Navigating the drought's grip: Cocoa yield dynamics in Agroforestry Systems in Ghana and Togo

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Introduction

- **Society: conflict; migration**
- **Economy**
- **Food Security**

Adaawen et al., 2019;Naumann et al., 2021

Drought

Land Use Land Cover (Agriculture production, Forest Ecosystems, water resources)

Chen et al., 2016

Climate change increase the frequency and the intensity of extreme events, drought in particular making vulnerable rainfed crops systems (Driouech et al., 2020)

Example

Ghana, Togo West Africa (70%)

Cocoa (*Theobroma cacao* L.), *water sensitive crops*

- Cocoa yields losses
- Cocoa production value chain weakness
- Weak Country GDPs
- Economic instability
- Food insecurity
- Increased vulnerability of smallholders cocoa farmers

Objectives

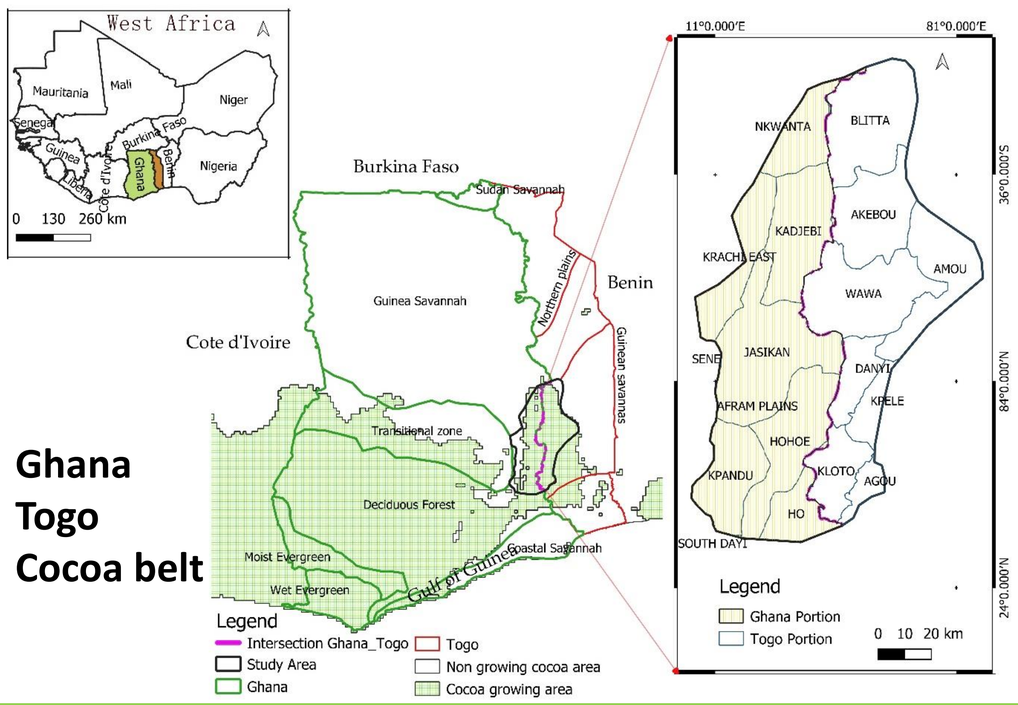
Assess the effect of drought on cocoa yield

Analyze the effect of drought on annual Cocoa Yield Variability (SO1)

Assess the Long-term Trends of Drought Events impact Cocoa Yield

Assessing the effects of drought helps quantify the extent of these shifts and develop strategies to mitigate climate change risks.

Study Area



Ghana
Togo
Cocoa belt

Methodology

Data Collection

Climatic variables: Rainfall, minimum temperature, maximum Temperature, climate water deficit, vapour pressure deficit (https://doi.org/10.7923/G43J3B0R)

Sources: GMET (Ghana); ANAMET(Togo)

