Potential of hybrids and genetically modified crops to mitigate climate change effects on agricultural productivity in developing countries

Mozambique as case study

UAB Universitat Autònoma de Barcelona
Imanol Duran
Genetics Degree
Bachelor's Final Project - *2019*

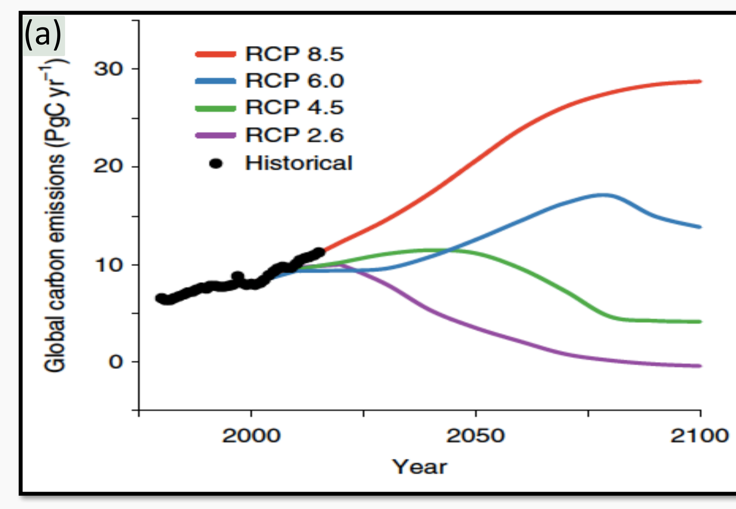
Introduction

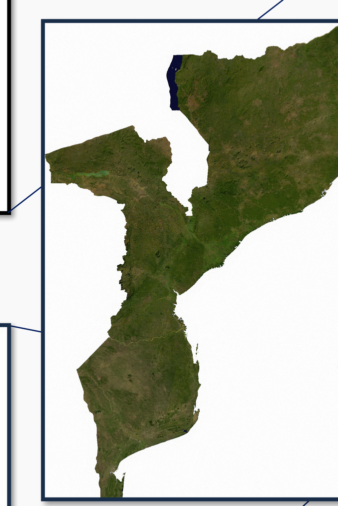
There is a growing **food insecurity** in the world and undernutrition has increased in Africa, affecting a record high of **256 million** people. Apart from armed conflicts and the economic slowdown in recent years, which paralysed agricultural development in developing countries, **climate change** is the sole biggest factor in the augmentation of food insecurity in the world.

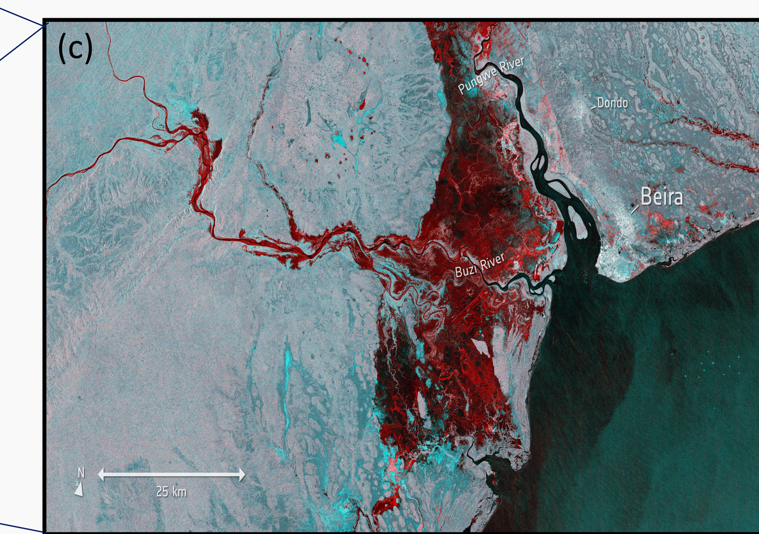
The unprecedented variability of the climate has undermined food access and the stability of crops, risking food supply chains and ruining harvests. This very variability is distorting agricultural productivity and cropping patterns, generating shortfalls that directly contribute to the undernourishment of local citizens. The rapid change of the environment is responsible for the **reduction of yield to half** of what was normal in the 1960s.

