United Nations Framework Convention on Climate Change

CGE TRAINING MATERIALS - VULNERABILITY AND ADAPTATION ASSESSMENT

CHAPTER 7

Agriculture

Objectives and Expectations

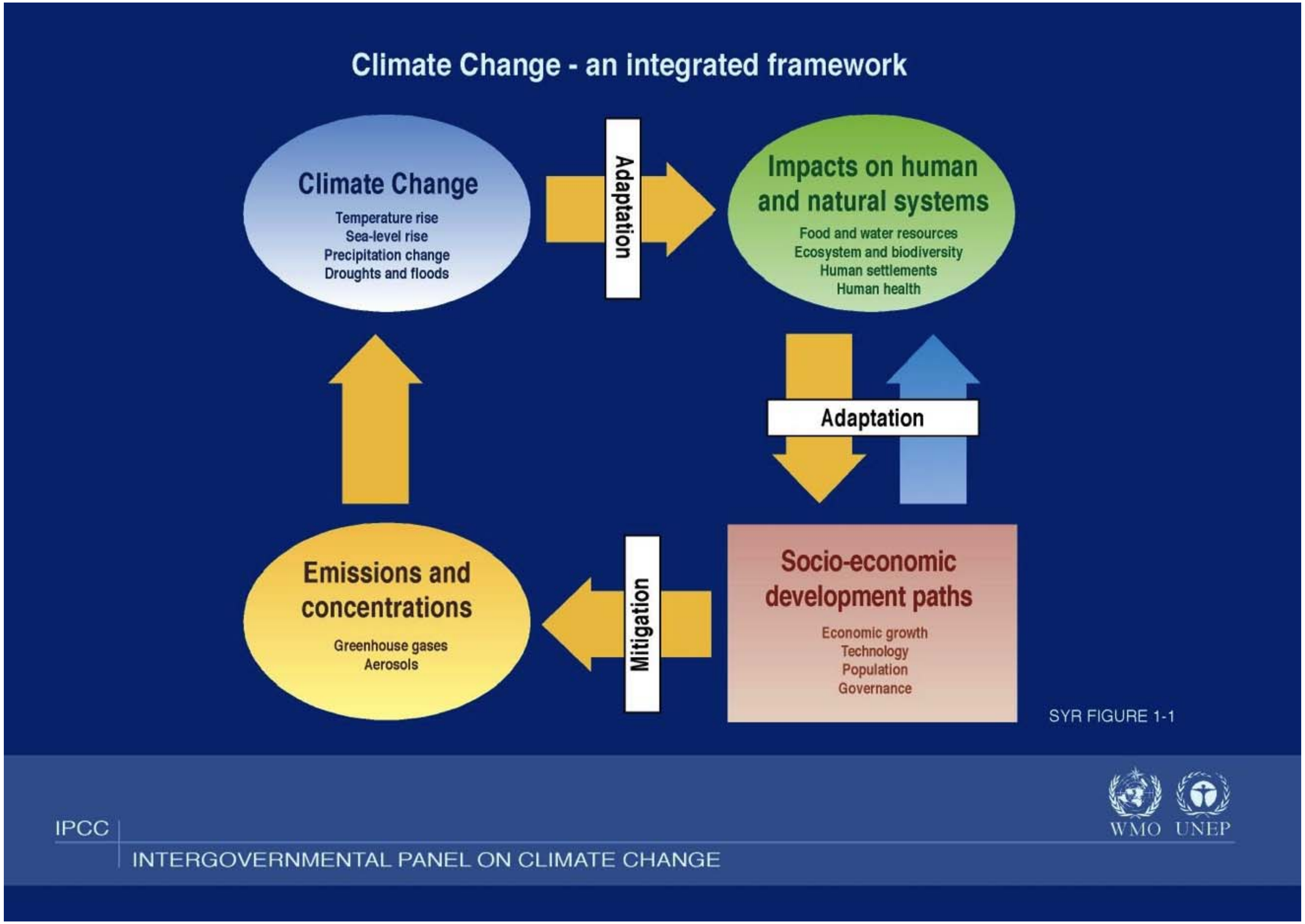
- Having read this presentation, in conjunction with the related handbook, the reader should:
  a) Have an **overview of climate change impacts** on agriculture and food security
  b) Have a general **understanding of tools, models** and the processes available and commonly used for vulnerability and adaptation (V&A) assessment in the agriculture sector
  c) Have gained knowledge of commonly used **process-based and statistical models and their practical applications**, such as DSSAT, for conducting sensitivity analyses, developing seasonal adaptation measures.

Outline

- Overview of drivers and potential impacts of climate change on agriculture
- Methods, tools and models for V&A assessment in agriculture
  a) Introduction to process-based crop models
  b) How we can estimate crop production functions
  c) General equilibrium models
- Changes in land productivity

OVERVIEW OF DRIVERS AND POTENTIAL IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

Climate Change: Context



Agriculture

- Provider of:
  a) Affordable food, feed, fibre and fuel
  b) Basis for livelihoods: jobs and income
  c) Services and goods
- Value chain: production and processing.

Global Trends

- Market-oriented agriculture
- Technology
- Environmental change
- Social and political change
- Productivity increase

Two Main Directions

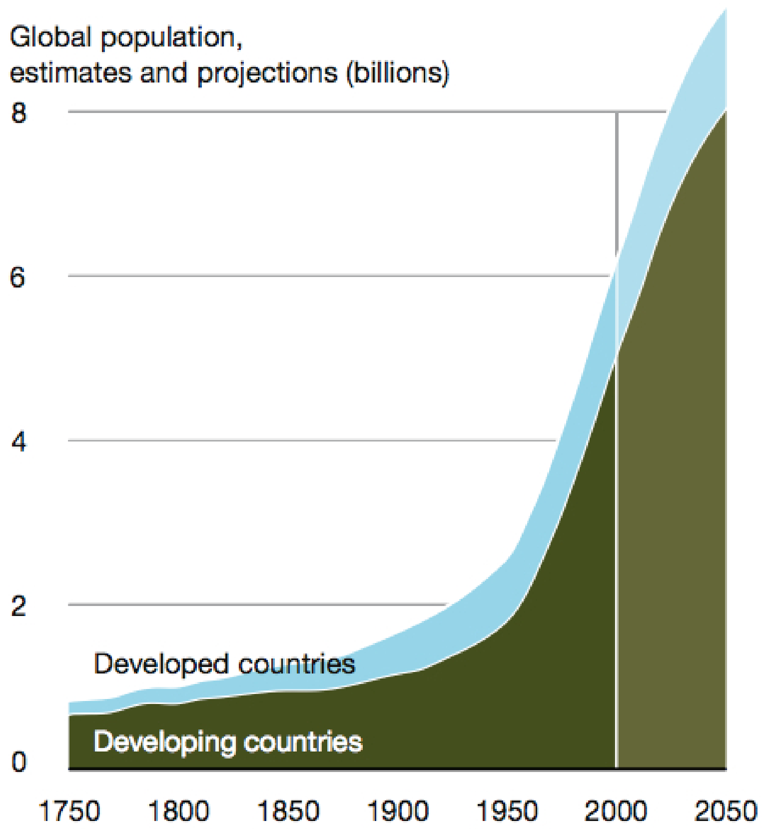
- Specialization
- Intensification
- Concentration
- Innovation and efficiency
- Combination of functions
- Agriculture is no longer the strongest pillar for the rural economy

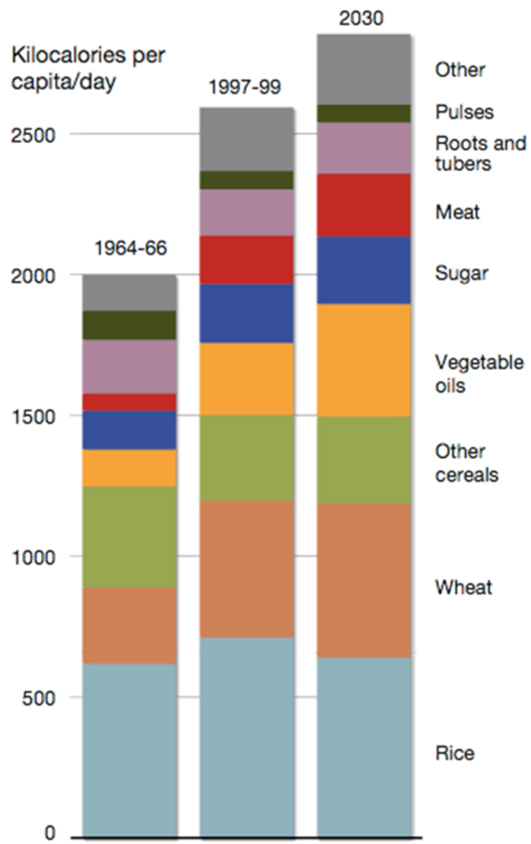
Food Security and Food Self-sufficiency

- Food security: having access to food, independent from the source.
- Food self-sufficiency: growing the food that is needed.

➔ Both can be addressed at different levels (individual, family, province, country, …).

Main Drivers: Population Increase and Diets

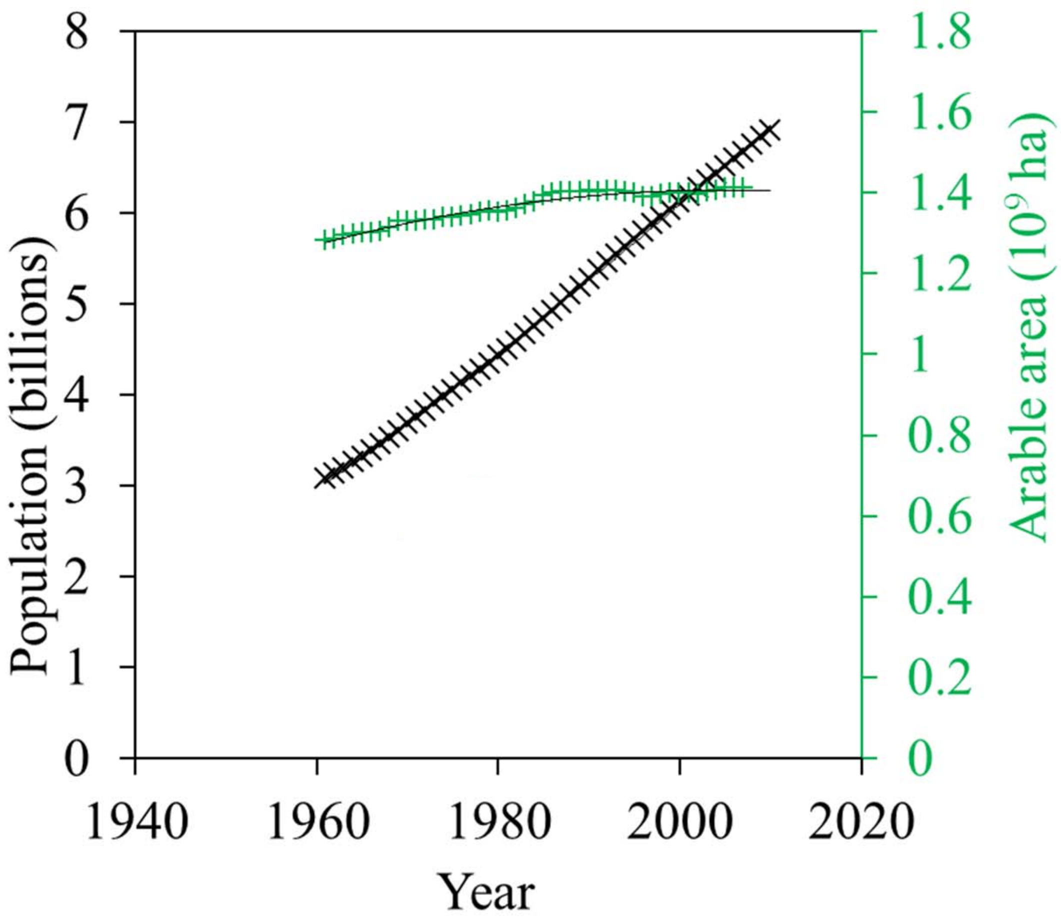




Source: UN Population Division, 2007

Source: FAO, 2008; FAOSTAT, 2009

Required Growth for Food and Feed is Nothing New



Arable land eq 12% of total land area.

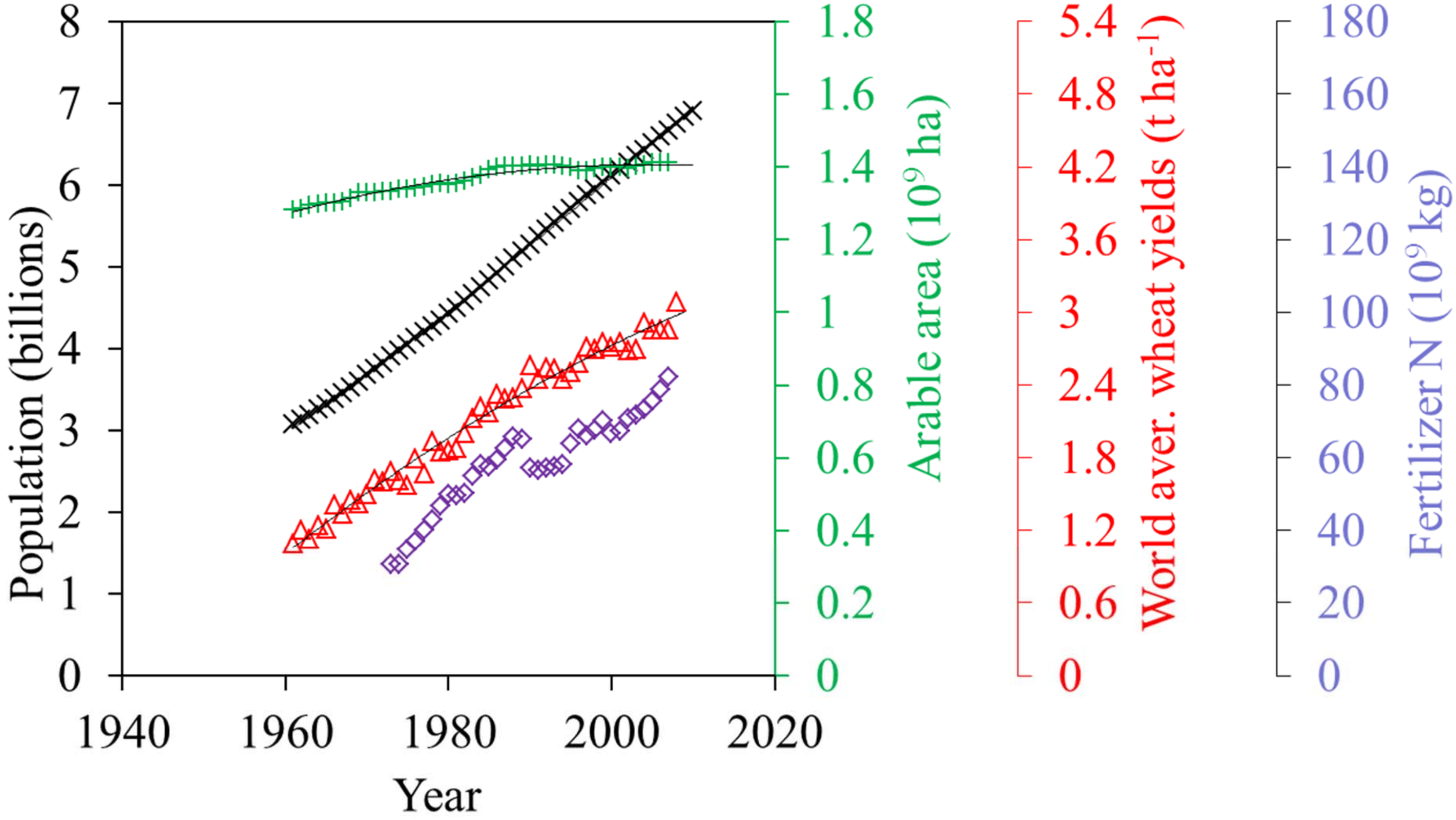
Grasslands = 24%

Forest = 31%

Rest = 33%

Source: van Ittersum, 2011 (updated from Evans, 1998)

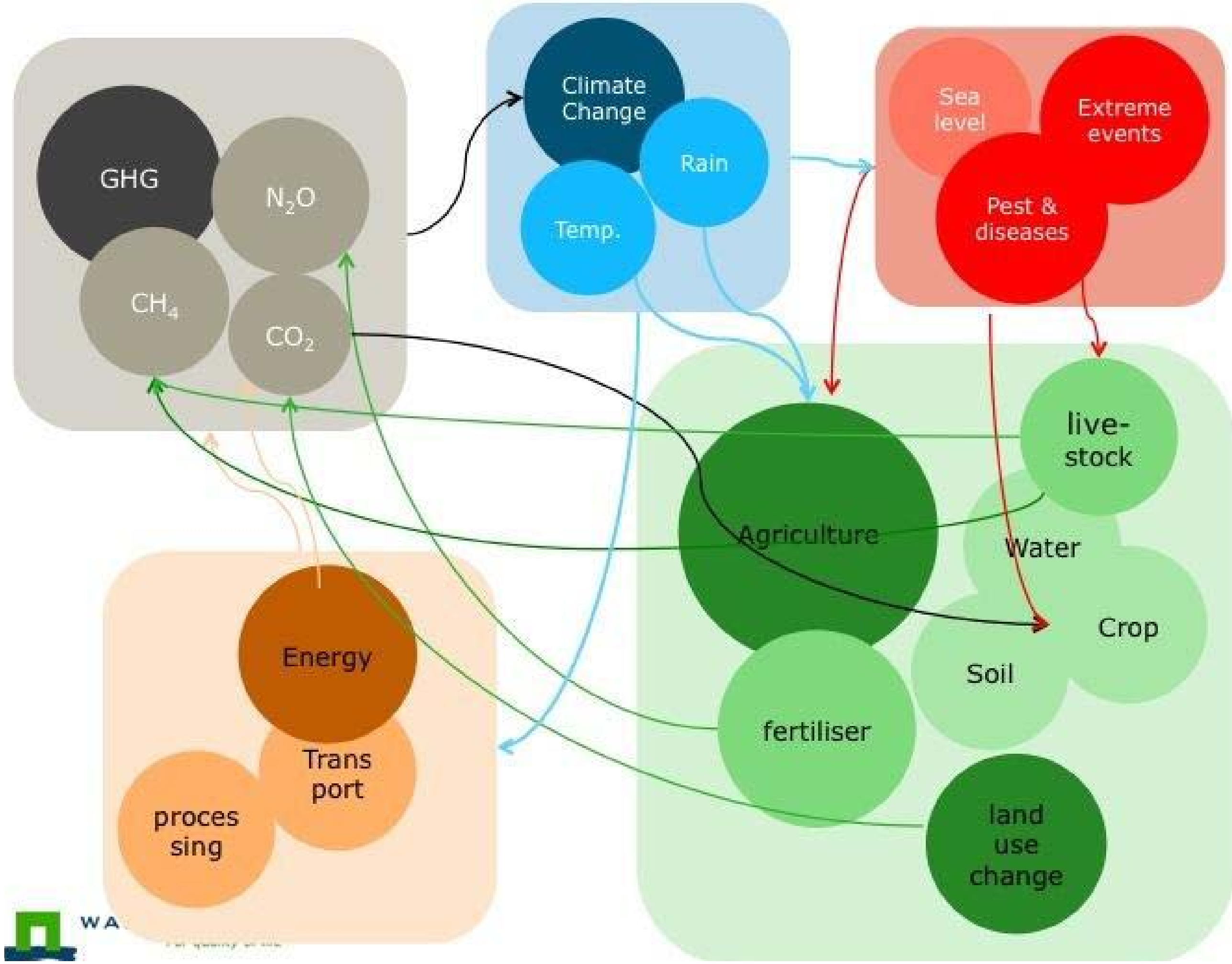
Required Growth for Food and Feed is Nothing New



Two strategies: expansion and increase output per hectare

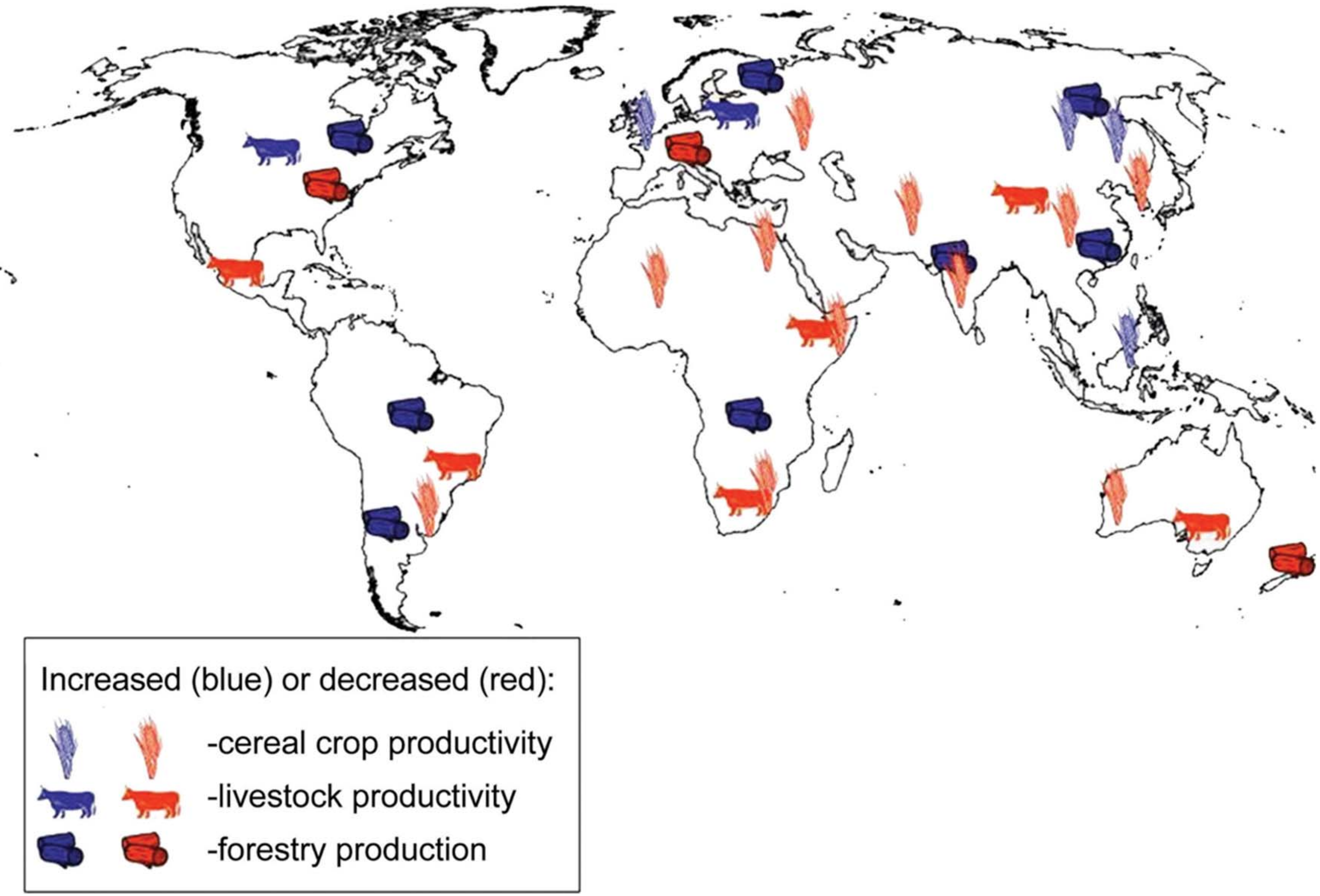
Source: van Ittersum, 2011 (updated from Evans, 1998)

Climate Change and the agricultural sector



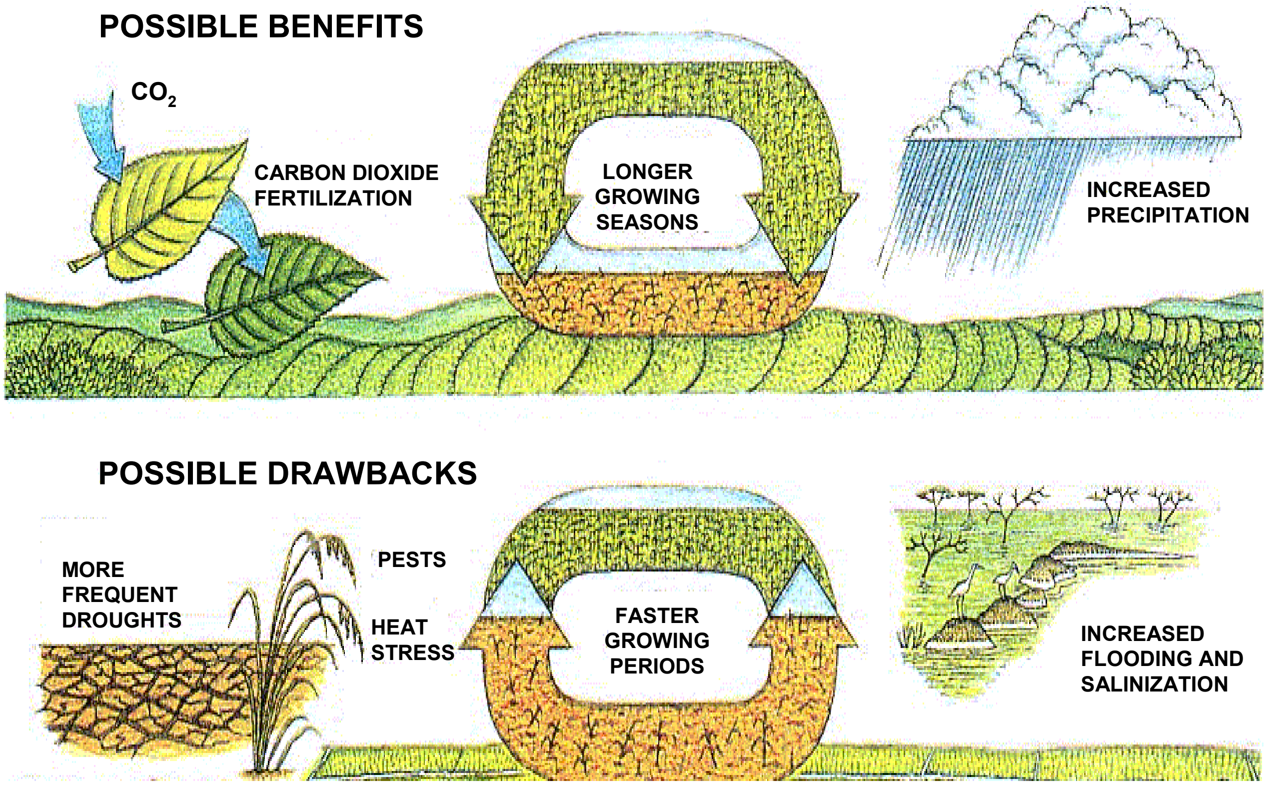
Source: Wageningen University

Climate Change and Agriculture: Impacts (2050) Adaptation is not taken into account



Source: Based on literature and expert judgement, IPCC, 2007, chapter 5

Climate Change Affects Crop Production

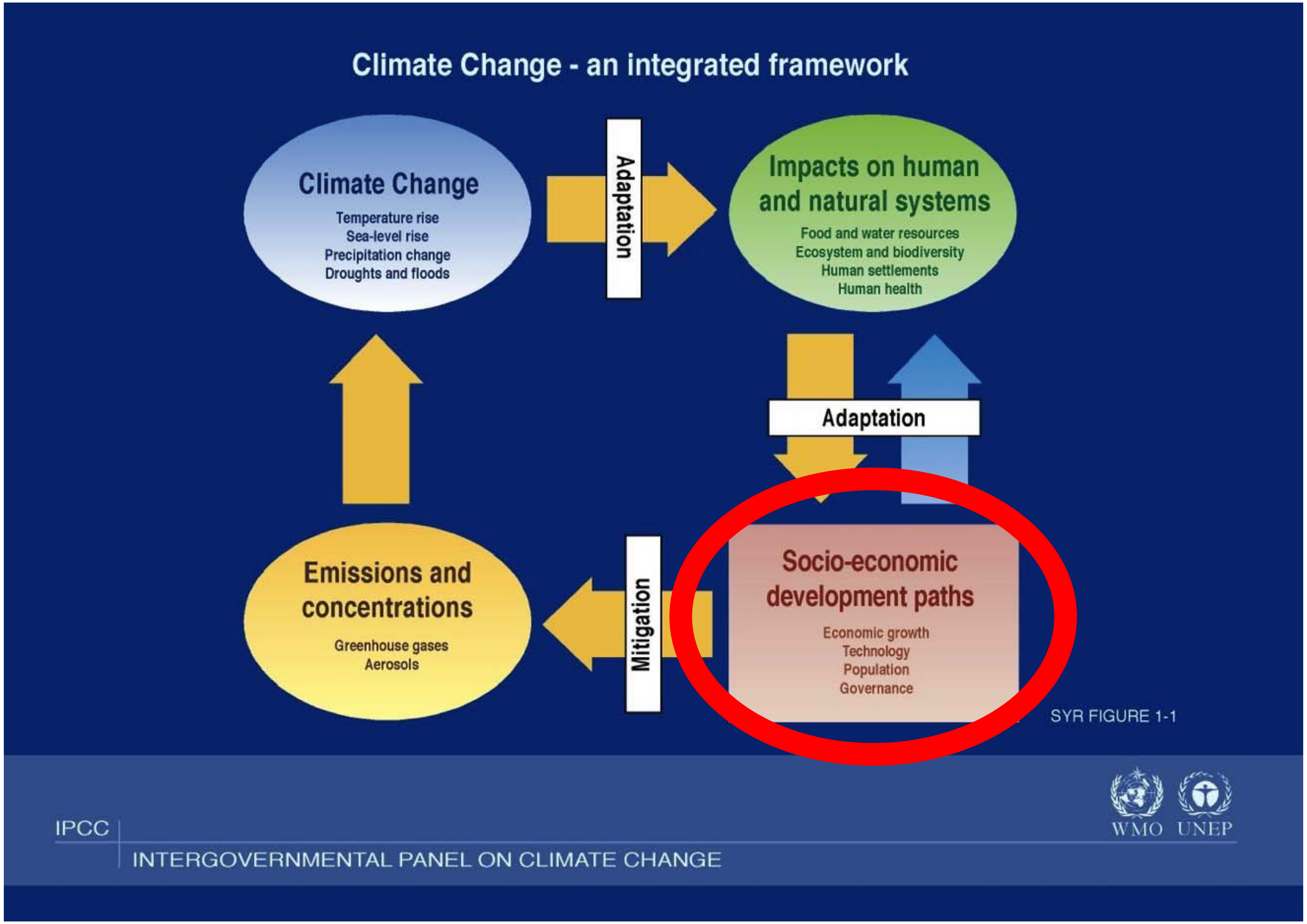


- Changes in biophysical conditions
- Changes in socio-economic conditions in response to changes in crop productivity (farmers' income; markets and prices; poverty; malnutrition and risk of hunger; migration)

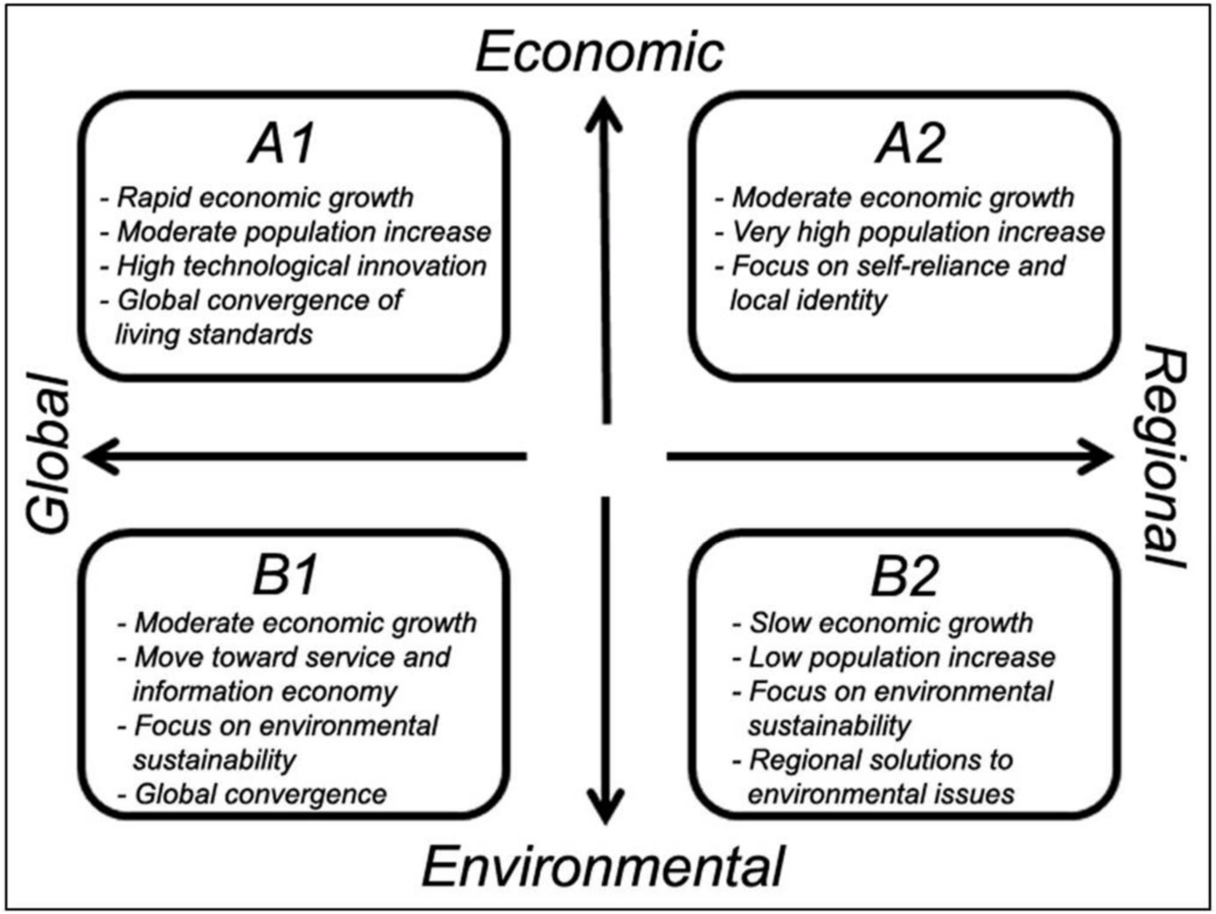
Agriculture: Impacts

- Direct impacts:
  a) Lower production related to erratic rainfall patterns, higher temperatures
  b) Higher production related to increase in carbon dioxide (CO_2). Increased water-use efficiency (WUE), changes in competition.
- Indirect impacts:
  a) Salt water intrusion related to sea level rise
  b) Increase and changes in pests and diseases.
- Extremes:
  a) Temperature, droughts and floods.

