AGROCLIMATIC ZONING OF CRAMBE AND BEAN FOR THE BACIA DO ALTO PARAGUAI – MT, BRAZIL

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Abstract

The economic activities of the Pantanal, were directly influenced by the periodic flooding process. Therefore, it became highly necessary to diversify the economic output of this region, especially in the area of agriculture. An expansion process is thus taking place in the Upper Paraguay River Basin. This study, therefore, aims at performing zoning for cultivation of the Crambe and common bean in the Mato Grosso portion of the Upper Paraguay River Basin. This research was conducted in the University of Mato Grosso - UNEMAT Campus of Tangara da Serra - MT. Data on the temperature and precipitation from 38 meteorological stations were provided by the National Institute of Meteorology - INMET, Forecasting Center Weather and Climate Studies - CPETEC and the Secretary of State and Environmental Development - SEDAM / RO. For the Crambe seeding culture done without utilizing the irrigation systems after the time 9, increases the risk of cultivation failure. In light of this fact it becomes evident that the lack of water is the main limiting factor for cultivating Crambe in the area under study. However, in general, most of the area available in the Upper Paraguay River Basin is able to sustain bean cultivation during all the sowing dates studied. Sowing Crambe from the first to the seventh day of the ten-day period is acertained as good for the fullest extent of the Upper Paraguay River Basin, whereas for the bean this period stretches until the ninth or ten-day period.

Keywords: Geostatistics. Kriging. ISNA.

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Resumo

Zoneamento agroclimático do crambe e do feijoeiro para a bacia do alto Paraguai – MT, Brasil

As atividades econômicas desenvolvidas no pantanal são diretamente influenciadas pelo processo de inundação periódica. Desta forma torna-se imprescindível a diversificação da produção econômica desta região principalmente quando se trata da agricultura que encontra-se em processo de expansão na Bacia do Alto Paraguai. Sendo assim este trabalho tem por objetivo realizar o zoneamento para as culturas do Crambe e do feijoeiro comum para a porção mato-grossense da Bacia do Alto Paraguai. A presente pesquisa foi desenvolvida na Universidade do Estado de Mato Grosso – UNEMAT no Campus de Tangará da Serra – MT, utilizou-se de dados de temperatura e precipitação de 38 estações meteorológicas cedidos pelos: Instituto Nacional de Meteorologia – INMET, Centro de Previsão do Tempo e Estudos Climáticos – CPETEC e Secretaria de Estado e Desenvolvimento Ambiental – SEDAM/RO. Para a cultura do Crambe a semeadura sem a utilização de sistemas irrigados após a época 9 aumentam o risco do insucesso do cultivo. Tendo em vista que o déficit hídrico é o principal fator limitante para o cultivo do Crambe na região estudada. Para o feijoeiro de maneira geral, a maior parte da área disponível da Bacia do Alto Paraguai é apta ao cultivo do feijoeiro em todas as épocas de semeadura estudadas. A semeadura do Crambe do primeiro até o sétimo decêndio do ano é considerada apta em toda a extensão da Bacia do Alto Paraguai em quanto para o feijoeiro este período se estende até o nono decêndio.

Palavras-chave: Geoestatística. Krigagem. ISNA.

INTRODUCTION

The Brazilian Pantanal is unique because of its intrinsic features when compared with the other parts of the world. Completely embraced within the Upper Paraguay River Basin, the Brazilian Pantanal covers an area equivalent to 363,000 km², of which the state of Mato Grosso ocuupies approximately 47% (SEPLAN, 2010).

The flood plains support the development of several economic endeavors, especially those of livestock, fisheries, tourism and agriculture, chiefly for subsistence. All the activities cited above are directly influenced by seasonal flooding of the plain, a characteristic peculiar to the Brazilian Pantanal. Keeping this natural dynamic in perspective, it becomes necessary to diversify the economic output, so as to ensure some means of income for the Pantanal populace, controlling the risks caused by the vagaries of the climate and the market, thus ensuring the development of the region and the maintenance of the wealth afforded by this natural source of invaluable biodiversity.

Family farming, according to Guimarães et al. (2011), has a fundamental part to play in the municipalities, as it is essential for the sustainable economic development of the region; however, their significance is limited by government programs which are not involved in developing family agribusinesses, the commonest producers of fresh produce.

In light of this, studies that enhance the endeavors prevealent here and facilitate the incorporation of new crops in the region are vital to the maintenance and better growth of the wetlands. The populations in the municipalities of the Upper Paraguay River Basin practice subsistence activities such as growing banana, cassava and common beans. Beans, in particular, forms an essential protein source for food. Due

to the significance of this crop culture for the region, bean zoning in the basin becomes an important means for families who inhabit and cultivate in the Basin. This process enhances the decision-making related to sowing times and improves the production system, while reducing the climate-induced production risks.

