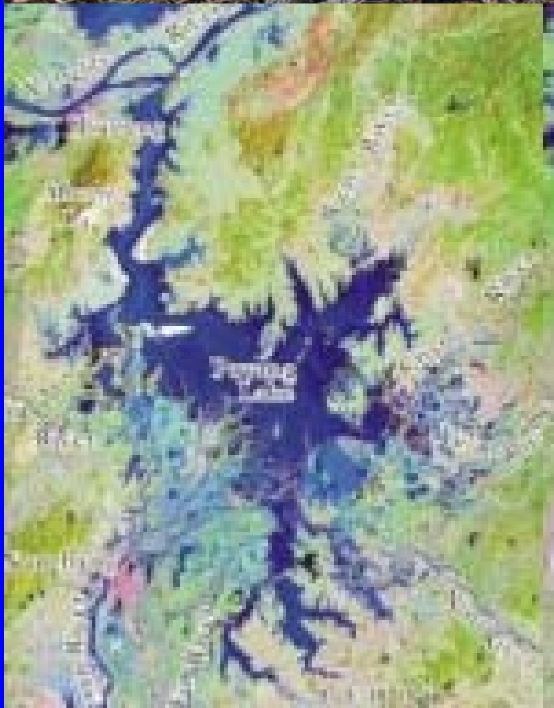
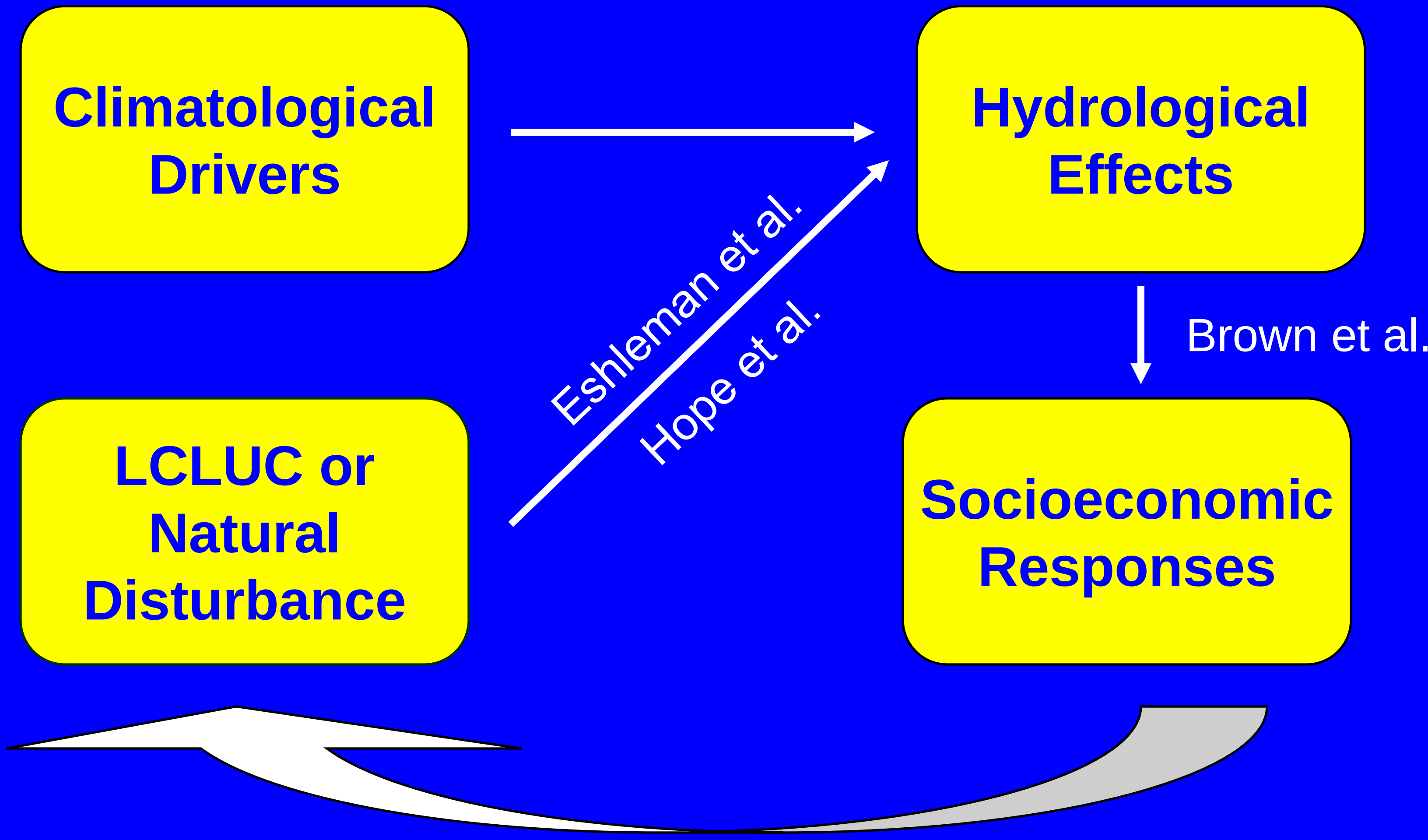
LCLUC, Floods and Fires

Three Projects

- Keith Eshleman (UMCES) *et al.* : Flooding responses in central Appalachians and Carpathians due to LCLUC (surface mining/reclamation, deforestation)
- Allen Hope (SDSU) *et al.*: River flow volumes in California chaparral ecosystems (fire)
- Dan Brown (UM) *et al.*: Poyang Lake flooding in SE China (climate, socio-economic changes)

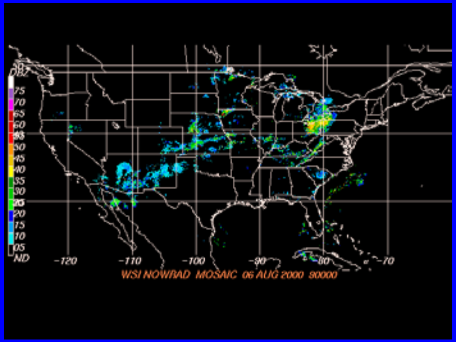


Conceptualization of the Effects of LCLUC and Disturbances on Hydrological Processes and Human Systems



Research Questions (Eshleman et al.)

- Do surface mining and land reclamation practices affect stormflow generation and flooding responses in catchments in the Central Appalachian Plateau region?



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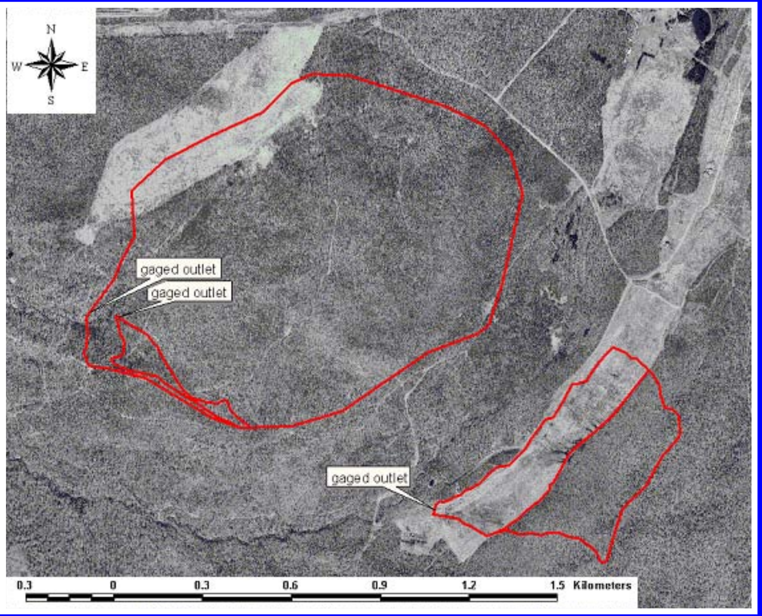
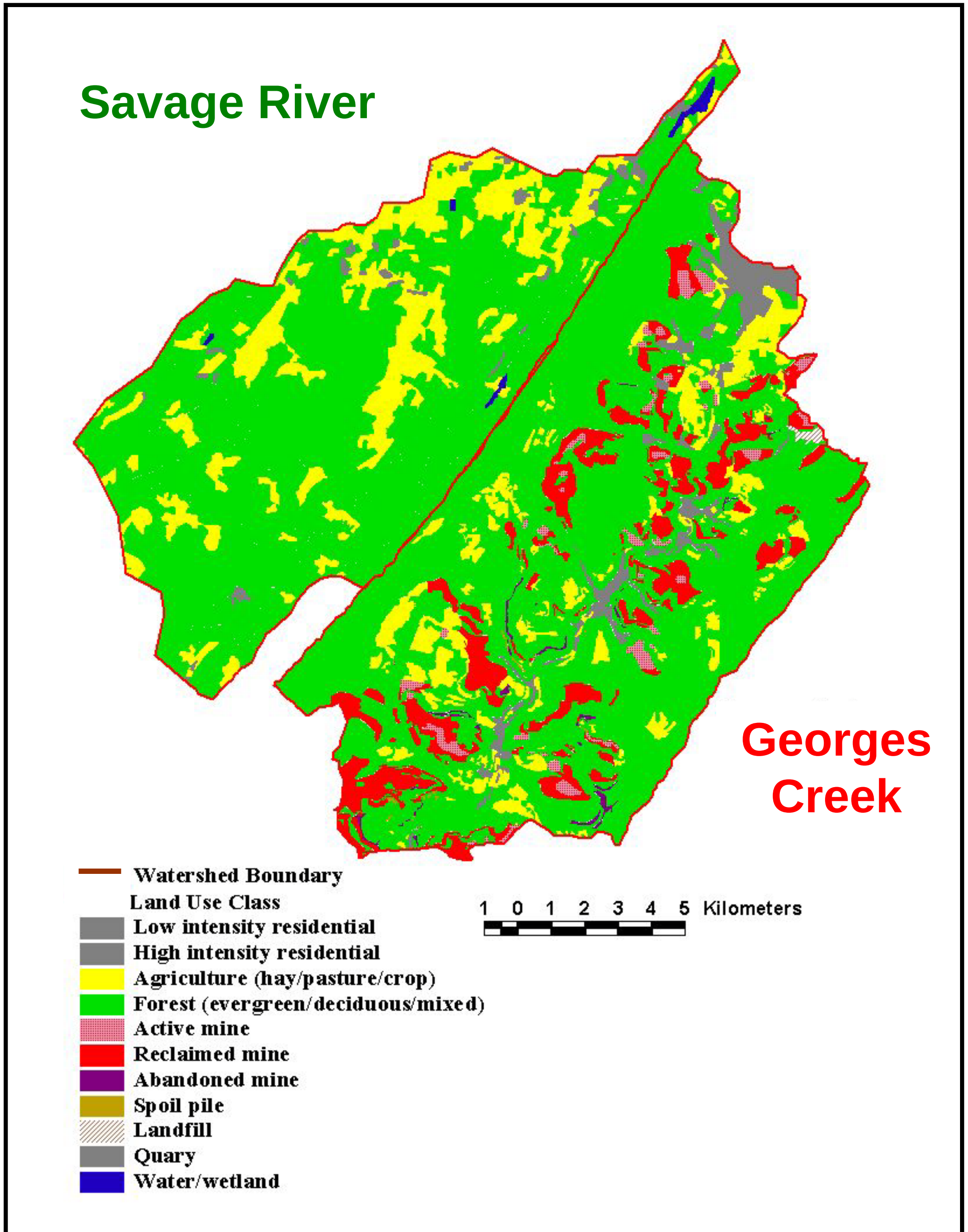
- If so, at what scale can these responses be detected and quantified?
  - Small catchment scale ($\sim 10^{-2} - 10^{1}$ km^2)
  - River basin scale ($\sim 10^{1} - 10^{3}$ km^2)

Results: Small ROCA Catchments[1,2]

