Advances in breeding climate-resilient maize varieties for West Africa and Central Africa: a review of current tools available to plant breeders

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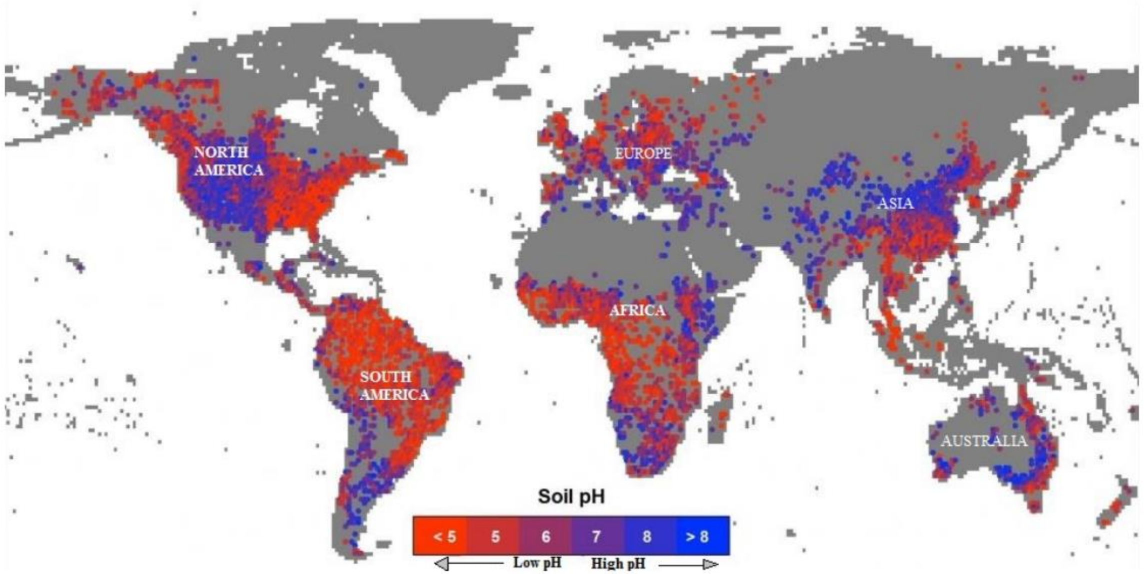
Multiple Stresses at Tropical Regions

- Tropical regions: combination of multiple stresses:
  - low mineral availability (P),
  - excess of toxic minerals (Al),
  - drought,
  - diseases, etc…

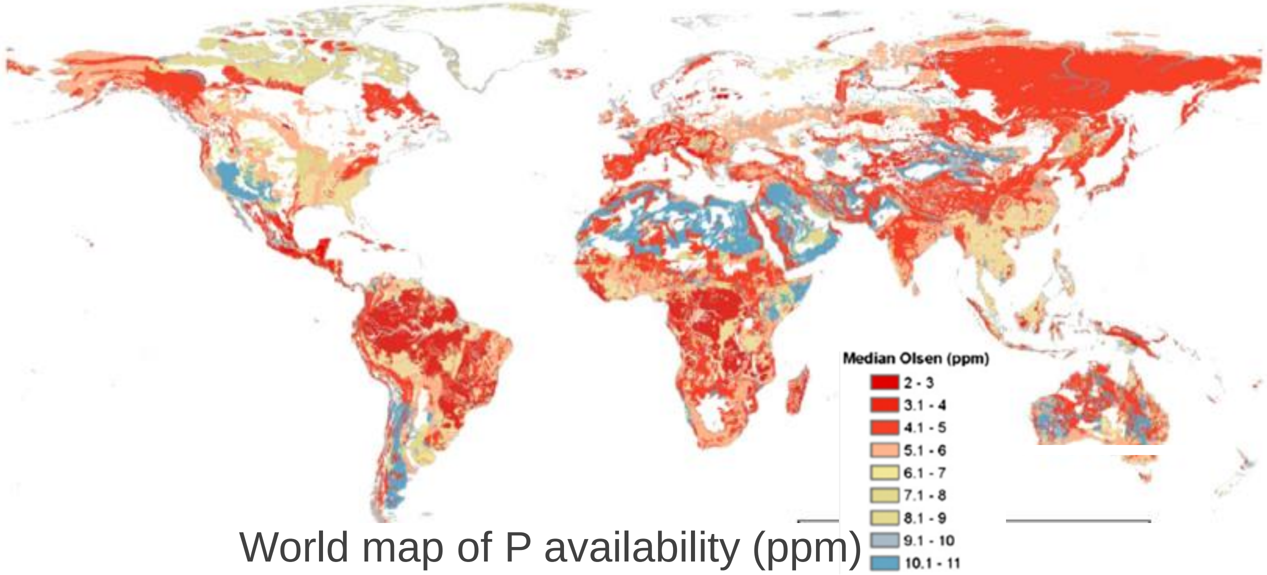
- Acid soils represents ~50% arable land

- Human activities: increase soil acidification causing irreversible CO_2 losses to atmosphere

- On acid soils ionic forms of aluminum (Al) limits root development



World map of estimated soil pH

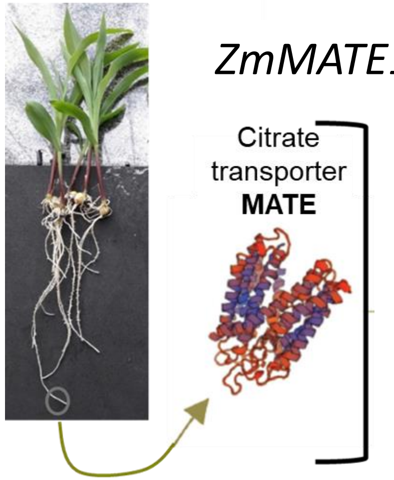


World map of P availability (ppm)