The poorest countries in the world, and the least prepared to tackle these events, are the most affected by climate change, adding to an already existing food insecurity crisis expanding decades. Mozambique is the paradigmatic case worth of analysis. It is one of the most exposed countries to climate change and suffers greatly from yield losses. Furthermore, annual crop loss surpasses 30% of total production and extreme climate events are steadily increasing over the last decades.

The most effective way of tackling the matter is through the establishment of improved varieties, both genetically modified (**transgenic varieties**) and those obtained by selective breeding (**hybrids**). It is necessary to move towards a balanced and sustainable agricultural system, through both conventional cropping technology and the best biotechnological tools, generating a system of hybrid and genetically modified crops, to achieve sustainable intensification and overcome climate related stress in cropland.







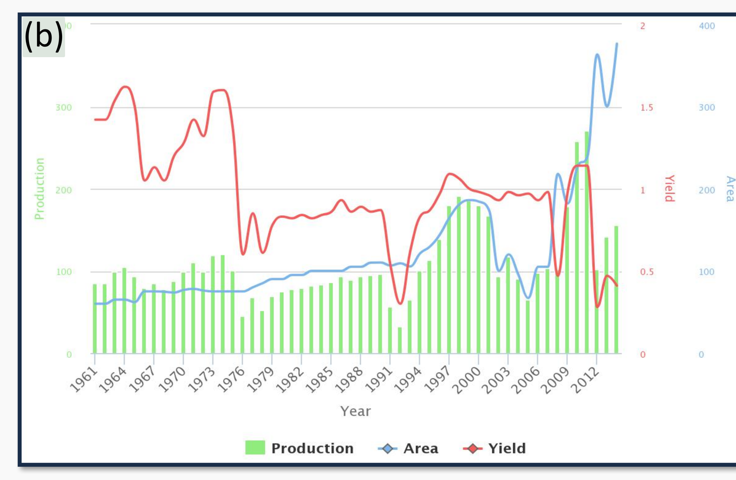


FIGURE 1. **(a)** *Historical trends in CO_2 emissions and atmospheric concentrations*. **(b)** *Fluctuation in crop production, area and yield in Mozambique (1961-2014).* **(c)** *Buzi river delta (Sofala Region) (20/03/19); Image obtained by Copernicus Sentinel-1, ESA.* [1]

