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Modeling Ertapenem: The Impact of Body Mass Index on Distribution of the Antibiotic in the Body

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Research article

Florida's recycled water footprint: a geospatial analysis of distribution (2009 and 2015)

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Abstract: Water shortages resulting from increased demand or reduced supply may be addressed, in part, by redirecting recycled water for irrigation, industrial reuse, groundwater recharge, and as effluent discharge returned to streams. Recycled water is an essential component of integrated water management and broader adoption of recycled water will increase water conservation in water-stressed coastal communities. This study examined spatial patterns of recycled water use in Florida in 2009 and 2015 to detect gaps in distribution, quantify temporal change, and identify potential areas for expansion. Databases of recycled water products and distribution centers for Florida in 2009 and 2015 were developed by combining the 2008 and 2012 Clean Water Needs Survey databases with Florida's 2009 and 2015 Reuse Inventory databases, respectively. Florida increased recycled water production from 674.85 mgd in 2009 to 738.15 mgd in 2015, an increase of 63.30 mgd. The increase was primarily allocated to use in public access areas, groundwater recharge, and industrial reuse, all within the South Florida Water Management District (WMD). In particular, Miami was identified in 2009 as an area of opportunity for recycled water development, and by 2015 it had increased production and reduced the production gap. Overall, South Florida WMD had the largest increase in production of 44.38 mgd (69%), while Southwest Florida WMD decreased production of recycled water by 1.68 mgd, or 3%. Overall increase in use of recycled water may be related to higher demand due to increased population coupled with public programs and policy changes that promote recycled water use at both the municipal and individual level.

Keywords: recycled water; water reuse; Florida; water management districts; kernel density estimation; geospatial analysis; spatiotemporal change

1. Introduction

Recycled water use is the reuse of highly treated wastewater for irrigation, industrial reuse, groundwater recharge, and wetland reclamation, among other uses. These applications are important for water conservation, the need for which has been intensified by climate change, population growth, groundwater withdrawal, and saltwater intrusion [1–3]. These have placed pressure on water resources such that water consumption has outpaced population growth, as a result, water use rates are unsustainable [2,3]. The use of recycled water could assist in water mitigation strategies focused on water conservation measures, drought protection, irrigation management, environmental protection, and social and economic benefits [2–4]. The approximately 12 billion gallons of effluent discharged from wastewater treatment plants into streams and oceans daily is a valuable resource that could be recycled to increase available freshwater stores, supplying up to 6% of the estimated total United States (US) freshwater demand and up to 27% of municipal supply for residential, commercial, and industrial uses [5].

Recycled water use dates back 5000 years to Minoan time (ca. 3200-1100 BCE) when the use of effluent discharge for agricultural irrigation, livestock watering, and proto-industries for silk was implemented by the Harrapan Civilization in the Indus [6,7]. In the US, recycled water was used for agricultural irrigation in the late 1800's, and was an important component of a project to combat seawater intrusion in California, beginning in 1962 [8]. Florida began recycling water in the mid-1960s to produce recycled water for agricultural spray irrigation for 120 acres at the Tallahassee Reclaimed Water Farm [9]. By 2015, Florida maintained 418 domestic wastewater treatment facilities that produced a variety of recycled water products [10].

A thorough literature review indicates a lack of geospatial, statistical, and temporal evaluation of recycled water use world-wide. Studies on the public perception of recycled water use (for example, [11–14]) have identified a barrier to implementation known as a "yuck factor". The "yuck factor" is described as a psychological barrier of perception that results in emotional discomfort with the use of recycled water [11]. Most people surveyed perceived recycled water to be unclean water of low quality with potential risks to community health. Interestingly, replacing the term "recycled water" with "repurified water" was preferred by participants of the study [11], however, the term "recycled water" pertains to water that has undergone secondary treatment while the term "reclaimed water" refers to tertiary treatment [2]. The only statistically significant variable preventing implementation of recycled water for direct potable reuse is the "yuck factor" [15], which is a barrier that may be overcome by community education of the recycled water treatment process, and proper branding [12,13,15]. While the "yuck factor" is of primary importance to community acceptance, it is only one of a number of factors that determine decision-maker support for use of recycled water. Cost, availability of alternate water sources, social factors, and legal factors are also considered [5].

Best management practices to ensure quality of discharge from wastewater treatment plants, to assess water consumption, and to evaluate public water intakes have also been investigated (for example, [16–21]). From a technological perspective, membrane bioreactor single systems are suitable for small urban and rural areas, whereas microfiltration and reverse osmosis dual systems are better suited for large urban areas [18]. From a spatial perspective, methods to assess water footprints (WF) (i.e., freshwater needed to produce goods and services consumed by a spatial entity) at different spatial scales were reviewed by Paterson et al. [19] who focused not only on direct water consumption, but also on virtual water (water used in production of goods outside of the region of consumption). The authors emphasized the need for analysis of water footprints at the local scale because that is the spatial scale at which many water decisions are made, however they recognized spatiotemporal challenges associated with changing urban boundaries. De Facto wastewater reuse, whereby a wastewater treatment plant discharges into surface water upstream of a public water supply intake was evaluated from a spatiotemporal perspective at 1210 sites across the US [20]. De Facto water reuse was found to depend largely on stream flow, such that at normal flows, half of the sites had treated wastewater intake of less than 1%, yet at low flows nearly half of the sites had intakes of 50% treated wastewater. Sites with higher De Facto water reuse appear to be clustered along the Gulf and Atlantic coastal states. The first econometric analysis of water reuse was conducted on Florida's water reuse capacity from 1996–2012 at the county-level [22]. This study investigated water quality and scarcity as drivers for recycled water distribution, and found that water quality was a major influence on Florida's dedication to recycled water distribution. An analysis of recycled water production and distribution at the facility level, however, is limited in the literature [24], and spatial analyses of production trends over time at the facility scale are lacking [22]. The present study helps to fill this gap by completing an empirical spatiotemporal analysis of recycled water use in Florida in 2009 and 2015 using weighted kernel density estimation, first applied to analyze recycled water production for California and Florida [4]. The purpose of the present study is to examine the spatial distribution of recycled water among five WMDs in 2009 and 2015 to identify gaps in distribution, temporal changes, and potential areas for expansion.

As population continues to rise, supply of freshwater is decreasing and use of recycled water has become an important and essential strategy to mitigate the reduction in freshwater availability for Florida. US population growth since the 1940s is associated with a doubling in water use, which has caused added stress to water management systems [22]. Florida's current water supplies are at risk of depletion by 2025 due to groundwater withdrawal from the Floridian aquifer and other groundwater sources since much of the state relies overwhelmingly on aquifers for municipal water supply [1]. Use of recycled water is one water management practice implemented to meet this demand, serving a dual purpose as a water conservation measure (especially in relation to groundwater recharge). Recycled water in Florida must meet, at minimum, secondary treatment and high-level disinfection before use in irrigation and must meet water quality standards of 5 mg/L Total Suspended Solids for subsurface application [23].

