The Impact of Climate-Change-Driven Species Distribution Shifts on Food Security

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INTRODUCTION

- **Global Challenge:** Climate change is altering **temperature and precipitation patterns** and driving widespread habitat shifts across species, **reshaping ecosystems and threatening global food security**.
- **Focal Species:** ***Spodoptera frugiperda*** (Fall Armyworm, FAW), a highly invasive pest, has rapidly expanded its range under warming climates.
- **Food Security Risks:** FAW infestations significantly **reduce maize production**, leading to declines in calorie availability and heightened hunger risks, especially in vulnerable regions.

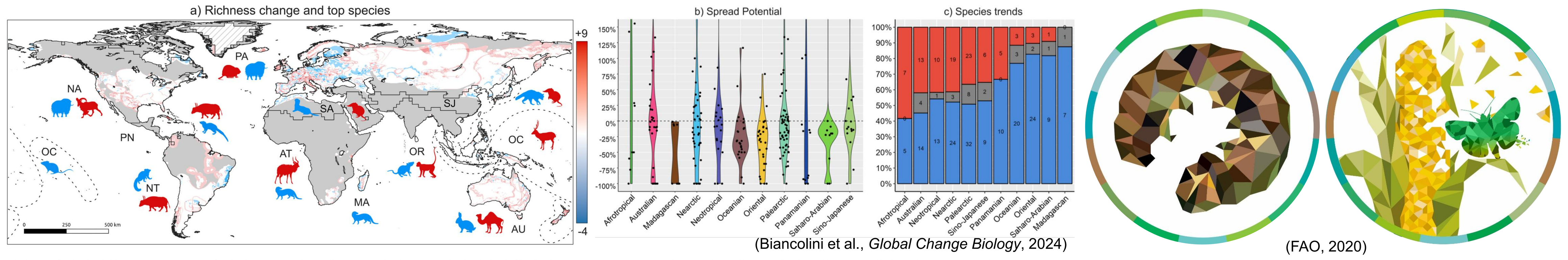


Fig. 1 (a) Alien mammal richness by Spread Potential, highlighting top expanders (red) and decliners (blue) per realm; (b) Spread Potential by realm; (c) Share of species with expanding (red), declining (blue), or stable (gray) ranges under SSP5-8.5; (d) Conceptual diagram of the Fall Armyworm.

- ➢ **Unaddressed Challenge:** Current research **lacks integrated models** connecting pest range shifts to crop loss and hunger, limiting understanding of ecological and economic risks to global agri-food system.
- ➢ **Study Objective:** This research **links climate-driven FAW distribution shifts with global maize production and calorie supply change**s, providing a novel framework to assess pest-induced hunger risks.

METHODOLOGY & DATA

Integrated Framework: Combined **species distribution model** (MaxEnt algorithm) with **agricultural economic model** (GLOBIOM) to assess pest-induced food security risks.

