Comparing Panama and California Droughts: Obtaining Water to Meet Human Consumption Demands

Eng. Julia E. Guardia[1], Dr. Gonzalo Pulido[2] and Dr. Samuel Sandoval[3]

Abstract

This study provides a comparative analysis of the current drought conditions in Panama and California considering multiple human, physical, cultural, economic and political perspectives, and identifying the most vulnerable social and economic sectors. A general background is provided, including definitions of *drought, water scarcity, water stress* and *water risk*, and current water resources conditions in both study cases. Currently, Panama and California lead the economic growth in their regions, which is threatened by the water resources limitations. The most vulnerable human groups are Indigenous people in Panama (11% of country population), while in California are illegal Hispanic immigrants. Panama suffers *water scarcity* during three months (January to March) every year in the "Arco Seco" region, approximately 40% of Panama total area. In contrast, California is experiencing *water scarcity* conditions statewide for the past four years. Panama is not under w*ater stress* while California certainly is. <u>The core statements of this study are: a) </u>*Panama water risk* is primarily associated with poor water culture and the key challenge is to drastically reduce domestic water consumption per capita; b) *California water risk* is mainly due to intensive water demand; a possible strategy to achieve sustainable water management is to reduce agriculture share in California economic activity.

[1]Panamá Water Supply and Sanitation Institute (IDAAN) Executive Director
[2]. IDAAN Advisor in Water Resources
[3]Assistant Professor in Water Resources. University of California, Davis

1. Introduction

The objective of this paper is to compare the ongoing drought on Panama and California, from multiple perspectives, taking into account human, socioeconomic, physical, and water policy factors. It draws similitudes, differences, and approaches which could help to both societies to learn from each other.

According to the United Nations, *“drought"* is defined as the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.” *(WMO-GWP, 2011).* Drought has different impacts in Panama and California, because it depends on the vulnerability and resilience of the water resources systems, cultural patterns, socioeconomic factors and demography.

Nowadays, Panama is the Latin American country with the highest GDP growth; similarly, California is the US state with higher GDP. Both societies have a high dependency on water resources: Panama’s economy is highly dependent from the Panama Canal and its related activities, while California holds the largest population in the western US and a highly diversified economy, including a large scale agricultural industry that provides food nationwide and overseas.

Along with the observed effects of climate change and “El Niño” phenomena, President Juan Carlos Varela proclaimed the Panama *State of Emergency* for water resources, on August 11th, 2015. One year before, on January 17th, 2014, California Governor Edmund G. Brown Jr. declared a *State of Water Emergency* statewide. Both leaders instructed government agencies and officials to take all the necessary action to prepare for drought conditions in the present and future.

It is clear for both cases that drought conditions are going to be worst in the following decades. To cope with this imminent critical situation, it requires an all-inclusive society compromise to develop and implement water resources policies for adapting to drought conditions and minimizing adverse effects in the people, the environment and the economy.

2. Human History

The geographical location of Panama set it up as a natural cross point of people, animals and vegetation. Aboriginal people exist in Panamá since 9,000 years BC; three pre-hispanic cultures developed in Panama: *Nahuas* and *Mayas* from Central America in the Pacific region; *Incas* from South America, in the Darien Area and *Caribes* from the Caribbean; it is estimated that more than 1 million people lived in Panama before the Spaniards conquered the *isthmus (Cepal, 2015).* The current Indigenous population is 417,000 (11% of total population, 2010), distributed in all Panamanian provinces, with emphasis in the *Comarcas* or indigenous provinces. Indigenous people are by far the poorest and more vulnerable social group at Panama, with the lowest coverage of drinking water and sanitation (Fig 1).

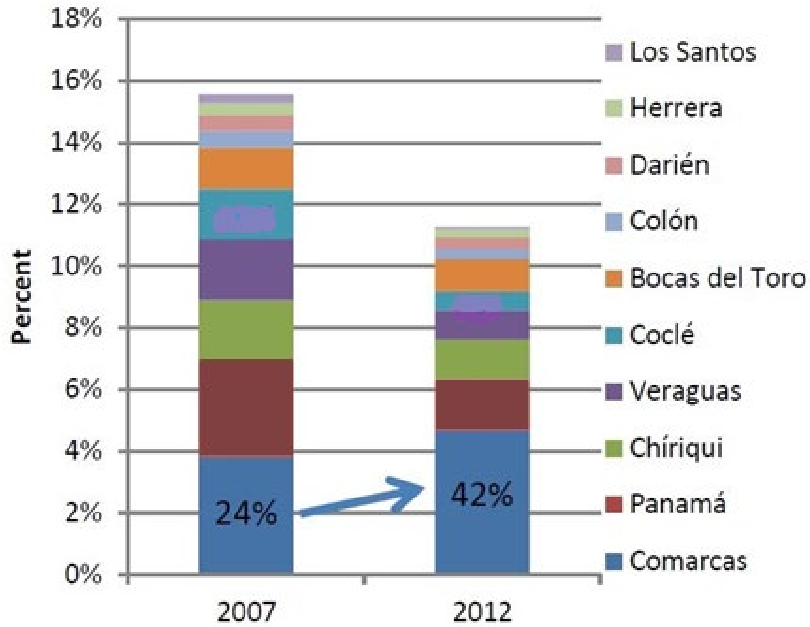


Fig 1. Changes in Geographic Concentration of the Extreme Poverty in Panama.(WB, 2015)

Since the Spanish conquest, people from all around the world has settled in Panama: Europeans, Africans and Asiatic crossed by Panama and some of them settled permanently in the country. The California gold rush promoted the construction of transcontinental railroad in Panama which was completed in 1855, when Panama was part of Colombia; labor force from Asia and the Caribbean later stayed in the country. Panama Canal construction started in 1880 under French initiative; tropical field conditions and financial issues caused failure of the project; US strong interest in the Canal, promoted separation of Panama from Colombia and the US assumed the Canal construction which was completed in 1914 using around 50,000 workers from more than 30 countries. The Canal administration followed a US military scheme of *free-of-charge* water, which ultimately generated a distorted water culture that is still prevalent, especially at the former Canal Zone. After 2000, when the Canal turned to Panamanian administration, an economic growth above its peer countries has been observed (Fig 2), which attracted new immigrants, mainly from America, and Europe.

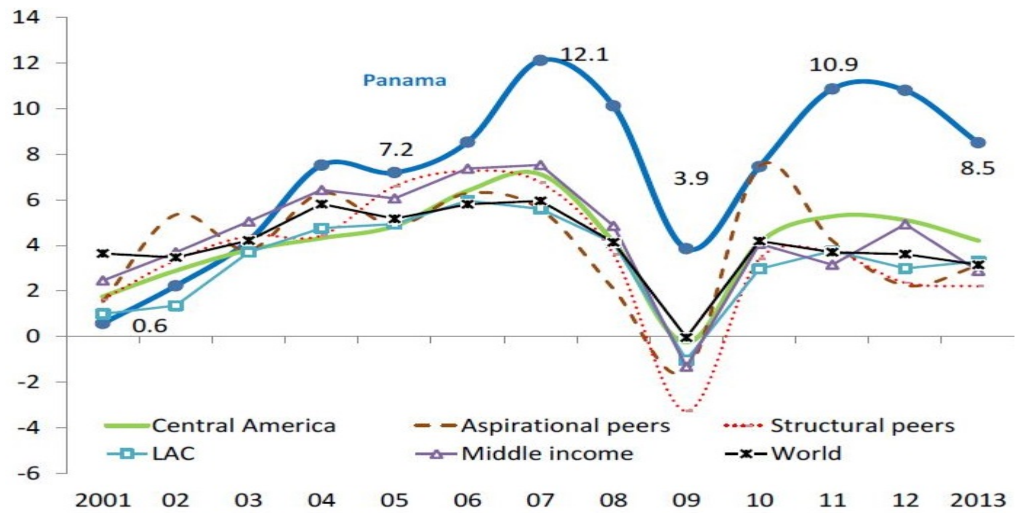


Fig 2. Real GDP Growth in Panama and its Peer Countries. (WB, 2015)

In Panama, African-descendant population has socio economic living standards comparable to the rest of the population (Table 1). In contrast, Indigenous people who lives with other ethnical groups, experience a significantly lower socio economic level; the worst living conditions are experienced by Indigenous people living in the protected semi-autonomous areas called *Comarcas.*

Table 1. Basic Characteristics of Panama Population by Ethnicity, *(WB, 2015)*

	Indigenous in *Comarcas*	Indigenous outside *Comarcas*	Afro-descendants	All others
Share of national population (%)	5.7	6.3	8.8	79.2
Income levels				
Income Per Capita Per Day (2010 USD)	1.3	4.8	13.2	11.9
Dwelling characteristics				
Access to electricity (%)	5.9	60.5	96.7	89.6
Access to water (%)	44.8	80.1	96.8	95.4
Flushing Toilet (%)	0.9	34.5	81.4	64.6
Household Demographics				
Age of head	45.3	41.4	47.7	48.0
Proportion age 0-12(%)	39.3	30.2	17.0	17.7
Proportion age 13-18(%)	12.8	12.3	8.0	8.4
Proportion age 19-70(%)	44.3	55.1	68.6	66.8
Proportion age 70+(%)	3.7	2.4	6.4	7.2
Household Characteristics				
Education of head (years)	3.5	5.9	10.9	9.5
Enrollment 6-18 yr olds (%)	82.8	82.9	93.0	91.5
Household size	6.0	5.4	3.4	3.5
Male headed HH	68.4	80.8	66.9	71.2

Source: Population and Housing Census, 2010.
Note: Less than two percent of the Afro-descendants also self-identify as Indigenous. For purposes of this analysis these p were considered Afro-descendants

In California, Native-American arrived 13,000 years BC, mainly from *Great Basin*, *Plateau* and *Baja California* tribes. Prior to their contact with Europeans, population was around 200,000 inhabitants, distributed in many small tribes, which accounted approximately one-third of all Native-Americans in the US *(Starr, 2005)*.

