wheat is in May (CUNHA et al., 2001) and for Caxias do Sul region, in June. Thus, the NDVI values in the months of May and June should be low, indicating the stages of germination and early vegetative growth of winter cereals. The temporal profiles of Class 2 indicated properly this early stage of the crop cycle, in all regions, with minimum NDVI values near 0.40.

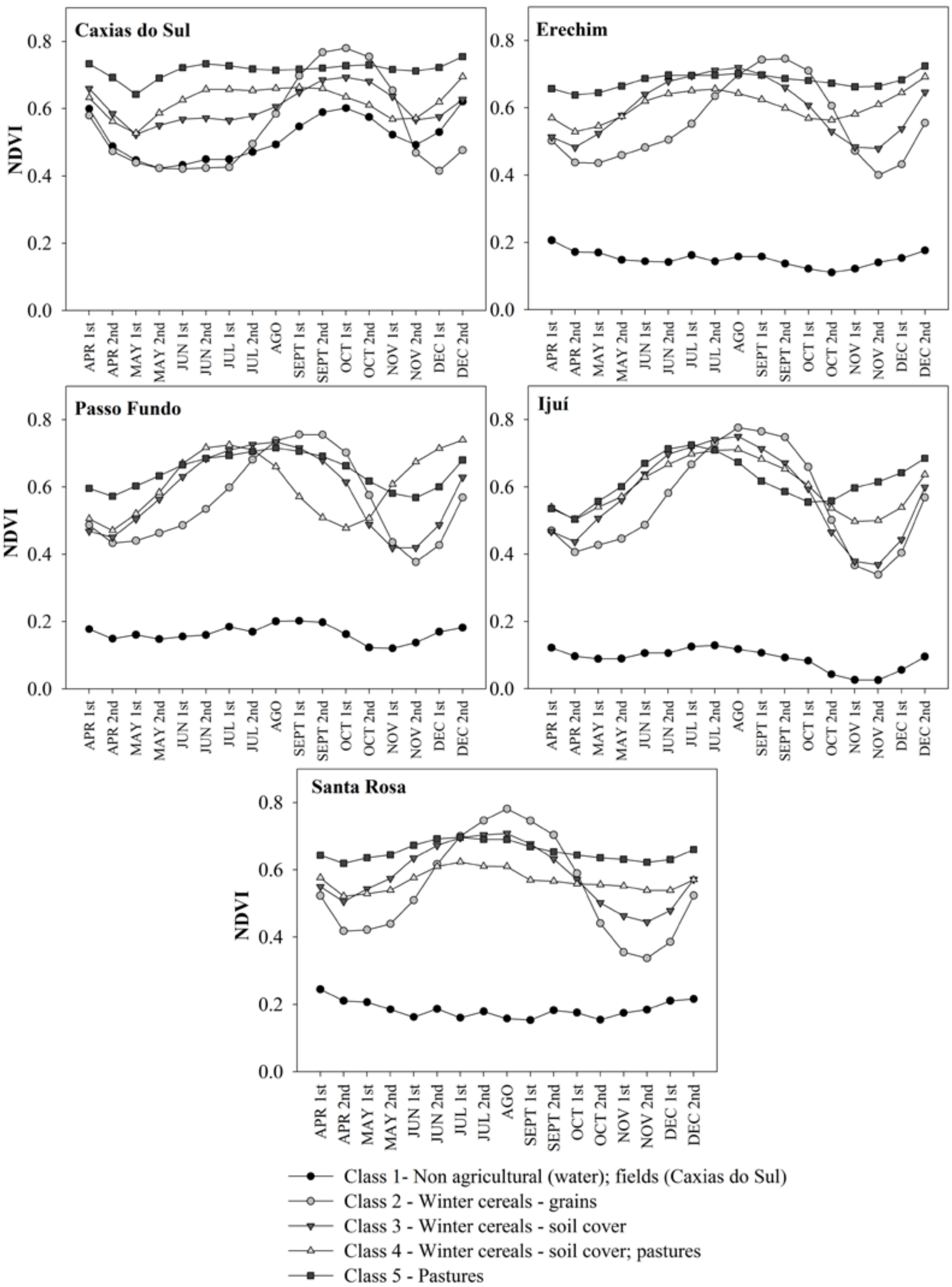

FIGURE 3. Average NDVI/MODIS temporal profiles, fortnights from April to December, of classes 1 to 5 (water bodies, pastures, winter cereals for grain production and for soil cover), in Caxias do Sul, Erechim, Passo Fundo, Ijuí and Santa Rosa regions; averages from 2000 to 2008.

