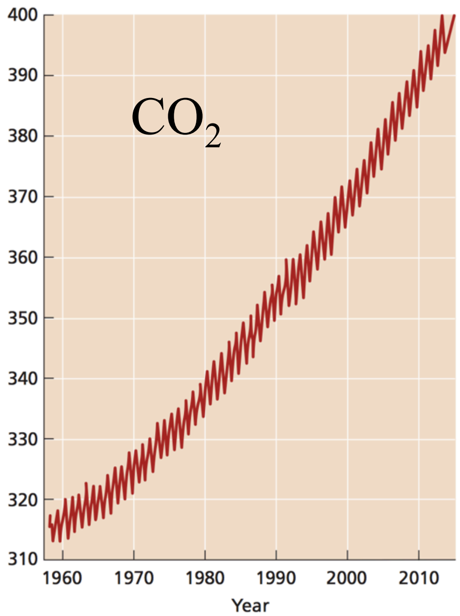
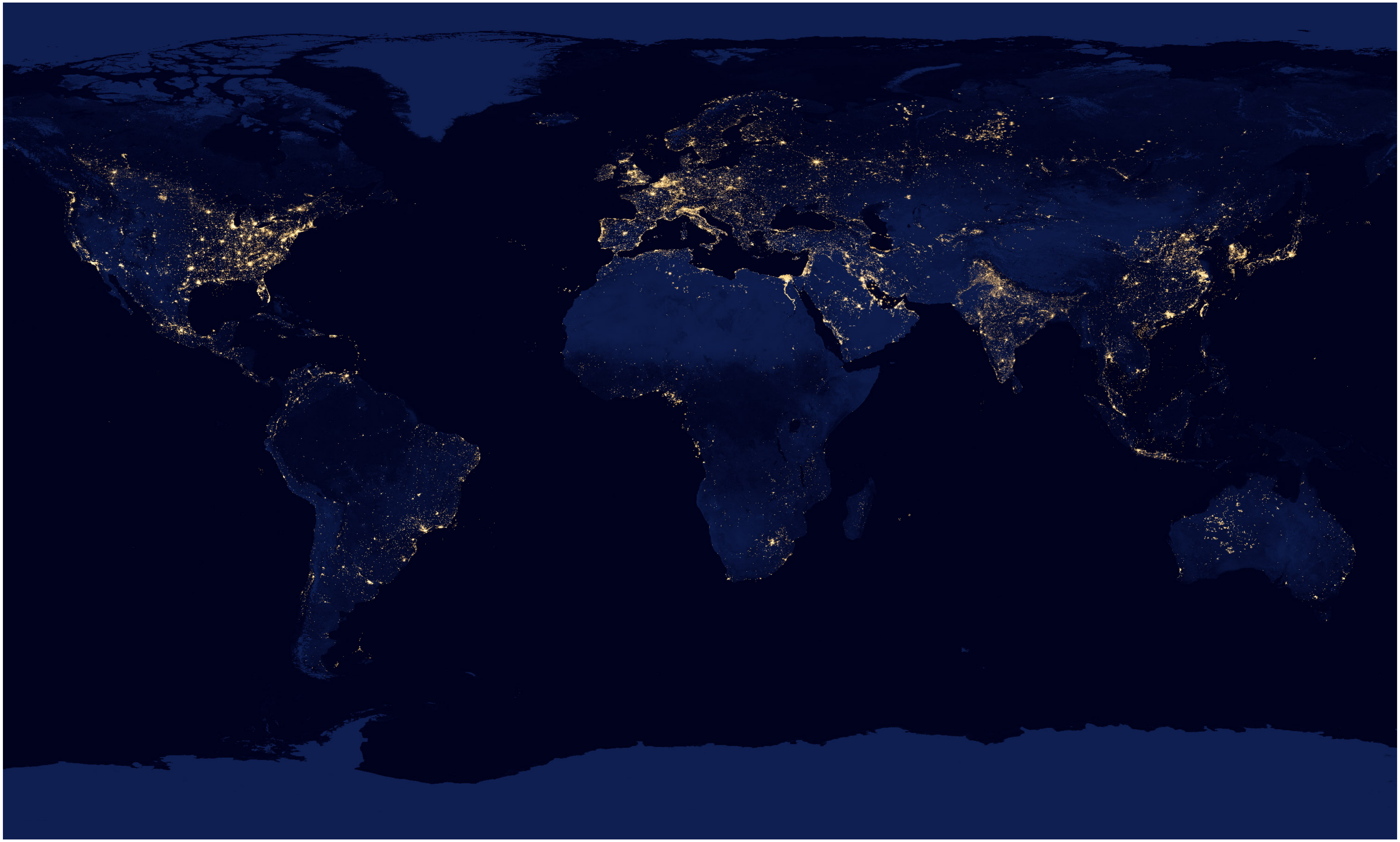



# Urban ecosystems: ecology in a human-built environment

Plant Ecology in a Changing World

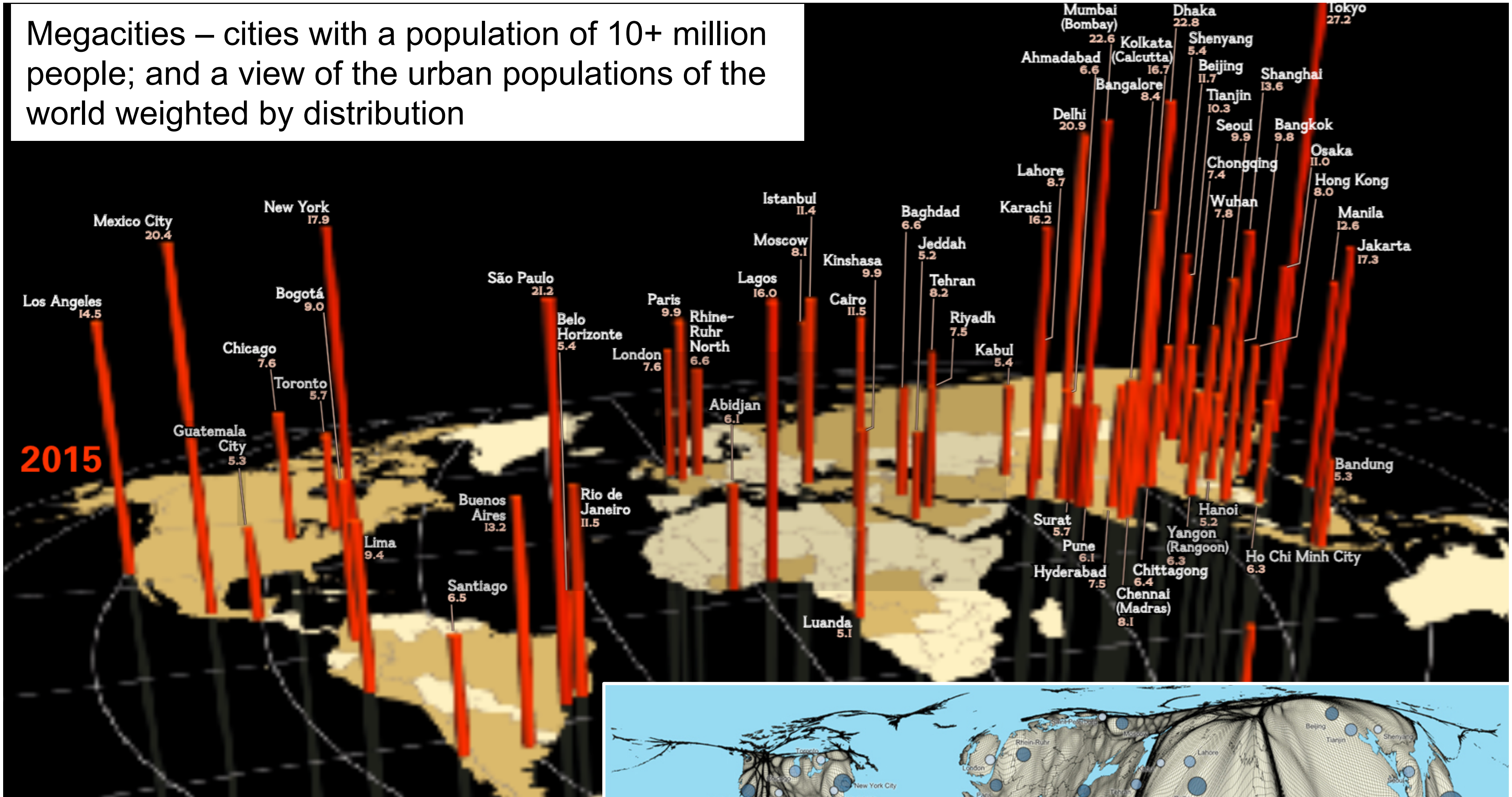

Jim Ehleringer, University of Utah
http://plantecology.net


# Urban and rural ecosystems: human impacts on the landscape



December 7, 2012

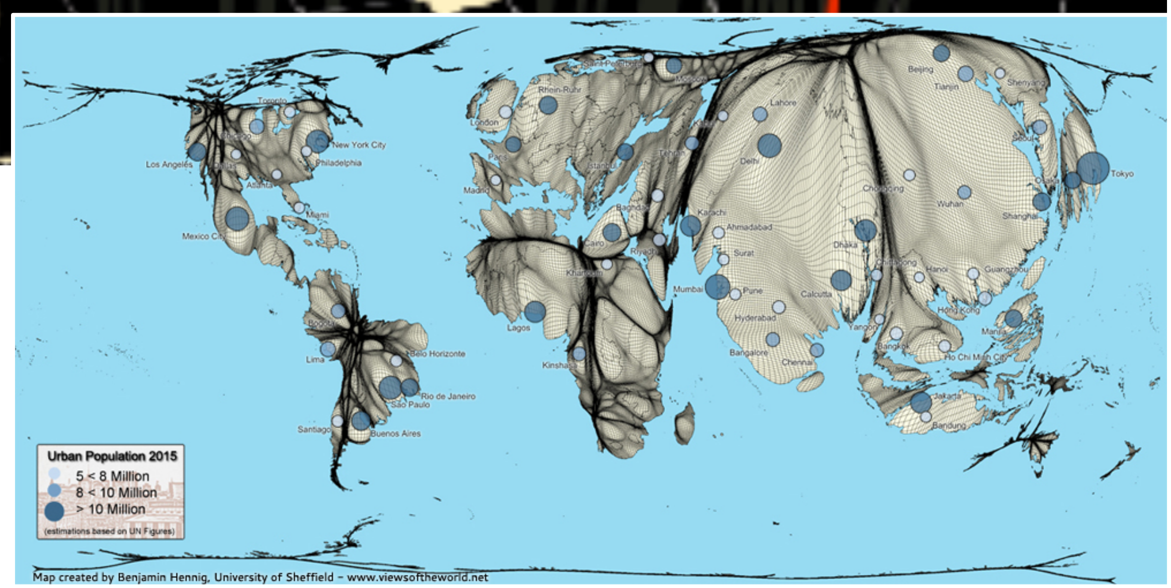
Megacities – cities with a population of 10+ million people; and a view of the urban populations of the world weighted by distribution




## Megacities on the Map

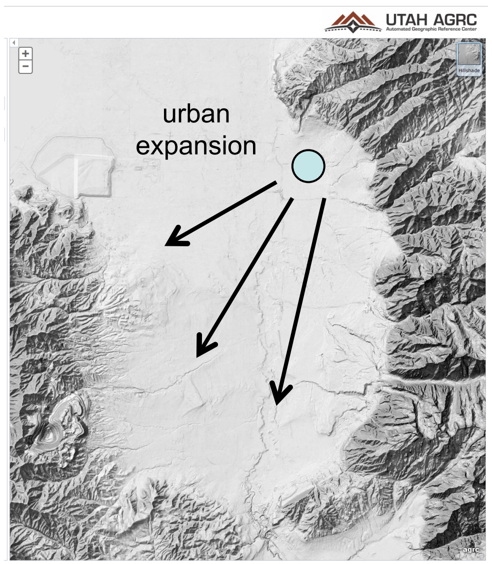
published June 7, 2011

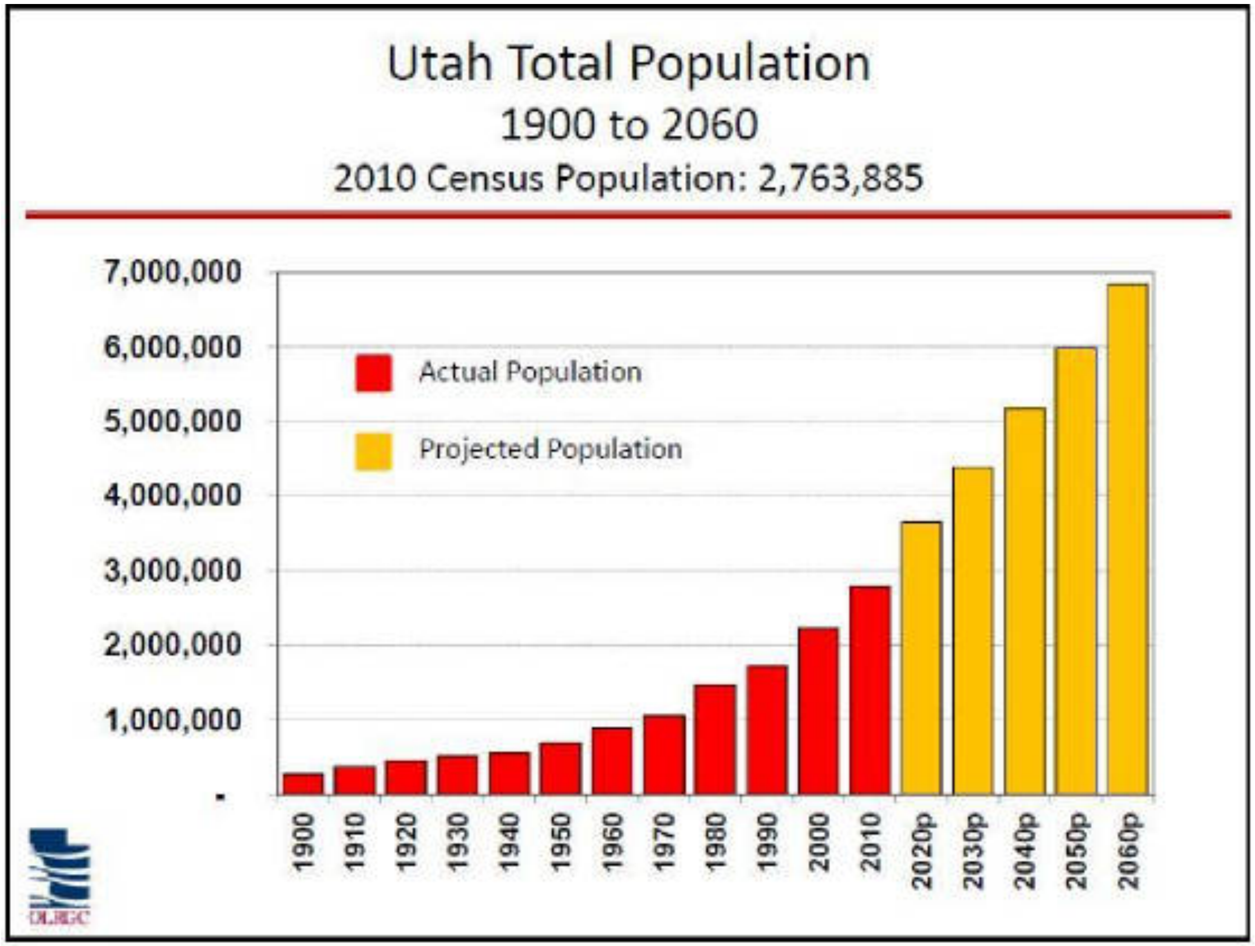
*Megacities are major global risk areas. Due to highest concentration of people and extreme dynamics, they are particularly prone to supply crises, social disorganization, political conflicts and natural disasters. Their vulnerability can be high.*