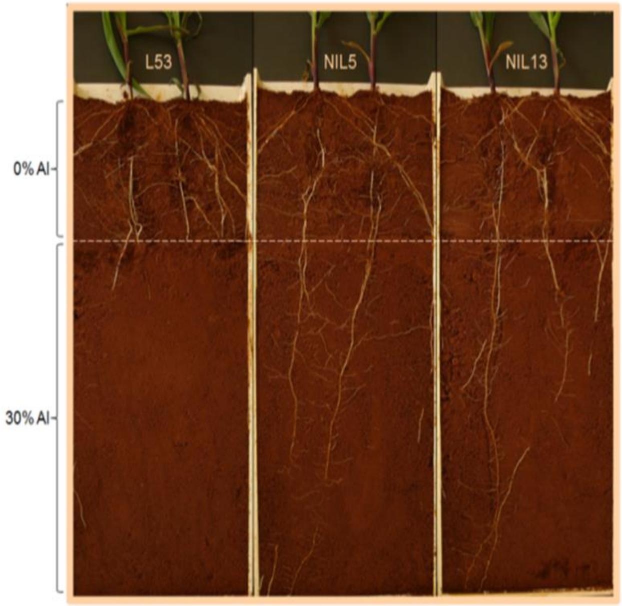
Maize Production in Brazil

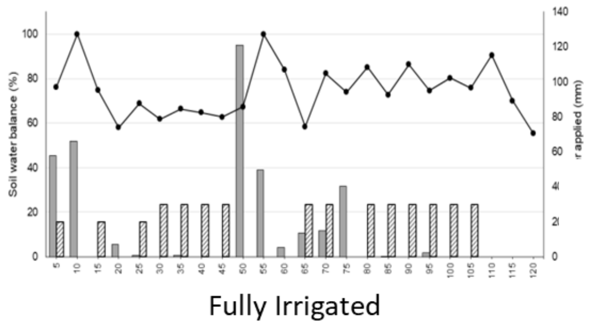
- Cerrado occupies 23% of Brazil, which is responsible for 50-70% of the agriculture
- Cropping system in two seasons: 70% maize is produced in the second season (dry season) and mostly in the Cerrado biome
- A large biodiversity and important fresh water source that need to be preserved
- To develop cultivars more resilient to multiple stresses should be a target for breeding programs
- Associated with conservative agronomic practices for a sustainable food production

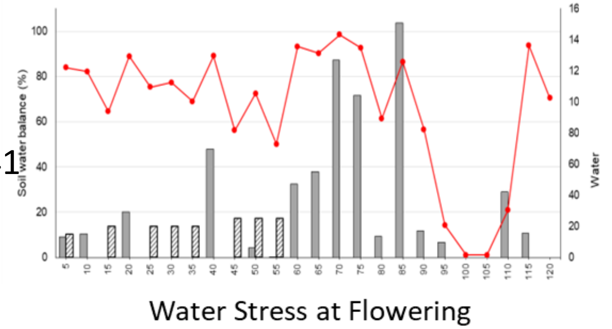
Al Tolerance to Improve Maize Yield Stability on Acid Soil

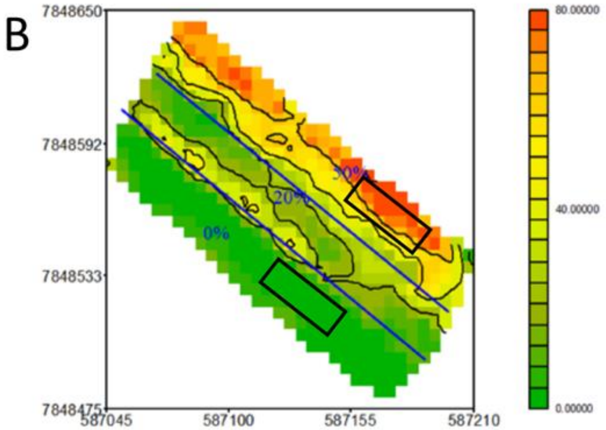


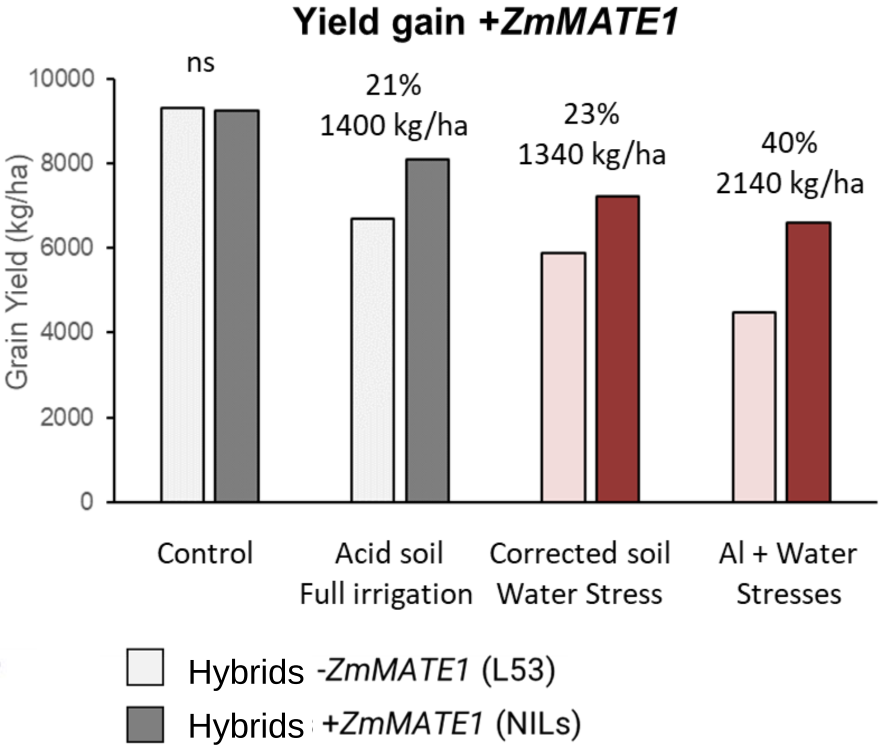
Maron et al. 2010 Plant J 61: 728
Maron et al. 2013 PNAS 110: 5241





