zalf Leibniz Centre for **Agricultural Landscape Research** (ZALF)

Land Use & Governance

# Exploring the impacts of climate change on food security and household income: A CGE Model Approach

**Saidaqa Ayar[1,2], Götz Uckert[1], *Stefan Sieber*[1,2]**

[1] Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany;
[2] Department of Resource Economics, Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences, Humboldt-Universität zu Berlin, Berlin, Germany

## 1. Background

- Climate change threatens agricultural productivity, food security, and rural livelihoods in Afghanistan.
- Fruits and vegetables are vital for food, income generation, and agricultural commercialization.
- Climate variability, including temperature, precipitation, heatwaves, and frost, can reduce productivity and affect markets, household income, and food consumption.

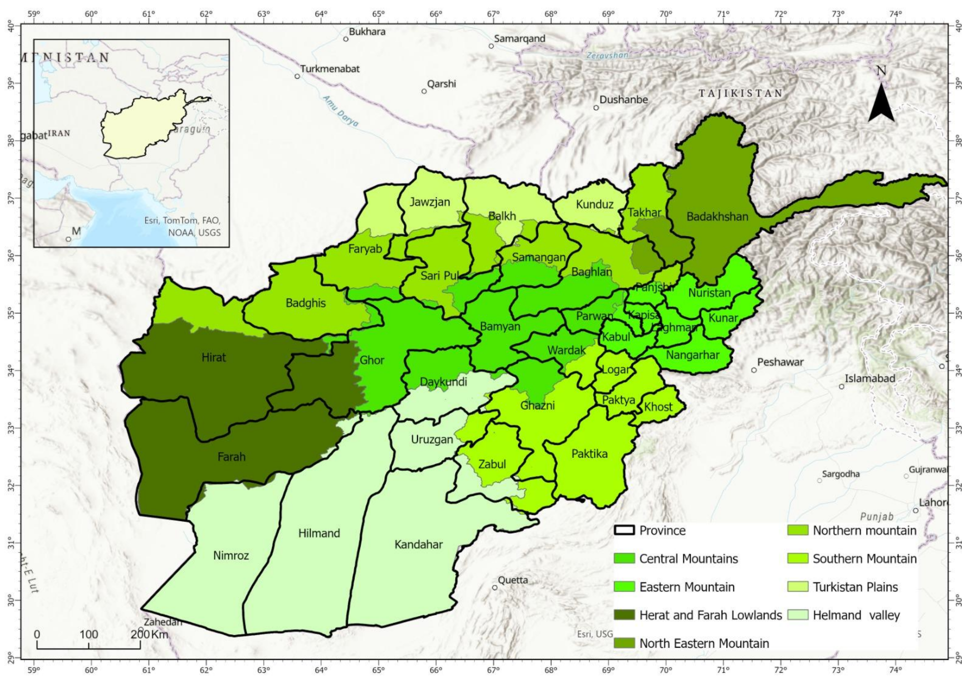
### 1.1. Objectives

To assess how climate change affects horticultural commercialization, household income, food security, and food expenditure across socioeconomic groups, and to evaluate the role of policy interventions in Afghanistan using a scenario-based CGE model.

## 2. Methodology

### 2.1.Study Area

Eight Major Agroecological Zones (AEZ) of Afghanistan



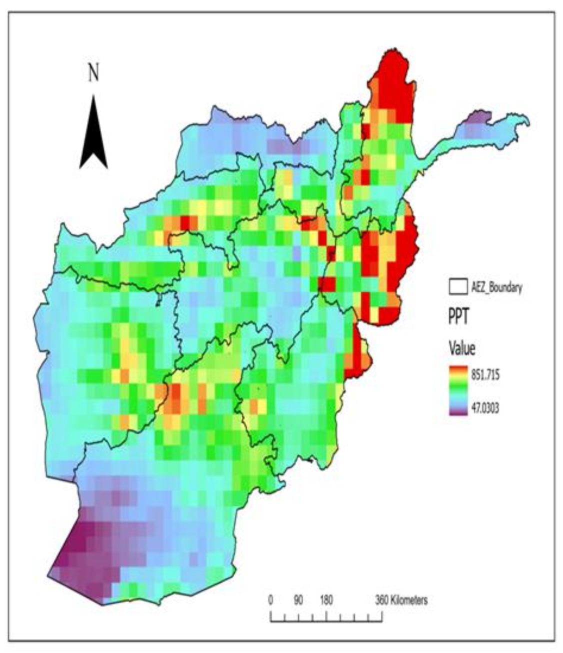




Fig.1 Left: Map of agroecological zoning of Afghanistan (AEZ). Source: Ayar et all. Right: Precipitation gradient of AEZ of AFG

