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Climate change and its influence on planting of cassava in the Midwest region of Brazil

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Abstract

Climate change is the main cause of biotic and abiotic stresses on plants and has adverse effects on agriculture in a region. Cassava is fundamental for the socioeconomic development of the region Midwest of Brazil. Establishing the appropriate places for planting in future climate change scenarios collaborates in the planning of public policies and adaptation measures. The objective of the study is to carry out the agroclimatic zoning of cassava (*Manihot esculenta* Crantz) for the Midwest region of Brazil in future scenarios of climate change. We analyzed information on the relationship of climatic needs with the development of plants and establish the adaptive capacity of cultivation in the region. We used data corresponding to the historical series of 1988–2018 of the National Aeronautics and Space Administration/Prediction of Worldwide Energy Resources—NASA/POWER, referring to average air temperature daily (°C) and annual rainfall (R_{mm}). We consider areas suitable when T_{AIR} was between 20 and 27 °C and R_{mm} between 1000 and 1500 mm. The air temperature was increased by 1.5, 3.0, 4.5 and 6.0 °C, and the rainfall change scenarios at −30, −15, + 15 and + 30% R_{mm} were carried out as adopted by Pirttioja et al. The potential cultivation area of cassava will be reduced in most scenarios in relation to the current scenario, which has 44% of the suitable region, except in scenario 1 (−30% R_{mm}) and scenario 2 (−15% R_{mm}) with an increase of + 12% and + 20% in the adequate area, respectively. It is essential to adapt management systems to mitigate climatic changes' effects on cassava growth, development and productivity, with the introduction of genes tolerant to biotic and abiotic stress in cassava varieties to increase their production, regardless of changes in climatic conditions. It appears that in addition to global awareness of climate change, agriculture must seek criteria based on science that meet the sustainable development of cassava.

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1 Introduction

Cassava is the fourth most important crop in the world (Tuo et al., 2021), in 2019 global production corresponded to 291.99 million tons (FAO, 2019). Its domestication occurred about 9000 years ago in the Amazon region, and South America is considered the center of genetic origin and diversity (Alves-Pereira et al., 2018). Consumed by more than 800 million people and grown in 102 countries in the tropics and subtropics (Reifschneider et al., 2014; Modesto Júnior and Alves, 2016; Janket et al., 2020), cassava is an essential source of carbohydrates (McCallum et al., 2017; Putpeerawit et al., 2017), contributing to food security (Okwuonu et al., 2021).

The Midwest is a consolidated example of an area of modern agro-industrial production and strong economic dynamism in Brazil (Buainain et al., 2019; Le Bourlegat, 2014; Miragaya, 2014). Several crops are implanted in the Midwest, the main ones being soybean, sugarcane, maize, herbaceous cotton and cassava (Castro, 2014; IBGE, 2017). The share of agricultural activities in the Midwest in the national gross domestic product (GDP) has grown significantly in the last decades, from 2.45% in 1960 (Neto & Gomes, 2000) to 10.1% in 2016 (IMB and SEGPLAN, 2018). Currently, the participation of cassava is equivalent to 2.42%, when compared to the Brazilian GDP of the agricultural sector (Marini, 2016).

Agriculture is the economic activity most dependent on climatic conditions, presenting a direct relationship in all stages of agricultural production (Koren et al., 2021; Moreno et al., 2016). The climate is the main regulator of agricultural production (Embrapa, 2018; Vesco et al., 2021), as it influences the crop growth, development and yield, as well as the relationship of plants with microorganisms, insects, fungi and bacteria, favoring or not the occurrence of pests and diseases, which requires adequate control measures (Bergamaschi & Begonci, 2017; Pereira et al., 2002).

Studies of the relationship between climate and agricultural production are important to explain the influences of interannual variability of climatic elements (Brito et al., 2019; Nguyen et al., 2016). Before carrying out any cultivation, it is recommended that agroclimatic zoning is verified or carried out due to the great variations in climatic conditions (Medauar et al., 2021). Air temperature and rainfall are the main meteorological variables to be considered in agroclimatic zoning (Hussain et al., 2020; Richardson et al., 2017).

Climate change includes abnormal changes in the climate, both natural and man-made (Adedeji et al., 2014; Remmits et al., 2020). The climate change and food security are the two main issues of the twenty-first century (Dreyfuss, 2018; Raza et al., 2019; White et al., 2018; Karimi et al., 2020). With the progress of climate change, vulnerability assessments are used spatially by governments and other institutions that aim to reduce vulnerability and improve food security (Wichern et al., 2019).

Climate change has a strong influence in agricultural production. Agriculture is considered the most climate-dependent of all human activities (Hansen, 2002), with socioeconomic impacts whose severity varies from one region to another (Ogallo et al., 2000). Some analysis reports expose that changes in air temperature, precipitation and extreme weather events were expected to reduce agricultural production in many regions of the world (Gornall et al., 2010). For this reason, the main task is to reduce pressure on food security and the likely gap in the supply of food demand can be filled with cassava cultivation (Campbell et al., 2016; Manners & van Etten, 2018), because culture can be harvested throughout the year, grows well with minimal water input and is easily propagated, adapting well to many aggressive environments (Atwijukire et al., 2019; Byju & Suja, 2020; Peixoto, 2009).

Alternative scenarios are commonly selected to represent uncertainties in the projected regional climate for variables relevant to agricultural production, such as air temperature and precipitation (Pirttioja et al., 2019). Agrometeorological simulation models have proven to be valuable tools for predicting the influences of climate change on crops and informing needed interventions (da Silva et al., 2021). However, cassava has been less studied compared to other crops, despite its importance as a food and commercial use in many developing countries (Karlström et al., 2016; Leal et al., 2014).

Thus, analyzing the performance of cassava and possible interferences in the agroclimatic suitability of the areas based on projections of future climate change is of great economic and social relevance for the sector in which the crop is inserted, since, in addition to presenting an overview of the regions of cultivation, it provides input for decisions on adaptation measures that can be implemented to reduce future climate impacts.

Therefore, the objective of this work was to carry out the agroclimatic zoning of cassava (*Manihot esculenta* Crantz) for the Midwest region of Brazil in future scenarios of climate change.

2 Literature reviews

The impact response surfaces (IRSs) represent the response of an impact variable to changes in two explanatory variables as a plotted surface (Pirttioja et al., 2015). The IPCC noticed many signs of climate change around the world, such as increase in air temperature; more frequent heavy rainfall events (storms, floods or snowstorms) in many areas; and more intense and longer droughts throughout wider areas, especially in the tropics and subtropics (Adefisan, 2018).

