Spatial Scaling Effects On Estimating Variability Of Water Supply And Use

John Helly [1, 2, 3]

[1]Member, Board of Water Supply, County of Maui
[2]San Diego Supercomputer Center
[3]Scripps Institution of Oceanography,
University of California, San Diego, La Jolla, California

Outline

1. Background
2. Why Does This Matter?
3. Background: How We Got Here
4. Water Balance and Water Profiles
5. Variability as a Function of Scale
6. Behavior of Outliers in Data: California and Maui

Acknowledgment and Caveats

1. California work funded by California Department of Water Resources (CDWR) and NOAA following initial USEPA funding
    1. Collaboration with Dan Cayan/UCSD SIO, Jennifer Stricklin/CDWR, Laurel DeHaan/UCSD SIO and
    2. Depends on the work of a lot of dedicated CDWR folks collectively the Water Balance Team
    3. Full acknowledgements are in the papers
2. This talk focuses on
    1. Preliminary results applying the approach to Maui
    2. Maui data provided by the County of Maui Department of Water Supply, Director John Stufflebean (no private water system data available)
    3. Work in progress; not yet peer-reviewed
    4. Maui work is funded by me and results, opinions, thoughts, implications are strictly my own

Publications Related to California Data

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE
Sponsored by the Delta Science Program and the UC Davis Muir Institute

RESEARCH

Patterns of Water Use in California

John Helly*[1,2], Dan Cayan[1], Tom Corringham[1], Jennifer Stricklin[3], Todd Hillaire[3]

ABSTRACT

Recent patterns of water use and supply in California are presented based on a new data set compiled from the California Department of Water Resources water balance data for 2002 through 2016. The water use and supply include surface water and groundwater, although groundwater reporting has been incomplete. These data are used to support the Water Plan released every 3 to 5 years and are the most comprehensive and finest spatial- and temporal-scale data set for California water resources. First, using the Bay–Delta watershed as a case example, we show that recent fluctuations in water use are highly correlated with variations in precipitation. Developed water supplies and use show these fluctuations, but they are modified by reservoir inflows and releases, groundwater supplies, and Delta outflows. Second, although the annually precipitated water supply in the Bay–Delta varies by about 30%, the developed water supply damps this considerably. The water management system maintained nearly constant agricultural water use even in periods of intense drought, with year-to-year variation of about 7%. Variability in urban water use is higher (~20%), largely from conservation during periods of drought. Finally, this information can help improve water resource management because it connects regional-scale data to meaningful policy decision-making at county and sub-county levels. At a time when water policy and management are being re-evaluated across the American West in the light of changing climate, decision-making informed by science and data is urgently needed. The statewide water balance data provide the means to establish a consistent, quantitative framework for water resource analysis throughout the state.

SFEWS Volume 19 | Issue 4 | Article 2
https://doi.org/10.15447/sfews.2021v19iss4art2

* Corresponding author: hellyj@ucsd.edu

1 Climate, Atmospheric Science and Physical Oceanography, Scripps Institution of Oceanography, University of California–San Diego, La Jolla, CA 92098 USA

2 San Diego Supercomputer Center, University of California–San Diego, La Jolla, CA 92098 USA

3 California Natural Resources Agency, Department of Water Resources, Sacramento, CA 95814 USA

KEY WORDS

California, water, hydrology, Bay–Delta, precipitation, regional, data, agriculture, urban, managed wetlands, California Water Plan

SFEWS, 19(4), 2021, 25 pp.

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE
Sponsored by the Delta Stewardship Council and UC Davis Institute of the Environment

RESEARCH

Spatial Patterns of Water Supply and Use in California

John J. Helly[1,2], Daniel Cayan[1], Jennifer Stricklin[3], Laurel Dehaan[1]

ABSTRACT

Spatial and temporal patterns of water supply and consumptive water use were analyzed from 475 Detailed Analysis Units by County (DAUCOs) spatial units across California during 2002 through 2016 to evaluate spatial and temporal variability and how it might associate with precipitation variability and other factors. Many, but not all, DAUCOs have relatively low total water supply variability compared to that of state-wide precipitation. Such low variability, in DAUCOs having sufficient diversity of water supply sources, is the result of switching between sources as needed to maintain a reliable total water supply. We used multiple approaches to explore these variations which involved four categories of water supply (local, groundwater, imported, and other) and two categories of water use (agricultural and urban). First, a cluster analysis of the volumetric water balance data identified a small set of clusters having similar magnitudes and proportions of water supply sources and water use—some of them composed of only a few DAUCOs but accounting for a disproportionate amount of the state's water use. Second, a principal components analysis identified leading modes of anomalous water supply and water use among the 475 DAUCOs, capturing most of the time variation during 2002 to 2016. The most prominent mode exhibits a multi-year trend, most strongly involving increasing groundwater supply and agricultural water use, and decreasing urban water use and imported water supply. Over the study period, trends in both supply and use were pronounced, but differed considerably across California DAUCOs. One predominant subset of DAUCOs grew their agricultural water use with increased groundwater supply; in contrast to a widespread group of DAUCOs which reduced their urban water use. An important result for planners is our finding that variation in precipitation—itself important—is amplified by the human response to water supply availability and regulatory policy.

