Human-Climate-Water Interactions in the Context of Managing Florida's Water Supplies

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Introduction

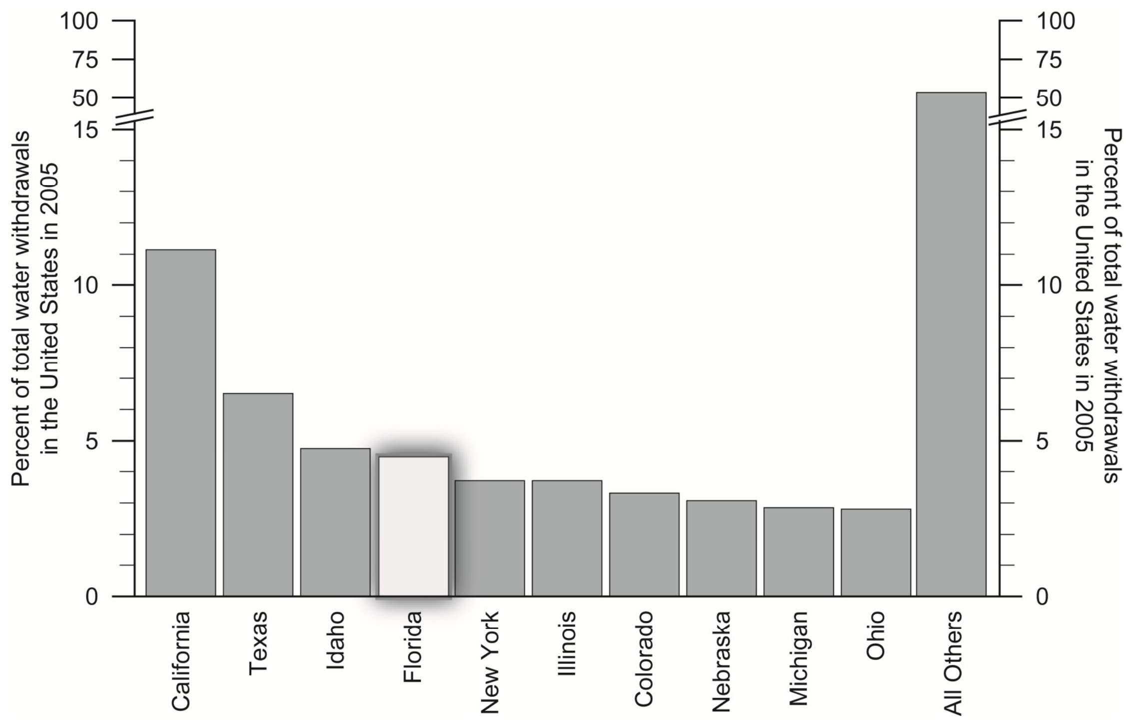
Global climate change is expected to result in more intense tropical storms and more intense high-precipitation events for much of the southeastern U.S. However, in some parts of the subtropics, including the area where Florida resides, more frequent and intense droughts are also likely to occur (Berry et al., 2011; IPCC, 2007; Misra et al., 2011). As such, climate change is predicted to result in both increasing intense rainfall events and more frequent and prolonged droughts in Florida. Such shifts in weather patterns will alter the amount of water available to recharge the state's fresh water supplies. Additionally, higher temperatures will enhance evapotranspiration, thereby increasing the loss of freshwater from surface water and shallow groundwater. Thus climate change will directly influence the availability of freshwater in Florida and will challenge water managers to develop strategies for sustaining the state's water supplies under highly variable hydrologic conditions (Berry et al., 2011; Misra et al., 2011).

Water management strategies have traditionally focused on managing supply to meet demand rather than on managing demand itself (NRC, 2010). Furthermore, water managers typically assume that hydrologic conditions and demand for water remain relatively stationary, and thus rely on historical hydrologic and water use data to regulate and manage water supplies (Milly et al., 2008; NDWAC, 2010). Such supply-side management strategies and assumptions of stationarity disregard the complex human-environmental interactions that drive water availability and quality. Because of this mindset toward water management, "[t]he interactions between and couplings of climate, population, urbanization, and development, as well as how they affect water have been largely outside the scope of most analyses" (NRC, 2010, p. 20). In this paper, we discuss some of the complex interrelationships between climate change, human society, and water, within the context of managing Florida's water supplies. Through this discussion we aim to illustrate that effective management of Florida's water resources in the face of climate change will require a systems approach that recognizes the significance of human-water-climate interactions.