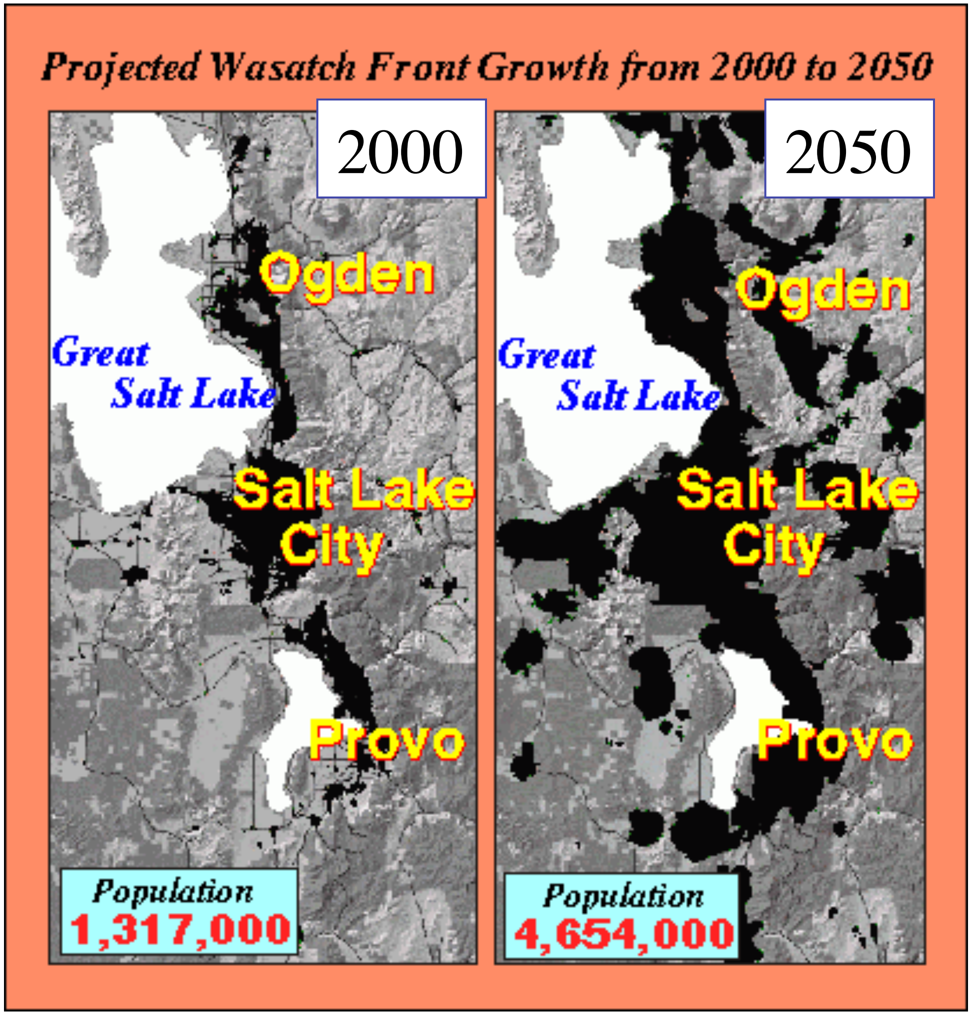
Rather than a global perspective, let's consider Utah urban ecology.
We will explore three issues:

land use change
water availability and use
emissions and air quality



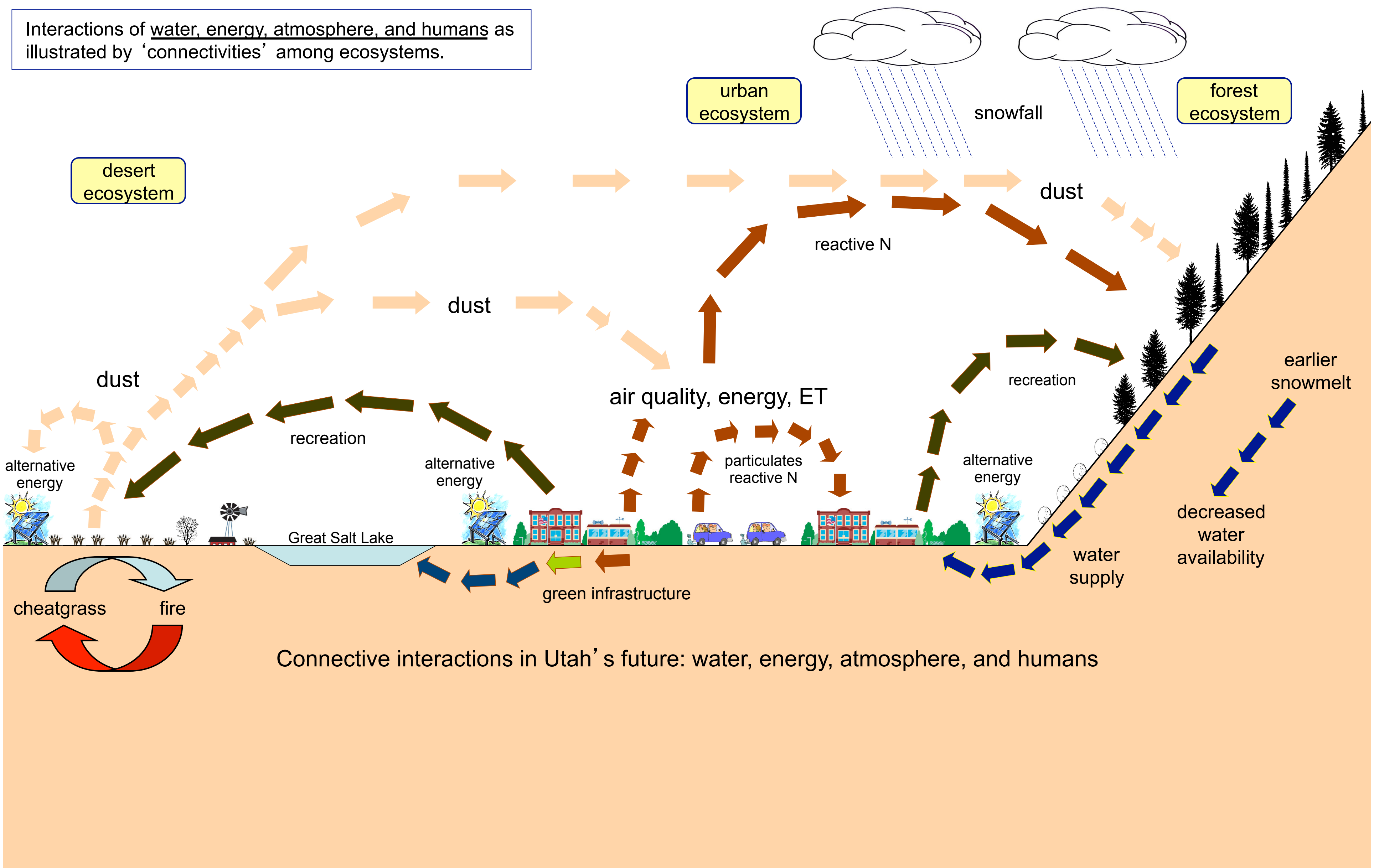



Urban growth projections suggest increased urbanization and conversion of wild and managed land to urban regions



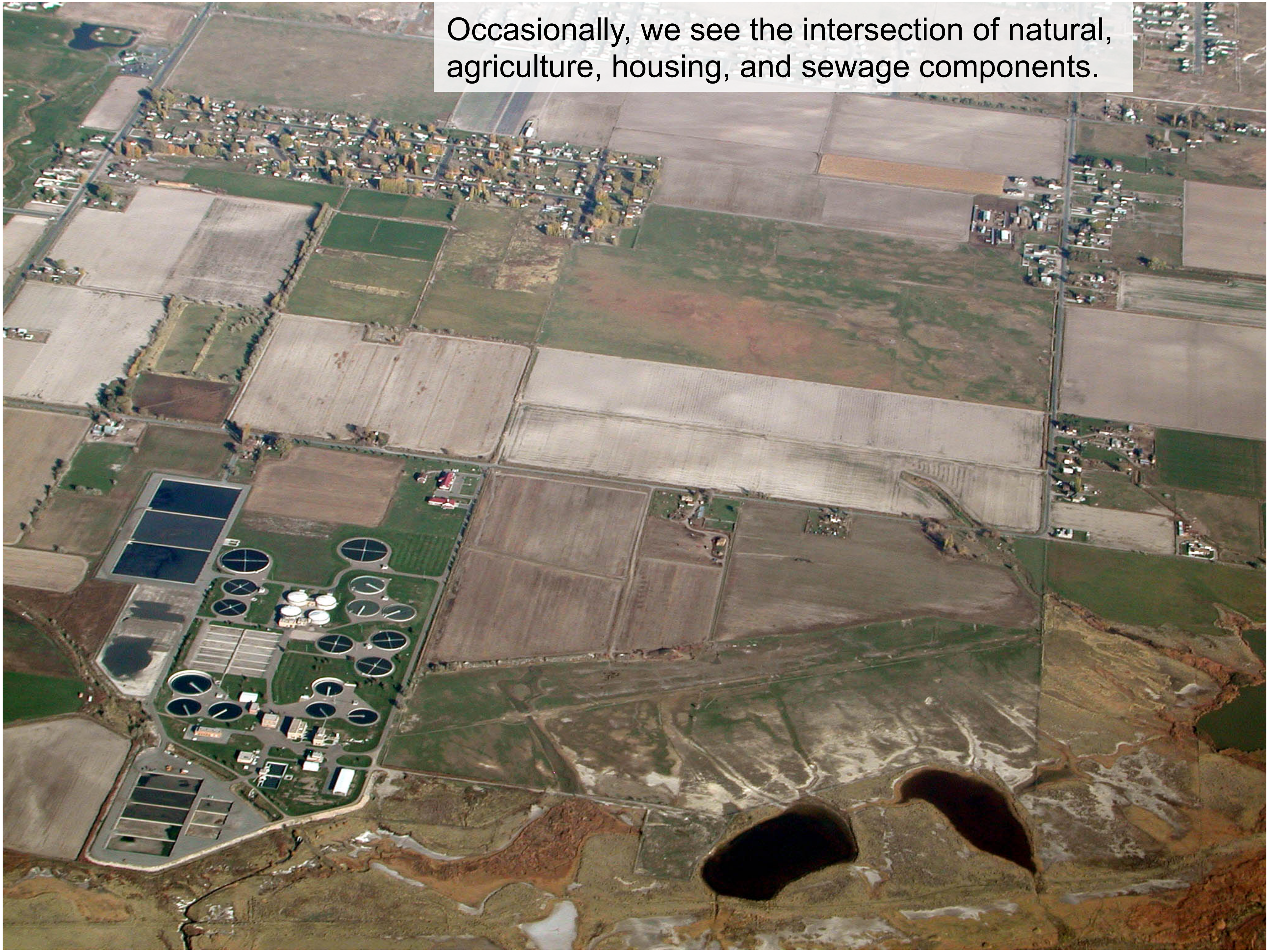
# We live in a coupled natural-human system

Interactions of water, energy, atmosphere, and humans as illustrated by 'connectivities' among ecosystems.




http://3dnworld.com

Urban growth in Utah is largely expansion into semi-arid ecosystems adjacent to mountains. Land-use history is conversion of rangeland into urban dwellings.

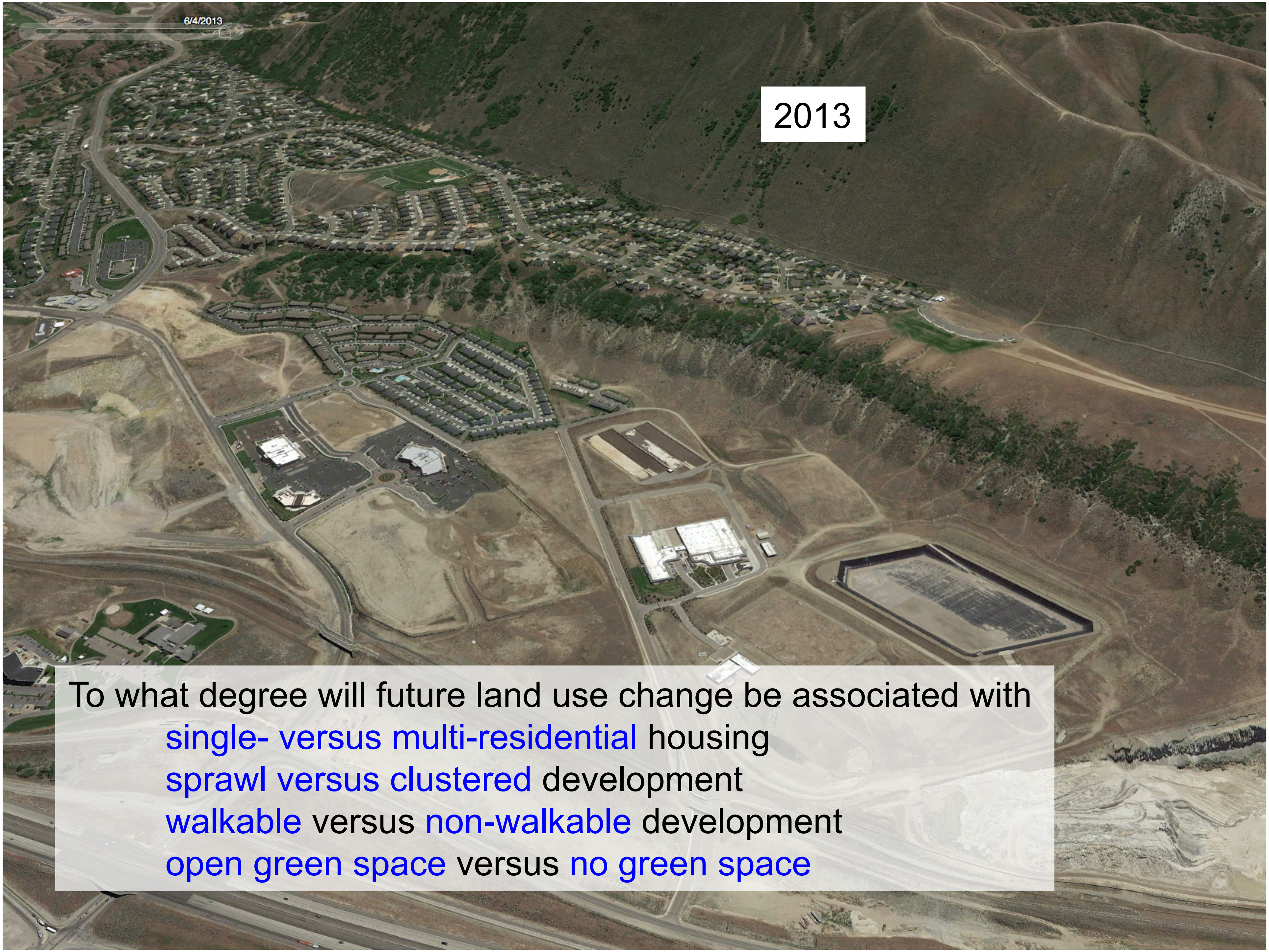

Occasionally, we see the intersection of natural, agriculture, housing, and sewage components.

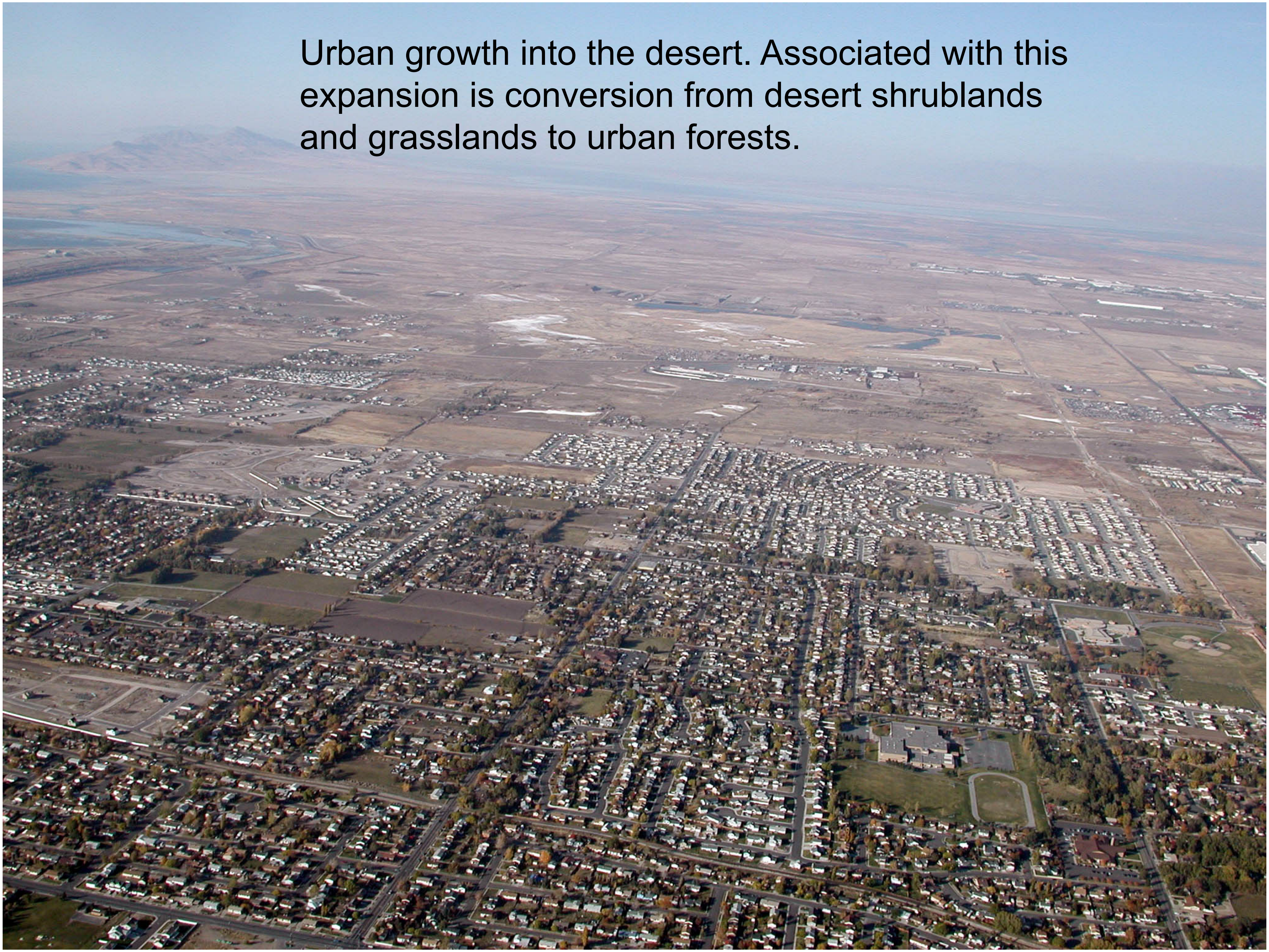
Land use change is fast, because of rapid population growth and urban sprawl. Consider the “Point of the Mountain” and how land use has changed in your lifetime.

