Long-term Riparian Forest Change on the Upper San Pedro River

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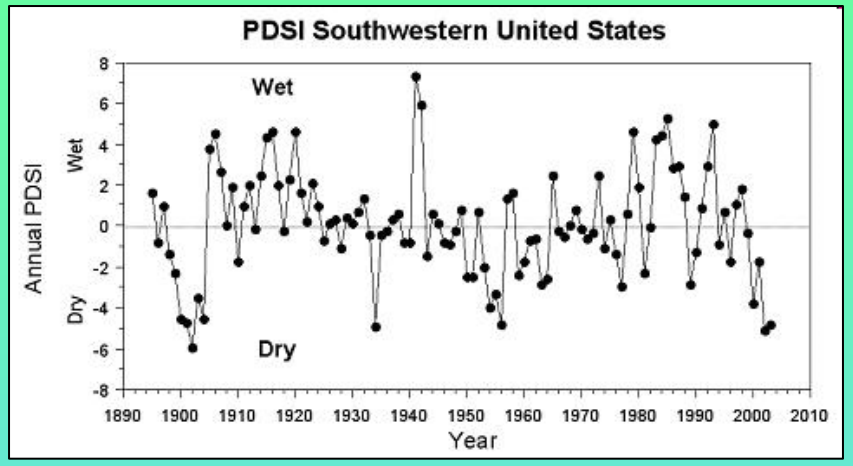
Extreme events exert major influence on ecosystem structure and function

Jentsch, A; Kreyling, J; Beierkuhnlein, C. 2007. A new generation of climate-change experiments: events, not trends. Frontiers in Ecology and the Environment 5: 365-374

The San Pedro River underwent extreme disturbance ca. 1900

Climate extremes:
* Severe drought
* Extreme flooding in late 19th/early 20th century



Intense land use
* High stocking rates
* Woodcutting

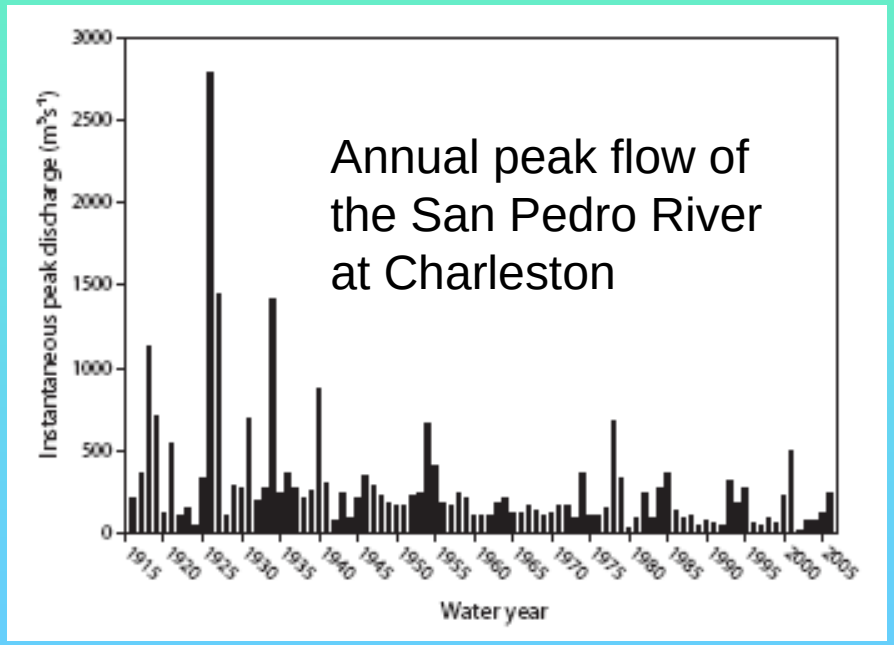
Ely LL, Enzel Y, Baker VR, Cayan DR. 1993. A 5000-year record of extreme floods and climate-change in the southwestern United States. Science 262: 410-412.

Southern Arizona cattle drive, 1900-1910. Arizona Historical Society.

Net effect: Channel entrenchment followed by widening during subsequent large floods.

"It was probably during the 1896 flood that a channel almost 244 m wide and 6 m deep developed…" (Hereford and Betancourt 2009).

Extreme floods



Hereford H, Betancourt JL. 2009. Historic geomorphology of the San Pedro River: Archival and physical evidence. *In* JC Stromberg, B Tellman, eds., *Ecology and Conservation of the San Pedro River*. University of Arizona Press.

Goals and Objectives

Goal: Determine how this past extreme disturbance (flood-induced river entrenchment) and present management practices are interacting to structure riparian forest cover along this semiarid region river.

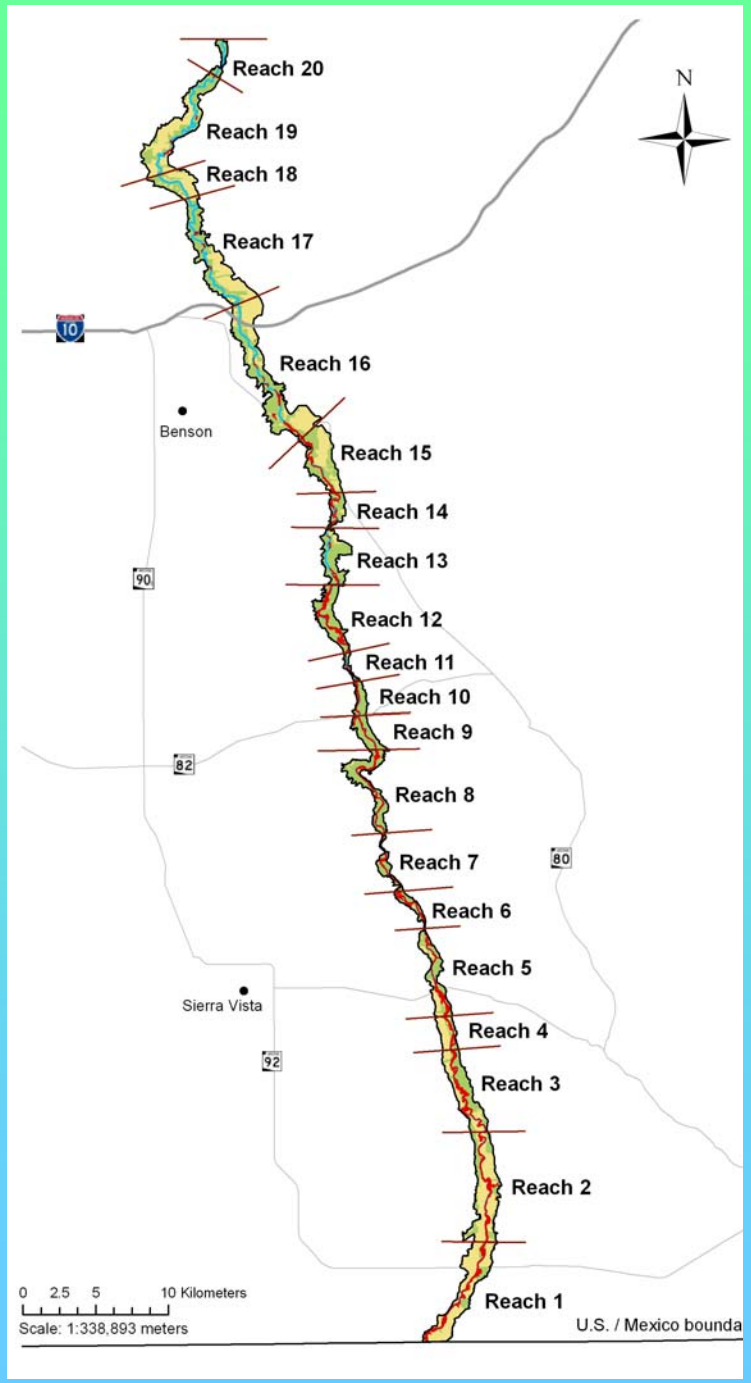
Objectives:

1) assess temporal trajectories of change in forest cover and composition
2) determine how patterns vary over the length of the river
3) contrast patterns between hydrogeomorphic zones

Methods

Study area encompassed the Upper San Pedro River from US/Mexico border to Benson Narrows

