Acequia Hydrology Foundations of Community Resilience to Changing Climate and Land Use

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[6] New Mexico Acequia Association

Acequias in the Global Perspective – Las Cruces, NM March 2-3, 2013

Ribbons of green

- Traditional acequias are the primary irrigation systems in northern New Mexico areas without large water projects

Acequias
Brought to New Mexico in 1500s by Spanish settlers

(From Rivera, 1999)

Acequias

- Ditch systems to irrigate fields
- Community acequia associations to allocate water

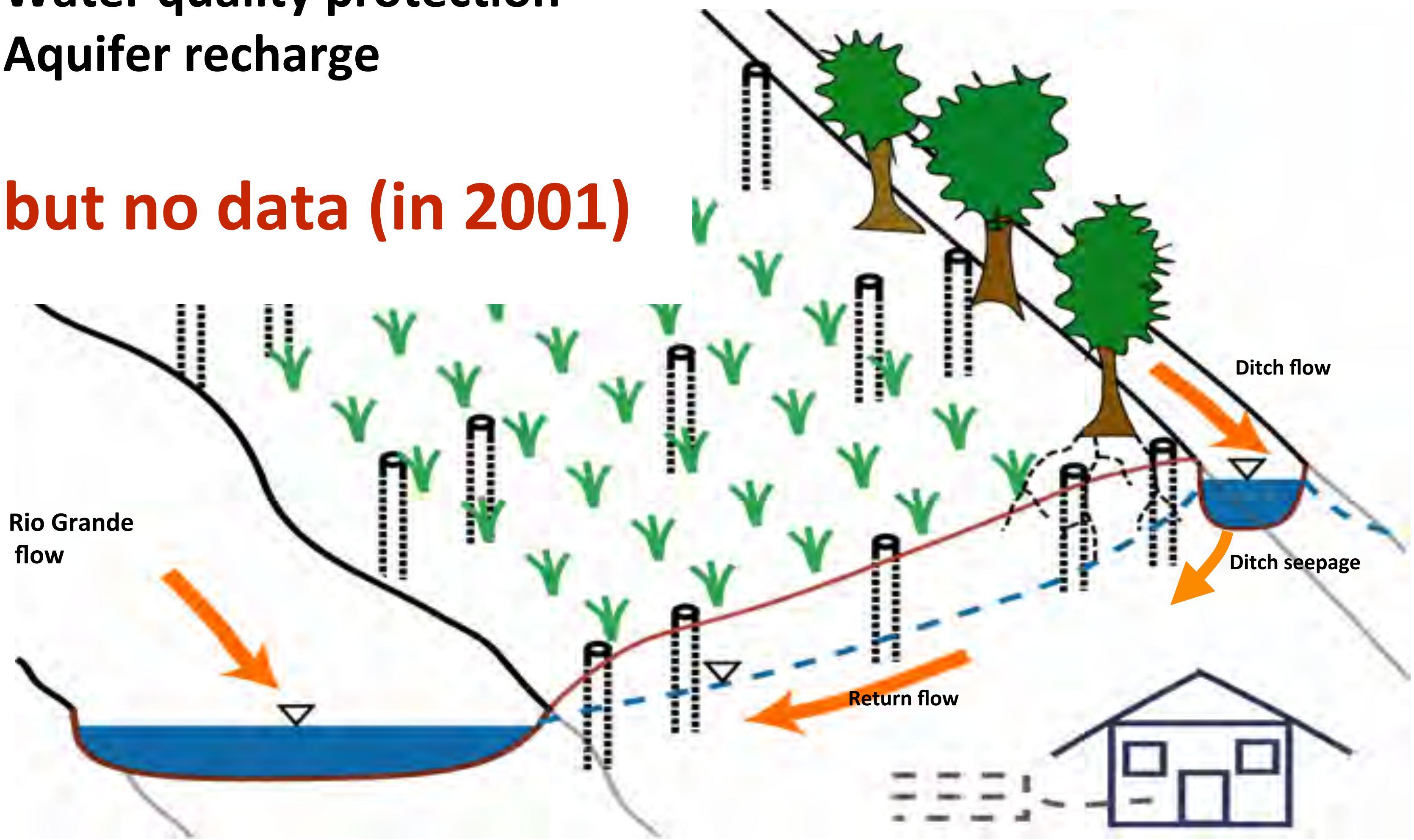

Acequia-irrigated fields


Alcalde Acequia

WISDOM OF THE ANCIENTS
BENEFITS OF ACEQUIA SEEPAGE

- **Riparian vegetation**
- **Water quality protection**
- **Aquifer recharge**

...but no data (in 2001)



OUTLINE

I. Traditional acequia hydrology

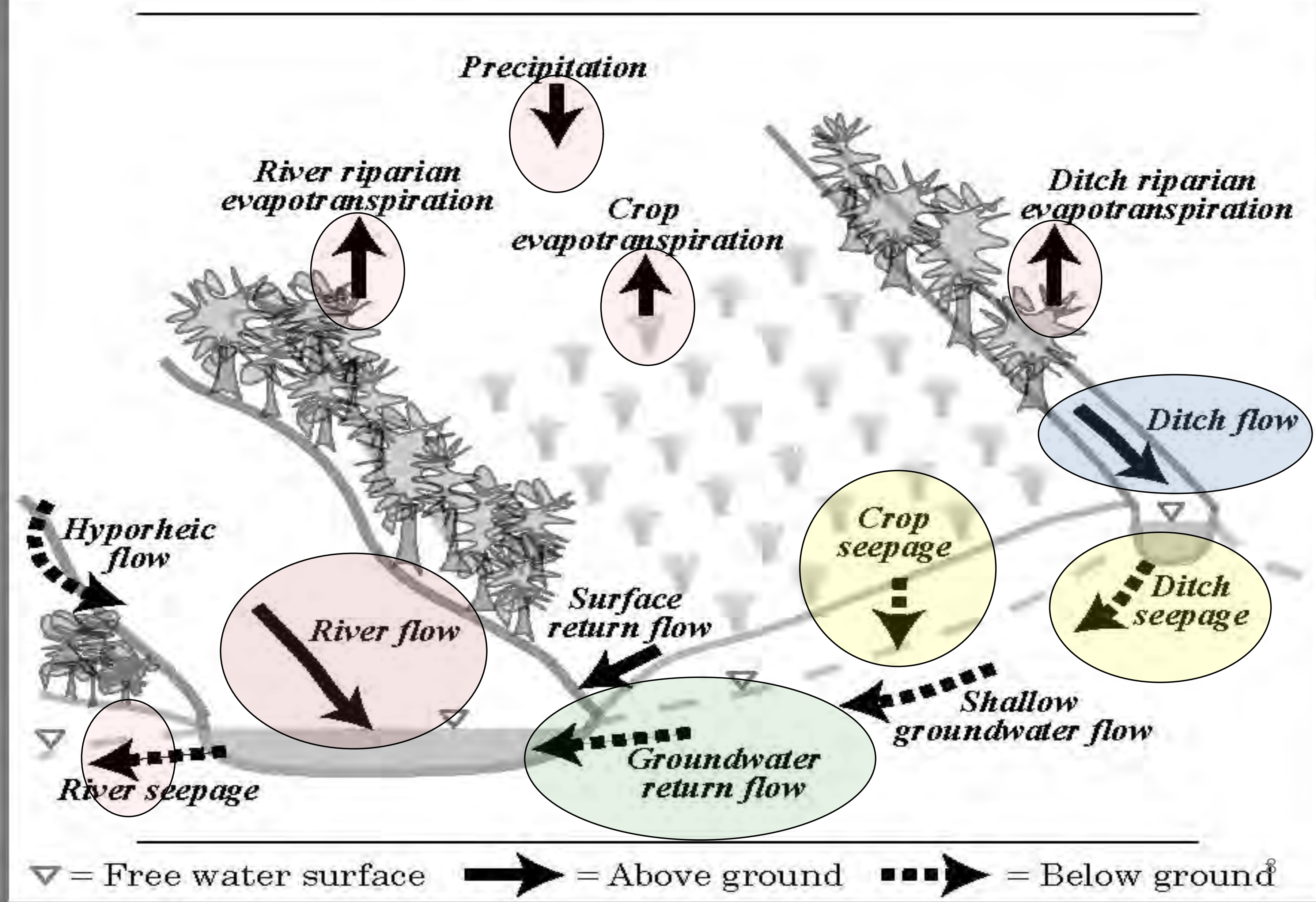
- Hydrologic benefits of traditional irrigation systems

II. Acequia-linked natural and human systems

- Clues to sustainability

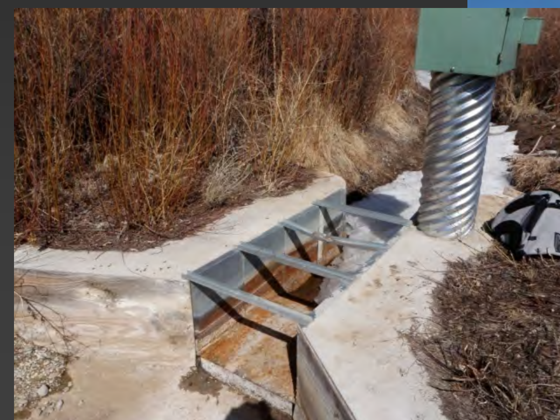
I. TRADITION ACEQUIA HYDROLOGY

HYDROLOGIC BUDGET APPROACH



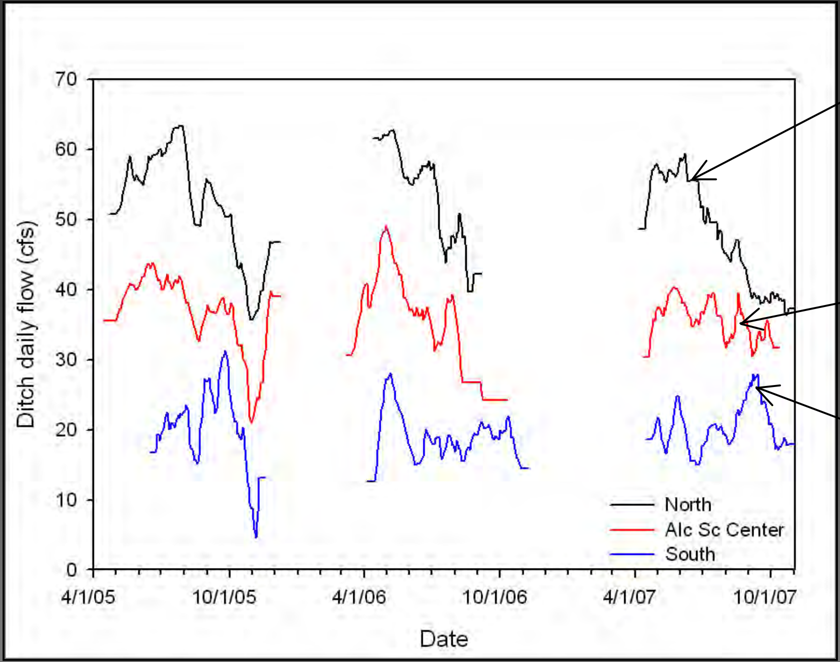
Measurement infrastructure

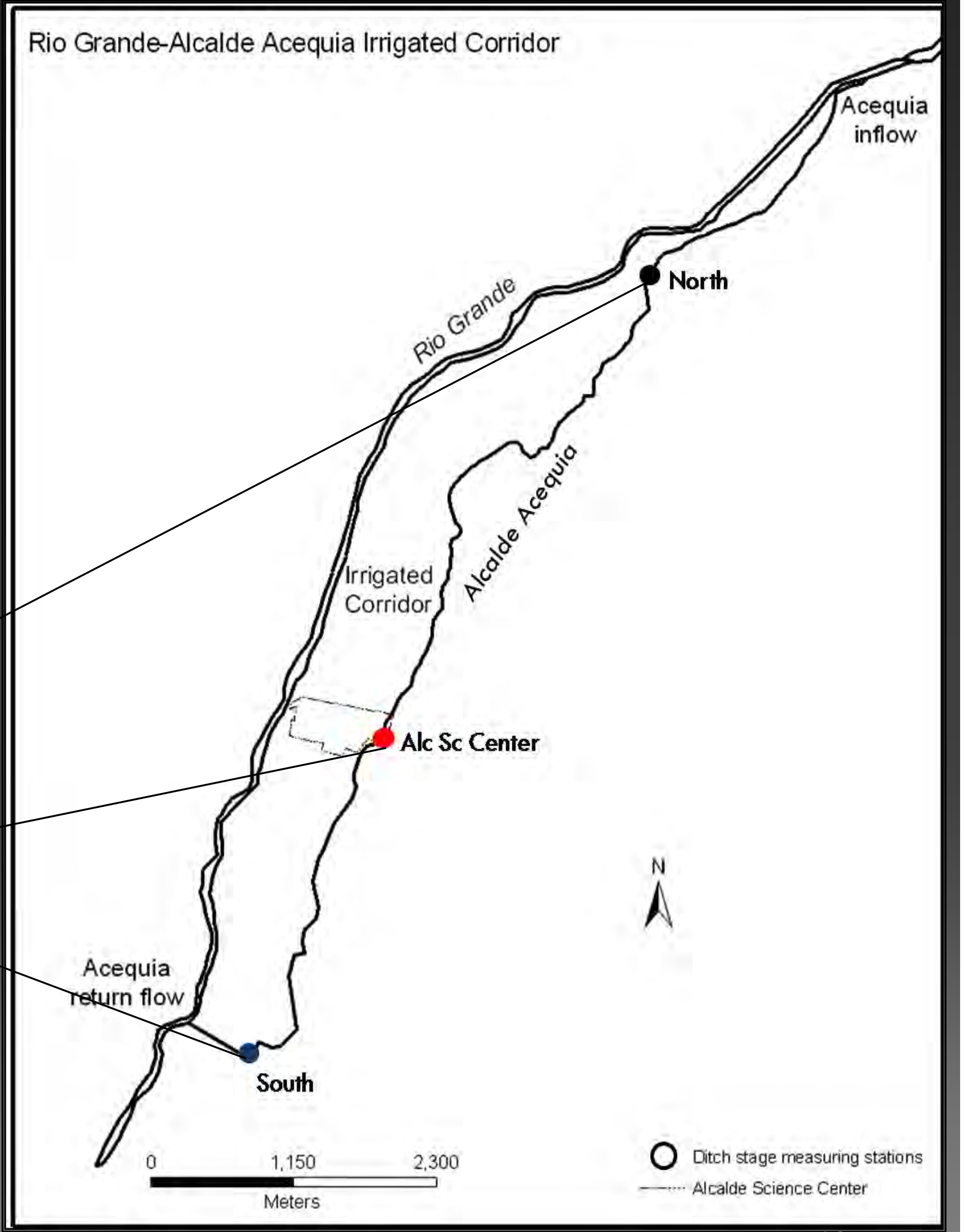
- Flow of river and acequias
  - -stilling wells and flumes
- Weather parameters
  - -central weather station (temperature, rain, wind, etc)
- Soil moisture
  - -various soil moisture stations located in representative fields in region
- Groundwater
  - Sensors placed in wells in region


Ditch flow:

Three automated stage-measuring stations in the 6-mile Alcalde acequia.





Ditch seepage:

Impoundment tests

Inflow-outflow tests

Irrigation:

- Irrigation studies to determine field water balance

Irrigation and runoff:

Propeller flow meter

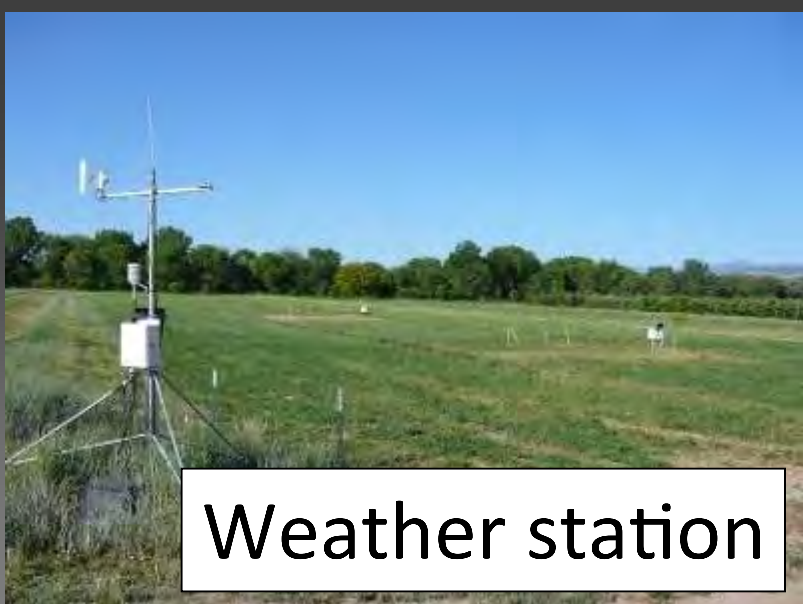
Irrigation applied

S-M flow meter

Crop field runoff

Irrigation deep percolation and crop ET:

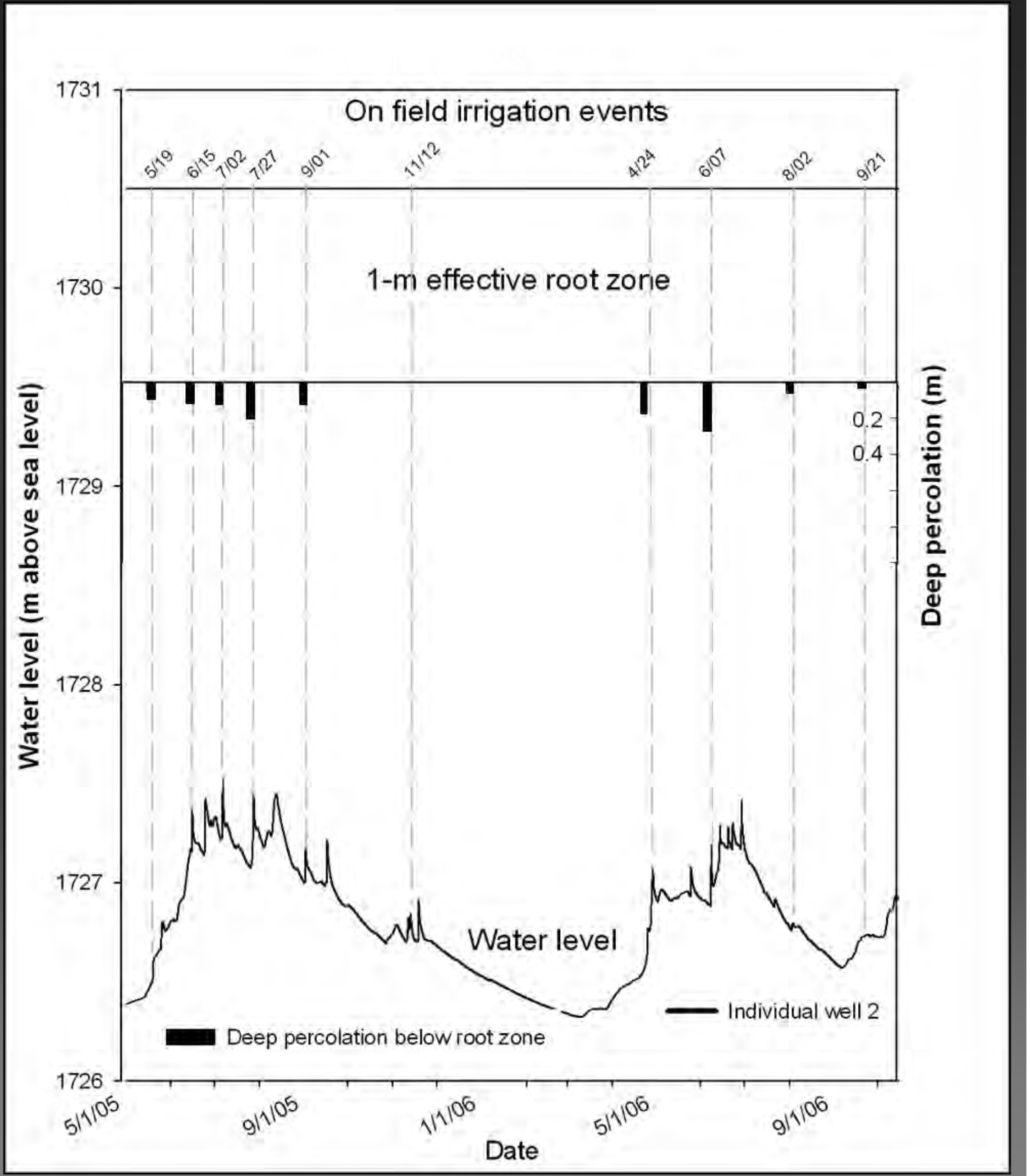
Deep percolation below the root zone



Crop ET

Deep percolation and water table fluctuations:

- Spikes in water level observed in response to deep percolation.



