

Water Demand Estimation with Satellite Data

DCDC Water Demand Workshop

Daniel Brent
University of Washington



April 18th 2013

OUTLINE

INTRODUCTION

LANDSCAPE

MARGINS OF ADJUSTMENT

PREVIEW OF RESULTS

METHODOLOGY

SATELLITE DATA

ESTIMATING LANDSCAPE

RESULTS

WATER AND LANDSCAPE

CONDITIONAL DEMAND

LANDSCAPE CONVERSIONS

CONCLUSIONS

ACKNOWLEDGMENTS

- ▶ Center for Environmental Economics and Sustainability Policy
 - ▶ Kerry Smith, Michael Hanemann, Nick Kuminoff, & Josh Abbott
- ▶ City of Phoenix Water Services Department
 - ▶ Doug Frost, Adam Miller
- ▶ Decision Center for a Desert City
 - ▶ Ray Quay, Dave White (and others)
- ▶ School of Geographical Sciences & Urban Planning
 - ▶ Soe Myint

LANDSCAPE

- ▶ Outdoor use can comprise up to 67% of urban demand
- ▶ Urban turf estimated to be single irrigated crop in the U.S. (Milesi, Elvidge, Nemani; 2009)
 - ▶ irrigated turf area: 4,503,668 - 9,602,148 ha
 - ▶ total irrigated cropland: 22,310,529 ha
 - ▶ corn for grain: 3,929,445 ha
- ▶ Tangible benefits of landscape (lot's of ASU/DCDC research here)
 - ▶ Monetary value
 - ▶ Social status
 - ▶ Ameliorate urban heat island effect

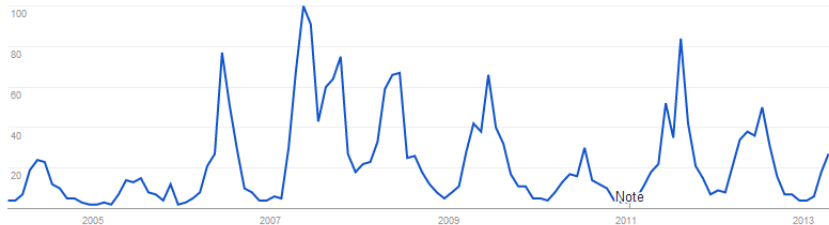
LANDSCAPE & WATER DEMAND

- ▶ Demand is counter-cyclical to supply
- ▶ Discretionary component of demand
- ▶ Often target of mandatory restrictions

Interest over time ?

The number 100 represents the peak search interest

News headlines Forecast ?



MARGINS OF ADJUSTMENT

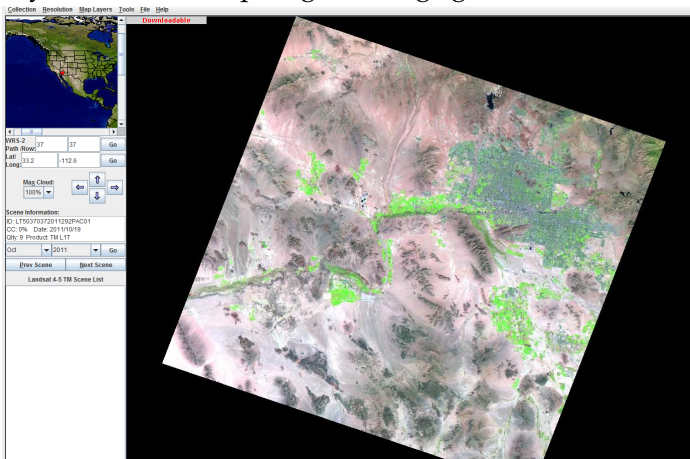
- ▶ Intensive margin - behavioral change
 - ▶ Often transient changes in demand (Price et al. 2011)
 - ▶ Composition of "water capital" impacts adjustment
- ▶ Extensive margin - change in "water capital"
 - ▶ Leads to persistent reductions in energy (Alcott & Rogers, 2012)
 - ▶ Associated with long-run demand
- ▶ Difficult to distinguish the two margins