Results I

RICE *(Oryza sp.)*

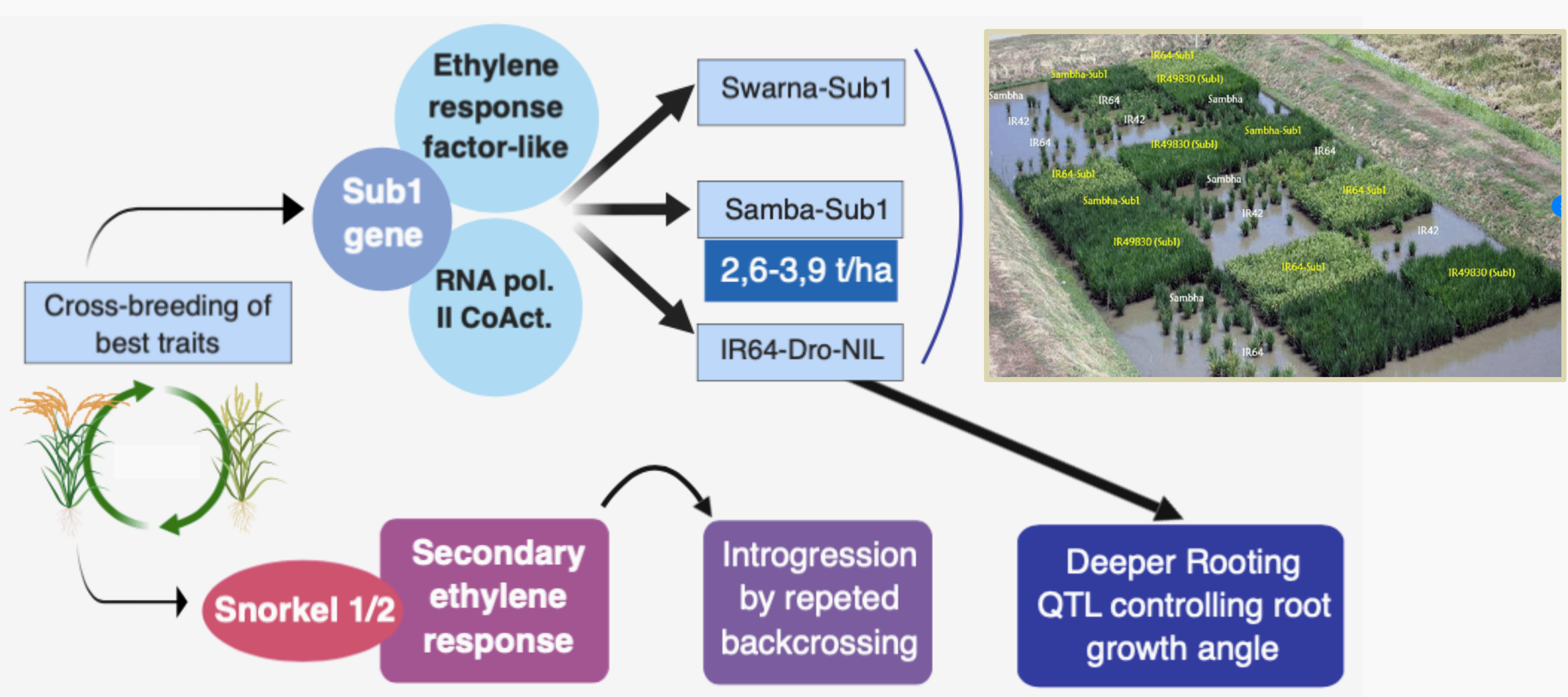
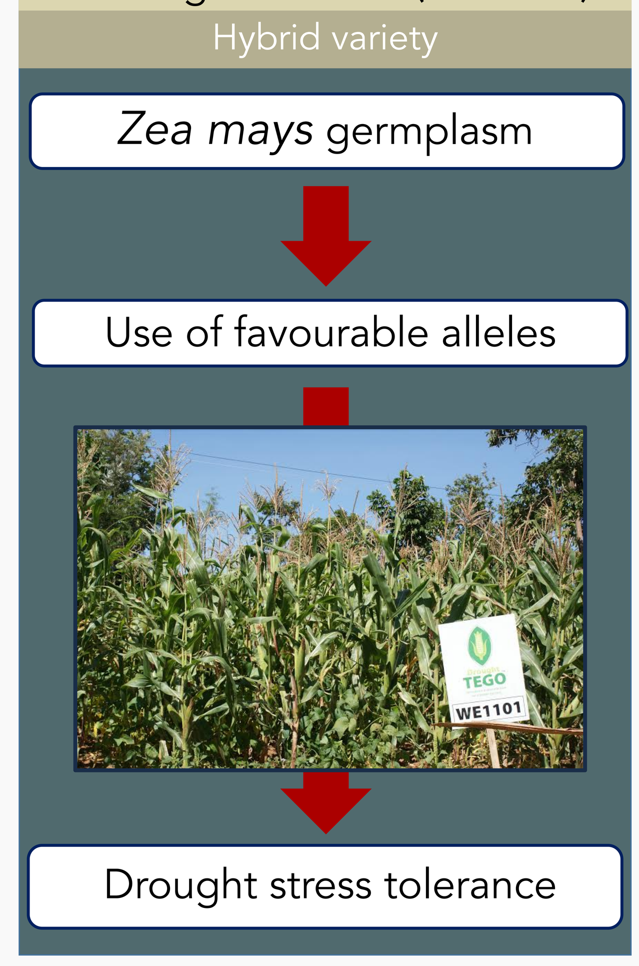


FIGURE 2. *Gene structure and performance of rice varieties from South and South-East Asia and the Sub1 "upgraded" varieties after 17 days of controlled submergence; 2007 dry season at IRRI.*