- **Three river stage-measuring stations**
  - Embudo station
  - Alcalde
  - Ohkay Owingeh

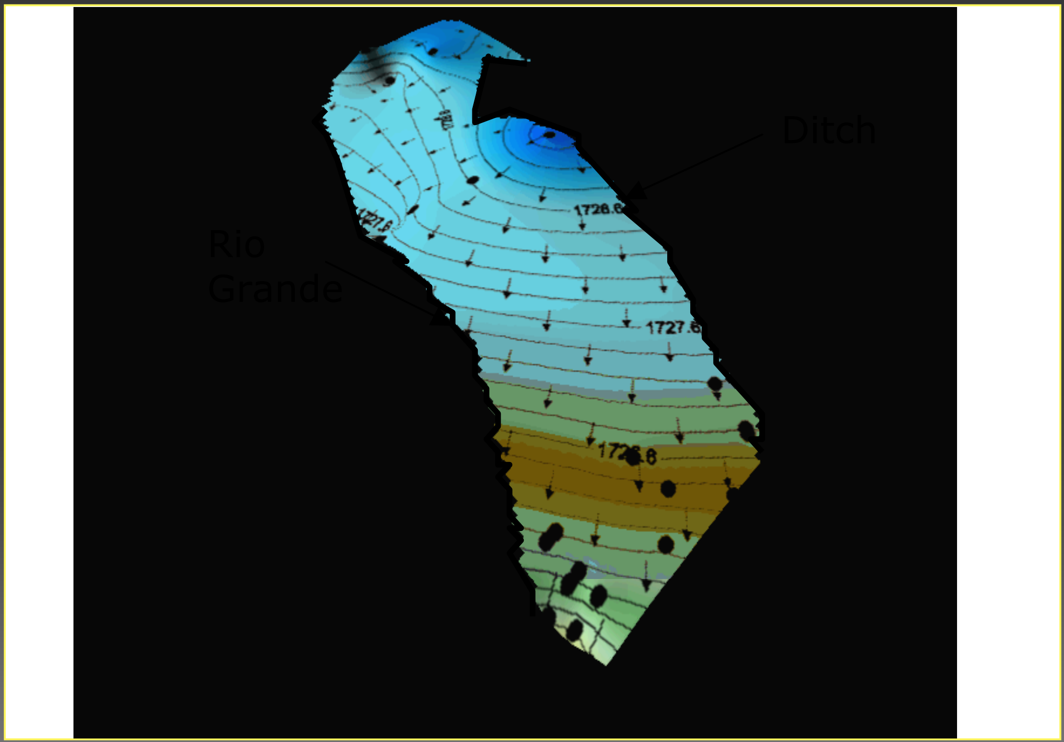
Water budget

Alcalde Acequia three year (2005-2007) averaged water balance.

Component		Amount from canal diversion (%)	Range (%)
Surface water return flow	Turnouts	9.5	0 to 14
	Crop field tailwater	8.9	0 to 19
	Canal outflow	40.9	28 to 67
Ground water return flow	Ditch seepage	12.1	5 to 17
	Deep percolation	21.2	9 to 32
Evapotranspiration		7.4	1 to 15
	Total	100.0	

GAINING RIVER

•River below floodplain water table, gains water from groundwater



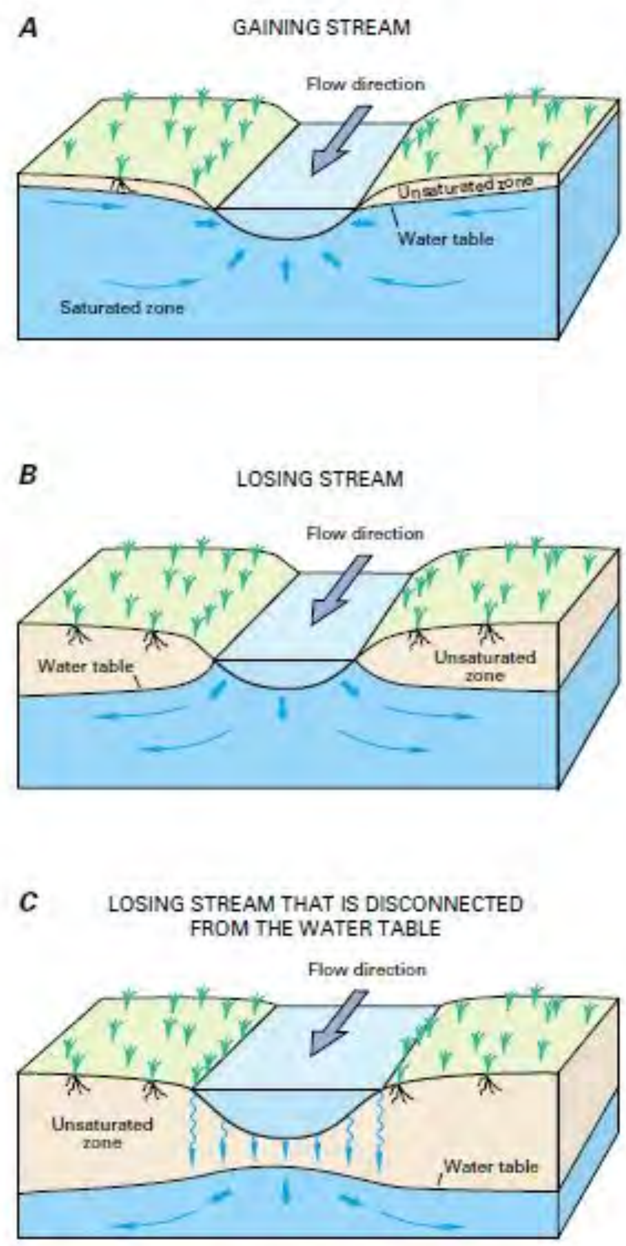
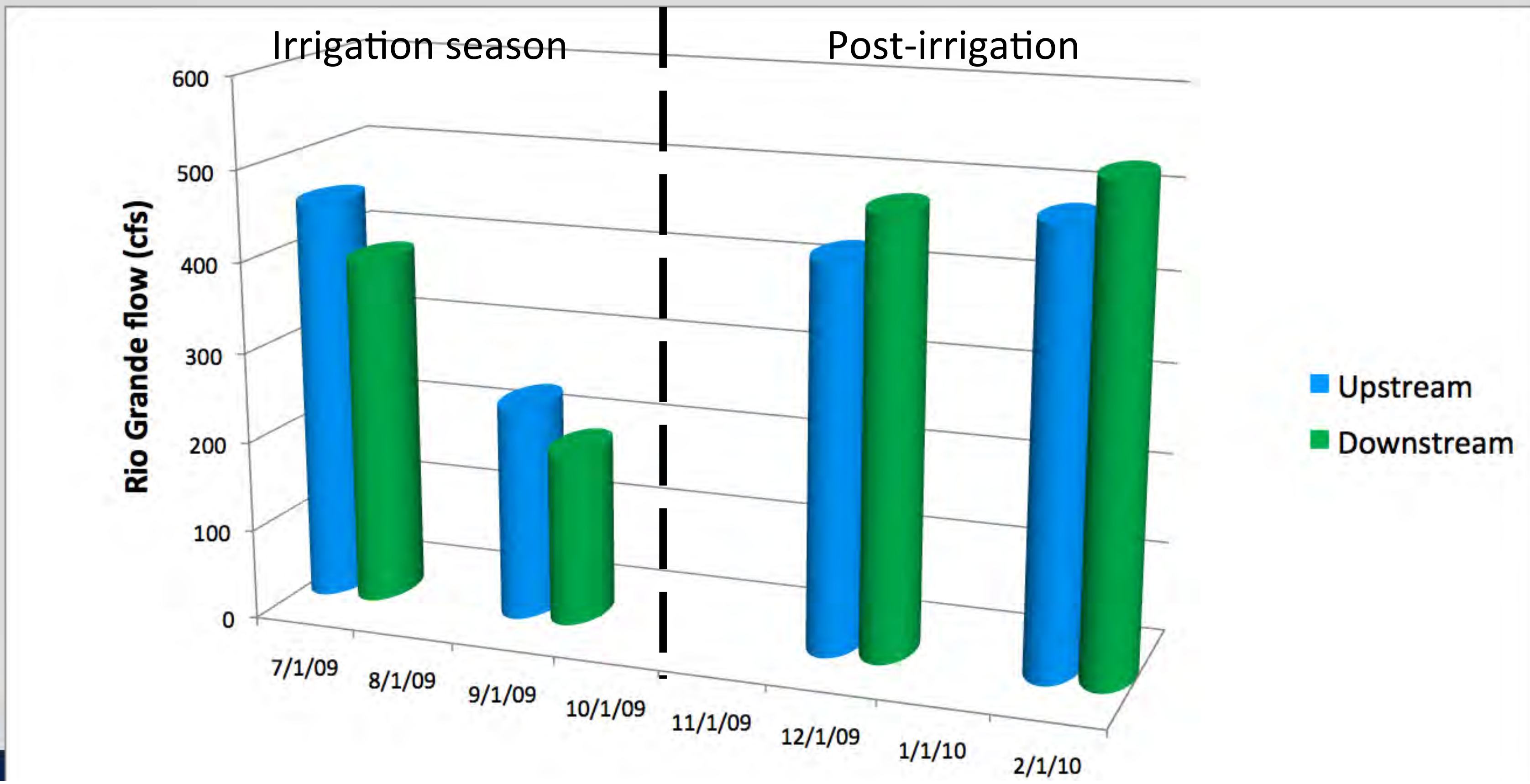


Figure 12. Interaction of streams and ground water. (Modified from Winter and others, 1998.)

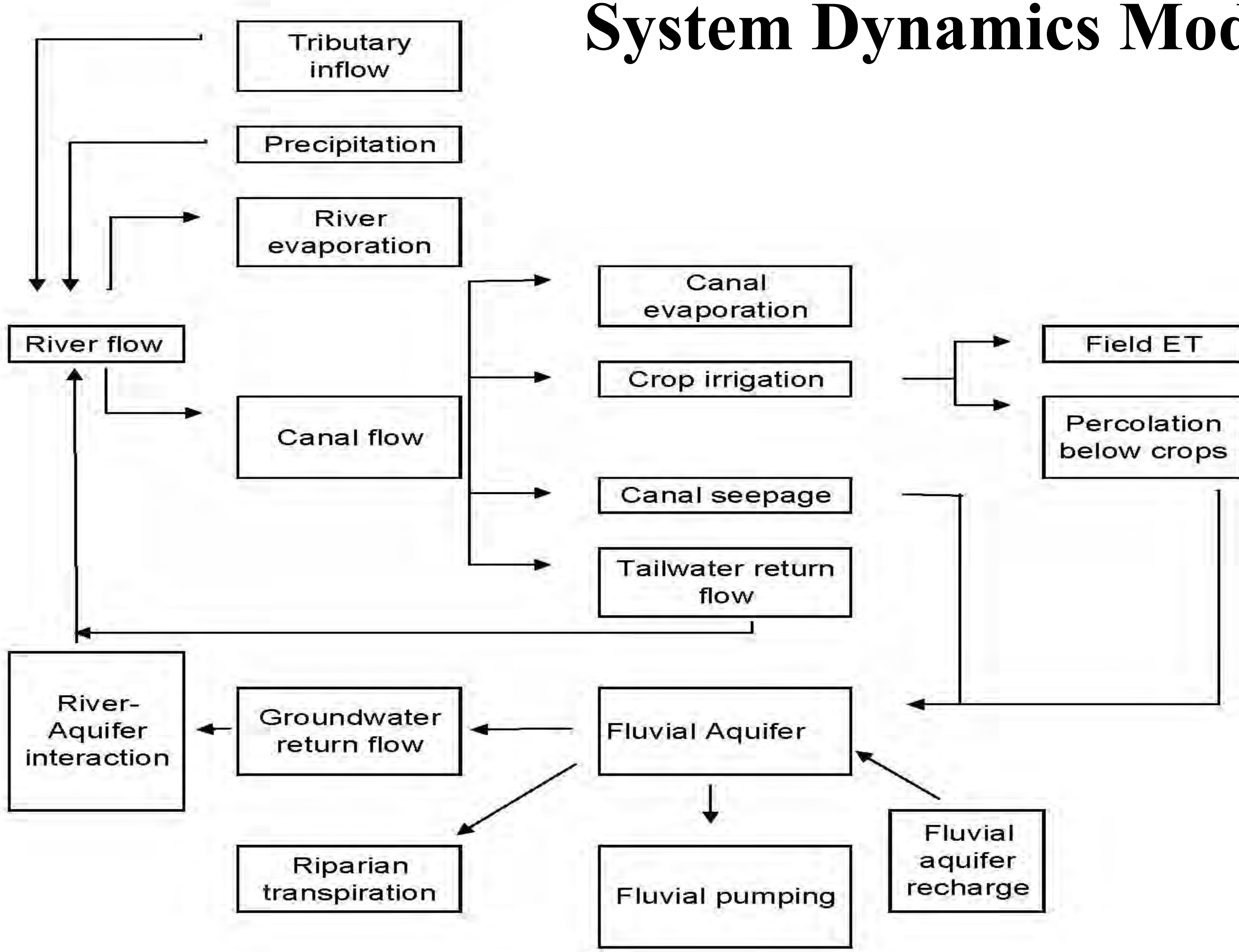
River flow and delayed return flow

- **Higher flow in downstream river in response to delayed groundwater return flow at the end of the irrigation season.**

- **The irrigation systems collectively take spring and summer runoff from the river and retransmits the flow to later in the year through seepage and groundwater return flow**

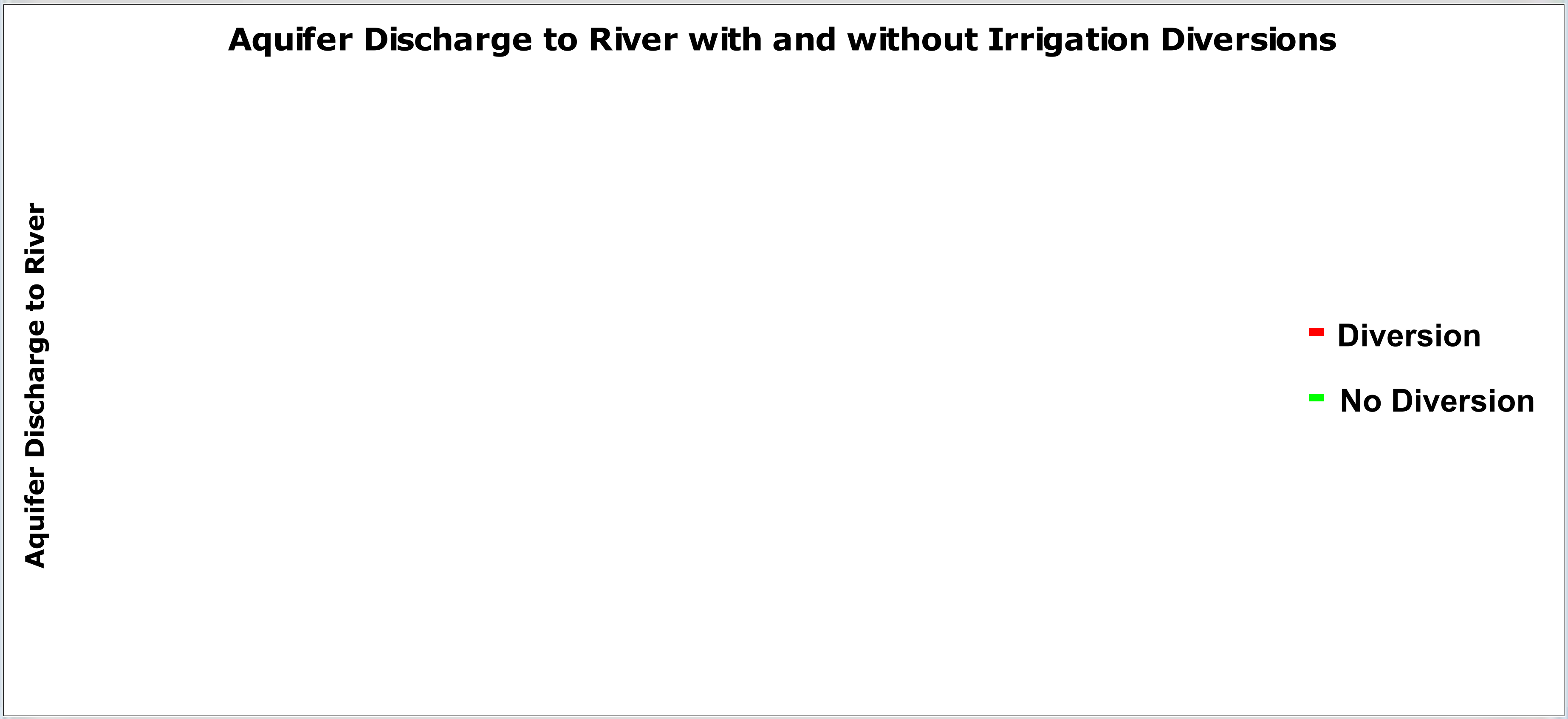


System Dynamics Model



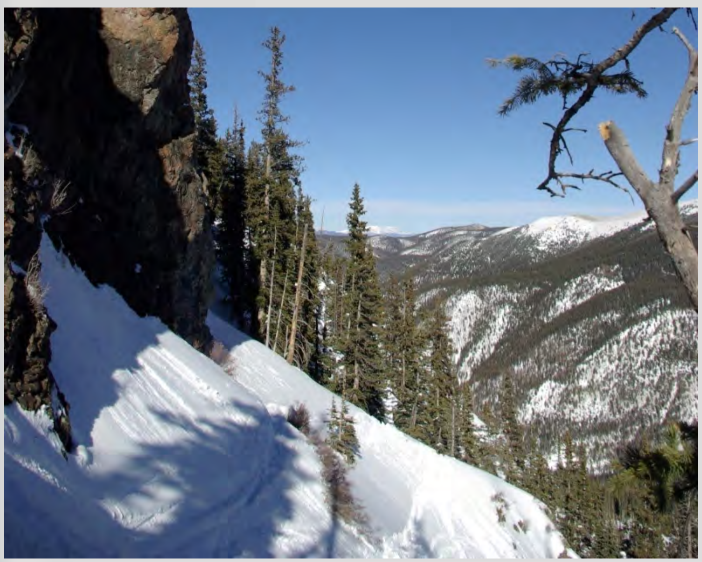
System Dynamics Model Future Scenario Testing

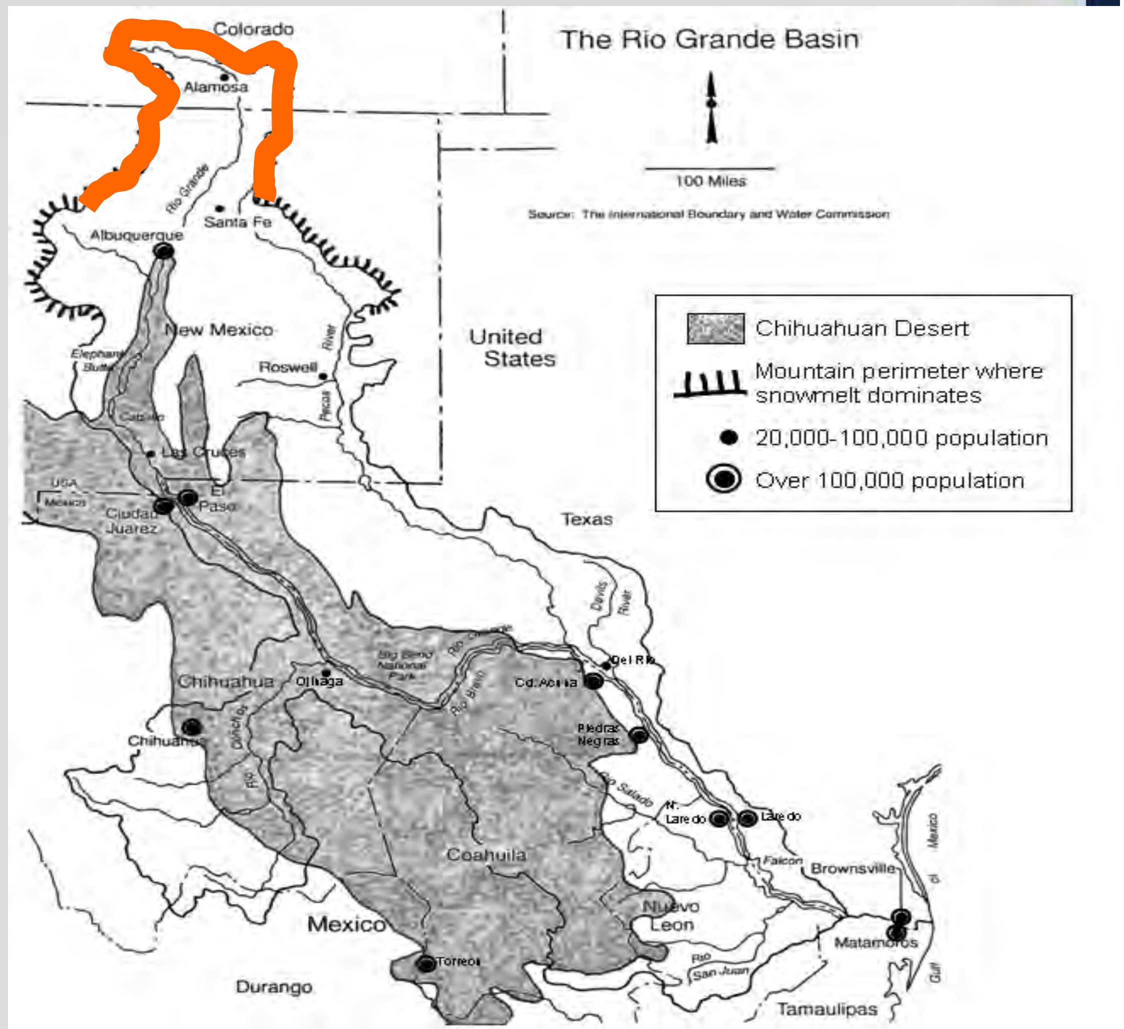
- The system dynamics model allows scenario testing of aquifer-river interactions with and without irrigation diversions.
- Aquifer discharge to the river is reduced without diversions.