As this crop is a new culture and still in the adaptation phase in the state budget, it appears to be a potential crop for the region. The inherent characteristics of the crop are its tolerance to the climatic conditions of the region, and its water requirements (150 to 200 mm) until the full flowering phase (PITOL, 2008), and even a high early in your cycle (JASPER et al., 2010). As a result of these unique characteristics relating to the variable climatic factors, Crambe seems to be a good potential alternative as a second crop in the state of Mato Grosso and other regions of the Midwest, South and Southeast of Brazil (PITOL et al., 2010).

The IPCC studies (2007) indicate that Brazil has been experiencing climatic changes, and the same changes taking place in the state have augmented the risk of yield loss. The environmental factors such as excessive rainfall in short periods and high temperatures interfere directly with the planning and decision making. Therefore, new studies are being conducted to reduce the risk of losses in the production system; one way of doing this is by the introduction of new crops, which can minimize such risks and increase the possibilities of new markets in the agricultural sector.

In the context of this dynamic, the spatial interpolation of climate data and the importance of the crop with respect to the studies on agro-climatic suitability, as well as the variability of the hydrological regimes must be considered. Based on the results, Kriging has been shown to be the best among all the interpolation methods used (MELLO et al., 2003; VIOLA et al., 2010). In the basic work done by Farias et al. (2001), the authors showed that for soybeans during the drought periods there was the most demand for the introduction of the methods of interpolation and geostatistics, water balance and estimates of the water requirement satisfaction index - ISNA.

Thus, the aim of this researcher was to prove that the zoning of the agroclimatic cultures of Crambe and common bean could be based on the water requirement satisfaction index for the Mato Grosso portion of the Upper Paraguay River Basin.

MATERIAL AND METHODS

This research study was performed at CEPEDA (Center for Research, Studies and Agri-Environmental Development), in the Agrometeorology Laboratory, on the campus of Tangara da Serra - MT State University of Mato Grosso - UNEMAT.

To focus on the main objective of this study, we used the data from ten-day periods of temperature and precipitation recorded from 38 meteorological stations found in Mato Grosso and the regions close to the State for the possible interpolation and data analysis for the Upper Paraguay River Basin. The data were collected from the stations of the National Institute of Meteorology - INMET, Prediction Center Weather and Climate Studies - CPETEC and Secretary of State and Environmental Development - SEDAM / RO, as well as from those provided by the Agritempo site of the Brazilian Agricultural Research Corporation - EMBRAPA Computer agriculture, which have a minimum storage of 12 years of observed data. In order to organize the data, check for consistency and fault fills the CLIMATE software was used (Faria et al., 2003).

After processing the weather data the sowing time and Water Requirement Satisfaction Index - ISNA were determined for each crop according to the methodology adapted by Rolim, Sentelhas and Barbieri (1998) for ten days 1-12, and considered

Crambe and the common bean for the second crop in Mato Grosso. The indices thus generated were classified based on the methodology proposed by Farias et al. (2001) in which ISNA unable = <0.55; Restricted = 0.55 <Isna <0.65 and Apt = ISNA> 0.65, and compared to the critical stage of the crop (flowering / grain filling) for each sowing date. The ISNA values were determined for the three water capabilities available, viz., 30, 50 and 75 mm for the Upper Paraguay River Basin.

While the Pantanal includes areas that flood all the time over the years, zoning for the non floodplains of the municipalities found wthin the basin under study was accomplished (Figure 1). Thus, it disregarded the entire city of Barão Melgaço, 59% of Caceres, 29% of Curvelândia, 42% of Itiquira, 3% of Lambari D'Oeste, 21% of Nossa Senhora do Livramento, 83% of Poconé, 3% of Porto Estrela, 19% of Rondonópolis and 77% of Santo Antonio do Leverger. This represents an area of approximately 55,451 km², which is a little over 30% of the Upper Paraguay River Basin in the state of Mato Grosso. Also, the sum of the areas suitable for urban areas and those for reserves and permanent preservation was reduced.