MAIZE *(Zea mays)*

DroughtTEGO™ (WE1101) — Hybrid variety



Mon87460 (Genuity®) — Genetically modified

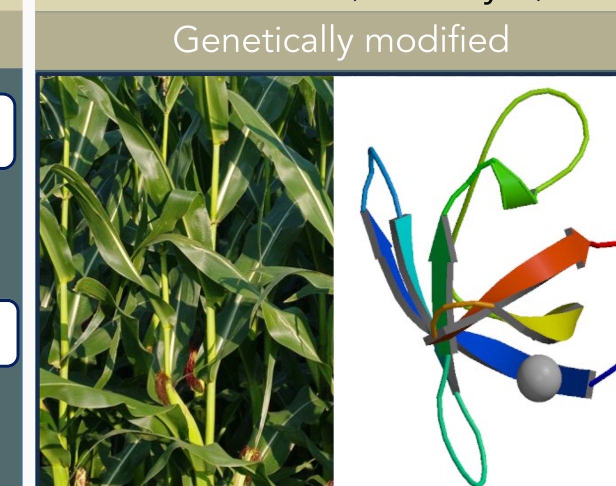


FIGURE 3. **(a)** *Genuity® sample.* **(b)** *Major cold-shock protein (cspB)*

It harbours *CspB* gene from *B. subtilis*, acting as a transcriptional activator of cold shock genes through the recognition of ATTGG-box elements. Its drought tolerance comes from the preservation of RNA stability, maintaining normal cellular functions under water.

