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

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1. Background

- Agriculture is the backbone of livelihoods (22% of GDP, 79% of population engaged in farming/livestock).
- Horticulture contributes significantly to income and exports.
- Afghanistan is highly vulnerable to the impacts of climate change.
- Climate change disrupts temperature, rainfall, and water availability, reducing crop yields.
- Limited research on climate shocks' impact on horticulture and household welfare.
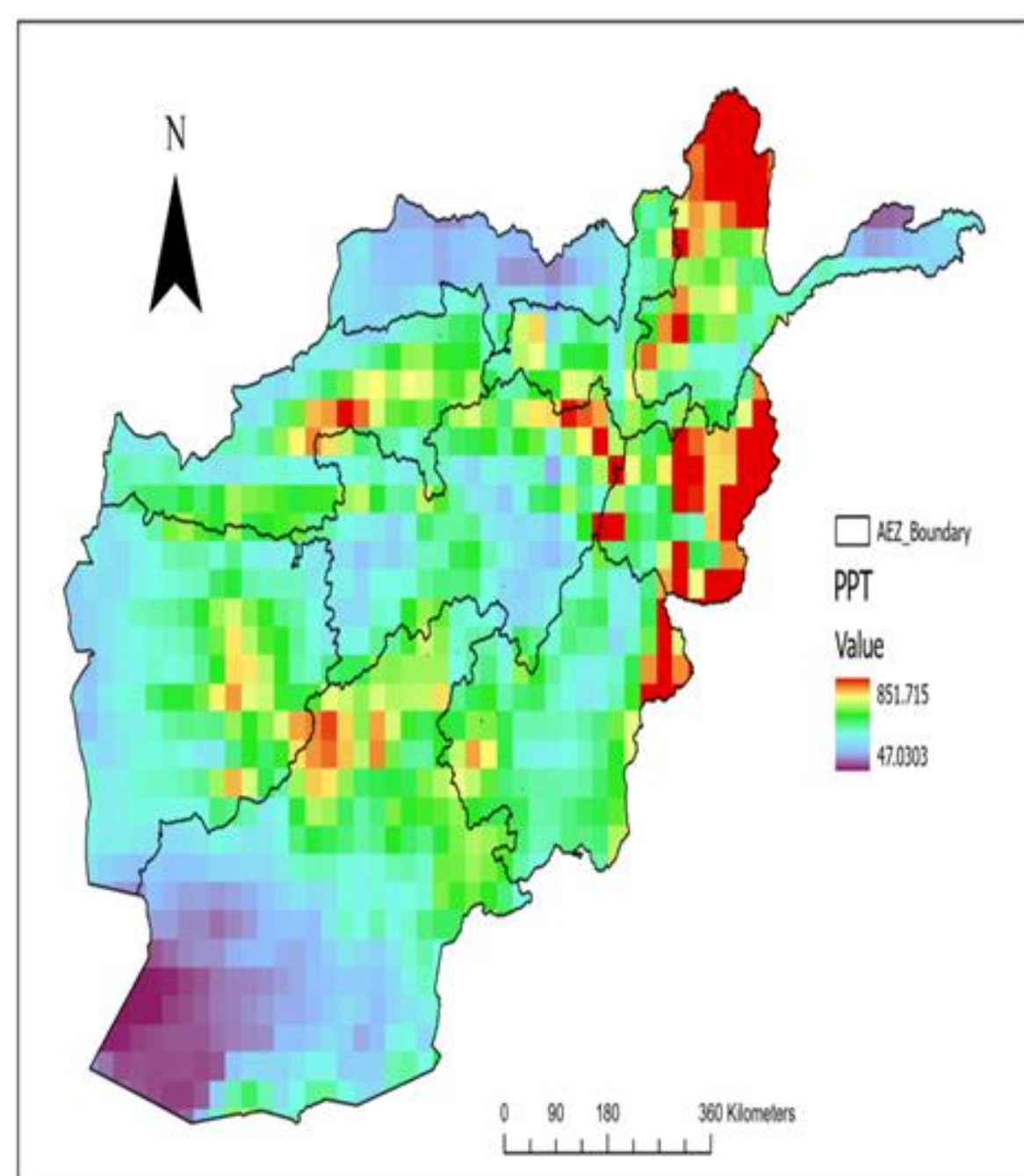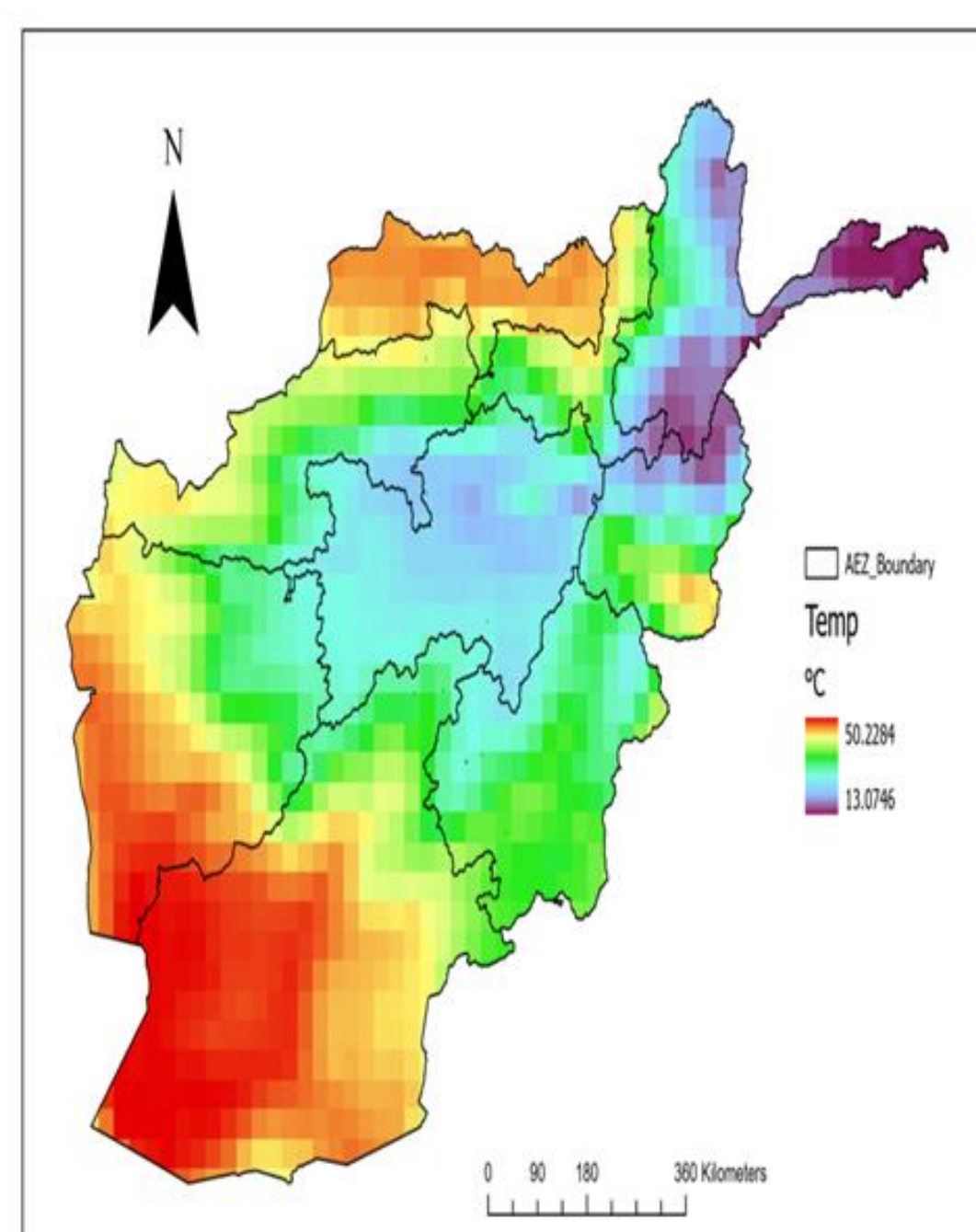