Divided into 20 reaches



Methods

Aerial Photography Analysis

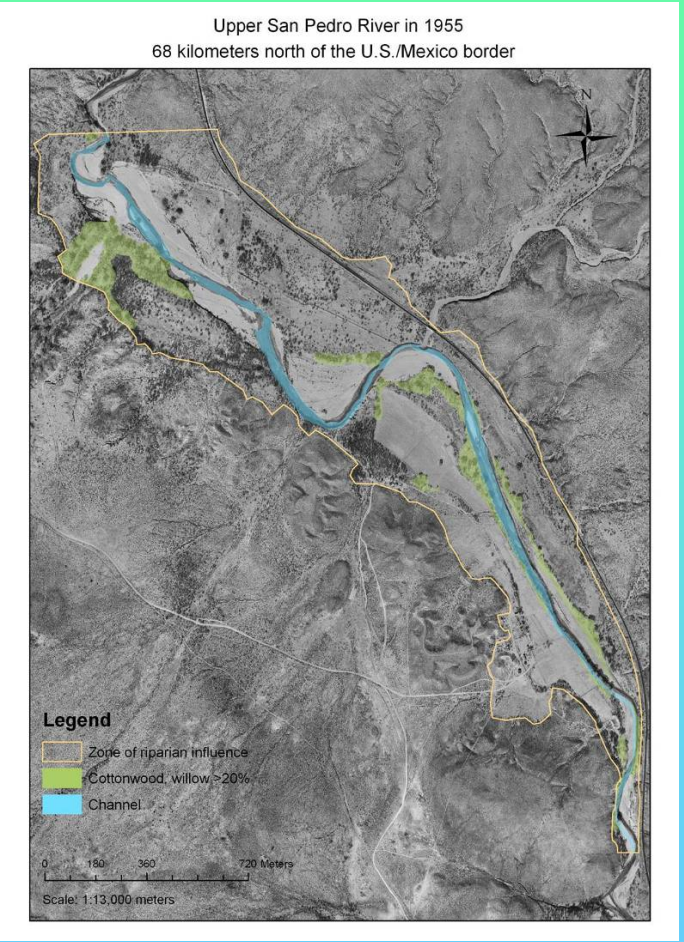
Primary photo series

1955 B&W photos (USDA)

1978 Color photos (USGS)

2003 Color infrared DOQQs

+ Coverage of selected reaches for 1935, 1983/84, and 1996/97.



Aerial Photography Analysis

Geomorphic zones*

Boundaries between channel, floodplain, terrace, and upland delineated using various techniques including LIDAR elevation data.

Polygons

Polygons drawn around homogeneous vegetation patches in ArcMap while viewing images at a scale of 1:3,000. Minimum mapping unit of 10,000 m^2.

Vegetation cover

Percent cover of each cover type visually estimated in polygons using cover classes (0, 1-5, 6-20, 21-40, 41-60, 61-80, and 81-100%), within 20 reaches.

*Floodplain and channel = post-entrenchment surfaces
River terraces = pre-entrenchment surfaces

Methods

Cover Types

Cover type	Description
Populus/Salix forests	Tall, broadleaf forests of *Populus fremontii* with sub-dominant *Salix gooddingii*. Minor occurrences of *Fraxinus velutina* and *Celtis reticulata*.
Shrubland/ woodland	On floodplains, **primarily** *Tamarix sp.* **and** *Prosopis velutina*. Also includes smaller shrubs (*Baccharis* spp*., Hymenoclea monogyra*, *Ericameria nauseosa).* On terraces, *Prosopis velutina* with lesser amounts of *Acacica constricta* and *Acacia greggii*. Also includes smaller shrubs (*Atriplex canescens, Isocoma sp*., *Ziziphus obtusifolia)*.
Grassland	On floodplains, various grasses including *Cynodon dactylon*, *Sorghum halepense*, *Sporobolus* spp., and forbs. On terraces, primarily *Sporobolus* grasslands. Also includes cienega wetlands.
Bare ground	Bare sediment in channel or unvegetated soil (also includes water).
Agricultural fields	Active (irrigated) and recently abandoned fields.
Urban/infastructure	Buildings, roads, railroads.
Dead trees	Cover type discernable only on 1978 and 2003 photos.

Data Analysis

Accuracy assessment

Classification accuracy for the 2003 photos assessed by comparing photo data to field data collected at 60 randomly selected points (25-m radius).

Spatial patterns: Reach analysis

The area of each cover type within each reach calculated by summing the products of cover-class midpoint for each polygon and the polygon's relative area.

Temporal patterns: Transition tables

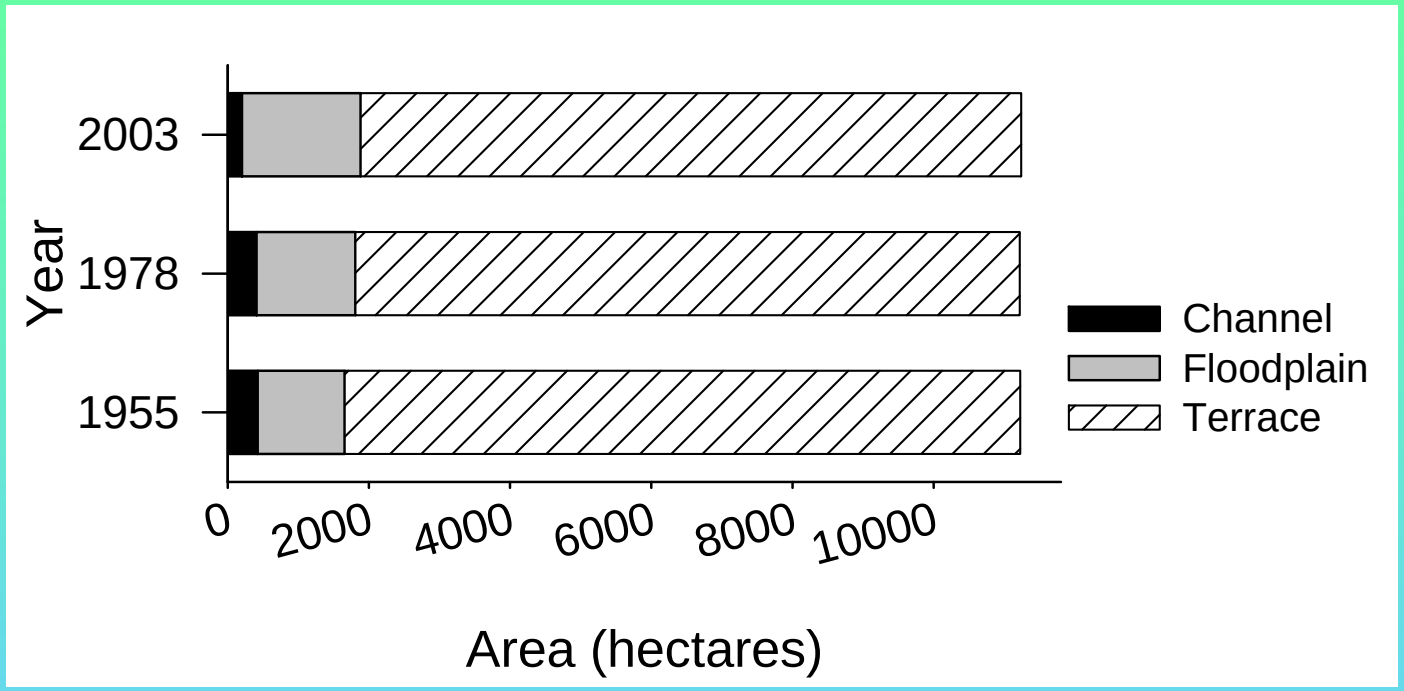
1001-point grid generated in ArcMap to determine cover type transitions between photo years.

Results

Outline

Geomorphic change
Vegetation change in channel/ floodplain zone (post-entrenchment surfaces) - Whole river - By reach
Vegetation change in terrace zone (pre-entrenchment surfaces) - Whole river - By reach
Vegetation change in entire riparian zone