Consider the “Point of the Mountain” and how land use has changed in your lifetime


8/13/1993
1993
“Point of the mountain”; urban
expansion need not be continuous


2002
“Point of the mountain”; urban
expansion need not be continuous


6/4/2013
2013
To what degree will future land use change be associated with
single- versus multi-residential housing
sprawl versus clustered development
walkable versus non-walkable development
open green space versus no green space



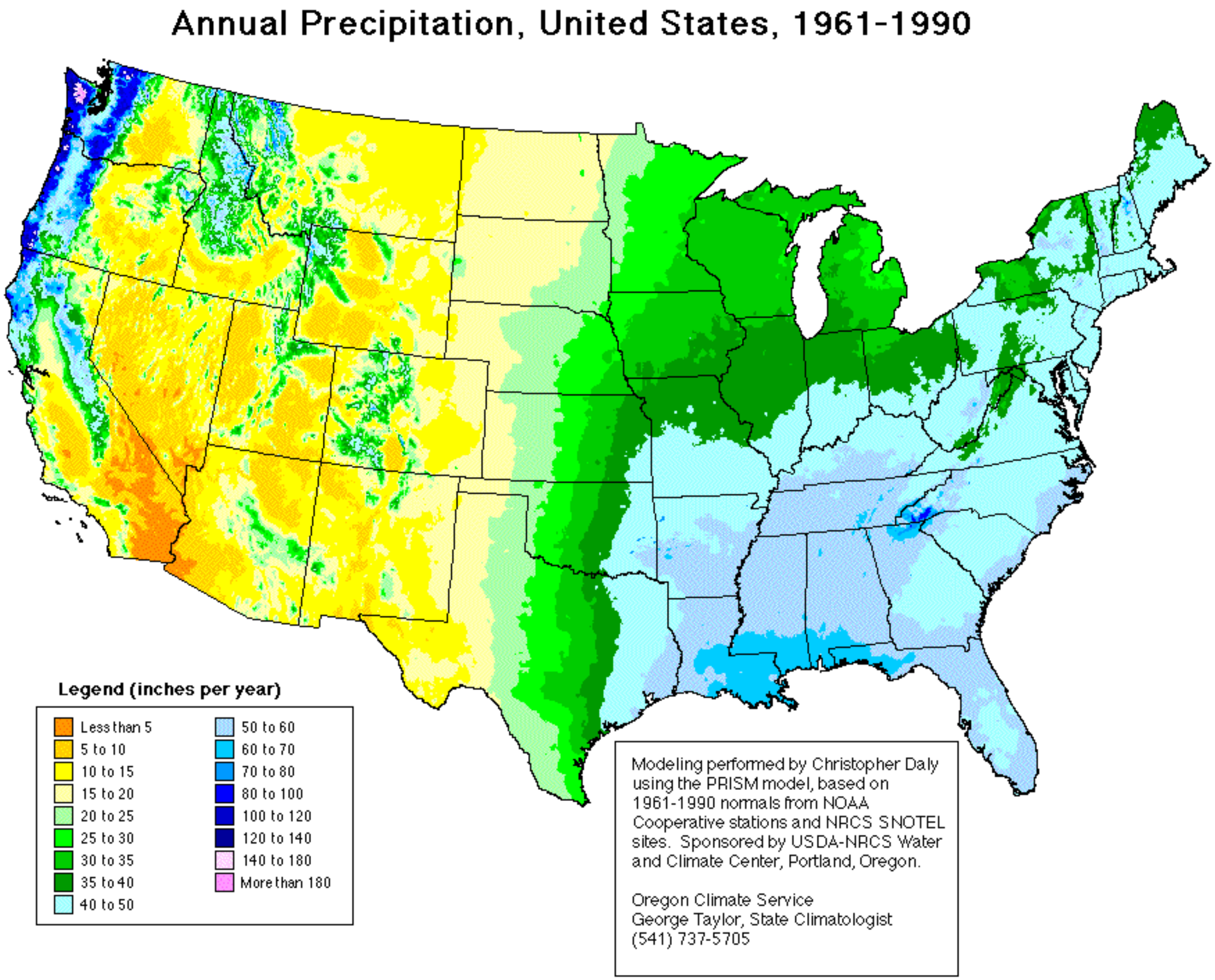
Urban growth into the desert. Associated with this expansion is conversion from desert shrublands and grasslands to urban forests.

Urban development in Utah is associated with urban forest ecosystems.

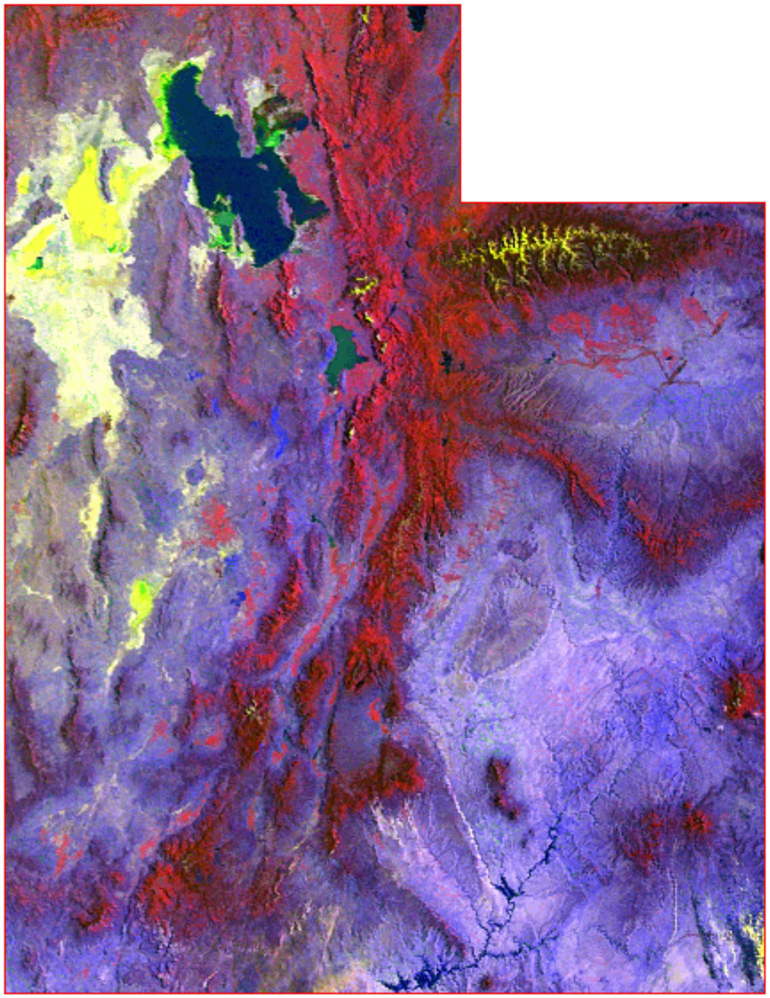
Few of the tree species planted are native to Utah. Invasive trees tend to be from Eurasia (e.g., Russian olive, Siberian elm, tamarisk)

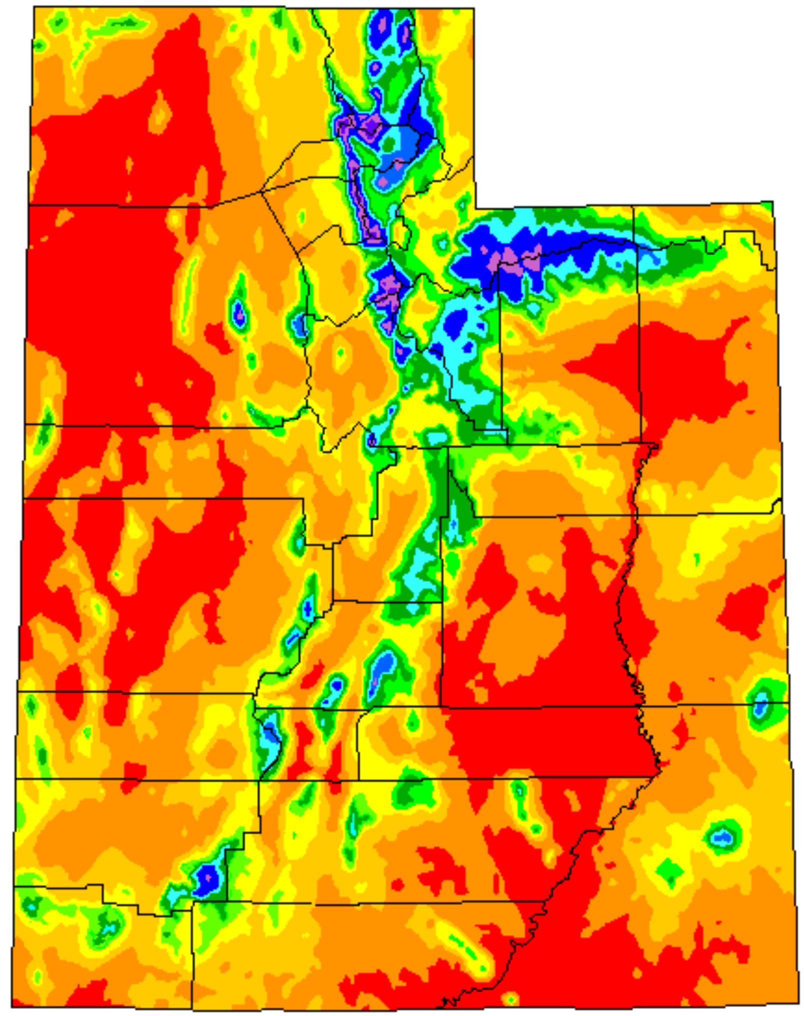

Salt Lake Valley has an urban forest, which requires irrigated water.
(400 mm precipitation supplemented by 1,250 mm irrigation)

# Strong precipitation gradients exist today across North America; urban developments in the Intermountain West are influenced by water availability



Urban development spatially dependent on stable water supply.
Long-term montane water sustainability is key to urban systems.



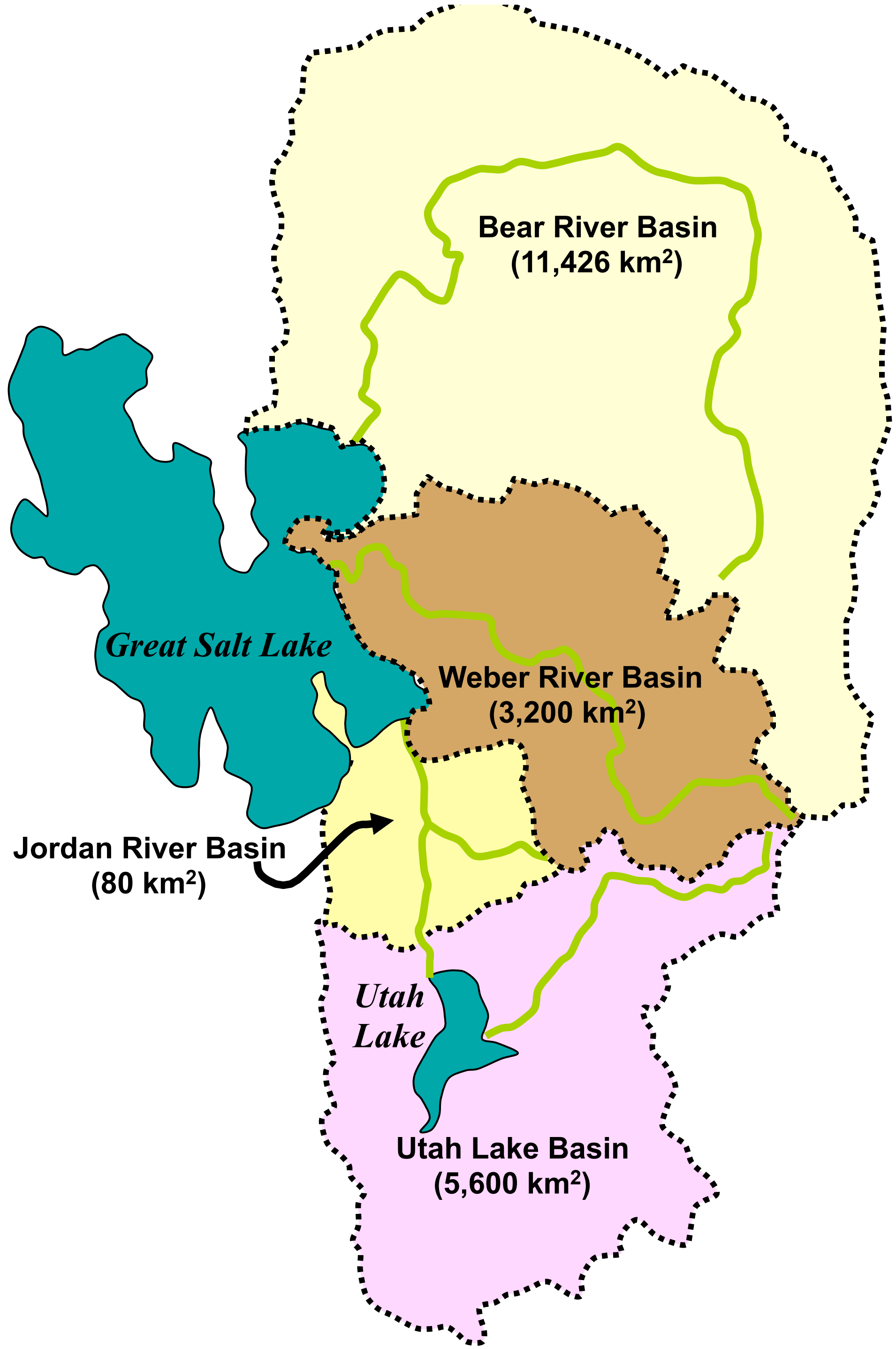


Where does our water come from?

What pressures does urbanization place on water resources?

How does urbanization impact the agricultural needs for water?

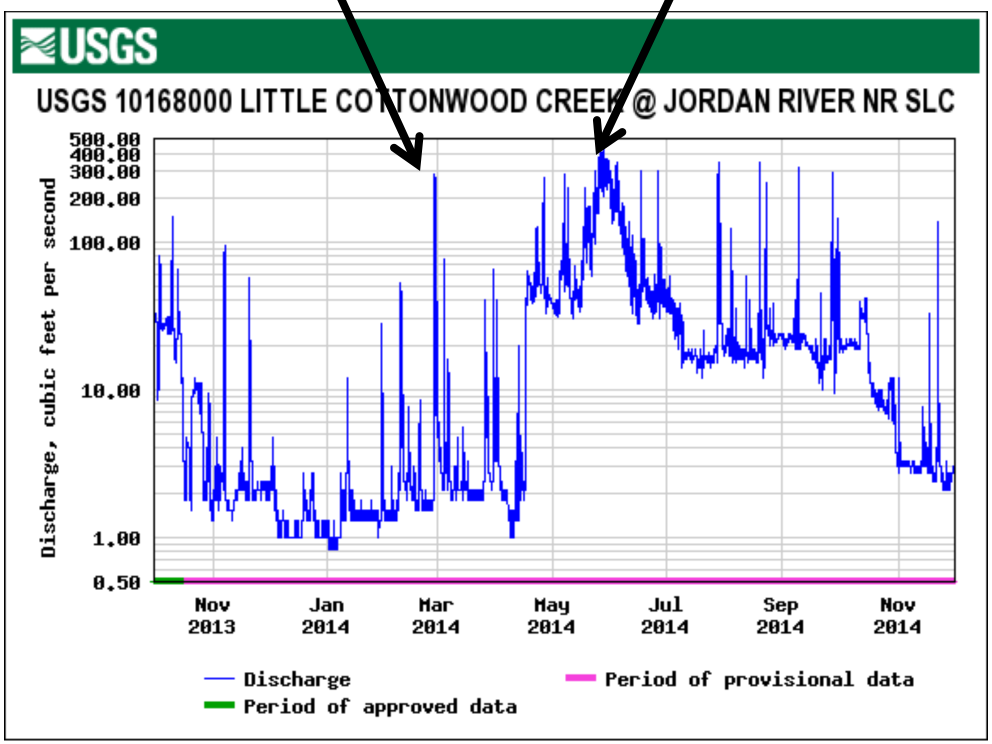
What pressure does urbanization place on our quality of life?



Our water is montane-derived. For example, in Little Cottonwood Creek, water is diverted upstream for culinary purposes, but stormwater greatly influences episodic stream flows within the valley.

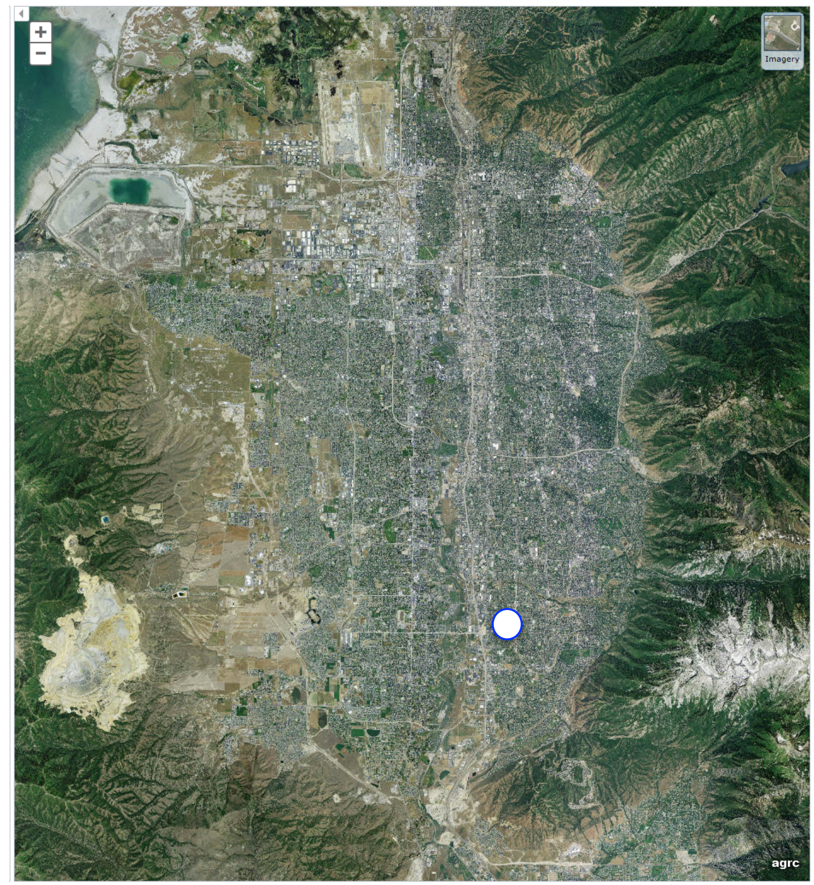
Episodic stormwater
Runoff within the city

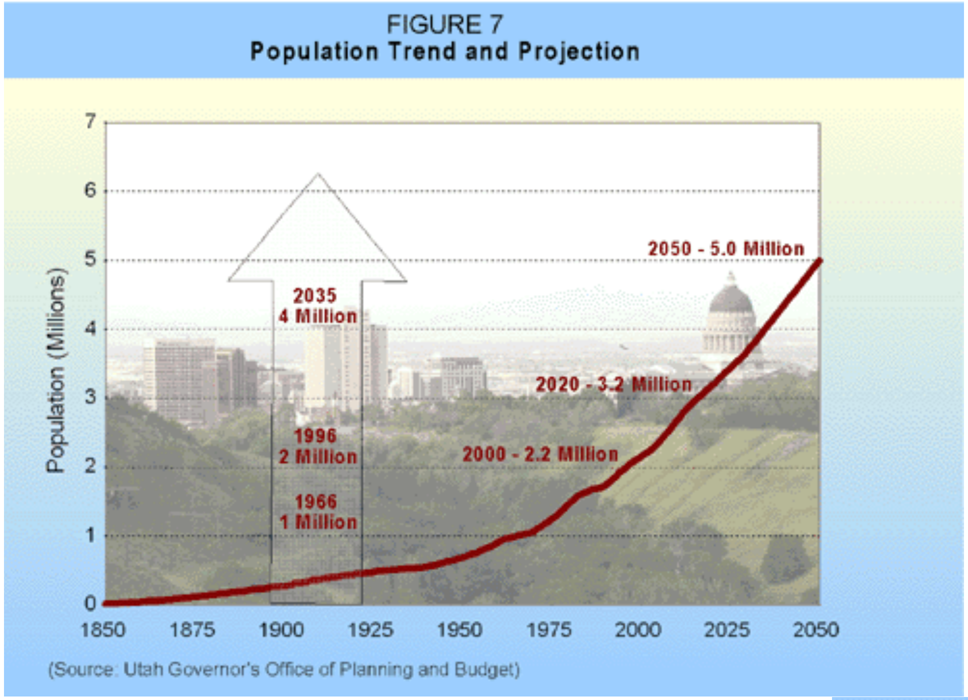
Spring runoff




Note that stormwater runoff can be equivalent to peak
Springtime snowmelt in terms of flows