Rio Grande headwaters

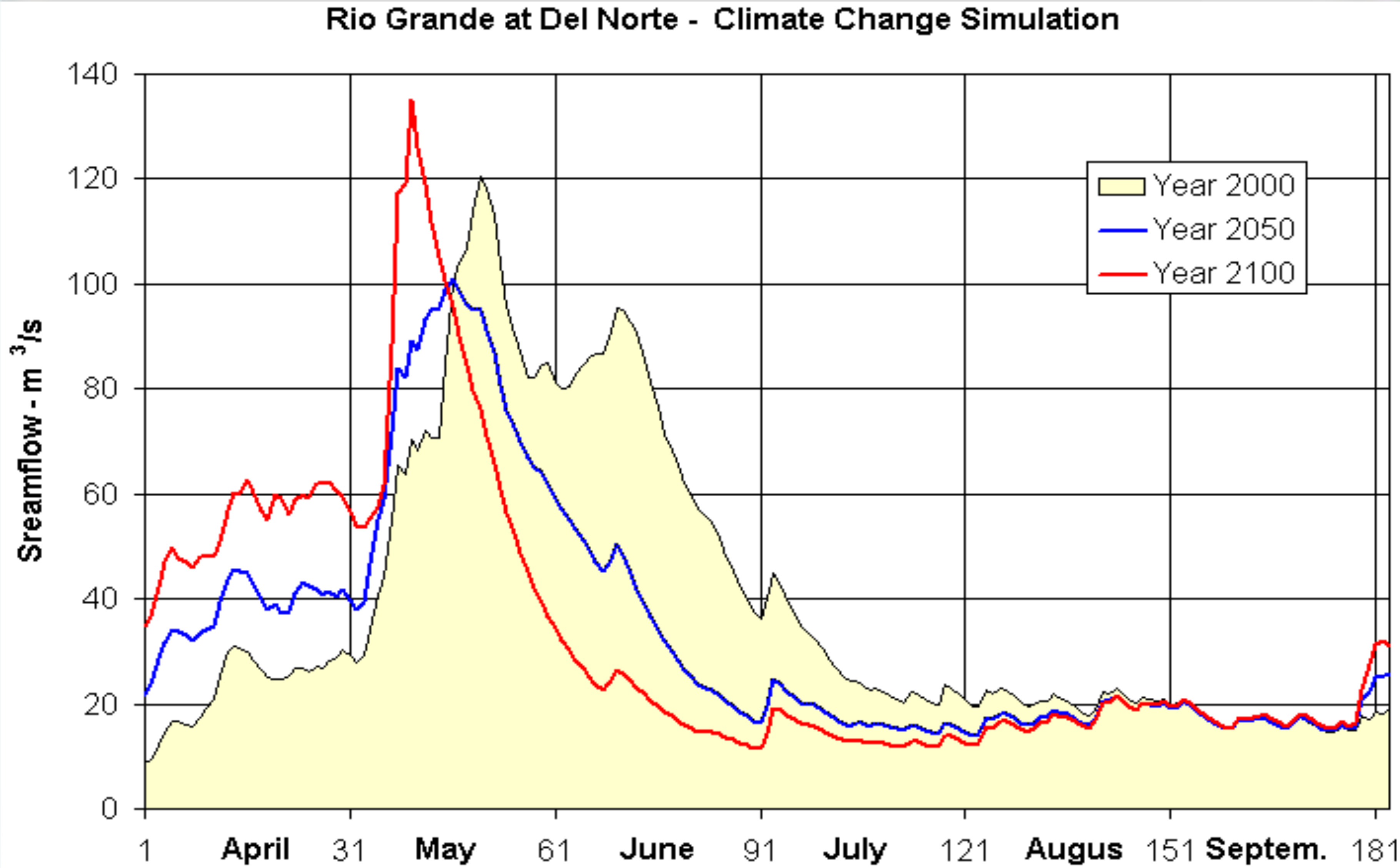
Most Rio Grande flow is snowmelt from the mountains of southern Colorado and northern New Mexico (Rango, 2006)





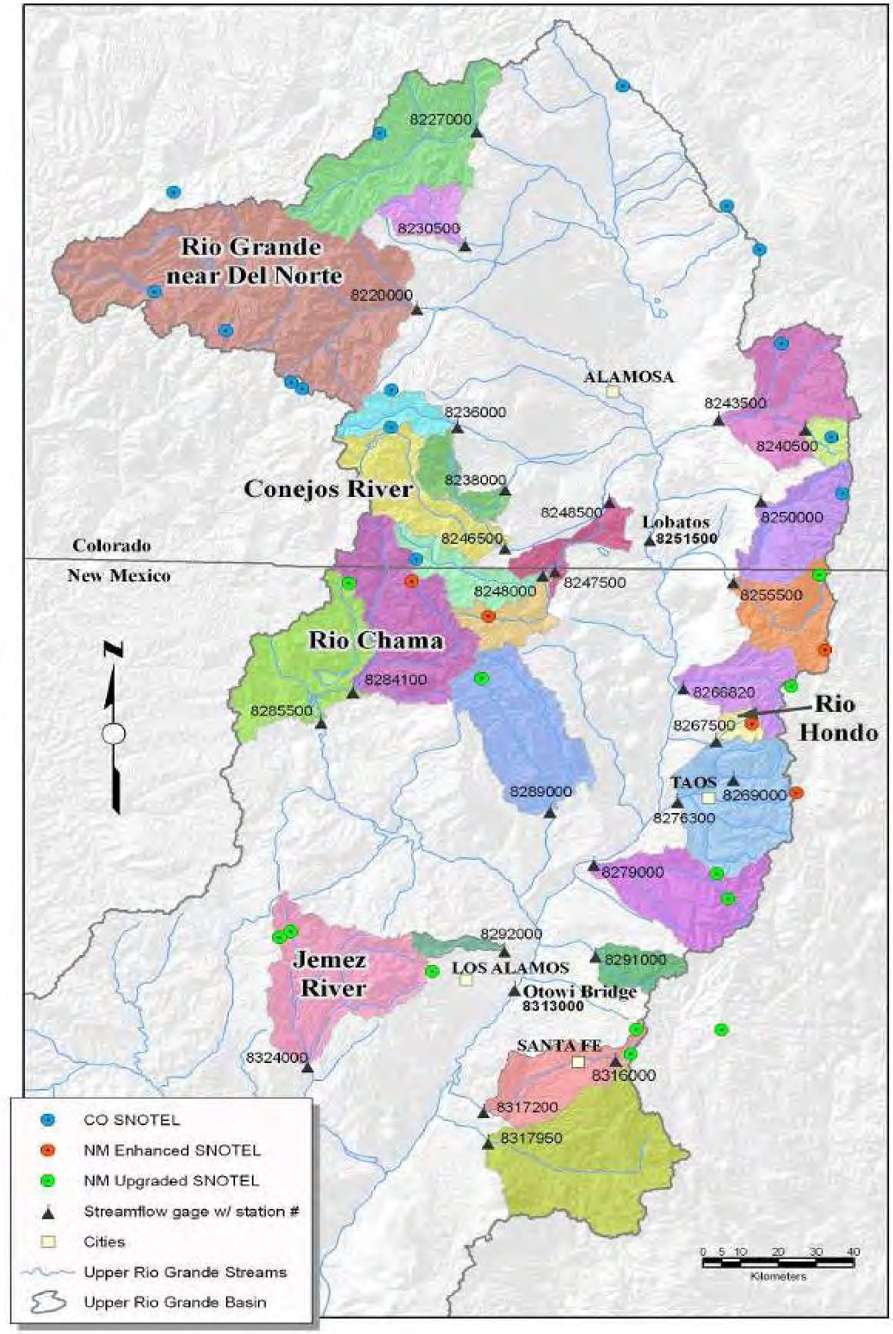
Rango, A. 2006. Snow: The real water supply for the Rio Grande Basin, New Mexico Journal of Science. 44:99-118.

Climate change simulation Rio Grande at Del Norte with periodic changes throughout the 21st century. By 2100, temperature has increased by 4°C, and snowmelt runoff is earlier in the year by ~30 days

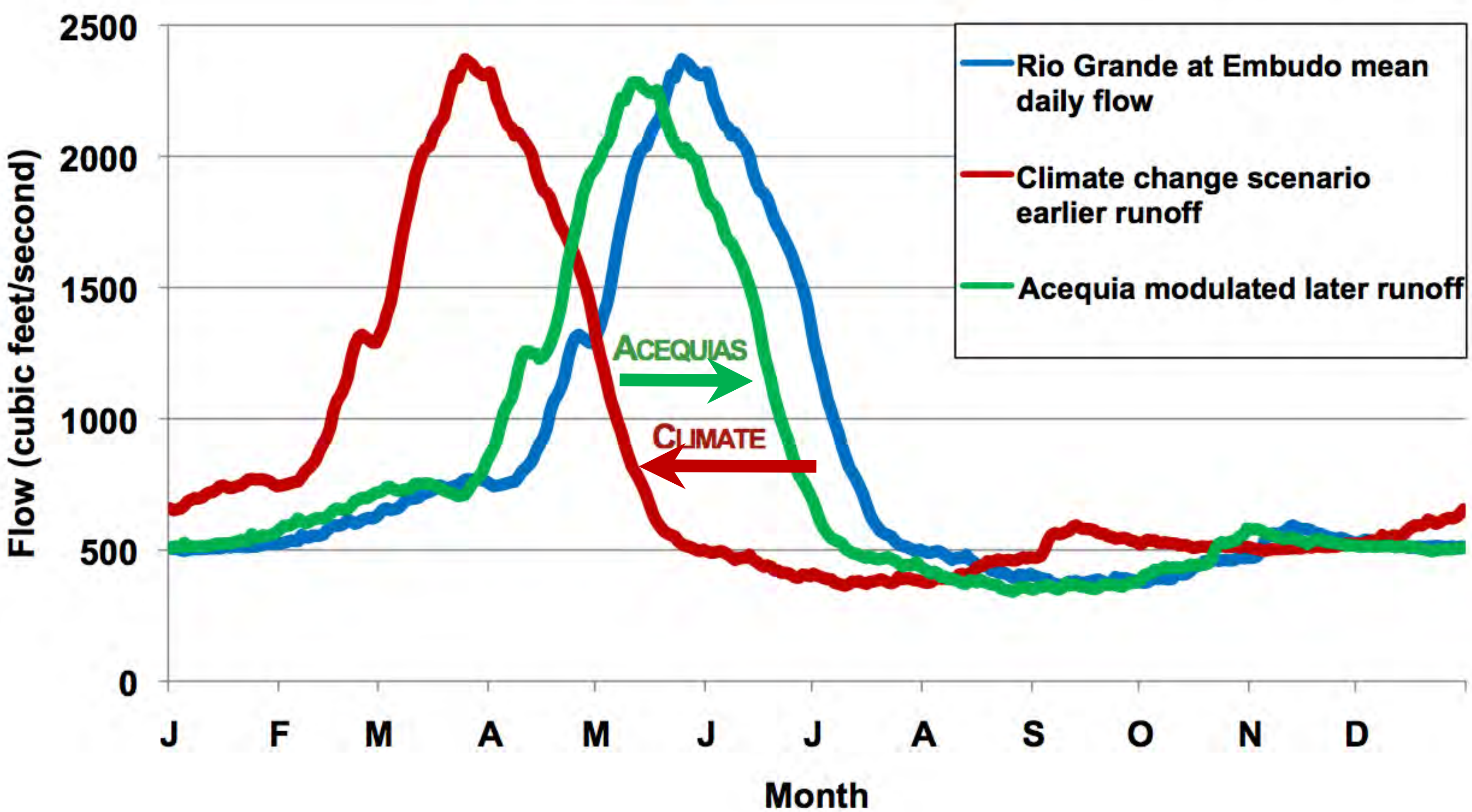


Snow melt basins

Acequias are at outlets of snowmelt basins

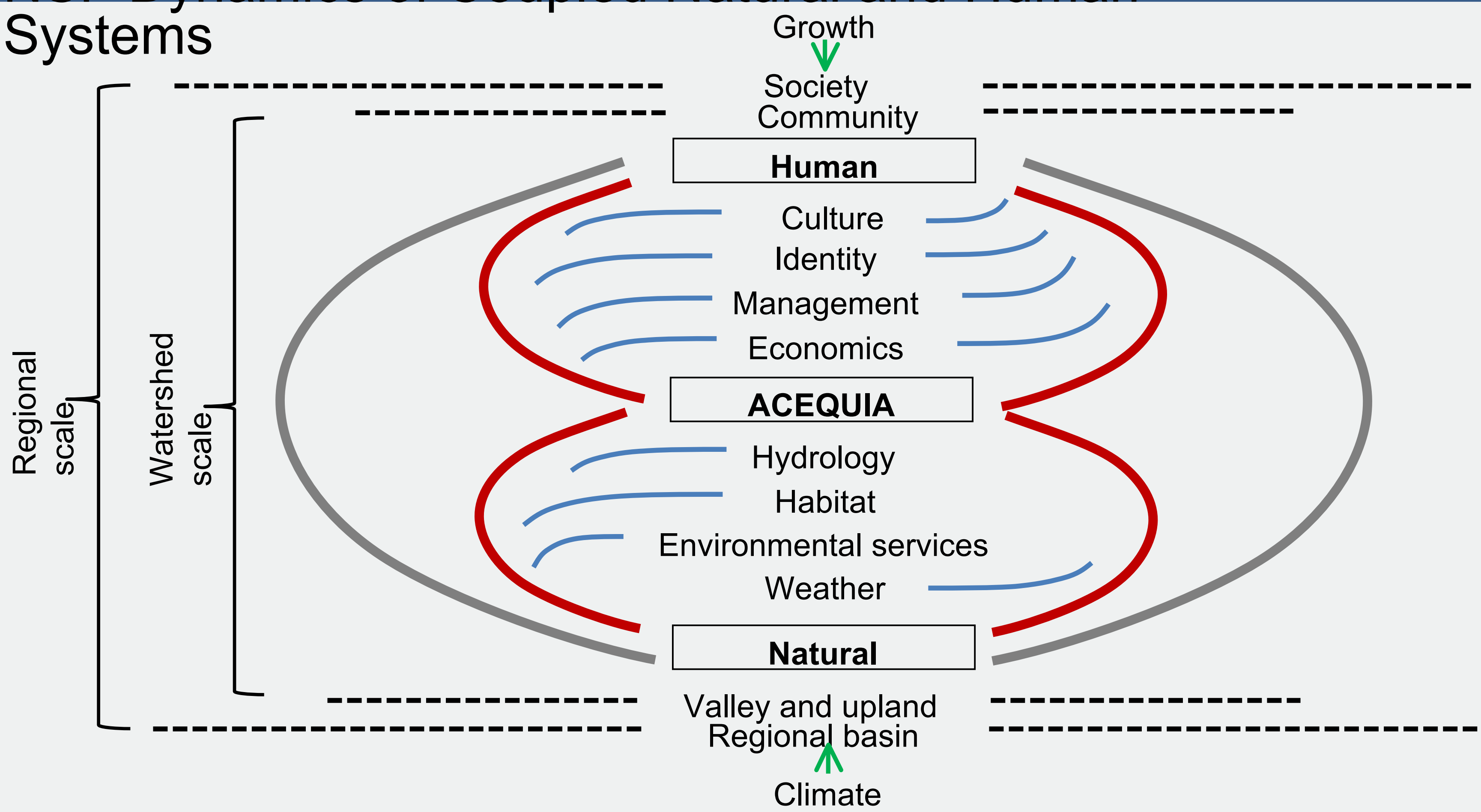


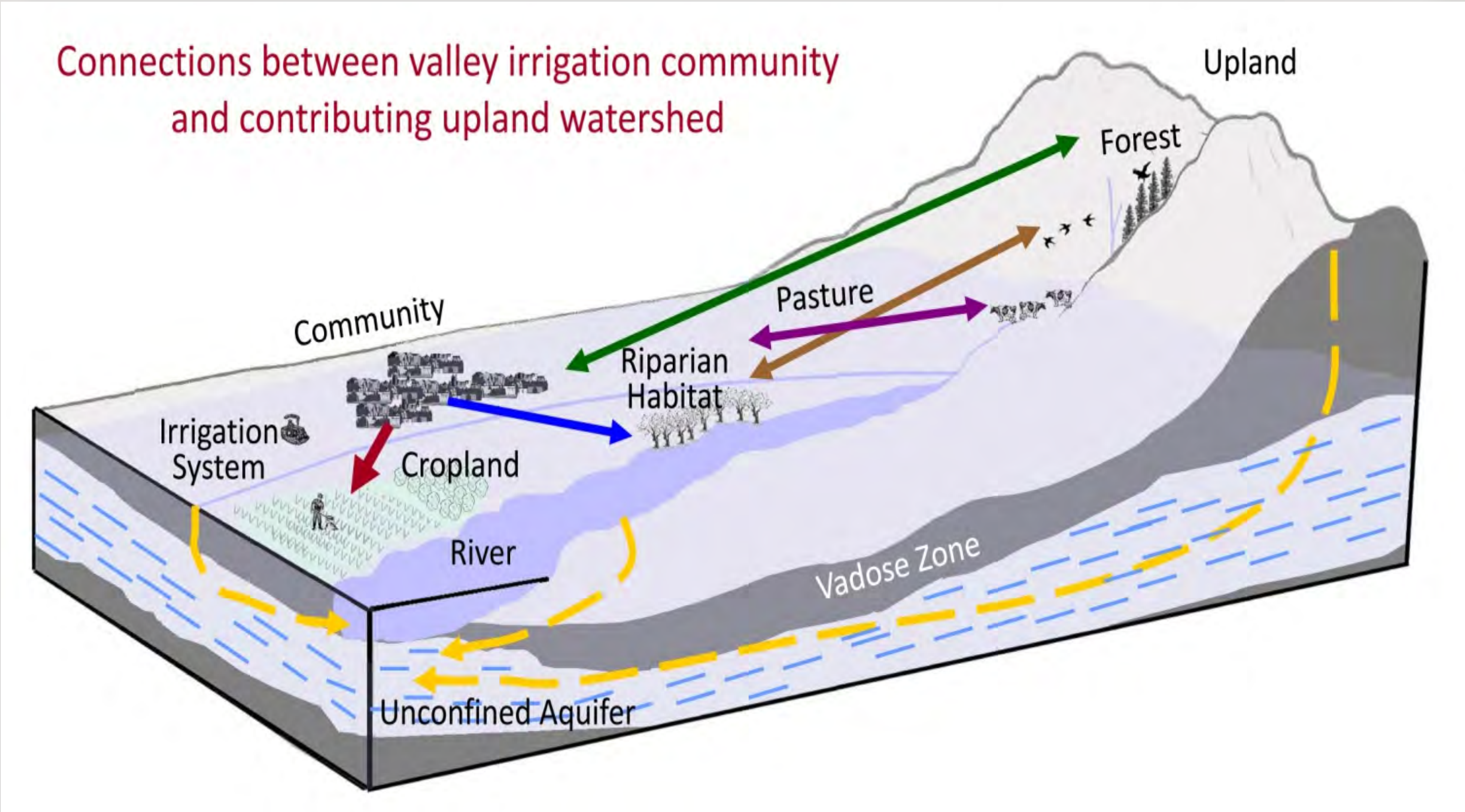
At a regional scale, the acequia surface-groundwater interactions may ameliorate effects of climate variability by delaying spring runoff that is projected to be earlier in the year



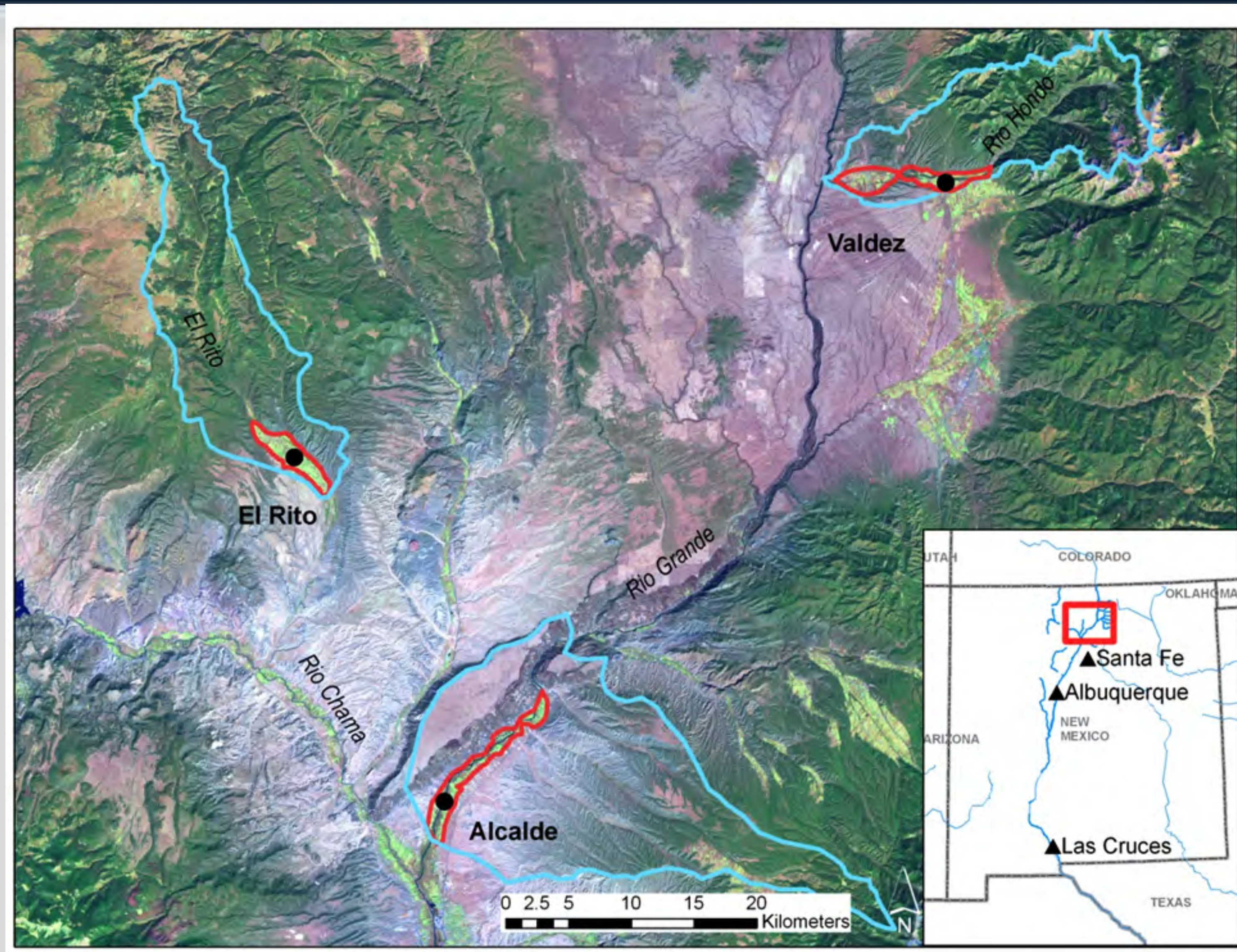
II. “Acequia Water Systems Linking Culture and Nature: Integrated Analysis of Community Resilience to Climate and Land Use Changes”