SFEWS Volume 22 | Issue 2 | Article 2
https://doi.org/10.15447/sfews.2024v22iss2

* Corresponding author: hellyj@ucsd.edu

1 Climate, Atmospheric Science and Physical Oceanography, Scripps Institution of Oceanography, University of California–San Diego, La Jolla, CA, USA 92093

2 San Diego Supercomputer Center, University of California–San Diego, La Jolla, CA, USA 92093

3 California Department of Water Resources, Sacramento, CA, USA 95814

SFEWS, 22(2), 2024, 39 pp.

Why Does This Matter?

1. Water supplies have limits generally ignored until threatened (i.e., depleted)
2. One *obvious* thing to do is account for use and balance against availability
    1. How much are we using *(use*)?
    2. How variable, and potentially elastic, is that use?
    3. How much is available *(supply*) ?
    4. How variable, is supply and what is required the make that supply sustainable (*developed supply*)?
3. Then, make political, social and economic decisions to remain within those limits

From Hydrology to Water Supply and Decision-making

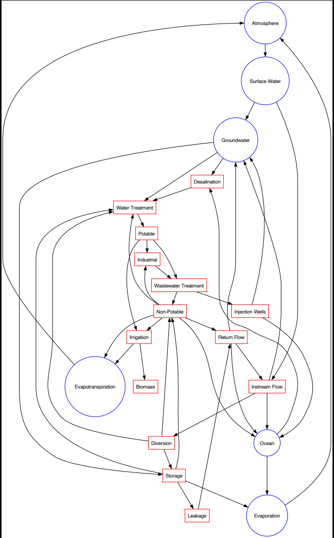
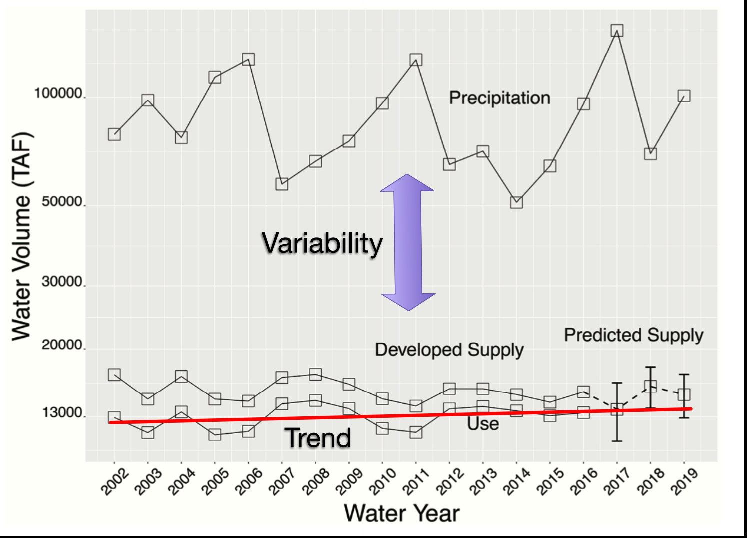


Table 11: Water balance for the Lahaina Aquifer Sector Area.

