

IDENTIFICATION OF MEGA ENVIRONMENTS IN THE BRAZILIAN UPLAND RICE PRODUCTION AREA

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ABSTRACT: The goal of this study explores possibilities to adjust the upland rice regional breeding systems to optimally fit the range of environments they are targeting, based on a historical yield data set of the IBGE. The specific objectives of this study were: to identify and classify environment groups in the Brazilian upland rice (UPR) production area; to validate these environment groups using yield data set from the upland rice multi-trial experiments (MTEs); and to identify the most representative site for each environment group. For that, the historical upland rice yield data from 54 microregions were detrended from the effects of technological advances and adjusted to the reference year, 2006. A matrix was built with the adjusted yield data and submitted to a cluster analysis allowing to identify three different environment groups. These groups were classified as: high favourable environment (HFE); favourable environment (FE); and low favourable environment (LFE). The HFE has as characteristic being less affected by inter-annual rainfall variability than the other two.

KEYWORDS: environment classification, cluster analysis, yield.

IDENTIFICAÇÃO DE MEGA-AMBIENTES NA REGIÃO PRODUTORA DE ARROZ DE TERRAS ALTAS

RESUMO: O objetivo geral deste estudo foi explorar as possibilidades para ajustar o programa de melhoramento de arroz de terras altas em função dos diferentes ambientes alvos que pretende atingir, baseado nos dados históricos de produtividade do IBGE. Os objetivos específicos foram: identificar e classificar diferentes grupos de ambientes na região produtora de arroz de terras altas (UPR); validar os grupos ambientais classificados utilizando um conjunto de dados provenientes das experimentações regionais do programa de melhoramento de arroz de terras altas; e identificar os locais mais representativos nos diferentes ambientes identificados. Para isso, os dados históricos de produtividade de 54 micro-regiões foram filtrados, com a finalidade de retirar os efeitos do avanço tecnológico, e ajustados para o ano de 2006. Os dados de produtividade ajustados foram utilizados para construir uma matriz, a qual foi submetida à análise de agrupamento para identificar os diferentes grupos ambientais. Os grupos identificados foram classificados em altamente favorável (HFE), favorável (FE) e pouco favorável (LFE). O HFE tem como característica ser menos afetado pela variabilidade inter-anual das chuvas que os outros dois.

PALAVRAS-CHAVE: classificação de ambientes, análise de agrupamento, produtividade.

INTRODUCTION: One of the main environmental limiting factors for upland rice production is the soil water availability, mainly in the Brazilian savannahs where subsoil acidity leads to restricted rooting depth, which increases the effects of moderate droughts. Therefore, better quantification of existing climatic risks for upland rice (ULR) production is urgently needed. Brazilian ULR breeding program looks for developing genotypes (G) with wide adaptability across all environments (E) based on G and E interaction (G×E) from the multi-trial experiments yield data (MTEs). In many cases, the analyses of large scale METs can be a major impediment for genetic progress of the crop. To reduce the G×E or specifically the cross-over interaction, it was proposed the classification of mega-environments (MEs). ME is defined as the growing region of a crop species where the environmental conditions are relatively homogenous. Due to the extension of the ULR production area, the determination of MEs is generally limited by the lack of the required MTE data. The objectives of this study were to identify and classify environment groups in the Brazilian ULR production area, to validate and classify these groups using an independent yield data set from MTEs.

MATERIAL AND METHODS: Upland rice historical yield data from 1976 to 2006 were obtained from IBGE. The yield data in this study represents 54 microregions located in four Brazilian states: Goiás, Mato Grosso, Rondonia, and Tocantins (Figure 1). Microregions in Brazil was established and defined by IBGE as a group of contiguous counties in the space at the same state. The yield from a microregion represent an average of counties yields that belongs to the same microregion. Figure 1 illustrates all microregions located in the four states, which do not consider the tropical rice flood area. Basically, for all microregions used, upland rice yield has increased exponentially over this period. However, the historical upland rice yield data collected by IBGE represents the interaction of climate variability and technological advances for the period. As we only have interest on the yield impact caused by climate variability in this period, there is a need to detrend the effects of technological advances from the yield data by adjusting them to the reference year, 2006. This procedure was done using a similar methodology applied by Fernandes et al. (2010). A trend line was fit to the yield data for each microregion using a non parametric locally weighted polynomial regression known as loess. The predict trend line values were considered as technological advances. The relative deviation represents the climate variation, and it was calculated based

on the equation $RD_1^n = \frac{x - \bar{y}}{\bar{y}}$ (1), where RD_1^n is the relative deviation from the initial (1) to

