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Development of a Co-evolutionary Decision Support System - Food and Water Security Integrated Model System (FAWSIM)

Yinpeng Li*[1]*, W. Ye, X. Yan

Corresponding author[1]
START Regional Centre for Temperate East Asia (TEACOM), Institute of Atmospheric Physics, Chinese Academy of Sciences, China. Email: lyp@mail.iap.ac.cn

Abstract
This study presents FAWSIM – Food and Water Security Integrated Model System, which is a co-evolutionary decision support system for climate change impact assessments. The objective of the system is to assist with the assessment of adaptation options and sustainable development opportunities in relation to water and food security at global, regional and local scales. This is achieved through the effective transfer of climate change and impact information to planners, policy-makers and the wider scientific community. Case studies in Jilin province, China and Mongolia verifies and validates the feasibility of the system. The application of the FAWSIM system extends our understanding of the local food and water security issues in the context of climate change.

Keywords: *FAWSIM, SimCLIM, food and water security, climate change, Integrated Assessment Model, Decision Support System*

Introduction
Adapting to climate change while sustaining and/or improving food and water security has become a strategically important question for scientists and policy-makers at various levels (United Nations, 2010). This challenge has been identified as one of the major knowledge gaps. In an attempt to close the gap, we detail the development of a Decision Support System, FAWSIM – Food and Water Security Integrated Model System, developed through an APN-funded project and conducted by researchers from China, New Zealand, Mongolia and Russia (Li *et al.*, 2010).

Methodology
A multi-disciplinary approach was required to develop the food and water assessment system as a single model cannot cover concerns of all stakeholders especially as each has different interests with regard to how climate change may impact food and water

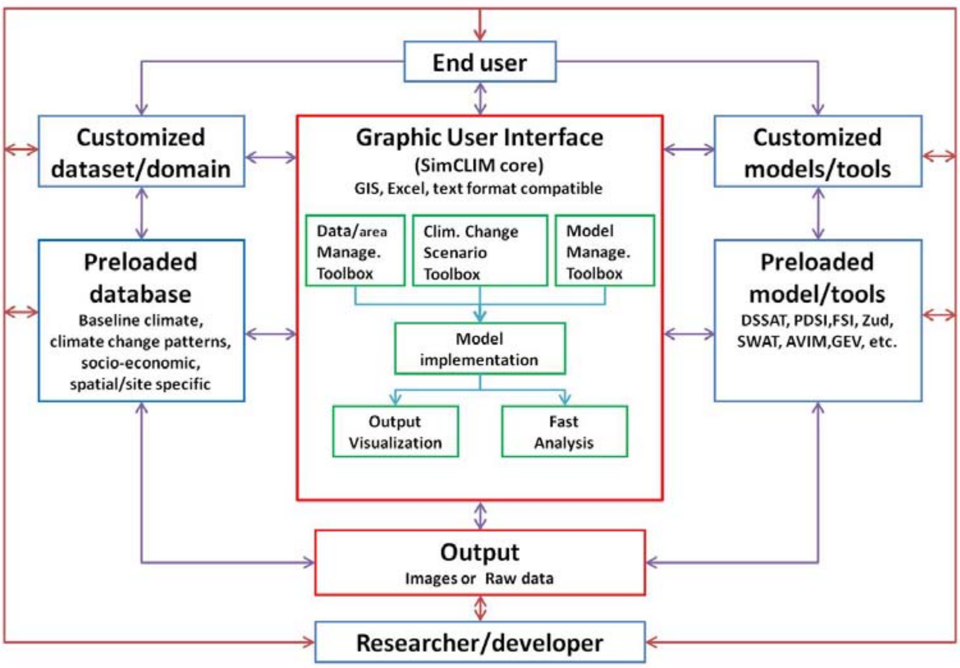

Figure 1. FAWSIM schematic illustration

security at different spatial/temporal scales. Paramount to system development is interaction and information exchange among stakeholders, experts and model developers. In the present study, such information exchange was carried out through a participatory assessment approach, with stakeholders' concerns and ideas of potential solutions being collected by the research team for the target area. SimCLIM, a state-of-the-art climate change impact assessment software system, was used to integrate the information and data collected, and to generate climate change scenarios. SimCLIM's open framework structure and user-friendly interface provided the foundation for this study. Figure 1 shows the flowchart of the FAWSIM system.