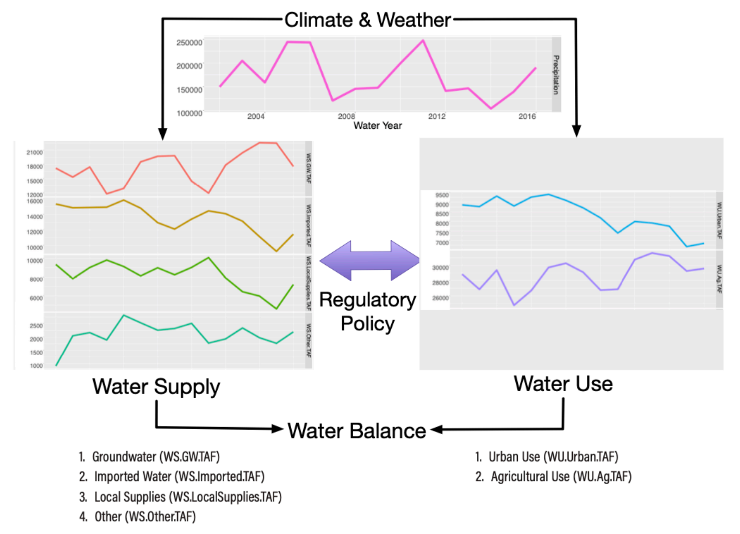
			Watershed												
			Honokahua	Honokohau	Honokowai	Honolua	Kahana	Kahoma	Kauaula	Launiopoko	Launiupoko	Olowalu	Ukamehame	Wahikuli	Subtotal
			MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD	MGD
CategoryA	CategoryB	CategoryC	sum	sum	sum	sum	sum	sum	sum	sum	sum	sum	sum	sum	sum
Supply	Groundwater/MDWS	MUN.County	.	0.28	.	.	0.11	0.04	0.09	.	.	.	.	.	0.52
		UNU.Unused	.	.	0.00	.	0.00	.	.	.	.	.	.	0.00	0.00
		Subtotal	.	0.28	0.00	.	0.11	0.04	0.09	.	.	.	.	0.00	0.52
	Groundwater/Private	ABN.Lost	.	.	.	.	.	.	.	.	.	.	.	0.00	0.00
		AGR.Agriculture	.	.	.	.	.	.	0.01	.	.	.	.	.	0.01
		AGR.Crops + Processing	.	.	1.84	.	.	.	0.02	0.00	.	.	.	.	1.86
		DOM.Single + Multi Low-Rise + High-Rise Households	.	0.01	.	0.00	.	0.00	.	0.01	.	.	.	.	0.02
		IND.Geothermal, Thermoelectric Cooling, Power Develop	.	.	.	.	.	.	.	.	.	.	.	0.66	0.66
		IND.Mining, Dust Control	.	.	.	.	.	.	0.00	.	.	.	.	.	0.00
		IRR.Golf Course	.	.	.	.	.	.	.	.	.	.	.	0.08	0.08
		IRR.Landscape/Water Features	.	.	0.00	.	0.01	0.01	0.03	0.02	.	0.05	.	.	0.12
		IRR.Parks	.	.	.	.	0.01	.	.	.	.	.	.	.	0.01
		MUN.Private (but Public.DOH definition)	.	0.28	0.22	.	0.33	.	0.19	0.04	.	.	0.03	0.30	1.38
		UNU.Unused	.	0.00	0.00	.	.	0.00	0.00	.	.	0.00	0.00	0.00	0.00
		Subtotal	.	0.28	2.07	0.00	0.34	0.01	0.26	0.07	.	0.05	0.03	1.04	4.14
	Interbasin.Transfer	Lahaina.WTF.Distribution	.	.	.	.	.	0.39	-0.39	.	.	.	.	.	0.00
		Lahaina.WTF.Intake	.	.	.	.	.	-0.77	0.77	.	.	.	.	.	0.00
		Mahinahina.WTF.Distribution	.	.	0.29	.	.	0.29	.	.	.	.	.	.	0.57
		Mahinahina.WTF.Intake	.	.	.	-0.86	.	.	.	.	.	.	.	0.14	-0.72
		Subtotal	.	.	0.29	-0.86	.	-0.10	0.39	.	.	.	.	0.14	-0.14
	Recycled.Water	Lahaina.WWTF	.	.	.	.	.	.	.	.	.	.	.	0.50	0.50
		Subtotal	.	.	.	.	.	.	.	.	.	.	.	0.50	0.50
	Surface.Water	Honokohau	.	13.57	.	.	.	.	.	.	.	.	.	.	13.57
		Honokohau Stream IFS	.	-8.60	.	.	.	.	.	.	.	.	.	.	-8.60
		Honokowai	.	.	3.49	.	.	.	.	.	.	.	.	.	3.49
		Honolua	.	.	.	2.46	.	.	.	.	.	.	.	.	2.46
		Honolua Stream IFS	.	.	.	0.00	.	.	.	.	.	.	.	.	0.00
		Kahoma	.	.	.	.	.	3.75	.	.	.	.	.	.	3.75
		Kanaha	.	.	.	.	3.17	.	.	.	.	.	.	.	3.17
		Kapaloa Stream IFS	.	.	0.00	.	.	.	.	.	.	.	.	.	0.00
		Kauaula	.	.	.	.	.	.	6.14	.	.	.	.	.	6.14
		Launiupoko	.	.	.	.	.	.	.	0.30	.	.	.	.	0.30
		Olowalu	.	.	.	.	.	.	.	.	.	3.94	.	.	3.94
		Subtotal	.	4.97	3.49	2.46	3.17	3.75	6.14	0.30	.	3.94	.	.	28.20
		Total	.	5.53	5.84	1.60	3.62	3.70	6.87	0.38	.	3.99	0.03	1.68	33.22
Use	DWS	A-1 Apartment	.	.	-0.07	.	-0.10	-0.08	-0.03	.	.	.	.	.	-0.27
		A-2 Apartment	.	.	-0.27	.	-0.06	-0.01	.	.	.	.	.	.	-0.34
		AG Agriculture	.	-0.00	.	.	-0.20	-0.15	-0.06	.	.	.	.	.	-0.42
		B-2 Business - Community	.	.	-0.04	.	-0.05	-0.07	-0.04	.	.	.	.	.	-0.20
		B-3 Business - Central District	.	.	-0.00	.	.	.	.	.	.	.	.	.	-0.00
		CID Napili Bay Civic Improvement District	.	.	.	.	-0.32	.	.	.	.	.	.	.	-0.32
		D-1 Duplex	.	.	.	.	-0.00	.	0.00	.	.	.	.	.	-0.00
		H Hotel	.	.	-0.20	.	.	.	-0.01	.	.	.	.	.	-0.21
		H-1 Hotel	.	.	.	.	.	.	-0.10	.	.	.	.	.	-0.10
		H-2 Hotel	.	.	-0.12	.	-0.24	.	.	.	.	.	.	.	-0.36
		H-M Hotel	.	.	.	.	-0.10	.	-0.00	.	.	.	.	-0.16	-0.27
		HD-1 Historic District 1	.	.	.	.	.	-0.02	-0.10	.	.	.	.	.	-0.12