Examples of humans as components of the water cycle

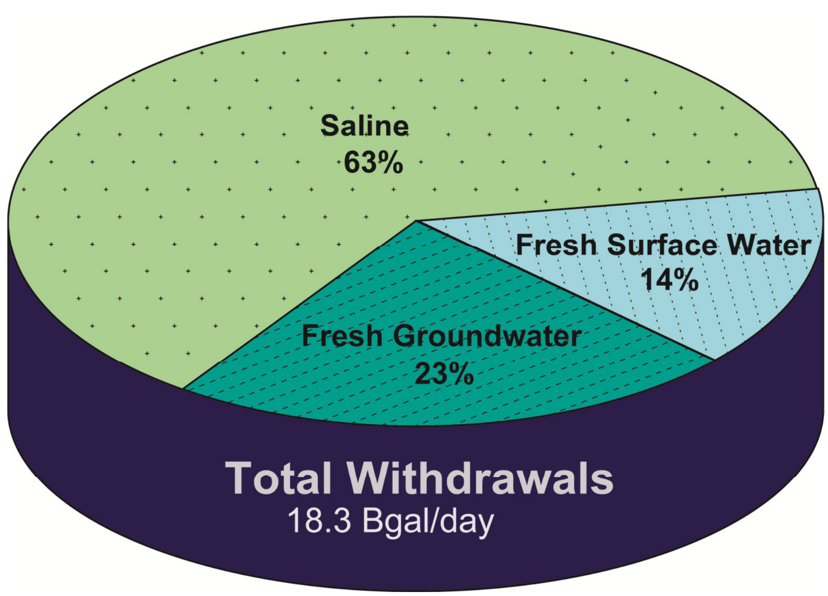
There is ample evidence that human activities have significantly changed the global water cycle. Deforestation and agricultural irrigation have altered river flows and the spatial distribution of evapotranspiration (Gordon et al., 2005; Milly et al., 2008; Rost et al., 2008). More than 60% of the world's rivers have been fragmented by Dams (World Commission on Dams, 2000). In cities throughout the world, storm water is diverted and natural soils are covered by concrete, asphalt, and other impervious surfaces causing substantial changes in runoff and infiltration (Haase, 2009). In Florida, humans have become a significant component of the water cycle through consumption of fresh water, disposal of wastewater, alterations in land cover, and control of surface water flows. Modifications to the natural hydrologic cycle have been particularly intense in southeastern Florida where, over the last century, an extensive system of

Figure 1: Individual state's contribution to nation-wide total water withdrawals in 2005.



Source: Data are from Kenney et al., 2009, Figure produced by Author

Figure 2. – Total 2005 water withdrawals in Florida.



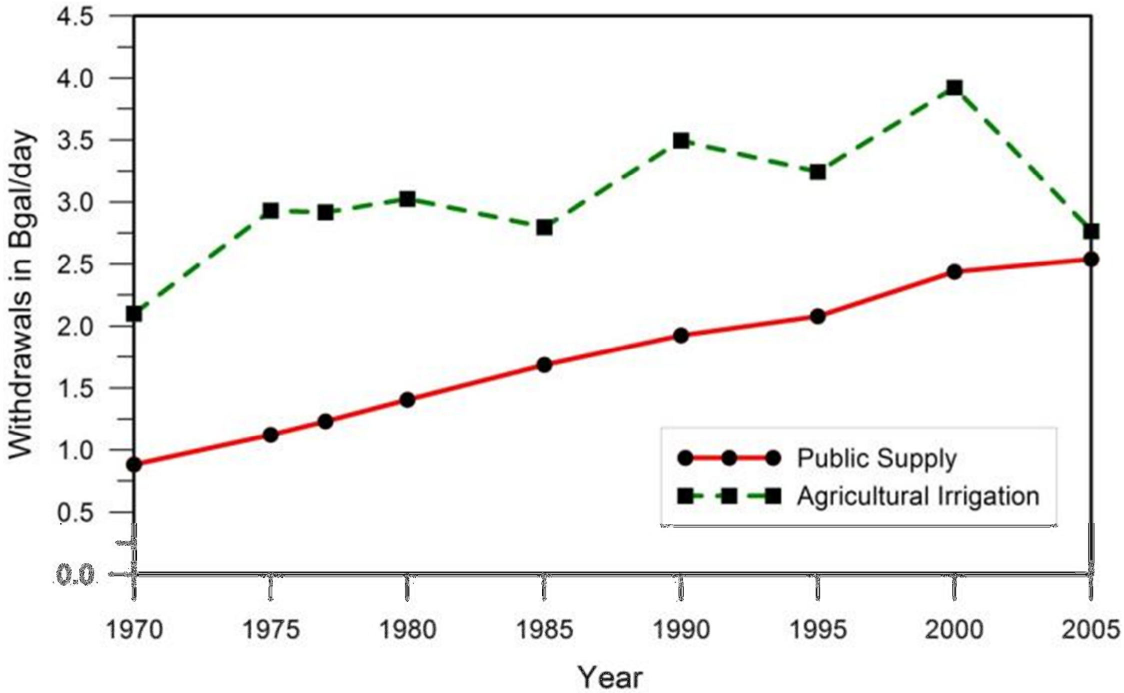
Source: Modified from Marella, 2009. Figure also appears in Berry et al., 2011.

