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Exploring cacao genetic diversity for resilience to climate change – validating or contradicting current predictive models of production suitability

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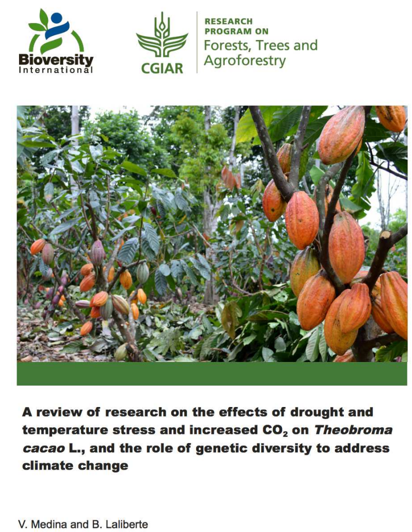
Climate Change Models: What do they say?

- Temperatures could increase in average by 2.1°C for 2050 passing through 1.2°C in 2030 in current production regions.
- Combination of increased evaporative demand and reduced water availability is of most concern.


Bioversity International
RESEARCH PROGRAM ON Forests, Trees and Agroforestry
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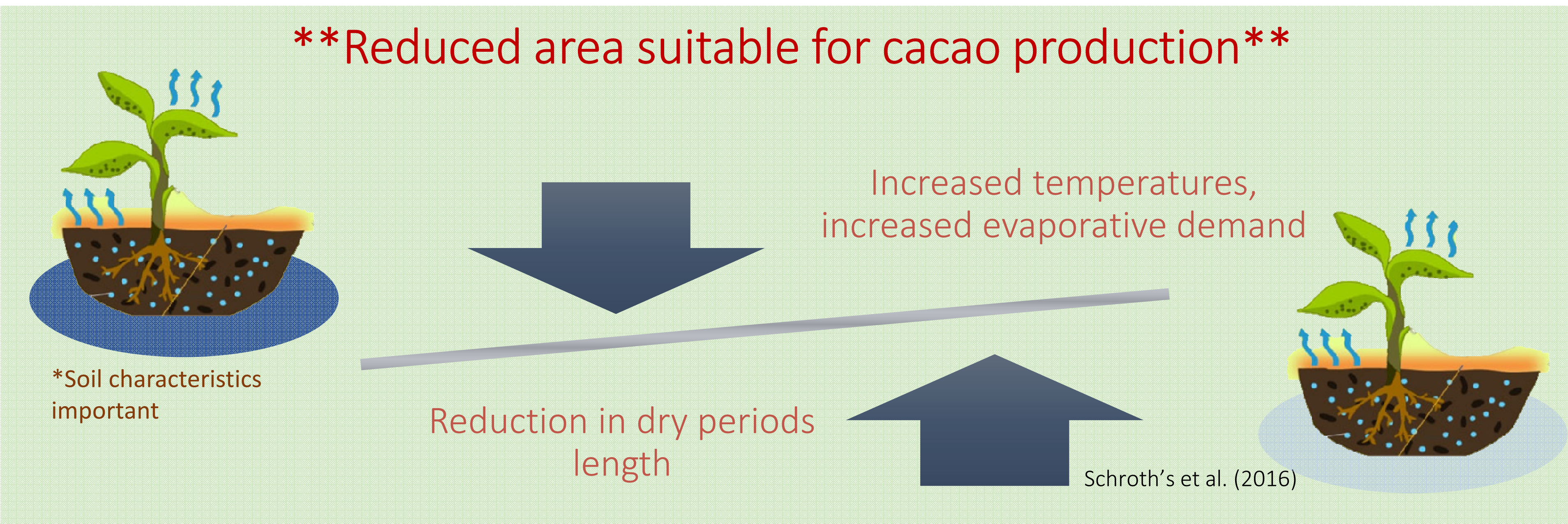
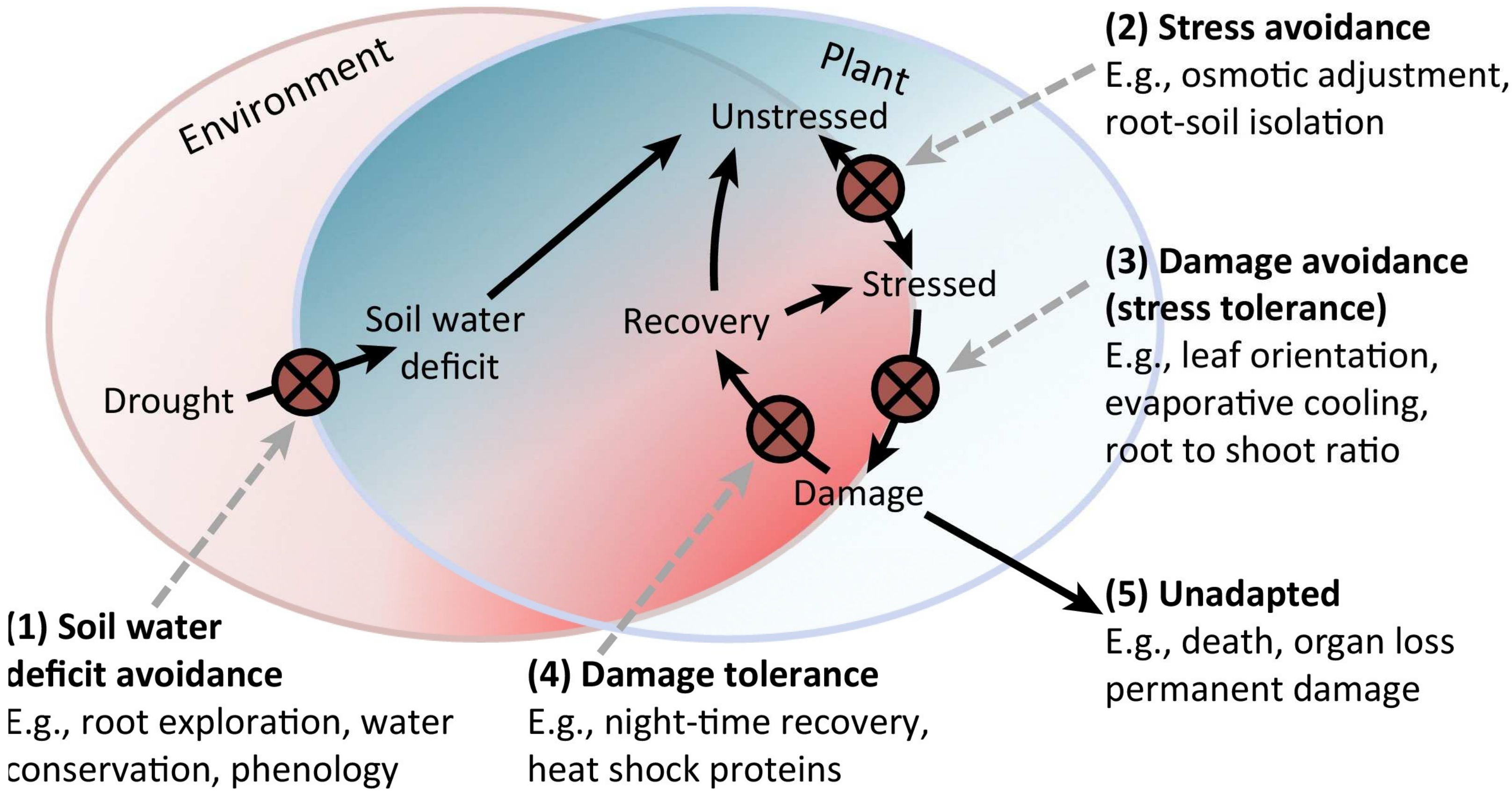
A review of research on the effects of drought and temperature stress and increased CO_2 on *Theobroma cacao* L., and the role of genetic diversity to address climate change