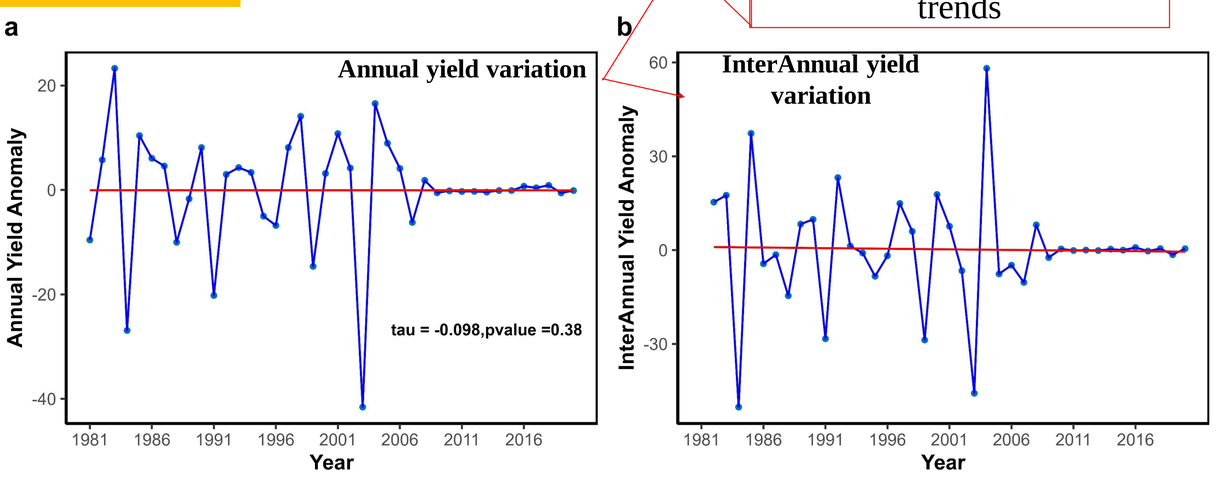
Cocoa Yield: FAO statistics; 1981-2020.

Data Analysis

- Partial correlation; Computation of Yield Anomaly and Interannual yield anomaly **(Dependent variables);**
- Computation of drought indices SPEI (3, 6, 9,12, 18, 24) using Thornton Waive methods (**Independent variables**);
- CWD, VPD (**Independent variables**);
- PCA to select most contributing SPEI;
- Binary Logistic Regression (0= Yield anomaly <median and 1> median).

Results

No statistical significant trends



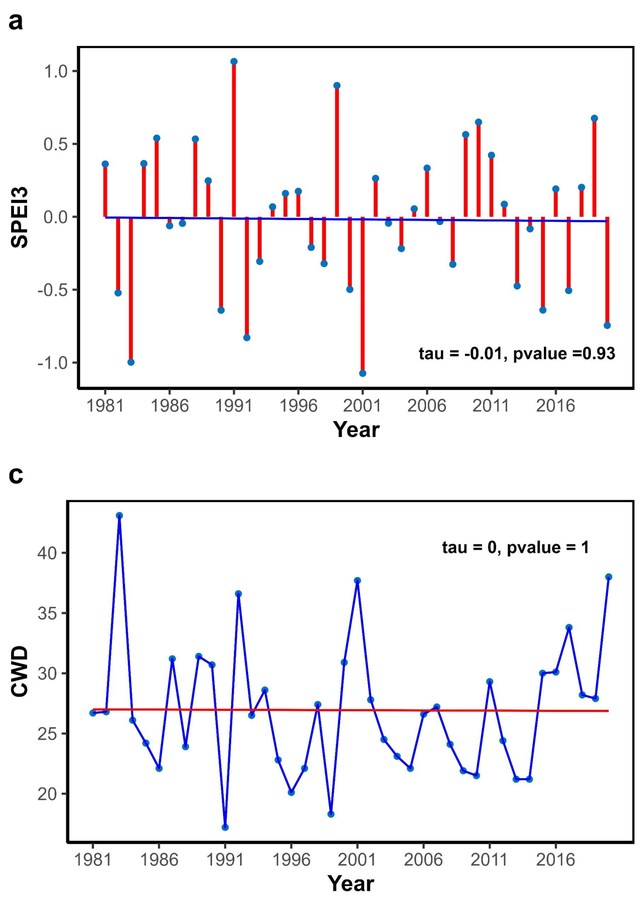


Figure 3: Drought Indices (a-SPEI3; b- SPEI12; c-Climate Water Deficit; d-Vapour Pressure Deficit)

No particular trends observed in the drought indices; however high variability is noted

(a-SPEI3, 281%; b- SPEI12, 404%; c-Climate Water Deficit,20%; d-Vapour Pressure Deficit.8%)