Florida ranked fourth in the US for total freshwater withdrawal according to a 2010 United States Geological Survey (USGS) report on water use [24]. In terms of recycled water production in US states, by 2006 Florida (663 mgd) was ranked first in the US followed by California (580 mgd), Texas (31.4 mgd), Virginia (11.2 mgd), Arizona (8.2 mgd), Colorado (5.2 mgd), Nevada (2.6 mgd), and Idaho (0.7 mgd) [26]. Florida continues to rank first among US states for recycled water distribution [10].

2. Dataset and methods

2.1. Study area

Florida's recycled water production is managed by five Water Management Districts (WMDs) (Figure 1). These WMDs are the "general supervisory authority" which delegates water resource responsibilities intended to manage the quality and quantity of water between city, county, and state level government under the oversight of the U.S. Environmental Protection Agency (USEPA) [27]. Such responsibilities include flood protection, technical duties, development of water management plans, and procedures for recycled water use.

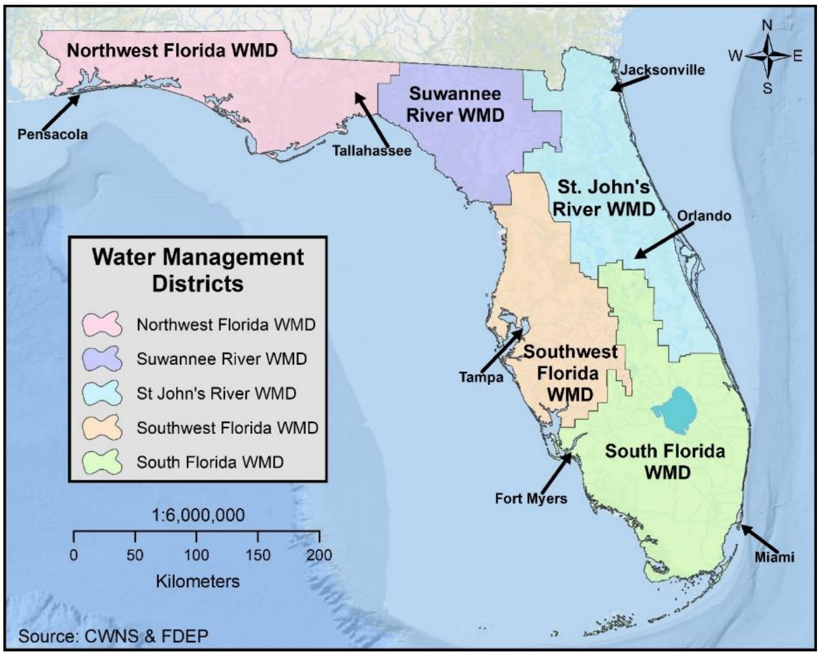

Figure 1. Florida Water Management Districts.

Florida's WMDs produce recycled water for five use categories: public access areas, agricultural irrigation, groundwater recharge, industrial, and wetlands and other (toilet flushing, fire protection, and other) (Table 1). These recycled water products are distributed across the state and are regulated by consumptive use permits that identify the level of treatment at wastewater facilities, limit withdrawal based upon the need of recycled water (e.g., agricultural and industrial), and prevent saltwater intrusion (e.g., groundwater recharge injection well locations near estuaries) [5].

Table 1. Florida's recycled water product categories [10].

Type	Explanation
Public Access Areas	Golf courses, cemeteries, parks, landscape areas, hotels, motels, private property, residential dwellings and highway medians irrigation
Agricultural Irrigation	Includes edible crops and crops used for feed and fodder
Groundwater Recharge	Groundwater injection and indirect potable reuse (withdrawn for drinking water)
Industrial	Manufacturing facilities, cooling towers
Wetlands and Other	
• Wetlands	Addition to wetlands
• Toilet Flushing	Reuse for toilet flushing
• Fire Protection	Reuse for fire protection
• Other	Permitted uses include—decorative fountains, commercial laundries, cleaning of roads and sidewalks, vehicle washing, concrete making, and other permitted uses

2.2. Source datasets

Databases of recycled water products for Florida were developed for 2009 and 2015, and compared both spatially and temporally using statistical analysis and kernel density estimation (KDE) to evaluate spatial trends in recycled water production over time. To assemble the databases, Publicly Owned Treatment Works (POTWs) locations, population total, and volume of production were extracted from the Florida 2008 and 2012 Clean Water Needs Survey (CWNS) database [28,29] and combined with Florida's 2009 and 2015 Reuse Inventory database using permit numbers as the key [30,10] (Figure 2).

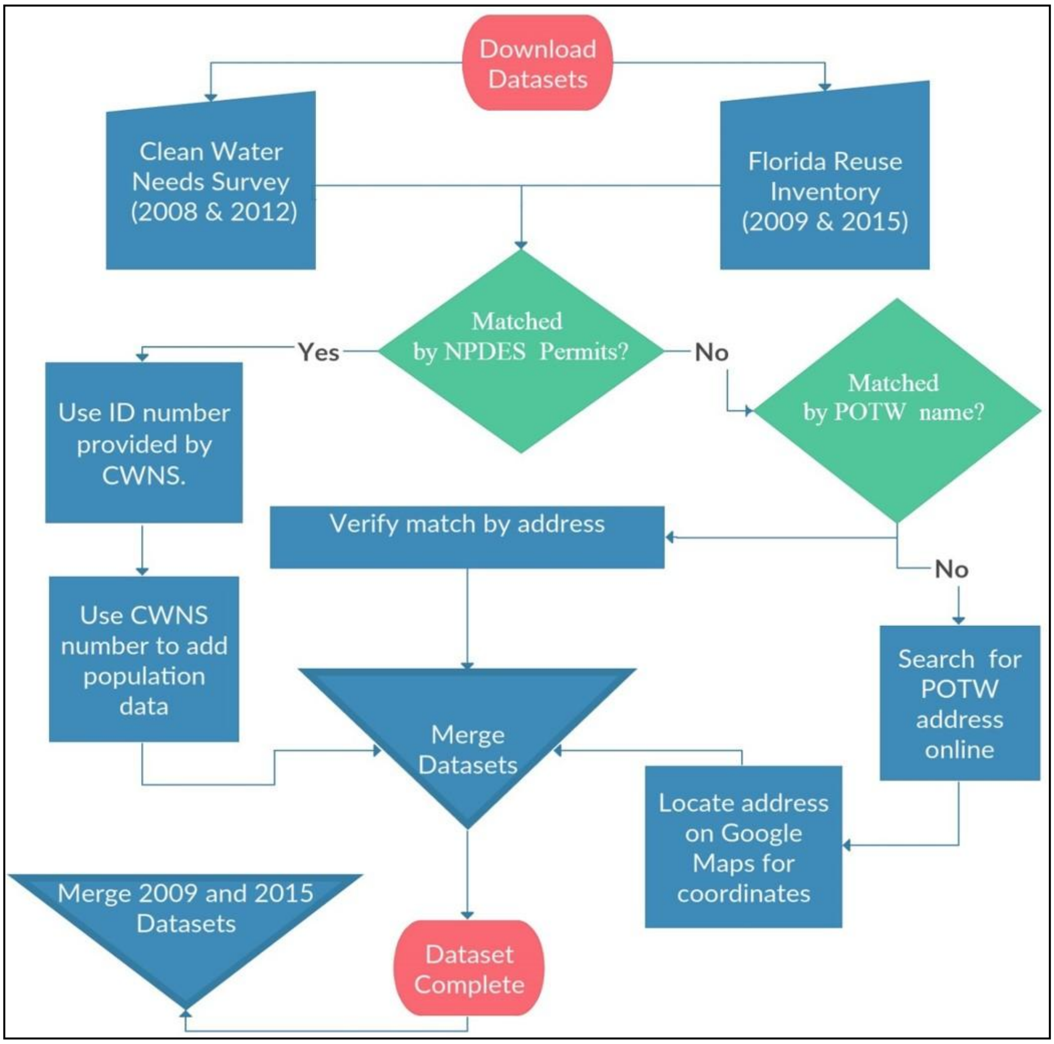

Figure 2. Flowchart for dataset organization procedures.

