Public adaptation through the backdoor: Can we move to adaptive water governance?

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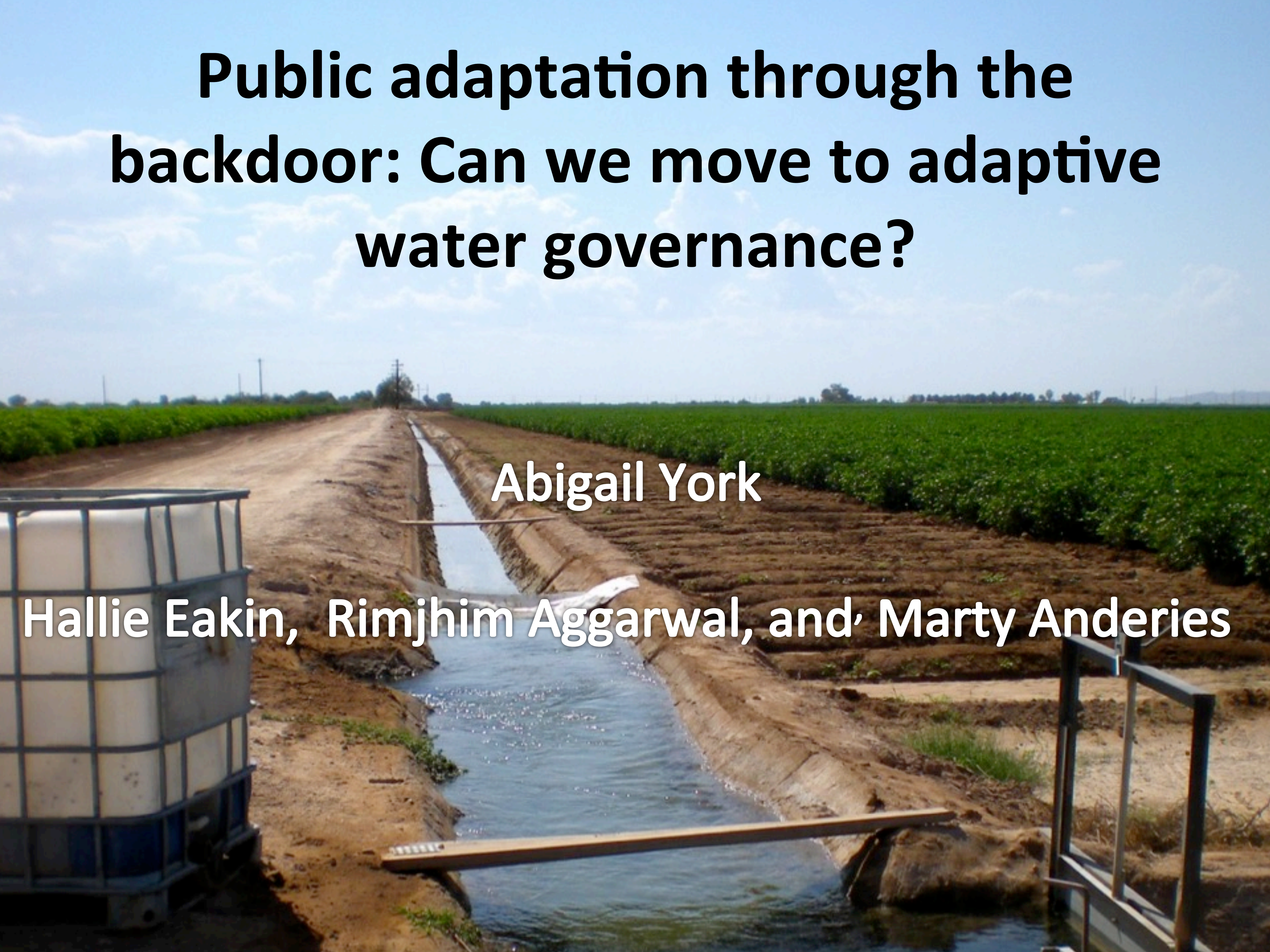
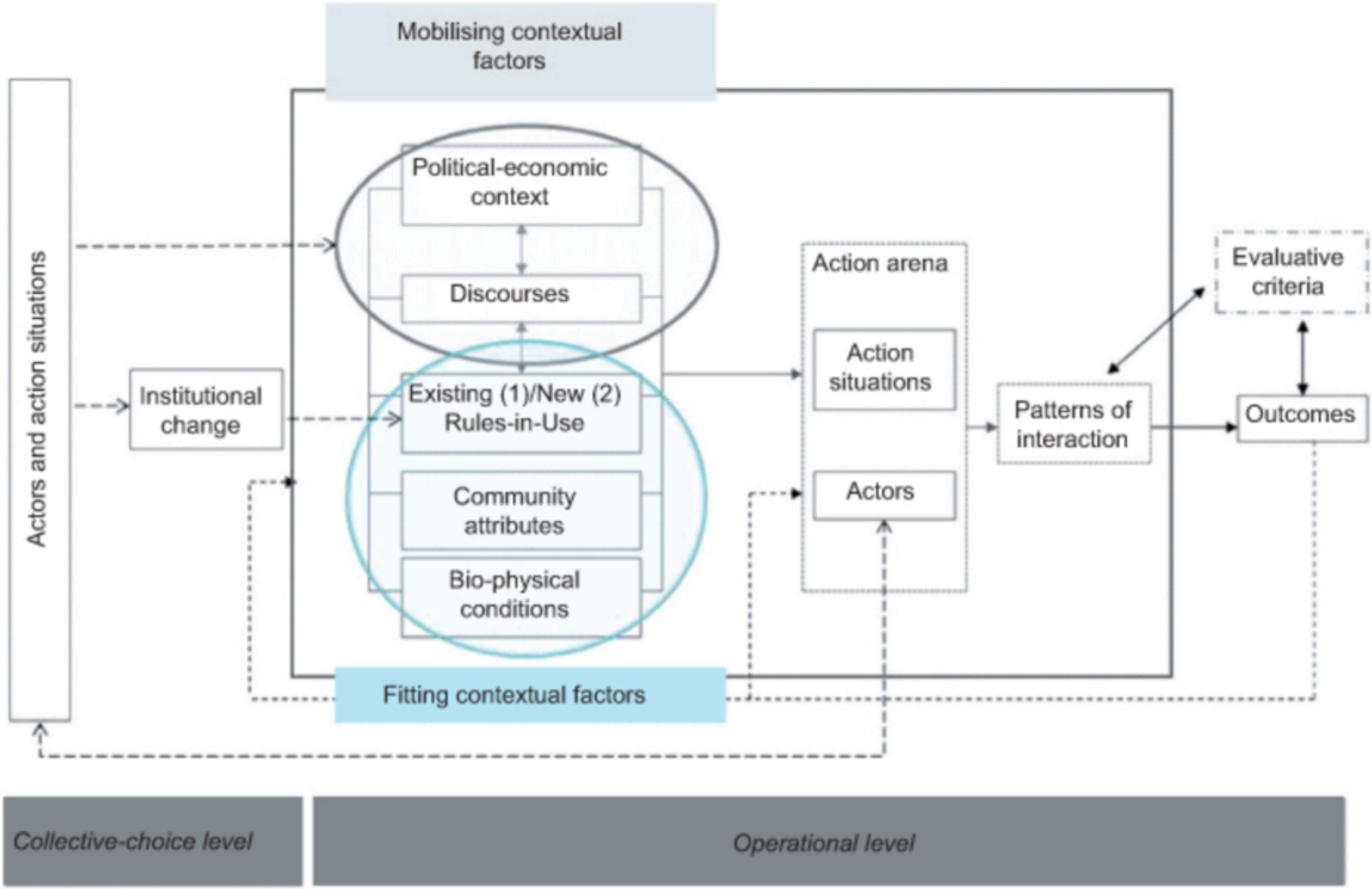
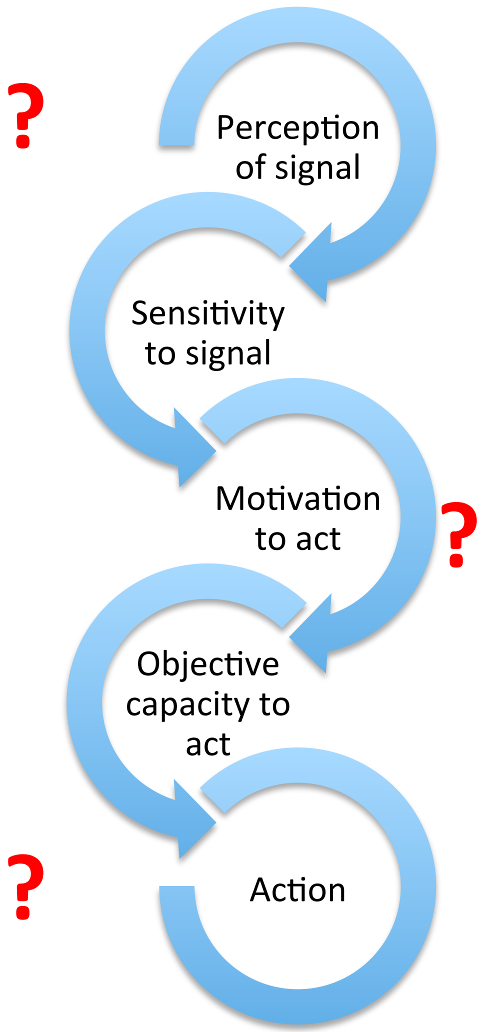