FAWSIM Description

FAWSIM consists of three major components: a database that supports climate change scenario generation; a set of impact models; and an interface for end-users.

1. Database

Climate change scenarios

Climate change scenarios drive the system. All FAWSIM functions, data and models are linked to the scenarios. FAWSIM provides scenarios at the global level, as well as customised local scenarios at the scale of the case study.

The ensemble pattern scaling method made use of six IPCC illustrative emission scenarios and all 21 IPCC Fourth Assessment Report (IPCC AR4) Global Climate Models (GCMs) results. All data was pre-processed and stored in the system. The inclusion of a wide range of emission scenarios and GCM simulation results makes climate sensitivity analysis easier within the FAWSIM system.

To support impact assessments at the local scale, a statistical downscaling method was applied to the GCM data. The Self Organising Maps Statistical Downscaling (SOM-SD) approach embraces the advantage of a synoptic classification method and a stochastic re-sampling technique. The SOM-SD output allows probability and risk analysis, which is important, especially given uncertainties in climate change projections (Yin *et al.,* 2010).

Baseline climate data

FAWSIM integrated various historical data, from gridded spatial data to time series data of sub-daily, daily and monthly climate data at global, regional and local (for the case study area) levels, to meet the site-specific impact assessment requirement.

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Integrated Model Development for Water and Food Security Assessments and Analysis of the Potential of Mitigation Options and Sustainable Development Opportunities in Temperate Northeast Asia

Project Leader:

Prof. Xiaodong Yan
START Regional Centre for Temperate East Asia (TEACOM), Institute of Atmospheric Physics, Chinese Academy of Sciences
Deshengmenwai, Qijiahuozi 100029, Beijing
CHINA
Tel: +86 10 6238 3015
Fax: +86 10 6204 5230
Email: yxd@tea.ac.cn

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Research Highlights

- Development of a co-evolutionary decision support system -Food and Water Security Integrated Model System (FAWSIM): A software package
- Climate change and drought: a risk assessment of crop-yield impacts. (Published in *Climate Research*, Li *et al.*, 2009)
- Statistical downscaling of regional daily precipitation over Southeast Australia based on self-organising maps. (Published in *Applied and Theoretical Climatology*, Yin *et al.,* 2010)
- Climate change and maize production: Impacts and potential adaptation measures: A case study in Jilin Province, China. (publishing in *Climate Research*, *Wang et al.,* 2011)

Socio-economic census data

Based on the specific requirement of an impact model, FAWSIM can integrate other census data related to crop and/or food production, such as agricultural census, soil types and vegetation cover.

2. Impact models applied for the case studies

Food Security Index (FSI) Model

An FSI model was developed to assess the food security level for each county in Jilin province, China. The FSI integrates relevant indicators from food production to consumption to classify the food security level at the county level (Figure 2).

Partial equilibrium food balance model: The model includes production (supply), and consumption (demand) specified separately for rural and urban consumers, buffer stocks, trade, and market clearing for 18 food commodities or commodity groups. Agricultural supply is assumed to respond to the product's own-price, prices of other commodities and inputs, quasi-fixed inputs, and other exogenous shocks.

Crop production model – Decision Support System for Agrictechnology Transfer (DSSAT)

The DSSAT simulations show that yield is highly likely to decline in the western and central regions of Jilin. The average maize yield in the west and central regions is thus projected to decrease by 15% or more by 2050 as predicted by 90% of 120 projected scenarios. Two potential adaptation strategies, i.e., improving irrigation facilities and cultivar shift, were identified from the vulnerability assessment and were further tested for the reduction areas (Wang *et al.*, 2010) (Figure 3).