canals, levees, and flood control structures has been built to support agricultural and urban development (Finkl and Charlier, 2003). In addition to these extensive engineering modifications to the hydrologic cycle, enormous volumes of water are withdrawn from the state's aquifers, fresh surface waters, and estuaries to provide water to Florida's industries, businesses, and nearly 18 million residents.

In 2005, total fresh and saline water withdrawals in Florida were about 18.3 Bgal/d, which represented 4.5% of all water withdrawals in the United States (Figure 1) (Kenny et al., 2009). About 11.5 Bgal/d of the state's total water withdrawals were saline water used mostly for cooling power plants (Figure 2) (Marella, 2009). Floridians consumed 6.8 Bgal/d of fresh water in 2005, and the state's fresh water consumption is predicted to increase to 8.7 Bgal/d by 2025 (FDEP, 2010a). Florida relies very heavily on its groundwater supplies, using more groundwater than any other state east of the Mississippi and ranking sixth in the nation in terms of groundwater withdrawals (Marella, 2009). Many areas of the state are already facing critical water shortages that have resulted from population growth and overreliance on groundwater as a sole source for water supply (FDEP, 2010a).

For centuries, the largest withdrawals of freshwater worldwide have been for agricultural irrigation. Therefore, it is not surprising that historically the agricultural sector has been the largest consumer of water in Florida. In 2010, Florida led the country in the value production of several crops including, oranges, grapefruits, bell peppers, squash, sweet corn, and watermelons (FDACS, 2011). Thus Florida is a major contributor to the total agricultural production of the United States, and demand for water for agricultural irrigation will continue to constitute a large portion of the state's total water demand. However, in recent years a number of factors including declines in irrigated acreage, improved water conservation techniques and long-term water restrictions, have led to a decrease in withdrawals for agricultural irrigation in Florida. At the same time, population growth has led to a steady increase in public water supply withdrawals, and such withdrawals are expected to eclipse those for agriculture within the next few years (Figure 3) (FDEP, 2010a). This increase in the proportion of public supply withdrawals combined with the fact that Florida's population is expected to increase to nearly 25 million by 2025 (FDEP, 2010a) underscores the magnitude of the impact of public water supply on the water cycle in Florida.

Figure 3: Historical state-wide public supply and agricultural irrigation water use.



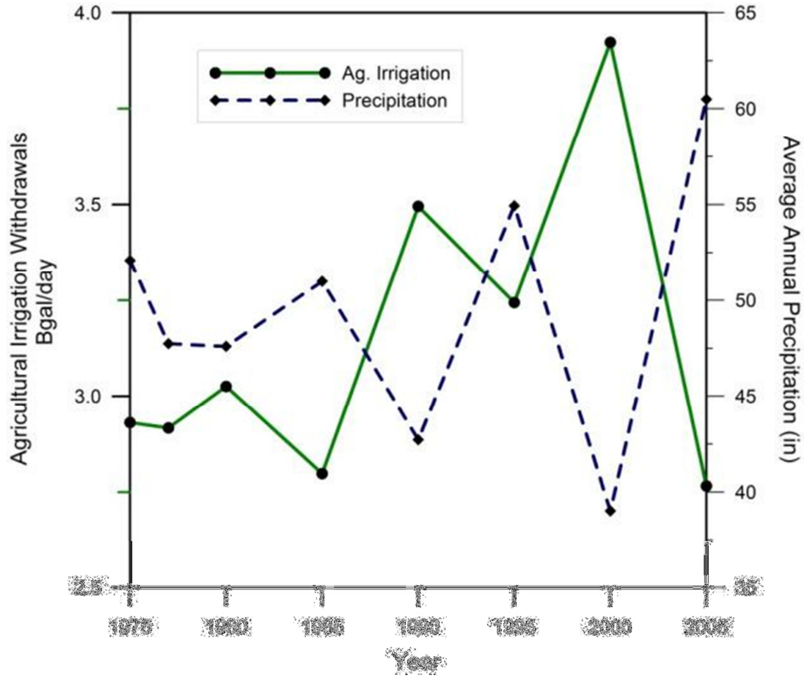
Source: Data from USGS Florida Water Science Center website, accessed 9/25/11. (Figure also appears in Berry et al., 2011.)