Clement and Amezaga, 2013

Privately-provided public adaptation goods

(Tompkins and Eakin, *GEC*, 2012)

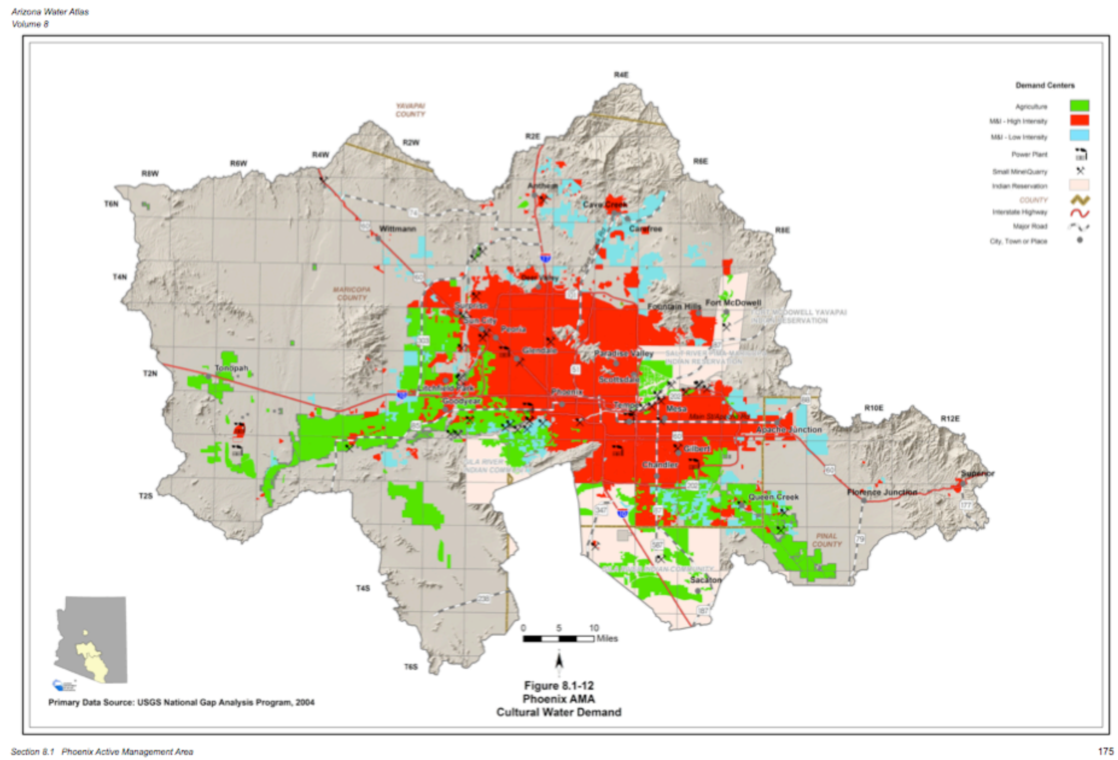


- *Private provisioning for private benefit:*
  - Focus on the benefits to individual actor/ organization from acting to reduce vulnerability
- *Privately provided public adaptation goods*:
  - adaptation process and outcomes contingent on the action of private individuals, who see little benefit in this action

		Beneficiaries	
Providers		*Private*	*Public*
	Private	Private action → private benefit *Farmers switching crops, adopting drip technology to maintain productivity*	Private action → public benefit *Farmers adopting conservation measures to enhance reliability of future public water supply*
	Public	Public action → private benefit *Public subsidies for adoption of drought tolerant crops; public subsidies for input costs*	Public action → public benefit *Public investment in desalinization, dam construction, water infrastructure or pricing*

The Central Arizona Case

- Agricultural history
- Irrigation = 38% of water use in metropolitan area
- Water-intensive cotton and alfalfa primary crops



Map source: Arizona Department of Water Resources (ADWR). (2010). *Arizona Water Atlas, Volume 8: Active Management Area Planning Area.* P. 175

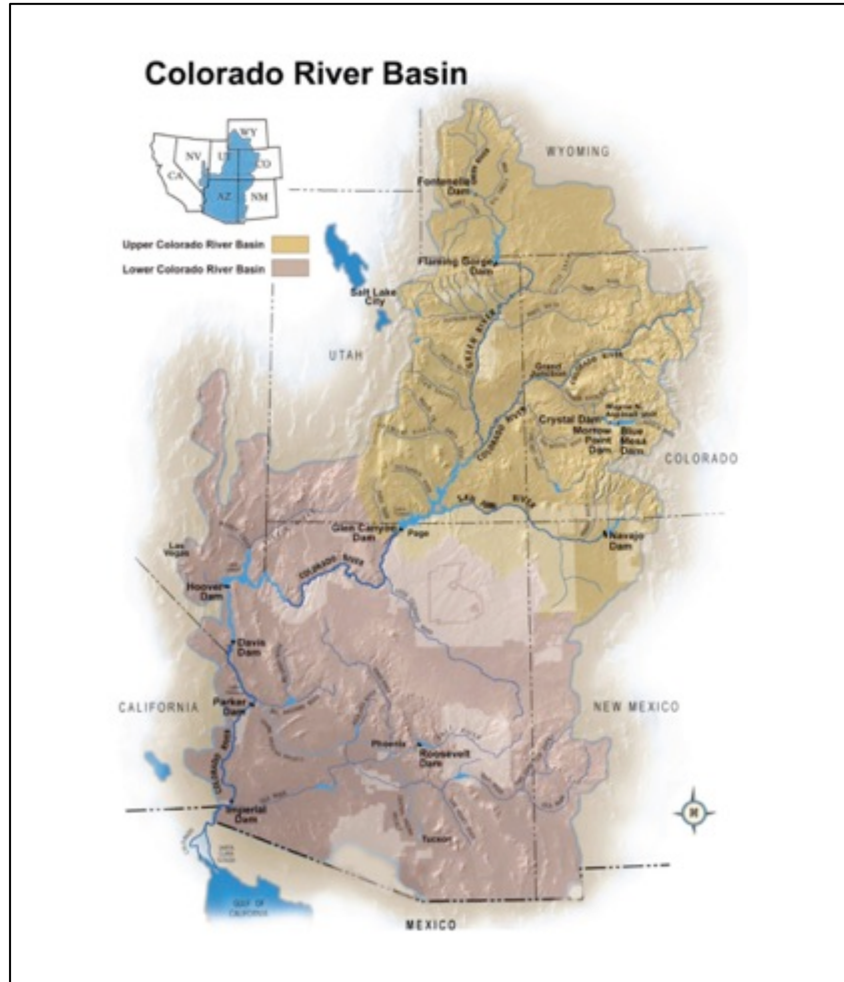
Institutions and common understanding

	1970s	*1980s-Present*	*20XX?*
Property regime	Open access *Pre-GMA:* *"Reasonable use" regulation of transport but not appropriation*	State property *Post-GMA:* *State determines allocations* *CAP water augments resource base*	? *Climate-adaptive future paradigm*
Common understanding	Appropriation of groundwater is an individual right of private land owners	Groundwater conservation for future generations is a public interest; Compensation necessary for cooperation	?

Institution	Public good: safe yield	Public good: full use of CAP
CAP water priced below cost (direct subsidy)	Positive effect; Shifts groundwater extraction to surface water use	Positive effect; Increases use beyond market demand
Base Program with flex credits (market-based)	Minimal effect	Minimal effect
BMP Program (technical assistance/ performance standards)	Negative effect compared to Base Program	Positive effect

Agriculture Sector Participation in Public Good Provisioning

- Public Good: "Safe Yield" by 2025
  - Irrigation non-expansion and limited water rights
  - Graduated efficiency requirements
  - *Flex credits*
  - *Best Management Plan*
- Public Good: full use of CAP
  - Municipalities subsidize CAP use by agriculture until 2030

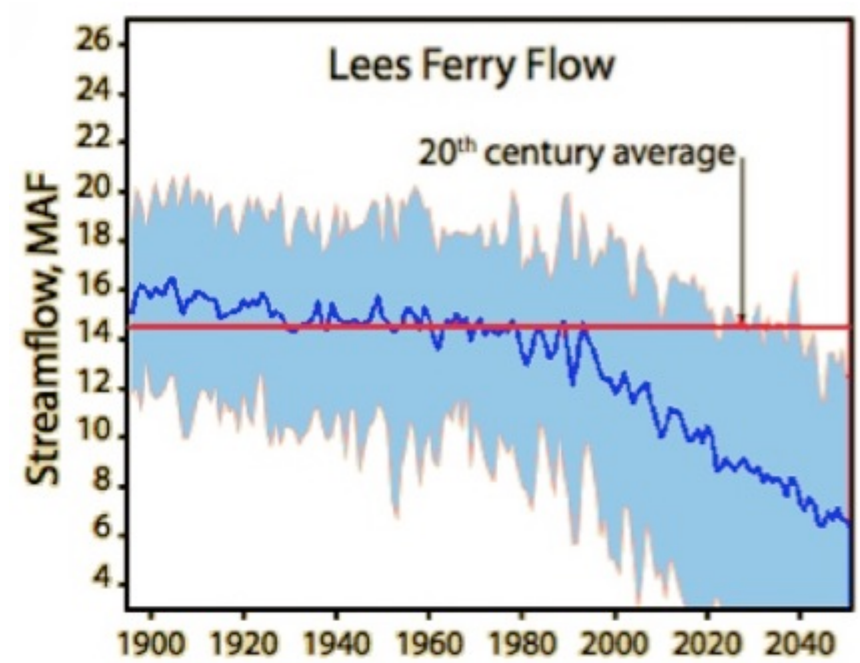


Public provisioning outcomes?

