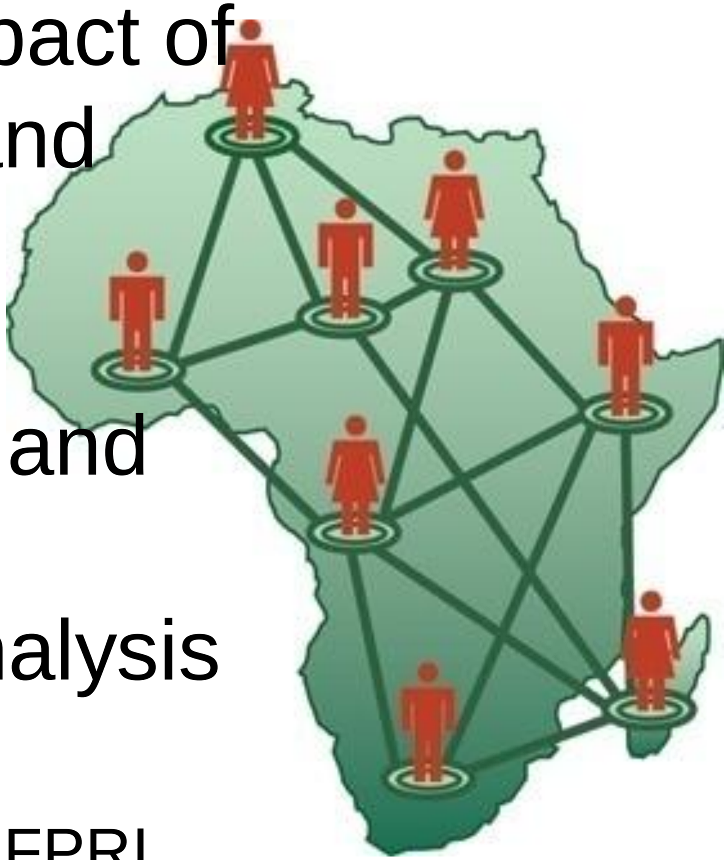
Simulating the Impact of Climate Change and Adaptation Strategies on Farm Productivity and Income: A Bioeconomic Analysis



Presented by:
Ismael Fofana, IFPRI

AGRODEP Workshop on Analytical Tools for Climate Change Analysis

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Simulating the Impact of Climate Change and Adaptation Strategies on Farm Productivity and Income: A Bioeconomic Analysis

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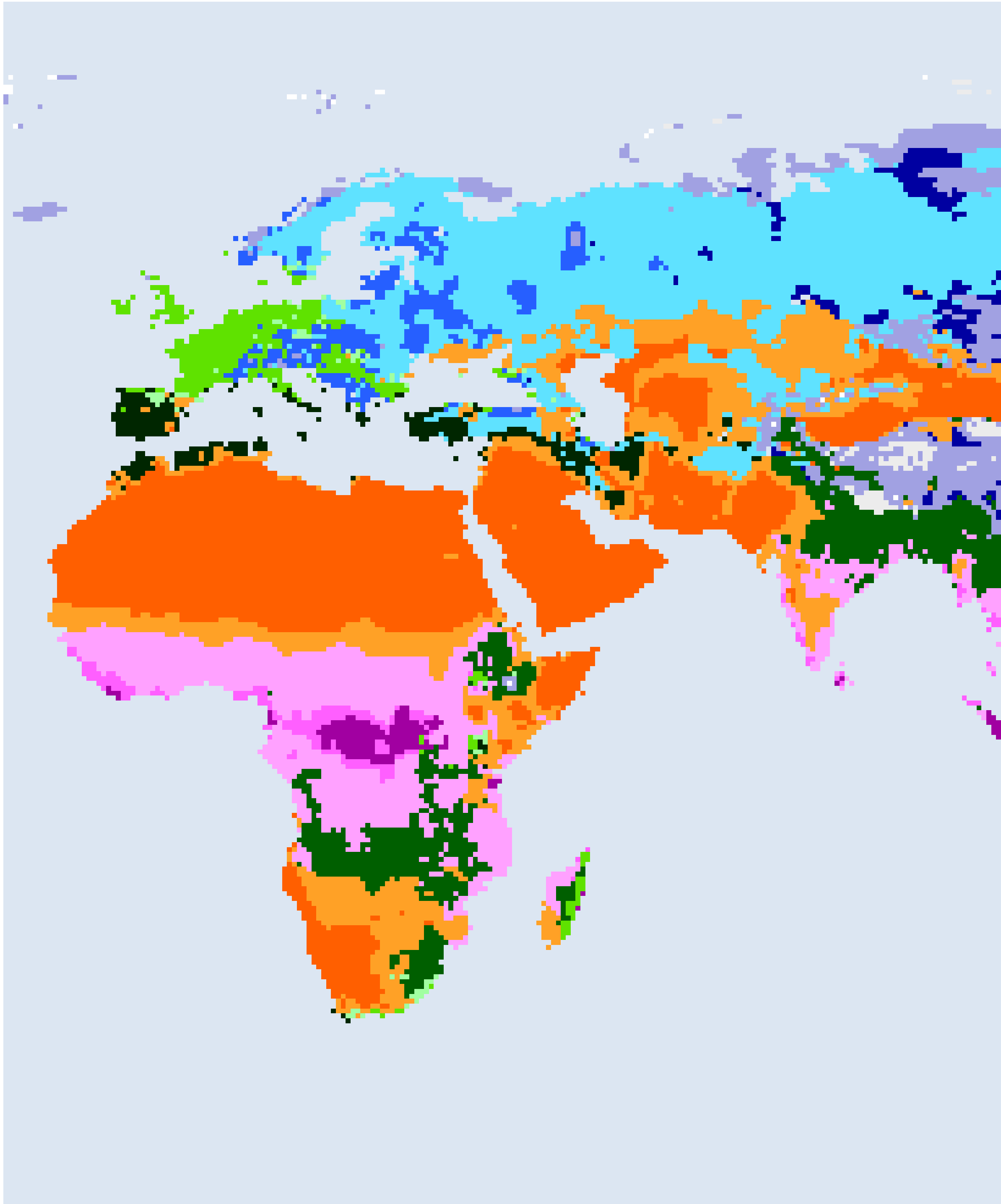
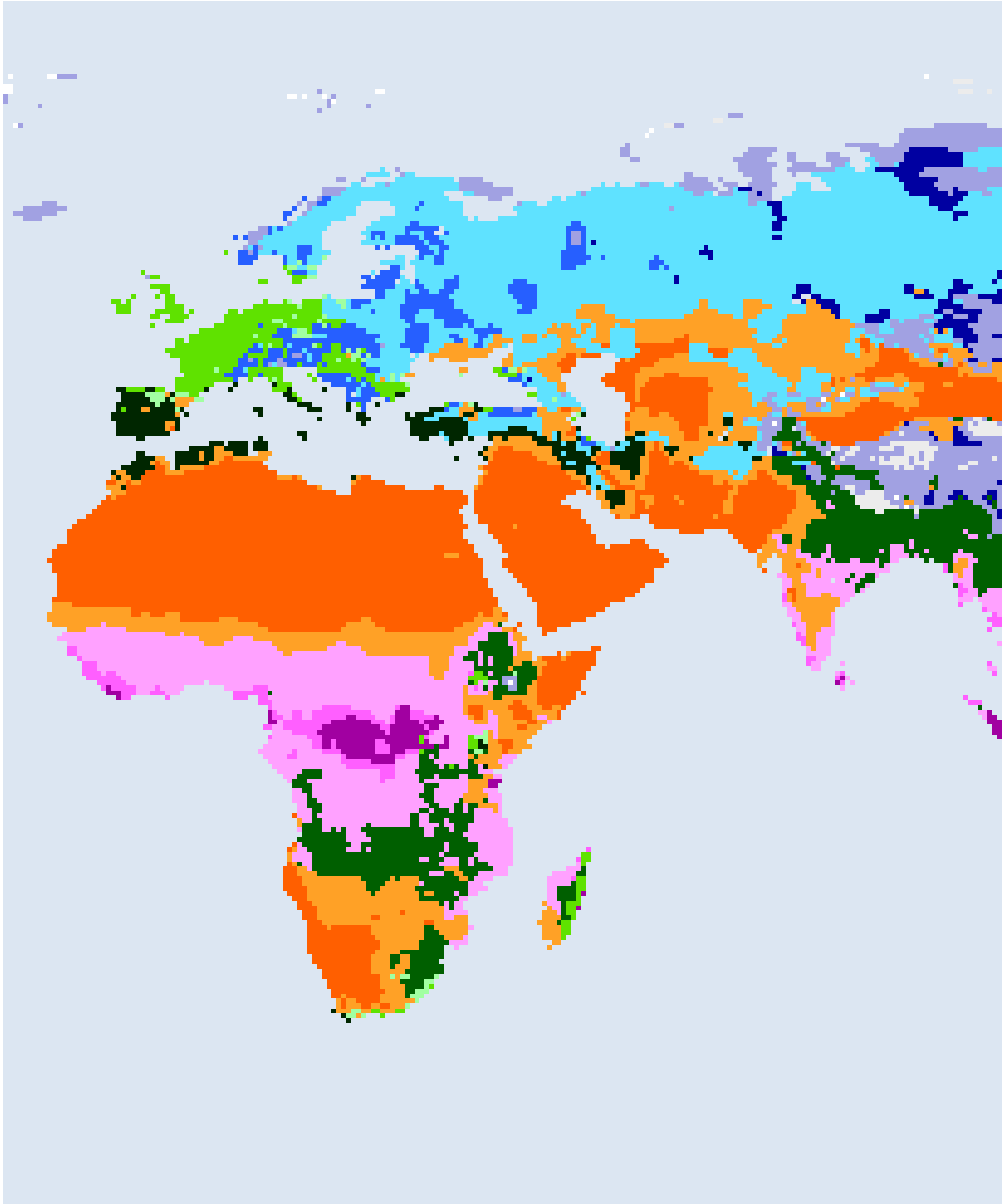