- Similar annual and long-term water balances
- No significant difference in timing of stormflow
- Similar unitgraphs
- Higher peak runoff and total storm runoff due to mining/reclamation (on average by a factor of 2-3)
  - Reduced soil infiltration capacity due to loss of forest floor and topsoil; soil compaction
  - Overland flow vs. subsurface stormflow
- Observed differences are conservative



[1]Negley and Eshleman (*Hydrological Processes*, 2006)
[2]Simmons *et al.* (*Ecological Applications*, 2008)



2006 Land Use/Land Cover

Georges Creek

69% Forested
17% Mined/Reclaimed
8% Agriculture
7% Developed

Savage River

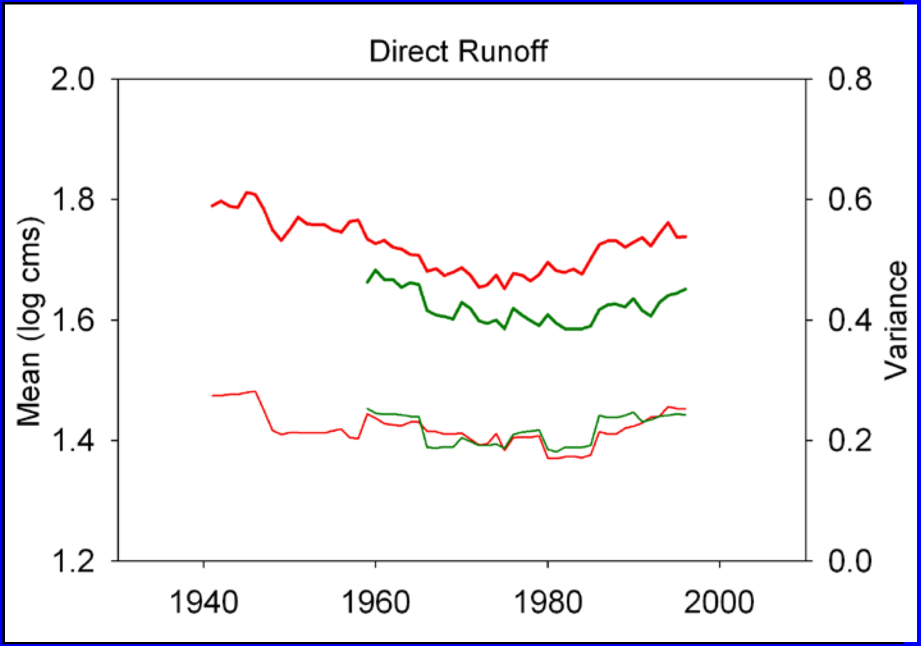
82% Forested
15% Agriculture
3% Developed

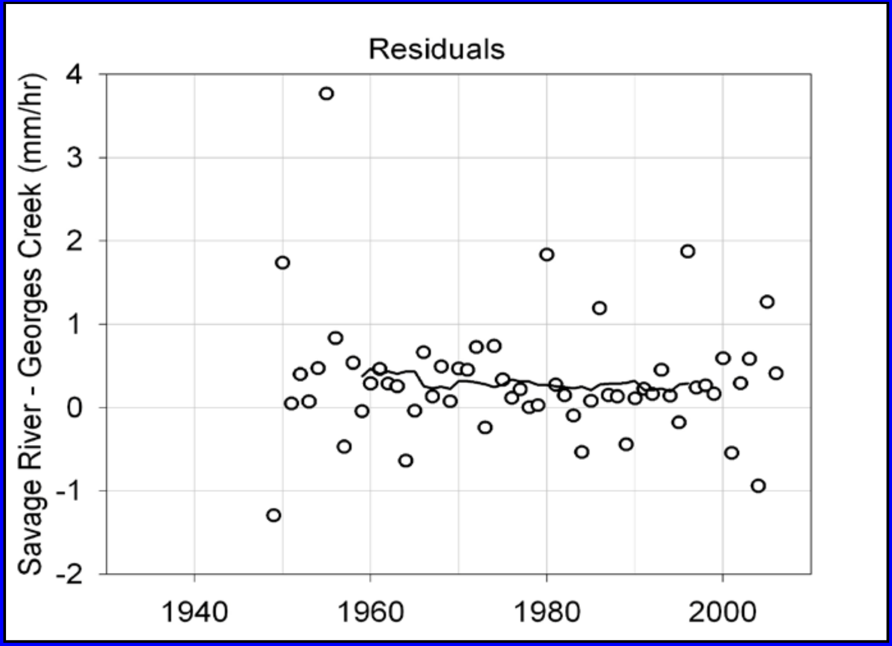
Method #1

Comparison of flood frequency distributions (log Pearson Type III = LP3 w/ weighted skew) computed using the annual maximum series of daily streamflow (AMSS)

a) Differences for 2 time periods (1949-1975; 1976-2006): assumes ***episodic*** non-stationarity

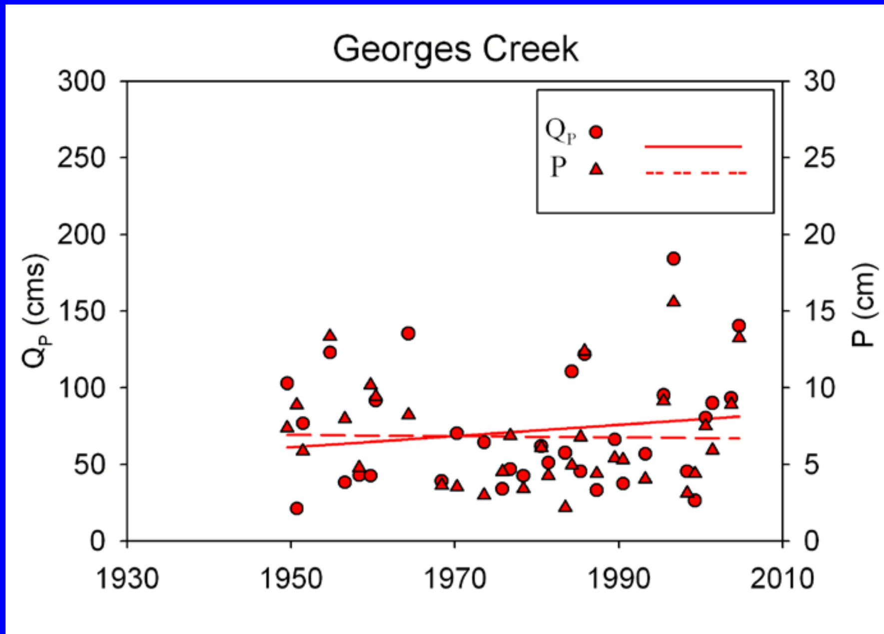
b) Differences in moments using a 21-year moving window: better for addressing a ***secular*** change

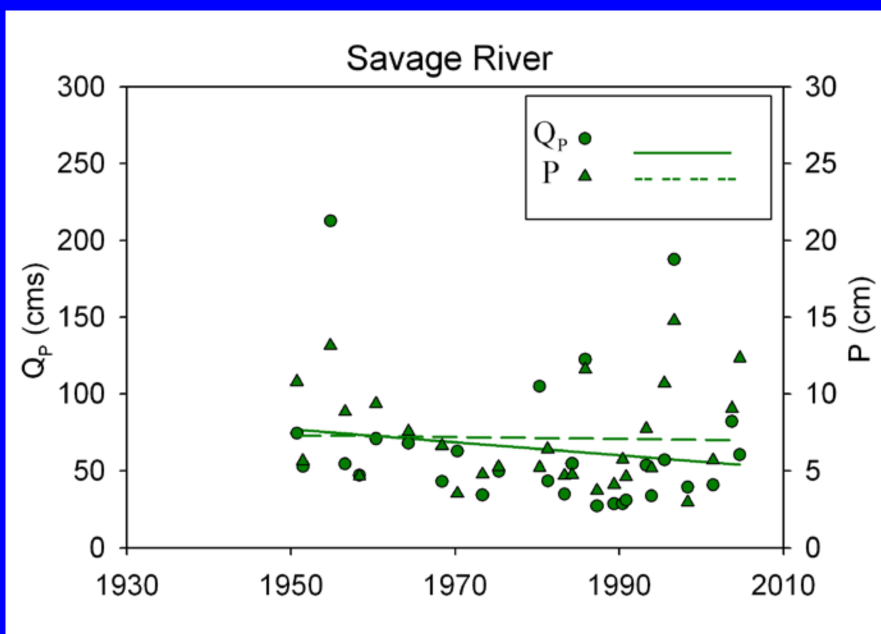




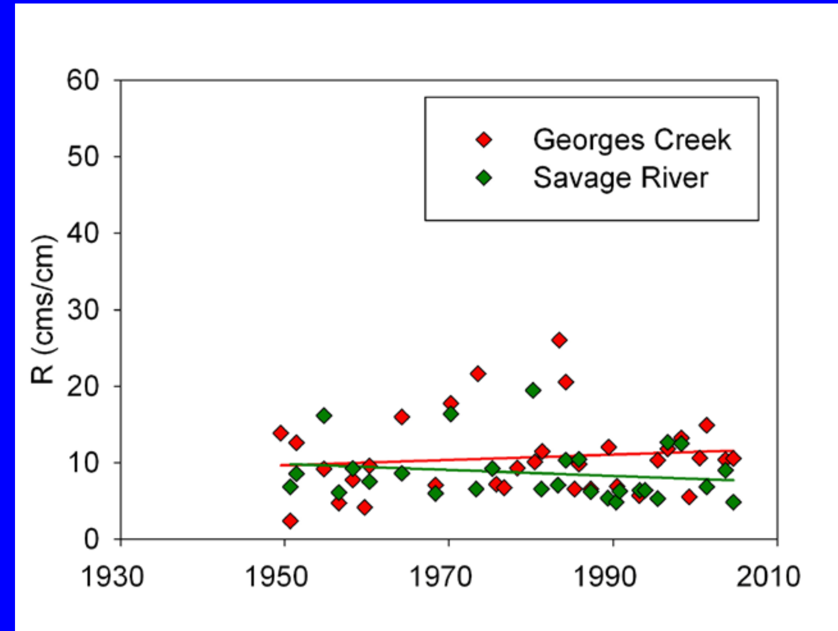
McCormick *et al.*, *WRR*, in revision

Q_P and *P* Trends*





R' Trends*



Method #2

*regression lines shown

*no trends were statistically significant ($p \leq 0.05$) using 3 different tests

McCormick *et al.*, *WRR*, in revision

Method #3

Paired rainfall-runoff analysis of 27 contemporary warm season storm events (1996-2006)