Examples of climate change impacts on water demand

Because demand for water is highly dependent on temperature and precipitation (Karl et al., 2009; USGCRP, 2001), climate change adds uncertainty to water demand forecasts. Florida's distinct wet and dry seasons result in seasonal variation in fresh water withdrawals that are primarily due to the need for supplemental irrigation for agricultural crops, golf courses, and lawns during the dry season (Marella, 2009). Therefore, any shifts in seasonal norms or timing of seasonal changes in precipitation and temperature caused by climate change will impact the magnitude and timing of irrigation water demand. Additionally, historical state-wide water use and climate data demonstrate that past droughts have caused significant year-to-year fluctuations in water demand for agricultural irrigation (Figure 4) (Marella, 2004; Verdi et al., 2006; Marella, 2009). Therefore, if climate change causes precipitation in Florida to decline or increases the frequencies of droughts, water demand for agricultural, recreational, and lawn irrigation will increase.

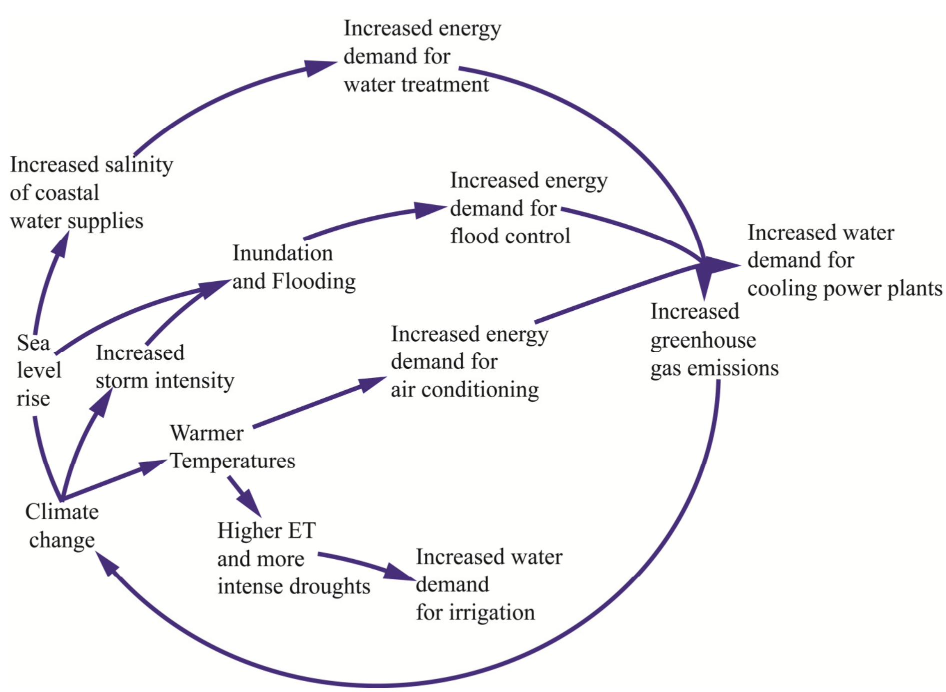
Although temporal fluctuations in water demand for public supply, commercial-industrial supply, and power generation are less significant than those for irrigation, these are also influenced by temperature and precipitation (Marella, 2009). In particular, climate change is expected to lead to increased demands for power, and therefore water withdrawals from power plants are expected to increase. For example, sea level rise and salt water intrusion will require the state to develop energy intensive water treatment facilities, such as desalination plants, to maintain public water supplies. Additionally, demand for power to operate pumps for flood

Figure 4: Agricultural irrigation withdrawals and average annual precipitation from 16 stations across the state