Relative to Spanish exploration in the American continent, the geographical location of California was not of major interest for the newcomers. Indeed, the first Spanish contact in California happened in 1542, almost half century after Columbus' arrival. In 1769, Spaniards started to settle 21 missions in California, originating the first conflict with indigenous people. When Mexico took over California after its independence from Spain, only about 4,000 Europeans inhabited California. In 1848, after the US-Mexico war, California became part the US. That same year, in January 24th, James W. Marshall found gold at Sutter's Mill, which marked the beginning of the gold rush that brought more than 300,000 adventurers from all around the world. Native-Americans were virtually exterminated and as low as 25,000 of them survived. Nowadays, they are the largest Indigenous population in the US, with 700,000 inhabitants, less than 2% of California's population. According to *UCLA, 2015*, Native-Californians are among the most economically deprived groups in the US, including indicators such as unemployment (40%), poverty (34%), income and education.

Internal migrations from other states have a deep share in Californian demography. The railroad construction in 1869 connected California with the rest of the US, providing the means for exporting agricultural goods to the other states and bringing migrants from other states attracted by California's agriculture and oil production; this large migration became very important since early 20th century. During the Great Depression in the 1930s, around 250,000 immigrants from other states settled in California looking for a better life. The amount of industries and business established in California increased astronomically after educational laws were released in the 1950s; migrants from other states and countries doubled the population by 1970, including African-American people which nowadays represent 7% of California´s population.

Hispanic immigration had outnumbered any other human group since 1950, when this group reached 12% of total population. By 2015, Hispanic population, mainly from Mexico, represent 50% of California population (Fig 3); most of them are young people (less than 29 years old); illegal immigrants are by far, the most vulnerable human group, with 80% of them living under the poverty line.

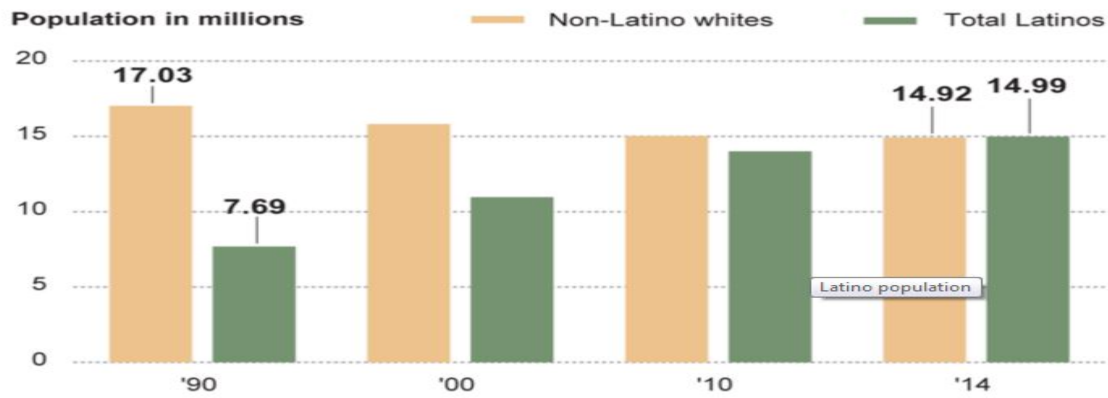


Fig 3. Californian Hispanic Population Trend. (LAT, 2015)

Table 2 shows a comparison of Panama and California population. Panama population represent 10% of California´s, with half its population density. Panama features one metropolitan area, which is Panama City, whereas California has three large metropolitan areas: Los Angeles, San Diego and San Francisco. Panama rural population is 23%; twice as much as California's rural population.

Table 2. Demographic parameters for Panama and California. *Census Bureau)*

Parameter	***Panamá***	***California***
Population (2015)	3,926,000	38,700,000
Rural Population	902,000	5,187,019
Population Density (persons/Km2)	52	95
Immigrants (first and second generation)	100,000	20,000,000
Native People	418,000	700,000

3. Physical Contexts

Following the ideas of *Shulte, 2014*, <u>*Water Scarcity* is used here as the volumetric deficit of water supply,</u> calculated as the ratio of human activities water consumption to available water supply.

Water resources are much more naturally abundant in Panama than in California as it exhibits six times more precipitation than California (Table 3). Nevertheless, in both cases, the annual rainfall pattern contains three dry months, January to March for Panama and June to August for California (Figs 4 and 5). These natural conditions regularly have generated *water scarcity* in Panama and California during their dry seasons; nevertheless, for the last four years, California has experienced an unprecedented drought with water scarcity all year round.

Table 3. Natural Settings Comparison

Parameter	***Panamá***	***California***
Area [Km2]	75 420 *(FAO, 2015)*	423 970
Climate	Humid tropical	Dry Summer, Subtropical (Mediterranean Climate)
Temperature [Celsius]	26 (ANAM, 2011)	15-37 (seasonal)
Rainfall [mm / year] (total, over the country/state)	2 928 *(FAO, 2015)*	563
Number of Groundwater basins	Unknown	515
Number of Surface water basins	52	10

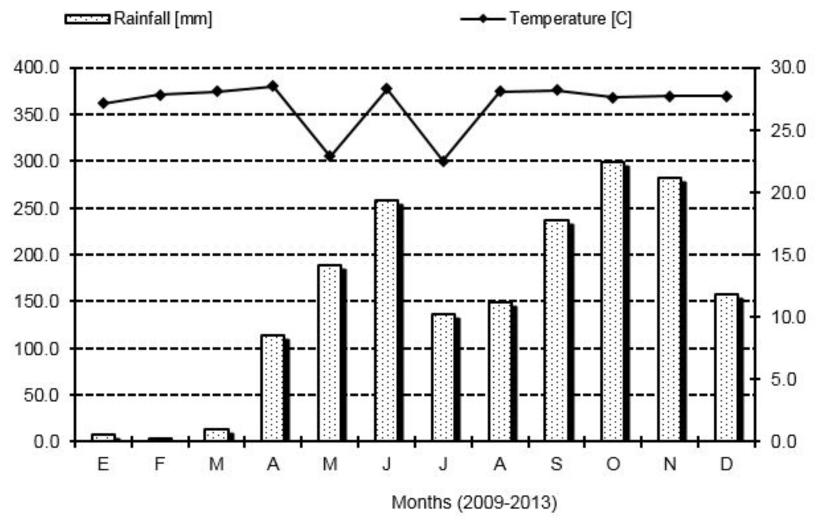


Fig 4. Panamá Monthly Rainfall and Temperature 2009-2013 at Tocumen Airport (INEC, 2015)

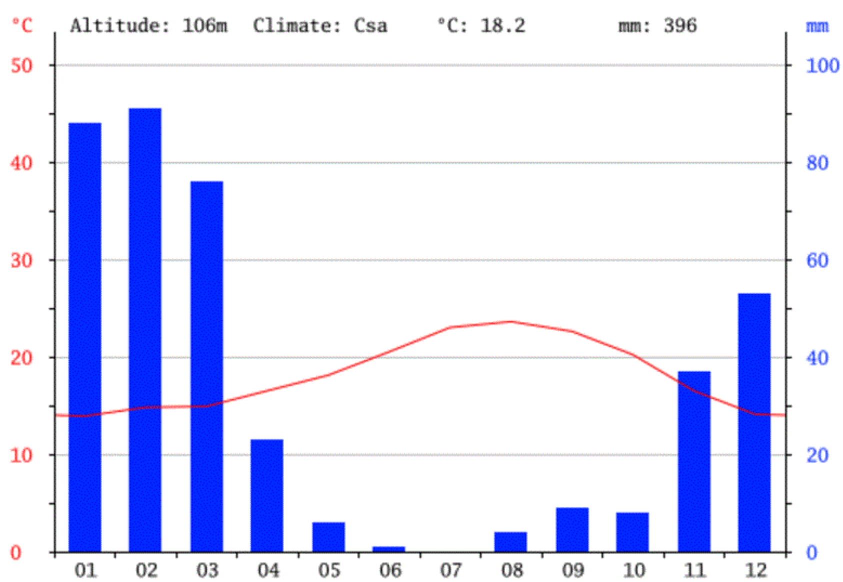


Fig 5. California Rainfall at temperature at Los Angeles (CDO, 2016)

Drought intensity and its geographical distribution are much more benign in Panama than in California. During Panama's dry season, rainfall range between 0.7-320 mm/month and less of the 40% of the country has rainfall absence *("Arco Seco").* In contrast, during California dry months, just a small portion of the territory receives 60 mm/month and more than half of the state has no rain at all. (Fig 6).