MaxEnt Algorithm

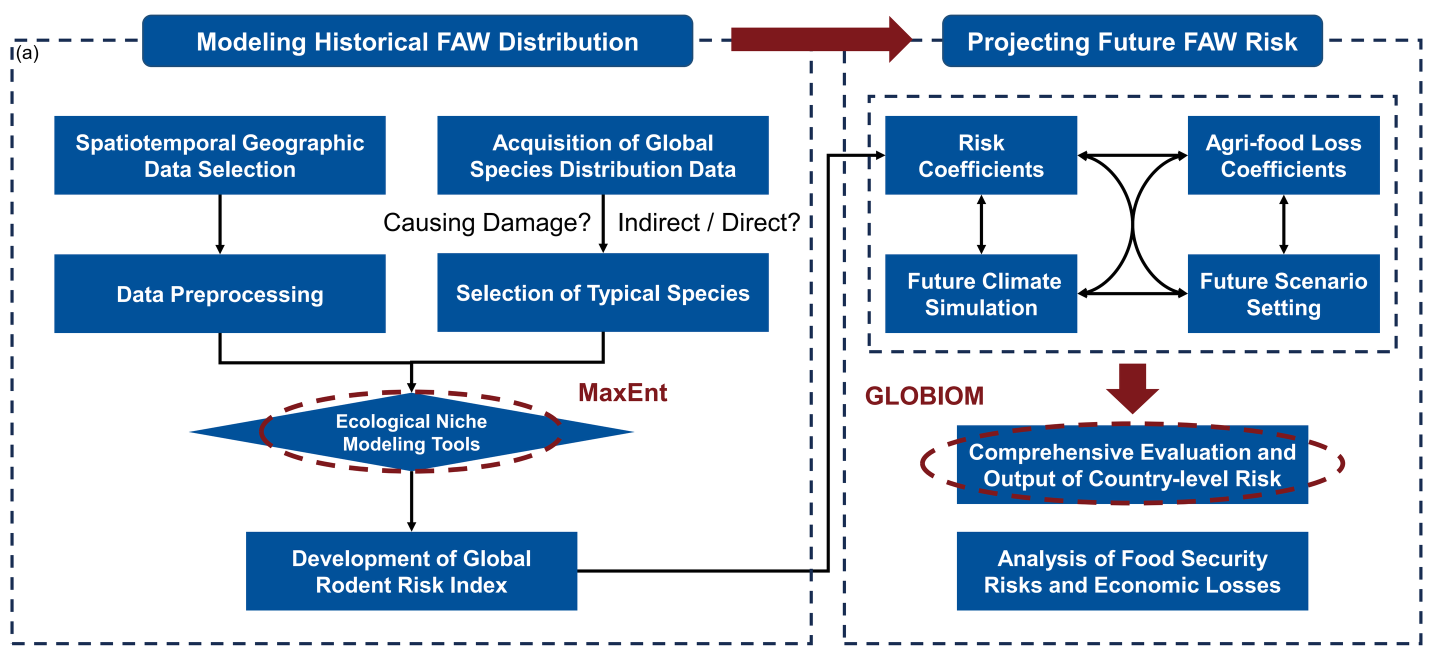
- **625** global occurrence records from **GBIF**, filtered and spatially rarefied
- Environmental variables: **19 bioclimatic factors, elevation, slope, NDVI**
- Scenarios: **SSP1-2.6** to **SSP5-8.5** × **10 GCMs**, projected for **2021–2100**
- Output: Global habitat suitability maps at **1/12°** resolution

GLOBIOM

- Incorporated FAW suitability into GLOBIOM as **spatial pest stress**
- Simulated FAW impacts on **maize production and calorie availability**
- Captured **regional disparities** under different SSP scenarios

(b)

Variables	Description	Period & Time Interval	Resolution	Source
Bio1	Annual mean temperature	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio2	Mean diurnal temperature range	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio3	Isothermality (Bio2/Bio7)(×100)	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio4	Temperature seasonality (standard deviation ×100)	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio5	Maximum temperature of warmest month	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio6	Minimum temperature of coldest month	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio7	Temperature annual range	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio8	Mean temperature of wettest quarter	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio9	Mean temperature of driest quarter	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio10	Mean temperature of warmest quarter	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio11	Mean temperature of coldest quarter	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio12	Annual precipitation	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio13	Precipitation of wettest month	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio14	Precipitation of driest month	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio15	Precipitation seasonality (Coefficient of Variation)	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio16	Precipitation of wettest quarter	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio17	Precipitation of driest quarter	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio18	Precipitation of warmest quarter	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Bio19	Precipitation of coldest quarter	Historical, 30 years mean (1970-2000); Future, 20 years mean (2021-2100)	1/12°	WorldClim
Elevation	Altitude above sea level (Topographic Position)	Constant	1/12°	WorldClim
Slope	Rate of elevation change across space (Terrain Steepness)	Constant	1/12°	Calculated
NDVI	Normalized Difference Vegetation Index	Historical, 18 years mean(1982-2000)	1/12°	PKU