Impacts Depend on Timescales and Scenarios



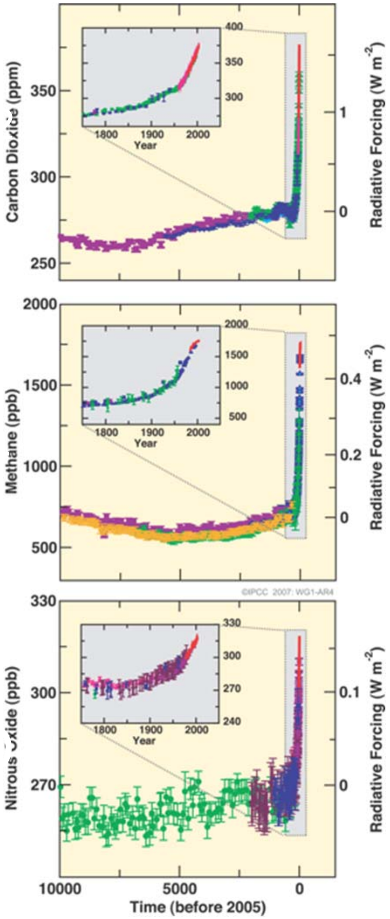
Scenarios

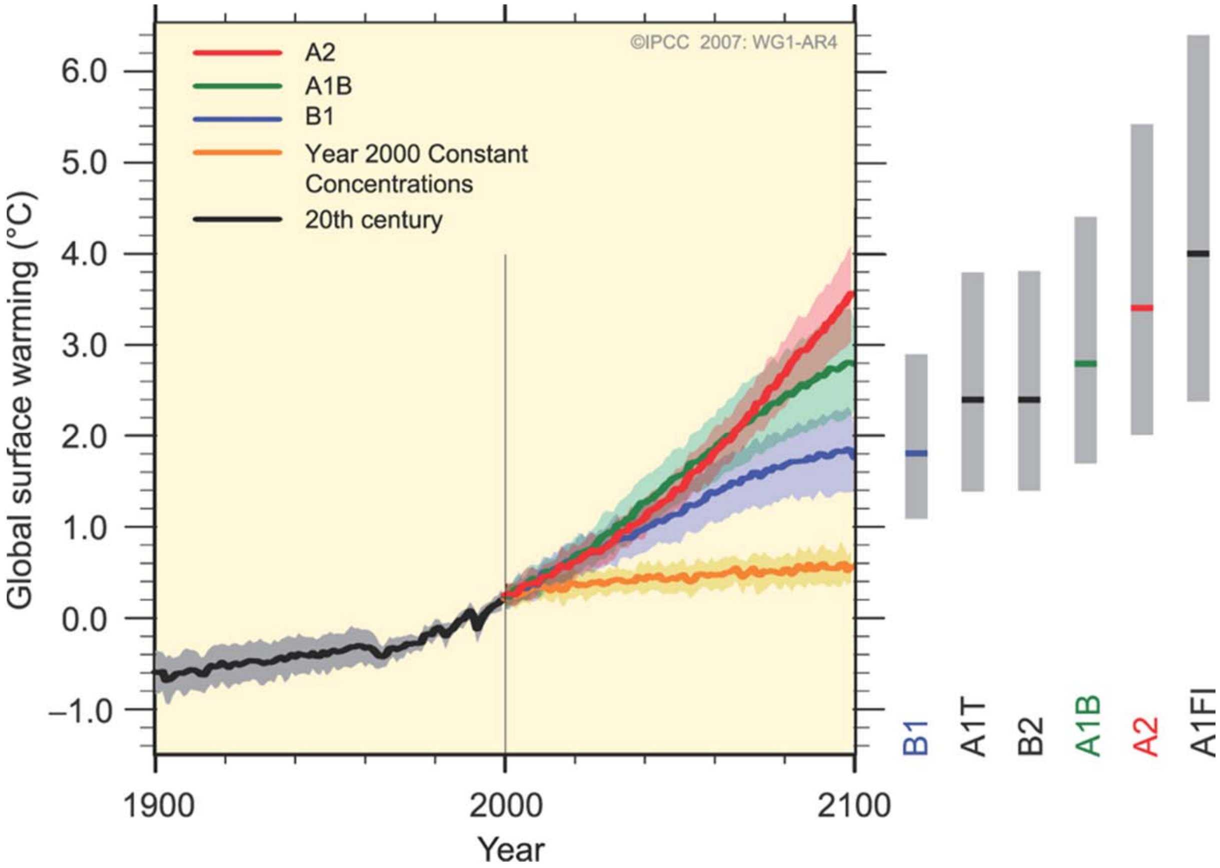


IPCC SRES storylines are oriented along two axes: 1) economic vs. environmental priorities, and 2) global vs. regional development. The four scenarios each describe divergent, yet plausible futures.

Source: http://www.usgs.gov/climate_landuse/land_carbon/Scenarios.asp

Greenhouse gases (GHGs) and Temperature Projections





Source: IPCC, 2007

Climate Change and Other Factors

- Climate change has to be seen in relation with other changes:
  a) Economic
  b) Technological
  c) Societal.

Who is at Risk?

- People and/or countries depending for their livelihood on climate sensitive sectors such as agriculture, forestry and fishing.
- People living in low-lying coastal areas
- People closer to the margin of tolerance: for temperature and precipitation changes (more drought- and flood-prone areas)
- Countries with a poor nutrition and health infrastructure
- People and countries with a ***low adaptive capacity.***

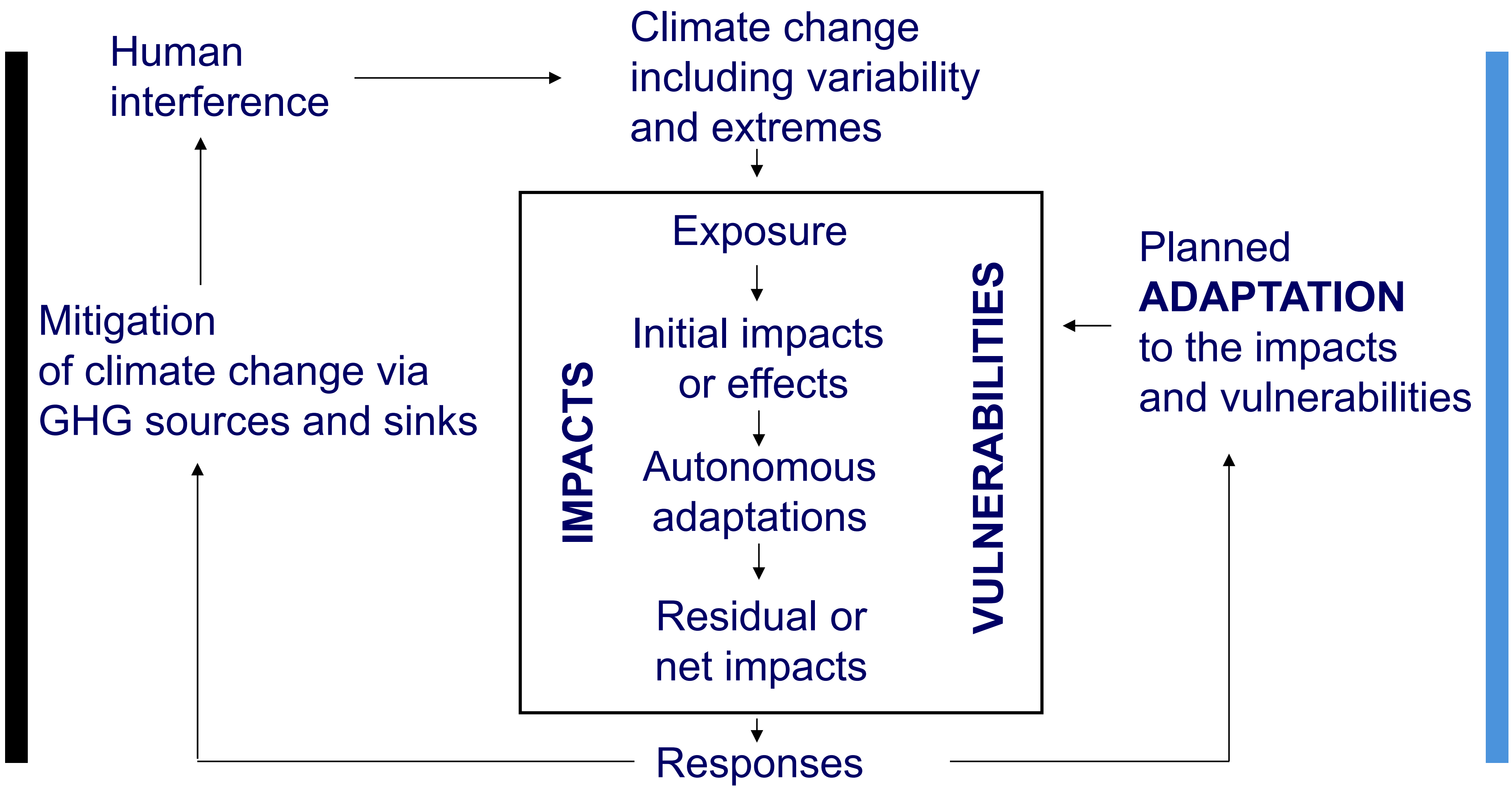
Adaptive capacity depends on:

- Natural capital: soil, water, vegetation, landscape, …
- Financial capital: savings, credit, …
- Physical capital: infrastructure, technology, …
- Human capital: skills, education level, health, …
- Social capital: legal system, political system, networks, …

Multiple Interactions

- Climate change is one stress among many now affecting agriculture and the population that depends on it:
  a) Integration of results is essential if we are to formulate assessments that are relevant to policy.
- Potential future consequences depend on:
  a) The region and the agricultural system
  b) Impacts in other countries
  c) The direction and order of magnitude
  d) The socio-economic response.

Impact, Vulnerability and Adaptation



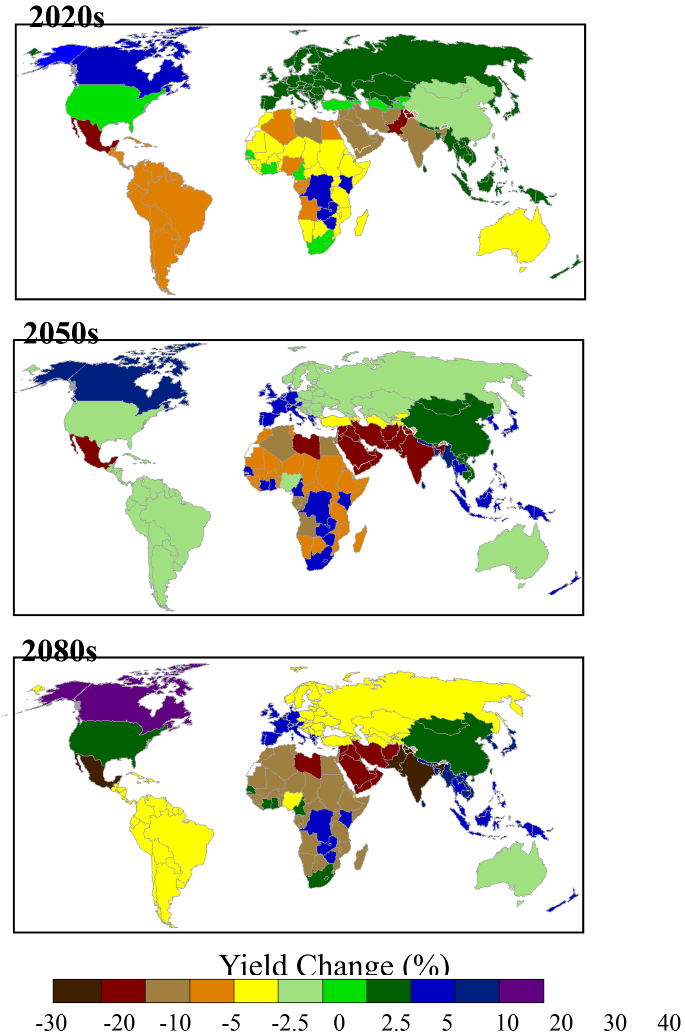
Source: IPCC, 2001; Smit et al., 1999

Types of Adaptation

		Anticipatory	Reactive
Natural			Changes in length of growing season
Human	private	Purchase of insurance Changes in system composition	Changes in farm practices
	public	Early warning systems	Compensatory payments, subsidies

Source: IPCC, 2001

How Might Global Climate Change Affect Food Production?



Percentage change in average crop yields for the Hadley Centre global climate change scenario (HadCM2). Direct physiological effects of CO_2 and crop adaptation are taken into account. Crops modelled are wheat, maize, and rice.

Source: NASA/GISS; Rosenzweig and Iglesias, 1994

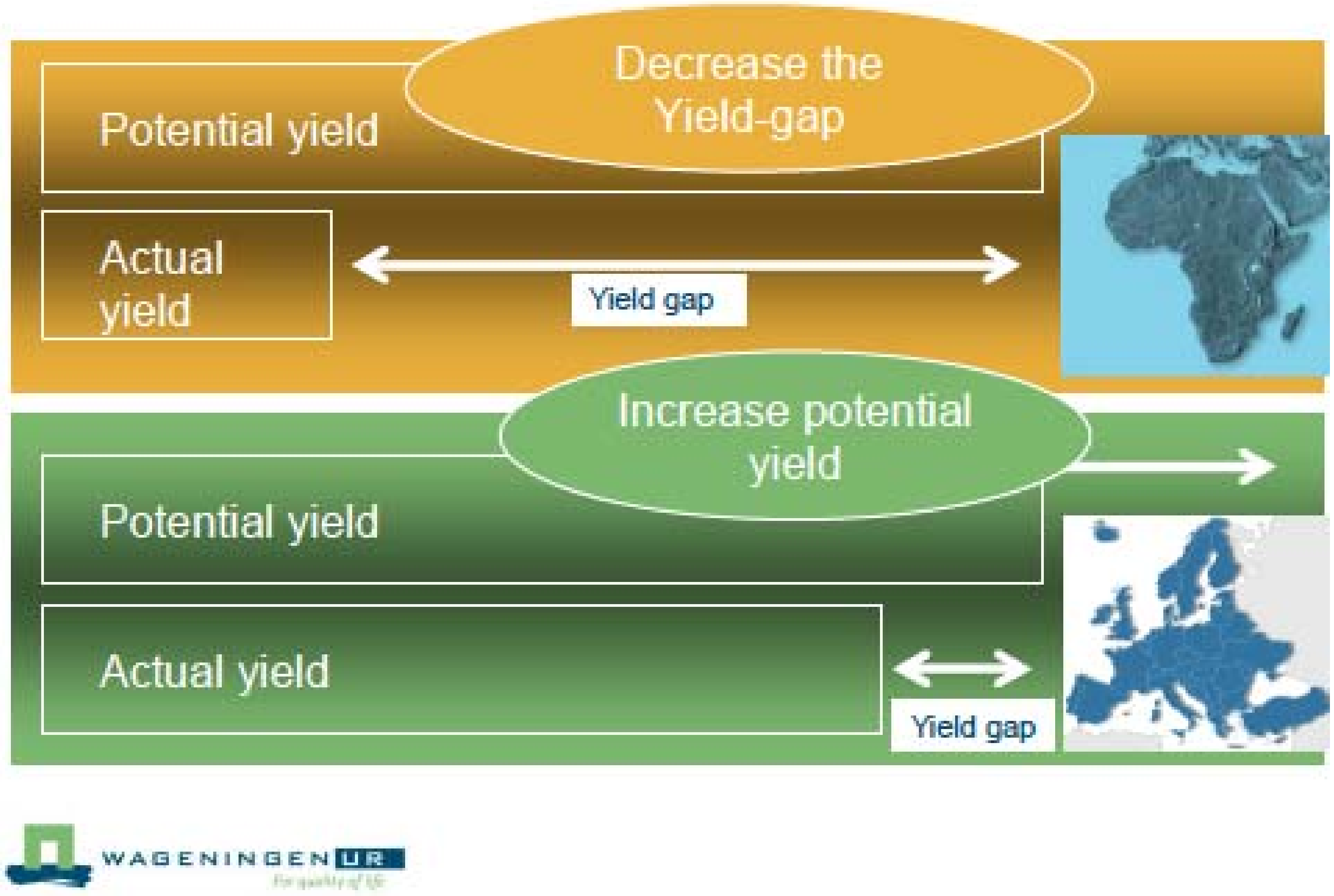
What Happens in Response to Change?

- Adaptive capacity (internal adaptation)
- Planned adaptation.

Adaptation is Not New

- Adapt to environmental and market changes is part of agriculture
- Governments change policies and programmes to better achieve broad societal goals (e.g. food security)
- Short-term and medium- and long-term planning.
- Managing risk → informed decision-making

Two Strategies:



Source: Wageningen University

Barriers to Adaptation

- Natural: crop tolerance to water-logging or high temperatures, …
- Financial: costs, benefit, risk, …
- Physical: infrastructure, technology, …
- Human: skills, education level, health, …
- Social: legal system, acceptance of technology, political system, …

METHODS, TOOLS AND MODELS FOR V&A ASSESSMENT IN AGRICULTURE

Methods, Tools, and Datasets

1. The framework
2. The choice of the research methods and tools depends on:
   - Demand-driven methods: responding to stakeholders
   - Key characteristics, strengths, weaknesses
   - Common sense
   - Experiments
   - Scenarios
   - Models
3. Datasets:
   - Sources
   - Scales
   - Reliability

Spatial and System Scales Linking Crop Production to Food Security

Spatial Scales

System Scales

Field	Farm	Region	National	Global
Crop	**Cropping System**	**Farming System**	**Food Supply**	**Food Security**

Natural Resource Base

Agronomic & Farm Practice

Markets and Distribution

Macro-economics and Politics

Crop and soil science

Farm systems research

Economics and policy research

Levels

- Field:
  a) Environmental and management conditions
  b) Demonstration
- Farm:
  a) Impact of new management
  b) Policy intervention measures
- Regional/national:
  a) information on local water demand and supply
  b) Planning tool
  c) Land-use change
- Global:
  a) Trade/World Trade Organisation (WTO)

Models

- Field: crop models
- Farm: farm household models (integration biophysical and economic models)
- Regional/national: land-use models, farm models
- Global trade: economic models

INTRODUCTION TO PROCESS-BASED CROP MODELS

Crop Models

Based on

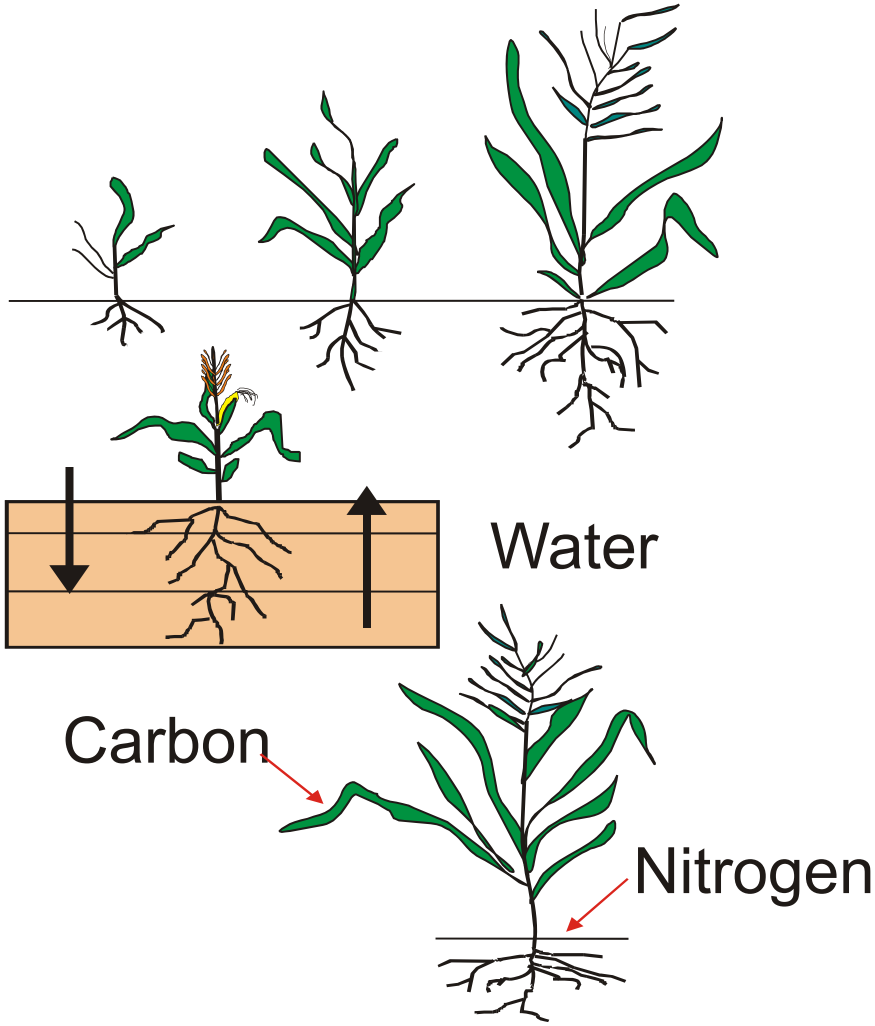
Understanding of plants, soil, weather, management

Calculate

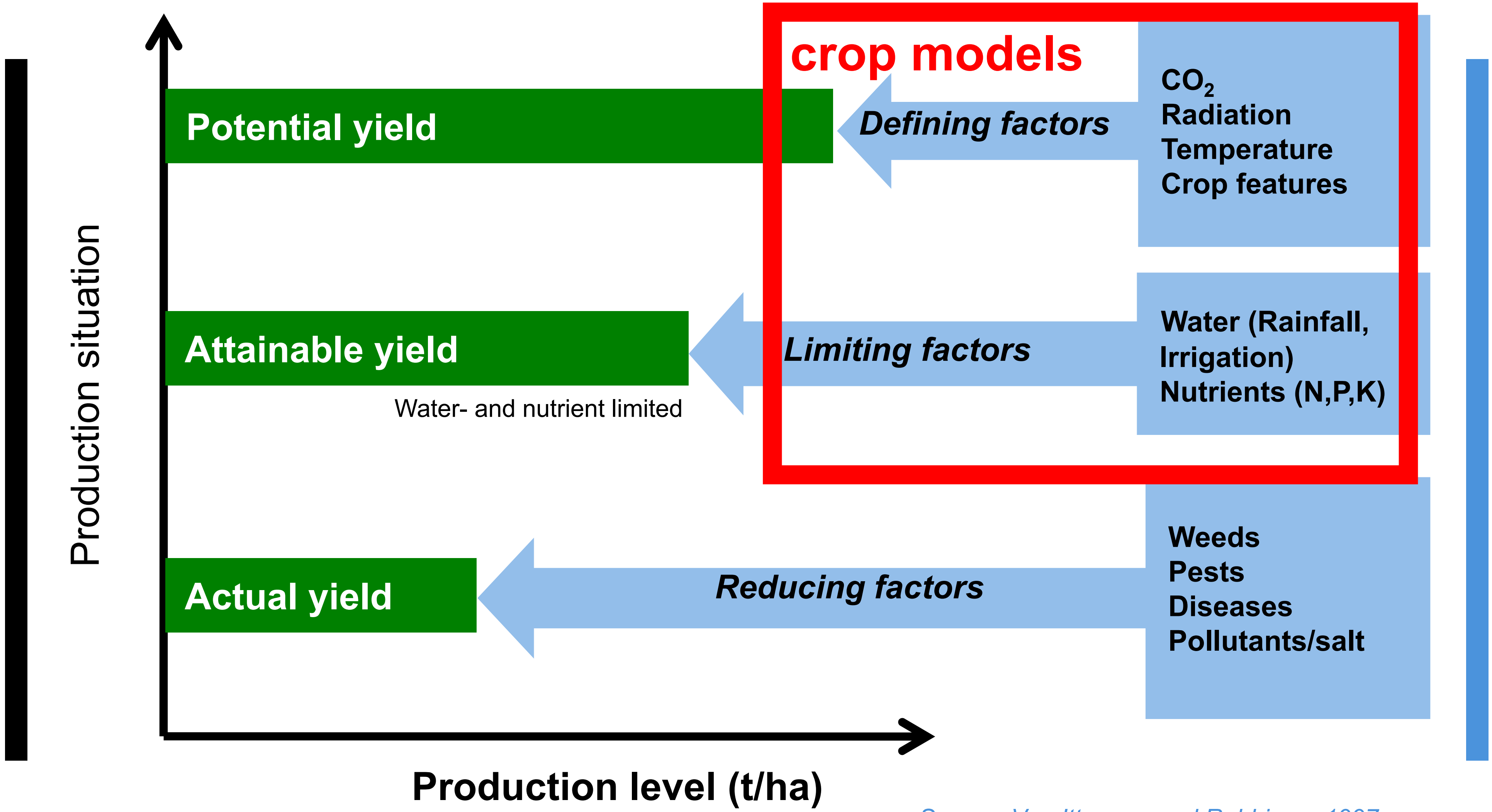
Growth, yield, fertilizer and water requirements, etc

Require

Information (inputs): weather, management, etc

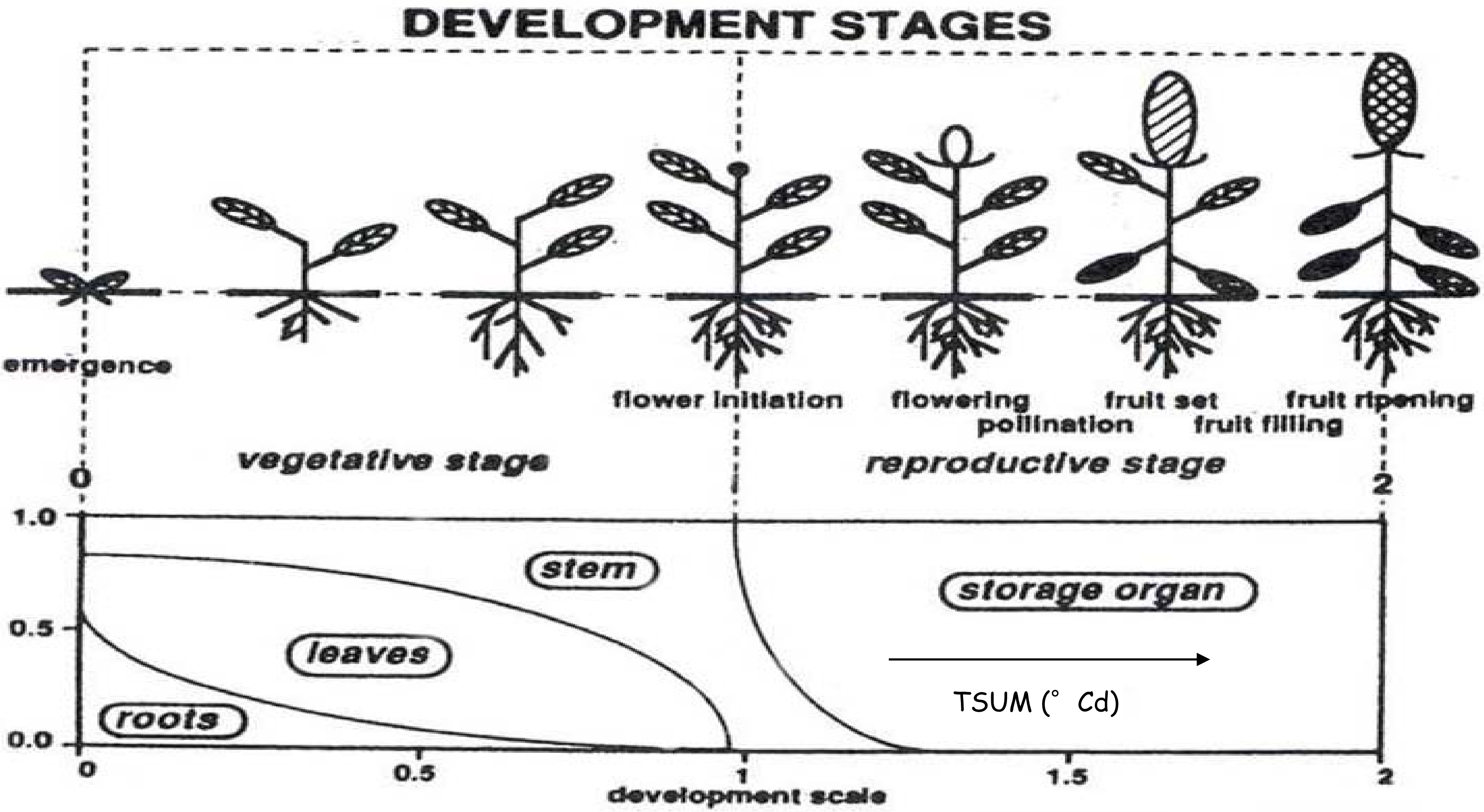


Production: Ecological Principles of Yield Levels



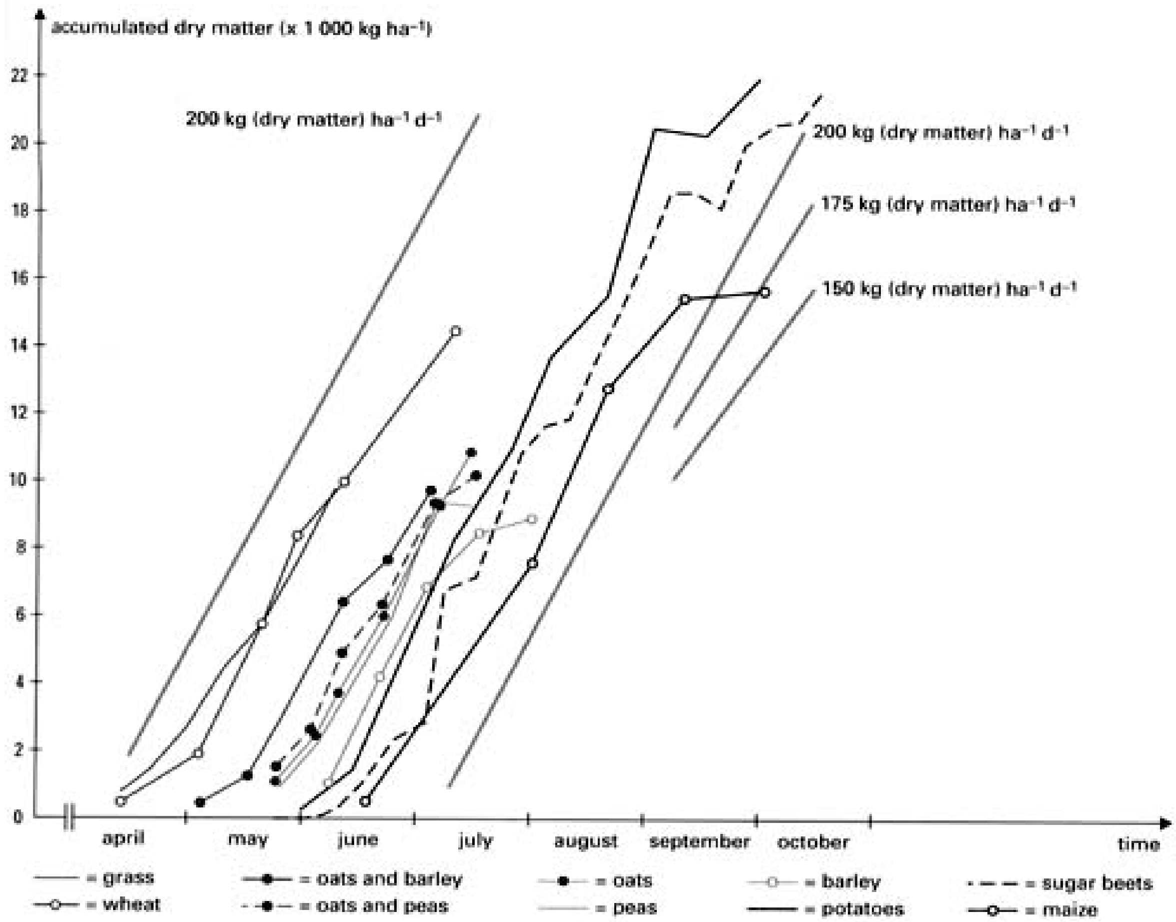
Source: Van Ittersum and Rabbinge, 1997

Crop Development Stages



Source: Lövenstein, et al., 1995

Optimal growth rates

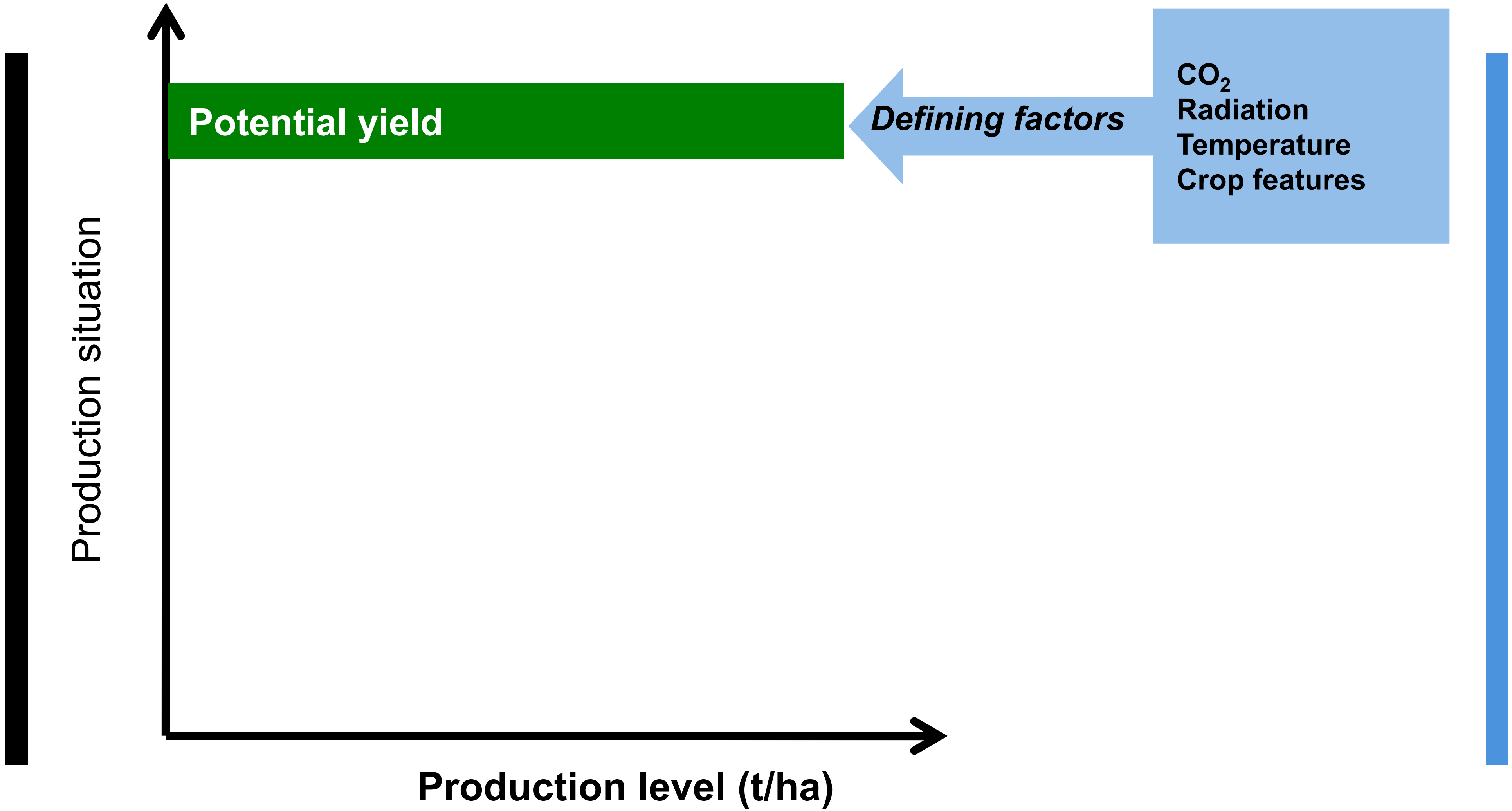


Growth rates of the main agricultural crops in the Netherlands under (near)-optimal growth conditions, compared to growth rates of 200, 175 and 150 kg (dry matter) ha^{-1} d^{-1}

(Source: Sibma, 1968)

