Original Research Article
Zoning of water deficiency risk for conventional cotton, in Mato Grosso

ABSTRACT

The agroclimatic zoning of cotton is a very important tool because it allows to establish the most favorable periods for its cultivation, when the environmental conditions are more propitious, in order to reduce agricultural activity risks. The objective of this work was to elaborate the zoning of the risk estimation of cotton productivity reduction in Mato Grosso, using the FAO method. Cultivars of precocious, medium and late cycles were considered, with four sowing dates (12/11, 12/21, 1/01 and 1/11) and three available water capacities (60, 140 and 200 mm). Results were specialized by ordinary kriging. The state southernmost regions are the ones with the highest reduction risk, due the lower precipitation in these places, and the sowing season 1 was the one with the lowest productivity reduction risk, and the late-cycle cultivar season 4 was the one that presented the highest reduction risk. Trough the validation of the obtained results, it can be considered that the methodology adopted in this work to verify the risk of a productivity decrease was efficient.

1. INTRODUCTION

Mato Grosso state is currently the largest cotton producer in the country, according to data from CONAB (National Supply Company), with production of 880.5 thousand tons in 2015/16 cotton crop [1].

In the state, precipitations occur in the spring-summer season, when agricultural activities are intensified, and precipitation anomalies can occur, resulting in dry day sequences during the rainy season, which interferes negatively in crop productivity [2].

Rainfall is one of the most significant and influential meteorological elements in environmental conditions, specific to the agricultural sector, playing a fundamental role in the development of agricultural crops and in final production [3]. Considered one of the factors that most influence cotton development, considering that, through the water deficit, there are significant reductions in growth, development, production per plant and consequently in final productivity, and that such severity depends on the stress duration and the stage of plants development when it occurs [4].

Climate risk zoning is an alternative used to establish more favorable periods for different crops, where environmental conditions are conducive to crop development. When sowing is carried out in periods in which climatic conditions are adequate to the crop needs, there is a reduction in losses risks due to deficit or water surplus at the critical stages of crop development [5].

Simulation models are used to study and define the most favorable sowing times for cotton cultivation in which there is no water restriction. A world-wide methodology to verify the effect of water deficiency on cotton productivity was advocated by FAO [6], where the

36 relative productivity decrease is estimated considering the relative evapotranspiration
37 reduction and a response coefficient.

38 Once sowing times are defined, with a lower risk of reduced productivity, it is possible to
39 define the favorable regions for conventional cotton cultivation, and zoning through data
40 interpolation and map generation. Considering the above, the objective was to elaborate the
41 zoning of the risk estimation of conventional cotton productivity considering different cycles,
42 sowing times and soil water storage capacity in Mato Grosso, as well as the validation of the
43 model used.
44
45 **2. MATERIAL AND METHODS**
46
47 The study area corresponds to Mato Grosso state, located in Center-West region of Brazil,
48 whose territory is 903,198,091 km^2 [7]. The success of agriculture and cotton in the cerrado
49 region has been driven by favorable climate conditions, flat reliefs, favoring agriculture
50 mechanization, programs to encourage the culture implemented by region states and,
51 specially, intensive use of modern technologies [8].

52 The daily temperature data (maximum, average and minimum), relative humidity, wind
53 speed and precipitation were obtained from National Institute of Meteorology (INMET).
54 Regarding precipitation data, these were obtained from National Water Agency (ANA). In
55 this study, stations that had a minimum of 10 years of observation were used, totaling 15
56 conventional INMET stations and 169 ANA rain stations.

57 Data were organized in tens and analyzed to verify their homogeneity, data organization in
58 tenties consists of dividing the daily values into 36 groups with ten days each, disregarding
59 the periods in which observations failed, so that the occurrence or not of interruptions
60 (failures) in the climatological series was what determined which tests would be applied.

61 For time series that did not present interruption, Wald-Wolfowitz test was applied for
62 randomisation. This test application consisted of determining the series median, then
63 comparing the values sequence number above or below the median, in the observations
64 chronological order, at the 5% significance level. When series presented an interruption,
65 Wald-Wolfowitz test was used for two samples, whose application consisted in arranging the
66 data in ascending order, identifying the sequences number in which data appeared before or
67 after the interruption [9, 10, 11].

68 The nonparametric Kruskal-Wallis test was applied for series with two or more interruptions,
69 which was used to test if a samples set comes from the same distribution, at a significance
70 level of 5%. Trough this test, it is possible to test the null hypothesis that all populations have
71 equal distribution functions against the alternative hypothesis that at least two of the
72 populations have different distribution functions [12].

73 The interruptions that occur in the climatological series do not make them unfeasible, failing
74 to fill in, since it is not possible to estimate missing data without changing the frequency
75 distribution dispersion scale [13].

76 After verification of the data homogeneity, the potential evapotranspiration (ETo) (mm d^{-1}) for
77 the 15 INMET stations was calculated, using the equation proposed by [14], which considers
78 the variables: radiation at the top of the atmosphere, maximum, average and minimum daily
79 temperature. This equation is an alternative for estimating potential evapotranspiration in
80 sites with limited data availability, according to [15], and is expressed by the following
81 equation:

82

$$ETo = 0{,}0023 \, (T_{med} + 17{,}8) \times (T_{max} - T_{min})^{1/2} \, \times \, Ra \, \times 0{,}408$$

83

84 Where:

85 *ETo*: evapotranspiration reference potential, in mm day^{-1};

86 *Tmed*: average daily temperature in ºC;

87 *Tmax*: maximum daily temperature in ºC;

88 *Tmin*: minimum daily temperature in ºC;

89 *Ra*: radiation at the top of the atmosphere, in MJ m^{-2} day-^{1}.