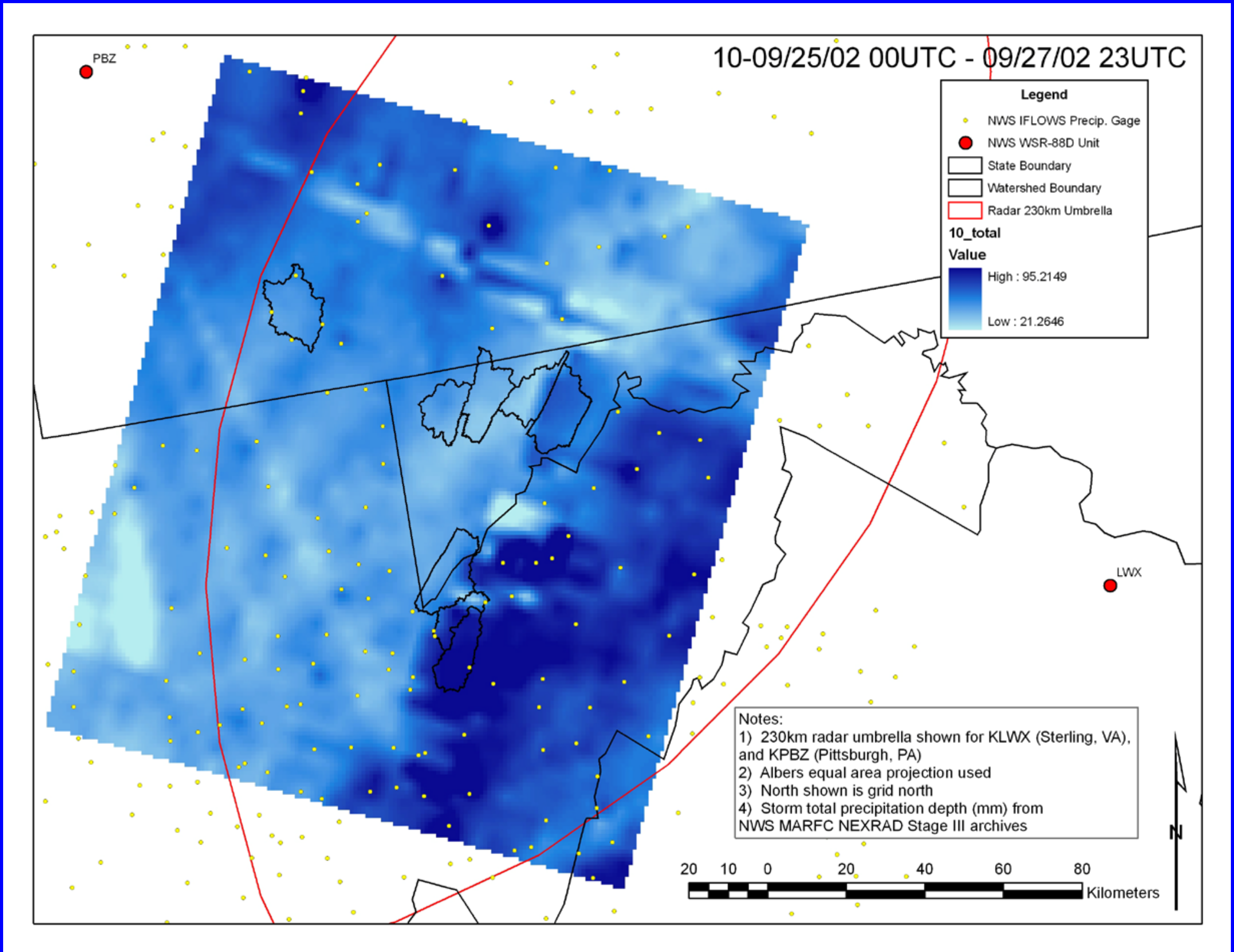
a) Classical hydrograph separation: computation of normalized runoff volume (R_V) and peak runoff (R_P)

b) Total event areal rainfall (P) and peak areal intensity (p_{max}) from the NWS WSR-88D (NEXRAD) "Stage III" operational radar rainfall product (archived)

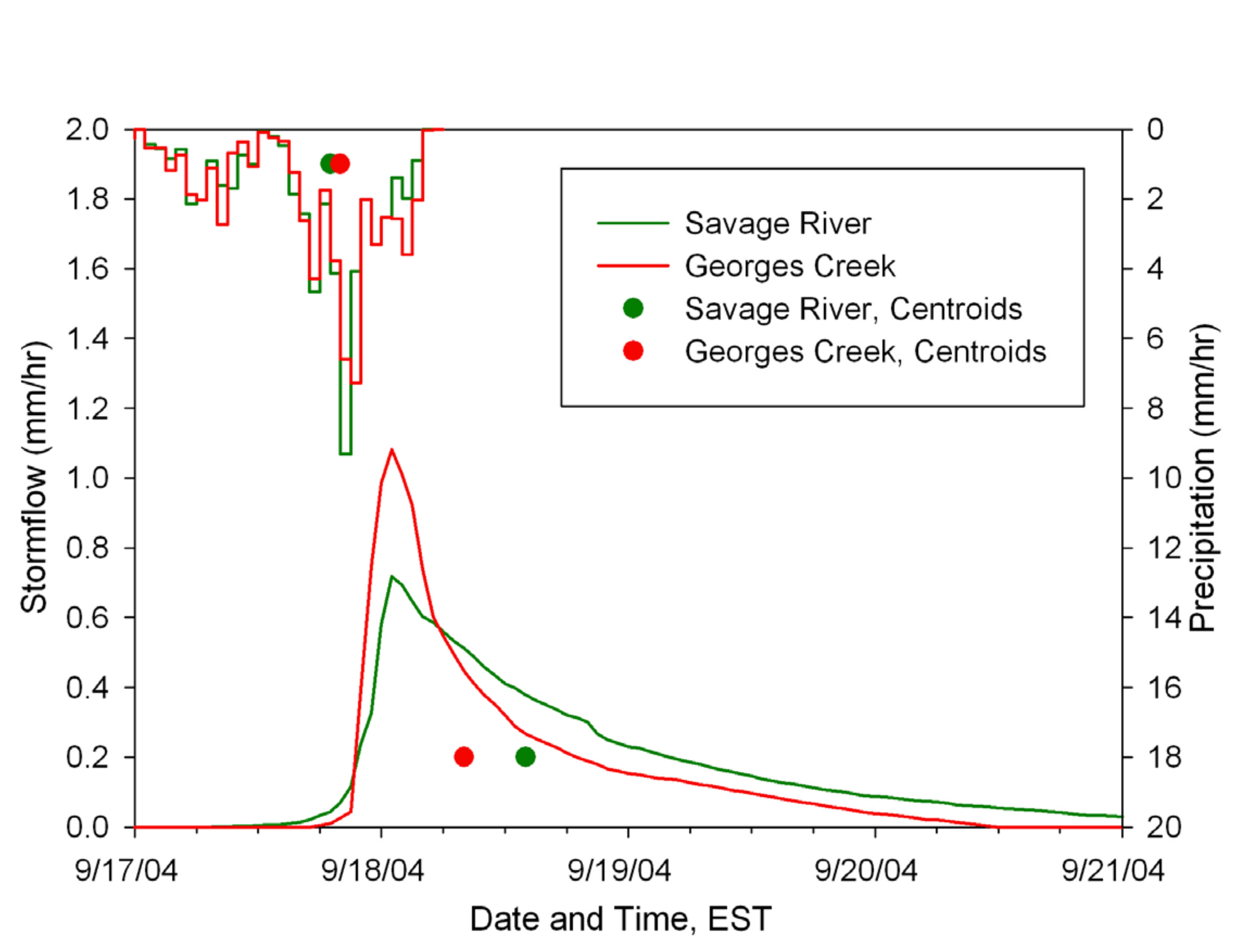
c) Compare R_V:P, R_P:p_{max}, and centroidal lag (L_C)

d) Eleven events culled *a priori* for violating pre-set conditions

NEXRAD Stage III Product

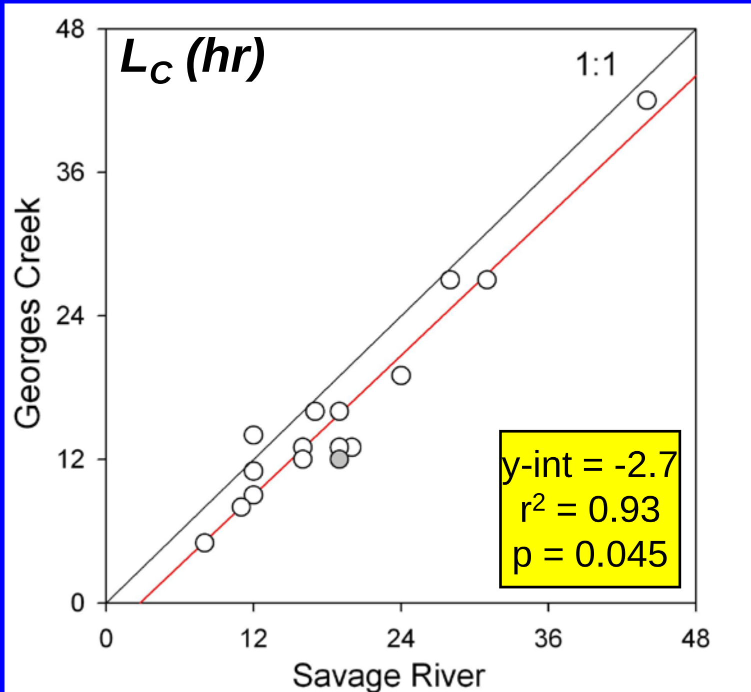


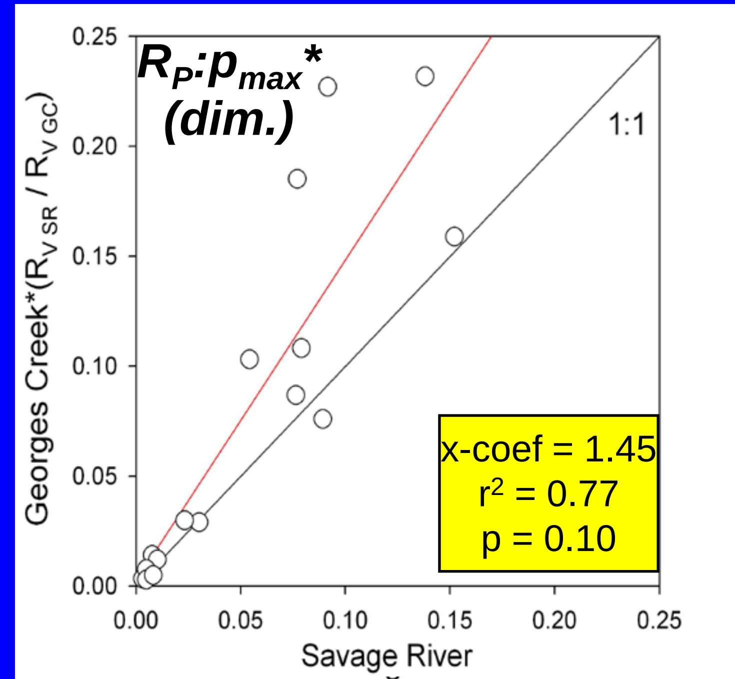
Remnants of Hurricane Ivan (September 2004)