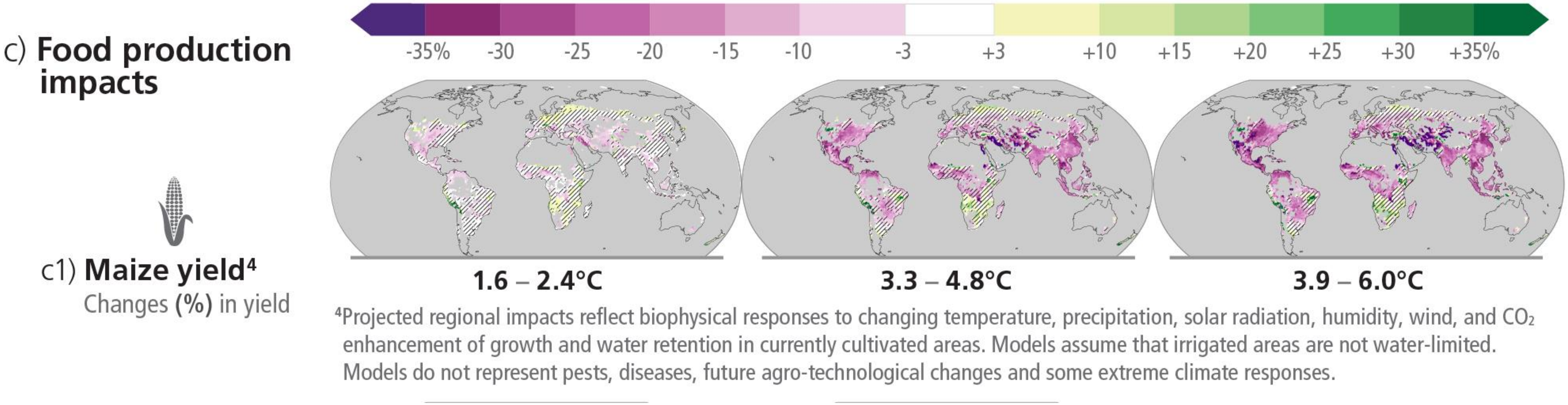






Vasconcellos et al. 2021 Crop Science
DOI: 10.1002/csc2.20575

Changes in maize yield by 2080-2099 relative to 1986-2005 at projected by global warming levels of 2.0°C, 4.1°C and 4.9°C



Intergovernmental Panel on Climate Change, 2023

Breeding programs aiming at developing climate-resilient maize varieties

Advances in Breeding Climate-Resilient Maize Varieties for West and Central Africa: A Review of Current Tools Available to Plant Breeders

Presented by
Gloria Boakyewaa Adu, PhD

Crops to End Hunger Case Studies in Africa and Beyond: Supporting CGIAR Partners through Genotyping Services

9th November, 2023

CSIR-SARI

Introduction

- Maize is a vital crop that provides food, nutrition, and income for countless resource-limited small-scale farmers in sub-Saharan Africa (SSA). However, in tropical regions where maize is predominantly grown under rainfed conditions, the crop is becoming increasingly susceptible to a variety of stressors caused by climate change.

- These stresses include:
  - Drought
  - heat
  - Waterlogging
  - salinity
  - cold temperatures
  - diseases, and insect pests.

- Often, these stressors occur simultaneously, causing significant damage to maize crops.