PREVIEW OF RESULTS

- ▶ Satellite data does a decent job as a proxy for landscape
- ▶ Landscape has a crucial role in water use; and in demand parameters
 - ▶ Response to prices
 - ▶ Response to weather
- ▶ Price and neighbors' landscape influence conversions
- ▶ Landscape conversion significantly decreases water usage

LANDSAT

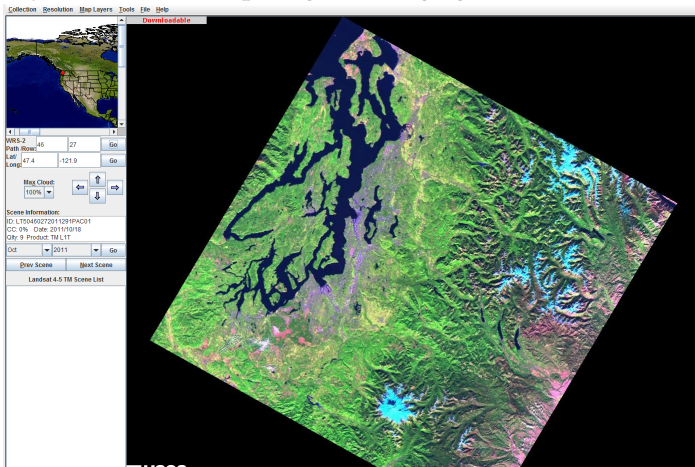
Publicly available @ <http://glovis.usgs.gov/>



Phoenix - October 2011

LANDSAT

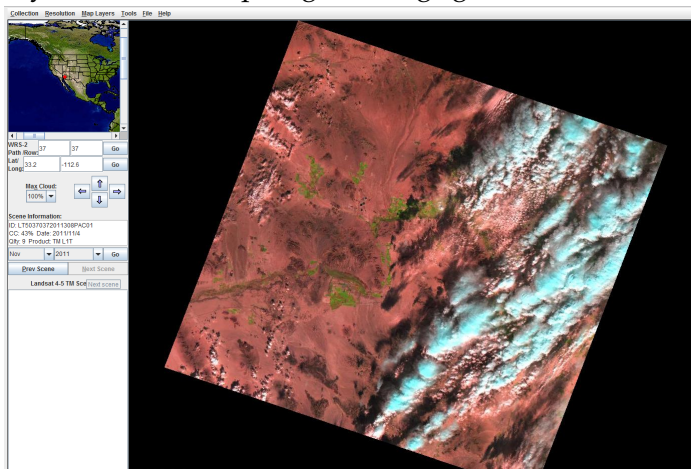
Publicly available @ <http://glovis.usgs.gov/>



Seattle - October 2011

LANDSAT

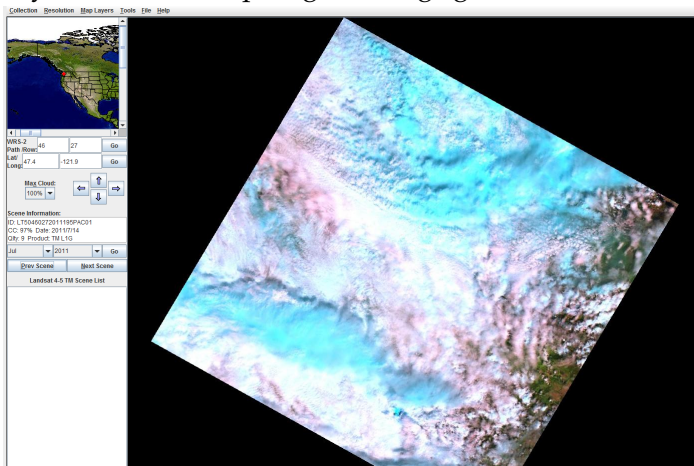
Publicly available @ <http://glovis.usgs.gov/>