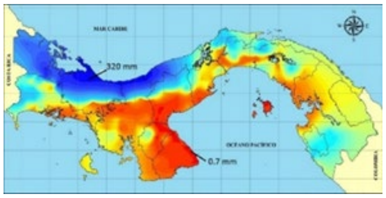
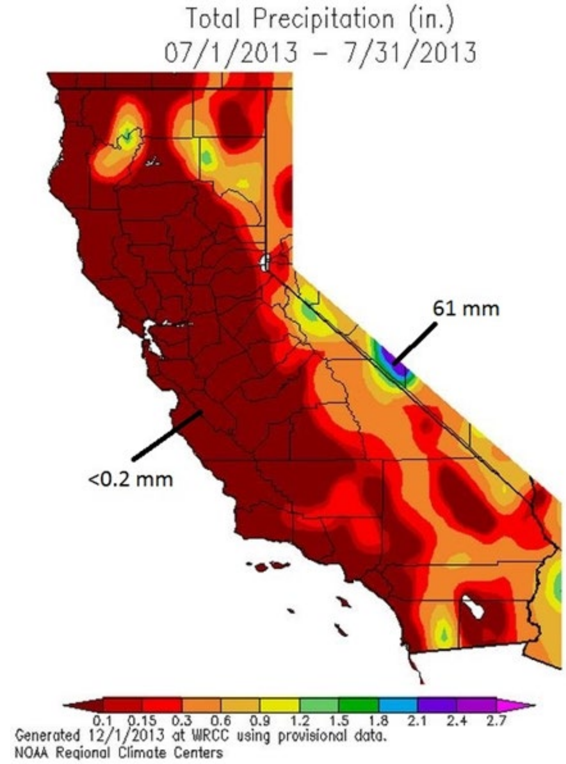


Fig 6. Comparison of Rainfall Conditions During Driest Months. A.) Rainfall distribution during February, the driest month in Panamá (ETESA, 2015). B. Rainfall distribution during July, the driest month in California (WRCC, 2015). Maps sizes show natural scales between Panama and California.



The Standardized Precipitation Index (SPI) is used to evaluate and compare drought conditions *(ETESA, 2015)*. The *3-month SPI* is the number of standard deviations that observed 3-month cumulative precipitation deviates from the climatological average *(UNESCO, 2014)*. Based on this indicator, Panama was not under drought conditions in October 2015 (Fig 7), even not under 2016 "El Niño" phenomena. At the same time, California is under extreme drought conditions, the most severe in North America (Fig 8).

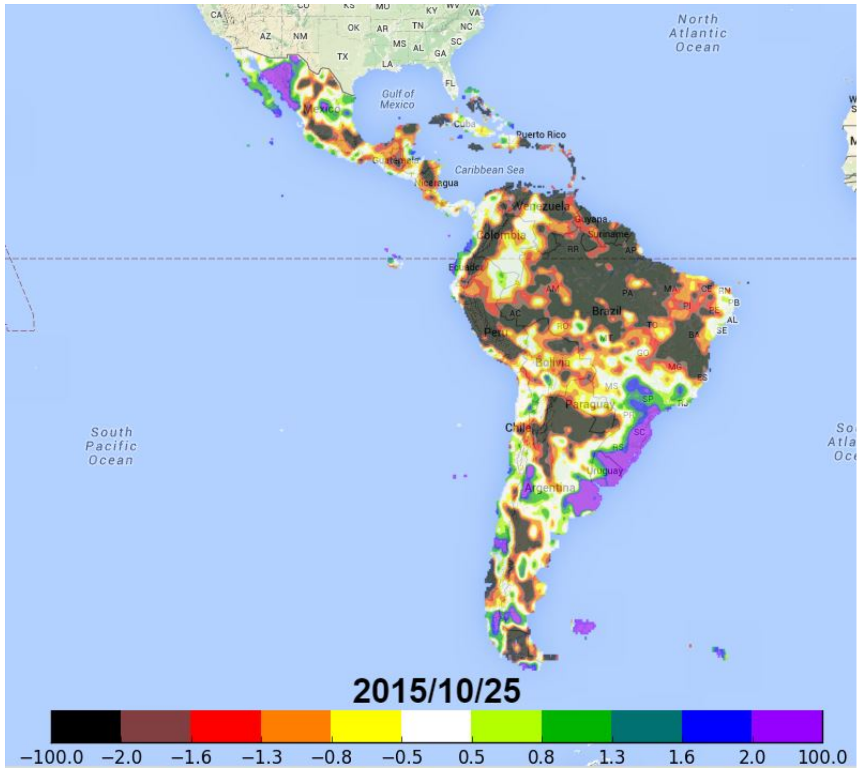


Fig.7. Latin America Drought Conditions (UNESCO, 2015)

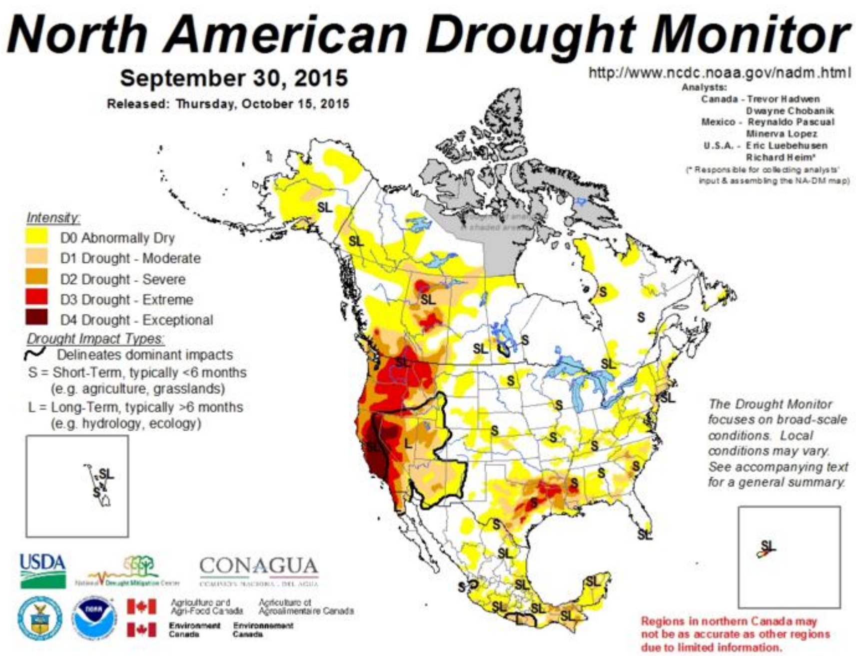


Fig. 8. Long Term Drought Conditions in California

The “El Niño” Sourthen Oscilation (ENSO) is a climate variability event that affects worldwide oceanic circulation each 2 to 7 years, during 12 to 18 months period, which is currently occurring in 2016. In Panama, this climate variability reduces rainfall in the Pacific watersheds and increases rainfall in the Atlantic ones *(ETESA, 2015)*. In California there is a correlation between a strong ENSO and high precipitation (Swain 2015); while it is expected wetter than normal conditions from January to March 2016, it is very likely that the extended drought will continue after the rainy season. *Water Stress* of a country or a region is the lack of ability to meet water demand, including ecological demand; it is a boarder concept that includes *water scarcity*, but also water quality, environmental flows, accessibility, water culture and water uses *(Shulte, 2014)*. Panama Water Stress rate is 0.74%; thus, Panama is far to be under Water Stress. California rates greater than 100% and is clearly under water stress: the total water extracted is greater than the natural water resources available; in essence, California imports water from basins outside the state, such as the Colorado River, and uses more water from aquifers that their natural recharge of water; thus, California uses more water than its natural availability.