Climatic variability must be considered when assessing the impact of cassava (Pera et al., 2019; Adejuwon and Ogundiminegha, 2019). Some studies simulating cassava yield have been carried out for some regions of the world in future climate scenarios, mainly with changes in air temperature and rainfall (Assad and Pinto, 2008; Rosenthal and Ort, 2012; Tironi et al., 2017). Cassava showed a decrease in yield of about 5% in simulation with an increase in air temperature and decrease in rainfall for Brazil (Jarvis et al., 2012; Lobell et al., 2008; Schlenker & Lobell, 2010).

The scale of the problem or benefit generated by the cassava activity will be associated with its mitigation capacity against the resilient intensity of climate change based on the climatic elements of air temperature and precipitation in the Midwest region of Brazil. The cassava is normally grown in rainfed systems; air temperature and precipitation are the most limiting factors for its production (Pola et al., 2019). Therefore, climate is an important factor in cassava yield, characterized by the agrometeorology of the crop according to its thermal and water needs (Quaye et al., 2018).

The air temperature range required for commercial cassava exploitation is between 16 and 38 °C, with the ideal range between 20 and 27 °C (Rao et al., 2016; Gomes Júnior, 2018; Marques, 2020). Temperatures below 16 °C affect its yield due to dormancy and delay in budding (Ghini et al., 2011; Peixoto, 2009). The export of sucrose from the leaves and the synthesis of starch in the roots are negatively affected at air temperatures close to 40 °C (Sakurai et al., 2007; Ravi et al., 2008; Lebot, 2020); in addition to that, high temperatures can divert the photoassimilates route to lignification (Amthor, 2003; Boerjan et al., 2003).

The water requirement of cassava is 1000–1500 mm year^{-1}, with good distribution over 6 to 8 months of the vegetative cycle (El-Sharkawy, 2007; Ghini et al., 2011; Marques, 2020; Oliveira et al., 2006). Cassava can be grown in areas with an average annual rainfall of 400 mm (Sasakanda, 2015; Séry et al., 2016); however, high yields can be obtained with larger volumes of water (FAO, 2013), so it is important to adapt to the planting season (Casagrande et al., 2010; Mithra et al., 2018), because growth and yield are reduced by prolonged periods of water deficit (Duque & Setter, 2013; Pinheiro, 2019; Pipatsitee et al., 2018). The critical period of the effect of the water deficit in cassava is 1 to 5 months after planting (Alves, 2006; Shan, 2018), with reduced root yield from 32 to 60% (Kengkanna et al., 2019; Pina Filho, 2018) and reduced shoot growth, with the growth of leaves and stems more impaired compared to the growth of roots (Nunes and Peruch, 2018; Mélo Neto et al., 2018). In tropical regions, cassava produces in places with indices of up to 4000 mm year^{-1}, without a dry season at any time of the year; however, it is important that the soils are well drained to avoid waterlogging and favor root rot (Antwi et al., 2017; Anikwe and Ikenganya, 2018; Muniz, 2018).

Agroclimatic zoning identifies areas suitable for the cultivation of a given crop, helping to increase its exploitation in a given region (Fiorin and Ross, 2015; Singh et al., 2021). In this context, these locations characterize the highest possible probability of success in productivity (Nabati et al., 2020; Pezzopane, 2012). Therefore, research that establishes the appropriate places for the implementation of crops in a given region, mainly taking into account the future scenarios of climate change, can contribute to the planning of public policies that benefit the socioeconomic development of the region (Kipling et al., 2019; Wollmann & Galvani, 2013). Also, farmers can reduce the risks of losing their crops through decision-making (Bracale, 2012).

3 Material and methods

The methodology used in the study was divided into four steps and summarized as shown in Fig. 1. The steps consisted of characterization of the study area, preparing the meteorological station database and interpolating agroclimatological variables; modeling the agroclimatic suitability of cassava; presentation of the adopted climate model to climate change; and comparison between current and future expansion areas.

3.1 Characterization of the study area

The study was carried out in the Midwest region of Brazil, which comprises a territorial area of 1,606,404 km^2 (IBGE, 2010) and has an estimated population for the year 2020 of approximately 16.5 million inhabitants (IBGE, 2020). The Midwest region comprises the states of Mato Grosso (MT), Mato Grosso do Sul (MS) and Goiás (GO), in addition to the Federal District (DF) (Fig. 2). The great potential of cassava production in the Midwest region is due to its favorable climatic conditions (Nussenzveig, 2011; Haddad, 2017; Buainain et al., 2019). The predominant climate of the Midwest region according to the Köppen classification is characterized by Aw (high temperatures, rainfall in summer and drought in winter) present in 62.84% of the territory, with annual means of precipitation of