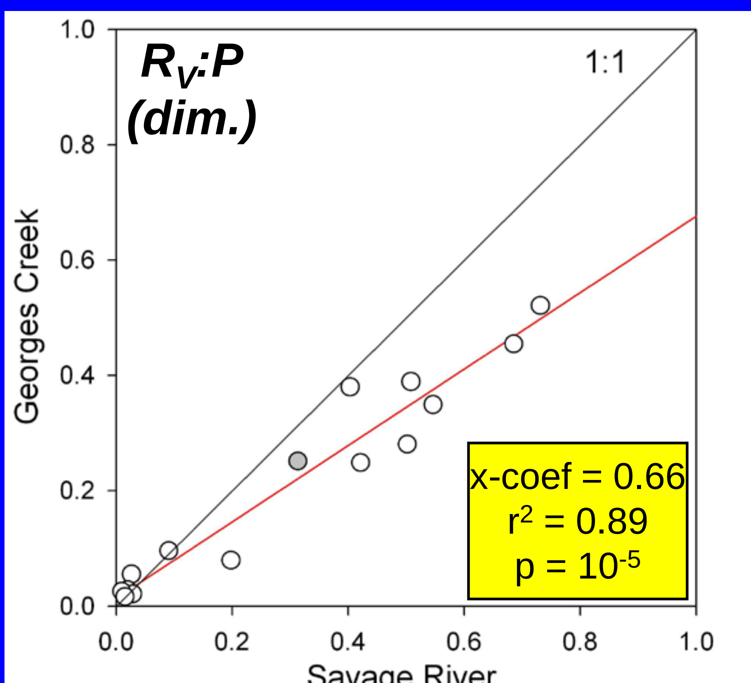


McCormick *et al.*, *WRR*, in revision

16 Runoff Events (1999-2006)







The Legacy of Deep Mining in Georges Creek

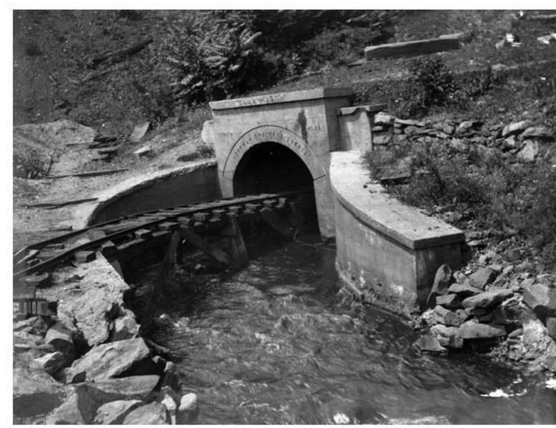
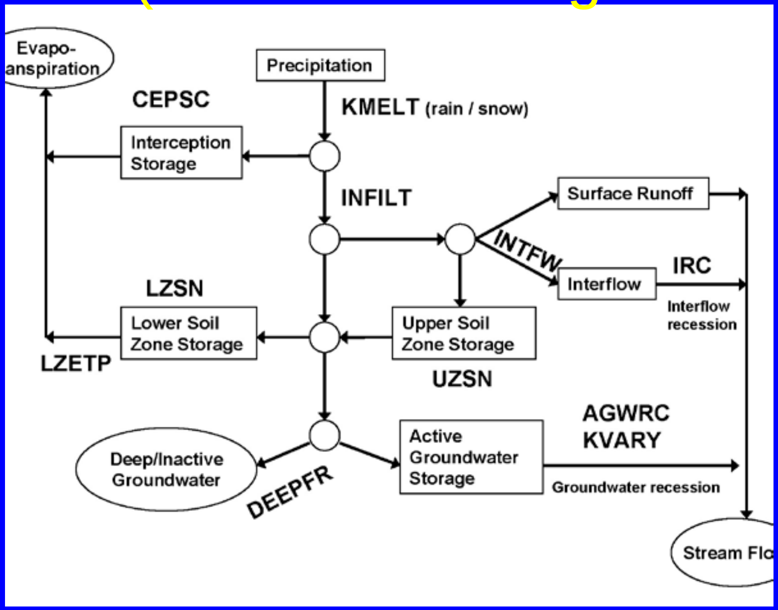


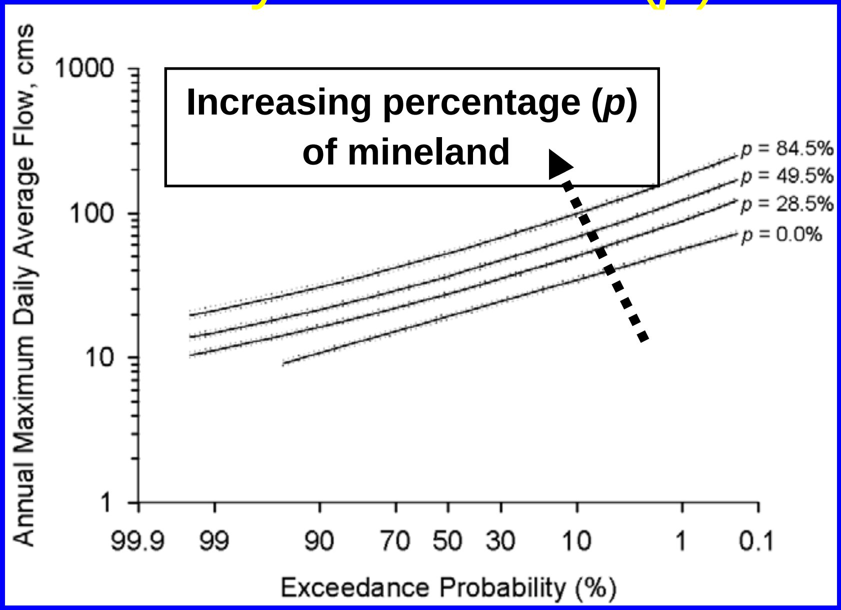
Photo Credit: USGS

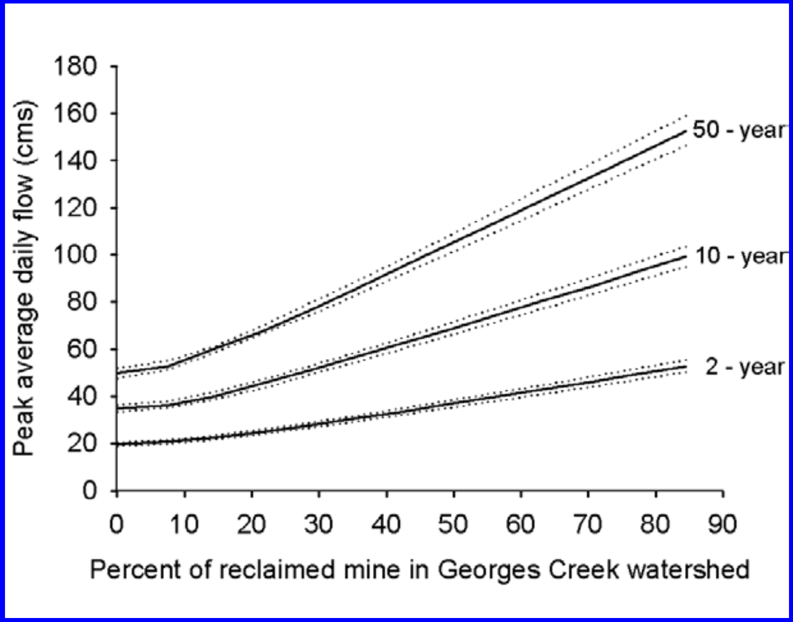
McCormick *et al.*, *WRR*, in revision

HSPF (calibrated using PEST)



"Family" of FFCs = f(*p*)





Stormflow peaks increase with increasing LCLUC: 25% mineland causes enhancement by a factor of about 40% at all frequencies

Ferrari *et al.*, *WRR*, in press

Conclusions

- Surface mining and land reclamation clearly *amplify* storm runoff responses of small catchments.
- This amplification was not *detectable* at the river basin scale using long gage records and conventional flood frequency methods, however.
- A *comparative paired analysis* produced significant results, however.
  - Comparable flood volumes (assumed)
  - Decreased centroidal lag (~ 3 hr)
  - Higher normalized peaks (~ 40%, across the board)
- Modeling suggests that increased mining and reclamation will further “enhance” flooding responses in Georges Creek.

Impacts of Fires on River Flow Volumes in Semiarid Shrubland Watersheds

Reduction in Transpiring Vegetation

↓

Less Evapotranspiration (ET)

↓

More River Flow

But : Conflicting findings in published studies.

Also: How do findings scale to large river basins?

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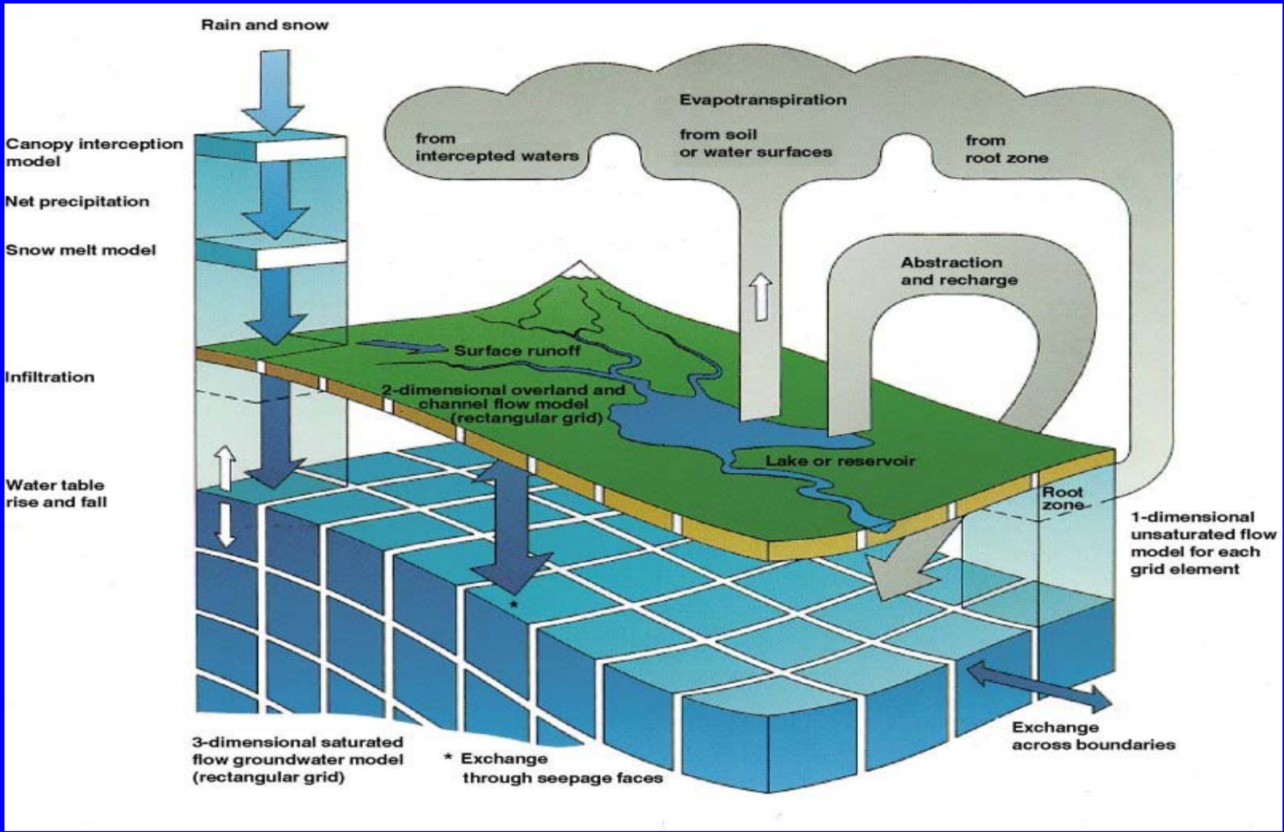
Standard Experimental Methods

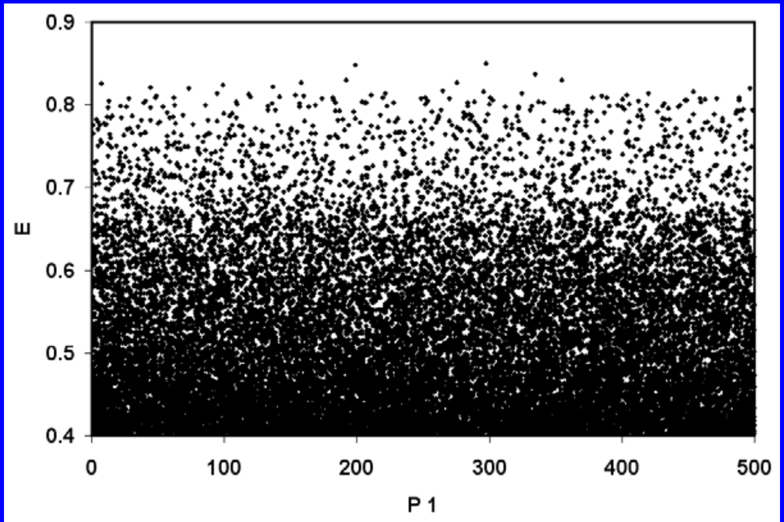
1. Modify vegetation in a detailed process model.
2. Use a model as a virtual control watershed (longitudinal approach).
3. Use an actual control watershed (paired watershed).