Results: Hydrogeomorphic zones



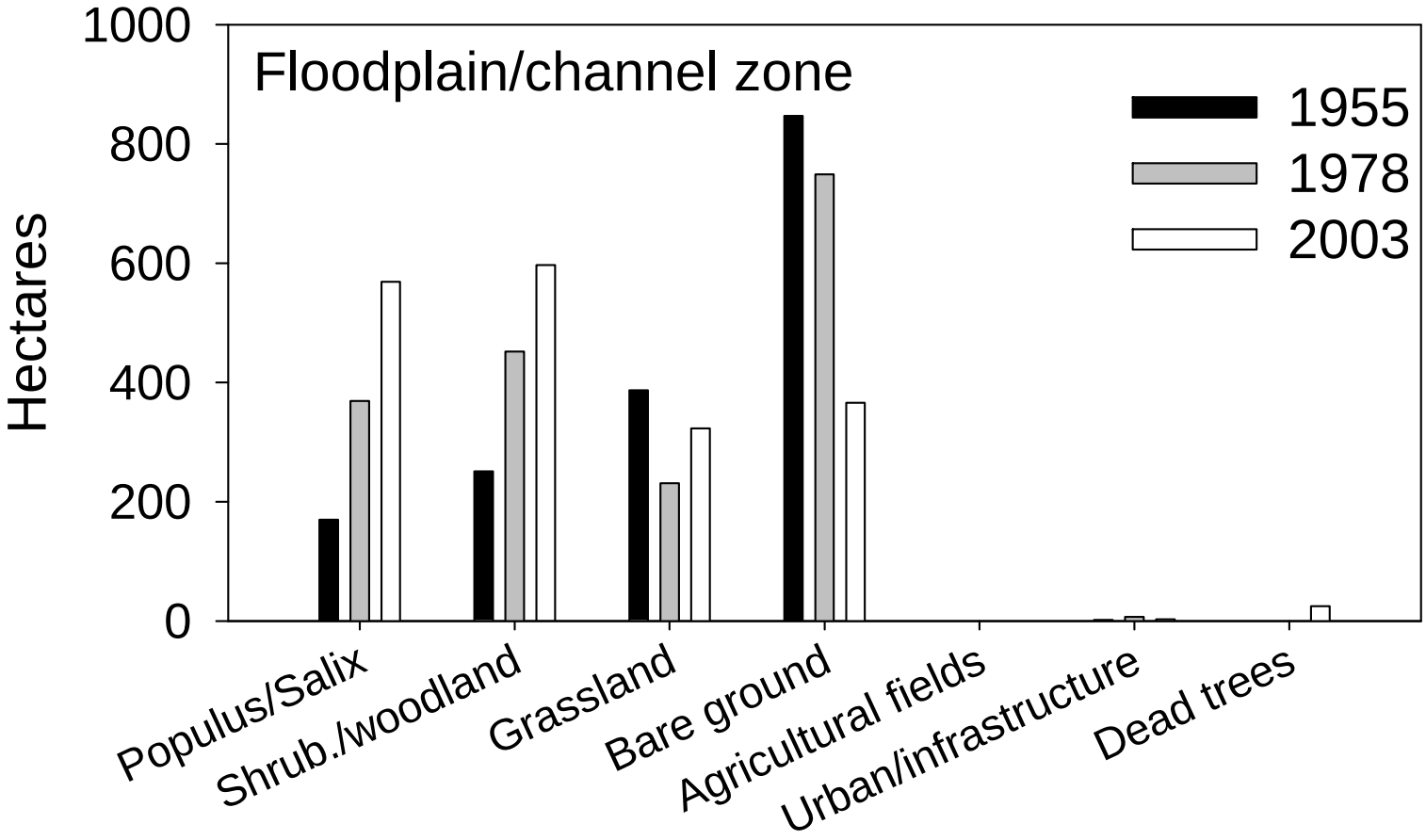
Highlights:

Low-flow channel has narrowed

Floodplain/channel zone collectively has widened

Post-entrenchment zone has declined slightly, as floods have eroded the terrace walls

Results: Vegetation in floodplain/channel



Highlight: Marked expansion of woody vegetation and decline of bare ground

Results: Vegetation in floodplain/channel

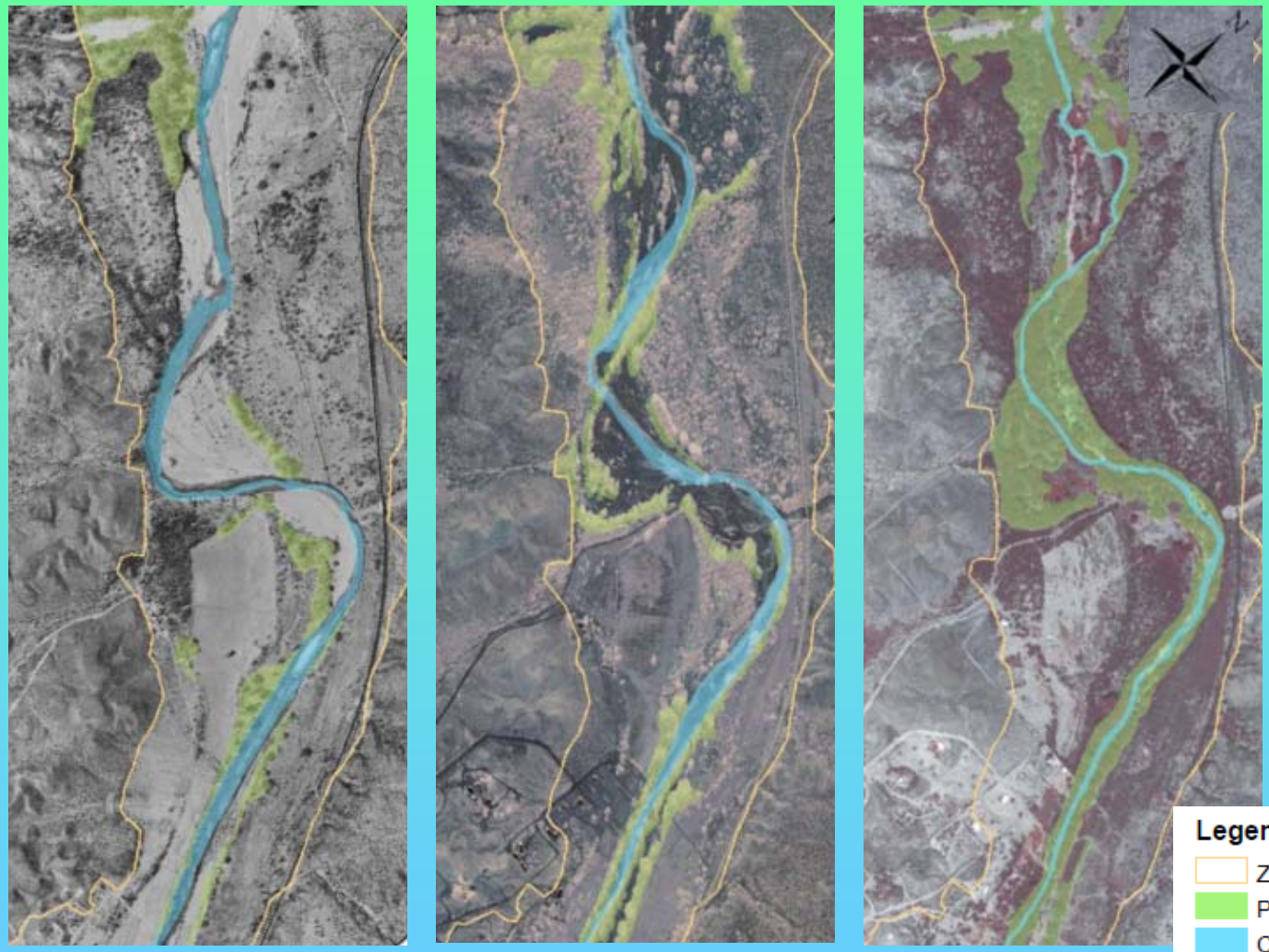
Cover type origin table:
The percentage of points mapped in 2003
that arose from cover types as mapped in 1955

	Status in 2003				
	Populus Salix	Shrub./ wood.	Grass-land	Bare ground	Farm +urban
Status in 1955					
Populus/Salix	15%	3%	7%	9%	0%
Shrub./wood.	10%	46%	4%	23%	0%
Grassland	19%	22%	41%	18%	0%
Bare ground	56%	29%	48%	50%	0%
Farm + urban	0%	0%	0%	0%	0%
Sum	100%	100%	100%	100%	100%

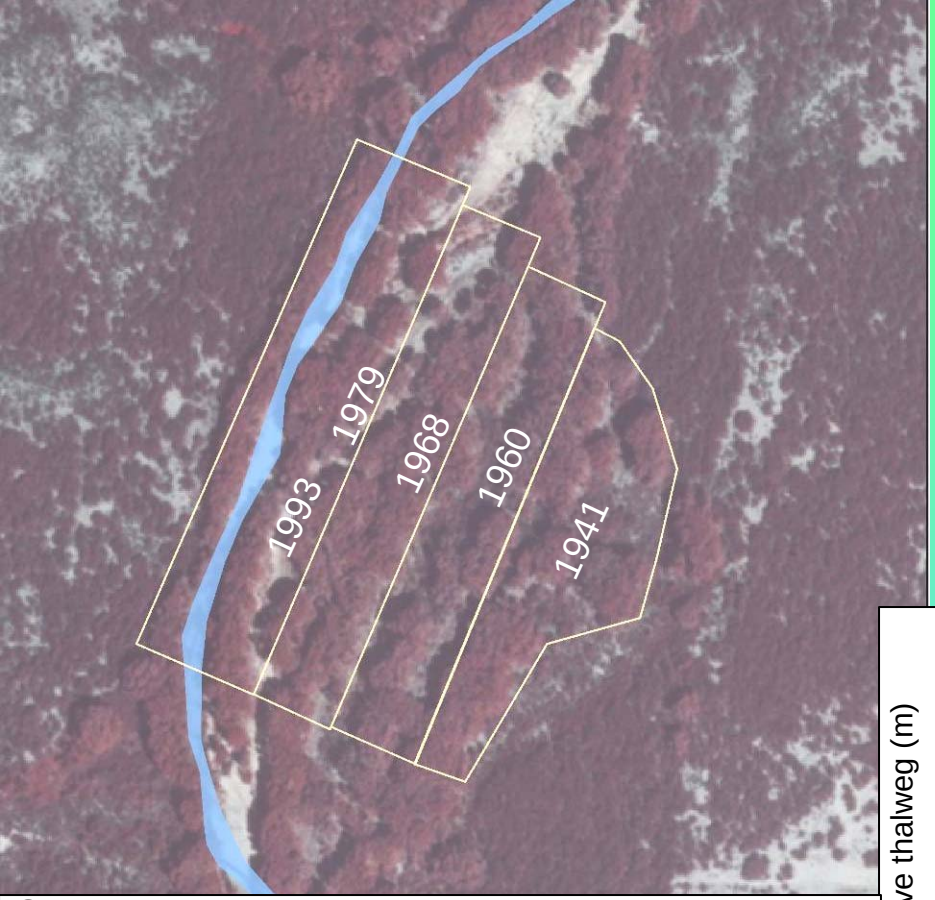
Highlight: Most *Populus/Salix* originated from bare ground (including channel sediments)