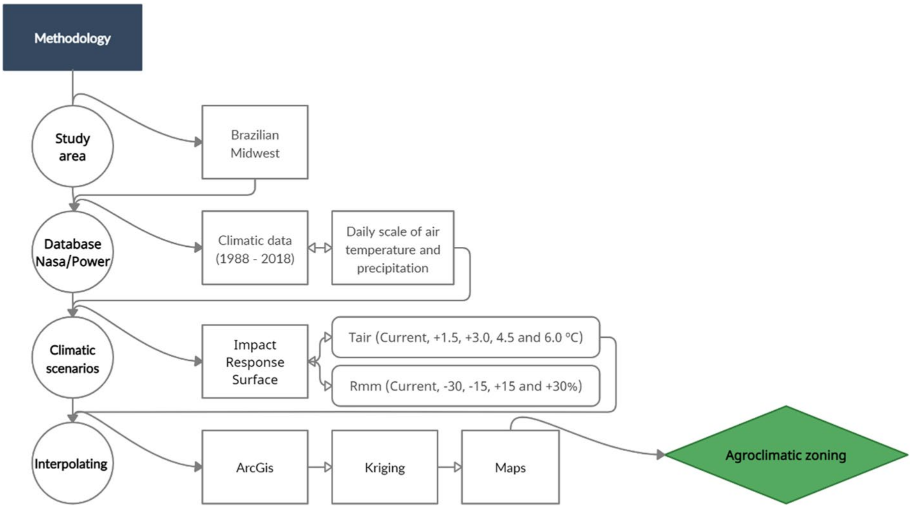

Fig. 1 Flowchart of all stages of the study. *Source* authors

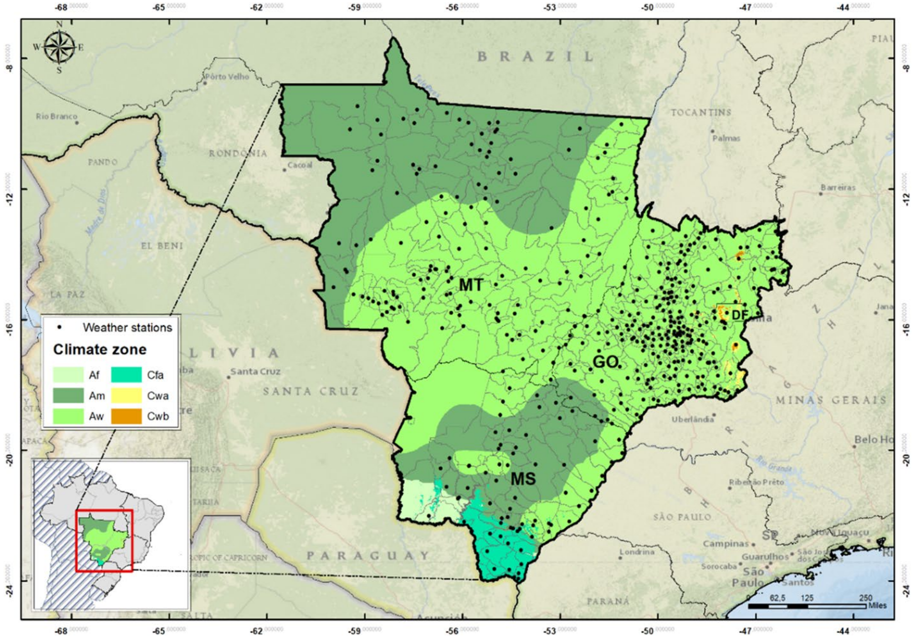

Fig. 2 Spatial distribution of weather stations in the Midwest region of Brazil. *Source* authors

1534.5 ± 336.5 mm and air temperature of 22.1 ± 2.97 °C. In smaller proportions occur climate zones Am (24.23%), Cwa (5.90%), Cfa (2.80%), Cwb (2.58%) and Af (1.65%) (Cavalcanti, 2009; Alvares et al., 2013).

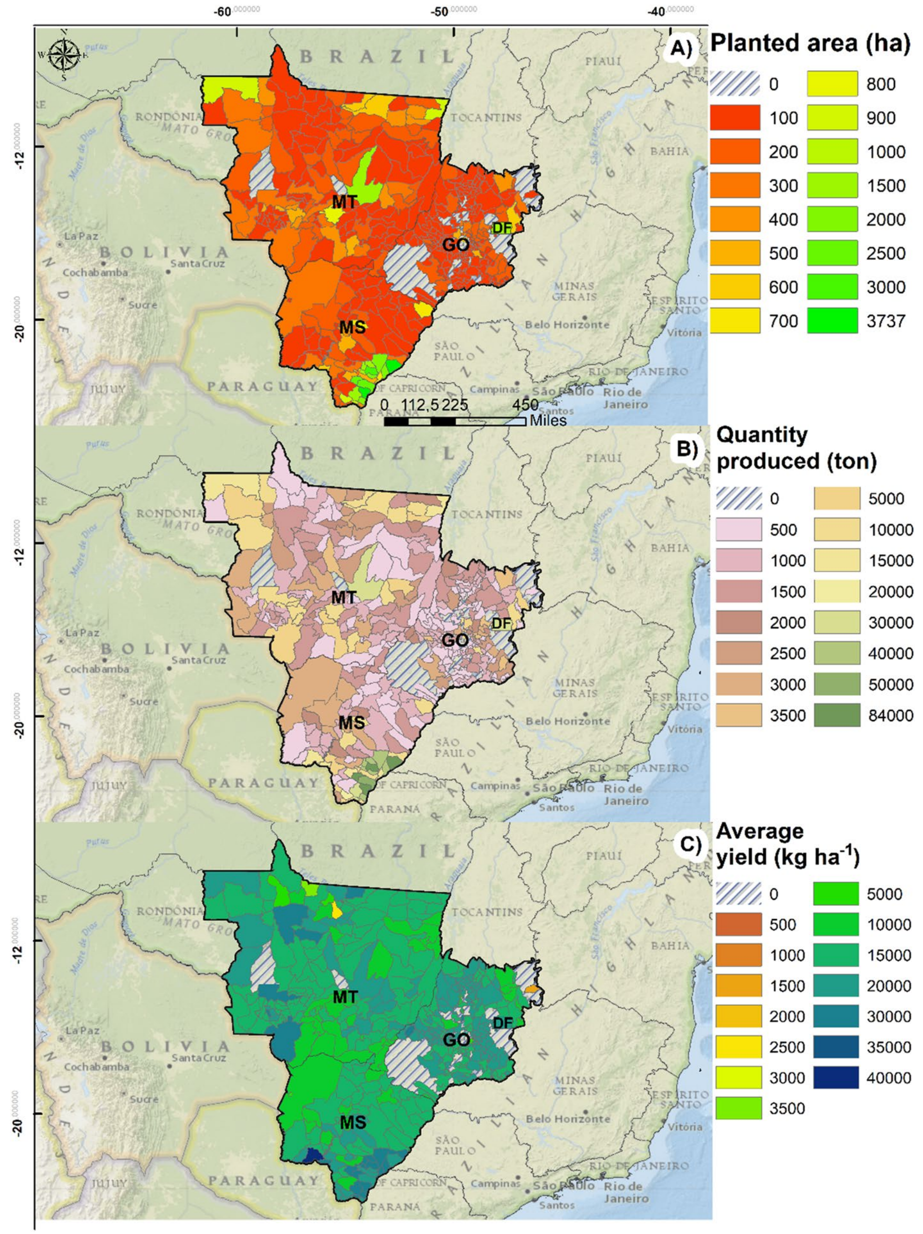

Fig. 3 Spatialization of cassava agronomic indices in the Midwest region of Brazil. *Source* authors

In relation to the mandioculture in the Midwest region (Fig. 3), the estimate of cassava 2019 crop corresponds to 70,836 cultivated hectares, production of 1,299.906 tons and average yield of 16,959.5 kg ha^{-1} (IBGE, 2019), ranking second in terms of productivity among Brazilian regions (Fernandes, 2018), highlighting the south region. The results obtained in this work can complement strategic decision-making considering territories with homogeneous agricultural and livestock characteristics.