The EPA's CWNS database was downloaded from https://www.epa.gov/cwns and summaries of facility, permit, and population data were extracted. Summary of facilities included: CWNS number for each POTW, the name of POTWs, county of origin, geographic coordinates for location, and permit number. Summary of permits included: CWNS number for each POTW with a permit, permit number, and permit type. Summary of population included: CWNS number for each POTW and the present residents connected to public sewer lines. The CWNS number was used to extract data for all POTWs that recycle water.

Florida's 2009 and 2015 Reuse Inventories were obtained from the Florida Department of Environmental Protection (FDEP). This database included information on the distribution of recycled water: POTW name, water management district location, recycled water product(s), volume of recycled water used (in millions of gallons per day (mgd)), and acres served. In 2009, 414 of 426 (97%) and in 2015, 407 of 418 (97%) POTWs in Florida's Reuse Inventory database were matched by permit numbers to entries in the CWNS database, which contained geographic coordinates for each facility. Wastewater treatment facilities with unmatched permits (2009 N = 15; 2015 N = 11) were located using Google Maps and manually geocoded. The geocoded datasets were mapped using ArcGIS 10.4.1 [31] (Figure 3 and 4).

2.3. Analytical methods

The 2009 and 2015 databases were analyzed for differences over the 6-year period. These data included POTW name, geographic coordinates, and parameters for each of years 2009 and 2015: daily volume of recycled water produced (hereafter termed flow) (mgd), acres served, and average population served by the POTWs. Population data were provided only in the CWNS published every four years, and because of missing values in 2008 and 2012, averages were used.

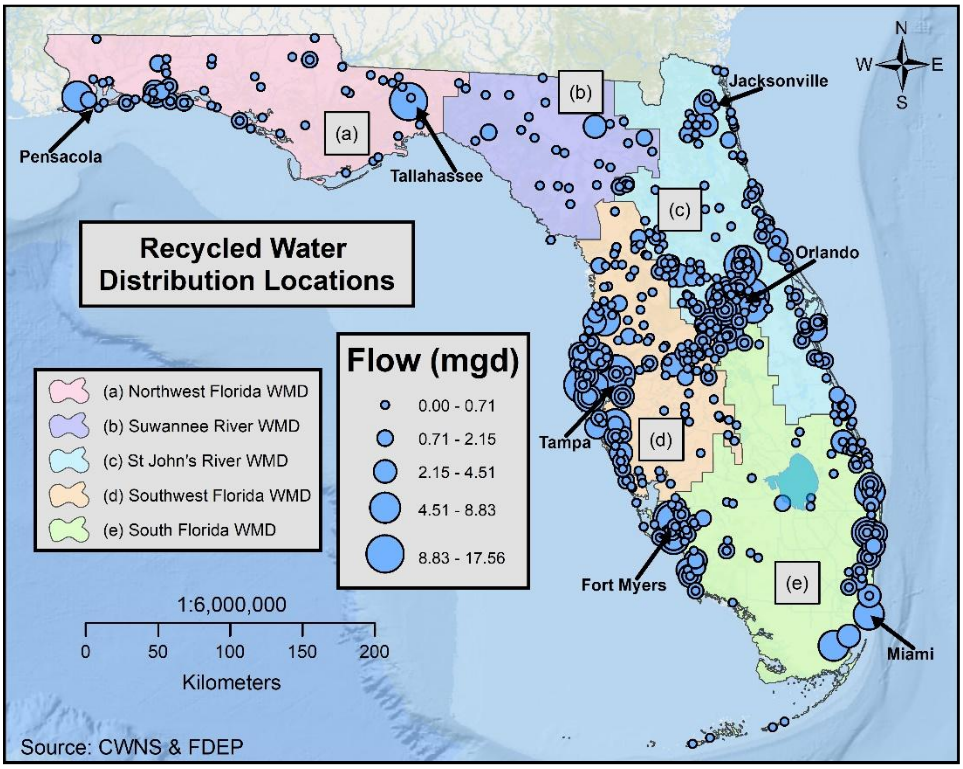

Figure 3. 2009 Florida recycled water distribution locations.

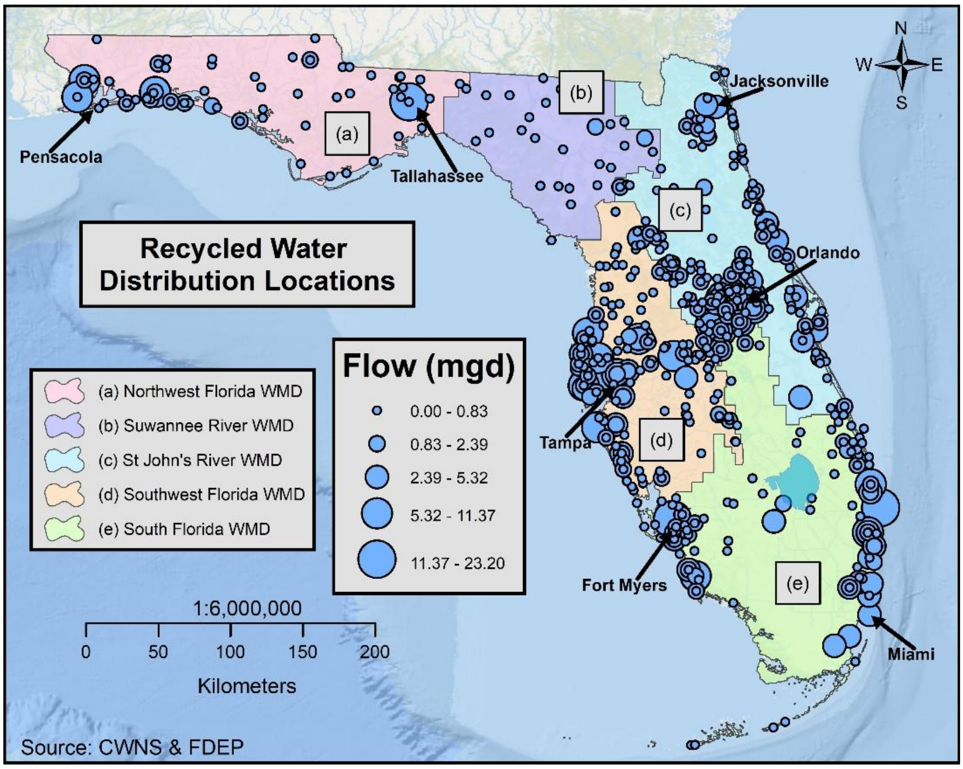

Figure 4. 2015 Florida recycled water distribution locations.