Phoenix - November 2011

LANDSAT

Publicly available @ <http://glovis.usgs.gov/>

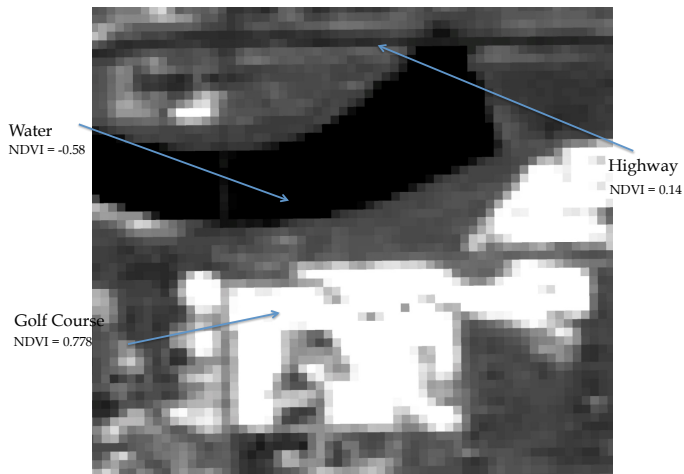


Seattle - July 2011

SATELLITE DATA

- ▶ Landsat 5 Thematic Mapper captures 7 bands of the electromagnetic spectrum
 - ▶ 30m resolution
 - ▶ Records an image at the same location every 16 days
- ▶ Normalized Difference Vegetative Index (NDVI) captures live vegetation
 - ▶ Deforestation
 - ▶ Land use change
 - ▶ Evapotranspiration and water rights

NDVI



Northwest of ASU - Summer 2003

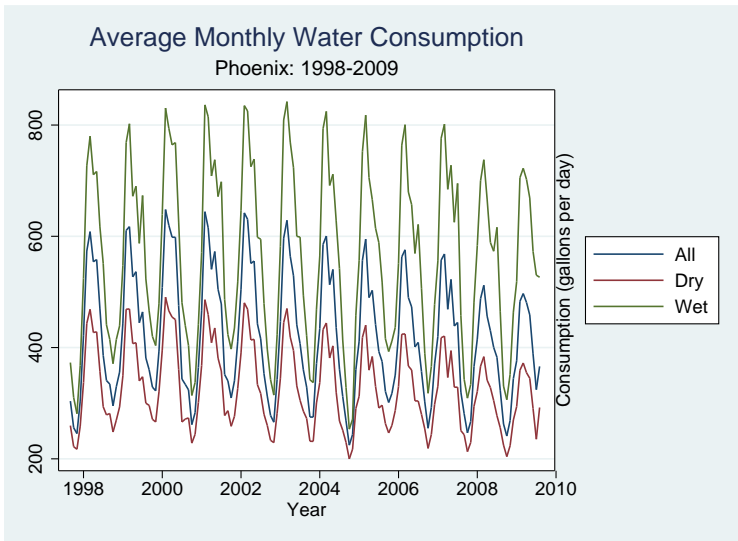
ADDITIONAL DATA

- ▶ Monthly water metering records for $> 185,000$ households in City of Phoenix from 1998-2009 ($\approx 24\text{m}$ obs)
 - ▶ Thanks Doug & Adam!
- ▶ Structural characteristics of the house (lot size, pool, rooms, etc)
- ▶ Weather data
- ▶ Census demographic and socioeconomic data