Effects of Climate Change on Agriculture, Food Security and Livelihoods in SSA

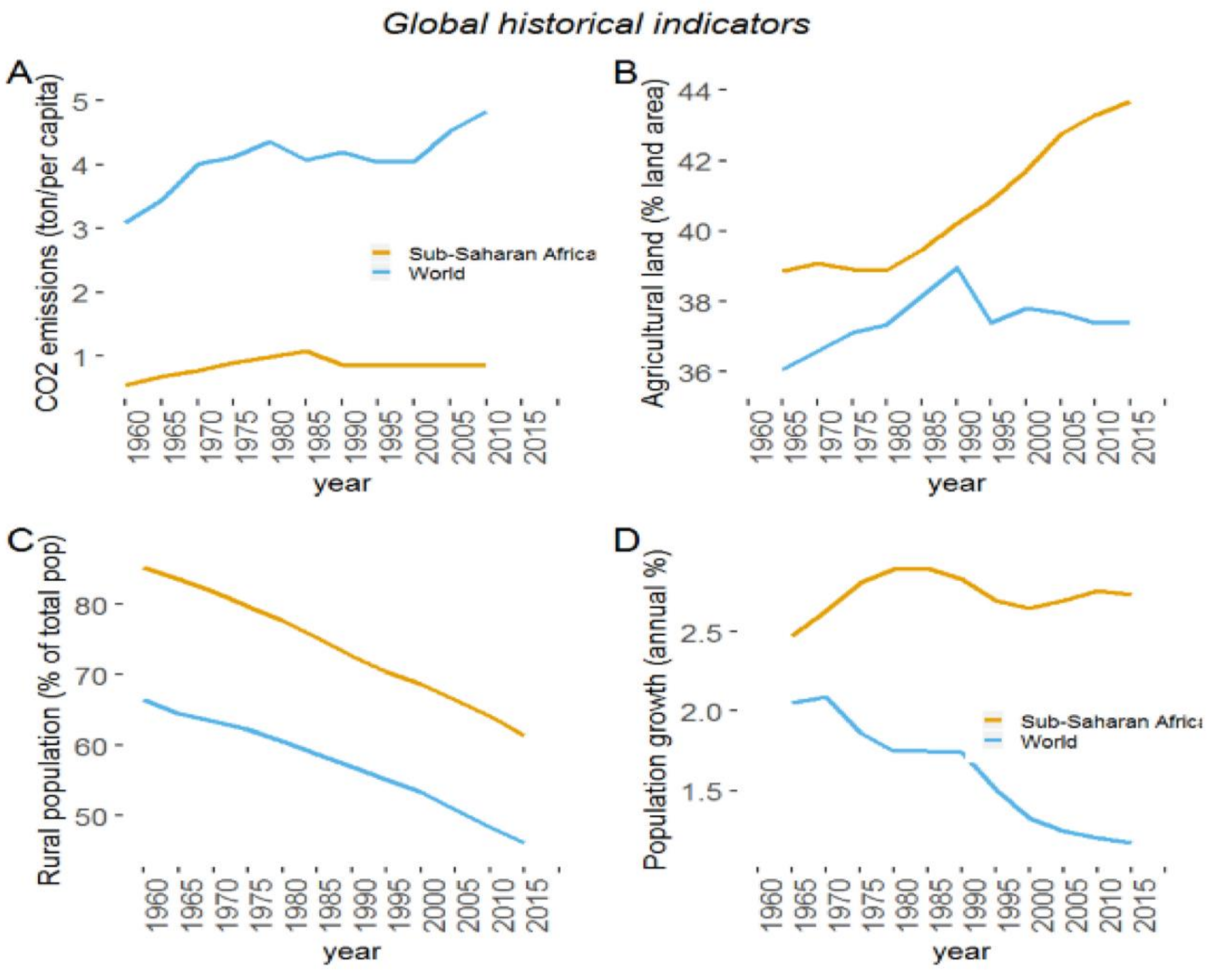


Figure 1. Comparison of global historical indicators (1960–2015) between Africa and the rest of the world for: (**A**) CO_2 emissions, (**B**) agricultural