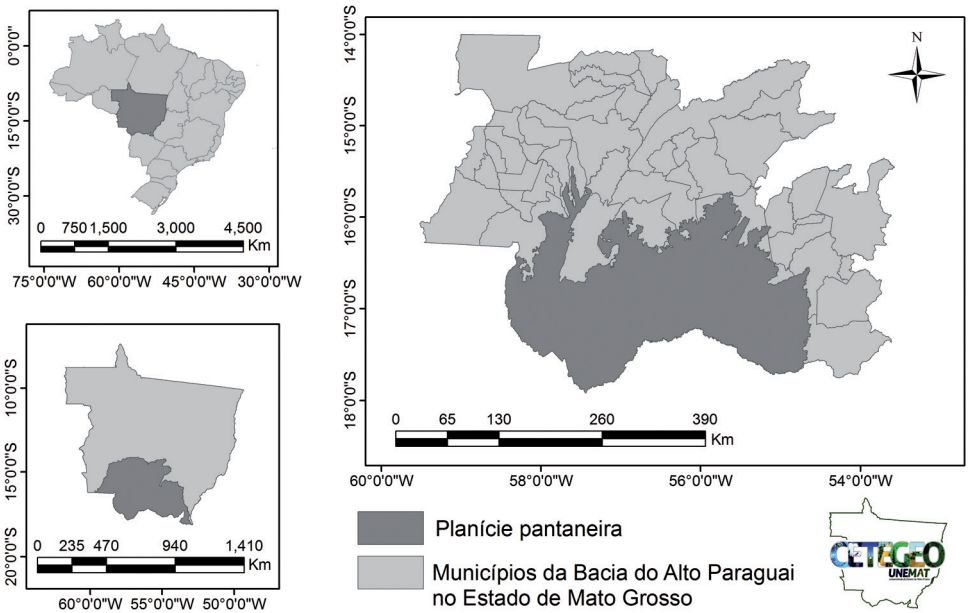

Figure 1 - Location of the Upper Paraguay River Basin - MT, 2014

The ISNA values were calculated spatially with the weather stations being considered as a reference, and then fitted as a semivariogram for each season. Finally, the models that presented the best fitting were selected, in which one of its parameters showed the spatial dependence (GDE). Dalchiavon et al. (2012) classified the GDE as follows: DGE <20% - very low spatial dependence; GDE 20% <40% - low dependence; GDE 40% <60% - average dependence; GDE 60% <80% - high dependence and 80% GDE <100% - very high dependence. According to the authors, the greater these indices the greater the reliance on the variable they indicate, relative to the distance.

After the data and the indexes were entered into the ArcGIS software, version 10.0TM, ESRI, in which the ordinary Kriging from certain coefficients were incorporated into the semivariogram settings. The maps with fitness classes for the Upper Paraguay River Basin, Mato state Grosso were generated. The maps for each time span in their CADs (30, 50 and 75 mm) were cut and put togehter to form a single map representing the three CADs, enabling the interpretation of the information generated.

RESULTS AND DISCUSSION

The ISNA values for the different CADs in both the crop cultures studied revealed similar behavior over the ten day-period. It is well known that the standard deviation on average is lower in the first ten-day period and this is influenced by the increased precipitation (Figure 2). For the prior ten-day spans when the rainfall index is lower, the standard deviation is greater. This is justified by the fact that the extra length of the concentrated dry season throughout the Mato Grosso, due to the movement of air masses over the active state, produced a greater variability in the average rainfall, resulting in a higher randomness of the data and thus increasing the deviation in the data. According Marcuzzo et al. (2011), the state of Mato Grosso has intrinsic features of vegetation and relief which increase the variability and distribution of rainfall in the state.

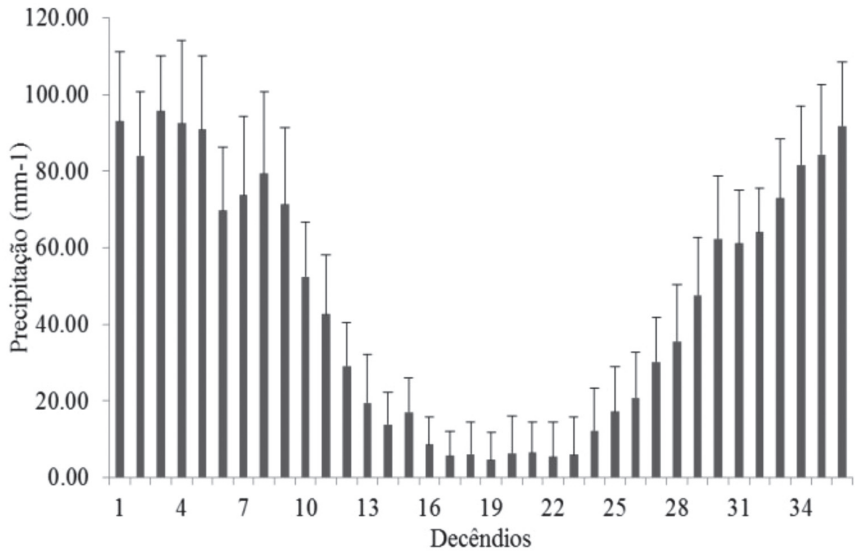

Figure 2 - Precipitation and standard deviation for ten days for the state of Mato Grosso

CRAMBE

The ISNA values for Crambe in CAD 30, from the first to seventh ten days show averages of above 0.83 and standard deviation below 0.14. This does not represent a spatial variability considering the three fitness classes; the same is noted for DAC 50 and 75, as well as for the first ISNA. The mean values are always found to be higher than 0.88 with a standard deviation less than 0.11; however, the second ISNA average values are higher than 0.91 with the standard deviation below 0.09. This enables the adjustment of the semivariograms and consequently the Kriging to generate the suitability maps. Thus, the seeding of Crambe across the upper Paraguay basin has been concluded as being suitable for ten-day periods of 1 to 6 for the DAC 30, from 1 to 7 for the DAC 50 and 1 to 8 for the DAC 75 (Table 1).

