EPA STAR Seminar

UNIVERSITY OF ILLINOIS AT URBANA – CHAMPAIGN

Civil and Environmental Engineering

Integrated Assessment of Climate Change Impact in Typical Agricultural River Basin of the Midwestern US

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EPA Region 5 Chicago, July 14, 2004

Projects

- US. EPA Star program : Award No. EPA R827451-01

Publications

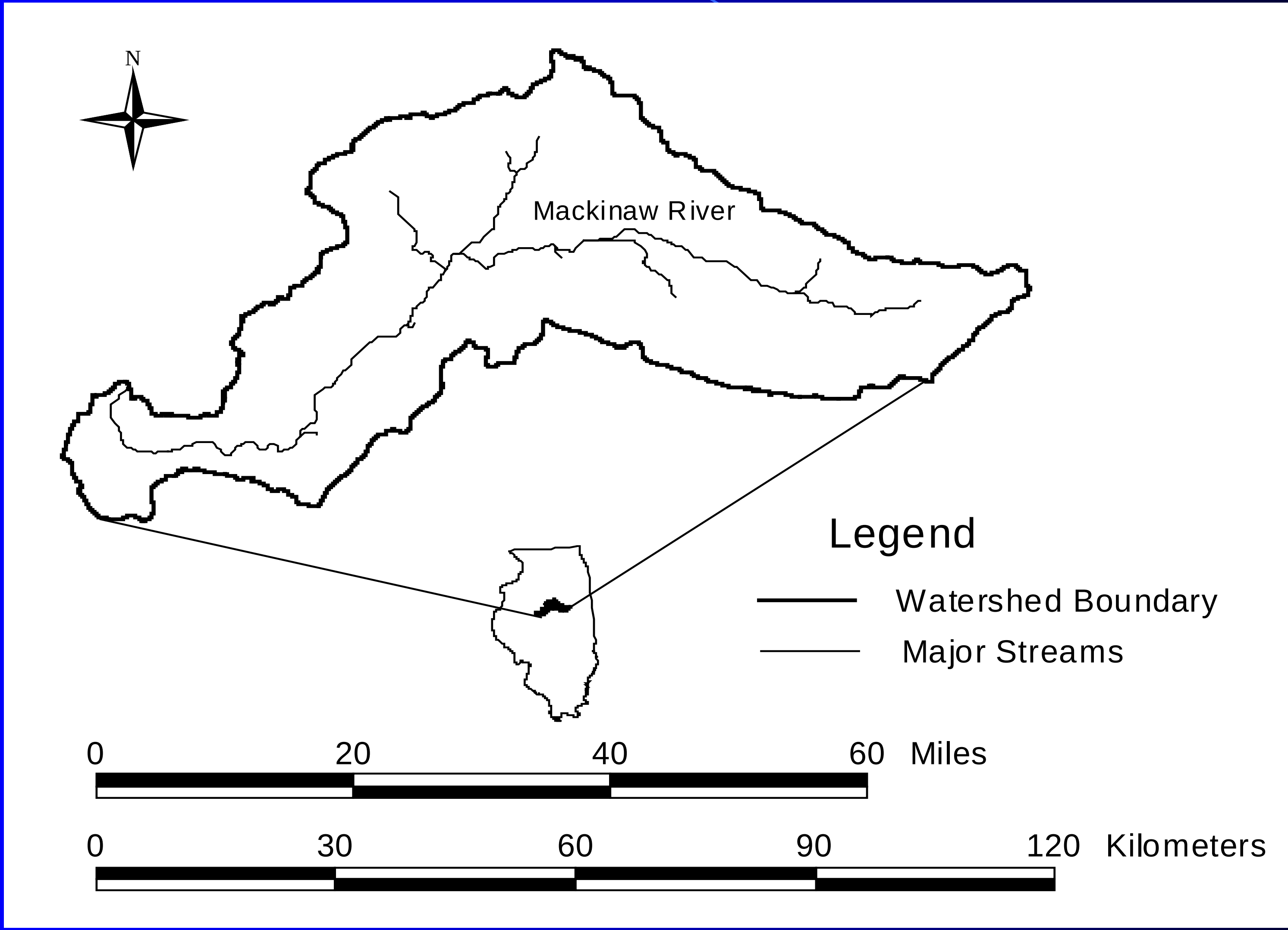
- Eheart, J.W. and Tornil, D.W. Low flow frequency exacerbation by irrigation withdrawals in the agricultural midwest under various climate change scenarios, Water Resources Research Vol. 35, no. 7, p.2237 2246 Jul 1999.

- Wollmuth, J.J. C. and J.W. Eheart, Surface Water Withdrawal Allocation and Trading Systems for Traditionally Riparian Areas, Journal of the American Water Resources Association, April 2000.

- Hyunhee An and J. W. Eheart, Protecting Midwestern stream from Climate change impact, Annual meeting of EWRI, Orlando, FL, May 20-24, 2001

- Hyunhee An and W Eheart, Investigation of Trading of stream withdrawal permits in traditionally humid areas, Annual meeting of EWRI, Roanoke, VA, May 19-22, 2002
- Hua Xie and J. W. Eheart, Assessing Vulnerability of Water Resources to Climate Change in Midwest, Annual meeting of EWRI, Philadelphia, PA, June 23-26, 2003
- Hyunhee An and J. W Eheart, Evaluations of regulatory programs that constrain water withdrawals based on a regulated riparian legal foundation, Annual meeting of EWRI, Salt Lake City, UT, June 27-July 1, 2004
- Hua Xie and J. W. Eheart, Implications of Climate Change for a Typical Agricultural River Basin of the Midwestern US , Annual meeting of EWRI, Salt Lake City, UT, June 27- July 1, 2004