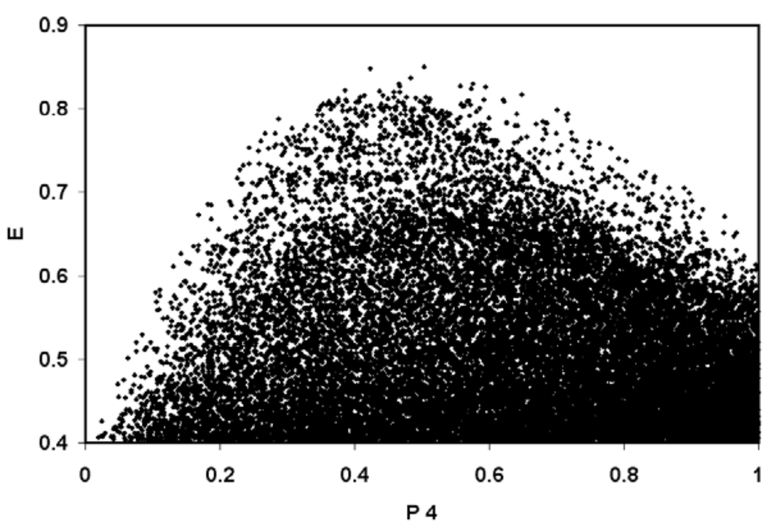
MIKE-SHE (Danish Hydrological Institute)



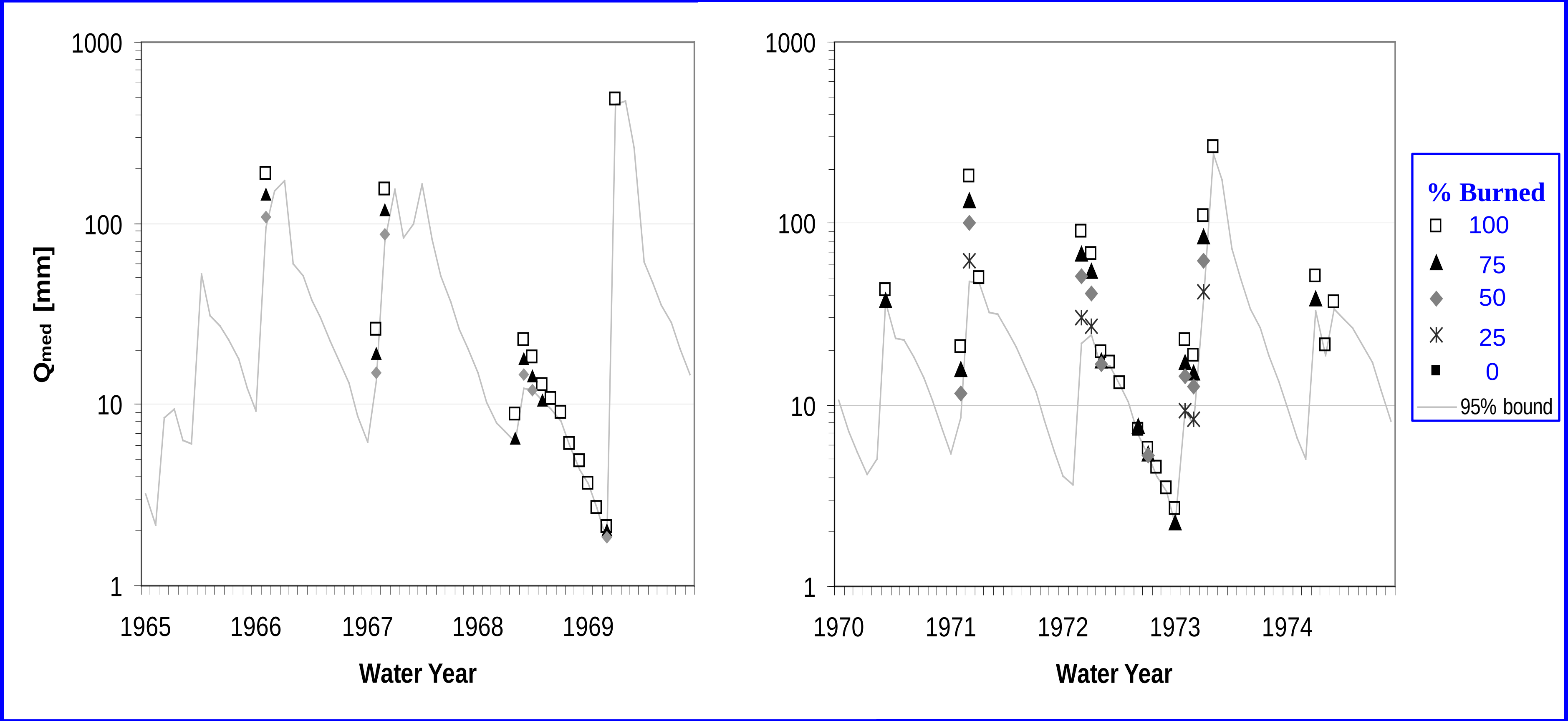
Equifinality and Parameter Identification

Parameter Set	P1	P2	P3	P4	E
1	298	15.5	4.38	0.504	0.85
2	199	15.6	3.89	0.424	0.848
3	335	13.6	1.3	0.484	0.836
4	192	15.8	4	0.466	0.829
5	355	13.2	1.37	0.576	0.829
6	276	15.4	4.74	0.467	0.826
7	158	14.5	2.17	0.557	0.826
8	7.43	16.6	4.17	0.595	0.825
9	99.5	15.7	3.23	0.574	0.823
10	137	14.5	1.65	0.386	0.821
11	44.9	3.18	3.33	0.438	0.82
12	73.3	1.02	0.66	0.459	0.819
13	497	0.686	1.4	0.467	0.819
14	265	12.2	0.973	0.649	0.816
15	454	5.59	2.52	0.442	0.815
…	…	…	…	…	…
n	27.5	5.22	4.24	0.153	0.401





MIKE-SHE Simulated Fire Effects on River Flow



- Fire size: required at least 25% of the watershed to be burnt before any effect on the hydrograph could be detected
- Model uncertainty: a major challenge (ignored in many studies)

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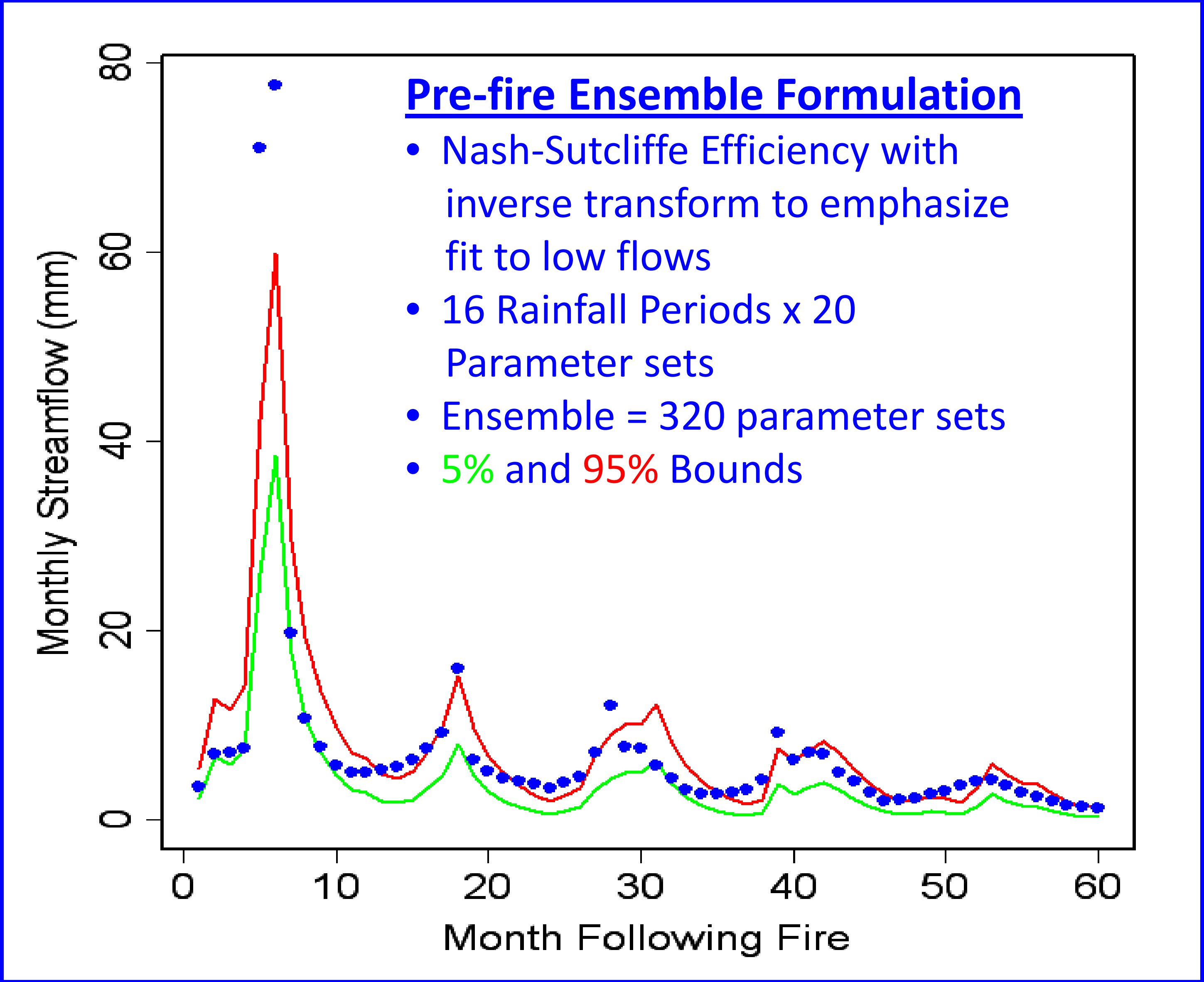
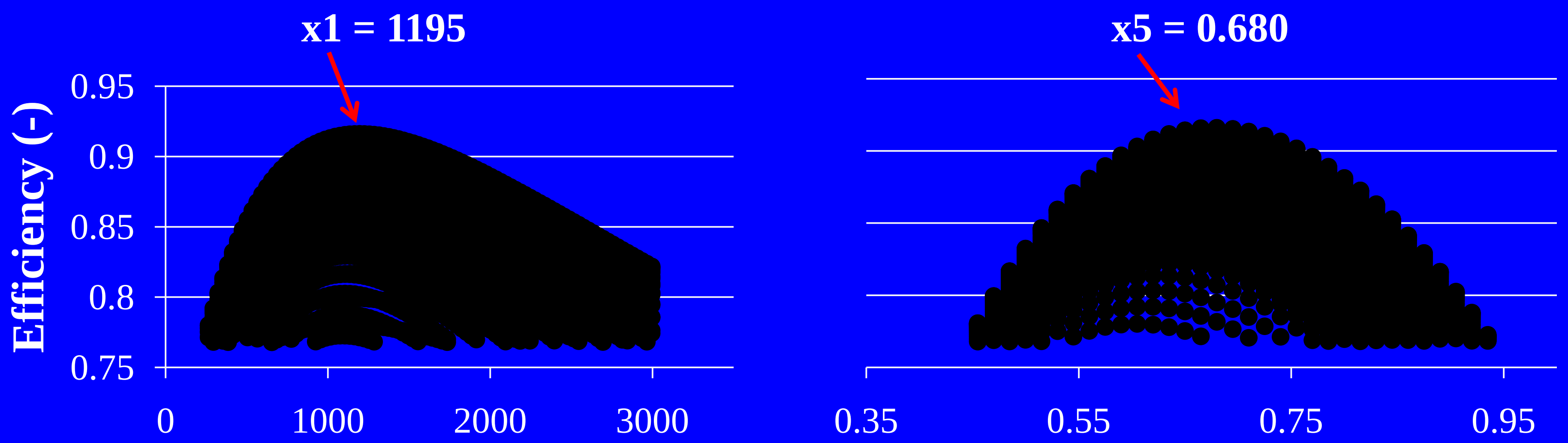
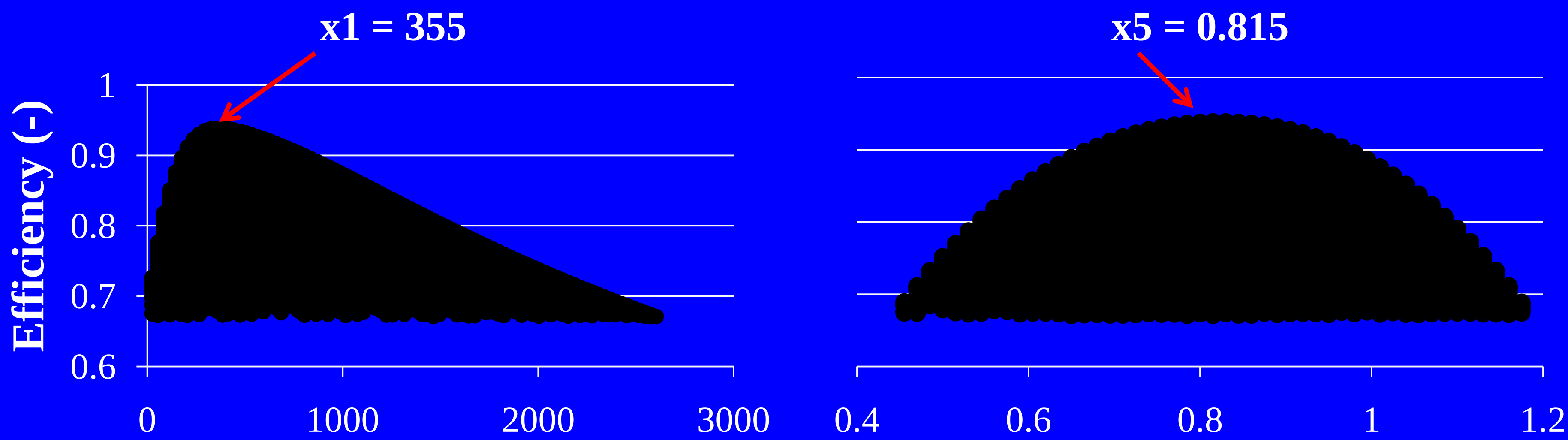
Longitudinal Studies: Lopez Watershed Post-Fire Simulation Using Ensemble Approach