### 2.2. Data sources

- SAM: Biruni Institute (Joya, 2019); disaggregated to AEZs using production and area shares.
- Climate: ERA5-Land daily temperature and precipitation (1974–2024); AEZ-specific frost/heatwave thresholds based on 1981–2010 percentiles.
- Evapotranspiration: ETa and ETm estimated using FAO-56 Penman–Monteith.
- Crop Yield: Apple, grape and potato yields (1974–2024); reconstructed by backcasting and aggregated to AEZs. Potential yield = 95th percentile.
- Yield Response: Crop-specific Ky coefficients from FAO-33.

### 2.3. Analytical Framework

The study uses an integrated three-stage econometric–stochastic–CGE framework to link climate variability with crop productivity and economy-wide outcomes.

### 23.1. ECONOMETRIC ESTIMATION:

$$\ln(Y)=\alpha+\beta_1 GST+\beta_2 GST^2+\beta_3 GSP+\beta_4 GSP^2+\beta_5 T+\beta_6 T^2+\beta_7 HWD+\beta_8 FRD+\beta_9(AEZ\times Climate)+\varepsilon \quad (1)$$

### 2.3.2 Yield Response to Evapotranspiration

FAO yield-response model: yield ↔ evapotranspiration.

$$\frac{Y^a}{Y^m} = (1-\mathrm{Ky})+\mathrm{Ky}\left(\frac{ET^a}{ET^m}\right) \quad (2) \qquad Y^a = Y^m(1-\mathrm{Ky})+\mathrm{Ky}\left(\frac{ET^a}{a+b.TEM}\right) \quad (3)$$

### 2.4. Monte Carlo Stochastic Modeling

- Historical climate data (1974-2024) were used to fit climate distributions.
- AEZ-specific percentile bounds defined Best, Average, and Worst climate scenarios.
- Monte Carlo simulation (10,000 draws) generated climate realizations.
- Adjusted scenario orientation according to the AEZ-specific marginal effects of climate variables.
- Crop yields were estimated using AEZ-specific coefficients.
- Productivity shocks ($R$) were calculated and applied in the IFPRI-CGE model.

$$f(Q_c) = \mathrm{prob}\,(Q) \le q_c) \qquad r\int_c^s = 1 + wh_c^s \quad (4)$$

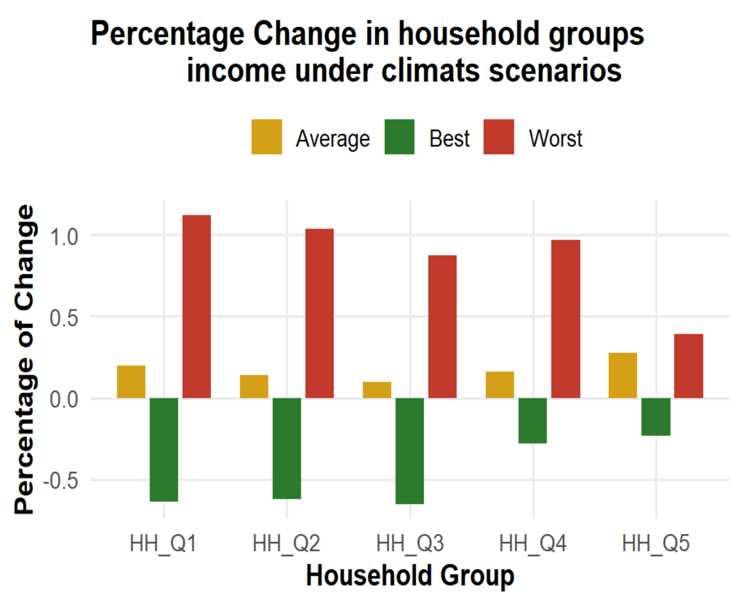
### 2.5. Computable General Equilibrium (CGE) Model

