United Nations Framework Convention on Climate Change

# CGE TRAINING MATERIALS ON VULNERABILITY AND ADAPTATION ASSESSMENT

## Agriculture

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# *I. Overview and introduction*

# Objectives

- The objectives of this presentation are:

  a) To provide an overview of the method tools and associated data requirements that are commonly used in the agricultural sector for vulnerability and adaptation assessment

  b) To provide some background information on the vulnerability of agriculture to climate change and adaptation options

## *II. Summary of agriculture vulnerability*

# Summary of agriculture vulnerability

- The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) Working Group II stated that climate change will have, with varying degrees, a broad impact on agricultural crops and livestock

- AR5 also emphasized the importance of food security, access to food, utilization, and price stability

- The basic question is how to feed the world in 2050 (FAO) under a changing climate

# Summary of agriculture vulnerability (cont.)

- Many studies have shown that climate change is a significant threat to sustainable development, especially to non-Annex I Parties
- Identifying which regions, populations, and food production systems are at greatest risk from climate change can help in setting priorities for adaptations
- This presentation provides an overview of the methods that are currently being used for making these assessments and provides example applications

# Summary of agriculture vulnerability (cont.)

- Based on studies that have been conducted so far, it is clear that climate change will have varied impacts on food and livestock systems
- The projected changes in the frequency and severity of extreme events can have a more damaging impact than the projected gradual changes in temperature and precipitation
- Moderate changes from climate change may benefit crop and pasture yields in mid- to high-latitude regions
- Slight warming will likely decrease yield in dry and low-latitude regions

## ***III. Drivers of change in agriculture***

# Related climate factors relevant to agriculture

| Climate factor | Direction of change | Consequences and factors that interact with agricultural production and food security |
|---|---|---|
| Sea level rise | Increase | Sea level intrusion in coastal (agricultural) areas and salinization of water supply |
| Precipitation intensity/run-off | Intensified hydrological cycle, so generally increases, but with regional variations | Changed patterns of erosion and accretion; changed storm impacts; changed occurrence of storm flooding and storm damage, water logging, increase in pests |
| Heat stress | Increases in heat waves | Damage to grain formation, increase in pests |
| Drought | Poorly known, but significant increased temporal and spatial variability expected | Crop failure, yield decrease, competition for water |
| Atmospheric carbon dioxide ($CO_2$) | Increase | Increased crop productivity but also increased weed productivity and therefore competition with crops |

# Drivers of change in agriculture

- Effects of current climate variability
  a) Flood and drought problems that result in socioeconomic impact
  b) Agriculture is extremely sensitive to the year-to-year fluctuations in weather conditions

- Drivers of agricultural response to climate change
  a) Biophysical effects
  b) Socioeconomic factors

# Drivers of change in agriculture (cont.)

- Non-climate drivers
  a) Land use, land degradation, geological processes, urbanization, and pollution
  b) Affect the agricultural sector directly and indirectly through their effects on climate

- Non-climate drivers of change
  a) Global scale drivers
  b) Country scale drivers
  c) Local scale drivers

# ***IV. Methods, tools, and data requirements***

# Methods, tools, and data requirements

- Agriculture is a very complex system due to the interaction between the biophysical and socioeconomic components. Many of the processes are difficult to model.

- Different approaches have been developed to assess the impact of climate change on agriculture:
  a) Agroclimatic indices
  b) Statistical models
  c) Process-based crop models
  d) Economic models
  e) Household and village models
  f) Geographic information systems (GIS)

# Characteristics of biophysical impact tools

| **Type of model/tool** | **Description and use** | **Strengths** | **Weaknesses** |
|---|---|---|---|
| Agroclimatic indices | Based on combinations of climate factors important for crops.<br><br>Used in many agricultural planning studies. Useful for general audiences. | Simple calculation.<br><br>Effective for comparing across regions or crops. | Climate-based only; lack management responses or consideration of carbon fertilization. Cannot capture adaptation. |
| Statistical models | Based on the empirical relationship between observed weather and crop responses.<br><br>Traditional tools used for yield prediction. | Crop yield and weather variations are well-described and can capture annual variability for long-term data. | Do not explain causal mechanisms, especially short stresses that occur during the growing season. Cannot capture future climate – crop relationships, $CO_2$ fertilization, and adaptation. Management and other variables often incomplete or lacking. |
| Process-based crop models | Based on the dynamic simulation of crop growth and development using local weather and soil information, crop management, and genetics as input.<br><br>Used by many agricultural scientists for research and development. | Process-based, widely calibrated, and evaluated. Can be used for testing a broad range of adaptation and mitigation strategies simultaneously.<br><br>Available for most major food, feed, and fiber crops. | Require detailed weather, soil, and management data for best results. Some models also require some type of genetic information. Do not represent all types of management. Do not represent pests, diseases, and weeds. |

# Characteristics of other impact tools

| Type of model/tool | Description and use | Strengths | Weaknesses |
|---|---|---|---|
| Economic models | Used to calculate economic impacts of climate change and the value of adaptation and mitigation | Useful for representing net impacts of climate change, assuming farmers adapt efficiently to climate change | Not all social systems, households, and individuals appropriately represented.<br><br>"Reduced form" models assume historical effects of policies, social conditions, and adaptation capability are the same in the future, and assume prices are constant. "Structural" models are more flexible but require more data. Assume profit and utility-maximizing behavior.<br><br>Models are complex and require much data. |
| Household and village models | Description of coping strategies for current conditions by household and village as the unit of response | Useful to understand causal relationships in complex farming systems and related household behaviors | Models are complex and case-specific; require large amounts of detailed data. |
| GIS | Tool to scale up point or grid-based simulations to a regional or national scale | Useful for regional assessments | Requires extensive spatial data as input, depending on the tool used. Requires some special GIS skills. |

# Common tools used in the agricultural sector

- DSSAT (Decision Support System for Agricultural Applications)
- APSIM (Agricultural Production Systems Simulator)
- WOFOST
- EPIC (Erosion Productivity Impact Calculator)
- AquaCrop
- CENTURY
- ORYZA 2000
- AgroMetShell
- Local Climate Estimator (New_LocClim)
- FAOClim 2.0
- CLIMWAT 2.0
- CROPWAT
- TOA-MD (Tradeoff Analysis Model for Multi-Dimensional Impact Assessment)
- Microeconomic Models: Reduced-form econometric models
- Microeconomic Models: Structural-form econometric, optimization, and simulation models
- Economic Land Use Models
- Partial and General Equilibrium Economic Models (GTAP)
- Regional and Global Integrated Assessment Models
- Agent Based Models

# Limitations and sources of uncertainty

- Climate change scenarios
- Climate variability
- Agricultural models
- Effects of $CO_2$ on crops
- Issues of aggregation and scale
- Socioeconomic projections
- Economic models

# Combining scenarios with tools and models

- Use multiple GCMs and scenarios as input for agricultural models
- Use downscaled climate models such as PRECIS or SDSM (Chapter 4) as input for agricultural models
- Use crop model ensembles
- Conduct sensitivity analyses with agricultural and economic models, and with scenario assumptions
- Analyse past statistical climate trends and use these to project forward
- Partner with climate scientists, social scientists, and others, including stakeholders

# Agroclimatic indices and GIS

- Agroclimatic indices are based on simple relationships of crop suitability or potential to climate
- Agroclimatic indices are useful for broad-scale impact assessment
- Agroclimatic indices can be combined with spatial databases of climate and crops for thematic mapping with GIS

# Statistical models and yield functions

- Multivariate models based on local weather and management can provide a statistical explanation of yield differences
- Multivariate models cannot be used for extreme weather events, especially those that were not part of the model development
- Multivariate models are based on statistical relationships and cannot provide an understanding of underlying causal mechanisms

# Process-based crop models

- Process-based models predict the response of a given crop to specific weather, soil, management, and crop factors

- They are based on simplified functions that express the interactions between crop growth and development, and ultimately yield weather and soil conditions, crop management, and genetic characteristics

- Most models are embedded in decision support systems

# Process-based crop models (cont.)

- Crop models are available for most agronomic crops including cereals, legumes, and root and tuber crops
- Crop models are less common for specialty crops, such as vegetables, tree fruit, nuts, etc.
- Most crop models predict abiotic stresses, such as drought and nitrogen stress, very well
- Most crop models are weak with respect to simulating biotic stresses by pests, diseases, and weeds

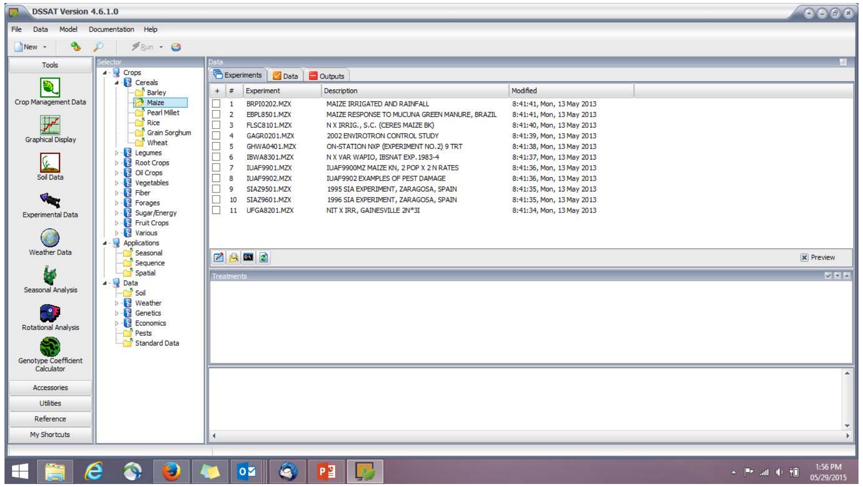
# Generic crop models

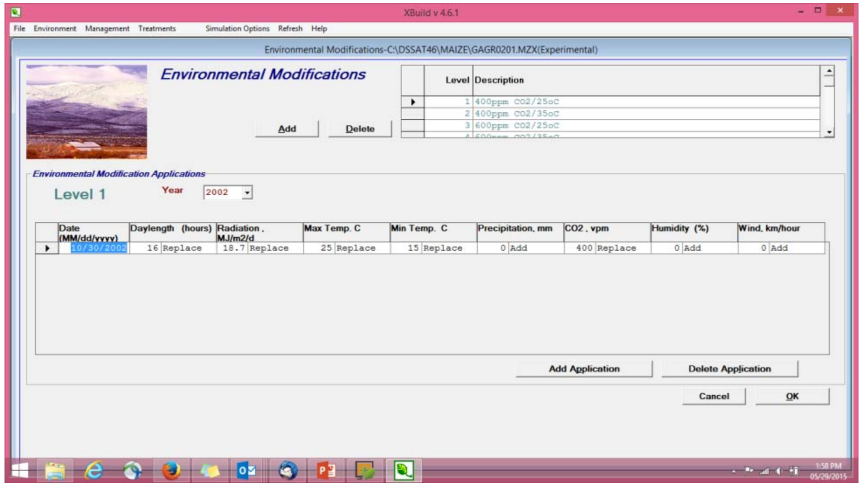
| Model | Crop |
|---|---|
| AquaCrop | Specific parameters for many crops (www.fao.org) |
| WOFOST | Specific parameters for maize, wheat, sugar beet, and other crops (www.wageningenur.nl) |
| EPIC | Specific parameters for maize, soybean, wheat, and other crops (www.epicapex.tamu.edu) |
| CROPSYST | Specific parameters for maize, wheat, potato, and other crops (modelling.bsyse.wsu.edu) |
| APSIM | Specific parameters for maize, wheat, potato, rice, and other crops (www.APSIM.info) |
| DSSAT | Specific models for different crops (www.DSSAT.net) |

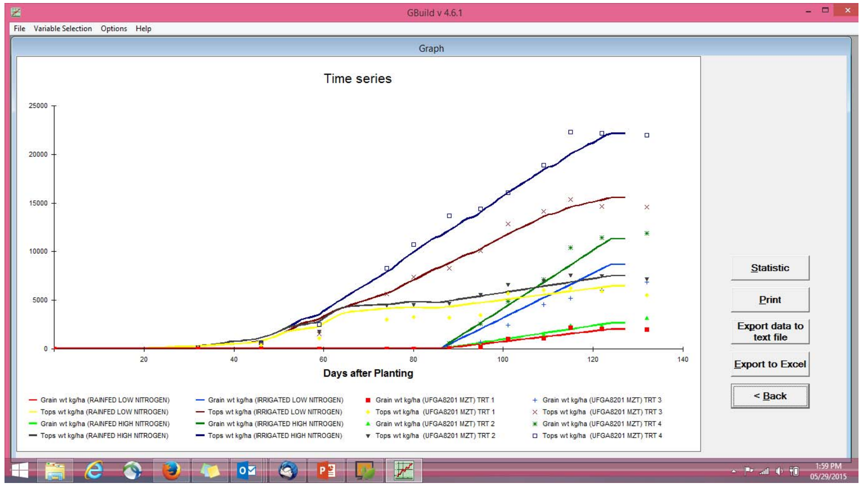
# Common crop models

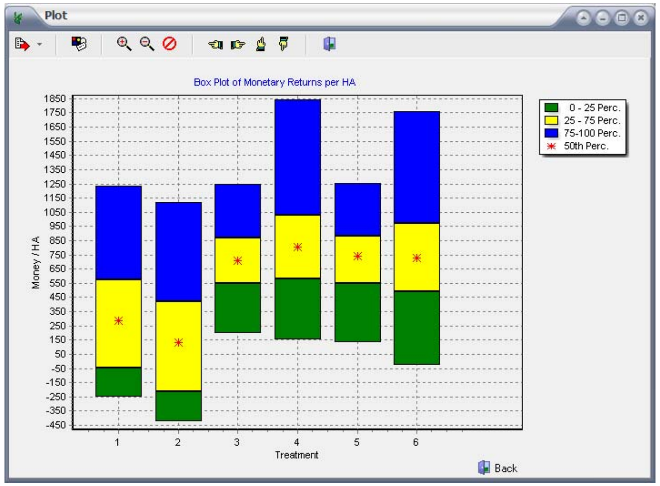
| Crop | Model |
|---|---|
| Barley | CSM-CERES-Barley (DSSAT) |
| Cotton | CSM-CROPGRO-Cotton (DSSAT), GOSSYM |
| Dry beans | CSM-CROGRO-Dry Bean (DSSAT) |
| Maize | CSM-CERES-Maize (DSSAT), CSM-CERES-IXIM (DSSAT) |
| Peanuts | CSM-CERES-Peanut (DSSAT) |
| Pearl millet | CSM-CERES-Millet (DSSAT) |
| Potatoes | CSM-SUBSTOR-Potato (DSSAT) |
| Rice | CSM-CERES-Rice (DSSAT), ORYZA2000 |
| Sorghum | CSM-CERES-Sorghum (DSSAT) |
| Soybeans | CSM-CROPGRO-Soybean (DSSAT), GLYCIM |
| Sugarcane | CSM-CANGRO (DSSAT) |
| Wheat | CSM-CERES-Wheat (DSSAT), APSIM-Wheat, AFRC-WHEAT, NWHEAT, SIRIUS |

# DSSAT modeling system



# Calibration and evaluation of crop models

- Participation by technical stakeholders for local data collection
- Adjustment of crop coefficients that describe crop characteristics and responses to environmental conditions using local data
- Evaluate representativeness of model with results with local data
- Scaling up of model results

# Steps for model calibration and evaluation

| Step | Concept/procedure |
|---|---|
| 1. Calibrate crop phenology | The crop developmental stage determines how the biomass is accumulated and to which organ of the plant growth is directed.<br><br>First adjust the reproductive development coefficients so that the simulated flowering date matches the observed flowering date; then adjust the next set of coefficients so that the simulated physiological maturity date matches the observed maturity date from the field data. |
| 2. Calibrate vegetative growth and biomass | The Leaf Area Index (LAI) and above-ground biomass determine light capture and potential photosynthetic rates. Adjust the vegetative growth and development coefficients so that simulated maximum LAI and total biomass matches the observed data. |
| 3. Calibrate grain production | The adequate rate and quantity of reproductive accumulation determines final crop productivity.<br><br>Adjust the reproductive growth coefficients so that simulated grain yield and yield components matches the observed data. |
| 4. Evaluate the calibrated model | Ensure that the crop model can predict yield accurately for similar conditions based on the calibrated cultivar coefficients.<br><br>Determine if the simulated flowering and maturity dates and grain yield represent data collected from farmers' fields or similar experiments. |