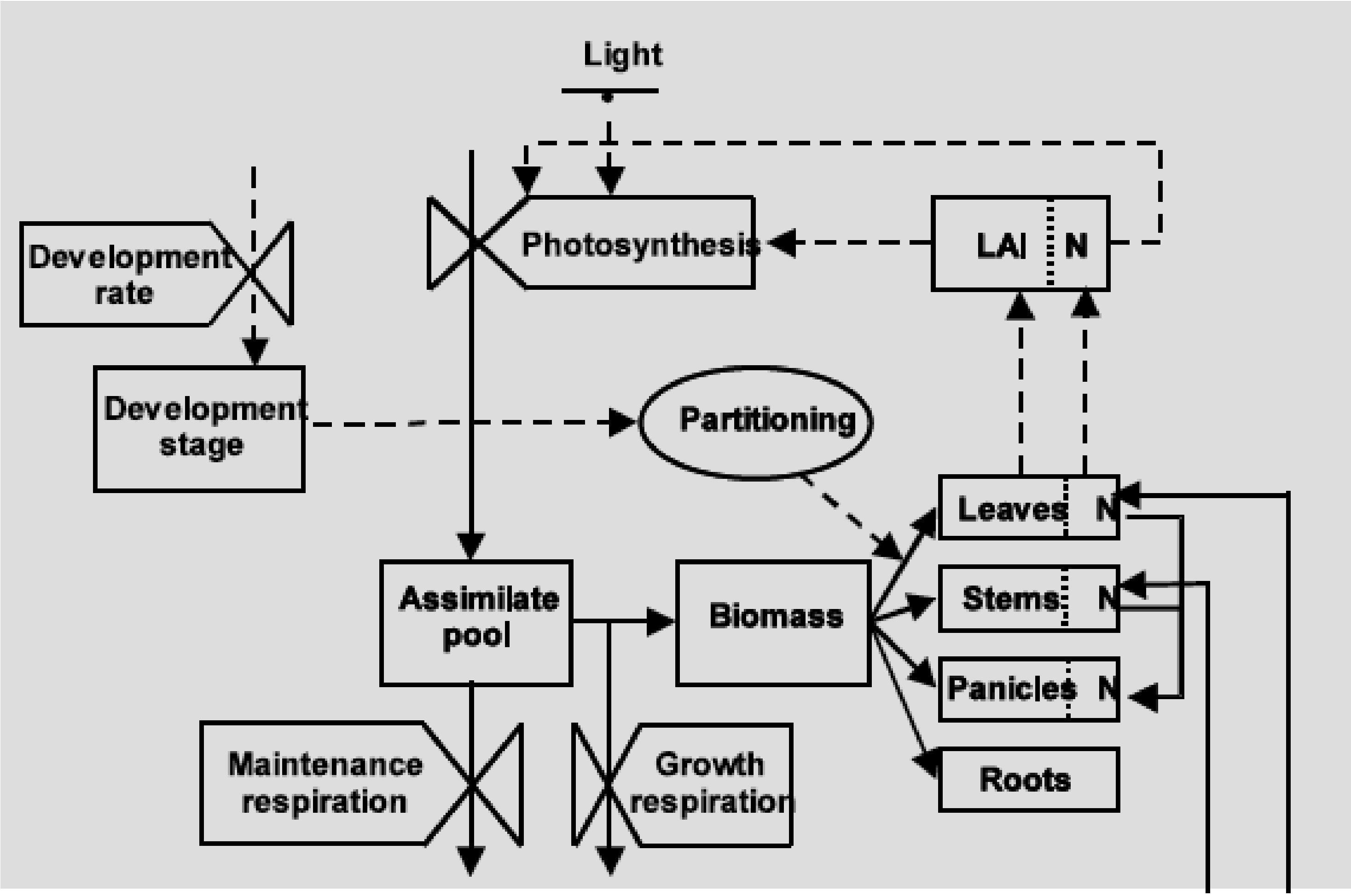
Source: Sibma, L., 1968

Production: Ecological Principles of Yield Levels (continued)



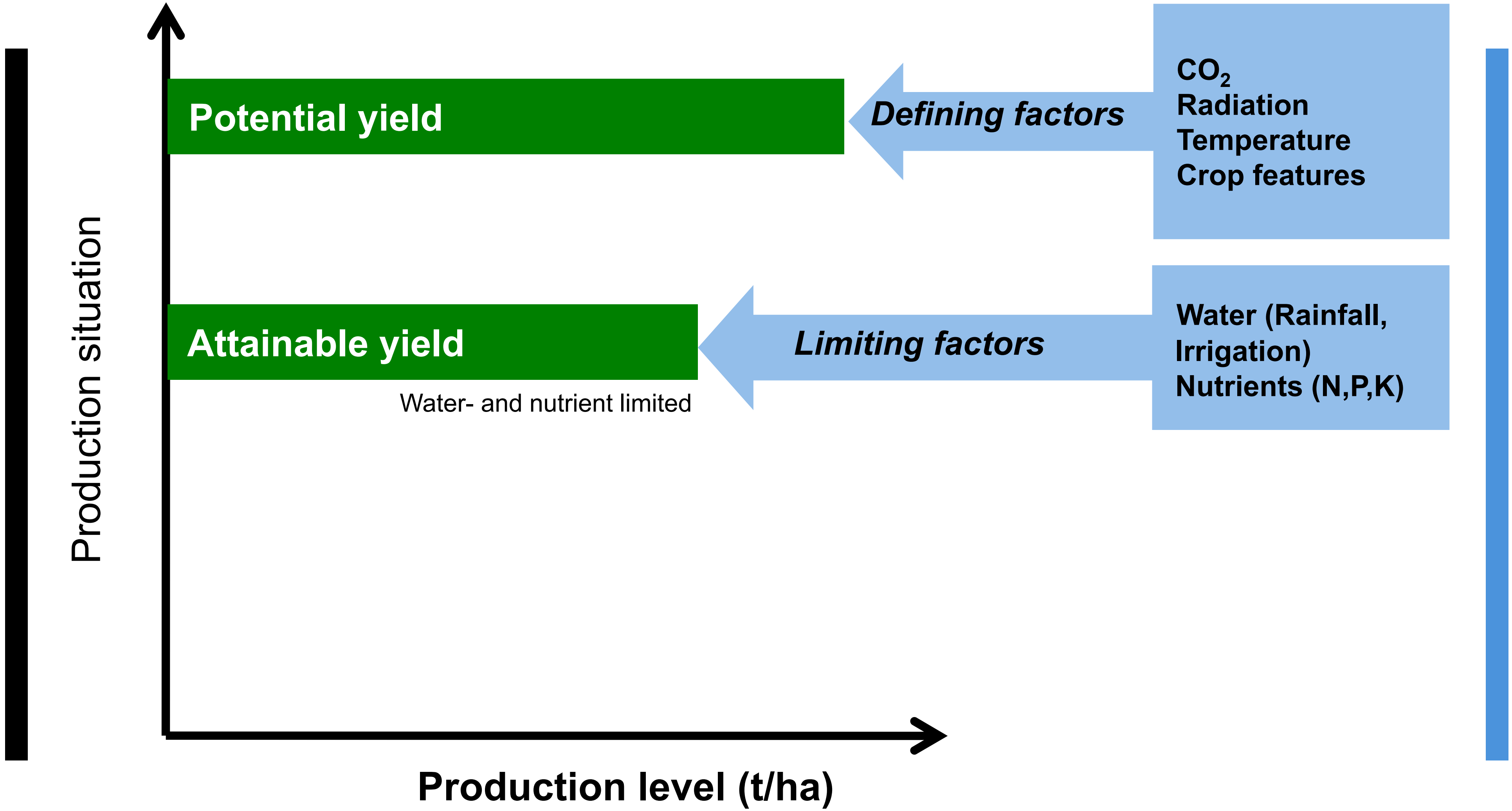
Source: Van Ittersum and Rabbinge, 1997

Potential Production



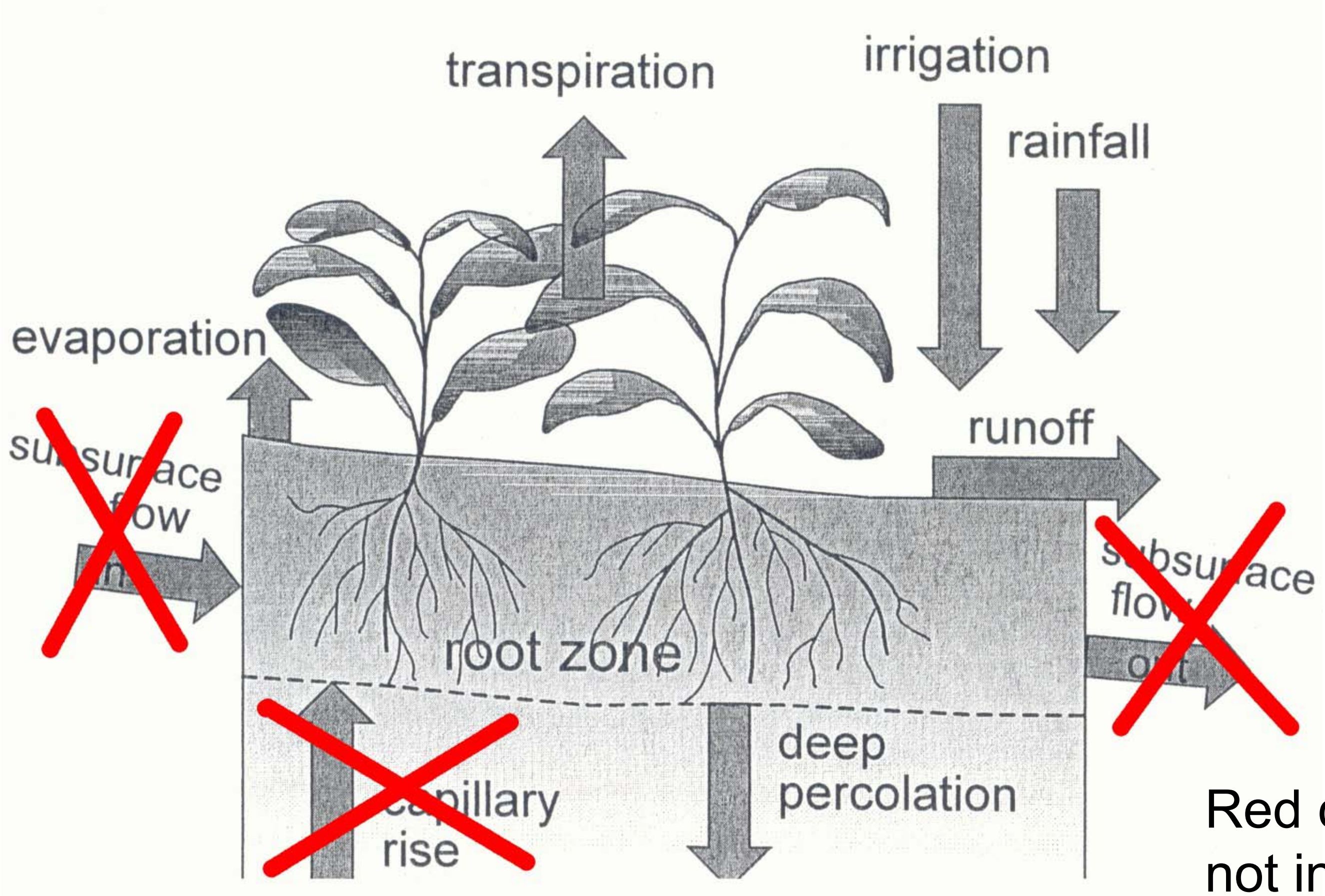
Source: van Ittersum, et al., 2003

Production Ecological Principles of Yield Levels



Source: Van Ittersum and Rabbinge, 1997

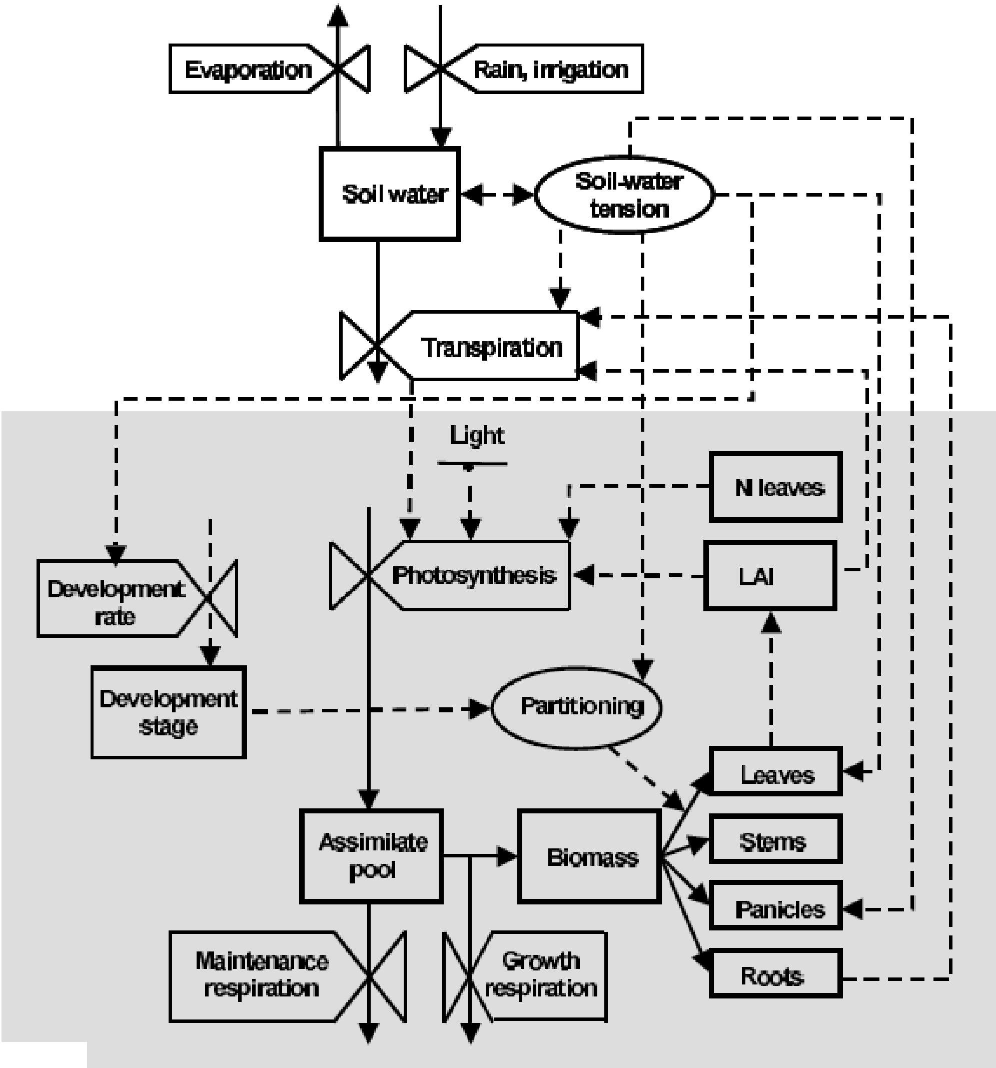
Soil Water Balance Terms: Root Zone



Red crosses:
not in LINTUL2

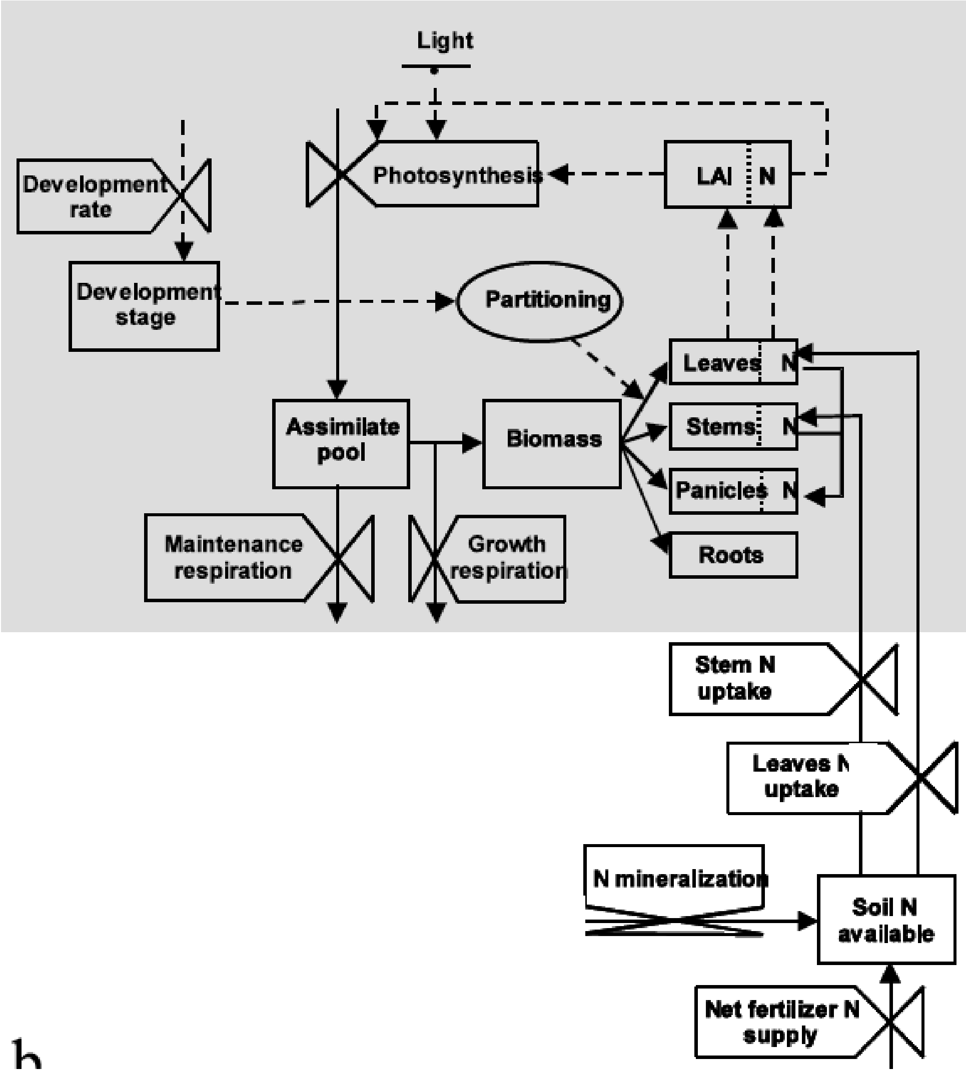
Source: Allen, et. Al., 1998

Water Limited



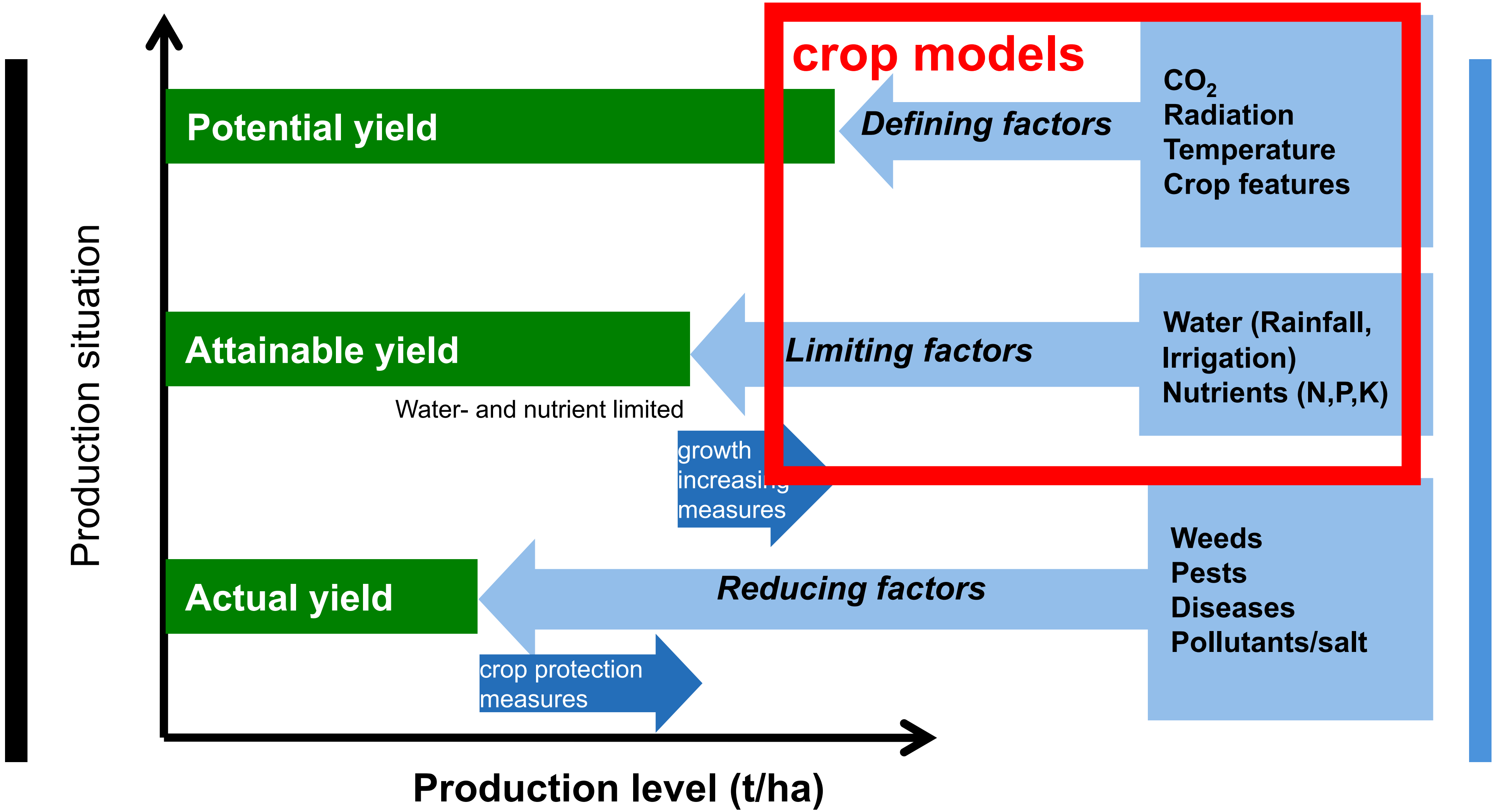
Source: van Ittersum, M.K., et al., 2003

Nutrient Limited



Source: van Ittersum, M.K., et al., 2003

Management is the Most Important Factor



Source: van Ittersum and Rabbinge, 1997

Simple Calculations (wheat) (after van Keulen; Driessen)

- Growing season 90 days, with a grain filling period of 30 days.
  a) Given a growth rate of 200 kg DM/day/ha potential yield is 6000 kg/ha:
     - Note process is temperature-driven, so higher temperatures would reduce the season (i.e. grain filling period) and hence the potential production.
- Assume 500 mm rainfall only 250 mm is transpired by the crop.
  a) So 2,500,000 mm^3/ha is used by the crop, assuming a WUE of 200 (kg water/ kg DM) a total biomass production of 12500 kg DM is produced.
     - For wheat, assume belowground (roots) to be 15% of total biomass. Above ground biomass is then 10,625.
     - With an Harvest Index (weight ratio of harvested product of total above ground plant) of 0.4 a grain yield of 4250 kg/ha can be achieved.

  b) 500 mm is semi-arid, in an area with 800 mm rainfall and 50% is used by the crop.
     - Thus 400 mm would result in yields of 6800 kg/ha, if 60% or 480 mm is used yield could go up to 8160 kg/ha.

Simple calculations (wheat) (after van Keulen; Driessen)

- Nitrogen (N) from soil organic matter:
  a) With a top soil of 15 cm and a bulk density of 1500 kg soil/m^3 for an hectare you have 2,250,000 kg soil. With an organic matter content of 1% you have 22,500 kg organic matter. Assuming that organic matter contains 58% organic carbon (C) we get 13051 kg organic C for the topsoil per hectare.
  b) Assuming a C/N ratio of 10, we have 1305 kg N.
  c) With a decomposition rate of 2% per year we have an N released of 26.1 kg.
  d) Assuming that for each 55 kg grain (wheat) 1 kg N is required we can reach a nutrient-limited production of 1435 kg/ha.
  e) Note that 1% soil organic matter is low, assuming 2% we would be able to get yields of 2870 kg/ha.
  f) All numbers have ranges and can be determined/measured.

Models – Advantages

- Models are assisting tools; stakeholder interaction is essential
- Models allow us to ask "what if" questions, the relative benefit of alternative management can be highlighted:

  a) Improve planning and decision-making

  b) Assist in applying lessons learned to policy issues
- Models permit integration across scales, sectors, and users.

Models – Limitations

- Models need to be calibrated and validated to represent reality
- Models need data and technical expertise
- Models alone do not provide an answer; stakeholder interaction is essential.

Crop Models

	Value
Spatial scale of results	Daily to centuries
Time to conduct analysis	Site to region
Data needs	4 to 5
Skill or training required	5
Technological resources	4 to 5
Financial resources	4 to 5
Range for ranking: is 1 (least amount) to 5 (most demanding).	

Examples: CROPWAT, CERES, SOYGRO, APSIM, WOFOST, etc.

Conclusions

- Common sense is important when using models
- If possible, go back to basics and also use “cigar box” calculations
- Crop models do not calculate actual production levels.

HOW CAN WE ESTIMATE CROP PRODUCTION FUNCTIONS?

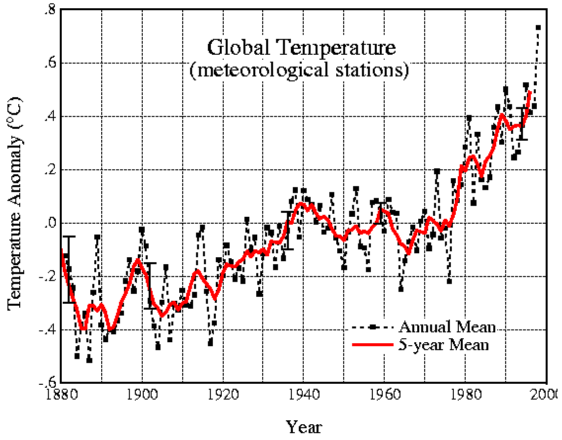
Outline

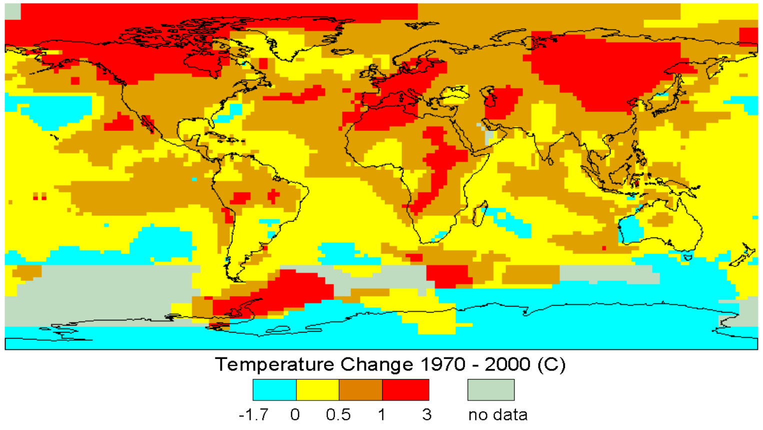
- Data issues
- Selection of variables: specification of the model
- Selection of the specific functional relationship: estimation
- Diagnosis of the results: validation of the model

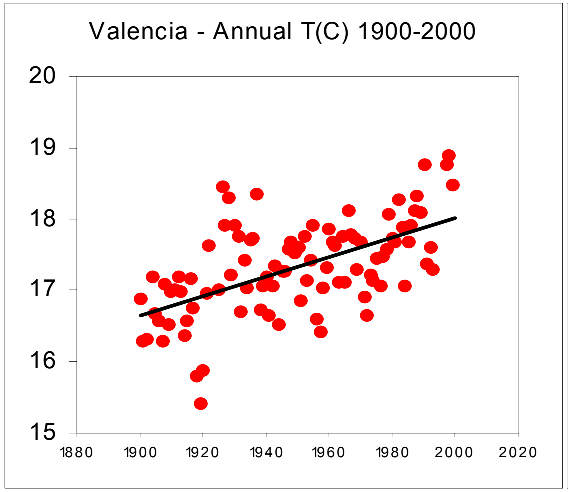
Datasets

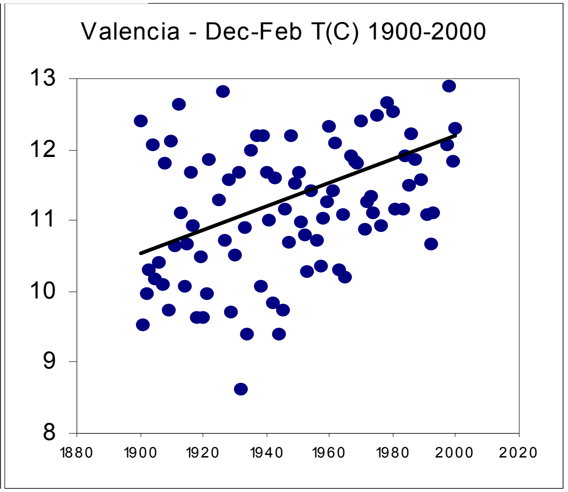
- A set of observed or simulated data representing the variables we want to analyse
- Types of datasets: time series, cross-section
- data, panel data, spatial data
- Data are required data to define climatic, nonclimatic environmental and socioeconomic baselines and scenarios
- Data are limited
- Discussion on supporting databases and data sources

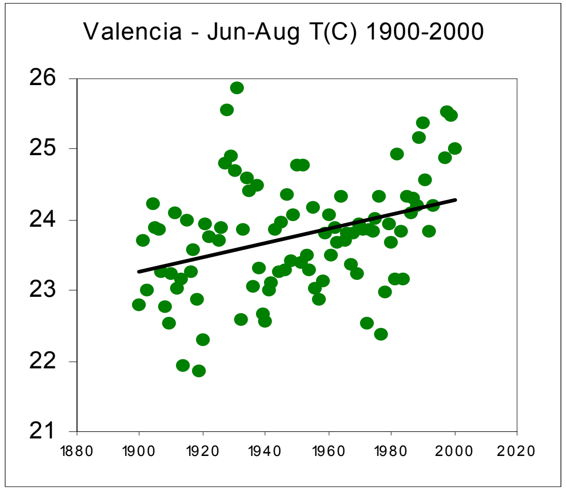
IPCC Working Group 1: “A Collective Picture of a Warming World”





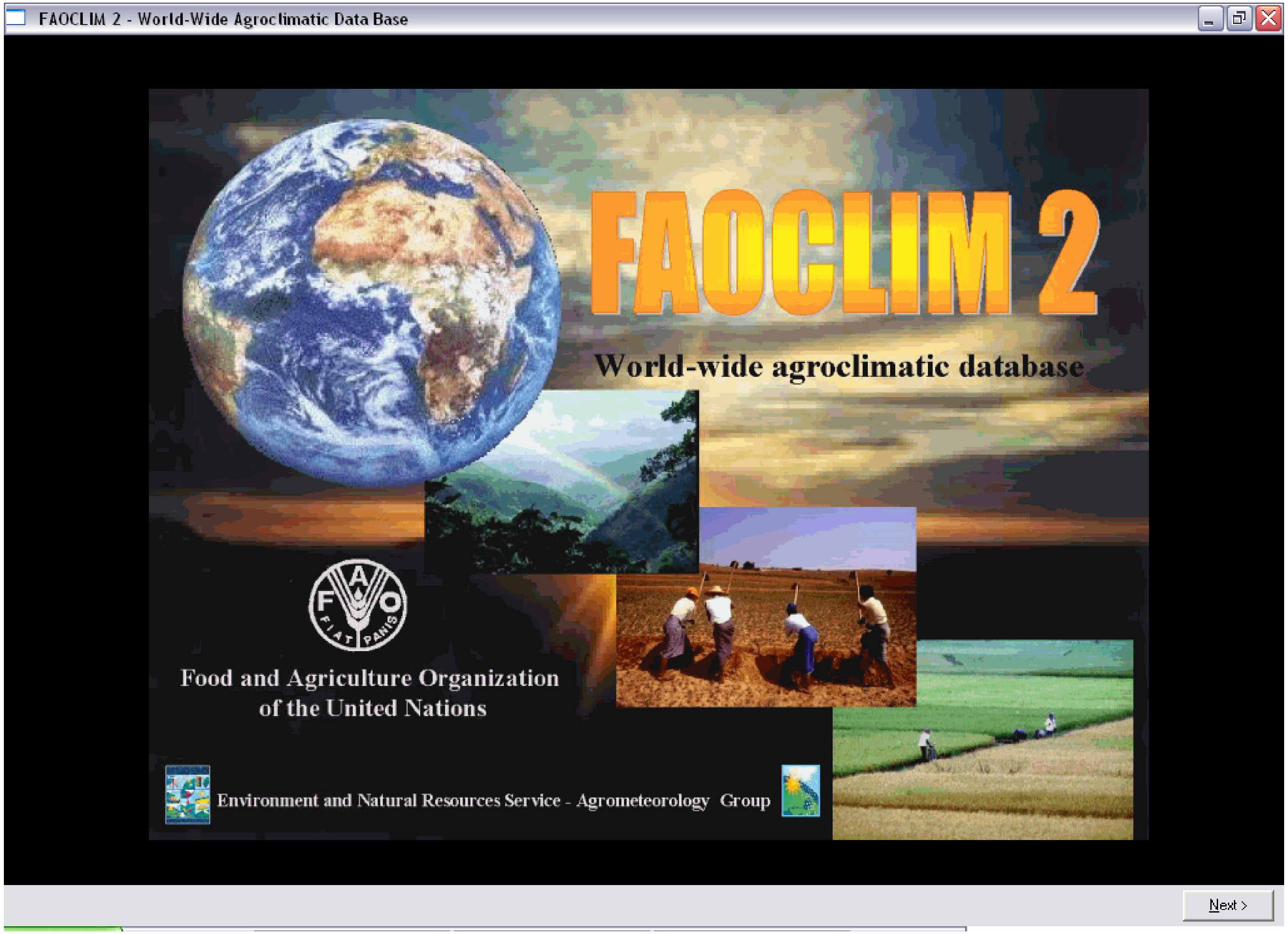






Source of data: GISS/NASA

FAOCLIM


FAOCLIM 2 - World-Wide Agroclimatic Data Base
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World-wide agroclimatic database
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Food and Agriculture Organization
of the United Nations
Environment and Natural Resources Service - Agrometeorology Group
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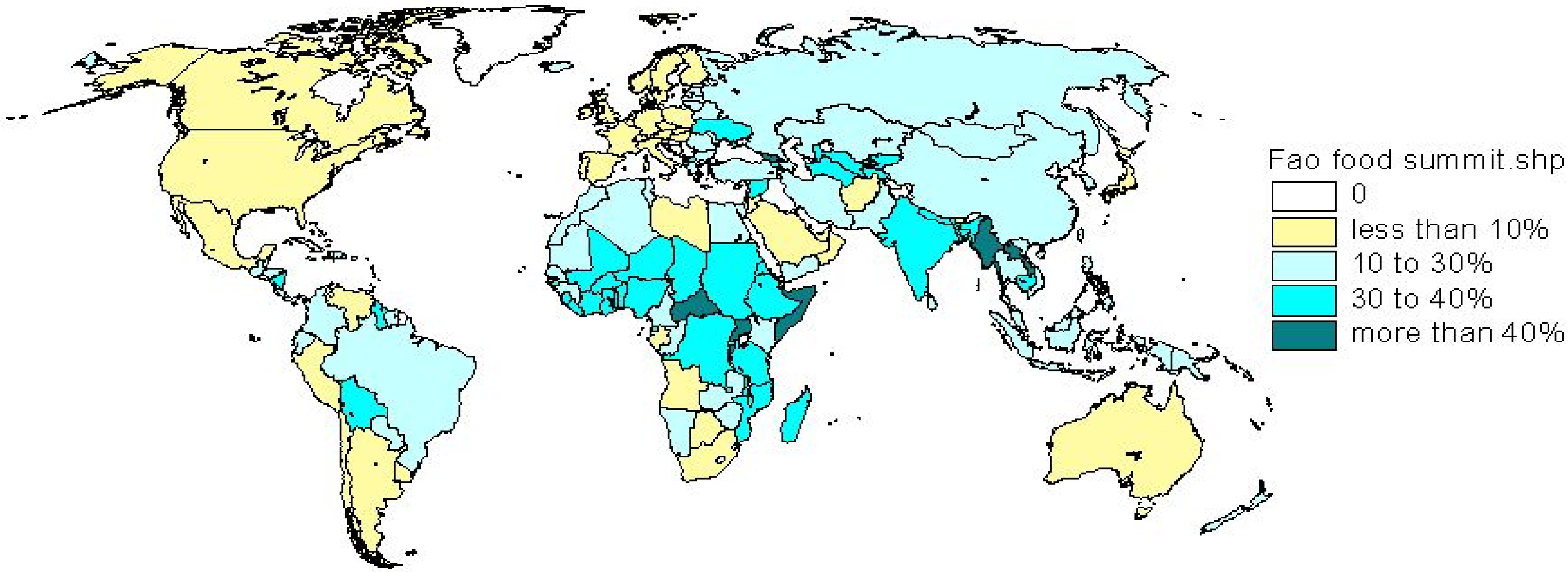
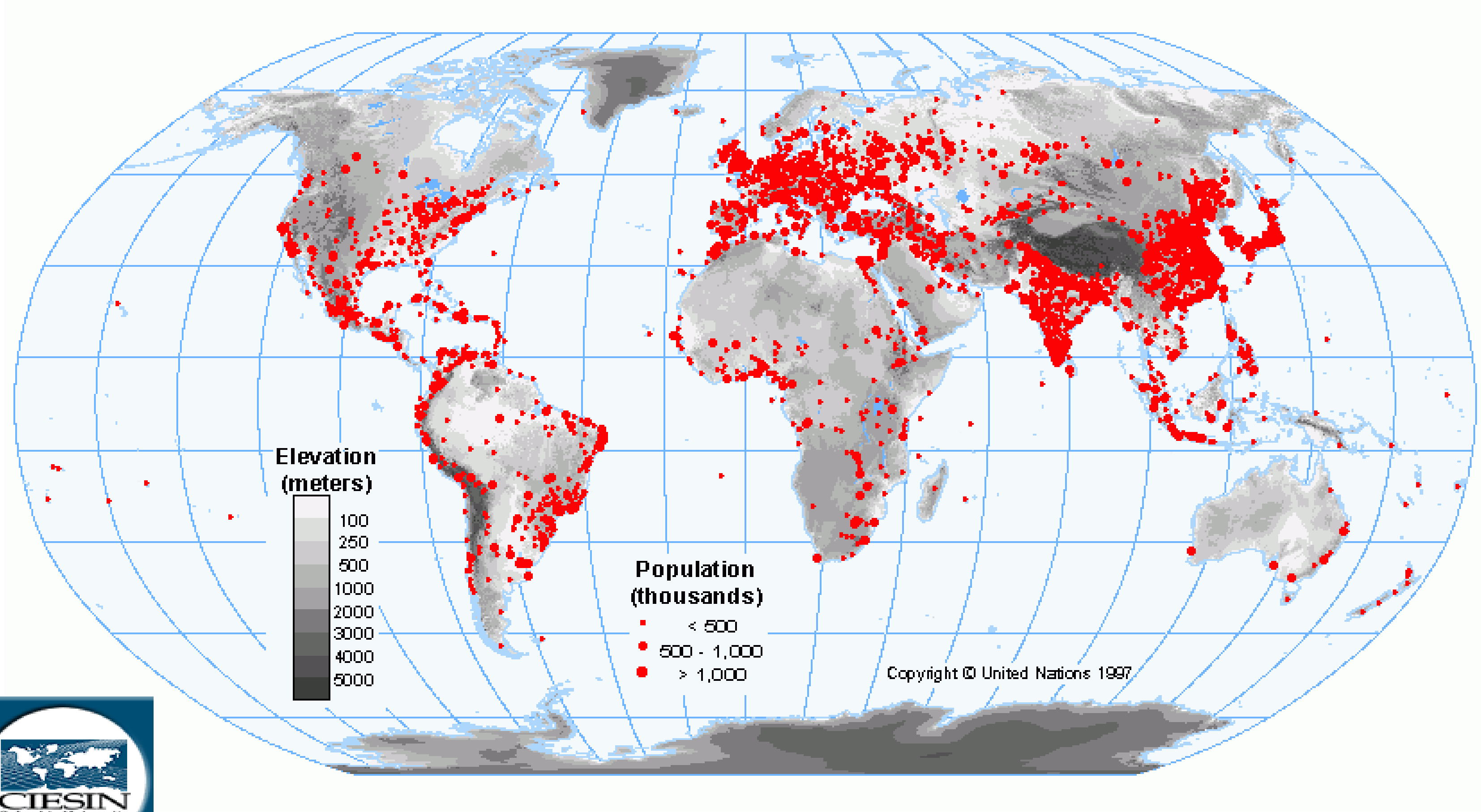
FAO and the World Bank