the last (n) yield in the period; x is the observed yield (kg ha^{-1}); \bar{y} is the predicted yield calculated by loess regression (kg ha^{-1}). The adjustment of all yields for the last available yield data from IBGE, e.g. 2006, was done based on the equation $AY_1^n = (RD_1^n + 1) * \bar{y}_n$ (2),

where AY is the adjusted yield (kg ha^{-1}); \bar{y}_n is the predicted yield calculated by loess regression for 2006 (kg ha^{-1}). In equation (2), RD must be added to 1 due to all values are always less than 1. To develop the environmental characterization of the production area (Figure 1), a matrix was established consisting of microregion names and years (from 1975 to 2006), taking into account the respective adjusted yield from each microregion and year obtained by the process of detrend. This classification employed a hierarchical agglomerative clustering method with a squared Euclidian distance as the dissimilarity measure, and incremental sum of squares as the fusion criterion. The same methodology for environment characterization was used by Heinemann et al. (2008). Three classes were adopted to classify the environment groups in the upland rice production area: high favourable environment (HFE); favourable environment (FE); and low favourable environment (LFE).

RESULTS AND DISCUSSIONS: Based on the cluster analysis of the historical adjusted yield data from IBGE database, the upland rice production region was classified in three environment groups: high favourable (HFE); favourable (FE); and low favourable (LFE), as presented in Figure 2. The HFE is composed by 11 microregions: Sinop (3); Colider (4); Alta Floresta (6); Arinos (32); Alto Teles Pires (31); Parecis (37); Norte Araguaia (45); Jauru (41); and Alto Pantanal (39), in the state of Mato Grosso, and Colorado do Oeste (35) and Vilhena (24), in the state of Rondônia (Figures 1 and 2). This environment showed the highest average of adjusted yield (2740 kg ha^{-1}) and minimum and maximum adjusted yield of 1720 and 4629 kg ha^{-1} (data not showed). The average adjusted yield for each microregion classified as HFE is illustrated in the upper part of Figure 3. The highest averaged adjusted yield for this environment was obtained in the microregion of Arinos, MT, with more than 3000 kg ha^{-1} (Figure 3). The HFE is characterized by having higher average yield in the north region of Mato Grosso State and it decreases moving to south, with exception to Jauru and Alto Pantanal, east and west directions. Probably, the decrease on the average adjusted yield from north to south can be explained by changing in the rainfall inter-annual variability due to north area is affected by systems from Amazonia region, such as tropical Mesoscale Convective Complex and south region by extratropical system such as cold front and instabilities (Reboita et al. 2009). The FE is composed by 16 microregions distributed in three States, Rondônia, Mato Grosso, and Goiás. In this environment, the minimum, maximum and average values of adjusted yield were 1061 , 3260 and 2247 kg ha^{-1} (data not showed). The highest averaged adjusted yield was found in Anápolis microregion in Goiás State (Figure 3). The LFE is composed by 27 microregions located in four states, Tocantins, Goiás, Mato Grosso and Rondônia, considered the largest part of the upland rice production area. However, most of the microregions in this environment are located in Tocantins and Goiás States. In this environment, the minimum, maximum and average values of adjusted yield were 859 , 3129 and 1725 kg ha^{-1} (data not showed). The highest average adjusted yield was found in Ceres microregion, state of Goiás, and the lowest in Araguaína microregion, in the state of Tocantins (Figure 3). This analysis and the subsequent site clustering were based solely on grain yield. We assumed adjusted grain yield as representative of all traits that collectively determine upland rice productivity in an environment. Basically, breeding activities for upland rice in Brazil are based on direct selection for grain yield. Based on that, the HFE can be considerate the best environment group to compare the genotypes performance for direct selection for grain yield. In this environment group is expected to have less influence of climatic variability, as those caused by El Niño Southern Oscillation (ENSO) phenomena in the other environments, and, consequently, the lowest difference between potential and actual upland rice yields. For this environment, upland rice genotypes that have high effective water use should be recommended for production. Effective water use implies maximum soil moisture capture for transpiration which also involves reduced non-stomatal transpiration and minimum water loss by soil evaporation (Blum, 2009). According to Heinemann et al. (2011), modern cultivars, i.e. BRS Primavera and BRSMG Curinga, are good examples of genotypes with higher effective water use than old cultivars such as Douradão. On the other hand, breeding programs focusing on drought resistance or tolerance should have their trials conducted preferably in LFE, where climatic variability will allow the upland rice crop to face water deficit more frequently. Breeding programs such as the Brazilian upland rice can benefit from this knowledge by actively selecting parental materials from key sites for crossing, and by selecting and testing the derived lines at key locations within these environment groups.

CONCLUSION: This study allowed to identify three different mega environments in the Brazilian upland rice production region: high favorable environment (HFE); favorable environment (FE); and low favorable environment (LFE). HFE is the best one for high grain yield selection, whereas LFE is recommended for drought tolerance breeding programs.