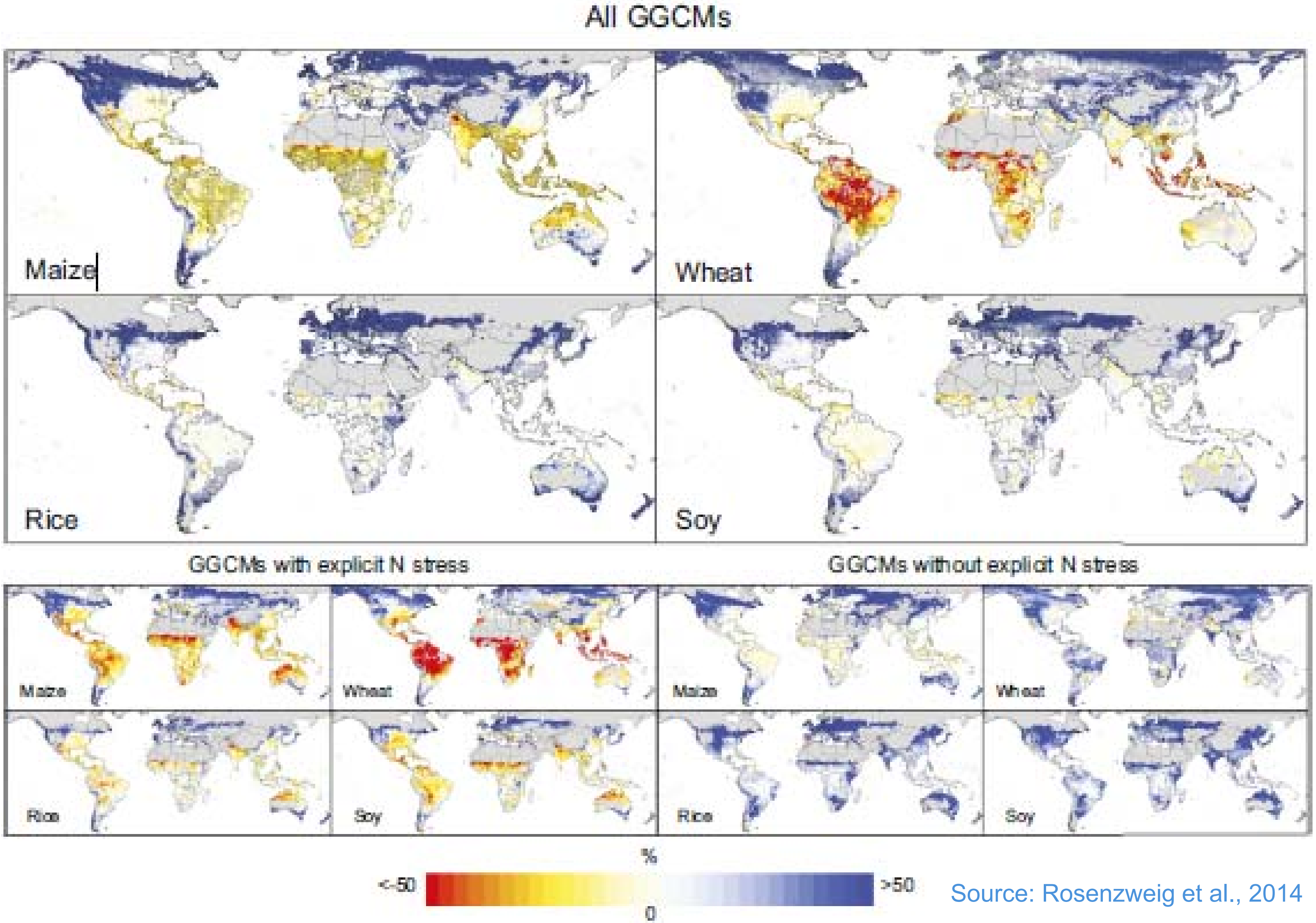
# Coupling crop and statistical models

- Crop simulation models are data intensive, requiring daily weather data, local soil characteristics, and crop management as input
- Data constraint can limit potential applications
- An alternative approach is to simulate crop responses to climate and management for select sites where detailed input data are available
- Develop statistical models of yield response using crop model outputs and associated inputs
- Can be expanded to larger areas for regional assessment

# Gridded modeling

- Crop simulation models are point-based systems
- As an alternative, models can be run for a fixed spatial area or grid
- Conditions within the grid are assumed to be uniform, including weather, soil conditions, and crop management
- Implement on High Performance Computers (HPCs) for large-scale applications at a region, a country, or a continent

# Median yield changes (%) for RCP 8.5 for 2070–2099 in comparison to 1980–2010 baseline




Source: Rosenzweig et al., 2014

## *V. Economic models and integrated assessments*

# Econometric models

- Reduced-form econometric models
  a) Statistically relate economic outcomes (land values, revenues, net returns) to climate variables, using historical data; then use these models with climate projections to estimate climate impacts
  b) Implicitly assume adaptation occurs as in historical periods
  c) Hold technology, prices, and all other socioeconomic factors constant, so cannot be used to represent climate impacts under future socioeconomic conditions
- Microeconomic structural models: Econometric, optimization, and simulation
  a) Various types of economic models that are used for farm-level and regional impact assessment
  b) Combine economic-behavioral models (econometric-simulation or optimization) or bio-physical models (crop models, livestock models)
  c) Can be linked to future scenarios and outputs from global models
- Land use models
  a) Many studies have investigated various drivers of land use change, including climate variables, using econometric models
  b) These models can be linked with other economic and biophysical models

# Market equilibrium models

- Two types of economic models have been used for national and global assessments of climate impacts: partial equilibrium (PE) and computable general equilibrium (CGE) models
- These models represent production according to spatial units that are typically sub-national regions for large countries, or individual countries, and represent consumption and trade at national levels
- These models use crop and livestock models to represent the productivity effects of climate
- Two examples are the IMPACT model, a PE developed by the International Food Policy Research Institute, which is linked to a globally gridded version of the DSSAT crop simulation model (see Figure 7-3); the GLOBIOM model developed by the International Institute of Applied Systems Analysis is linked to a globally gridded version of the EPIC model

# Information on datasets

- High-quality data are critical for assessments that lead to new policies by decision-makers
- Specific data requirements include a quantitative description of the study including current crop management, yield, and socioeconomic information
- Future conditions, including climate, management, prices, and policies
- Use a multi-disciplinary approach so that discipline experts are responsible for obtaining the data

# Summary of required data

| Dataset | Possible sources |
|---|---|
| Experimental crop phenology, yield, and yield components | At the local level, research and extension services of most agricultural universities or national research institutes of the ministries of agriculture |
| Yield and typical management for the crops to be studied | At the local level, extension services or national statistic services of the ministries of agriculture |
| Climate data | National Meteorological Service, national climate institutes, international organizations (e.g., WMO, UNFCCC, CCAFS, others) |
| Soil characteristics | Ministries of agriculture, international organizations (e.g., FAO, ISRIC) |
| Production (both regional and national statistics) | At the regional level, agricultural yearbooks of the ministries of agriculture, international organizations |
| Crop management | At the local and regional levels, extension services of the ministries of agriculture, international organizations, stakeholder consultation, farm surveys |
| Land use | Maps or digital images from the ministries of agriculture or the environment, satellite data from international organizations |
| General socioeconomic data | Ministries of agriculture; international organizations; stakeholder consultation (including women); farm surveys, including World Bank Living Standards Measurement Surveys |
| Other | Stakeholder consultation (including women) |

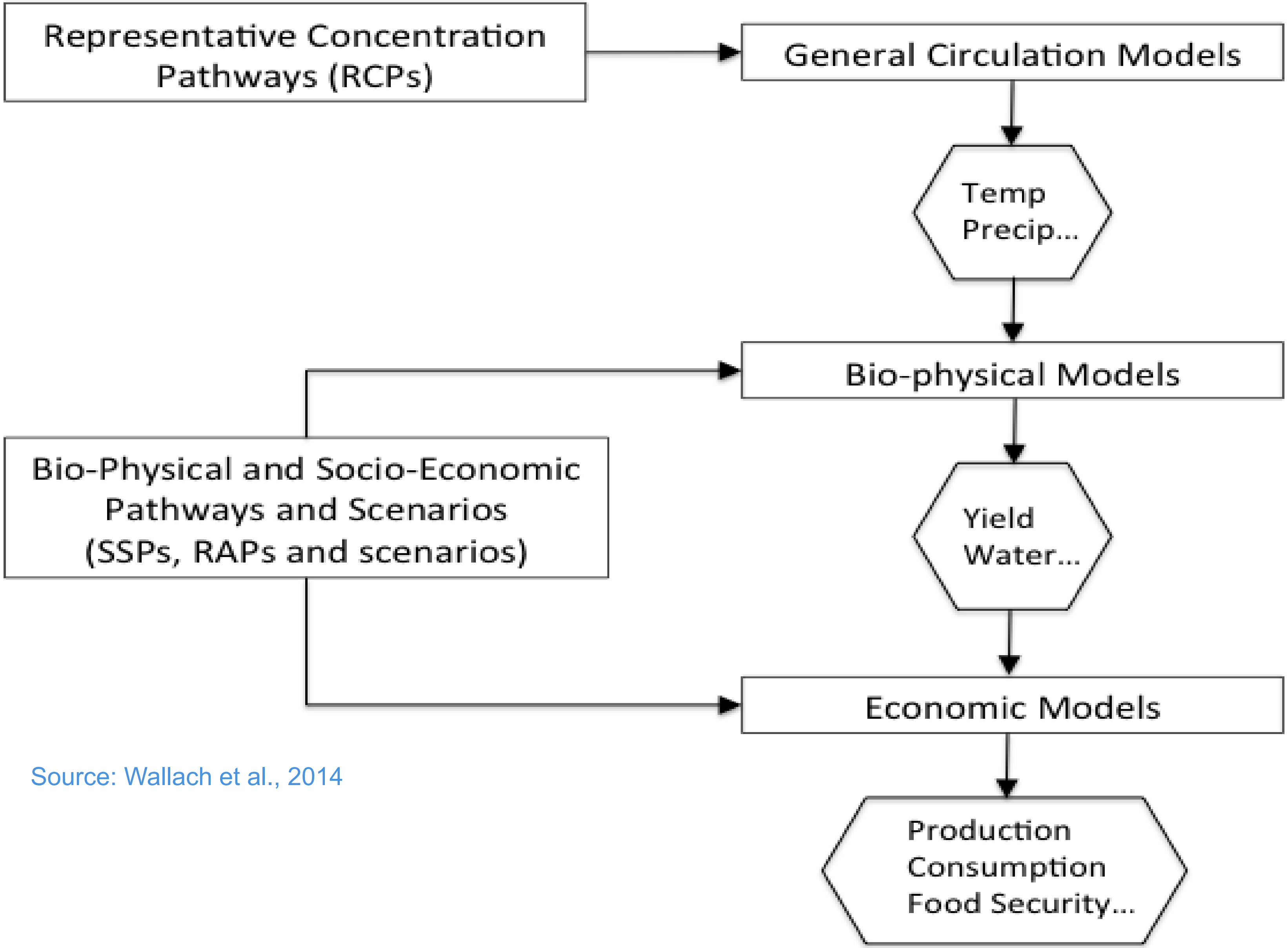
# Integrated assessment

- The Agricultural Model Inter-Comparison and Improvement Project (AgMIP)
  a) AgMIP (agmip.org) is a new global community of science that is working to improve agricultural systems models and their use for climate impact assessment and analysis of agricultural system sustainability
  b) Teams within AgMIP are addressing the many data, methodological, and modeling issues related to the use of agricultural systems models
  c) AgMIP is leading coordinated global and regional integrated assessments in collaboration with other major institutions such as CGIAR's Climate Change and Food Security Program
  d) AgMIP has develop new, protocol-based methods for global and regional integrated assessments

# Key components of integrated assessments

- **Representative Agricultural Pathways (RAPs)**: AgMIP has developed methods that can be used by global and regional impact assessment researchers to create agriculture-specific pathways that can be linked to the global pathways and scenarios (http://www.agmip.org/representative-agricultural-pathways/)
- **Global Integrated Assessment**: AgMIP's global economics team carried out the first systematic inter-comparison of global agricultural economics models (see Nelson et al., 2014), and is continuing to improve those models and develop agriculture-specific pathways and scenarios that link to the new Shared Socio-Economic Pathways (SSPs) (see Chapter 3)
- **Global Gridded Crop and Livestock Models**: AgMIP's global gridded crop modeling team is working with experts worldwide to improve the use of crop models with the globally gridded soil and climate data that are used in global climate impact assessments
- **Regional Integrated Assessments**: AgMIP has developed new methods for protocol-based regional integrated assessments, now being used by teams in various regions of the world

# General modeling structure of agricultural and food system impact assessments



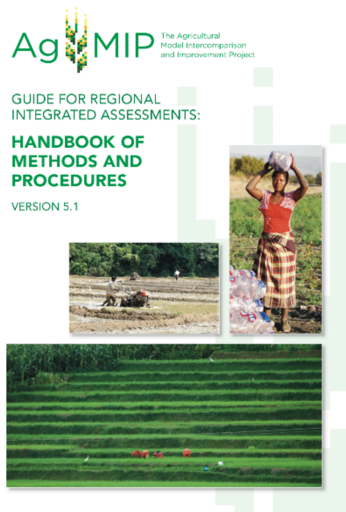

Source: Wallach et al., 2014

# AgMIP's regional integrated assessment methods

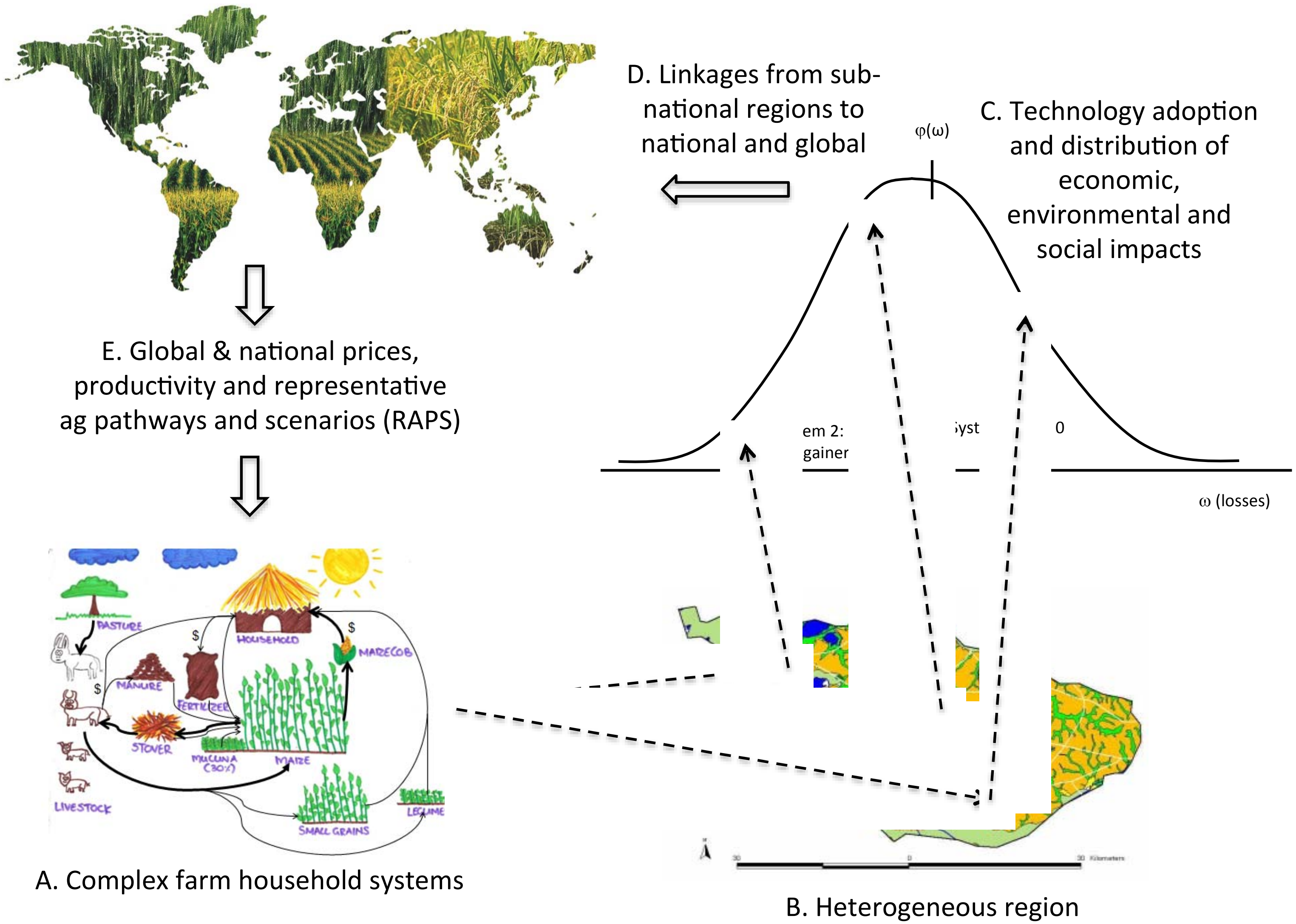
- AgMIP's team of climate scientists, crop and livestock modelers, economic modelers, and IT experts have developed a new approach to Regional Integrated Assessments that provides a consistent, protocol-based approach to climate impact, adaptation, and vulnerability assessments

- The approach utilizes documented, publicly available data tools and models, together with region-specific socioeconomic pathways and scenarios, summarized in a handbook available at http://www.agmip.org/regional-integrated-assessments-handbook/#

- AgMIP and its partners can provide training in the use of the data tools and models, including the DSSAT and APSIM crop models and the TOA-MD economic impact assessment model (tradeoffs.oregonstate.edu).