1. Issue

2. Methodology

3. Results



1. Issue

- Our climate is changing; strong evidences on rising temperature, sea-levels, frequency and severity of droughts and floods, ...
- More confidence on IPCC's near-term projections

IPCC projected global average warming until 2100 under various scenarios

	Economic growth	Environmental sustainability
Homogeneous world	**A1** {**A1FI**; **A1T**; **A1B**}: Rapid technological change and economic growth [**1.4 - 6.4 °C]**	**B1**: Economic structures toward a service and information economy **[1.1 - 2.9 °C]**
Heterogeneous world	**A2**: Slow technological change and economic development **[2.0 - 5.4 °C]**	**B2**: Local solutions to economic, social, and environmental sustainability **[1.4 - 3.8 °C]**

1. Issue (cont.)

- Agricultural sector is highly climate sensitive
- Climate defines production areas for crops
- Climate’s effect on yield is important

Objective: Contribute to better understand the impact of climate change on agriculture and food security in Africa

Analysis at the farm level is a crucial step before moving into a large and general analysis

2. Methodology

- Building of climate scenarios upon changes in temperature, precipitation, and carbon dioxide concentration in the atmosphere

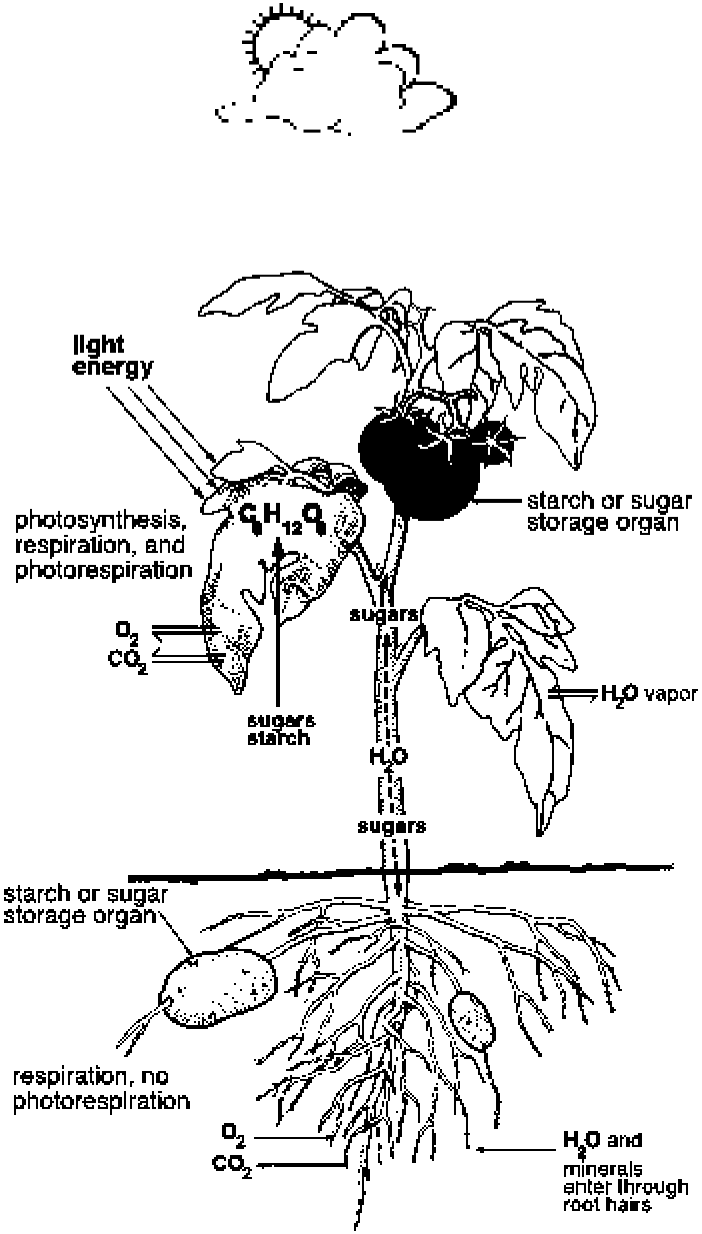
- Performing climate sensitivity tests with the climate scenarios using a farm model
    - **Farm model** combines a crop systems model and an economic model run sequentially (Bioeconomic model)
        - **Crop systems model**: CROPSYST
        - **Economic model**: Linear optimization

CropSyst or Cropping System

LOCATION
- **WEATHER**
- Storms
- **Evapotranspiration**
- Freezing climates
- Wind

CROP
- Classification
- Planting
- **Growth**
- Morphology
- Phenology
- Vernalization
- Photoperiod
- Harvest
- Residue
- Nitrogen
- Salinity
- CO2
- Dormancy