90

91 As the number of stations with only precipitation data (169) was often higher than that of
92 stations with data to calculate potential evapotranspiration (15), the ANA rainfall series were
93 grouped by INMET meteorological station. For this grouping, Thiessen polygon method was
94 used, in order to obtain estimates of actual and maximum evapotranspiration for the 184
95 stations. This method consists of connecting the stations by straight sections, drawing lines
96 perpendicular to these stretches, passing through the middle a line connecting the two
97 stations. The perpendicular lines are then extended until they find the others [16].

98 Climatological water balance was performed on a decendial scale, and only precipitation
99 data with 75% probability were used, that is, precipitation values were used with 75%
100 confidence that an event corresponding to that or higher occurred. For an empirical
101 determination of rainfall probability, it is enough that rainfall values are organized in a
102 decreasing manner, together with the probability in ascending order and the following
103 equation was used, where: *P* = probability; *M* = order number of appearance of the value in
104 the ordered series; *N* = number of data in the series.

105

$$P = \frac{M}{N + 1}$$

106

107 The use of rain probability values is important due the variation in distribution over the years,
108 so for the purposes of agricultural activities planning, it is recommended to use the rainfall
109 frequency distribution, which is the case of this work, [17]. In addition, it is important to note
110 that the probability of precipitation is higher than precipitation.

111 The maximum evapotranspiration (ETm) was estimated by the following equation, according
112 to [6]:

113

$$ETm = ETo \; x \; Kc$$

114

115 Where:

116 *ETo*: potential evapotranspiration (mm day^{-1});

117 *Kc*: coefficient of culture.

118

119 The values of Kc used, varied according to the cotton crop cycle phases, being equal to 0.5
120 in initial development, 0.8 in growth, 1.05 in the reproductive period, and 0.8 at the end of
121 the cycle, as proposed by [6].

122 For water balance preparation, an early-cycle cultivar (150 days), one medium-cycle (160
123 days), and one late-cycle cultivar (170 days) was considered. Four sowing seasons were
124 simulated for each cultivar (11/12, 21/12, 01/01 and 11/01). The sowing dates were selected
125 according to Embrapa recommendations, following the sowing window of the cotton crop for
126 Mato Grosso state [8].

127 In water balance calculation, the estimation of soil water storage and the "accumulated
128 negative" was done using the First Order Potential equation [18], which considers the
129 fraction p, that is, a water fraction, as a function of the AWC, that is readily available in the
130 soil for extraction by plants without impairing growth, and for this the following conditions are
131 taken into account [19]:

132

133 When *AWC* $\times$ *(1 − p) < ARM ≤ AWC*, that is, in the humid zone.

134

135 $ARM \; = \; AWC \; - \; L$

136

137 When *0 < ARM ≤ AWC* $\times$ *(1 − p)*, that is, in the dry zone.

138

$$ARM = AWC * (1 - p) \; e^{\left[\left(p - \frac{L}{AWC}\right) * \left(\frac{1}{(1-p)}\right)\right]}$$

139

140 Where:

141 *AWC:* available water capacity (mm);

142 *p*: fraction of available water (mm);

143 *ARM*: soil water storage (mm);

144 *L*: accumulated negative (mm).

145

146 Available water fraction values available can be seen in Table 1, according to [6]. From
147 these values, a regression was generated so that it was possible to determine the values of
148 the fraction p at each site as a function of potential evapotranspiration.

149

150 Table 1: P fraction of soil water for cotton and maximum evapotranspiration

ETm mm/day	2	3	4	5	6	7	8	9	10
Fraction *p*	0,875	0,8	0,7	0,6	0,55	0,5	0,45	0,425	0,4

151 Source: [6].

152

153 General values for the available water capacity (AWC), as a function of soil texture, were 60,
154 140 and 200 mm [6]. Trough the climatic water balance, it is determined the water
155 accounting of a determined soil layer, defining the dry periods (water deficit) and wet (water
156 surplus) of a given location [20].

157 Productivity reduction estimates were made according to a methodology proposed by [6],
158 considering that productivity decreases proportionally to the reduction of relative water
159 consumption, in a certain proportion that depends on the crop under study.

160 The productivity reduction was estimated by the following equation:

161

$$R = Ky_d \cdot \left(1 - \frac{ETR}{ETm}\right) + Ky_f \cdot \left(1 - \frac{ETR}{ETm}\right) + Ky_m \cdot \left(1 - \frac{ETR}{ETm}\right)$$

162

163

164 Where:

165 *R*: productivity reduction fraction, decimal;

166 Ky_d: crop response factor to the hydric deficiency in vegetative phase, decimal;

167 Ky_f: crop response factor to water deficit in flowering, decimal;

168 Ky_m: crop response factor to the water deficit in the maturation, decimal;

169   *ETR*: actual evapotranspiration or water consumption, decendial in mm; and

170   *ETm*: crop maximum evapotranspiration or water demand, decendial in mm.

171   The values of Ky used, varied according to crop cycle phases, being: 0.20 for vegetative
172   development; 0.50 for flowering; and 0.25 for maturation [6].

173   The model aims to determining the potential productivity penalty due to water deficiency,
174   which is due to the sum of the products Ky * (1-ETR / ETm) that quantify the productivity
175   reduction caused by water deficiency.

176   To characterize the spatial variability of risk values of productivity reduction, data were
177   analyzed, using geostatistical methods by means of semivariograms calculation.

178   As the semivariograms showed a tendency, that is, they did not stabilize in a plateau with
179   the distance growing uninterruptedly, a polynomial surface was adjusted, calculated
180   according to [21], being realized then a new adjustment with the residues obtained by the
181   difference between the original data and the surface adjusted.