# AgMIP regional integrated assessment framework




Source: Antle et al., 2014

# AgMIP integrated assessments: Key results

- A network of sites where multiple crop/livestock models have been calibrated using local management, soils, cultivars, and climate to simulate food production regions that are important for regional food security
- A set of RAPs for each region for use in analyses of regional climate impacts and adaptation
- Downscaled regional scale historical climate and climate change scenarios
- Assessment of distribution of production and economic impacts (winners/losers and changes in poverty) for a subset of agricultural regions under future climate change, adaptation, and socioeconomic scenarios
- Assessment of adaptation packages (agronomic, economic, and policy) that improve outcomes under future conditions
- Experienced regional teams in advanced trans-disciplinary methods for integrated assessments across climate, crop, livestock, economic, and IT disciplines
- Established harmonized databases for sustaining such efforts in the regions

# AgMIP integrated assessments: Capacity building

- AgMIP Climate, Crop/Livestock, and Economic Model Teams have trained hundreds of scientists to work in teams to implement Regional Integrated Assessments and evaluate adaptation strategies
  a) Africa, South Asia, Latin America, China, Europe, USA

- Training is available for disciplinary scientists in
  a) Climate – data tools and downscaling CMIP data to regional scale
  b) Crops and livestock – use of DSSAT, APSIM, RUMINANT models
  c) Economics – TOA-MD economic impact assessment model

- Training is available for teams to implement the AgMIP RIA methods

- Contact AgMIP leadership – see agmip.org

# Integration

- The agricultural sector is also impacted by the impact of climate change on other sectors

- Consider the interrelationships between sectors and how they influence risk prioritization and adaptation planning

- Two approaches to integrating adaptation in agriculture, forestry, and fisheries
  a) Use integrated assessment models
  b) Cross-compare the results from a number of geographically focused or crop-specific assessments and develop a coherent view of adaptation priorities and actions

## *VI. Economic assessment based on market equilibrium models (under the auspices of the Peseta and ClimateCost Projects)*

JRC Scientific and Technical Reports

## Climate change impacts in Europe

### Final report of the PESETA research project

Juan-Carlos Ciscar (editor)

http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2879

EUR 24093 EN - 2009

http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=2900

JRC EUROPEAN COMMISSION ipts ies

# The full costs of climate change (http://www.climatecost.cc/)

- Objective: to contribute to a better understanding of the possible economic impacts induced by climate change over the 21st century

- For the first time in Europe and globally, the project followed an innovative, integrated approach combining high resolution climate and sectoral impact models with comprehensive economic models based on market general equilibrium (agriculture, river basin floods, coastal systems, tourism, and human health), able to provide first estimates of the impacts for alternative climate futures

ClimateCost

Project Funders:

SEVENTH FRAMEWORK PROGRAMME

# GTAP database

- 113 world regions
- 57 sectors
- Factors: land, labour, capital and natural resources

- GTAP is a global database representing the world economy in one year (2004) including a representation of the most important economic sectors.
- Countries are linked through trade flows, market prices and commercial flows. It considers balanced markets without excesses of supply or demand.
- Changes in relative prices result in effects in the general equilibrium and change economic flows.

| Region | Countries |
|---|---|
| USA | USA |
| MEUR | France, Portugal, Spain, Italy, Macedonia, Servia, Slovenia, Albania, Bosnia Herzegobina, Croatia, Cyprus Greece |
| NEUR | Norway, Finland, Sweden, German, Austria, Ireland, UK, Belgium, Denmark, Finland, Luxemburg, Netherlands, Switzerland |
| EEUR | Czech Republic, Estonia, Latvia, Lithuania, Poland, Slovakia, Romania, Hungary, Bulgaria |
| FSU | Belarus, Ukraine, Azerbijan, Moldova, Georgia, Russia, Armenia, Tajikistan, Turmekistan, Uzbekistan, Kazakhastan |
| KOSAU | South Africa, Republic of Korea, Australia |
| CAJANZ | Japan, New Zealand, Canada |
| NAF | Argelia, Tunisia, Libya, Moroco, Egypt |
| MDE | Turkey, Israel, Jordan, Lebanon, Syria, Iran, Iraq, Saudi Arabia, Kuwait, Oman, United Arab Emirates, Yemen |
| SSA | Eritrea, Guinea, Benin, Burkina Faso, Gambia, Ghana, Guinea-Bissau, Ivory Coast, Liberia, Nigeria, Mauritania, Mali, Central Africa Republic, Angola, Togo, Cameroon, Rep. Dem. Congo, Rep Congo, Equat. Guinea, Senegal, Niger, Sudan, Sierra Leone, Chad, Kenya, Ethiopia, Tanzania, Burundi, Mozambique, Rwanda, Zambia, Botswana, Gabon, Malawi, Djibouti, Somalia, Zimbawe, Lesotho, Namibia, Uganda, Zimbawe, Madagascar |
| SASIA | Afganistan, Nepal, India, Sri Lanka, Pakistan, Bangladesh |
| CHINA | China, Taiwan |
| EASIA | Mongolia, Indonesia, Papua New Guinea, Malaysia, Cambodia, Laos, Myanmar, Thailand, Philipines, Vietnam, Korea Democ. Peoples Rep. |
| LACA | Mexico, Nicaragua, Belice, Costa Rica, Cuba, Dominican Republic, El Salvador, Guatemala, Guyana, Haiti, Honduras, Argentina, Uruguay, Jamaica, Nicaragua, Panamá, Puerto Rico, Suriname, Colombia, Ecuador, Venezuela, Peru, Bolivia, Brazil, Paraguay, Chile |

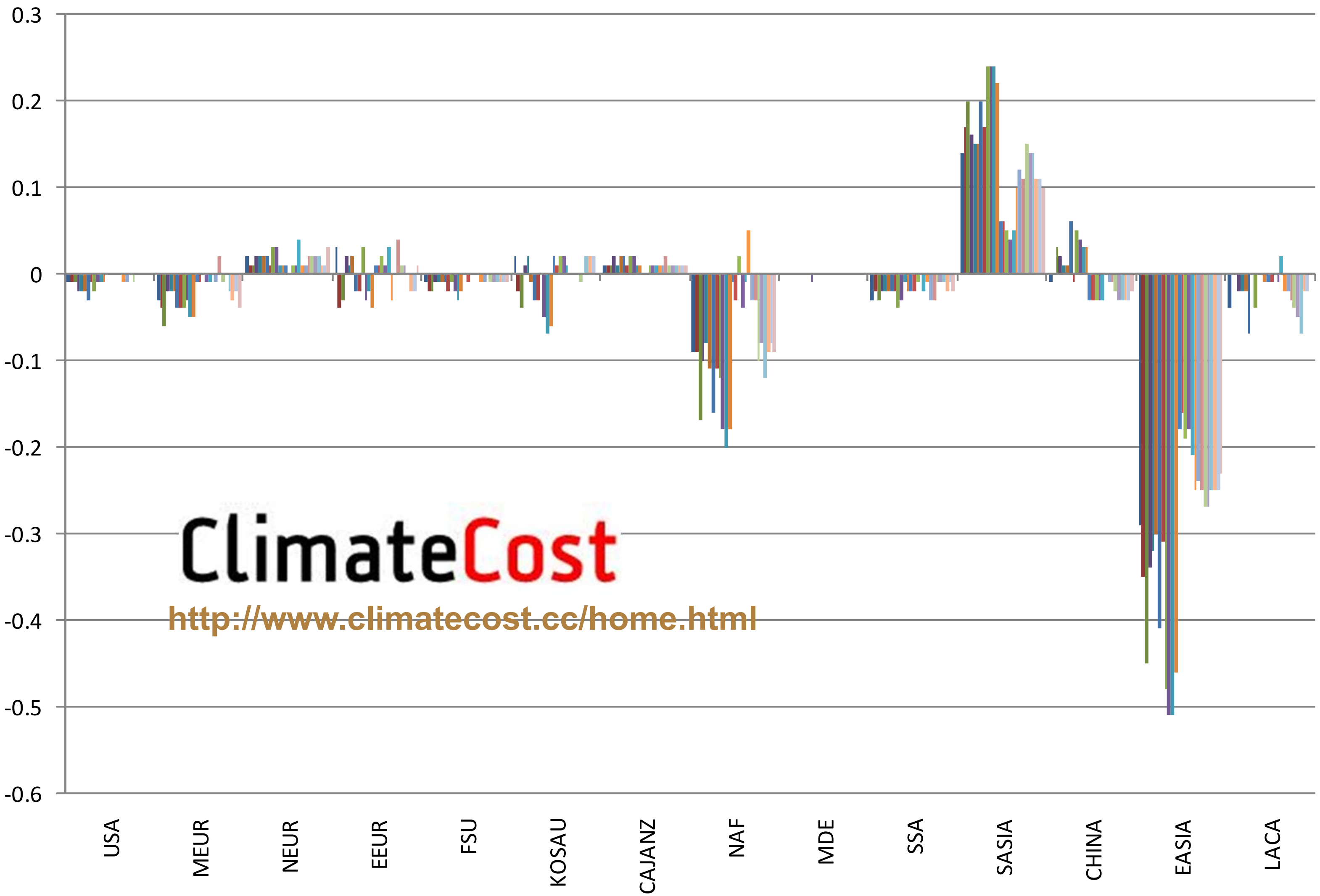
# Food represents agricultural sector

| Old sector | New sector | Old sector description |
|---|---|---|
| 1 pdr | 1 Food | Paddy rice |
| 2 wht | 1 Food | Wheat |
| 3 gro | 1 Food | Cereal grains nec |
| 4 v_f | 1 Food | Vegetables, fruit, nuts |
| 5 osd | 1 Food | Oil seeds |
| 6 c_b | 1 Food | Sugar cane, sugar beet |
| 7 pfb | 1 Food | Plant-based fibers |
| 8 ocr | 1 Food | Crops nec |
| 9 ctl | 1 Food | Cattle,sheep,goats,horses |
| 10 oap | 1 Food | Animal products nec |
| 11 rmk | 1 Food | Raw milk |
| 12 wol | 1 Food | Wool, silk-worm cocoons |

# GTAP model


File Copy View Version Tools Help
Title
RunGTAP
Version
Closure
Shocks
Solve
Results
RunGTAP
A CGE Model of World Trade
https://www.gtap.agecon.purdue.edu/
Global Trade Analysis Project

# Climate change induced changes in GDP % (US$ constant 2004)



# ***VII. Agriculture adaptation***

# Agronomic impacts, adaptive capacity, and sector outcomes

| Biophysical impact | Uncertainty level | Expected intensity of negative effects | Adaptive capacity | Socioeconomic and other secondary impacts |
|---|---|---|---|---|
| Changes in crop growth conditions | Medium | High for some crops and regions | Moderate to high | Changes in optimal farming systems, relocation of farm processing industry, increased economic risk, loss of rural income, pollution due to nutrient leaching, biodiversity decrease |
| Changes in optimal conditions for livestock production | High | Medium | High for intensive production systems | Changes in optimal farming systems, loss of rural income |
| Changes in precipitation and the availability of water resources | Medium to low | High for developing countries | Moderate | Increased demand for irrigation, decreased yield of crops, increased risk of soil salinization, increased water shortage, loss of rural income |
| Changes in agricultural pests | High to very high | Medium | Moderate to high | Pollution due to increased use of pesticides, decreased yield and quality of crops, increased economic risk, loss of rural income |
| Changes in soil fertility and erosion | Medium | High for developing countries | Moderate | Pollution by nutrient leaching, biodiversity decrease, decreased yield of crops, land abandonment, increased risk of desertification, loss of rural income |

# Aggregated farming system impacts, adaptive capacity, and sector outcomes

| Socioeconomic impact | Uncertainty level | Expected intensity of negative effects | Autonomous adaptation (private coping capacity) | Other impacts |
|---|---|---|---|---|
| Changes in optimal farming systems | High | High for areas where current optimal farming systems are extensive | Moderate | Changes in crop and livestock production activities, relocation of farm processing industry, loss of rural income, pollution due to nutrient leaching, biodiversity decrease |
| Relocation of farm processing industry | High | High for some food industries requiring large infrastructure or local labor | Moderate | Loss of rural income, loss of cultural heritage |
| Increased (economic) risk | Medium | High for crops cultivated near their climatic limits | Low | Loss of rural income |
| Loss of rural income and cultural heritage | High | (Not characterized) | Moderate | Land abandonment, increased risk of desertification, welfare decrease in rural societies, migration to urban areas, biodiversity decrease |

# Potential impact areas in agriculture

| **Biophysical impact** | **Direction of change** | **Level of confidence** |
|---|---|---|
| Optimal location of crop zones | Mixed | High |
| Crop productivity | Mixed | High |
| Irrigation requirements | Increase | High |
| Soil and salinity erosion | Increase | Medium |
| Damage by extreme weather events | Increase | Medium |
| Environmental degradation | Increase | Medium |
| Pests and diseases | Increase | Medium |

# Agricultural adaptation

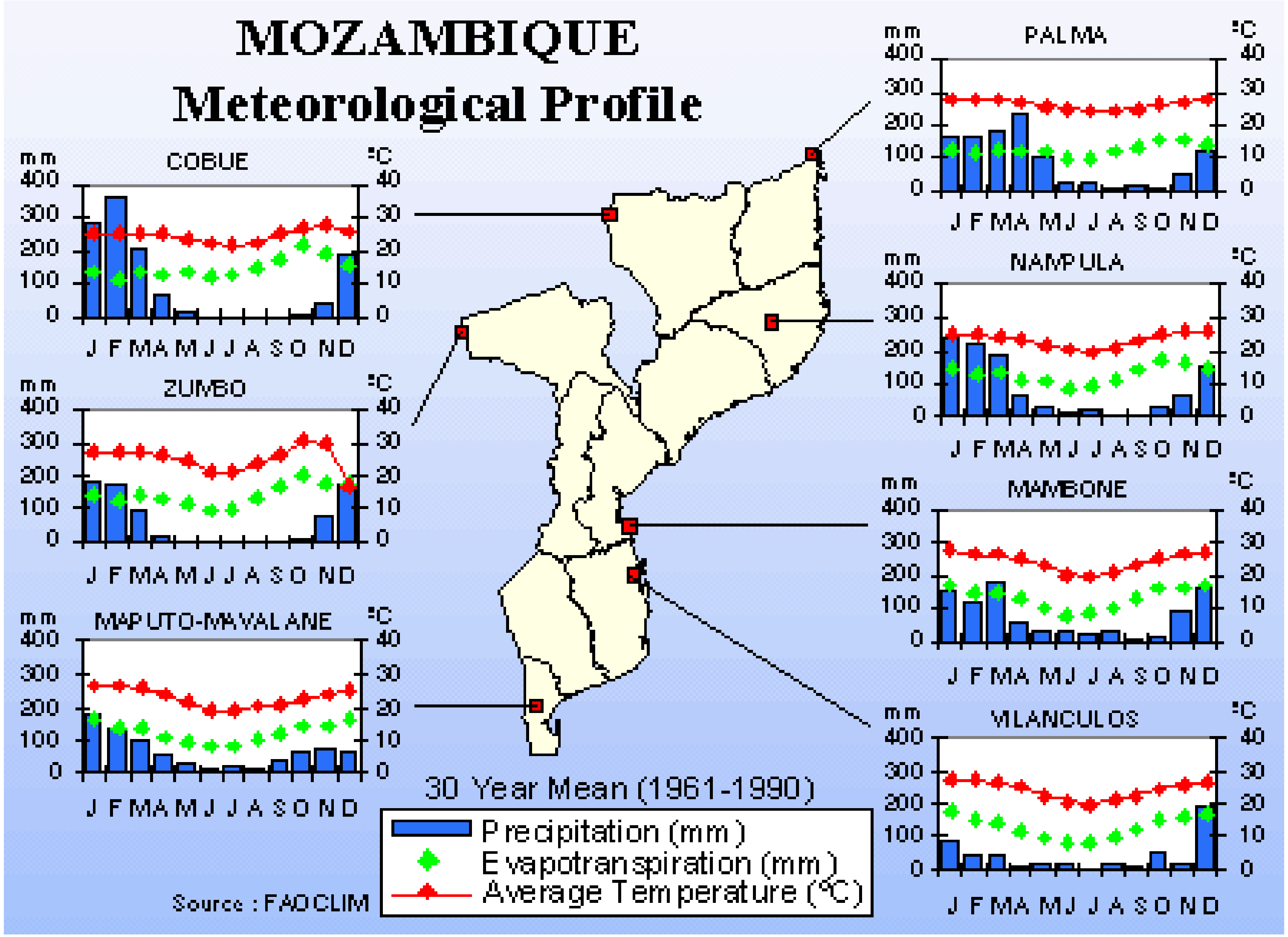
- Farmers adapt to changing conditions continuously by changing their management practices to maximize income and optimize yield
- In regions of the world climate change might be occurring more rapidly or the projected climate might represent conditions in which certain crops can no longer be grown
- Specific technologies and management styles will need to be developed and adopted by local farmers to avoid potentially negative effects
- Evaluate current technologies and potential capabilities in the future

