Maize Production Environments Revisited

A GIS-based Approach

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Abstract: This publication presents a GIS-based approach for revising the definitions of global maize production environments, called "mega-environments" (MEs), used by CIMMYT and its partners. A cluster analysis was performed on climate data, representing a four-month growing season, for key maize producing locations. Assuming rainfed production, the onset of the growing season was determined based on the month when the ratio of precipitation over potential evapotranspiration exceeds 0.5. Diagnostic criteria for mapping MEs were based on cluster analysis results and expert knowledge. The resulting maps can be used to select appropriate target environments for maize germplasm and trials, as well as in priority setting and site selection for global maize breeding programs.

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Executive Summary

To improve the targeting of germplasm by its staff and partners, in the 1980s CIMMYT defined a set of global maize production environments known as "mega-environments" (MEs). Center staff interviewed research partners in approximately 70 maize producing countries of the developing world. Based on the results, the major, non-temperate maize production ecologies were subdivided into 30 large, not necessarily contiguous areas according to such factors as maturity, preferred grain color and texture, and important production constraints (drought, low N conditions, diseases, insect pests). These ME definitions are very useful for targeting and priority setting, but also have shortcomings. They are based on expert knowledge and are therefore subjective. Crop losses due to diseases, pests and abiotic stress factors are estimated and not based on trials. The timing and severity of common stresses are not defined, thus precise aggregation of areas with similar stress ratings is difficult. Furthermore, definitions focus on regions where CIMMYT has strong contacts, leaving some areas poorly characterized. In some regions, different MEs overlap, making the system difficult to use. Finally, maize cropping locations, circumstances, and systems have changed considerably since the original ME study, but updating of MEs has been sketchy for lack of resources to do a complete, methodical revision.

This publication presents a revision of the maize MEs that draws on geographic information systems (GISs). A cluster analysis was performed on climate data, representing a four-month growing season, for key maize producing locations. The onset of the growing season was determined based on the month when the ratio of precipitation over potential evapotranspiration exceeds 0.5, assuming rainfed production conditions. Diagnostic criteria for mapping MEs were based on cluster analysis results and expert knowledge, and resulted in divisions based on daylength, mean temperature, and precipitation. The resulting maps and classifications can be used to select appropriate target environments for maize germplasm and trials at the regional level, as well as in priority setting and site selection for global maize breeding programs. The full ME classification and map (Table 5 and Appendix H) is more detailed than many users will want to deal with, so a simplified map **(Centerfold)** and table of criteria (Table 1) were prepared that eliminate the subdivisions based on precipitation. In any case, the creation of surfaces for precipitation is more problematic than for temperature. Variation in precipitation often shows no relation to elevation, and precipitation amounts may change rapidly over relatively short distances (e.g., in rain shadows). We expect that users of the map will usually have a good understanding of such local variation.

The ME definitions need further refinement using actual maize production[1] and distribution data; long-term trial results that represent genotype-by-environment interaction and the incidence and severity of stresses; improved data on soils; information on consumer preferences; and the identification of irrigated maize areas in developing countries, to name a few important factors.

[1] Including planting dates for main and secondary seasons.

Table 1. Descriptions, regions, countries, and key sites associated with global maize mega-environments.

ME	Name	Daylength (h)	Mean temperature (ºC)	Description *
1	Tropical lowland	11-12.5	>=24	Equatorial Central and South America and Southeast Asia, as well as coastal regions of Africa. Largely high humidity, rainfed systems. Includes some winter season regions at higher latitudes. Key sites: Suwan (W), Thailand; Bangalore (W), India; Tarapoto, Peru; Mvuazi, DRC; Kwadoso, Ghana.
2	Tropical midaltitude	11-12.5	>= 18 < 24	Much of inland equatorial sub-Saharan Africa, Central and South America. Key sites: Sete Lagos, Brazil; Palmira, Colombia; Turrialba, Costa Rica; Nazareth, Ethiopia; Embu, Kenya; Poza Rica (W), Mexico.
3	Tropical highland	11-12.5	< 18	Equatorial highlands, typically over 2,000 masl. Key sites: Rio Negro, Colombia; Ambo, Ethiopia; Cajamarca, Peru.
4	Non-equatorial Tropical - Subtropical lowland	12.5-13.4	>=24	Major environment of Central and South America, sub-Saharan and West Africa and Asia. Key sites: Ludhiana, India; Chiredzi, Zimbabwe; Santa Cruz, Bolivia; La Ceiba, Honduras; Poza Rica (S), Mexico; Tlaltizapan (S), Mexico; Suwan (S), Thailand.
5	Non-equatorial Tropical - Subtropical midaltitude	12.5-13.4	>= 18 < 24	Major environment of sub-Saharan Africa and the Mexican highlands. Typically less than 1,800 masl. Usually rainfed but with large variation in rainfall. Key sites: Harare, Zimbabwe; Celaya, Mexico.
6	Non-equatorial Tropical - Subtropical highland	12.5-13.4	< 18	Many scattered highland regions of Central and South America and Africa. Typically over 1,800 masl. Key sites: El Batan, Mexico; Thaba Seka, Lesotho.
7	Subtropical winter hot	< 11	>=24	No regions fit these criteria. The category is included only for completeness. Key sites: None.
8	Subtropical winter warm	< 11	>= 18 < 24	Typically irrigated regions at lower elevations. Key sites: Los Mochis (W), Mexico; Joydebpur (W), Bangladesh.
9	Subtropical winter cold	<11	< 18	Very limited area with cool, subtropical climate, but no frost in winter season. Key sites: Good Hope, Botswana.
10	Subtropical -Temperate hot	>= 13.4	>=24	Ranges from very dry irrigated to humid rainfed environments. Key sites: Sakha, Egypt; Chokwe, Mozambique; Rampur (S), Nepal; Islamabad, Pakistan; Temple, Texas.
11	Subtropical -Temperate warm	>= 13.4	>=18 <24	Major temperate maize production regions of USA and China. Key sites: Kunming, China; Lumle, Nepal; Potchefstroom, South Africa; Toulouse, France; Ferrara, Italy; Pyongyang, North Korea; Ames, Iowa, USA; Davis, California, USA.
12	Subtropical -Temperate cold	>= 13.4	< 18	Highest latitude regions where maize production is possible. Key sites: La Platina, Chile; Guelph, Ontario; Orleans, France.

* For key sites, S = summer season and W = winter season.