182

$$Z * (x, y) = A_0 + A_1 X + A_2 Y + A_3 X^2 + A_4 XY + A_5 Y^2$$

183

184   Where:

185   Z: attribute value at point X, Y;

186   X, Y: point coordinates;

187   An: coefficients to be calculated.

188

189   The semivariograms were adjusted for each sowing season, AWC and cultivar cycle,
190   selecting the models that presented the best adjustments, adopting as one of the
191   parameters the spatial dependence degree (SSD). According to [22], the SDDrepresents the
192   portion of spatial variability that is due to chance and has the following proportions: (a)
193   strong spatial dependence, <25%, (b) moderate spatial dependence, 25-75%; and (c) weak
194   spatial dependence,> 75%.

195

$$SDD = \left(\frac{Co}{Co + C}\right) \times 100$$

196

197   Where:

198   *SDD*: spatial dependence degree;

199 *Co*: nugget effect;

200 *Co+C*: sill.

201

202 After analyzing the semivariograms and establishing spatial dependence among the
203 analyzed variables, the spatial variability of the productivity reduction for Mato Grosso state
204 was mapped using the ordinary kriging technique.

205 In order to validate the estimates, yield, precipitation, soil and cultivar characteristics were
206 collected in six commercial cotton production plots, located in Tangará da Serra, Campo
207 Novo do Parecis and Deciolândia counties in Mato Grosso.

208 With the information collected, calculations of decendial climatological water balance were
209 performed, in the same way as it was done to estimate the zoning of productivity decrease
210 risk, this procedure was carried out with the objective to verifying that the precipitation that
211 occurred during the crop cycle would be a limiting factor for the productivity obtained in the
212 commercial plots where the surveys were made. For this, the commercial plots productivities
213 were compared with the cultivars average productivity values in the regions and crop
214 analyzed.

215
216
217 **3. RESULTS AND DISCUSSION**
218
219 Table 2 shows the semivariograms parameters of productivity risk reduction percentage as a
220 function of water deficit, used to analyze the spatial dependence and reliability of the
221 generated maps.
222
223 **Table 2: Parameters of spherical model semivariograms used for spatialization of**
224 **productivity risk reduction values (%) in Mato Grosso state.**

VARIABLES	PARAMETERS				
	Nugget effect	Sill	Range (km)	r^2	SDD (%)
AWC 60 SP1 EARLY	50.49	7.50	78.90	0.624	12.93
AWC 60 SP1 MEDIUM	39.85	24.40	312.28	0.710	37.97
AWC 60 SP1 LATE	30.62	17.42	305.61	0.769	36.26
AWC 60 SP2 EARLY	50.03	7.10	68.90	0.633	12.42
AWC 60 SP2 MEDIUM	34.46	23.70	324.50	0.706	40.74
AWC 60 SP2 LATE	39.45	6.70	71.12	0.587	14.51
AWC 60 SP3 EARLY	24.67	15.42	302.27	0.707	38.46
AWC 60 SP3 MEDIUM	25.04	12.98	303.39	0.615	34.13
AWC 60 SP3 LATE	18.55	9.30	301.16	0.724	33.39
AWC 60 SP4 EARLY	21.41	2.76	65.56	0.501	11.41
AWC 60 SP4 MEDIUM	22.43	3.85	71.12	0.521	14.64
AWC 60 SP4 LATE	13.38	8.95	321.17	0.594	40.08
VARIABLES	PARAMETERS				

	Nugget effect	Sill	Range (km)	r²	SDD (%)
AWC140 SP1 EARLY	58.00	34.30	298.94	0.676	37.16
AWC140 SP1 MEDIUM	45.39	26.60	316.72	0.781	36.94
AWC140 SP1 LATE	58.26	10.10	84.46	0.600	14.77
AWC140 SP2 EARLY	74.83	12.20	67.79	0.612	14.01
AWC140 SP2 MEDIUM	56.80	9.80	75.56	0.657	14.71
AWC140 SP2 LATE	48.51	8.10	71.12	0.641	14.30
AWC140 SP3 EARLY	38.86	6.40	76.68	0.629	14.14
AWC140 SP3 MEDIUM	31.64	2.40	78.90	0.658	7.05
AWC140 SP3 LATE	25.84	1.02	71.12	0.606	3.79
AWC140 SP4 EARLY	33.33	4.70	71.12	0.546	12.35
AWC140 SP4 MEDIUM	28.78	4.29	71.12	0.649	12.97
AWC140 SP4 LATE	20.84	2.80	75.56	0.595	11.84
VARIABLES	PARAMETERS				
	Nugget effect	Sill	Range (km)	r²	SDD (%)
AWC 200 SP1 EARLY	67.64	9.00	75.56	0.534	11.74
AWC 200 SP1 MEDIUM	69.43	0.80	70.01	0.491	11.39
AWC 200 SP1 LATE	56.36	21.80	323.39	0.759	29.00
AWC 200 SP2 EARLY	49.52	31.00	322.39	0.700	38.49
AWC 200 SP2 MEDIUM	64.90	9.10	67.79	0.551	12.29
AWC 200 SP2 LATE	59.23	10.70	65.56	0.530	15.30
AWC 200 SP3 EARLY	55.71	8.00	70.01	0.635	12.55
AWC 200 SP3 MEDIUM	37.64	5.40	62.23	0.477	12.54
AWC 200 SP3 LATE	31.53	5.72	86.68	0.528	15.35
AWC 200 SP4 EARLY	35.15	5.30	68.90	0.532	13.10
AWC 200 SP4 MEDIUM	34.13	5.30	60.01	0.416	13.44
AWC 200 SP4 LATE	26.10	4.70	78.90	0.467	15.25

225 AWC: available water capacity (mm); SP: seeding period; EARLY, MEDIUM, LATE: crop
226 cycle (days); r^2: coefficient of determination of semivariogram; SDD: spatial dependence
227 degree
228
229 The SDD values indicated strong and moderate spatial dependence for regionalized
230 variables (Table 2) according to Cambardella et al. (1994) classification, considering that all
231 semivariograms presented values between 3.79% and 40.74% for this parameter. This result
232 indicates that the semivariogram has the capacity to represent the data spatial variability in
233 Mato Grosso state.