## *VIII. Starting a simulation in DSSAT: Can optimal management be an adaptation option for crop production in Africa?*

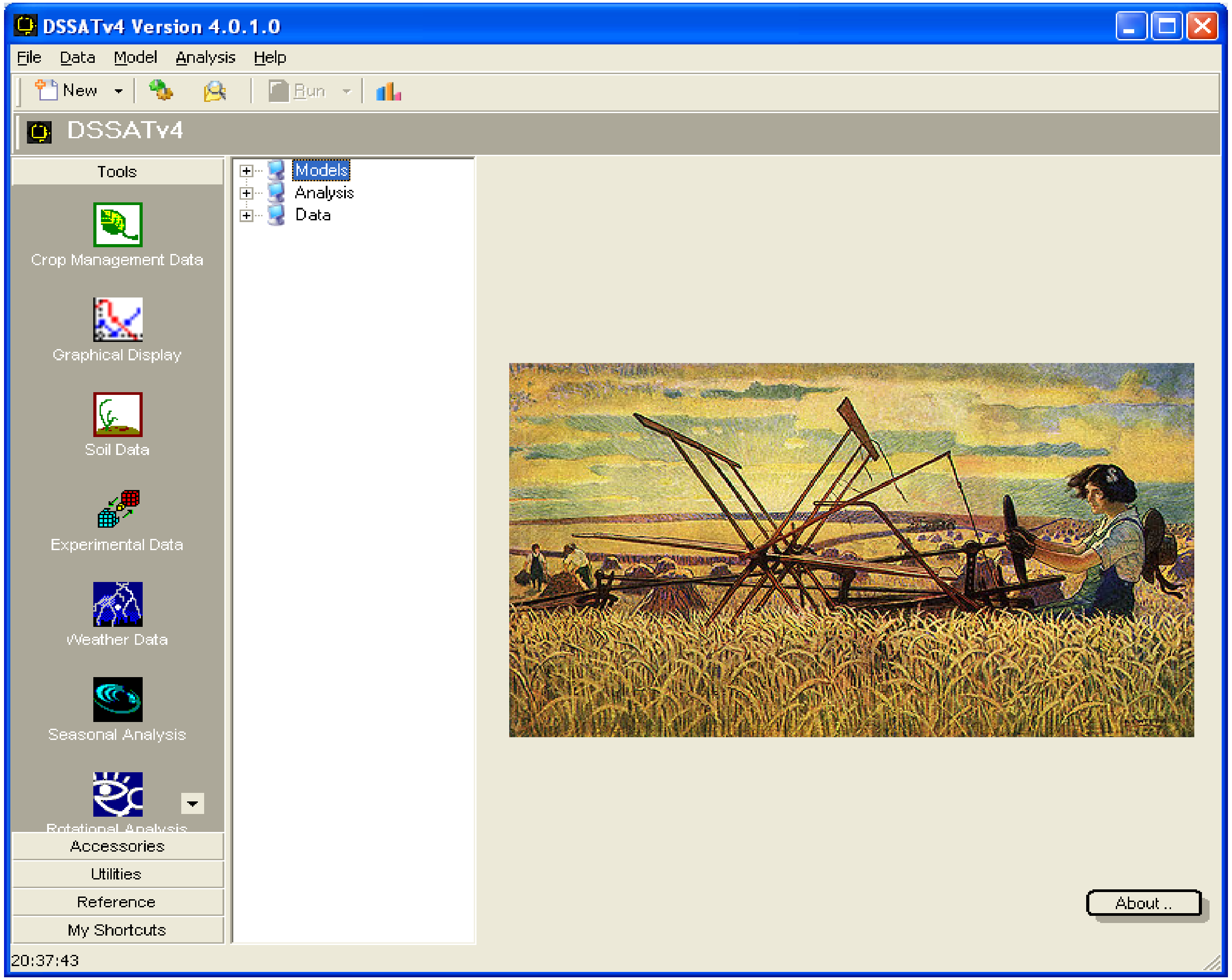
# Input requirements

- Daily weather (precip, tmax, tmin, SR)
- Soil texture
- Management (planting date, variety, row spacing, irrigation and N fertilizer amounts and dates)
- DSSAT libraries and examples
- Additional validation requirements: crop dates of flowering and maturity, biomass and yield

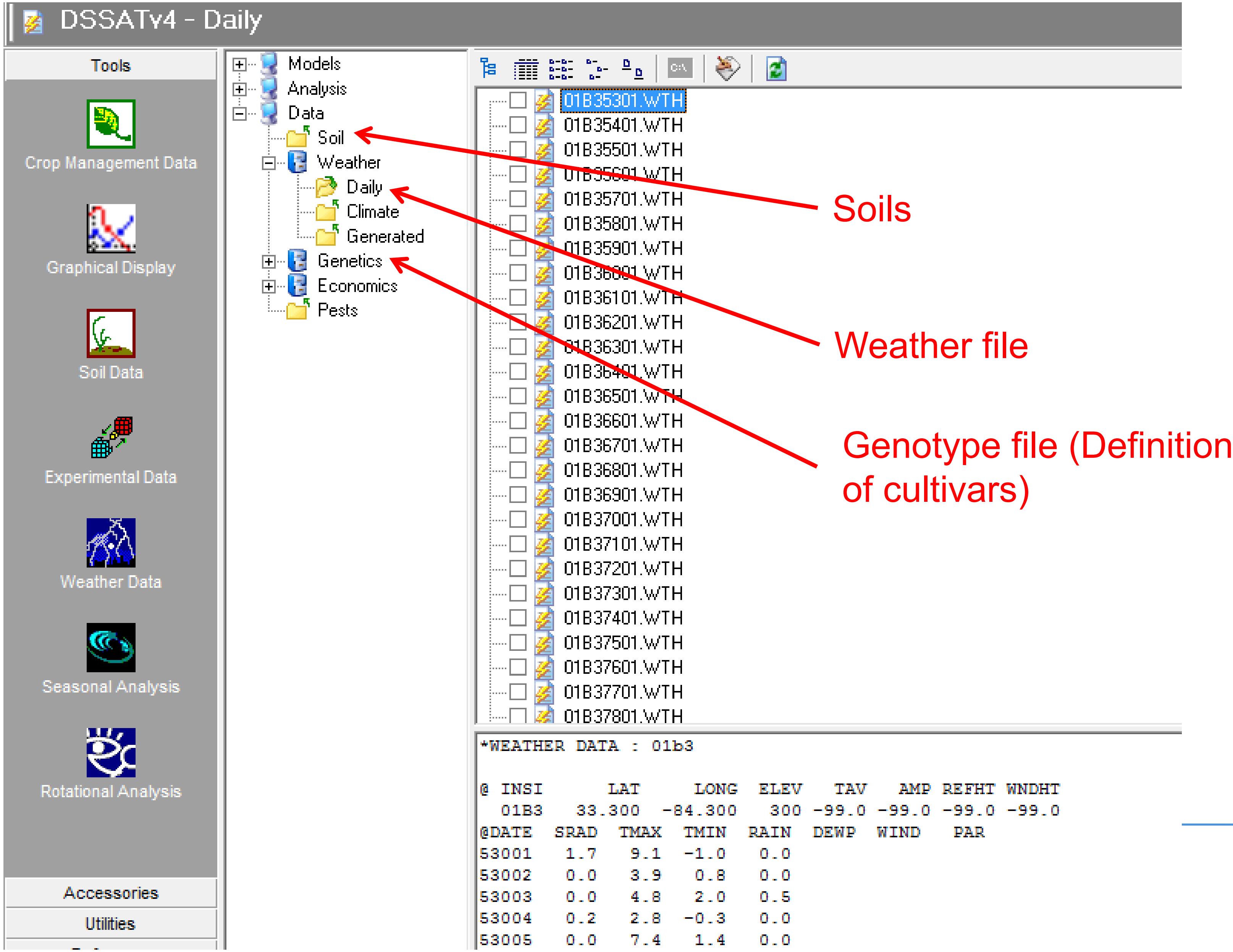
# Climate


MOZAMBIQUE
Meteorological Profile
COBUE
ZUMBO
MAPUTO-MAVALANE
PALMA
NAMPULA
MAMBONE
VILANCULOS
mm
°C
J F M A M J J A S O N D
30 Year Mean (1961-1990)
Precipitation (mm)
Evapotranspiration (mm)
Average Temperature (°C)
Source : FAOCLIM

# Open DSSAT …


DSSATv4 Version 4.0.1.0
File
Data
Model
Analysis
Help
New
Run
DSSATv4
Tools
Crop Management Data
Graphical Display
Soil Data
Experimental Data
Weather Data
Seasonal Analysis
Rotational Analysis
Accessories
Utilities
Reference
My Shortcuts
Models
Analysis
Data
About ..
20:37:43

# Examine the data files …



```
 MOLDOVA
@NOTES
 MOLDOVA WORLD BANK STUDY, 2010

*TREATMENTS                        -------------FACTOR LEVELS------------
@N R O C TNAME.................... CU FL SA IC MP MI MF MR MC MT ME MH SM
 1 1 0 0 04BR BASE MZ D             1  4  0  1  1  0  1  1  0  0  0  0  1
 2 1 0 0 16SO BASE MZ D             1 16  0  1  1  0  1  1  0  0  0  0  1
 3 1 0 0 06CA BASE MZ D             1  6  0  1  1  0  1  1  0  0  0  0  1
 4 1 0 0 15RI BASE MZ D             1 15  0  1  1  0  1  1  0  0  0  0  1
 5 1 0 0 01BA BASE MZ D             1  1  0  1  1  0  1  1  0  0  0  0  1
 6 1 0 0 13FA BASE MZ D             1 13  0  1  1  0  1  1  0  0  0  0  1
 7 1 0 0 03BR BASE MZ D             1  3  0  1  1  0  1  1  0  0  0  0  1
 8 1 0 0 11CO BASE MZ D             1 11  0  1  1  0  1  1  0  0  0  0  1
 9 1 0 0 12DU BASE MZ D             1 12  0  1  1  0  1  1  0  0  0  0  1
10 1 0 0 09CO BASE MZ D             1  9  0  1  1  0  1  1  0  0  0  0  1
11 1 0 0 02BA BASE MZ D             1  2  0  1  1  0  1  1  0  0  0  0  1
12 1 0 0 08CH BASE MZ D             1  8  0  1  1  0  1  1  0  0  0  0  1
13 1 0 0 18TI BASE MZ D             1 18  0  1  1  0  1  1  0  0  0  0  1
14 1 0 0 14LE BASE MZ D             1 14  0  1  1  0  1  1  0  0  0  0  1
15 1 0 0 17ST BASE MZ D             1 17  0  1  1  0  1  1  0  0  0  0  1
16 1 0 0 10CO BASE MZ D             1 10  0  1  1  0  1  1  0  0  0  0  1
17 1 0 0 07CE BASE MZ D             1  7  0  1  1  0  1  1  0  0  0  0  1
18 1 0 0 05CA BASE MZ D             1  5  0  1  1  0  1  1  0  0  0  0  1

*CULTIVARS
@C CR INGENO CNAME
 1 MZ 990002 medium

*FIELDS
@L ID_FIELD WSTA....  FLSA  FLOB  FLDT  FLDD  FLDS  FLST SLTX   SLDP  ID_SOIL
 1 01BA0001 01BA5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
 2 02BA0001 02BA5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
 3 03BR0001 03BR5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
 4 04BR0001 04BR5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
 5 05CA0001 05CA5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
 6 06CA0001 06CA5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
 7 07CE0001 07CE5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
 8 08CH0001 08CH5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
 9 09CO0001 09CO5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
10 10CO0001 10CO5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
11 11CO0001 11CO5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
12 12DU0001 12DU5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
13 13FA0001 13FA5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
14 14LE0001 14LE5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
15 15RI0001 15RI5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
16 16SO0001 16SO5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
17 17ST0001 17ST5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
18 18TI0001 18TI5301 -99      0 DR000     0     0 00000  -99      90 IBML000990
```

Type of variety

Where? Weather, soil

**Initial conditions**

```
*INITIAL CONDITIONS
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE
 1    MZ 53120  1200   -99  1.00  1.00
@C  ICBL  SH2O  SNH4  SNO3
 1     5 0.262   0.5   4.6
 1    15 0.262   0.5   4.6
 1    30 0.262   0.5   4.4
 1    45 0.262   0.2   3.8
 1    60 0.262   0.2   3.8
 1    90 0.261   0.2   2.8
```

**Planting details (date, depth, density)**

```
*PLANTING DETAILS
@P PDATE EDATE  PPOP  PPOE  PLME  PLDS  PLRS  PLRD  PLDP  PLWT  PAGE  PENV  PLPH
 1 53130   -99   5.0   5.0     S     R    15     0   5.5   -99   -99 -99.0 -99.0
```

**Fertilisers inorganic (type, date, depth, amount)**

```
*FERTILIZERS (INORGANIC)
@F FDATE  FMCD  FACD  FDEP  FAMN  FAMP  FAMK  FAMC  FAMO  FOCD
 1 53120 FE001   -99    15     0     0     0     0     0
```

**Fertilisers organic (type, date, depth, amount)**

```
*RESIDUES AND OTHER ORGANIC MATERIALS
@R RDATE  RCOD  RAMT  RESN  RESP  RESK  RINP  RDEP
 1 53120 RE001  1000  1.10   -99   -99   -99    15
```

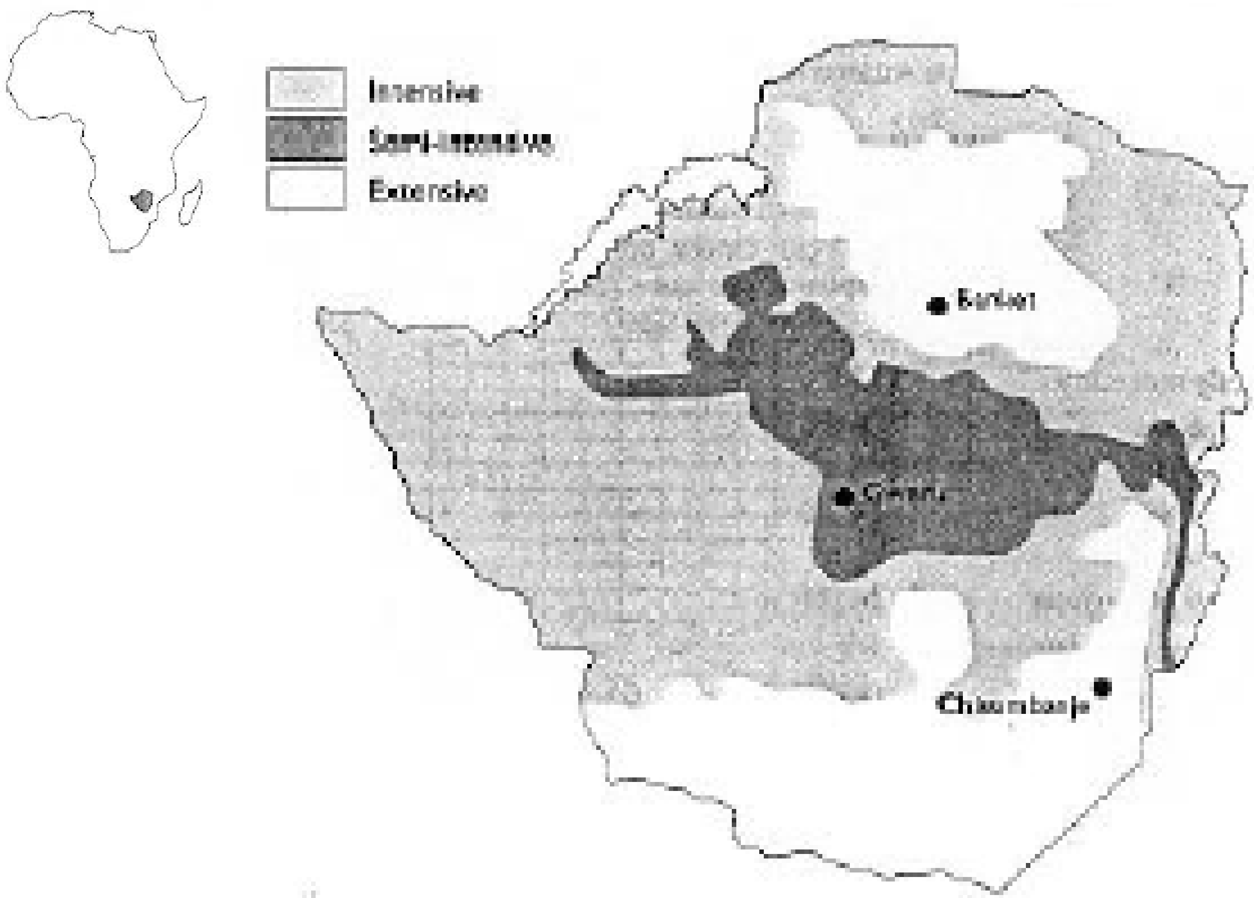
**Env Modifications**

```
*ENVIRONMENTAL MODIFICATIONS
@E ODATE EDAY  ERAD  EMAX  EMIN  ERAIN ECO2  EDEW  EWIND
 1 53001 A 0.0 A 0.0 A 0.0 A 0.0 M 1.0 A   0 A 0.0 A 0.0
```

**Simulation controls**

```
*SIMULATION CONTROLS
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME....................
 1 GE              1     1     S 53120  2150 MZ
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES
 1 OP              Y     Y     N     N     N     N
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO
 1 ME              M     M     E     R     S     C
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 1 MA              R     R     A     N     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT  LONG
 1 OU              Y     Y     Y     5     N     N     Y     N     N     N     N

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 1 PL            100   150    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 1 IR             50    80   100 GS000 IR001    10  1.00
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 1 NI             15    20    10 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 1 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 1 HA              0   365   100     0
```

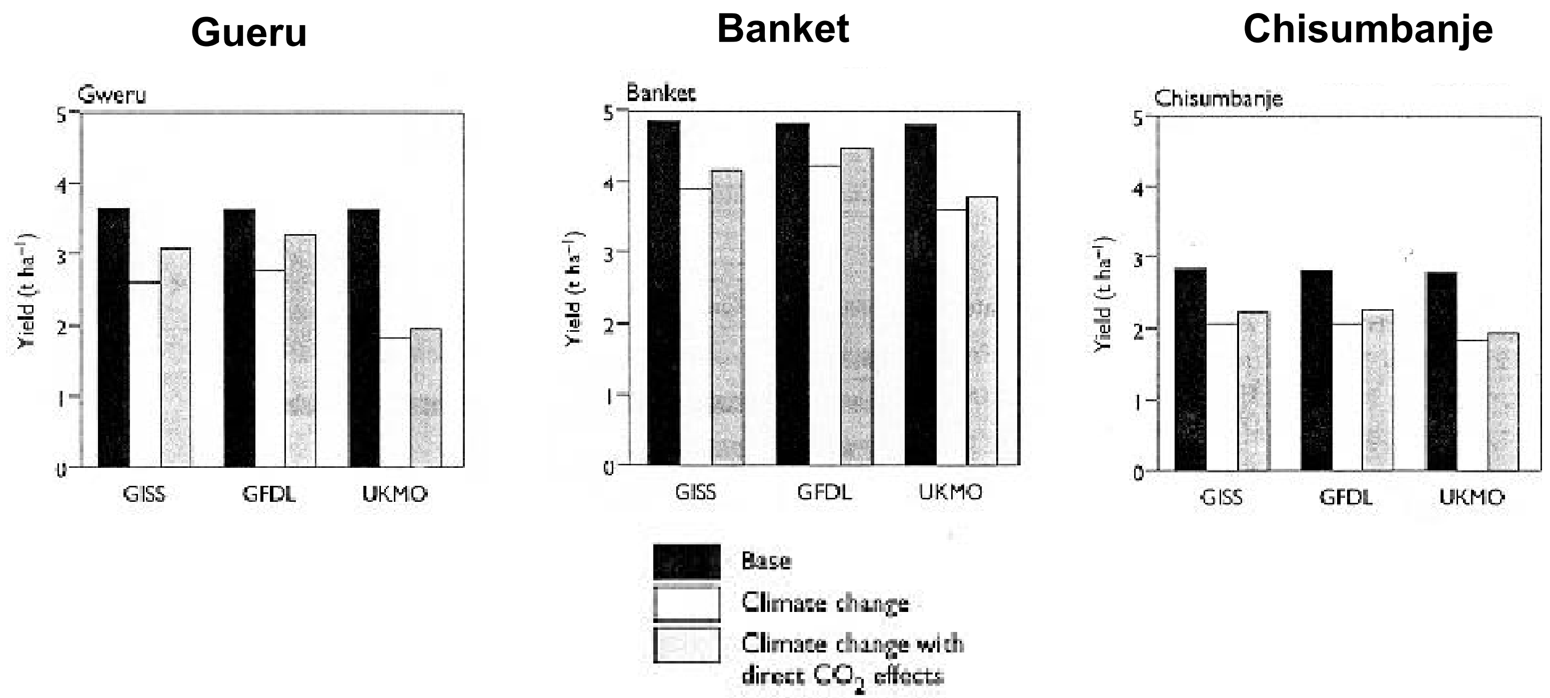
# Can optimal management be an adaptation option for maize production in Zimbabwe?