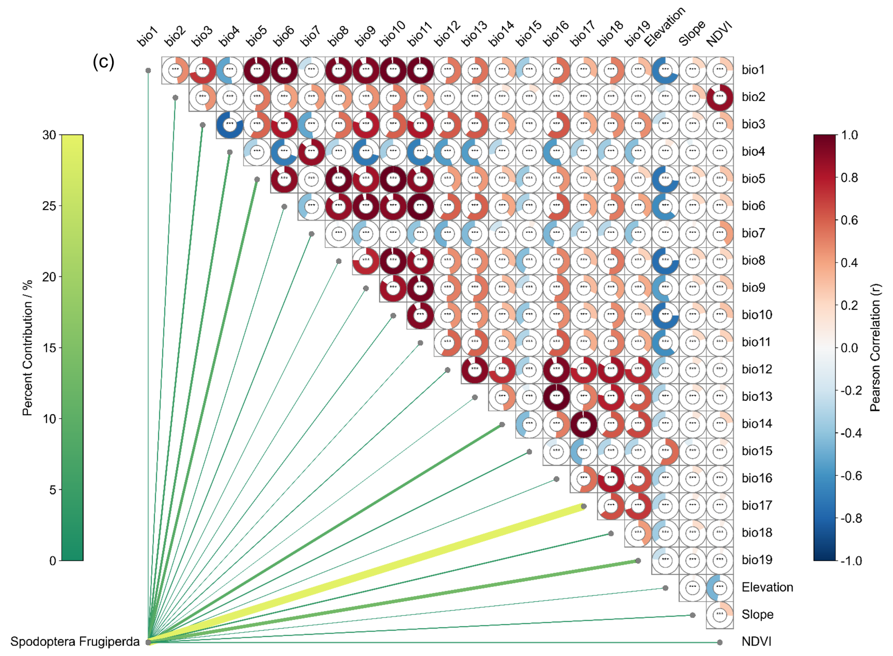


Fig. 2 (a) Workflow of the modeling framework; (b) Interpretation of environmental variables; (c) Variable correlation analysis and variable contributions to FAW habitat suitability.

RESULTS & FINDINGS

Global Expansion of FAW Habitat

- FAW habitat suitability expands significantly under all scenarios.
- Under **SSP5-8.5,** FAW suitable area expands to over **14 million km²**, with strong **poleward and elevational shifts**.
- In contrast, **SSP1-2.6** limits expansion, with suitability stabilizing or declining in tropical zones due to reduced warming.

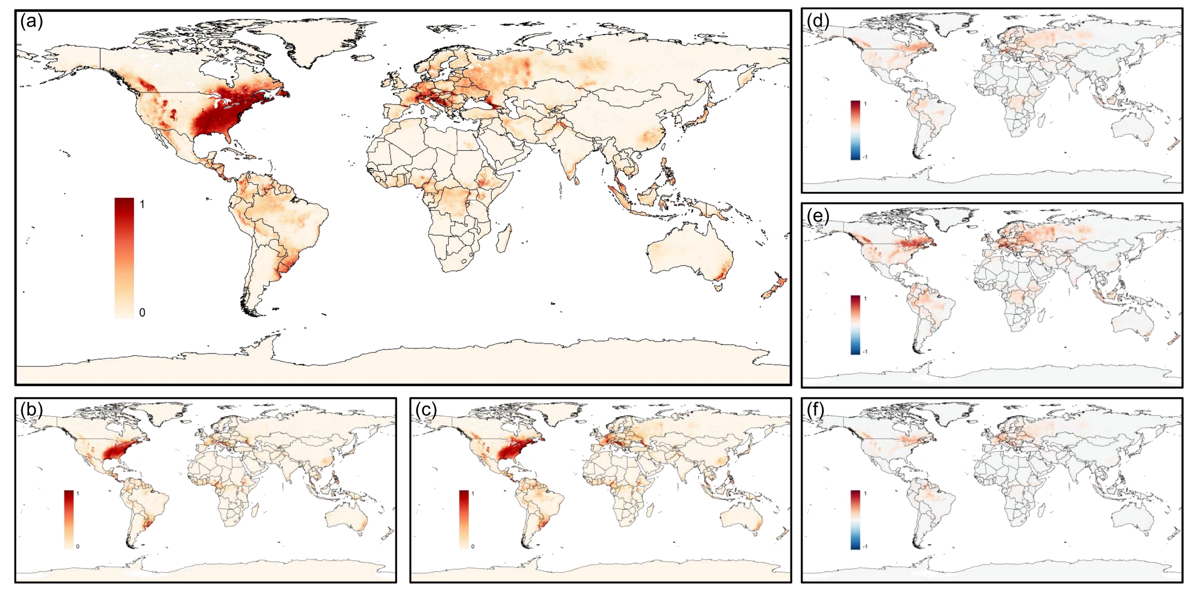


Fig.3 Projected Global Distribution Probability of FAW: (a) SSP5-8.5 scenario for 2081–2100; (b) Baseline scenario (current conditions); (c) SSP1-2.6 scenario for 2081–2100; (d) SSP5-8.5 vs SSP1-2.6 (2081–2100): increasing (red), decreasing (blue); (e) SSP5-8.5 (2081–2100) vs baseline: increasing (red), decreasing (blue); (f) SSP1-2.6 (2081–2100) vs baseline: increasing (red), decreasing (blue).