NSF Dynamics of Coupled Natural and Human Systems



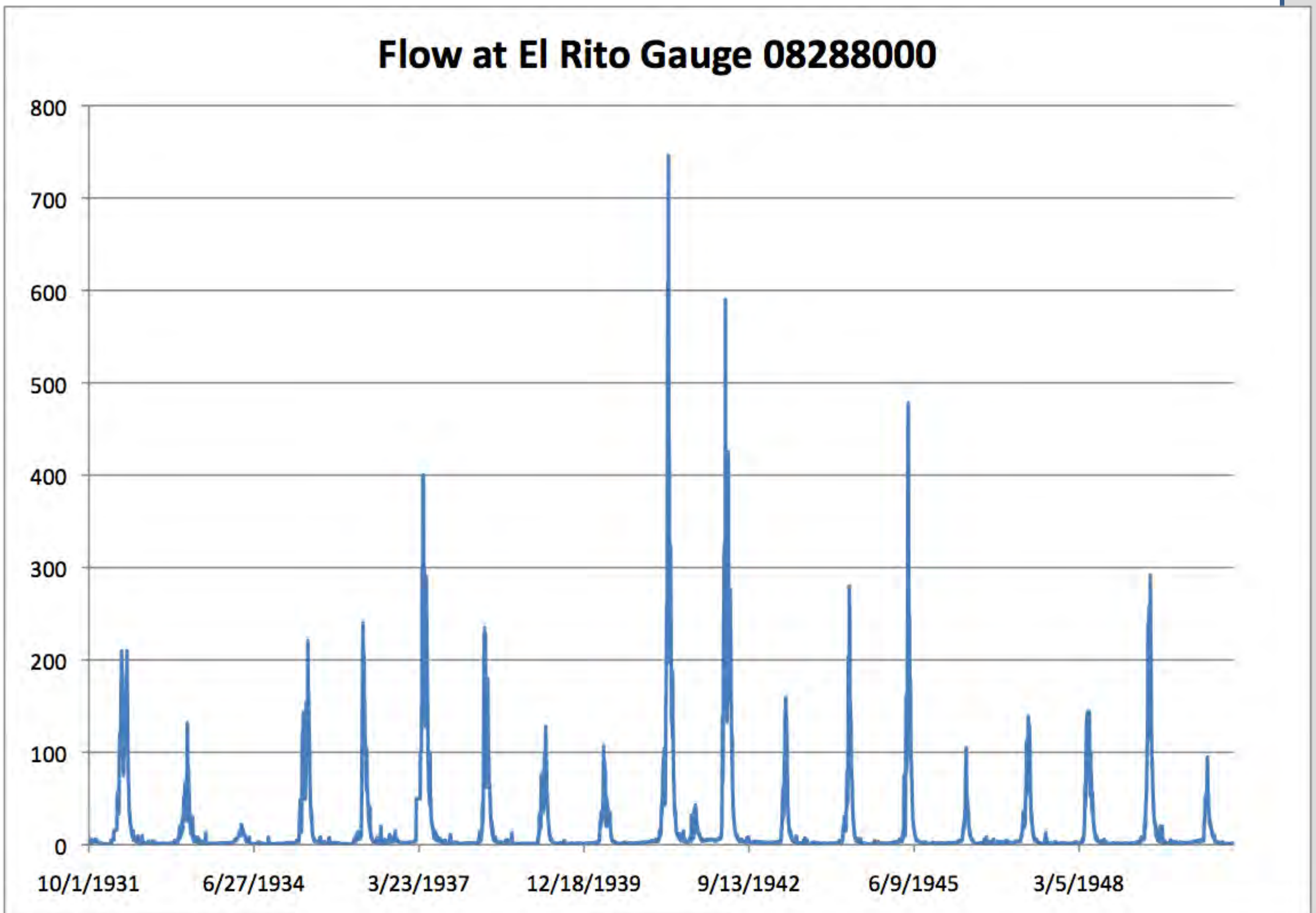


Coupled valley and upland watershed showing example connections between elements of surface and groundwater hydrology, community irrigation and land use, grazing of lowland and upland pastures, and wildlife use of valley riparian areas and upland forests.



Study communities (black circles), their associated irrigated valleys (red lines) and contributing watersheds (blue lines).

Acequias and community water supply face low stream flow in dry years



Acequia systems share water in wet and dry year

Acequia water management

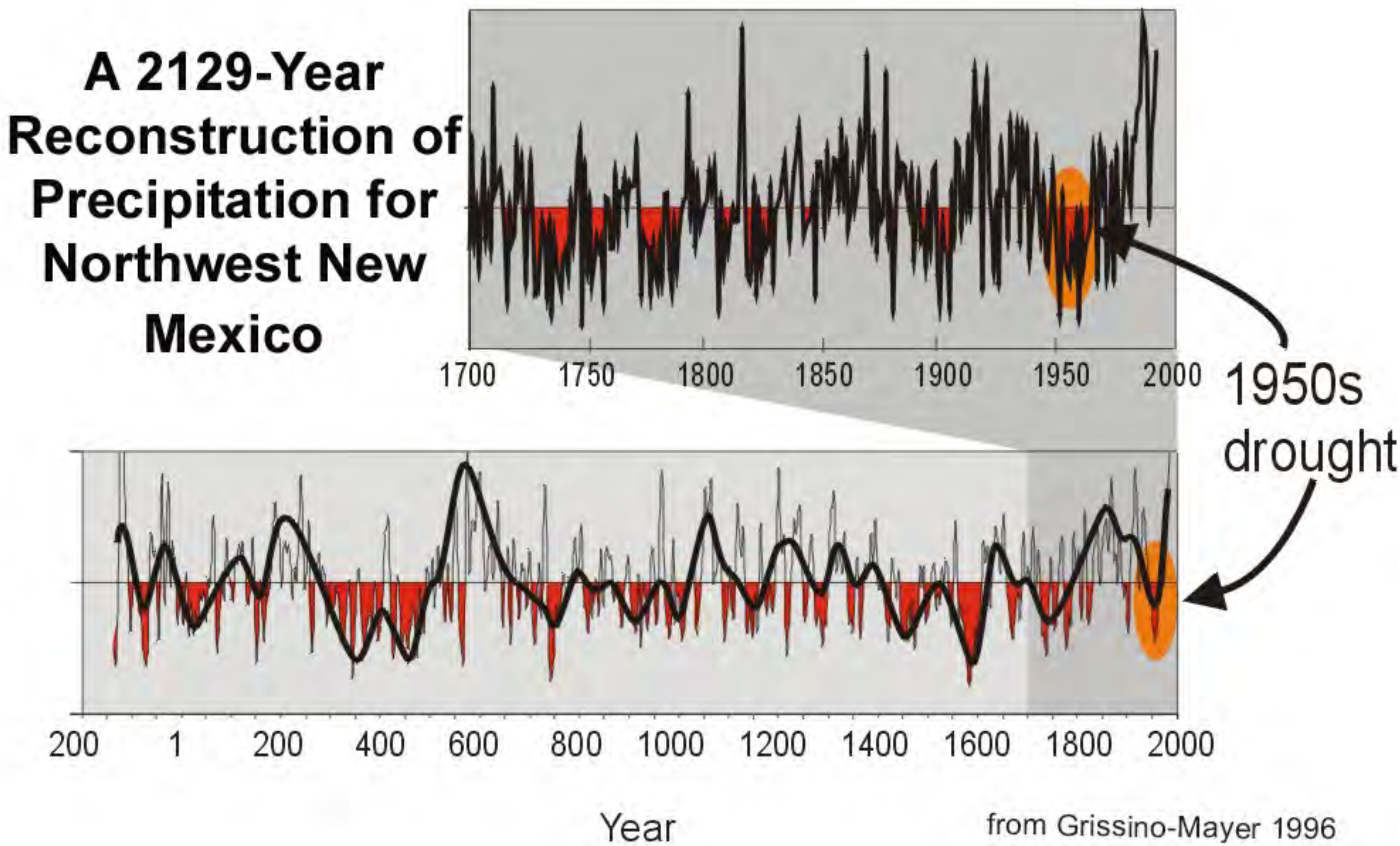
The *repartidor* illustrates equal water sharing during high and low flow. Acequia systems are well suited for drought-prone regions.

Priority water law

New Mexico water law states "*Priority in time shall give the better right*". During very dry years, senior water rights get their water first and those with junior water rights may get less or no water.

(photo Jose Rivera – Cuchilla Rebalse – 2/3 - 1/3)

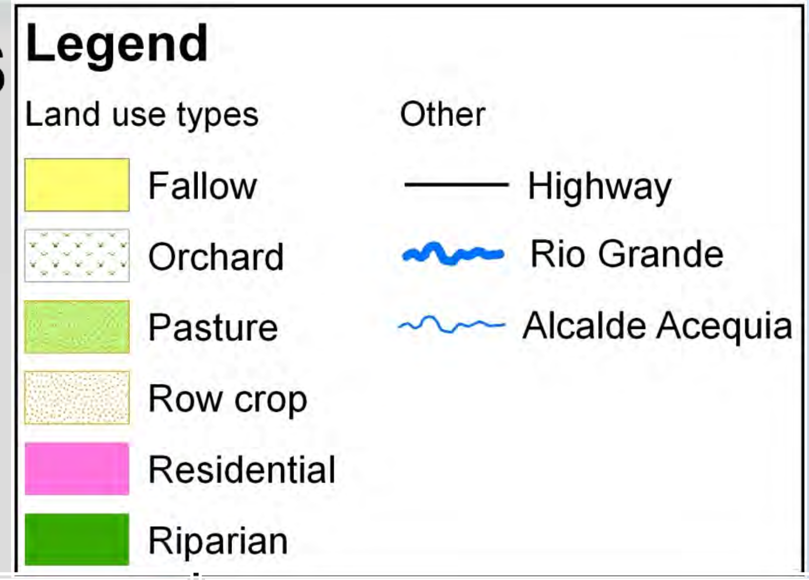
Paleohydrology shows severe pre/historic droughts

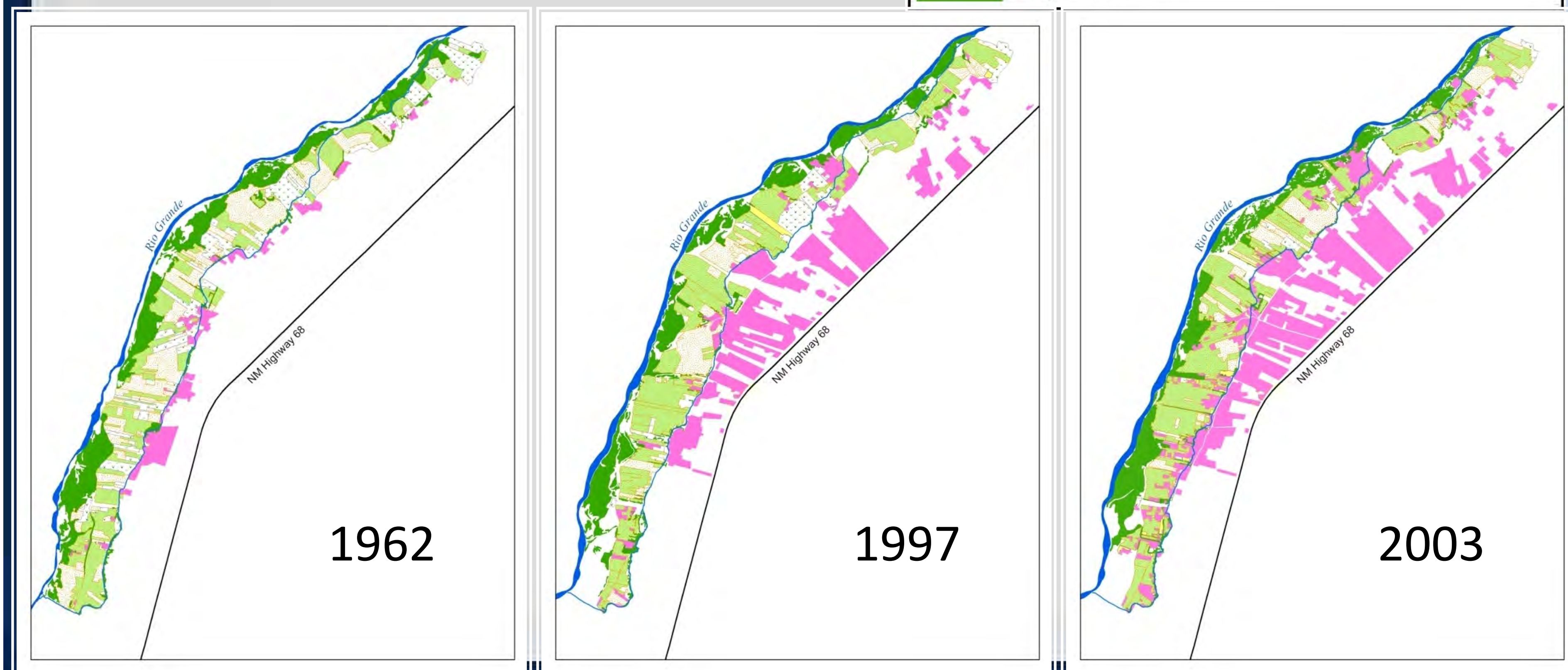


PRESSURES ON ACEQUIAS

- **Agricultural to residential land use**
- **Water transfers out of agriculture**

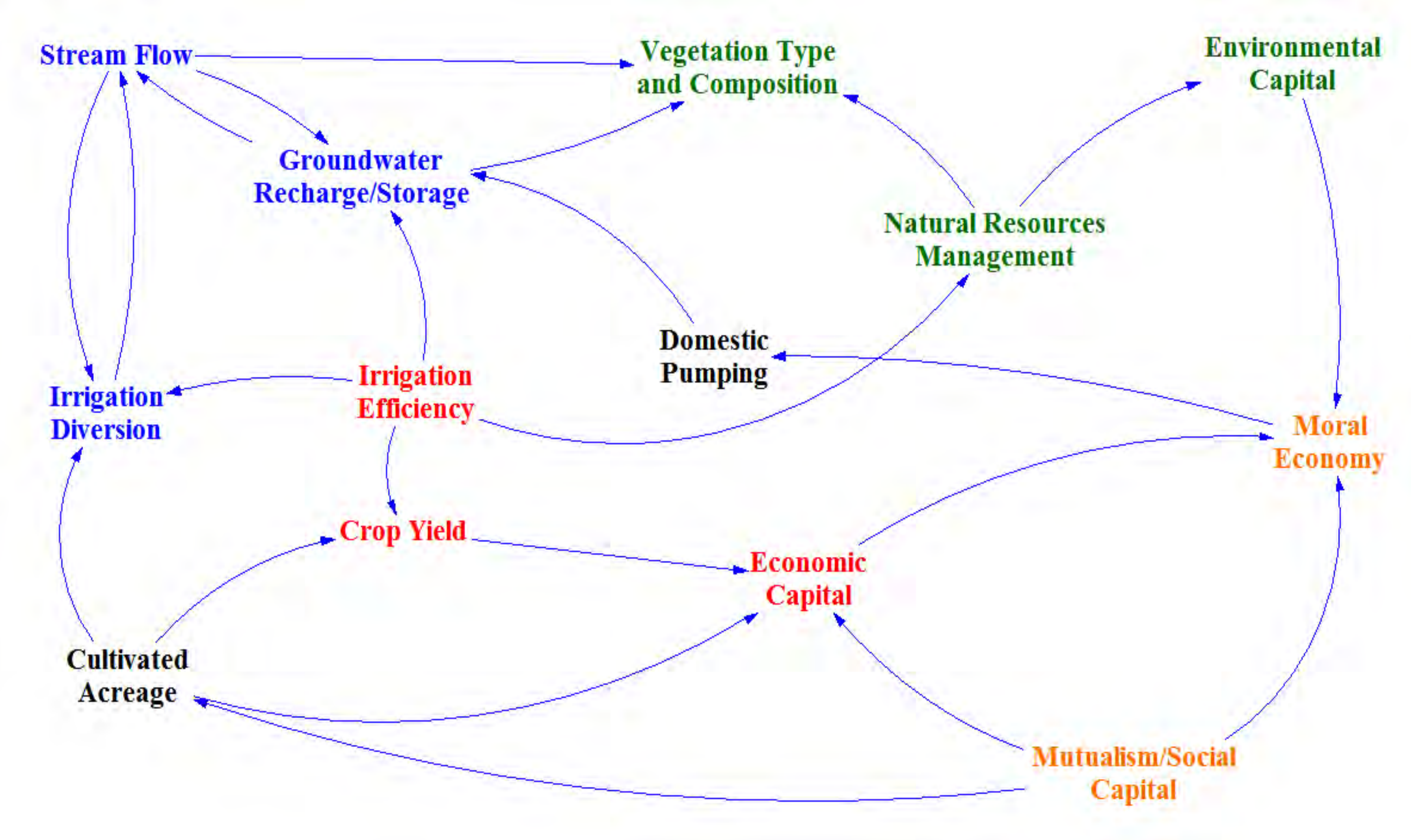
(From Ortiz 2008)



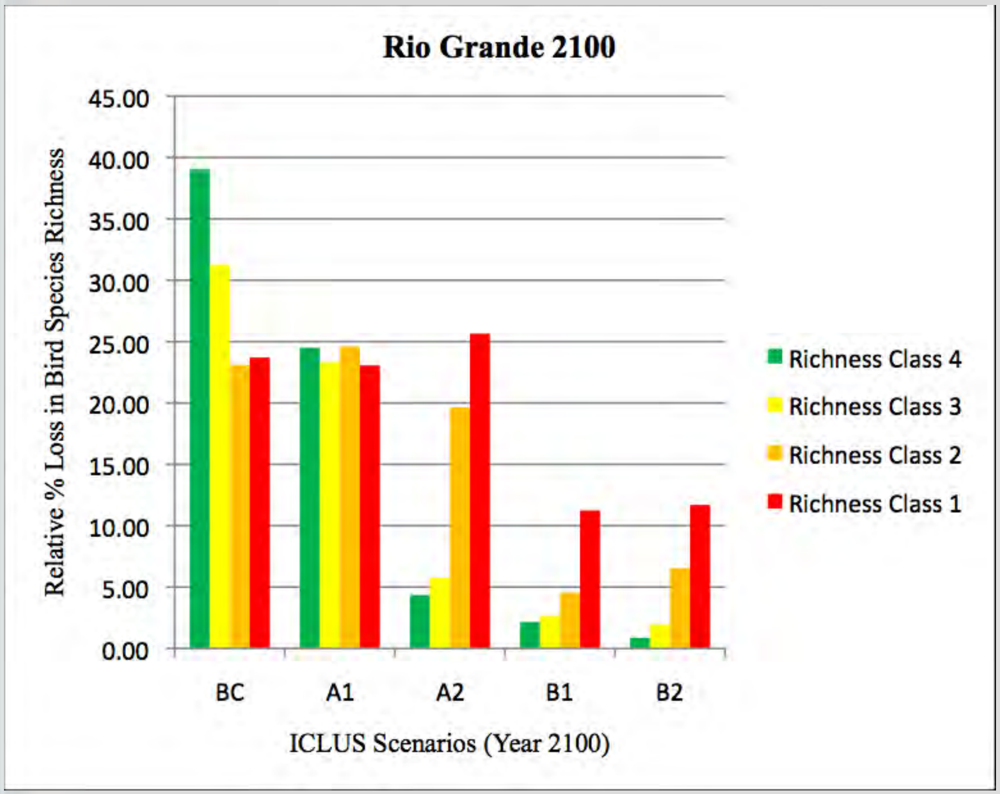


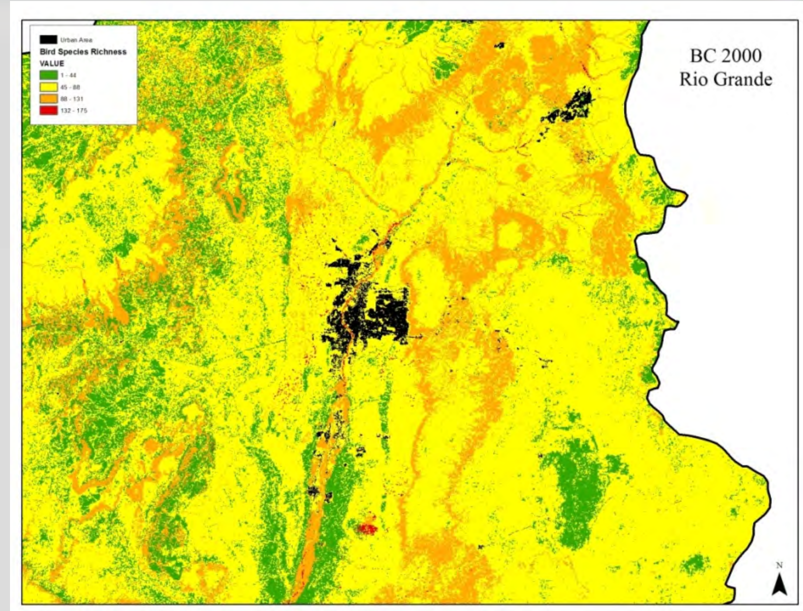
Essential subsystem variables

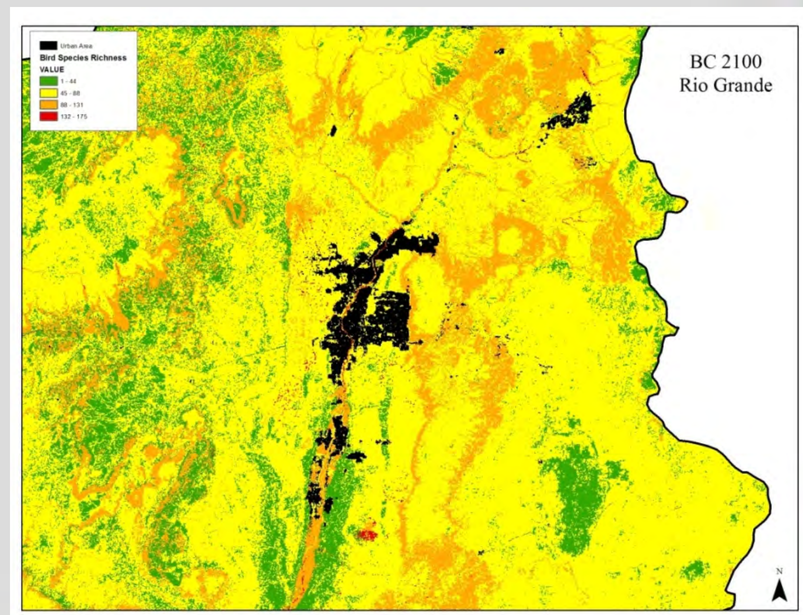
Sociocultural subsystem causal loop diagram. Orange colored variables are primary to the sociocultural subsystem and other colors are primary to other subsystems (blue are hydrology, green are ecosystem, and red are land use/economics). Black are critical variables integrating across multiple subsystems.