Agroclimatic zones

Source: Muchena, 1994

# Impacts: Zimbabwe

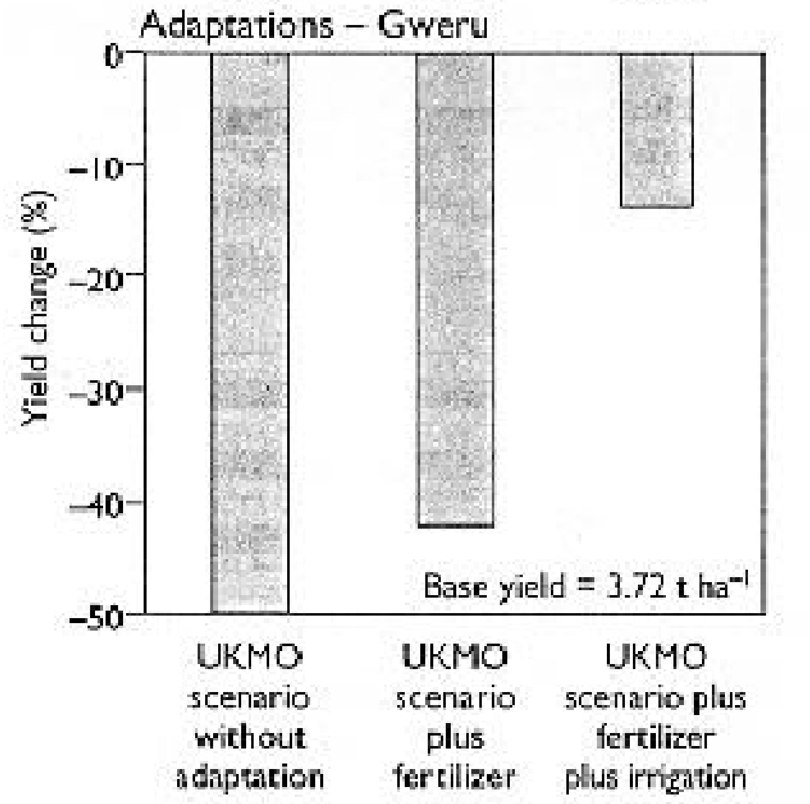



**Impacts of climate change: CERES-Maize model**

Source: Muchena, 1994

# Adaptation: Zimbabwe

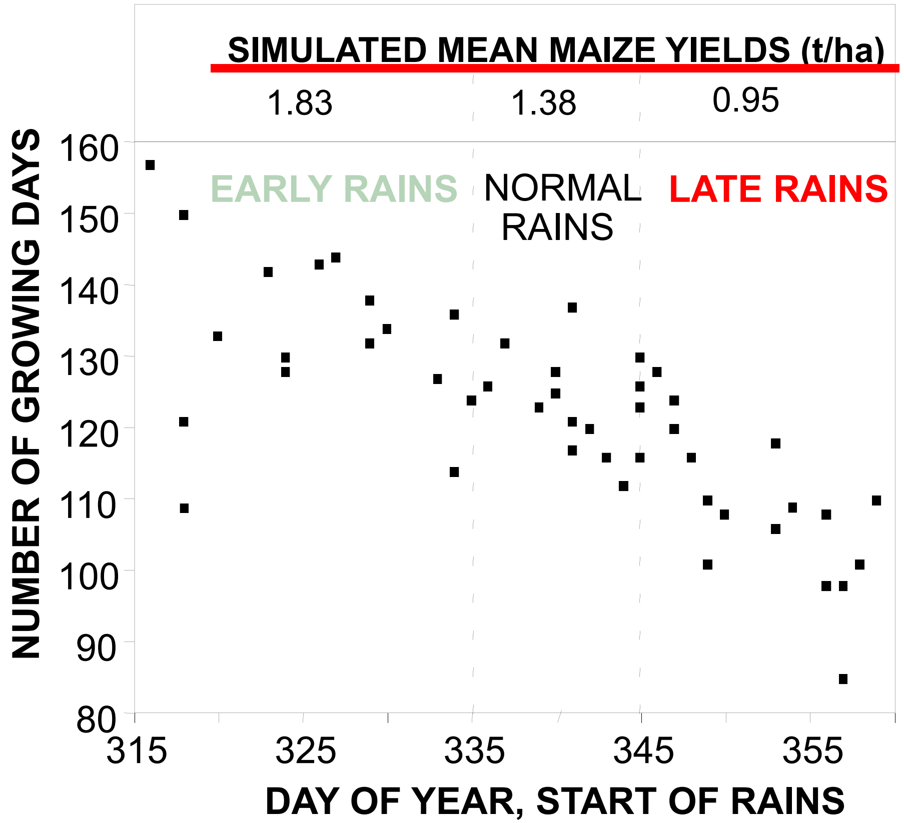
**Adaptation strategies in Gueru: CERES-Maize model**




- Increased inputs and improve management:
  a) Fertilizer
  b) Fertilizer and irrigation

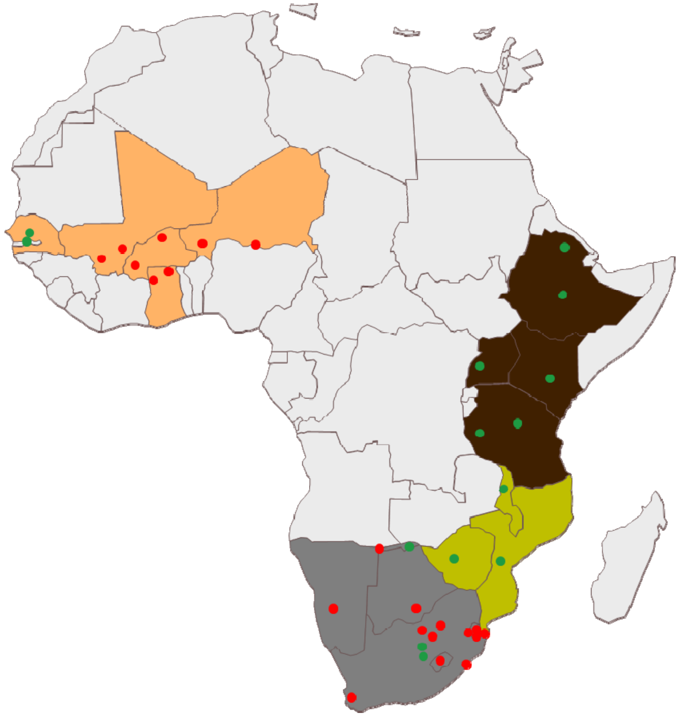
Source: Muchena, 1994

# Does the start of the rainy season affect maize yield in Kasungu, Central Malawi?

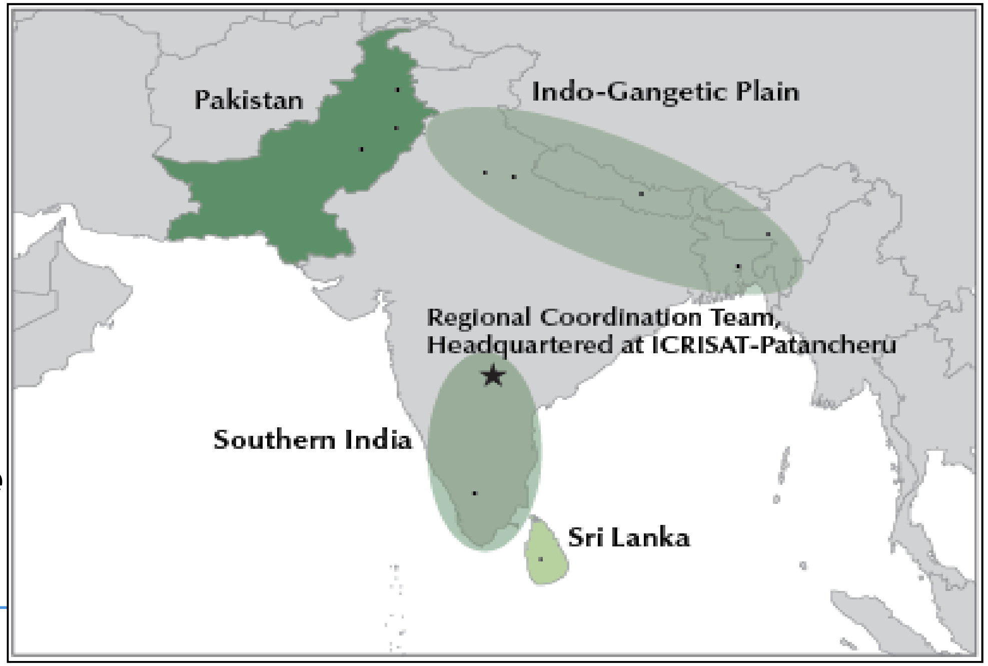


## *IX. Case studies: Sugarcane pilot (under the auspices of the AgMIP Project)*

# Example: AgMIP-led regional integrated assessments in Africa and South Asia



DFID funded
8 regional teams, 18 countries,
≈ 200 scientists
Data, models, scenarios designed and implemented by multi-disciplinary teams and stakeholders




Hillel, D. and C. Rosenzweig (eds.). 2015. *Handbook of Climate Change and Agroecosystems.*

# Sugarcane pilot

- Collaborating scientists are intercomparing their models for response to $CO_2$, temperature, rainfall, and other factors at four sentinel sites representing variation in sugarcane productivity.

- The effort to date has been distributed amongst the sugarcane research community, with various meetings between the team leaders (commencing in Brazil, August 2011).

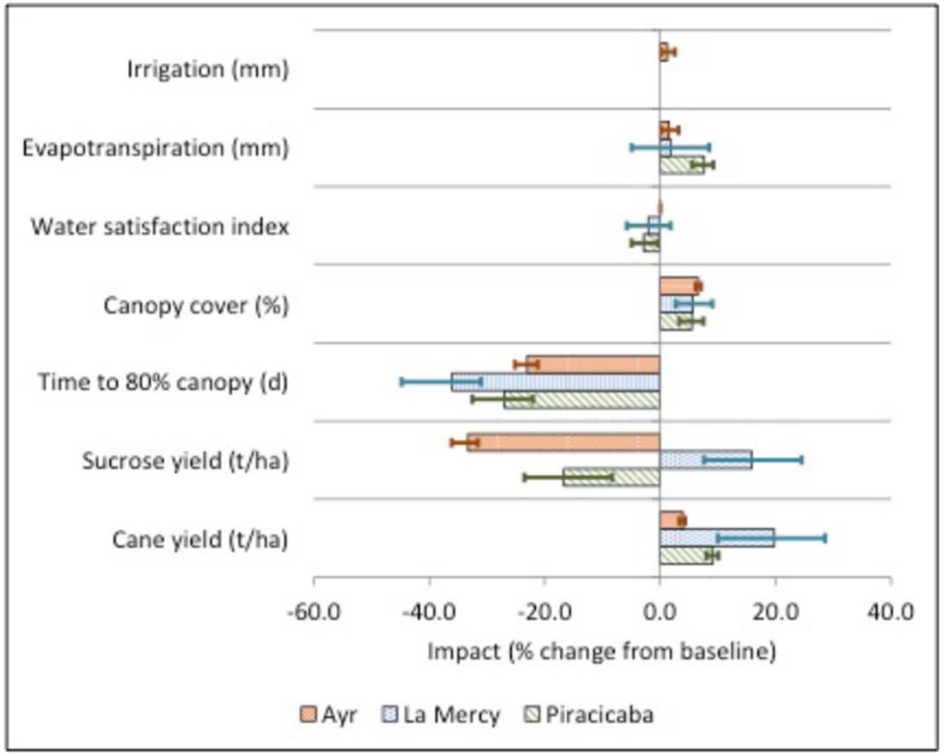
- Work to date has centered on developing parameterisations and calibrations of the models at various sites (Singels et al., 2013; Marin et al., 2013), and commencing the exploration of climate change sensitivities.

- Pilot sites located in Australia, Brazil, Reunion Island, USA and Zimbabwe have been selected and data from those are in the process of being entered into a central database in standard format.

Source: Singels et al., 2013

# Sugarcane pilot (cont.)

The average climate change impact (difference in long term mean values of various model output variables between future scenarios and the Baseline scenario) predicted for the 3 sites by the **DSSAT-Cane-gro(v4.5)** sugarcane crop model. The bars show the range of impacts predicted using the different climate scenarios projected by the three climate models




Source: Singels et al., 2013

# Case study: Results

- Results of difference in long term mean values of various model output variables between future scenarios and the baseline scenario in Piracicaba (Brazil):

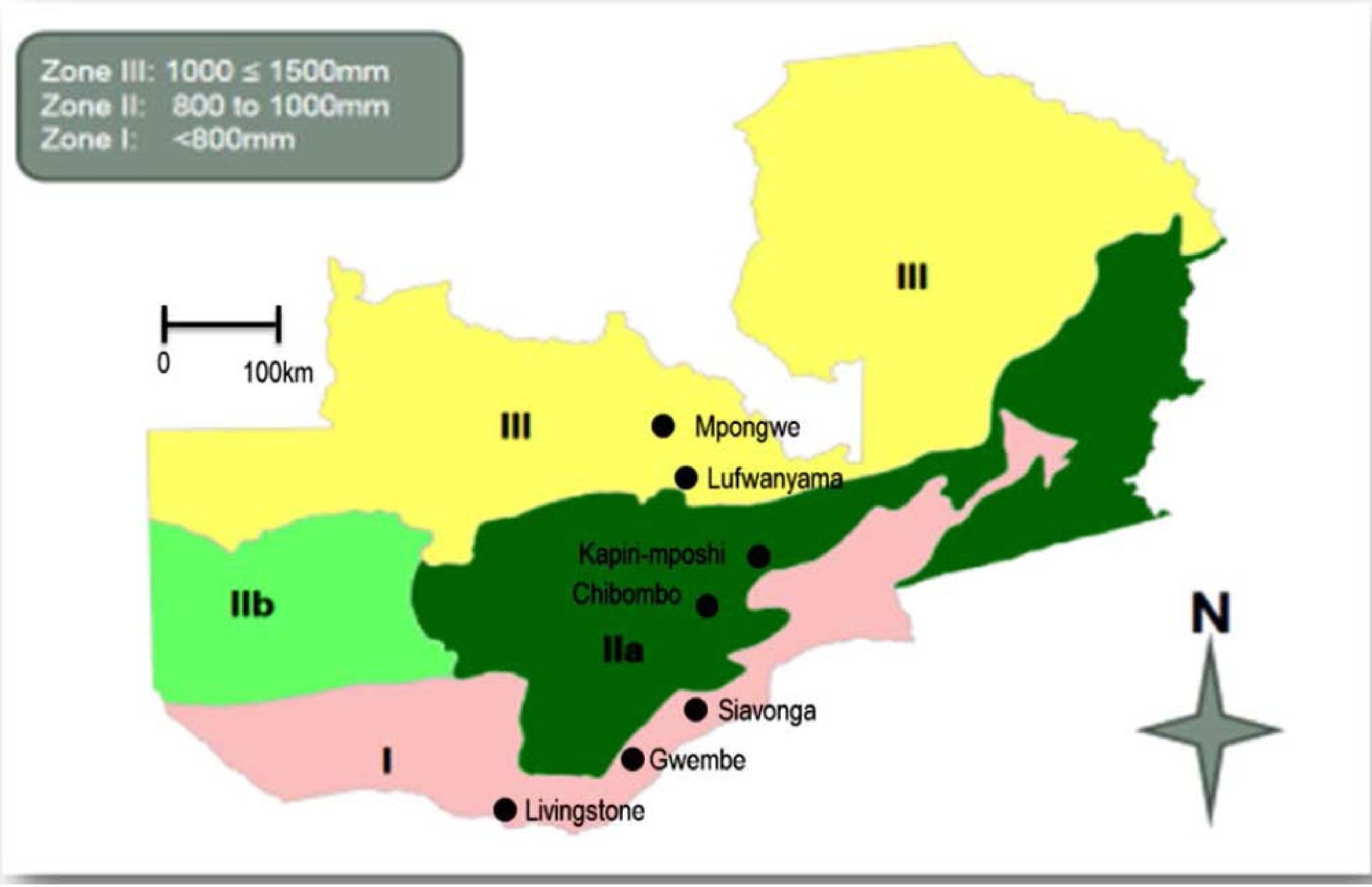
    a) Mean yield reduction for sucrose yield was more than 15%