On average of the evaluated the years, the maximum values of NDVI of class 2 occurred in August (Santa Rosa and Ijuí regions), first half of September (Passo Fundo and Erechim regions) and first half of October (Caxias do Sul region). The maximum values occurred in the previous fortnight corresponding to flowering (Table 1 and Figure 3). Analyzing the variation of NDVI, obtained with active remote sensor throughout the cycle of wheat cultivars subjected to different doses of nitrogen, VARIANI et al. (2010) found higher NDVI values in the previous stage to flowering: at booting (18 days before flowering), at the application of 40, 60 and 80kg ha^{-1} of N, and at heading (10 days before flowering) when doses of N in cover were 0 and 20kg ha^{-1} N (VARIANI et al., 2010).

From the flowering, the plants begin to translocate nutrients to grain formation. The grain filling depends on photosynthesis by green parts of the plant and the remobilization of nutrients previously stored in the stem, leaves and roots. The reduction of green biomass after flowering happens both from the remobilization of nutrients and foliar senescence. This reduction was observed in the average temporal profiles of Class 2, with a decrease of NDVI values from the half in which the wheat is in the grain filling (Table 1 and Figure 3). Most of the cultivated area of wheat is harvested until the second half of November (regions of Erechim, Passo Fundo, Ijuí and Santa Rosa) and first half of December (region of Caxias do Sul) (Table 1), consistent with the lower values of NDVI temporal profiles of class 2 observed in these fortnights.

The temporal profiles of Class 2 were considered consistent with the cycle of growth and development of crops established for grain production and reflected the expected differences between regions, regarding the evolution of the vegetation index given the different sowing dates (Table 1 and Figure 4). In this work, it was considered that the timing of monitoring of wheat crops is also representative of the cycle of other winter cereals grown for grain production during autumn-winter-spring in the study area. Relating NDVI to biomass accumulated in the aerial part of cultivars of wheat and barley, upon the issuance of the sixth leaf, GROHS et al. (2009) found that reflectance values did not differ between species and cultivars.

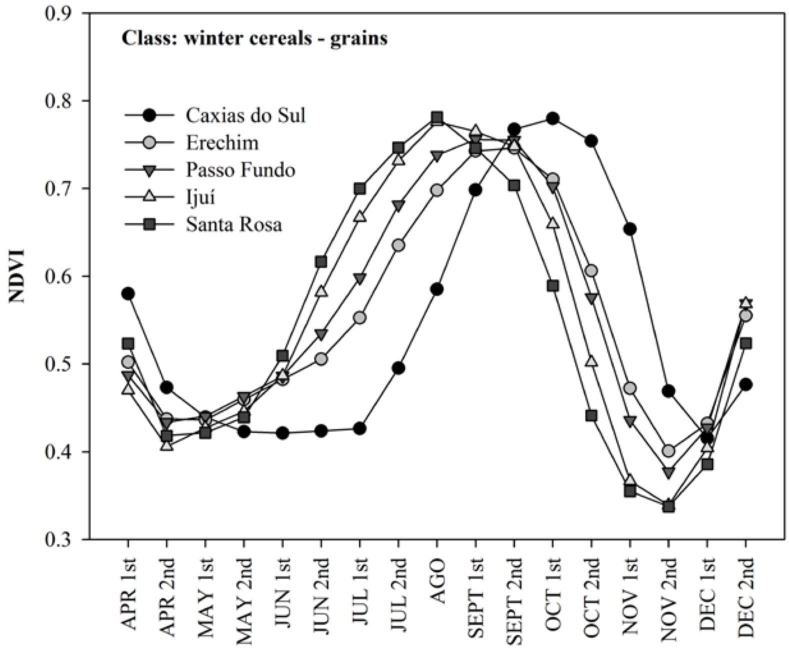

FIGURE 4. NDVI/MODIS average temporal profiles of class 2 (winter cereals for grain production), fortnights from April to December, in the Caxias do Sul, Erechim, Passo Fundo, Ijuí and Santa Rosa regions; average from 2000 to 2008.

The temporal profiles of areas classified as belonging to class 3 presented low values of NDVI in the second fortnight of April. These values started to increase in May (Figure 3). This temporal variation was also verified in the profiles of Class 2. However, in the profiles of Class 3, the values of NDVI in the month of May, and the rate of increment of NDVI in the first analyzed fortnights, were larger, comparatively to NDVI values of Class 2 in the same period. This result indicates that areas belonging to class 3 are characterized by the rapid biomass accumulation, characteristic of black oat crops. According to SILVA et al. (2006), the rapid initial development from black oat makes this the main species established for soil cover in the Brazilian southern region.