- Safe yield progress via agricultural land retirement and shift into CAP water, *not change in farm water management*
- Agriculture's role absorbing CAP water does not incentivize change in agricultural or water practices

Need for Adaptation in Public Domain

- Possibility of the "Mega-drought"
  - E.g., Seager et al 2007
- Declining flows in Colorado
  - E.g., Hoerling et al. 2007; NRC 2007; Christensen et al., 2004
- New awareness of water vulnerability
  - E.g., Gober et al 2010; Megdal et al. 2009; NRDC 2010; Garfin and Lenhart 2007; Maguire 2006



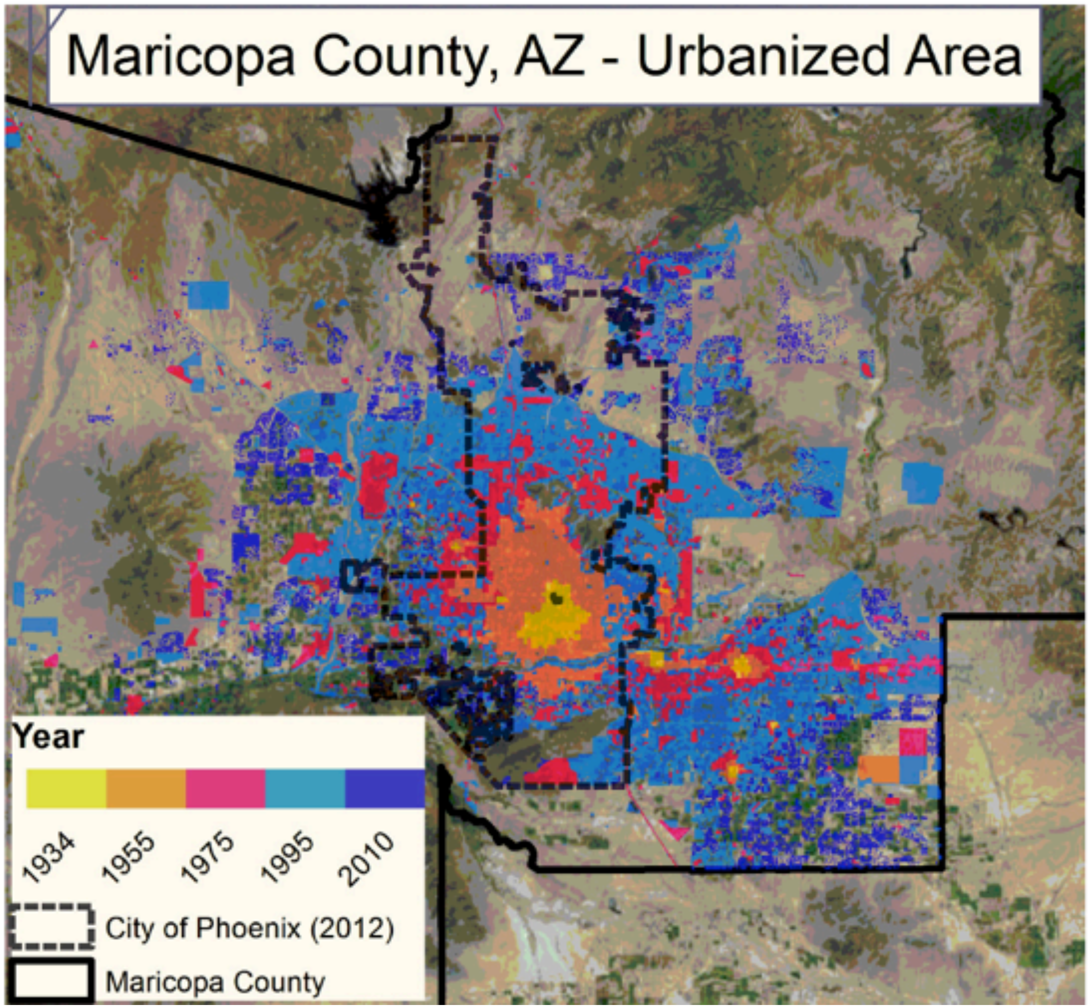
Source: Hoerling, M., & Eischeid, J. (2007). Past Peak Water in the Southwest. *Southwest Hydrology, 2007(January/February), 18-19, 35.*

Farmers appear to manifest characteristics of social resilience

- Respondents are more concerned about future water risk
- Acknowledge that their active participation as individuals and collectively is essential for the viability of agriculture in the future.
- Participants demonstrate an entrepreneurial attitude.
- They feel confident in their skills and knowledge to cope with future water problem
- However most of them feel that they may have to change their strategies for dealing with water issues in the future.

Our findings indicate that CAZ farmers are capable of responding to new stressors related to water supply in flexible and entrepreneurial ways. However, farmers may need improved information and targeted support on adaptation options.

The Phoenix area's urban morphology is subject to a lot of heavy-handed critique:



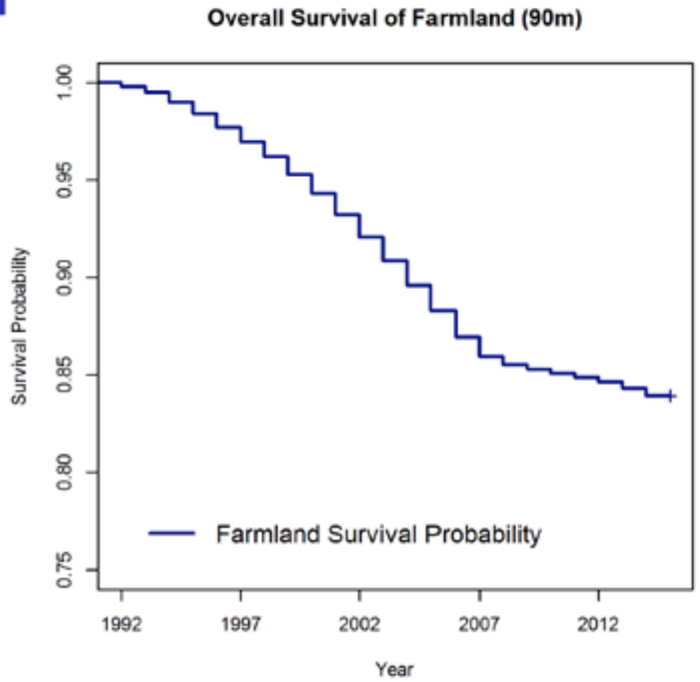
- Sprawled development, fragmentation, homogenous landscapes (Heim 2012, Ross 2011, Shrestha et al. 2011)
- Early decline of the downtown core (Luckingham 1989)
- Environmental justice and social segregation (Guhathakurta and Stimson 2007; Gober 2006; Bolin, Grineski and Collins 2005)
- Booms and Busts (Agarwal et al., 2012; VanderMeer 2002)

- Greenfield development would typically involve a farmer and a developer
- Little incentive for farmland preservation or agricultural zoning
- Farmer $\Rightarrow$ Developer $\neq$ Farmland $\Rightarrow$ New Housing
  - due to holding costs and timing
- A decisionmaker converts parcel i according to:

$$max \pi_{it} = \int_0^t A(x_{it}, t^*)e^{-rt} + (H(x_{it}, t^*) - C(x_{it}, t^*))e^{-rt}$$

where r is the discount rate, A is agricultural rent, H is housing rent, C is conversion cost (adapted from Wrenn and Irwin, 2012).

