__Original Research Article__

ESTIMATING OF CORN YIELD BASED ON AGROMETEOROLOGICAL MODELS IN THE STATE OF MATO GROSSO

RESUMO

Aims: The objective of this work was to evaluate the performance of agrometeorological models for estimating the yield potential of corn in municipalities of the State of Mato Grosso, referring to the 2014/2015 harvest period.
Location and duration of the study: Due to their great potential on corn crop cultivation, four cities were chosen within the State of Mato Grosso: Nova Mutum, Lucas do Rio Verde, Sorriso and Sinop.2014/2015 harvest period.
Methodology: The yield data were obtained by the Farming Economy Institute of Mato Grosso-IMEA. The physiological ripening cycle considered was 120 days and the seeding period 02/02/2015 and harvest 01/06/2015.In order to calculate yield and the water stress, it was necessary to gather data from meteorological stations near the cities where the work was produced, these data were available at the National Institute of Meteorology. The estimated potential yield data were compared among the agrometeorological models, as well as the real yield obtained in the selected municipalities.
Results: The estimated potential yield data were compared among the agrometeorological models, as well as the real yield obtained in the selected municipalities. There were variances amongst the agrometeorological models studied, on average the model 1 estimated ~~(~~5413,68 kg ha^{-1}~~)~~ and the Model 2 ~~(~~6766,45 kg ha^{-1}~~),Table 3.~~It was observed that Model 1 estimated greater yield for Nova Mutum, followed by Sinop, Sorriso and Lucas do Rio Verde, and yet the Model 2 estimated greater potential for Lucas do Rio Verde, followed by the municipalities of Sinop, Sorriso and Nova Mutum (Picture 1 and Table 3). In this regard, the model 2 has characterized the closest potential yield, from the environment yield reality.
Conclusion: The Model 2 has characterized the potential yield closer to the reality of production environment.The difference of all potential yield of corn from all municipalities studied were all directly related to factor interaction which interferes on its growth and development, consequently the difference among these environments. Taking into account the effects of water conditions, the chosen period for seeding can harm the corn yield in the municipality of Lucas do Rio Verde.

Comment [PTS1]: There were variances between the agrometeorological models studied, on average estimated 5413,68 kg ha-1 at model 1 and 6766,45 kg ha-1 at the model 2 (Table 3).

Keywords: Agro-climatology, agrometeorological models, productivity, potential yield,,zea mays.

1. INTRODUCTION

Currently, the corn (Zea Mays) is regarded as second most important crop cultivation in Brazilian Agriculture. Brazil is the third greatest agricultural producer and the second country that exports this cereal [6].

In Brazil, Zea Mays production was approximately 82,1 million tons during the harvest of 2017/2018 [6]. Considering the State of Mato Grosso as the greatest producer of this cereal, obtained during the harvest of 2017/2018it was harvested 27.49 million of tons representing around 43,1% of national production[6].

Differently from other regions in Brazil, the corn produced in Mato Grosso, most of it is characterized as inter-harvest or interim-harvest corn. According to the Conab's research data, 97,94% of cereal in the state is second crop [7].

The Agriculture is an economic activity which has a great dependency on weather conditions, such as: the rain, the air temperature and solar radiation, the main meteorological variation can interfere the crops' growth, development of its cultivation [8].

Amongst the factors that could affect the corn yield are the precipitation and temperature.

In regard to the precipitation regime, the corn can be cultivated in regions where the rain is common from 250 up to 5000mm annually, and the plant average consuming on its early cycle remains around 600mm. The daily cereal consuming on its early stages tend not to exceed values beyond than 2,5mm whereas the ripening process, these values could reach 10mm/day at places where the lowest levels of humidity and higher temperatures are presented [9]. Thus, the cultivation could present limitations, especially related to a possible water stress, bearing in mind as the seeding season could occur by the end of the rain season in most regions, it could result in a certain productivity loss due to the water stress problem.

In addition, higher temperatures allied to the absence of precipitation are responsible for drying the stigma and style and also to produce cob flaws resulting to losses in productivity. In the event of plant blooming, temperatures below than 15,5ºC can slow down its development. In conclusion, Summer days with the average temperatures below 19ºC, and below 12,8ºC during the night time are not recommended to corn production [9].

Turns out the corn yield is highly dependent on its interaction between the weather and phenological periods.

In order to attain a better understanding on these interactions, agrometeorological models have been used aiming to distinguish weather variation effects upon grain production. The productivity estimate models based on weather factors allows it to follow the weather effects along the crop cultivating cycle and relate them to its final yield enabling to assess restrictions on agrarian development and to achieve strategies in order to increase production [10].