Descriptive statistics were calculated using Statistical Package for the Social Sciences Version 23 (SPSS) [32] for volume of flow at Florida's WMDs for 2009, 2015, and the changes from 2009 to 2015. Flow volume of recycled water products in 2009 and 2015 were compared between Florida's five WMDs with a one-way Analysis of Variance (ANOVA). Tukey *post hoc* tests were conducted to determine statistical significance of differences between WMD flow volume (mgd) in 2009 and 2015.

Paired *t*-tests were performed to identify statistically significant differences between the 2009 and 2015 flow volume of recycled water products for each WMD. A Wilcoxon signed-rank test was used to assess differences between 2009 and 2015 flow volume of recycled water products. All bivariate data were analyzed with SPSS Version 23 [32].

Hotspots for recycled water production were identified using KDE analysis. Quartic Kernel was selected because it has a gradual, spherical-shaped curve which halts at a defined radius limit. This prevents the kernel from extending to infinity and limits the area of influence to the immediate area around the POTW [33]. Adaptive bandwidth was selected, and the minimum number of points was set as fifteen points per cluster. KDE was performed on flow (raw recycled water production), flow normalized by acres served (to factor in the service area of the facility), and flow normalized for average population served (to factor in the population served by the facility). CrimeStat IV was used to analyze all data [33].

3. Results

In 2009, 426 of 548 (78%) POTWs distributed recycled water products with a total flow of 674.26 mgd [30]. By 2015, more recycled water was produced (738.15 mgd) from fewer POTW facilities, with more facilities (418 of 524, 87%) participating in recycled water product distribution [10]. For both years, major metropolitan areas (Orlando, Tampa, Fort Myers, and Miami) had higher recycled water production. The highest mean production in 2009 was 1.13 mgd in South Florida WMD, whereas the lowest mean production was 0.34 mgd in Suwannee River WMD (Table 2). In 2015, the highest mean production was 1.32 mgd in South Florida WMD, whereas the lowest mean production was 0.28 mgd in Suwannee River WMD (Table 3). Production, therefore, increased by 0.19 mgd (17%) in South Florida WMD and decreased by 0.06 mgd (18%) in Suwannee River WMD over the study period.

Table 2. 2009 Florida descriptive statistics with number of POTWs for flow (mgd) per WMD.

WMD	#POTW	Mean	Coefficient of Variation	Minimum	Maximum	Median	Flow
Northwest Florida	58	0.64	2.98	0.002	17.14	0.22	59.91
South Florida	97	1.13	1.77	0.00036	17.56	0.34	238.60
St. John's River	129	0.57	2.17	0.00005	13.73	0.22	167.92
Southwest Florida	119	0.80	2.03	0.0001	11.99	0.24	198.45
Suwanee River	23	0.34	1.38	0.007	2.30	0.14	9.39
Average Total	426	0.69	2.25	0.0005	12.08	0.20	674.26

Table 3. 2015 Florida descriptive statistics with number of POTWs for flow (mgd) per WMD.

WMD	#POTW	Mean	Coefficient of Variation	Minimum	Maximum	Median	Flow
Northwest Florida	59	0.69	3.04	0.0003	17.10	0.20	70.11
South Florida	97	1.32	2.12	0.001	23.20	0.32	282.98
St. John's River	124	0.61	1.96	0.001	11.37	0.20	178.62
Southwest Florida	112	0.73	1.90	0.001	7.90	0.23	196.77
Suwanee River	26	0.28	1.43	0.005	2.18	0.16	9.68
Average Total	418	0.73	2.43	0.002	12.35	0.22	738.15

In 2009, public access area irrigation was the most common recycled water product accounting for a total distribution of 381.38 mgd (57% of state total), most of which was distributed by South Florida WMD (154.56 mgd; 41%) (Figure 5A). The next largest was industrial reuse at 91.64 mgd (14% of all recycled water production), with the largest share distributed by Southwest Florida WMD at 43.01 mgd (47%) (Figure 5B). Groundwater recharge followed next with a total of 86.72 mgd (13% of state total), with the largest share distributed by South Florida WMD at 43.29 mgd (50%) (Figure 5C). Recycled water used for agricultural irrigation totaled 75.57 mgd (11% of state total), with the largest portion distributed by Northwest Florida WMD at 32.09 mgd (42%) (Figure 5D). Wetlands and other (which include toilet flushing and fire protection) totaled 38.96 mgd (6% of state total), with a majority (69% at 27.72 mgd) distributed by St. John's River WMD (Figure 5E).