ECOLOGY – Mapping and scenarios



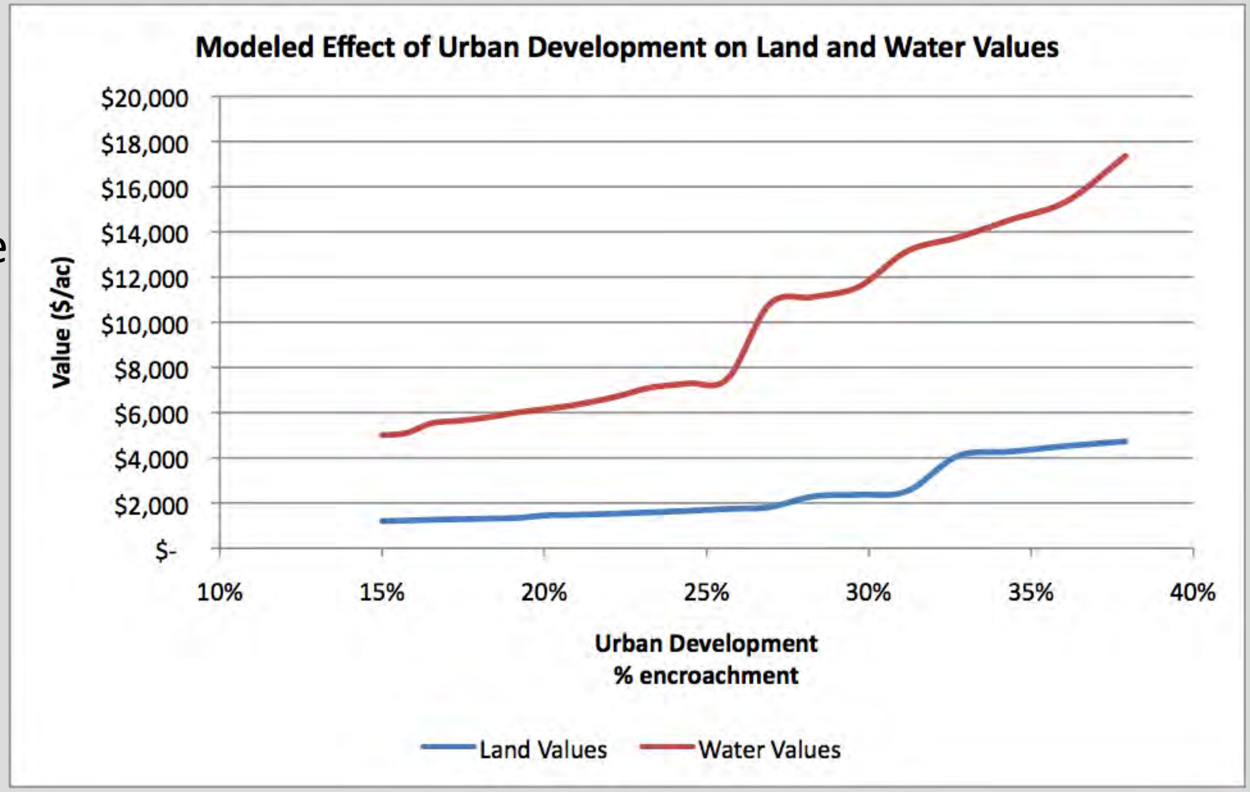




ECONOMICS – Surveys and models

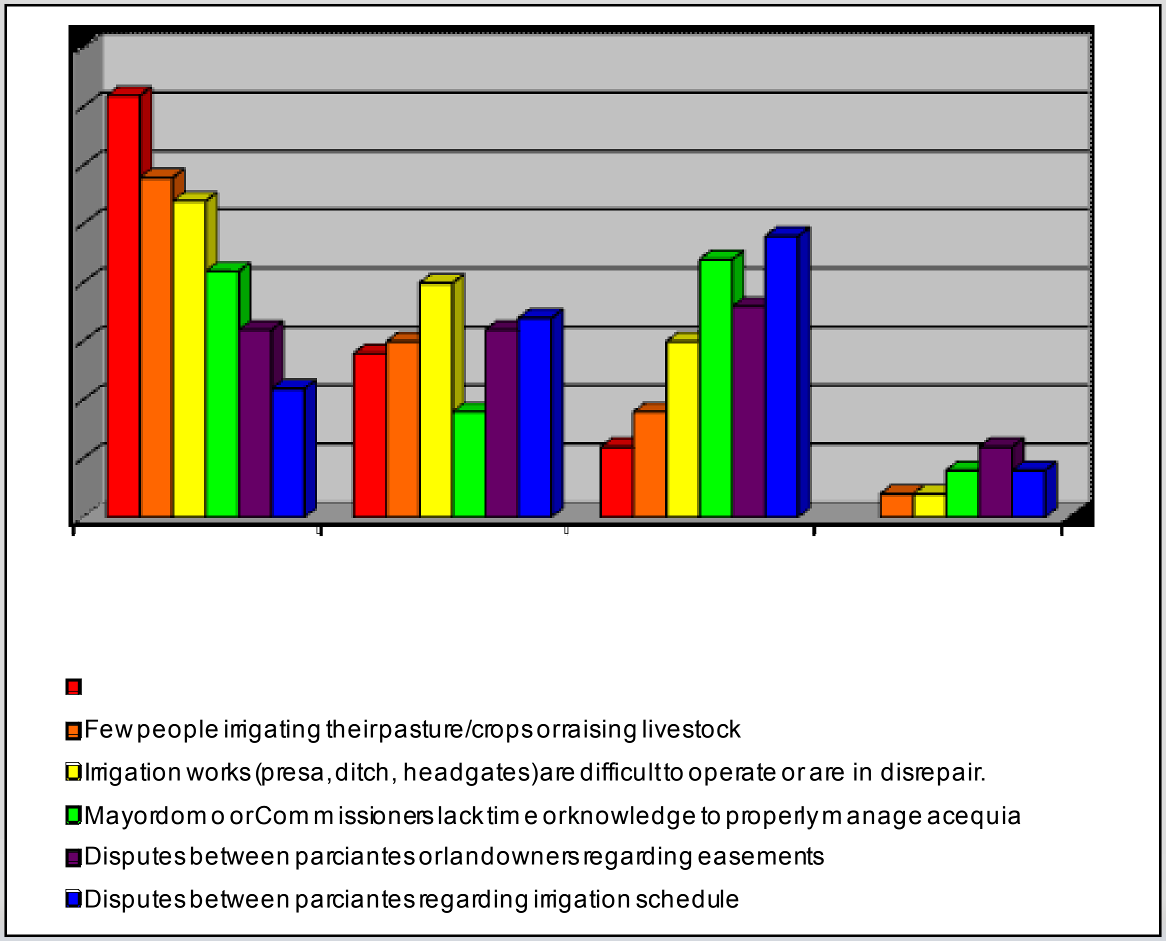
Aspects of the Agricultural Economy

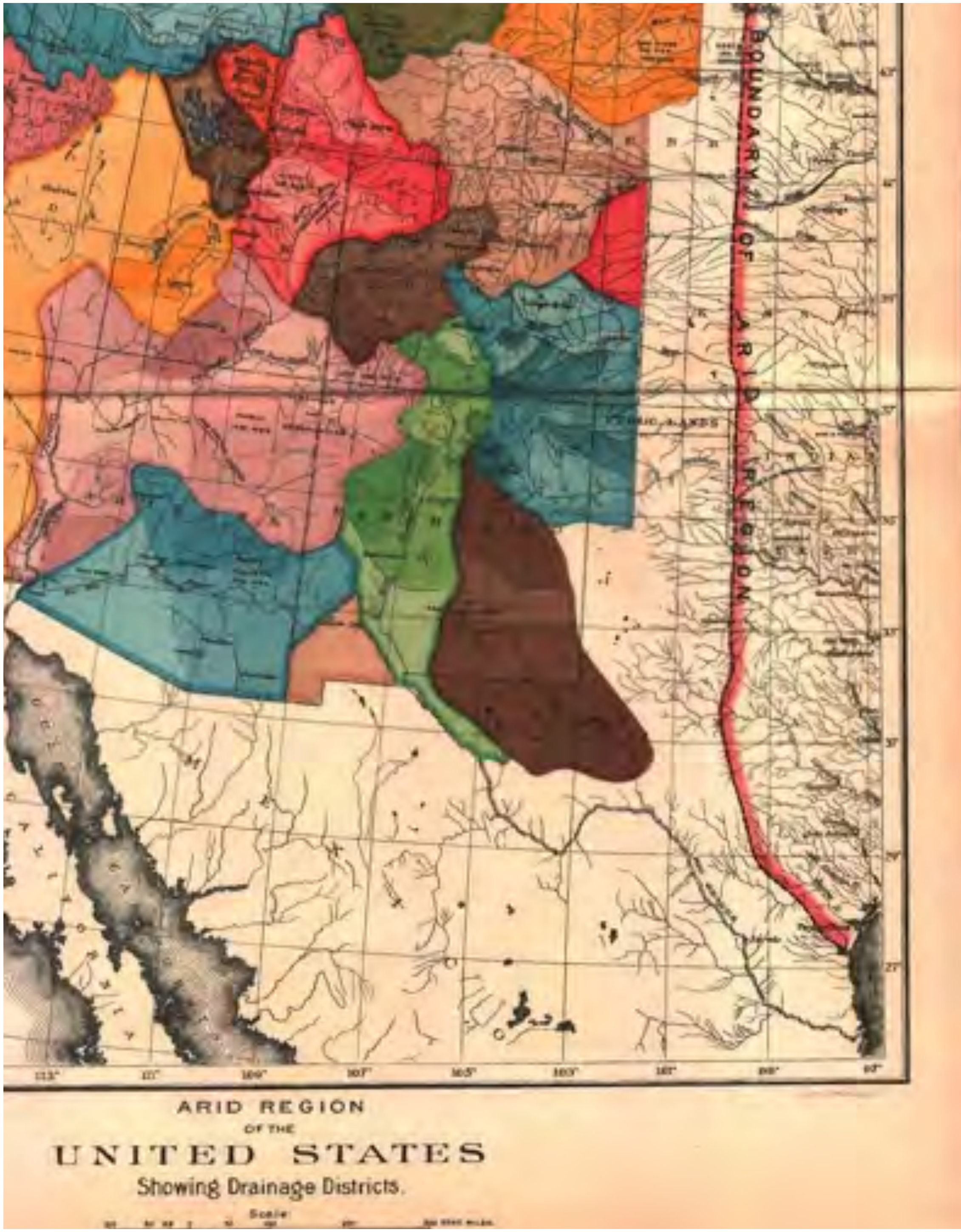
- Economic Capital
  - Land value
  - Water rights value
  - Economic returns
    - Production
      - crops
      - livestock
    - Markets



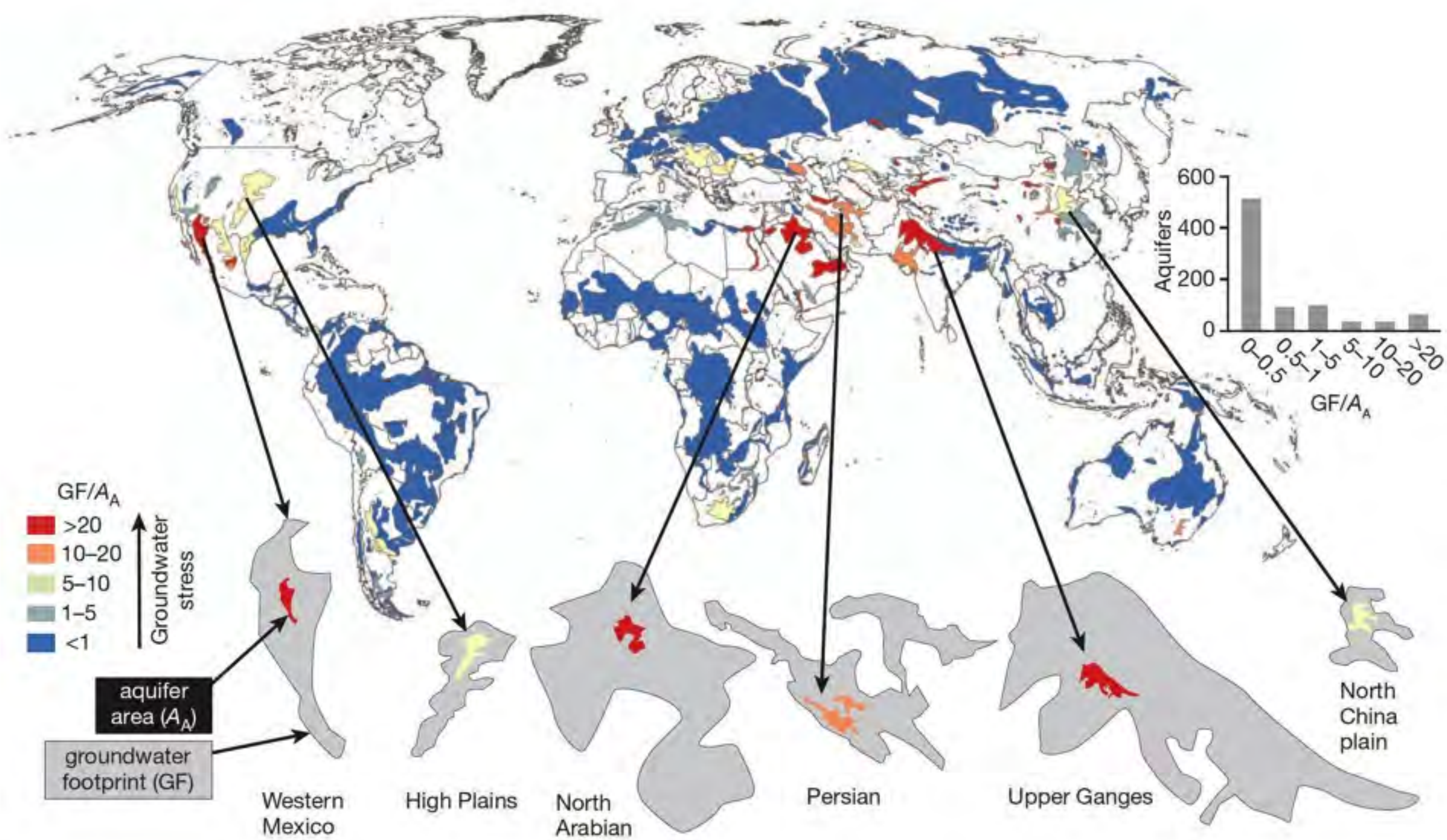
SOCIAL - Focus groups and surveys

What *do you believe are the important challenges within your acequia?* The results show that community participation, lack of irrigation, and infrastructure issues were of main concern (see chart below).

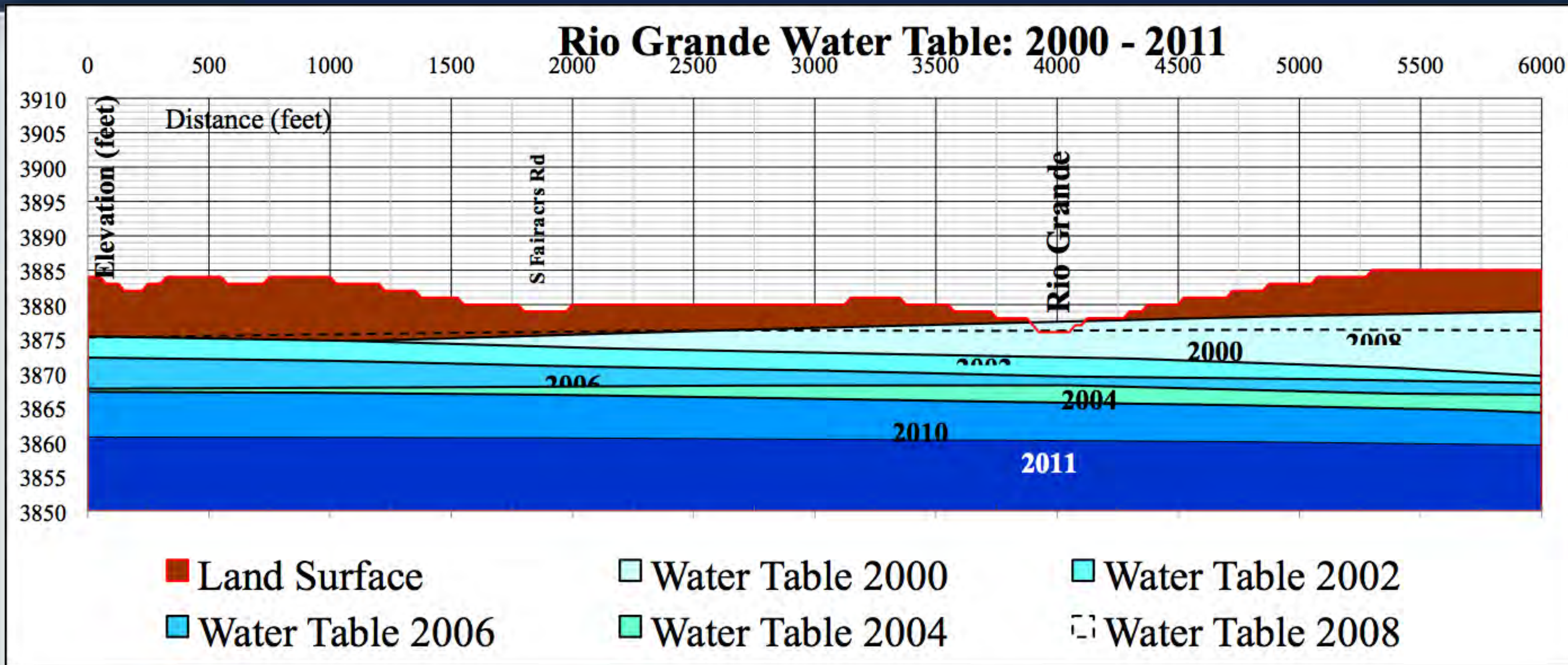


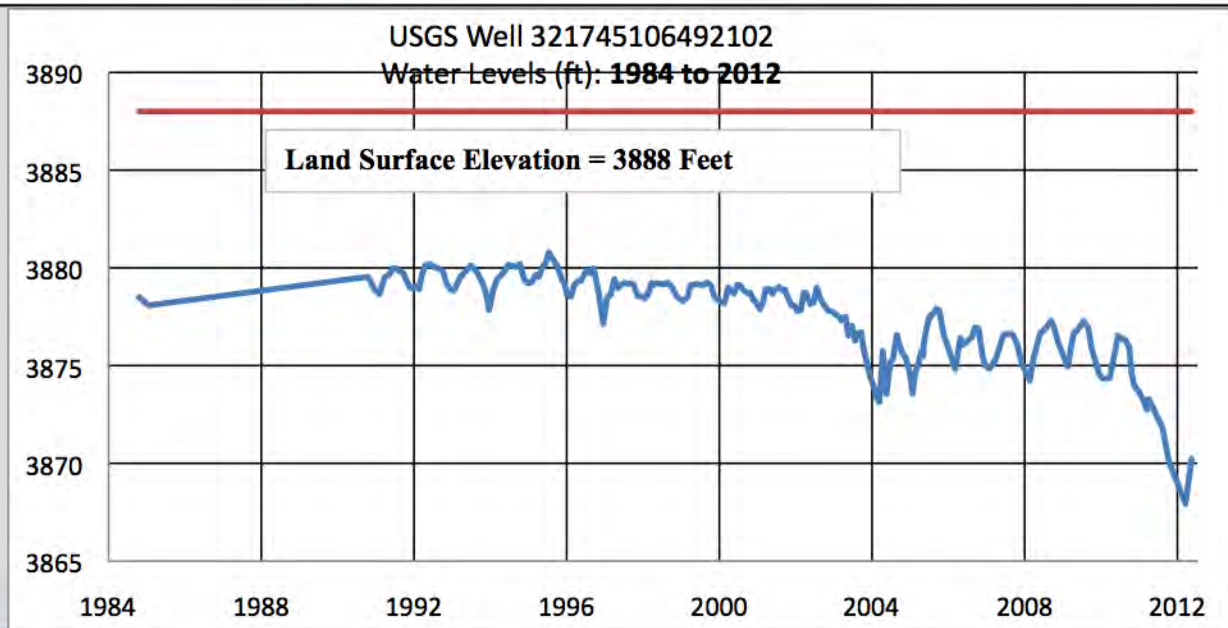


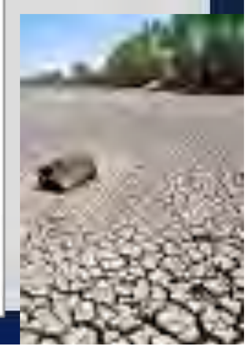
BASIN SCALE CONNECTIVITY



Source: "Water Balance of Global Aquifers Revealed by Groundwater Footprint. Gleeson et al, Nature, Aug. 2012


Rio Grande Water Table: 2000 - 2011
Distance (feet)
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
Elevation (feet)
3910
3905
3900
3895
3890
3885
3880
3875
3870
3865
3860
3855
3850
S Fairacrs Rd
Rio Grande
2000
2004
2010
2011
Land Surface
Water Table 2000
Water Table 2002
Water Table 2006
Water Table 2004
Water Table 2008


USGS Well 321745106492102
Water Levels (ft): 1984 to 2012
Land Surface Elevation = 3888 Feet
3890
3885
3880
3875
3870
3865
1984
1988
1992
1996
2000
2004
2008
2012



[redacted]

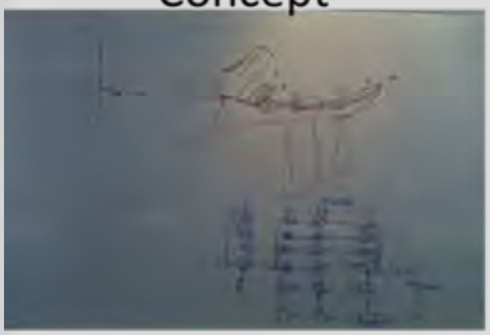
THANK YOU!