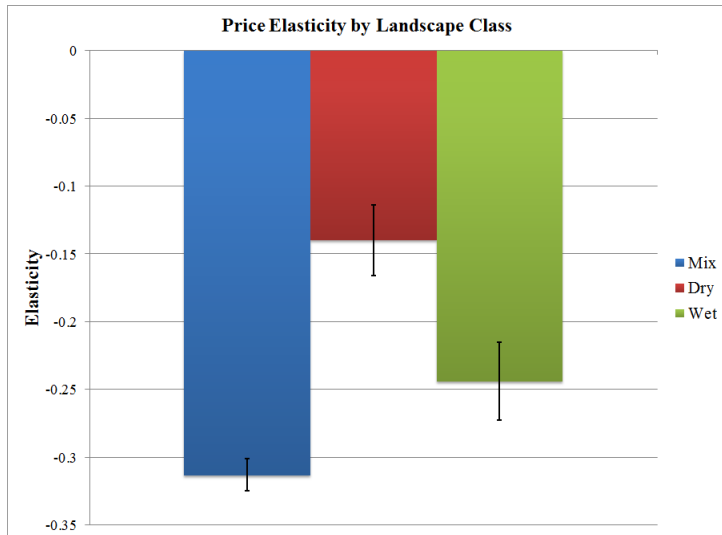
FEASIBILITY

- ▶ Spatially merge a time series NDVI to each parcel
 - ▶ Landsat pixel = 900m^2 & average lot size = 861m^2
 - ▶ Tradeoff between resolution and scale
 - ▶ Thanks Soe!
- ▶ compare to Stefanov et al. (1998) & recent landscape
- ▶ NDVI performs well in the "tails"

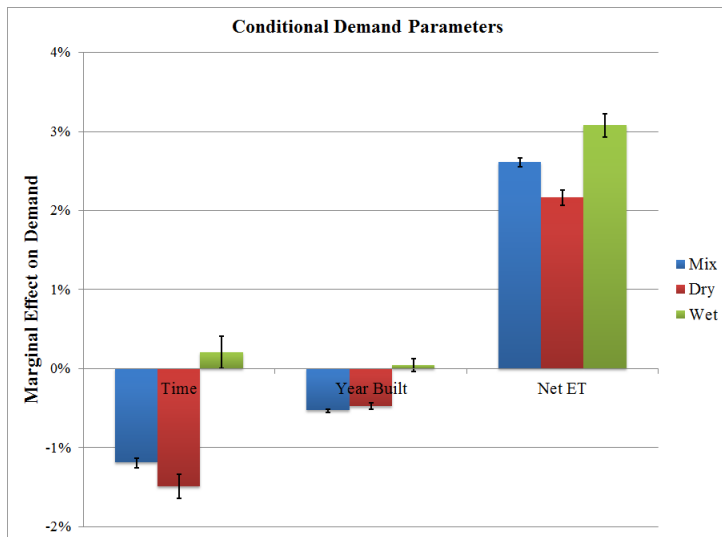
WATER AND LANDSCAPE



CONDITIONAL DEMAND



CONDITIONAL DEMAND



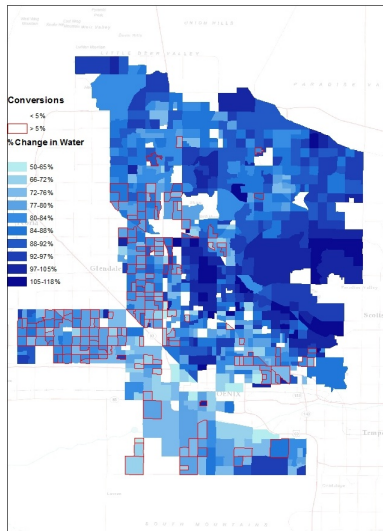
LANDSCAPE DECISIONS

- ▶ Landscape capitalization into home prices (Smith & Klabier; 2010)
 - ▶ MWTP for green parcel landscaping is \$17
 - ▶ MWTP for green neighborhood is \$116
- ▶ Social perceptions based on landscape (Ledlow, Sadalla, & many other DCDC affiliates)
 - ▶ more sexual attractive
 - ▶ more family oriented
 - ▶ more extroverted
- ▶ Urban heat island effect (Gober, Brazel, Quay, Myint, Grossman-Clarke , Miller & Rossi; 2010)

LANDSCAPE CONVERSIONS

- ▶ Price, and even stronger lagged price, increases probability of conversion
- ▶ Presence of neighbors with dry landscape makes conversion more likely
- ▶ Landscape conversions cause a 20-30% drop in water usage

CONVERSIONS & LONG-RUN DEMAND



Relative Water Use 2008-09 to 1998-99 with landscape conversions

CONCLUSIONS

- ▶ Satellite data for modeling water demand
- ▶ Heterogeneity in demand due to landscape
- ▶ Landscape conversions as a driver in reducing demand
- ▶ Joint evolution of water demand and landscape

FUTURE WORK

- ▶ Compare across cities
- ▶ See response to policy initiatives
 - ▶ Water restrictions
 - ▶ Landscape conversion incentives: Christa Brelsford
- ▶ Water-energy nexus