    b) Mean yield increase for cane yield was almost 10%

Source: Singels et al., 2013

## *X. Climate change vulnerability: A case of rain dependent small-holder farmers in Zambia*

# Agro-ecological regions in Zambia




Makondo et al., 2014

# Indicators for vulnerability index

| Main component | Sub-component | Zone I | Zone II | Zone III |
|---|---|---|---|---|
| Food | Percent of households dependent solely on family farm for food. | 0.980 | 0.690 | 0.720 |
| | Average number of months households struggle to find food. | 0.583 | 0.417 | 0.333 |
| | Average crop diversity index. | 0.167 | 0.256 | 0.444 |
| | Percent of households that do not save crops. | 0.900 | 0.110 | 0.130 |
| | Percent of households that do not save seeds. | 0.280 | 0.580 | 0.340 |
| | **Food Index[a]** | **0.582** | **0.411** | **0.393** |
| Natural Disaster/ Climate Change | Average number of flood, drought events in the past 6 years. | 0.667 | 0.500 | 0.500 |
| | Percent of households that did not receive a warning about the pending natural disasters. | 0.100 | 0.100 | 0.100 |
| | Mean standard deviation of monthly average of mean maximum daily temperature (years: 2010-2013). | 0.675 | 0.325 | 0.250 |
| | Mean standard deviation of monthly average of mean minimum daily temperature (years: 2010-2013). | 0.794 | 0.441 | 0.500 |
| | Mean standard deviation of monthly average precipitation (years: 2010-2013). | 0.284 | 0.194 | 0.191 |
| | **Natural disaster/Climate Change Index[a]** | **0.504** | **0.312** | **0.308** |
| Social-Demographics | Percent of households headed by women. | 0.627 | 0.500 | 0.485 |
| | Land tenure: Access to land ownership by gender (women: men ratio). | 0.250 | 0.310 | 0.350 |
| | Crop yield. | 0.188 | 0.326 | 0.490 |
| | Access to credit facilities by gender (women: men ratio). | 0.140 | 0.150 | 0.190 |
| | **Social-Demographics Index[a]** | **0.301** | **0.322** | **0.379** |

Source: Makondo et al., 2014

# Likelihood vulnerability index

[a]Using Equation (2); $M_d = \frac{\sum_{i=1}^{n} \text{index} \cdot S_{di}}{n}$.

Table 6. LVI-IPCC contributing factors calculation for Zones I, II, and III: after [21].

| IPCC contributing factors to vulnerability | Main component values | Zone I | Zone II | Zone III | No. of subcomponents per major component | Contributing factor values | | | LVI–IPCC values | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Zone I | Zone II | Zone III | Zone I | Zone II | Zone III |
| **Exposure** | Natural disasters/ climate change | 0.504 | 0.312 | 0.308 | 4 | 0.504 | 0.312 | 0.308 | | | |
| **Adaptive capacity** | Social demographic<br>Strategies;<br>Crop diversity | 0.301<br>0.250 | 0.322<br>0.330 | 0.379<br>0.500 | 5<br><br>3 | 0.281 | 0.325 | 0.567 | **0.149** | **−0.0059** | **−0.098** |
| **Sensitivity** | Food:<br>crop and seed storage | 0.582<br>0.900 | 0.411<br>0.580 | 0.393<br>0.340 | 5<br>2 | 0.672 | 0.459 | 0.378 | | | |

Source: Makondo et al., 2014

## *XI. Case study: Punjab, Pakistan (under the auspices of the AgMIP Project)*

# Case study: Punjab, Pakistan

- The Rice-Wheat cropping system is the bread basket of Punjab, Pakistan
- It is the largest agricultural production system in South Asia, covering 13.5 m ha
- 20% of the world population depends on its production

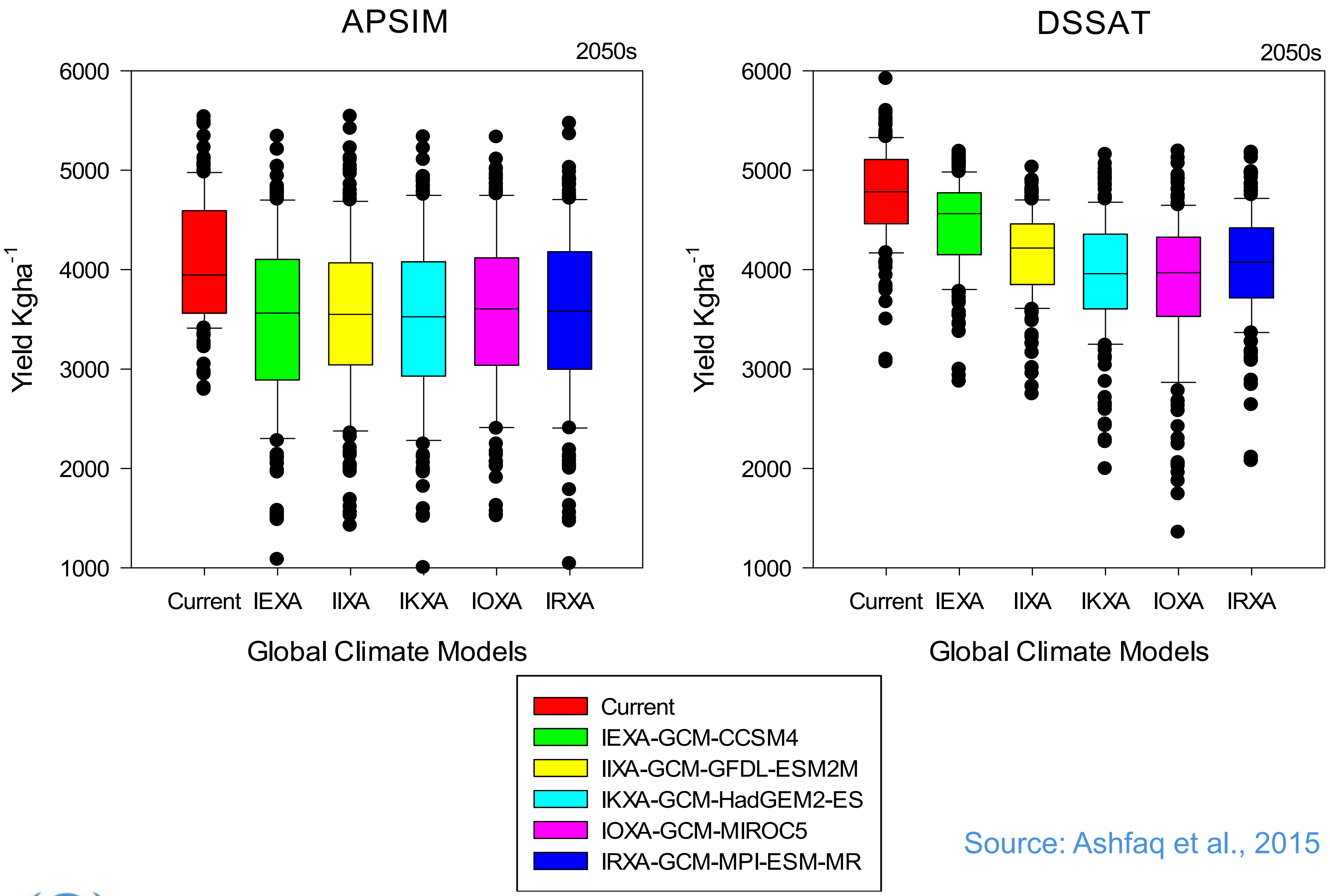
Source: Ashfaq et al., 2015

# Case study: Methodology

- Data of three experiments were used for rice and wheat model evaluation
- Yield and socio-economic data were collected by surveying 155 farmers in five districts of Punjab
- Two crop models (DSSAT and APSIM) were used to assess climate change impact and adaptation
- Five General Circulation Models (GCMs) under RCP 8.5 were used to generate future weather data
- Economic model (TOA-MD) was used to quantify the climate vulnerability and adaptation strategies in the study area

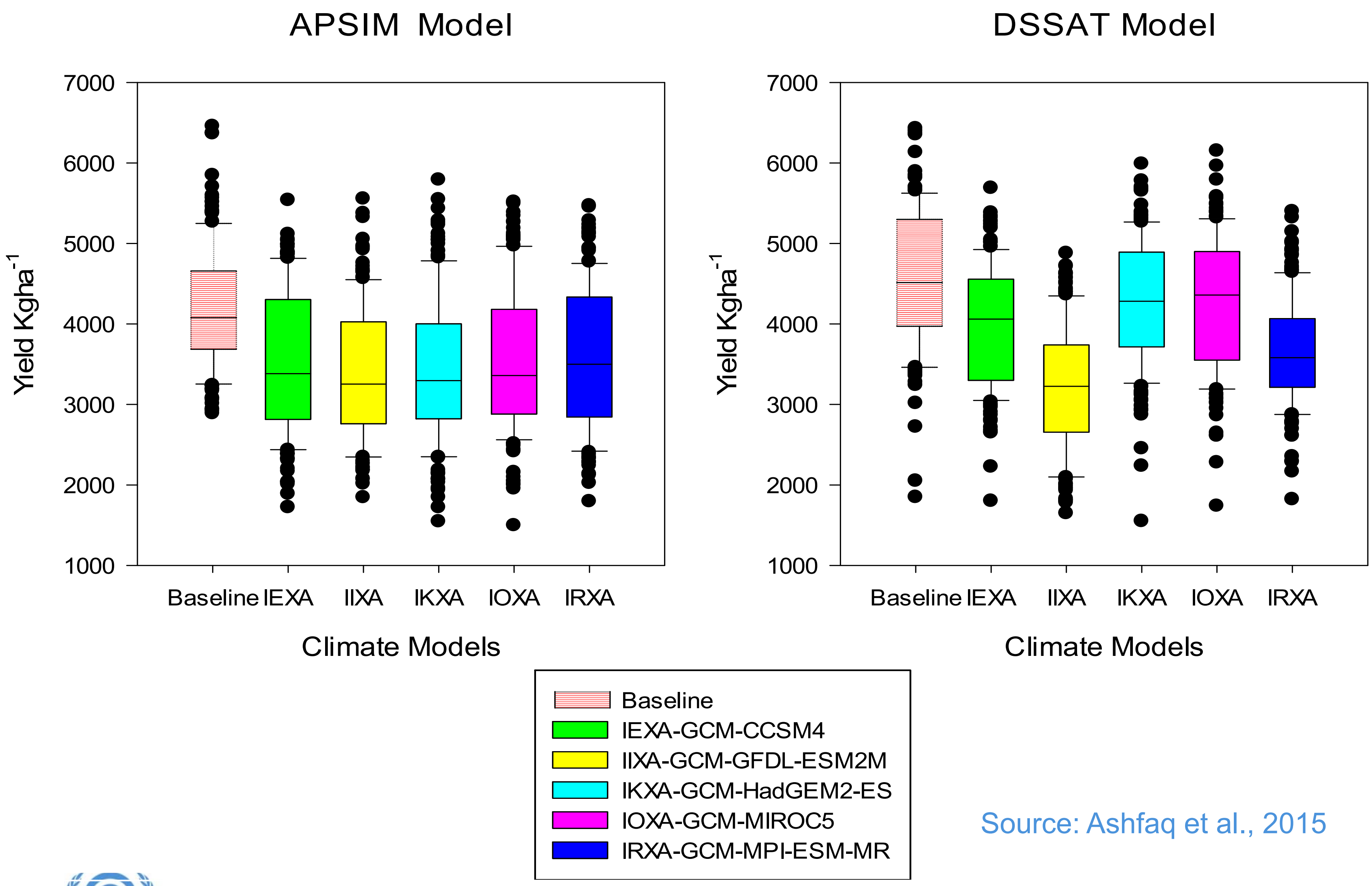
Source: Ashfaq et al., 2015

# Climate change impact on wheat




Source: Ashfaq et al., 2015

# Climate change impact on rice




Source: Ashfaq et al., 2015

# Case study: Results

- Results of DSSAT and APSIM for 155 farms with 5-GCMs in the wheat-rice region of Punjab-Pakistan:
  a) Mean yield reduction for rice was 15.2% for DSSAT and 17.2% for APSIM
  b) Mean yield reduction for wheat was 14.1% for DSSAT and 12% for APSIM

Source: Ashfaq et al., 2015

# Case study: Adaptation

- Planting of wheat should be 15 days earlier than present
  a) 25% increase in planting density for wheat
  b) Use of 20% more fertilizer in wheat
  c) Decrease the number of irrigations by 25%
  d) Agro-climatic advisory services for farmers (Early Warning System)
  e) Selection of improved cultivars (Short lag phase, Early canopy development, Enhance Leaf Area Duration etc.)

Source: Ashfaq et al., 2015

# Case study: Policy brief

AgMIP The Agricultural Model Intercomparison and Improvement Project

**Policy Brief**
June 2014

## Food Security in Punjab, Pakistan

Adapting rice-wheat farming to climate change

*Harvesting rice in Pakistan.*

**Key Messages Punjab, Pakistan**

**Adaptations using different crop varieties and management practices can help reduce projected losses and poverty rates caused by increases in temperature and greater rainfall extremes.**

**CLIMATE**

- **Climate change in the Pakistan Punjab** region is already occurring with **temperature increases of up to 1°C,** record-breaking floods, and drought.
- Temperatures are **projected to increase an average of 2°C** by 2050.
- **Heavy rainfall** and **increasing flooding** may occur during the wet seasons; **dry seasons could get drier.**

**IMPACTS**

- **Major losses of irrigation water** for the Punjab area could result from Himalayan glacier melt.
- **Yields** trends of rice, wheat, and cotton **have recently plateaued,** partly due to changes in climate.
- **Rice yield losses** could range from **8-30%** and **wheat yield losses** could range from **6-19%** by 2050.
- Poverty might increase by about 6% due to climate change in the Punjab by 2050.

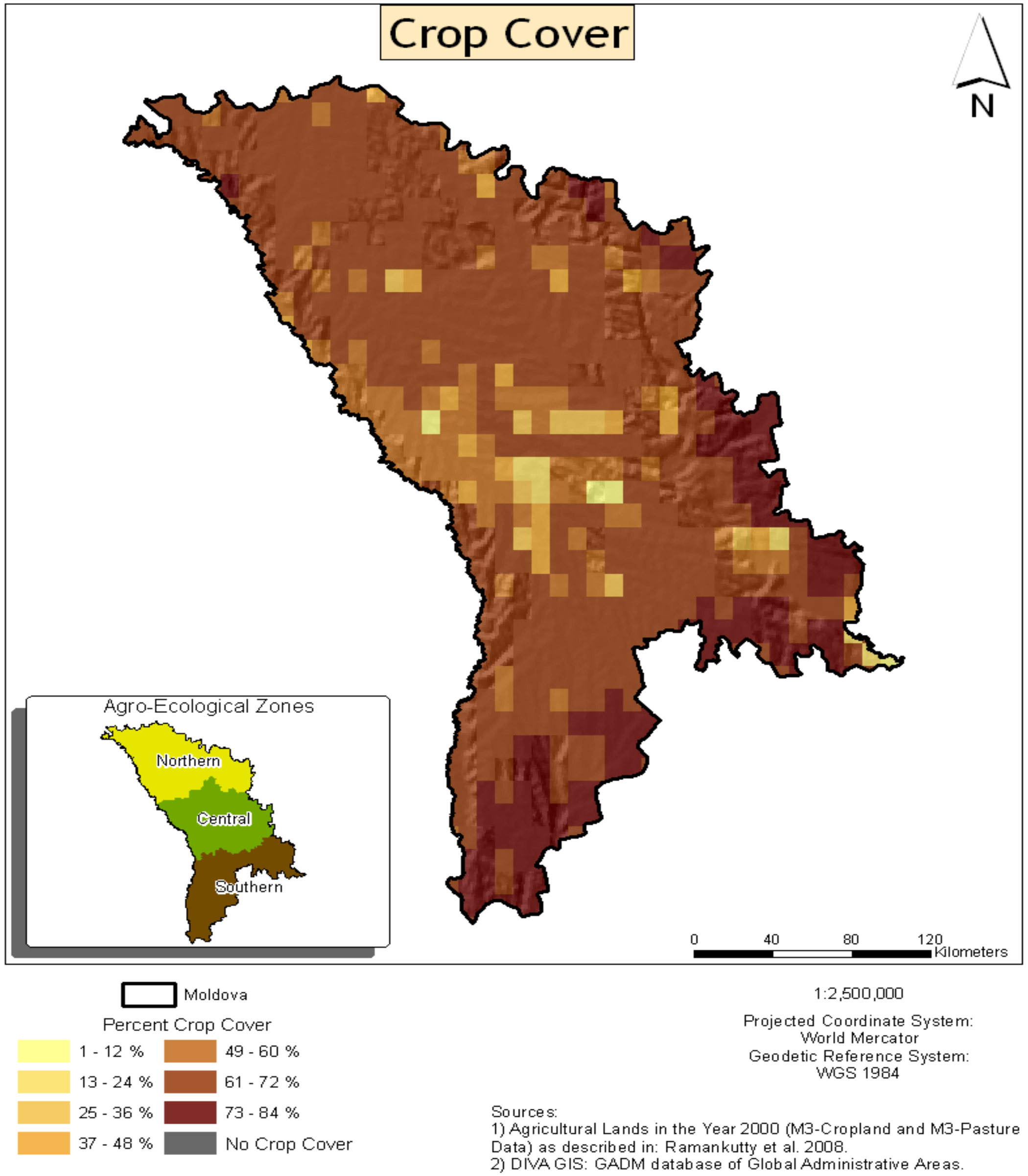
**ADAPTATIONS**

- The **adaptation package** evaluated consisted of new varieties, earlier sowing dates, increase in fertilizer, and higher sowing density.
- The models predict that the **majority of farmers** would likely **adopt** the simulated adaptation packages.
- **Additional adaptations could be tested** to understand how to mitigate the negative impacts of climate change.