Climate & Weather & Developed Water Supply

What Happens When … ?



For Any Spatial Domain, There is A Water Balance ...



Fine-scale Resolution Can Reveal Import Distinctions Not Apparent At Coarser Scales

pers. comm. D. Cayan

1. Different use-types (e.g. Ag vs Urban, Resort vs Residential) can exhibit very different responses to climate and regulatory environments
2. Large variations across spatial scales
    1. A few locales might consume a disproportionate fraction of total water supply
3. Crucial to monitor supply and use at fine scales

MS1 Example of A Water Balance Profile For A Single Spatial Unit

Table 1 Water-balance profile example for DAUCO 00125: Lost River, Modoc County, Upper Klamath Hydrologic Region. Water-supply variables are prefixed WS.* and water-use variables are prefixed WU.*. TAF is a suffix for volumetric units. Variables based on percentages have a PCT suffix.

Time	Supply				Use	
	WS.GW.TAF	WS.Imported.TAF	WS.LocalSupplies.TAF	WS.Other.TAF	WU.Urban.TAF	WU.Ag.TAF
2002	8.7	82.5	15.3	18.4	0.3	107.8
2003	6.1	62.7	15.3	10.0	0.3	79.6
2004	6.5	91.8	7.6	1.8	0.3	86.4
2005	5.9	70.0	11.4	1.3	0.3	74.2
2006	8.2	68.3	15.3	30.3	0.2	106.3
2007	9.3	86.5	11.4	21.2	0.2	110.6
2008	8.0	90.0	7.6	21.2	0.3	109.5
2009	8.2	95.7	11.4	17.9	0.2	115.0
2010	8.3	48.3	15.3	42.1	0.2	99.9
2011	12.9	67.8	0.7	34.9	0.2	96.7
2012	19.6	74.8	0.7	36.0	0.2	111.5
2013	13.6	58.5	0.7	30.8	0.2	88.8
2014	13.6	54.1	1.2	24.7	0.1	79.6
2015	12.5	52.8	1.2	23.4	0.2	76.3
2016	15.8	88.8	1.2	0.0	0.1	90.1

1. Multivariate (i.e., 6D)
2. Replicated (e.g., temporally (7D))
3. Each observation is a 7D vector

Summary: California Statewide Annual Water Balance Data 2002-2016 / 485 Spatial Units(univariate)

Table 2 Summary of statistics describing aggregated state-wide water-balance variables and state-wide precipitation. WS.* prefixes water-supply variables and WU.* prefixes water-use variables. TAF is suffix for volumetric units of thousands of acre-feet. Mean and standard deviation are in TAF units. Proportion, coefficient of variation, correlation, trend and r^2 are dimensionless. Proportion is fraction of total water supply or total water use, respectively. Total water supply is the sum of groundwater, imported, local, and other supply components and total water use is the sum of agricultural and urban use. Trend is the standardized slope (Equation 5) of the variable's time-series.

	Supply				Use				
Statistic	**WS.GW.TAF**	**WS.Imported.TAF**	**WS.LocalSupplies.TAF**	**WS.Other.TAF**	**WU.Ag.TAF**	**WU.Urban.TAF**	**WS.Total.TAF**	**WU.Total.TAF**	**PPT.TAF**
Proportion	0.42	0.33	0.20	0.05	0.78	0.22	1.00	1.00	—
Mean	17339.75	13499.70	8116.82	2091.83	28768.24	8329.26	41048.09	37097.50	172033.8
Standard deviation	3474.70	1851.69	1525.65	443.2	1972.67	883.23	2158.12	1991.08	46663.2
Coefficient of variation	0.20	0.14	0.19	0.21	0.07	0.11	0.05	0.05	0.27
Correlation with precipitation	-0.92	0.47	0.59	0.12	-0.87	0.03	-0.63	-0.84	1.0
Correlation (*p*-value)	0.00	0.08	0.02	0.66	0.00	0.91	0.01	0.00	0
Trend	0.31	-0.37	-0.42	0.11	0.11	-0.30	-0.06	0.02	-0.24
Trend (r^2)	0.22	0.64	0.43	0.02	0.23	0.72	0.13	0.01	0.07

However, As Spatial Resolution Is Improved ...