focus is on t^*: the timing of housing development



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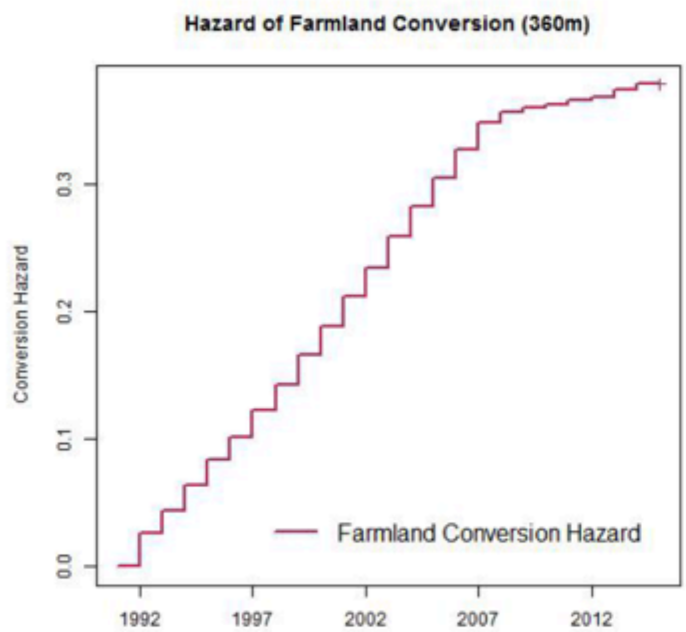
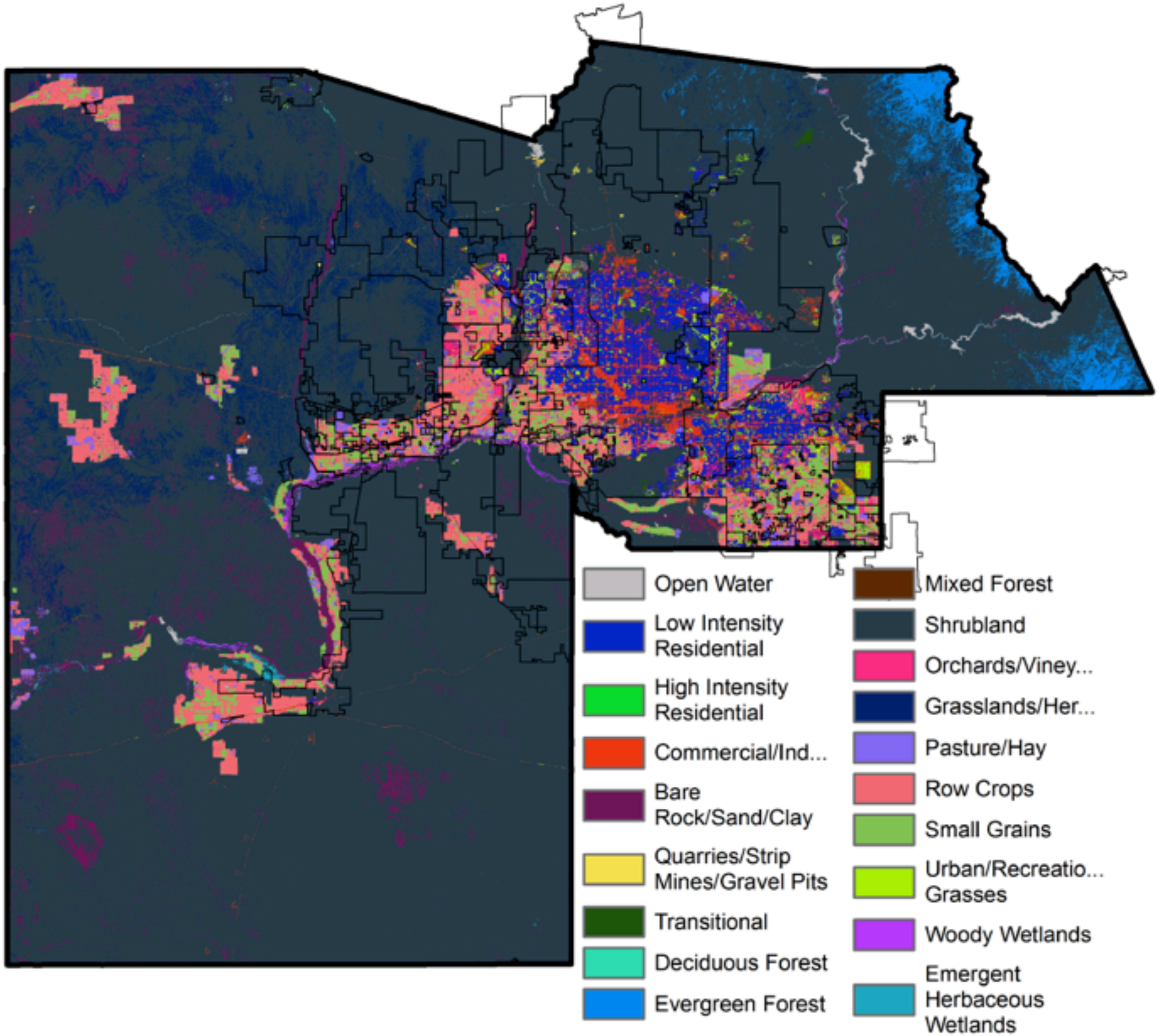


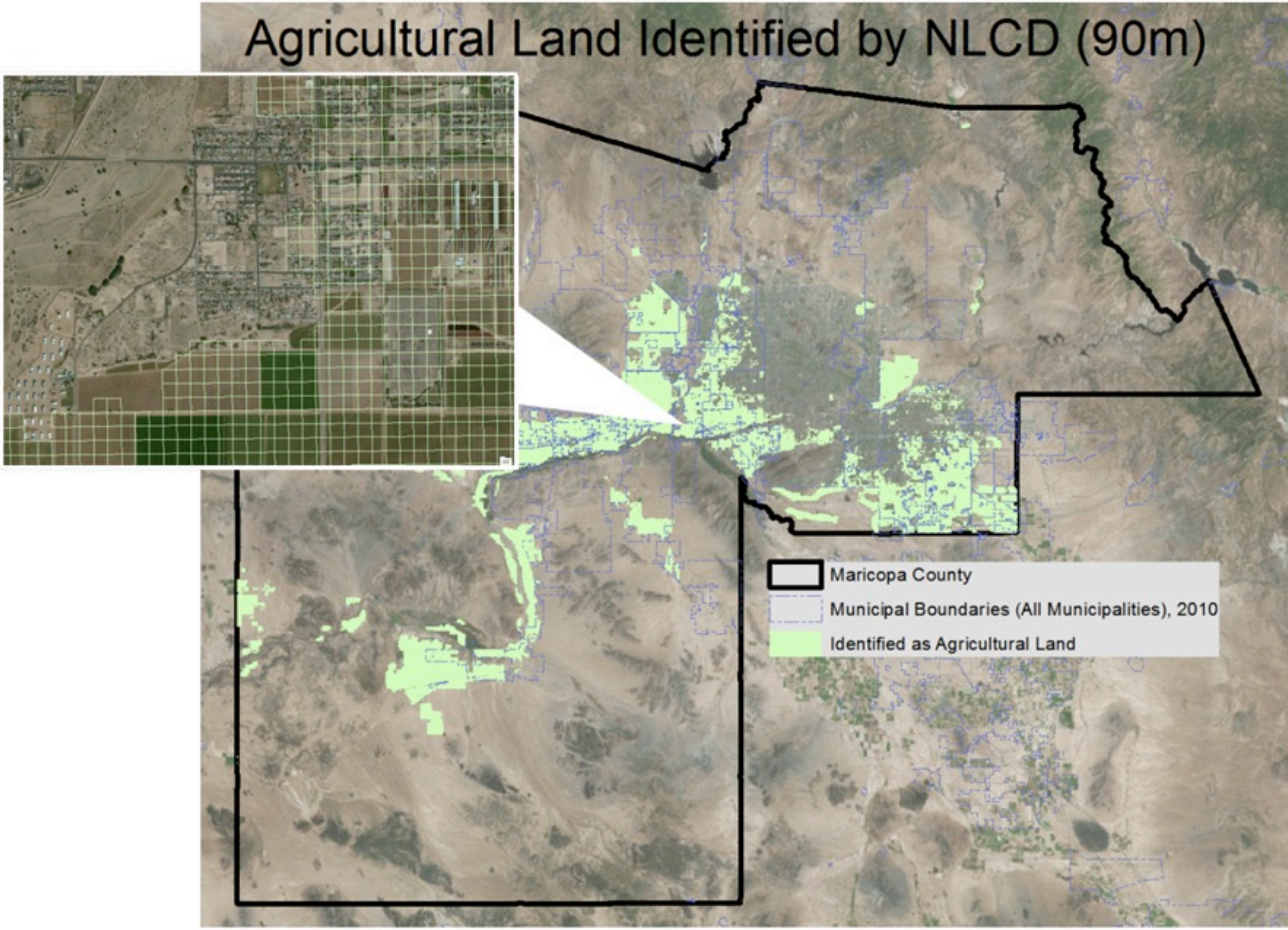
- Survival curve (top) indicates how much farmland remains at each time point
- Main component of interest in regression is the hazard function $h(t)$ (below)
- $h(t) = \frac{f(t)}{S(t)}$
- Describes the relative likelihood of conversion occurring at time t, conditional upon its survival up to that point.
- Cox Proportional Hazards Model

What are the spatial, institutional, and market factors that impact the hazard of land conversion?