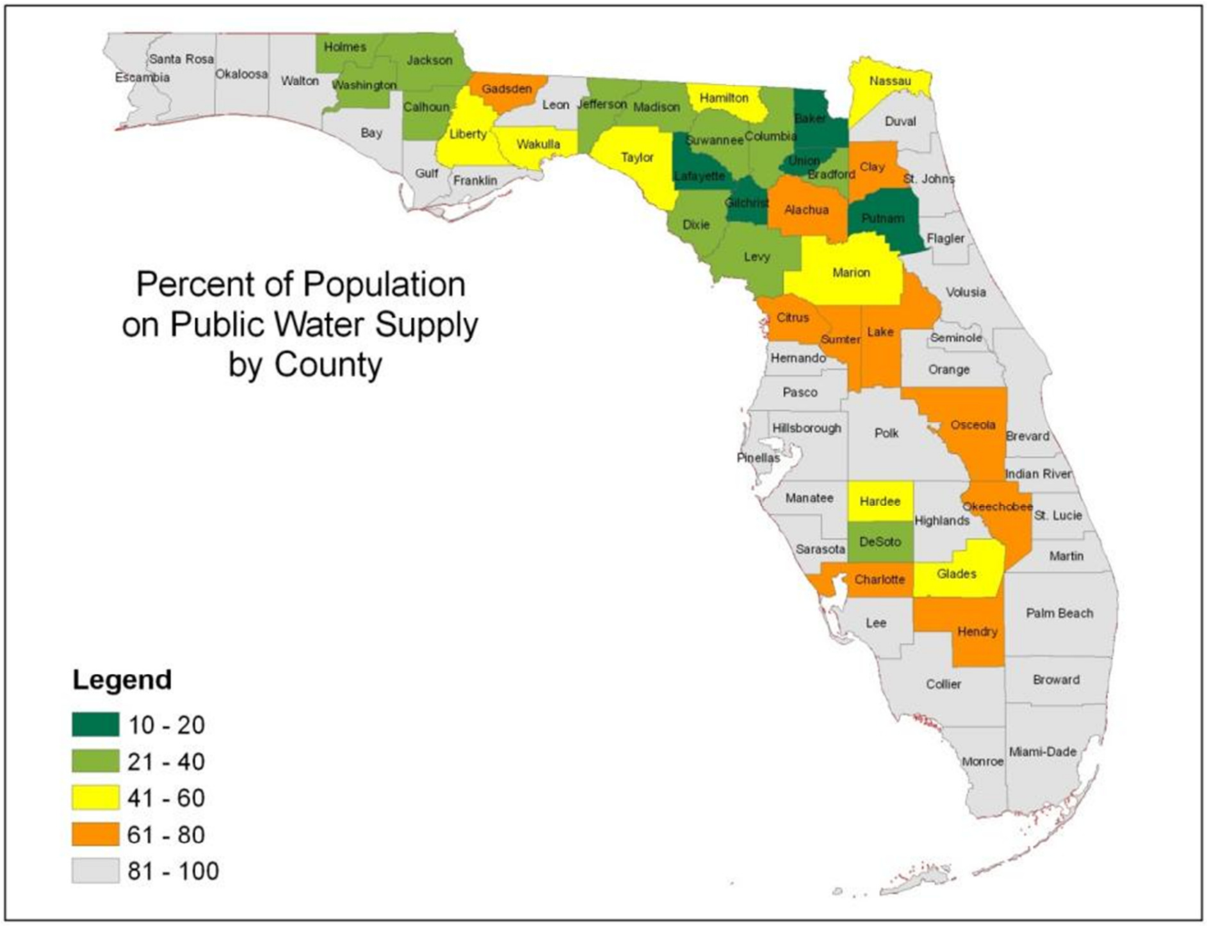
Source: Irrigation withdrawals data from Florida Water Science Center and precipitation data from Southeast Regional Climate Center. (Figure also appears in Berry et al., 2011).

Figure 5: Examples of climate-humans-power-water interactions.