DECEMBER 2021

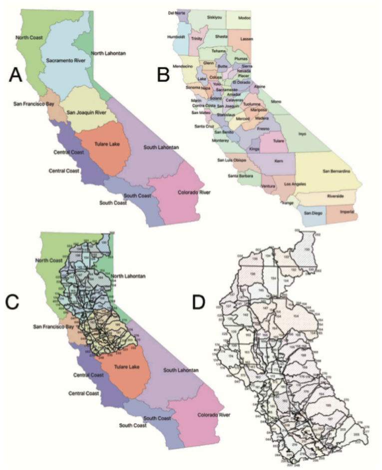


Figure 1 (A) California's Hydrologic Regions (HRs) as defined by the California Department of Water Resources. (B) Counties. (C) Bay-Delta watershed formed from Sacramento River and San Joaquin River HRs partitioned into counties and labeled with Detailed Analysis Unit (DAU) codes. (D) DAUs within the Bay-Delta watershed. Note that there may be multiple DAUs within a county or multiple counties with parts of one or more DAUs.

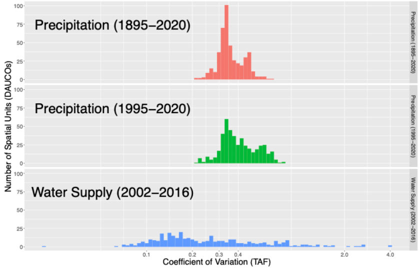
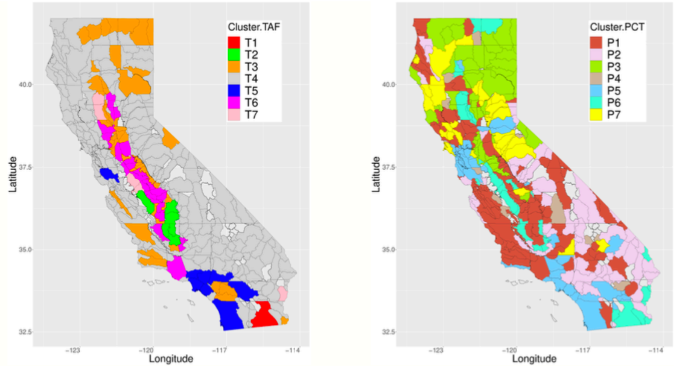


Figure 4 Distributions of CVs of DAUCO precipitation (1895–2020 and 1995–2020) and of total water supply (2002–2016). See corresponding maps in Figure 3.

… Hidden Spatial Variability is Revealed via Clustering of Water Balance Profiles



(**A**) Volumetric units (TAF)

(**B**) Percentages of volumetric units (%, PCT)

Figure 9 Comparison of the spatial distribution of clusters derived from (**A**) volumetric units versus those from (**B**) percentages. The T-clusters in (**A**) are strongly regionalized based on amount of water used and supplied, as well as the type of supply. The clusters in (**B**) are also organized by land use, but these P-clusters incorporate a wider mixture of land use between urban and agriculture. Blank polygons (NA) denote DAUCOs with only zero values for total water supply.

Where Does This Get Us?

1. Multivariate profiles, of spatial units, provide a consistent way to describe variability across spatial scales and time (upscale, downscale, in a consistent manner)
2. Categorization (e.g., clustering) could be done on each individual supply or use variable but ...
    1. Non-independent variables, ≥ 8 special cases of interactions (e.g. urban/imported vs urban/groundwater)
    2. Hard to understand, harder to explain
3. Multivariate clustering results in useful, narrative, descriptions; easier to understand and explain
4. CA data still limited to annual: no seasonality, no sub-annual events (i.e., storms, short-term droughts)

Explanatory Value in Relation to Water Balance

Example Statement: *T2 is comprised, mostly, of agricultural land-use, at 94%, with a conjunctive water supply that is 60% groundwater-dependent*

Table 4 Summary of DAUCO membership in each volumetric cluster (TAF) with profiles summarized by water supply and use patterns. Integers in columns are the number of DAUCOs in each T-cluster (T1-T7). Water Use and Water Supply columns contain brief descriptions of the mean characteristics of the corresponding T-cluster.

T1	T2	T3	T4	T5	T6	T7	Water Use	Water Supply
1							Imperial DAUCO only. Agriculture (97%), Urban (3%)	Imported water (94%)
	6						Mostly agricultural (94%).	Mixed (GW 60%)
		56					Mostly agriculture (84%).	Mixed (GW 50%)
			375				Split between urban (45%) and agricultural (55%)	Mixed (GW 44%)
				8			Mostly urban (83%)	Mixed (Imported 50%)
					24		Mostly agriculture (91%)	Mixed (GW 47%)
						5	Mostly agriculture (99%)	Mostly imported (73%)

What Has This To Do With Maui?