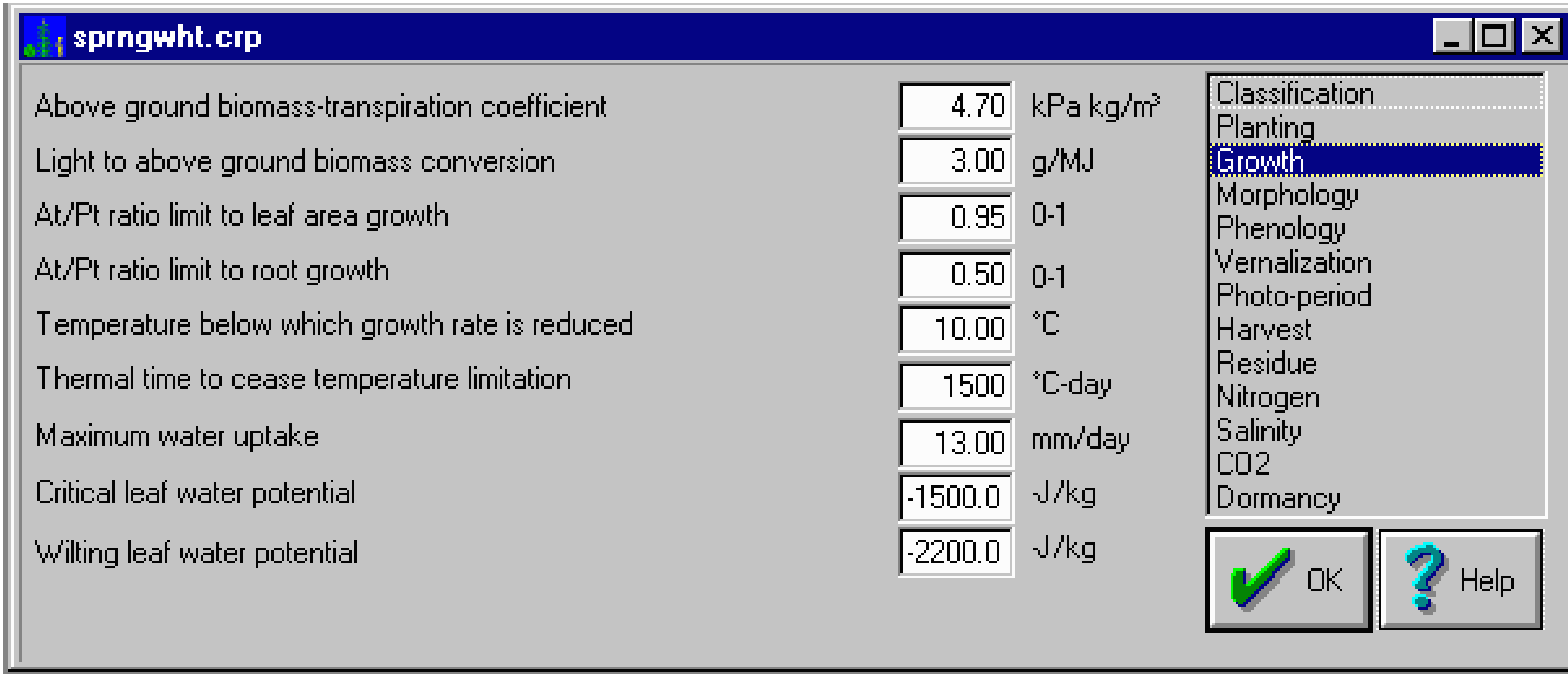
SOIL
- Leaching
- Runoff
- RUSLE
- Volatilization
- **Texture**
- Hydraulics



MANAGEMENT
- Harvest
- **Irrigation**
- Clipping
- Nitrogen
- Conservation
- Tillage

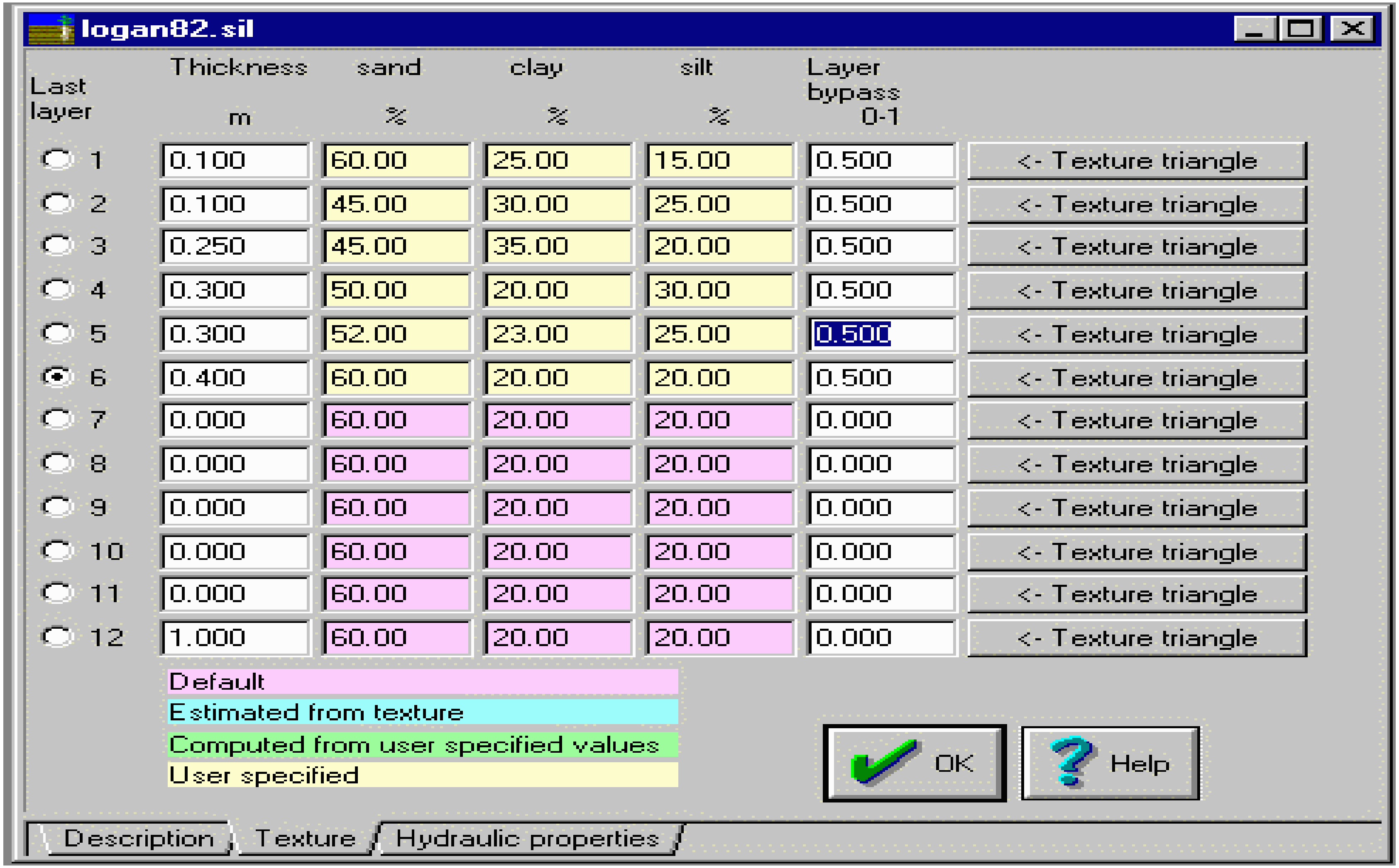
CropSyst (cont.)

Crop growth



CropSyst (cont.)