Agricultural GDP as share of total GDP

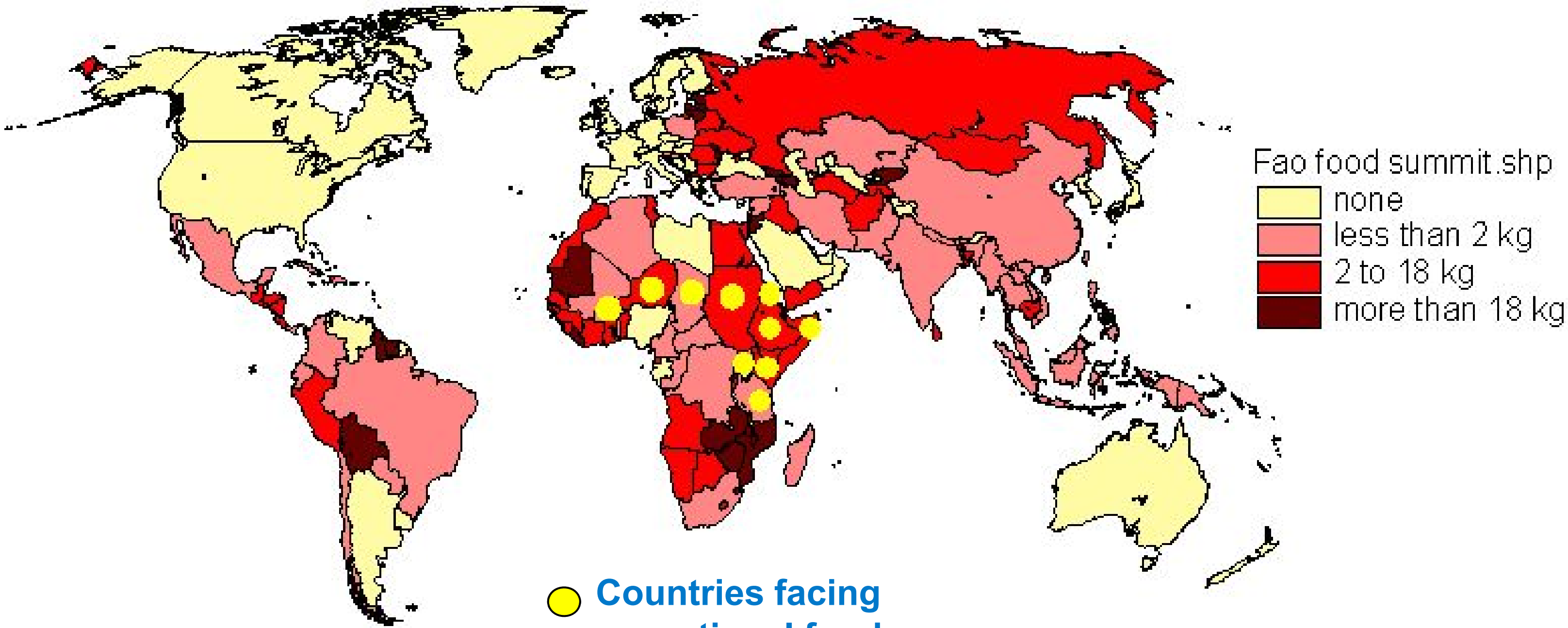


Population


Elevation
(meters)
100
250
500
1000
2000
3000
4000
5000
Population
(thousands)
< 500
500 - 1,000
> 1,000
Copyright © United Nations 1997

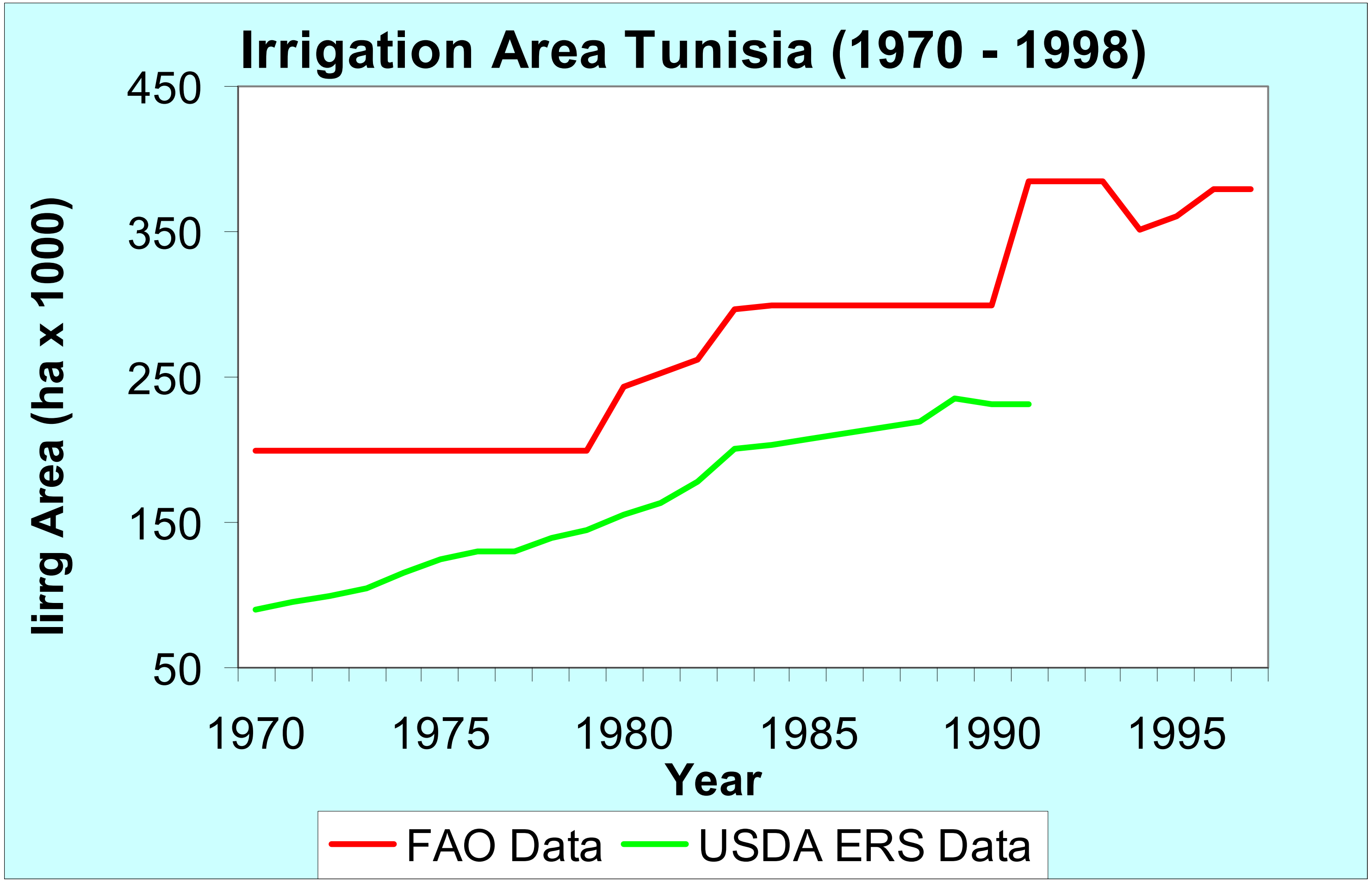

CIESIN
Columbia University

Food aid received from external sources 2000



Countries facing exceptional food emergencies due to the drought August 2001

Data: Scales, Sources, Reliability



Selection of Variables

Economic

Water

Management

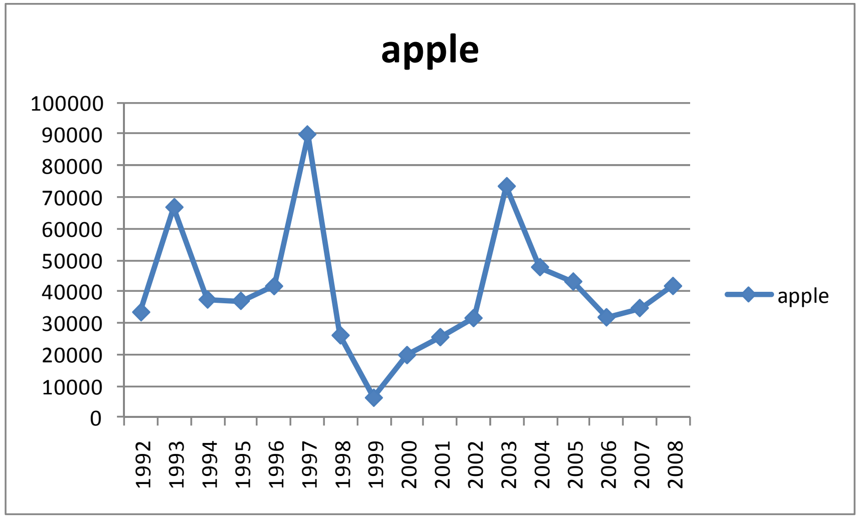
Geographic

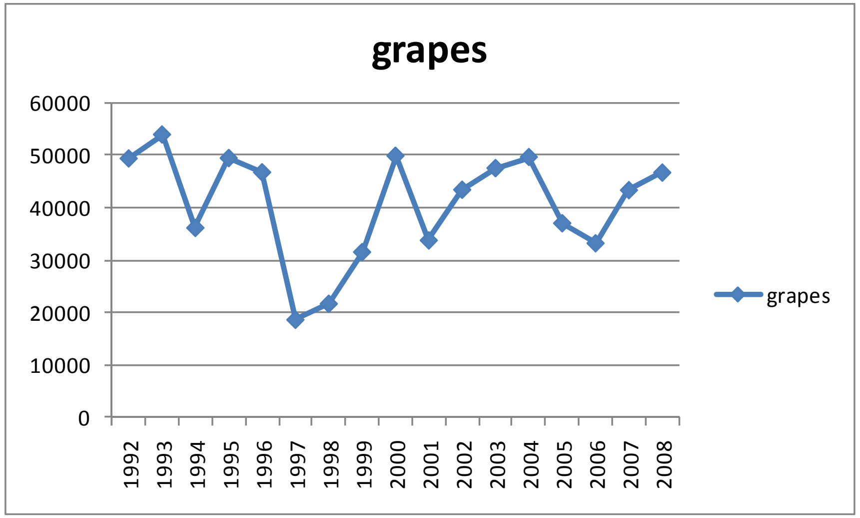
Climate

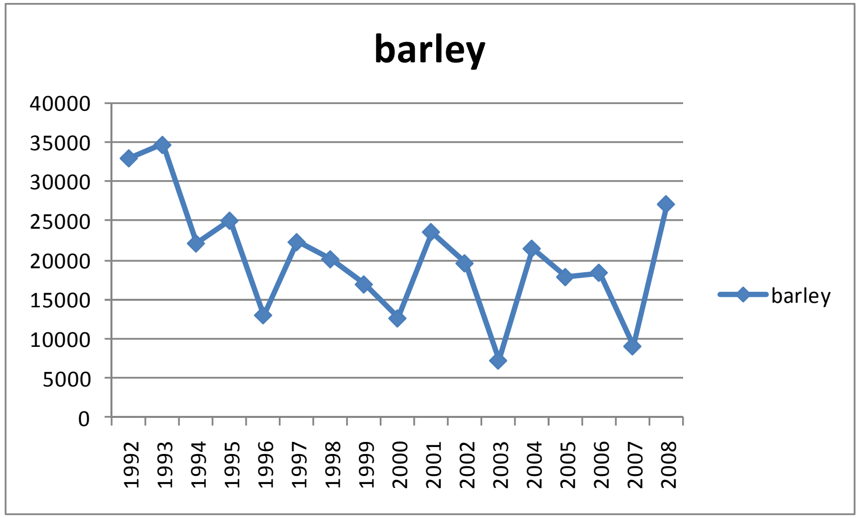
Type of variable	Name	Definition	Unit	Source of Data
Economic	Y_t	Crop yield at a site in year t	T/ha	MARM
	GAV_t	Gross added value of agriculture a site in year t	K€ current prices	MARM and INE
	L_t	Total employment of agricultural sector at a site in year t	1000 People	Labour Force Survey (LFS). INE
	P_t	Farm product price index	Base year: 2000=100	INE
Water	$Irrig_{it}$	Net water needs of crops in the ith month in year t	mm / month	Planning Hydrographic Office - CHEBRO
	$Prec_{it}$	Total precipitation in the ith month/ 3 month period in year t	mm / month	AEMET
Managment	Mac_t	Machinery in year t	Nº	FAO
Geographic	T_t	Irrigated area by crop type	ha	MARM
	$Altitude_t$	Dummy variables indicating 0-600, 601-1000 and more than 1000 meters		INE
	$Area\_ebro_t$	Dummy variables indicating the 3 main areas of the basin: Northern, Central and Low Ebro		
Climate	T_Max_{it}	Maximum temperature in the ith month / 3 month period in year t	° C	AEMET
	T_Mean_{it}	Average temperature in the ith month / 3 month period in year t	° C	AEMET
	Fr_{it}	No. of days with temperatures below 0° C in the ith month/ 3 month period in year t		AEMET

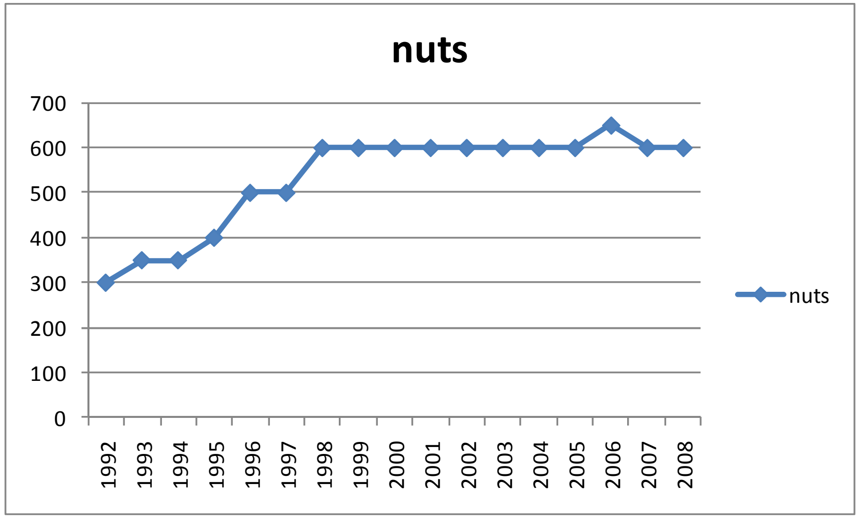
Source: Quiroga, Iglesias, 2011

Moldova: Crop yields (1992-2008)



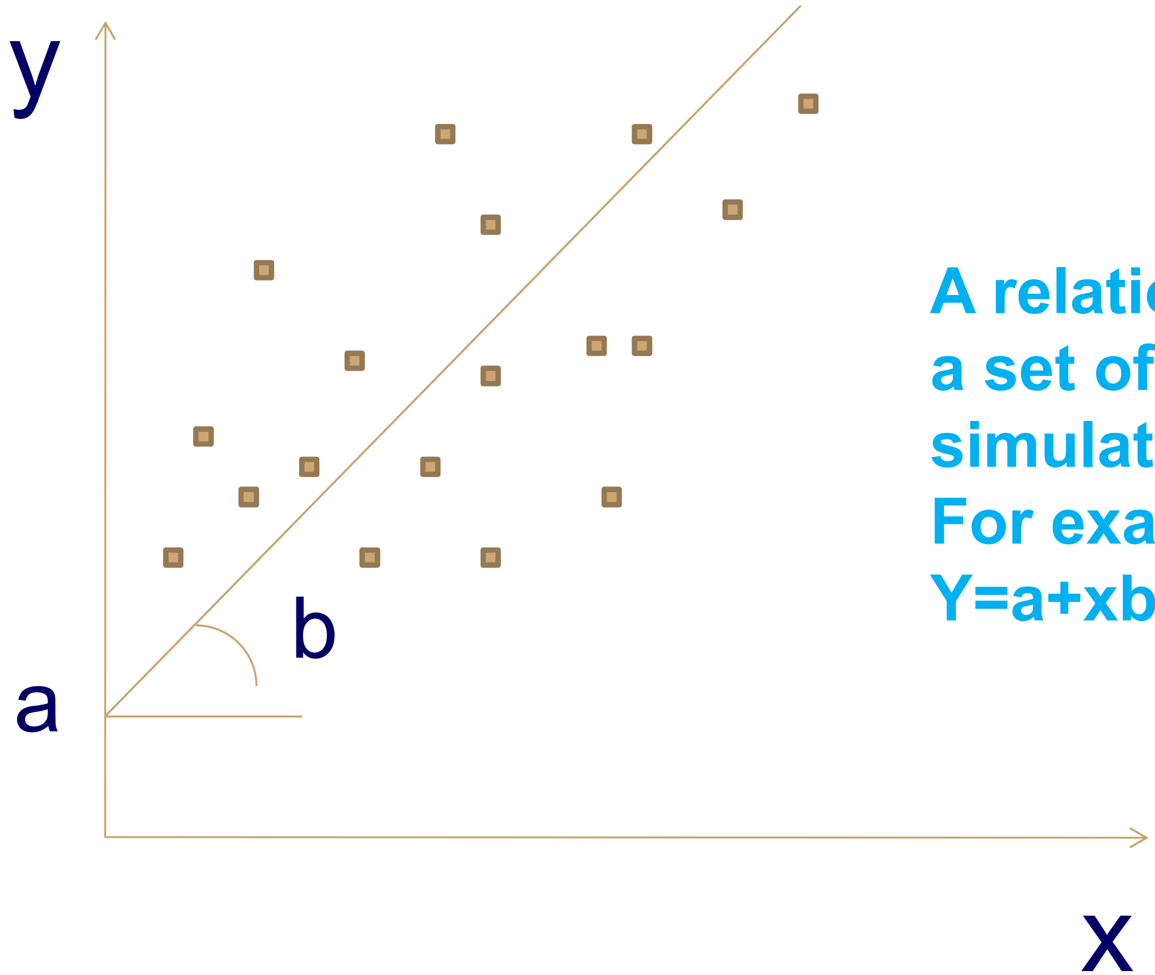






Source:FAO

What to Estimate…



A relationship between a set of observed or simulated dots(x,y)
For example:
Y=a+xb

Ordinary Least Squares

- Because squared values are always positive, we use the "ordinary least squares" method for the calculation
- To select “a” and “b” such that minimize the sum of squared residuals. This allow to avoid the compensation among positive and negative values
- We use specific software (E-views, R, STATA,SPSS,…)

Interpretation of the Estimation

$$Q_t = \alpha + \beta E_t + u_t$$

Dependent Variable: Q
Method: Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3.268859	0.123597	26.44769	0.0000
E	0.519333	0.138008	3.763072	0.0024

R-squared	0.521367	Mean dependent var	3.335333
Adjusted R-squared	0.484550	S.D. dependent var	0.659901
S.E. of regression	0.473775	F-statistic	14.16071
Sum squared resid	2.918019	Prob(F-statistic)	0.002368

Where Q= production; E=employment

Coefficients

- Each of the coefficients represent the effect of the explanatory variable on the dependent variable (Y).
- The estimated value for “b” indicates the variation that occurs on the dependent variable (Y) when the explanatory variable (X) vary in a unit and the rest remain constant.
- In the example on the previous slide: An increase of a unit in employment produces an increase of 0.52 units in production.

Practical Application

1. Estimating statistical functions of yield response for some crops in Spain
2. Evaluate climate change effects
3. Adaptation: Changes in management to improve yield under climate change

LOCAL CASE STUDY
Climate, technological and management variables

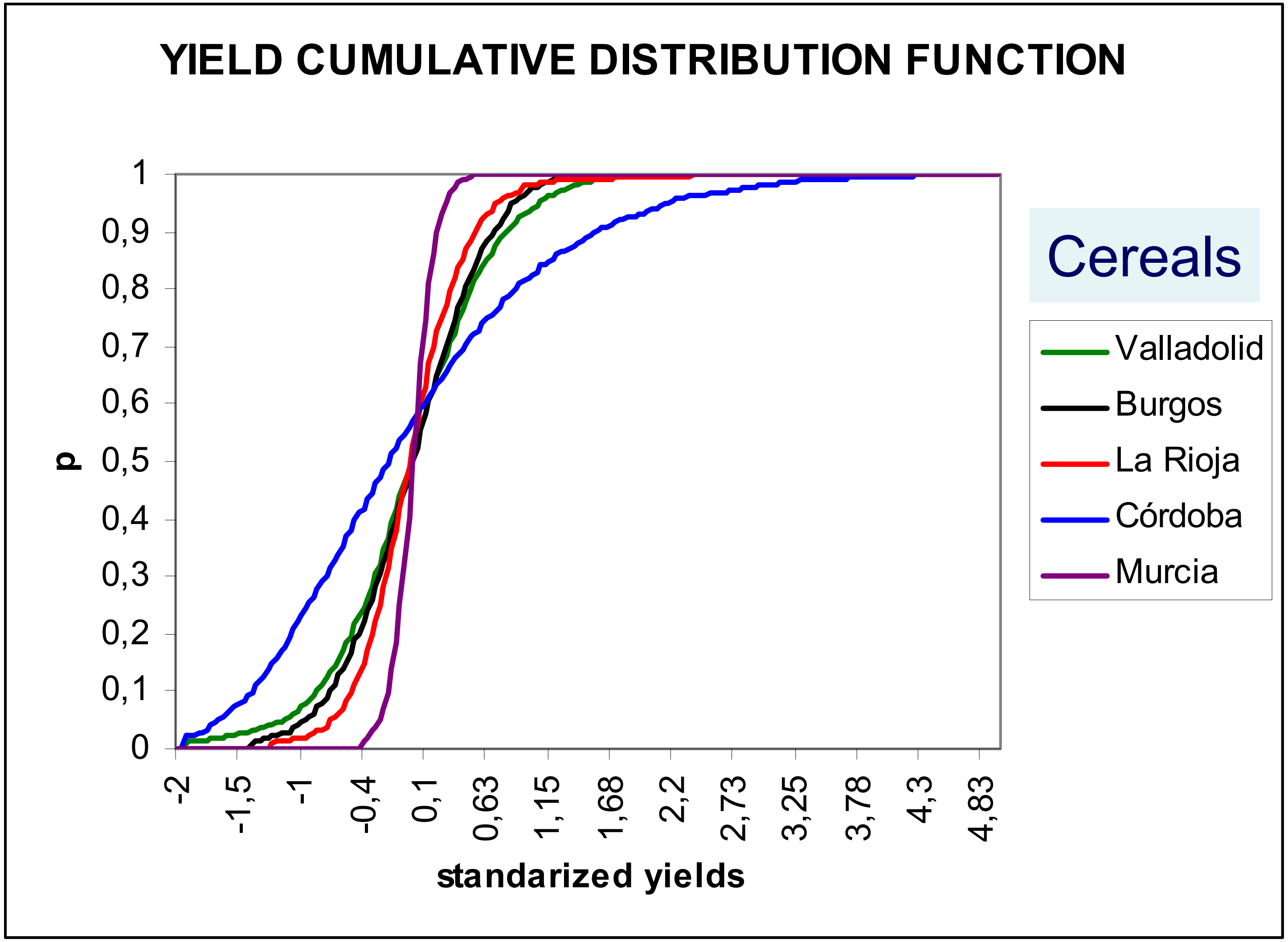
Crops	Sites for the analysis
Wheat	Burgos, Córdoba, Murcia & La Rioja
Grapes	Burgos, Córdoba, Murcia & La Rioja
Olive	Córdoba, Murcia & La Rioja
Orange	Valencia, Murcia & Córdoba
Barley	Valladolid

How Does Drought Affect Yield for Grapes?

Regression Model Estimation

Crop/Site		Grapes / Córdoba			Grapes / La Rioja	
		Estimation	P-value		Estimation	P-value
Variables	$\ln R_{t-1}$	0.2553	(0.0316)	Mac	0.0025	(0.0000)
	Tmeoct	-0.1162	(0.0000)	Tmedec	-0.0488	(0.0442)
	Tmedjf	0.0781	(0.0155)	Plutfeb	0.0055	(0.0263)
	Plutfeb	-0.0043	(0.0000)	Plutsep	-0.0022	(0.0496)
	Plutaug	0.0130	(0.0148)	Tmaxmay	0.0748	(0.0000)
	Dro	-0.2101	(0.0046)			
	Imp^{76}	-0.7094	(0.0005)			
Ljung-Box	Q_1	0.6293	(0.428)		0.2939	(0.588)
	Q_2	2.3256	(0.313)		0.3180	(0.853)
	Q_3	2.3476	(0.503)		0.7825	(0.854)
	Q_4	3.1141	(0.539)		0.8015	(0.938)
White test		0.6028	(0.8089)		1.3900	(0.2230)
R^2		0.84			0.73	

Estimating Climatic Risk



GENERAL EQUILIBRIUM MODELS

Market mechanisms: GTAP model

Computable General Equilibrium

- The market impact estimates and their associated direct economic effects are introduced into a **computable general equilibrium (CGE)** model, modelling individually most EU countries.
- This framework captures not only the direct effects of a particular climate impact but also the indirect effects in the rest of the economy.
- The CGE model ultimately translates the climate change scenarios into consumer welfare and GDP changes, compared to the baseline scenario without climate change.

General equilibrium theory

- General equilibrium theory is a branch of theoretical neoclassical economics.
- It seeks to **explain the behaviour of supply, demand and prices in a whole economy** with several or many markets, by seeking to prove that **equilibrium prices for goods exist and that all prices are at equilibrium**, hence general equilibrium, in contrast to partial equilibrium.
- As with all models, this is an **abstraction** from a real economy, but it is a useful model, both by considering **equilibrium prices as long-term prices**, and by considering actual prices as deviations from equilibrium.
- A CGE model is based on trade relationships between countries globally (this is a theoretical model based on economic theory).

Computable General Equilibrium Models: GTAP

- 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.

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

GTAP DATABASE

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

GTAP DATABASE

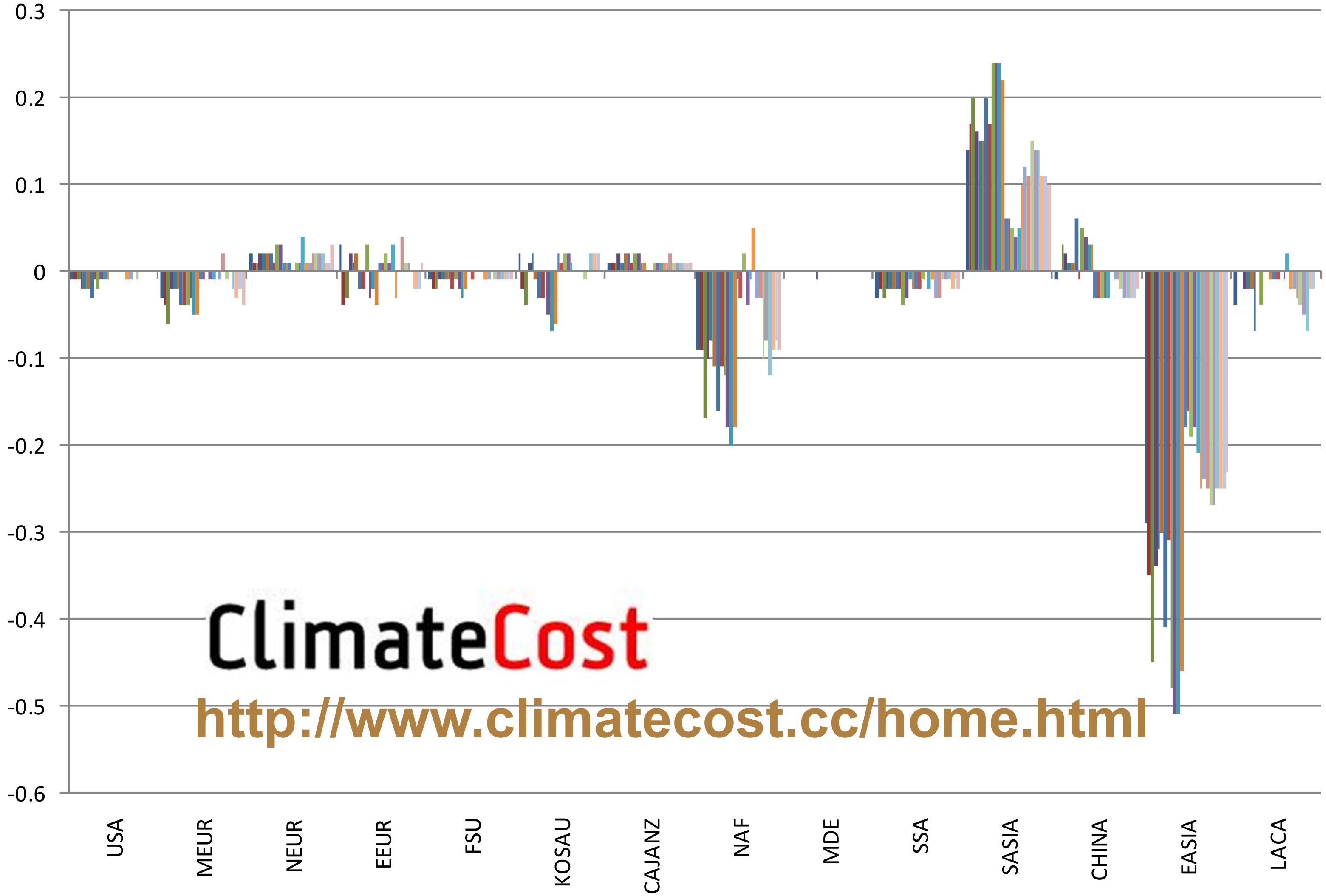
Old sector	New sector	Old sector description
1 pdr	1 Food	Paddy rice
2 wht	1 Food	Wheat
3 gro	1 Food	Cereal grains nec
4 v_f	1 Food	Vegetables, fruit, nuts
5 osd	1 Food	Oil seeds
6 c_b	1 Food	Sugar cane, sugar beet
7 pfb	1 Food	Plant-based fibers
8 ocr	1 Food	Crops nec
9 ctl	1 Food	Cattle,sheep,goats,horses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

Food represents agricultural sector

GTAP DATABASE

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

Climate-change Induced Changes in GDP % (US $ constant, 2004)