3.2 Climatic data

The climatic variables of mean air temperature (T_{AIR}) and total annual precipitation (R_{mm}) are considered of greatest importance for cassava planting (Akinwumiju et al., 2017; Rop & Ib, 2017). A 30-year historical series (1988–2018) was used with data on average air temperature and average annual rainfall, obtained by the National Aeronautics and Space Administration/Prediction of Worldwide Energy Resources platform (NASA/POWER), on a daily scale. The platform provides meteorological information in a grid with a spatial resolution of 1°, corresponding to approximately 110.57 km (Stackhouse et al., 2016; NASA-POWER, 2019). The analysis of the climate variability of the Midwest was divided between its states and the Federal District, with the plotting of a monthly thermopluviometric graph, used by Gil-Guirado and Pérez Morales (2019).

The performance of spatial analysis in a geographic information system (GIS) environment has the advantages of speed, flexibility and the power of extensive database synthetic evaluation (da Silva et al., 2021). We made the maps, using ArcGIS software version 10.8 and the Geostatistical Analyst tool. The data of average annual rainfall and average air temperature were interpolated by the ordinary kriging method, with statistical adjustment of the semivariogram suggested by Cecílio et al. (2012) and Gasparini et al. (2015). With the matrix images generated by the semivariogram modeling and later reclassified, the combination of the bands was performed, generating the areas of aptitude and restriction according to the characteristics of each location.

3.3 Agroclimatic zoning

Raster or matrix images, corresponding to the average annual temperature and annual precipitation, were superimposed to create cassava suitability classes, according to crop requirements (Fig. 4). The limit temperatures required for the commercial exploitation of cassava culture are between a minimum of 16 °C and a maximum of 38 °C, with restrictions of low (16–20 °C) and high (27–38 ºC) temperature. The ideal temperature range for the cultivation of cassava is between 20 and 27 ºC, and regions that presented T_{AIR} below 16 °C and above 38 °C were considered inadequate. The amplitude of rainfall for the commercial exploitation of cassava requires the water regime between 400 and 4000 mm, with restrictions of excess rainfall (>1500 mm) and water deficit (<1000 mm), with an ideal range of 1000–1500 mm (Séry et al., 2016; Antwi et al., 2017; Mithra et al., 2018; Pipatsitee et al., 2018; Anikwe and Ikenganya, 2018; Pinheiro, 2019; Marques, 2020). The classes of agroclimatic aptitude for the cultivation of cassava were established by the combination of climatic variables of air temperature and annual rainfall (Lopes et al., 2008; Perin et al., 2015). With the interaction of these variables, it was possible to elaborate on the agroclimatic zoning of cassava for the Midwest region of Brazil in future climate scenarios.

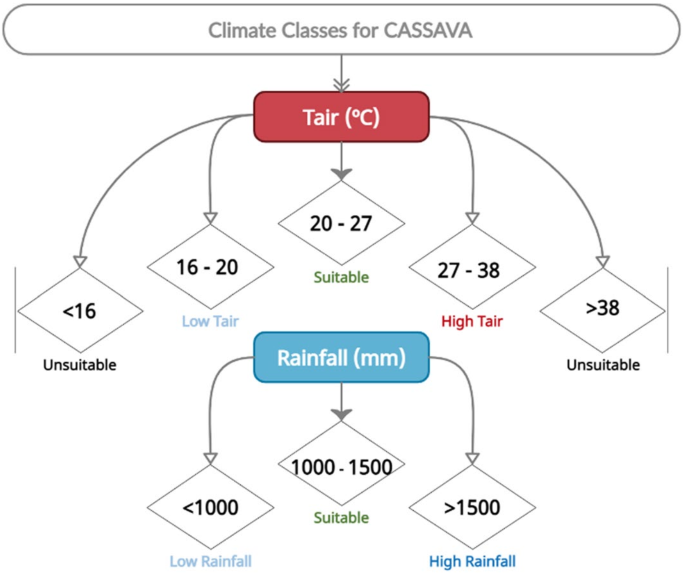

Fig. 4 Cassava climatic classification key. *Source* authors

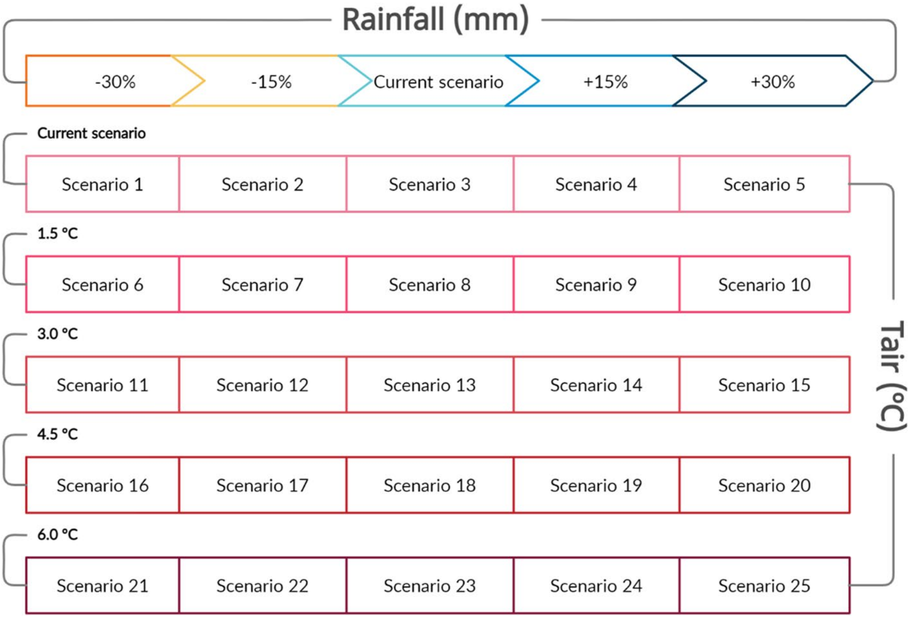

Fig. 5 Interaction of possible climatic scenarios. *Source* adapted from Pirttioja et al. (2015)

3.4 Climate change scenarios

The possible scenarios of climate change were idealized through the variables of air temperature (°C) and rainfall (R_{mm}). The interaction of future climatic scenarios occurs with a gradual increase in temperature by 1.5, 3.0, 4.5 and 6.0 ºC and the variation of rainfall in −30, −15, 0, + 15 and + 30%, with CO^2 concentration fixed at 360 ppm adapted according to the model impact response surface (IRS) adopted by Pirttioja et al. (2015). We elaborated a simulation on the interaction of possible climate scenarios, making it possible to observe the numerous combinations, totaling 25 climatic scenarios (Fig. 5).