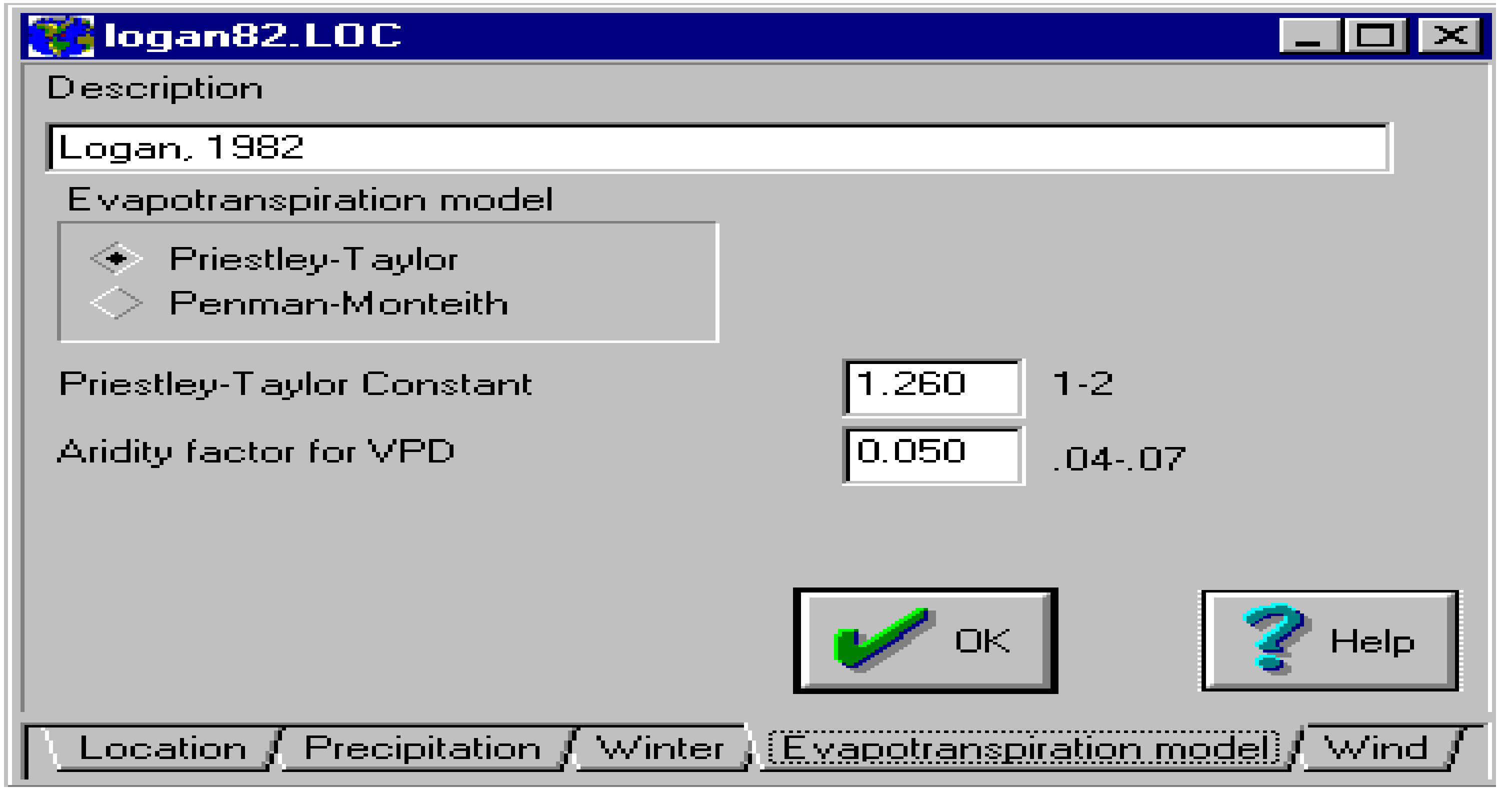
Soil texture



Last layer	Thickness m	sand %	clay %	silt %	Layer bypass 0-1	
1	0.100	60.00	25.00	15.00	0.500	<- Texture triangle
2	0.100	45.00	30.00	25.00	0.500	<- Texture triangle
3	0.250	45.00	35.00	20.00	0.500	<- Texture triangle
4	0.300	50.00	20.00	30.00	0.500	<- Texture triangle
5	0.300	52.00	23.00	25.00	0.500	<- Texture triangle
6	0.400	60.00	20.00	20.00	0.500	<- Texture triangle
7	0.000	60.00	20.00	20.00	0.000	<- Texture triangle
8	0.000	60.00	20.00	20.00	0.000	<- Texture triangle
9	0.000	60.00	20.00	20.00	0.000	<- Texture triangle
10	0.000	60.00	20.00	20.00	0.000	<- Texture triangle
11	0.000	60.00	20.00	20.00	0.000	<- Texture triangle
12	1.000	60.00	20.00	20.00	0.000	<- Texture triangle

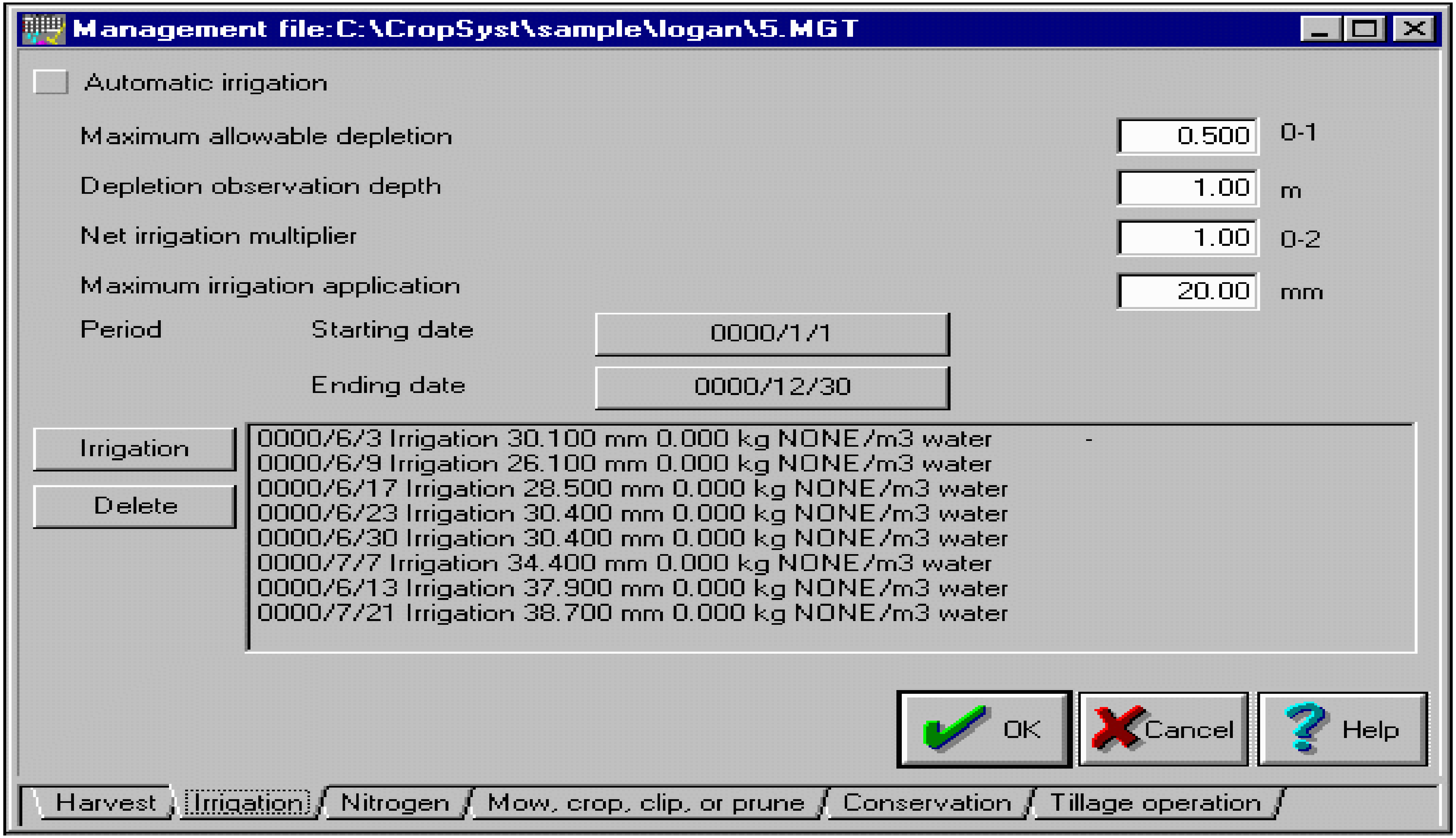
CropSyst (cont.)