The hydrological model – Soil and Water Assessment Tool (SWAT)

The SWAT model is a basin-scale distributed hydrological model. In this study, the Diersonghuajiang River basin was chosen as the study area. SWAT generates a comprehensive range of hydrological results, including: water yield, soil water, and snow melt. The integration of the SWAT model provided an assessment the climate change impacts on water resources.

The snow storm hazard model

The snow storm hazard (Zud or Dzud) model was developed to simulate the frequency and magnitude of Zud risk in Mongolia. The Zud Index combines the growing season humidity index (HI), cold season precipitation index (PI) and cold season temperature anomaly (TA). The future Zud Index was calculated based on the ensembled monthly precipitation and temperature projections of GCMs.

Drought risk assessment model

This model simulates climate change impacts on global drought using a revised Palmer Drought Severity Index (PDSI) (Li *et al.*, 2009).

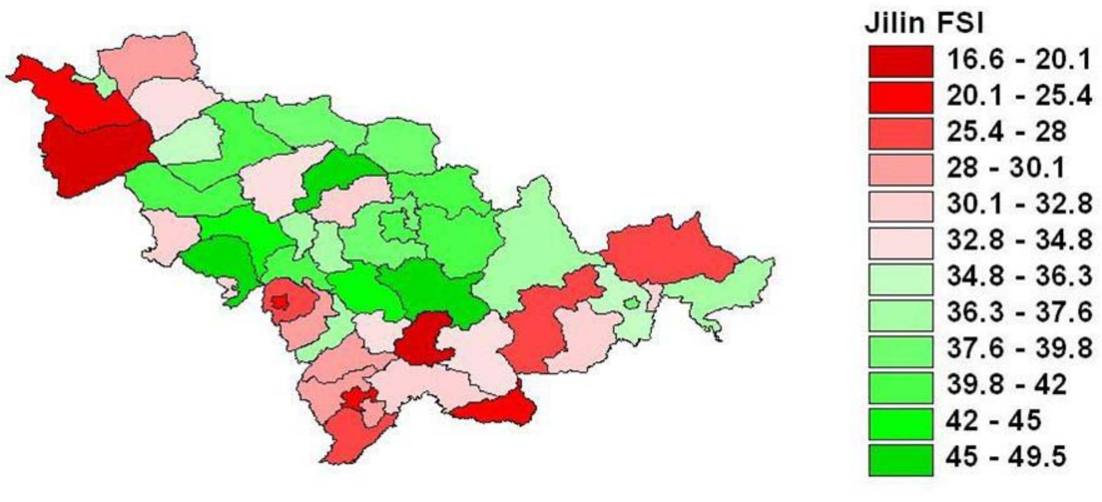

Figure 2. Spatial distribution of the FSI model in Jilin province, China

3. User Interface

The Graphic User Interface (GUI) of FAWSIM employed and enhanced SimCLIM's open framework structure developed by the SimCLIM team (Warrick, 2009). SimCLIM essentially facilitates a series of toolboxes:

Climate change scenario generator tools enable users to generate climate change projections for any year in the 21st century. The scenario generator's functionality, including global projection, ensemble, pattern viewer tools, facilitates the effective transfer of climate change projections to users' for applications in impact and risk assessments (Figure 4).