Mackinaw River Basins



Study Basin: Economy & Ecology

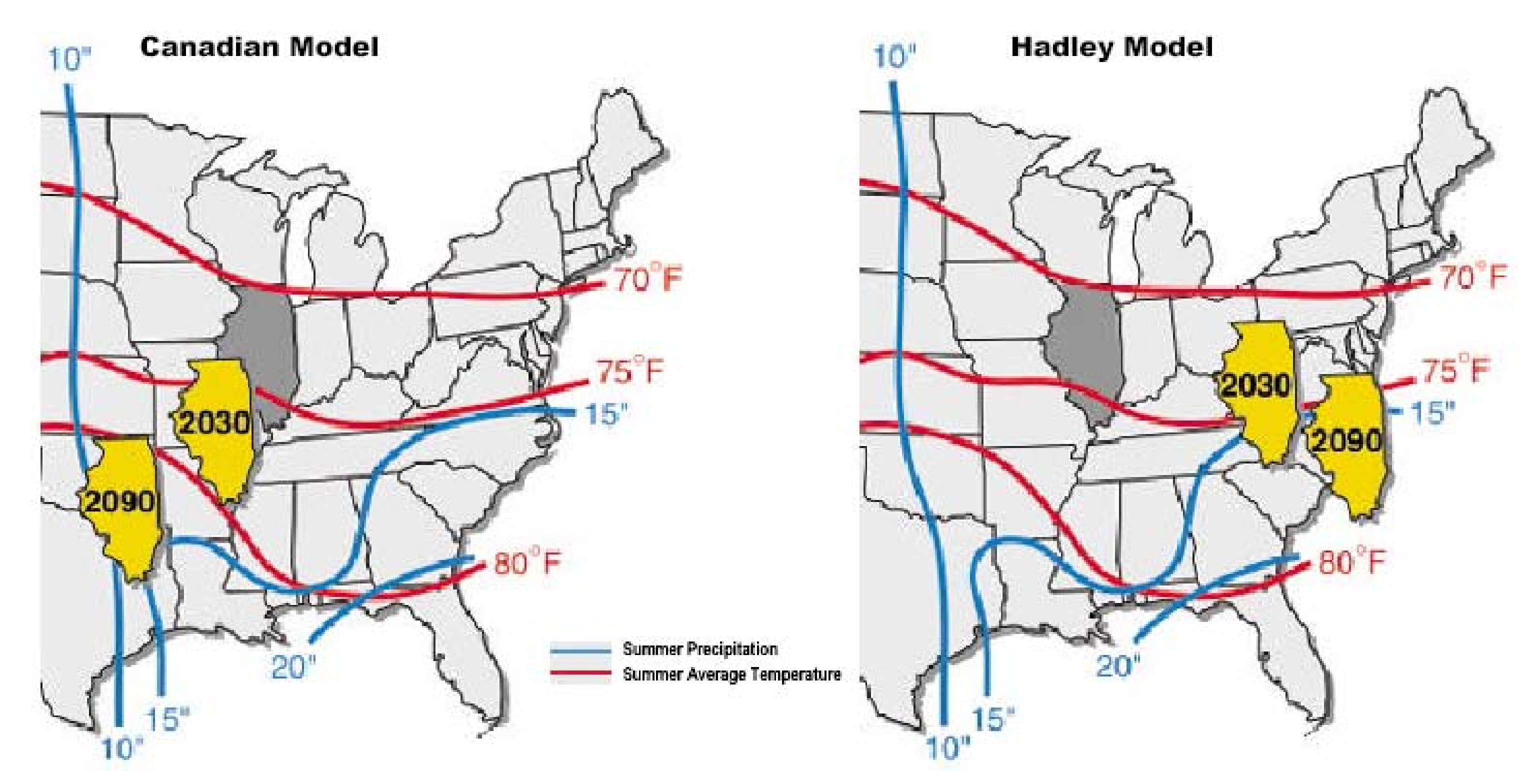
Sequence

1. Selection of climate change scenarios
2. Mitigation efforts: irrigation, alternative crops
3. Selection of criteria to demonstrate impacts: LF and Profits
4. Model Run and analysis

1. Selection of Climate change scenarios

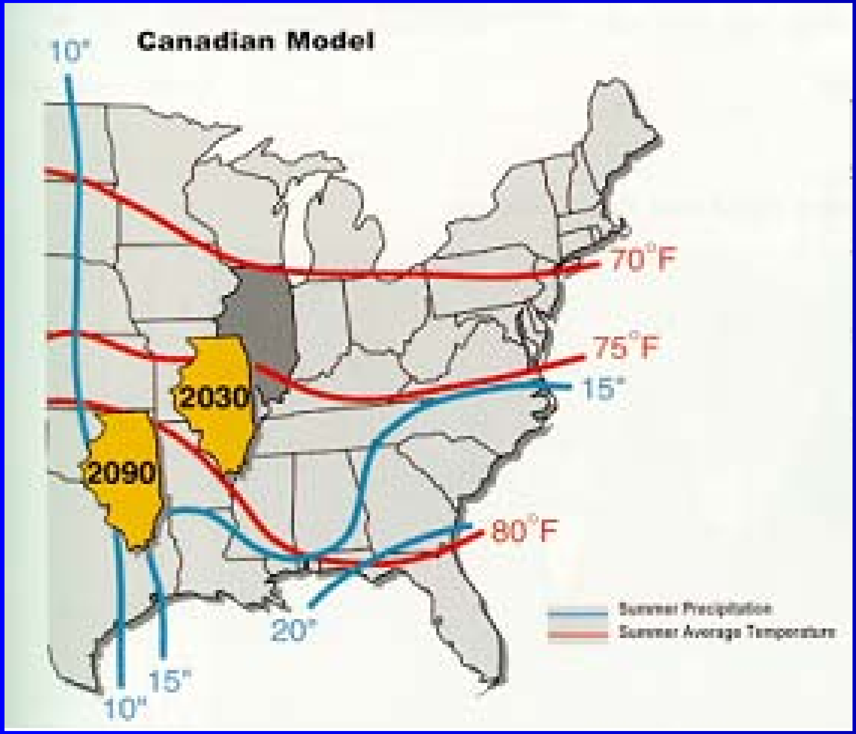
Two GCMs for climate change scenarios

(National Assessment Synthesis Team, 2000)



More frequent droughts with irregular rainfall

Canadian Model



Temperature & Precipitation

Data Source: Oklahoma City, OK

Atmospheric CO2

Increased use of fossil fuels

➔ 700 ppm by 2100

National Assessment Synthesis Team, 2000

Climate change scenarios

1. Current climate

   - Bloomington, IL, 1963-1992

2. Future climate

   - Oklahoma City, OK 1963-1992 (CO_2= 350ppm)

   - Oklahoma City, OK 1963-1992 (CO_2= 700ppm)