Evapotranspiration model

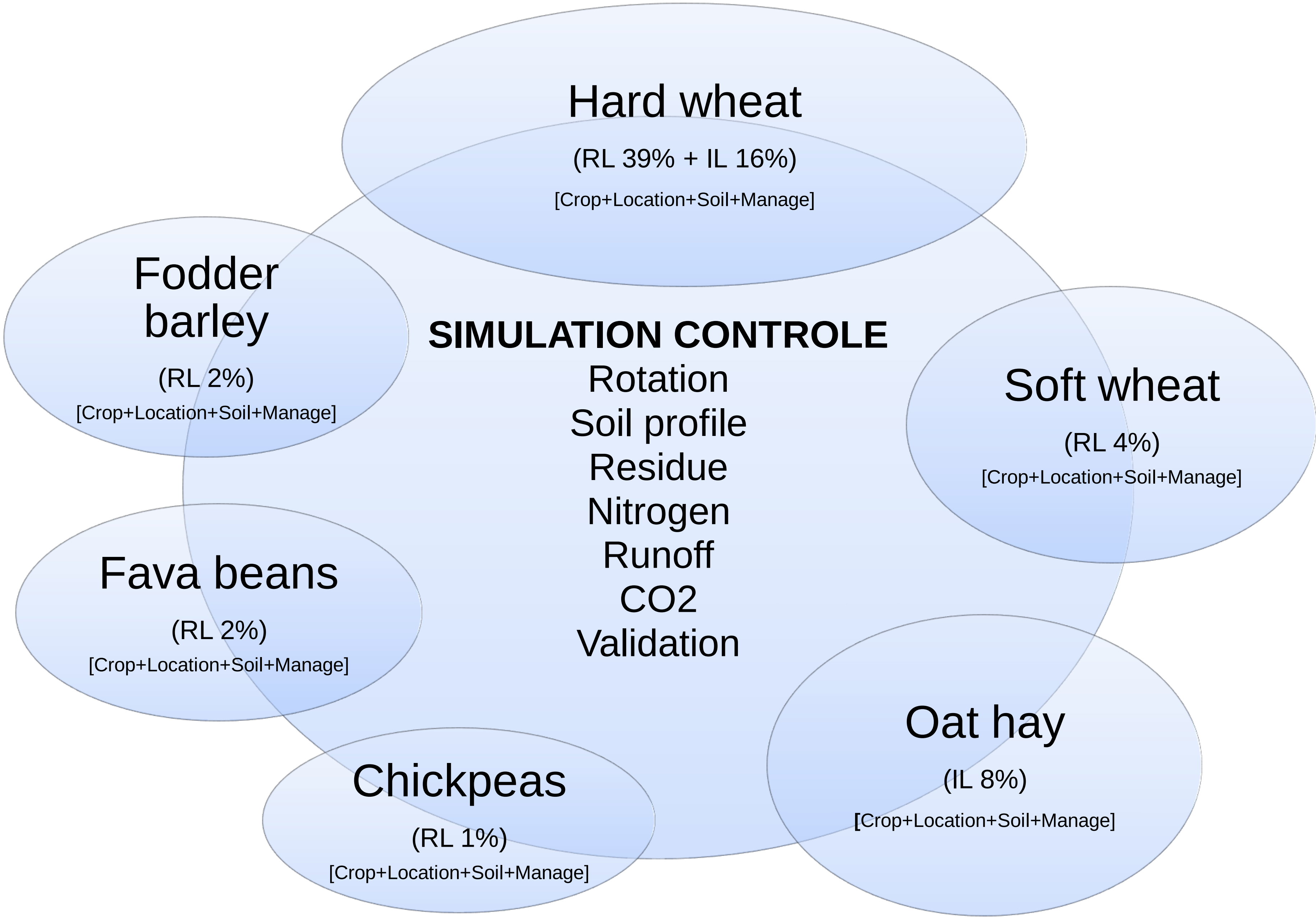


CropSyst (cont.)

Irrigation

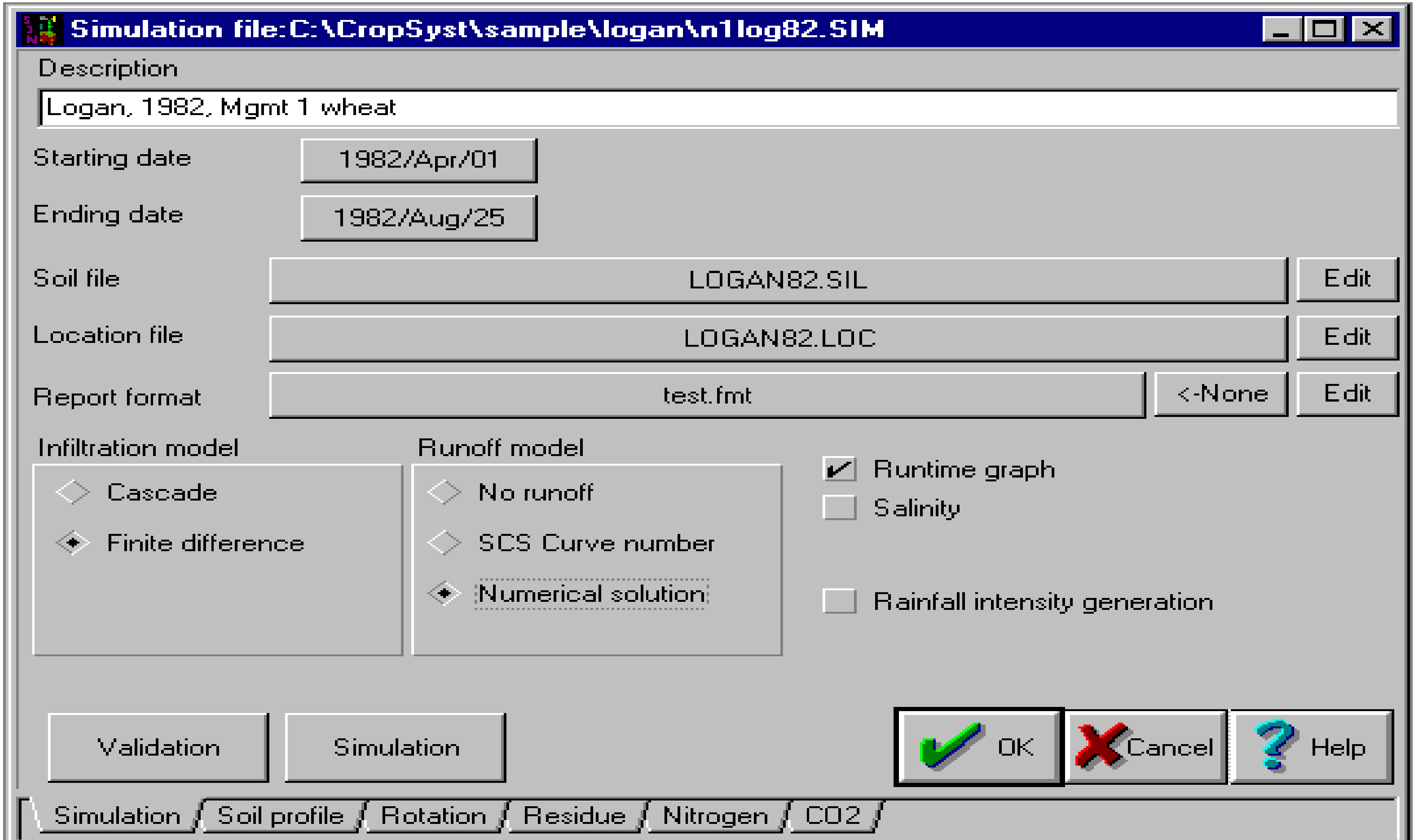


CropSyst (cont.)



CropSyst (cont.)

Simulation controle



The Economic Model

Objective

$$\max_{L} \Omega = \sum_{c,m} \left(\pi_{c,m} \times T_{c,m} \right) \quad \text{with} \quad \pi_{c,m} = \left(\sum_{j} y_{c,m,j} \times \overline{p_{c,j}} \right) - \left(\sum_{i} q_{c,m,i} \times \overline{p_{c,i}} \right)$$

Constraints

Soil occupation: $\sum_{c} \sum_{m} T_{c,m} \leq \overline{T^{S}}$

Rotation: $S_{cc,mi} \leq S_{cf,mi}$ and $\overline{S}_{c}^{\min 5 years} \leq S_{c} \leq \overline{S}_{c}^{\max 5 years}$

Water: $\sum_{c} W_{c,t} \leq \overline{W_{t}^{s}}$

Animal food: Surface allocated to barley fodder compensated for the change in supplies of animal food (stubbles)

Hypotheses

- Rational decision making with gross margins the only variable influencing surface allocation
- Fixed products and factor prices (price taker)
- No constraint on the farm’s access to other productive factors, e.g. labor and capital

Hypotheses (cont.)