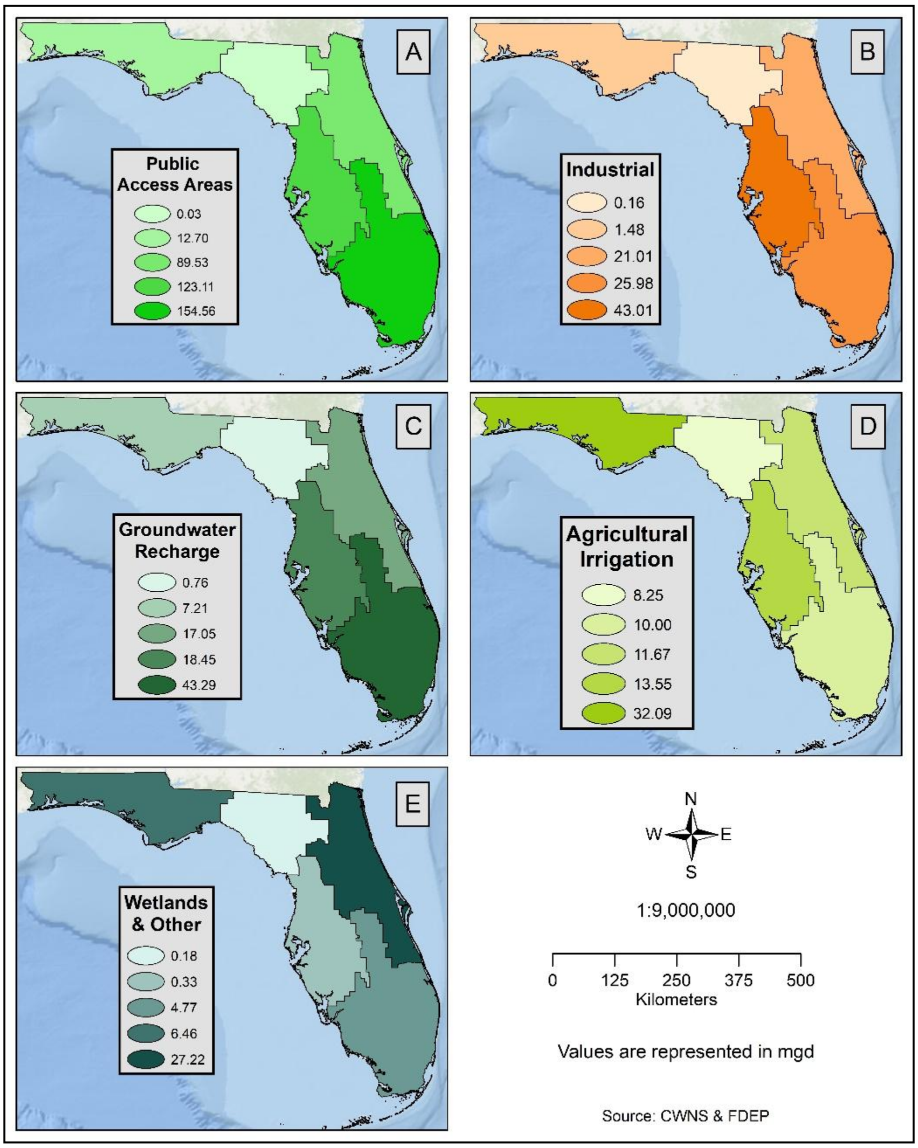

Figure 5. Recycled water products in 2009 (A) public access areas, (B) industrial, (C) groundwater recharge, (D) agricultural irrigation, (E) wetlands recharge and other.

In 2015, the most common use for recycled water was public access area irrigation at 419.82 mgd (57% of total production), mostly distributed by South Florida WMD (43% at 179.48 mgd) (Figure 6A). Following the same trend as 2009, the next two largest categories of recycled water products was industrial reuse at 123.84 mgd (17% of state total) and groundwater recharge at 94.68 mgd (13% of state total). Both were distributed most widely by South Florida WMD at 46.15 mgd (37% of production) and 48.79 mgd (52% of production), respectively (Figure 6B and 6C). Agricultural irrigation reuse totaled 64.69 mgd (9% of state total), a drop from 2009, with the largest proportion distributed by Northwest Florida WMD at 28.50 mgd (44%) (Figure 6D). Finally, water discharged to wetlands and other uses (which include toilet flushing and fire protection) was also reduced in 2015, totaling 35.12 mgd (5% of state total), with a majority (69% at 24.24 mgd) distributed by St. John's River WMD (Figure 6E).

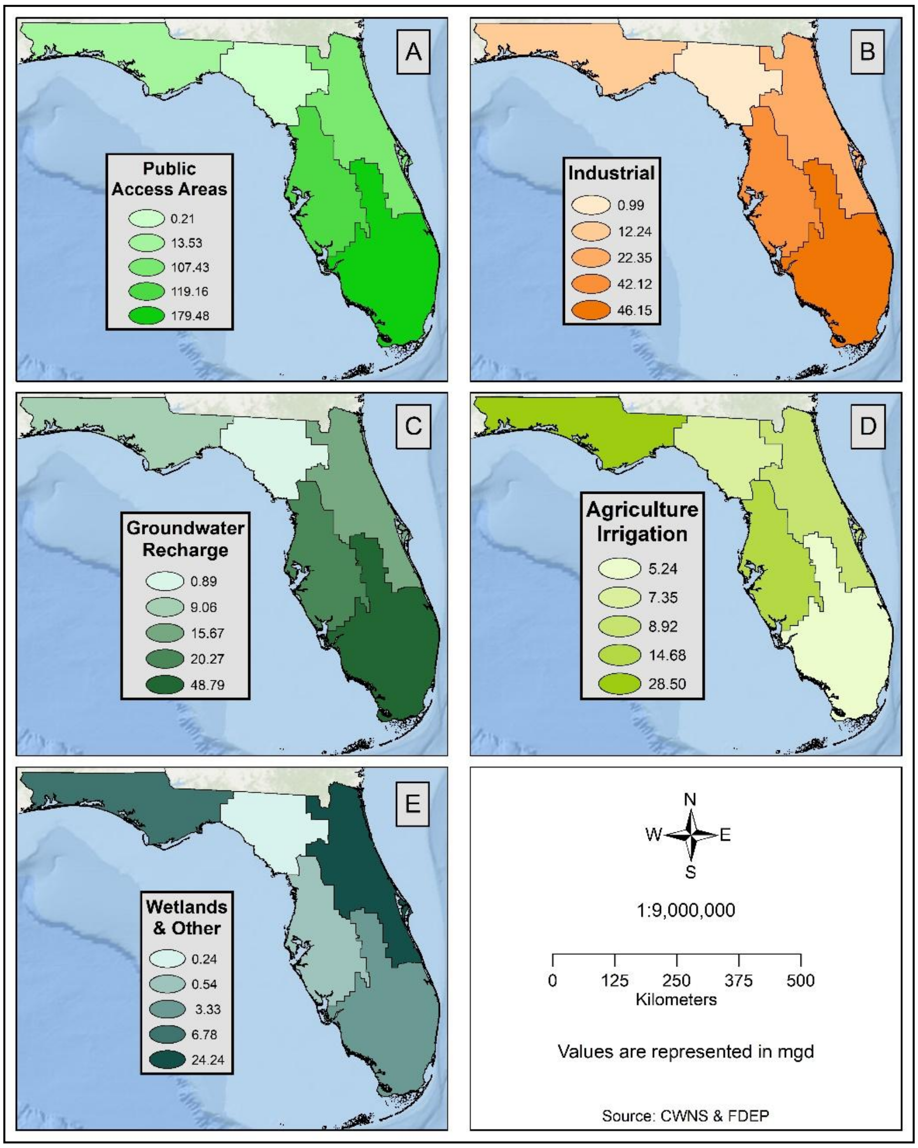

Figure 6. Recycled water products in 2015 (A) public access areas, (B) industrial, (C) groundwater recharge, (D) agricultural irrigation, (E) wetlands recharge and other.

In both 2009 and 2015, Suwanee River WMD was the lowest-producing district with a total production of 9.39 mgd (1.4%) and 9.68 mgd (1.3%), respectively (Figures 7 and 8). ANOVA for 2009 indicated significant differences ($p < 0.05$) in recycled water production between WMDs. Additional assessments with Tukey *post-hoc* tests indicated significant differences ($p < 0.05$) between South Florida and St. Johns River WMDs in 2009. While Suwannee River WMD had the lowest mean production at 0.34 mgd (per POTW) in 2009, it was not significantly different from the other WMDs. In 2015, ANOVA results again indicated significant differences ($p < 0.05$) in recycled water production between WMDs. Tukey *post-hoc* tests indicated significant differences ($p < 0.05$) between South Florida and St. Johns River, Southwest Florida, Northwest Florida, and Suwanee River, WMDs. Paired *t*-tests showed 2009 and 2015 volume of recycled water flow and WMDs were highly and positively correlated, r = 0.94, $p = 0.05$. Flow volume in 2015 increased significantly over 2009, $t_{372} = 1.939$, $p = 0.05$, d = 0.1.

The 373 POTWs that generated recycled water products in both 2009 and 2015 were assessed for changes in production over time with a Wilcoxon signed-rank test which showed symmetrical distribution, as assessed by a histogram. Volume of flow was significantly higher for POTWs producing recycled water in 2015 compared to the production of those same POTWs in 2009, a statistically significant increase in median flow from 0.395 mgd in 2009 to 0.475 mgd in 2015, $z = -1.973$, $p < 0.009$.