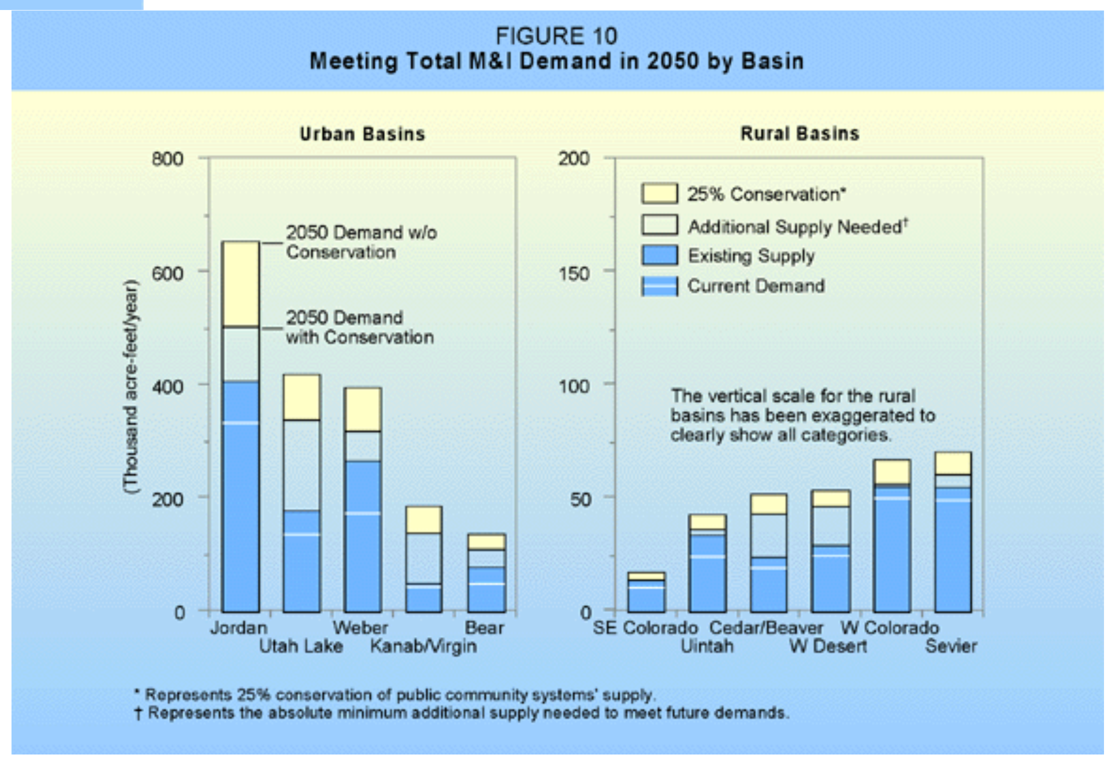
UTAH AGRC
Automated Geographic Reference Center

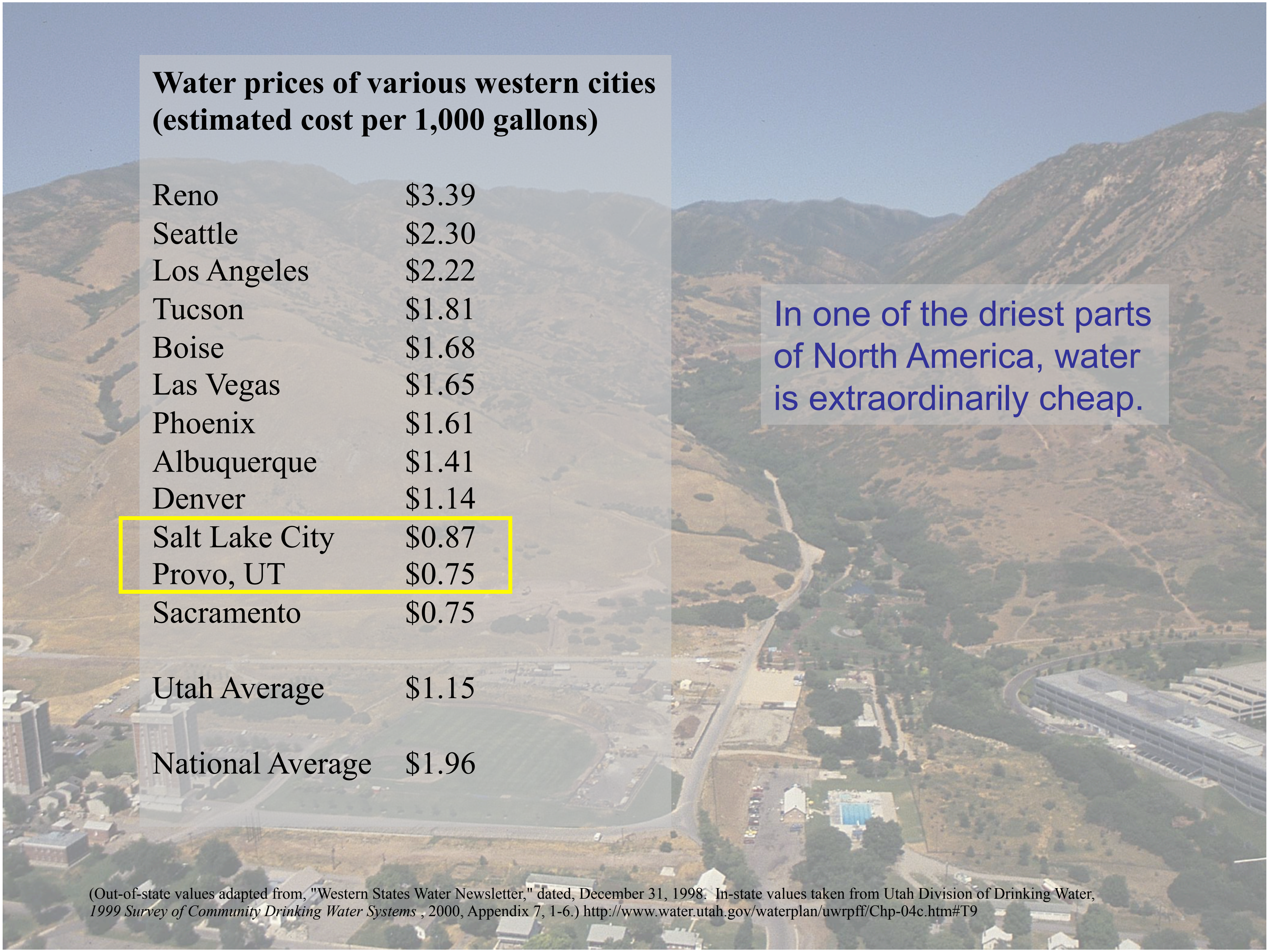





Projections from the Governor's Office indicate that changes in water use will be required to sustain the projected population growth.

- What will cities look like tomorrow?
- How will urbanites adjust?
- What do we value sufficiently that may not change in the foreseeable future?





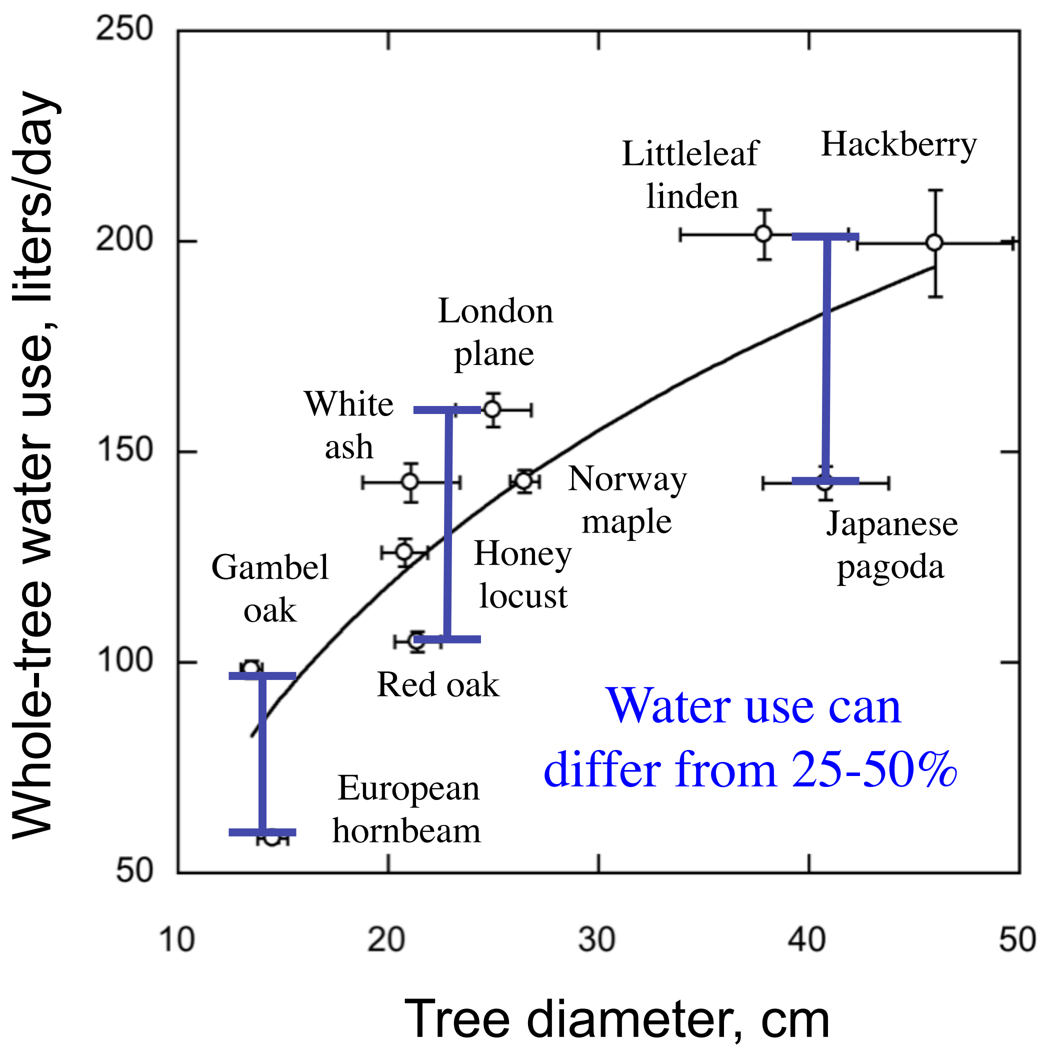
**Water prices of various western cities**
**(estimated cost per 1,000 gallons)**

| | |
|---|---|
| Reno | $3.39 |
| Seattle | $2.30 |
| Los Angeles | $2.22 |
| Tucson | $1.81 |
| Boise | $1.68 |
| Las Vegas | $1.65 |
| Phoenix | $1.61 |
| Albuquerque | $1.41 |
| Denver | $1.14 |
| Salt Lake City | $0.87 |
| Provo, UT | $0.75 |
| Sacramento | $0.75 |
| Utah Average | $1.15 |
| National Average | $1.96 |

In one of the driest parts of North America, water is extraordinarily cheap.

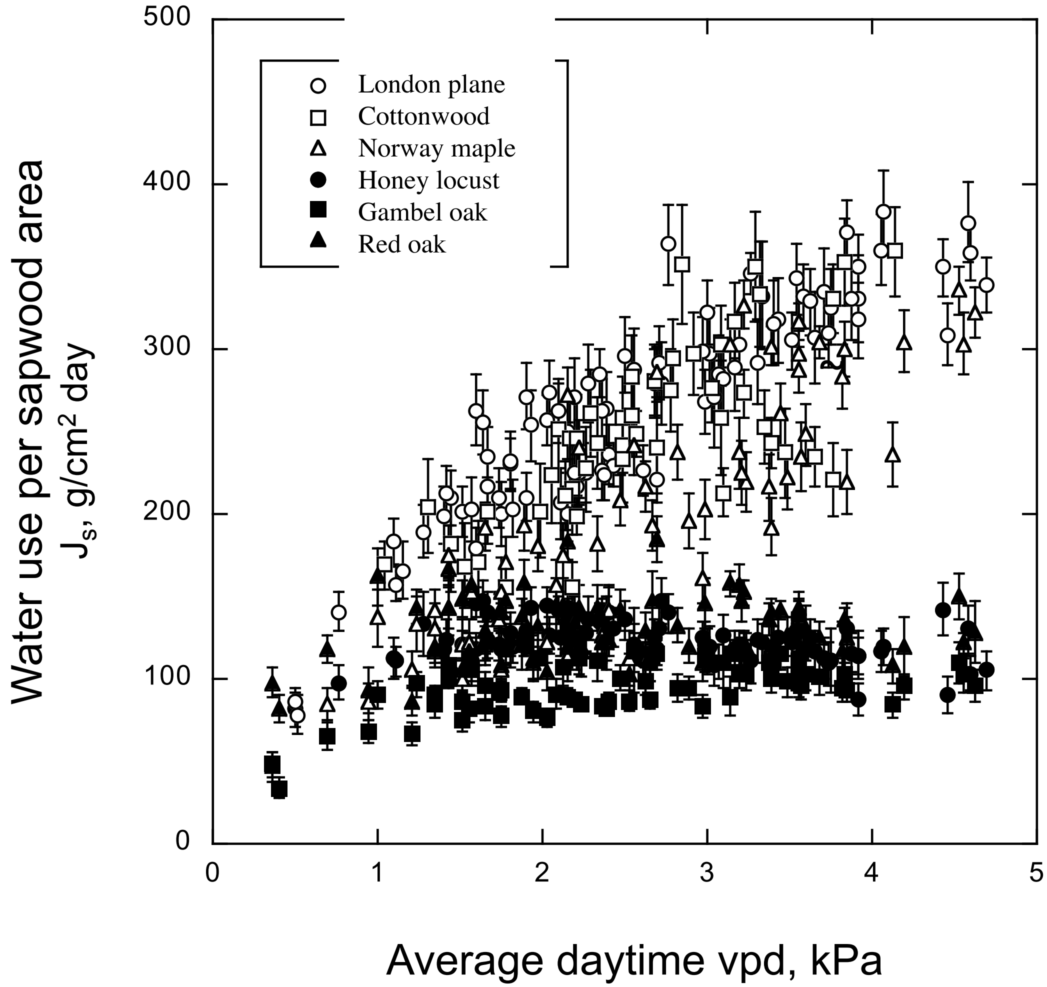
(Out-of-state values adapted from, "Western States Water Newsletter," dated, December 31, 1998. In-state values taken from Utah Division of Drinking Water, *1999 Survey of Community Drinking Water Systems* , 2000, Appendix 7, 1-6.) http://www.water.utah.gov/waterplan/uwrpff/Chp-04c.htm#T9

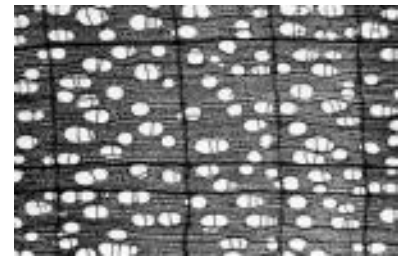
# Tree size impacts water use



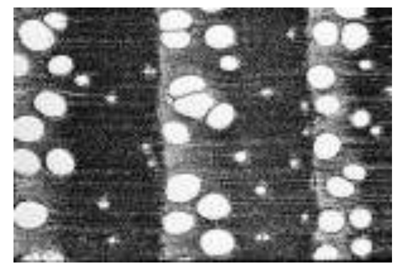
# The consequence of choices we make are trees with very different rates of water loss

## Two distinct transpiration patterns are observed



Diffuse-porous wood type

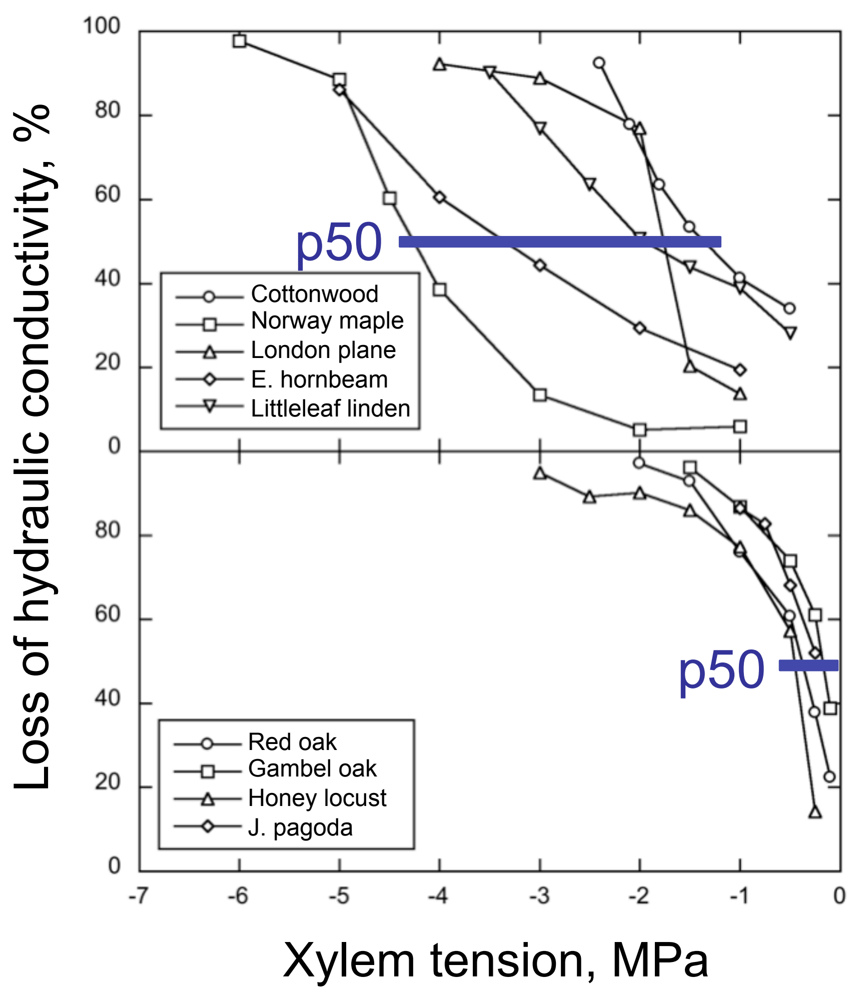


Ring-porous wood type

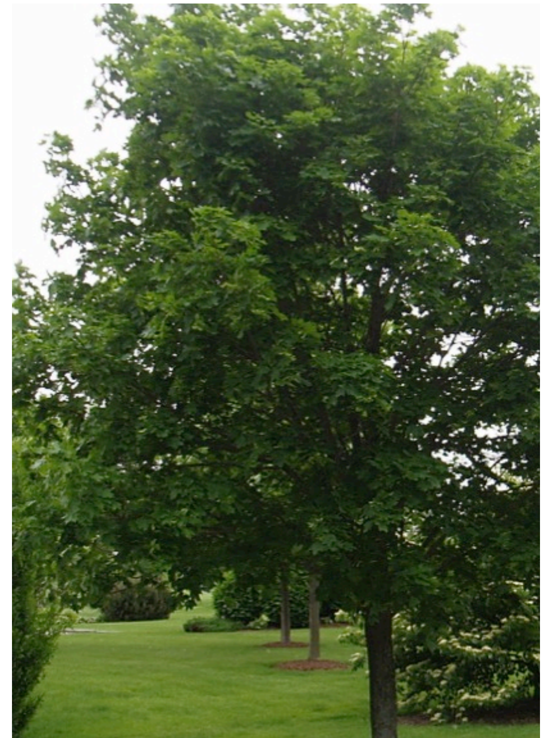
What are commonly planted ring- and diffuse-porous species?