- Climate change is not associated directly with the appearance of weeds, diseases, and pests
- Climate change does not affect soil's physical and chemical characteristics
- Climate change does not affect Plant's basic physiological, morphological, and agronomic characteristics
- Tree crops are not seriously affected by climate change

Hypotheses (cont.)

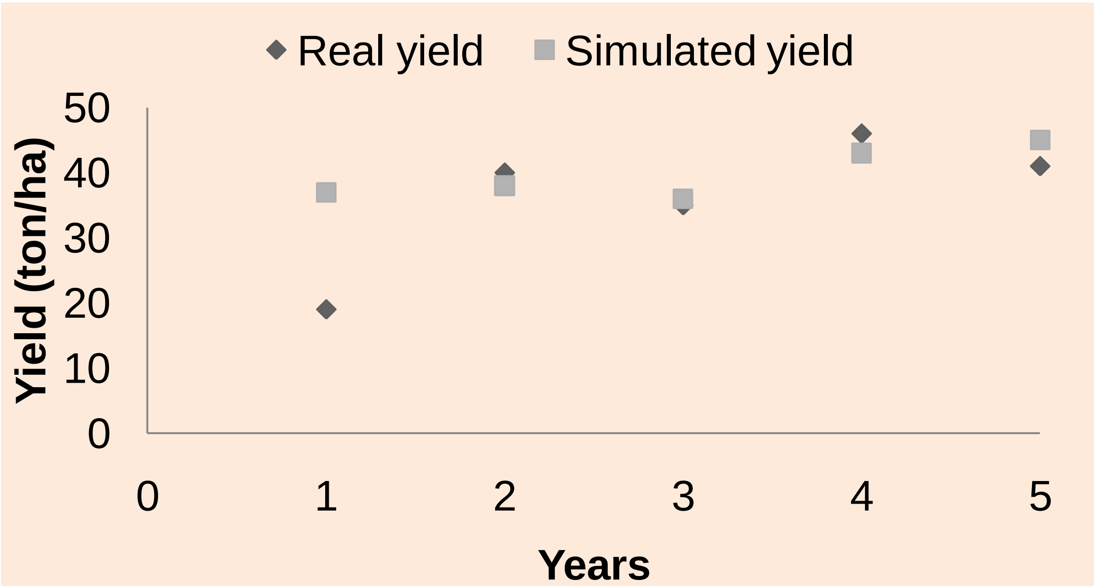
- The contribution of pastureland used to feed animals remained unchanged

- The capacity to ingest of animals and the quality of food are not modified with climate change

- Water requirements for animals do not significantly affect the availability for crops

- Water supply mostly comes from surface water and its availability is proportionally affected by the change in rainfall

