



# Climate Change Effects on Cocoa Production: Effects of Current Climatic & Soil Conditions on Cocoa Yield

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## Introduction

Determining effects of current climatic and soil condition on cocoa yield is relevant for improving current cocoa systems and adapting to climate change. Thus, this paper seeks to identify the environmental factors that influence cocoa yield and variability in space and time.

## Materials & Method

### Materials:

#### 1. Cocoa yield data

Field level data on cocoa fields; location, area, cocoa and shade trees characteristics and yields over time was obtained from AGROECOM, Mondelez, CRIG, CARGILL, Authors: Blaser et al., 2018. A total of 4,003 yield data points from 3,472 farms was collected.

A 10-year district level cocoa production and area statistics records for 25 out of the 61 cocoa districts of Ghana was obtained from the Ghana Cocoa Board.

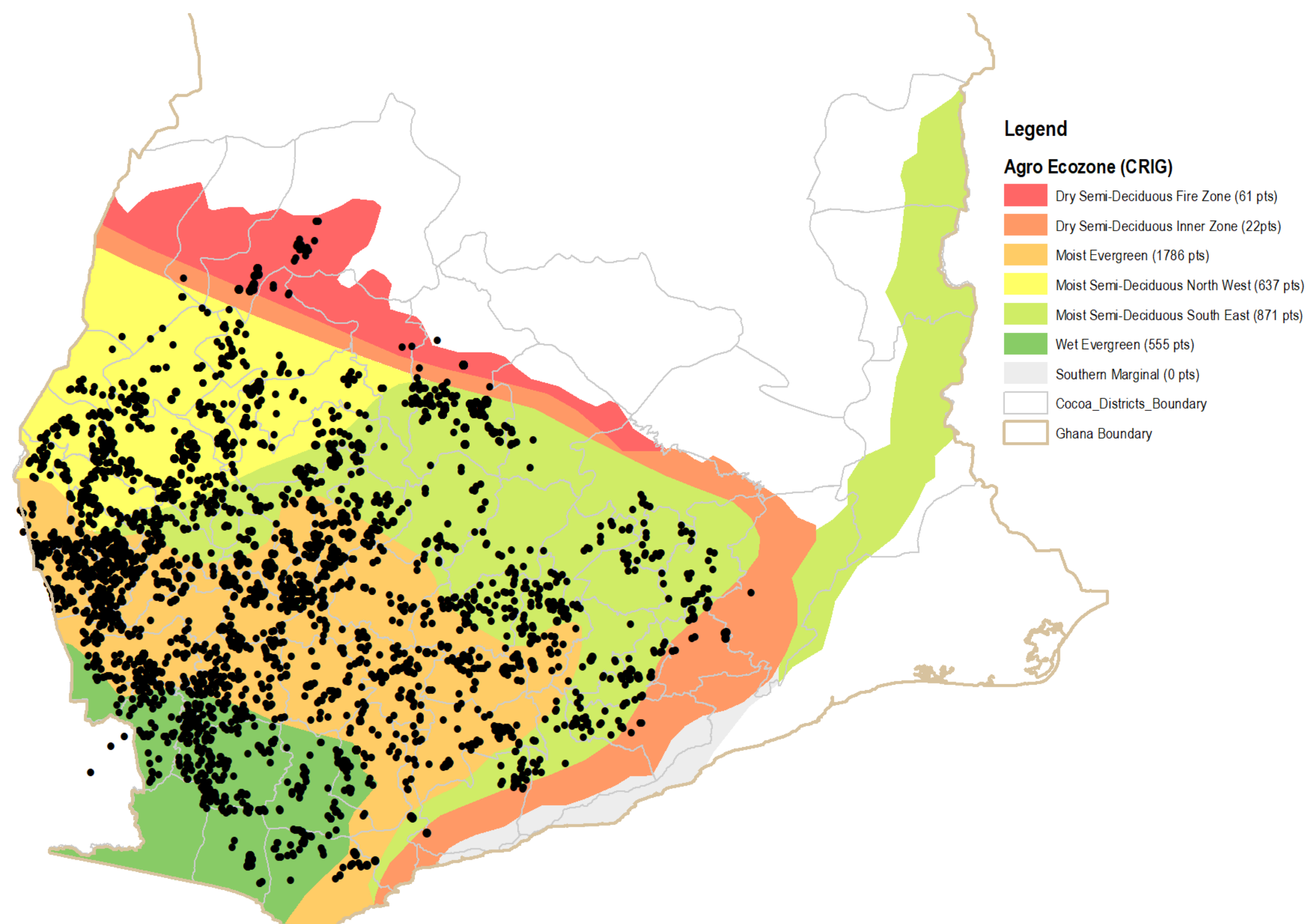


Fig. 1.1 Spatial distribution of cocoa fields data across agroecological zones

#### 2. Climate data

Monthly climate data on temperature, precipitation, solar radiation and vapour pressure with spatial resolution of ~4-km for 1958-2015 period was downloaded from TerraClimate database. Measured monthly climate data was obtained from CRIG and GMET.