Parameter Dependence on Rainfall Characteristics (Arroyo Seco Watershed)

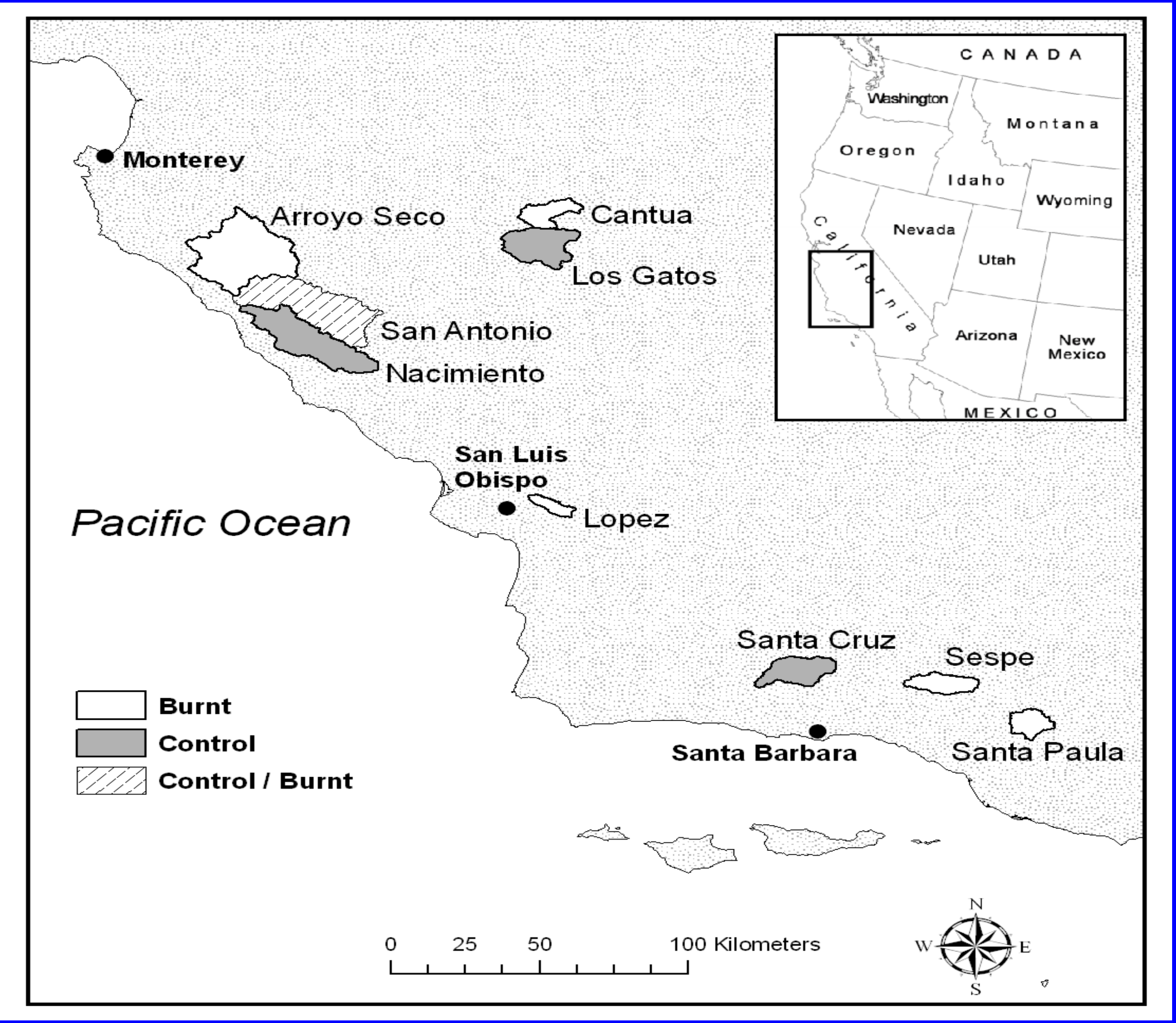


Period A – total rainfall = 7937.009 mm

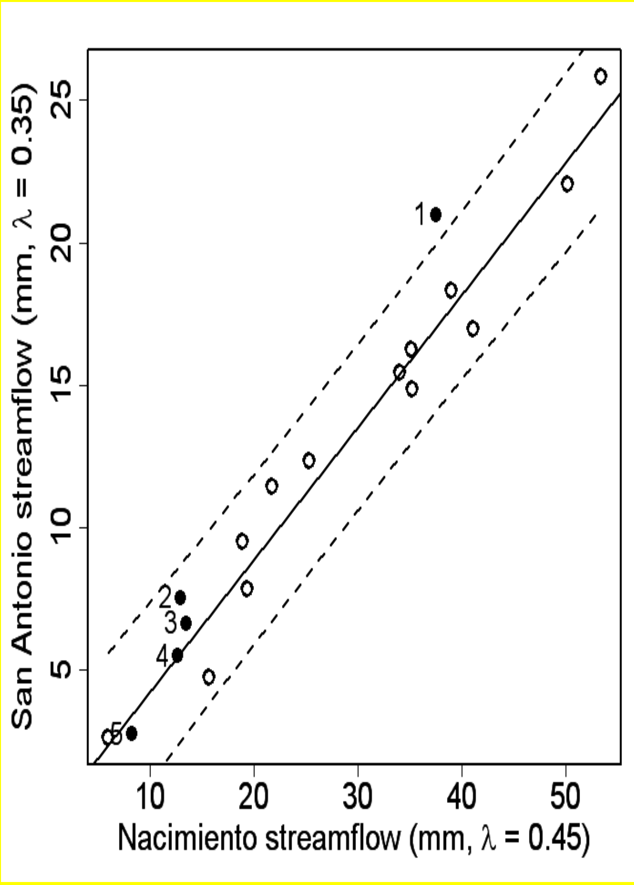


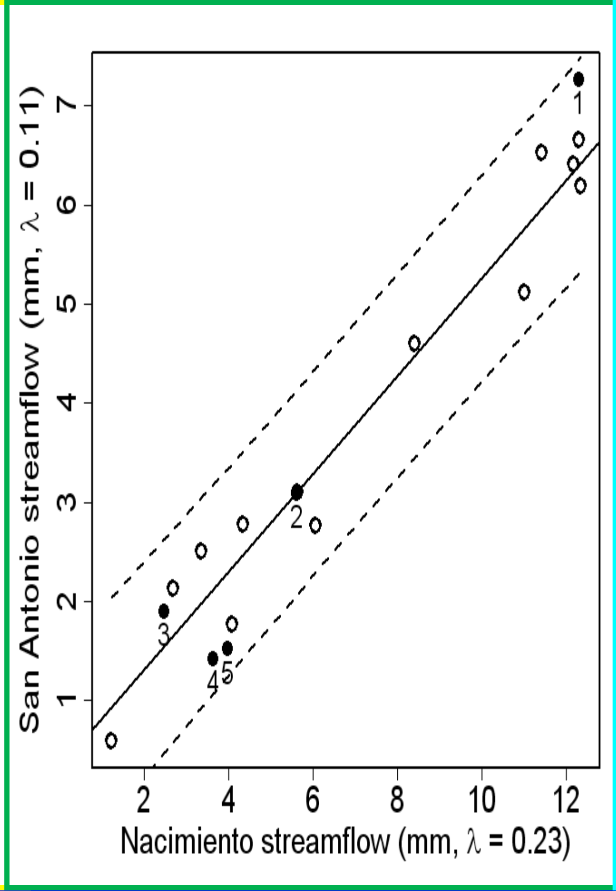
Period B – total rainfall = 3428.130 mm

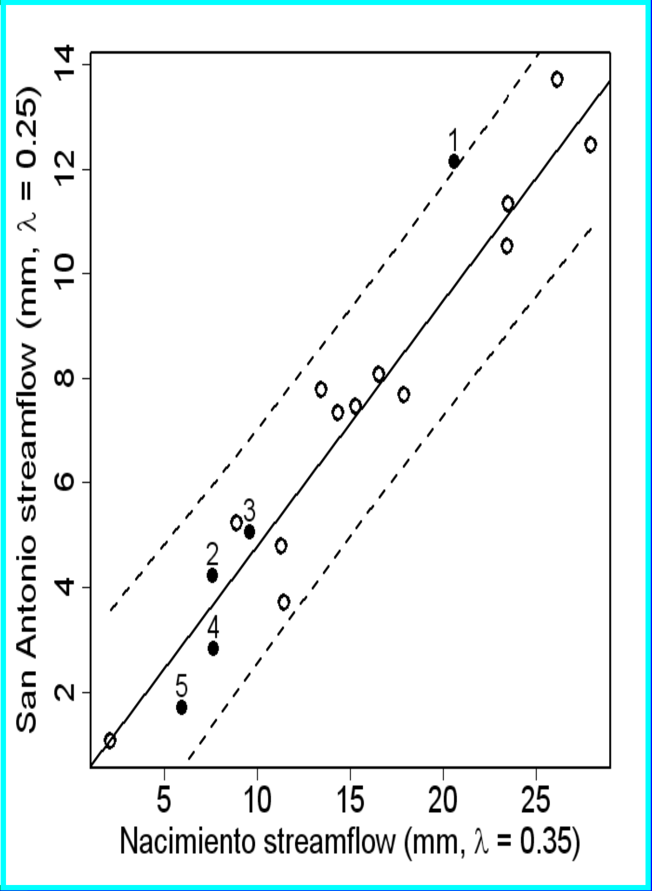
Paired Watersheds (California Existing Network)