land, (**C**) rural population and (**D**) population growth.
Source: World Bank, 2020

Map of West and Central Africa (WCA)

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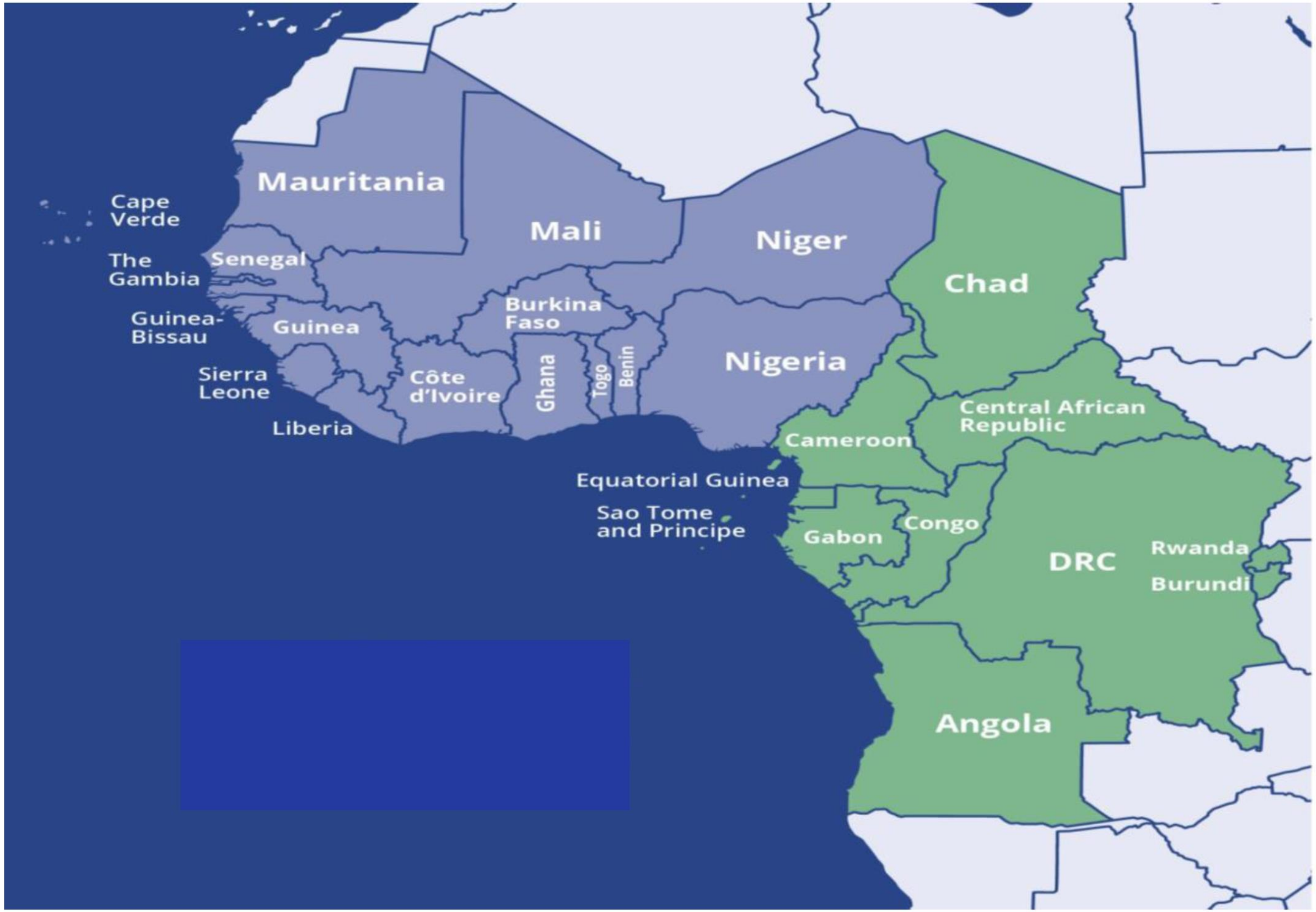
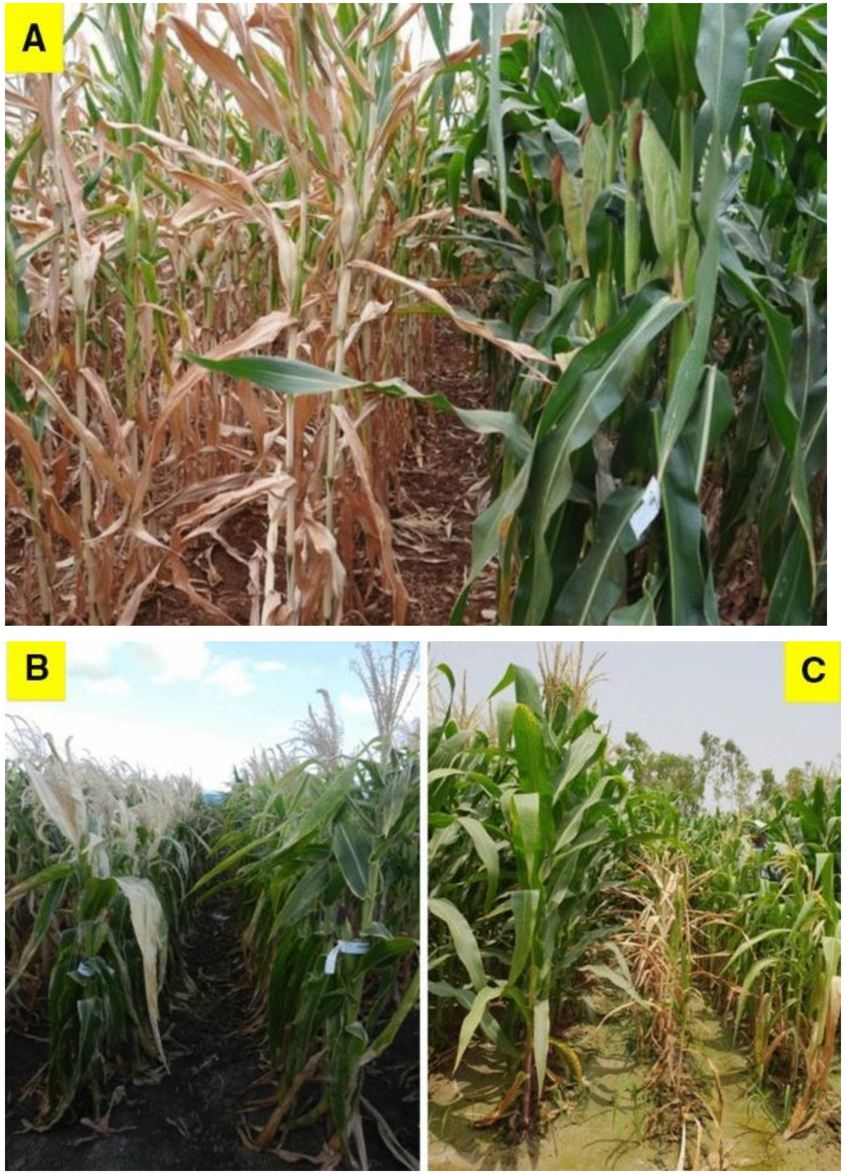