234 Figures 1, 2 and 3 shows the cotton productivity reduction risk maps for Mato Grosso state,
235 using three AWC's (60, 140 and 200 mm). The risk of reduced productivity increases in the
236 north to south direction of the state, following the precipitation distribution direction, due the
237 fact that rainfall is associated with the air rise and can occur due to factors such as thermal
238 convection and frontal action of masses, as highlighted by [23].

239 In a study by [24], it was possible to identify that there is an irregular rainfall variability in
240 Mato Grosso, and the average annual precipitation of a rainier core to the north of Mato
241 Grosso can reach values higher than 2750 mm. These values decrease in the east, west
242 and south directions of the state, resulting in precipitation with maximum values in summer
243 and minimum in winter, and 70% of the accumulated rainfall during the year precipitate
244 between November and March, corresponding to summer, whose rainier months are
245 concentrated in January to March interval.

246 There are two air masses that operate in Mato Grosso (continental equatorial mass and
247 Atlantic polar air mass), which affect the distribution and amount of rainfall in Mato Grosso
248 territory: equatorial air mass, present between spring and summer, due to the thermal effect
249 and the high humidity, contained in Amazon, moves towards the country interior in northwest
250 direction to the southeast, causing rains. The Atlantic polar mass is characterized by polar
251 air accumulation, which acts more frequently in the winter, in south-north direction, favoring
252 temperature and drought decrease [25, 26]. However, it is worth mentioning that, due the
253 period in which cotton is cultivated, the continental equatorial air mass is the one that exerts
254 most influence in its development, since it is responsible for the rains in this period.

255 Considering the occurrence of three large biomes in Mato Grosso: Amazonia, Cerrado and
256 Pantanal, it is possible to verify the variation in rainfall distribution in the state. The highest
257 rainfall averages are found in Amazon biome, located in the extreme northwest and north,
258 and the lowest indices located in the extreme southwest and south, corresponding to
259 Pantanal biome [25]. This rainfall variation in these biomes corroborates the results
260 obtained, considering that, in the region corresponding to Pantanal biome, greatest
261 productivity reduction risk was found, and in Amazon biome the lowest risk.

262 Thus, through the results obtained, the relationship between water availability and cotton
263 productivity is evident, mainly due the oscillation of precipitation in time and space.

264 By adopting AWC values corresponding to 60 mm (Figure 1), it is possible to observe a
265 variation in reduction risk between 0 and 75.71% for AWC 140 mm (Figure 2), variation was
266 between 0 and 67.3 %, and for 200 mm AWC (Figure 3) the observed interval was 0 and
267 60.31%. The variation of these values is basically due to the different available water
268 capacities, sowing times and cultivars cycle length. However, it is observed that reduction
269 risk is lower in soils whose available water is 200 mm, due the lower water restriction to the
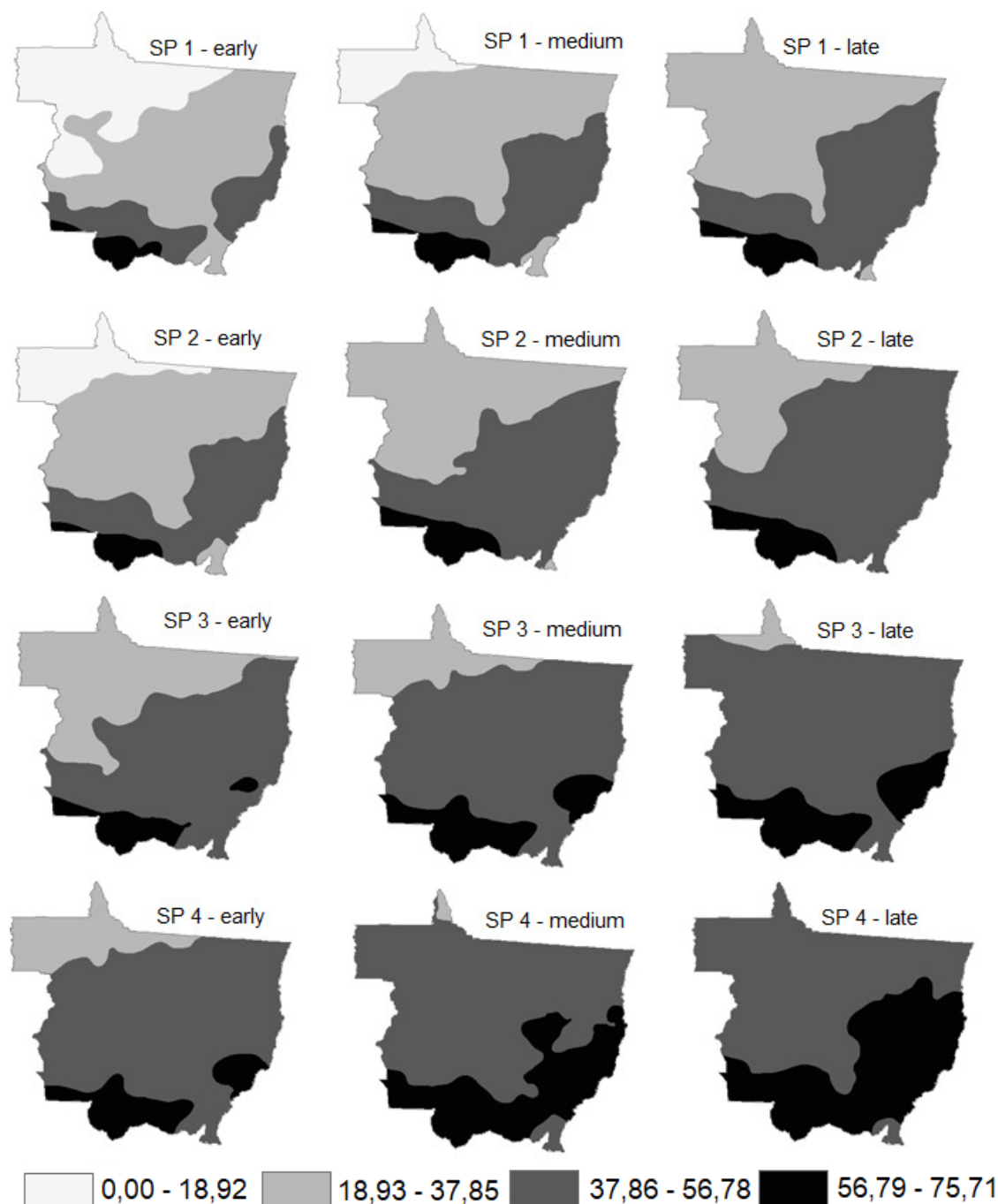270 plants.