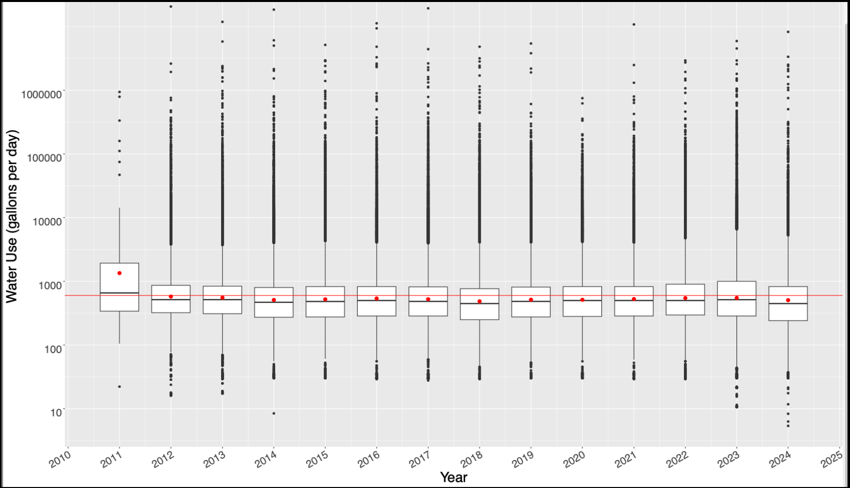
1. *New Case study:* Can water balance methodology (i.e., profiles) be usefully applied to Maui?
    1. Water balance problems resulting from abandoned, long-term agricultural land-use; typical development pressures on old Ag land with demand for *potable water*
    2. exacerbated by COVID pandemic, wildfires' effects on housing and re-construction
    3. Impacts of tourism on small, well-circumscribed spatial domain

2. What have we got for data?
    1. What's the best spatial resolution available?
        1. Limiting case for developed water supplies is to use tax-parcel polygons (in the US)
    2. What's the best temporal resolution available?
        1. Approximately monthly meter reading transformed into volume per day (e.g., gallons per day)

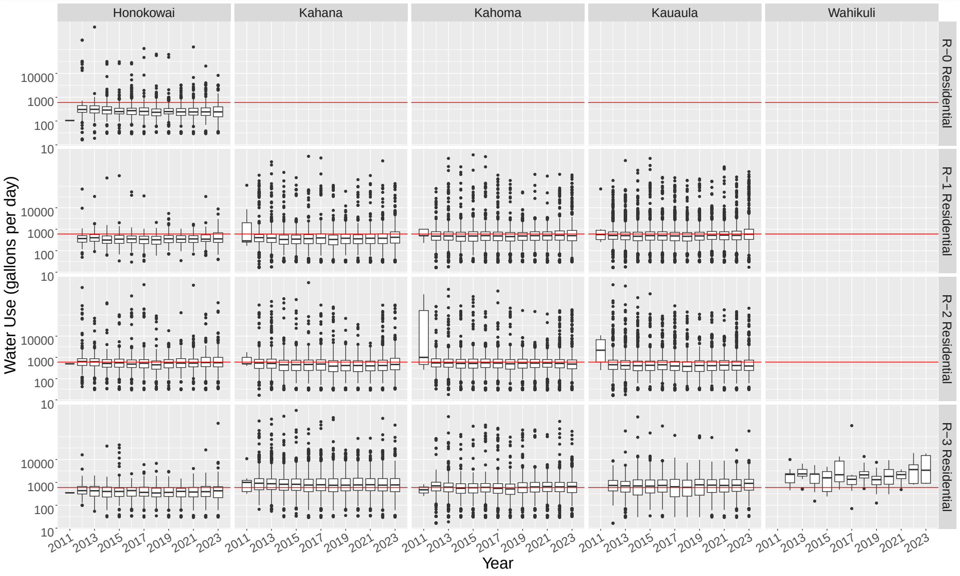
Maui Data *No ka 'oi*: Metered and Tax-parceled

1. County of Maui Department of Water Supply (MDWS) data only; no private water system data
2. Metered volumetric data
   1. Reading-oriented with better temporal resolution
   2. Monthly data in units of mean volume per day *(i.e., flow rate)* between readings
   3. Can see seasonality but not storm events
   4. Increasingly automated data collection and proliferation
3. Spatial partitioning by tax parcel
   1. Associated with zoning, watershed units, aquifers, other socio-economic data tied to households
   2. Aggregated into larger spatial units by the union of polygons so that outer spatial boundaries are consistent at different scales of aggregation
   3. Big problem with CA data at present due to inconsistent polygons at various spatial scales
   4. Mapping into USGS HUCs could lead to refined HUC boundaries

However, wide range of values not well-described by univariate statistics …



Zoning and Watershed Classifications Not Much Help



Problem: How to Apply Multivariate Method to Univariate Data with Heavy Outliers?