San Antonio Watershed







Annual Streamflow

Monthly Streamflow

Seasonal Streamflow

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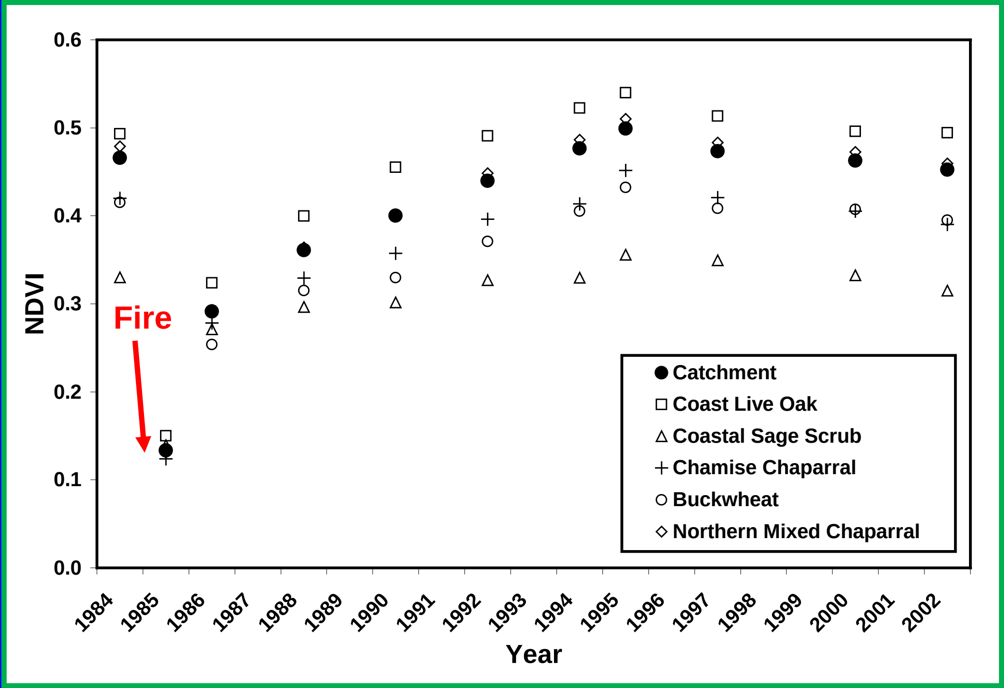
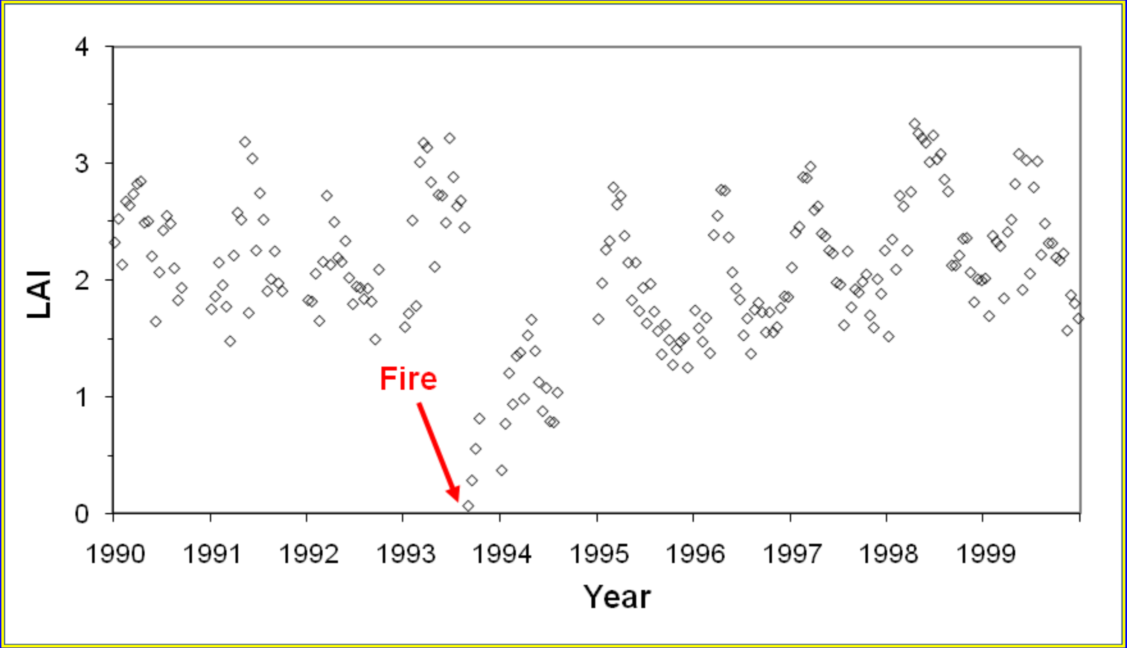
Chaparral Recovery Curve



TM/ETM

AVHRR



Conclusions

- Effect of fire on post-disturbance flow volumes is inconsistent among sites and transient.
  - Forest recovers very rapidly (“fire-adapted”)
- Model uncertainties are relatively large, but can be quantified using ensemble approach.
- Existing river flow networks can help extend small experimental watershed studies to be regionally relevant.
  - Challenge finding paired watersheds
- Post-fire rainfall/soil moisture seems to be a major determinant of river flow response to fires (droughts mute the effects of fires).

SDSU

Land Use and Vulnerability to Environmental Variability and Change: The Case of Flooding at Poyang Lake, China

Dan Brown

with Qing Tian, Kathleen Bergen, Tingting Zhao, Shuming Bao

NATURAL RESOURCES AND ENVIRONMENT
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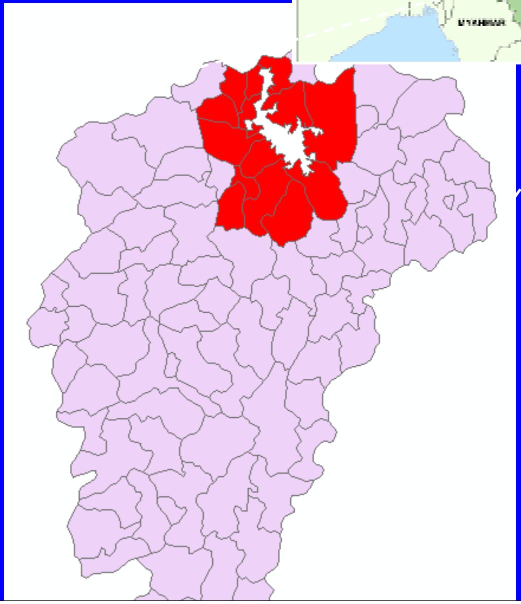
Vulnerability and Land-Change

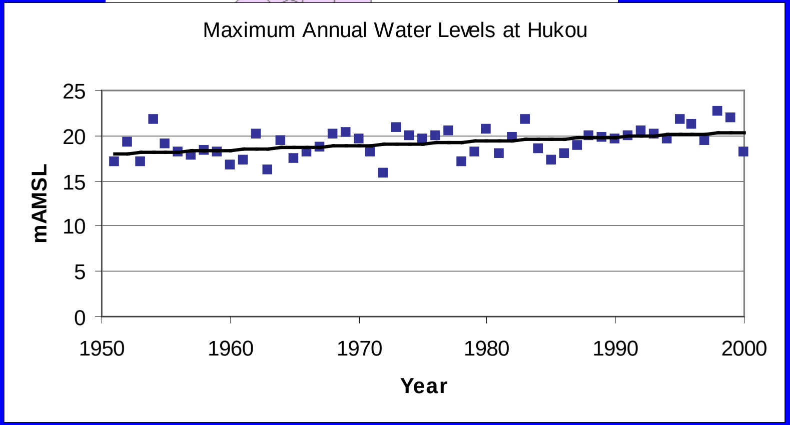
IPCC Working Group II uses three dimensions to describe vulnerability. We are developing approaches to link these to land change.

1. Exposure assessed regionally via remote sensing observations of land-cover change.
2. Sensitivity examined at village level using social surveys of land-use practices
3. Adaptation strategies modeled at household level with agent-based modeling
4. Also assessed implications of flood levels for ecologically important wetland habitats.

Poyang Lake Region

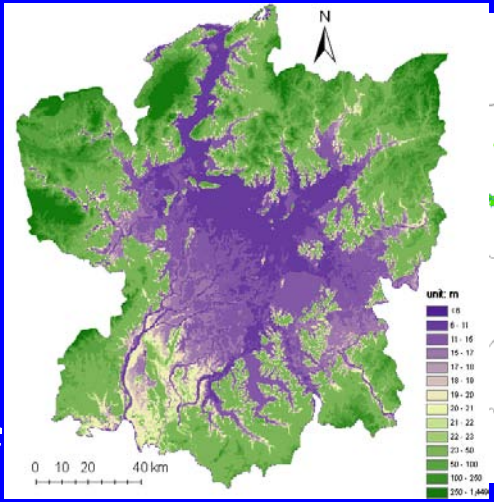
- Poyang Lake is largest freshwater lake in China.
- Connected to Yangtze
- Population of the Poyang Lake Region increased from 7.7 million to 8.7 million from 1990 to 1999.
- Flood waters rising over 50 years, largest flood in 1998.
- One of the most important areas in all Asia for migratory waterbirds, including IUCN Redlist.

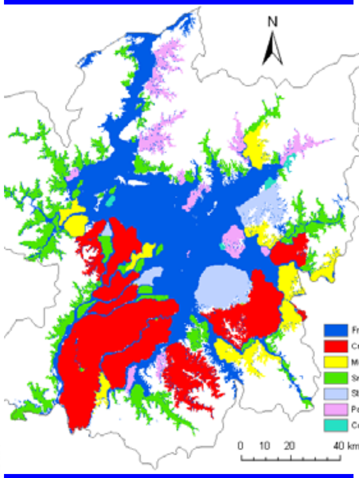


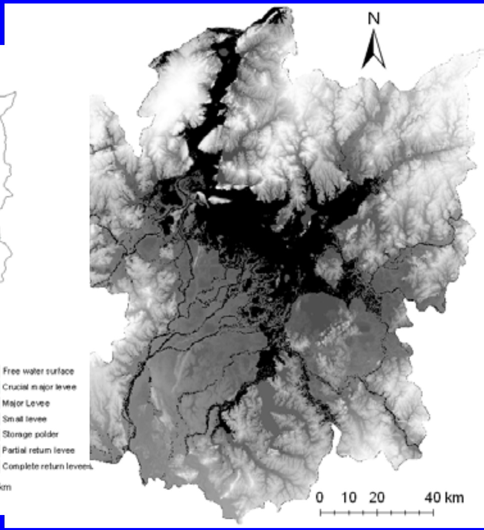


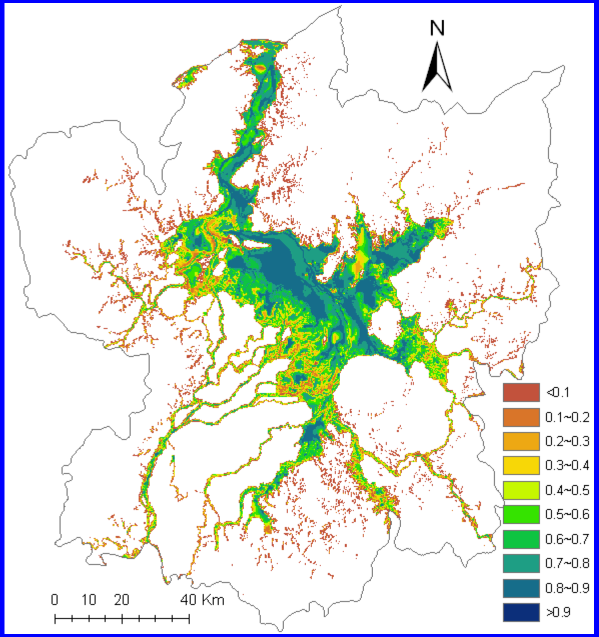
Characterizing Lake-Stage Dynamics

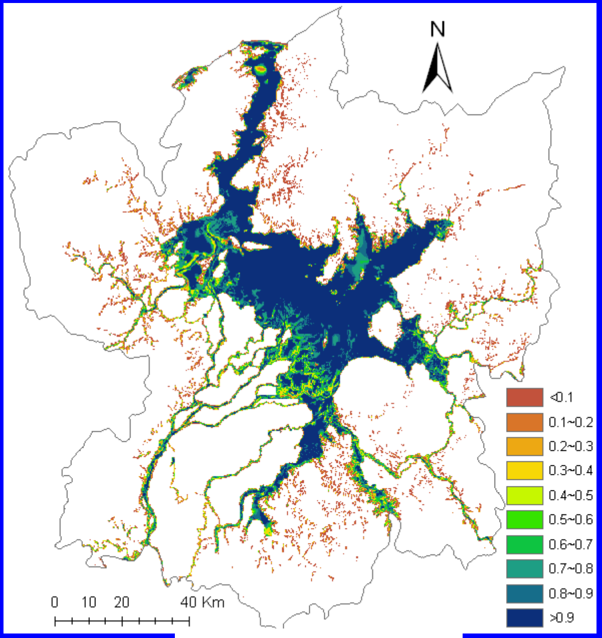
- We combined DEM data, levees data, lake gaging data, and multiple Landsat images of lake extent to map probability of inundation.