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Figure 1. Map of conventional cotton productivity reduction risk (%) for Mato Grosso state, under AWC 60 mm. AWC: available water capacity (mm), SP: seeding period, early, medium, late: crop cycle (days).

In a study by [27], whose objective was to determine the peanut crop agroclimatic zoning to the Upper Paraguay Basin region, in Mato Grosso, a smaller restriction was observed for peanut cultivation in soils with AWC, which is similar to those obtained in this work. The

281 lower restriction risk in soils whose AWC's are higher are due the greater soil water storage
282 in these soils, allowing late cultivation.

283 The sowing season 1 presented a satisfactory performance, being the season with lower
284 productivity reduction risk, mainly for early cycle cultivars. According to [17], it is possible to
285 verify that rainfall in Mato Grosso reaches maximum values in late December and early
286 January, gradually decreasing until dry season beginning, which favored season 1, which
287 corresponds to 12/11. In this sense, the sowing season choice is determinant for the
288 success in the seek for high yields, which are possible when juxtaposing the development of
289 crop phenological stages with the climatic environment favorable to the productivity
290 expression of the cultivar in use [28].

291 In addition, the sowing season 1 obtains a lower risk in the regions located to north and
292 northwest, compared to other state's regions, since according to [25] the month of December
293 shows a rainfall pattern with rainfall maximums located at extreme north and northwest, in
294 Amazonian biome and lowest in south, in Pantanal biome.

295 Seeding period 4 (1/11) was the one that presented the highest productivity reduction risk,
296 mainly the late cycle cultivar, this occurred due the water availability decrease in this period.
297 [17] states that with the delay of sowing, in relation to water deficit, the possibility of the
298 cotton critical phase occurring in the dry season increases. Thus, when sowing in times
299 when climatic conditions are adequate to the needs of any crop, it is possible to reduce
300 losses risks due to water deficit at the critical stages, which occur in reproductive phase,
301 when the crop water requirement is bigger.

302 Thus, one of the determining factors for success in cotton cultivation is the sowing season,
303 which, when carried out until the end of December, causes a lower productivity losses risk
304 due the water deficit occurrence.

305 Generally, zoning is a fundamental tool to prevent losses and to increase profits, increasing
306 the competitive potential of agricultural enterprises that grow cotton, as observed by [5], in
307 which yield losses were higher than 100%, it being evident that the cotton is sensitive to
308 environment variables behavior, be they climatic, edaphic or biotic, having productivity
309 directly related to the time and place of sowing, corroborating with the results obtained in this
310 work, in which it was verified that the time and place of sowing can reduce in up to 75% of
311 the productivity.

312 With the zoning adoption it is possible to minimize the climate elements oscillations effects,
313 since such unforeseen climatic variabilities have always been the main sources of risk to
314 agricultural activity [29]. It was verified that the success of agriculture is related to the
315 anticipated knowledge of the local conditions of soil, solar radiation and rainfall, and their
316 variation along a crop cycle are significant to obtain satisfactory yields, since these factors
317 are determinants for crop success [30].