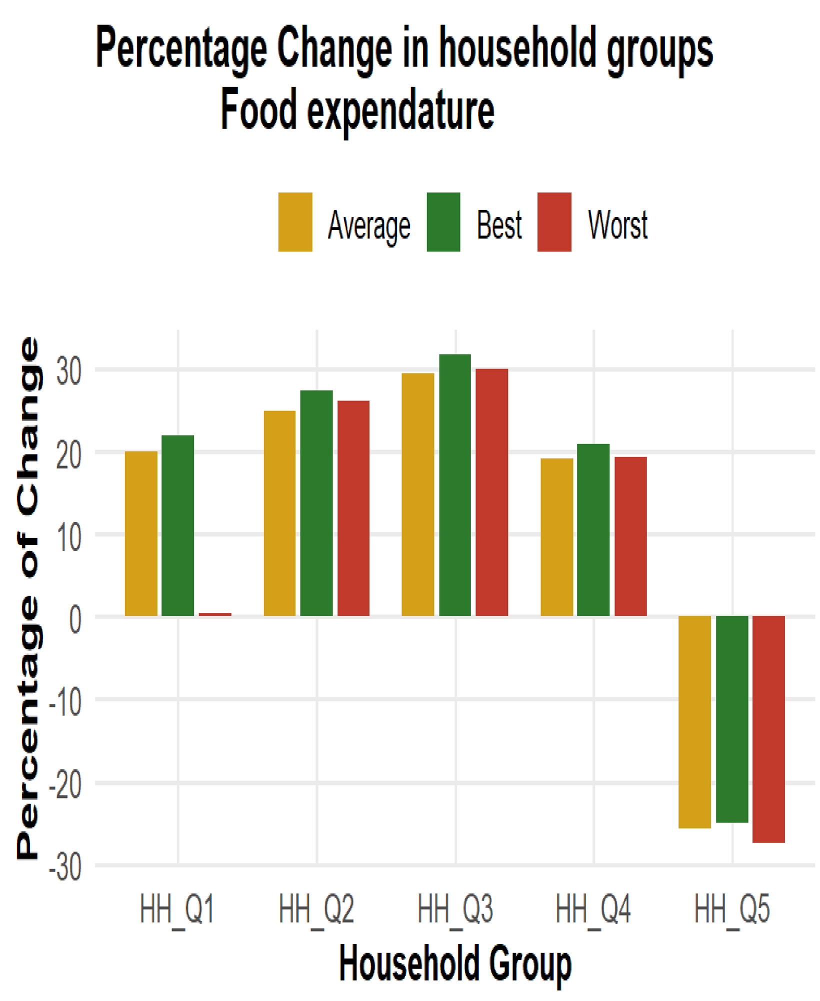
Integrates productivity shocks and assesses impacts on supply, prices, income, and food security using a SAM-calibrated GAMS model and the IFPRI CGE model.