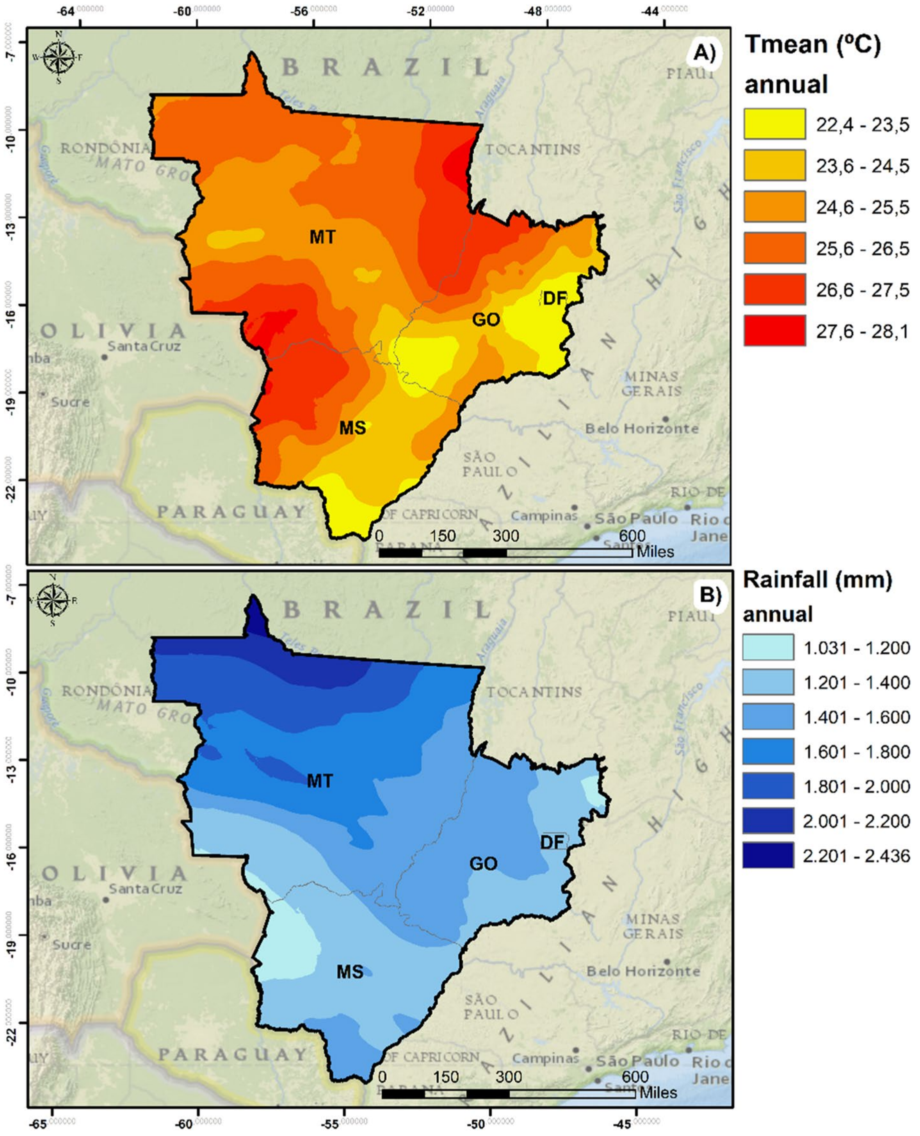

Fig. 6 Spatialization of air temperature and rainfall for the Midwest region of Brazil. *Source* authors

4 Results and case study

The Midwest region of Brazil presents an important spatial meteorological variation along its geographical extensions (Barros & Balero, 2012), with well-defined periods of drought and rain between the months and high temperatures throughout the year.

The average air temperature in the region over the 30-year period (1988–2018) was 24.8 °C with a range from 22.4 to 28.1 °C (Fig. 6). The lowest averages were 22.4 to 25.5 °C and occurred in the areas located to the south, southeast and east, in addition to a large strip moving from the central region, west–northwest. The northeast, north, northwest, west and southwest regions reached the highest temperature averages, ranging from 25.6 to 28.1 °C. The Midwest region of Brazil has satisfactory water volumes in most of the weather stations; the annual average for the period in the region was 1469 mm with a variation between 1031 and 2436 mm. Rainfall of 1200–1800 mm covers the largest proportion of the Midwest region of Brazil, with these bands being found in the southwest, south, southeast, east, northeast and central regions. The largest rainfall volumes range from 1800 to 2436 mm and are concentrated in areas located to the northwest and north.

In the seasonal variability of the Midwest region of Brazil, we observed that the highest values of T_{AIR} occur between the months of August to March, with averages reaching up approximately 25 °C. The lowest averages of air temperatures correspond between the months of May and August, averages below 23 °C. The greatest thermal amplitudes or variability occur between the months of May and September, with a variation above 7.7, 10, 11.6, 11.1 and 10.4 °C, respectively, while from October to April, there were small variations, below 7 °C, relatively at 7, 6.4, 6.7, 7, 6.6, 5.9 and 5.8 °C.

For rains (R_{mm}), the highest volumes are between October and April, with R_{mm} values above 100 mm, and averages above 200 mm are in December, January, February and March. (Fig. 6B). The lowest volumes of R_{mm} correspond to the months of April to September, with lower average volumes close to 60 mm, reaching values below 20 mm in the periods of June, July and August. The greatest variations occur in the wettest months, and on the contrary, the smallest in months with a water regime restricted to the deficit.