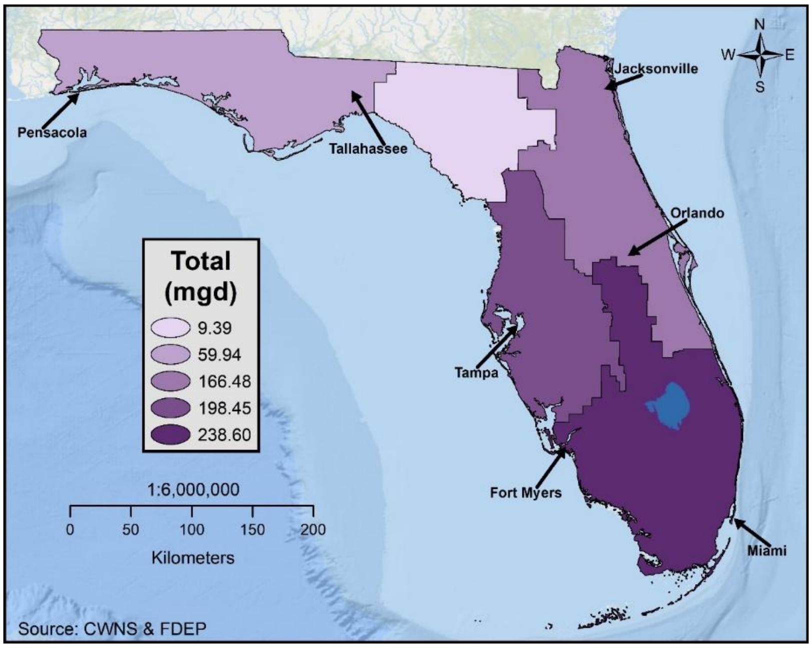

Figure 7. 2009 Florida total flow per district.

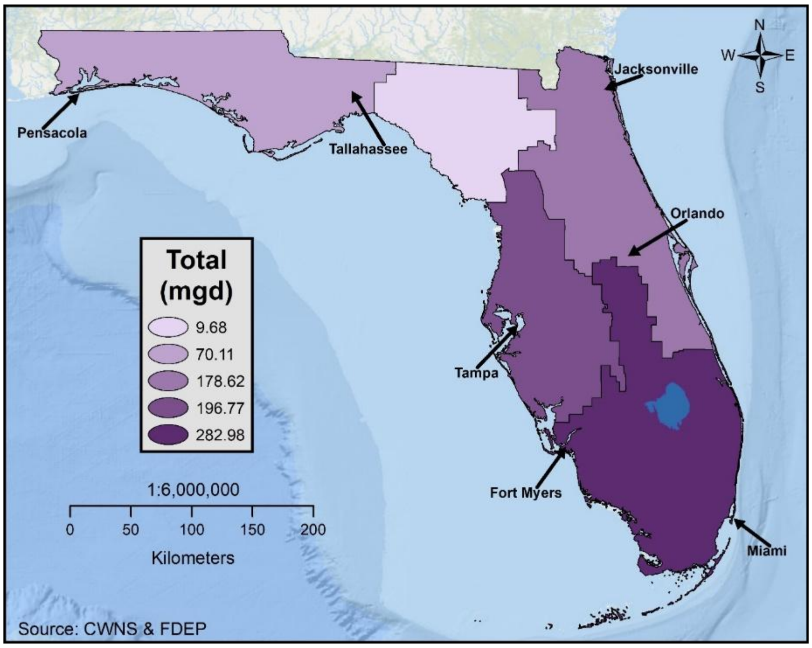

Figure 8. 2015 Florida total flow per district.

KDE of flow volume identified hot spots near most major cities in both 2009 (Figure 9A) and 2015 (Figure 9B). Dark areas indicate greatest production, whereas light areas may be areas with potential for increased production. To account for the size of the service area for each POTW, flow data were normalized by area served (Figure 9C,D), showing an increase in production per acre of service area around the Tampa area. To assess per capita recycled water production, flow data were normalized by average population served (Figure 9E,F). Per capita flow increased in urban areas from 2009 to 2015, suggesting that growth in recycled water production was concentrated in urban areas. One important observation is that this trend was not observed in the Miami area.

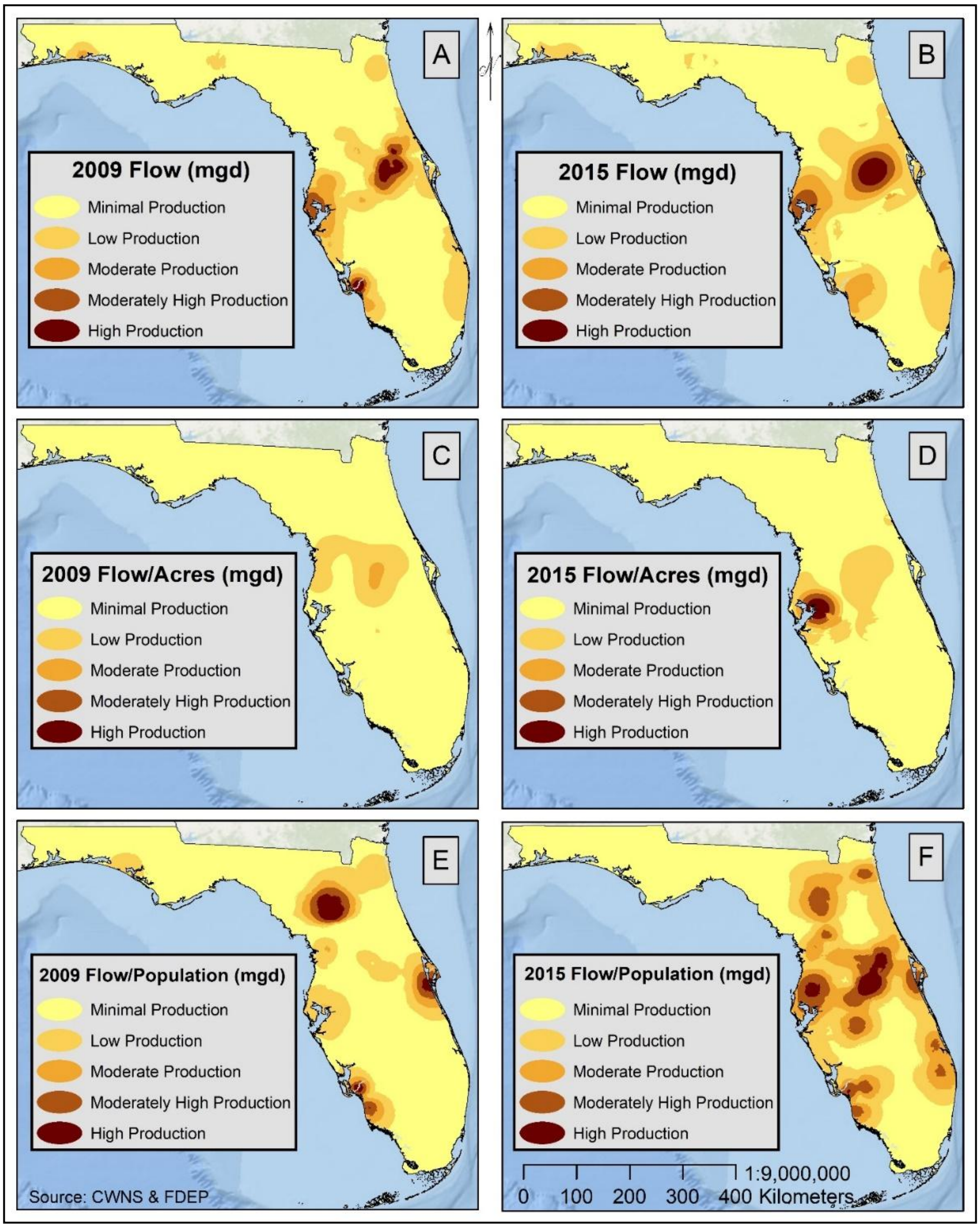

Figure 9. 2009 Florida kernel density estimation for (A) and (B) flow, (C) and (D) flow/acres served, and (E) and (F) flow/population served.