1. Maui Does Not Have A Conjunctive (i.e., Multivariate) Water Supply
2. $\sim$ 100% Groundwater
    1. Some streamflow (i.e., surface water) when, where available
    2. *State of Hawaii* instream-flow requirements further limit the diversion of surface water more, recently, than during plantation agriculture period ($\sim$ 100% diversion)
3. So, we need to construct variables to describe the variability and magnitude of water use to compare with water supply

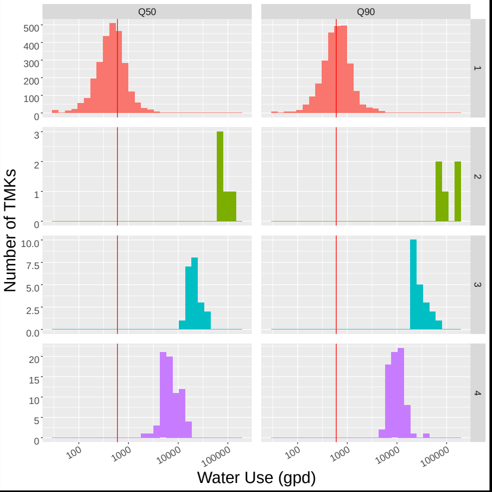
New Approach: Make Water Use Profiles From Quantiles for Each Tax Parcel

1. Treat each quantile as a variable and use as input to multivariate analyses (e.g., cluster, PCA, regression)
2. Uses information of whole distribution, integrated over time, for each tax parcel
3. Think of as N-quantile (N-dimensional) vector profile for each tax parcel
4. 13 years $\times$ 12 months $=$ 156 observations per parcel
5. N-dimensional, quantile profile space

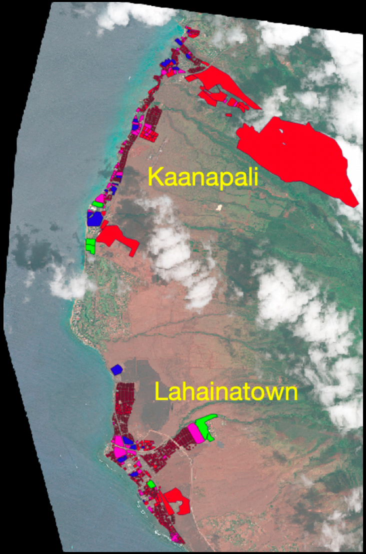
Water-use by Tax Parcel (TMK) & Quantile Profile (2012-2024)

			Quantiles (gallons per day)									
	TMK	Year	Q10	Q20	Q30	Q40	Q50	Q60	Q70	Q80	Q90	Q100
1	241002011	2012	268	274	290	306	314	322	338	355	406	458
2	241002011	2013	250	250	310	355	414	414	455	531	1500	1857
3	241002011	2014	227	243	255	269	274	276	280	296	330	2067
4	241002011	2015	252	292	310	336	360	400	482	649	721	1594
5	241002011	2016	600	690	697	750	750	759	759	824	862	964
6	241002011	2017	683	722	734	738	742	747	756	831	856	857
7	241002011	2018	606	625	719	767	966	1059	1100	1167	1536	22733
8	241002011	2019	461	541	652	698	721	751	790	877	962	1000
9	241002011	2020	668	681	700	724	729	743	756	792	806	848
10	241002011	2021	316	369	400	487	567	635	675	700	753	786
11	241002011	2022	320	344	345	364	365	388	395	420	440	500
12	241002011	2023	328	350	357	357	357	530	1136	35169	61410	69833
13	241002011	2024	210	357	504	651	798	945	1092	1239	1386	1533

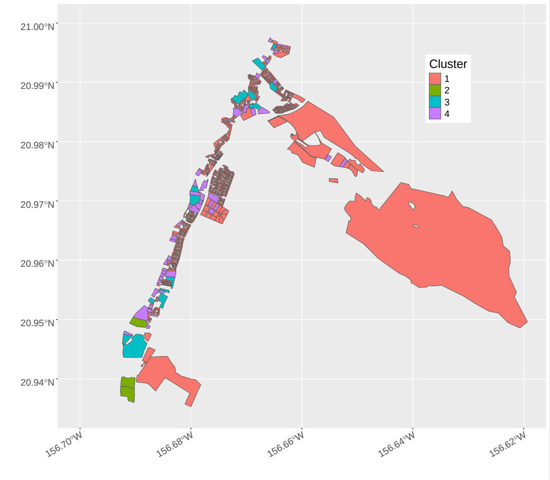
Water Use Well-represented by Tax Parcel Cluster Membership



Map Tax Parcels Based on Cluster Membership (i.e., Water use



Tax Parcels by Cluster (i.e., water use)