Source: AgMIP

*XII. How irrigation contributes to adaptation in agriculture in Moldova?*

# How irrigation contributes to adaptation in agriculture in Moldova?




Iglesias, Quiroga

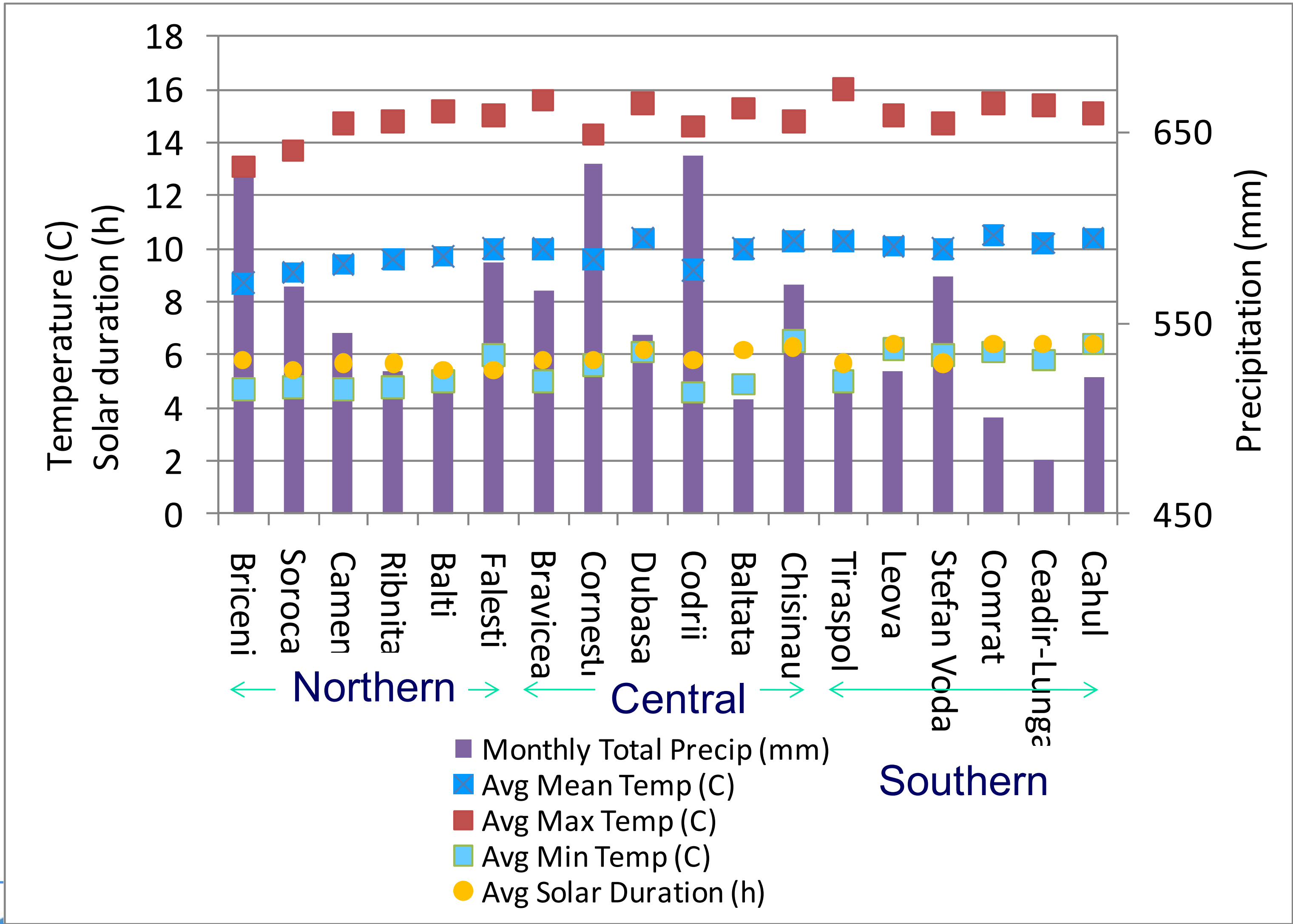
World Bank project,

2011.

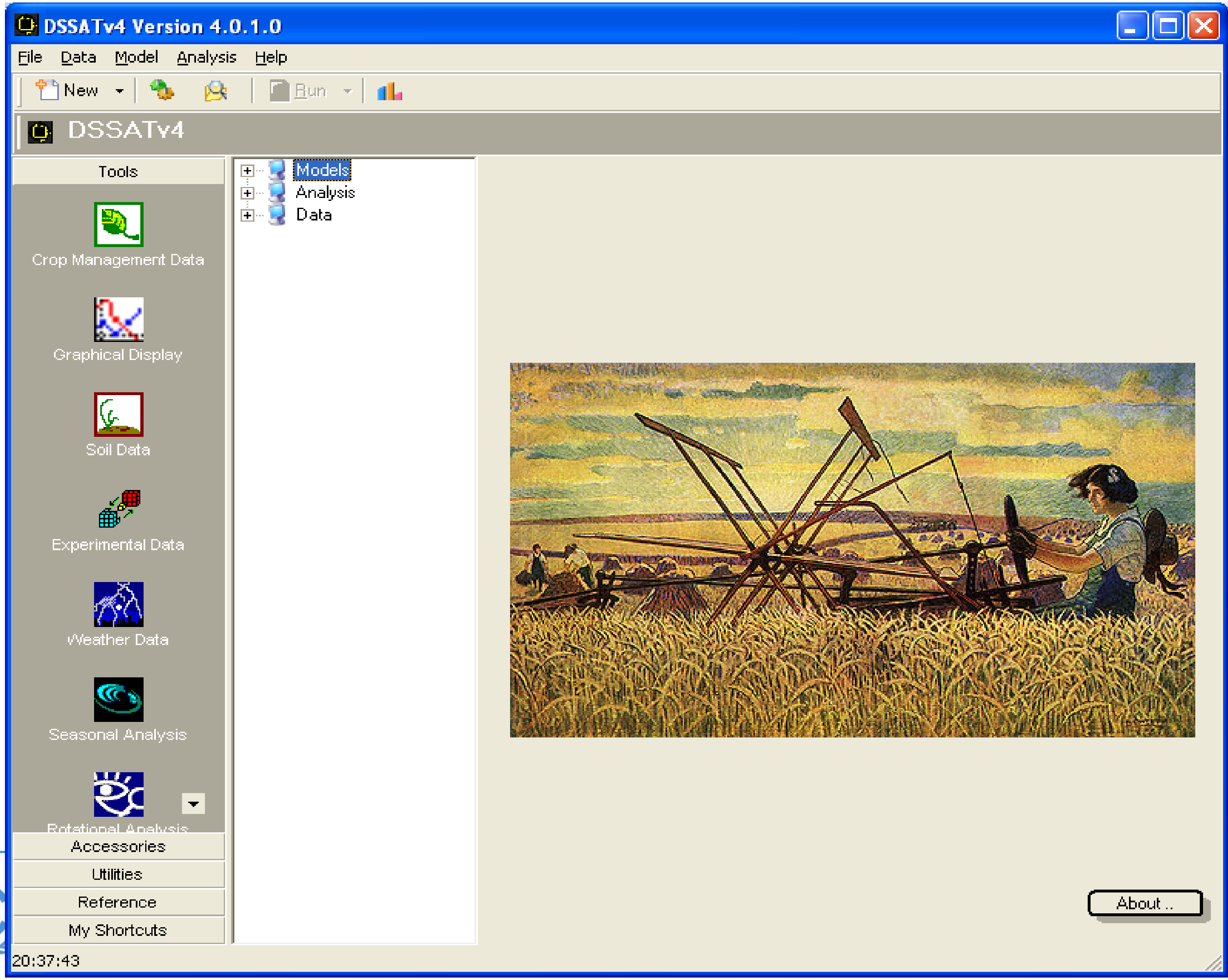
# Input requirements

- Daily weather (precip, tmax, tmin, SR)
- Soil texture
- Management (planting date, variety, row spacing, irrigation and N fertilizer amounts and dates )
- DSSAT libraries and examples
- Additional validation requirements: crop dates of flowering and maturity, biomass and yield

# Weather

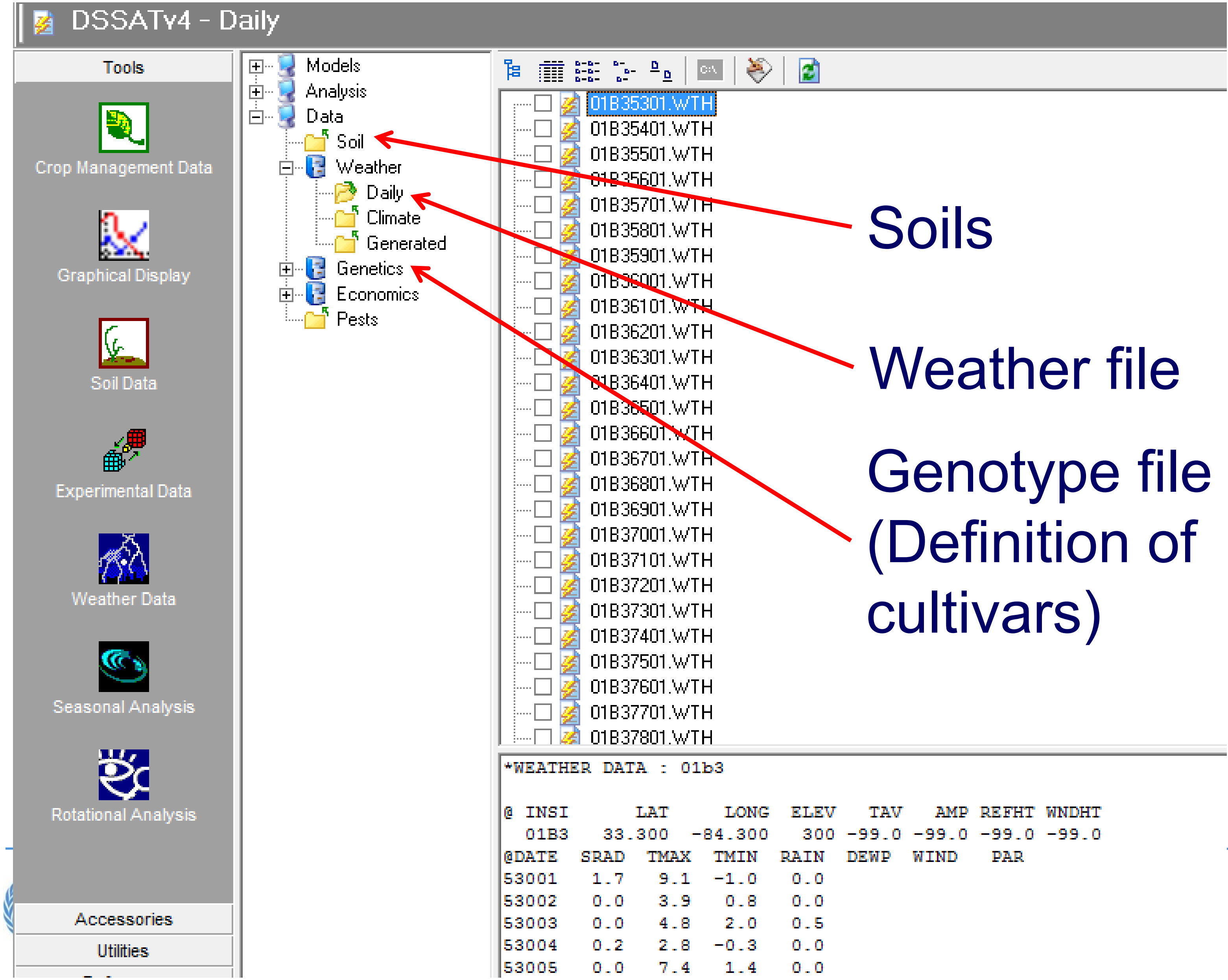

18
16
14
12
10
8
6
4
2
0
Temperature (C)
Solar duration (h)
650
550
450
Precipitation (mm)
Briceni
Soroca
Camen
Ribnita
Balti
Falesti
Bravicea
Cornesti
Dubasa
Codrii
Baltata
Chisinau
Tiraspol
Leova
Stefan Voda
Comrat
Ceadir-Lunga
Cahul
Northern
Central
Southern
Monthly Total Precip (mm)
Avg Mean Temp (C)
Avg Max Temp (C)
Avg Min Temp (C)
Avg Solar Duration (h)

# Open DSSAT …



DSSATv4 Version 4.0.1.0
File Data Model Analysis Help
New
Run
DSSATv4
Tools
Crop Management Data
Graphical Display
Soil Data
Experimental Data
Weather Data
Seasonal Analysis
Rotational Analysis
Accessories
Utilities
Reference
My Shortcuts
Models
Analysis
Data
About ..
20:37:43

# Examine the data files …



```
 MOLDOVA
@NOTES
 MOLDOVA WORLD BANK STUDY, 2010

*TREATMENTS                        -------------FACTOR LEVELS------------
@N R O C TNAME....................  CU FL SA IC MP MI MF MR MC MT ME MH SM
 1 1 0 0 04BR BASE MZ D              1  4  0  1  1  0  1  1  0  0  0  0  1
 2 1 0 0 16SO BASE MZ D              1 16  0  1  1  0  1  1  0  0  0  0  1
 3 1 0 0 06CA BASE MZ D              1  6  0  1  1  0  1  1  0  0  0  0  1
 4 1 0 0 15RI BASE MZ D              1 15  0  1  1  0  1  1  0  0  0  0  1
 5 1 0 0 01BA BASE MZ D              1  1  0  1  1  0  1  1  0  0  0  0  1
 6 1 0 0 13FA BASE MZ D              1 13  0  1  1  0  1  1  0  0  0  0  1
 7 1 0 0 03BR BASE MZ D              1  3  0  1  1  0  1  1  0  0  0  0  1
 8 1 0 0 11CO BASE MZ D              1 11  0  1  1  0  1  1  0  0  0  0  1
 9 1 0 0 12DU BASE MZ D              1 12  0  1  1  0  1  1  0  0  0  0  1
10 1 0 0 09CO BASE MZ D              1  9  0  1  1  0  1  1  0  0  0  0  1
11 1 0 0 02BA BASE MZ D              1  2  0  1  1  0  1  1  0  0  0  0  1
12 1 0 0 08CH BASE MZ D              1  8  0  1  1  0  1  1  0  0  0  0  1
13 1 0 0 18TI BASE MZ D              1 18  0  1  1  0  1  1  0  0  0  0  1
14 1 0 0 14LE BASE MZ D              1 14  0  1  1  0  1  1  0  0  0  0  1
15 1 0 0 17ST BASE MZ D              1 17  0  1  1  0  1  1  0  0  0  0  1
16 1 0 0 10CO BASE MZ D              1 10  0  1  1  0  1  1  0  0  0  0  1
17 1 0 0 07CE BASE MZ D              1  7  0  1  1  0  1  1  0  0  0  0  1
18 1 0 0 05CA BASE MZ D              1  5  0  1  1  0  1  1  0  0  0  0  1

*CULTIVARS
@C CR INGENO CNAME
 1 MZ 990002 medium
```

Type of variety

Where? Weather, soil

```
*FIELDS
@L ID_FIELD WSTA....  FLSA  FLOB  FLDT  FLDD  FLDS  FLST SLTX   SLDP ID_SOIL
 1 01BA0001 01BA5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
 2 02BA0001 02BA5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
 3 03BR0001 03BR5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
 4 04BR0001 04BR5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
 5 05CA0001 05CA5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
 6 06CA0001 06CA5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
 7 07CE0001 07CE5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
 8 08CH0001 08CH5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
 9 09CO0001 09CO5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
10 10CO0001 10CO5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
11 11CO0001 11CO5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
12 12DU0001 12DU5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
13 13FA0001 13FA5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
14 14LE0001 14LE5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
15 15RI0001 15RI5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
16 16SO0001 16SO5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
17 17ST0001 17ST5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
18 18TI0001 18TI5301 -99     0 DR000     0     0 00000  -99     90 IBML000990
```

Initial conditions

```
*INITIAL CONDITIONS
@C   PCR ICDAT  ICRT  ICND  ICRN  ICRE
 1    MZ 53120  1200   -99  1.00  1.00
@C  ICBL  SH2O  SNH4  SNO3
 1     5 0.262   0.5   4.6
 1    15 0.262   0.5   4.6
 1    30 0.262   0.5   4.4
 1    45 0.262   0.2   3.8
 1    60 0.262   0.2   3.8
 1    90 0.261   0.2   2.8
```