Table 1 - Water Requirement Satisfaction Index of the average values (ISNA) and standard deviations (SD) for the water storage capacity in the soil of 30, 50 and 75 mm, for ten-day periods 1-12 for the state of Mato Grosso

Ten-day	ISNA (CAD 30)		ISNA (CAD 50)		ISNA (CAD 75)	
periods	Average	DP	Average	DP	Average	DP
1	1.00	0.0140	1.00	0.008	1.00	0.006
2	0.99	0.0253	1.00	0.016	1.00	0.011
3	0.98	0.0497	0.99	0.035	1.00	0.015
4	0.98	0.0733	0.98	0.055	0.99	0.043
5	0.94	0.1120	0.97	0.086	0.98	0.067
6	0.90	0.1248	0.94	0.102	0.95	0.079
7	0.83	0.1338	0.88	0.108	0.91	0.089
8	0.74	0.1523	0.80	0.126	0.84	0.105
9	0.65	0.1734	0.72	0.158	0.79	0.135
10	0.54	0.1982	0.63	0.191	0.70	0.164
11	0.46	0.2351	0.54	0.201	0.63	0.179
12	0.37	0.2365	0.48	0.221	0.57	0.195

Table 2 lists the coefficients of the semivariograms and the adjustments, the adjusted models, number of pairs in the first Lag, nugget effect, range and degree of spatial dependence (GDE).

Table 2 - The coefficients of the semivariograms adjusted for CADs 30, 50 and 75 mm and their sowing dates for the state of Mato Grosso

CAD	Ép.	Mod.	*Lag*	Nugget (Co)	Landing (Co+C)	Range (km)	GDE (%)
	8	Exp.	76	0.00900	0.02460	960	63.4
	9	Gau.	78	0.01410	0.03960	1200	64.4
30	10	Gau.	80	0.01760	0.04640	1040	62.1
	11	Gau.	76	0.02280	0.07380	1176	69.1
	12	Exp.	90	0.02400	0.06000	1028	60.0
	8	Exp.	80	0.00580	0.01840	1117	68.5
	9	Gau.	80	0.01110	0.03180	1118	65.1
50	10	Gau.	80	0.01440	0.04640	1118	69.0
	11	Gau.	80	0.02040	0.05160	1118	60.5
	12	Exp.	76	0.01600	0.06200	1200	74.2
	8	Esf.	102	0.00460	0.01240	885	63.0
	9	Gau.	82	0.01140	0.02280	1260	50.0
75	10	Gau.	76	0.01230	0.03510	1092	65.0
	11	Esf.	76	0.01240	0.04000	1092	69.0
	12	Exp.	102	0.01480	0.04280	980	65.4

Semivariograms were adjusted only for those periods which revealed spatial dependence, i.e.times when no pure nugget effect was evident, which implies when the current sample was not significantly the sampled area, and Kriging could not be performed, the spatial continuity could not be found.

Figure 3 shows the semivariogram models adjusted for the ISNA values of the CADs 30, 50 and 75 mm in the Mato Grosso state. According to Dalchiavon et al. (2012), in all the CADs, for all the times, the ISNA values revealed great spatial dependence except for season 9 in CAD 75 which showed an average spatial dependence.These results imply a good fit of the data, and Kriging is thus possible, as shown in figure 3.