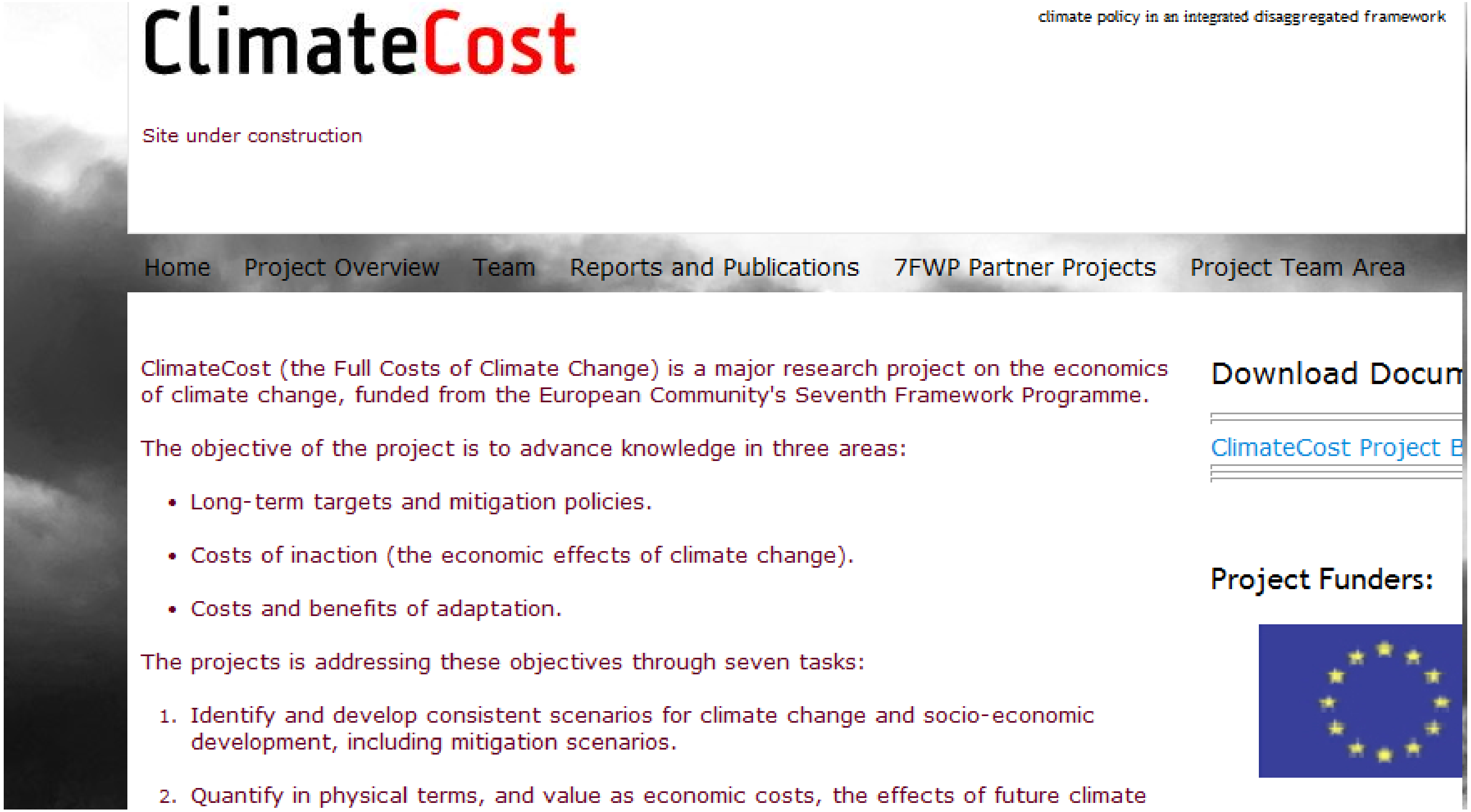
CHANGES IN LAND PRODUCTIVITY

Reasons for Concern

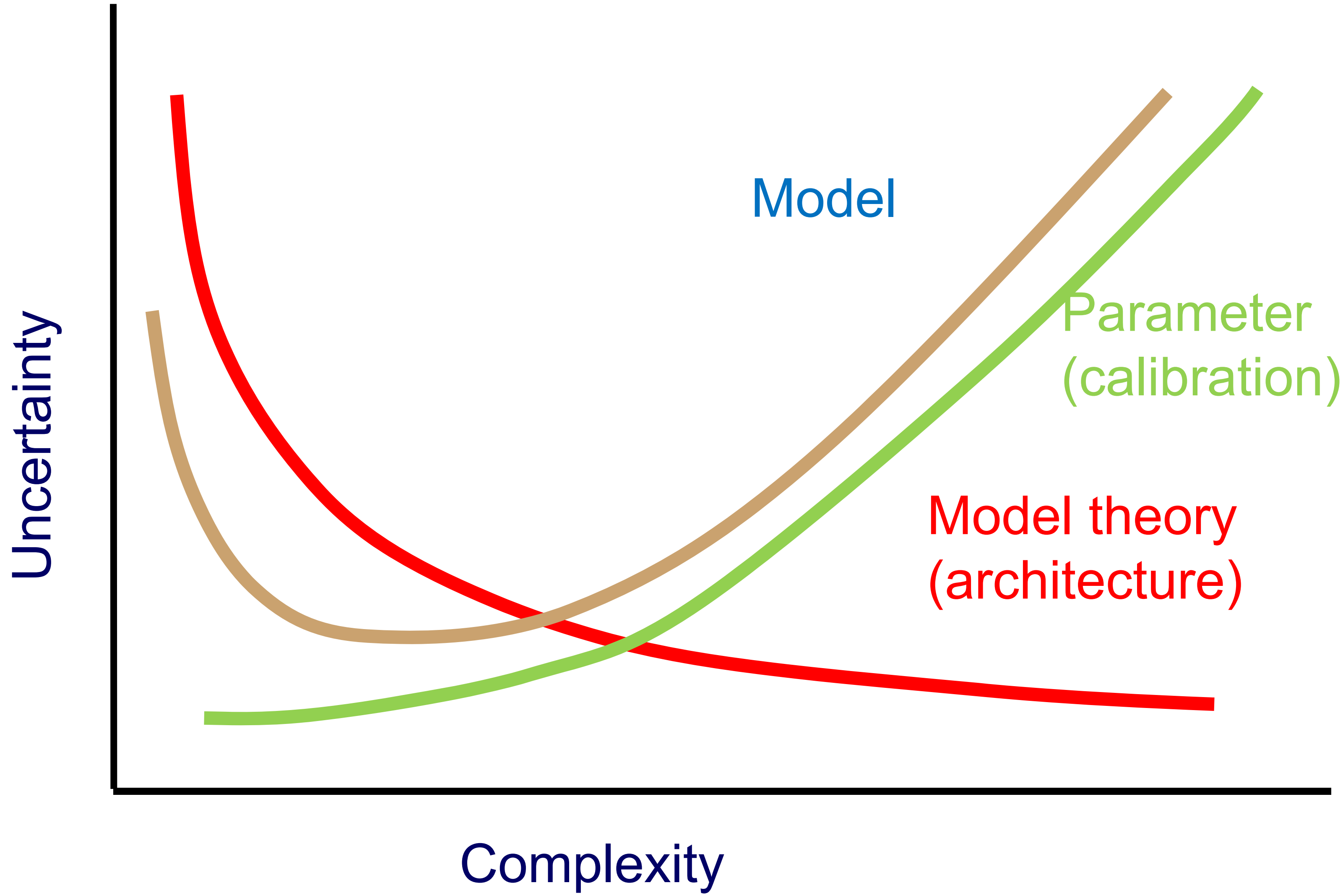
	Possible effect	Confidence level
Optimal location of crops (zones)	change	high
Crop productivity	change	high
Irrigation requirements	increase	high
Soil salinity and erosion	increase	medium
Damage by extremes	increase	medium
Environmental degradation	increase	medium
Pests and diseases	increase	medium

Source: Iglesias, et al., 2011

http://www.climatecost.cc/



Issues: Discount Rate, Sustainability and Uncertainty



ClimateCrop model

1 Agro-climatic regions
Output: Agro-climatic regions that include climate, farm types, irrigated areas, adaptive capacity

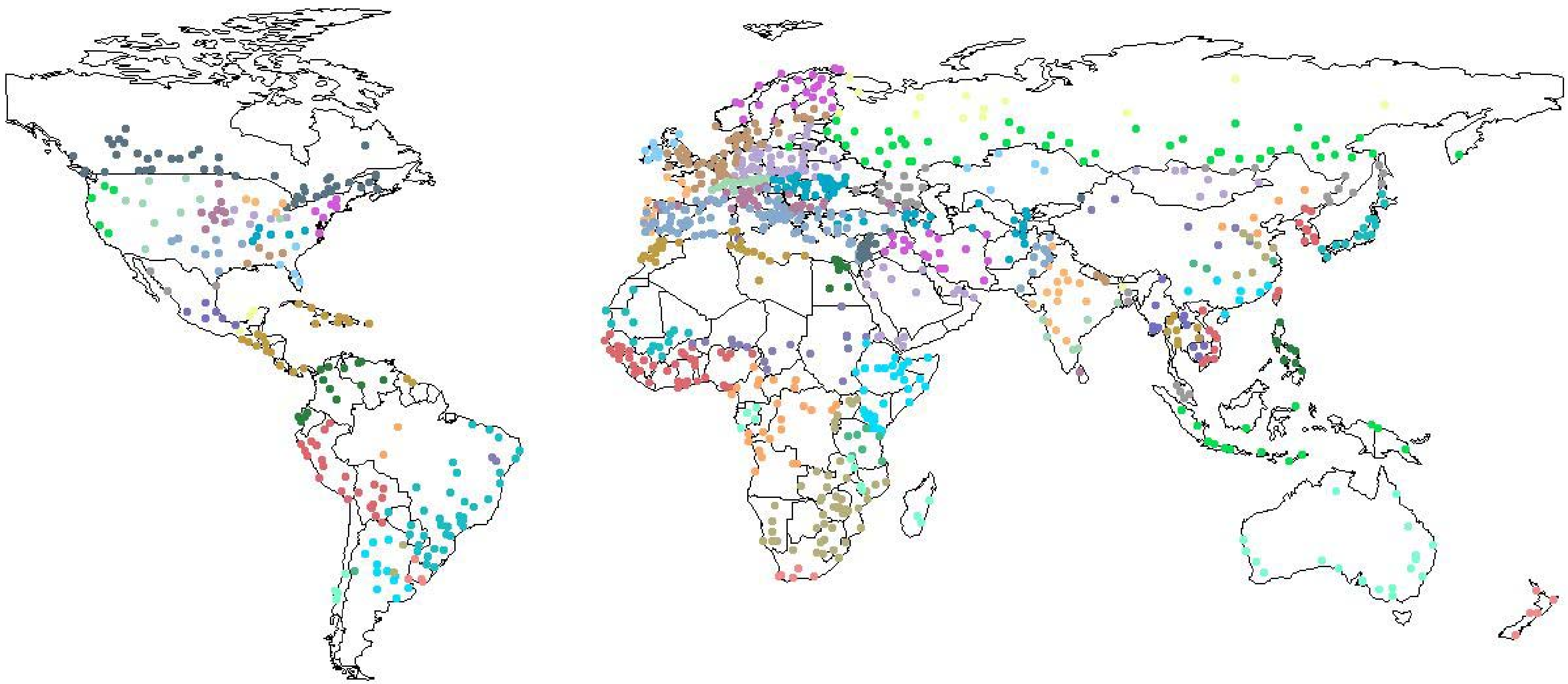
2 Crop models (DSSAT)
Output: Database of simulated crop responses to climate, environment, and adaptive management

3 Agricultural production functions
Output: Land productivity and water demand estimated functions

4 Climate change analysis
Output: Land productivity and water demand estimates responding to climate and farm adaptive management

5 Climate change policy analysis
Output: Land productivity and water demand estimates responding to climate and policy (environmental and energy)

Understanding Global Uncertainty, Land and Water (Iglesias et al., 2011)



Stations (1141) and agroclimatic zones (73)

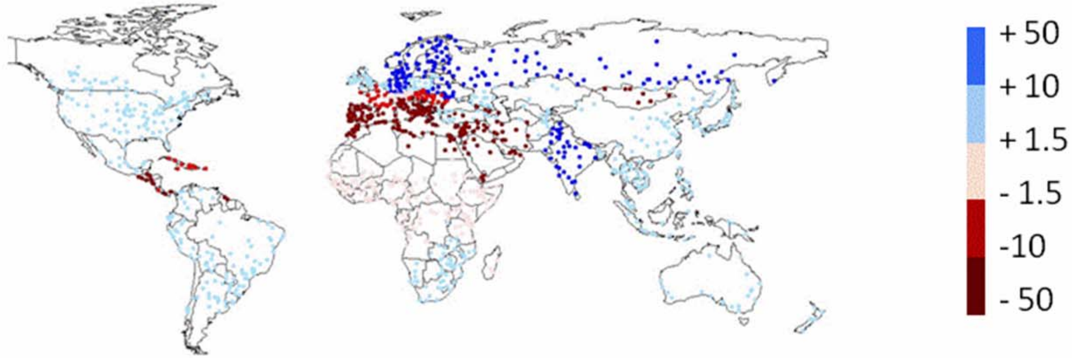
Climate Scenarios

Climate Scenarios	Name	Climate Scenarios	Name
A1B.BCM2_1_M.2080	A1B_1	E1.CNCM33_2_M.2080	E1_1
A1B.CNCM3_1_M.2080	A1B_2	E1.DMICM3_1_M.2080	E1_2
A1B.DMIEH5_4_M.2080	A1B_3	E1.DMICM3_2_M.2080	E1_3
A1B.EGMAM_1_M.2080	A1B_4	E1.EGMAM2_2_M.2080	E1_4
A1B.EGMAM_2_M.2080	A1B_5	E1.EGMAM2_3_M.2080	E1_5
A1B.EGMAM_3_M.2080	A1B_6	E1.HADCM3C_1_M.2080	E1_6
A1B.HADGEM_1_M.2080	A1B_7	E1.HADGEM2_1_M.2080	E1_7
A1B.INGVSX_1_M.2080	A1B_8	E1.INGVCE_1_M.2080	E1_8
A1B.IPCM4_1_M.2080	A1B_9	E1.IPCM4v2_1_M.2080	E1_9
A1B.MPEH5_1_M.2080	A1B_10	E1.IPCM4v2_2_M.2080	E1_10
A1B.MPEH5_2_M.2080	A1B_11	E1.IPCM4v2_3_M.2080	E1_11
A1B.MPEH5_3_M.2080	A1B_12	E1.MPEH5C_1_M.2080	E1_12
		E1.MPEH5C_2_M.2080	E1_13
		E1.MPEH5C_3_M.2080	E1_14

Scenario A1B _1

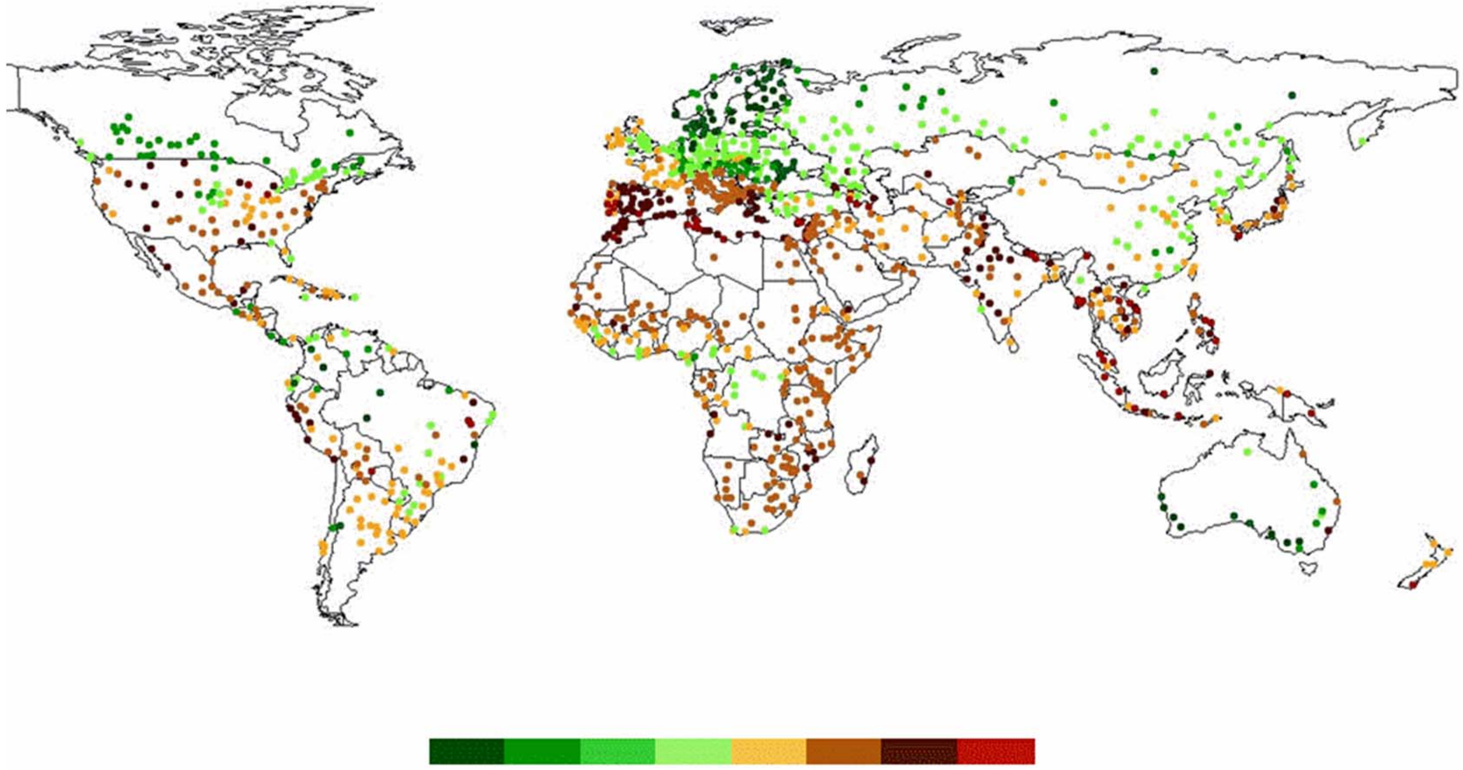
Temp change (C)

Precip change (%)

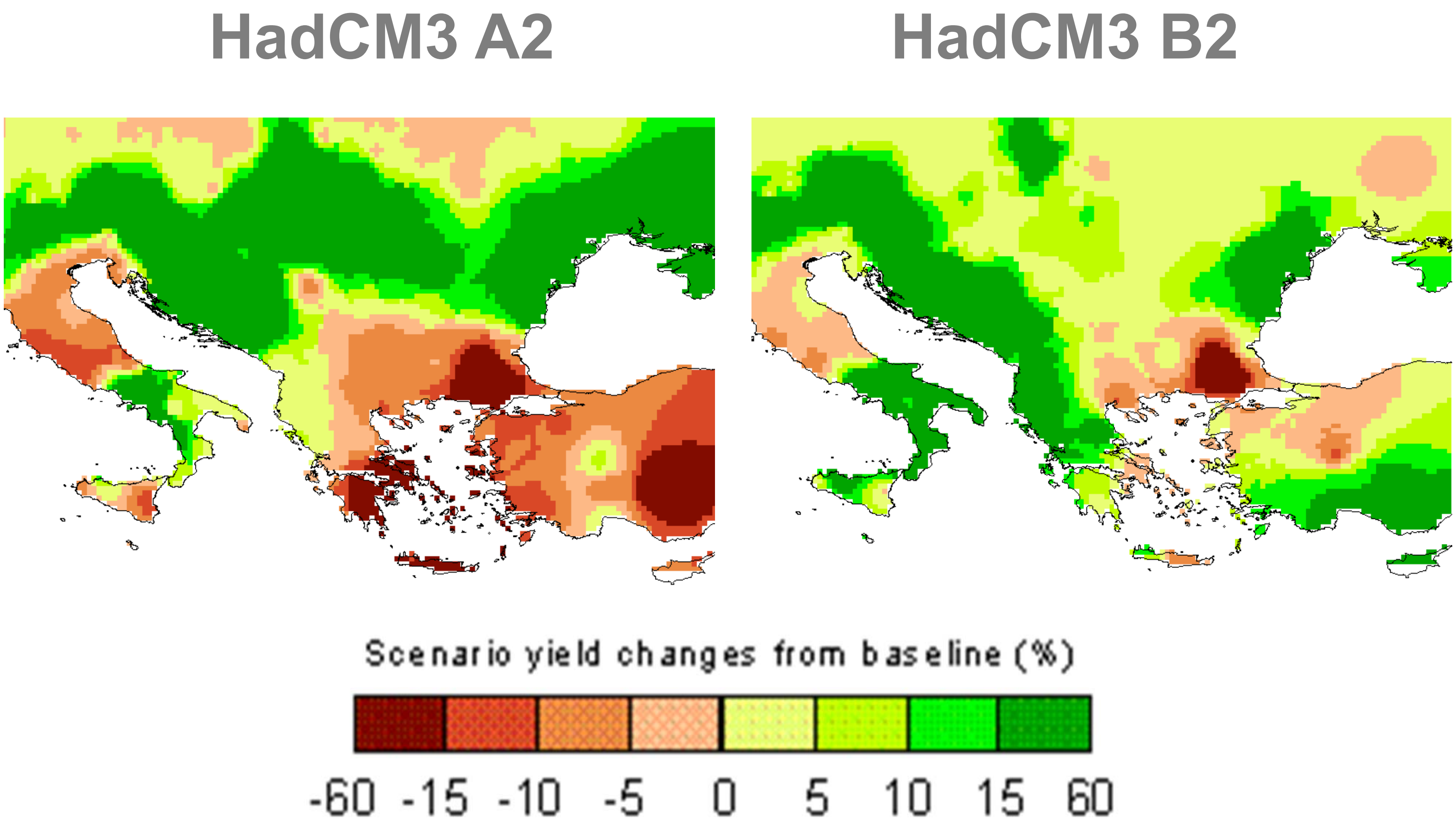


Scenario A1B _1

Agricultural productuivity changes (% of baseline)



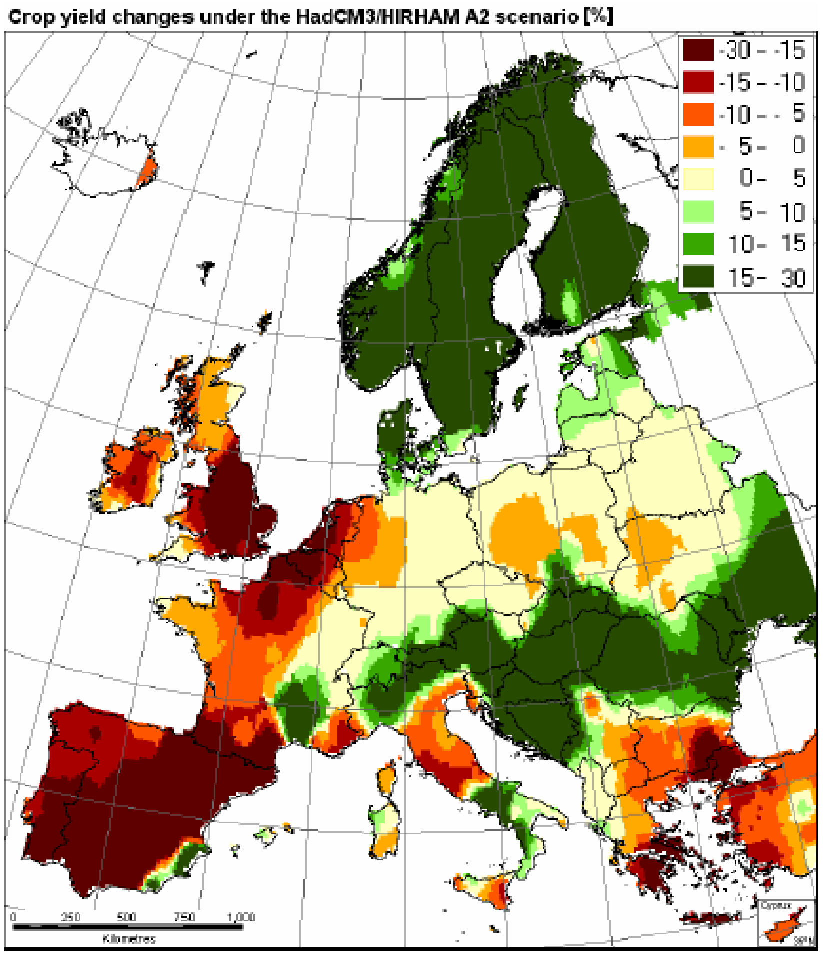
Changes in land productivity

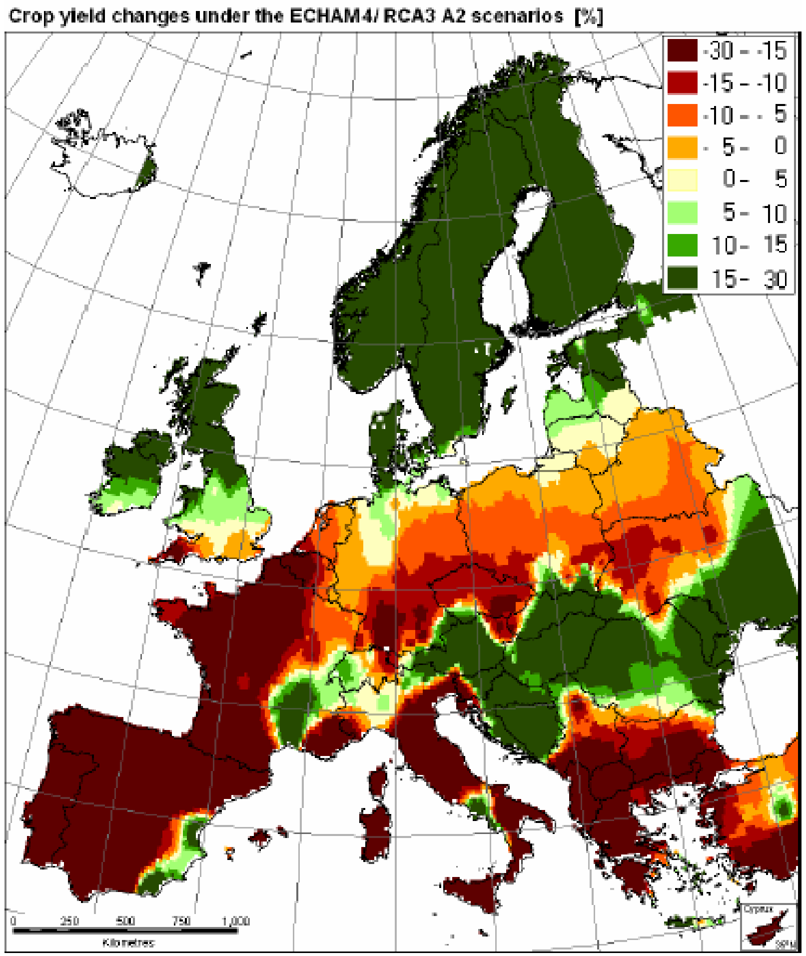


Source: Iglesias et al., 2012

Complexity: need to understand local vulnerabilities

PESETA project





Crop yield changes under the HadCM3/HIRHAM A2 scenario and for the ECHAM4/ RCA3 A2 scenario for the 2080s

Starting an experiment using DSSAT

Questions to Ask Yourself

- Do you think the models/tools presented can be useful for your needs?
- What are the main entry barriers you find to begin to use some ot the tools?
- Make an initial plan of your objectives, and how can be achieved with the tools we have disscussed.

Practical Application of DSSAT

- Effect of management (nitrogen and irrigation)

- Effect of climate change on wet and dry sites

  a) Sensitivity analysis to changes in temperature and precipitation (thresholds) levels

Input Requirements for DSSAT

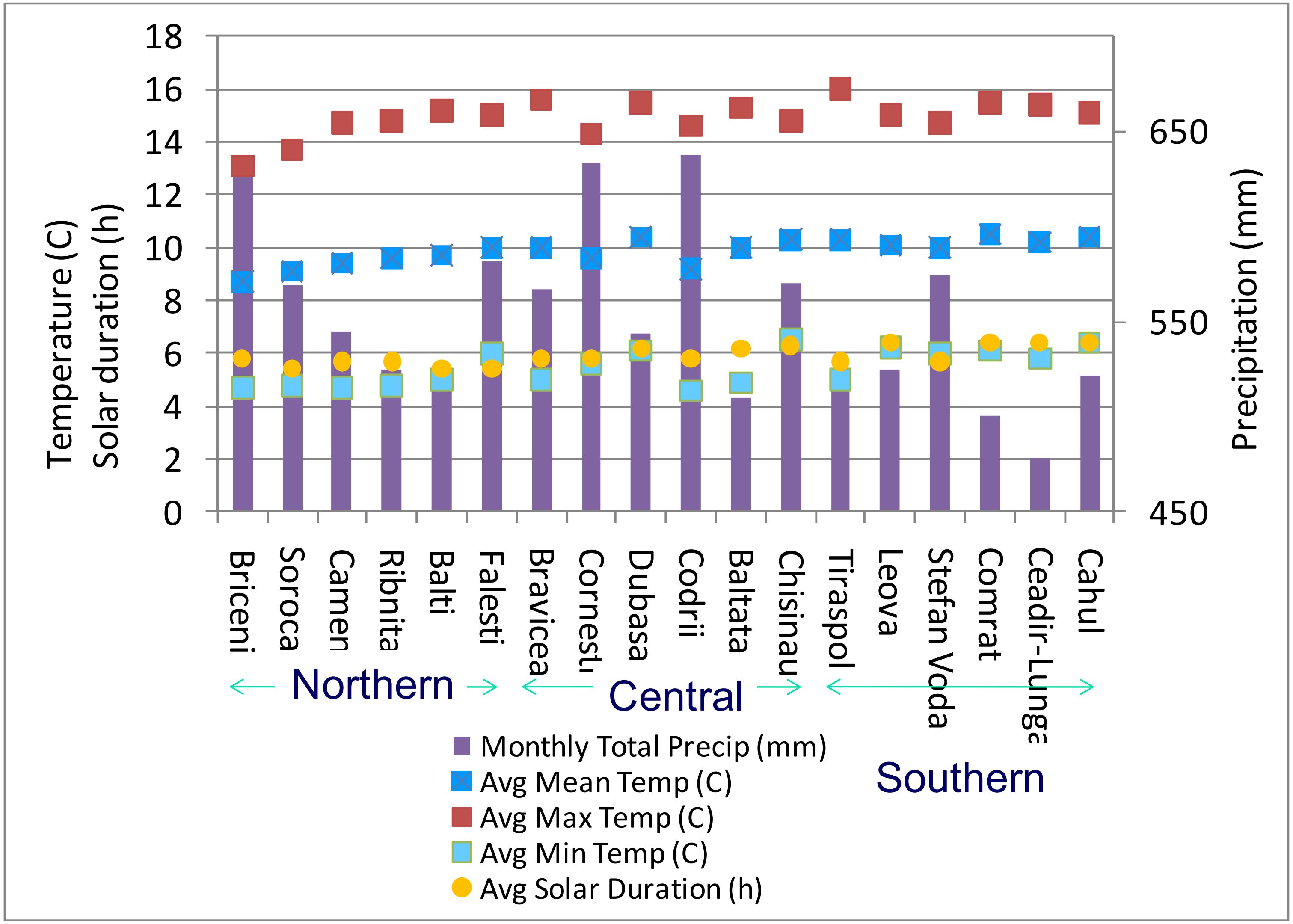
- Daily **weather** (Tmin, Tmax, Precipitation and Solar Radiation)
- **Soil** texture
- **Management** (planting date, variety, row spacing, irrigation and nitrogen (N) fertilizer amounts and dates)
- DSSAT libraries and examples
- Additional **validation** requirements:

  a) Crop dates of flowering and maturity, biomass and yield.

Input Files Needed

- Weather
- Soils
- Cultivars
- Management files (*.MZX files) plus description of the experiment.

Weather



Temperature (C)
Solar duration (h)
18
16
14
12
10
8
6
4
2
0
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)

Modelling Crop Responses to Changes in Climate and Management DSSAT

Databases

- soil
- weather
- genetics
- economics
- pests

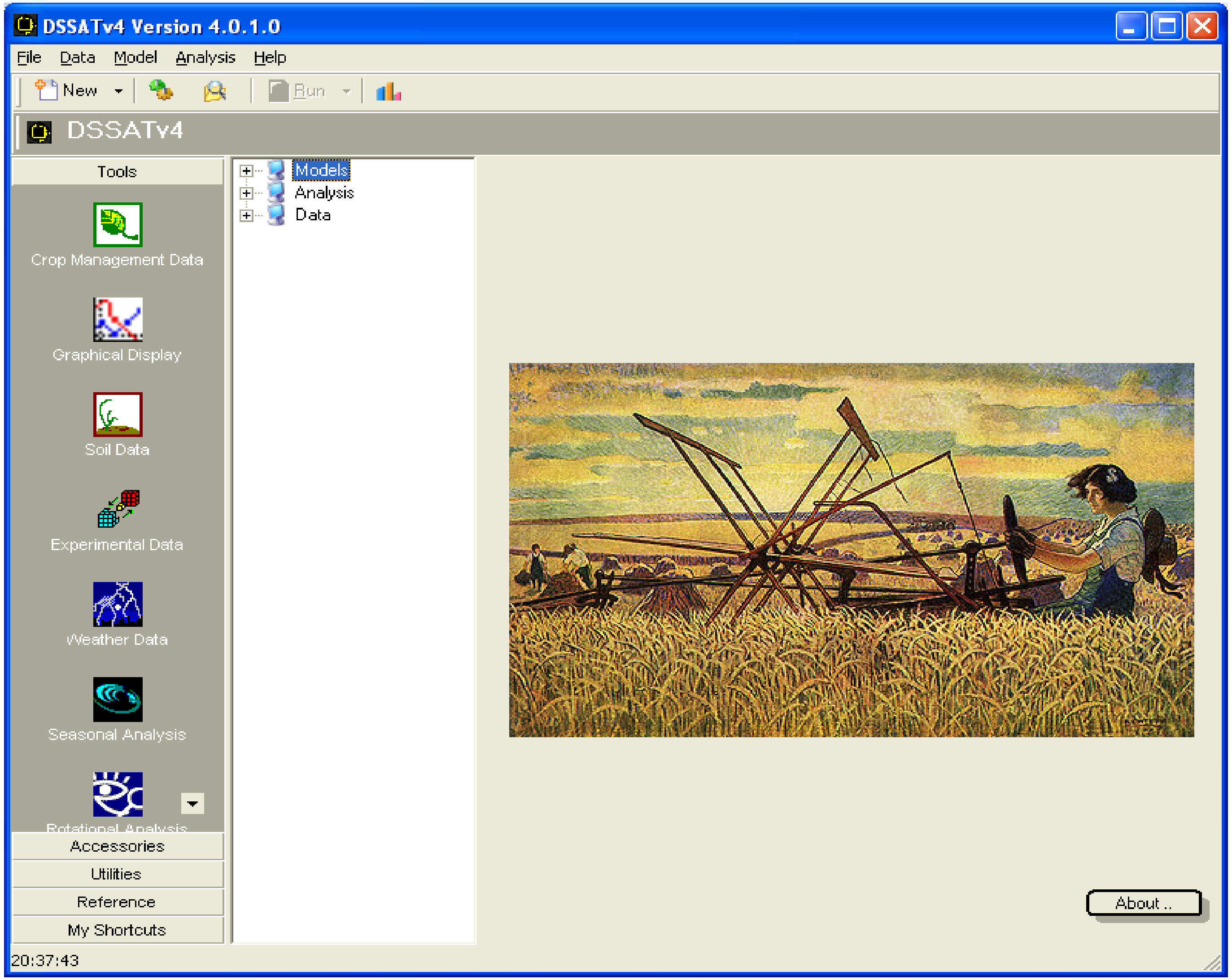
Models

- crop models
- experiments & management
- support graphics

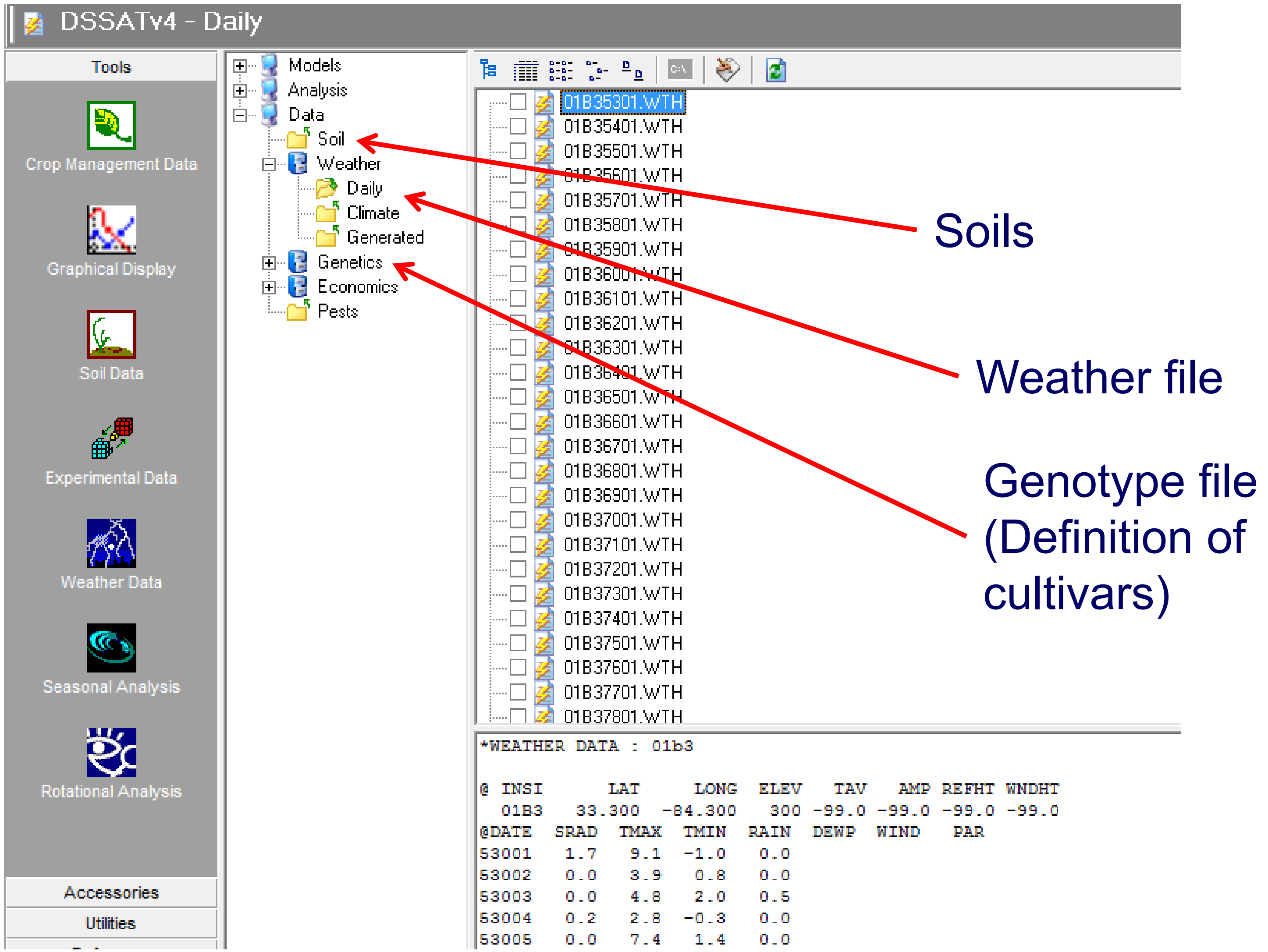
Applications

- validation
- sensitivity analysis
- crop rotation (sequence)
- spatial analysis