4. Discussion

Production of recycled water in Florida increased by a total of 63.88 mgd from 2009 to 2015. First, considering how distribution changed spatially, most of the increase in distribution occurred in South Florida WMD at 44.38 mgd (69%). This overall increase in South Florida WMD resulted from increases in recycled water for public access area irrigation (24.92 mgd) (Figure 10A), industrial reuse (20.17 mgd) (Figure 10D), and groundwater recharge (5.50 mgd) (Figure 10B). Most of the decrease in distribution occurred in Southwest Florida WMD with a drop in production of 1.68 mgd (3%). A slight increase was observed in Suwannee River WMD (0.29 or 0.5%), which was a region identified for potential increase in a prior study [4]. Tukey *post-hoc* tests indicated the recycled water production gains in South Florida WMD were significantly greater than gains in St. Johns River, Southwest Florida, and Suwanee River.

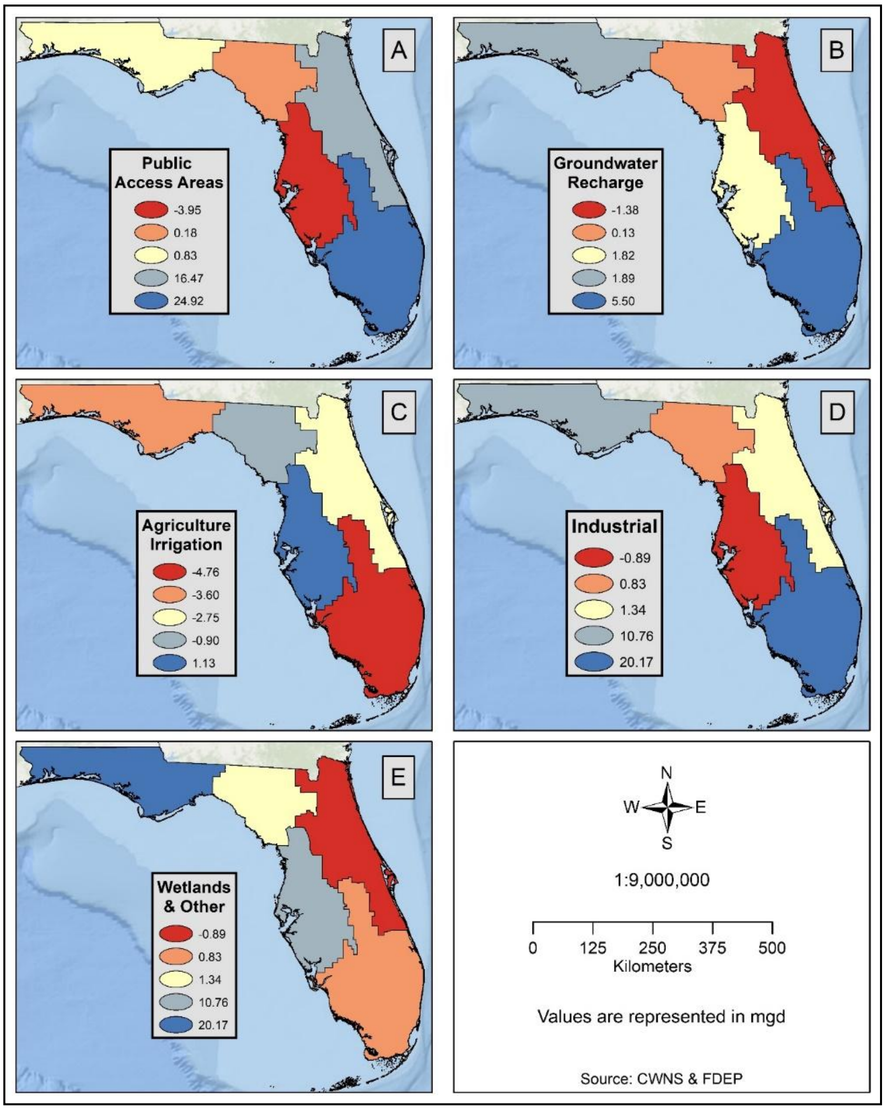

Figure 10. 2015–2009 production differences based on classification type for (A) Public access areas, (B) groundwater recharge, (C) agricultural irrigation, (D) industrial uses, (E) wetlands recharge and other.

Second, considering first recycled water products, increases were seen in public access areas (38.44 mgd), groundwater recharge (7.96 mgd), and industrial reuse (32.21 mgd), all within the South Florida WMD (Figure 10). In contrast, a decrease in agricultural irrigation (10.87 mgd) occurred in South Florida WMD (Figure 10C), possibly due to changes in land use related to urban growth. Moreover, a decrease in recycled water used in wetlands reclamation (3.84 mgd) was observed in St. Johns River WMD (Figure 10E).

Increase may be attributed to population and urban growth to meet water supply demand [34]. For example, in 2010 the City of Pompano in South Florida WMD began an "I Can Water" campaign to connect single family homes to recycled water lines which would be used for public access area irrigation of lawns [34]. This campaign did not target commercial and multi-family dwellings because they were already mandated for connection to recycled water lines [34]. In 2008, the FDEP, WMD officers, utilities, and local governments met to discuss regulatory authorization of recycled water for consumptive use to optimize the use of recycled water [35]. In 2014, Senate Bill 536 passed which covered "expansion of beneficial use of reclaimed water, stormwater, and excess surface water" [36]. These meetings continued throughout 2016 and have impacted regulation and increased recycled water use [10].

KDE results indicated growth in recycled water production in major cities (Figure 11). Miami was a low production area in 2009 given its population but increased flow (mgd) was observed in 2015 (Figure 11A). Miami was identified in a prior study [4] as an area primed for expansion, and while increased production addressed the gap in Miami, future population increase and saltwater intrusion suggests recycled water production is barely keeping pace, and greater use of recycled water will be necessary in the future. A 2007 Reuse Feasibility Study for Miami-Dade-County outlined multiple options for the use of reclaimed water county-wide, focusing on expected increases in wastewater discharges and options for reuse that incorporate existing infrastructure. The study recommended implementation of an Aquifer Recharge Pilot Project and the Coastal Wetlands Rehydration Demonstration Project to evaluate the process for recharging the Biscayne Bay Aquifer and application of reclaimed water to the surrounding wetlands [37]. This project, as of 2016, was still in the planning stages [38].