ARGOS8 — CRISPR-Cas9

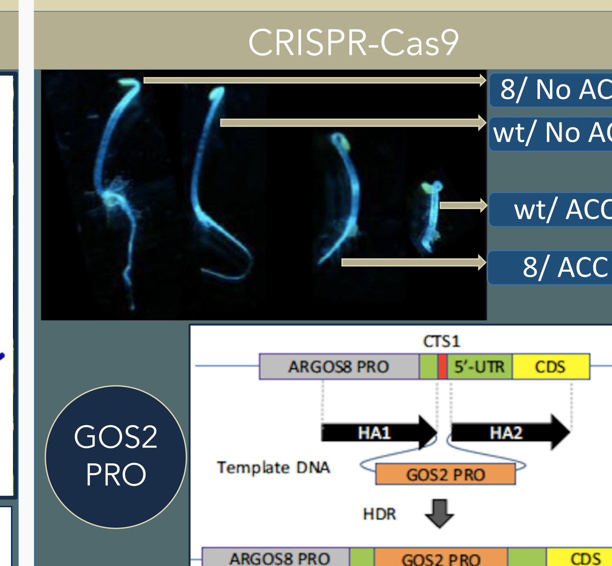


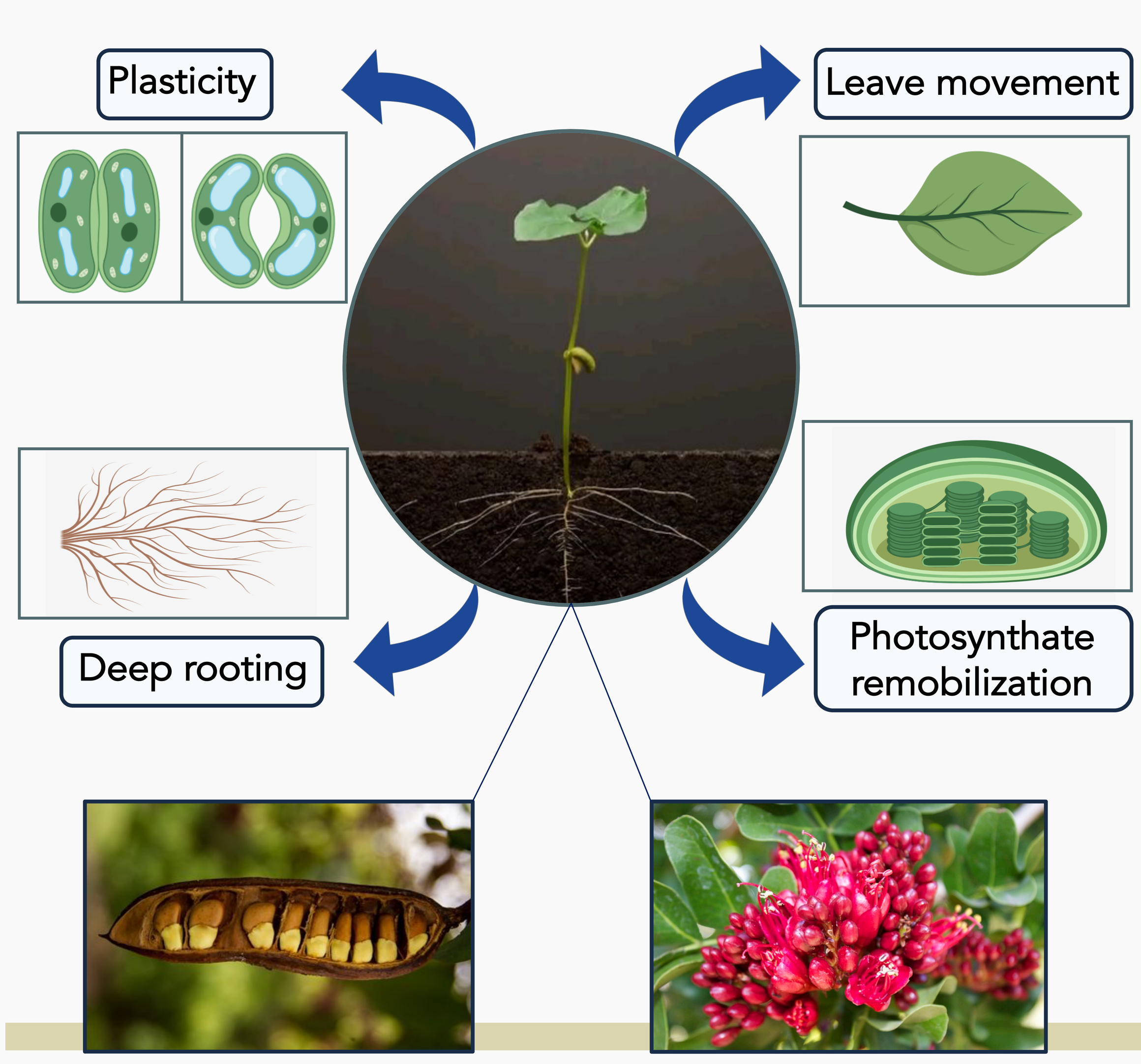
FIGURE 4. **(a)** *Ethylene triple response of Arabidopsis ARGOS8 transgenic plants (ARGOS8) and wild-type (WT) controls* **(b)** *Schematic drawing illustrating the insertion of GOS2 PRO into the 5'-UTR of ARGOS8 and the promoter swap.* [2]

BEAN *(Phaseolus sp.)*

Common bean is grown in Mozambique, even though *P. vulgaris* is not the most common variety in the country: Boer bean (*Schotia brachypetala*) and "Uloco bean" have proven more successful production wise.

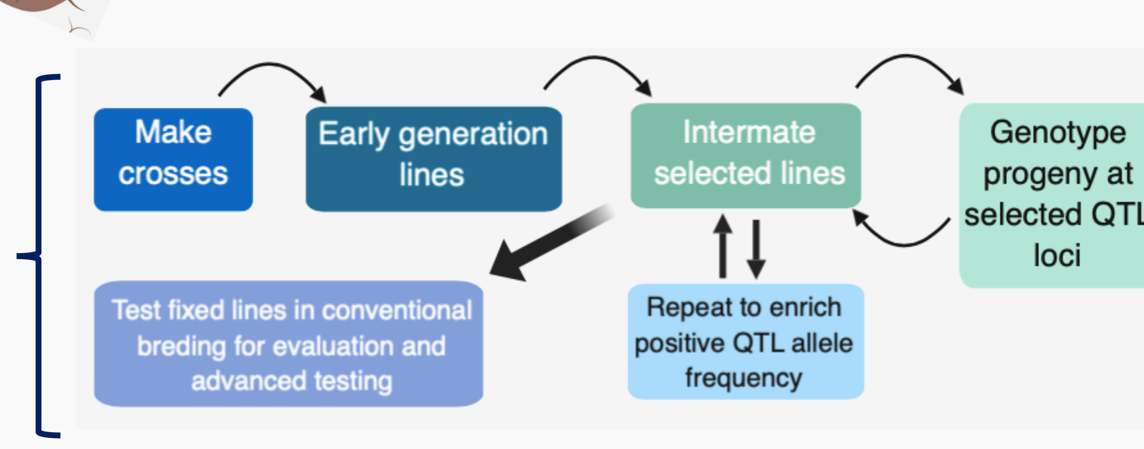
Breeding studies and **QTL analysis** have been performed towards the improvement of the bean, aiming the development of resistance to abiotic stress through the employment of **intraspecific and interspecific genetic variability**.