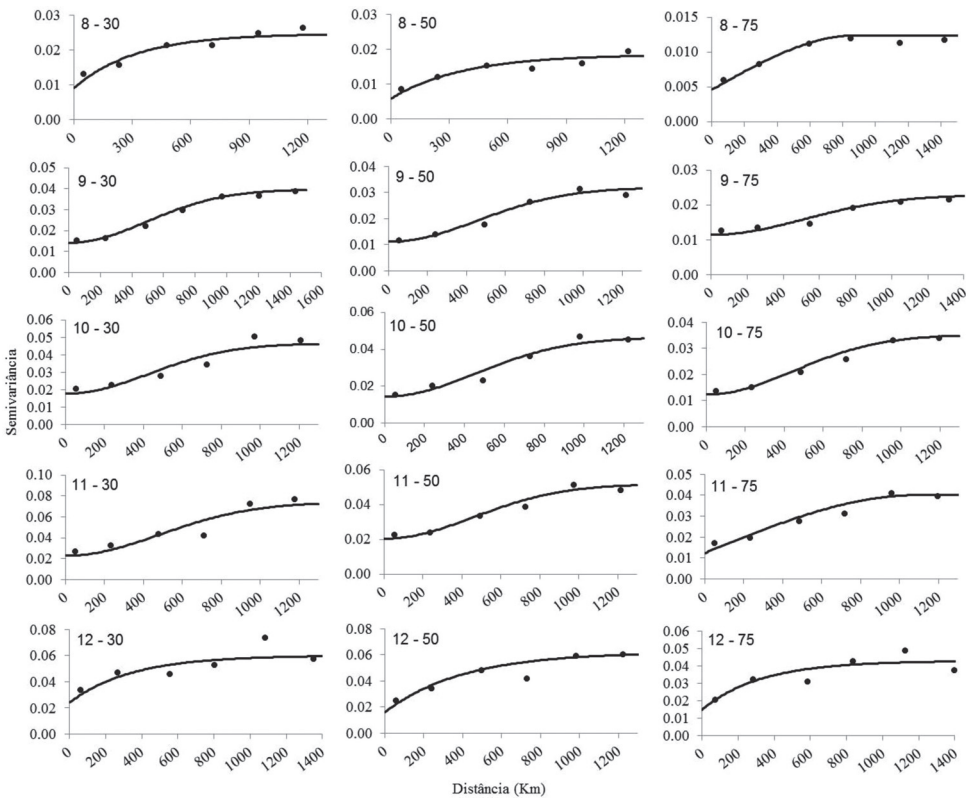

Figure 3 - The semivariograms adjusted with the ISNA values for the Crambe culture at different times for CADs 30, 50 and 75 mm, for the state of Mato Grosso

Figure 4 Zoning of the water requirement satisfaction index for the Upper Paraguay Basin in the set times of the data, their sowing seasons and CADs of the basin soils.

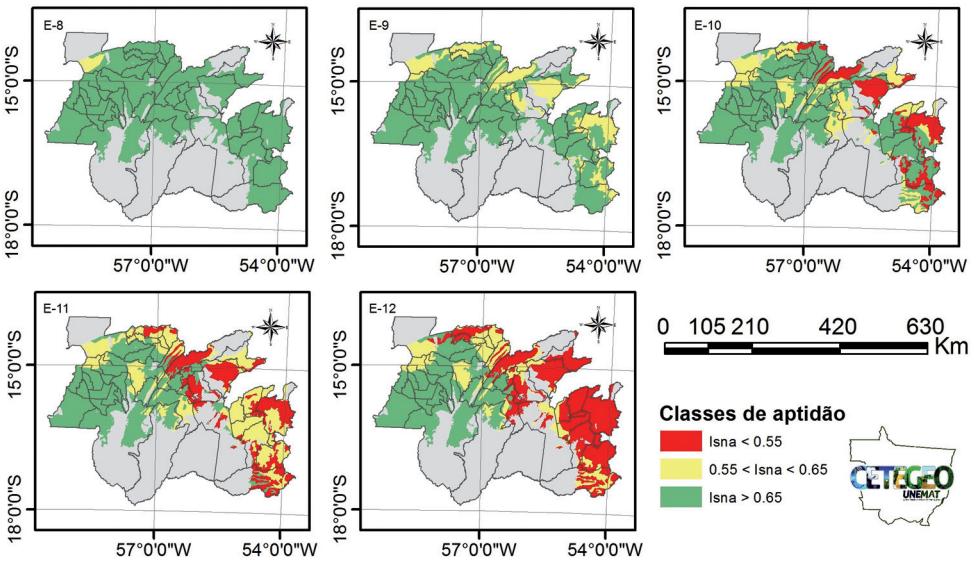

Figure 4 - Risk ratings of the ISNA Zoning and Crambe sowing in the Upper Paraguay River Basin for CADs 30, 50 and 75 mm

For sowing 8, about 98.6% of the Upper Paraguay River Basin available area is revealed to be capable of sowing Crambe, and only a fraction of the Tangara da Serra municipality had restricted cultivation, representing 24.2 % of the area. For sowing in season 9, about 80,775.9 km² (79.7% of the available areas of the Upper Paraguay River Basin) show fitness for seeding the Crambe. In fact, 19 of the 43 cities studied demonstrated this feasibility in their entire territory, including Araputanga, Arenapolis, Cáceres, Curvelândia, Denise, Figueirópolis D'Oeste, Gloria D'Oeste, Indiavaí, Jaciara, Jauru, Lambari D'Oeste, Mirassol D'Oeste, Nossa Senhora do Livramento, Nova Olímpia, Poconé, Porto Esperidião, Porto Estrela, Rio Branco and São José dos Quatro Marcos. Only one city showed a small disability area, accounting for less than 1% of the basin area.