Normalizing recycled water production by acres (Figure 11B) indicated an increase in Tampa, Orlando, Fort Myers, and Jacksonville, suggesting that recent increases in recycled water production are concentrated in urban areas. Normalizing by average population (Figure 11C) showed a large increase in Orlando and minor increases in Tampa and Fort Myers. Normalizing by population was most representative of persons served by recycled water, such that gains in production could be offset by population growth. In central Florida (Orlando and Tampa), recycled water production grew faster than the population, while in Miami the opposite was true.

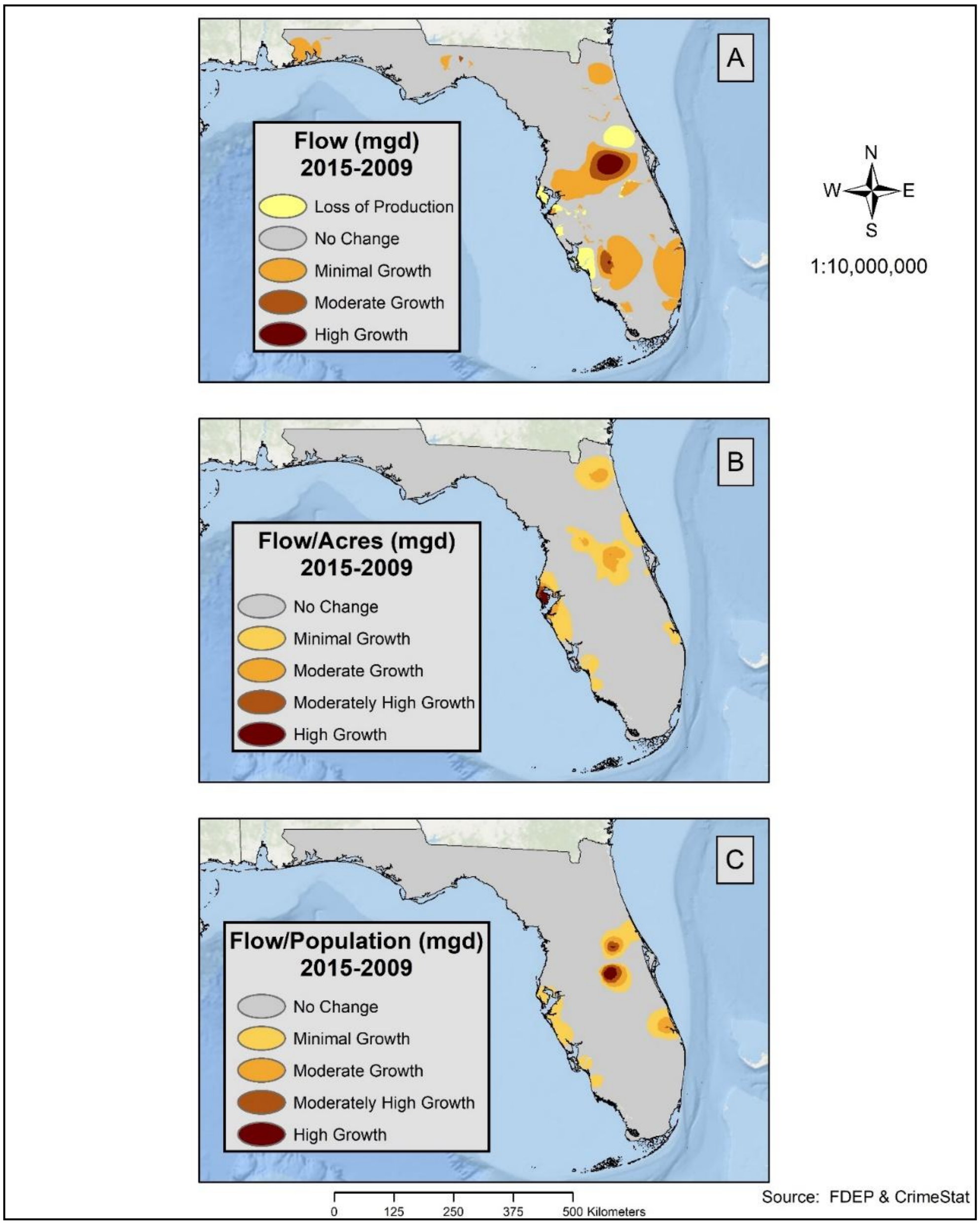

Figure 11. 2015–2009 Florida kernel density estimation for (A) flow, (B) flow/acres served, and (C) flow/average population served.

Florida has become the pioneer state for recycled water production and distribution, an innovative water mitigation strategy for freshwater conservation. Florida's success in recycled water production could be used as a model to integrate recycled water production within any municipality, county, or state. Florida has an abundance of precipitation and surface waters; interestingly, the principal driver for recycled water production increases in Florida was less focused on increasing supply and more focused on water quality [22]. This problem is not unique to Florida; nationwide 55% of assessed streams were identified as impaired due to pollutants, primarily pathogens, sediment, or nutrients such as phosphorus and nitrogen [39]. Release of recycled water to streams can mitigate surface water pollution through dilution and improved habitat associated with improved flow. Florida waters in particular are targeted for improvement through Basin Management Action Plans

(BMAPs) [36]. In 1998, Florida adopted the Numeric Nutrient Criteria (NNC) which calculates nutrient load as a water quality standard across the state [34]. Wastewater effluent is a significant source of increased nutrient load in already impaired waters [36], which could be eliminated with advanced treatment of wastewater such that it meets recycled water standards [36].

Coastal areas that experience saltwater intrusion, water-stressed regions, poor water quality conditions, and low precipitation locations should consider recycled water as a valuable component of future water supply and conservation plans [3].

One limitation to the per capita changes in recycled water presented in this study was the inconsistency in population data provided by CWNS. Because counts of population served by each POTW were reported infrequently, the average population was used for KDE analysis. Future work should continue analysis of changes in Florida's recycled water production spatially, by product, and longitudinally through time as annual FDEP data are released. Continued monitoring can identify where growth has occurred, providing tangible information on the success of new regulations and programs relevant to recycled water production.

5. Conclusion

Spatial examination of Florida's recycled water production based on the five Water Management Districts from 2009 to 2015 indicated an increase in production for Suwanee River WMD and Miami in South Florida WMD and a decrease of production in Southwest Florida WMD. Water reuse is not balanced between each WMD even after accounting for the uneven spatial distribution of service areas and populations. KDE indicated most growth occurred in Orlando, and growth is predominantly in urban areas, with the exception of Miami. In Miami, increased production of recycled water has not kept pace with population growth.

Recycled water use is a valuable tool for water conservation, especially in water-stressed states and coastal communities with saltwater intrusion or surface water quality problems. Recycled water production has been on the rise in Florida for decades, and Florida has led the US in water reuse since 2006. As such, recycled water programs, policy, and production may be used as a model to integrate recycled water into municipal water systems in other locations.

Conflict of interest

The authors declare there is no conflict of interest.

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