2. Mitigation efforts

Basin response to climate change

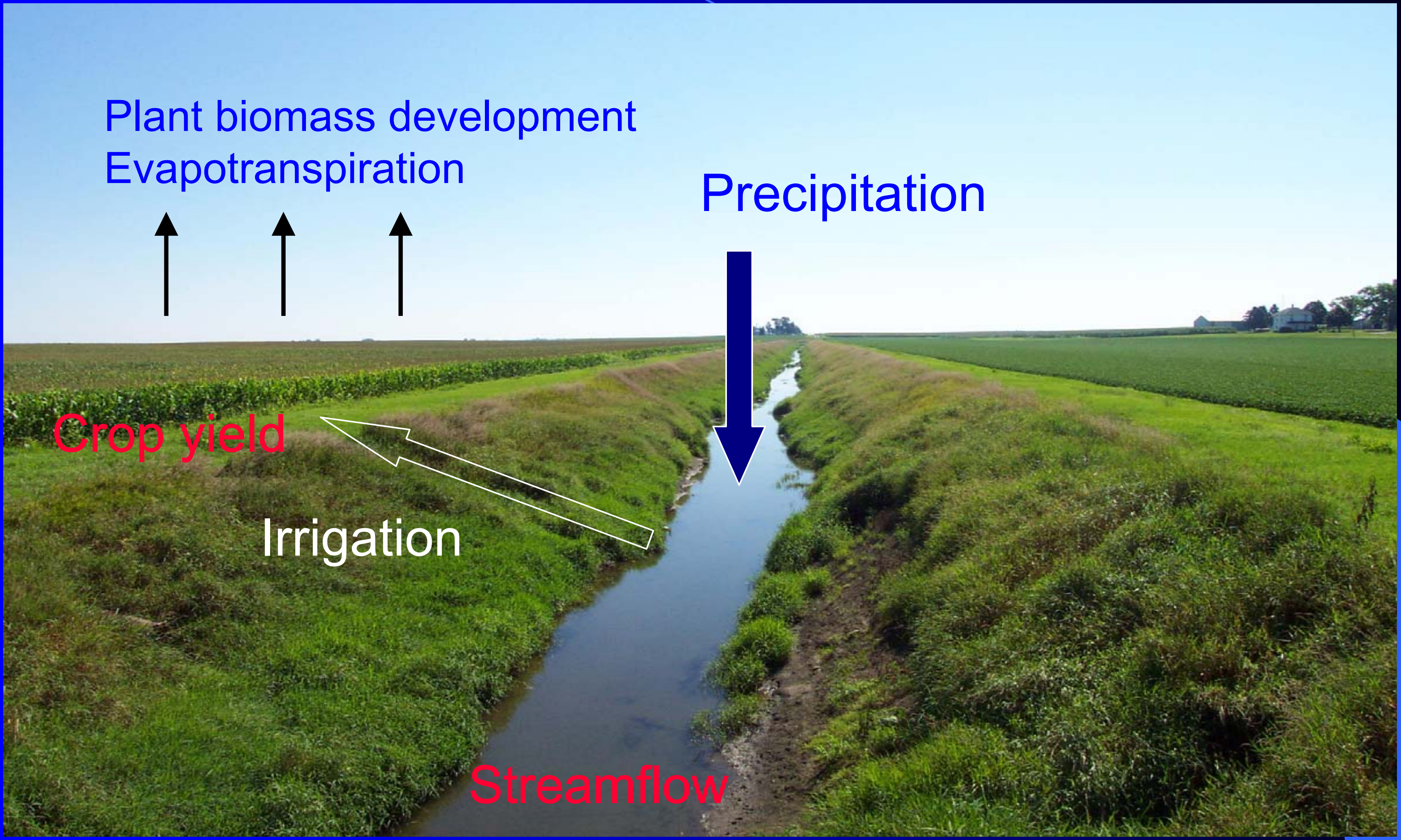


Photo from Jian-Ping Suen

Mitigation efforts

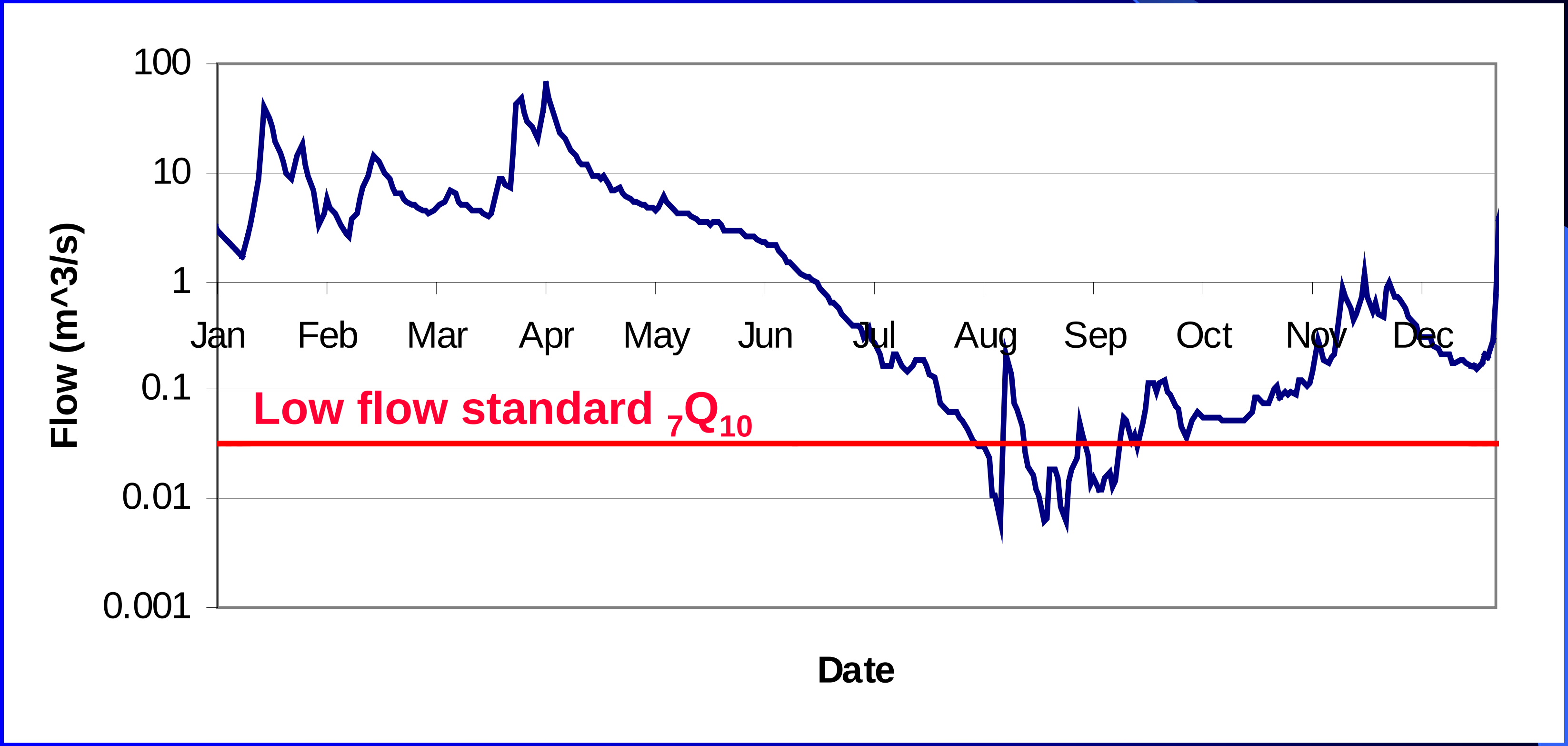
- Irrigation

- Alternative crops
  - Corn
  - Soybean
  - Double cropping (Soybean + winter wheat)

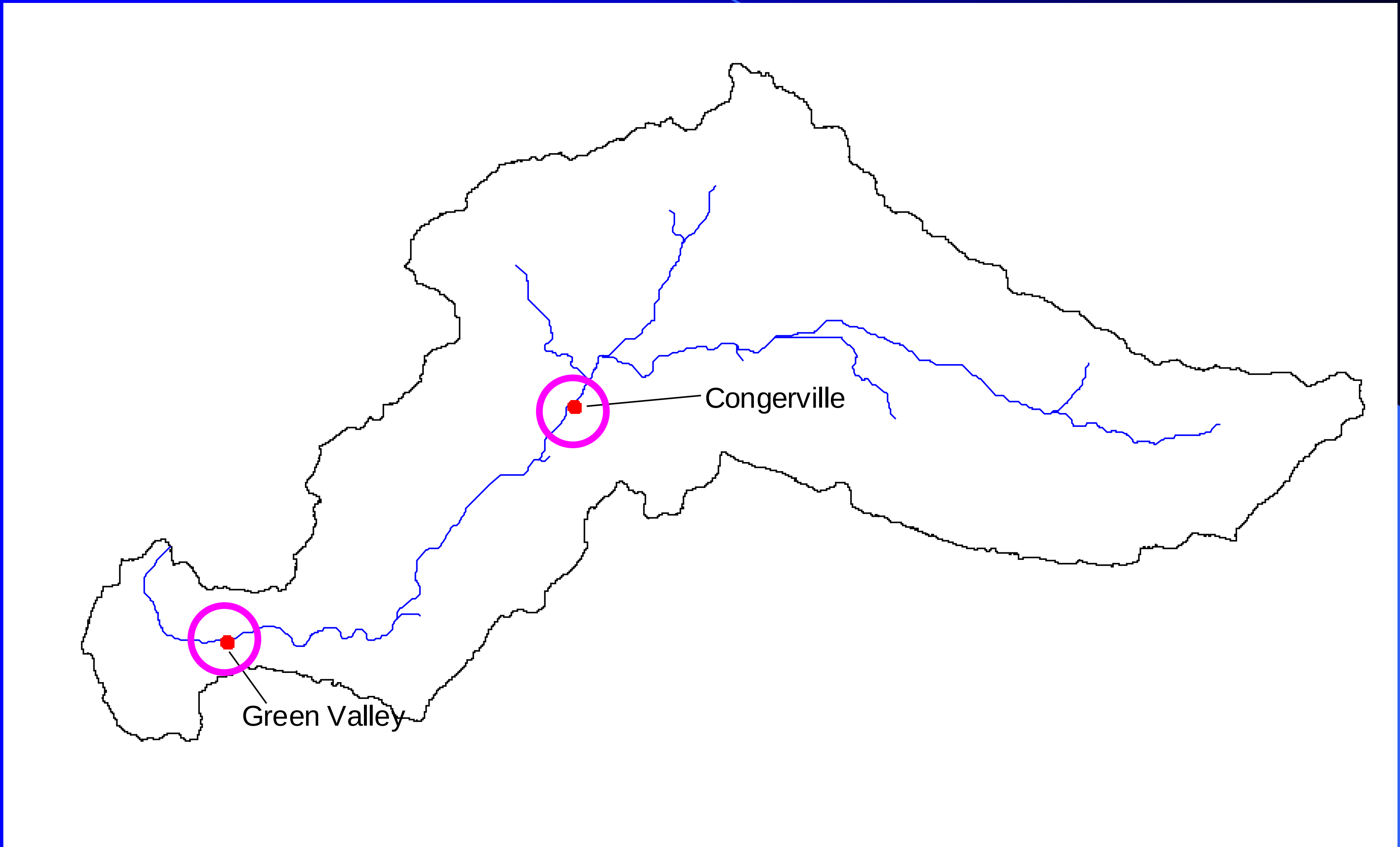
3. Selection of criteria to demonstrate impacts:

Low flow frequency
Profits

Criterion 1
Vulnerability of Regional Water Resources: Low flow frequency



Locations of Reference Gauging Stations



Criterion 2
Impacts on agricultural economy

- Farmers' aggregate Profits

$$profits = \sum_{t} \sum_{i} (Y_{it} \times CP - IR_{it} \times VIRC_{it} - FIRC_{it} - NIRC_{it}) \times A_i$$

Y_{it} = crop yields (bushel/ha-yr)
CP = Crop market price ($/bushel)
IR_{it} = the amount of irrigation (mm/yr)
$VIRC_{it}$ = variable irrigation cost ($/ha-mm)
$FIRC_{it}$ = fixed irrigation cost ($/ha-yr)
$NIRC_{it}$ = Non-irrigation cost for crop production ($/ha-yr)

Assessment Framework

	I	II	III
Scenario	Current climate + un-irrigated agriculture	Future climate + un-irrigated agriculture	Future climate + irrigated agriculture
Criteria	Profits & Low flow frequency	Profits & Low flow frequency	Profits & Low flow frequency