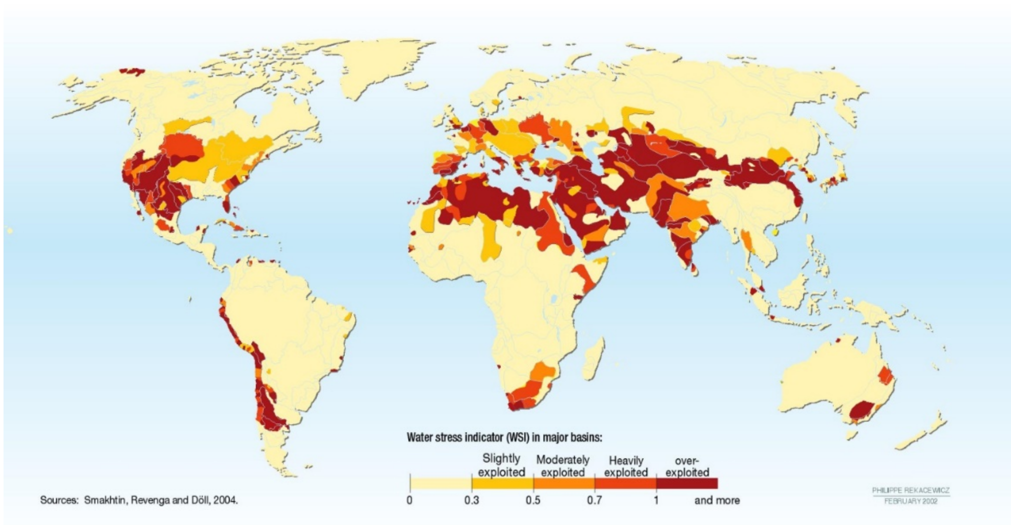


Fig 9. Water Stress in Major Basins, 2004.(UNEP, 2015)

4. Water Uses

Table 4. Water Use Comparison		
Parameter <u>PER YEAR</u>	***Panamá***	***California** (Hanak, 2015)*
Total Renewable Hydraulic Resources [km^3]	139.3 *(FAO, 2013)*	85.2
Total Hydraulic Resources per capita [m^3]	35 481 *(WB, 2015)*	2 200
Dams Capacity [Km3]	9.1	51
Total Water Extracted [Km^3]	1	100 *(PPIC)*
Groundwater Basins Capacity [km3]	Unknown	1048-1603
Agricultural Water Use [Km^3]	0.446	41 *(DWR, 2013)*
Cultivated Area [Km^2]	7 480 *(FAO, 2013)*	38 000 *(USDA, 2012)*
Urban Water Use [Km^3] (residential, commercial and industrial)	0.672*(FAO, 2015),*	10.5 *(DWR, 2013)*
Urban Water Use per capita [Liters/DAY]	405 *(INEC, 2015)*	326 *(SWRB, 2015)*
Total Water Use per capita [m^3]	272.8 *(FAO, 2015)*	271.3
Total Water Extracted as % of Hydraulic. Resources	0.74% *(FAO, 2015)*	117%

Agriculture use accounts for 43% of fresh water used in Panama (Fig 10) while in California represents 77% (Fig 11). This shows that decision-making policies in agriculture will have strong impact on water resources in the long term for both cases. Panama surface area is 17% of California, but the cultivated area in Panama is just 7 % of California Agricultural area, indicating the high share of agriculture land use in California; the total water used for agriculture per cultivated area in Panama is 6% of California, indicating low use of irrigation in Panama, where most of crops depend on rainfall; on the contrary, in California almost all crops depend on irrigation, and the statewide irrigation efficiency is estimated as 78% *(Sandoval et al. 2013).*

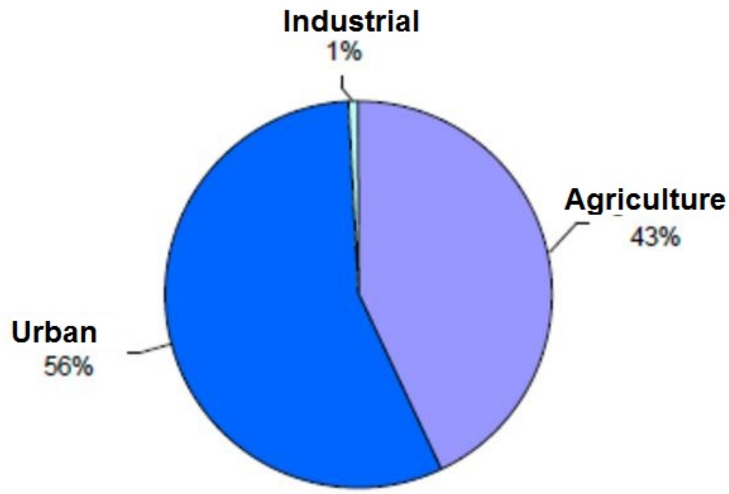


Fig 10. Panama Water Uses *(FAO, 2015)*

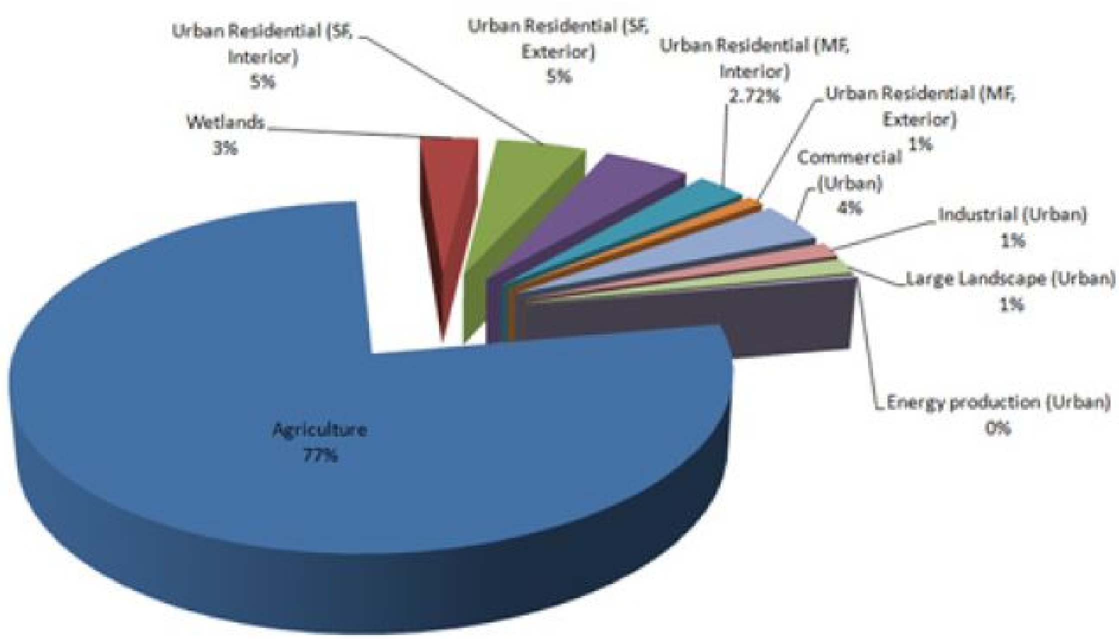


Fig 11. California Water Uses (UCLA, 2015)

Regarding municipal water use, Panama has the highest consumption per capita in Latin America: 366 Liters/person/day, more than twice the Latin America average of 170 Liters/person/day *ADERASA, 2014*. This poses a clear threat to Panamanian hydraulic resources and environment, not only because of the misuse of fresh water, but also due to the high volumes of residual water to be managed; no domestic water savings has happened during the present century. On the other hand, California water consumption per capita fell 26% of current water use, from 412 L/p/d before the drought to 326 L/p/d in October 2015, including all commerce and industrial uses (WB, 2015).

It is well known that local water consumption trends are hidden under the national or statewide averages. In Panama, the highest consumptions by province are registered in the urban areas historically associated with Panama Canal (Colón City, former Canal Zone and Panama City downtown; all three zones shows consumptions higher than 337 L/p/d, the national average (Fig 12). From the many possible explanations, it is relevant that these zones were historically developed under the military-focused US Administration of Panama Canal, where drinking water was provided for free for all population. In contrast, the lowest consumption is at Los Santos Province, 30% less than nationwide average. It is interesting to underline that Los Santos Province drinking water is provided almost totally from groundwater wells and is located at "Arco Seco", the Panama region with highest water scarcity. It is reasonable to hypothesize that Los Santos people use water in a more rational way because they know the meaning of drought and the wells are within the communities, more visible and familiar than the distant water treatment plants for Colon downtown and Eastern Panama City.

It is clear that Panama municipal water consumption is a regional outlier; thus the priority in Panama for water security is to reduce municipal water consumption (56% of total water use), by promoting water savings culture and reducing water losses in the distribution networks.