Qi, et al. 2009. *GIScience and Remote Sensing* , 46(1). 101-127.

1: Land Cover and Regional Patterns of Exposure

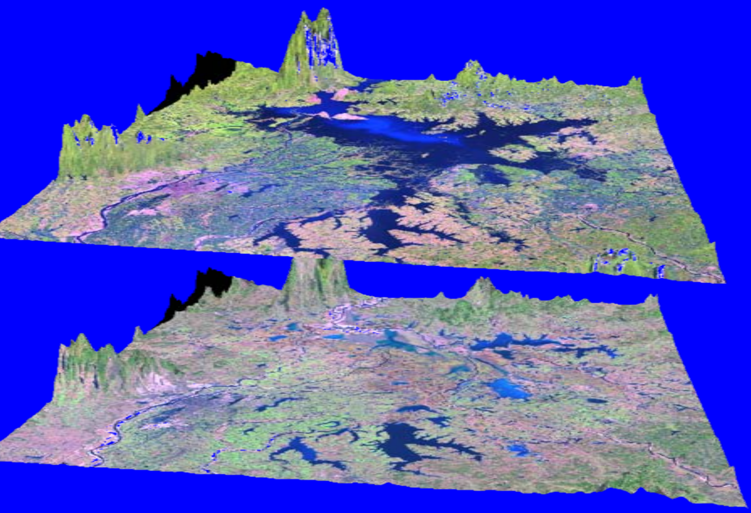
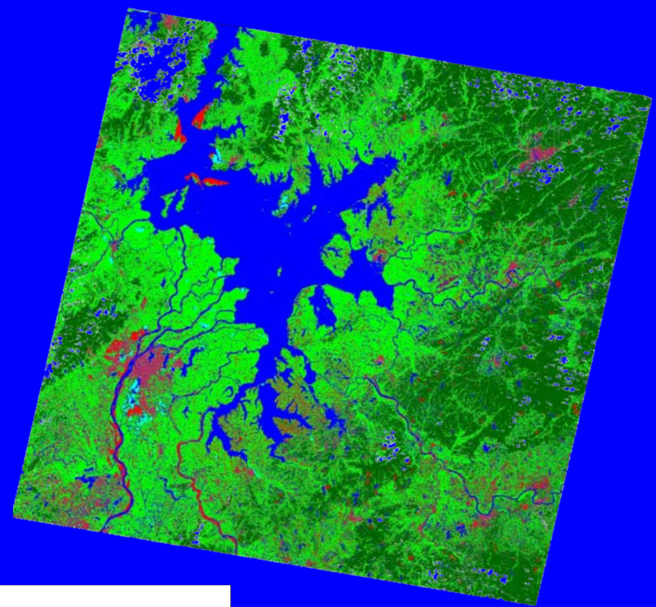
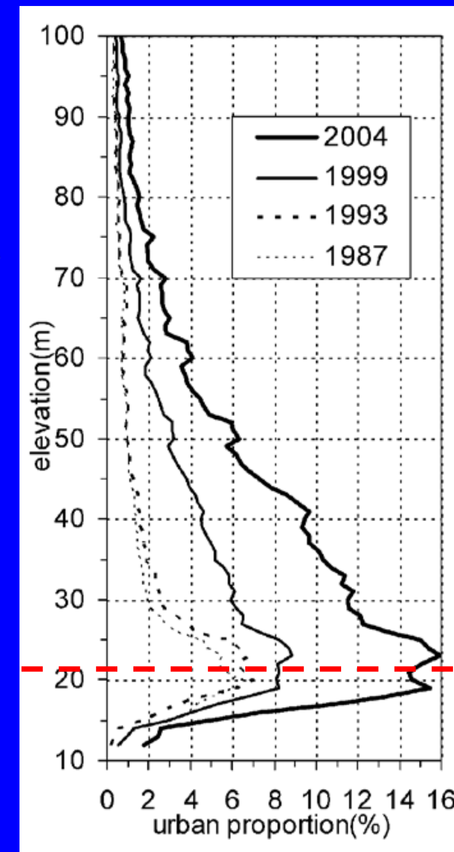


Image pairs used in classification: Summer flood season image (above) and winter low-water image



Urban and agricultural land covers indicate human activity that is susceptible to disruption or harm

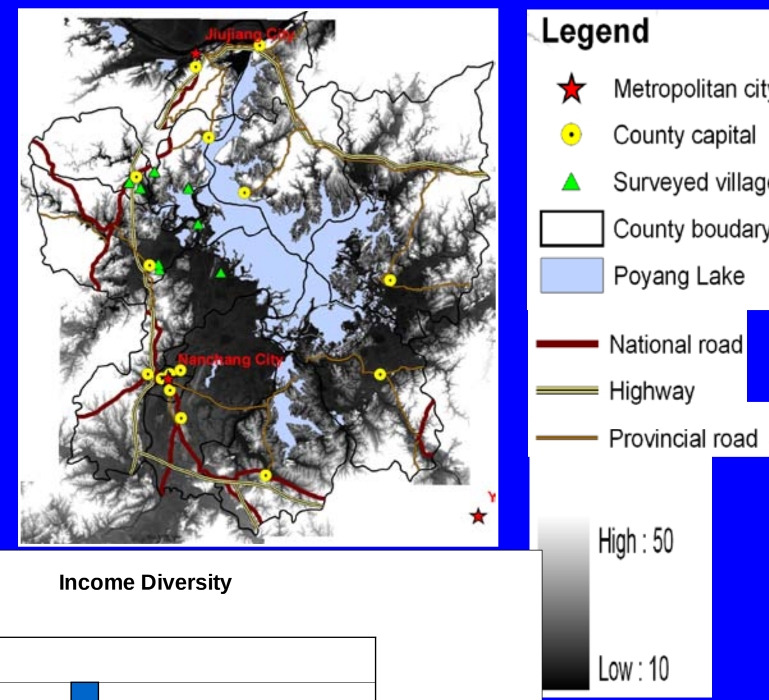


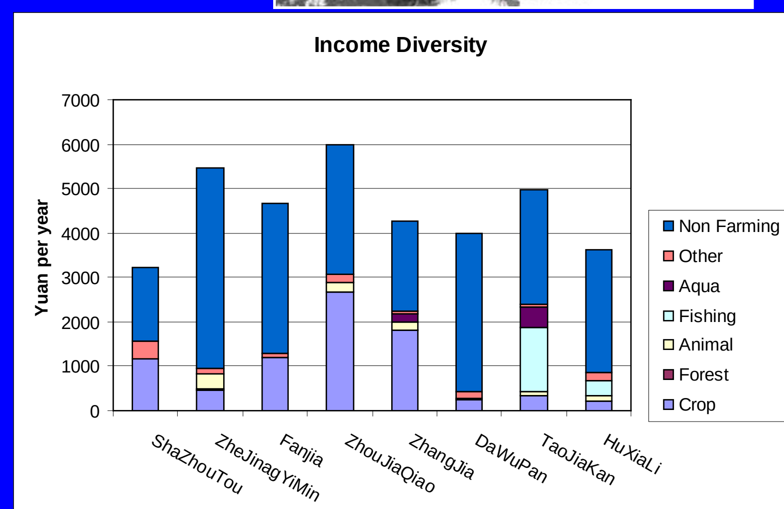
Most new urban land is at higher elevations or behind the strongest levees. Exposure seems to be declining as a result of policies.

Jiang, L. et al., 2008. *Photogrammetric Engineering and Remote Sensing*, 74(6): 775-786.

2: Land Use and Sensitivity

- Eight villages surveyed on west side of lake, 193 households total.
- Stratified by (a) exposure to flooding and (b) distance from towns.
- Survey conducted Feb 2007, with follow-up interviews 2008.
- With survey data, we are examining the effects *Land Tenure, Entitlement* and *Endowments*, and *Diversification* of economic activities as indicators of sensitivity of households to flooding.





3: Modeling Adaptation

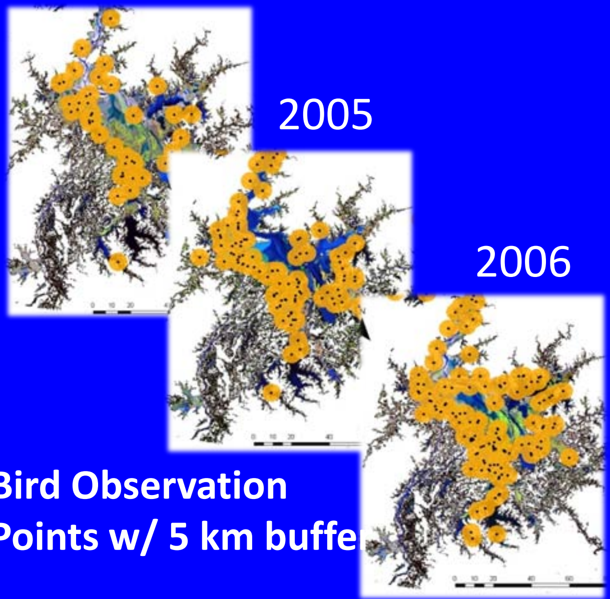
- Adaptation is a dynamic process whereby human actions are modified in response to environmental stresses, like exposure to flooding.
- Implications of alternative strategies are being investigated by dynamic simulation.
- An agent-based model has been developed to explore how farmer households can respond to flooding and socio-economic changes, reduce vulnerability, and achieve increased overall well-being.
- With the model, we are measuring income as a function of farming, affected by flooding, and other economic activities.

4: Habitat Assessment

2004

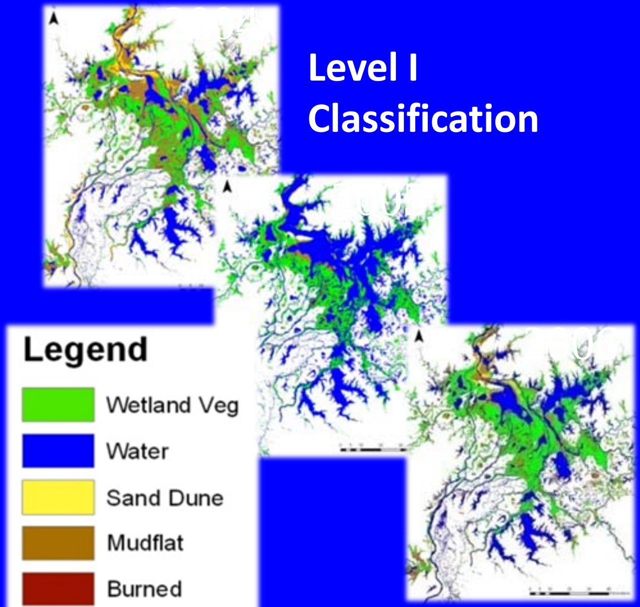
2005

2006



Bird Observation Points w/ 5 km buffer

Level I Classification



- Birds were observed winters 2004, 2005 and 2006 at over 100 sites by in-country scientists.
- ~500,000 individuals in 34 genera and 75 species observed each year.
- We created new classifications of wetland covers using image data corresponding to the timing of the surveys.
- Relationships between a) bird presence/absence/abundance and b) wetland land-covers and c) landscape structure variables at two hierarchical levels are being modeled.
- Hypothesize that damping the annual variability of wetland water levels (i.e. by dams) could significantly influence habitat characteristics.

Contributors

- Phil Townsend et al. (University of Wisconsin)
- Todd Lookingbill, Joseph Ferrari, Brian McCormick, Jeff Griffith (University of Maryland Center for Environmental Science)
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- Doug Stowe (San Diego State University)
- Qing Tian, Kathleen Bergen, Tingting Zhao, Shuming Bao (University of Michigan)
- Shuhua Qi (Jiangri Normal University)
- Luguang Jiang (IGSNRR, CAS)