Source: Author

Figure 6: Percent of population on public water supply by county, 2005

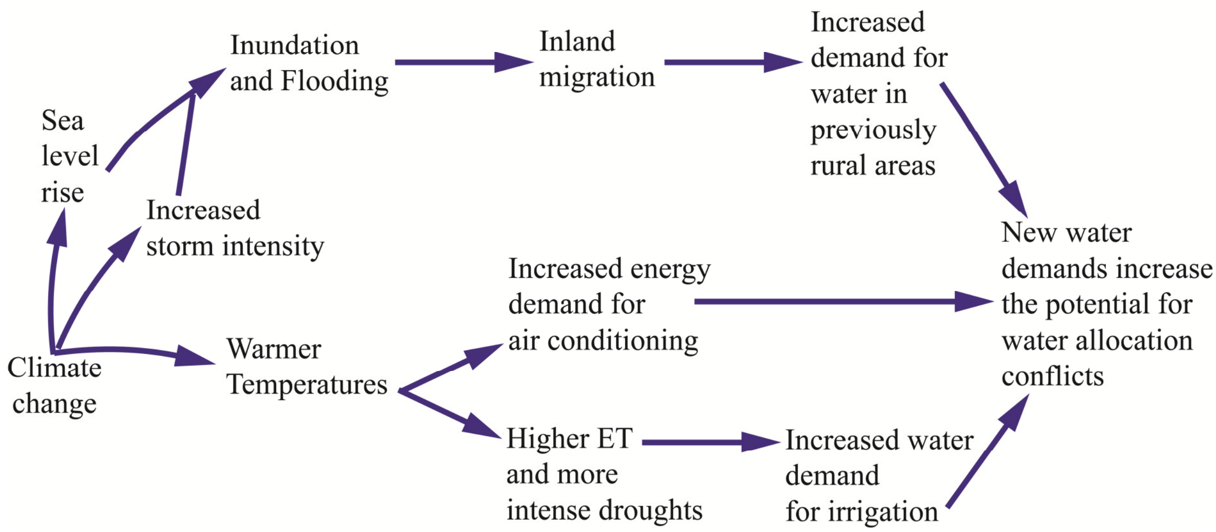


Source: Data from USGS Florida Water Science Center website, accessed 9/25/11. (Figure also appears in Berry et al., 2011.)

control is expected to increase as sea level rise and increased storm intensities cause inundation and flooding (Berry et al., 2011). Furthermore, higher temperatures will create greater demand for power for air conditioning (Karl et al., 2009; NAST, 2010). These interrelationships between climate, humans, power, and water (Figure 5) are complex and poorly understood. Thus, while it is clear that climate change will impact the magnitude and timing of water demand, there remain vast uncertainties in predictions of future water demand under changing climatic conditions.

In addition to influencing the magnitude of water demand, climate change is also likely to impact the location of the state's water demand centers. Currently about 75% of Florida's population resides in coastal counties (Berry et al., 2011; U.S. Bureau of Census, 2010 Census), and accordingly the majority of the state's infrastructure for public water supply is located in these densely populated coastal areas, as contrasted by the relatively low percentage of population served by public water supply in non-coastal counties (Figure 6). Sea level rise and increased tropical storm intensity, which are expected with climate change, will likely cause migration from coastal areas toward the interior of the state. Under this scenario, there would be rapid population growth and urbanization in previously rural areas. New municipal and industrial

Figure 7: Examples of potential climate change impacts on water allocation.



Source: Author

water demands in these areas could potentially create water allocation conflicts with pre-existing agricultural and ranching water demands (Figure 7). Furthermore, developing new water supply infrastructure requires significant financial investment and long construction times, and climate-related shifts in demographics are likely to occur before the state is able to fully develop the new infrastructure necessary to provide safe and sustainable water supplies for growing populations in areas with little or no existing water supply infrastructure.

Climate change, water policy, and public perceptions

Although most of Florida has historically relied on relatively inexpensively treated fresh groundwater, population growth and overreliance on groundwater as a single source has diminished the state's groundwater resources. Consequently, many areas of the state are struggling to find alternative sources of water and are also stepping up their water conservation programs (FDEP, 2010a). Because sea level rise, inundation, saltwater intrusion, increased evaporation, and other climate change-related factors will further decrease the availability of relatively inexpensive water supplies, climate change is further elevating the importance of developing alternative water supplies and effective water conservation measures (Berry et al., 2011). The public will be asked to fund implementation of these alternative supplies and to participate in water conservation programs; therefore, the success of these strategies for insuring the long-term sustainability of Florida's water resources will require public support. The importance of the public's role in sustaining Florida's water resources is further exemplified by the fact that, as described above, public water supply will soon represent the greatest demand for water in the state.