318
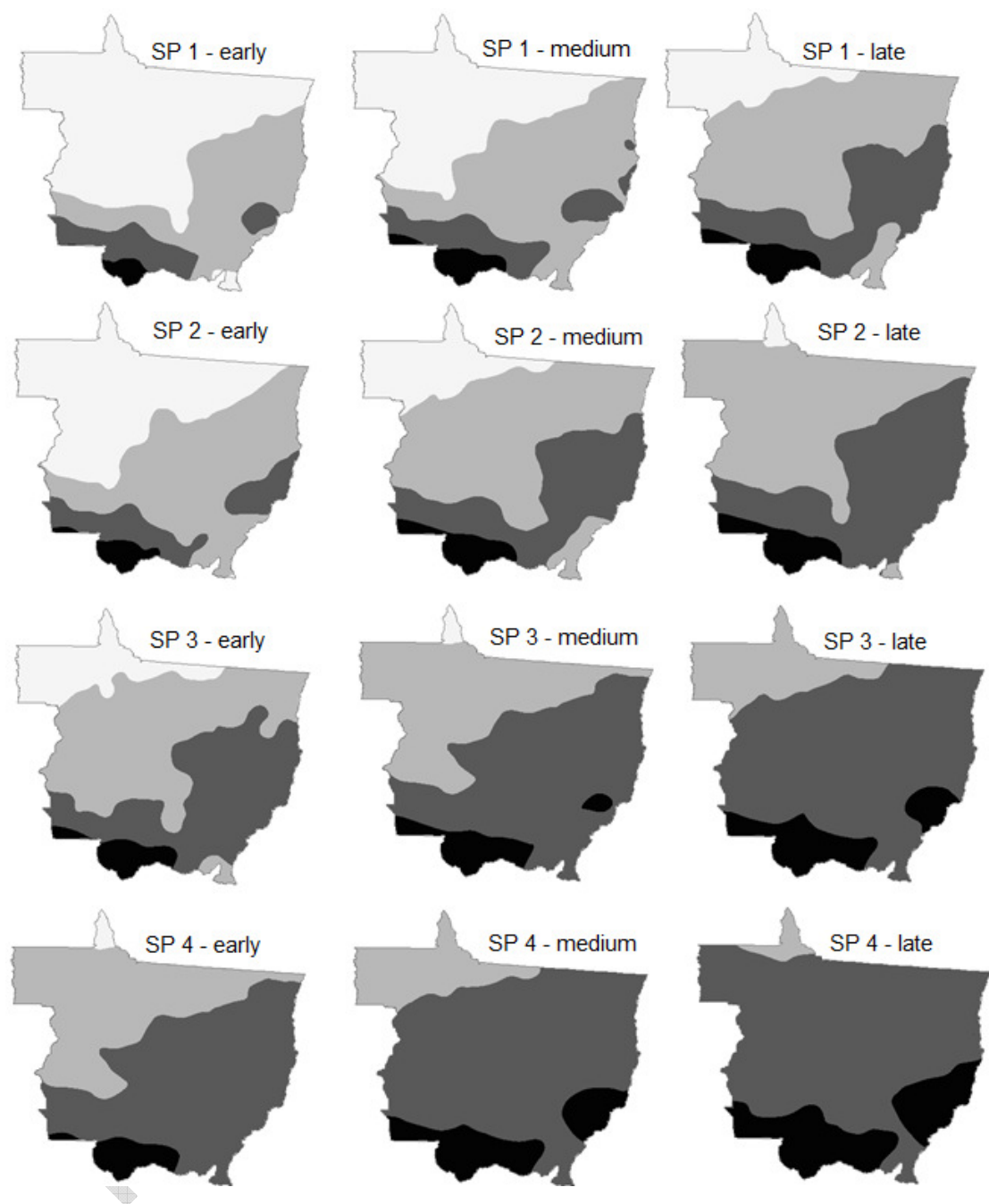
Figure 2. Map of conventional cotton productivity reduction risk (%) for Mato Grosso state, under AWC 140 mm. AWC: available water capacity (mm), SP: seeding period, early, medium, late: crop cycle (days).
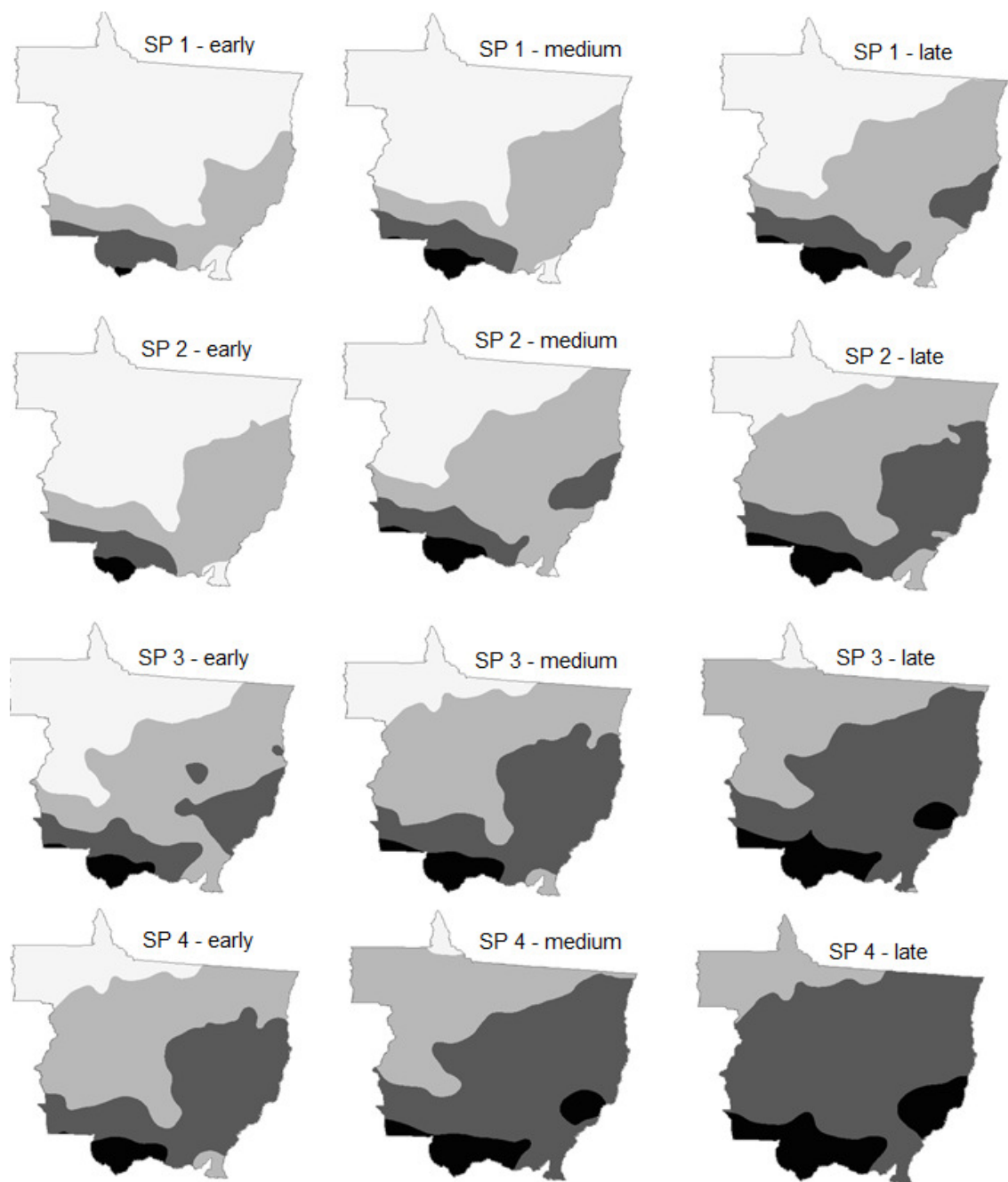
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325
326 **Figure 3. Map of conventional cotton productivity reduction risk (%) for Mato Grosso**
327 **state, under AWC 200 mm. AWC: available water capacity (mm), SP: seeding period,**
328 **early, medium, late: crop cycle (days).**