Therefore, the objective of this work was to assess the agrometeorological model's performance estimating the potential corn yield in municipalities in the State of Mato Grosso.

2. MATERIAL AND METHODS

2.1 Study Fields

Nova Mutum, Lucas do Rio Verde, SorrisoandSinop, Municipalities of the State of Mato Grosso, located in the centre-west of Brazil, they were all chosen for this study due to their high yield of corn cultivation.

2.2 Estimated Potential Yield

The estimated potential yield calculation has been performed to all four cities, referring to the 2014/2015 harvest period and it was based on two agrometeorological models: Model 1 from [1], with [2] and Model 2 from [3] Adapted [4] and also from [5].

The estimate yield stablished by Model 1, [1], equations were used where the plants are divided by four groups regarding to photosynthetic and phenological aspects, the corn being framed on the third group belonging to C4 plants, whereas the optimal photosynthesis temperature situates around 30 and 35ºC. The maximum yield is given by the equation below in kg/ha^{-1}:

$$By = (Bn * HI * (100+U))/100$$

Where:
• HI – Represents the harvest index found at table 1, for corn used the inferior value (0,35);
• U – Product unity on dry base (table 1);
•O Bn is the dry matter accumulated during all cycle and it is calculated by the equation:

$$Bn = (0,36 * bgm) / (1/N + 0,25 * C) \text{ - kg/ha}$$

Table 1. Harvesting Index (Cc) and humidity level (U%)

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Crop	Product	Cc	U%
Corn	Grain	0,35 – 0,45	10 – 13

Font: [3] and [4].

Where:

• N is the crops' total cycle and the average photosynthesis gross which is obtained by the following equation:

$$\mathbf{bgm = F \times bo \times (0{,}8 + 0{,}01 \times Pmax) + (1\text{-}F) \times bc \times (0{,}5 + 0{,}025 \times Pmax)}$$

Where:

• F – Fractioned time of cloud covering [1];

• bo- absorption rate during cloudy days (kg/ha/d):

$$\mathbf{bo = 31{,}66 + 0{,}55 \times Ac}$$

• bc- absorption rate during clear days (kg/ha/d):

$$\mathbf{bc = 107{,}00 + 0{,}90 \times Ac}$$

• Pmax – Maximum CO2 Exchange rate [1];

• Ac- This work, regarded that Ac corresponds to 80% of atmospheric transmittance. In this case:

$$\mathbf{Ac = 0{,}5x0{,}8xQ0}$$

Where:

• Q0 is the extra-terrestrial short waves of radiation (Table 2).

Table 2. Values Qo (mm/d) for South latitude

Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	14,5	15	15,2	14,7	13,9	13,4	13,5	14,2	14,9	14,9	14,6	14,3
10	15,9	15,7	15	13,8	12,4	11,6	11,9	13	14,4	15,3	15,7	15,7
20	16,7	16	14,5	12,4	10,6	9,6	10	11,5	13,5	15,3	16,2	16,8
30	17,2	15,7	13,5	10,8	8,5	7,4	7,8	9,6	12,2	14,7	16,7	17,6

Font: [11].

The gross photosynthesis was corrected (bgm). The value C for crops with lower protein levels was C30 = 0,0108. Yet, it was considered the adjustment of C with the temperature (T), according with:

$$\mathbf{C= (0{,}0283*(0{,}044+(0{,}00019*T) + (0{,}001*T2)))}$$

Where:

$$\mathbf{T= Td = (3 \times Tmax + Tmin) / 4}$$

• Tmax: Maximum temperature;

• Tmin: minimum temperature.

The model 2 is the method of Agroecological Zone described by [3], where the potential productivity (maximum yield) is given buy the following equation:

$$\mathbf{PP_R = PPBp\ C_{IAF}\ Cr\ CcND\ (kg\ ha^{-1})}$$

Where:

• PPBp: is the production of gross matter in standard crop, which is considered the presence or absence of clouds expressed in kg MS ha^{-1} d^{-1} and the extra-terrestrial global solar irradiance (Qo), mm/d (Table 2).

• C_{IAF}: is the correction for the leaf area index giving by the equation 2: 0,0093 + 0,185 IAF – 0,015 IAF2, o IAF considered in this work was 4.

• C_R (Correction for the ventilation) it could attain the following values: CR=0,6 for T < 20°C and CR =0,5 T ≥20°C, on T which is the average temperature during the considered period.

• Cc (Correction for the harvested part) was stablished according to Table 2.

• ND: is the considered number of days.