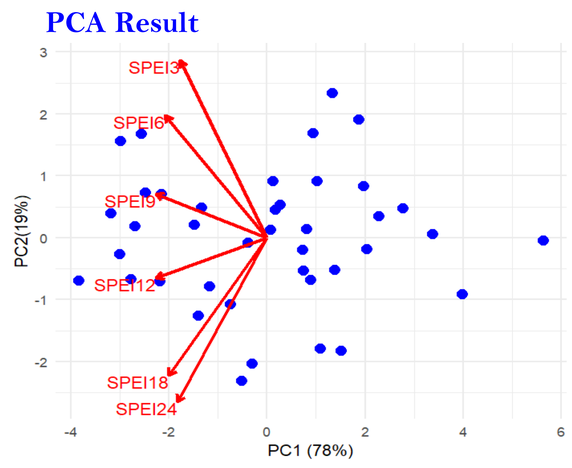


Table 1: Variables Contribution on the Axis(PCA1 et PCA2)

Variables	SPEI9	SPEI12	SPEI6	SPEI18	SPEI24	SPEI3
PCA1	0.45	**0.45**	0.41	0.40	0.36	0.35
	SPEI3	SPEI24	SPEI18	SPEI6	SPEI9	SPEI12
PCA2	**0.57**	**0.53**	0.44	0.39	0.14	0.12

Variables codes	Explanations
SPEI 3	Standardized Precipitation Evapotranspiration Index, moisture conditions over the past 3 months, capturing the cumulative effects of drought or wetness over 3 months
SPEI 12	Standardized Precipitation Evapotranspiration Index, moisture conditions over the past 12 months, capturing the cumulative effects of drought or wetness over one year
SPEI24	Standardized Precipitation Evapotranspiration Index, moisture conditions over the past 24 months, capturing the cumulative effects of drought or wetness over two year
VPD	Vapor Pressure Deficit, difference between the amount of moisture in the air and the amount it can hold when fully saturated
CWD	Climate Water Deficit, difference between potential evapotranspiration (the amount of water plants need) and actual evapotranspiration (the amount of water plants receive)
Yield Anomaly	yearly deviation of the cocoa yield from the long-term average.
Interannual yield Anomaly	Cocoa yield changes from one year to the next

Table 2: Binary Logistic Regression output

INTERANNUAL YIELD ANOMALY (SO1)				
	Estimates	Std. Error	z value	Pr(>|z|)
(Intercept)	-4.46	4.75	-0.94	0.35
PCA1	0.36	0.22	1.7	0.09 .
PCA2	-0.93	0.43	-2.15	0.03 *
CWD	-0.027	0.12	-0.22	0.82
VPD	5.17	6.23	0.83	0.40
YIELD ANOMALY (SO2)				
	Estimates	Std. Error	z value	Pr(>|z|)
(Intercept)	-0.46	4.76	-0.098	0.922
PCA1	0.64	0.25	2.5	0.01 *
PCA2	-0.24	0.38	-0.64	0.052 *
CWD	0.068	0.12	0.53	0.59
VPD	-1.21	6.35	-0.19	0.85

- PCA1 (SPEI12) is significantly associated with positive cocoa yield both annually and in the long term;
- PCA2 (SPEI 3, 24) is significantly associated with a decrease in the cocoa yield both annually and in the long term;
- CWD negatively influences cocoa yield in the short term while showing the opposite in the long term;
- VPD positively influence cocoa yield in the short term while showing the opposite in the long term.

Results' Implications

- Cocoa plant is **more sensitive to shorter and longer periods of droughts** where **recent droughts** (≤3 months) significantly impact growth and productivity reflected in the yield.
- The long-term drought might reduce the soil water storage availability and the replenishment process will be delay, impact cocoa yield.
- The farming systems (adaptation or managements practices) may not be fully adapted to recover from shorter drought cycles, leading to yield reductions in the face of recent droughts.
- Cocoa crops in the study region may experience positive effects from medium drought (SPEI12) due possible variability observed in precipitations, making the yield to perform better within the one year period of growing; Use of drought-resilient variety.

Management recommandations

- Focus on mitigating short-term drought impacts by improving farming practices such as mulching, pruning, shade or canopy management; adopting water-efficient farming practices during the growing season.
- Application of long-term water management strategies, such as soil conservation, and water storage solutions (reservoirs) to ensure long-term cocoa productivity.
- Monitoring and Forecasting: Using seasonal forecasting tools and monitoring both short-term (e.g., SPEI12) and long-term (e.g., SPEI24) moisture conditions can help inform better water management and decision-making for cocoa sector stakeholders.

References

https://doi.org/10.3390/su8101069; https://doi.org/10.1038/s41558-021-01044-3 ; https://doi.org/10.1016/j.scitotenv.2019.01.278; https://doi.org/10.1016/B978-0-12-814820-4.00002-X