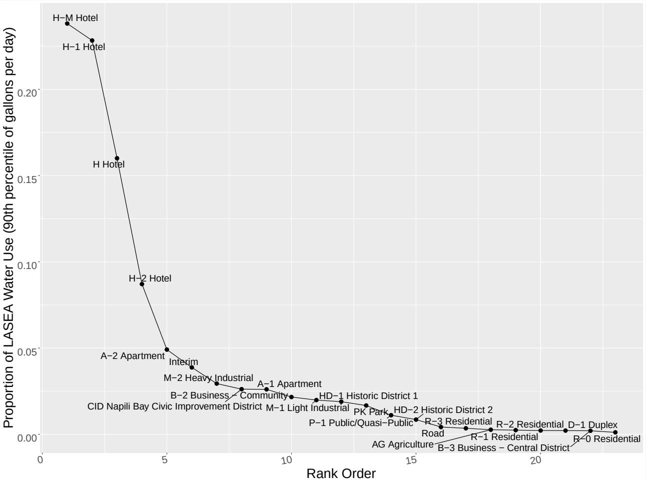


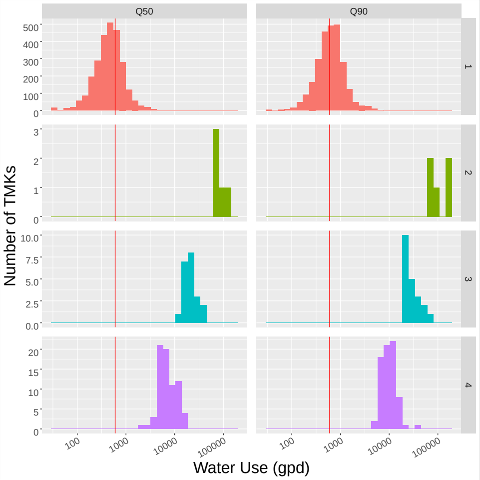
Water-use by Zoning and Cluster Membership

	Cluster 1	2	3	4	All
zone_class	n	n	n	n	n
A-1 Apartment	42	0	2	8	52
A-2 Apartment	4	0	4	14	22
AG Agriculture	308	0	1	5	314
B-2 Business - Community	38	0	1	7	46
B-3 Business - Central District	2	0	0	0	2
CID Napili Bay Civic Improvement District	27	0	3	8	38
D-1 Duplex	2	0	0	0	2
H Hotel	0	1	1	2	4
H-1 Hotel	0	1	0	0	1
H-2 Hotel	0	0	3	3	6
H-M Hotel	2	2	0	3	7
HD-1 Historic District 1	16	0	1	4	21
HD-2 Historic District 2	40	0	1	4	45
Interim	11	1	0	1	13
M-1 Light Industrial	34	0	3	6	43
M-2 Heavy Industrial	3	0	0	1	4
P-1 Public/Quasi-Public	1	0	0	0	1
PK Park	0	0	0	1	1
R-0 Residential	46	0	0	0	46
R-1 Residential	1016	0	0	1	1017
R-2 Residential	682	0	0	2	684
R-3 Residential	320	0	1	3	324
Road	1	0	0	0	1
All	2595	5	21	73	2694

1. Land-use indicated by zoning
2. Water use indicated by cluster membership
3. Land-use and water use do not align well

Comparison of Zoning and Cluster Membership





What Are Advantages and Opportunities in the Method?

Provides

1. basis for multivariate analysis based on water use *variability and magnitude*
2. insight into how water is used, where, by whom by *user behavior*
3. identification of opportunities for conservation
4. identification of capacity issues
5. objective basis for rate structuring incorporating tiering; based soley on water use

Why Does This Matter? (Reprised)

1. Water supplies have limits that are generally ignored until supplies become depleted
2. One obvious thing to do is to account for what we use and balance it against what is available
   1. How much are we using (*use*)?
   2. How variable, and potentially elastic, is that use?
   3. How much is available (*supply*) ?
   4. How variable, is supply and what is required the make that supply sustainable (*developed supply*)?
3. Then, make political, social and economic decisions to sustain supplies within those limits
4. Promote consistent, long-term monitoring of supply and use at fine scales as a matter of practice

Backup

Variability As A Function of Scale (Sample Density)

1. Limit discussion to temporal and spatial variability (i.e., versus measurement or modeling errors)
2. Sources of Variability
   1. Spatial scale variability is (primarily) due to mixing land-use categories (relatively static)
   2. Temporal scale uncertainty is (variously) due to time-series of patterns, fluctuations and events all superimposed (relatively dynamic; multiple-sources of uncertainty)
3. Developed land-use can be cleaned-up at the tax parcel level (generally)
4. At that spatial granularity, frequent measurements of meters integrate a wide-range of human behaviors (e.g., irrigation, domestic, tourism, recreation, industry, absence, weather, climate, maintenance, storage)