Then after taken the PPR (Dry matter from the harvest collected) it should be added the residual humidity (U%) which normally is withheld on the product (Table 1), then reaching the final potential yield value (PPF), obtained by the following equation:

$$PPF = PPR/(1 – 0{,}01\ U\%)$$

2.3 Water stress effect upon productivity

In order to get acquainted with the water stress, it was necessary to elaborate the water balance sheet according to the methodology adapted by [11]. The materials used to its preparation were: medium temperature, precipitation (obtained at meteorological stations), potential evapotranspiration and available water capacity (CAD) of 100 mm, for annual cultivation.

The FAO model, proposed by [3], links the relative yield drop (1-PR/PP_F) with the relative deficit of evapotranspiration (1-ETR/Etc), regarding PR the real yield to be calculated on the following equation below:

$$PR=(1-ky\ (1-ETR/ETc))*PP_F$$

Where:

The ky is the response factor for the crops' initial state; reproductive and ripening, their values were incorporated according to [3].

In the calculation of limited yield by the water availability to maximum crop evapotranspiration (ETc) is linked with the evapotranspiration baseline (ETo) through a crop coefficient (Kc), as presented in the equation:

$$ETc = Kc\ *\ ETo$$

The evapotranspiration baseline was calculated by [12] method which proposed the following calculation

$$ETP = 0{,}01\ Qo\ T\ ND$$

Whereby:

Qo is the global extra-terrestrial solar irradiance (Table 2), T the average air temperate (oC), at the considered period; and ND the number of days considered.

The crop coefficient values (Kc) for early stages; reproductive and ripening, were incorporated according to [3] proposal.

2.4 Yield data

The yield data were obtained by the Farming Economy Institute of Mato Grosso-IMEA. The physiological ripening cycle considered was 120 days and the seeding period 02/02/2015 and harvest 01/06/2015.

The physiological ripening cycle and the seeding season were chosen through agricultural zoning performed by the Department of agriculture, livestock and refuelling, which identifies the capable municipalities and the seeding season for the corn second crop for the state of Mato Grosso.

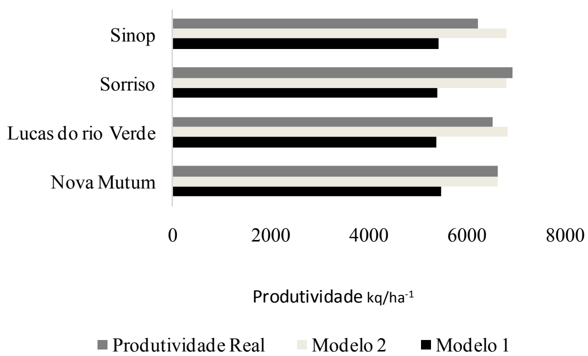
In order to calculate yield and the water stress, it was necessary to gather data from meteorological stations near the cities where the work was produced, these data were available at the National Institute of Meteorology [13].

3. RESULTS AND DISCUSSION

The estimated potential yield data were compared among the agrometeorological models, as well as the real yield obtained in the selected municipalities.

There were variances amongst the agrometeorological models studied, on average the model 1 estimated (5413,68 kg ha^{-1}) and the Model 2 (6766,45 kg ha^{-1}), Table 3.

It was observed that Model 1 estimated greater yield for Nova Mutum, followed by Sinop, Sorriso and Lucas do Rio Verde, and yet the Model 2 estimated greater potential for Lucas do Rio Verde, followed by the municipalities of Sinop, Sorriso and Nova Mutum (Picture 1 and Table 3).



Picture 1. Comparison between estimated yield: models 1 and 2 with the real yield obtained in the municipalities, harvest of 2014/2015

According to [14], the difference of the potential yield amongst the models is associated to the number and quality of input parameters, which constitutes lower or greater level of complexity among themselves, characterizing the determining factor among the agrometeorological models.

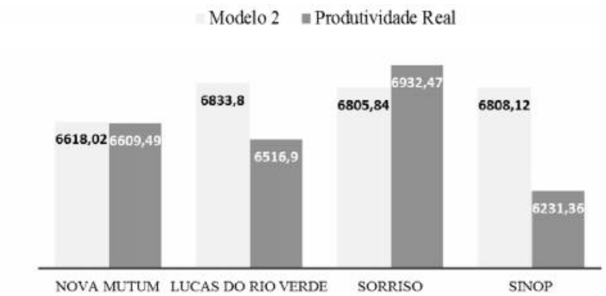
[14], still indicates the variation of potential yield on the location (production environment), it could possibly be related to the interaction among the facts that stress culture's growth and development, which diverge from each environment.

In this regard, the model 2 has characterized the closest potential yield, from the environment yield reality.