What are Climate-Resilient Crop Varieties:



- Climate-resilient crops refer to those crops and crop varieties that possess an inherent and enhanced ability to withstand both biotic and abiotic stress factors.

- Phenotypic differences among climate-resilient maize hybrids and others that are not resilient: **(A)** a comparison between drought-tolerant and drought-susceptible maize hybrids; **(B)** a contrast between heat-tolerant and heat-susceptible maize hybrids; **(C)** a distinction between waterlogging-tolerant and waterlogging-susceptible varieties. (Source: Prasanna et al. 2021).

- Significant progress has been made in breeding climate-resilient maize varieties in WCA (Badu-Apraku et al. 2023; Menkir et al. 2022).

Impact of Climate-Resilient Maize Varieties

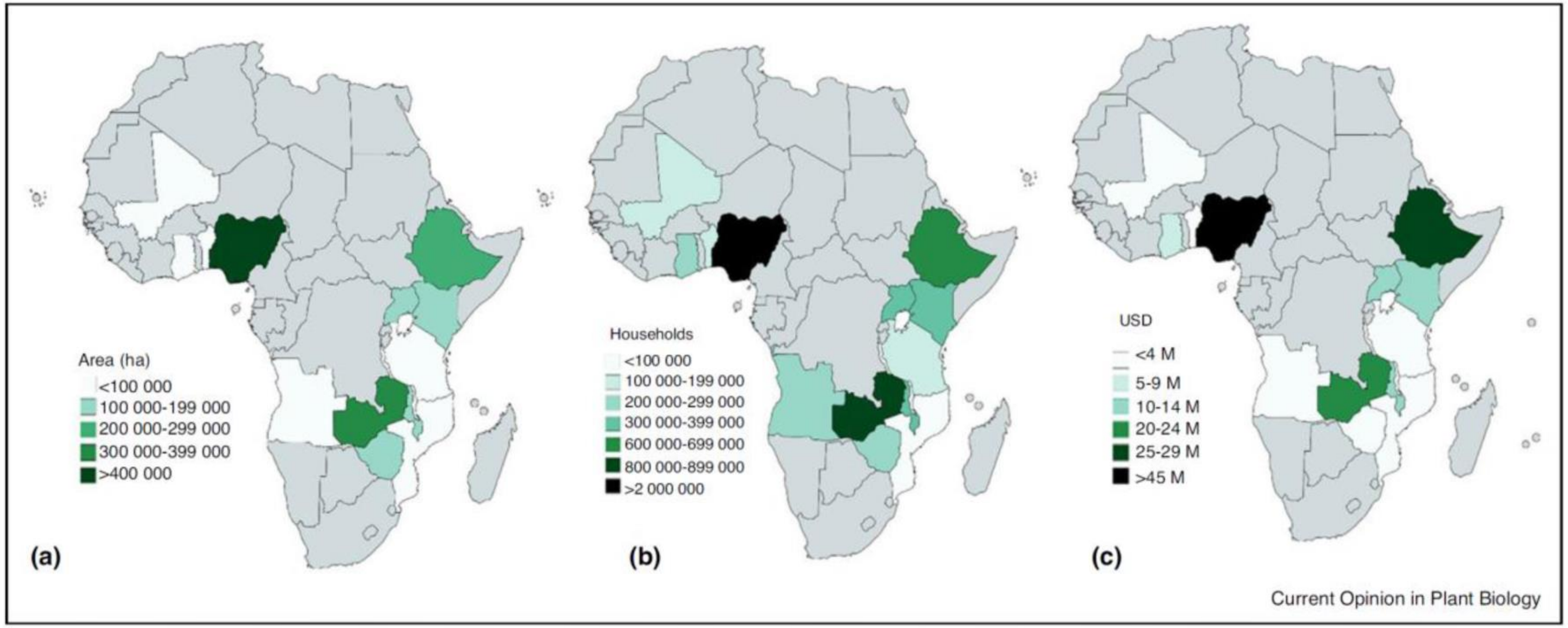
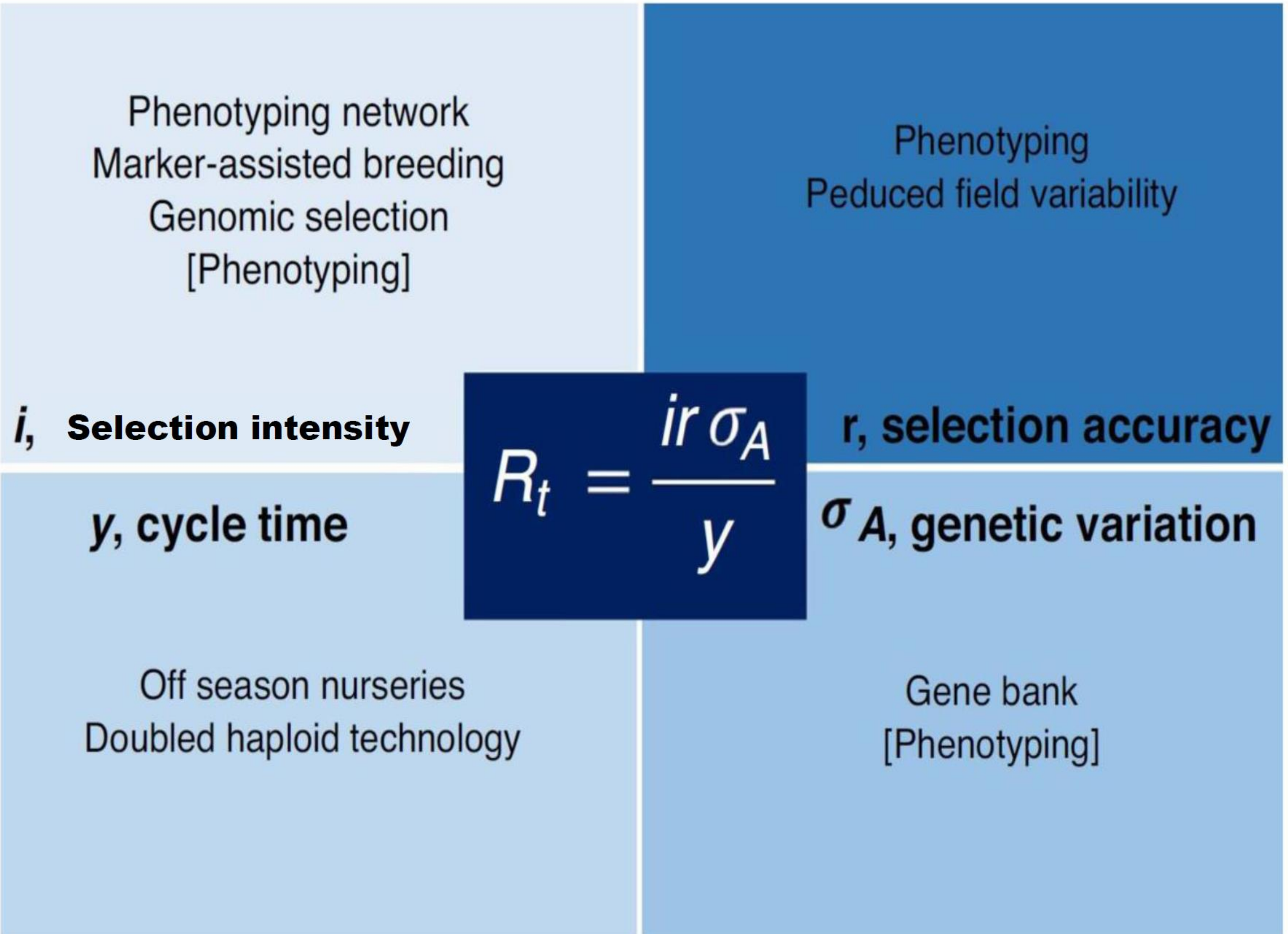


Figure 2: Estimated **(a)** maize area under climate-resilient maize, **(b)** number of households benefited from climate-resilient maize, and **(c)** economic value of increased maize production due to climate-resilient maize in 13 countries in SSA