Yield increase has proven **problematic**, since it has only been achieved in favourable climatic conditions, not under stress.



CASSAVA *(Manihot esculenta)*

- Production average of **6,4 t/ha**.
- Not currently being improved, since it is the most <u>drought tolerant</u> species in cultivation.
- Breeding values' indicators are being used to study inherent resistance.



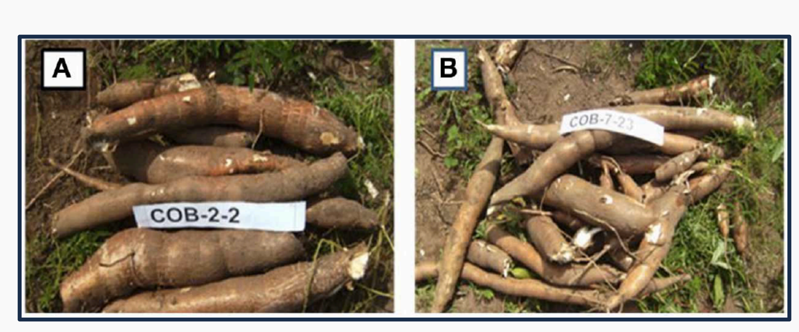


FIGURE 5. *Good bulking genotypes (at 7 months after sowing) developed in the Cassava breeding programme at National Root Crops Research Institute, Umudike, Nigeria.* [3]

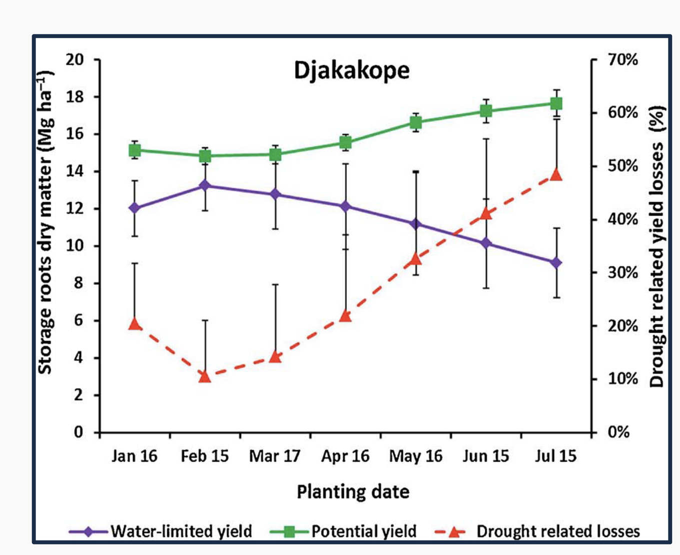
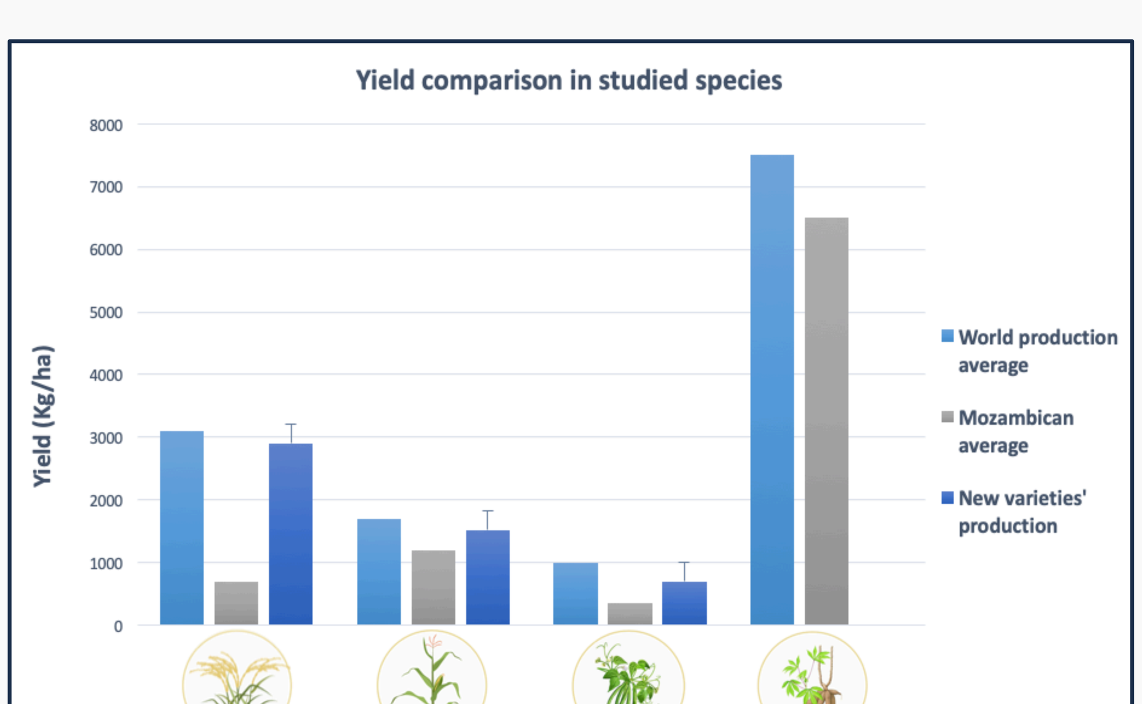
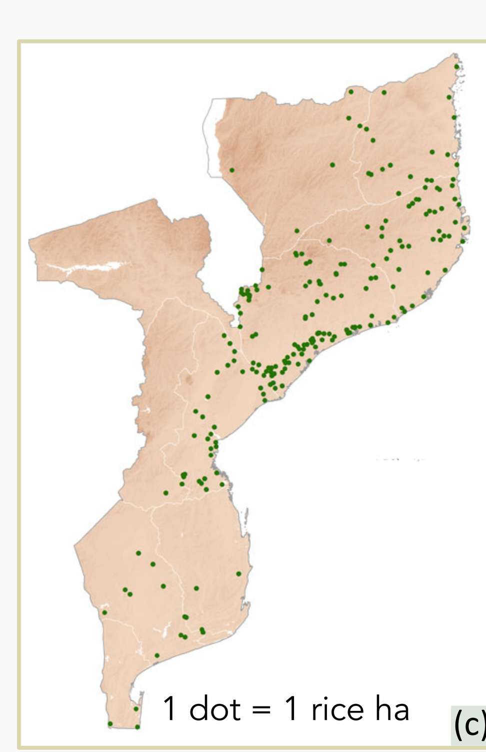