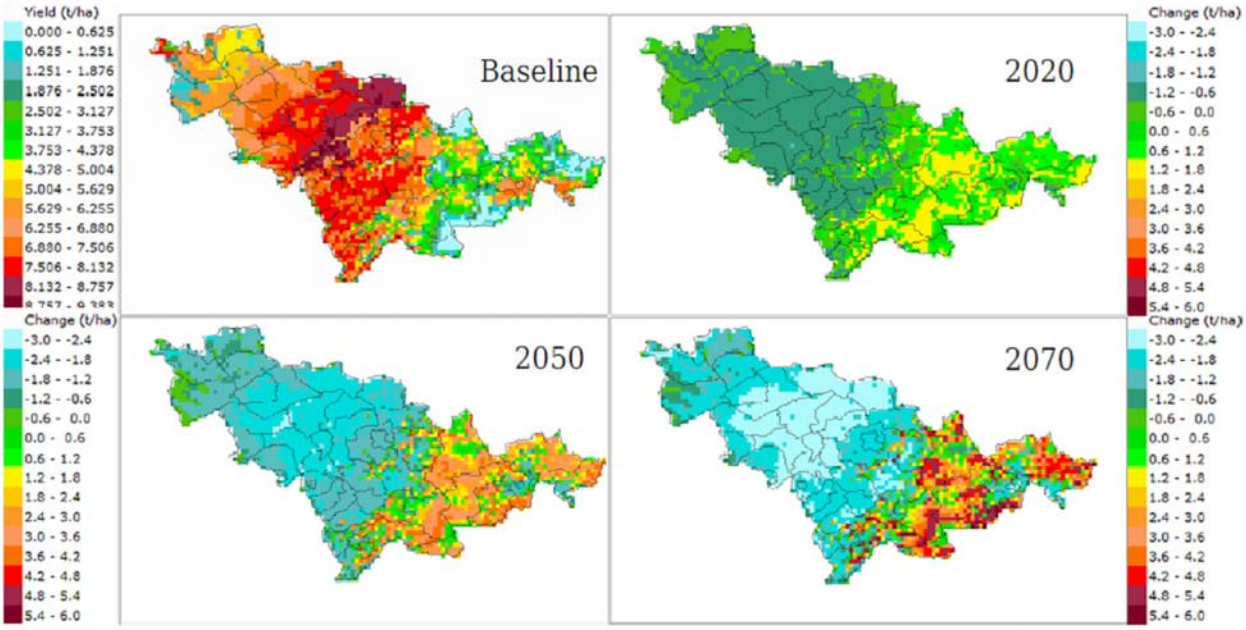

Figure 3. Climate change impact on maize production in Jilin province, the simulated maize yield (t ha^{-1}) at baseline and the changes in 2020, 2050, and 2070

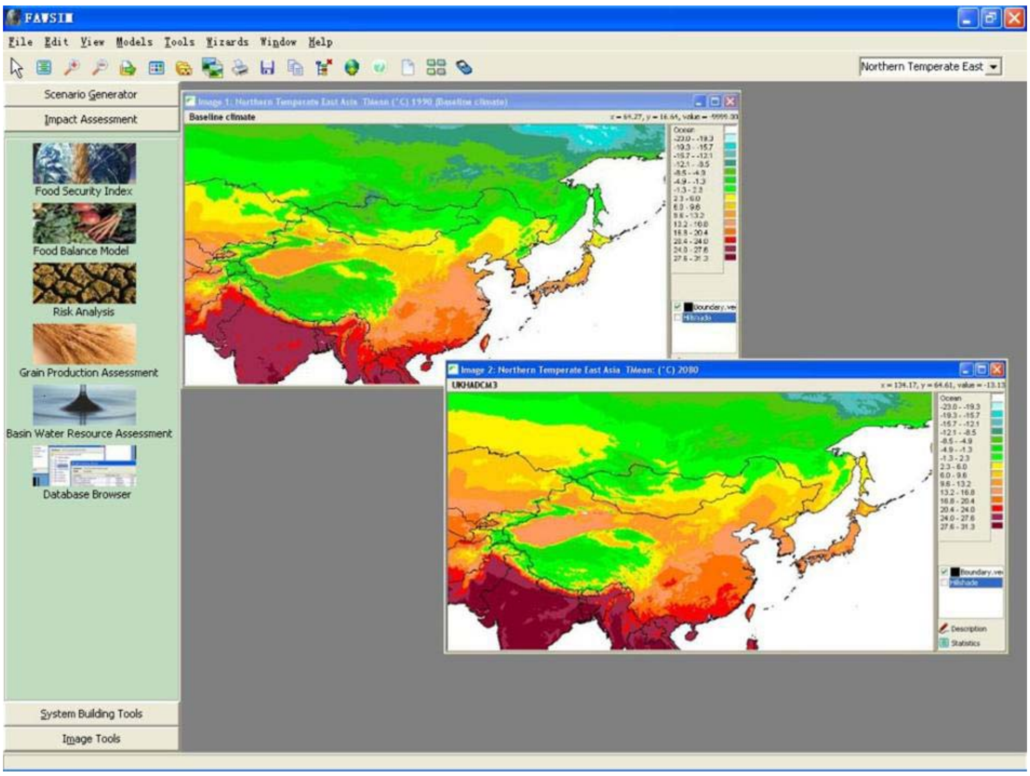

Figure 4. Annual mean temperature of East Asia: baseline (top) and 2080 projection (bottom)