The example of public support for alternative water supplies

Increased re-use of wastewater after it has been highly treated (reclaimed water) is central to Florida's overall water sustainability plans (FDEP, 2007, 2010a). Even today, Florida uses more reclaimed water than any other state (663 Mgal/d or 43% of wastewater) (FDEP, 2010a). Most reclaimed water in Florida is used for irrigating residential areas, golf courses, parks, athletic fields, and agricultural feed crops (Martinez and Clark, 2009). While Florida residents have generally accepted these non-potable uses of reclaimed water, there is likely to be some public and political concern about the safety of recycled water as utilities seek to further increase reclaimed water use. Research has shown that people tend to be accepting of using recycled water in ways that involve little human contact. However, public acceptance of reclaimed water for uses that involve personal contact, like bathing, washing produce, or drinking, is relatively low (Dolnicar et al., 2011; Dolnicar and Hurlimann, 2010; Rygaard et al., 2011).

While programs to augment drinking water with reclaimed water have been successfully implemented in some places including Orange County, California and Singapore (Chu, 2011), there are also examples of communities rejecting so called "toilet-to-tap" programs due to concerns about the safety of reclaimed water and the cost of upgrading wastewater treatment facilities to produce water that meets drinking water standards. For instance, in 2006 residents in Towoomba, Australia, which has perpetual water shortages, rejected a proposition to augment the city's drinking water reservoirs with reclaimed water. Towoomba's mayor and city council saw the plan as the most economically and environmentally viable solution to the city's water supply problems (Rygarrd et al., 2011); however, opponents rallied as "Citizens Against Drinking Sewage" and achieved victory when 62% of the city's residents voted no to the proposition (The Sydney Morning Herald, 2006). In Florida there has already been some controversy about increased use of reclaimed water. In 2009, a Tampa Bay city council member, revived a proposal that was first considered in the 1980's to send treated wastewater back into the aquifers that the city uses for its public water supply in order to mitigate water shortages caused by droughts and/or future population growth (Zink, J., 2009a). However, there is ongoing public and political objection to the initiative due to concerns about the health risks of drinking reclaimed water and the costs of the infrastructure upgrades that would be required to implement the proposal (Zink, J., 2009b).

Desalination is also a central component of Florida's long-term water supply strategy. Currently, Florida leads the country in desalination with more than twice the capacity of California, which has the second highest capacity. As saltwater intrusion contaminates Florida's coastal aquifers, it will be more cost effective to desalinate the brackish groundwater than to transport fresh water from inland sources. Therefore, the state is expected to increase its desalination capacity even further (FDEP, 2010b). Studies suggest that people are generally more accepting of desalinated water than reclaimed water for uses involving physical contact. However, while people have fewer health concerns about desalinated water, they often express concern about the environmental impacts of desalination, which is very energy intensive and generates a saline waste residue that must be discarded (Dolnicar and Hurliman, 2011). The primary methods of managing desalination residue in Florida are deep well injection, land application, and discharge to sanitary sewer or surface water (FDEP, 2010b). Furthermore, in the current period of slow economic growth, it could prove very difficult to gain public support for funding initiatives to upgrade or develop new infrastructure, for desalination, wastewater reclamation, or other alternative water supplies (Berry et al., 2011).

The state of Florida is actively pursuing alternative water supplies and is taking steps to insure that the future water needs of Florida's residents, businesses, tourists, and natural systems are met. Due to continual advances in water and wastewater treatment technologies, there are a growing number of feasible options for augmenting traditional water supplies with alternative supplies, such as desalinated or reclaimed water. While new and improved technologies will be essential for sustaining water resources under a changing climate, as illustrated in Towoomba, public resistance to alternative water supplies can derail the implementation of water supply initiatives. Therefore, to insure the successful implementation of alternative water supply projects, it will be essential that "new initiatives are preceded by public engagement and interaction between decision makers and the public" (Rygaard et al., 2011).