- $Hazard\ Ratio = exp(B_1(x_2 - x_1))$
  - Elasticity interpretation: impact of a 1% change in covariate value on the likelihood of land conversion
- Time-varying covariates
  - A land parcel's distance to a highway, inclusion in a municipality, etc. can change over the study period
- Innovation:
  - Cox proportional hazard model doesn't require a baseline hazard function. Instead we include covariates based on market indicators in each year (home value, oil price, etc.)
  - Allows for comparing impact of, e.g., highway proximity vs. impact of gasoline price on land conversion

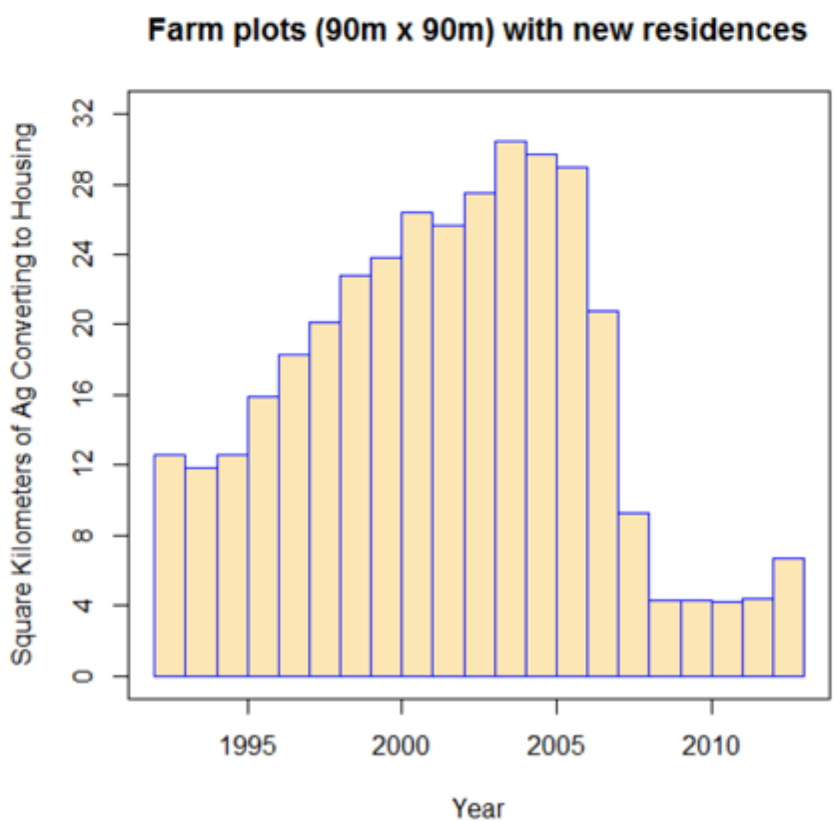


National Land Cover Database, 1992 (Maricopa County)



60m, 90m, and 360m cells created from sattelite imagery (90m shown)

Survival analysis is a discrete-choice linear model using the time to an event as the outcome measure



- Observations are units of agricultural land
- Outcome variable: if and when farmland converts to housing, $f(t)$ (left)
- Land change examples: Wrenn and Irwin 2012, An and Brown 2008

- 594,150 new homes in Maricopa County since January, 1992
- Time point: certificate of occupancy granted by a municipality

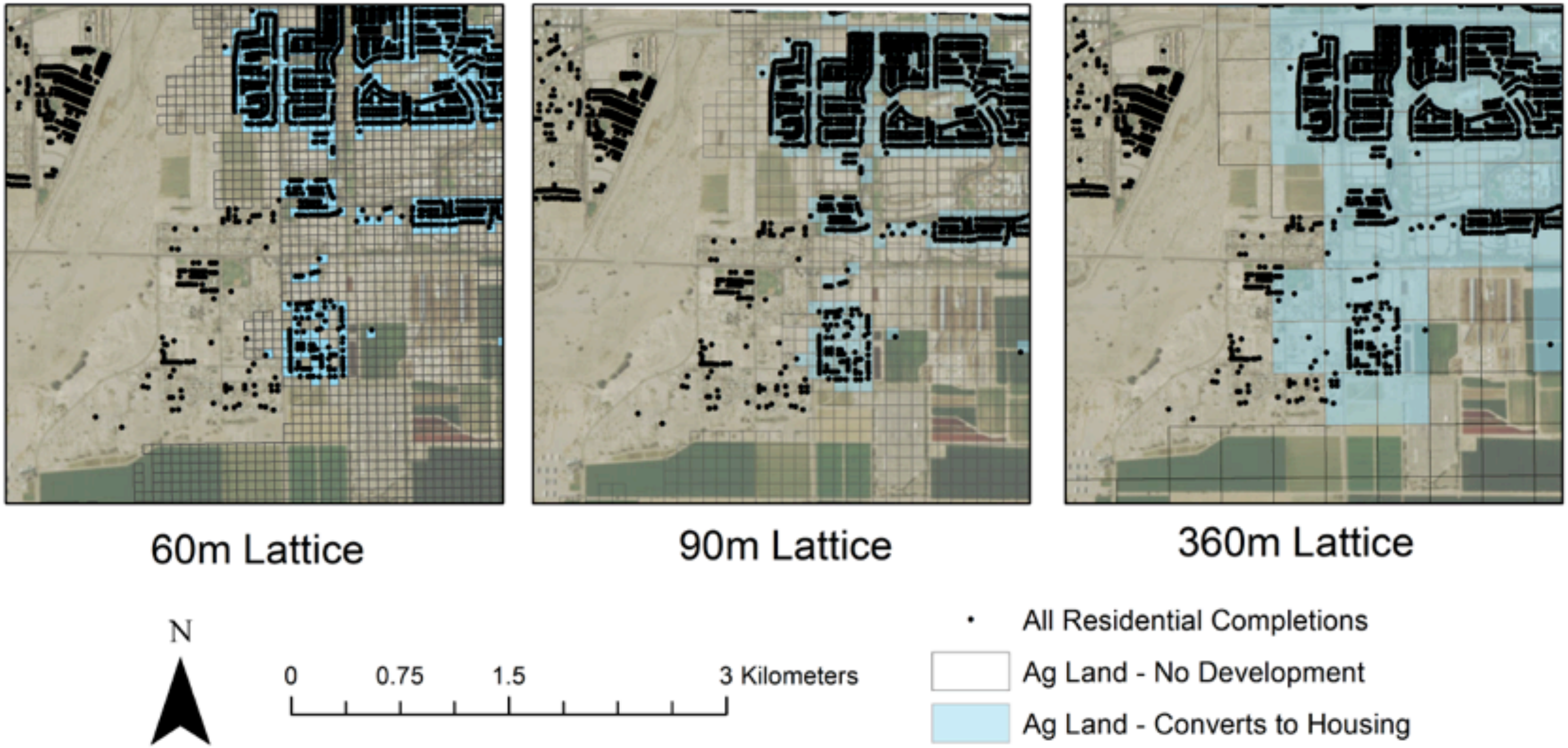
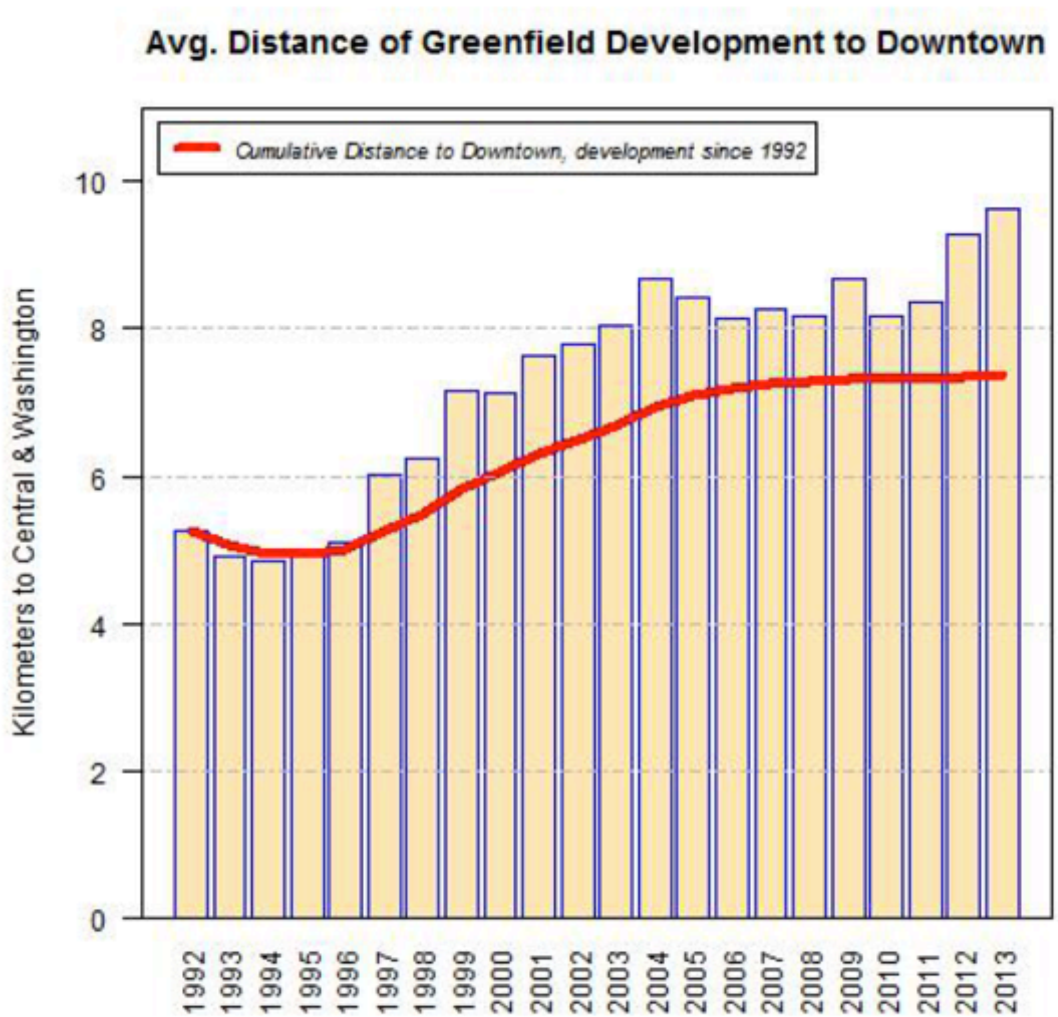