V. Medina and B. Laliberte



Drought and plant stress



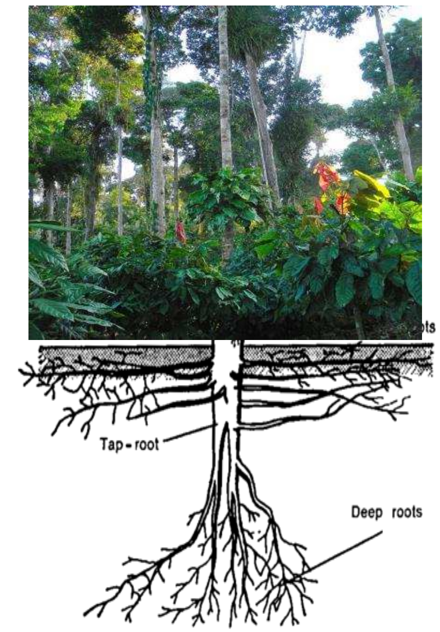
Gilbert and Medina 2016

Which of these mechanisms does cacao have??

Root Responses

- Differential root growth, specifically fine root growth, showed potential as an important drought tolerance trait mainly in seedlings
- In the field, majority of cacao active roots are in the 0.2-0.4m
- Companion planting with deeper rooting species such as *Gliricidia* appeared beneficial during times of water stress

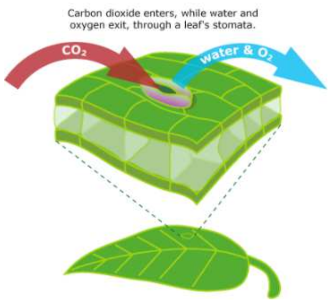
Agroforestry



Authors	Trial Location	Trial Type	Main Conclusions
Deng, et. al, (1990)	USA	Greenhouse	A reduction in ^{14}C-labelled assimilates exported to sink leaves and expanding flush leaves, but increased to roots potentially allowed roots to access deeper water.
Schwendenmann (2010);	Indonesia	Field	*Gliricidia* appeared to be a good companion tree even in prolonged periods of water stress, with complementary ecophysiological responses.