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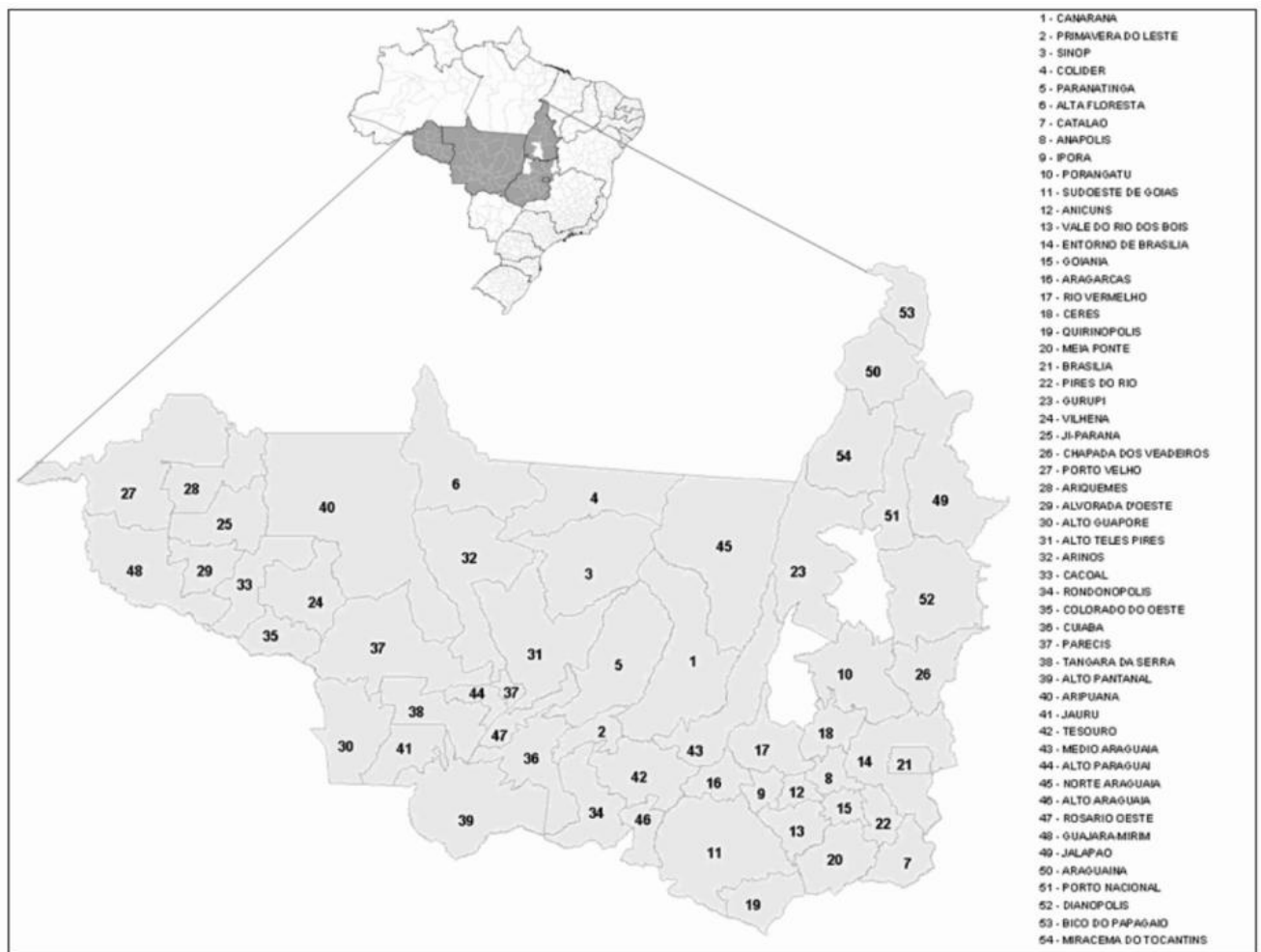


Figure 1. Brazilian upland rice production area. The numbers are related to each microregion and white counties are those not considered in this study for producing irrigated rice.