Results: Vegetation in floodplain/channel

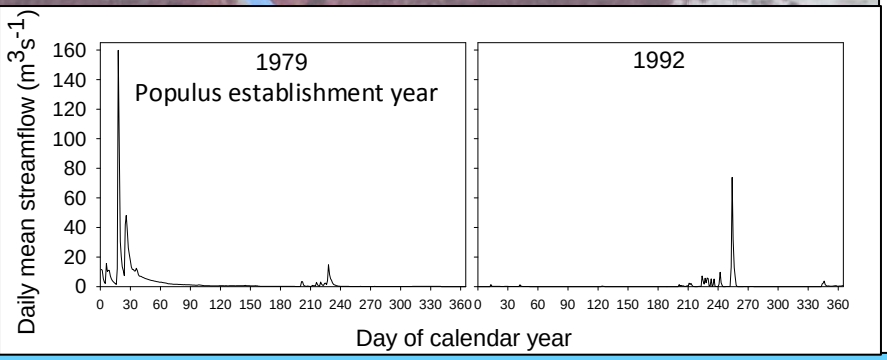
1955 1978 2003

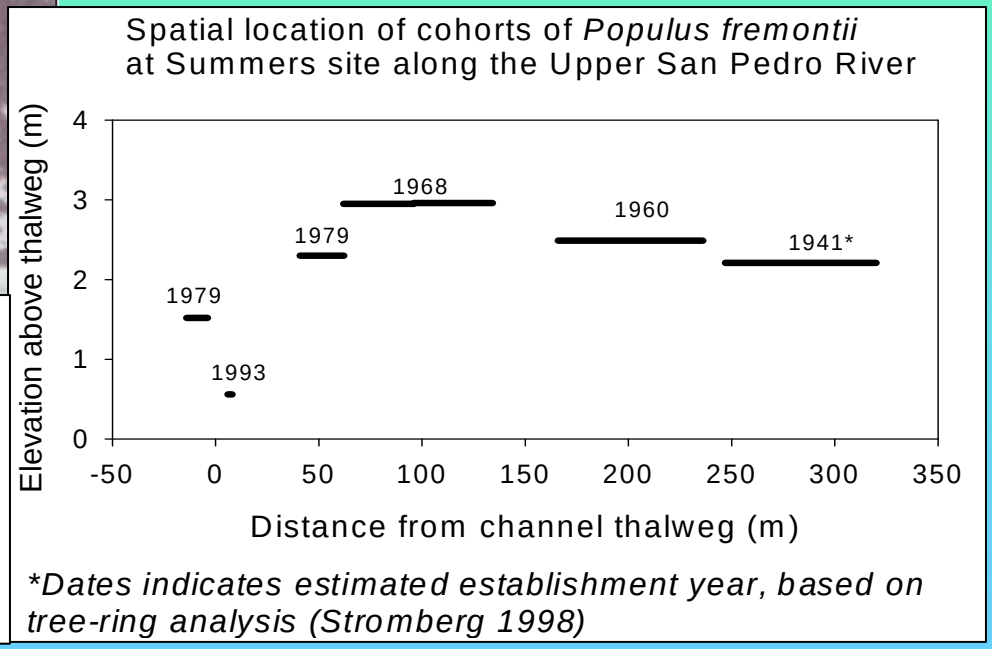


Highlight: Expansion of cottonwood forests,
decline of bare ground, narrowing of channel



Feedbacks between vegetation and geomorphic processes:
As forest density increased, flood intensity decreased, allowing further vegetation infill.



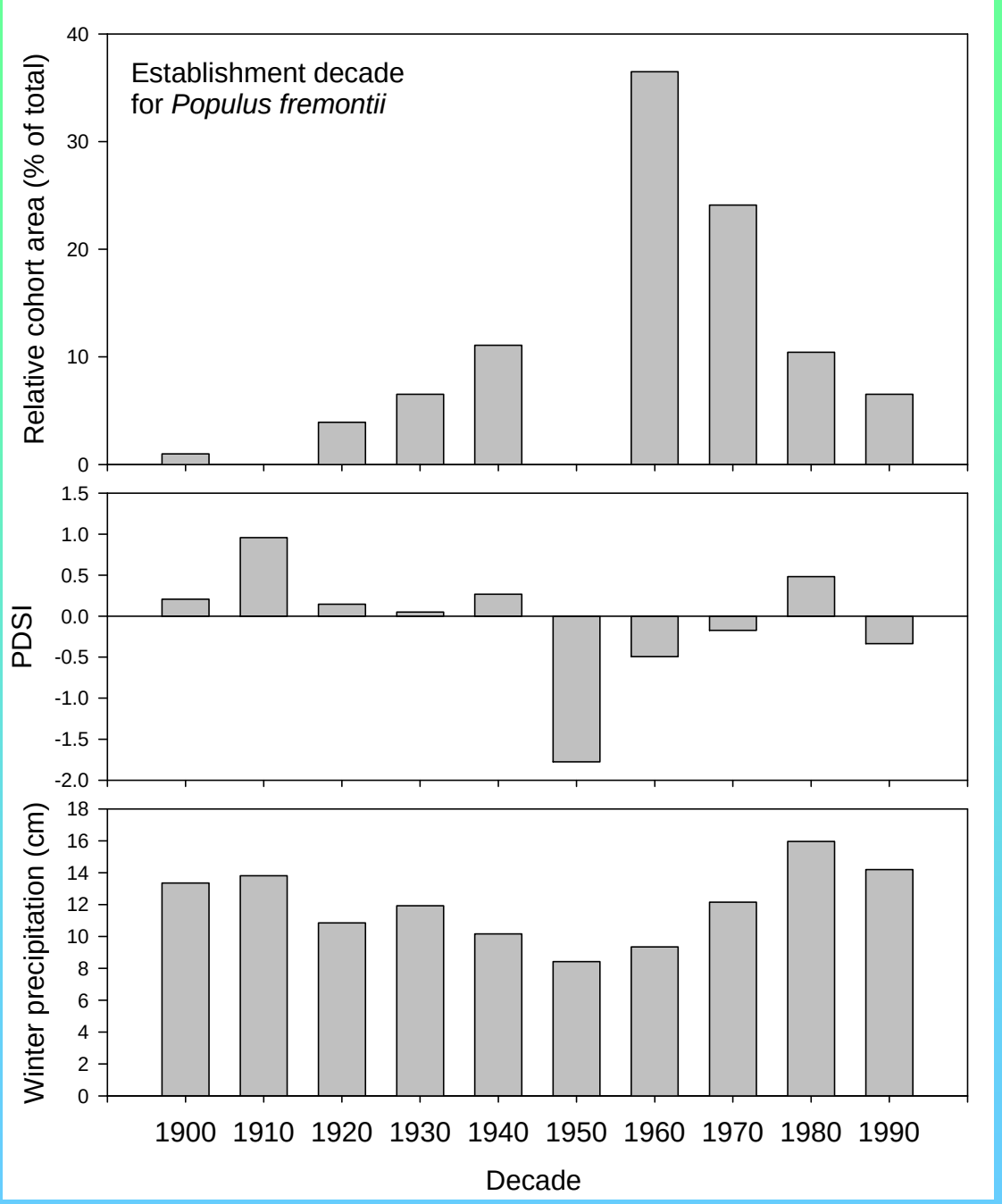


Pioneer trees have sequentially established during years with suitable flood conditions.

Available recruitment area is declining:

Despite high recent *frequency* of suitable flood years, the *area* of recents recruits is small. Young *Populus* cohorts form narrow bands that line and stabilize the channel.

The width of *Populus* recruitment bands peaked in 1960 and then narrowed.