NSF
USDA
NM AG EXP STN
COLLABORATORS
STUDENTS
COMMUNITIES

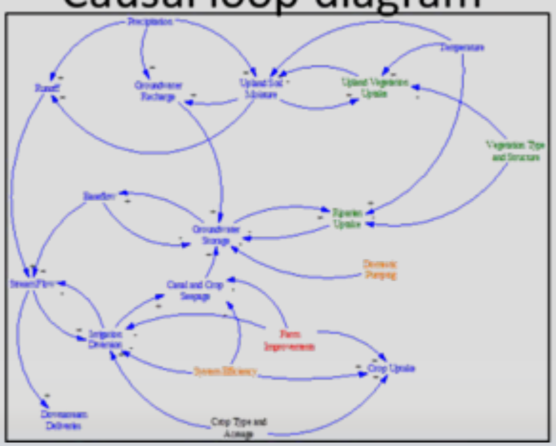
III. Collaborative modeling

System Dynamics - Cooperative Modeling

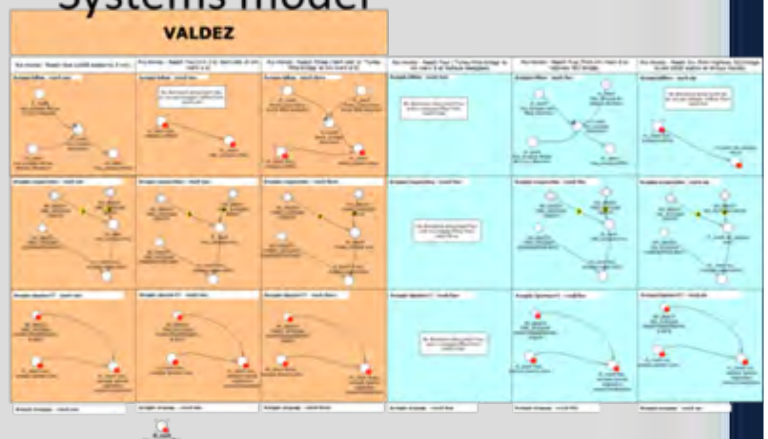
Concept



Causal loop diagram

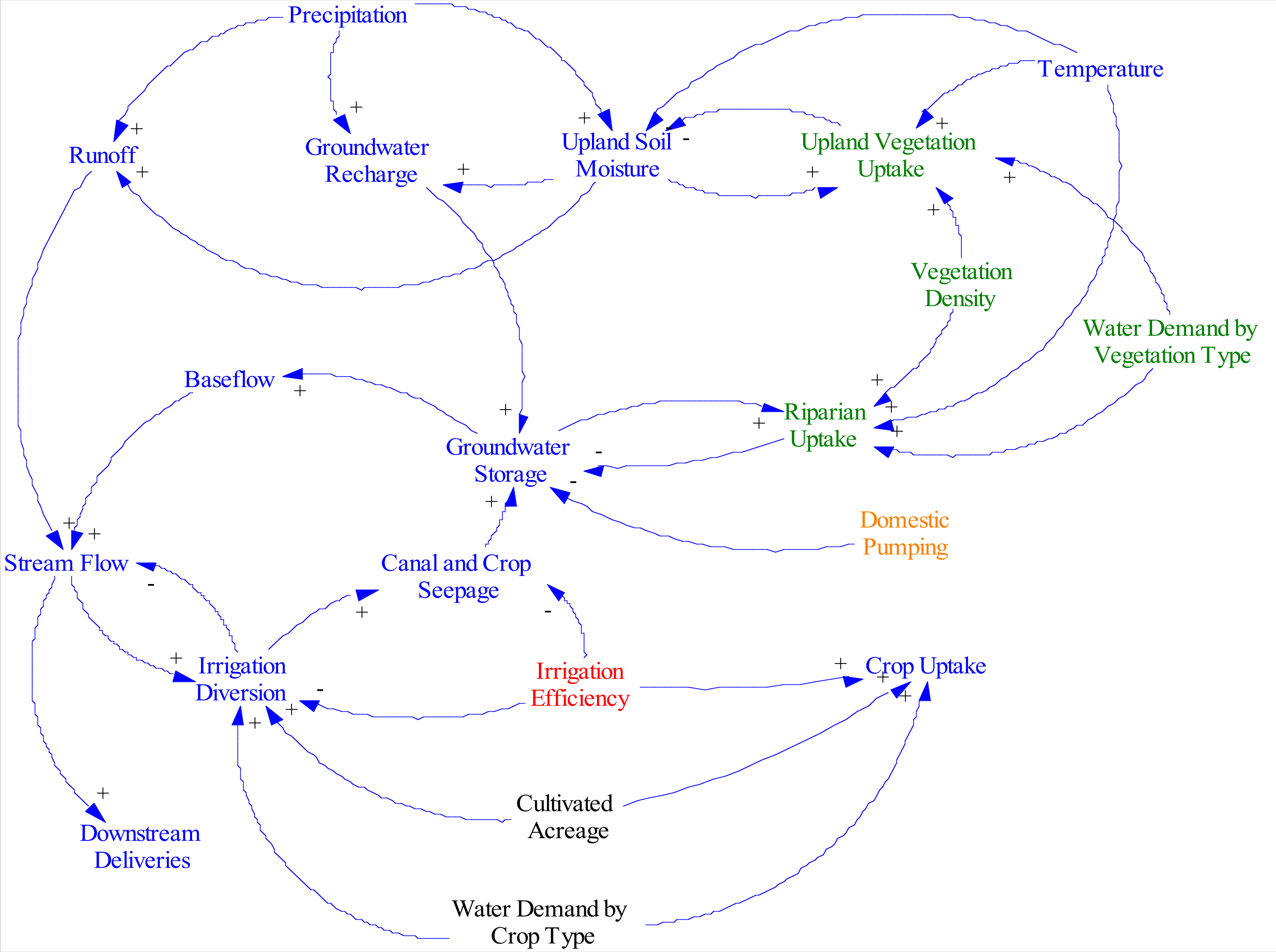


Systems model



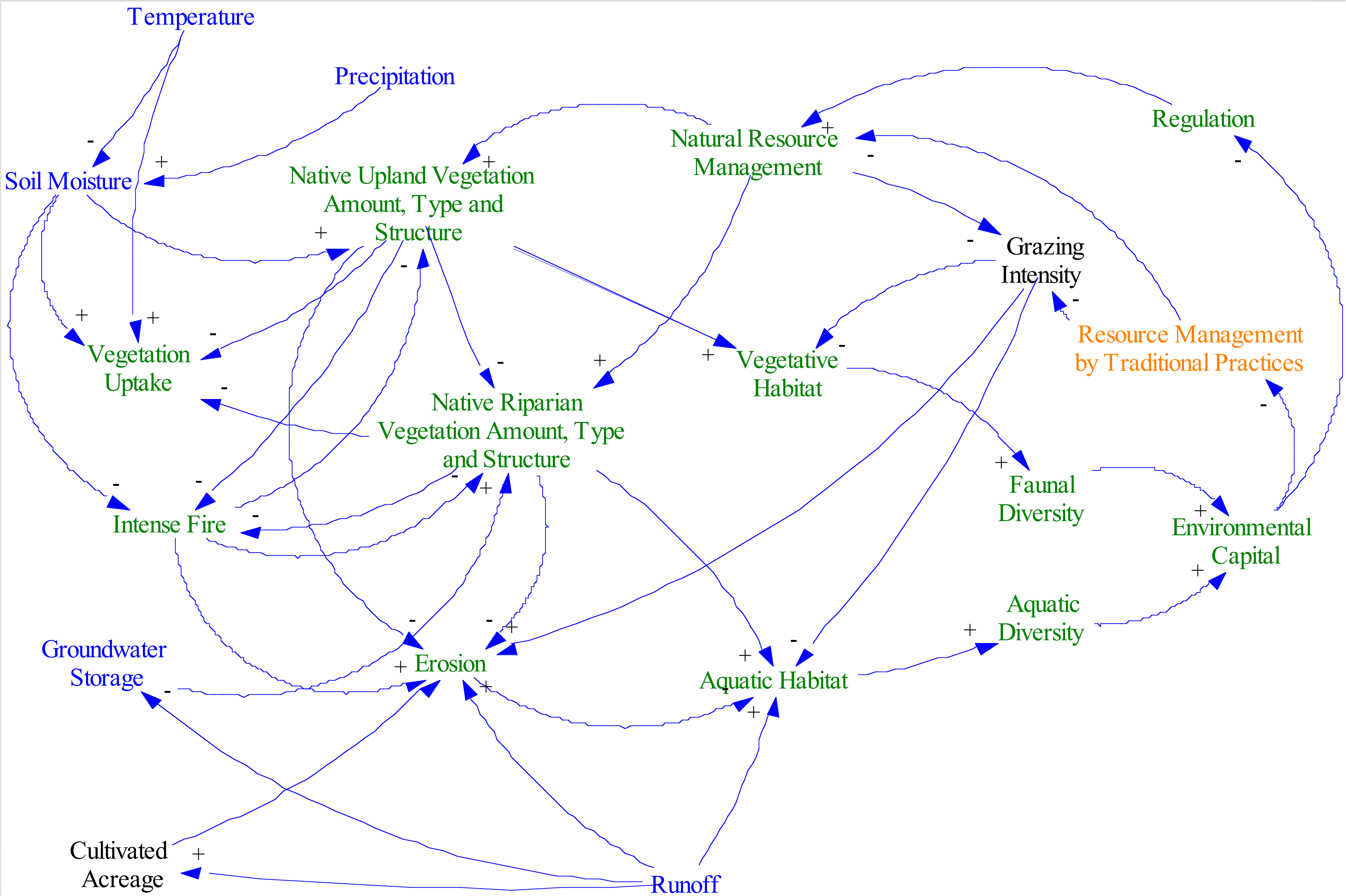
Ochoa

HYDROLOGY – PARTICIPATORY CAUSAL LOOP DIAGRAM

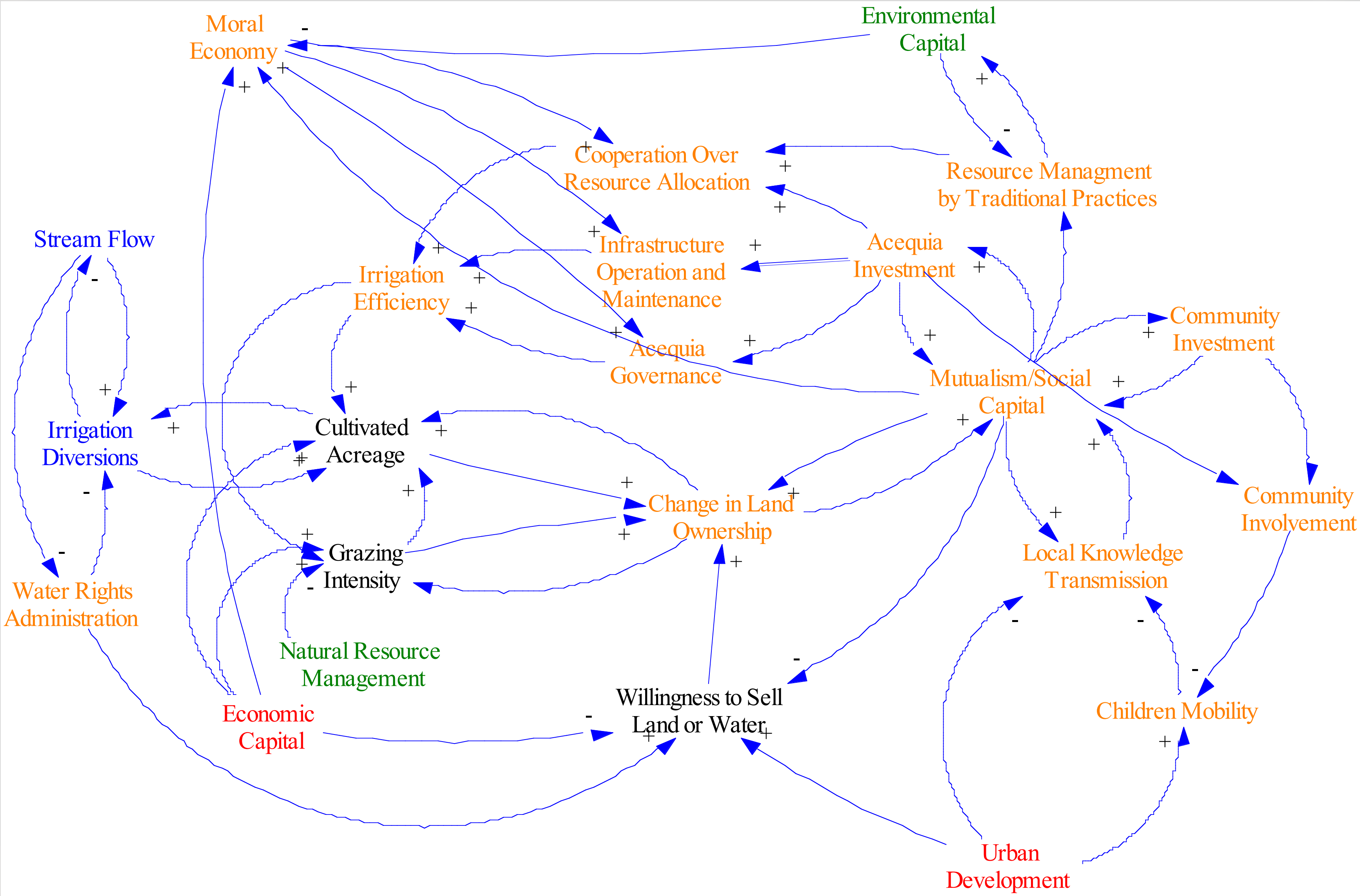


Hydrology subsystem causal loop diagram. Blue variables are primary to hydrology and other colors are primary to other subsystems (green ecosystem, red land use/economics, and orange sociocultural). Black are critical variables integrating across multiple subsystems.

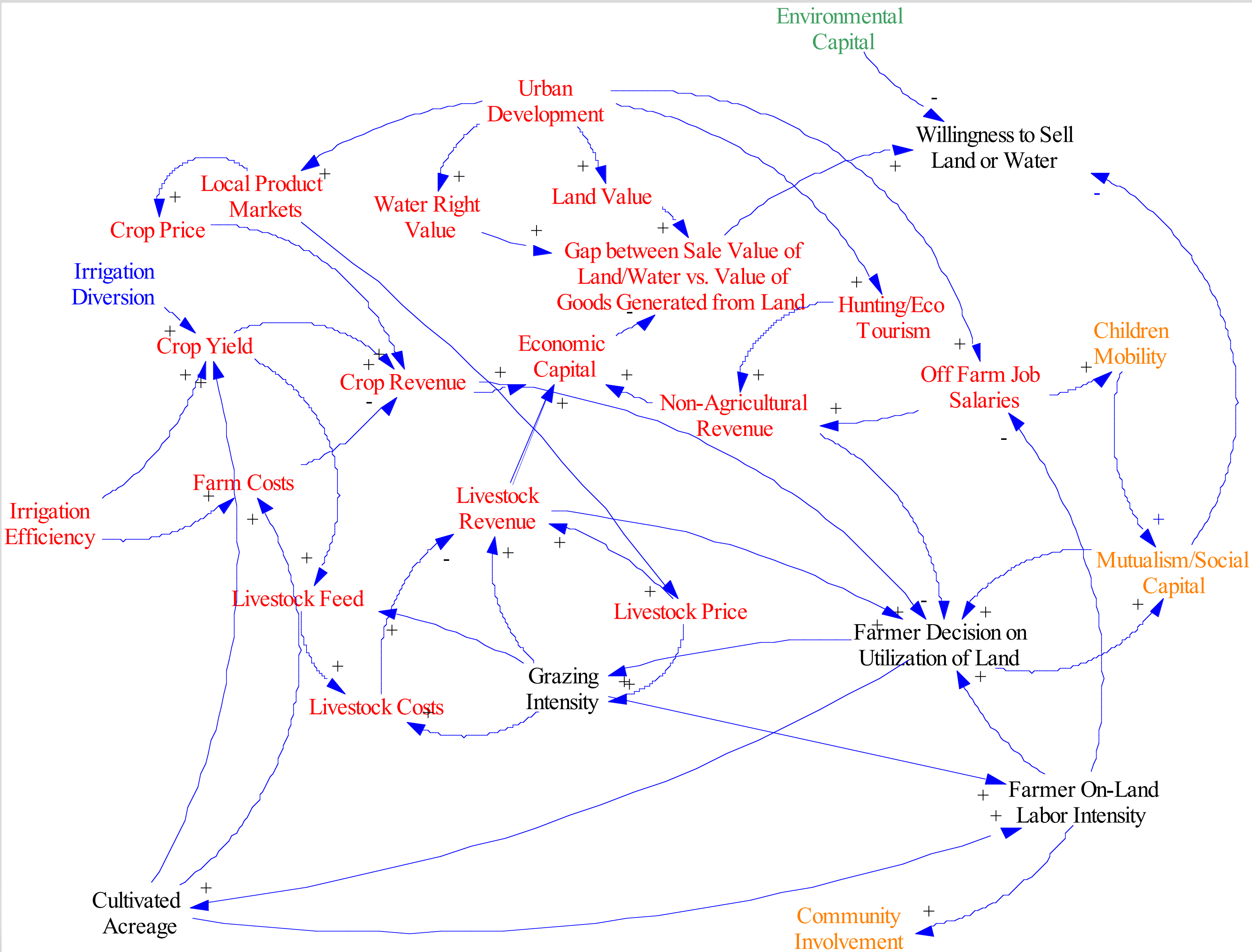
ECOLOGY – PARTICIPATORY CAUSAL LOOP DIAGRAM