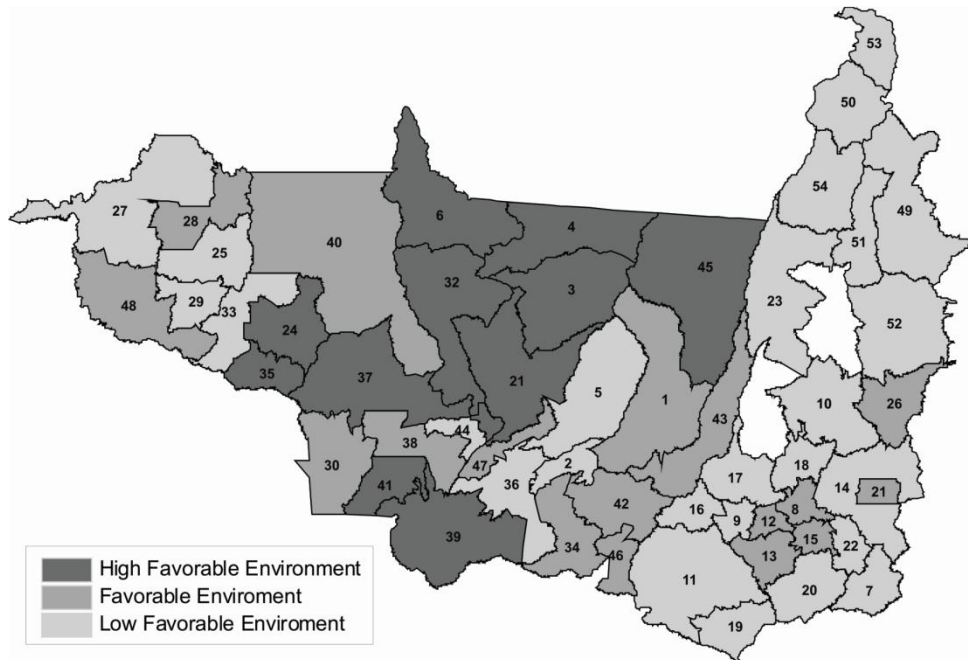


Figure 2. Distribution of the three environment groups identified based on adjusted yield classification for upland rice production area for the states of Goiás, Mato Grosso, Rondônia and Tocantins, Brazil. Numbers refer to legend of Figure 1 and white counties are those not considered in this study for producing irrigated rice.

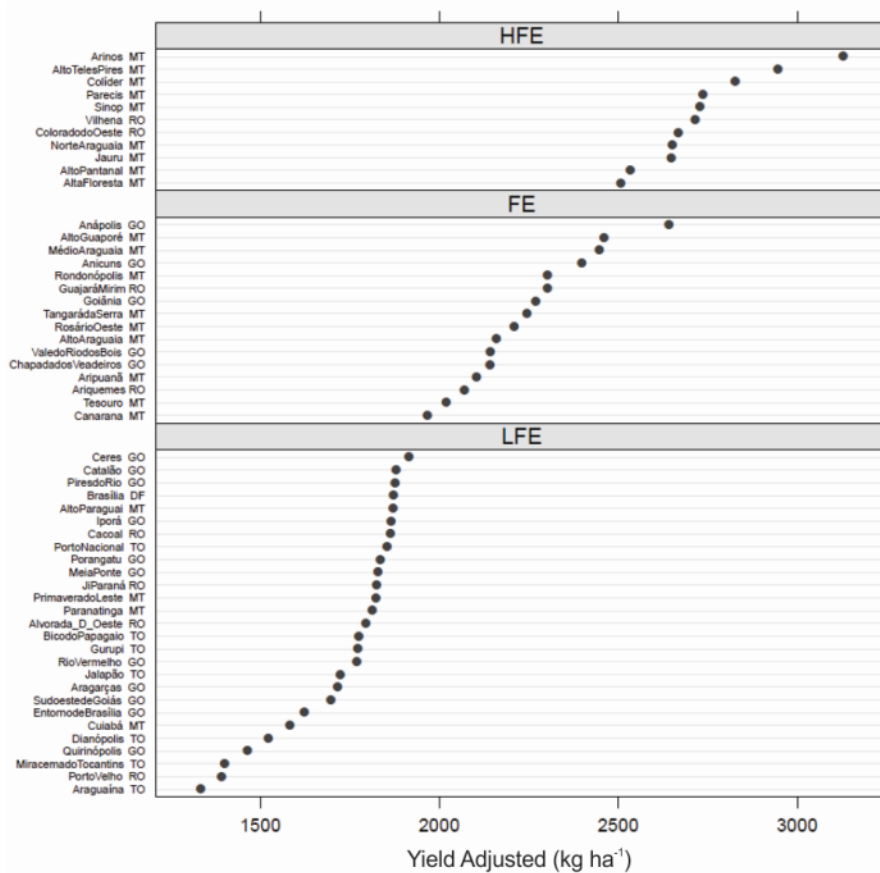


Figure 3. Average upland rice adjusted yield (IBGE data base) for each microregion of the states of Goiás, Mato Grosso, Rondônia, and Tocantins, Brazil Central region, classified as high favourable (HFE), favourable (FE) and low favorable (LFE) environment groups.