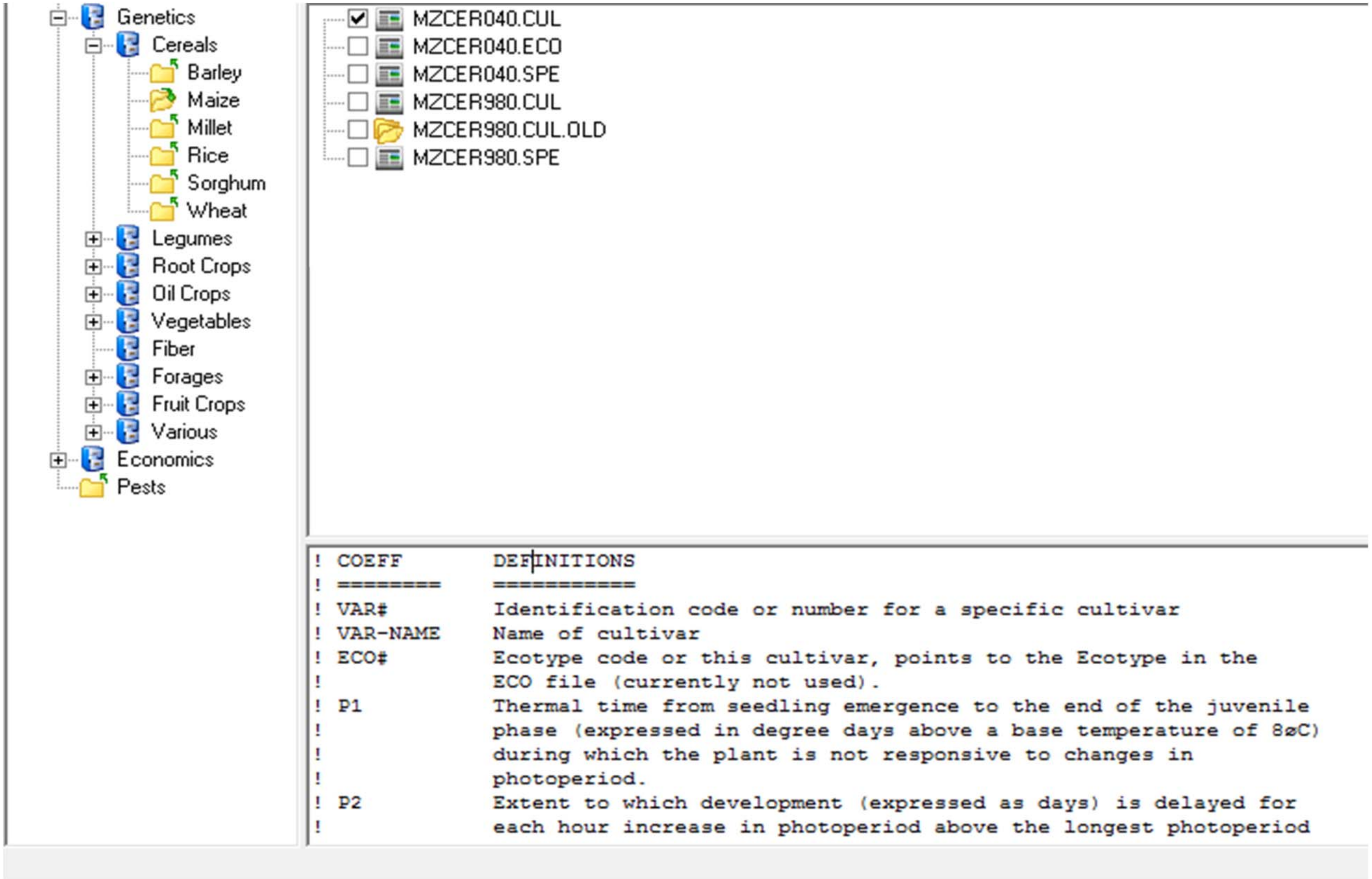
Open DSSAT …


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

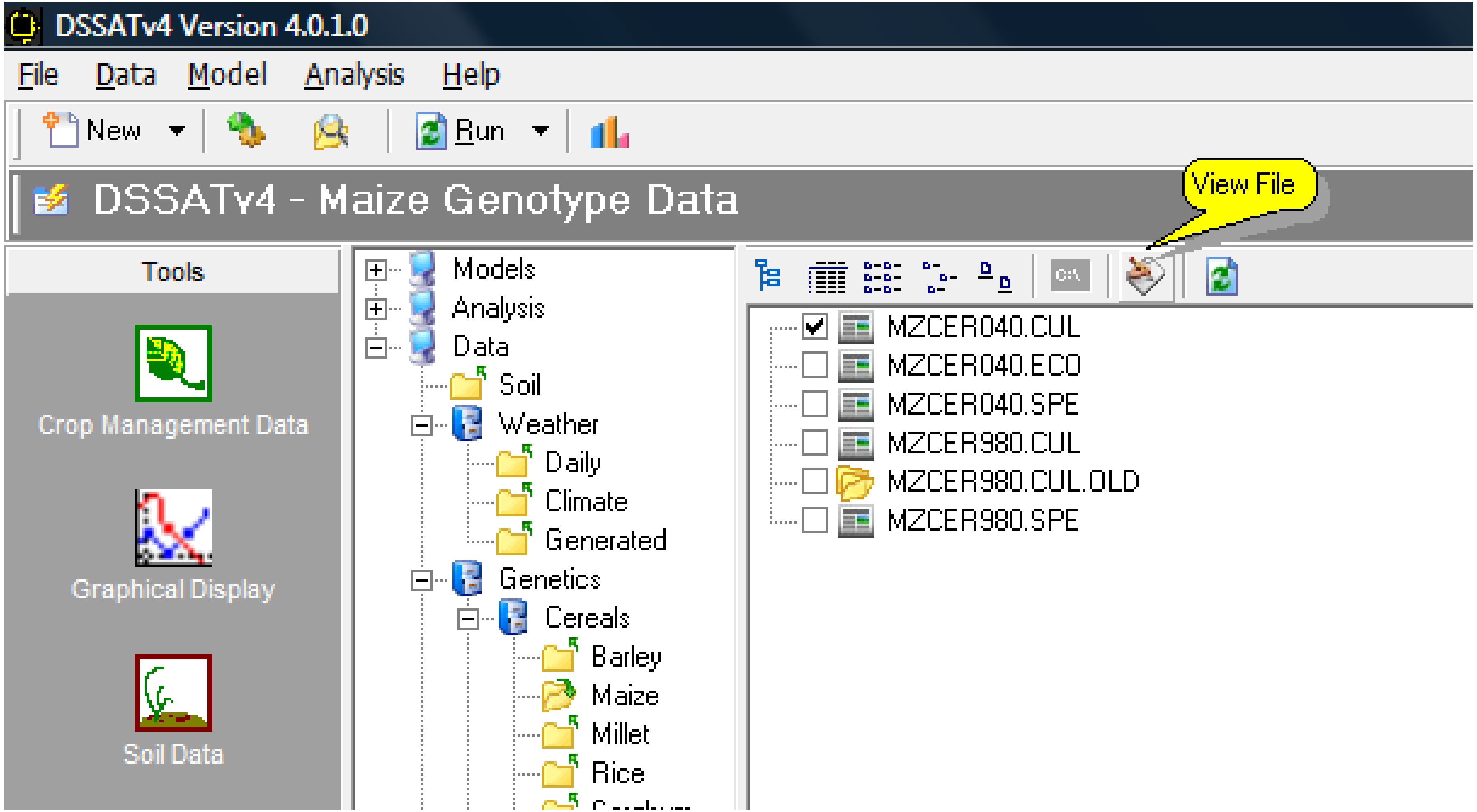
Examine the Data Files …



Examine the Cultivar file …



Examine the Cultivar File …



Examine the Cultivar File …

MZCER040.CUL - Bloc de notas

Archivo Edición Formato Ver Ayuda

```
*MAIZE CULTIVAR COEFFICIENTS: GECER040 MODEL
!
!The P1 values for the varieties used in experiments IBWA8301 and
!UFGA8201 were recalibrated to obtain a better fit for version 3
!of the model. After converting from 2.1 to 3.0 the varieties
!IB0035, IB0060, and IB0063 showed an earlier simulated flowering
!date. To correct this, the P1 values were recalibrated.
!The reason for this is that there was an error in PHASEI in
!version 2.1 that had TLNO=IFIX(CUMDTT/21.+6.) rather than
!TLNO=IFIX(SUMDTT/21.+6.); see p. 74 of Jones & Kiniry.
!-Walter Bowen, 22 DEC 1994.
!
!All G2 values were increased by a factor of 1.1 for Ritchie's
!change to RUE -Walter, 28 DEC 1994
!
! COEFF       DEFINITIONS
! ========    ===========
! VAR#        Identification code or number for a specific cultivar
! VAR-NAME    Name of cultivar
! ECO#        Ecotype code or this cultivar, points to the Ecotype in the
!             ECO file (currently not used).
! P1          Thermal time from seedling emergence to the end of the juvenile
!             phase (expressed in degree days above a base temperature of 8øC)
!             during which the plant is not responsive to changes in
!             photoperiod.
! P2          Extent to which development (expressed as days) is delayed for
!             each hour increase in photoperiod above the longest photoperiod
!             at which development proceeds at a maximum rate (which is
!             considered to be 12.5 hours).
! P5          Thermal time from silking to physiological maturity (expressed
!             in degree days above a base temperature of 8øC).
! G2          Maximum possible number of kernels per plant.
! G3          Kernel filling rate during the linear grain filling stage and
!             under optimum conditions (mg/day).
! PHINT       Phylochron interval; the interval in thermal time (degree days)
!             between successive leaf tip appearances.
!
! PIO         Pioneer
! AS          Asgrow (Monsanto)
! DK          Dekalb (Monsanto)
! LH          Holden (Monsanto)
! C/LOL       Land of Lakes
!
@VAR#  VRNAME.........  ECO#    P1    P2    P5    G2    G3 PHINT
!                                1     2     3     4     5     6

PC0001 2500-2600 GDD    IB0001 160.0 0.750 780.0 750.0  8.50 49.00
PC0002 2600-2650 GDD    IB0001 185.0 0.750 850.0 800.0  8.50 49.00
PC0003 2650-2700 GDD    IB0001 212.0 0.750 850.0 800.0  8.50 49.00
PC0004 2700-2750 GDD    IB0001 240.0 0.750 850.0 800.0  8.50 49.00
PC0005 2750-2800 GDD    IB0001 260.0 0.750 850.0 800.0  8.50 49.00
```

Examine the Weather File …

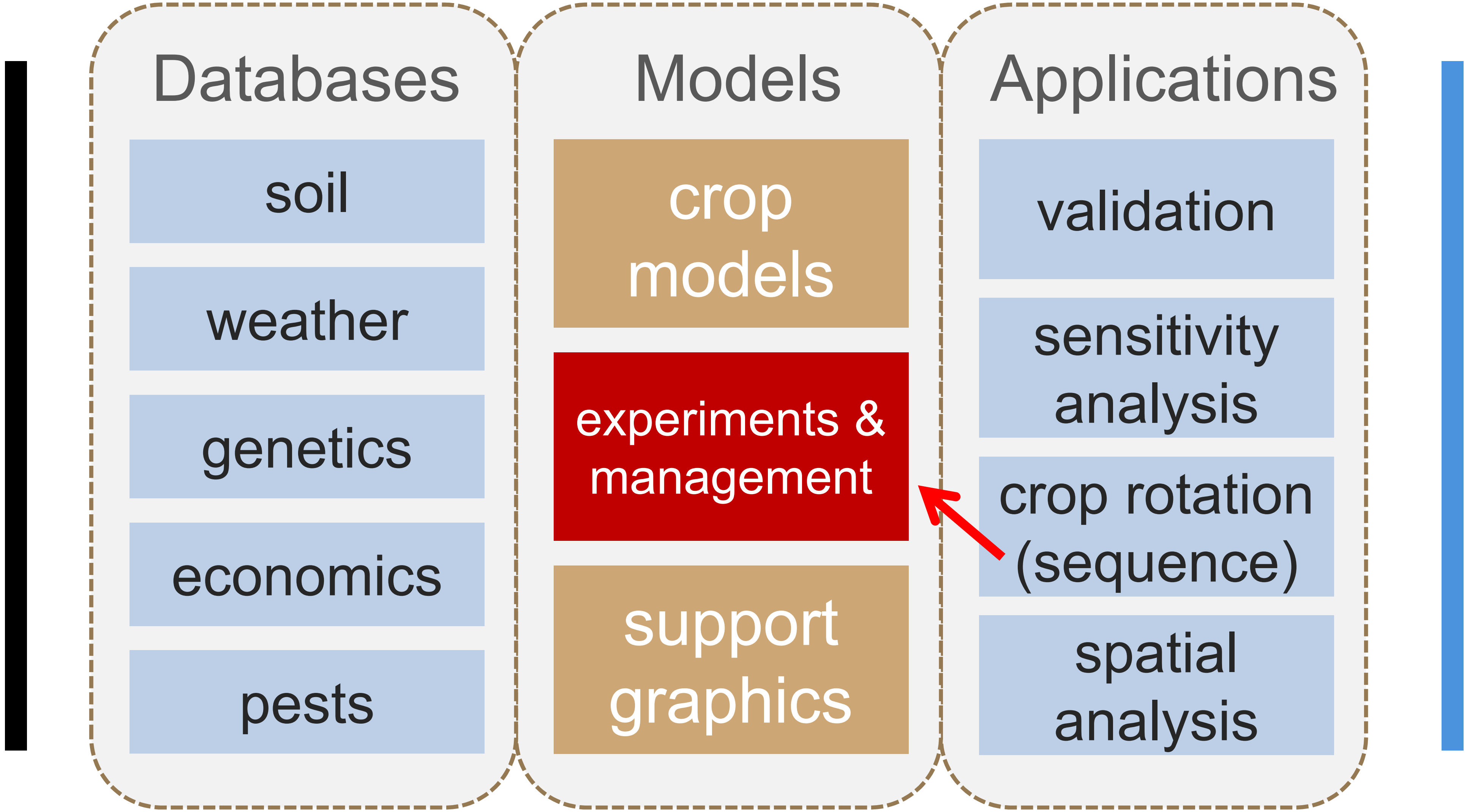
01B35301.WTH - Bloc de notas

Archivo Edición Formato Ver Ayuda

```
*WEATHER DATA : 01b3

@ INSI      LAT     LONG  ELEV   TAV   AMP REFHT WNDHT
  01B3   33.300  -84.300   300 -99.0 -99.0 -99.0 -99.0
@DATE  SRAD  TMAX  TMIN  RAIN  DEWP  WIND   PAR
53001   1.7   9.1  -1.0   0.0
53002   0.0   3.9   0.8   0.0
53003   0.0   4.8   2.0   0.5
53004   0.2   2.8  -0.3   0.0
53005   0.0   7.4   1.4   0.0
53006   6.2  11.3   0.4   0.0
53007   6.4  10.0  -1.2   0.0
53008   0.0   5.5   1.5   0.0
53009   0.0   6.0   2.1   0.0
53010   0.0  10.1   5.7   0.0
53011   5.9  10.5   5.5   0.0
53012   0.0   7.3   5.6   0.0
53013   0.0   8.3   5.5   0.0
53014   0.0   9.6   5.2   0.0
53015   0.0   7.8   4.5  13.1
53016   0.0   5.8   2.7   0.5
53017   0.0   5.5   0.9   5.4
53018   0.0   5.2   0.9   0.7
53019   4.9   4.5  -3.6   0.0
53020   0.0   4.9   1.3   0.0
```

Program to Generate Weather Data …

Modelling Crop Responses to Changes in Climate and Management DSSAT



Program to Generate the Experiments …

XBuild

Version: 4.0.1.0

Creating Crop Management Files for Documenting Experiments and Simulating Crop Growth and Yield

Developed by:

Agricultural and Biological Engineering Department The University of Florida

UNIVERSITY OF FLORIDA IFAS

Central Lab for Agricultural Climate Egypt Ministry of Agriculture and Land Reclamation

CLAC

Department of Biological and Agricultural Engineering University of Georgia

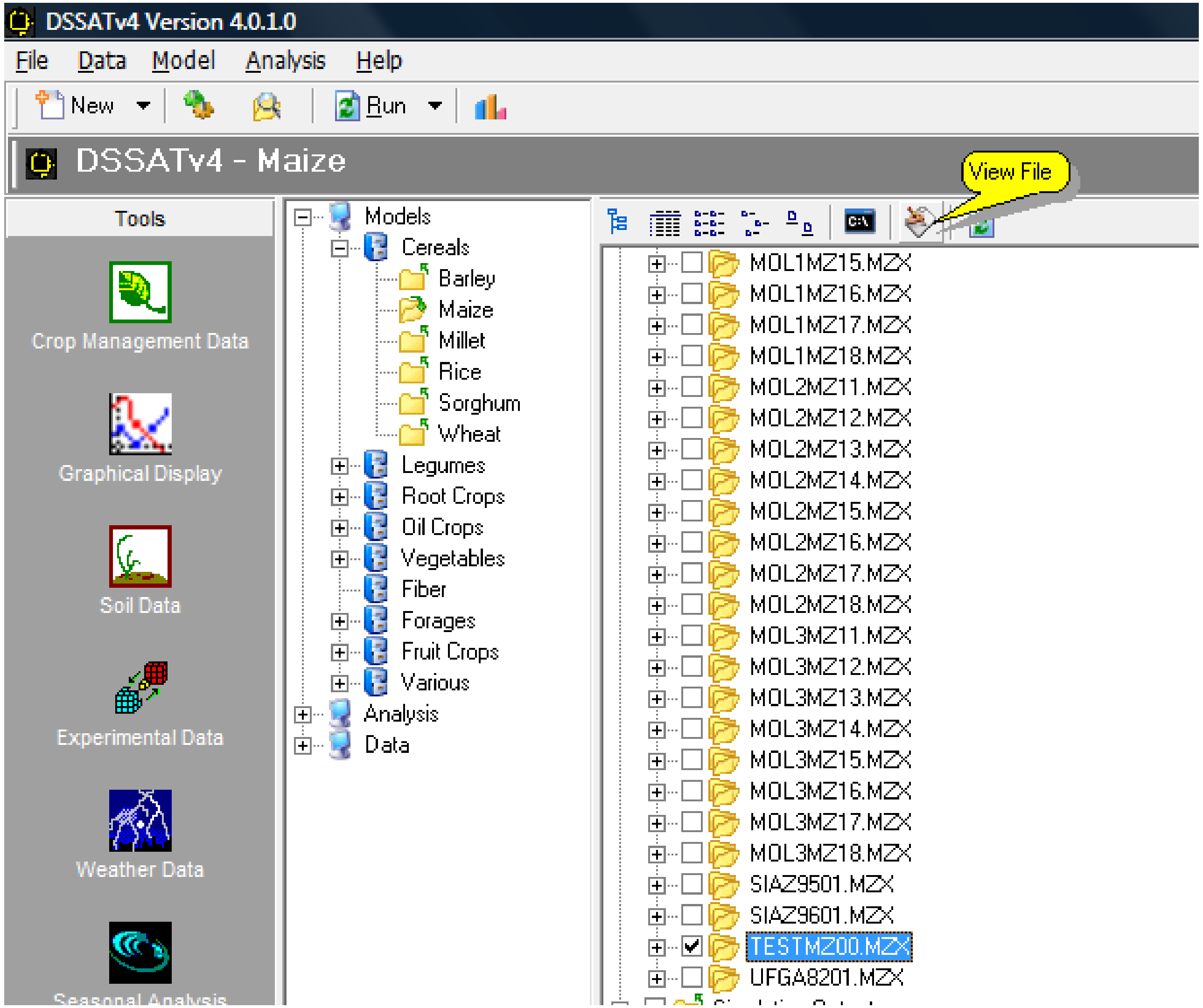
The University of Georgia

International Consortium for Agricultural System Applications

ICASA

Supported by USDA-FAS Project: Integrated Crop Management Information System

The Experiment File can also be Edited Using a Text Editor (Notepad) …



Moldova World Bank Using DSSAT

```
 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

Moldova World Bank Using DSSAT

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
```

Fertilizers 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
```

Fertilizers 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
```

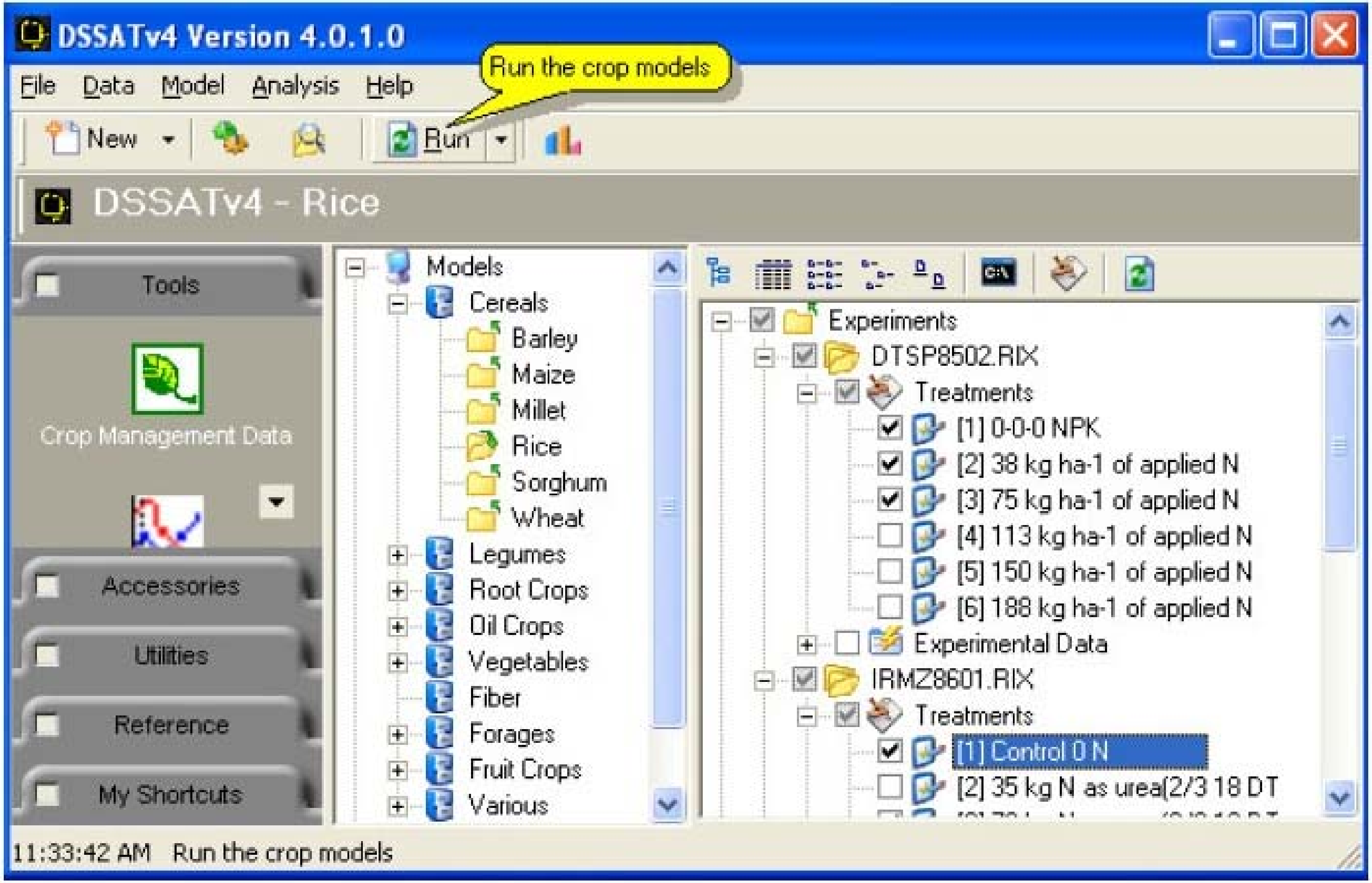
Env Modifications

```
*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
```

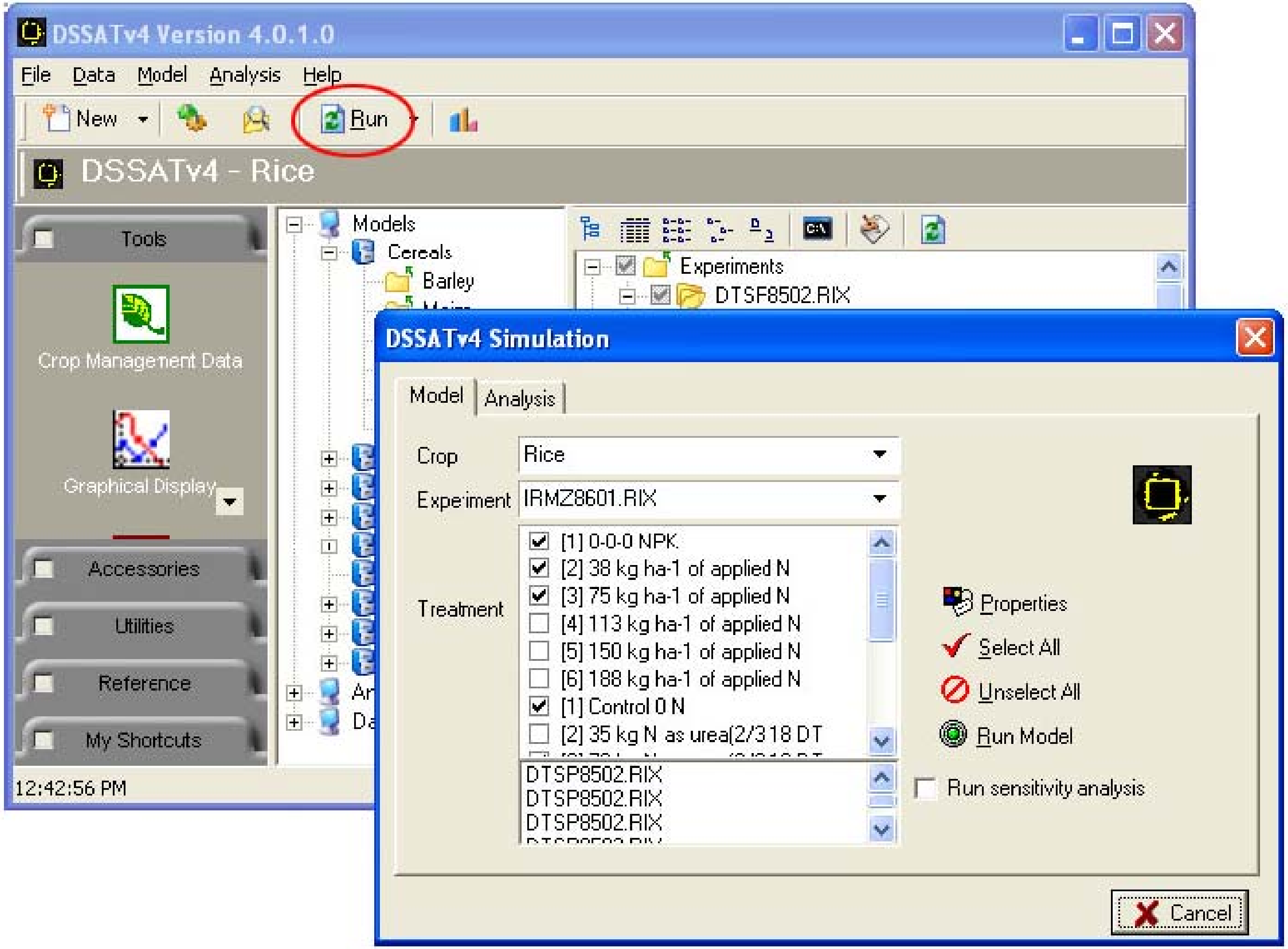
Simulation controls

```
*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
```

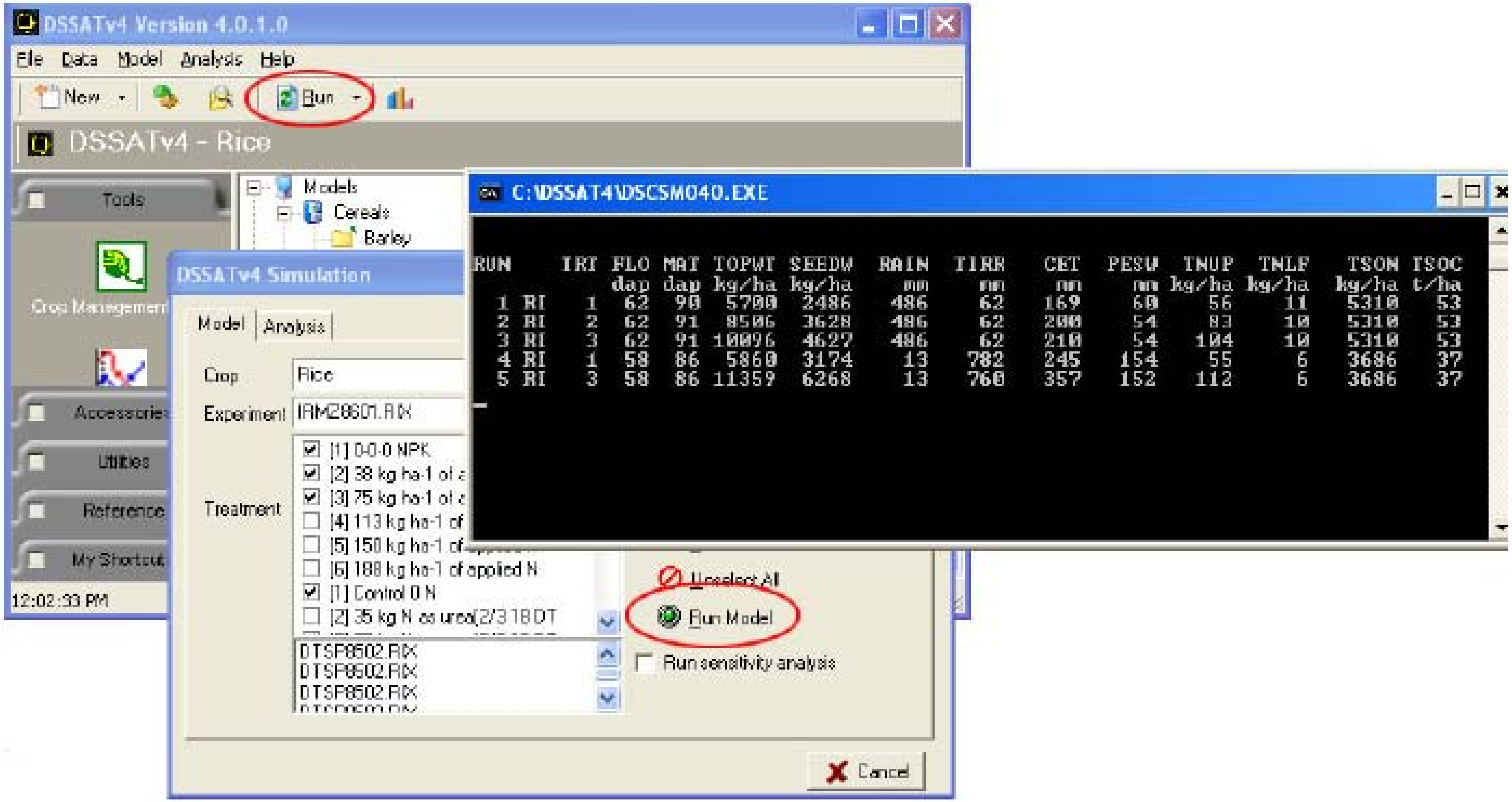
To Run the Model



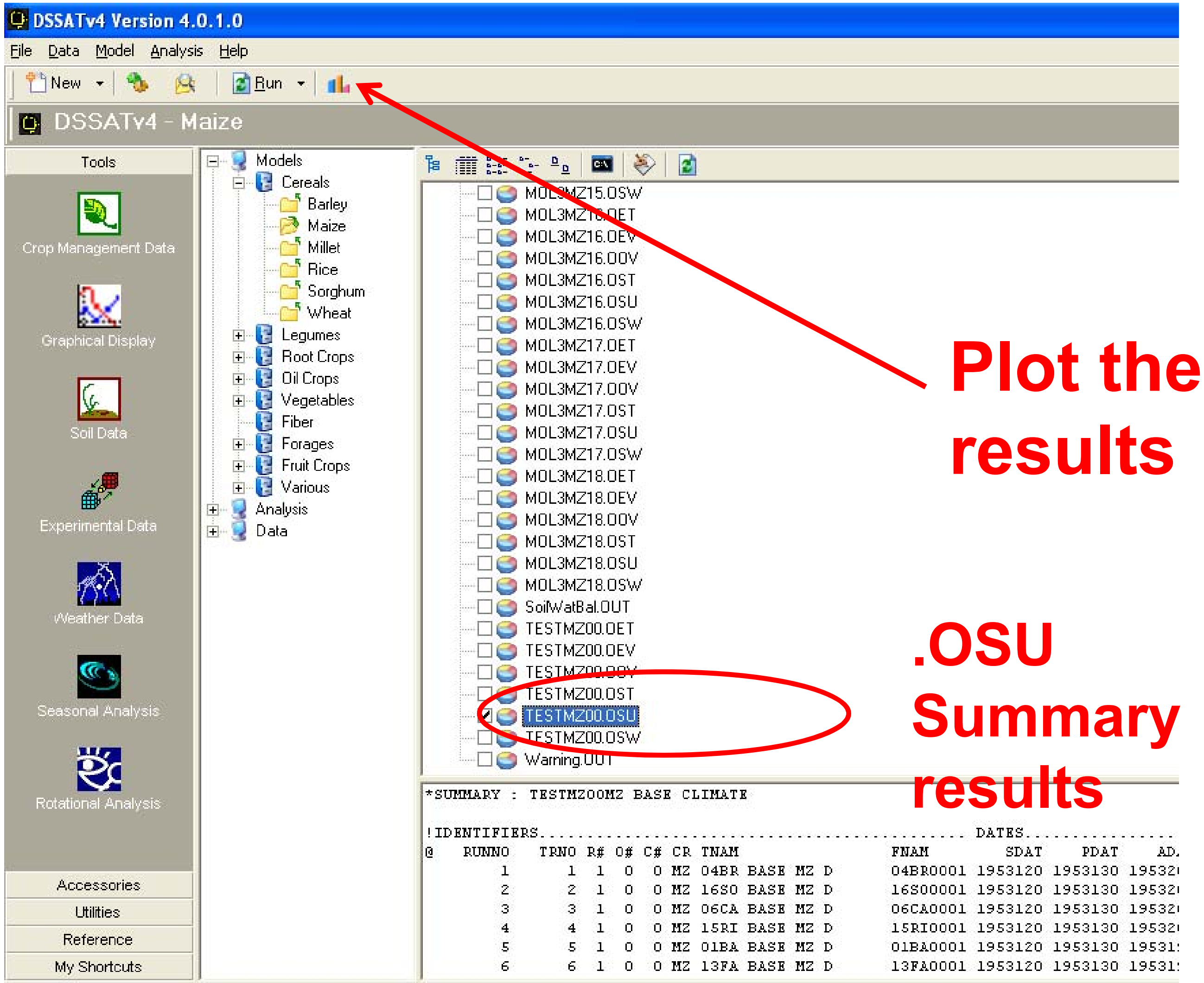
To Run the Model (continued)