TABLE 1: AGRICULTURAL CELL CONVERSION AT MULTIPLE RESOLUTIONS

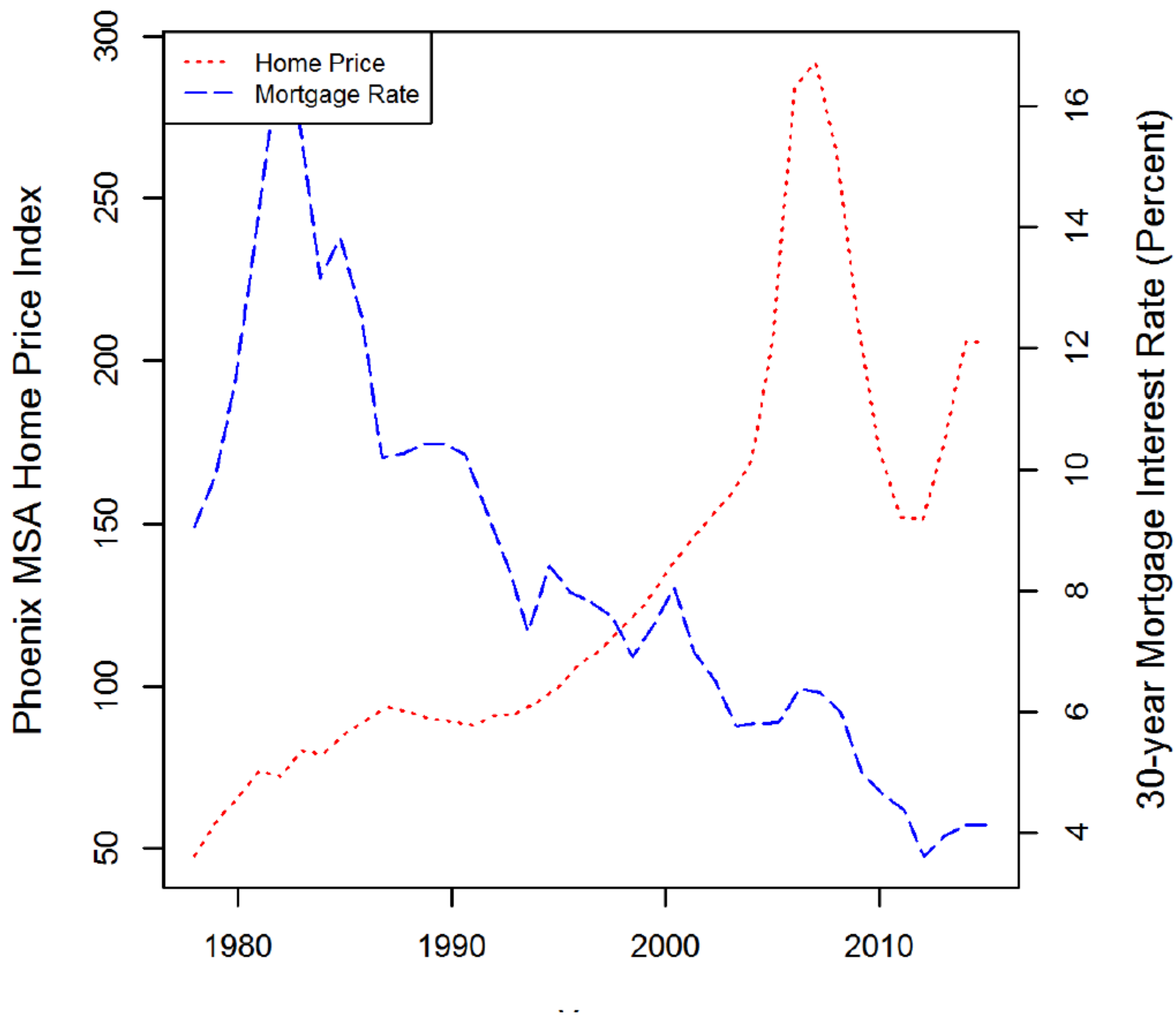
Resolution	Number of ag cells, 1992	Number of ag cells that convert to residential, 1992-2014 total	Area per cell (acres)	Number of average-sized homes per cell*	Average number of actual new homes on converting cells	Residential completions on former ag land
360m	19,188	6,044	32.0	112	47.87	289,302
90m	265,892	45,422	2.0	7	5.85	265,759
60m	573,029	82,244	0.9	3	3.15	259,387

**based on approximate average residential density of 3.5 units per acre*

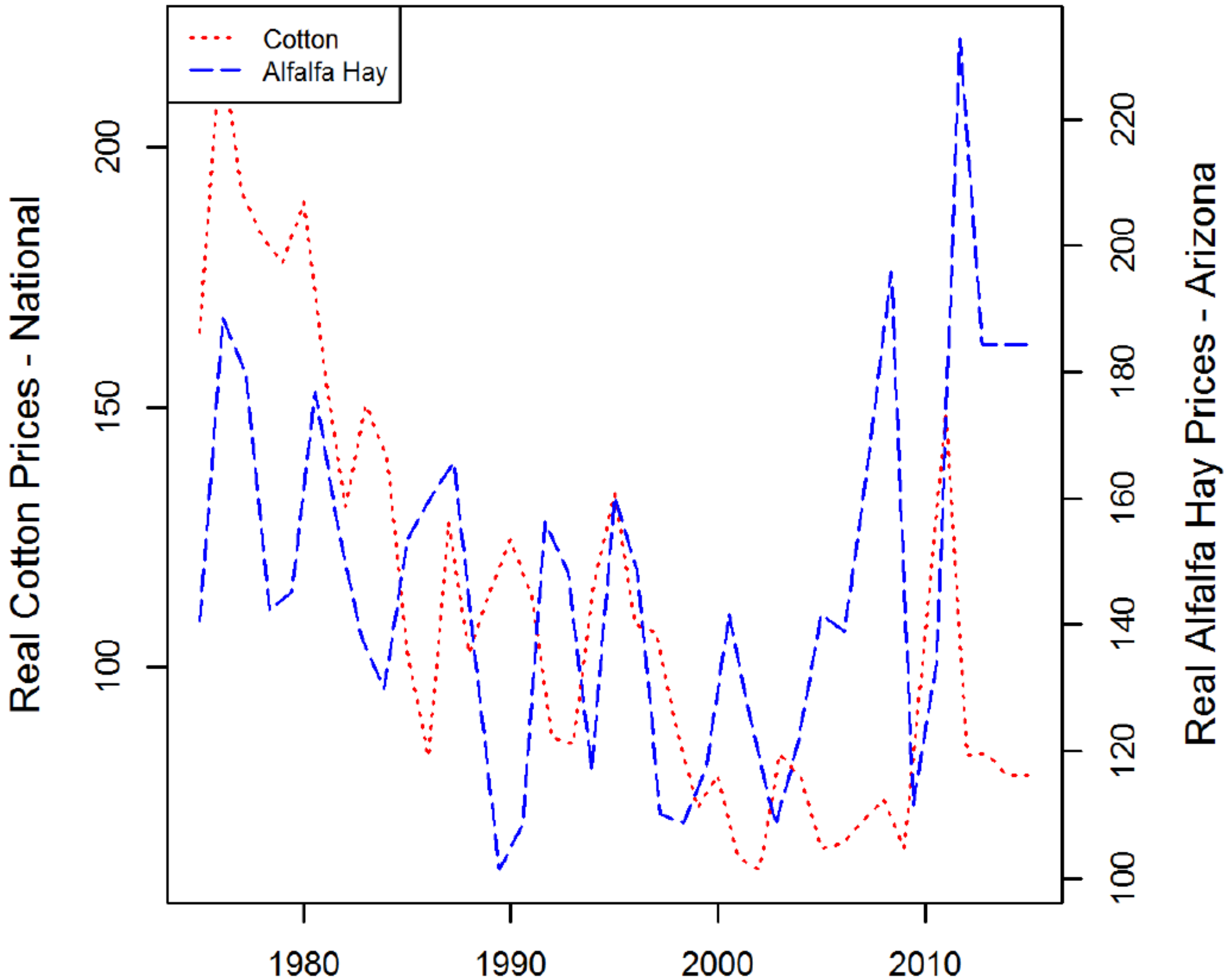


1. Distance to Region's Center
2. Side of Town (Central, West, Southeast)
3. Soil Quality

7. Region-level home price index - Phoenix/Mesa/Scottsdale (FRED)
8. 30-Year Mortgage Interest Rate (FRED)



9. National Cotton Price ("A" Index)
10. Arizona Alfalfa Hay Price



- Location: about a 72% decrease per log kilometer
    - Location, given gas price: varies from 68% ($1.26/gal) to 78% ($3.12/gal)
- Freeway proximity: about a 0.4% increase per km - in some models only
- Municipal Incorporation: severalfold increase. But a 3.8% decrease per year since land was annexed; up to a 5.6% decrease during home price booms
- Ag Commodities Index: about 0.6% decrease for a 1% decrease in alfalfa hay price (cotton less)
- Regional Housing Market Index: about 0.7% increase for a 1% increase
- Mortgage Rate: about 1.2% decrease for a 1% increase - two years' prior
- Oil/Gasoline: about 2.1% decrease for a 1% increase - two years' prior

How did market factors fare in our spatially-explicit land conversion model?