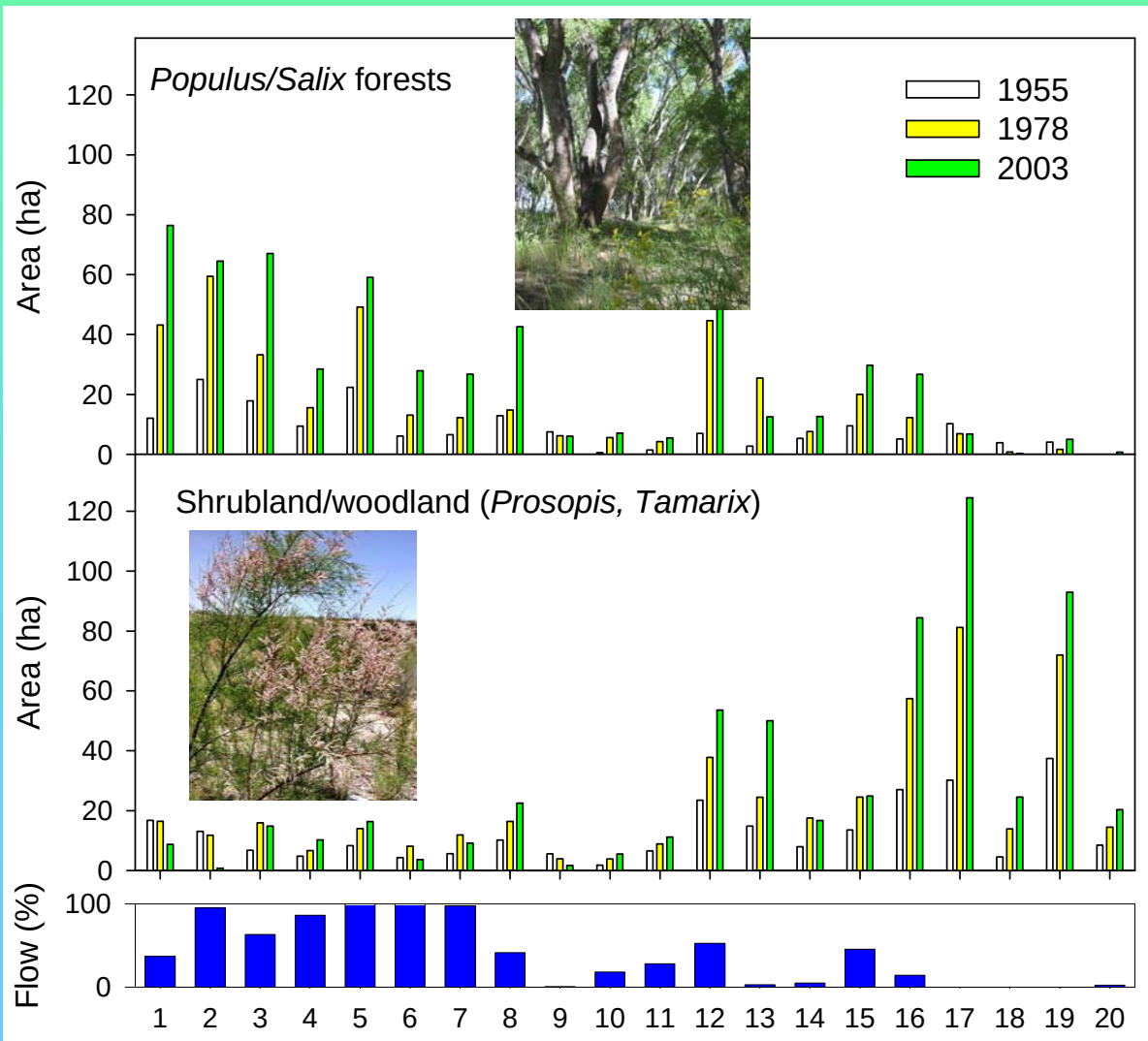


Stromberg, J. (1998) Dynamics of Fremont cottonwood (*Populus fremontii*) and saltcedar (*Tamarix chinensis*) populations along the San Pedro River, Arizona. *Journal of Arid Environments,* 40, 133-155.

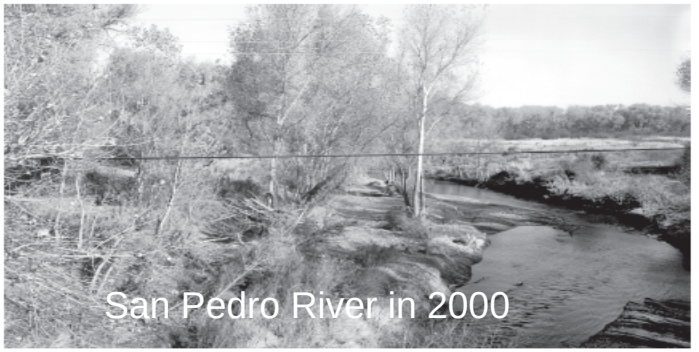
Results: Spatial patterns in floodplain

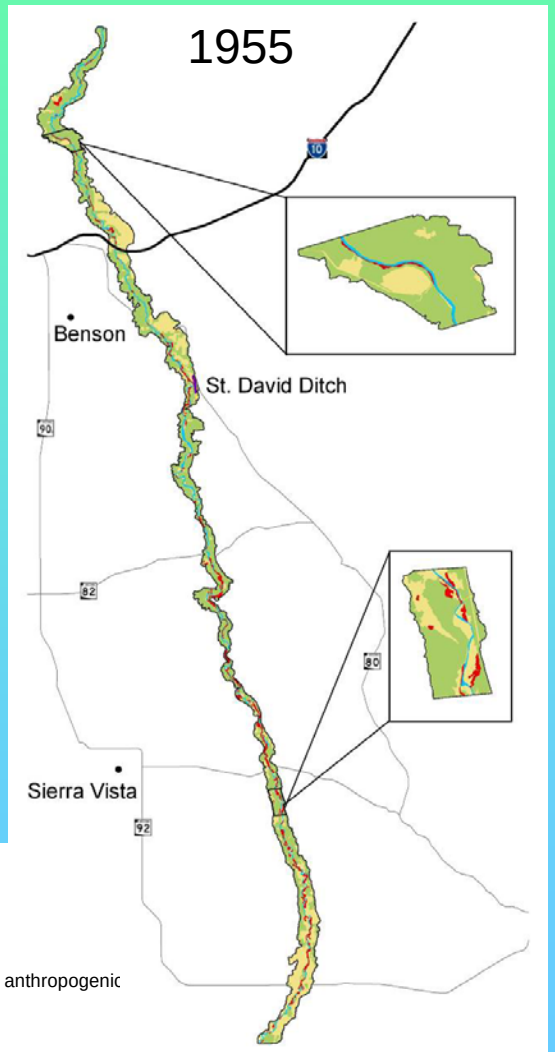
Highlight: Water availability has influenced spatial patterns of woody expansion.

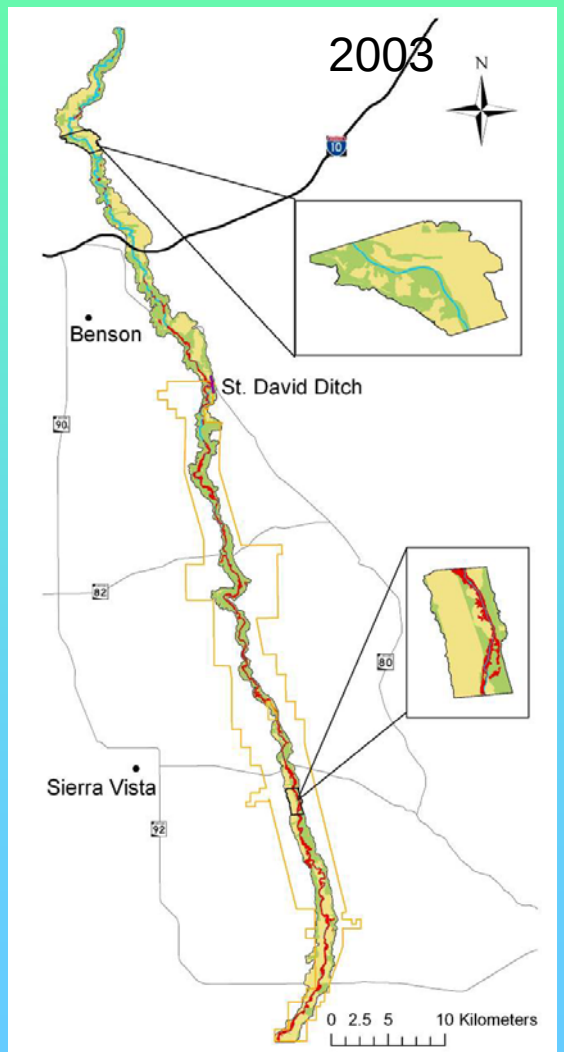
Populus/Salix had greatest increase in wetter reaches; *Tamarix/Prosopis*, deep-rooted facultative phreatophytes, had greatest increase in drier reaches.