The direct effects of climate change

The effects of irrigation

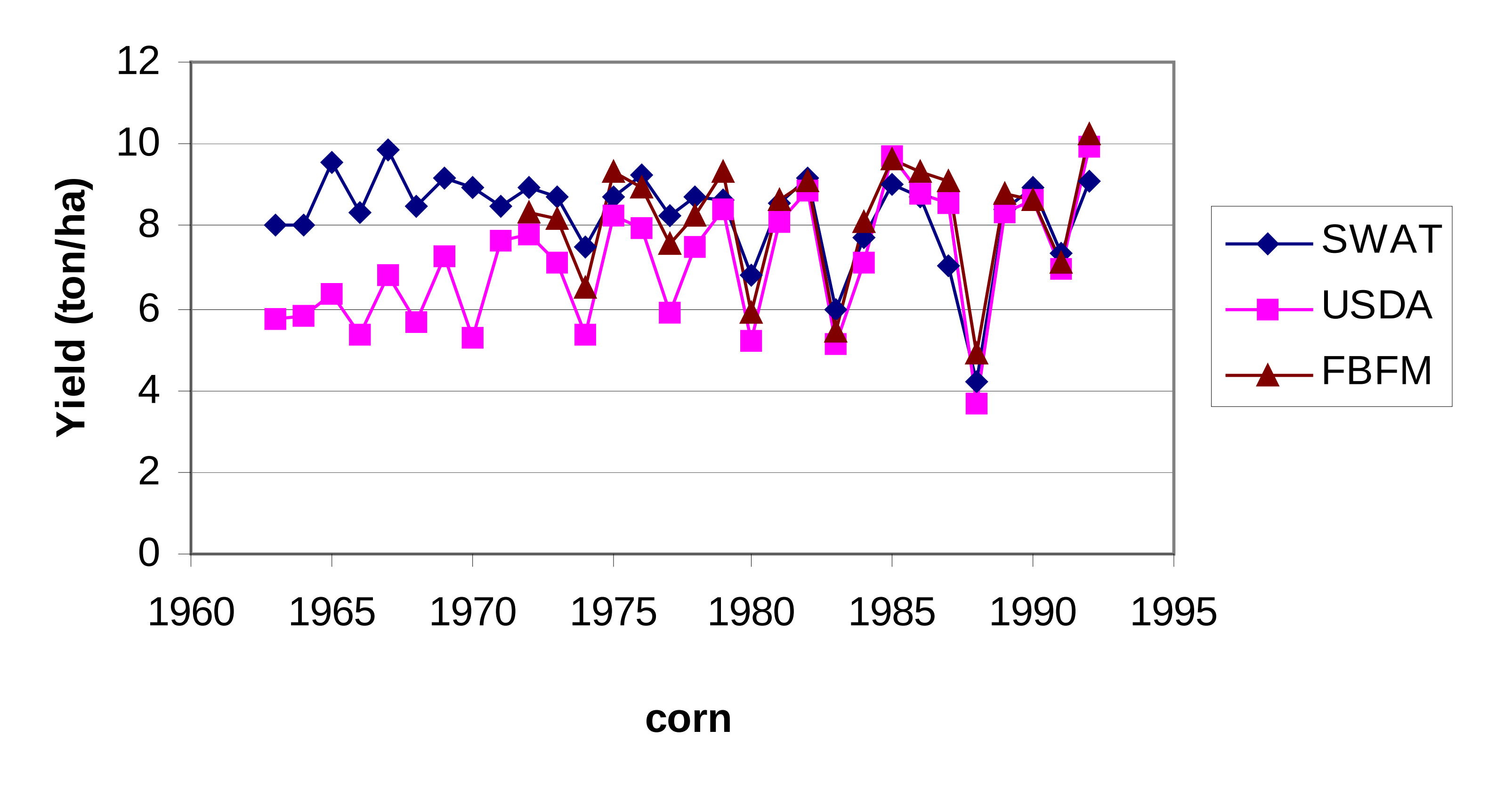
Alternative crops – Corn / Soybean / Soybean + winter wheat

4. Model Runs and Analysis

SWAT(Soil & Water Assessment Tool)

- SWAT is a river basin scale hydrological and agricultural model
- Predicts water movement, impacts of land management practices in a watershed with varying landuse and soil types under given climate