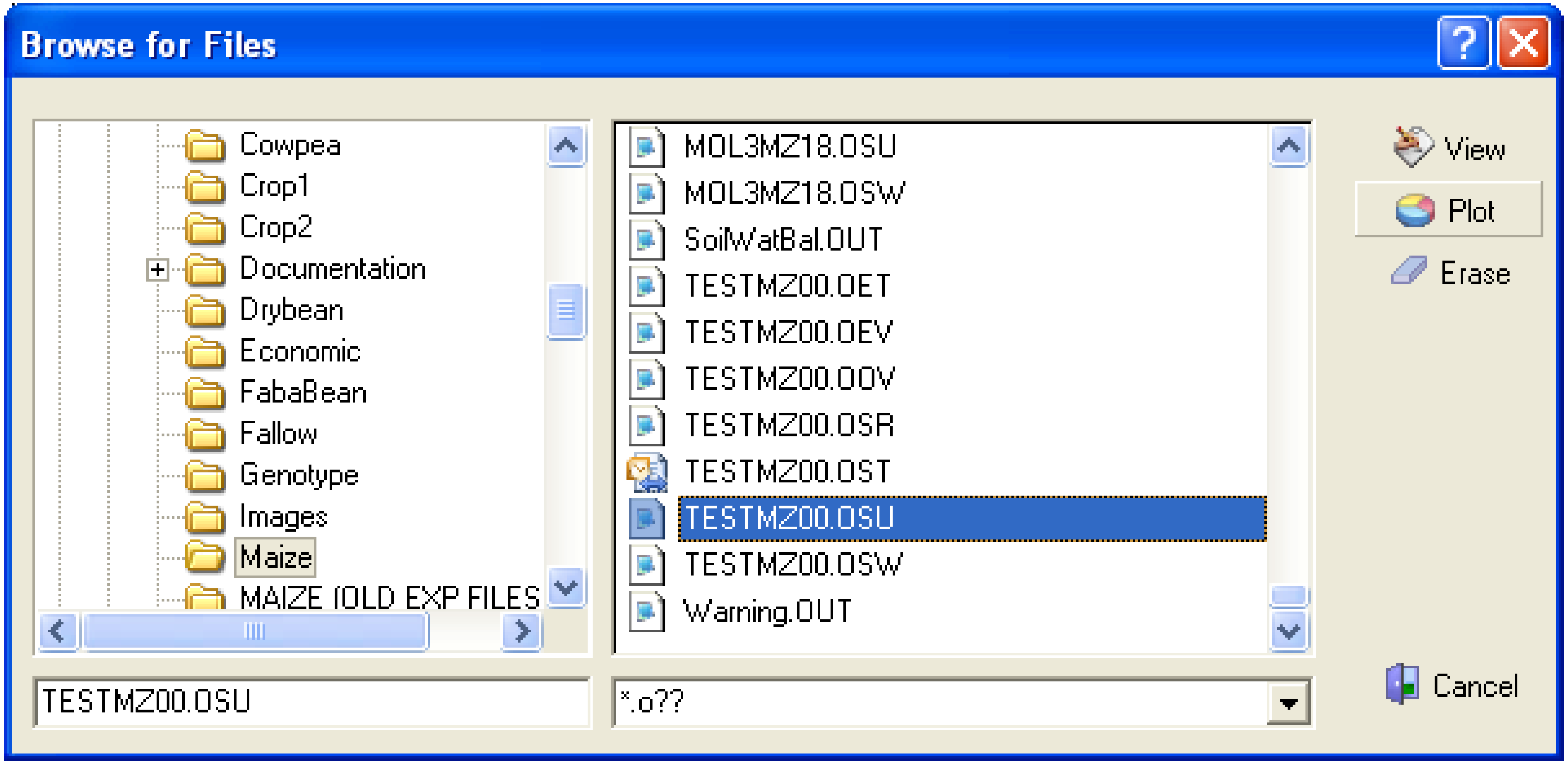
To Run the Model (continued)



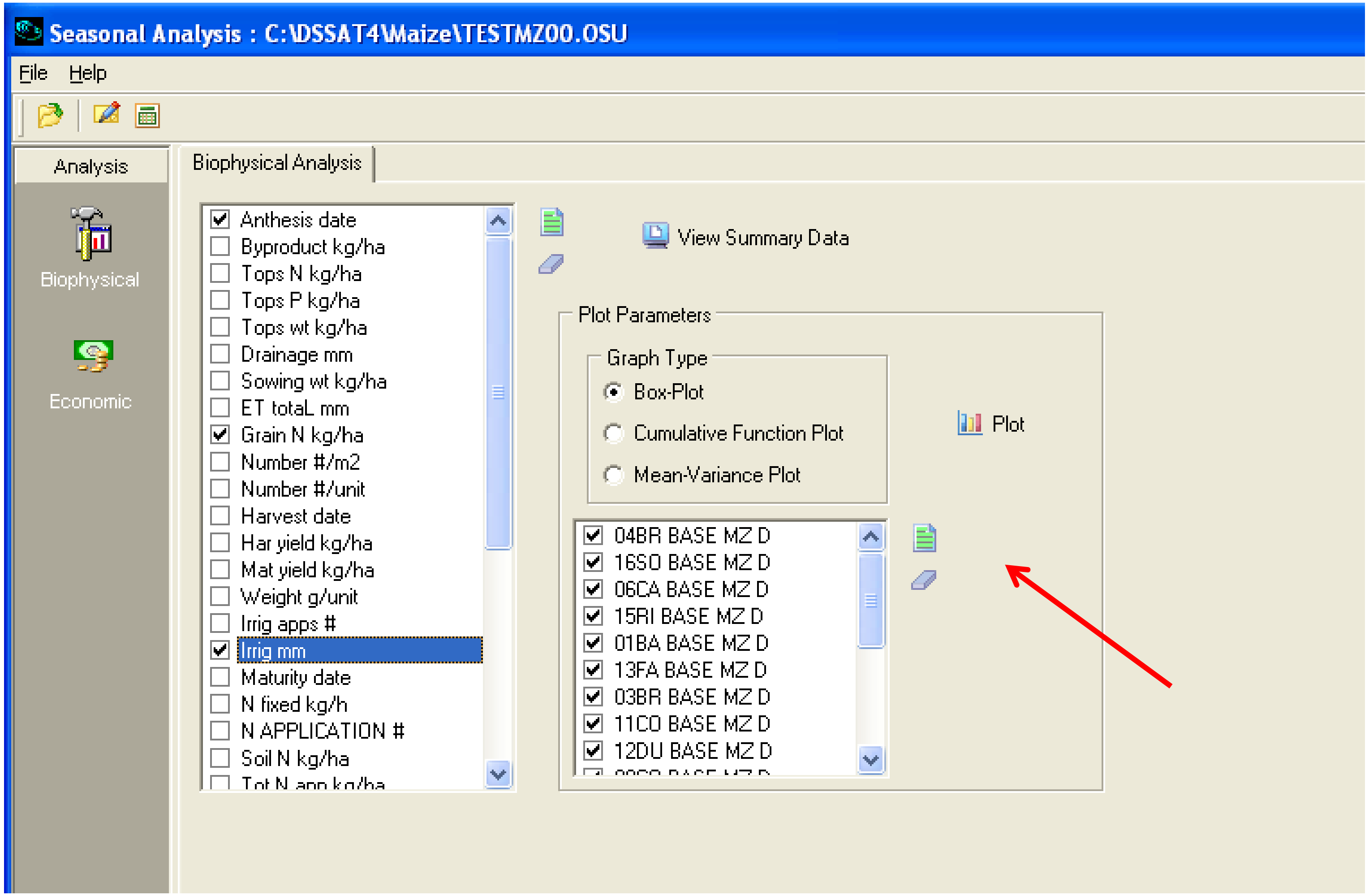
View the Results …



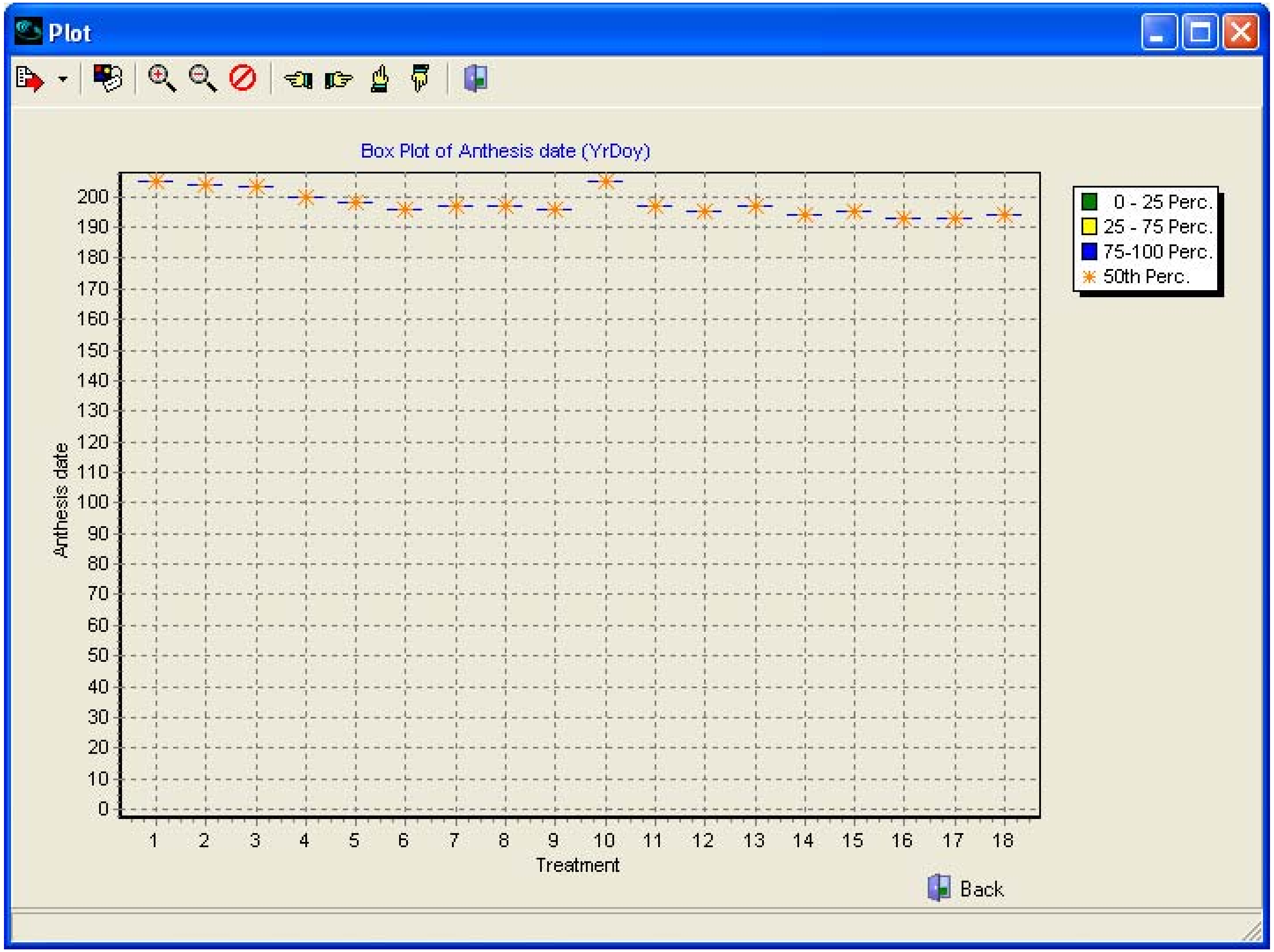
View the Results continued



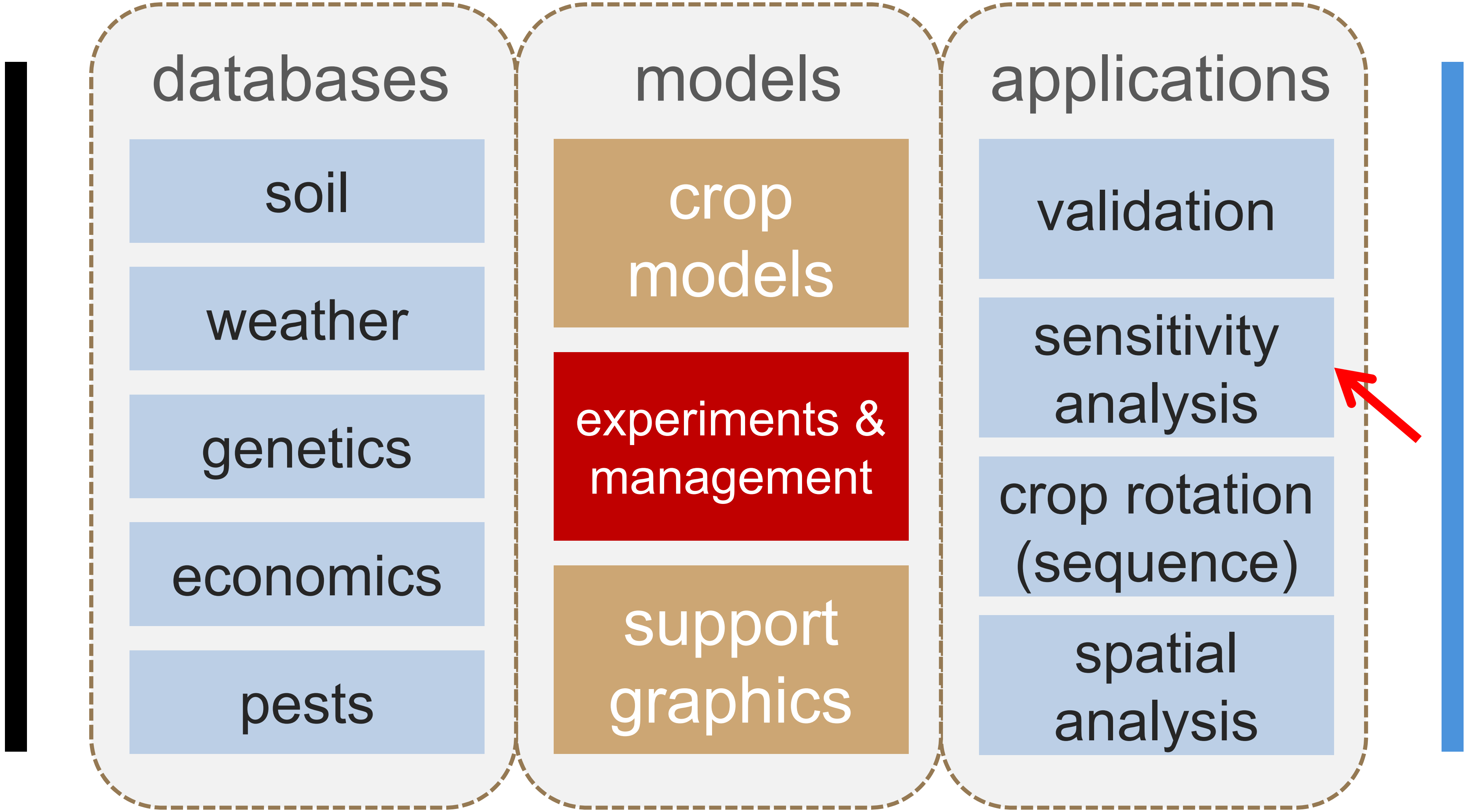
Choose the variables to plot



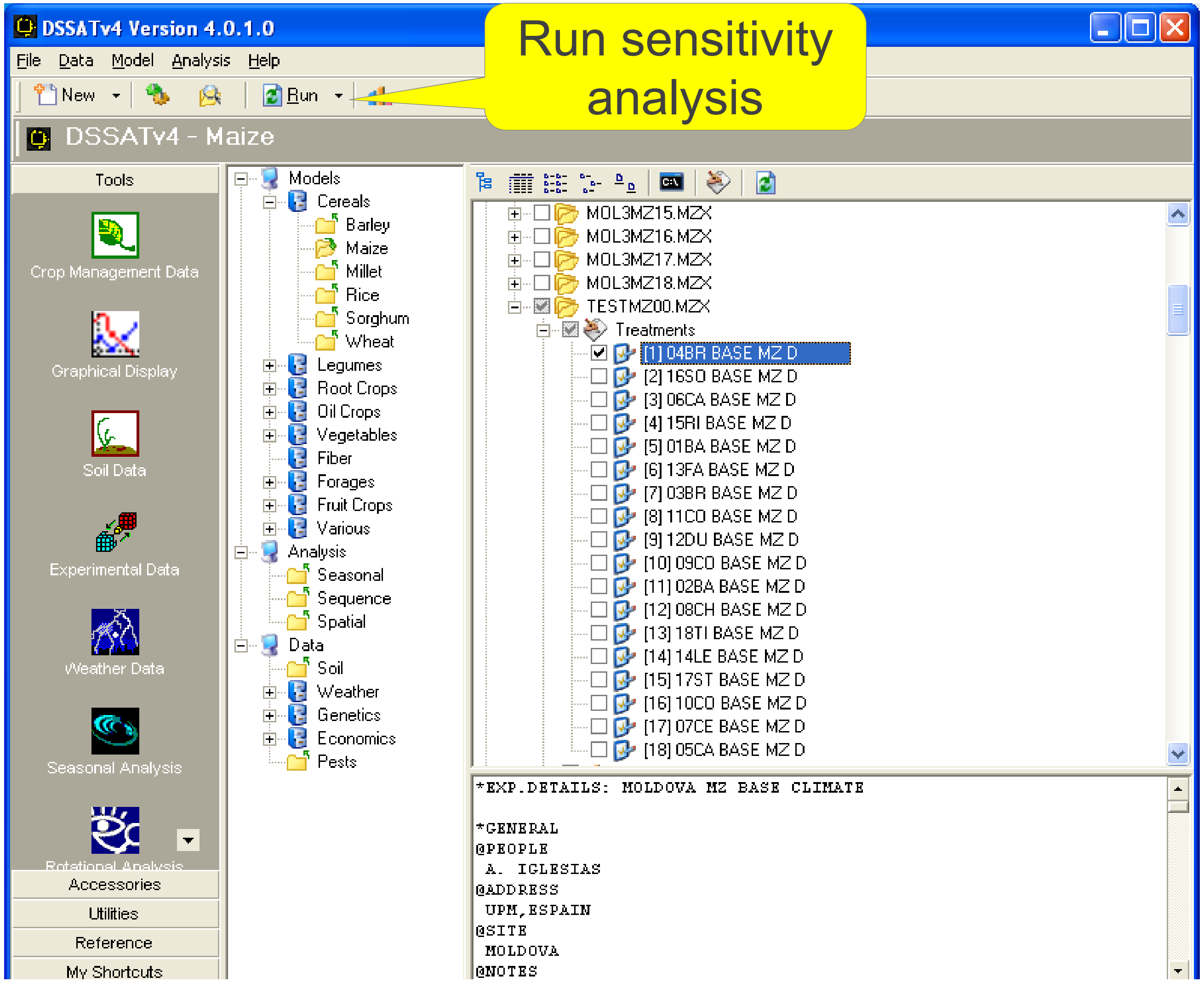
Example: Anthesis Date



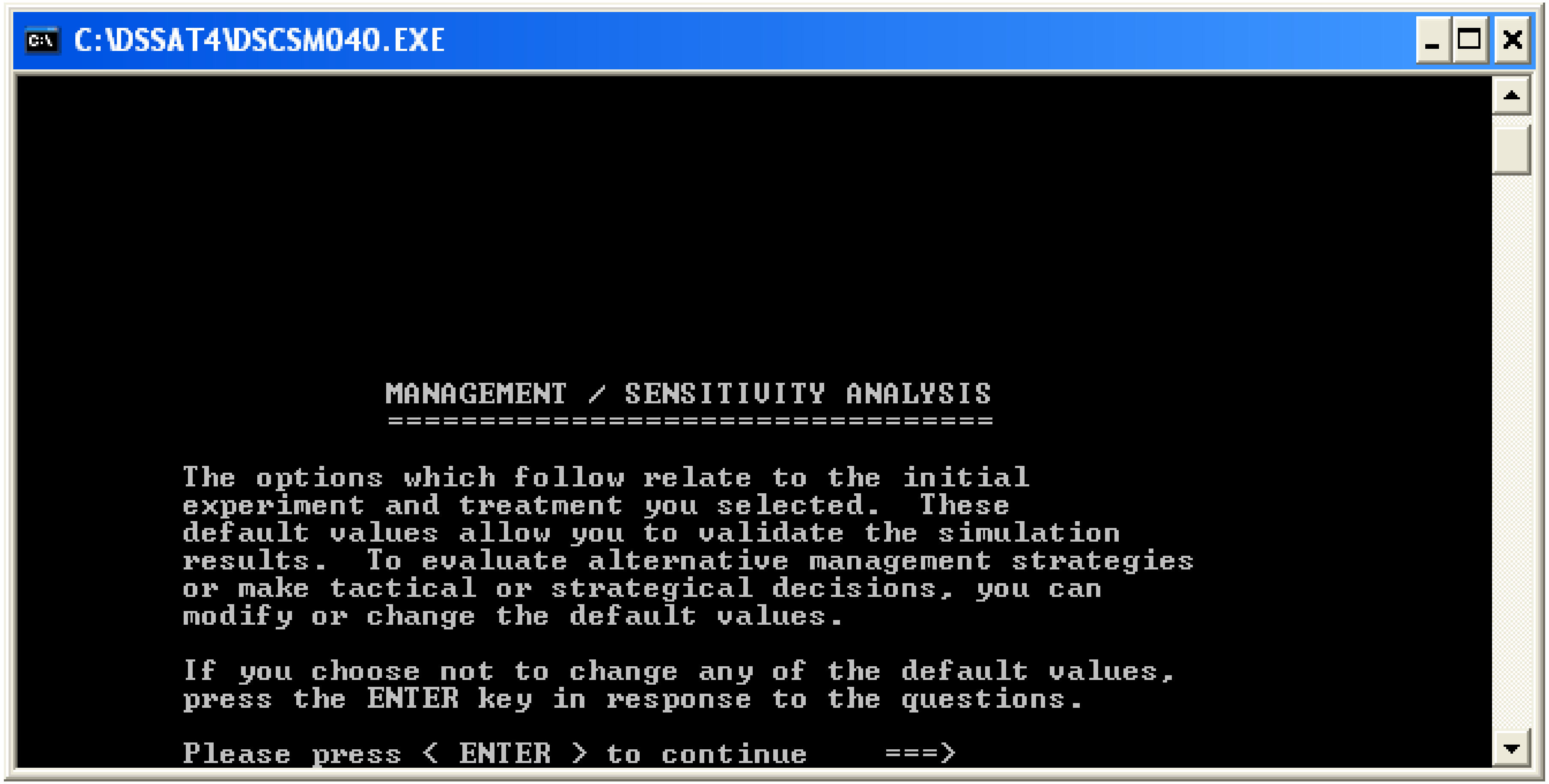
Modelling Crop responses to Changes in Climate and Management DSSAT



Sensitivity analysis



Start of Sensitivity Analysis



Create a Base Year without Changes

```
C:\DSSAT4\DSCSM040.EXE

    MANAGEMENT / SENSITIVITY ANALYSIS OPTIONS
    =========================================

 0. RETURN TO THE MAIN MENU

 1. Simulation Timing ........ APR 30 1953
 2. Crop ..................... MAIZE               MZCER040.SPE MZCER040.CUL
 3. Cultivar ................. MEDIUM SEASON       MAT : 0
 4. Weather .................. 04BR                OBSERVED    WMOD:N
 5. Soil ..................... IBML000990            -99
 6. Initial Conditions ....... AS REPORTED
 7. Planting ................. MAY 10 1953         ROW SP: 15. PLANTS/m2:   5.00
 8. Harvest .................. AT HARVEST MATURITY
 9. Water and Irrigation .... ON REPORTED DATE(S)
10. Nitrogen ................. AUTOMATIC N-FERTILIZER AP     NO N-FIX SIMUL.
11. Phosphorus ............... N/A
12. Residue .................. NO RESIDUE APPLICATION
13. Pests and Diseases ....... PEST & DISEASE INTERACTION NOT SIMULATED
14. Field .....................
15. Crop Process Options .... H2O:R NIT:Y N-FIX:N PEST:N PHOTO:C WTH:M ET:R
16. Output Control ........... FREQ: 5 OVV:Y SUM:Y GROWTH:N H2O:Y NIT:N PEST:N

    SELECTION ?  [Default = 0] ===>
```

Create a Base Year without Changes

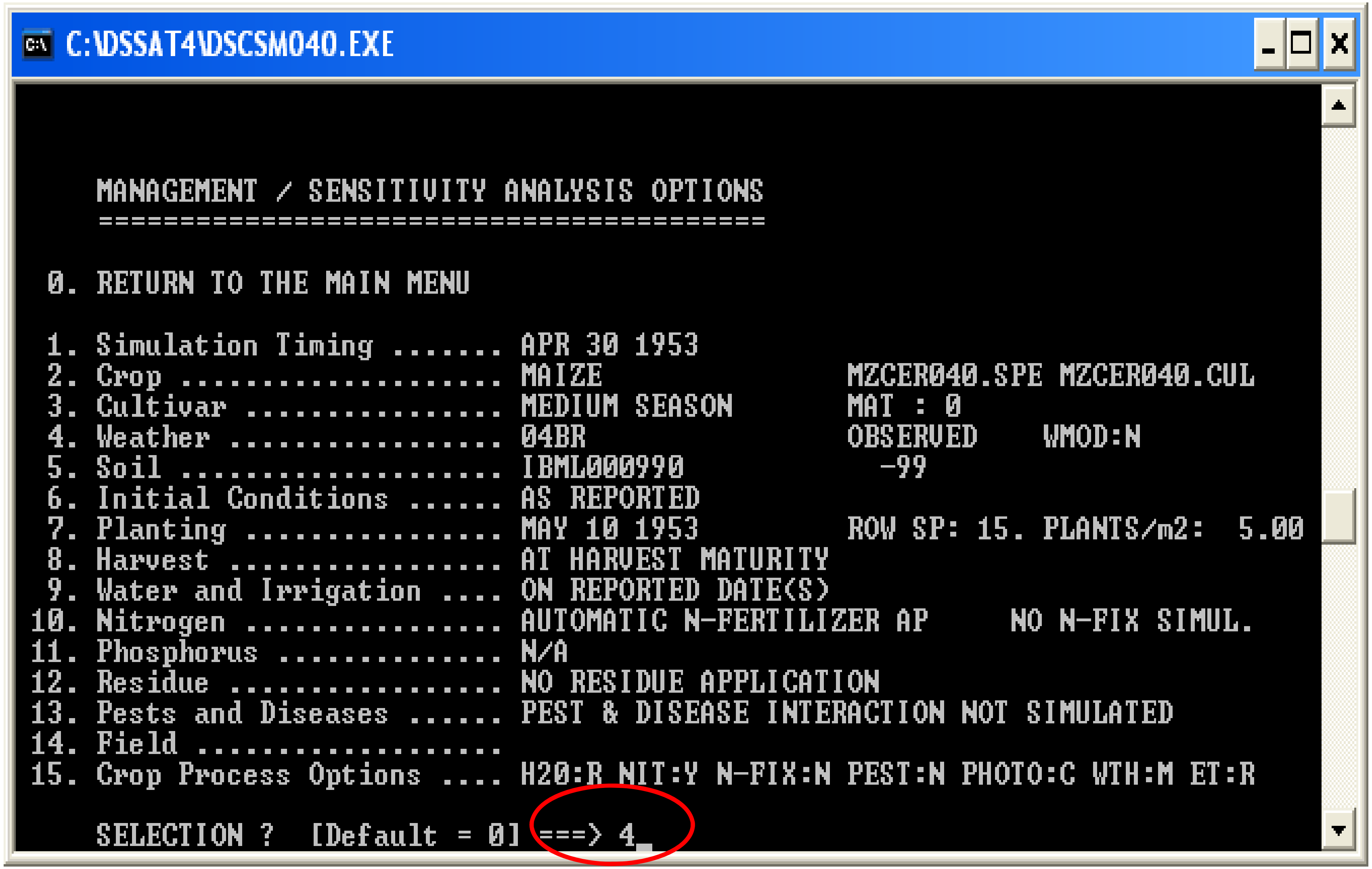
```
C:\DSSAT4\DSCSM040.EXE

    MANAGEMENT / SENSITIVITY ANALYSIS OPTIONS
    =========================================

 0. RETURN TO THE MAIN MENU

 1. Simulation Timing ........ APR 30 1953
 2. Crop ..................... MAIZE             MZCER040.SPE MZCER040.CUL
 3. Cultivar ................. MEDIUM SEASON     MAT  : 0
 4. Weather .................. 04BR              OBSERVED     WMOD:N
 5. Soil ..................... IBML000990          -99
 6. Initial Conditions ....... AS REPORTED
 7. Planting ................. MAY 10 1953       ROW SP: 15. PLANTS/m2:  5.00
 8. Harvest .................. AT HARVEST MATURITY
 9. Water and Irrigation ..... ON REPORTED DATE(S)
10. Nitrogen ................. AUTOMATIC N-FERTILIZER AP      NO N-FIX SIMUL.
11. Phosphorus ............... N/A
12. Residue .................. NO RESIDUE APPLICATION
13. Pests and Diseases ....... PEST & DISEASE INTERACTION NOT SIMULATED
14. Field ....................
15. Crop Process Options ..... H20:R NIT:Y N-FIX:N PEST:N PHOTO:C WTH:M ET:R
16. Output Control ........... FREQ: 5 OVV:Y SUM:Y GROWTH:N H20:Y NIT:N PEST:N

    SELECTION ?  [Default = 0] ===>

    Please enter Run  1 name : ===> base
```

Simulation with Changes

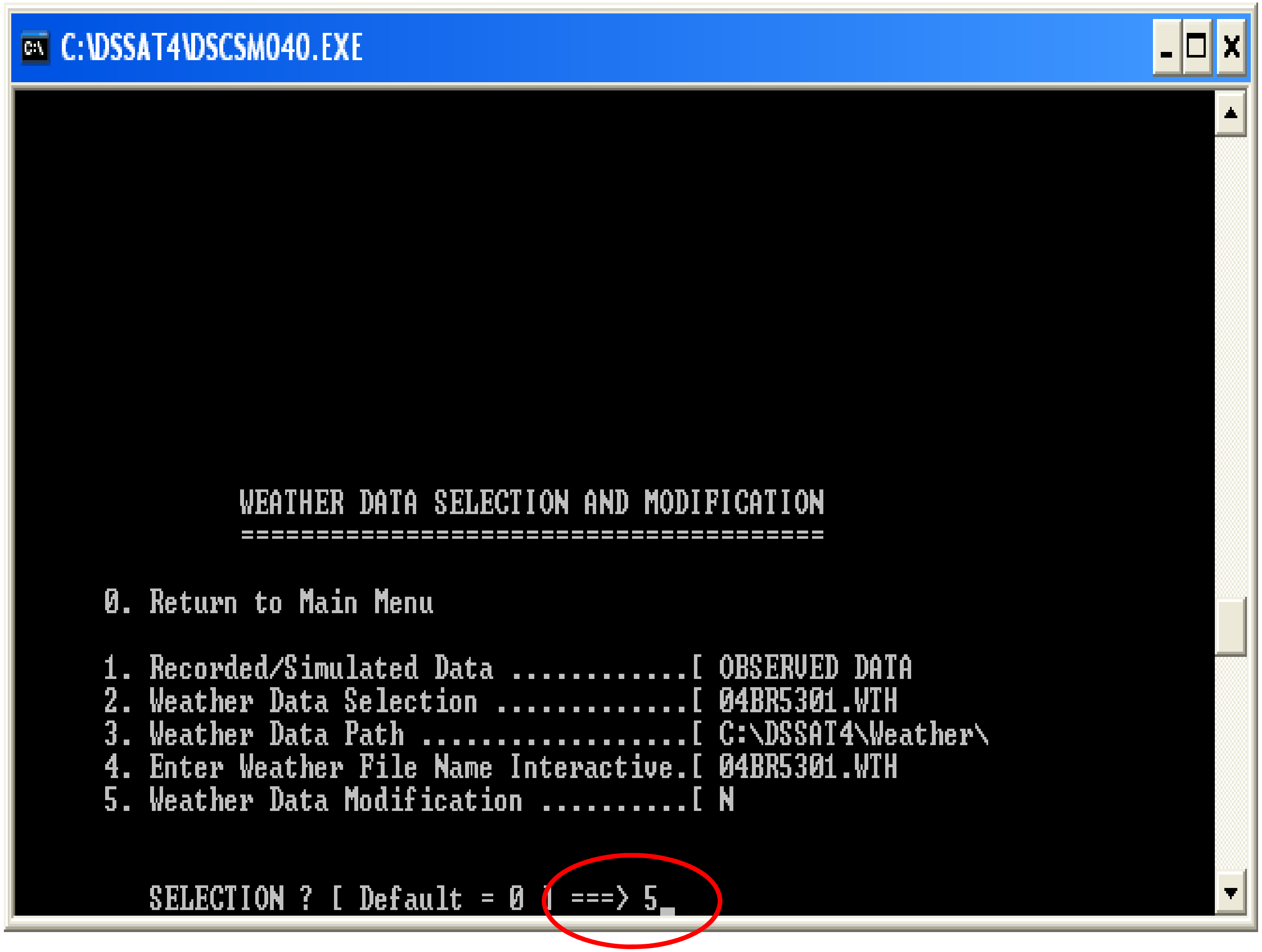
C:\DSSAT4\DSCSM040.EXE

```
      Grain N at maturity (%)                   1.7             -99
      Tops weight at anthesis (kg [dm]/ha      3314             -99
      Tops N at anthesis (kg/ha)                 44             -99
      Leaf number per stem, maturity          21.05             -99
*RUN       1     :  base                  ... Press < ENTER > key to continue



      Maize YIELD :       354 kg/ha     [DRY WEIGHT]


 Do you want to run more simulations ?
 Y or N ? [Default = "N"] ===> y
```