Validation

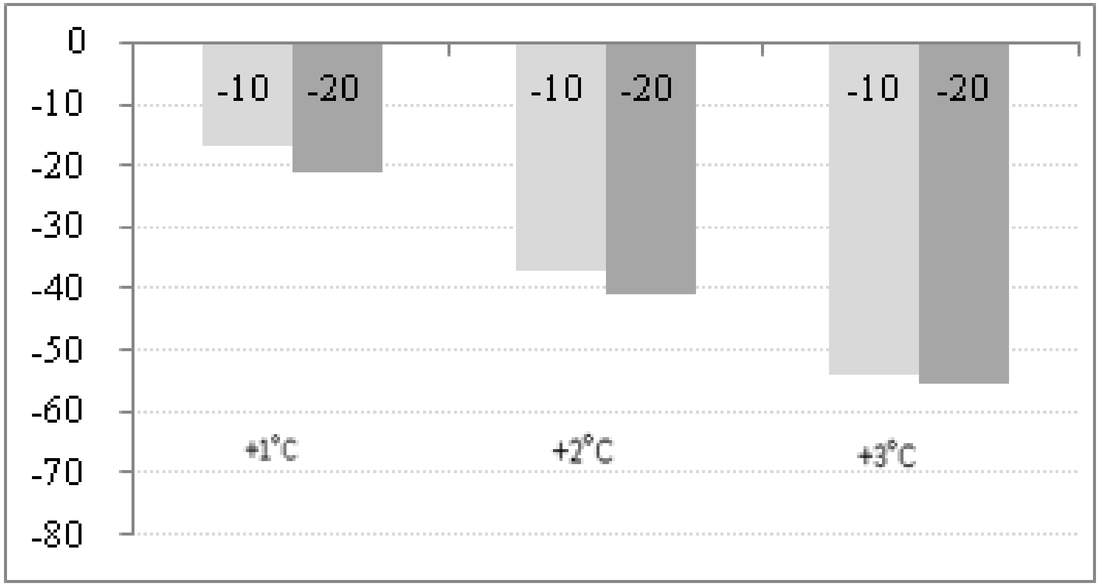


Calibration results for irrigated hard wheat

Calibration results for rainfed hard wheat

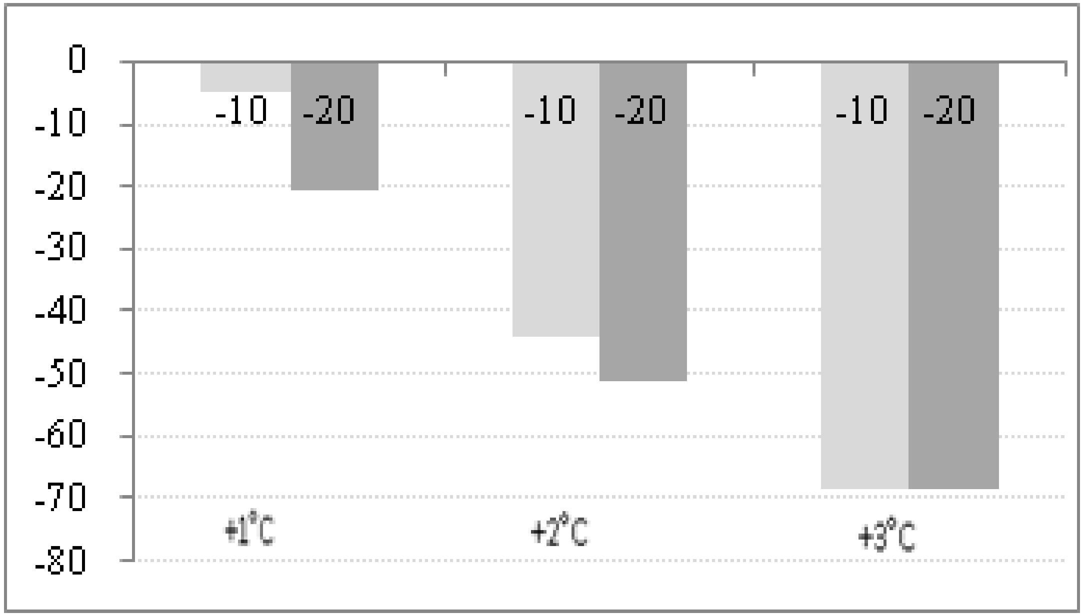
3. Results

Productivity effects



Productivity loss:15 to 20% in the near-term; 35 to 55% in the long run

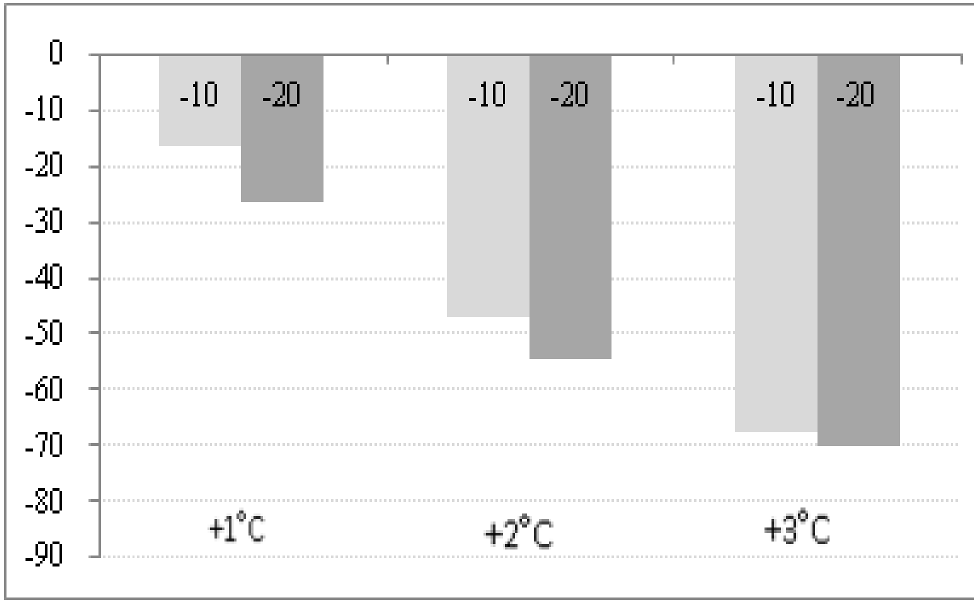
Income effects



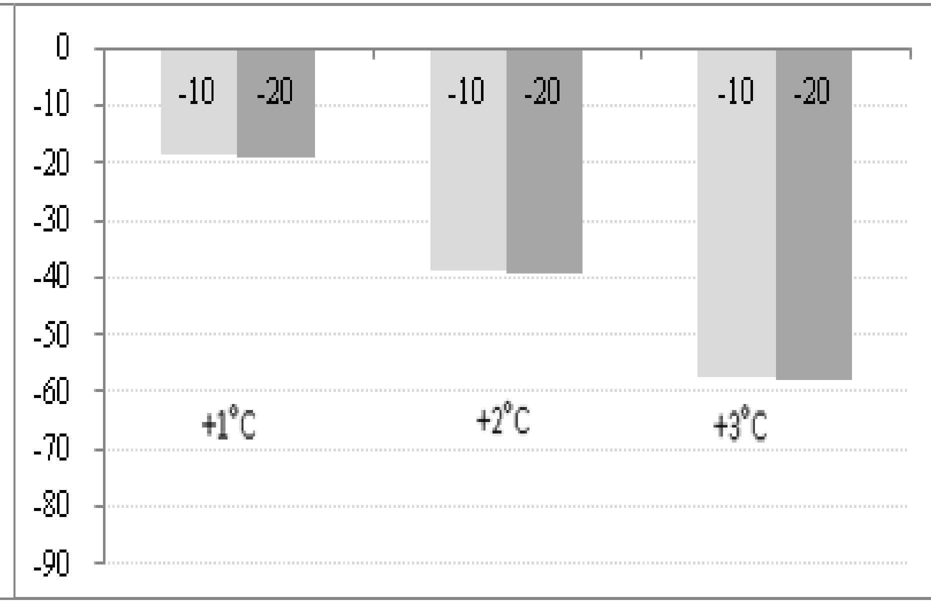
Income loss: 5 to 20% in the near-term; 45 to 70% in the long run

3. Results (cont.)

Yield of rainfed hard wheat



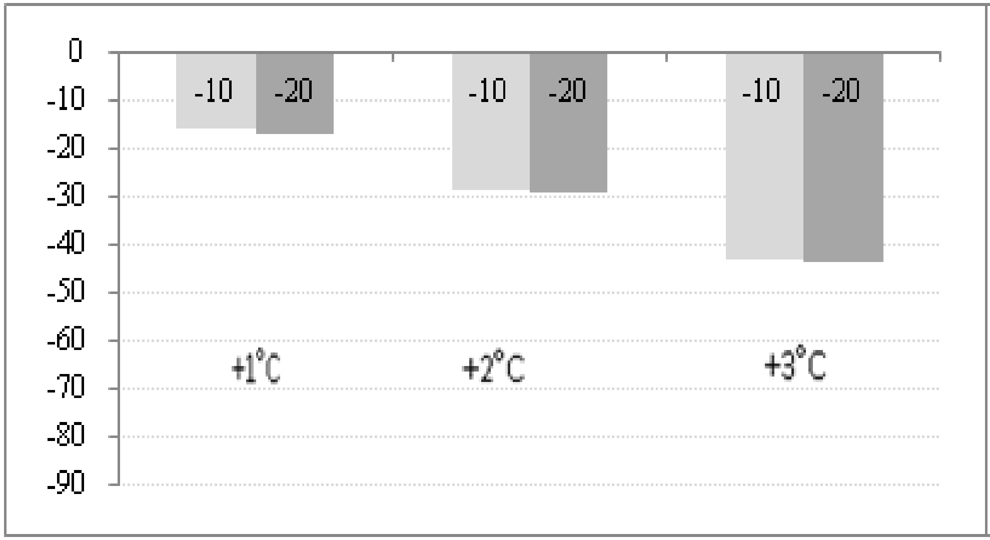
Yield of irrigated hard wheat



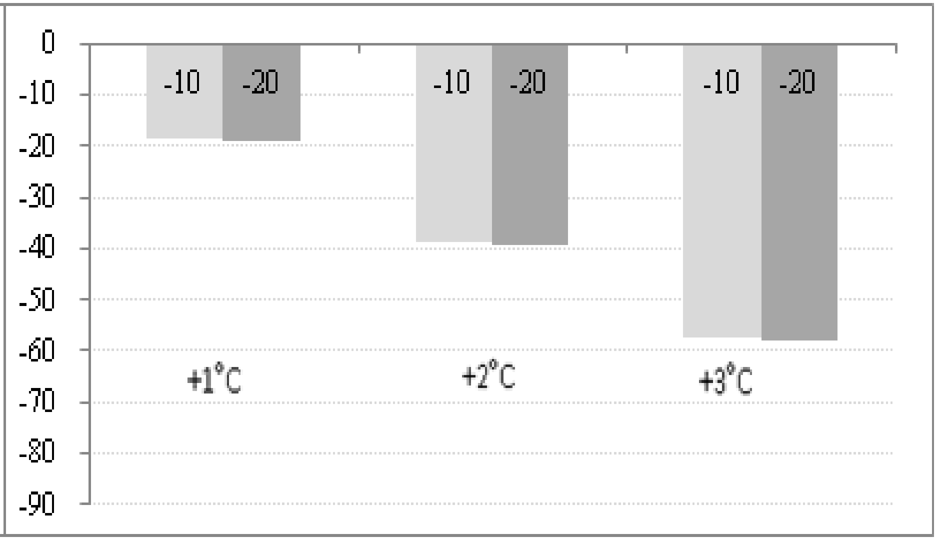
- Irrigated crops less affected than rainfed crops (with 10 percentage points of productivity gap)
- Precipitation-induced productivity gap lessens as the climate warms up

