Karlsruhe Institute of Technology

Onset of the rainy season and crop yield in Sub Saharan Africa - Tools and perspectives for Cameroon

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1. Motivation

- **Intra-annual rainfall distribution** has significant impact on water availability and socio-economy in the semi-arid Sub-Saharan Africa
- **Rainfed agriculture** is highly exposed to rainfall variability (70% of population depends on rainfed agriculture)
- Crucial problem for rainfed agriculture: Decision about the **sowing date**
  → Sowing as early as possible to avoid wasting of valuable growth time
  → Sowing too early may lead to crop failure and high economic losses because of occurrence of dry spells

Research questions: i) Estimation of "ideal" sowing date in terms of crop yield; ii) Impact of Climate Change on crop yield

Solution:

- Determination of the onset of the rainy season (ORS) in association with crop modelling for five sites in semi-arid Cameroon:

→ Application of a fuzzy logic-based algorithm for estimating the ORS, and hence, the "optimal" planting date

→ Physically based crop modelling (CropSyst) in combination with "optimal" planting dates improving attainable yield of maize and groundnut

- Statistical downscaling of scenario driven GCMs

2. Research Area and Data

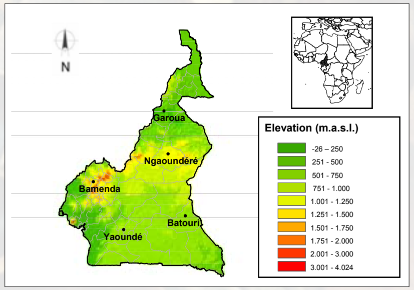


Fig. 1: Research Area Cameroon with five observation sites

- Daily time series (1979-2003) of rainfall, T_{min} and T_{max} of 5 observation sites within the research area
- Solar radiation estimated with physically based crop model CropSyst
- Required soil properties (layer thickness, hydraulic properties) from the International Soil Reference and Information Center (ISRIC)

3. Method

i. Calculation of planting dates based on **rainfall based ORS-Definition** (Laux et al. 2008) via fuzzy logic:

- ORS definition related to 3 criteria:
  1) A total of at least 25 mm of rainfall are observed within a 5-day period
  2) The starting day and at least two other dates in this 5-day period are wet (> 0.1 mm)
  3) No dry period of < 7 consecutive days is occurring in the following 30 days
- Evaluation of membership grades $\gamma 1$, $\gamma 2$, $\gamma 3$ by means of membership functions
- ORS = first day of the year, when membership grades $\gamma 1 * \gamma 2 * \gamma 3 = \gamma > k$ (k = 0...1)
- Example membership functions

  → e.g. triangular fuzzy numbers (Fig. 2) = (18,25,+∞) for total amount of rainfall in 5-day period

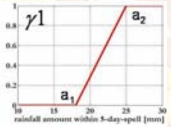


Fig. 2: Membership function of the first definition criterion

ii. Determination of crop yield with physical based model CropSyst (Stöckle et al. 2003):

- Calibration of CropSyst
- Computation of crop yield considering weather data, soil properties, plant physiological aspects, crop rotation and cropping system management (fertilization)

iii. Coupling of ORS-algorithm and CropSyst

- Integration of optimal planting dates calculated by ORS-Defintion in the cropping systems simulation model CropSyst → crop yield

iv. Optimization of ORS-Definition towards mean crop yield MCY by restriction of the three ORS definition criteria

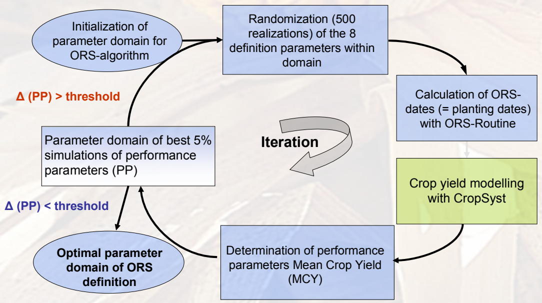


Fig. 3: Optimization of ORS-Definition to a performance parameter (PP)

4. Results

- **"Optimal" ORS definition** by restricting the initial parameter domain and obtaining of a robust parameter set depending on location and crop species
  → after 10 iterations improved crop yields in combination with low coefficient of variation values (Fig. 4)

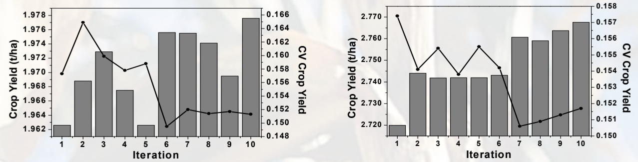
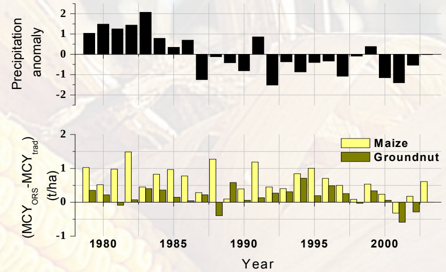


Fig.4: Simulated mean crop yield (bars) and coefficient of variation (line) for groundnut (left) and maize (right) at Garoua

- Significantly **increased mean attainable crop yield** up to 22.4% (7.8%) for maize (groundnut) at Garoua (Fig. 5) using "optimal" ORS definition in comparison to traditional planting date (DOY 135, May 15th)
- "Optimal" planting date for Garoua = DOY 214 (DOY 180) for maize (groundnut)

Fig. 5: Precipitation anomaly (top) and difference between simulated mean crop yield (MCY) using the ORS definition and simulated MCY using traditional planting dates (May 15th, DOY 135) for maize and groundnut (bottom) at Garoua



- **Impact of Climate Change on crop yields:**

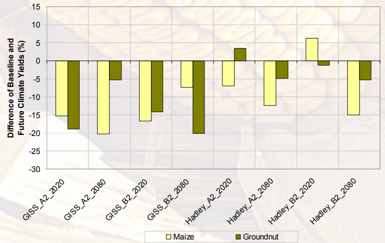


Fig. 6: Relative change in yields (%) between baseline and future climate for maize and groundnut at Garoua

- Increasing temperatures, decreasing precipitation and increasing CO_2-emissions within two A-OGCM (GISS, HadCM3), two emissions-scenario (A2, B2) and two different time intervals (2020, 2080)

→ Decreasing crop yields at Garoua caused by shortened vegetation period and changing climate (Fig. 6)

References:

1) LAUX, P., KUNSTMANN, H., BÁRDOSSY A. (2008): Predicting the regional onset of the rainy season in West Africa. *International Journal of Climatology*, 28(3):329-342
2) STÖCKLE, C., DONATELLI, M., NELSON, R. (2003): CropSyst, a cropping systems simulation model, *European Journal of Agronomy 18 (2003) 289-307*

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