Reaches 1-14 are in Conservation Area. Reaches 1-10 are in Sierra Vista sub-watershed.
Flow % = percent of reach with perennial flow in 2007/2008, based on data from TNC





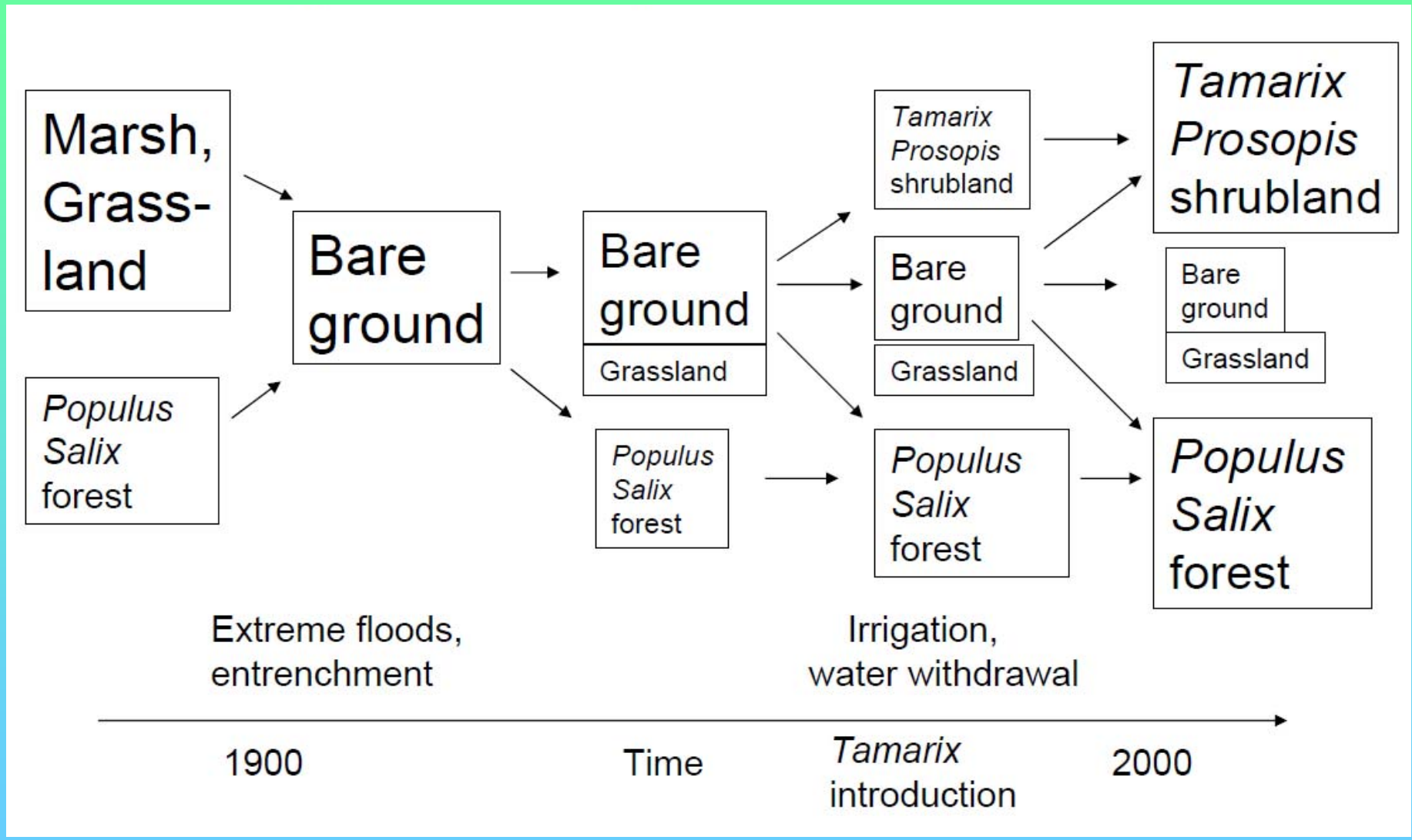


Although *Populus-Salix* increased in most reaches, it declined in 3 dry northern reaches

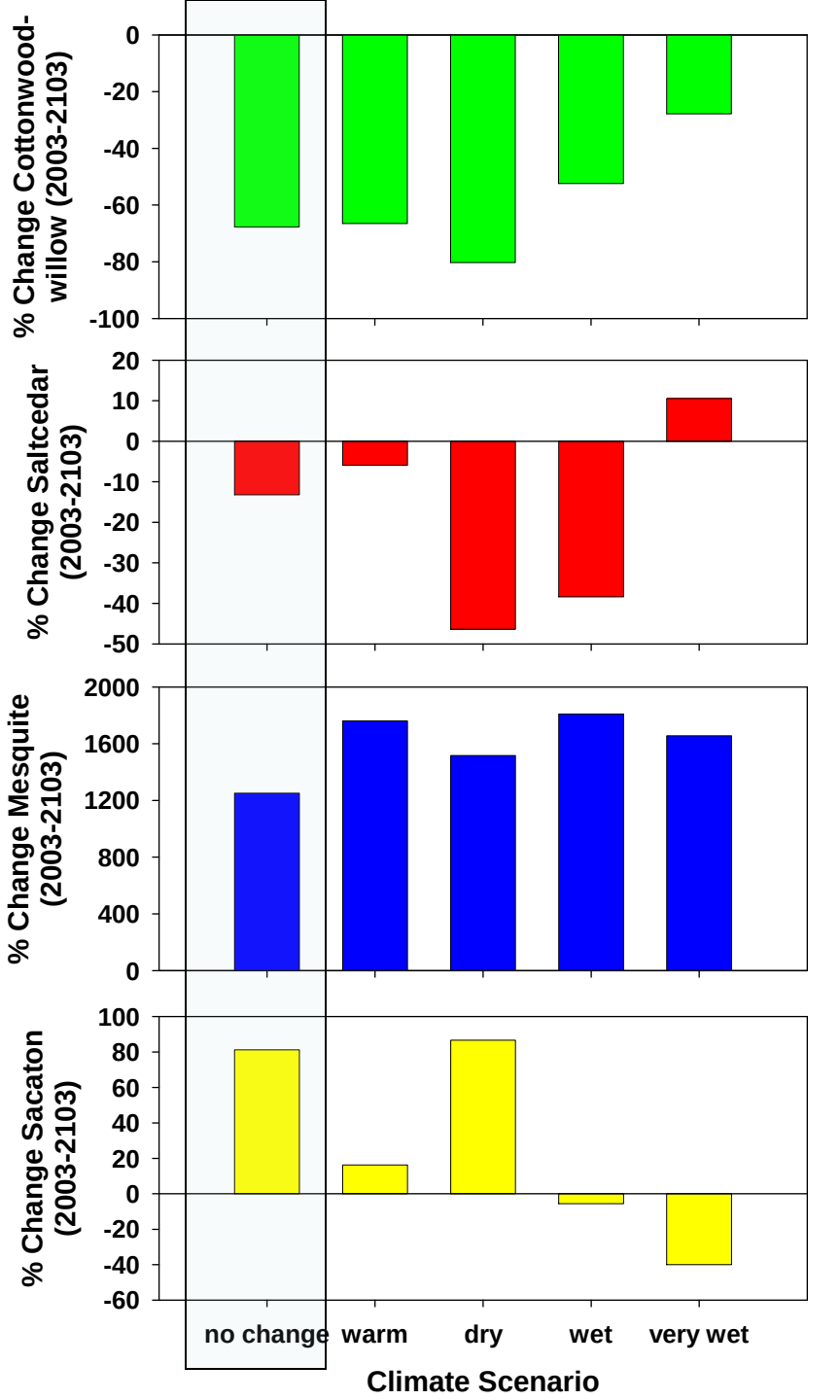
Legend

- Populus/Salix
- Shrubland/woodland
- Grassland, bare ground, anthropogenic
- Channel boundaries
- St. David Ditch

Hypothesized primary transitions on post-entrenchment surfaces



Modeling studies indicate that, barring extreme disturbance, pioneer forests and shrublands will senesce over the next century, giving way to late-successional *Prosopis* forest and *Sporobolus* grassland (Dixon et al. 2009).



Dixon MD et al. 2009. Potential effects of climate change on the upper San Pedro riparian ecosystem. *In* JC Stromberg, B Tellman, eds., *Ecology and Conservation of the San Pedro River*. University of Arizona Press.

Cases of progressive increases in pioneer forest area following extreme disturbance exist on other western North American rivers; changes occur over time scales from decadal to centennial.

What influence has livestock grazing had on forest processes? We speculate that grazing has prolonged the successional cycle by maintaining the system in a disturbed state.