Regarding the time 10 significant areas of disability for seeding Crambe are observed with about 15,100 km² constituting 14.9% of the basin area. The unfit areas include part of the Upper Paraguay municipalities (28.8%), Chapada dos Guimarães (74.4%), Cuiabá (28.8%), Dom Aquino (23.4%), Itiquira (27.4%) Juscimeira (6.4%), Nortelândia (19.5%), Nova Brasilândia (23%), Nova Marilândia (23.1%) Pedra Preta (36.6%), Poxoréo (54.2%), Rondonópolis (17.9%), Rosário Oeste (40.7%), Santo Antônio do Leverger (6.9%), São José do Povo (20.2%) and São Pedro da Cipa (60.9%). The areas suitable for sowing amount to approximately 66,000 square kilometers in total, mainly represented by the municipalities of Arenápolis, Curvelândia, Denise, Figueirópolis D'Oeste, Glória D'Oeste, Indiavaí, Jaciara, Mirassol D'Oeste, Porto Esperidião, Rio Branco and São José dos Quatro Marcos. These areas can fully support cultivation of the Crambe, while the restricted areas account for approximately 20,000 km².

For sowing in times 11 and 12, the 9 municipalities which continue to show fitness along the entire length are as follows: Curvelândia, Figueirópolis D'Oeste, Gloria D'Oeste, Indiavaí, Lambarí D'Oeste, Mirassol D'Oeste, Porto Espiridião, Rio Branco and São José dos Quatro Marcos. For that time period all the 11 suitable areas constituted approximately 46,000 km², while for time 12 it was only 42,000 km². With respect to the unsuitable areas for the time 12, nearly 38 825 km² were added, in which all the municipalities of Dom Aquino, Poxoréo, São José do Povo and São Pedro da Cipa were included in this class; for time 11 the total was 21,159 km².

It is evident therefore that the sowing time required the support of the irrigated systems after time 9, where there was a rise in the risk of cultivation failure, as water deficit was identified as the main limiting factor for growing Crambe in the study area.

The scenario produced by this zoning can be altered if the farmer desires to use the irrigation systems, thus reversing the restricted or even unsuitable areas mentioned above.

In general, most of the area of the Upper Paraguay River Basin that is available, is suitable for the cultivation of Crambe in sowing times 8, 9 and 10.

BEAN

For bean, the ISNA values in the different CADs showed that contemplating sowing during the first and eighth ten-day period was greater than 0.80, with standard deviations exhibiting the same behavior. This indicated a low variability in the study area and verifying their fitness was not possible by Kriging. Table 3 shows the ISNA values and standard deviation for the twelve ten-day periods of sowing in the three soil CADs in the basin.

Thus, the maps for the Upper Paraguay Basin are shown only for sowing times 10, 11 and 12 for CAD 30mm, and times 11 and 12 for CAD 50mm. All the other regions of the basin are considered suitable during the periods earlier than these dates, including for CAD 75 mm, except when the regions of the basin mentioned above where cultivation is restricted are flooded (Table 3).

Table 3 - Water requirement satisfaction index (ISNA) for the twelve ten-day periods of sowing and standard deviation (SD) for the three CAD studies during the twelve observation years

Ten-day periods	ISNA 30 mm		ISNA 50 mm		ISNA 75 mm	
	Average	DP	Average	DP	Average	DP
1	1.00	0.000	1.00	0.000	1.00	0.000
2	1.00	0.005	1.00	0.005	1.00	0.000
3	1.00	0.011	1.00	0.016	1.00	0.011
4	0.99	0.023	0.99	0.042	1.00	0.023
5	0.98	0.058	0.99	0.051	0.99	0.041
6	0.96	0.073	0.97	0.061	0.98	0.054
7	0.91	0.101	0.94	0.080	0.95	0.061
8	0.84	0.135	0.89	0.106	0.91	0.086
9	0.77	0.162	0.83	0.126	0.87	0.108
10	0.69	0.194	0.76	0.160	0.81	0.130
11	0.59	0.202	0.68	0.170	0.75	0.141
12	0.53	0.211	0.61	0.183	0.70	0.150

The values shown for the ISNA for the Upper Paraguay River Basin are similar to those for rainfall in that region, in which the values decrease significantly as the dry season proceeds. This behavior is probably due to the vegetation intrinsic to each state in each region. This increases the distribution of variability over the months, especially during lower accumulated periods (MARCUZZO et al., 2011).

Table 4 represents the coefficients of the constructed and adjusted semivariograms and the adjusted models, the number of pairs in the first Lag, nugget effect, range and degree of spatial dependence (GDE) for the bean crop in the various CADs and seeding seasons.