329

330 Analyzing the cultivar cycle effect, it was observed that the late cultivar presented a higher
331 productivity reduction risk in relation to the others, this occurred because with the longer
332 cycle of the late cultivar, the chances of critical phase increase, in relation to the water deficit
333 occurs in a period of low water availability, considering that rain plays a fundamental role for
334 agricultural crops and exerts influence in several processes, such as nutrient absorption,
335 transpiration and photosynthesis. It is also necessary to consider that, in the same place, in
336 different years and even at different times of year, the adequate water amount depends on
337 factors such as total rainfall over the days, sunshine, wind, temperature, plant size or the
338 spacing used in its cultivation, and the soil's ability to retain rainwater [9].

339 Table 3 shows the results of FAO method validation described by [6]. In Tangará da Serra
340 there was no risk of a reduction in productivity during the growing season, however, the
341 three cultivars did not reach the region productivity for the crop analyzed, presenting a
342 variation between 36 and 8 @ ha^{-1}. The occurrence of such differences indicates the
343 interference of other factors that are not related to the occurrence of water deficit, such as
344 the possible incidence of pests and diseases in crop.

345
346 Table 3: Results and validation information of FAO method (Doorenbos and Kassam, 1979)
347 for cotton crop in Mato Grosso.

Local	Cultivar	Sowing date	Average cultivar productivity @ ha^{-1}	Real productivity @ ha^{-1}	Risk Red. (%)
Tangará da Serra	TMG 81 WS	17/1/02	316.00	280.00	0.00
Tangará da Serra	FM 954 GLT	17/1/15	321.00	300.00	0.00
Tangará da Serra	FM 944 GLT	17/1/25	308.00	300.00	0.00
Campo Novo do Parecis	FM 975 WS	17/1/20	343.00	225.20	34.00
Campo Novo do Parecis	TMG 47 B2 RF	17/1/20	272.00	184.10	33.00
Deciolândia	FM 975 WS	17/1/08	328.00	280.00	18.00

348
349 For Campo Novo do Parecis there was a reduction risk of 34 and 33%, and for Deciolândia
350 the risk was 18%, being in agreement with the average productivity values. Thus, the
351 methodology proposed by FAO [6] guaranteed satisfactory results to analyze cotton
352 productivity reduction risk in Mato Grosso.

353 Thus, the regions and times with the lowest productivity reduction risk are defined,
354 information is extremely important for cotton farmers in Mato Grosso, making possible a
355 more reliable agricultural planning in relation to water availability.

356
357
358 **4. CONCLUSION**
359
360 The sowing season 1 was the one with the lowest cotton productivity reduction risk, and
361 season 4 was the inverse, presenting a higher risk. The month of December is considered
362 the most favorable for conventional cotton cultivation in Mato Grosso.

REFERENCES

1. CONAB, National Supply Company, Follow-up of Brazilian crop: grains, v. 4 - harvest 2015 / 16- n. 1 - first survey | OCTOBER 2016 / National Supply Company, - Brasilia: Conab, 2016.

2. SOUSA, R.R .; TOLEDO, L. G .; TOPANOTTI, D. Q. Rainfall oscillation in the center-west portion of the state of Mato Grosso, between 1996 and 2001. Goiano de Geografia, Goiânia, v. 27 n. 3, p. 71-89, 2007.

3. DALLACORT, R .; FREITAS, P. S. L; GONÇALVES, A.C. FARIA, R. T. de; RESENDE, R; BERTONHA, A. Probability levels of yield of four soybean cultivars at five sowing dates. Acta Scientiarum Agronomy, Maringá, v. 30, n. 2, p. 261-266, 2008.

4. ECHER, F. R. IMAMT, The cotton and abiotic stresses: temperature, light, water and nutrients, 2014, Instituto Mato-Grossense do Algodão - IMAmt. Cuiabá, 123 p.

5. AMORIM NETO, M. S., ARAÚJO, A. E., CARAMORI, P. H., GONÇALVES, M. S. W., LAZZAROTTO, C., LAMAS, F. M., SANS, L. M. A. Agroecological zoning and definition of sowing season of cotton in Brazil. Brazilian Journal of Agrometeorology, Passo Fundo, v. 9, n. 3, p. 422-428. 2001.

6. DOORENBOS, J. KASSAM, A, H. Yield response to water. FAO Irrigation and Drainage Paper n. 33, FAO, Rome, Italy, 1979.

7. IBGE Brazilian Institute of Geography and Statistics. Available at: <http://www.ibge.gov.br/home/presidencia/noticias/21052004biomashtml.shtm>. Accessed on: 13 June 2017.

8. EMBRAPA COTTON, Production systems, cotton cultivation in the cerrado, Nov / 2016, 2. ed. Available at: <https: // www, spo, CNPTIA, Embrapa, br / content p_p_id = conteudoportlet_WAR_sistemasdeproducaolf6_1ga1ceportlet & p_p_lifecycle = 0 & p_p_state = normal & p_p_mode = view & p_p_col_id = column-2 & p_p_col_count = 1 & p_r_p_-76293187_sistemaProducaoId = 7718 & p_r_p_-996514994_topicoId = 7985?>. Accessed on: 01 March 2017.