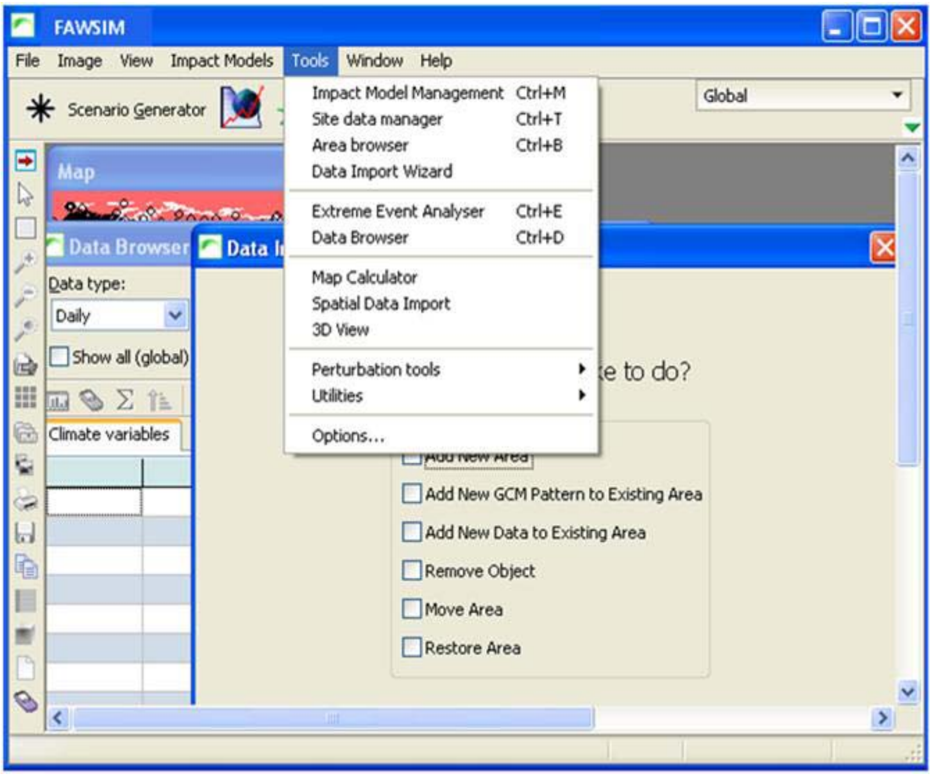

Figure 5. FAWSIM data management tools interface

Data management tools enable users to import and export climate, land and socio-economic data, in time series (monthly, daily, hourly, sub-hourly) or spatial patterns (ARC-GIS grids and polygon layers, for example) (Figure 5).

Model management tools enable users to incorporate impact models using FAWSIM compatible DLL and BPLs. Simple models, such as the Zud model and FSI were written in Delphi and incorporated into SimCLIM. More sophisticated models such as DSSAT and SWAT were built as Fortran DLLs, and linked with SimCLIM.

Conclusions

FAWSIM provides an efficient tool for stakeholders by integrating baseline climate, climate change scenarios and relevant environment, and socio-economic data with a series of impact models and a graphic user interface. FAWSIM currently includes in its system models of DSSAT, SWAT, PDSI, FSI, ZUD; as well as the land cover and socio-economic data of China and Mongolia.

FAWSIM allows for multi-scale, multi-disciplinary impact assessments; climate change scenario uncertainty analysis; and, with a built-in GIS tool, the assessment results can be visualised and further analysed thus facilitating training and capacity building.

The open framework makes FAWSIM a co-evolutionary Decision Support System that can be regularly upgraded and improved through interaction between end-users and the developers.

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workshop photos