- Annexation is still the biggest driver of land conversion
- Persistent preference for ‘new’ land in Arizona
- Region’s core still relevant, despite polycentricity/fringe growth
- Commodity prices and regional home prices offset fairly well
- New homes hit the market when prices are high, but a couple of years after low interest rates
- Strongest impact on land conversion: oil prices (negative)
- **Spatially-explicit evidence of increased land conversion on the urban fringe of a large, Sunbelt metropolis when fuel prices are low**

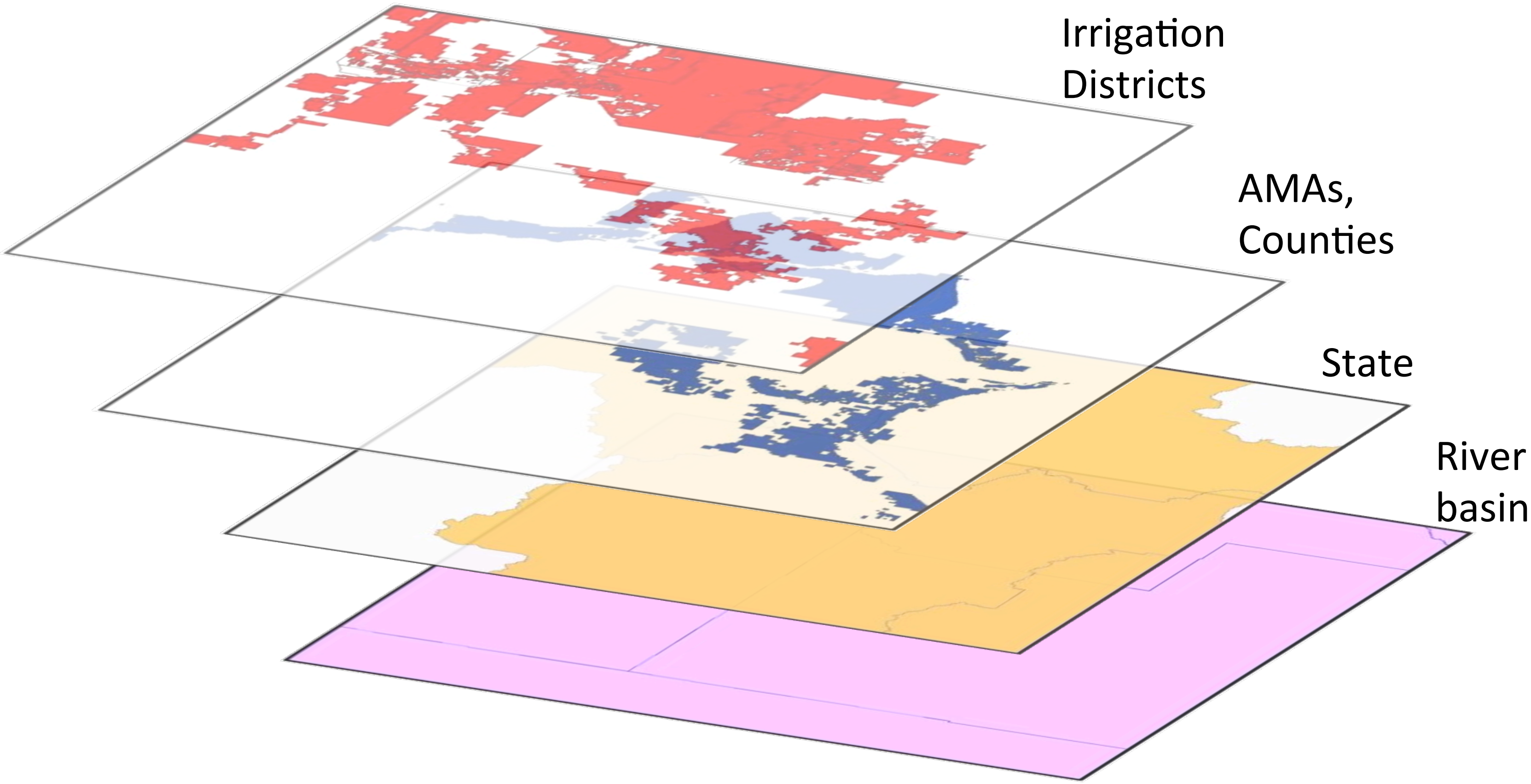
Agricultural Conversion

- Responsive to commodity prices
- Institutions matter

- Need to consider the changes in desert lands conversion versus earlier periods (contrast)

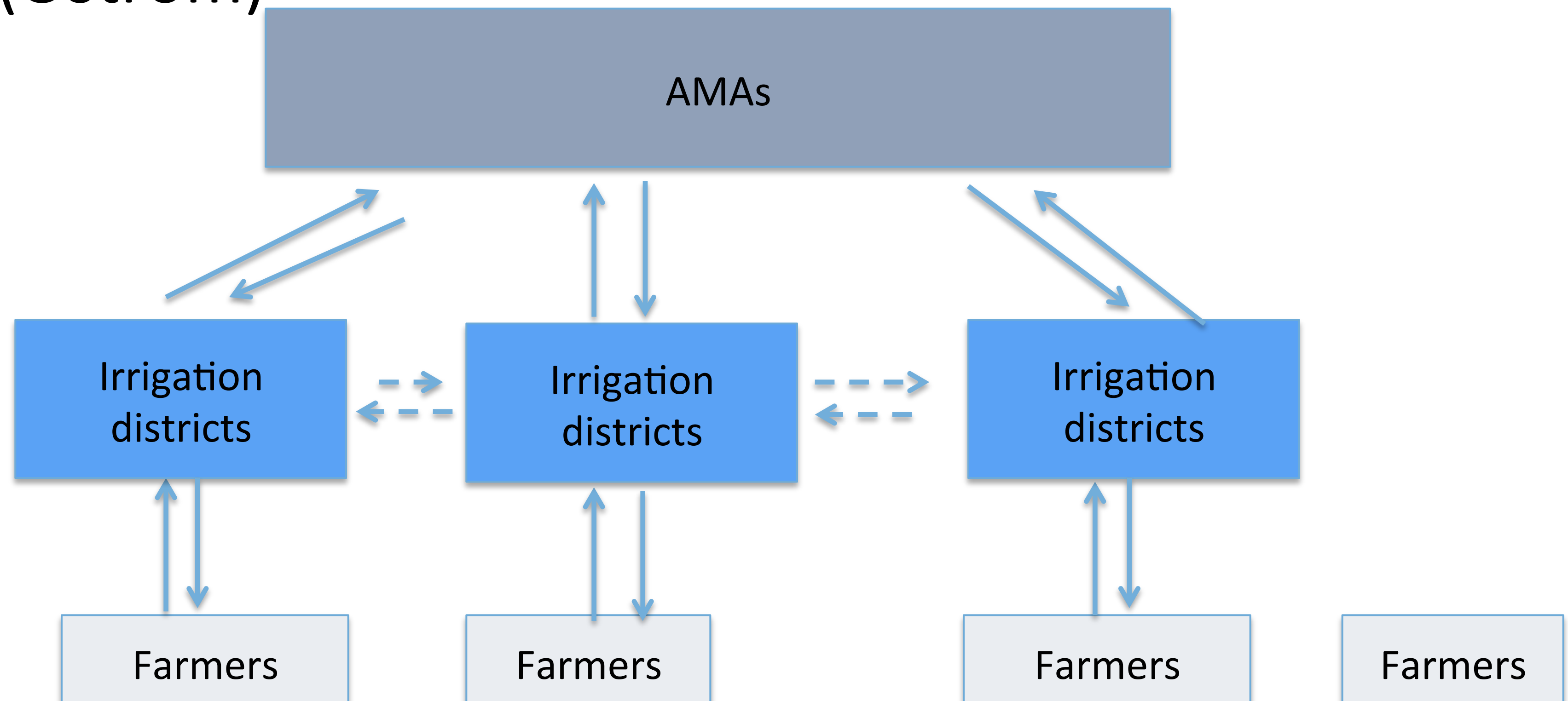
- Better understanding the process may allow intervention
  – But would it improve adaptive capacity and in what ways