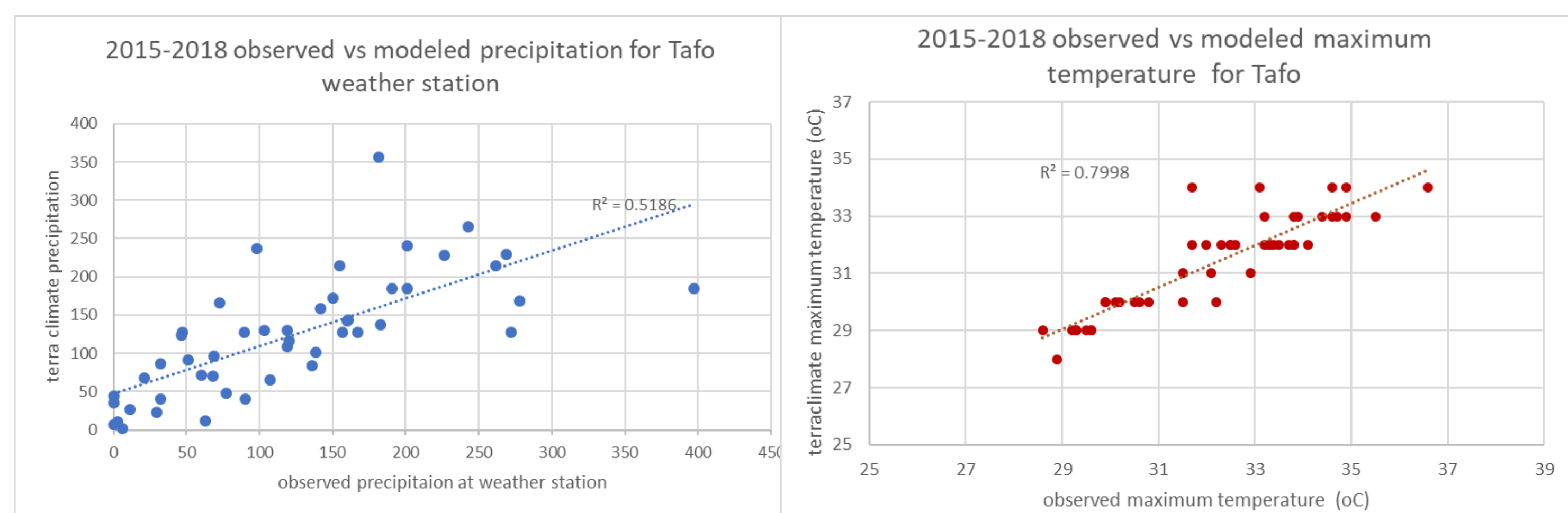


Fig. 1.2 Observed & modeled precipitation & maximum temperature climate data comparison

#### 3. Soil data

Soil texture classes (USDA system) data for 6 standard soil depths (0, 10, 30, 60, 100 and 200 cm) at 250m was downloaded from ISRIC soil database.

#### 4. Ancillary spatial data:

Shapefiles of Administrative boundaries, forest and agroecology was obtained from COCOBOD.