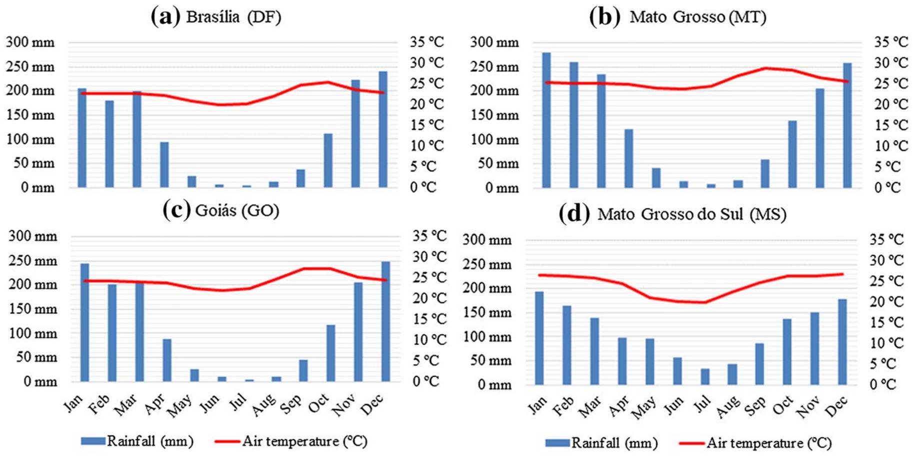

Fig. 7 Thermopluviometric variability in the Midwest region of Brazil

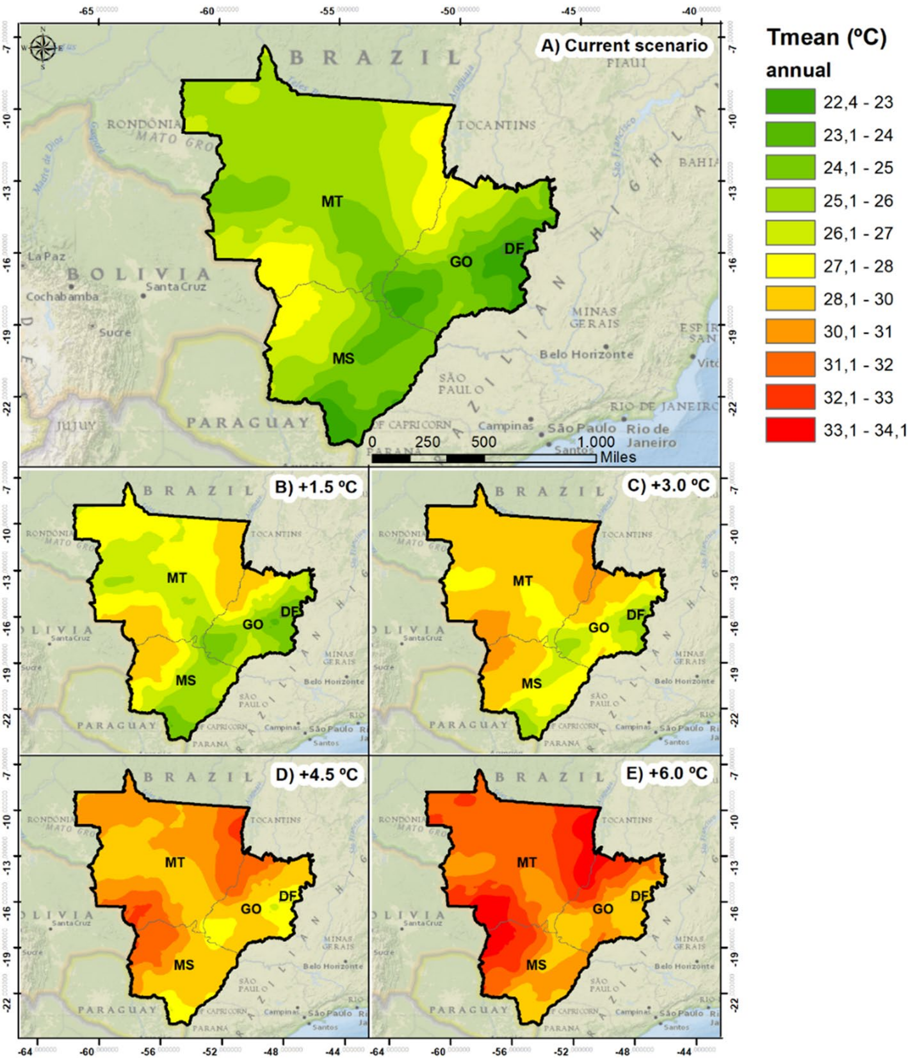

Fig. 8 Climatic air temperature scenarios for the Midwest region of Brazil. *Source* authors

The air temperature was within the recommended range for the cultivation of cassava in the central-west region of Brazil; however, attention should be paid to excess water, mainly characterized in the state of Mato Grosso.

Air temperatures (T_{AIR}) in climatic scenarios (current scenario, + 1.5, 3.0, 4.5 and 6.0 °C) in the Brazilian Midwest (Fig. 8) ranged from a minimum of 22.4 ºC in the current scenario (Fig. 10A) at a maximum of 34.1 °C in the fifth scenario (Fig. 10E). The smallest T_{AIR}, with classes below the limit considered optimal for cassava of 27 ºC, corresponds to the largest proportion of the region, except in the areas located to the northwest and southwest in the current scenario (Fig. 7A). However, in the following scenario (Fig. 7B), with the increase in T_{AIR}, the northern region with air temperature above 27 °C is included. In the third scenario (Fig. 7C), the only areas with T_{AIR} below 27 °C cover a