The NDVI/MODIS temporal profiles of the class 4 were similar to those of Class 3, especially in the first fortnights of the period (April and May) (Figure 3). In the other fortnights, however, they did not present a homogeneous temporal evolution, when comparing between the regions. In Passo Fundo region, the class 4 presented a decrease in the values of NDVI from the second fortnight of July and minimum values in the first one of October. This result can indicate that these areas are grown mainly with corn in the period of spring-summer. The increase of the values of NDVI from the first fortnight October indicates the beginning of plant development of corn and corroborates with the work of BERGAMASCHI et al. (2007), which showed that 50% of the area were sown on October 10th, in the region of Passo Fundo.

In the other regions, NDVI/MODIS temporal profiles of class 4, along with those of class 5, were not considered typical of croplands established for grain production (Figure 3). Given the smallest index variation in the period from April to December, these areas may indicate areas of pastures, even of black oat. Similar profiles were obtained by FONSECA et al. (2010) in areas of annual ryegrass. Higher NDVI values at the beginning of the ryegrass cycle, when compared to those observed in wheat, derive from the higher seed density per area employed in pasture establishment, while that the stabilization of NDVI values is associated to the area management (deletion of grazing in short periods or animal load decrease) (FONSECA et al., 2010).

The class 2 was denominated "winter cereals-grains" because the temporal profiles of NDVI/MODIS were representative of the temporal evolution of the vegetation index expected of agricultural areas for the production of grains. Moreover, the class 2 was adapted to the reference data (official area and points of control). The comparison between the official area cultivated with winter cereals and the area of the class of winter cereals, in each region, indicated that, in average of the years there were a difference of 16.8% in the Caxias do Sul region, 19.2% in Erechim, 12,2% in Passo Fundo, 17.1% in Ijuí and 11.5% in Santa Rosa region (Table 3). The largest difference values occurred in 2003, in Ijuí (classified area 38.5% lower than the official area) and in 2001 in Santa Rosa (classified area 45.2% higher than the official area).

TABLE 3. Official areas with winter cereals (LSPA/IBGE) and class 2 (winter cereals - grains) in Caxias do Sul, Erechim, Passo Fundo, Ijuí and Santa Rosa regions;, average, standard deviation and coefficient of variation from 2000 to 2008.

Region	Area (ha)			
	Statistics	Class	Official	Difference (ha, %) (1)
Caxias do Sul	Average	64,514	61,116	9,274 (16.8%)
	Deviation	13,615	15,437	-
	CV (%)	21	25	-
Erechim	Average	92,860	95,366	18,561 (19.2%)
	Deviation	4,318	22,048	-
	CV (%)	4.6	23.1	-
Passo Fundo	Average	230,153	227,781	27,402 (12.2%)
	Deviation	26,226	41,472	-
	CV (%)	11.4	18.2	-
Ijuí	Average	286,139	277,880	49,539 (17.1%)
	Deviation	49,235	51,647	-
	CV (%)	17.2	18.6	-
Santa Rosa	Average	191,626	183,713	19,548 (11.5%)
	Deviation	22,897	34,604	-
	CV (%)	11.9	18.8	-

(1) Difference = area delimited by class – official areas (LSPA/IBGE) with winter cereals in hectares (ha) and percentage of the official area (LSPA/IBGE), averages ranging from the years of 2000 to 2008.

The difference between the official (LSPA / IBGE) and classified areas as winter cereals for grain production can be attributed to the spatial resolution of the images and spectral mixture. Accordingly, in NDVI/MODIS images, crops winter cereals below the minimum area captured by the sensor (6.25ha) may not have been identified. The non-uniformity of most of the images taken from the environment usually results in a spectral mixture, i.e. the spectral response of the pixel is the result of the combination of the spectral responses of the targets that comprise the pixel. The spectral mixture restricts the application of digital classification of images based exclusively on the spectral behavior (PONZONI & SHIMABUKURO, 2010). In this work, the morphological and spectral similarities of winter cereals may have hindered the identification (classification) of the correct pixel. Furthermore, the official estimates of cultivated areas are obtained by applying questionnaires, quite a subjective methodology which does not allow the evaluation of any reporting errors.

The temporal profiles of NDVI/MODIS, obtained from the control points in the seasons of 2006 and 2010, were similar to the temporal profiles of the winter cereals class for grain production of Passo Fundo region (Figure 5). In 2006, the temporal profile of wheat crops was similar to the profile of the class, especially from April to the second half of July. The temporal profile of wheat crops showed decreased values of the index in August and September. As the temporal profile of the winter cereals (grains) class indicated in Passo Fundo region, increasing values of NDVI would be expected until the first half of September. The lower values of NDVI in August and September can be related to regional frosts in Passo Fundo in the 2006 (JUNGES & FONTANA, 2009).