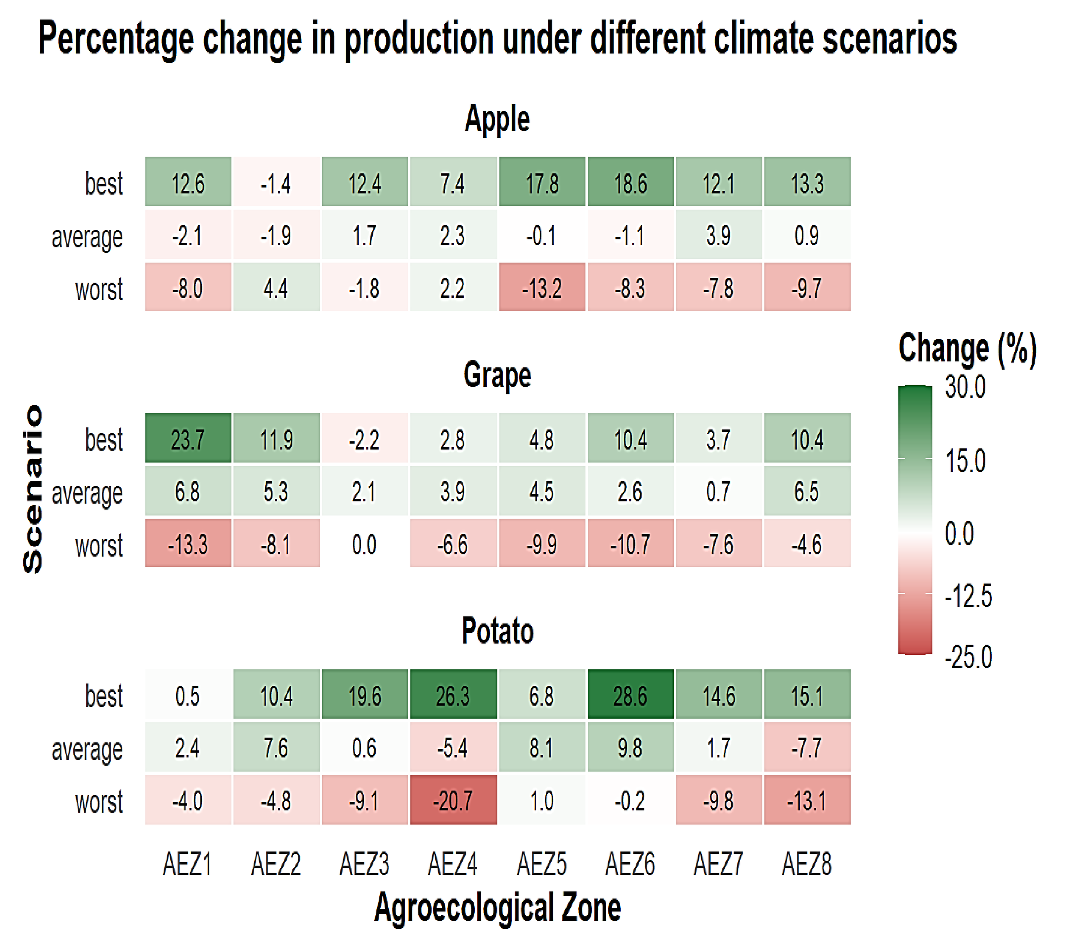
## 3. Result

**Tablle1:Climate parameter shock**

| Scenario | AEZ1 | AEZ2 | AEZ3 | AEZ4 | AEZ5 | AEZ 6 | AEZ7 | AEZ 8 |
|---|---|---|---|---|---|---|---|---|
| Apple-Worst | -8.0 | 4.4 | -1.8 | 2.2 | -13.2 | -8.3 | -7.8 | -9.7 |
| Apple-Average | -2.1 | -1.9 | 1.7 | 2.3 | -0.1 | -1.1 | 3.9 | 0.9 |
| Apple-Best | 12.6 | -1.4 | 12.4 | 7.4 | 17.8 | 18.6 | 12.1 | 13.3 |
| Grape-Worst | -13.3 | -8.1 | 0.0 | -6.6 | -9.9 | -10.7 | -7.6 | -4.6 |
| Grape-Average | 6.8 | 5.3 | 2.1 | 3.9 | 4.5 | 2.6 | 0.7 | 6.5 |
| Grape-Best | 23.7 | 11.9 | -2.2 | 2.8 | 4.8 | 10.4 | 3.7 | 10.4 |
| Potato-Worst | -4.0 | -4.8 | -9.1 | -20.7 | 1.0 | -0.2 | -9.8 | -13.1 |
| Potato-Average | 2.4 | 7.6 | 0.6 | -5.4 | 8.1 | 9.8 | 1.7 | -7.7 |
| Potato-Best | 0.5 | 10.4 | 19.6 | 26.3 | 6.8 | 28.6 | 14.6 | 15.1 |




## 4. Conclusion

Climate-induced changes in fruit and vegetable production affect commercialization pathways, leading to changes in household income and food expenditure, with the greatest implications for vulnerable households in Afghanistan

Contact person: Saidaqa Ayar
[Email: Ayar.Saidaqa@zalf.de and ayarsaid@student.hu-berlin.de

Date: [17.09.2026]

30 Years Leibniz Association