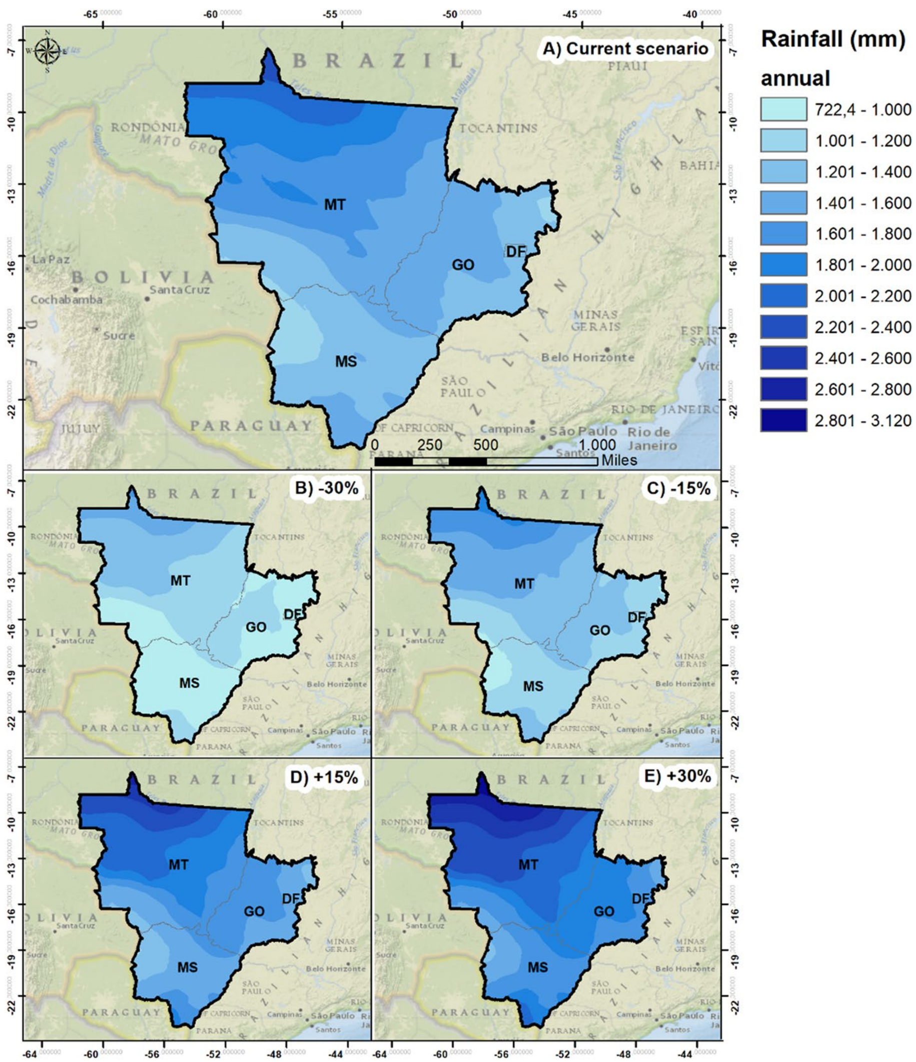

Fig. 9 Climatic rainfall scenarios for the Midwest region of Brazil. *Source* authors

small portion to the south and east. In the fourth scenario (Fig. 7D), high air temperatures predominate; T_{AIRs} above 27 °C are found in all areas of the Midwest region of Brazil. In the last scenario, air temperatures are above 28 °C throughout the region. Thus, above the limits required by the crop in the scenarios + 4.5 °C and + 6.0 ºC, cassava begins to suffer negative impacts on its growth and development.

Rainfall in the Brazilian Midwest varied from 7224 mm minimum volume in the scenario −30% R_{mm} to 3120 mm maximum volume in the scenario + 30% R_{mm} (Figs. 8, 9). Most of the Brazilian Midwest consists of good availability of R_{mm}, with volumes greater than 1000 mm. Even with the reduction in rain by -30% and -15%, the Midwest of Brazil has sufficient water regime for the cultivation of cassava in much of the region.

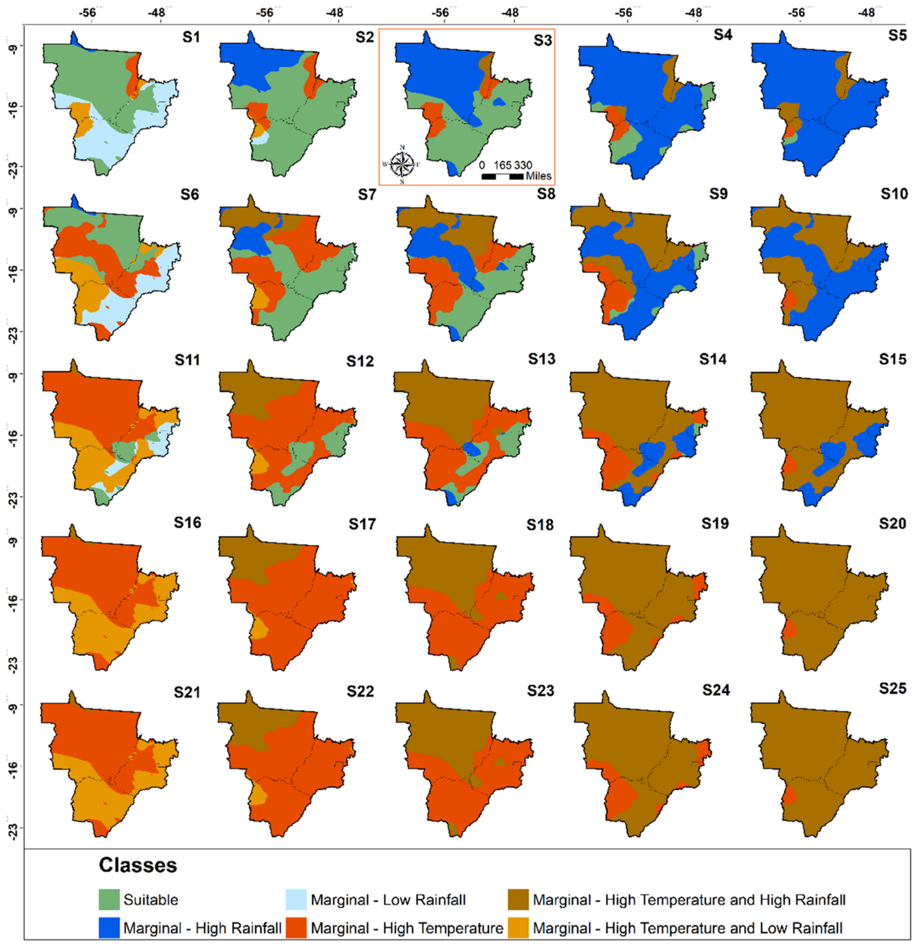

Fig. 10 Agroclimatic zoning of cassava for the Midwest of Brazil in future climate change scenarios. *Source* authors. Legend: S1—scenario 1; … S25—scenario 25

However, if the rainfall increases by + 15% and + 30%, the crop may suffer from excess water in much of the region.

With the interpolation of data from future climate scenarios in relation to annual precipitation and average air temperature, we obtained different agroclimatic zoning for cassava (*Manihot esculenta* Crantz) in the Midwest region of Brazil (Fig. 10).