Stomatal Conductance

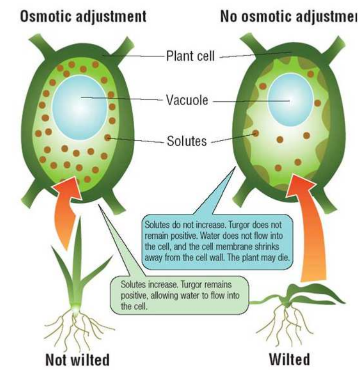
- Observed genetic variation for stomatal sensitivity
- Cacao stomatal regulation to sustain a relative water content, and reduced transpirational water loss is considered key response



Authors	Trial Location	Trial Type	Main Conclusions
Nunes (1967)	Sao Thomé	Greenhouse	Greater stomatal sensitivity allows for better water loss regulation.
Balasimha et al. (1988)	India	Field	Key tolerance response for decreased transpirational water loss.
Apshara (2013)	India	Field	Led to greater resilience by reducing transpirational water loss.
Ofori et al. (2014)	Ghana	Field	There is considerable genetic variation and differential responses.
Almeida, Tezara and Herrera (2016)	Venezuela	Field and Greenhouse	Stomatal closure was effective to preserve leaf-water status, but water potentials substantially decreased as the dry period progressed in the field.
Ayegboyin (2016)	Nigeria	Greenhouse	Frequency, rather than amount of irrigation is most important.

Osmotic Adjustment

- Occurs via net accumulation of solutes in response to stress
- Cultivars identified as tolerant based on osmotic adjustment capacity
- Its potential as tolerance trait might be limited



Authors	Trial Location	Trial Type	Main Conclusions
De Almeida (2002)	Brazil	Green house	Three clones were identified drought tolerant based on the degree of osmotic adjustment recorded.
Rada et al. (2005)	Venezuela	Field	Osmotic adjustment and sustained leaf turgor was observed in the initial 12 days, yet not sustained over a period of 25 days.
Moser (2010); Köhler (2010); Schwendenmann (2010);	Indonesia	Field	Root tissue osmotic adjustment is hypothesized to have aided in the stabilization of plant water status, as well as sustained leaf, stem and root growth.
Araque et al. (2012)	Venezuela	Field	Observed variation was enough to categorize some clones more tolerant, but not enough to rescue plants completely from stomatal conductance and photosynthetic reductions.

Water Potential

- Stable trait to measure as tolerance indicator
- Photosynthesis starts to decline in response to water deficit below about -0.8 to -1.0MPa
- Moderate stress -0.8 to -1.2MPa, Severe stress below -1.76 MPa

Authors	Trial Location	Trial Type	Main Conclusions
Joly and Hahn. (1989)	USA	Greenhouse	Net photosynthesis started to decline once water potential fell below about -0.8 to -1.0 MPa.
Deng et al. (1990)	USA	Greenhouse	The distribution of ^{14}C-labelled assimilates showed that moderate stress occurs when water potential values reaches -0.8 to -1.2 MPa, and severe stress below -1.76 MPa.
Balasimha et al. (1991)	India	Field	Genotypes able to maintain higher water potential values during midday hours, even under drought, were considered the most tolerant.
Balasimha (2013)	India	Field	Water potential levels are stable indicators of resilience/tolerance.
Kacou et al. (2016)	CPCRI	Greenhouse	Important to breed for maintenance of water status, gas exchange and photochemical activities.

Concerns with current models

- Lack of understanding and inclusion of cacao physiology into models and conclusions.
- Absence of current knowledge on cacao's interaction with increased CO_2 concentrations.
- Extrapolation from Species Distribution Models towards the future is problematic, season-to-season variation does not match the decadal time-scale on which climate change operates.
- It is difficult to judge the degree of uncertainty of cacao SDM studies, the model evaluation measures many report is not accepted as an uncertainty measure in the modelling literature.
- Many studies do not show awareness of the need to control for "spatial sorting bias", failure to account for spatial structure in the data may lead to inflated confidence in SDMs.

Recommendations

1. *Focus on variation and diversity in responses rather than trends and averages*. Much variation remains hidden in the modelling exercises.
2. *Drastically increase the use of existing and new data to understand climate responses*. Traceability programmes are creating large amounts of data.
3. *Include physiological and phenological responses into models and conclusions.* Key for climate adaptation.
4. *Generate insights for robust decision-making rather than only trying to improve uncertain predictions*. Using a broader decision science approach for robust decisions that work well across a number of future scenarios.

Greater caution when decision-making solely based on interpretations from current models.

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