Maize Production Impacts: Regional Disparities

- **Global**: Pest-induced stress reduces maize production across most regions (–2.1% to –2.5%).
- **Europe**: Consistent and severe losses (–11%) across all SSPs.
- **SSA**: Moderate production declines (–3.5% to –4.3%).
- **Oceania**: Production increases (+5.9% to +7.1%) across all SSPs.
- **Latin America**: Some resilience under SSP1-2.6, with gains (+7.4%).

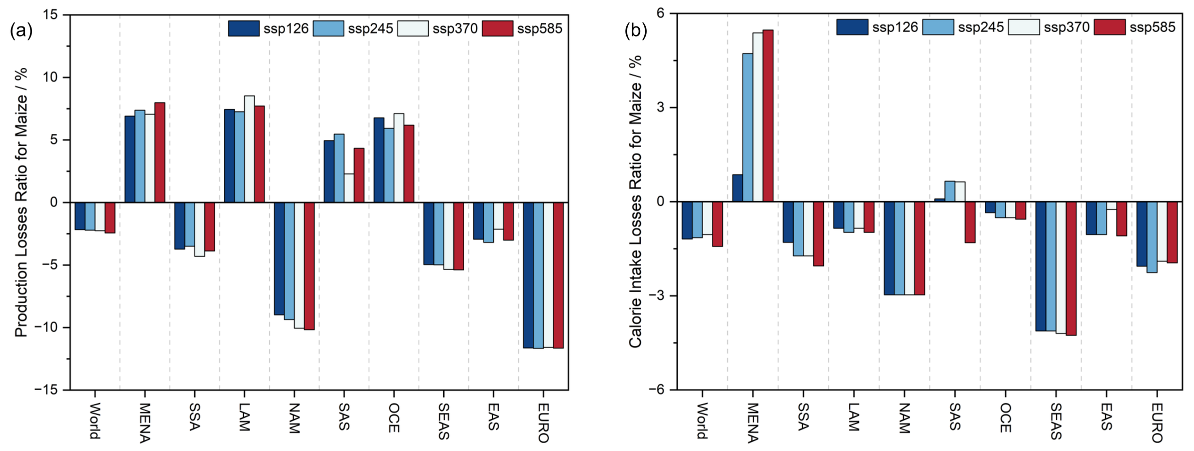


Fig.4 (a) Production and (b) Calorie Intake Losses Ratio for Maize. MENA: Middle East and North Africa; SSA: Sub-Saharan Africa; LAM: Latin America and the Caribbean; NAM: North America; SAS: South Asia; OCE: Oceania; SEAS: Southeast Asia; EAS: East Asia; EURO: Europe.

Nutrition & Calorie Supply

- **Global**: Per capita calorie availability declines in **all regions** (–1.3%).
- **SSA**: Most affected (–1.3% to –2.1%), with hunger risk intensified by ecological vulnerability.
- **Europe & North America**: Moderate nutritional declines (–2% to –3%) despite smaller production losses.
- **Latin America & Oceania**: Production gains **do not translate** into higher calorie intake—revealing systemic issues in dietary structure or market distribution mechanisms. (–0.5% and –0.9%).
- **MENA**: Under SSP1-2.6, lower temperatures increase pest suitability, leading to **production and calorie losses** (–5.98% and –4.37%).

Scenario Comparison: SSP1-2.6 vs SSP5-8.5

- Mitigation benefits are **clearest in tropical regions showing simultaneous gains in yield and nutrition.**
- However, **mid-latitude regions** face **worse outcomes** under SSP1-2.6 due to ecological niche shift.

SUMMARY & CONCLUSION

- Climate change is reshaping pest ecology: *Fall Armyworm* is projected to expand into **new regions** under warming scenarios, especially **SSP5-8.5**.
- These habitat shifts will lead to **nonlinear, regionally diverse impacts** on maize production and food security.
- **SSA** and **Europe** face the sharpest nutritional risks, while production gains in some regions **do not translate into better calorie access**.
- **Mitigation works—but not uniformly:** Low-emission pathways (e.g., SSP1-2.6) limits overall global expansion, but triggers local risks in mid-latitude and ecology transitional zones like MENA.
- Integrated modelling reveals that **ecological disruptions have cascading effects** on food systems, emphasizing the need for climate-informed pest management and **nutrition-sensitive agricultural strategies**.

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