Table 4 - Coefficients of the semivariograms adjusted for CADs 30, 50 and 75 mm and their bean sowing dates for the state of Mato Grosso

CAD	Ép.	Mod.	*Lag*	Nugget (Co)	Landing (Co+C)	Range (km)	GDE (%)
	8	Esf.	82	0.00579	0.02099	615	72.4
	9	Esf.	80	0.00600	0.03330	962	82.0
30	10	Esf.	82	0.00840	0.04840	1044	82.6
	11	Esf.	80	0.01350	0.04900	1001	72.4
	12	Exp.	82	0.01600	0.05450	1110	70.6
	8	Esf.	80	0.00380	0.02120	1059	82.1
	9	Gau.	80	0.00900	0.03450	988	74.0
50	10	Esf.	80	0.01020	0.03714	1035	72.6
	11	Esf.	82	0.01345	0.04237	1114	68.3
	12	Esf.	82	0.01320	0.04174	1112	68.4
	8	Exp.	82	0.00104	0.00856	650	87.9
	9	Esf.	82	0.00300	0.01420	923	78.9
75	10	Gau.	76	0.00560	0.02180	876	74.3
	11	Esf.	80	0.00620	0.02580	1131	76.0
	12	Esf.	80	0.01050	0.02670	1066	60.7

According to the classification proposed by Dalchiavon et al. (2012) in times 8, 11 and 12 a high dependency is exhibited, whereas in times 9:10 a very high spatial dependence is evident, for CAD 30 mm. For CAD 50 mm the time 8 scores alone are very high, with the remaining high spatial dependence of the variable. Finally, for the CAD 75 mm, the same behavior is observed as for the 50 mm CAD, where, with the exception of the time 8 with very high dependency, all the other periods are classified as high dependent variable distance. The high spatial dependence values represent a good fit of the data, therefore the realization of Kriging and later zoning is possible.

Figure 5 shows the semivariograms adjusted to the ISNA values in the times of sowing and soil CADs, respectively. Among the models (spherical, exponential and Gaussian), the spherical and exponential stood out from the Gaussian, showing the best settings for the most part.

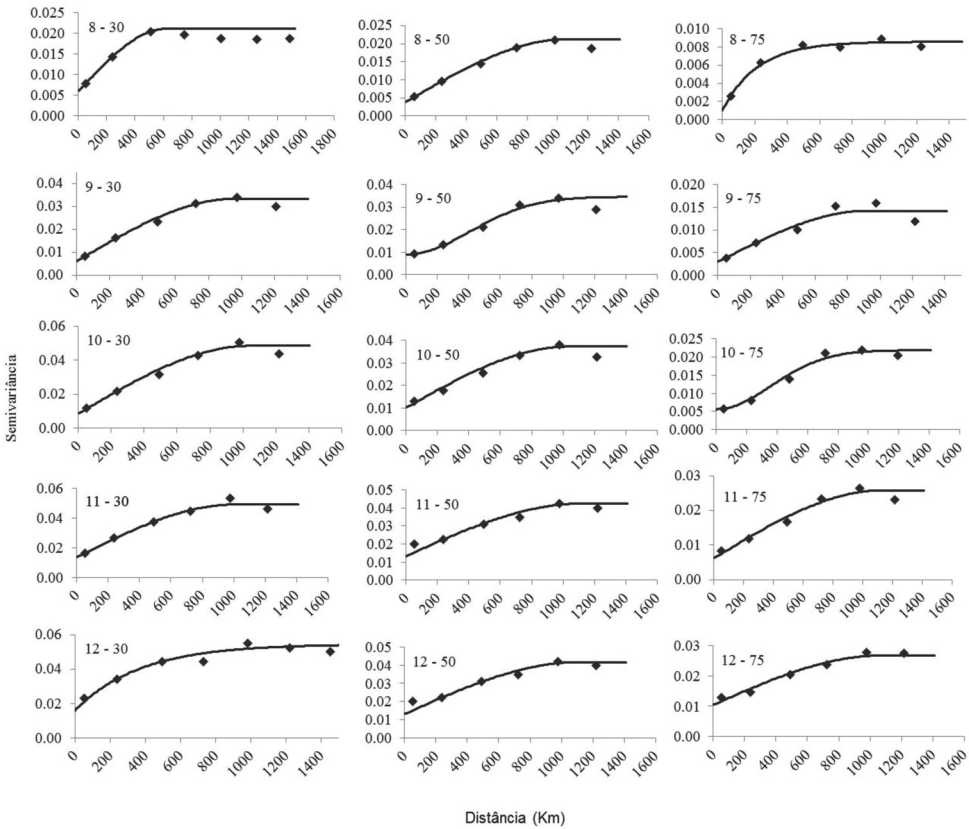

Figure 5 - Semivariograms adjusted to the ISNA values for the dry bean crop at different times for CADs 30, 50 and 75 mm, for the state of Mato Grosso