3. Results (cont.)

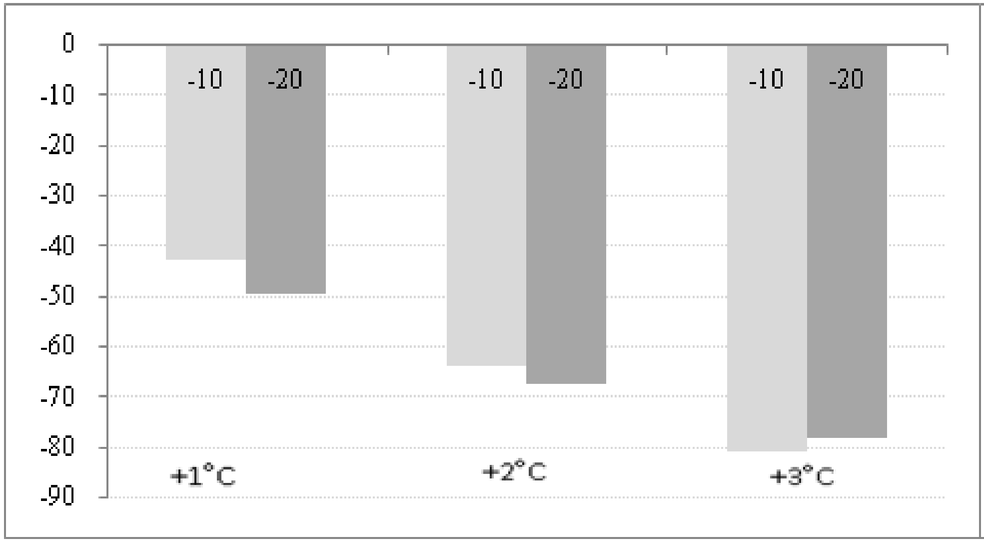
Yield of irrigated oat hay



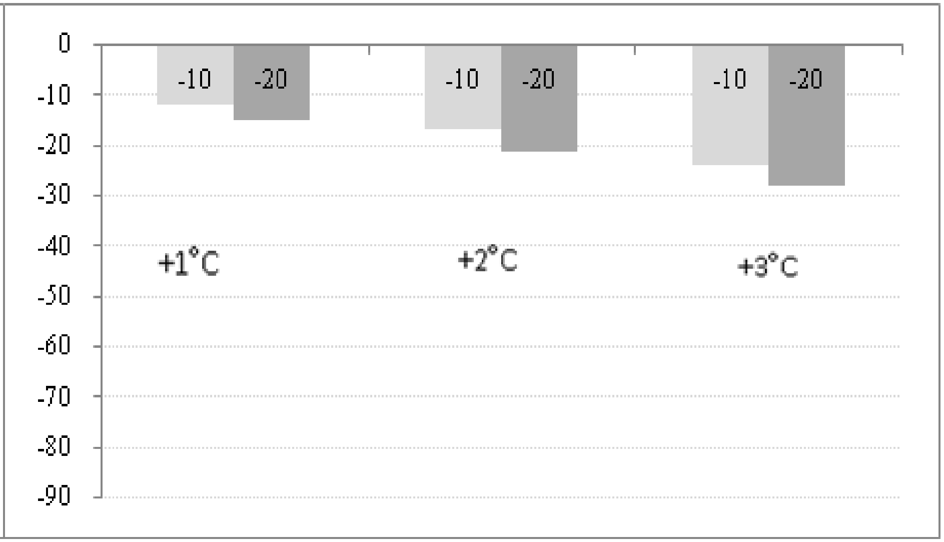
Yield of irrigated hard wheat



Yield of rainfed fava beans

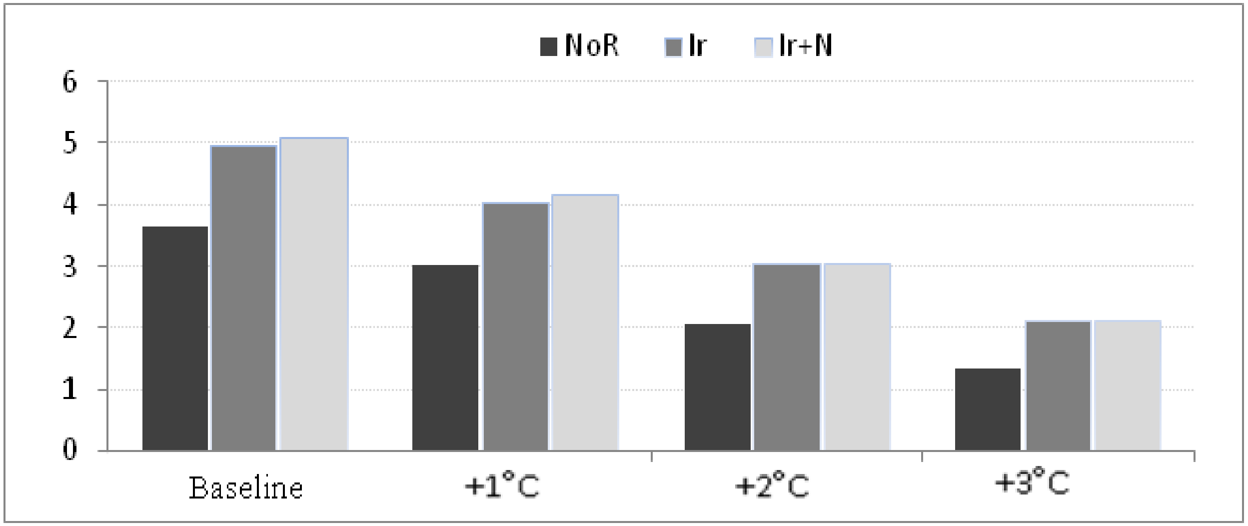


Yield of rained fodder barley

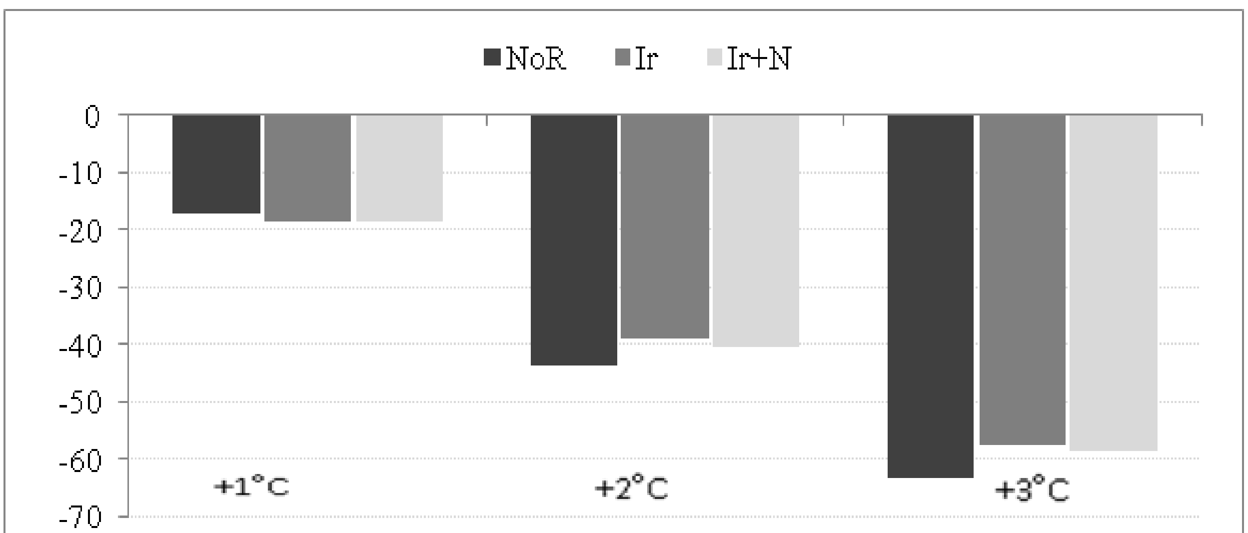


3. Results (cont.)

Hard wheat yield (tons/ha)



Percentage variation of hard wheat yield



Compensation for the negative effects of climate change through irrigation is worthwhile only for a 1°C increase in temperature

Summary

1. Yield loss: $1^{o}C$ ⇨ 15-20% ; $2^{o}C$ to $3^{o}C$ ⇨ 35-55%

2. Rev. loss: $1^{o}C$ ⇨ 5-20% ; $2^{o}C$ to $3^{o}C$ ⇨ 45-70%

3. Irrigated crops less affected than rainfed crops

4. Precipitation-induced productivity gap lessen as the climate warms up

5. Some crops less affected than others

6. Irrigation, as an adaptation strategy, is worthwhile only for a 1°C increase in temperature

Thank you for your attention

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