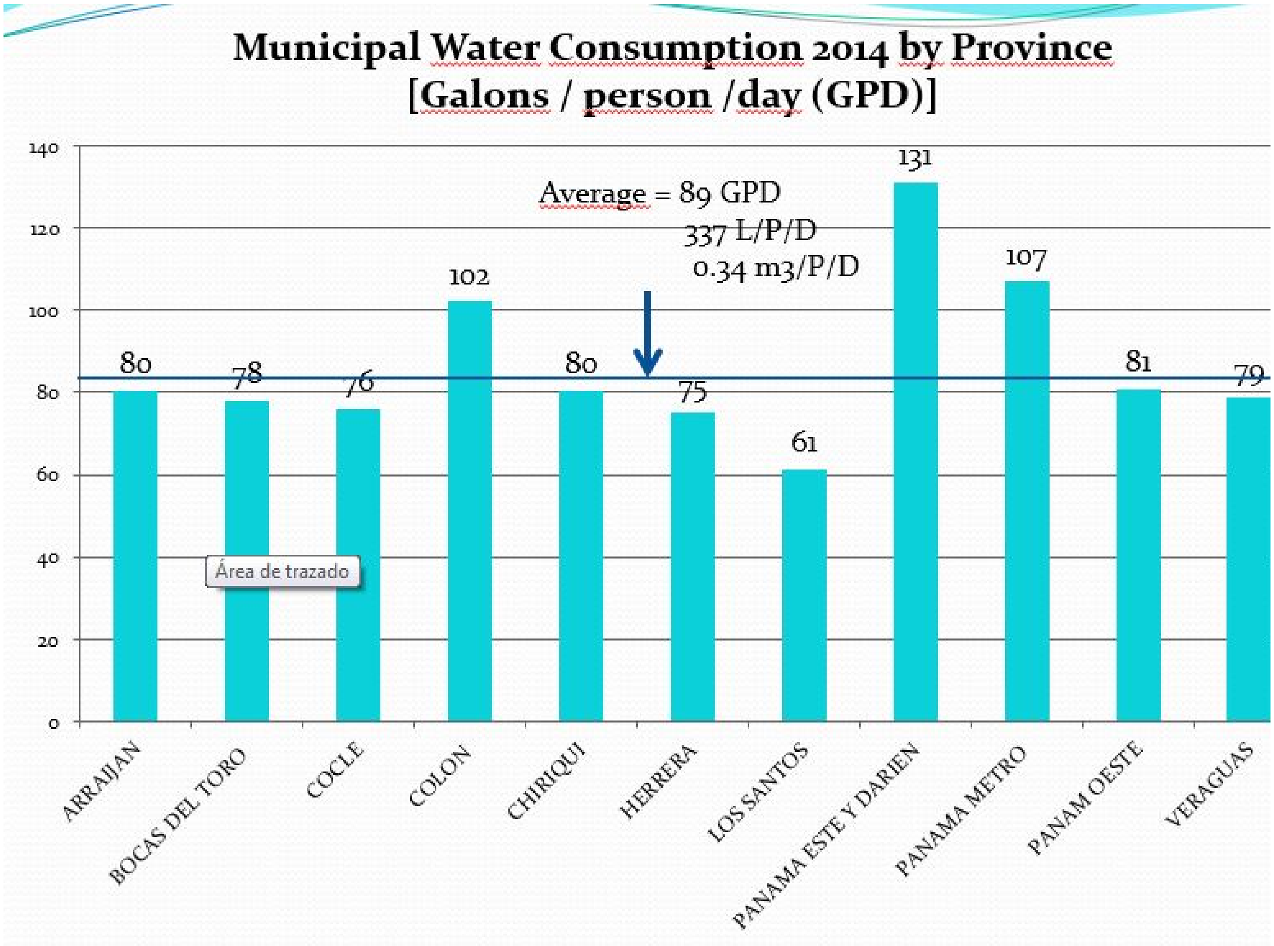


Fig 12. Panama Urban Water Consumption per capita per province. (ADERASA, 2014)

California per capita water consumption per selected cities shows dramatic differences, between 285 l/p/d in Westborough, a forward thinking community and 2760 L/p/d in Palm Springs, a high class,golf-oriented community (Fig 13) . Beyond the explanations related with water culture, which are stated in the chart, it is relevant to assess industrial share of municipal water consumption, which usually is not discriminated.

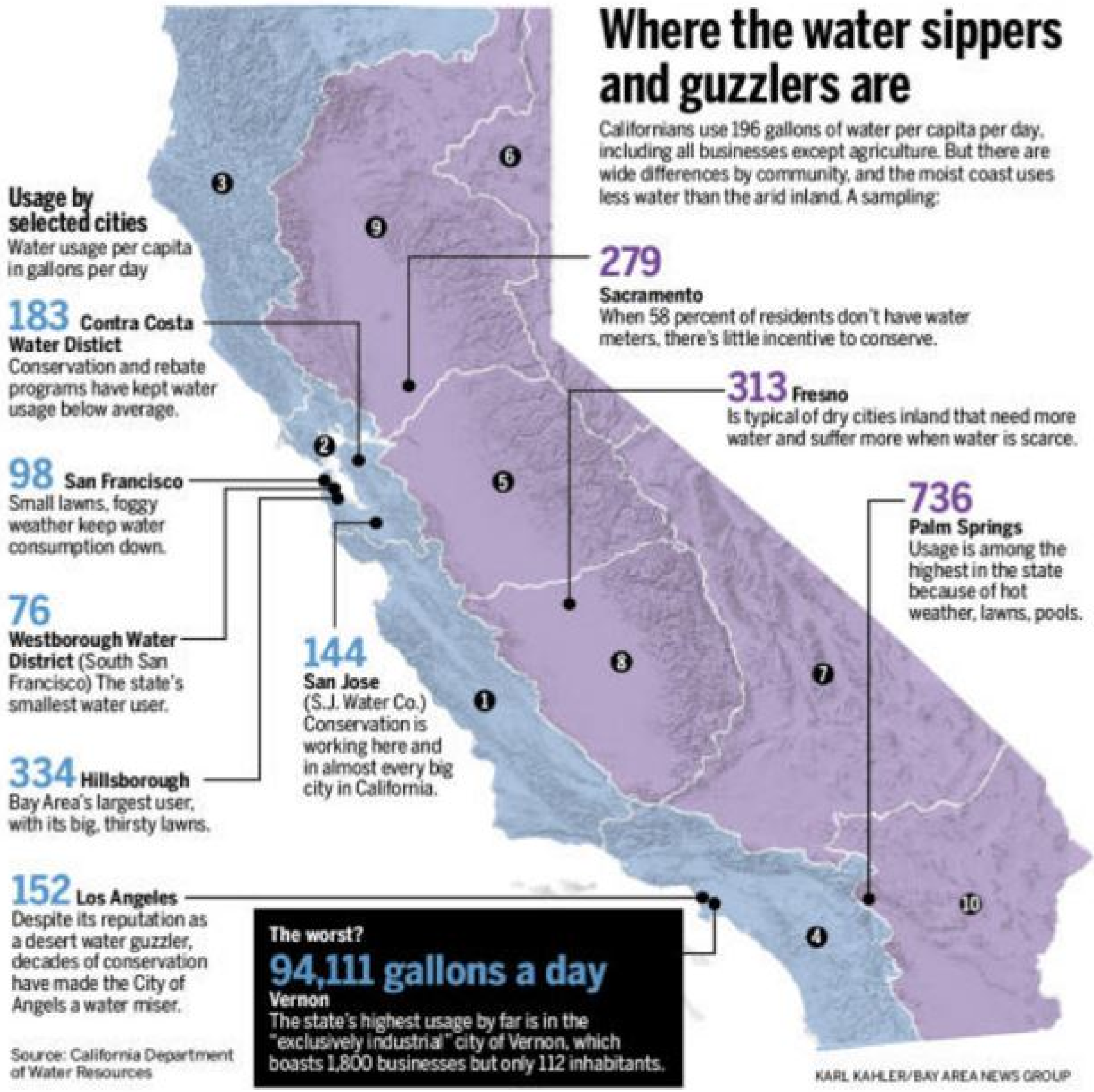


Fig 13. California´s Urban Water Consumption per capita. (SJMN, 2015)

Panama´s dams capacity is 20% than California, which has more than 1,000 dams; differences suggest higher surface water resilience in California, but its Mediterranean climate in comparison with Panama Tropical climate, could explain the differences even to the same resilience level. . Regarding groundwater resources, Panama' knowledge is very incipient: groundwater aquifers have not been and identified and mapped, thus the amount of available groundwater resources remains unknown. In Panama's rural areas, groundwater wells are very common; government statistics shows that 38,000 m3/day are extracted for human consumption by means of more than 700 wells. More than 80% of the wells are located at the *"Arco Seco"* region (Fig 14), which is the area most affected of the country during the dry season, because lack of surface water and groundwater overexploitation.