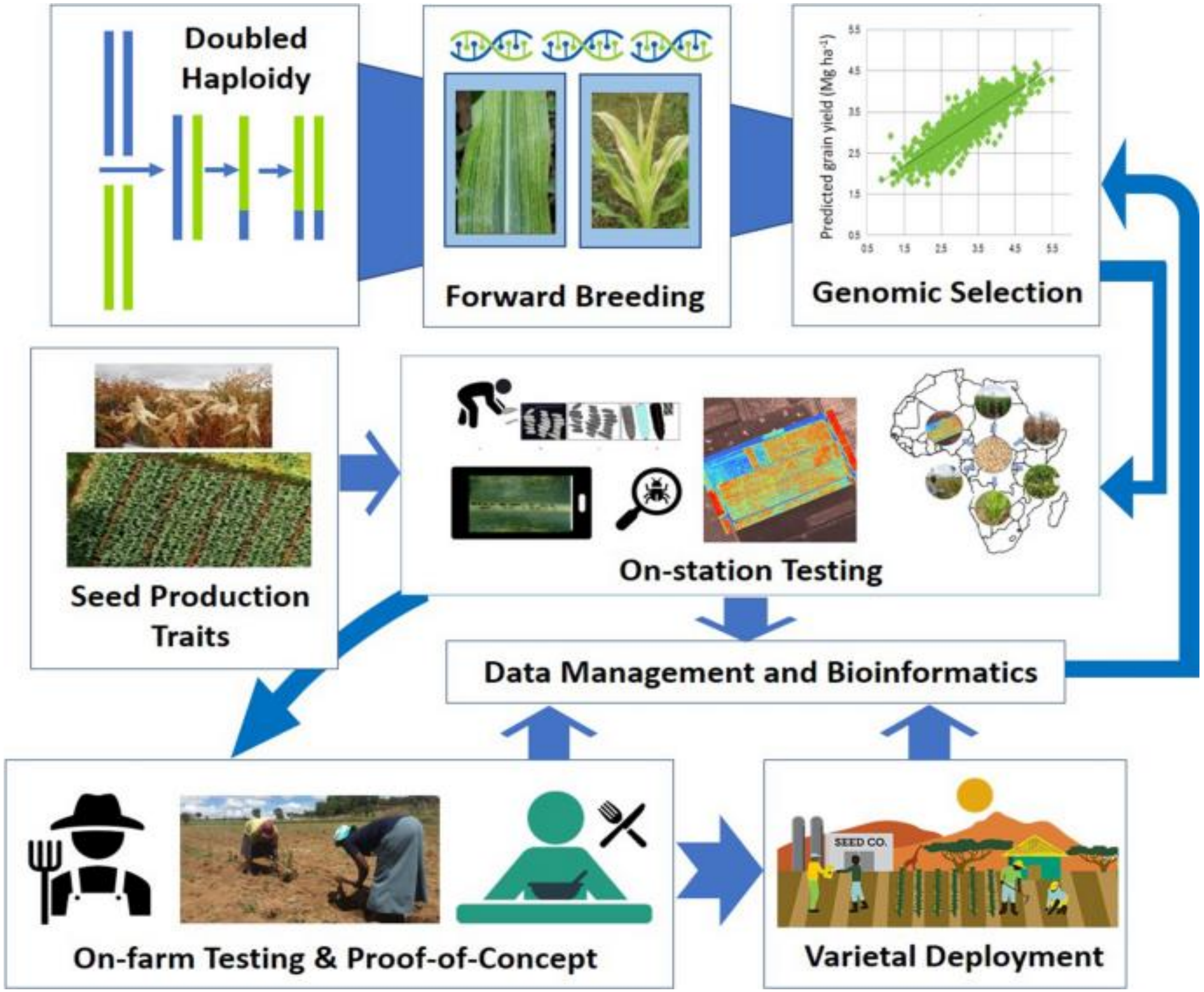
Source: Cairns and Prasanna, 2018

- Climate-resilient maize has the potential to increase yield by **5–25% in** Africa.
- Research has indicated that advancements in maize breeding have positively impacted an estimated **53 million individuals** in SSA (Cairns and Prasanna 2018).



The key to providing farmers with a consistent supply of climate-resilient varieties is to increase **genetic gain**, which includes **shortening the breeding cycle time**.

Current Tools Available to Breeders of Climate-Resilient Maize Varieties



Source: Prasanna et al. 2021

- High-throughput and precise Field-based Phenotyping,
- Doubled Haploid (DH) Technology,
- Genomics-assisted Breeding,
- Breeding Data Management, and Decision Support Tools.

Rate of Adoption of Modern Tools by Breeders in WCA

- Advances in Plant Phenotyping
- Advances in Genomic Selection
- Genome Editing and CRISPR-Cas9
- Use of Transgenic approaches to Introduce Foreign Genes into Maize
- Advances in Breeding Data Management, and Decision support tools

Development of climate-Resilient maize varieties at CSIR-SARI

Genotyping support received from CIMMYT and EiB

Molecular makers used:

- Single nucleotide polymorphism

Research interest:

- Genetic diversity and population structure of maize inbred lines and other genotypes.