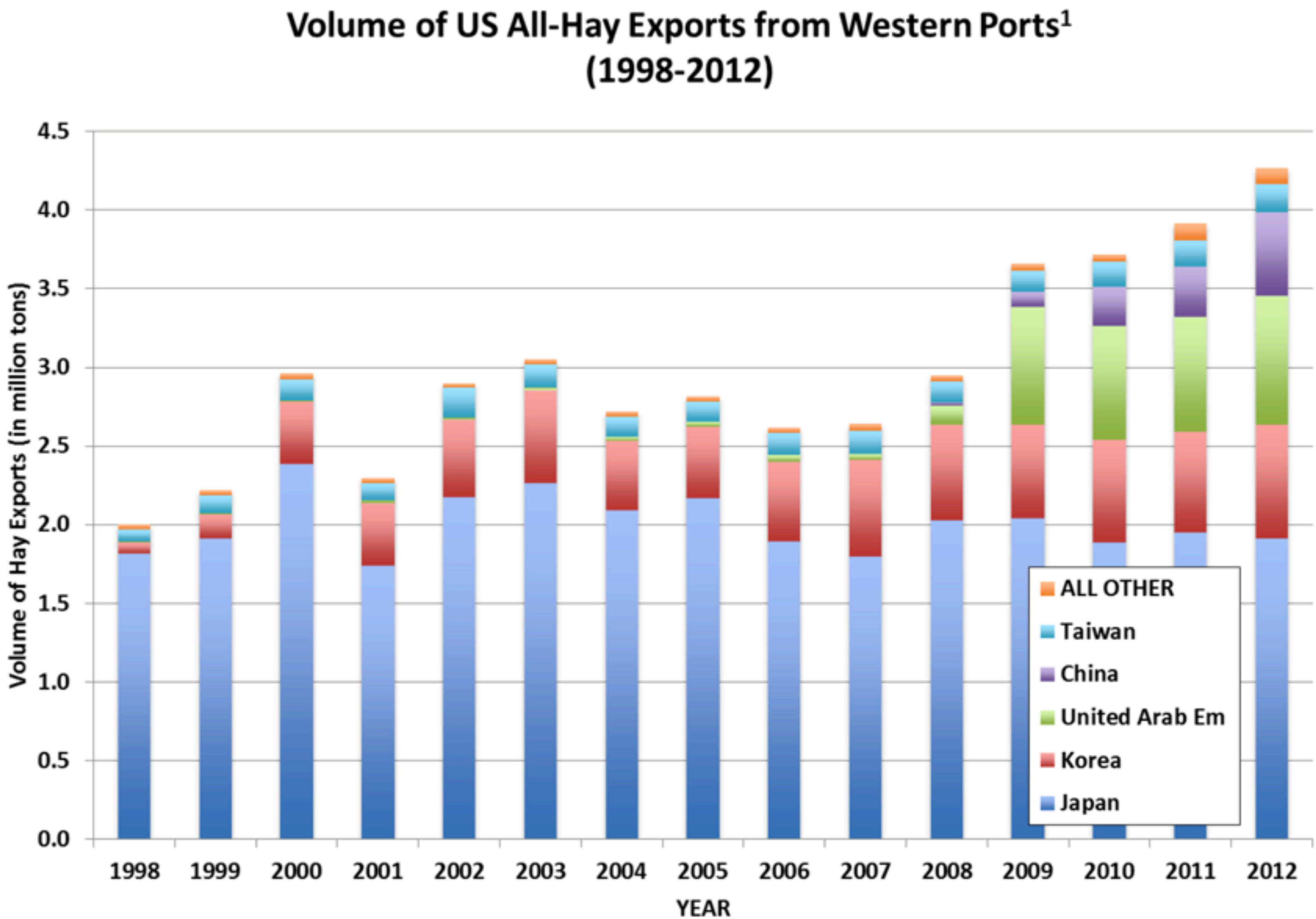
Multi-level structure



Theoretical framework: Polycentric governance

Meaning : governance systems that exist at multiple levels with some autonomy at each level (Ostrom)





[1] Western ports include all ports in California, Oregon and Washinton. Data from US Dept. Commerce.

New Thinking about Food and Cities

- Global food security and declining agricultural land
- Rise of urban agriculture and "locavore" movements
- Burgeoning interest in agricultural multifunctionality

Potential institutions for private-provisioning of public adaptation goods

<table>
<tr><th>Institution</th><th>Privately-provisioned public adaptation good</th></tr>
<tr><td>Incentive
Direct payments, subsidies</td><td rowspan="4">Flexible inter-sector water allocation, amplified recharge, heat island mitigation…
↓
Multifunctional agriculture</td></tr>
<tr><td>Market-based
Purchase of agricultural land, water markets</td></tr>
<tr><td>Technical assistance
Education, portable equipment</td></tr>
<tr><td>Norms of social responsibility
Voluntary gestures of solidarity, empathy, responsibility</td></tr>
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Conclusions

- Advantages of reframing existing and future policy in terms of public provisioning
- Several significant challenges to involving farmers in public adaptation good provisioning
- Need to understand decisions to maintain farmland
- Intersection of these choices with use of water
- Need to integrate farm sector in discussions of urban water policy futures → Defining meaning of *adaptation public good*

Acknowledgements

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- Funding:
  - The National Science Foundation under Grant SES-0951366, Decision Center for a Desert City II: Urban Climate Adaptation. (*all findings presented here are responsibilities of the authors, not of NSF*)
  - National Oceanic and Atmospheric Administration, CSI Award #NA110AR4310123. H. Eakin, PI.
- Generosity of interviewees in agricultural and water sector

TABLE 2: COX PROPORTIONAL HAZARDS MODEL RESULTS

	360m		90m		60m	
Covariate	**Hazard Ratio**	*(Wald $\chi 2$)*	**Hazard Ratio**	*(Wald $\chi 2$)*	**Hazard Ratio**	*(Wald $\chi 2$)*
Log Distance to CBD	0.284	*(1325.41**)*	0.272	*(7526.35**)*	0.284	*(11372.36**)*
Side of Town						
Central (vs. west)	0.5	*(157.19**)*	0.46	*(1476.14**)*	0.468	*(2515.32**)*
Northeast (vs. west)	0.197	*(136.13**)*	0.064	*(517.08**)*	0.054	*(620.09**)*
Southeast (vs. west)	2.66	*(1054.43**)*	2.431	*(6964.41**)*	2.281	*(10924.42**)*
Soil Quality						
Farmland of unique importance	0.303	*(293.44**)*	0.441	*(906.3**)*	0.52	*(1023.57**)*
Not prime farmland	0.582	*(40.45**)*	0.548	*(186.38**)*	0.603	*(217.57**)*
Prime farmland if irrigated	1.269	*(68.19**)*	1.276	*(541.81**)*	1.299	*(1118.74**)*

TABLE 2: COX PROPORTIONAL HAZARDS MODEL RESULTS

	360m		90m		60m	
Covariate	**Hazard Ratio**	*(Wald χ2)*	**Hazard Ratio**	*(Wald χ2)*	**Hazard Ratio**	*(Wald χ2)*
Distance to nearest highway	0.99	*(8.45*)*	0.999	*(0.9)*	1	*(0.13)*
Incorporated (vs. unincorporated)	2.304	*(356.22**)*	6.694	*(19745**)*	10.579	*(44373.3**)*
Number of years since annexed	0.975	*(163.87**)*	0.962	*(4988.29**)*	0.962	*(9155.1**)*

TABLE 2: COX PROPORTIONAL HAZARDS MODEL RESULTS

	360m		90m		60m	
Covariate	**Hazard Ratio**	*(Wald χ2)*	**Hazard Ratio**	*(Wald χ2)*	**Hazard Ratio**	*(Wald χ2)*
Phoenix MSA Home Price Index	1.006	*(226.1**)*	1.008	*(3475.8**)*	1.007	*(5842.69**)*
AZ Alfalfa Hay Price	0.995	*(72.61**)*	0.994	*(866.89**)*	0.993	*(1787.36**)*
Cotton Price (A Index)	1	*(0.15)*	0.999	*(15.59**)*	0.998	*(92.79**)*
Crude Oil Price	0.989	*(149.15**)*	0.987	*(1700.5**)*	0.987	*(3240.12**)*
30-yr Home Mortgage Rate	1.008	*(91.6**)*	0.997	*(128.14**)*	0.995	*(502.36**)*

The development process isn't instantaneous. The decision to develop can take place years before completion, though for houses in Phoenix during the recent boom, it was fairly quick.

TABLE 3: COX MODEL HAZARD RATIOS FOR LAGGED PRICE EFFECTS*

	90m	*60m*	*90m*	*60m*	*90m*	*60m*
	Current Year		**Prior Year**		**Two Years Prior**	
PHX Home Price	1.008	1.007	1.005	1.005	1.002	1.002
Alfalfa Hay	0.994	0.993	0.993	0.992	0.993	0.992
Crude Oil	0.987	0.987	0.983	0.982	0.979	0.978
Mortgage Rate	0.997	0.995	0.991	0.989	0.989	0.987
AIC *(x1000)*	1,331,980	2,525,242	1,333,430	2,527,262	1,332,516	2,524,721

**all results significant at $p<0.001$*

Gasoline Price and Dist. CBD		Home Price & Years Since Annexed	
Gas Price	Dist. CBD Hazard Ratio	Home Price Index	Yrs. Since Ann. Hazard Ratio
$1.26 (min)	0.333	121 (min.)	0.979
$1.53	0.314	170	0.976
$1.88	0.290	220	0.974
$2.55	0.250	270	0.967
$3.12 (max)	0.219	322 (max.)	0.944

*$p<0.05$, **$p<0.001$. 60m resolution model shown.*