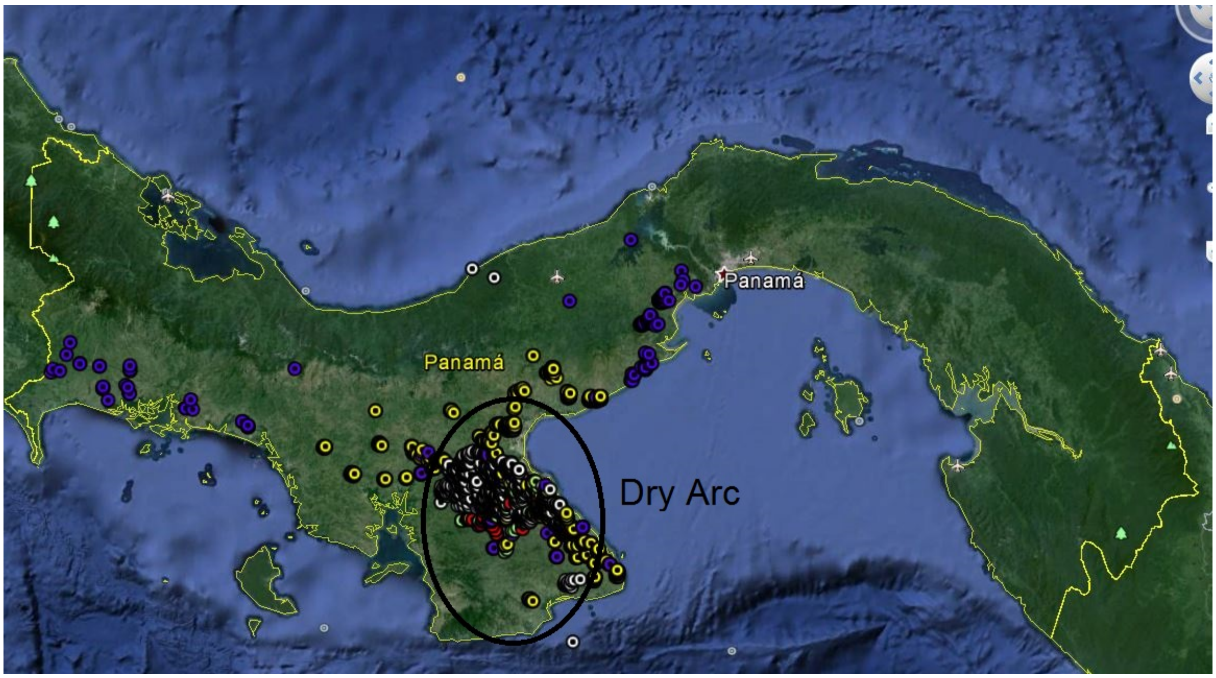


Fig 14. Groundwater wells in Panama (IDAAN, 2015)

In contrast, the hydrogeological understanding of California is highly advanced and the capacity of groundwater basin's storage is well known: between 1100 to 1750 km^3, 20 times the total water extracted per year in the state (table 4). Nevertheless, groundwater has been overexploited since 1960, in special during dry years, with an excessive pumping rate that is not recovered during wet years; thus, nowadays just remain around 20% of aquifers capacity (Fig 15).

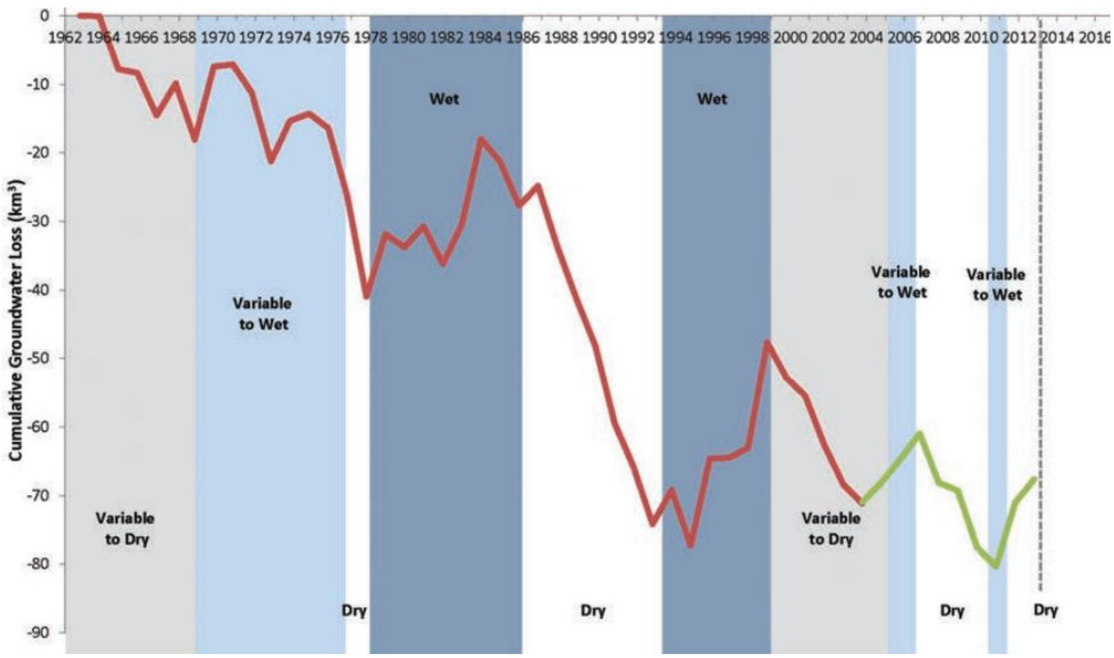


Fig. 15. California Groundwater Loss (1962-2012). (NRDC, 2015).

5. Water and Economy

Water Risk is the probability of a country or region of experiencing a negative water-related event; it is felt differently by every stakeholder, even under the same degree of *water scarcity* or *water stress* *(Shulte, 2014)*.

Compared with other Latin American countries' economies at 2014, Panama' PIB was USD $46.21 billon, the eleventh highest in the region; the PIB per capita was USD $21,634, the sixth in the region, and for three consecutive years, the annual GDP rate of growth was the highest in the region. All these indicators show Panama currently has a good economic performance *(WB, 2015)*.

Panama' GDP analysis by sector (Fig 16) shows that the economy is led by the services sector; starting with transportation and communications, closely associated to Panama Canal operations; this also explains strong sectors such as finance, business and other services. In contrast, agriculture represents just 3.5%, one of the smallest shares of the Panamanian economy. Then, agriculture is just important

<u>as a social sector of traditional farmers and cattle holders as a way of living, but it takes 43% of national water consumption. It could be worthly to assess a long-term political strategy in Panama consisting on warranty water for the existing agriculture to keep social welfare, without encourage large scale agriculture, which will set the country at high water stress.</u>

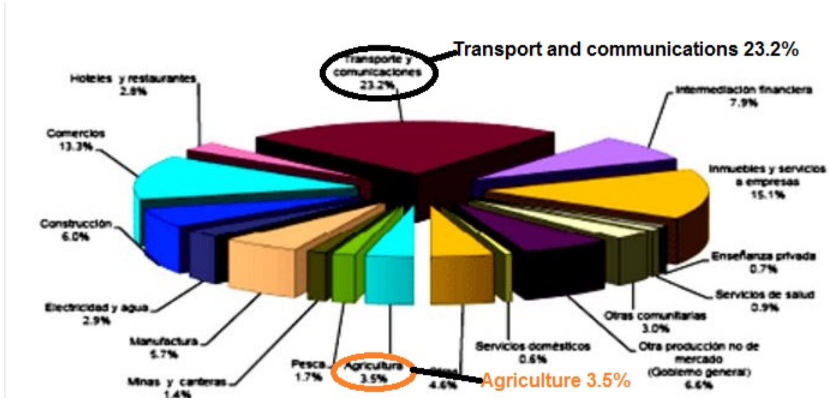


Fig. 16 Panama GDP by sector (PEI, 2015)

By 2014, US GDP was USD $17,419 billion, the first one worldwide; the GDP per capita was USD $55,904, the fifth in the world, and the GDP rate of growth was 2.4%, number 121 worldwide *(WB, 2014).* California's GDP was USD $2,396 billon, by far the first one in the US; the GDP per capita was USD $58,940, number twelve in the country, indicating a comparative high population in California; the GDP rate of growth is 2.8% , the highest in the country, <u>but the agriculture sector was the only with a negative growth (-7.2%)</u> *(LAO, 2015).*

California's diverse economy is integrated by important industrial and service sectors, such as the Silicon Valley high-tech industry and the movie-making industry of Hollywood. In comparison to these sectors, <u>the agriculture sector produces 1.2% of California's GDP (Fig 17), with 340,000 people employed (EDD, 2015), less than 1% of state population.</u> To the authors is clear that the strong and highly diversified Californian economy, is currently under high water risk, mainly because California spends 77% of available water for agriculture. This argument is supported by (Hanak et. al. 2015): *"The state's economy has evolved and no longer depends as directly on water to generate Wealth.*

Irrigated agriculture, which still consumes the lion's share of water, represents a small fraction of overall employment and economic output, and manufacturing accounts for only a small fraction of total water use."