## Preliminary Results

### a. Cocoa yield variability in time and space

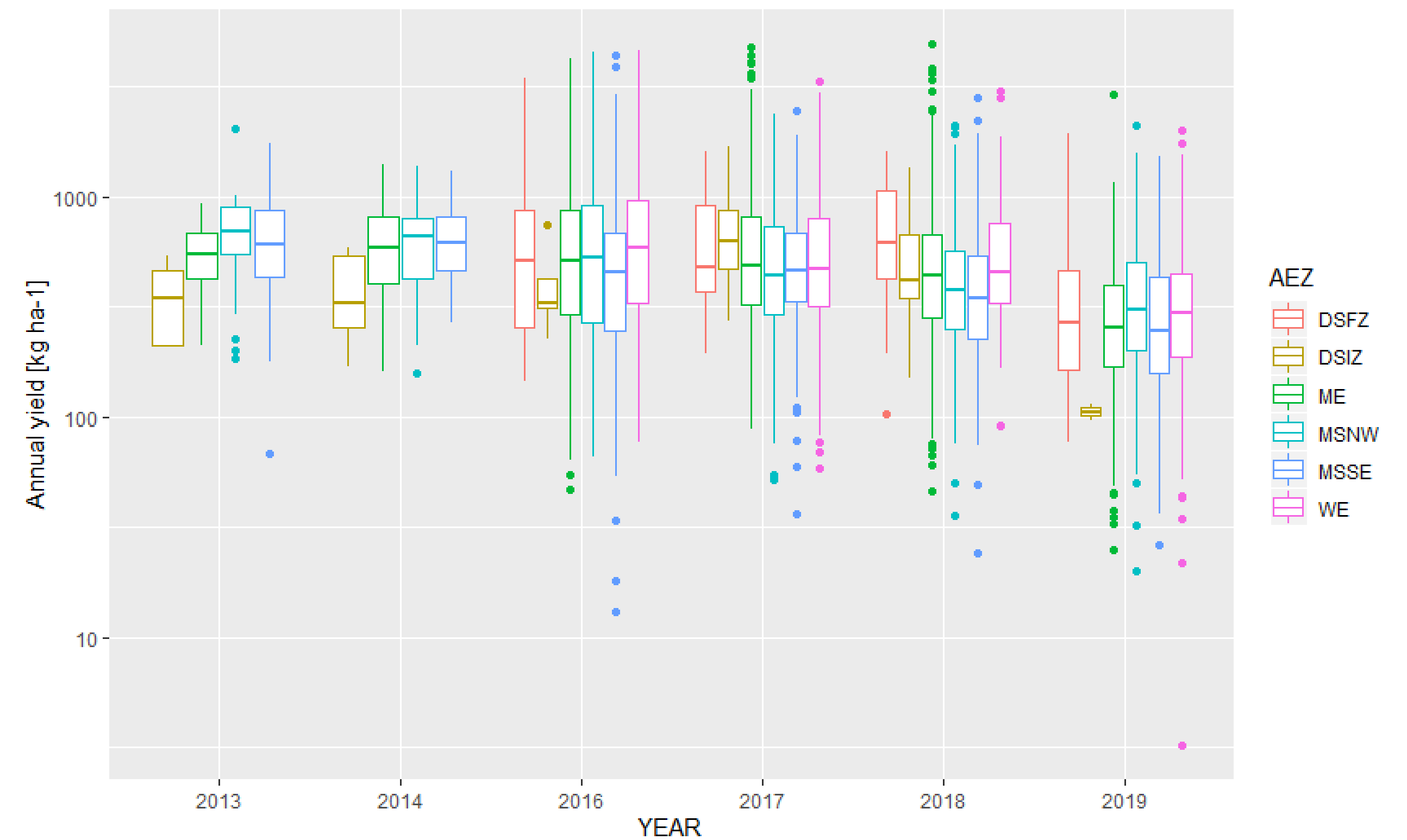


Fig. 1.3 Cocoa yield per ha for different agroecology zones and time

- Mean yields are in the range of 500-600 kg/ha (Fig. 1.3) and in some years as low as ~300 kg/ha but with clear variation (a range of 20kg/ha to >1000kg/ha) across the different ecology zones. In other words, relatively low values but also occurrence of higher ones indicating potential for yield increase.