| Ring-porous | Diffuse-porous |
|---|---|
| Elm | Maples |
| Ash | Cottonwoods |
| Catalpa | Beech |
| Hackberry | Birch |
| Honey locust | London plane |
| Oaks | Sycamores |
| Japanese pagoda | Linden |
| Japanese zelkova | Horse chestnut |
| Kentucky coffeetree | Boxelder |
| Mulberry | Hornbeam |
| Goldenrain tree | Fruit trees |
| Redbud | |

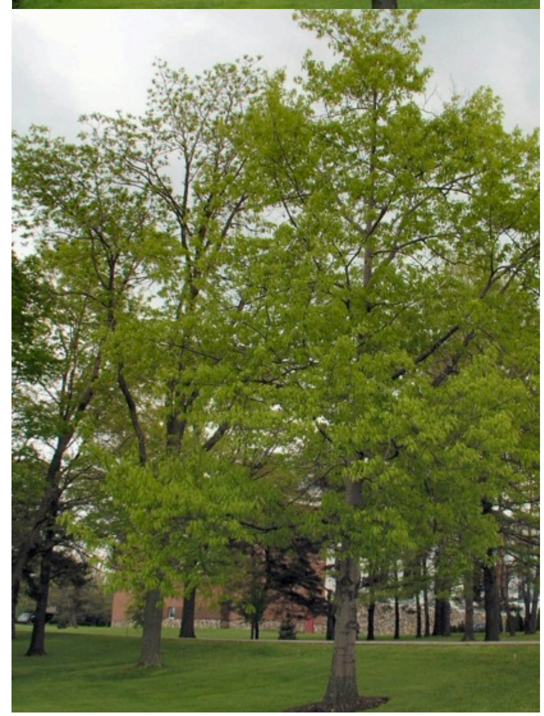
While cavitation vulnerability varies across species, diffuse-porous tend to be more drought tolerant




Diffuse-porous wood type



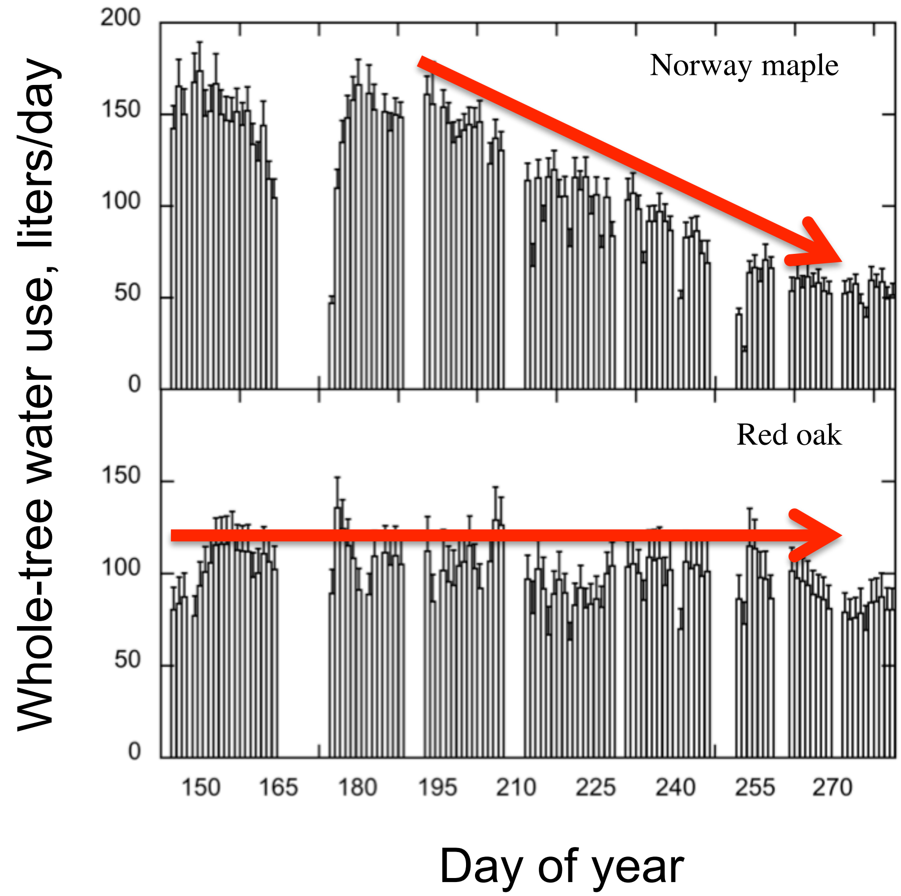
Ring-porous wood type



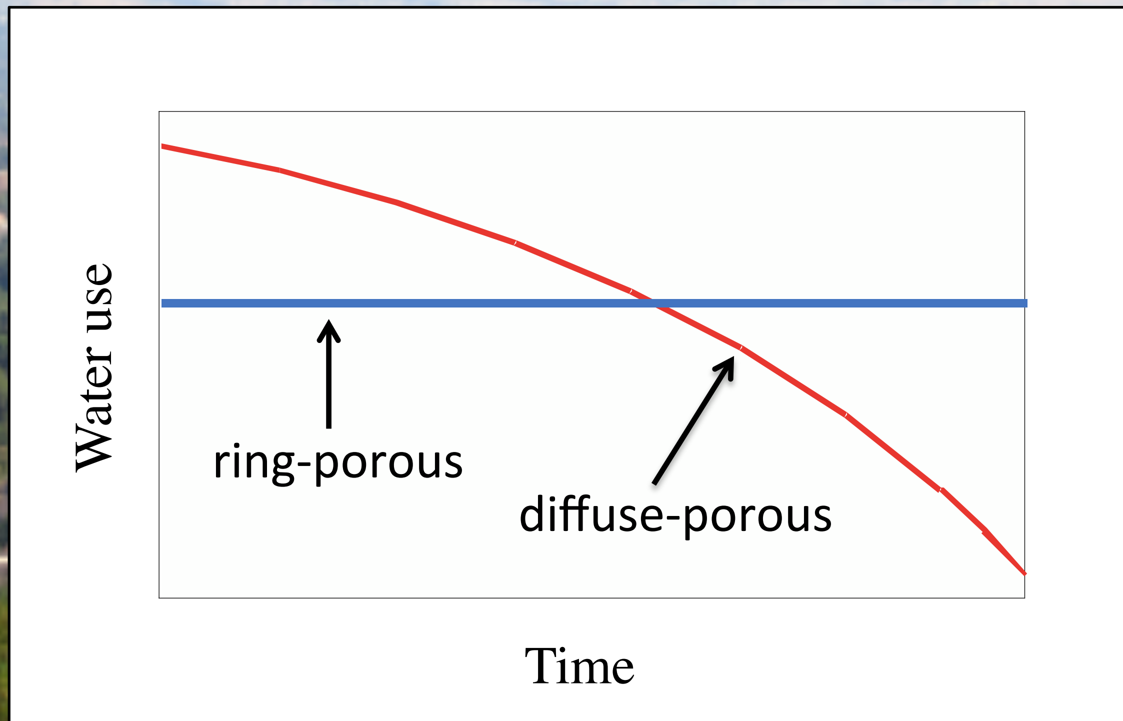
Increasing xylem embolism

Increasing tension

# Seasonal patterns of water use differ between diffuse-porous and ring-porous species

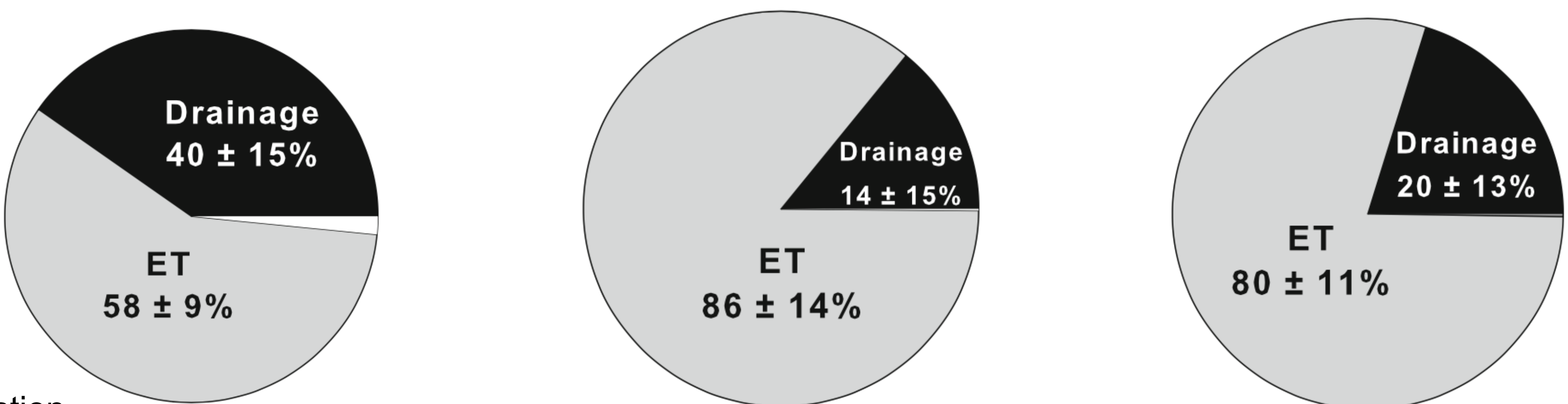


# Human decisions impact the magnitude and seasonality of fluxes



A comparative study of the water budgets of lawns under three management scenarios In Los Angeles (Bijoor, Pataki, Haver, and Famiglietti)


**Fig. 1** Photographs of the three simulated residences that were the subjects of this study. The landscape types for these residences were **a** the "Typical" landscape with a cool-season fescue and automatic timed irrigation, **b** the "Alternative1" landscape with a warm-season paspalum and "smart" soil moisture sensor-based irrigation, and **c** the "Alternative2" landscape with a cool-season native sedge and "smart" weather station-based drip irrigation




Irrigation applied 770 mm 355 mm 583 mm

Comparative nitrogen budgets of lawns under three management scenarios in Los Angeles (Wang, Haver, and Pataki)


**Photo 1** Photos of the three simulated residences in 2010 (**a** Typical, **b** Low Input, and **c** Low Impact). Lawns are planted in both front and back yards

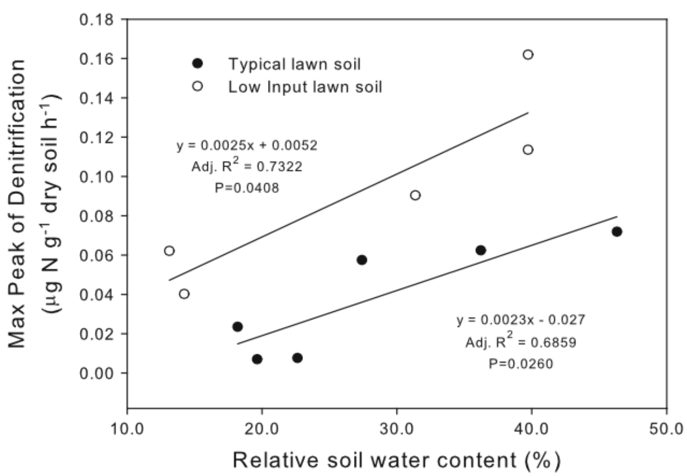



**Fig. 4** $NH_3$ volatilization in Typical (*filled squares*), Low Input (*gray squares*), and Low Impact (*dark gray squares*) following fertilization. In March 2011, Typical and Low Impact were fertilized on the 8th while Low Input was fertilized on the 29th. Data are shown as mean ± SE. The fertilization dates (Day 1) are shown in each panel

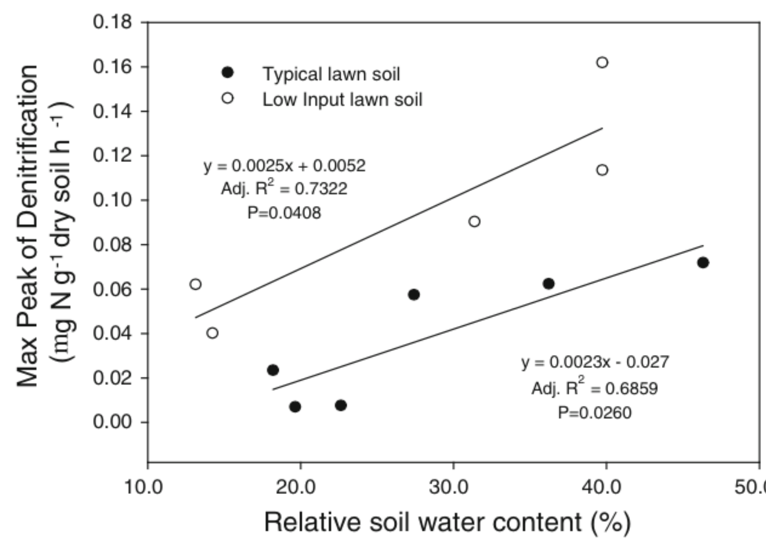



**Fig. 6** Relationship between the maximum denitrification rate following each fertilization event and the relative soil water content in Typical and Low Input

Mixing trees with lawn
reduces grass evapotranspiration

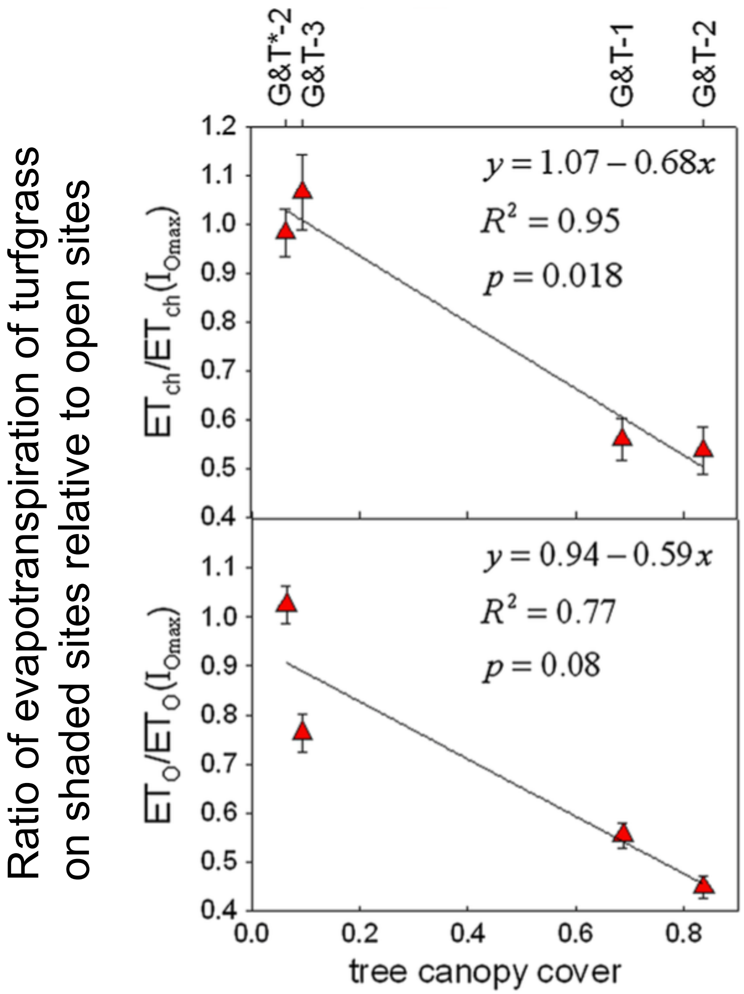
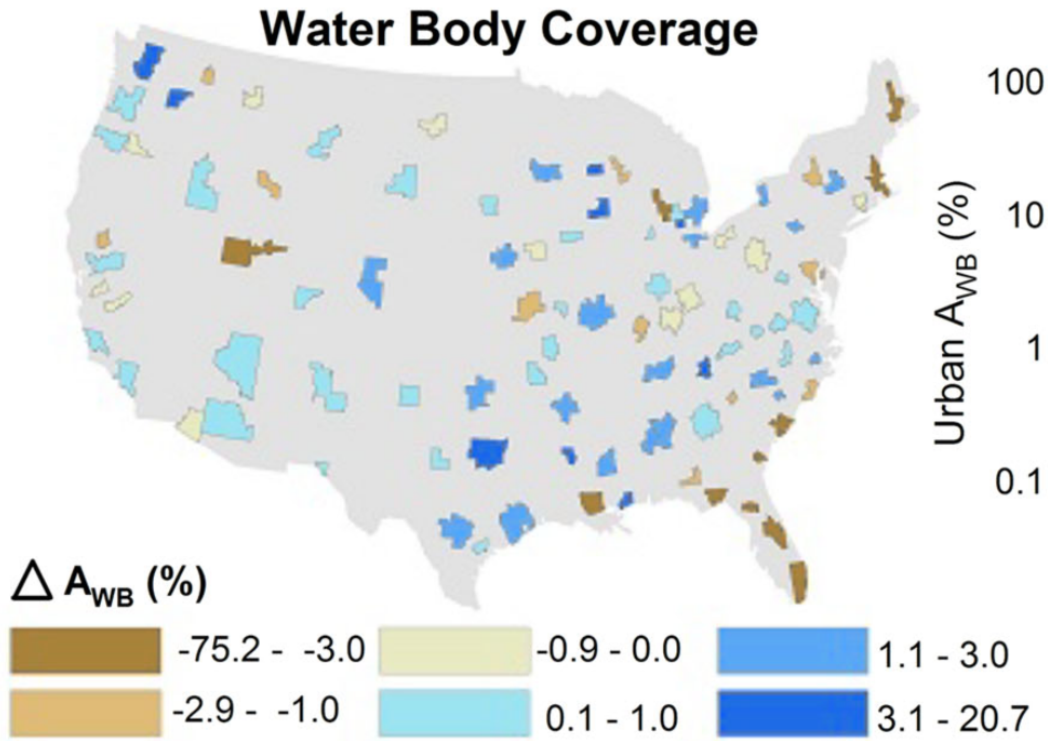
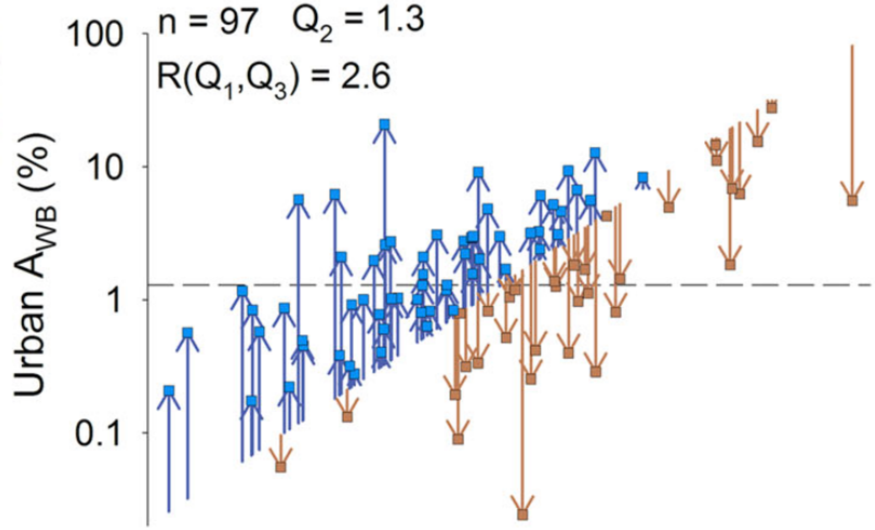