9. CAMPELO JÚNIOR, J. H .; AZEVEDO, E. C .; AMORIM, R. S. S .; BÉLOT, J-L. Date of planting and productive risk for the cotton plant in a densified system. IMA-MT (Instituto Mato-Grossense do Algodão), technical circular no. 2, Spring of the East, 2013.

10. SIEGEL, S. Non-parametric statistics. Publisher McGraw Hill of Brazil, São Paulo, 1981, 350 p.

11. PAIVA SOBRINHO, S .; MATOS, V. A. T .; PEREIRA, A. P. M. S. PIVETTA, F .; SEIXAS, G. B .; CAMPELO JUNIOR, J. H. Determination of the parameters of the gamma distribution and the decendial rainfall average for stations in the state of mato grosso, Brazilian Journal of Meteorology, São José dos Campos, v. 29, n. 2, p. 183-196, 2014.

12. TRIOLA, M. F. Introduction to statistics. 9 ed. Rio de Janeiro: LTC, 2005.

404 13. THOM, H. C. S. Some Methods of Climatological Analysis. Geneva: WMO, Techinal
405 Note, n. 81, 53 pp., 1966.

406 14. HARGREAVES, G. H .; SAMANI, Z. A. Estimating potential evapotranspiration. Journal
407 of Irrigation and Drainage Engeneering, v. 108, p. 225-230, 1982.

408 15. LIMA JUNIOR, C .; ARRAES, F. D. D .; OLIVEIRA, J, B .; NASCIMENTO, F.A. L .;
409 MACÊDO, K. G. Parameterization of the Hargreaves and Samani equation to estimate the
410 reference evapotranspiration in the State of Ceará, Brazil, Ciência Agronômica, Fortaleza, v.
411 47, n. 3, p. 447-454, 2016.

412 16. ANDRADE, N.L.R .; XAVIER, F. V .; ALVES, E. C. R. F .; SILVEIRA, A .; OLIVEIRA, C.
413 U. R. Morphometric and pluviometric characterization of the Manso River Basin - MT.
414 Journal of Geosciences, Rio Claro, v, 27, n, 2, p, 237-248, 2008,

415 17. FIETZ, C. R .; COMUNELLO, E .; LAMAS, F. M. Analysis of sowing time of cotton in
416 Mato Grosso based on probable precipitation. Dourados: Embrapa, 2009, 5p., Technical
417 Circular, 16.

418 18. RIJTEMA, P.E .; ABOUKHALED, A. Crop water use. In: ABOUKHALED, A. et al.
419 Research on crop water use, salt affected soils and drainage in the Arab Republic of Egypt,
420 Rome: FAO Regional Office for the Near East, 1975, p. 5-61.

421 19. SOUZA FILHO, J. L. and GOMES, S. Evaluation and performance of equations of
422 estimation of soil water storage in an irrigationist decendial climatological water balance,
423 Revista Acta Scientiarum. Agronomy, Maringá, v. 29. N. 4, p. 433-443, 2007.

424 20. REICHARDT, K. Water in agricultural systems. Barueri (SP): Manole. nineteen ninety.

425 21. DAVIS, J. C. Statistics and data analysis in geology. New York, John Wiley & Sons, p.
426 298-411, 1973.

427 22. CAMBARDELLA, C. A .; MOORMAN, T. B .; NOVAK, J. M .; PARKIN, T.B .; KARLEN,
428 D. L .; TURCO, R. F .; KONOPKA, A. E. Field-scale variability of soil properties in central
429 Iowa soils. Soil Sci. Soc. Am. J. 58: 1501-1511, 1994.

430 23. STRAHLER, A. N. Physical Geography. Barcelona, Ediciones Omega, 1986, 767p.

431 24. ROSA, V. G. C .; MOREIRA, M. A .; RUDORFF, B.F. T .; ADAMI, M. Estimation of coffee
432 productivity based on an agrometeorological-spectral model. Pesquisa Agropecuária
433 Brasileira, Brasília, v. 45, n. 12, p. 1478-1488, 2010.

434 25. MARCUZZO, F. F. N .; MELO, D.C. R .; ROCHA, H. M. Spatial and Seasonal
435 Distribution of Rainfall in the State of Mato Grosso. Brazilian Journal of Water Resources,
436 Porto Alegre, v. 16, n. 4, p. 157-167, 2011.

437 26. NIMER, E. Climatology of Brazil. Rio de Janeiro: IBGE, 1979. 422 p.

438 27. BARBIERI, J.D .; DALLACORT, R .; FARIA JUNIOR, C.A .; DE FREITAS, P. S. L .;
439 FENNER, W. Essay and plant density of two peanut cultivars. Nucleus, v. 13, n. 1, 2016.

440   28. SILVEIRA NETO, A. N .; OLIVEIRA, E .; OLIVEIRA, A. B .; GODOI, C.R. PRADO, C.L.
441   O .; PINHEIRO, J. B. Performance of soybean strains in different locations and sowing times
442   in Goiás. Pesquisa Agropecuária Tropical, Goiânia, v. 35, n. 2, p. 103-108, 2005.

443   29. CUNHA, G. R .; ASSAD, E. D. An overview of the RBA special issue on agricultural
444   zoning in Brazil. Brazilian Journal of Agrometeorology, Passo Fundo, v. 9, n. 3, p. 377-385,
445   2001.

446   30. SILVA, J. C., HELDWEIN, A. B., MARTINS, F. B., TRENTIN, G., GRIMM, E. Analysis of
447   rainfall distribution for Santa Maria, RS. Brazilian Journal of Agricultural and Environmental
448   Engineering, Campina Grande, v. 11, n. 1, p. 67-72, 2007.

449

450