Germplasm used:

- Drought and *Striga* 100 inbred lines (in 2014)
- Fall armyworm tolerant 932 inbred lines and 135 composites (in 2022)

Development of climate-Resilient maize varieties at CSIR-SARI

Support received from EiB to enhance plant phenotyping

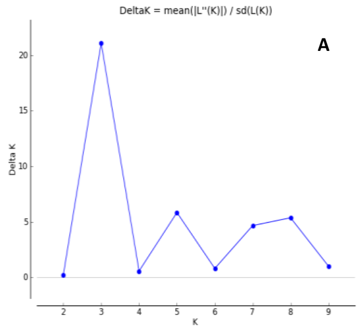
- Access to Breeding management system
- Capacity building

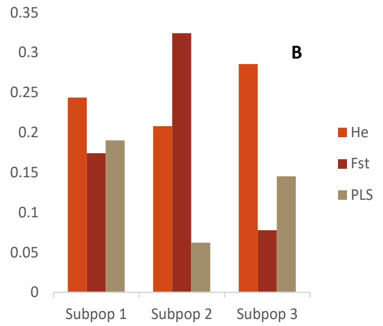
Development of climate-Resilient maize varieties at CSIR-SARI

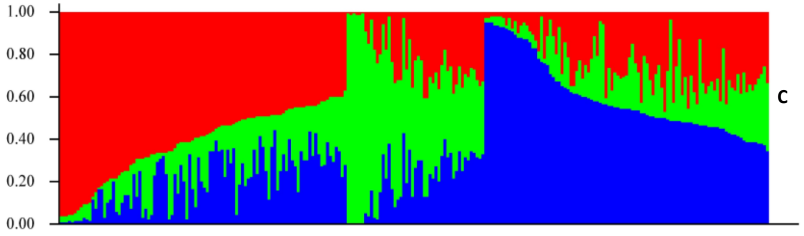
Genotyping services received from CIMMYT and EiB

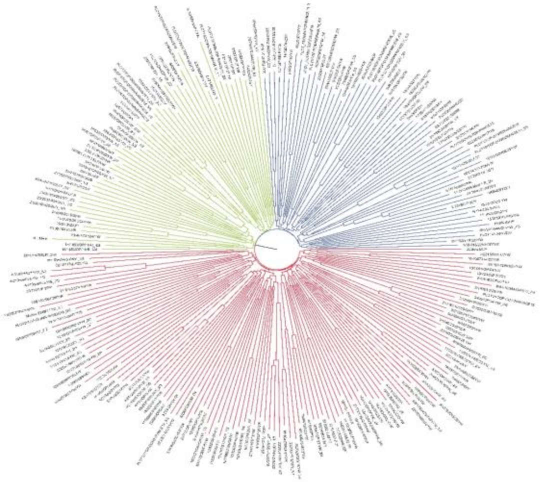
Oultcomes:

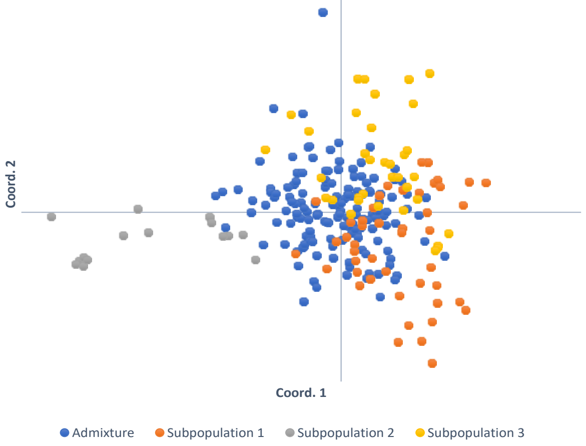
- Heterotic grouping
- Parental selection
- Hybrid development











In what ways are maize breeders in WCA acquiring and utilizing modern breeding tools?

- Donor funded projects
- Maize breeding/improvement projects, mainly coordinated by:

IITA Transforming African Agriculture CGIAR CIMMYT Excellence in Breeding PLATFORM

Rate of Adoption of Modern Tools by Breeders in WCA

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Challenges:

- High initial costs and usage of the technologies,
- Lack of capacity (technical and infrastructure)
- legislative barriers.

Way forward:

- Access to research funding
- Strategies for technology transfer
- legislative changes
- Capacity building in artificial intelligence and big data sciences

Conclusion

- There are some evidence on the dis-adoption of climate-resilient crops among farmers and end-users in Africa (Acevedo et al. 2020).

- The primary factors leading to the abandonment of climate-resilient crops by end-users include:
  - The technology not meeting the expectations of users due to sub-performance or quality of the technology.
  - Government policies
  - Technical constraints

- To address this problem, maize breeders in WCA should improve their technical expertise, and adopt existing modern technologies, collaborate with international counterparts, to enhance their capacity to developed user-preferred climate-resilient maize varieties.

- Maize breeders/ breeding institutions must be incentivized for meaningful research and contribution to food security in WCA and Africa as a whole.

Some Selected References

- Acevedo, M., Pixley, K., Zinyengere, N. et al. A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. Nat. Plants 6, 1231–1241 (2020). https://doi.org/10.1038/s41477-020-00783-z.
- Menkir A, Dieng I, Meseka S, Bossey B, Mengesha W, Muhyideen O, Riberio PF, Coulibaly M, Yacoubou A-M, Bankole FA, Adu GB and Ojo T (2022), Estimating genetic gains for tolerance to stress combinations in tropical maize hybrids. Front. Genet. 13:1023318. doi: 10.3389/fgene.2022.1023318
- Badu-Apraku B, Fakorede MAB, Annor B, Adu GB, Obeng-Bio E, Abu P, et al. Genetic Enhancement of Early and Extra-Early Maturing Maize for Tolerance to Low-Soil Nitrogen in Sub-Saharan Africa. Crop Breed Genet Genom. 2023;5(1):e230001. https://doi.org/10.20900/cbgg20230001.
- Prasanna, B.M., Cairns, J.E., Zaidi, P.H. et al. Beat the stress: breeding for climate resilience in maize for the tropical rainfed environments. Theor Appl Genet 134, 1729–1752 (2021). https://doi.org/10.1007/s00122-021-03773-7.
- Cairns JE, Prasanna BM (2018) Developing and deploying climate-resilient maize varieties in the developing world. Curr Opin Plant Biol 45:226–230. https://doi.org/10.1016/j.pbi.2018.05.004.

Thank you for your attention