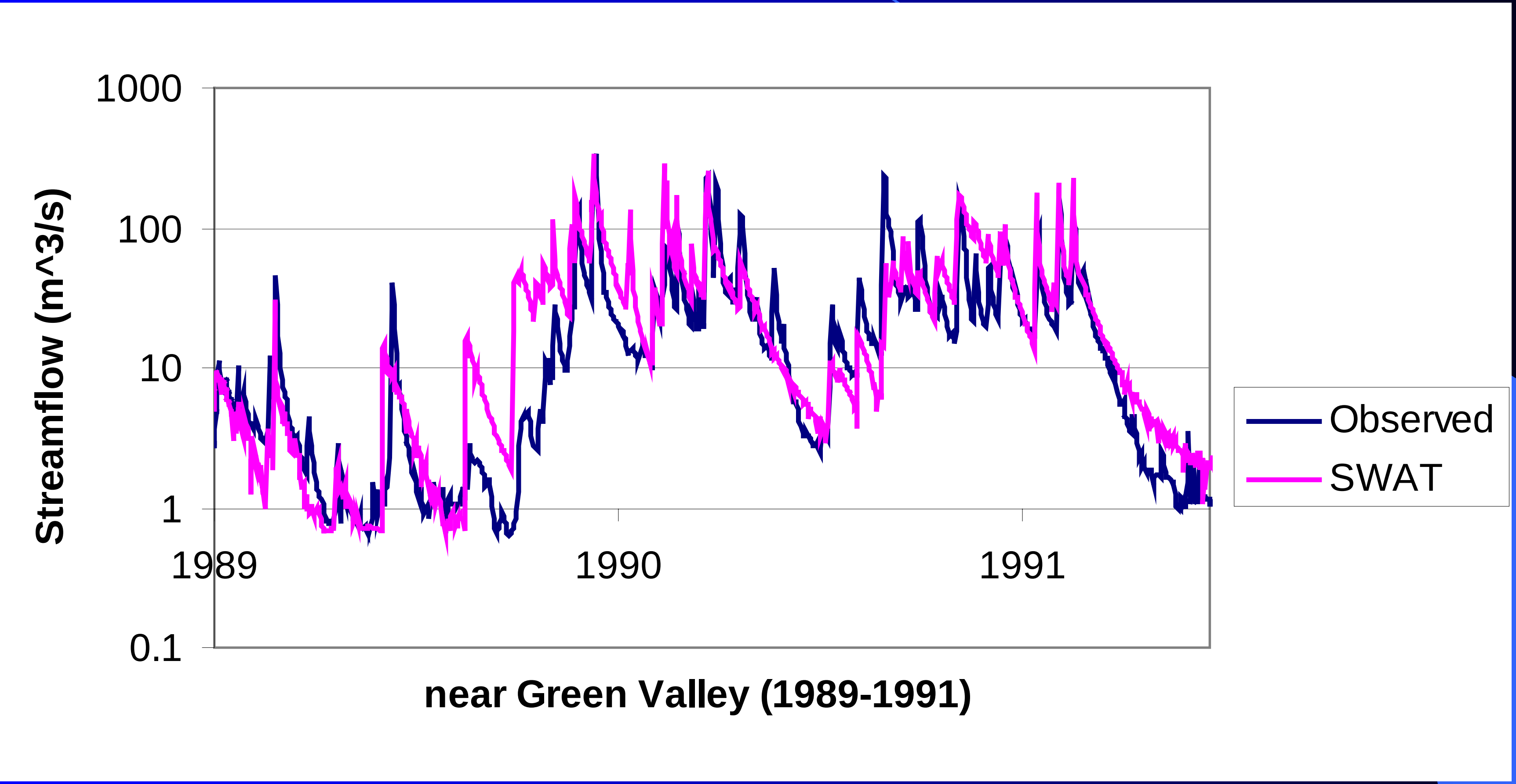
Model performance – Corn Yields



USDA: US Department of Agriculture

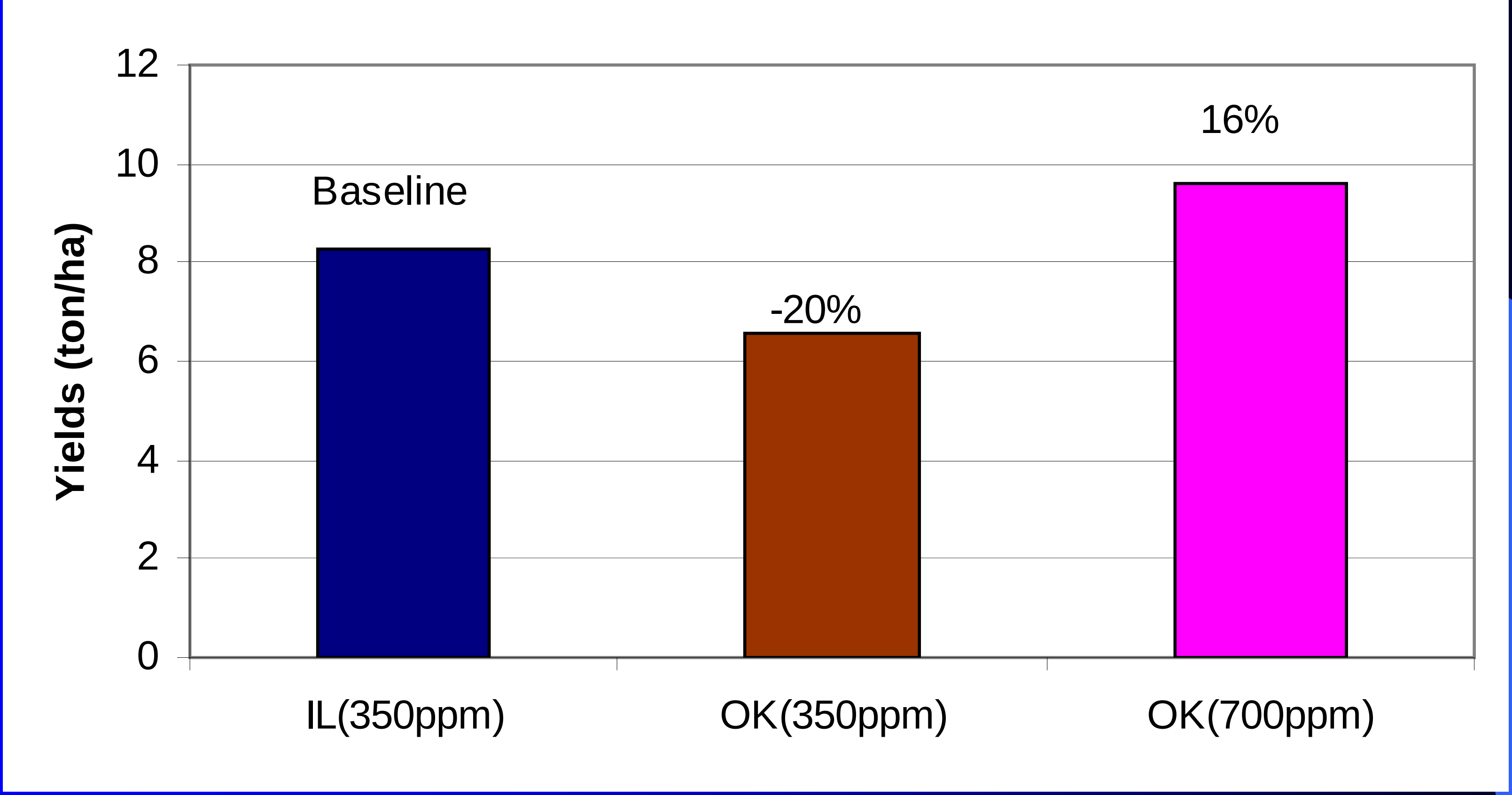
FBFM: Illinois Farm Business Farm Management Association