### b. Cocoa Yield relationship with climate variables & soil moisture

|  | precipitation_annual | precipitation_annual_prev | maximum_temperature_annual | maximum_temperature_annual_prev | minimum_temperature_annual | minimum_temperature_annual_prev | solar_radiation_annual | solar_radiation_annual_prev | actual_evapotranspiration_annual | actual_evapotranspiration_annual_prev | potential_evapotranspiration_annual | potential_evapotranspiration_annual_prev | soil_moisture_annual | soil_moisture_annual_prev | annual_yield_per_ha |
|--|----------------------|---------------------------|----------------------------|---------------------------------|----------------------------|---------------------------------|------------------------|-----------------------------|----------------------------------|---------------------------------------|-------------------------------------|--|----------------------|---------------------------|---------------------|
| precipitation_annual                     | 1.0                  | 0.8                       | -0.2                       | -0.1                            | 0.4                        | 0.5                             | 0.3                    | 0.2                         | 0.8                              | 0.7                                   | 0.1                                 | 0.1                                      | 0.6                  | 0.6                       | 0.02                |
| precipitation_annual_prev                |                      | 1.0                       | -0.3                       | -0.1                            | 0.3                        | 0.4                             | 0.3                    | 0.0                         | 0.6                              | 0.7                                   | 0.0                                 | -0.2                                     | 0.5                  | 0.5                       | -0.03               |
| maximum_temperature_annual               |                      |                           | 1.0                        | 0.6                             | 0.3                        | 0.3                             | 0.1                    | 0.3                         | 0.1                              | 0.1                                   | 0.5                                 | 0.6                                      | -0.1                 | -0.1                      | 0.13                |
| maximum_temperature_annual_prev          |                      |                           |                            | 1.0                             | 0.3                        | 0.3                             | 0.3                    | 0.3                         | 0.1                              | 0.1                                   | 0.5                                 | 0.5                                      | -0.1                 | -0.1                      | 0.07                |
| minimum_temperature_annual               |                      |                           |                            |                                 | 1.0                        | 0.7                             | 0.2                    | 0.3                         | 0.6                              | 0.5                                   | 0.5                                 | 0.4                                      | 0.4                  | 0.4                       | 0.13                |
| minimum_temperature_annual_prev          |                      |                           |                            |                                 |                            | 1.0                             | 0.3                    | 0.2                         | 0.3                              | 0.6                                   | 0.5                                 | 0.4                                      | 0.4                  | 0.4                       | 0.09                |
| temperature_annual_prev                  |                      |                           |                            |                                 |                            |                                 | 1.0                    | 0.3                         | 0.2                              | 0.6                                   | 0.5                                 | 0.4                                      | 0.4                  | 0.4                       | 0.10                |
| solar_radiation_annual                   |                      |                           |                            |                                 |                            |                                 |                        | 1.0                         | 0.5                              | 0.5                                   | 0.3                                 | 0.9                                      | 0.8                  | 0.4                       | 0.18                |
| solar_radiation_annual_prev              |                      |                           |                            |                                 |                            |                                 |                        |                             | 1.0                              | 0.5                                   | 0.3                                 | 0.9                                      | 0.8                  | 0.4                       | 0.18                |
| actual_evapotranspiration_annual         |                      |                           |                            |                                 |                            |                                 |                        |                             |                                  | 1.0                                   | 0.8                                 | 0.4                                      | 0.9                  | 0.8                       | 0.10                |
| actual_evapotranspiration_annual_prev    |                      |                           |                            |                                 |                            |                                 |                        |                             |                                  |                                       | 1.0                                 | 0.3                                      | 0.8                  | 0.8                       | 0.08                |
| potential_evapotranspiration_annual      |                      |                           |                            |                                 |                            |                                 |                        |                             |                                  |                                       |                                     | 1.0                                      | 0.3                  | 0.3                       | 0.19                |
| potential_evapotranspiration_annual_prev |                      |                           |                            |                                 |                            |                                 |                        |                             |                                  |                                       |                                     |  | 1.0                  | 0.2                       | 0.19                |
| soil_moisture_annual                     |                      |                           |                            |                                 |                            |                                 |                        |                             |                                  |                                       |                                     |  |                      | 1.0                       | 0.08                |
| soil_moisture_annual_prev                |                      |                           |                            |                                 |                            |                                 |                        |                             |                                  |                                       |                                     |  |                      |                           | 1.0                 |
| annual_yield_per_ha                      |                      |                           |                            |                                 |                            |                                 |                        |                             |                                  |                                       |                                     |  |                      |                           | 1.00                |

Fig. 1.4 Correlation between cocoa yields and mean precipitation (PREC), maximum (TMAX) & minimum (TMIN) temperature, solar radiation (SRAD), actual (AET) & potential (PET) evapotranspiration & soil moisture variables for the current and the previous year. Deep-Blue-fill to Light-Blue-fill indicates strong to weak correlation.

- Weak positive correlation between mean yields and PET and even weaker correlation with SRAD, TMIN & TMAX, AET and weakest with PREC. SRAD of previous year have a higher correlation than concurrent (Fig. 1.4).
- Across seasons, PREC (-0.09), AET (-0.07) of current year major rainy season (JJA) has negative correlation with cocoa yield. TMAX in Dry season (DJF) of previous year has weak positive (r=0.04) than concurrent (r=0.14).

## Next Steps

### Data on cocoa yield and environmental conditions

- Include cleaned cocoasoils yield data and soil texture
- Explore effects of agronomic practices on cocoa yield

### Linear Mixed Effects Modeling

- Model comparisons: yield ~ f(environmental variables)

### Yield Gap Analysis

- Simulation of Water-limited yields
- Calculation of yield gap
- Model comparisons: yield gap ~ f( environmental variables)