Figure 7. Average relative evapotranspiration (ET) of turfgrass at shaded sites with respect to ET of Grass sites [$ET(I_{Omax})$] at each location, as a function of tree canopy cover. Upper panel – average relative ET calculated using chamber data ($ET_{ch}$), lower panel – average relative ET calculated with modified Penman equation ($ET_O$). Notation: G&T = Grass&Trees. Site Grass&Trees*-1 is not included (see text for details). Error bars show propagated standard error.





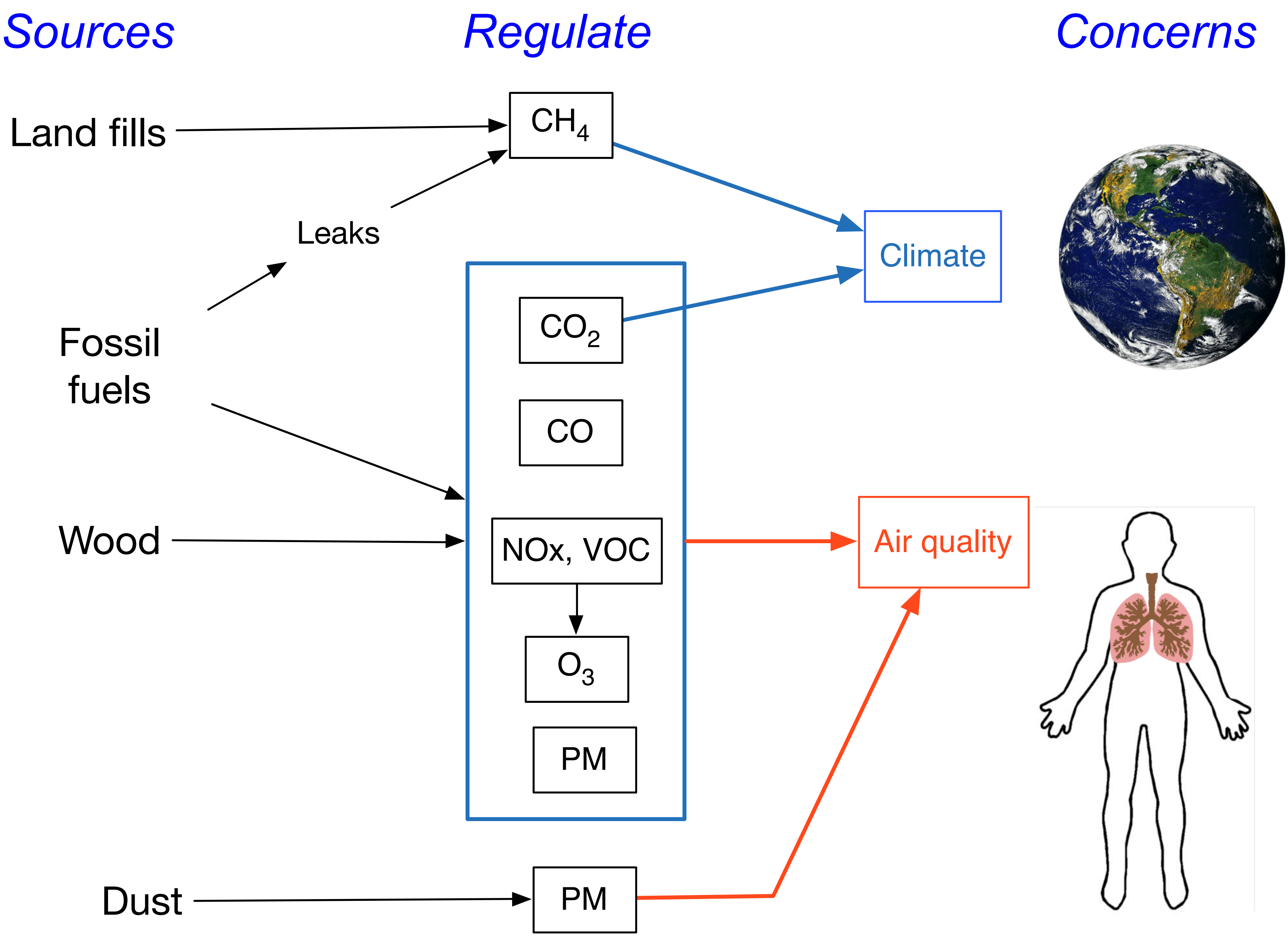
We bring “nature” to us.

In arid regions, such as Utah, urbanization is associated with an increase in surface waters.

Fossil fuel emissions are associated with increased CO, $CO_2$, $N_2O$, $O_3$, and $CH_4$
Increased pollutant levels are spatially correlated with urban development.


Why are there so few people in the carpool lanes?

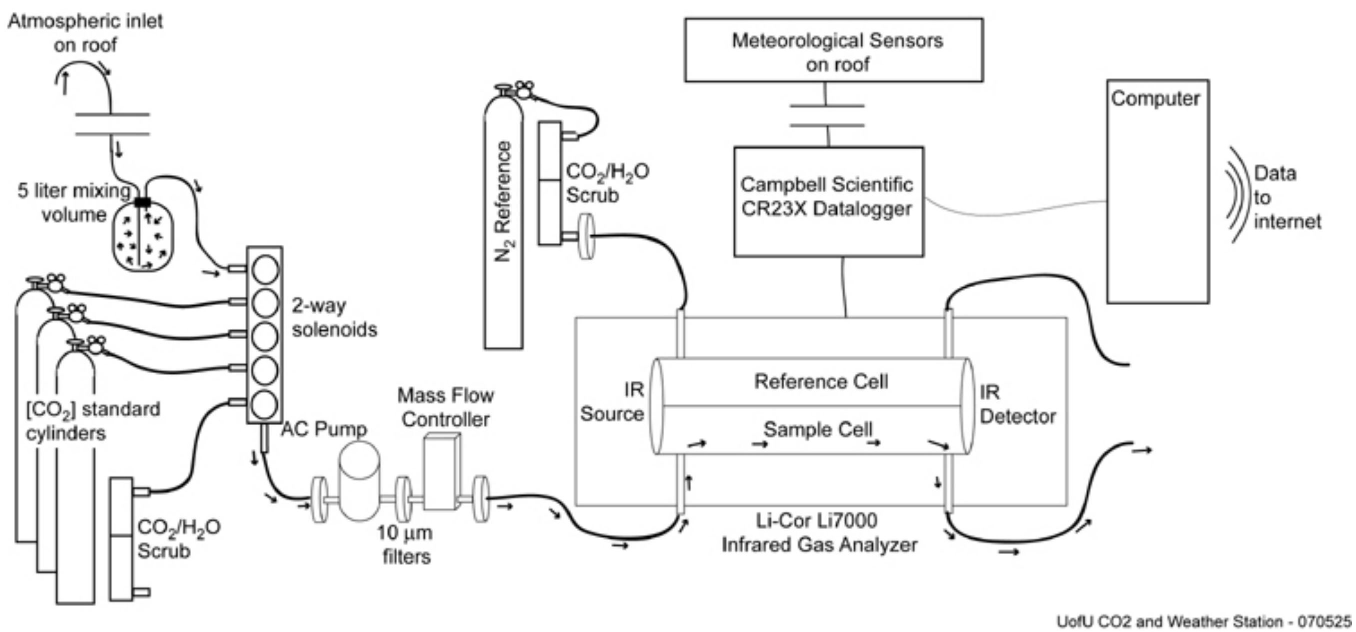
courtesy: Wasatch Front Regional Council



Sources
Regulate
Concerns
Land fills
$CH_4$
Leaks
Climate
Fossil fuels
$CO_2$
CO
Wood
NOx, VOC
Air quality
$O_3$
PM
Dust
PM

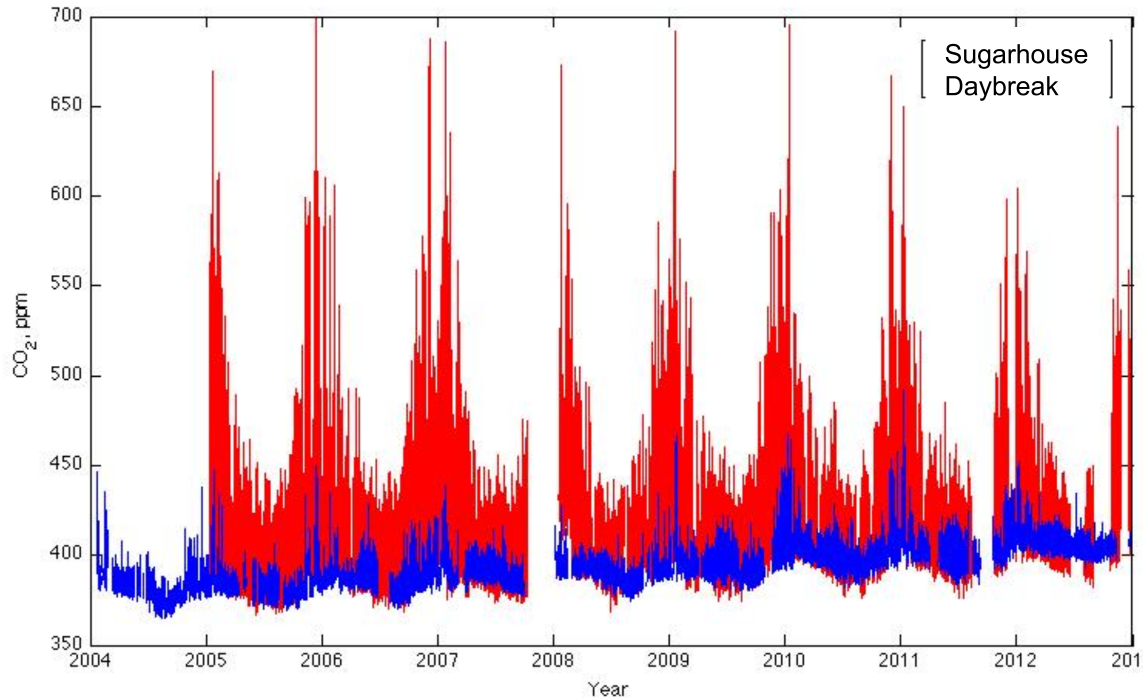
CO$_2$ in the SL Valley
http://co2.utah.edu