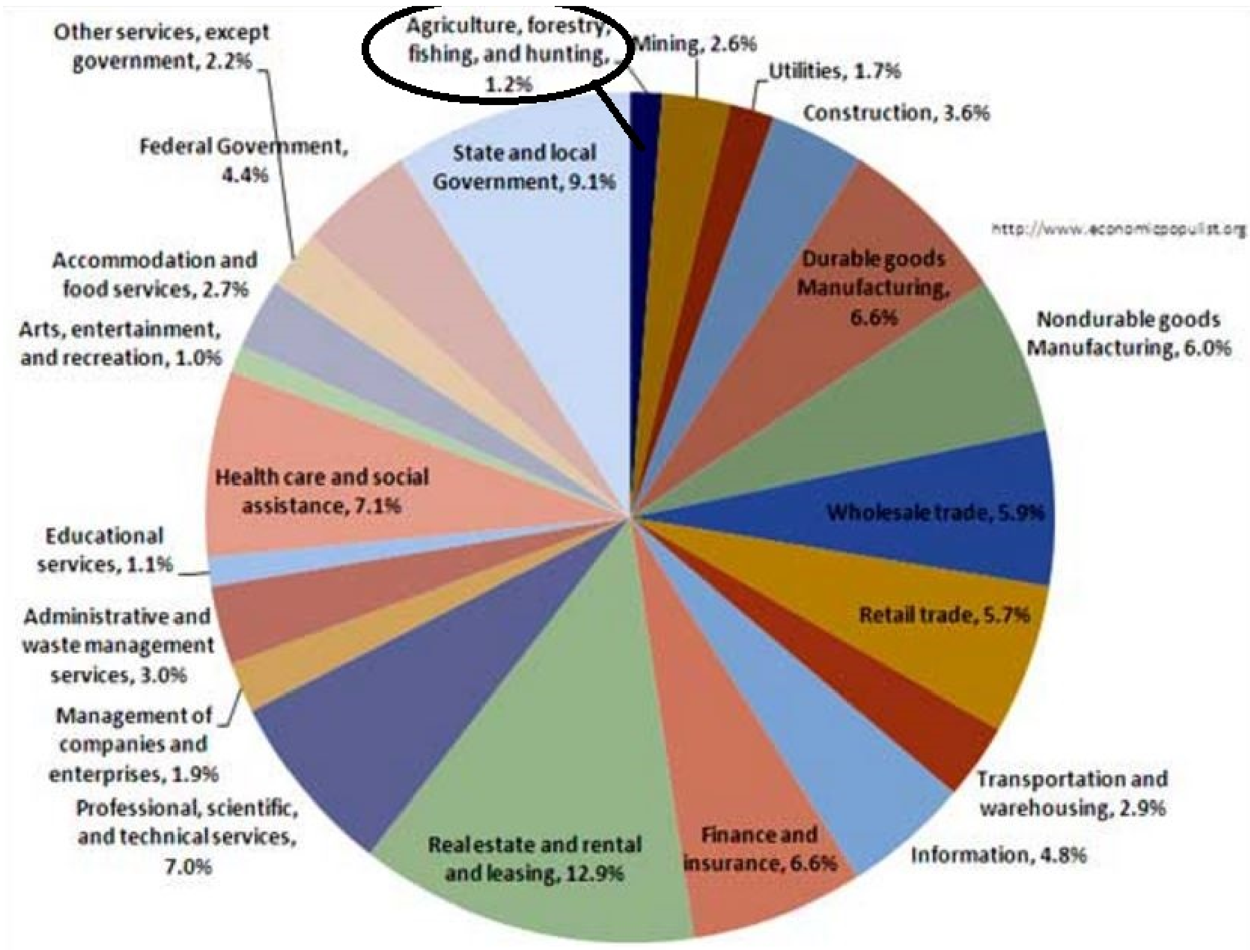


Fig. 17 California GDP by sector (Statista, 2015)

Agriculture is a $47 billion per year business, which is being seriously reduced by water scarcity during the last four years, with estimated losses of USD $2.7 billion, as shown in table 5 *(CWS, 2015).*

Table 5 . Summary of impacts of the 2015 California drought

Description	Impact	Base year levels	Percent change
Surface water shortage (million acre-ft)	8.7	18.0	-48%
Groundwater replacement (million acre-ft)	6.0	8.4	72%
Net water shortage (million acre-ft)	2.7	26.4	-10%
Drought-related idle land (acres)	540,000	1.2 million*	45%
Crop revenue losses ($)	$900 million	$35 billion	2.6%
Dairy and livestock revenue losses ($)	$350 million	$12.4 billion	2.8%
Costs of additional pumping ($)	$590 million	$780 million	75.5%
Direct costs ($)	$1.8 billion	NA	NA
Total economic impact ($)	**$2.7 billion**	NA	NA
Direct job losses (farm seasonal)	10,100	200,000#	5.1%
Total job losses	**21,000**	NA	NA

* NASA-ARC estimate of normal Central Valley idle land.

Total agriculture employment is about 412,000, of which 200,000 is farm production.

By the time being, no severe increase in produce prices has happened in the US and around the world (except for almonds) due to agriculture contraction in California, because other agricultural areas in Mexico, Chile, and other countries have supplied the shortage of fruits and vegetables currently not produced in California.

California is suffering from ongoing drought, with near-record-low reservoirs, lack of snowpack, soil moisture depletion, and very low river runoff. As a direct result, far less water than usual is available for cities, farms, and natural ecosystems. The current water use pattern is unsustainable, and there is a large and growing gap between the water desired and the water made available by nature -- even in wet years. Efficiency, water reuse, and storm water capture can provide effective drought responses in the near-term and permanent water-supply reliability benefits for the state, while also generating new jobs and business opportunities. *(NRDC, 2015)*.

6. Water Resources Policies

The key role of Water Resources Planning is to address water risks and develop resilient strategies for these risks, taking into account *water stress* factors such as *water scarcity*, people accessibility to the water, environmental flows and water quality, warrantying water governance *(Shulte, 2014)*.

Panamanian Water Resources management responsibilities are shared between several institutions, including ministries of Environment, Health, and Education; the Water Supply and Sanitation in urban areas is centralized in the National Institute of Drinking Water and Sanitation (IDAAN), which attends 76% of the country population; the remaining 24% corresponds to rural areas, served by Health Ministry. There are several other government agencies with responsibilities in drinking water and sanitation (Fig. 18).

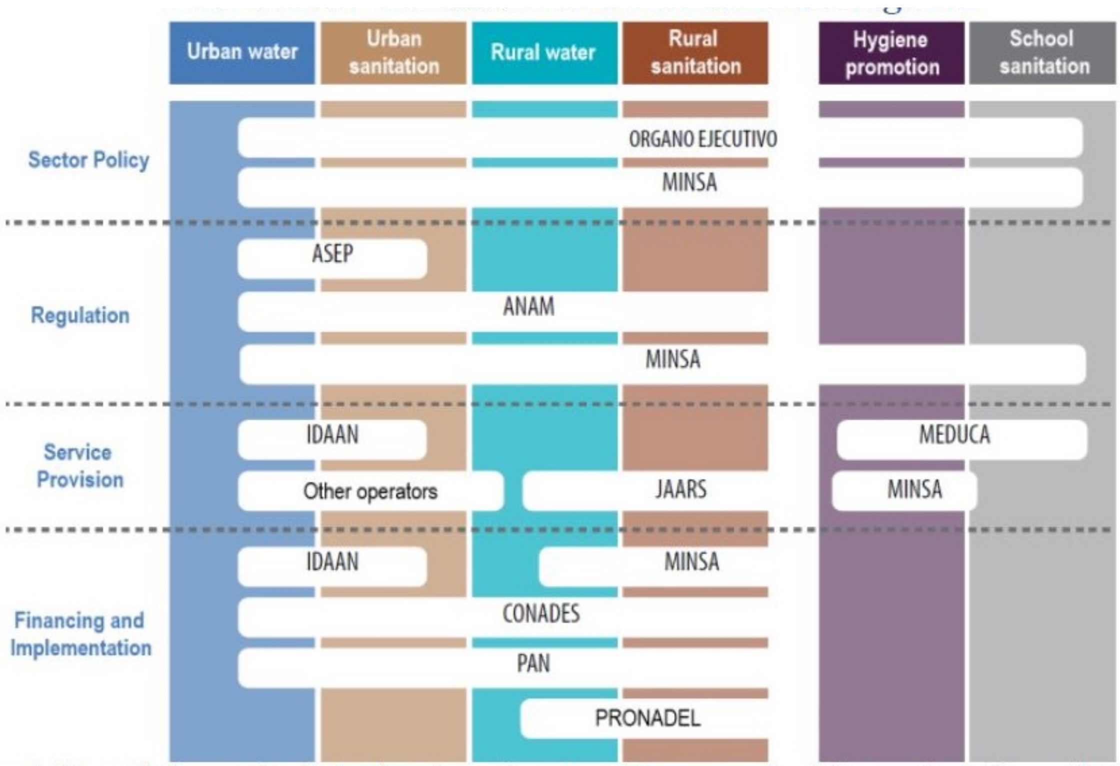


Fig 18. Panama Water Supply and Sanitation Institutional Framework (WB, 2015)

In Contrast, the Department of Water Resources (DWR) is responsible for managing California's water. The California Water Resources Control Board is the state institution in charge of water rights and water quality. The responsibility of drinking water supply and sanitation is distributed between more than 500 independent public agencies, which provides water and sanitation to more than 90% of communities (the remaining 10% are private). Most of they are members of the Association of California Water Agencies (ACWA) established more than a century ago, including irrigation districts, municipal water districts, county water agencies, community service districts, flood control districts and others. ACWA shape the laws, regulations and vision for advancing a sustainable, comprehensive water plan for the state's future *(ACWA, 2015).*

The keystone in water resources infrastructure in Panama is the Panama Canal, which holds Maddem Dam, an interbasin transfer from Chagres River that originally discharged to the Atlantic region. Madden Dam was built on the Chagres River and formed Alajuela Lake, where the intake for the

Panama City water system is located. Downstream, the Chagres River discharge is controlled by the Miraflores Locks in the Pacific and Gatun Locks in the Atlantic. Ever since Panama Canal construction, water planning has been implemented in the Panama Canal Watershed.