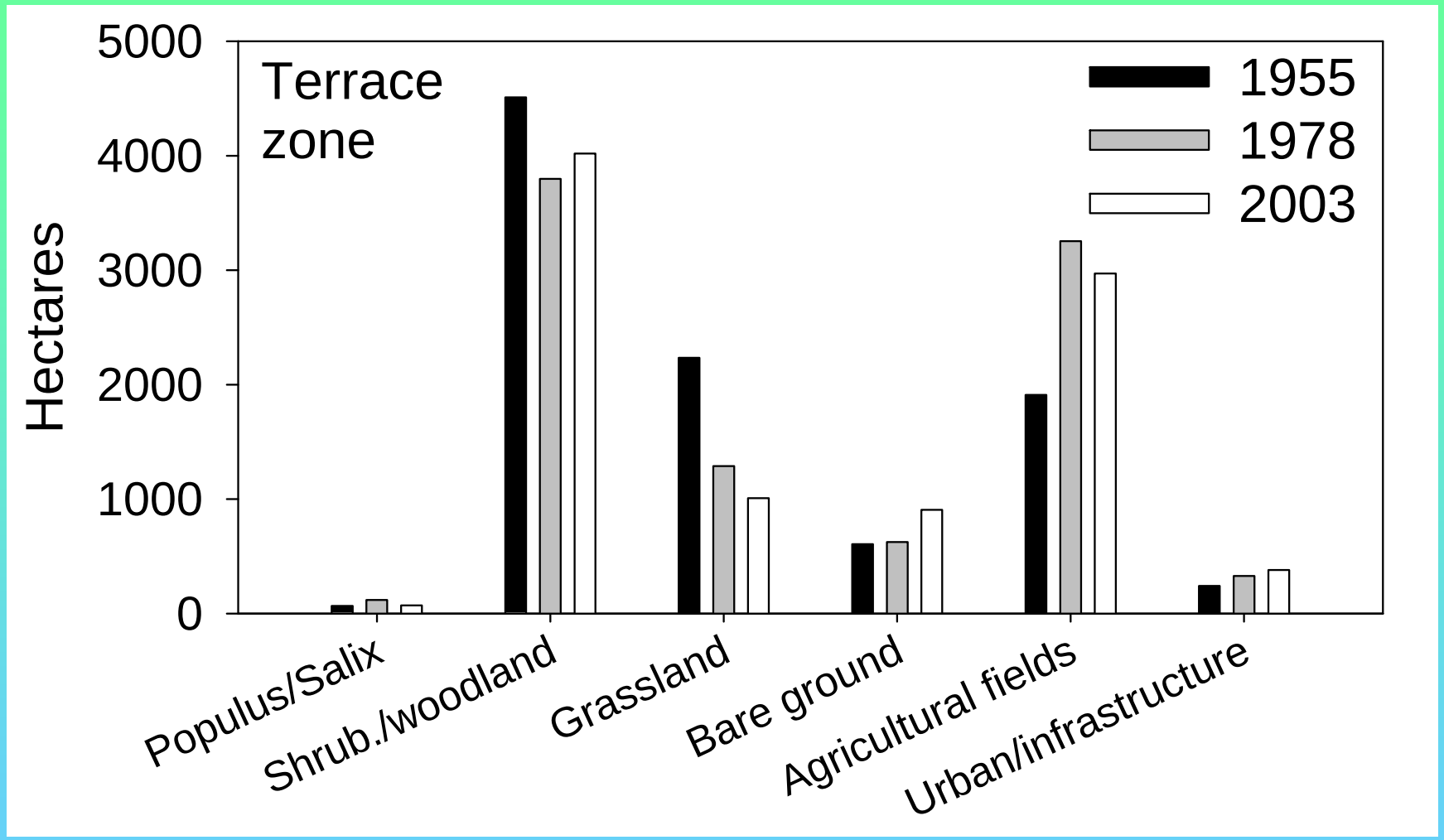
Cordes LD, FMR Hughes, M Getty 1997. Factors affecting the regeneration and distribution of riparian woodlands along a northern prairie river: the Red Deer River, Alberta, Canada. Journal of Biogeography 24:675-695.

Friedman JM, WR Osterkamp, WM Lewis. 1996. Channel narrowing and vegetation development following a Great Plains flood. Ecology 77:2167-2181.

Katz, GL; Friedman, JM; Beatty, SW. 2005. Delayed effects of flood control on a flood-dependent riparian forest. Ecological Applications 15: 1019-1035.

Turner RM. 1974. Quantitative and historical evidence of vegetation changes along the Upper Gila River, Arizona. USGS Professional Paper 655H.

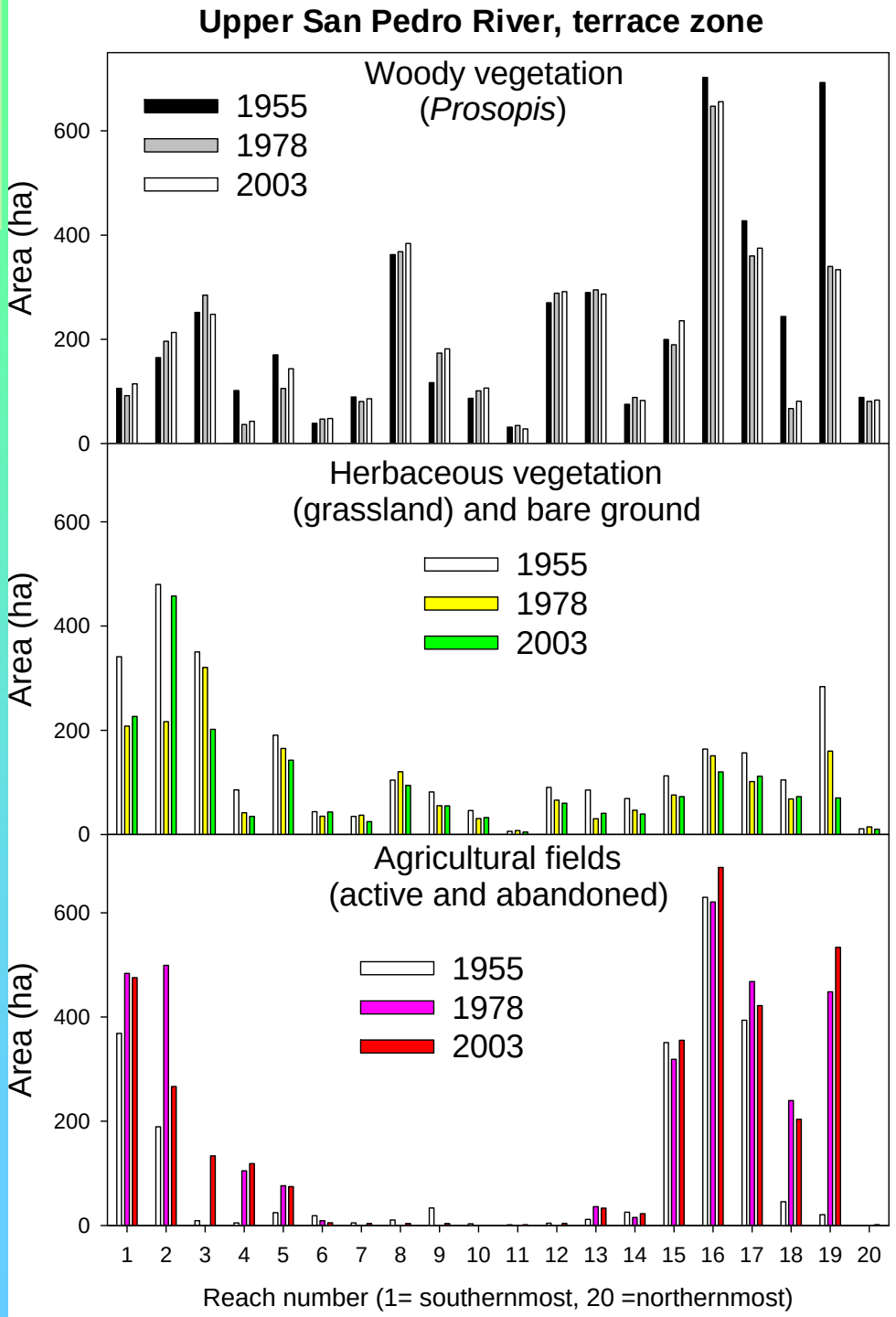
Results: Vegetation on terraces



Highlights: Riparian grasslands show sustained decline.
Prosopis shows decline followed by increase.
Farm fields show increase followed by decrease.

Results: Vegetation on terraces

In many reaches, woody vegetation declined slightly from 1955 in 1978 as forests were converted to farmland but increased from 1978 to 2003 as *Prosopis* established on fallowed fields.



Results: Vegetation on terraces

Cover type transition table

	Status in 1955					
	Pop/ Sal	Shrub./ wood.	Grass- land	Bare ground	Farm- land	Urban /inf.
Status in 2003						
Pop/Sal	0%	1%	1%	0%	0%	0%
Shrub./wood.	55%	69%	26%	55%	12%	43%
Grassland	9%	7%	27%	17%	2%	14%
Bare ground	18%	4%	9%	14%	3%	5%
Farmland	18%	20%	35%	14%	77%	10%
Urban/inf.	0%	0%	1%	0%	7%	29%
Sum	100%	100%	100%	100%	100%	100%

Highlight: 35% of riparian grasslands present in 1955 became farm, 26% became *Prosopis*, 27% remained as grassland.