Model Performance - Hydrograph



Results

Results - corn yields

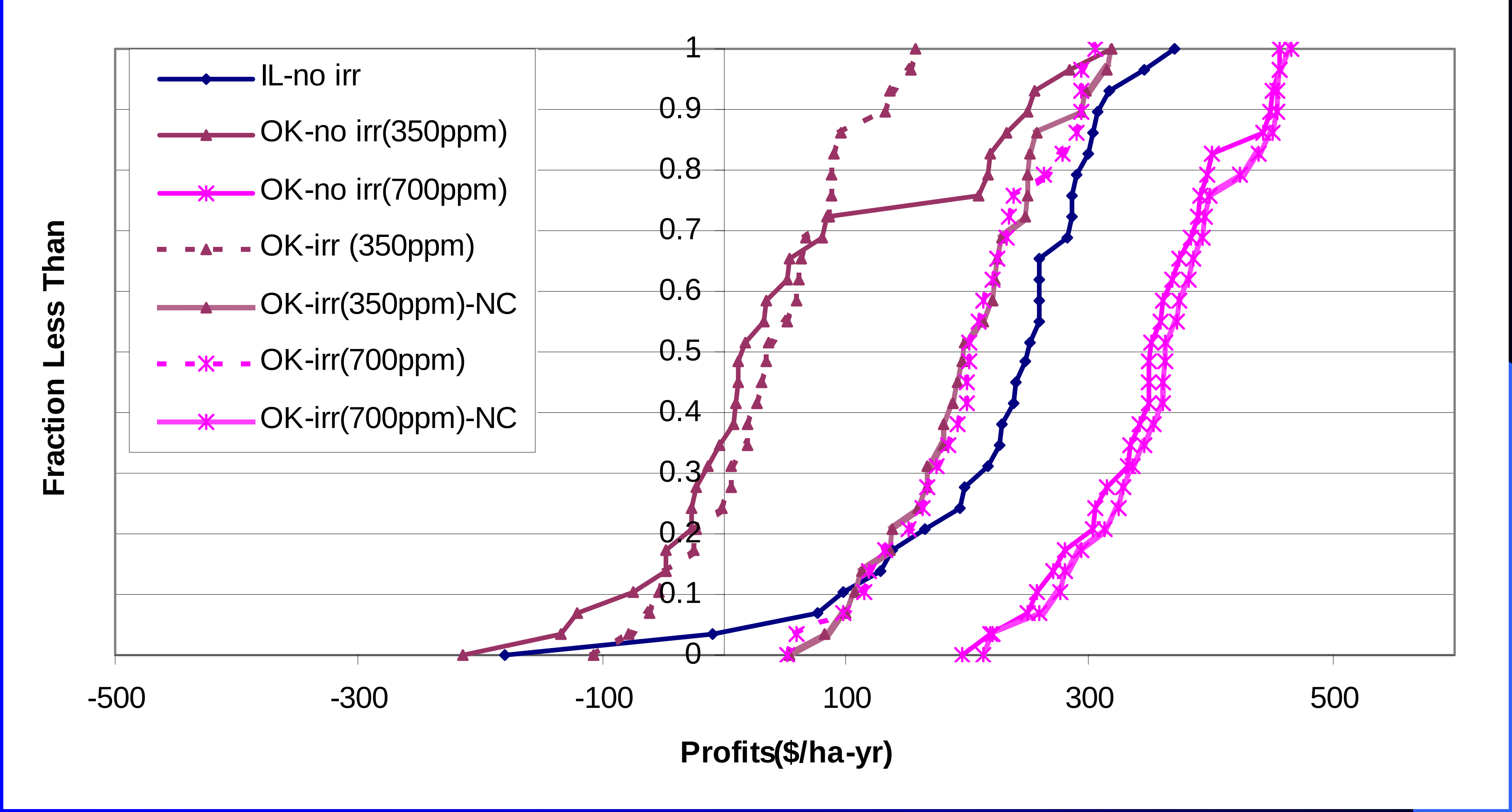


Field experiments

CO_2	Corn yields (ton/ha)
370ppm	9.4
550ppm	11.8

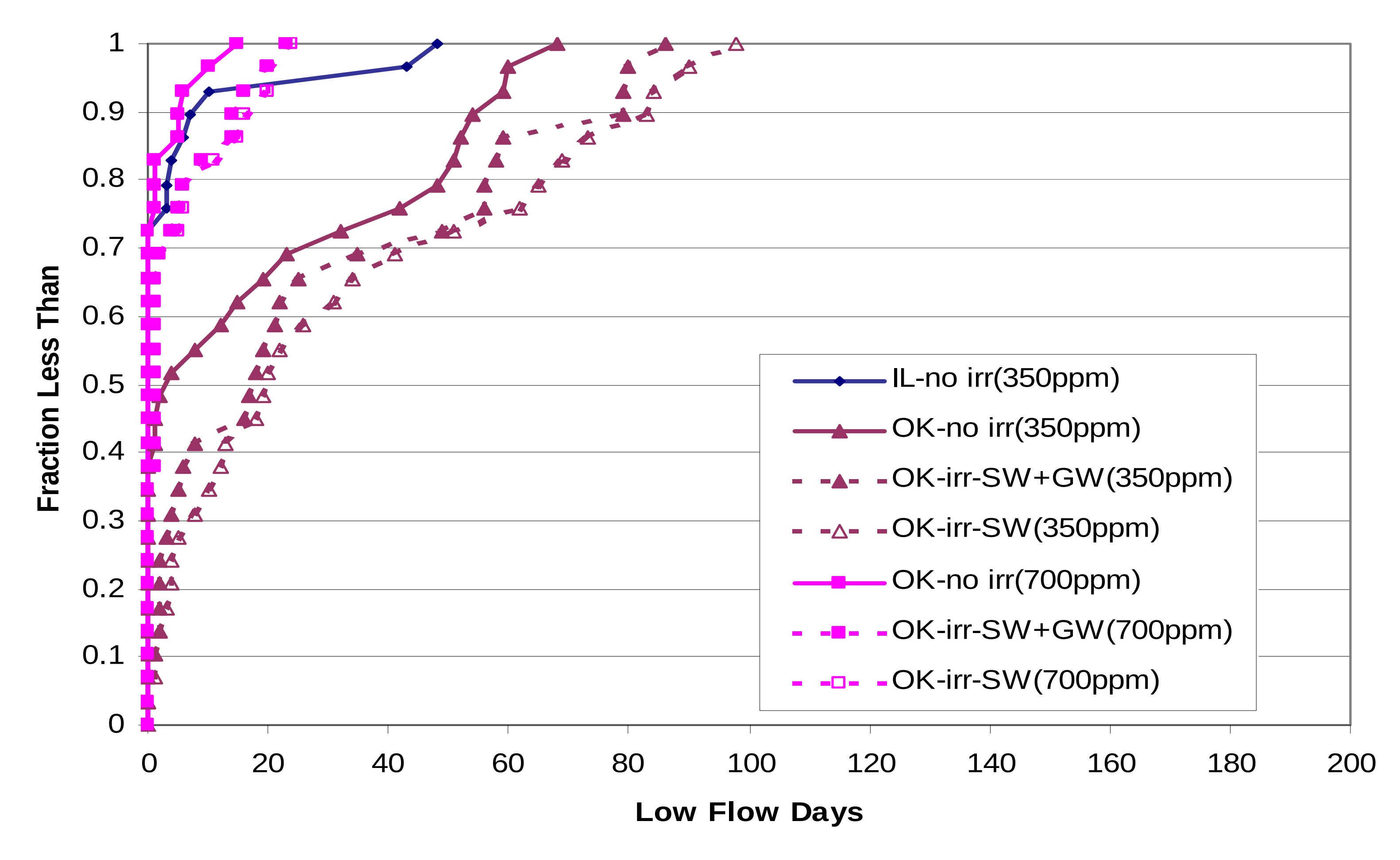
Uribelarrea et al., 2003

Profits – Cumulative distribution



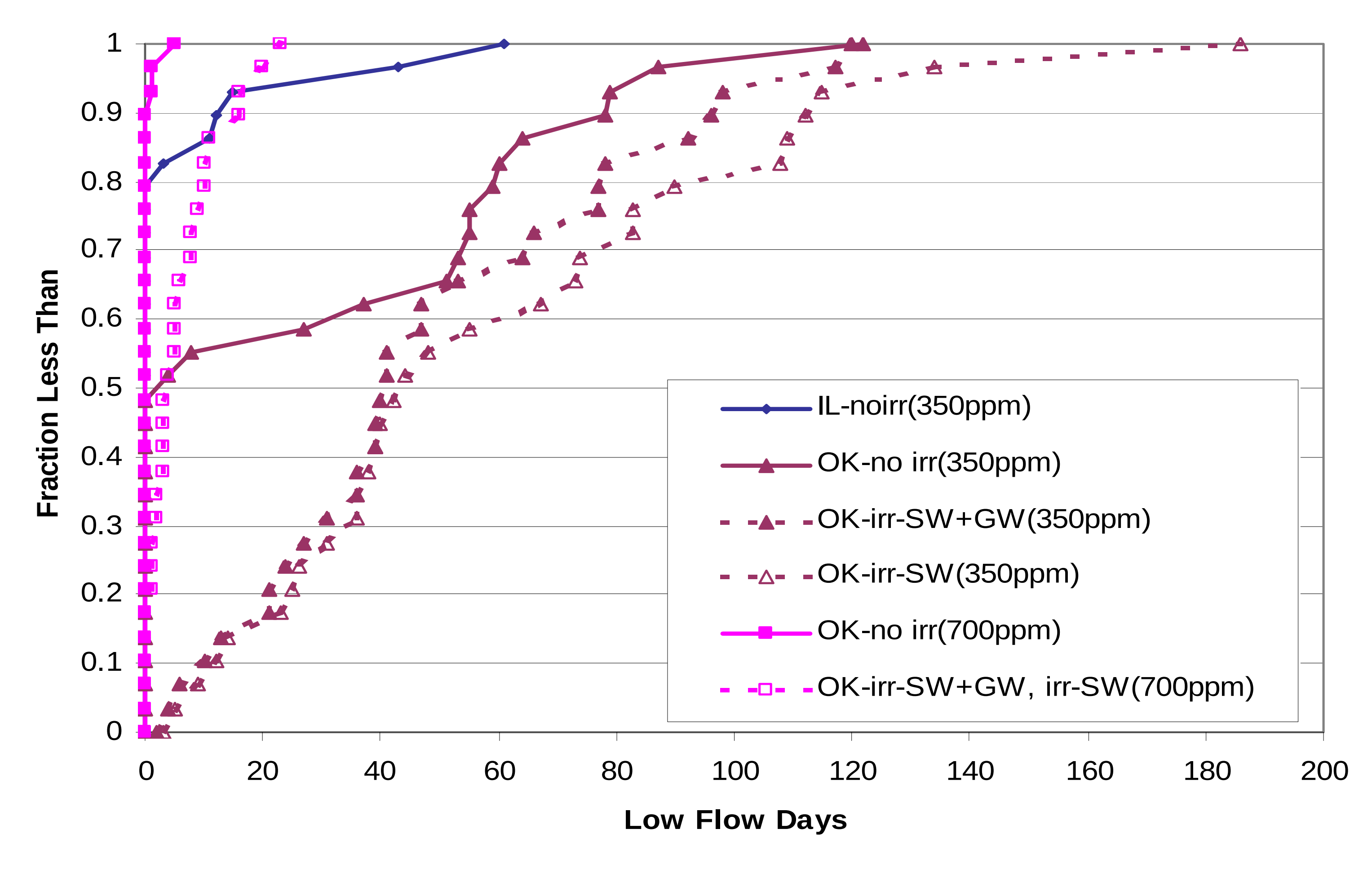
Low Flow Frequencies - CDF

near Congerville



Low Flow Frequencies - CDF

near Green Valley



Alternative crops – Profits

($/ha-yr)	Corn	Soybean	Double cropping
IL-noirr	219.20	268.32	-
OK-no irr(350ppm)	54.85	148.26	150.23
OK-irr(350ppm, capital costs)	37.18	48.56	27.76
OK-irr(350ppm, no capital costs)	198.24	209.62	188.82
OK-no irr(700ppm)	349.26	474.82	534.13
OK-irr(700ppm, capital costs)	200.04	317.28	374.15
OK-irr(700ppm, no capital costs)	361.09	478.34	535.20

Alternative Crops – Low flow frequency

	Corn	Soybean	Double cropping
IL	4.83		
OK-noirr(350ppm)	27.97	17	28.07
OK-irr-SW+GW(350ppm)	48.77	24.4	39.43
OK-irr-SW(350ppm)	58.67	37.37	49.43
OK-no irr(700ppm)	0.23	0.00	0.83
OK-irr-SW+GW(700ppm)	5.83	1.13	0.83
OK-irr-SW(700ppm)	5.93	1.13	0.83

Summary

	OK climate $[CO_2]$=350ppm		OK climate $[CO_2]$=700ppm	
	No Irrigation	Irrigation	No Irrigation	Irrigation
Agricultural Productivity	Worse	Same / better	Better	Worse / Same
Low flow frequency	Worse	Worse	Better	Worse

Alternative crops – similar results as corn

Implications

- Climate change could leave basins more or less unchanged

- Irrigation could threat health of aquatic systems

  → Regulatory program to control surface water withdrawals in IL

Limitations

- Uncertainty
  - climate change scenarios
  - Down-scaling techniques
  - Model adequacy for simulating elevated CO_2
  - Model adequacy for simulating double cropping

Acknowledgements

- Dr. Jeff Arnold, Dr. Susan Neitsch, and Ms. Nancy Sammons – USDA ARS Blackland Research Center , Temple, TX

Questions??

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