The first Panama nationwide Water Plan was developed with a 2008-2012 scope. It resulted on a diagnostic of national surface water resources, settled up work priority over 10 watersheds nationwide, calculated water balances of those priority watersheds; promoted the first watershed community committees, and proposed follow-up mechanisms. This plan was updated by the 2012-2030 scope Water Plan, which emphasizes an Integrated Water Resources Management (IWRM) approach. On 2016 was stated the current Water Security Plan with a 2015-2050 scope, to implement follow up mechanisms, to clearly establish government agencies responsibilities, to build country resilience to climate change and "El Niño" phenomena, to incorporate the new UN Objectives of Sustainable Development and the ongoing economic events. The Panama challenge in water resources is to effectively implement and follow up this Water Plan, by stating and measuring indicators to achieve the IWRM paradigm. The, most important water infrastructure project, currently under evaluation, is the interbasin diversion of "Rio Indio" watershed to guarantee water for human consumption for the foreseen development of Panama City and the water required to operate the expanded Panama Canal.

In constrast, Water Resources Management in California backs to the times of the gold rush (1850). Since then, it was clear that water is a constraining factor to California's sustainable development. The more important infrastructure projects in the history of California are:

- Hetch Hetchy project to bring water from the Sierra Nevada to San Francisco
- Los Angeles Aqueduct to bring water from Owens Valley to Los Angeles

- Central Valley project, to bring water from the Sacramento River to San Joaquin Valley and Tulare region
- State Water Project to bring water from Sacramento River to Central and Southern California,
- Colorado River Aqueduct to bring water of the Colorado River to Southern California, Imperial and Coachella Valleys. (Fig 19). The current Water Plan was updated in 2013 and include the State Strategic Plan, the Regional requirements, and the Water Resources Management Strategies.

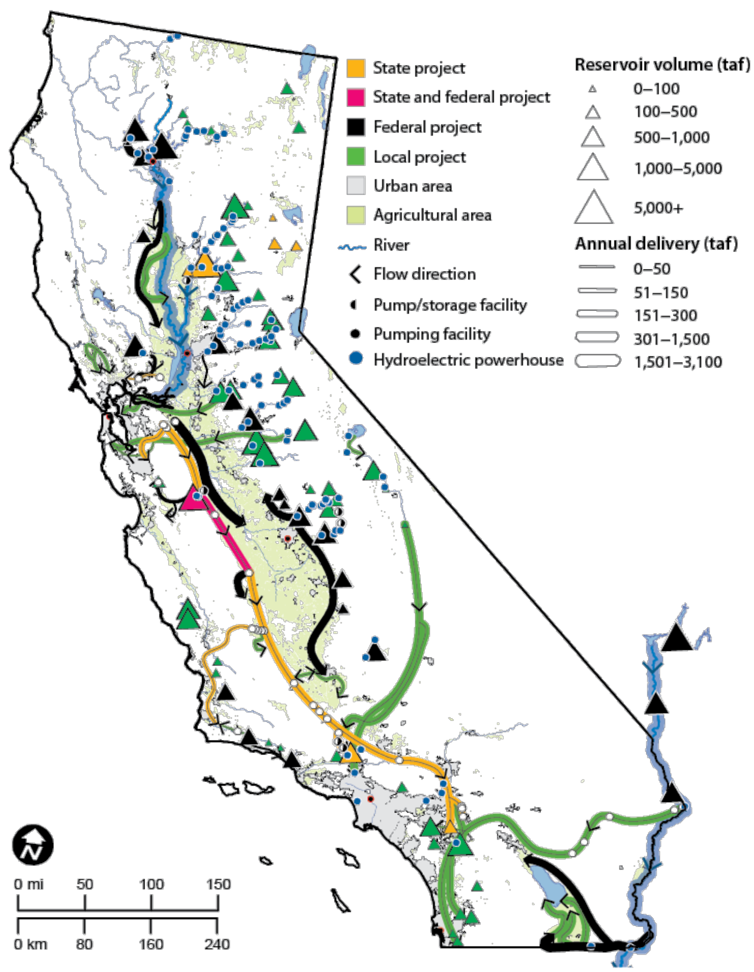


Fig 24. California Water Infrastructure. (Hanak et al. 2011)

California has implemented several strategies for water resources optimization such as interbasin transfer from another states, Colorado River water is stored in Hover and Glenn Canyon dam and moved downstream to lake Havasu to deliver water to the city of Los Angeles and San Diego; optimization of irrigation systems, intensively use of groundwater, including aquifer artificial recharge, reduction of domestic water consumption, grey water reuse, desalinization, etc.

Even with this strong background in Water Planning, currently California urges for a deep reform, addressing questions such as changes in water legislation, local agencies roles, dealing with political opposition, costs, and public involvement (Hanak et. al.,2015).

California water plans are looking for a broad range of alternative water management strategies, from water conservation, to irrigation efficiency, conjunctive use of multiple water sources (surface water, groundwater, recycled water, desalt-water, rainwater, etc.), groundwater banking, system's re-operation, new infrastructure, optimizing current storage, among other strategies.

7. Conclusions

Panama and California are currently (2015) under State of Water Emergency, because a complex consequence of physical, cultural, economic features; both societies face challenging decisions to succeed their current and future development.

Human history of Panama and California have several common points. Both societies have roots on Native People, which their cultures were deeply affected by migrations, but were able to survive and nowadays they are vulnerable human groups in socioeconomic terms. The current demography in both cases is a complex mixture of different types of migrants from all over the world, promoted by economic and political factors.

Regarding water resources natural settings, Panamanian conditions are much more favorable than California: Panama's yearly rainfall is six times higher. Although there are three-months dry seasons in both cases, that generates *water scarcity* in almost all California, while in Panama just in the “Arco Seco”, less than 40% of country territory. ENSO affects Panama reducing rainfall in the pacific region, where most of population lives; strong ENSO signals like 2015-2016 are likely to produce dry conditions and severe economic damage, but it will increase precipitation in California, Panama *water scarcity* extends by three months per year but in California is currently permanent. Panama *water stress* is less than 1% while California is over 100%. Panama moderate *water risk* is due to poor water rational use culture. In contrast, California’s high *water risk* is linked to excessive water demand, affecting severely the current and future sustainability of rivers and aquifers throughout the state. The ongoing drought in California has helped to control the *water risk*, by permeating throughout the entire Californian society effective education campaigns that shows the connection between rainfall, adequate land use management, river and aquifers interaction, water storage, water use, water conservation, and natural resources protection.

Regarding water uses, the more important one in Panama is domestic, with more than 50% of consumption. In California, 77% of water is used in agriculture, which represents less than 2% of the State economy. In both cases there are strong regional differences in water consumption per capita, stressing the importance to develop water culture for the immediate future.

Even tough Panama's modern society settled before than California´s and the key infrastructure efforts happened at the same time in both cases, Panama's water planning lags about more than a century behind California's water management. This could be an effect of the natural *water scarcity* in California and the need to adapt to overcome these natural conditions. Because of this, several infrastructure projects and water regulations have been implemented to incentivize and regulate water use throughout California. There are also differences in socioeconomic development between both cases, however, it is similar the large amount of water used by agriculture and the importance to develop a strategic plan to account for this sector while mitigating risk and scarcity threats to the society.

Panama water security depends largely on developing rational and sustainable water use, starting by domestic usage and the future interbasin transfer project “Rio Indio” to satisfy the increasing water demand of Panama City and the expanded Panama Canal. The current agriculture practices must be optimized to match the natural water availability with a crop and/or economic activity that provides the largest economic benefits without degrading the natural resources (soil, air and water), without promoting significant expansion of the agriculture boundary. A holistic approach as well as society inclusion in every step of water planning definition and implementation is needed for its successful implementation. At the same time it is required to significantly optimize water use and groundwater resources development.

Based on analyses from the cited references, and making clear that the sustainable development of hydraulic resources in California is a complex subject which is an active research topic conducted by thousands of researchers and stackholders, the authors argue that California's case is an overexploitation of water resources because high agricultural water demand, which counts for 77% of water use. While there are many strategies to mitigate this overexploitation [such as conjunctive use of surface water and groundwater, water conservation, etc.] it is feasible that reduction of the agricultural sector in certain part of the state are expected in the near future. The economy of the state will survive and thrive given the highly diversified economy of the state (TWP,2015).

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