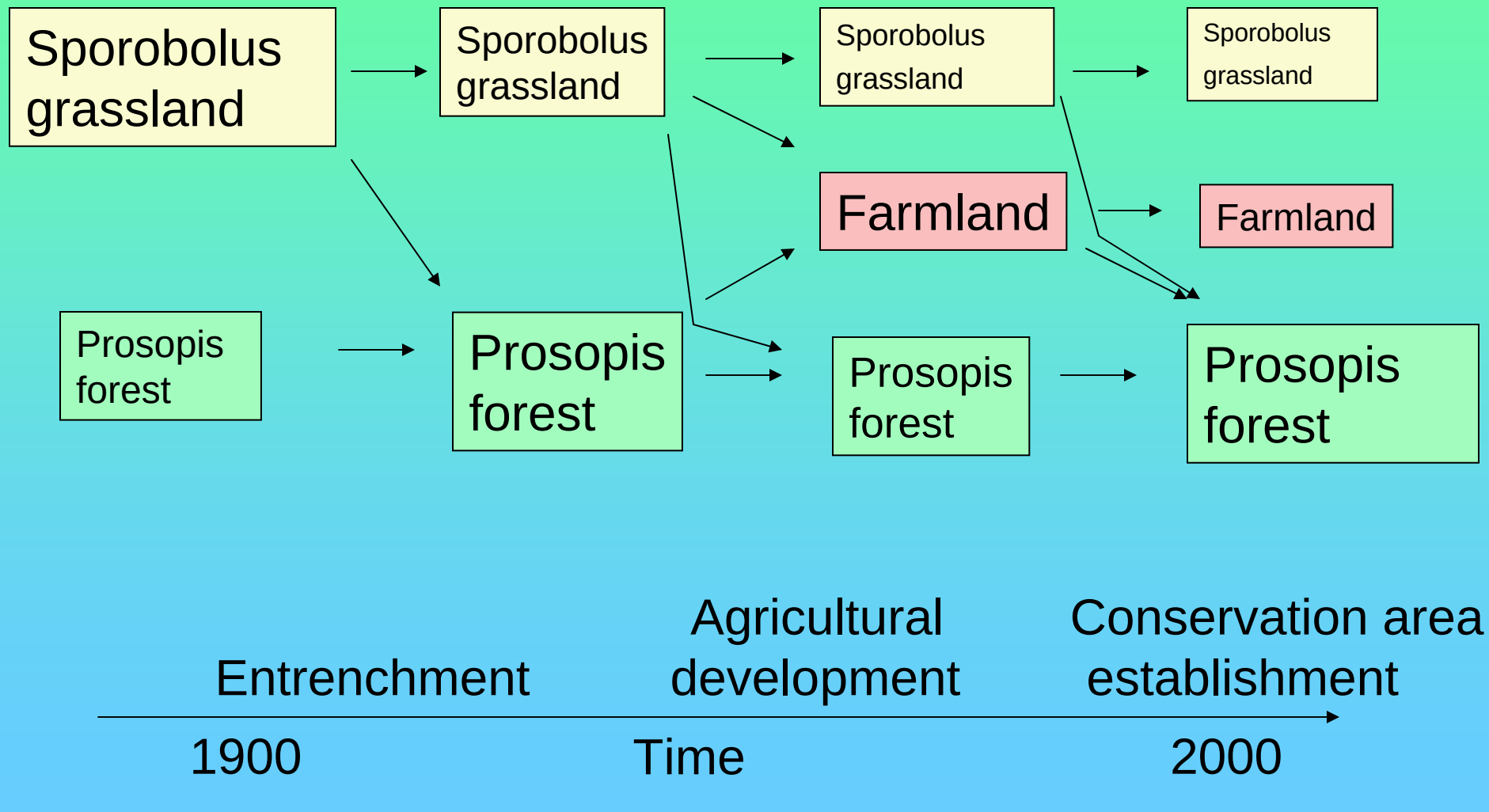
Some *Sporobolus* terrace grassland remnants survived entrenchment.

Some grasslands converted to *Prosopis* following entrenchment

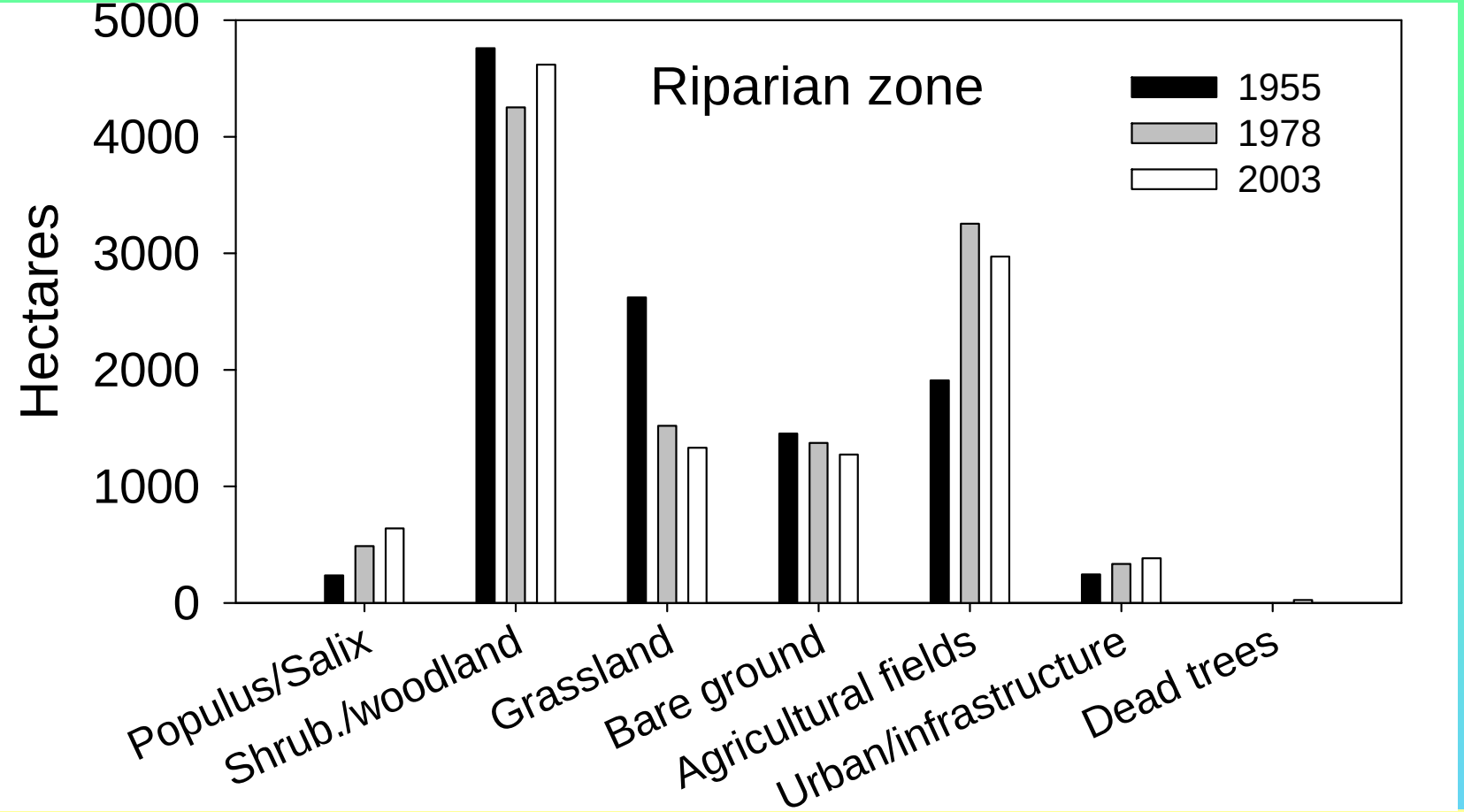
During the mid-1900s, many grasslands and forests were converted to agricultural fields.

Prosopis is establishing on the fields in the Conservation Area that have been fallowed.

Hypothesized transitions on terrace (pre-entrenchment surfaces)



Results: Vegetation in riparian zone



Highlights: The dynamics of change on the pre-entrenchment surfaces swamp those in the (smaller) post-entrenchment zone. Despite large increases in *Populus-Salix* in the floodplain, woody vegetation for the riparian zone as a whole showed a net increase of only 5% from 1955 to 2003.

CONCLUSIONS

Riparian forest landscape patterns are a product of interaction between present-day land and water use practices and of past events that set in motion long-term trajectories of change.

Long-term (decadal to century-scale) fluctuations in pioneer forest area, and in recruitment rates, are common in desert rivers.

Provides river managers with a long-term perspective about the rates and types of riparian vegetation change.

APPLICATIONS

Data can be used to help estimate time-series of riparian ET (evapotranspiration) rates.

These data then can be used to refine hydrologic models and hydrologic budgets, by incorporating more accurate ET rates for model time steps.

ACKNOWLEDGMENTS

Funding sources:
-USDA-Agricultural Research Service
-Sustainability of semi-Arid Hydrology and Riparian Areas
-EPA STAR Global Change Ecosystems Research Program

Photo credits:
Bisbee Mining and Historical Museum, BLM, Dominic Oldershaw, Liz Makings, Ron Tiller, Russ Scott, Julie Stromberg

Field or lab assistance:
Hoori Ajami, Jon Anderson (UA) and Mark Dixon (ASU) for photo georectifying; Jackie Betsch and Natalie Case (ASU) for field assistance

Site access:
US Bureau of Land Management and private landowners