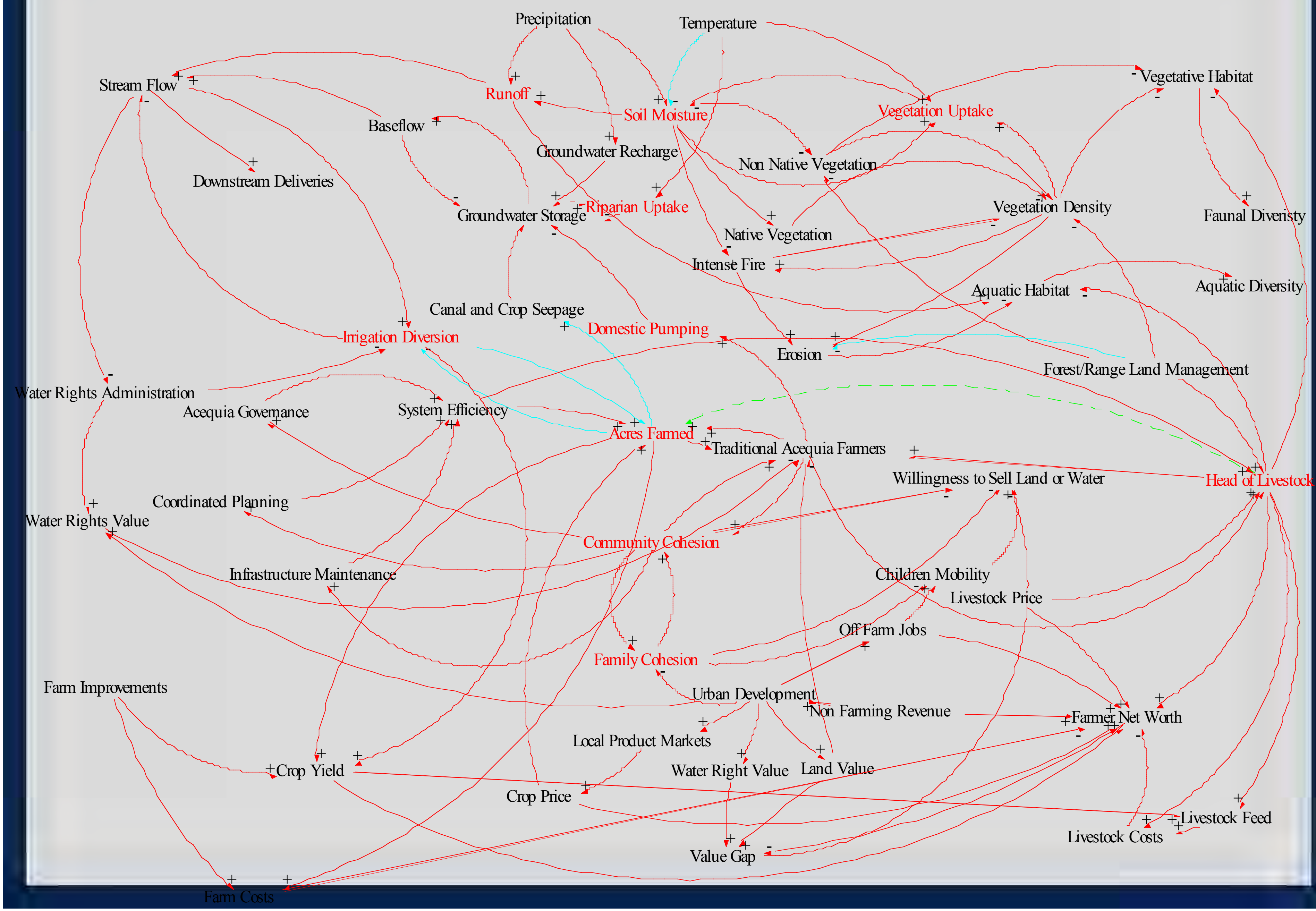
SOCIAL – PARTICIPATORY CAUSAL LOOP DIAGRAM



ECONOMICS – PARTICIPATORY CAUSAL LOOP DIAGRAM



All together – Causal loop diagram



‘Cultivated Acreage’ and total ‘Crop Yield’ of two crops as affected by ‘Farmer On-Land Labor Intensity,’ ‘Crop Price,’ ‘Local Product Markets’ (Acequia de Alcalde)

Cultivated Acreage		x Yield/A	= Total Yield	Gross Rev.
Forage	620	4-6 tons/A	2500-3700 t	$1-1.5 million
Apple/Orchard	90	20 tons/A	1800 t	$1.8 million

Although apples can potentially produce higher revenues per acre, acreage in apples vs. forage crops can be influenced by various factors/drivers:

Decrease in farm labor: ↓ apples & ↑ forage or ↓ total cultivated acres;

Increase in hay price: ↓ apples & ↑ forage;

Increase in local fresh food markets/price: ↑ apples (& ↓ forage?);

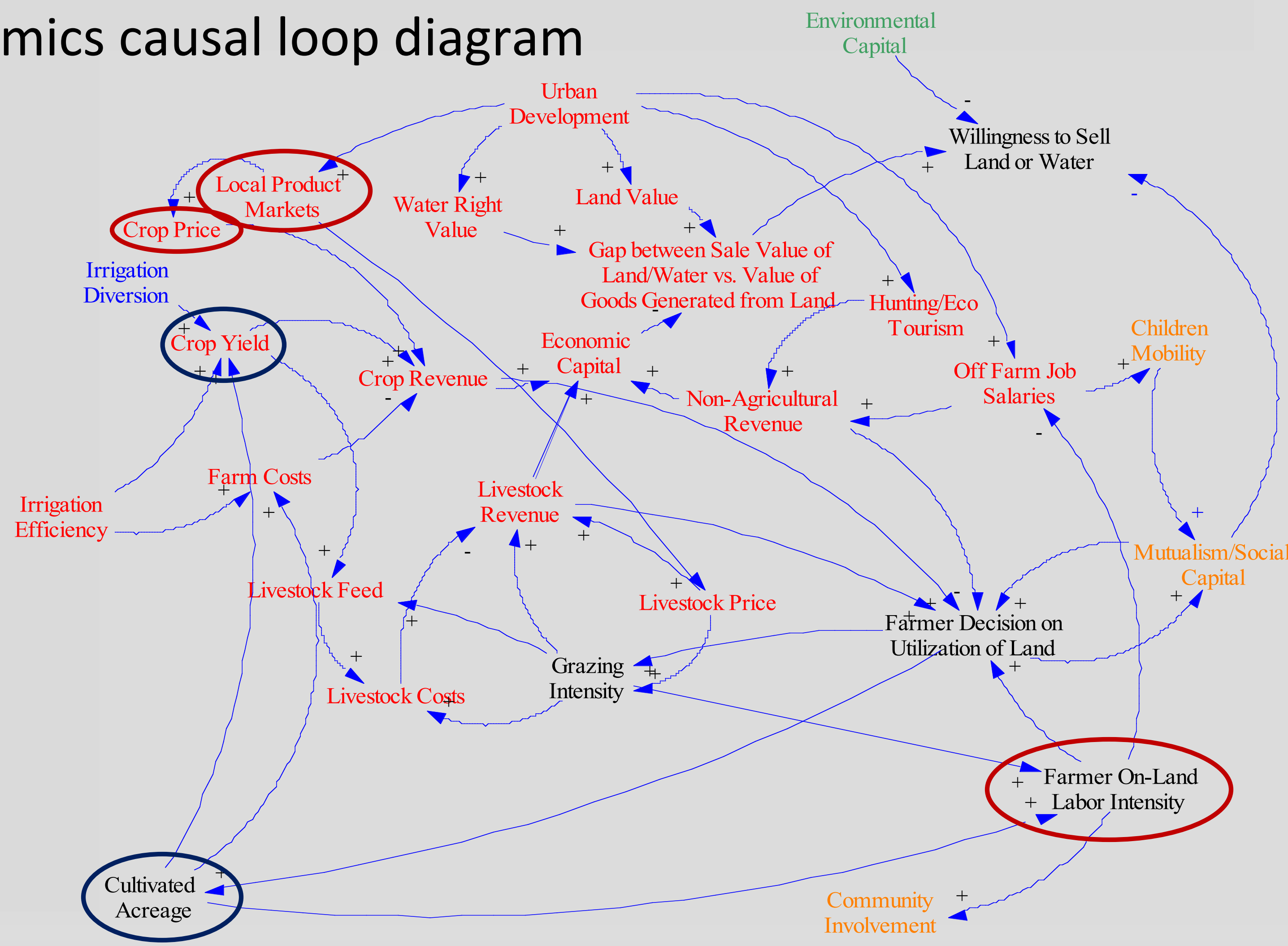
Effect of other causal loop variables:

More late frosts (climate?): ↓ apples & ↑ forage or ↓ total cultivated acres;

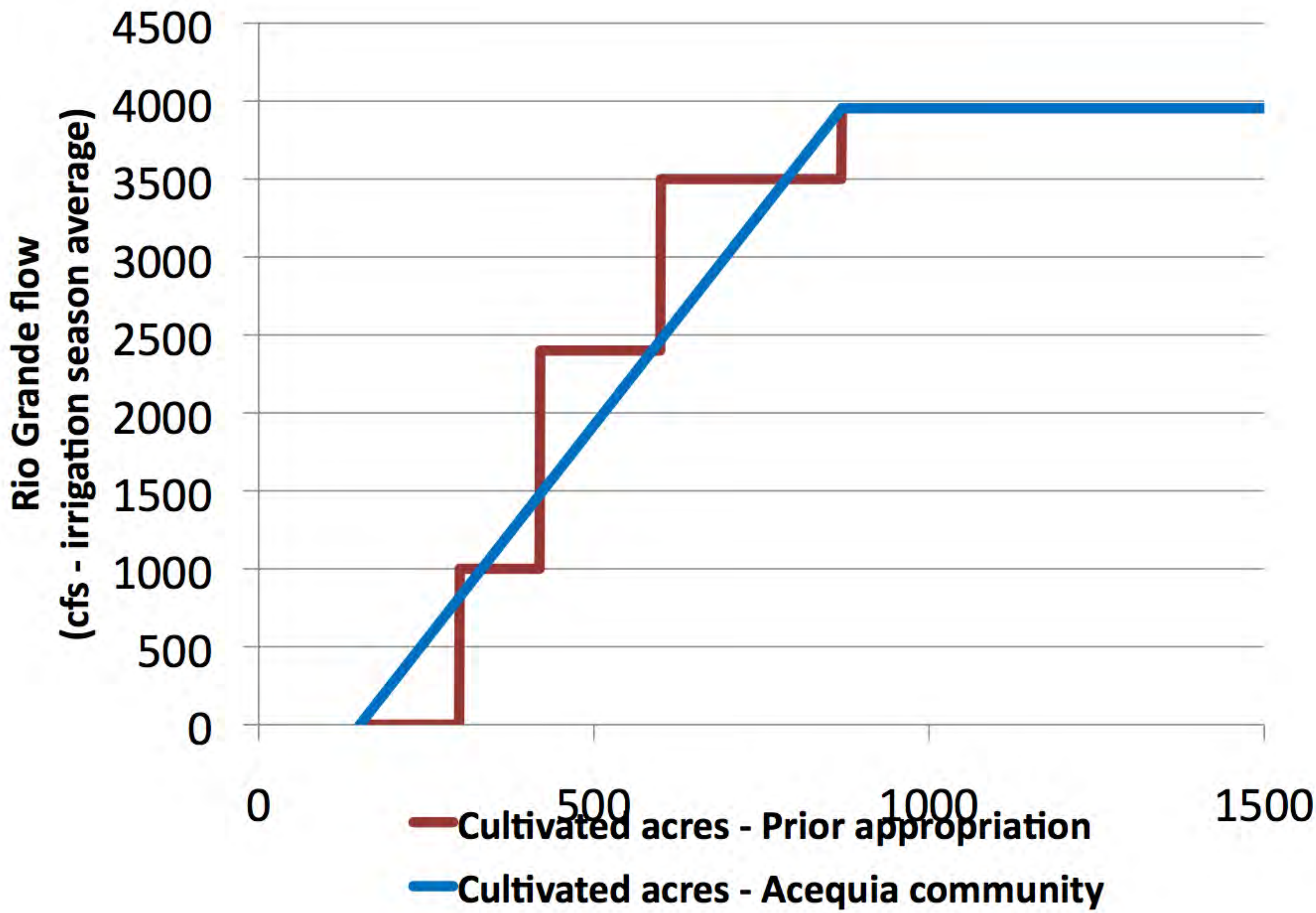
Restrictions grazing/cattle (policy and/or climate): ↓ forage (& ↑ apples?).

CROSSCUTTING- Historical data and collaborative analysis

Economics causal loop diagram

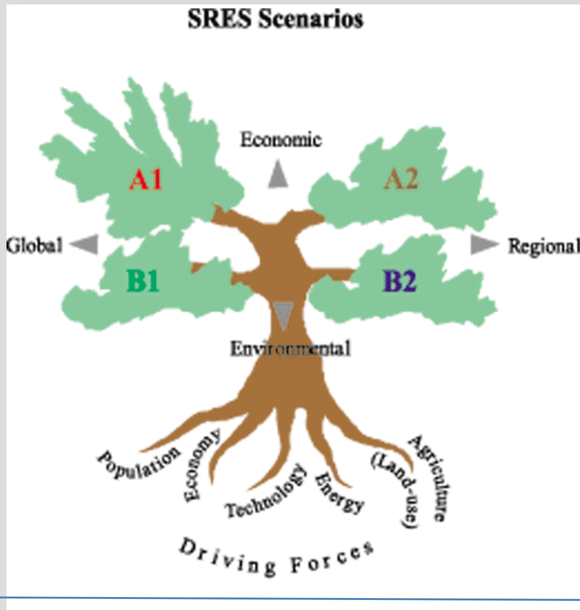


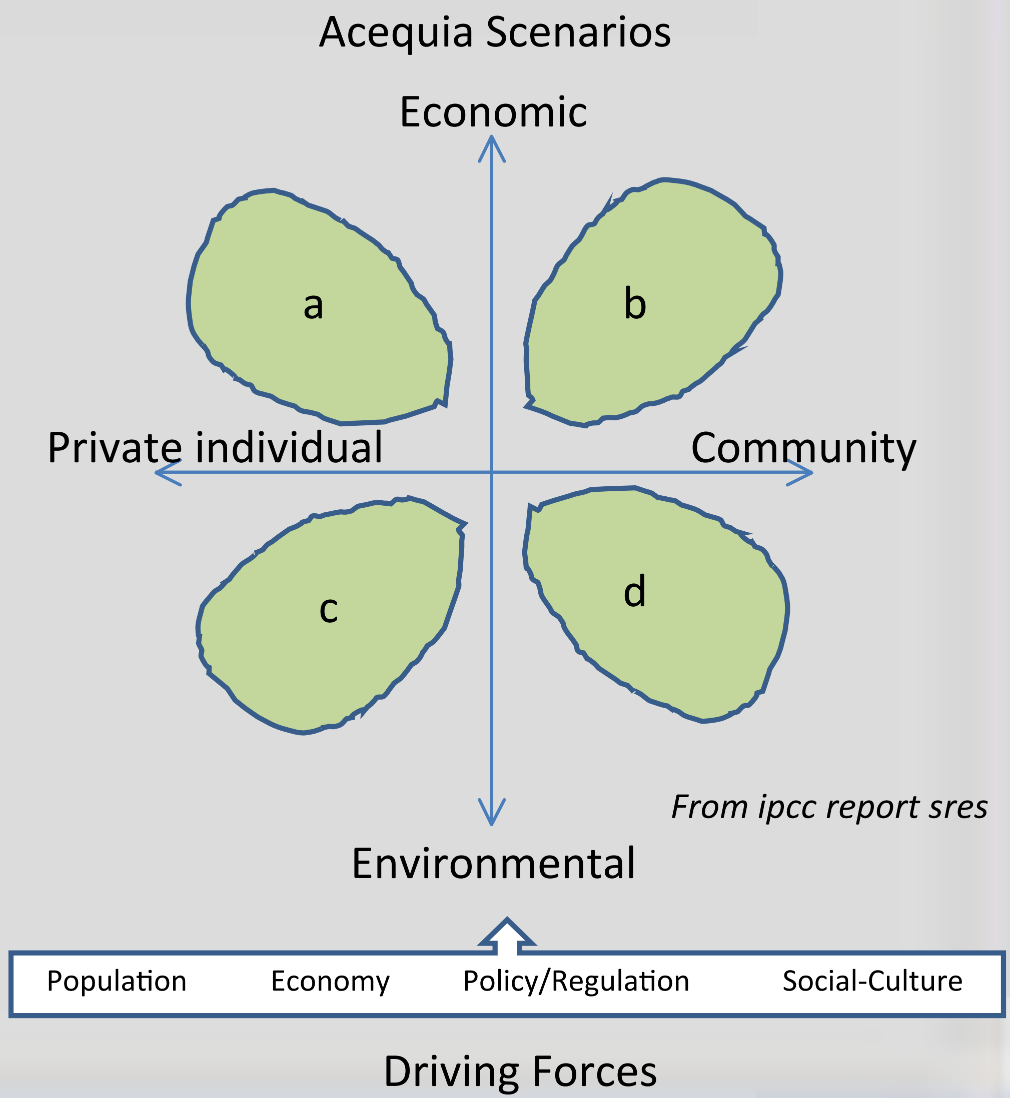
CROSSCUTTING- Historical data and collaborative analysis



IV. Continuing work

Acequia Baseline Scenario ‘Storylines’





Acequia storylines are:

- Adapted from the SRES scenario ‘storylines’ framework
- Used to develop internally consistent model scenarios and assumptions for parameters and variables
- Based on plausible trending social characteristics, values and attitudes and balancing between:
  - Enhancement in environmental versus economic outcomes
  - Reliance on community versus individual resources and capabilities

Community Capital, Capacity, Capability

- Community resilience and sustainability is supported by its ‘capital stock’ and ‘adaptive capacity’
- Community Capital
  - Economic Capital
    - income, growth, diversity, asset values
  - Social Capital
    - community cohesion, cooperation and mutualism
  - Environmental Capital
    - ecological and environmental health (diversity, productivity)
    - resource quality (air, land, water, wildlife)
    - aesthetics, locational desirability, characteristics
- Stressors such as Climate Change and Population Growth can accelerate erosion/degradation of capital
  - altering the flow patterns that contribute or consume capital
    - e.g., economic capital is affected by severe drought that dewaters acequias, reduces agricultural yields and acres, dries pastures and riparian systems, increases fire potential, which reduce revenues, incomes and jobs

Hurd

ECONOMICS – Surveys and models

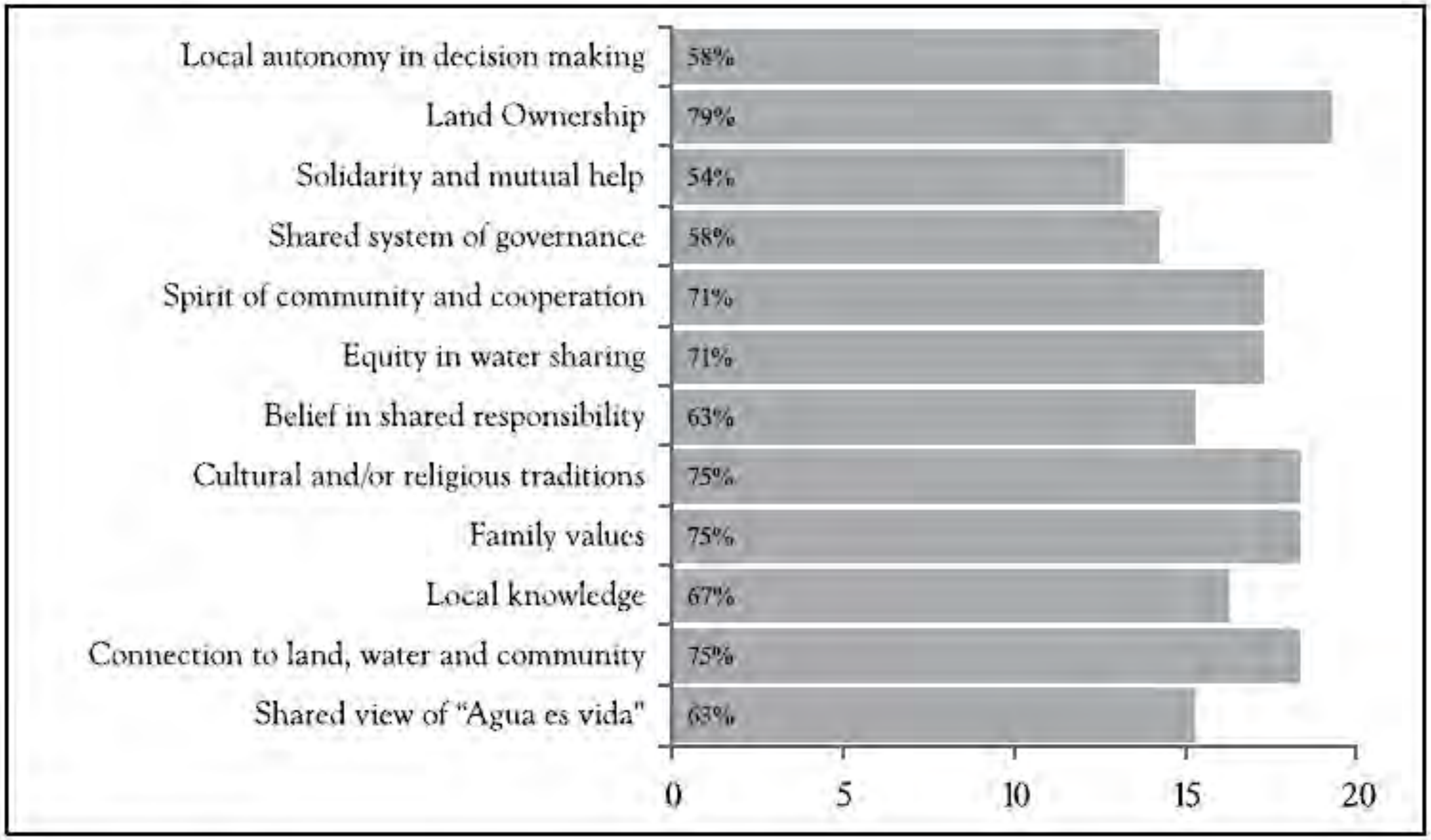
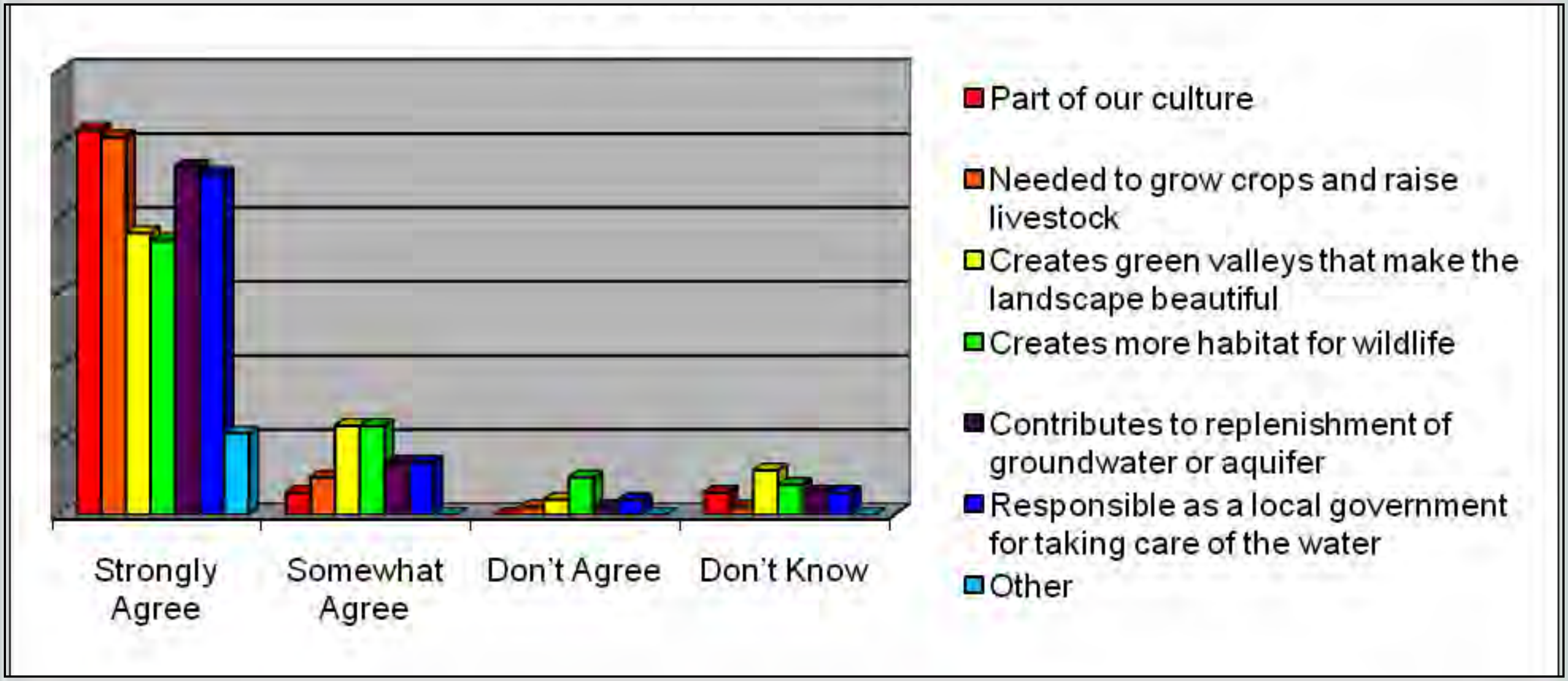


Figure 5. Acequia characteristics perceived to best contribute to acequia adaptive capacity, past adaptation, and resilience: Alcalde-Velarde region.