The example of public trust and support for water management policies

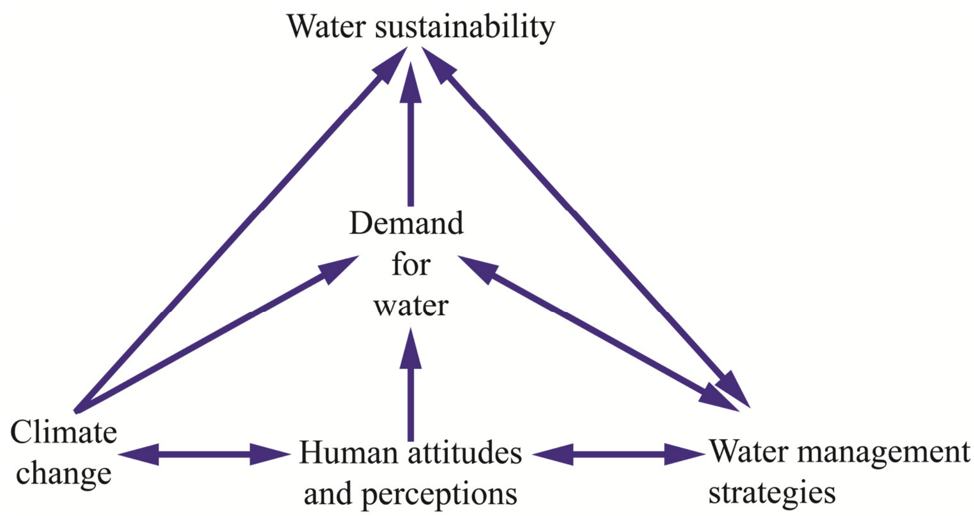
In urban areas in the United States, continuous delivery of safe potable water to homes and businesses is generally taken for granted; however, the reliability, aesthetic qualities, and cost of publicly supplied water are all likely to be impacted as climate change forces water utilities to switch to alternative water sources and/or water treatment technologies. Therefore, the public might notice changes in the taste, odor, and color of public water supplies (AWWA, 2007). Additionally, interruptions in water supply are conceivable due to water shortages during prolonged droughts or infrastructure damage during extreme storm events. As a result of greater weather extremes and shifting weather patterns, utilities and water managers may be forced to make rapid changes in water conservation policies, such as water restrictions and water pricing structure. Such rapid policy changes, especially when combined with changing aesthetics of public water supplies and potential interruptions in service, have the potential to erode public trust in policy makers. With 57% of Floridians reporting that they worry only a little or not at all about global warming (Leiserowitz and Broad, 2008), it is likely that many Floridians will not take water policies related to climate change seriously.

Another potential consequence of higher water prices, changes in the aesthetics of public water supplies, and lack of trust in utilities and water managers is an increase in bottled water consumption (Rygaard et al., 2011). Rapid growth of the bottled water industry would likely lead to increased water rights conflicts as bottled water companies compete with other local water demands for limited groundwater resources. Over the last two decades, there have already been numerous contentions over requests from water bottling companies to withdraw water from Florida's aquifers and springs (Brook, 2001; Davis, 2000; Klas, 2009; Penn, 2008; Thorner, 1998). Additionally, because bottle manufacturing and transportation of bottled water are both energy intensive and consumption of bottled water generates enormous volumes of plastic waste, this scenario would have negative environmental consequences (Rygaard et al., 2011). Thus, because the success of climate change adaptation strategies hinges in part on public perceptions and response, strategies for sustaining water resources should explicitly include education measures to inform the public about water scarcity, the need for policy and infrastructure changes, and sustainable water use practices.

Conclusions

Florida's water supplies are under intense pressure from both human and ecosystem demands. As climate change progresses, both natural and built hydrologic systems will adjust to sea level rise and changes in precipitation and evapotranspiration. In addition to directly impacting the water cycle, climate change will also influence the magnitude, timing, and location of water demand. Even in the absence of climate change there is "…little good, timely information on consumptive or non-consumptive water use, and associated forecasts of water demand...", and this information gap "hampers effective water decision making" (NRC, 2009, p. 88). The complex climate-people-water interactions discussed in this paper (Figure 8) will require water managers at all levels to make decisions and plan for a future with uncertain predictions of climate, water demand, infrastructure needs, and public and political sentiment towards water policies. Therefore, effective management of Florida's water resources in the face of climate change will require a systems approach - one that considers all components of the hydrologic cycle as interconnected parts of a single resource, one that cuts across political boundaries, and one that recognizes the significance of human-water-climate interactions.

Figure 8 Interrelationships between climate-humans and water.



Source: Author

Acknowledgements

This paper builds on Berry et al., 2011, a white paper that was completed as part of a State University System Climate Change Task Force project, funded by the Florida State University System. The authors wish to thank the P.I.s on that project, Len Berry (Florida Atlantic Univerwsity), Eric Chassignet (Florida State University), and James Jones (University of Florida). We also express our gratitude to all of co-authors of Berry et al., 2001, as well as all of the staff and graduate students that assisted with the Climate Change Task Force project.

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