Fig 1: Precipitation gradient of AEZ of AFG

Fig 2: Temperature gradient of the AEZ of AFG

1.1. Objectives

🌱 Assess the impact of climate change on the commercialization of fruits and vegetables.

💰 Examine how the commercialization of these products affects farmers' overall income levels.

🏠 Analyze the effects of climate change on household food expenditure across different socio-economic groups.

📋 Evaluate the combined impact of policy interventions on household incomes and food security.

2. Methodology
2.1.Study Area

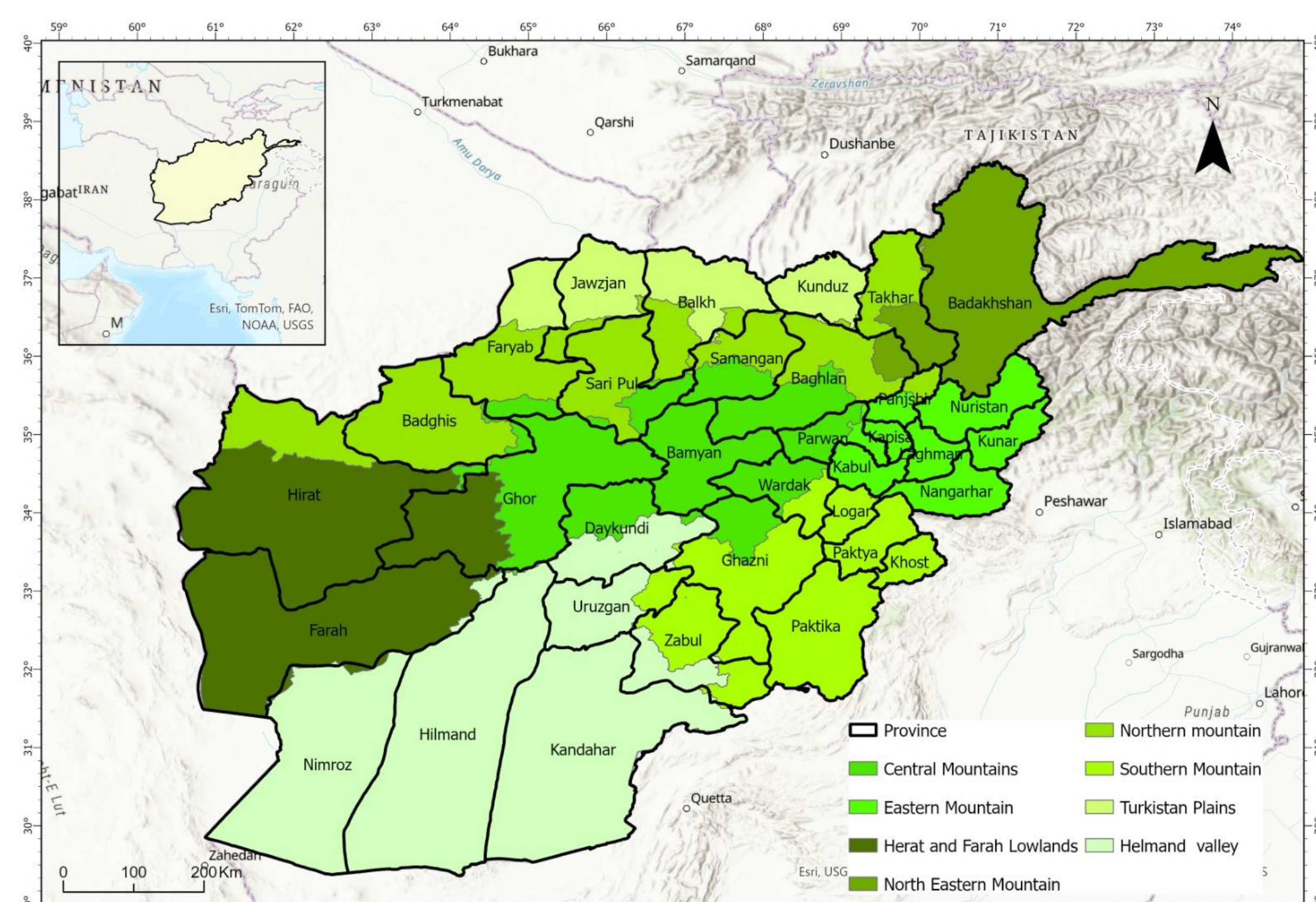Eight Major Agroecological Zones (AEZs) of Afghanistan

Fig.3 Map of agroecological zoning of Afghanistan (AEZ).
Source: Ayar et all.

2.2. Data sources

- The Social Accounting Matrix (SAM) was obtained from the Biruni Institute (Joya, 2019).
- Precipitation and temperature data were compiled from ERA5-Land Daily Aggregates (1974–2024) via Google Earth Engine.
- Actual (ET^a) and potential evapotranspiration (ET^m) were estimated using CROPWAT with the Penman-Monteith method (1974–2024), based on (AEZ).
- Required monthly climate inputs for CROPWAT, including precipitation, minimum and maximum temperatures, relative humidity, wind speed, and sunshine hours were extracted from ECMWF/ERA5-Land Hourly data.
- Crop yield response coefficients (Ky) were obtained from FAO Irrigation and Drainage Paper No. 33.
- Potential yields (Y^m) for grapes, apples, and potatoes were compiled from secondary sources.

2.3. Analytical Framework

🌱 Cropping Pattern → 🎲 Stochastic Simulation → 📈 CGE Model

23.1. Crop Yield Simulation:

Quadratic regression: yield ↔ precipitation & temperature.

$$y_{z,t} = \alpha + \beta_1 RF_t + \beta_2 RF^2_t + \beta_3 SDTem_t + \delta T_t + \varepsilon z, t \qquad (1)$$

2.3.2 Yield Response to Evapotranspiration

FAO yield-response model: yield ↔ evapotranspiration.

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

2.4. Monte Carlo Stochastic Modeling

Uses historical monthly climate data (1974–2024) → lower bound and an upper bound→ Generates Worst, Average, Best scenarios → Defines shock parameters for CGE.

$$f(Q_c) = prob (Q) \le q_{c)} \qquad r \int_c^s = 1 + wh_c^s \qquad (4)$$

2.5. Computable General Equilibrium (CGE) Model

○ Integrates climate shocks into the agriculture value-added function.

○ Evaluates commodity supply, prices, household income, and food security.

○ Calibrated using SAM and solved in GAMS.

3. Expected Outcomes

🌱 **Climate Change** → 💰 **Crop Commercialization** → 💰 **Farmers' Income** → 🏠 **Household Expenditure** → 📋 **Policy Response.**

- Projected changes in yields of grapes, apples, and potatoes under varying temperature and precipitation scenarios.
- Identification of agroecological zones most vulnerable to climate stress.
- Quantification of water stress effects on crop productivity using evapotranspiration models.
- Assessment of income variations for farming households across climate scenarios.
- Evaluation of changes in household food expenditure, highlighting socio-economic disparities.
- Insights into food availability and access at regional and national scales.

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Date: [10.09.2025]