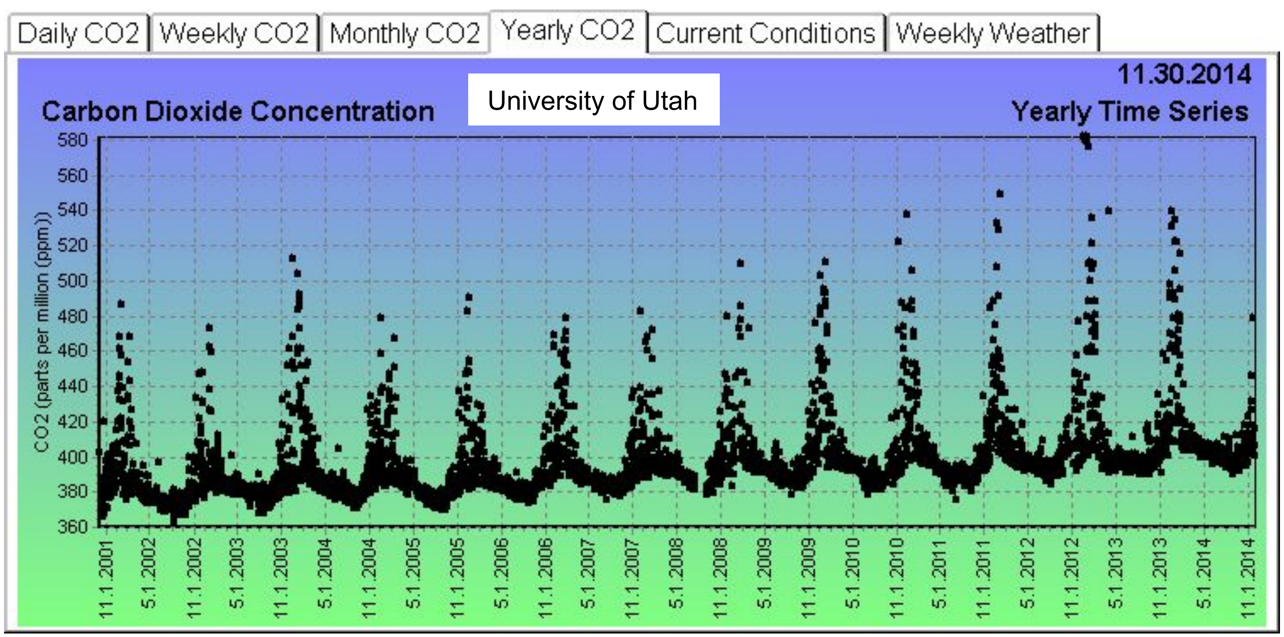
online data since 2001



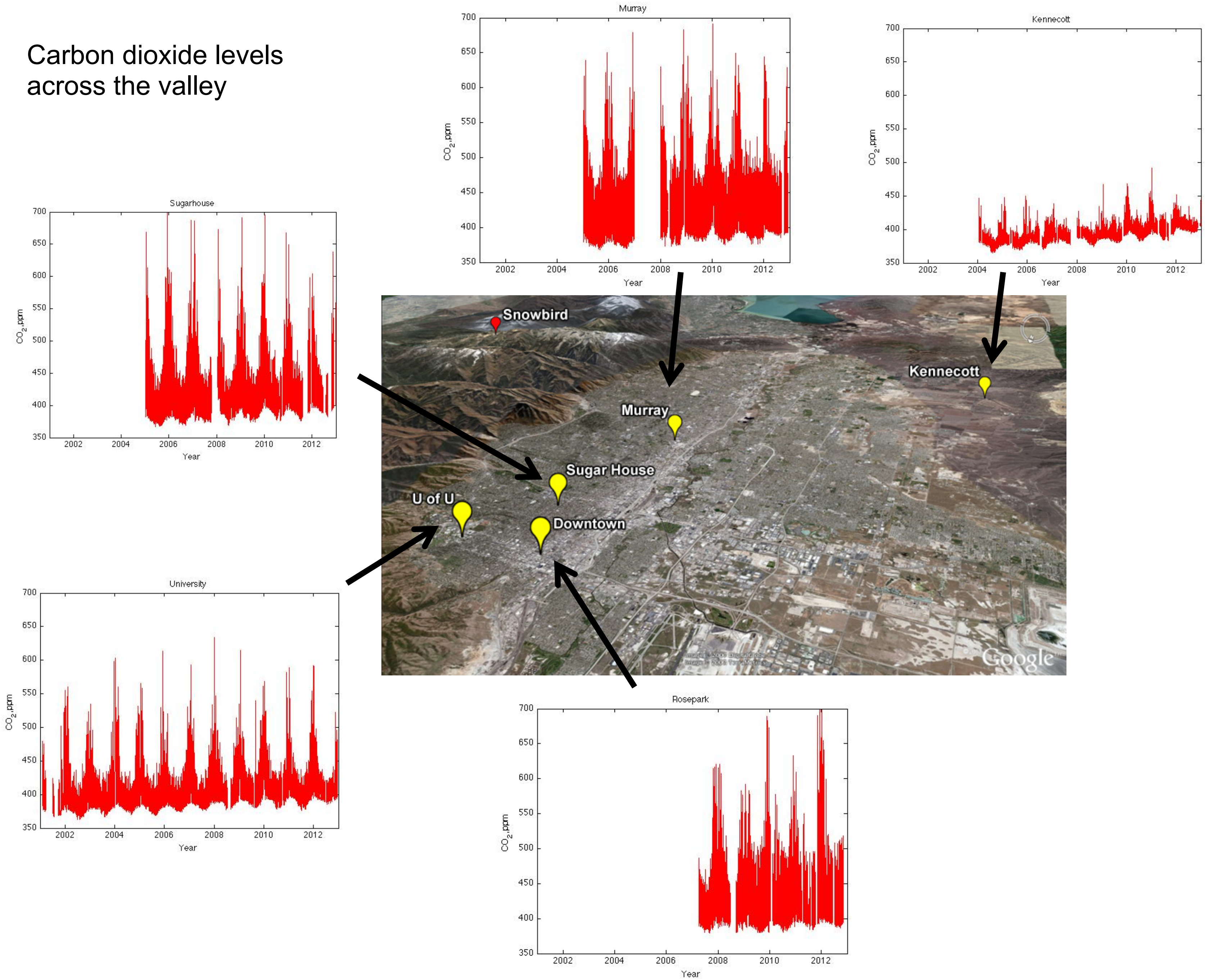
$CO_2$ in the SL Valley

http://co2.utah.edu

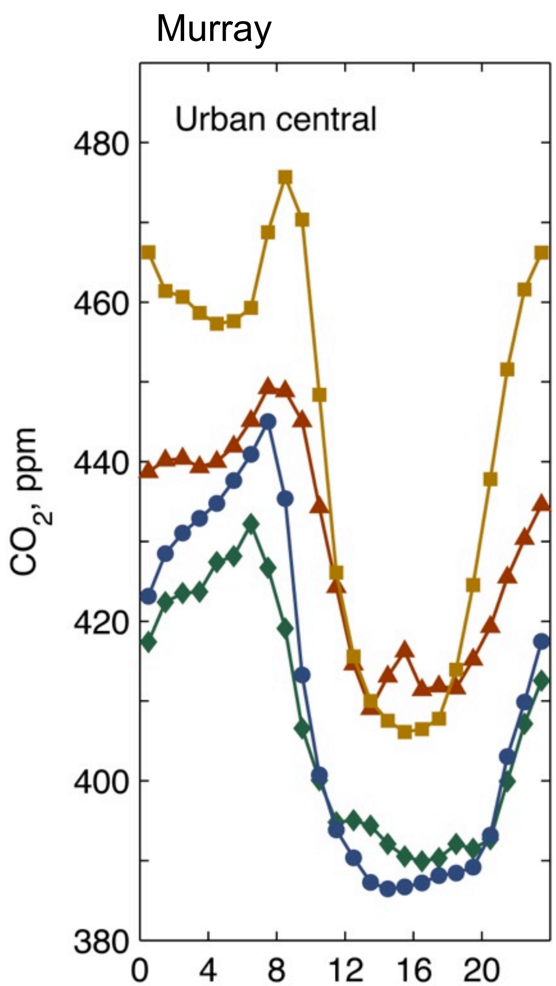


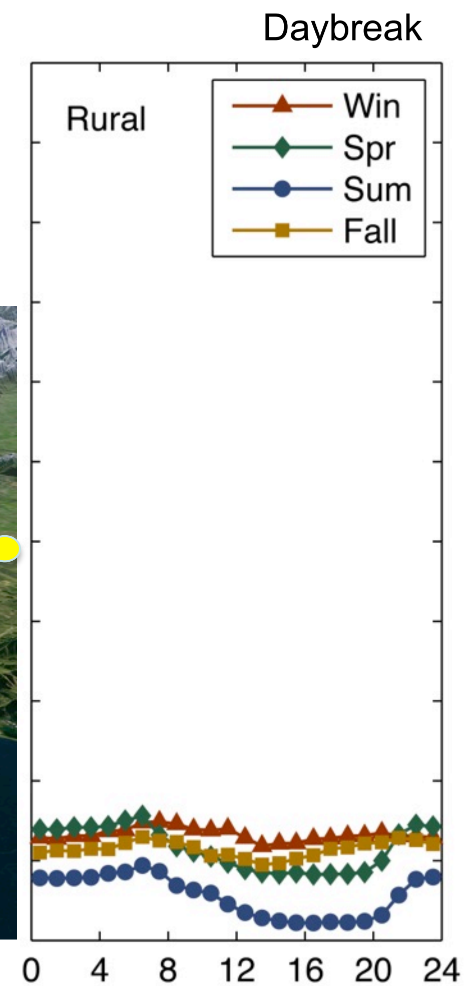
Carbon dioxide levels across the valley



# $CO_2$ levels are impacted by



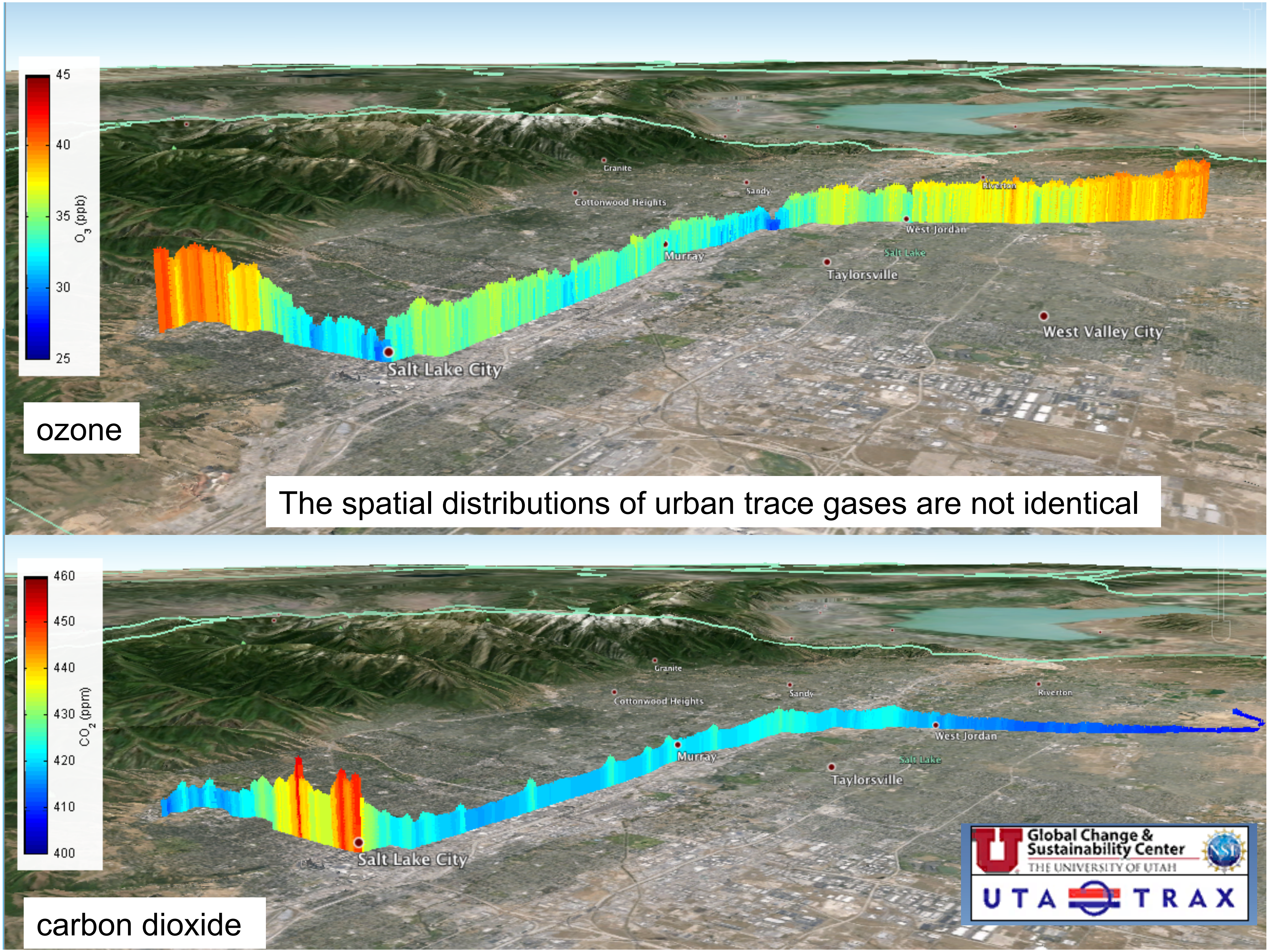

- location in dome
- time of day
- season of year




Hour of day

Hour of day

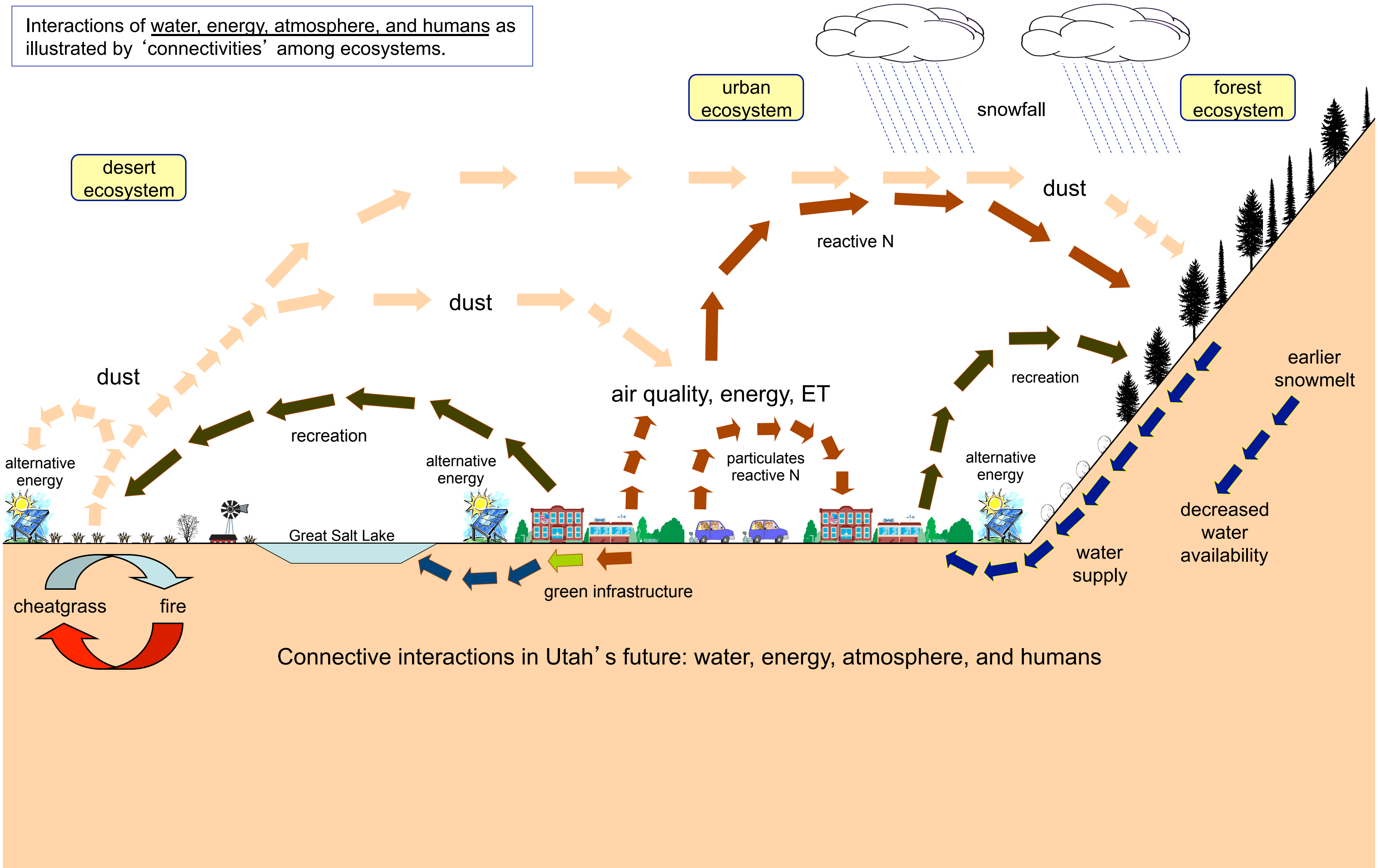
Ehleringer et al



The spatial distributions of urban trace gases are not identical
ozone
45
40
35
30
25
O3 (ppb)
Granite
Cottonwood Heights
Sandy
Riverton
Murray
West Jordan
Salt Lake
Taylorsville
West Valley City
Salt Lake City
carbon dioxide
460
450
440
430
420
410
400
CO2 (ppm)
Global Change & Sustainability Center
THE UNIVERSITY OF UTAH
UTA TRAX

# Aridland ecosystem management also impacts urban air quality

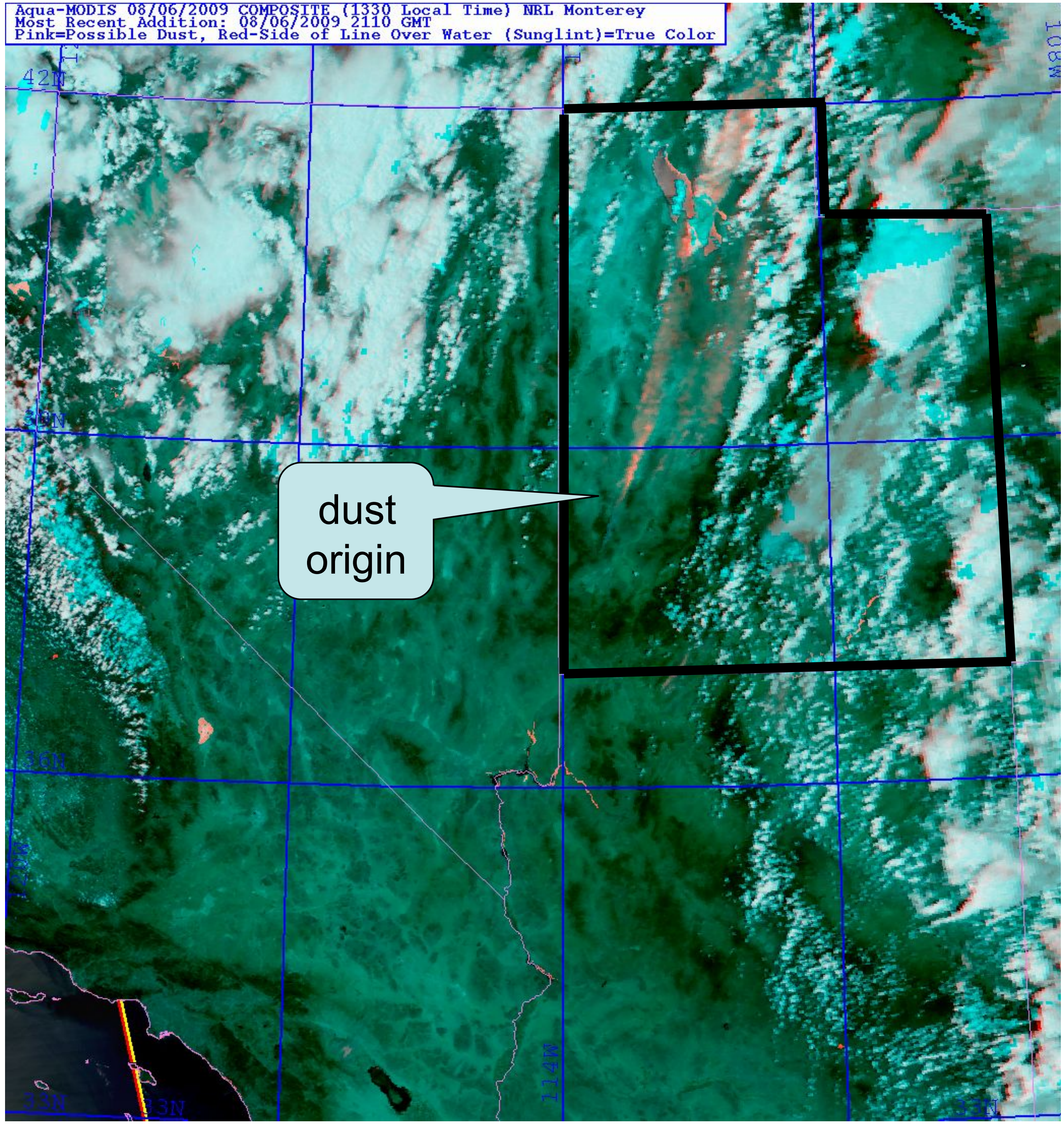
Interactions of water, energy, atmosphere, and humans as illustrated by ‘connectivities’ among ecosystems.