Table 3. Potential yield (kg ha^{-1}) estimated and real corn yield in the municipalities, harvest of 2014/2015

Municipalities	Model 1	Model 2	Real
Nova Mutum	5476,78	6618,02	6609,50
Lucas do Rio Verde	5371,33	6833,80	6516,90
Sorriso	5380,54	6805,84	6932,48
Sinop	5426,06	6808,12	6231,37
Average	5413,68	6766,45	6572,56

As Model 2 has come closer to real conditions, a comparison was carried out with the real yield obtained in the municipalities, it was noted that Nova Mutum has produced (99,87%), Lucas do Rio Verde (95,36%), Sinop (91,52%) of the average of estimated potential yield (Picture 2). Differently from all other municipalities, Sorriso estimated 1,82% less than real yield.



Picture 2. Comparison amongst estimated yield: Model 2, real yield obtained in the municipalities, harvest of 2014/2015

In terms of water conditions based on real yield (PR), which linked to the relative yield downfall (1 - PR/PPF) with the relative deficit of evapotranspiration (1 –ETR/ETc). Observing the real yield data (Table 4), It is noted that the municipality of Lucas do Rio Verde was the one which lost the most of its yield in regard of water effect, followed by the municipality of Nova Mutum which was the least to attain the real yield.

Table 4. The estimated potential yield (kg ha^{-1}) of water conditions, real yield and corn yield shortfall from different municipalities, harvest of 2014/2015.

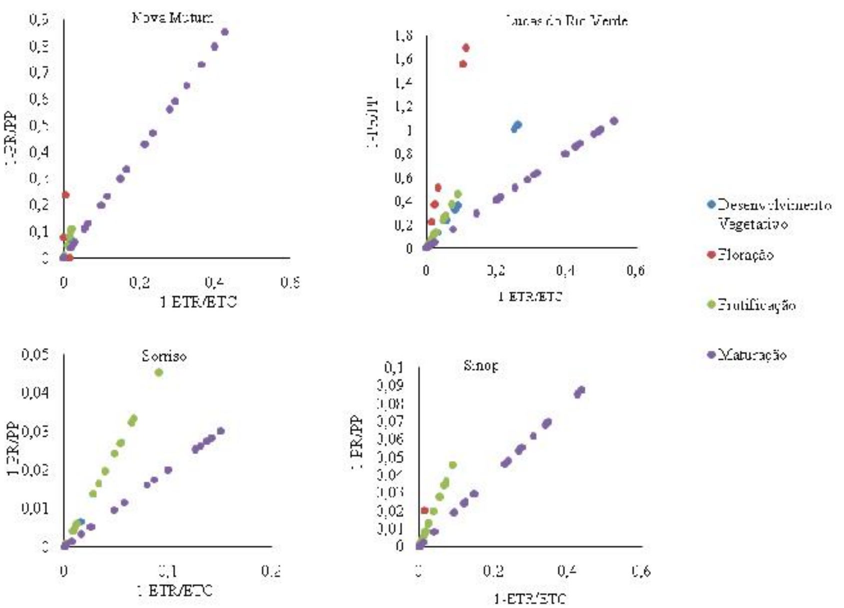
Cities	Estimates	Real	Yield Breakage%
Nova Mutum	5987,12	6609,49	9,53
Lucas do Rio Verde	4161,33	6516,9	39,11
Sorriso	6142,63	6932,47	9,74
Sinop	5942,511	6231,36	12,71

It can be also observed at Picture 3 the water deficit effect upon corn yield for all four phenological periods. There was a major water deficit in all municipalities during the ripening stage. According to [15] the corn presents a critical stage from its pre-flowering stage to its grain filling stage. At this phenological stage, the corn is delicate to water deficit, this sensibility can be noted during the physiological processes connected to zygote development and the grain filling, and by the elevated transpiration which occurs in this period due to its large leaf area.

In Lucas do Rio Verde the water deficit occurred during the flowering stages, ripening and plant development, presenting the major yield shortfall (39,11%) in this municipality due to its water deficit (Table 4).

Probably the major yield shortfall as observed in Lucas do Rio Verde is due to its estimated seeding period for this assignment. According to [16] depending on the seeding season, the risks of yield losses can be reduced by lowering the exposure of cultivation to more plausible periods of low water availability to the plants.

Thus, the chosen period for seeding and harvesting can harm the corn yield in the municipality of Lucas do Rio Verde.



Picture 3. Relation between relative yield and relative evapotranspiration in the four corn phenological stages

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4. CONCLUSION

1 The [3] model 2 has characterized the potential yield closer to the reality of production environment.

2The difference of all potential yield of corn from all municipalities studied were all directly related to factor interaction which interferes on its growth and development, consequently the difference among these environments.

3Taking into account the effects of water conditions, the chosen period for seeding can harm the corn yield in the municipality of Lucas do Rio Verde.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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