Planting details (date, depth, density)

```
*PLANTING DETAILS
@P PDATE EDATE  PPOP  PPOE  PLME  PLDS  PLRS  PLRD  PLDP  PLWT  PAGE  PENV  PLPH
 1 53130   -99   5.0   5.0     S     R    15     0   5.5   -99   -99 -99.0 -99.0
```

Fertilisers inorganic (type, date, depth, amount)

```
*FERTILIZERS (INORGANIC)
@F FDATE  FMCD  FACD  FDEP  FAMN  FAMP  FAMK  FAMC  FAMO  FOCD
 1 53120 FE001   -99    15     0     0     0     0     0
```

Fertilisers organic (type, date, depth, amount)

```
*RESIDUES AND OTHER ORGANIC MATERIALS
@R RDATE  RCOD  RAMT  RESN  RESP  RESK  RINP  RDEP
 1 53120 RE001  1000  1.10   -99   -99   -99    15
```

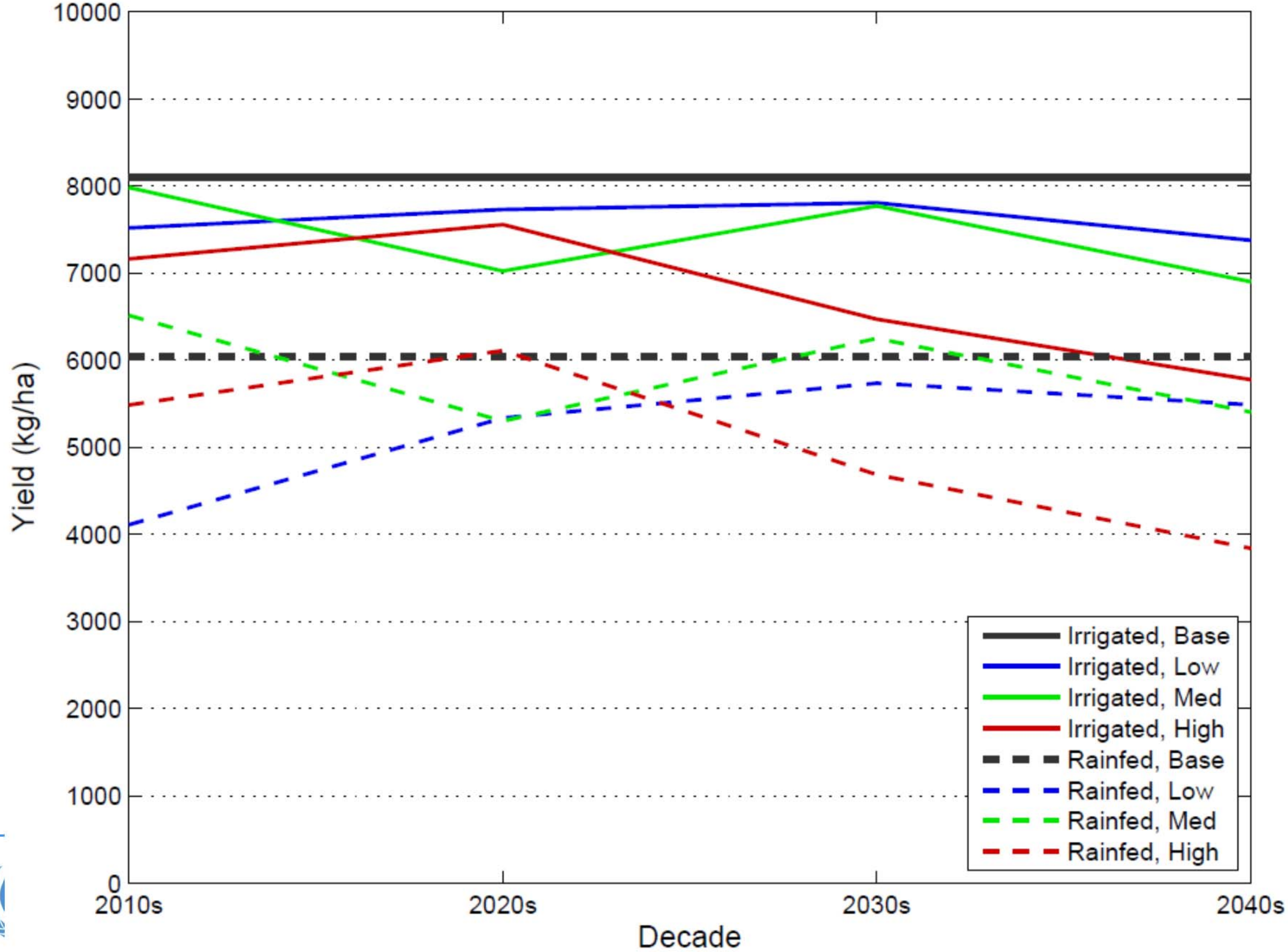
Env Modifications

```
*ENVIRONMENTAL MODIFICATIONS
@E ODATE EDAY  ERAD  EMAX  EMIN  ERAIN ECO2  EDEW  EWIND
 1 53001 A 0.0 A 0.0 A 0.0 A 0.0 M 1.0 A   0 A 0.0 A 0.0
```

**Simulation controls**

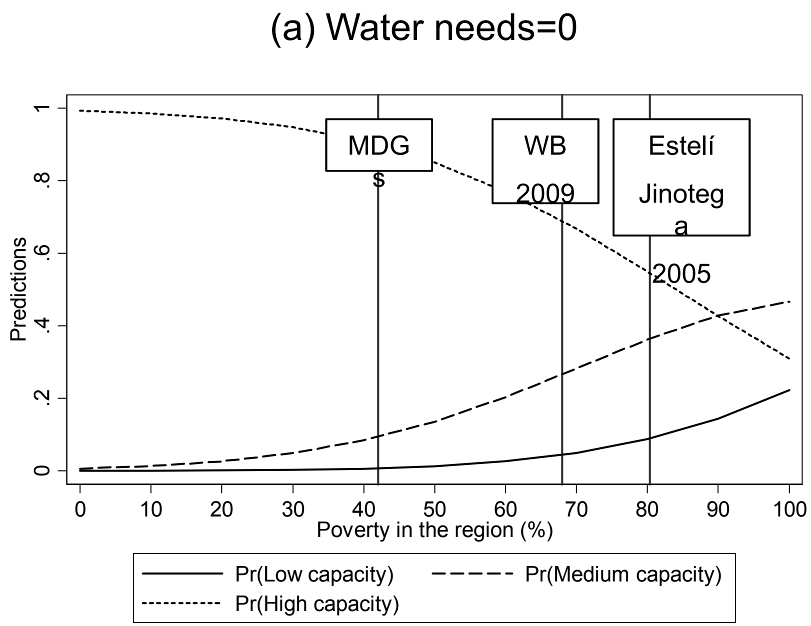
```
*SIMULATION CONTROLS
@N GENERAL     NYERS NREPS START SDATE RSEED SNAME....................
 1 GE              1     1     S 53120  2150 MZ
@N OPTIONS     WATER NITRO SYMBI PHOSP POTAS DISES
 1 OP              Y     Y     N     N     N     N
@N METHODS     WTHER INCON LIGHT EVAPO INFIL PHOTO
 1 ME              M     M     E     R     S     C
@N MANAGEMENT  PLANT IRRIG FERTI RESID HARVS
 1 MA              R     R     A     N     M
@N OUTPUTS     FNAME OVVEW SUMRY FROPT GROUT CAOUT WAOUT NIOUT MIOUT DIOUT  LONG
 1 OU              Y     Y     Y     5     N     N     Y     N     N     N     N

@  AUTOMATIC MANAGEMENT
@N PLANTING    PFRST PLAST PH2OL PH2OU PH2OD PSTMX PSTMN
 1 PL            100   150    40   100    30    40    10
@N IRRIGATION  IMDEP ITHRL ITHRU IROFF IMETH IRAMT IREFF
 1 IR             50    80   100 GS000 IR001    10  1.00
@N NITROGEN    NMDEP NMTHR NAMNT NCODE NAOFF
 1 NI             15    20    10 FE001 GS000
@N RESIDUES    RIPCN RTIME RIDEP
 1 RE            100     1    20
@N HARVEST     HFRST HLAST HPCNP HPCNR
 1 HA              0   365   100     0
```

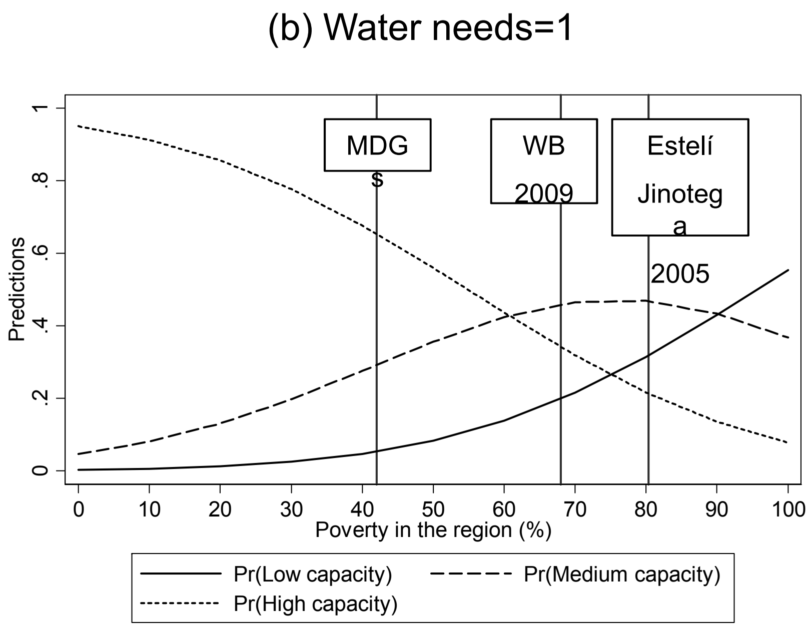
# Crop Yield Projections: Maize, Southern AEZ Moldova



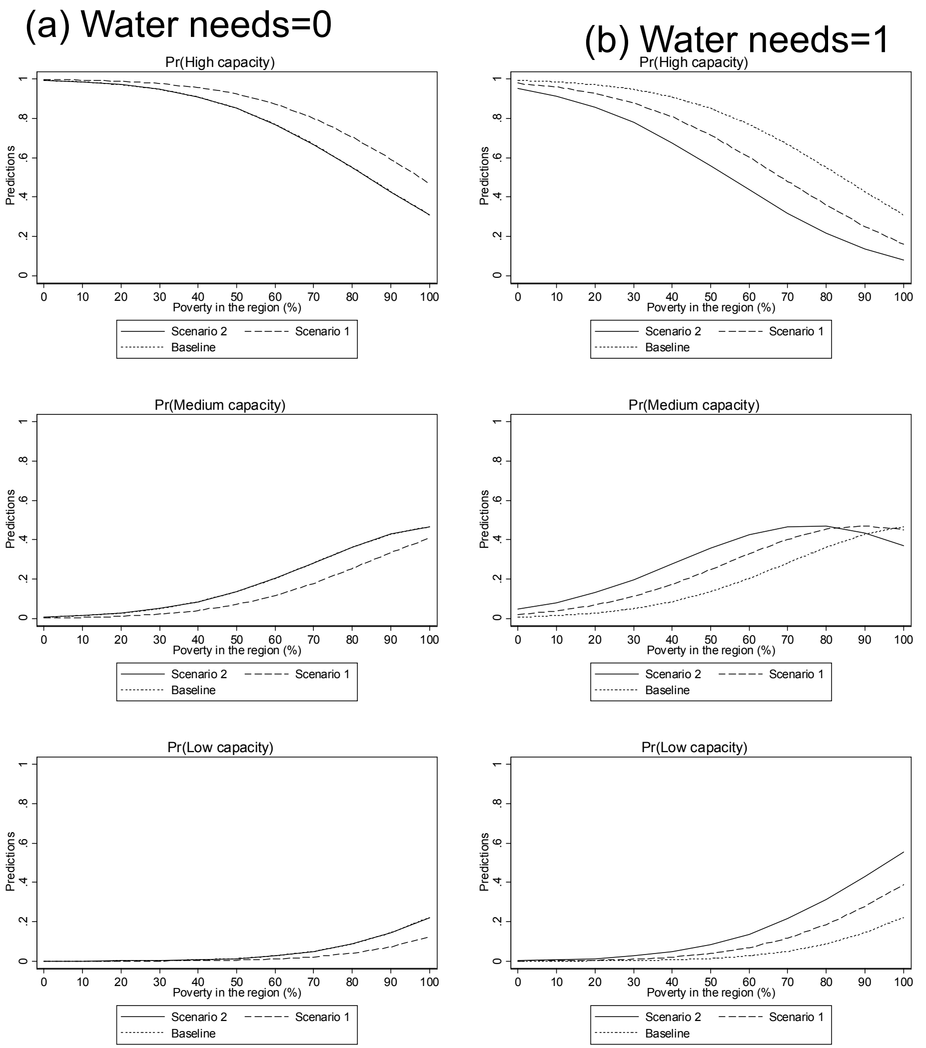
*XIII. How coffee farmers perceptions on climate change depend on water availability in Nicaragua?*

# Perceptions on adaptive capacity in Nicaragua

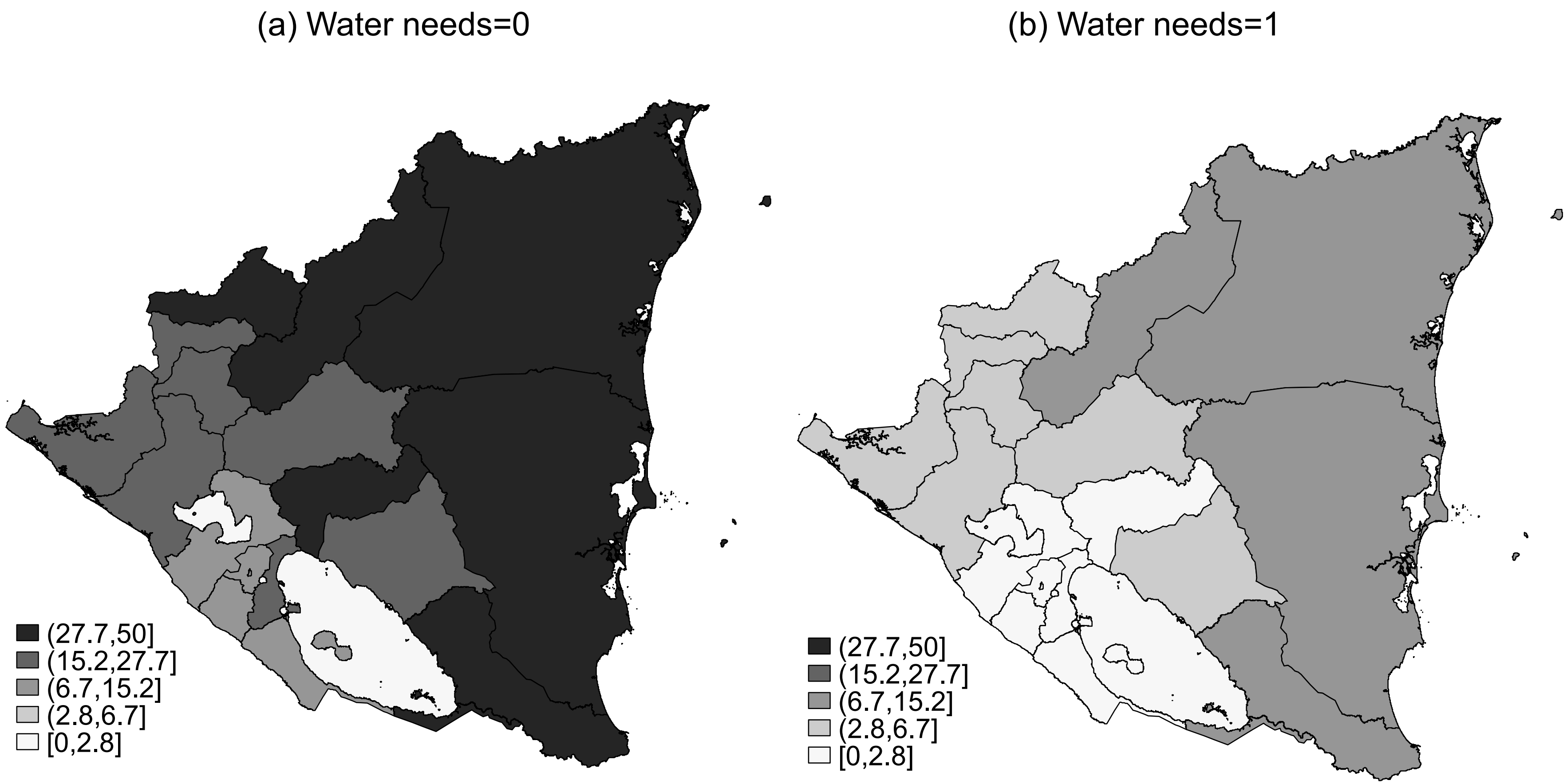


# Perceptions on adaptive capacity in Nicaragua



# Perceptions on adaptive capacity in Nicaragua



## ***XIV. Hands on: How to start to simulate impacts and vulnerabilities in agriculture?***

# Hands on vulnerability and adaptation in agriculture

Task 1:

- Do you think the models/tools presented can be useful somehow for your needs?

Task 2:

- What are the barriers and opportunities you find to begin to use some of the tools?

Task 3:

- Make an initial plan of your objectives, and how can be achieved with the presented tools.

  Data available:

  Software available:

  Technical difficulties:

Thank you