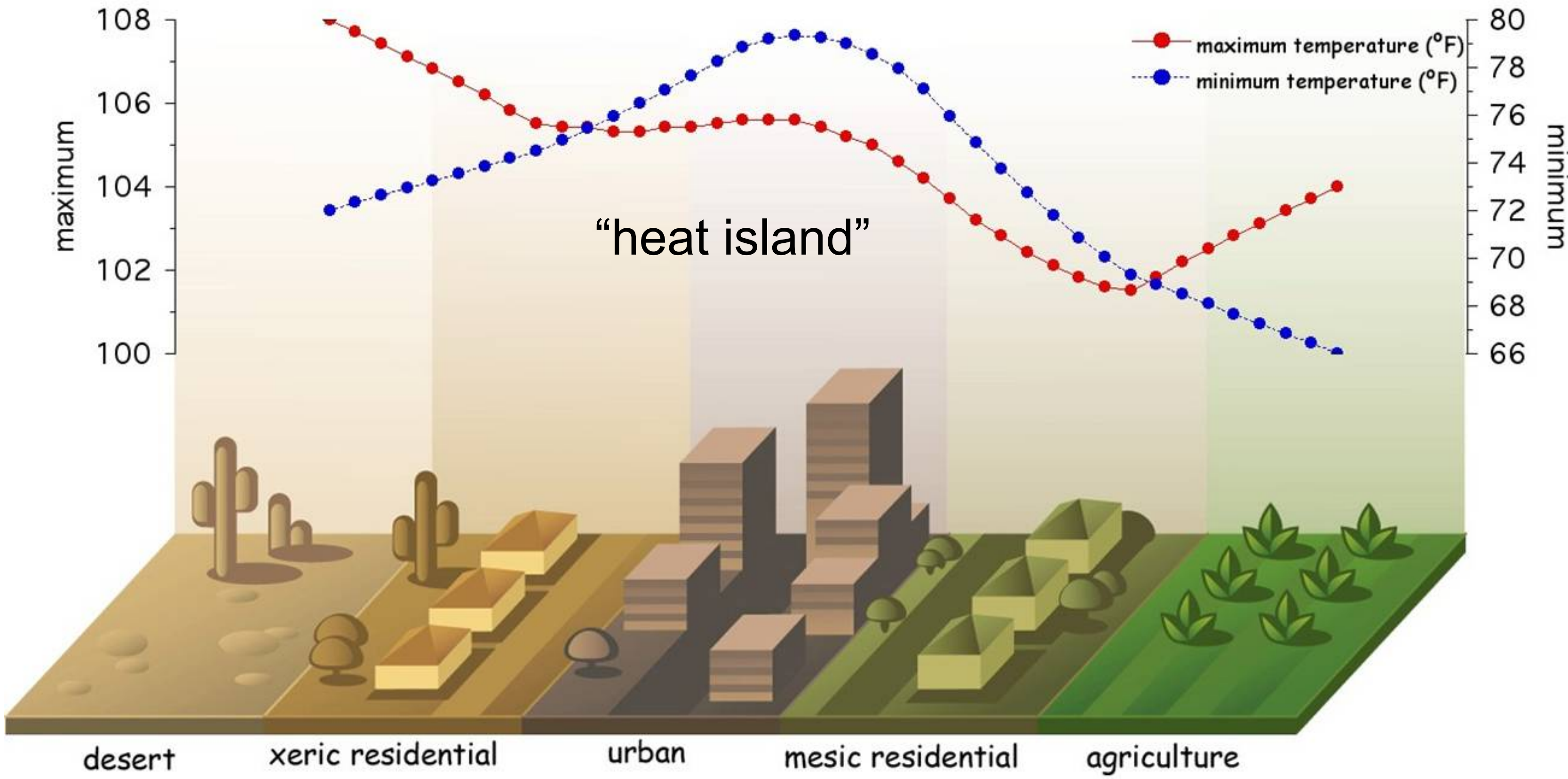

August 6, 2009 dust storm
August 8, 2009 after dust storm
distance to Mount Olympus ~ 4 miles
Views looking south from Foothill Drive in Salt Lake City
THUNDERBIRD DR
STRINGHAM AVE
FOOTHILL PLACE

MODIS dust retrieval using Miller algorithm for August 6, 2009

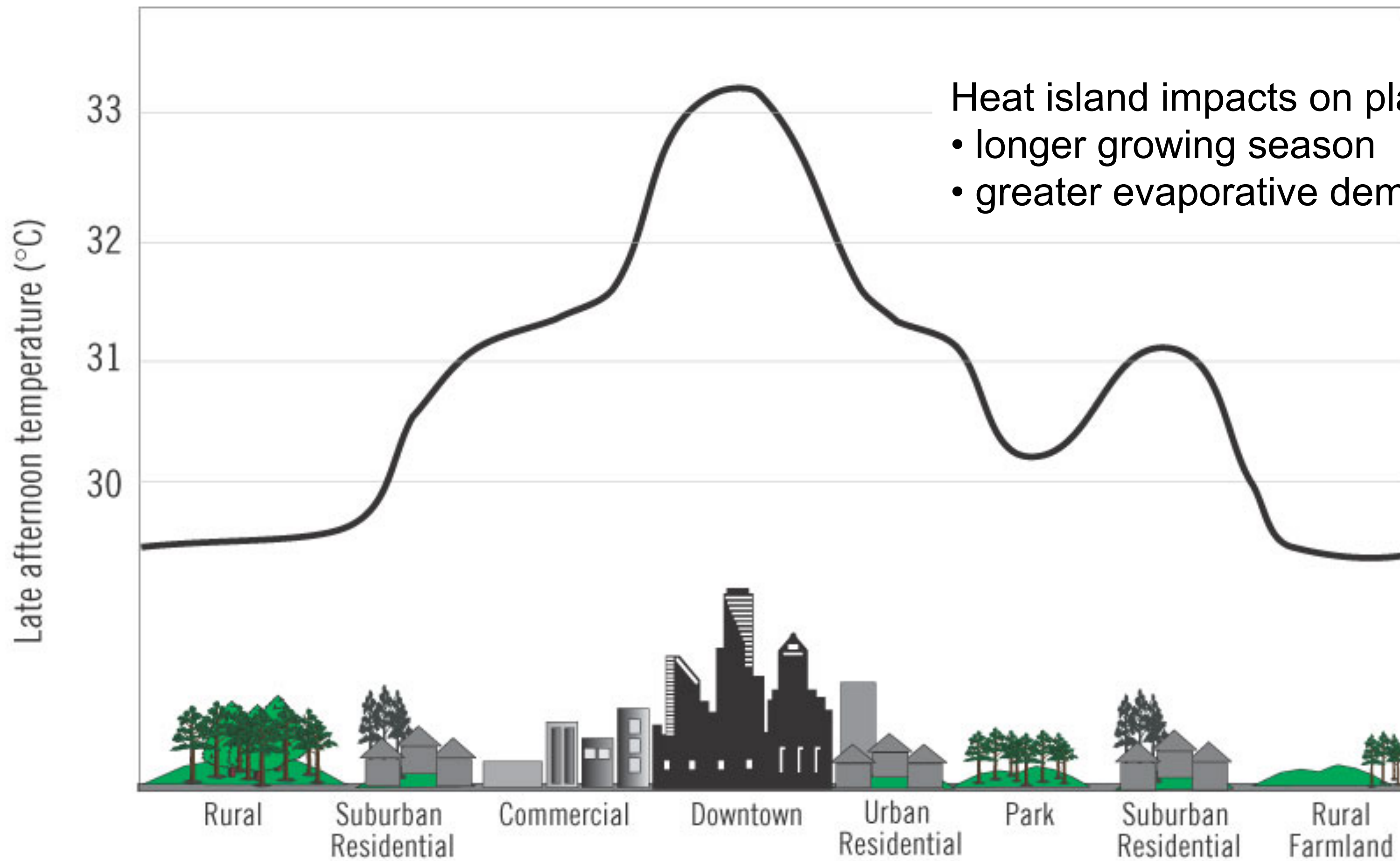
dust plume is about 300 km in length



$CO_2$ emissions are associated with increased energy production. Urban regions have warmer minimum temperatures, with impacts on biological wintertime persistence and summertime metabolism

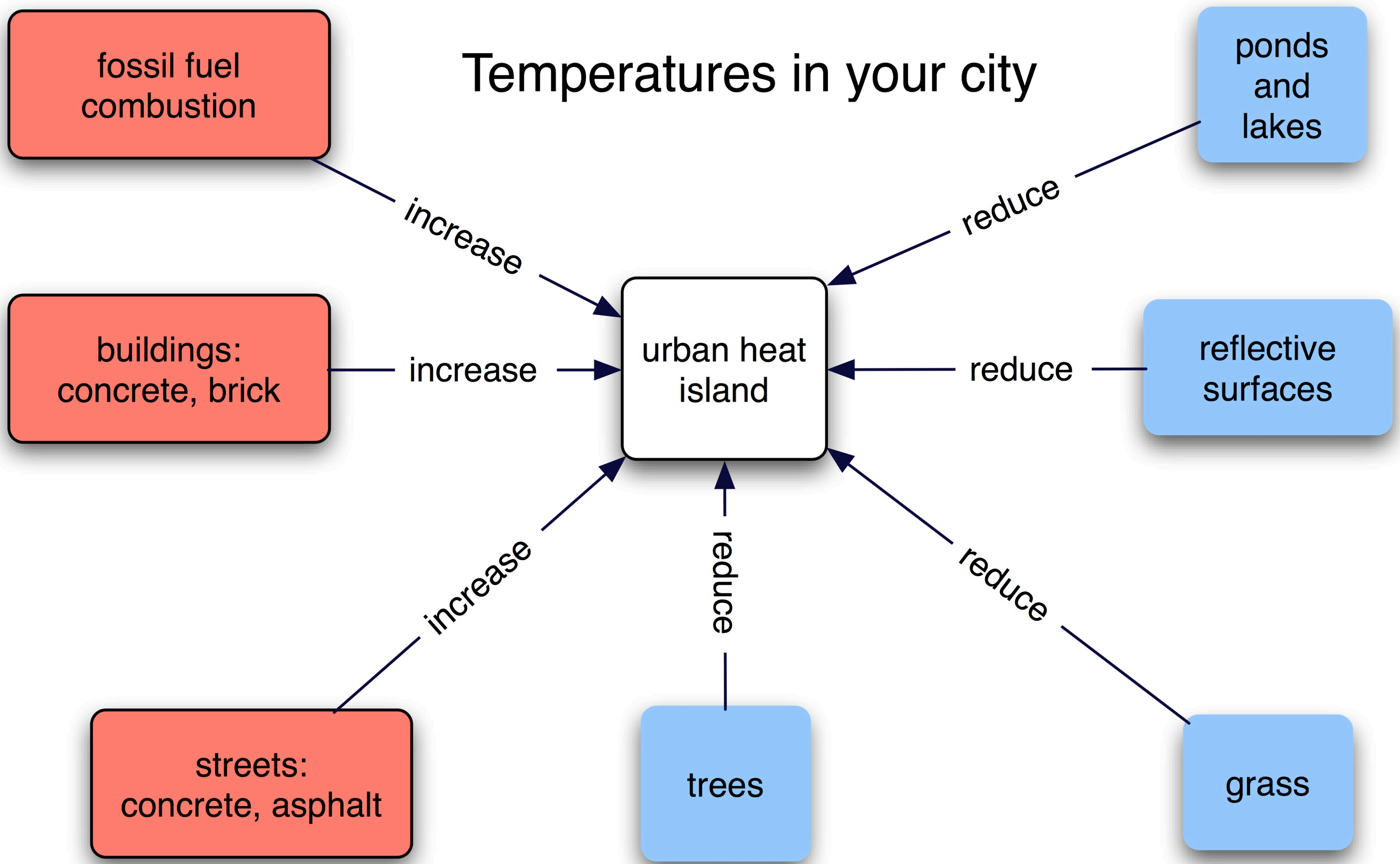


The urban heat island impact on humans becomes diminished because of the transpirational cooling associated with vegetation

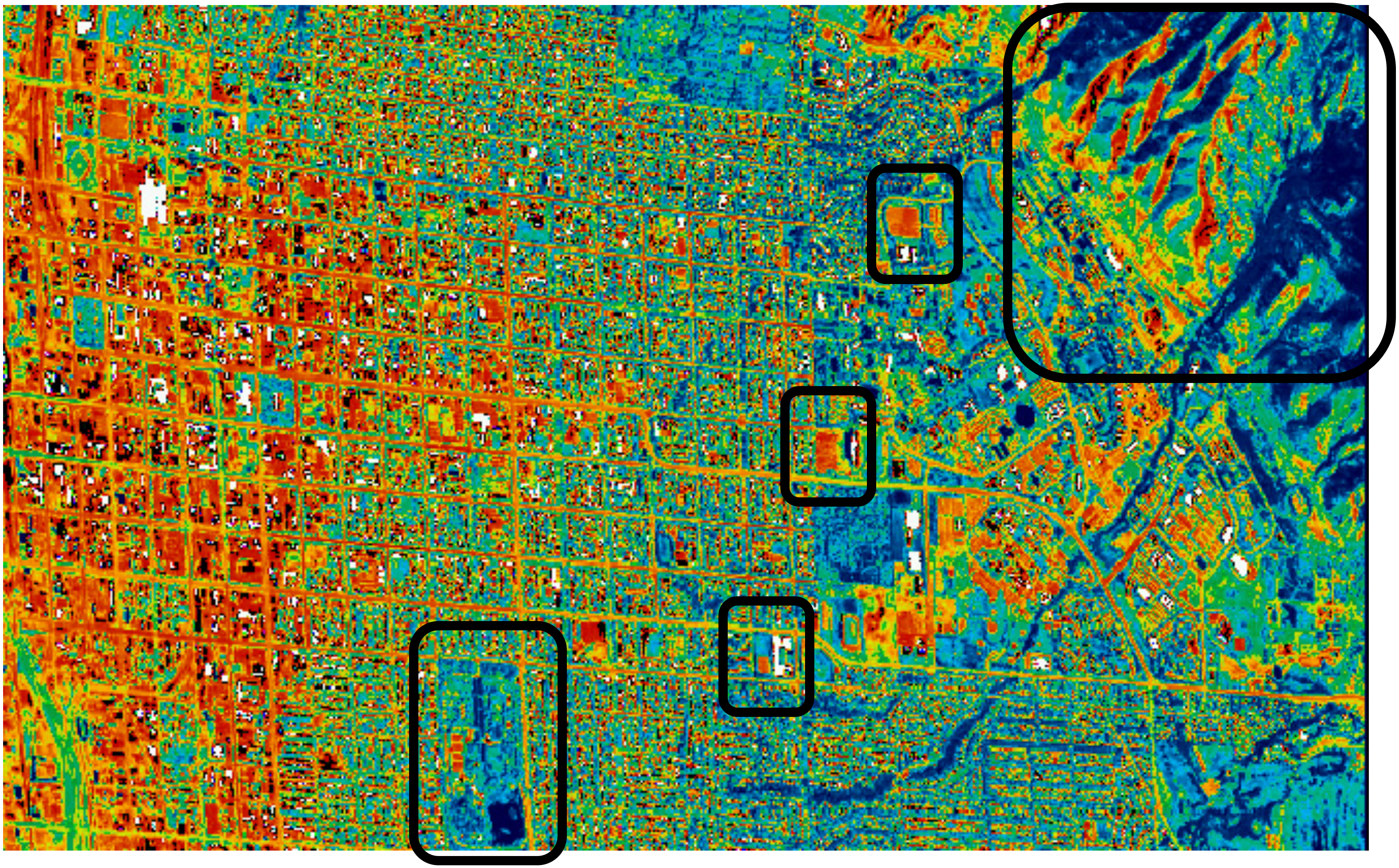



Heat island impacts on plants:

- longer growing season
- greater evaporative demand

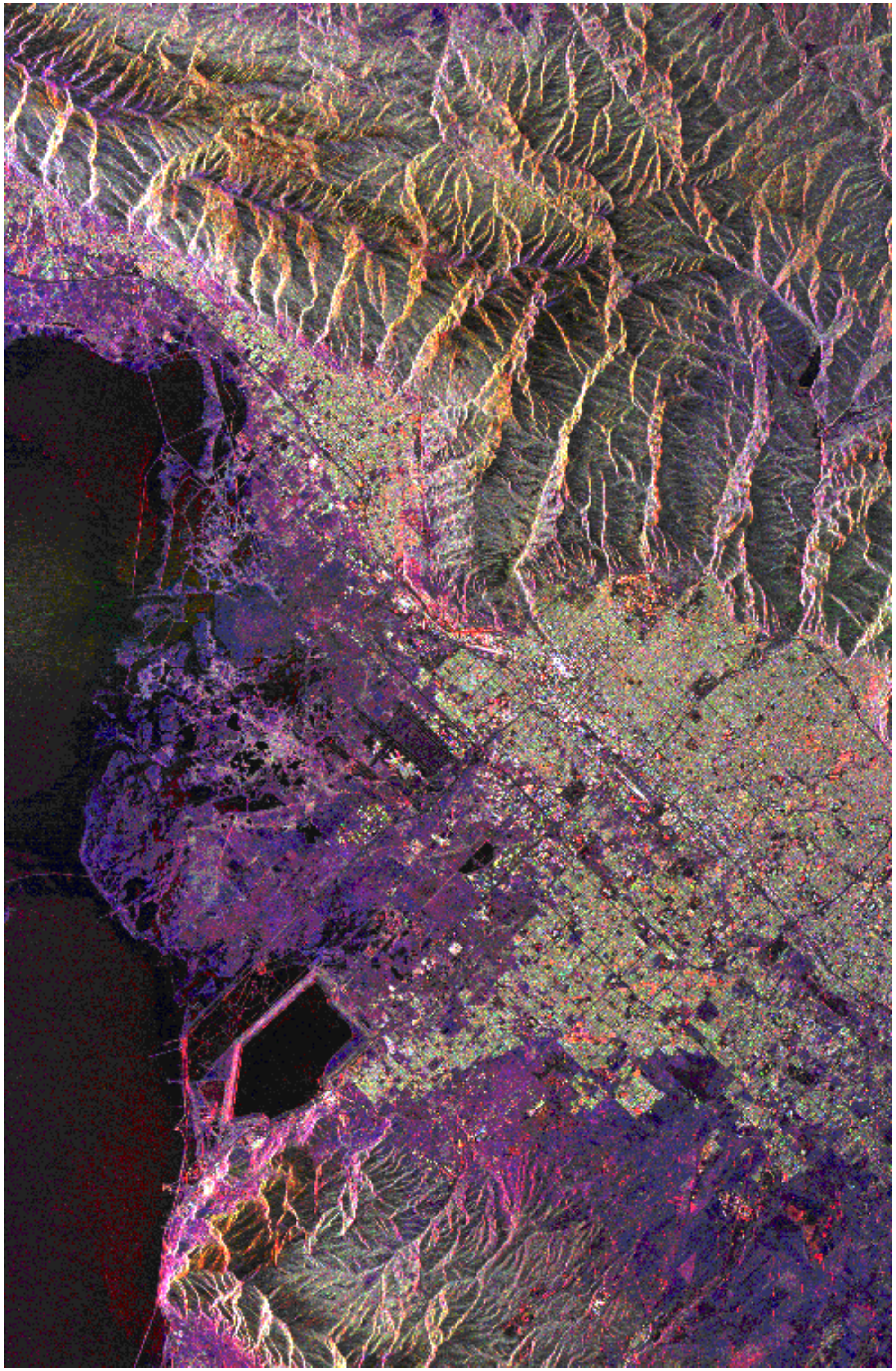

Temperatures in your city
fossil fuel combustion
increase
buildings: concrete, brick
increase
streets: concrete, asphalt
increase
urban heat island
ponds and lakes
reduce
reflective surfaces
reduce
trees
reduce
grass
reduce

How hot is Salt Lake City? Where are you in this remote sensed image?



Note strong east side vs west side differences in temperature - urban forest influences

note (1) parks, urban forest, and riparian corridors with reduced temperatures; (2) parking lots with higher temperatures; (3) slope differences in the foothills



Urban ecosystem challenges:

How and where we will grow?

What ecosystems will be impacted?

What about invasive species or and fire at the urban-wildland interfaces?

How will emissions influence mountain vegetation, snowpack, and nutrient transfers?

Is there a cooling vs. transpiration cost tradeoff in our future?

http://southport.jpl.nasa.gov/pio/srl1/sirc/slc.html

Sources and acknowledgment of data and illustrations used in the presentation:
original materials
http://ehleringer.net/publications.html
Ehleringer et al, Plant Ecology in a Changing World (book in preparation)
Susan Bush, PhD Thesis, University of Utah
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