Since, in this work, the unsupervised classification of images have been based on the time evolution of the NDVI for the period from April to December, a decrease in NDVI values in areas affected by frosts in August and September 2006 may have led to the classification of these as areas belonging to another class. Of the 77 points evaluated, 29 (37.6%) were located in class 2, 23 (29.9%) in class 3, 10 (12.9%) in class 5, five (6.5%) in class 4 and five (6.5%) in any of the classes. In 2010 the temporal profile of wheat crops was similar to the average profile of class 2 in Passo Fundo region, and all points (100%) were located in class 2.

It is noteworthy that the verification of consistency between profiles was performed considering wheat crops located in Passo Fundo region and reduced number of points (especially in 2010). The purpose of this stage of the research was to indicate the potential use of the methodology in the differentiation of cultivated agricultural areas, during the autumn-winter-spring period in the state of Rio Grande do Sul, Brazil, with species similar in morphology and phenology. The sample of cultivated areas, in adequate numbers to represent the variability of winter cereal crops established in the northern region of Rio Grande do Sul, can generate information that contributes to the improvement of this methodology, in order to reduce the difference between areas (classified and official), increase the accuracy of unsupervised classification and eventually serve as the basis for supervised classification of NDVI/MODIS.

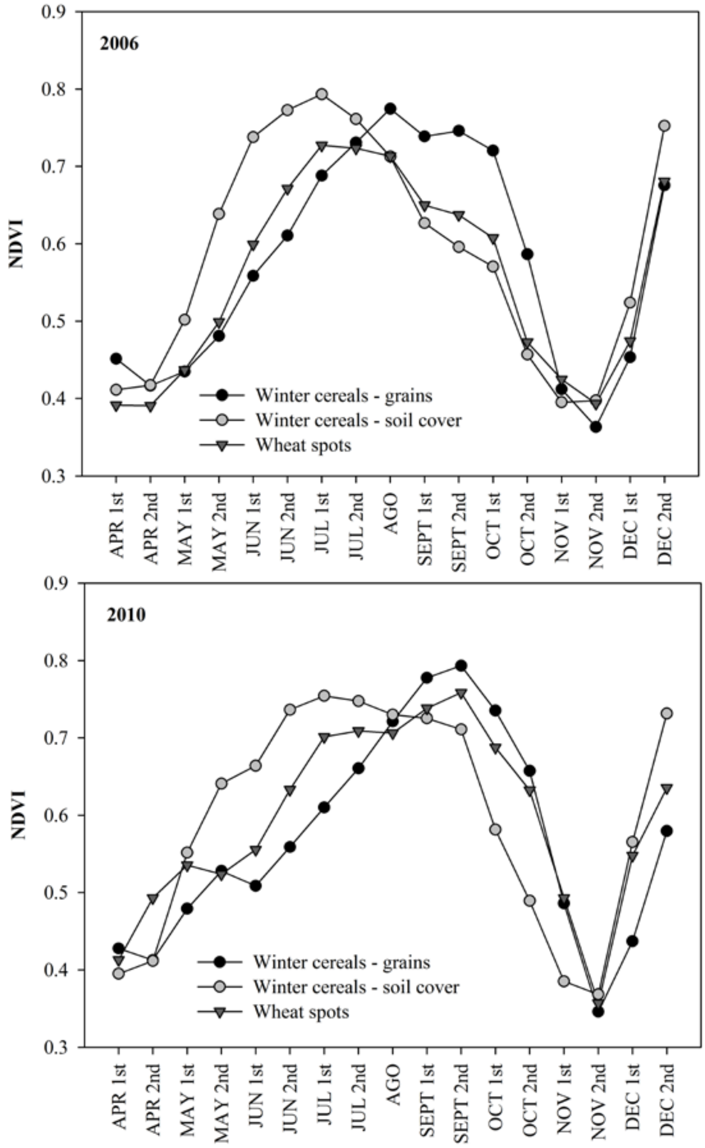

FIGURE 5. NDVI/MODIS temporal profiles of classes 2 (winter cereals for grain production) and 3 (winter cereals for soil cover) and of wheat crops in Passo Fundo region in 2006 and 2010.

CONCLUSION

The unsupervised classification of agricultural areas identified by crop masks, allowed discriminating agricultural areas established during the autumn-winter-spring period, in the analyzed regions. The multitemporal study was adequate to distinguish agricultural areas planted with winter cereals for grain production or ground cover and pasture. The collection of control points, in greater numbers and covering the whole wheat producing region, is necessary to verify the accuracy of the classification that was carried out.

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