FIGURE 6. *Simulated potential yield (G), water-limited yield (P) and drought related yield (R) losses as affected by planting dates* [4].

Results II

FIGURE 7
Comparison between yields: world average, Mozambican average and new varieties. Data in Mozambique is an adjusted interannual calculus. Data of new varieties requires testing in situ through field trials. Information absent in cassava is due to the lack of improvement and investigation on the plant. Data provided by: ***FAO, CIMMIYT, IRRI & WB.***





Conclusions

A **successful transition** from non-efficient varieties towards climate-resistant ones is possible, as a **medium-term solution**

Economic aspects of the introduction of these new varieties should be further studied, specially those regarding **seed pricing.**

Infrastructural development is essential for a long-term food security, to reduce crop loss in post-harvest activities and logistics.

It is essential to fully implement the **Paris Agreement** within the UNFCCC and transition towards a <u>carbon-neutral sustainable economy</u>.

REFERENCES: [1] Smith, M. R., & Myers, S. S. (2018). Impact of anthropogenic CO_2 emissions on global human nutrition. *Nature Climate Change*, 8(9), 834–839. Graph (b) & (c) was retrieved from www.ricepedia.com **[2]** Shi, J., Gao, H., Wang, H., et al. (2017). ARGOS8 variants generated by CRISPR-Cas9 improve maize grain yield under field drought stress conditions. *Plant Biotechnology Journal*, *15*(2), 207–216. **[3]** Okogbenin, E., Setter, T. L., Ferguson, M., et al. (2013). Phenotypic approaches to drought in cassava: Review. *Frontiers in Physiology*, 4, 93. **[4]** Ezui, K. S., Leffelaar, P. A., Franke, A. C., et al. (2018). Simulating drought impact and mitigation in cassava using the LINTUL model. *Field Crops Research*, *219*, 256–272. **[5]** FAO, IFAD, UNICEF, WFP and WHO. 2018. *The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition*. Rome, FAO. Icons were obtained from flaticon.com