SOCIAL - Focus groups and surveys

What is your opinion about the following statements about the importance of your acequia to your community?



New data to quantify narratives

Number of Farmers Markets in New Mexico
Growth Between 1971 and 2008

1971	3 markets (estimate)
1993	20 markets
1998	27 markets
2001	34 markets
2004	39 markets
2008	50 markets

Ortiz

Interdisciplinary modeling course

globalperspectives*2013.wrri.nmsu.edu/*

Acequias and the Future of Resilience in Global Perspective

Symposium & Workshop

March 2 - 3, 2013

Las Cruces Convention Center
Las Cruces, NM

Acequias and the Future of Resilience in Global Perspective

This symposium pursues a holistic understanding of acequia irrigation in the upper Rio Grande Valley as made up of interactive, interdependent biophysical, economic, ecological, and sociocultural systems. It brings together scholars whose perspectives on comparable social-ecological systems in other parts of the world can shed light on the particular and shared features of New Mexican acequias as well as on the challenges they face. Of special interest are questions about whether and how local common resource pool management can maintain or regain resilience under conditions of accelerating integration into a global economy and climate change.

NSF | WRRI | New Mexico EPSCoR | UNM | New Mexico Acequia Association | Sandia National Laboratories | NEW MEXICO TECH | NM STATE UNIVERSITY

FLOODPLAIN HYDROLOGIC COMPLEXITY

- Hydrologic complexity important for terrestrial and aquatic ecosystems

- Before channelization, Rio Grande floodplain more complex with side channels and islands

Photo of Rio Grande at Rio Jemez confluence (Yeo, 1937)

Landers D.H., A.G. Fernald, and C. Andrus. 2002. Off-channel Habitats.

HABITAT

Functional similarities
in river side channel
and acequia channel

Alcalde study site

River flow → Rio Grande at Embudo (>100 yr data) 1900-2012*

•Average monthly-averaged flow = 870 cfs

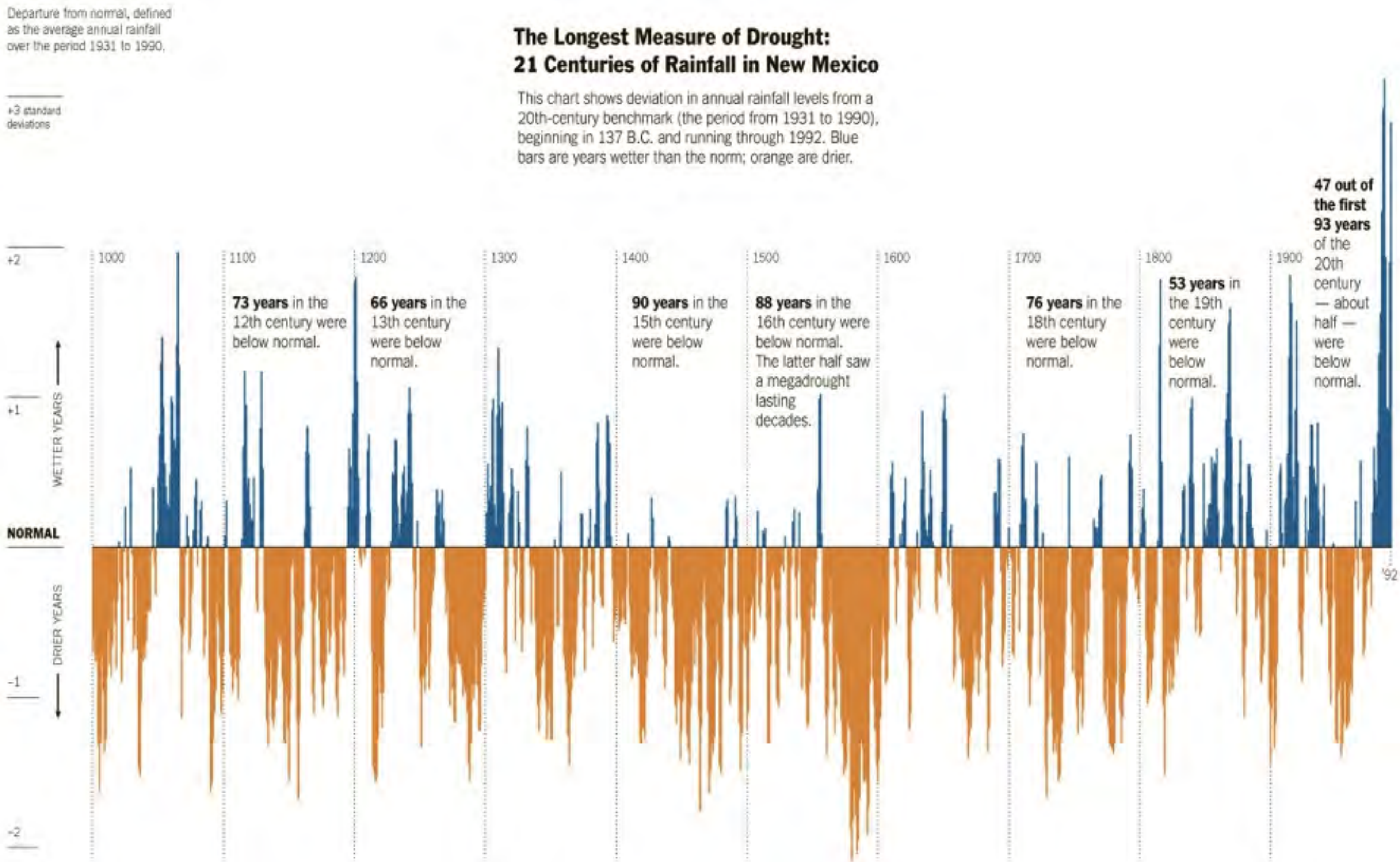
•Highest monthly-averaged flow = 8971 cfs (June 1903)

•Second highest monthly-averaged flow = 8602 cfs (June 1920)

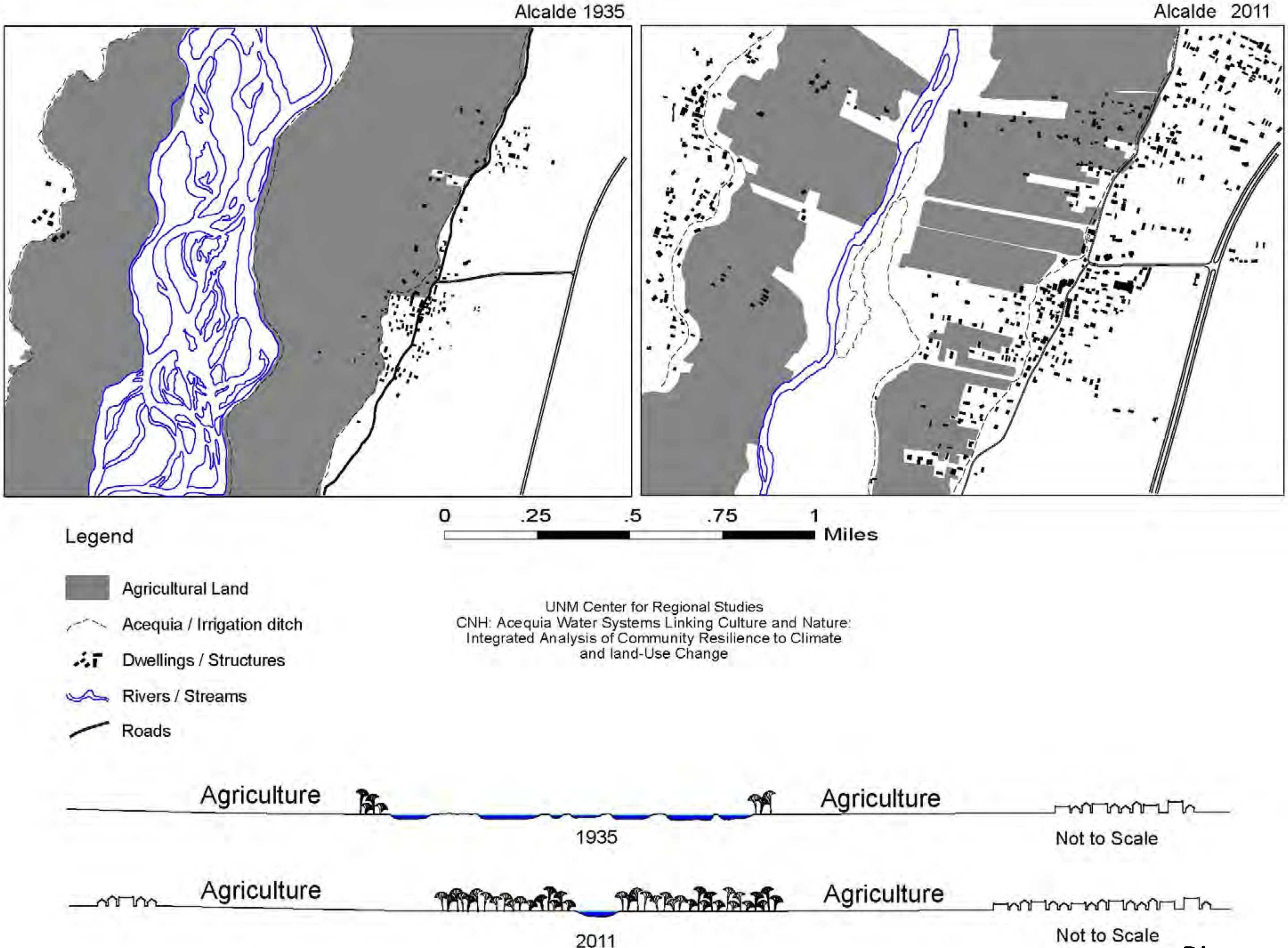
•Lowest monthly-averaged flow = 151 cfs (August 2002)

Threshold yearly-averaged flow for the model = 300 cfs (Oct 2001 – Sep 2002)

Ochoa

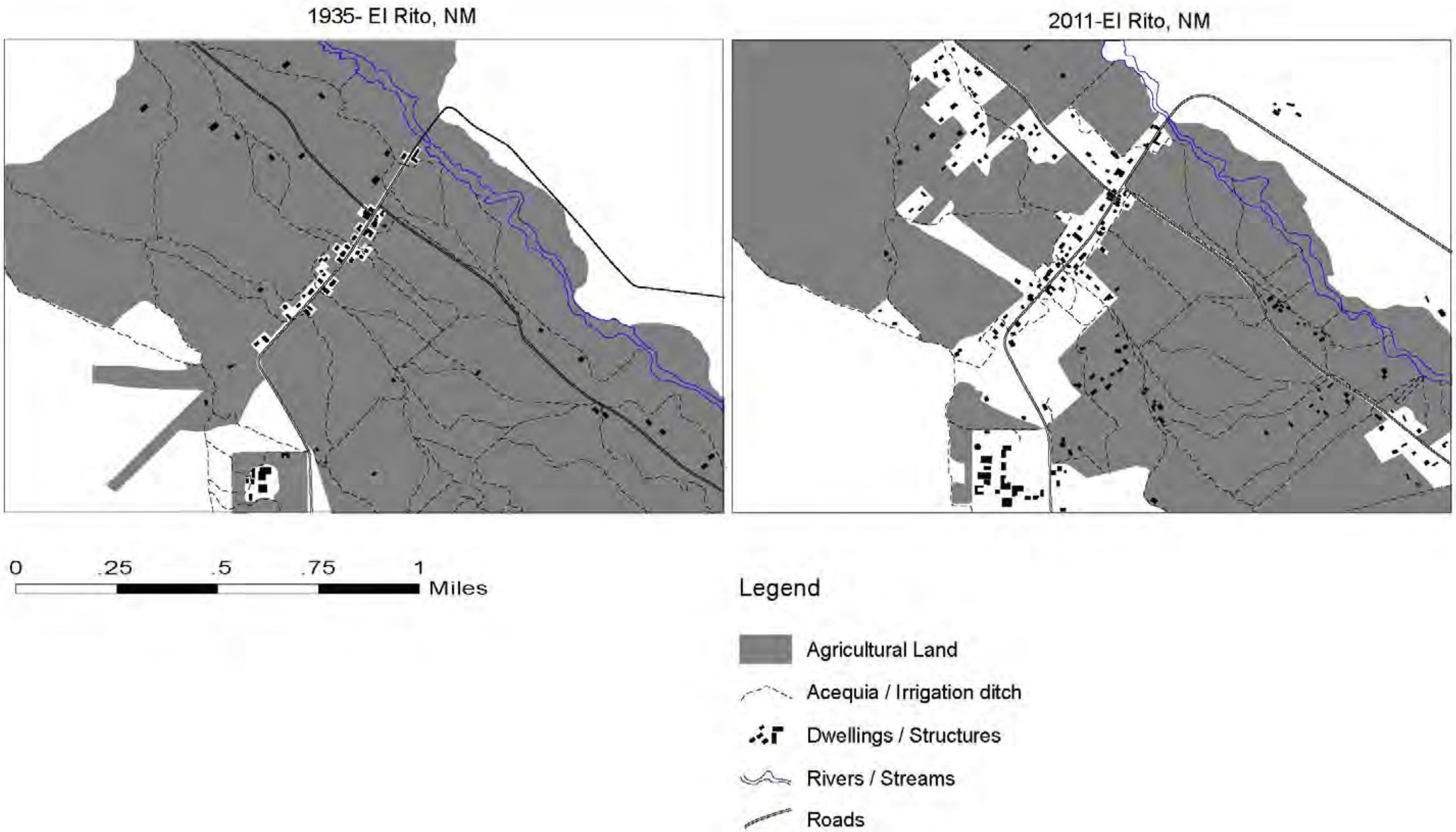


Sources: Henri D. Grissino-Mayer, University of Tennessee, "A 2,129-Year Reconstruction of Precipitation for Northwestern New Mexico, USA," 1996; David M. Anderson, National Oceanic and Atmospheric Administration National Climatic Data Center; Graph, Bill Marsh/NYTimes; August 12, 2012


Alcalde 1935
Alcalde 2011
0 .25 .5 .75 1 Miles
Legend
Agricultural Land
Acequia / Irrigation ditch
Dwellings / Structures
Rivers / Streams
Roads
UNM Center for Regional Studies
CNH: Acequia Water Systems Linking Culture and Nature:
Integrated Analysis of Community Resilience to Climate
and land-Use Change
Agriculture
Agriculture
1935
Not to Scale
Agriculture
Agriculture
2011
Not to Scale

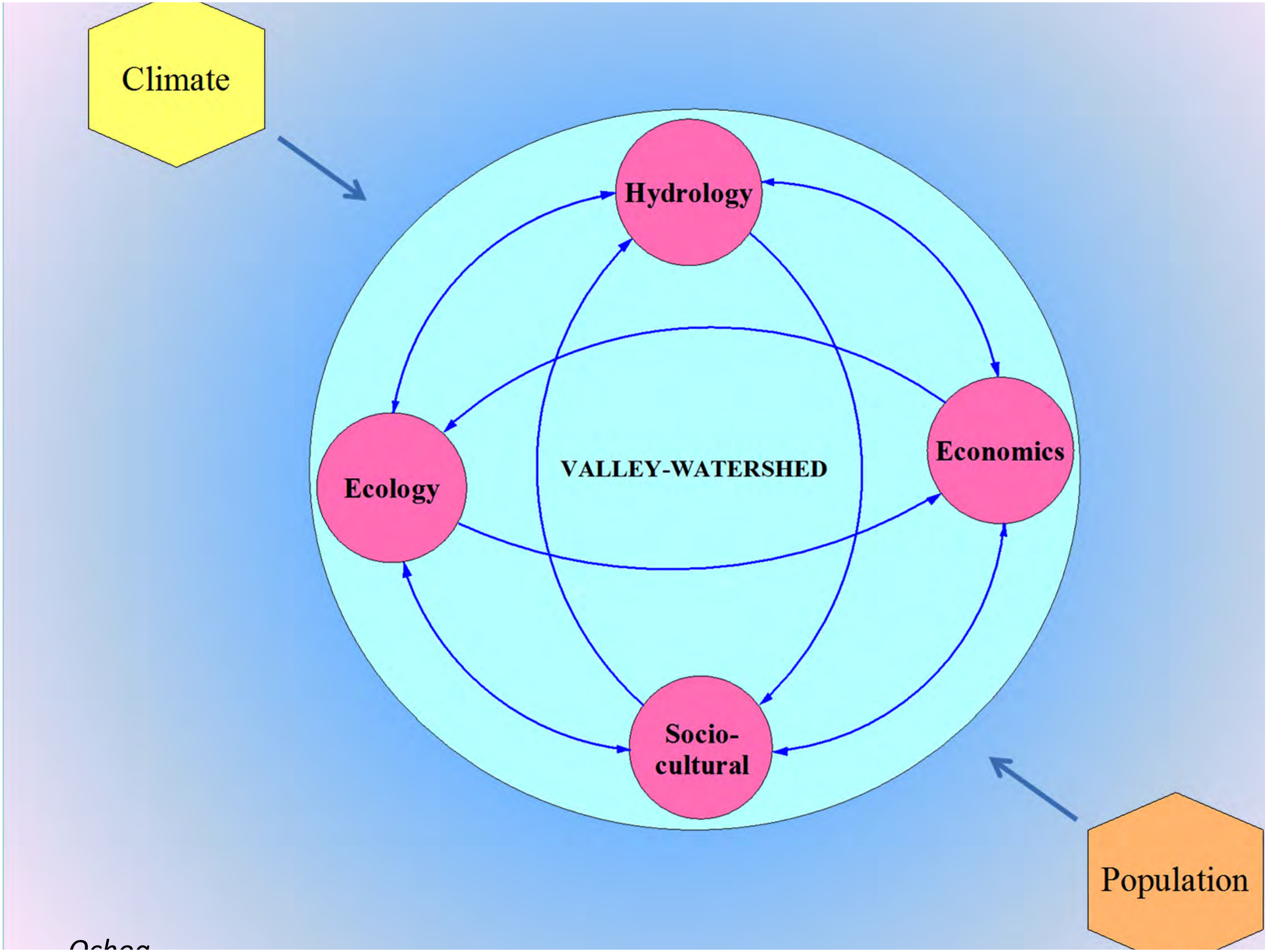
Rivera

Alcalde Science Center 2011



UNM Center for Regional Studies
CNH: Acequia Water Systems Linking Culture and Nature:
Integrated Analysis of Community Resilience to Climate
and land-Use Change

Rivera



Climate
Hydrology
Ecology
VALLEY-WATERSHED
Economics
Socio-
cultural
Population