The current scenario shows that 44% of the area in the Midwest of Brazil is suitable for the cultivation of cassava, mainly in the west, southwest, south and east. The biggest restriction to cultivation in the current scenario is the excess of rainfall with a value close to 46%, mainly in the central, northwest, north and northeast regions.

The scenarios S1, S2, S3 and S7 showed characteristics of precipitation and air temperature more suitable for the cultivation of cassava, with areas suitable of 56%, 64%, 44% and 41%, respectively. These areas of greatest adequacy occurred with a reduction of 30% (S1) and 15% (S2) in rainfall, without increasing air temperature. In scenarios

S10 and between S14 and S25, there are no suitable areas, due to the restrictions of T_{AIR} and/or R_{mm}, with indexes outside the limits required by cassava. The greatest restrictions occurred in scenarios with an increase in temperature of + 4.5, + 6.0 ºC and rain of + 30% mm, with S20 and S25 with a 98% restriction on T_{AIR} and R_{mm}.

The gradual increase in anthropogenic effects and natural climate variability reduced the areas of suitable conditions for the cultivation of cassava in the Midwest region of Brazil, leading to the calculation of areas with thermal restrictions (± 7.1 °C) and excessive rain (± 1620 mm); this fact should directly affect the growth, development and productivity of cassava in the region.

In scenarios from S3 to S14, except S10, there is a decrease in the area suitable for cassava compared to the current scenario with a decrease in:

- S4 of −33%;
- S5 (−43%);
- S6 (−13%);
- S7 (−3%);
- S8 (−16%);
- S9 (−39%);
- S11 (−37%);
- S12 (−29%);
- S13 (−32%); and
- S14 (−43%).

Subsequently, in the scenario S10 and between S15 and S25 there are no areas suitable for cultivation due to the restrictions of T_{AIR} and/or R_{mm}.

We found that with the progress of the climatic changes, in agreement with the agroclimatic zoning map, there is a gradual decrease in the areas suitable for the cultivation of cassava, not existing after the scenario 14 (S14), due to the increase in regions with high temperature and excessive rainfall (Table 1).

The elaboration of the agroclimatic zoning of cassava in function of climate change demonstrated the marginal regions, suitable and unsuitable for those involved in cassava, and possible solutions to mitigate the effects caused by changes in air temperature and rainfall, reducing the risks of loss in cultivation.

Finally, this research serves as a basis for further studies. It is advisable to cover the impacts of climate change on cassava cultivation by adopting highly accurate global or regional climate models or implementing field research. Attention is paid to the releases of the IPCC report to adapt the methodology. The inclusion of other edaphoclimatic agents that influence the potential for cultivation of cassava, such as soil, carbon emission, among others, is checked.

5 Discussion

The distinction of air temperature fluctuation influences decision-making in regions that are equally adaptable and have better development and sustainability characteristics throughout the crop cycle (Medeiros & Cavalcanti, 2020). Pipitpukdee et al. (2020) reports that the global supply of cassava will be vulnerable to climate change.

Table 1 Areas of the agroclimatic aptitude classes of cassava for the Midwest of Brazil in future scenarios of climate change. *Source* authors. Legend: S1—scenario 1; S2—scenario 2… S25—scenario 25

Scenarios	Classes area (%)					
	Suitable	High R (mm)	Low R (mm)	High T (ºC)	High T (ºC) High R (mm)	High T (°C) Low R (mm)
S1	56	1	33	4	0	6
S2	64	24	2	9	0	2
S3	44	46	0	8	3	0
S4	11	79	0	5	6	0
S5	1	89	0	1	10	0
S6	31	1	21	29	0	18
S7	41	9	0	33	14	3
S8	28	22	0	24	0	26
S9	5	45	0	11	39	0
S10	0	50	0	2	48	0
S11	7	0	8	53	1	31
S12	15	0	0	58	24	3
S13	12	3	0	40	45	0
S14	1	14	0	14	71	0
S15	0	15	0	2	83	0
S16	0	0	0	60	1	39
S17	0	0	0	73	24	3
S18	0	0	0	52	48	0
S19	0	0	0	16	85	0
S20	0	0	0	2	98	0
S21	0	0	0	60	1	39
S22	0	0	0	73	24	3
S23	0	0	0	52	48	0
S24	0	0	0	16	85	0
S25	0	0	0	2	98	0

Scenarios S1, S2 and S3–S7 presented the best trends, with more than 40% of their areas suitable for the cultivation of cassava. Restrictions are observed due to high temperature, water deficit and/or excessive rainfall. However, the use of resistant/tolerant varieties, soil management and irrigation practices can increase the efficiency of cultivation in these restricted places. Scenarios S11–S25 are worrying, as there is a predominance of areas restricted to high temperatures, with rates above 85% in all areas, in turn, linked to excessive rainfall and to a lesser extent to water deficit.

Climate change affects air temperature and rainfall distribution, impacting the crop cycle (Assad et al., 2020; Freitas et al., 2019). The increase in air temperature threatens the cultivation of various agricultural plants (Clemente, 2019; Machado, 2014), stopping them from being planted in these locations due to thermal stress (Bragança et al., 2016; Santos, 2018). The greater risk for the cultivation of cassava can be expected in larger thermal amplitudes, due to the great variation in air temperature, with maximums reaching above 30 degrees.

Cassava is tolerant to several climatic stresses, such as high temperatures and water deficit, but not to the flooding of the soil. Changes in rainfall may provide more intense and frequent extreme events (IPCC, 2014). Despite the extremes of rainfall, Aparecido et al. (2020) reports that the Center-West region has well-drained soils with a predominant clay content between 15 and 35%, making the cultivation of cassava viable. It is essential for rural people to understand the dynamics and spatial and temporal variability of rainfall, in order to obtain good results in their crops (Roldão, 2020), especially with regard to the planting season, months of greater rainfall between 1 and 5 months are recommended.

Thus, it is observed that climate change is a reality and its effects are increasingly worrying in agroclimatic zoning of cassava. It is essential to adapt management systems to mitigate climatic changes' effects on cassava growth, development and productivity, with the introduction of genes tolerant to biotic and abiotic stress in cassava varieties to increase their production, regardless of changes in climatic conditions.

As solutions, they present themselves genetic improvement, varieties resistant to high temperatures, water deficit and root rot; and physical, with well-drained soils. This study provides subsidies for the implantation of cassava culture and reduction in the risk of losses resulting from pre-planned decision-making and serves as an alert to promote awareness of possible climate changes.

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