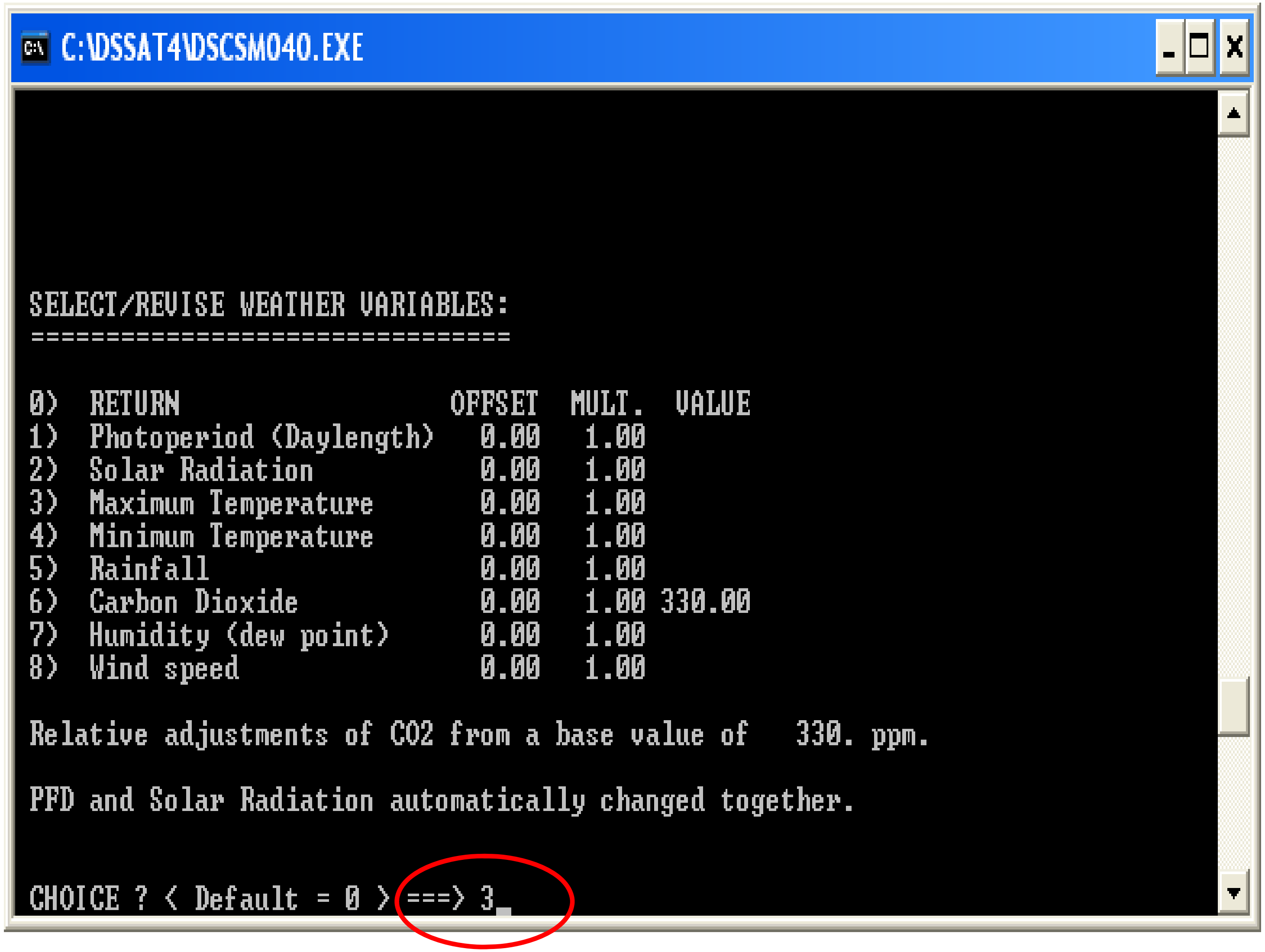
Simulation with Changes



Sensitivity to Weather Modification



Maximum Temperature

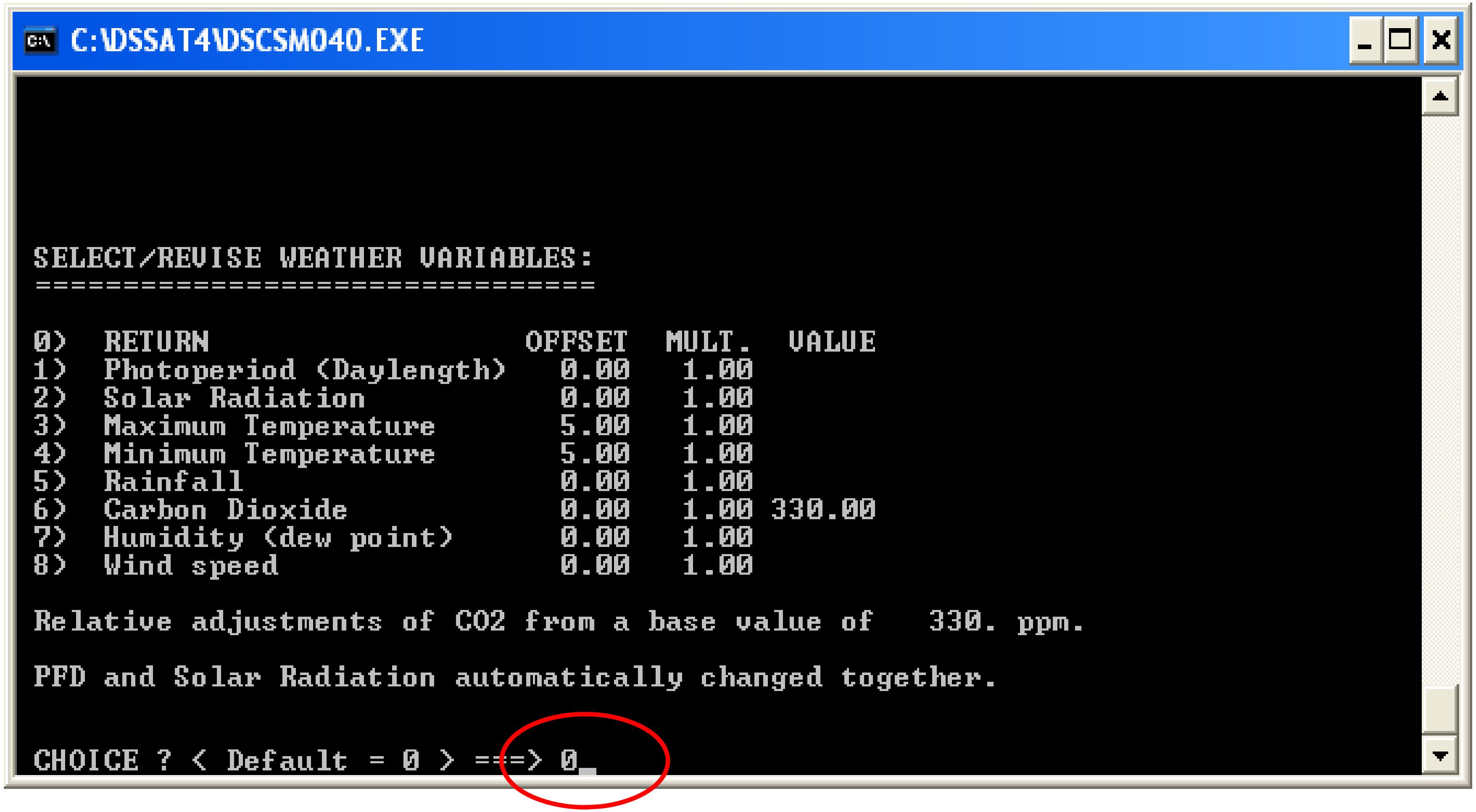


An Additive Change of 5ºC

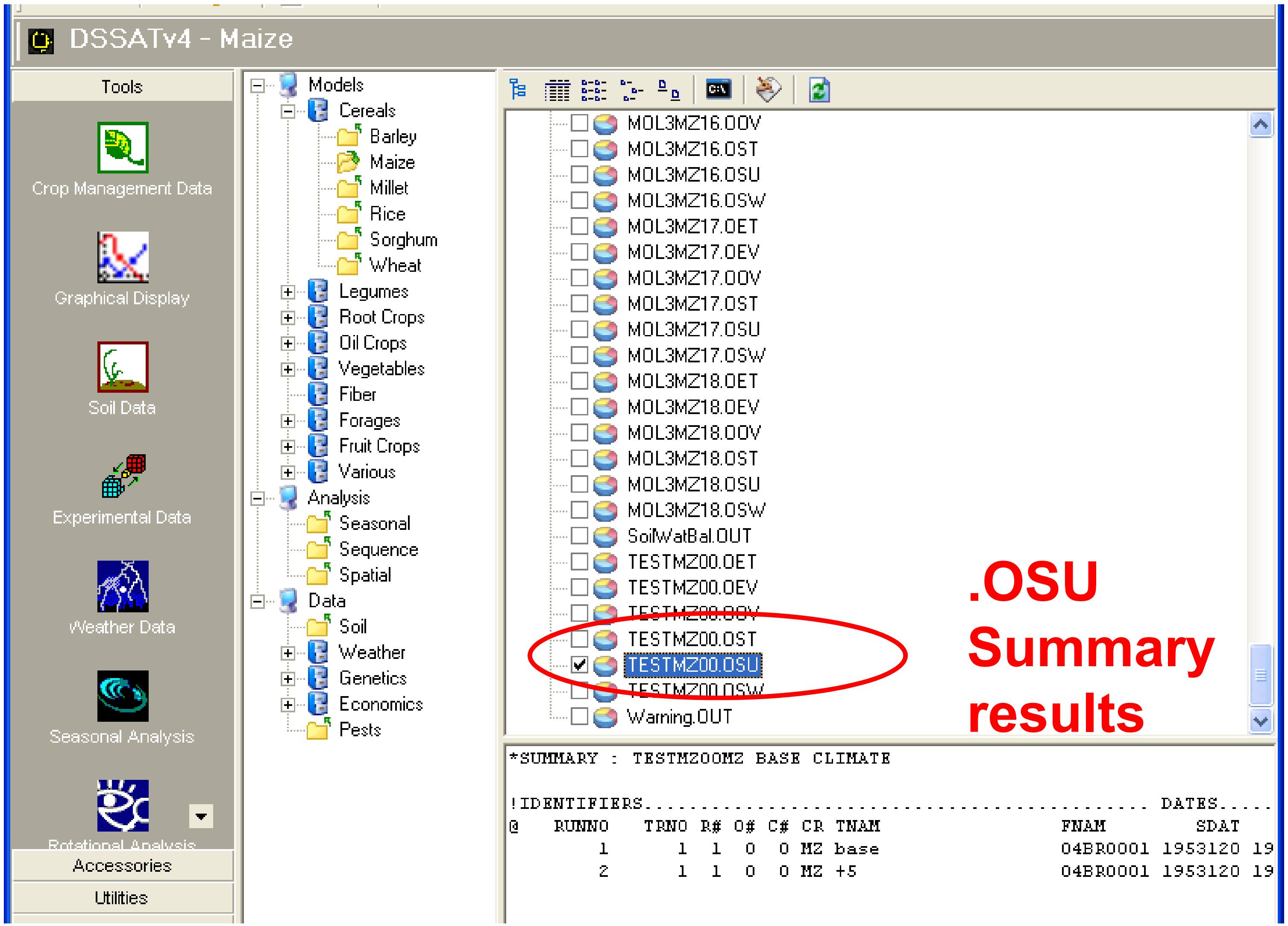
```
C:\DSSAT4\DSCSM040.EXE

 Select modification option, then enter amount:

 0)  NO CHANGE              ( ambient conditions )
 1)  Additive Change        ( 3.0 = 3 higher )
 2)  Subtractive Change     ( 3.0 = 3 lower )
 3)  Multiplicative Change ( 1.2 = 20% higher )
 4)  Constant Value         ( 100 = constant of 100 )

 <=== CHOICE? ( Default = 0 )
1

 <=== Amount
5_
```

Repeat this process for min. temp.

When the Changes are Finished …



View the Results …



.OSU Summary results

View the Results …

TESTMZ00.OSU - Bloc de notas

Archivo Edición Formato Ver Ayuda

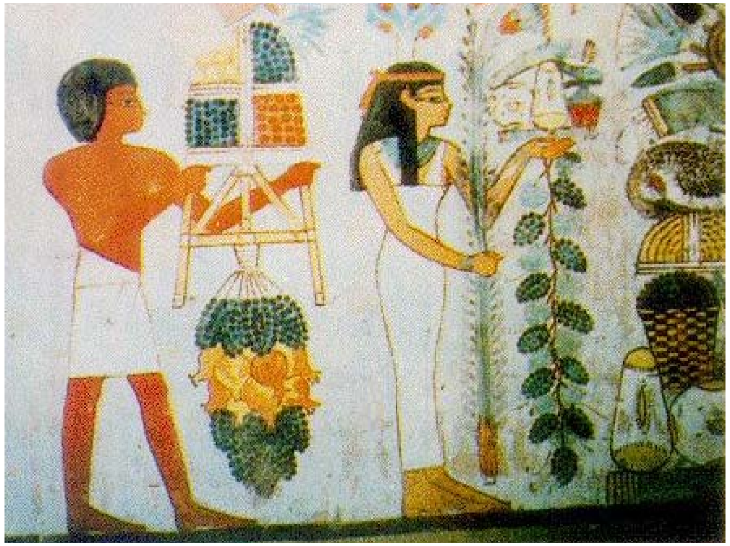
```
*SUMMARY : TESTMZ00MZ BASE CLIMATE                                              DSSAT Cropping System Model Ver. 4.0.

!IDENTIFIERS............................................... DATES.................................. DRY WEIGHTS..........
@    RUNNO    TRNO R# O# C# CR TNAM                FNAM        SDAT    PDAT    ADAT    MDAT    HDAT  DWAP  CWAM  HWAM  HWA
         1       1  1  0  0 MZ base                04BR0001 1953120 1953130 1953205 1953225 1953225   -99  3748   354   35
         2       1  1  0  0 MZ +5                  04BR0001 1953120 1953130 1953186 1953216 1953216   -99  4184  1015  101
```

United Nations Framework Convention on Climate Change

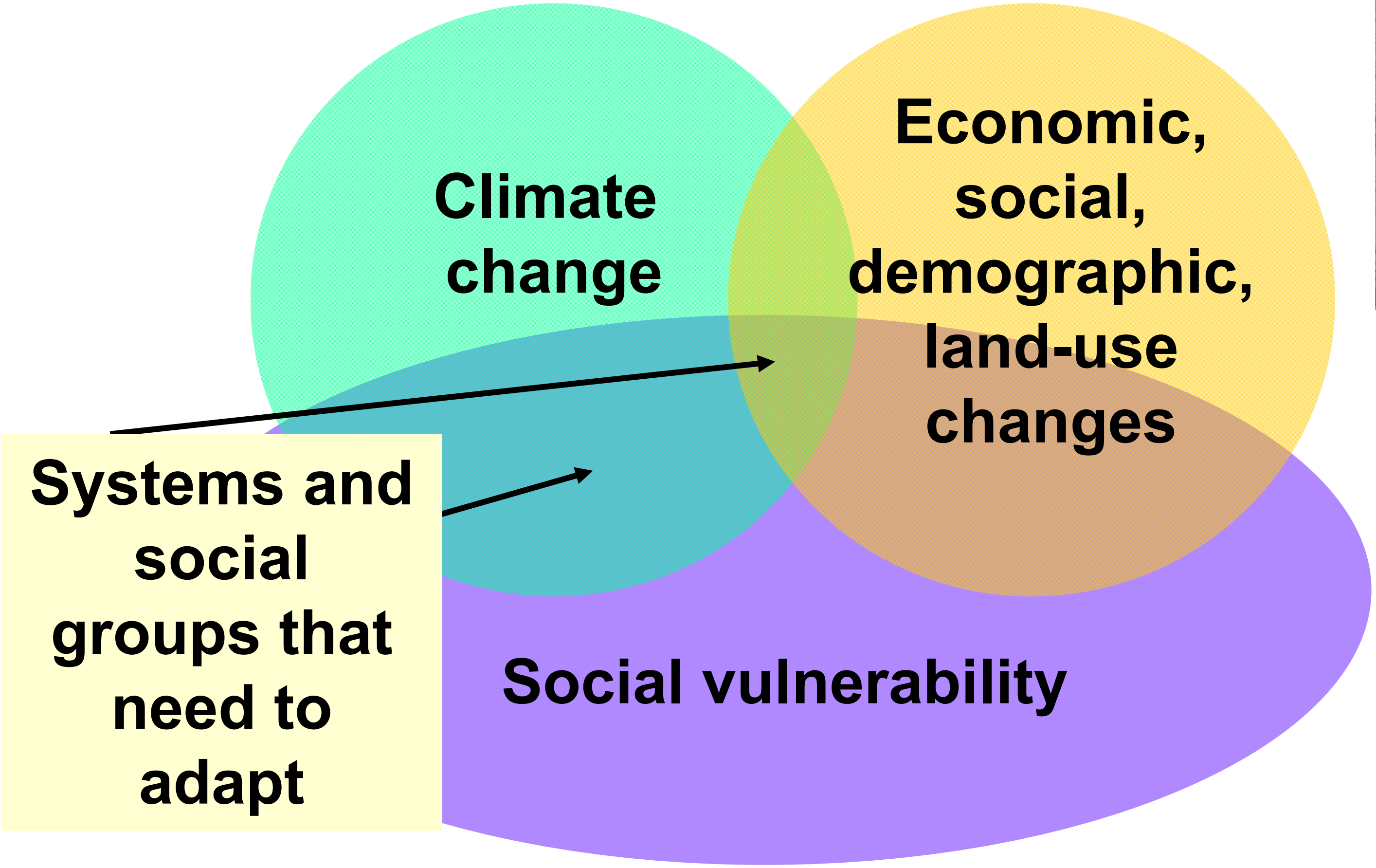
SUPPLEMENTARY INFORMATION ON AGRICULTURE

Climate Change, Agriculture, and Food Security

▪Climate change is one stress among many affecting agriculture and the population that depends on it.



Multiple Interactions, Vulnerability and Adaptation




Mozambique, floods

Multiple Interactions: Stakeholders Define Adaptation

Multiple Interactions

- Climate change is one stress among many now affecting agriculture and the population that depends on it
  a) Integration of results is essential to formulate assessments relevant to policy
- Potential future consequences depend on:
  a) The region and the agricultural system [Where?]
  b) The magnitude [How much? Scenarios are

Where? Systems and Social Groups

Cassava production, Mozambique

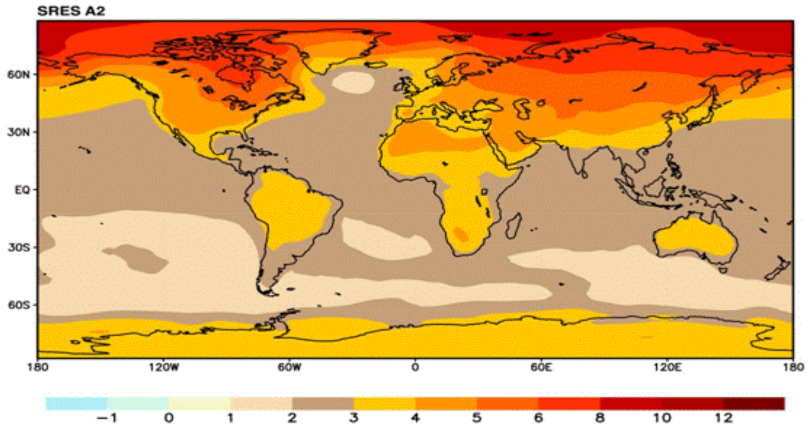
Vegetable production, Egypt

Coffee production, Kenya

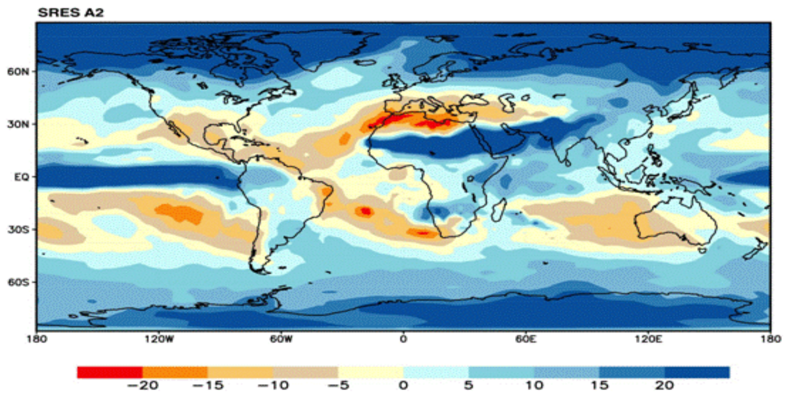
How Much? Climate and SRES Scenarios

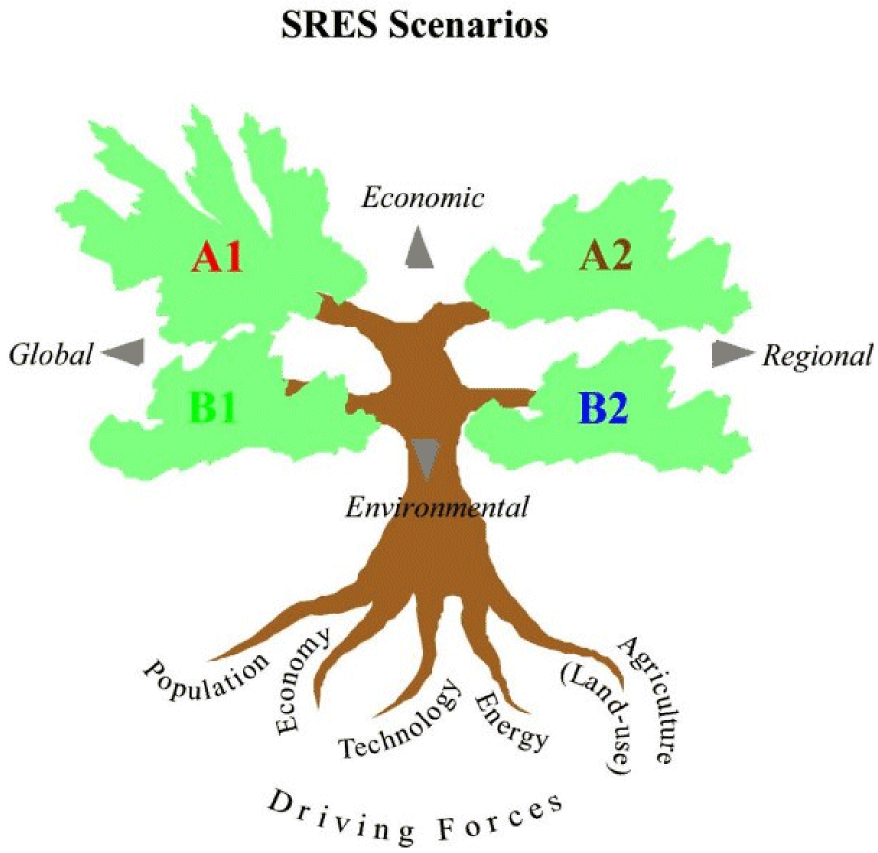
HadCM2 model, 2050s

Temperature change



Precipitation change





What Happens in Response to Change?

•Adaptive capacity (internal adaptation)

•Planned adaptation.

Limits to Adaptation

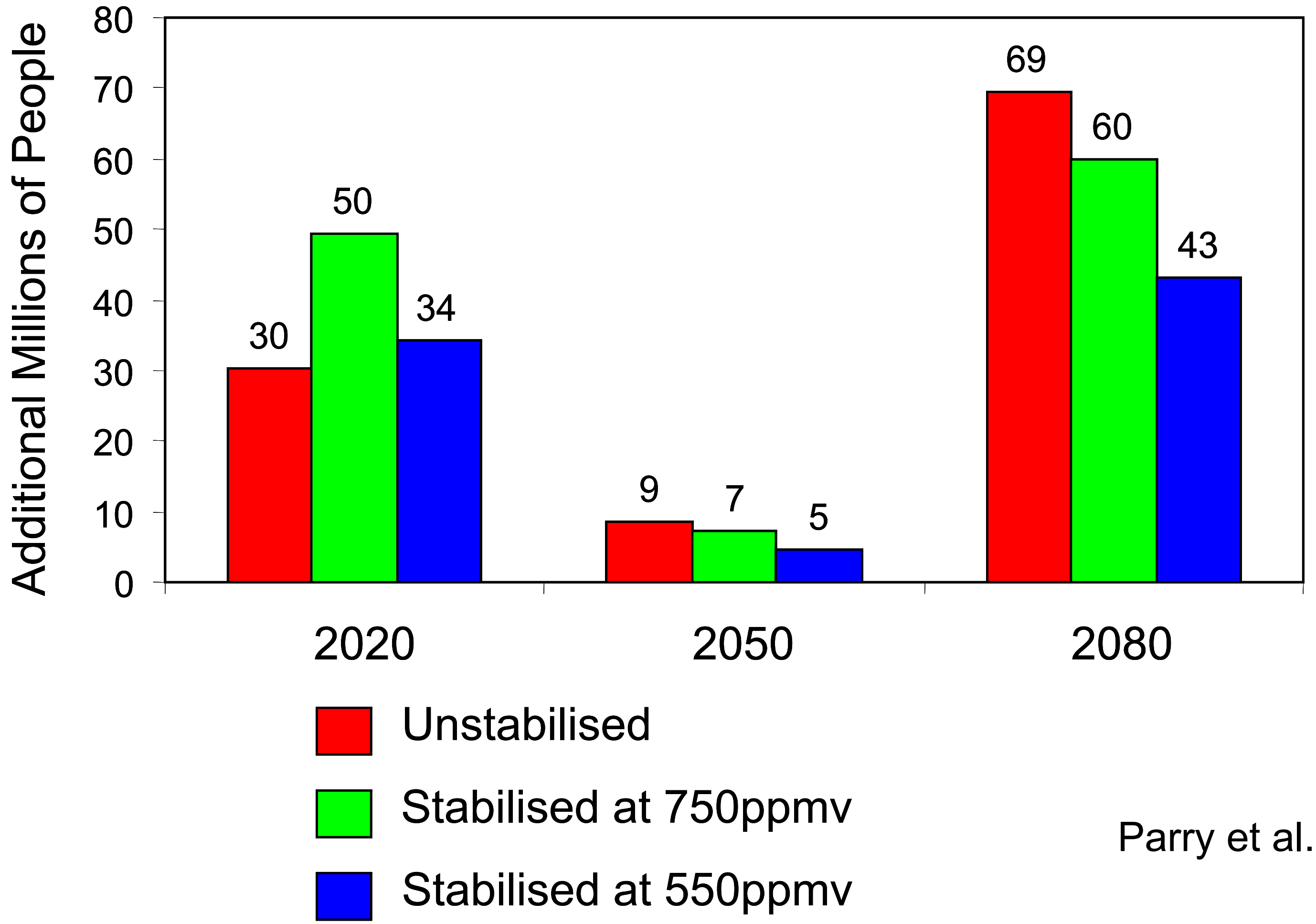
- Technological limits (e.g. crop tolerance to water-logging or high temperature; water reutilization)
- Social limits (e.g. acceptance of biotechnology)
- Political limits (e.g. rural population stabilization may not be optimal land-use planning)
- Cultural limits (e.g. acceptance of water price and tariffs).

Differences Between Developed and Developing Countries

Potential change (%) in national cereal yields for the 2080s (compared with 1990) using the HadCM3 GCM and SRES scenarios (Parry et al., 2004)

Scenario	A1FI	A2a	A2b	A2c	A2c	B1a	B2b
CO_2 (ppm)	810	709	709	709	527	561	561
World (%)	-5	0	0	-1	-3	-2	-2
Developed (%)	3	8	6	7	3	6	5
Developing (%)	-7	-2	-2	-3	-4	-3	-5
Developed – Developing) (%)	10	10	8	10	7	9	9

Additional People at Risk of Hunger



Parry et al., 2004

Additional People at Risk of Hunger (continued)

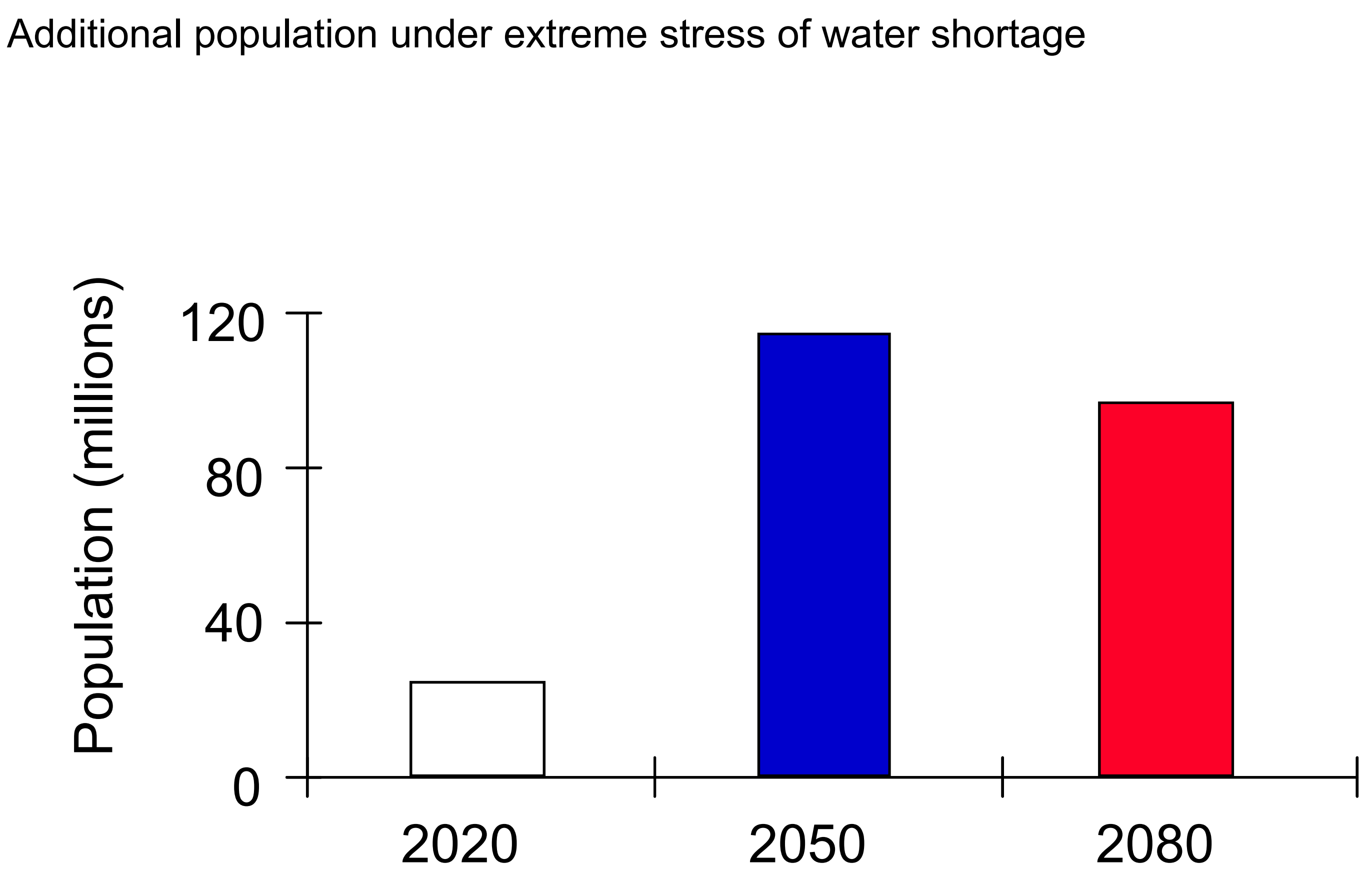
- Overall, the potential for additional people with risk of hunger is greater with the “unstabilized” scenario, although there are decadal variations.

  a) **In all decades, the “unstabilized” scenario is the warmest**

  b) **In the 2020s, the warming is beneficial for aggregated crop production**

  c) **In the 2080s, the warming exceeds the threshold of optimal crop tolerance in many low latitude regions with more people at risk.**

Interaction and Integration: Water



Parry et al., 2004

Conclusions

- Although global production appears stable, regional differences in crop production are likely to grow stronger through time, leading to a significant polarization of effects with substantial increases in prices and risk of hunger amongst the poorer nations
- Most serious effects are at the margins (vulnerable regions and groups such as women and children).

Methods, Tools and Datasets

- The framework
- The choice of the research methods and tools
  - a) Demand-driven methods: responding to stakeholders
  - b) Key characteristics, strengths, weaknesses
  - c) Examples
- Datasets: sources, scales, reliability

Frameworks

- Adaptation Policy Framework (APF), US Country Studies, IPCC, seven steps
- All have the essential common elements:
  a) Problem definition
  b) Selection and testing of methods
  c) Application of scenarios (climate and socio-economic)
  d) Evaluation of vulnerability and adaptation
- Studies may want to use a framework as guidance

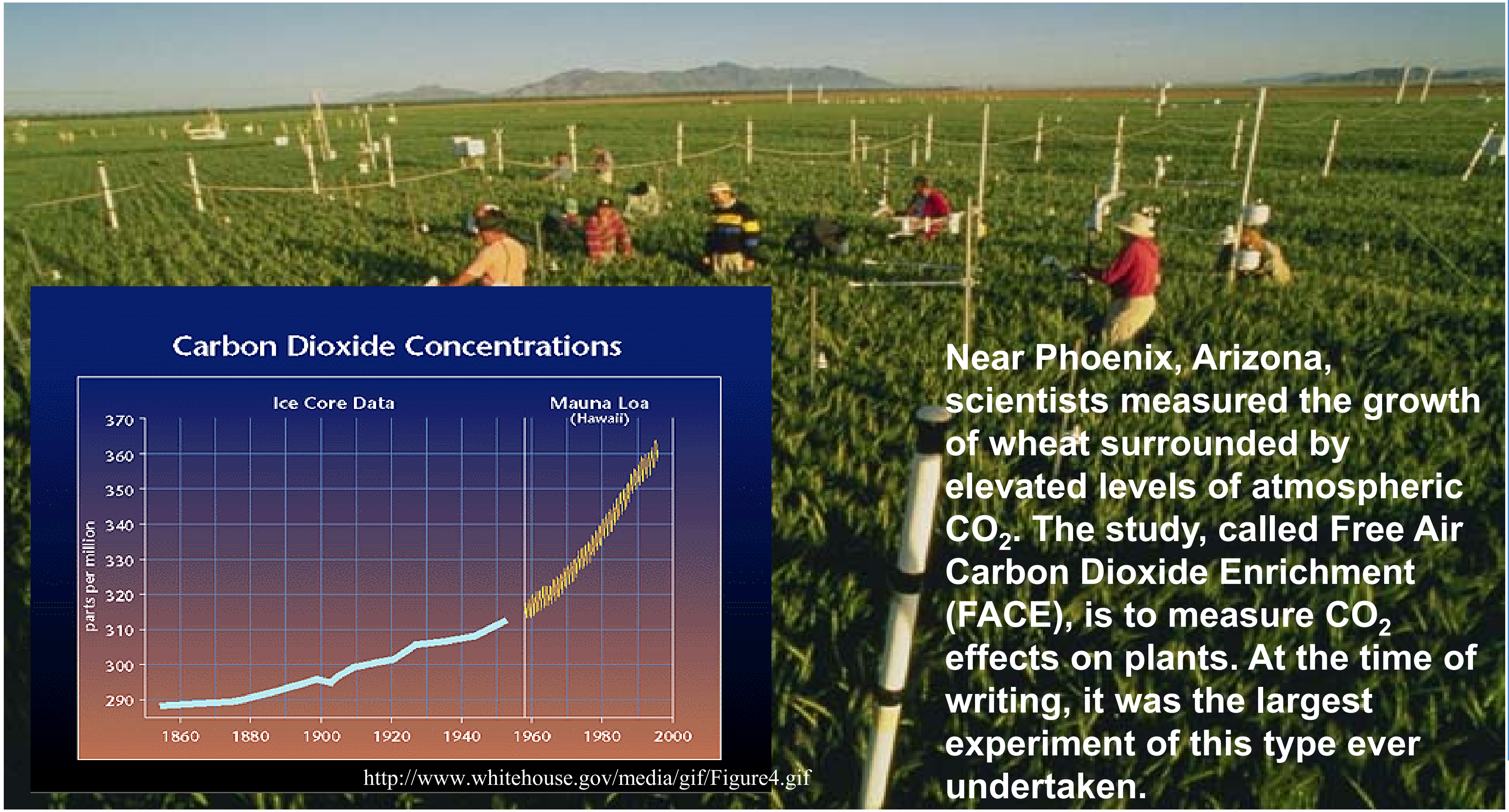
Demand-Driven Methods

- Need quantitative estimates:
  a) Models are assisting tools
  b) Surveys are assisting tools for designing adaptation options
- Key variables for agronomic and socio-economic studies: crop production, land suitability, water availability, farm income, …

Quantitative Methods and Tools

- Experimental
- Analogues (spatial and temporal)
- Production functions (statistically derived)
- Agroclimatic indices
- Crop simulation models (generic and crop-specific)
- Economic models (farm, national, and regional) – provide results that are relevant to policy
- Social analysis tools (surveys and interviews) – allow the direct input of stakeholders (demand-driven science), provide expert judgement
- Integrators: GIS.

Experimental: Effect of Increased CO_2



http://www.whitehouse.gov/media/gif/Figure4.gif

Near Phoenix, Arizona, scientists measured the growth of wheat surrounded by elevated levels of atmospheric CO_2. The study, called Free Air Carbon Dioxide Enrichment (FACE), is to measure CO_2 effects on plants. At the time of writing, it was the largest experiment of this type ever undertaken.

http://www.ars.usda.gov