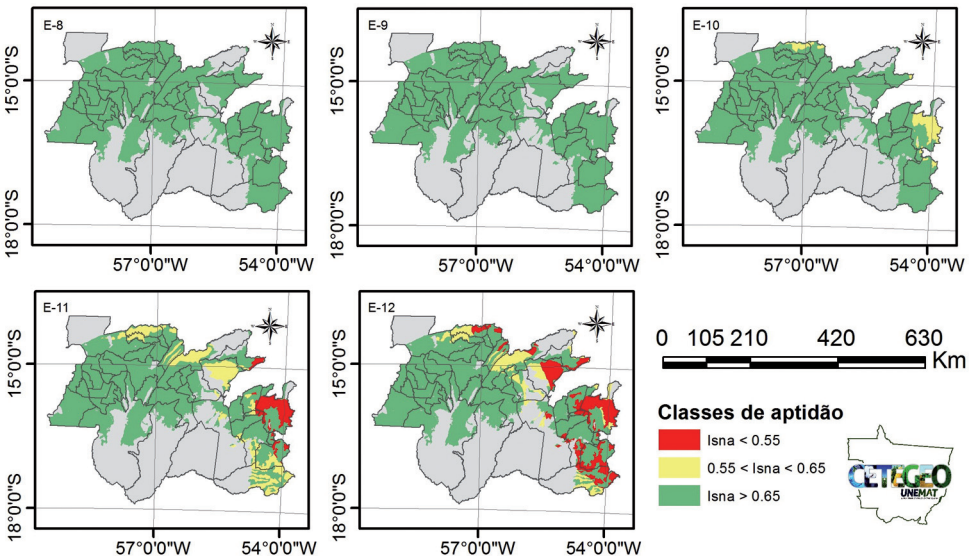

Figure 6 - ISNA Zoning and categories of sowing risk for the common bean in the Upper Paraguay Basin in CADs 30, 50 and 75 mm

Figure 6 reveals zoning of the water requirement satisfaction index for the Upper Paraguay River Basin in the set times of the data and their sowing seasons and CADs of the basin soils.

In the times of sowing 8 and 9 (Figure 6), the entire area available for the municipalities, with the exception of the urban areas of flooding or preservation, is able to support the bean cultivation in the rainfed system. It also takes into consideration the critical phase of the culture (i.e. flowering / grain filling). In the sowing season 10, about 96.11% of the available area of the basin is found suitable for cultivation. The restricted areas of cultivation include the towns of Nortelândia (15.67%), Nova Brasilândia (3.12%), Nova Marilândia (31.95%), Pedra Preta (5.07%), Poxoréu (43.07 %) and São José do Povo (18.10%), which altogether extend over an area of 3,943.03 km².

Considering sowing time 11, the areas observed unfit for cultivation represent a total of 4,475.05 km2 (4.71%). The unfit areas include the municipalities of Dom Aquino (6.13%), Juscimeira (6, 38%), Nova Brasilândia (17.77%), Pedra Preta (10.14%), Poxoréu (54.17%), São José do Povo (20.21%) and São Pedro da Cipa (23.85%). The next 13.77% area is restricted to cultivation (part of the Upper Paraguay municipalities, comprising Chapada dos Guimarães, Cuiabá, Dom Aquino, Itiquira, Juscimeira, Nortelândia, Nova Brasilândia, Nova Marilândia, Pedra Preta, Rondonópolis, Rosário Oeste, Santo Afonso, Santo Antônio do Leverger, São Pedro da Cipa and Tangará da Serra). The remaining 81.52% is considered suitable for cultivation. The evidence makes it very clear this time that the direction of risk reduction is from East to West, which goes hand in hand with the advancement of the water regime and the Pantanal areas.

Finally, in the sowing time 12 have an increase observed areas unsuitable for the common bean cultivation in the upland system. Currently, the 12.34% considered unfit for cultivation includes the municipalities cited in part for time 11, but to a larger

extent of unsuitable area. The restricted areas represent 9.36% and are situated in parts of the municipalities of Acorizal, Alto Paraguai, Chapada dos Guimarães, Cuiabá, Itiquira, Jangada, Nova Brasilândia, Nova Marilândia, Poxoréu, Rosário Oeste, Santo Afonso, Santo Antônio do Leverger and Tangará da Serra. The areas of the cities and other places are suited for the common bean rainfed crop.

If other cropping systems are considered like those being irrigated but having different cultural managements which emphasize the use of ground water, it may be possible to raise those crops in the restricted and unsuitable areas. However, it must be noted that in these areas the climate risk of cultivation failure is higher. In those specific areas, the prospect of bean sowing is recommended, so that risks are minimized.

In general, most of the area of the Upper Paraguay River Basin available is suitable to support bean cultivation in all the sowing dates.

FINAL CONSIDERATIONS

Crambe sowing during the first ten days of the year until the seventh is fully recommended to the utmost extent of the Upper Paraguay River Basin; for the bean this period is extended until the ninth and tenth days.

For Crambe, the sowing performed during times 8, 9 and 10, are recommended as suitable in most parts of the Upper Paraguay River Basin. For sowing from time 10, the municipalities located Northeast of the basin show some restriction and unsuitability, and the sowing inability extends to the Southwest.

The risk category for sowing bean also shows the Northeast to the Southwest trend, following certain characteristic movements of the air masses; however, it shows the unfit class for bean alone from the 11th ten days; therefore, the Crambe and beans are cultivars that can be utilized as good alternatives to rotate the second crop production system.

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