JUNE 28, 2019

FLORIDA STATEWIDE AGRICULTURAL IRRIGATION DEMAND ESTIMATED AGRICULTURAL WATER DEMAND, 2017 - 2040

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List of Acronyms

AFSIRS	Agricultural Field Scale Irrigation Requirements Simulation
ALG	Agricultural Lands Geodatabase
AWS	Actual Water Savings
CDL	Cropland Data Layer
CFWI	Central Florida Water Initiative
CUP	Consumptive Use Permit
DOC	Department of Citrus
DPI	Division of Plant Industry
ET	Evapotranspiration
EWUR	Estimated Water Use Report
FAPRI	Food and Agricultural Policy Research Institute
FDACS	Florida Department of Agriculture and Consumer Services
FDOR	Florida Department of Revenue
FLUCCS	Florida Land Use/Land Cover and Forms Classification System
FRIS	Farm and Ranch Irrigation Survey
GIS	Geographic Information System
GOES	Geostationary Operational Environmental Satellites
GPD	Gallons per Day
ILG	Irrigated Lands Geodatabase
INYR	Inches/Year
LKB	Lower Kissimmee Basin
LWC	Lower West Coast
MGD	Millions of Gallons per Day
MIL	Mobile Irrigation Labs
NAIP	National Agricultural Imagery Program
NASS	National Agricultural Statistics Service
NRSP	North Ranch Sector Plan
NWFWMD	Northwest Florida Water Management District
SFWMD	South Florida Water Management Districts
SJRWMD	St. Johns River Water Management District
SRWMD	Suwannee River Water Management District
SWFWMD	Southwest Florida Water Management District
UEC	Upper East Coast
UKB	Upper Kissimmee Basin
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WMD	Water Management District
WUP	Water Use Permit

Executive Summary

The Florida Department of Agriculture and Consumer Services (FDACS) is charged with developing estimates of statewide agricultural water demand[1]. The process is described as the Florida Statewide Agricultural Irrigation Demand project, or FSAID. The 2019 report is the sixth, annual update of FSAID water use estimates.

Water use for agriculture will continue to be an important factor in water supply planning in Florida. The objective of the FSAID planning process is to identify potential future agricultural water demands to inform planning at the statewide and regional level. Projected acreage and water use are estimated in five-year increments to cover the period 2020-2040. The estimates have been provided to the Water Management Districts (WMDs) for consideration in development of their regional water supply plans. The spatial data that provides the field-level acreage and water demand estimates for irrigation, livestock/aquaculture, freeze protection, and conservation have been provided in a geodatabase and have also been made available through a web-based interface.

Agricultural water use has intensified – as a share of total agricultural lands – nationally over the past three decades, while total agricultural land has contracted. The effects of citrus greening, the housing boom then bust, competition from Brazil, and drought conditions in the western U.S. have influenced the decisions of Florida farmers. At the same time, improved efficiencies in irrigation technology and management practices have slowed the rate of agricultural water use increase. The net effects of these factors are reflected in actual water use records. For the 2019 FSAID update, more than 60,000 water use records throughout the state were used to estimate the effects of location, irrigation equipment, crop choice (including multi-cropping where applicable), crop prices, and climate conditions on irrigation volumes. This year, a subset time series of about 12,000 records for farms with water use data for every year from 2007 – 2017 was used to test the sensitivity of price and other variables to improve the model.

Long-term projections of future crop prices prepared by the USDA (United States Department of Agriculture), the Florida Department of Citrus, and internally-produced forecasts were then applied to average climate conditions to simulate farmers' response to future market conditions, including expanding or reducing irrigated acreage and/or shifting future crop mix. New data from the five-year Agriculture Census produced by USDA's NASS[2] was integrated, and generally found to support previously projected trends for irrigated land area by county. The follow tables summarize the current and projected average-year agricultural water demands.

[1] Florida Statute 570.93. Department of Agriculture and Consumer Services; agricultural water conservation and agricultural water supply planning.

[2] USDA National Agricultural Statistics Service Information produces Census reports every five years providing acreage data by county

Table ES-1 summarizes the FSAID VI updated agricultural and irrigated agricultural areas.

Table ES- 1. Florida Agricultural Acreage in Production, by District

WMD	Agricultural Lands 2017	Irrigated Crop Land 2017
	Acres	Acres
NWFWMD	645,631	52,930
SFWMD	2,823,576	1,127,853
SJRWMD	1,089,587	168,822
SRWMD	776,272	136,625
SWFWMD	1,769,153	391,629
Total	**7,104,219**	**1,877,858**

Through 2040, irrigated acreage is forecast to increase by about 26,000 acres, or 1%. The associated average-year water use is projected to increase overall by about 3%, with varying impacts on individual WMDs. South Florida Water Management District (SFWMD), St. Johns River Water Management District (SJRWMD) and Southwest Florida Water Management District (SWFWMD) are forecast to see slight declines in irrigated areas, while the northernmost Districts are expected to see increases in the share of land that is irrigated.

The current total agricultural irrigation water use statewide is estimated at 1,974 MGD for an average year and 2,675 for a 1-in-10 dry year. **Table ES-2** provides a breakdown by District of total crop irrigation use. **Table ES-3** provides estimated water use for livestock and aquaculture.

Table ES- 2. Estimated Irrigated Cropland Water Use

WMD	2017	2017	2017
	Acres	MGD	Inches/Year
NWFWMD	52,930	42	10.7
SFWMD	1,127,853	1,243	14.8
SJRWMD	168,822	190	15.1
SRWMD	136,625	125	12.3
SWFWMD	391,629	374	12.8
Total	**1,877,858**	**1,974**	**14.1**

Table ES- 3. Estimated Livestock/Aquaculture Water Use (2017)

WMD	Livestock water use (MGD)	Aquaculture water use (MGD)
NWFWMD	2.0	4.6
SFWMD	12.2	2.4
SJRWMD	4.5	1.7
SRWMD	9.8	0.4
SWFWMD	10.1	6.2
Total	**38.7**	**15.3**

Table ES-4 shows projected water use estimates by crop, while **Table ES-5** summarizes District level irrigated acreage projections from 2017 to 2040. By 2040, total average-year agricultural irrigation water demand is estimated at 2,036 MGD.

Table ES- 4. Irrigation Demand, MGD by Crop, 2017-2040

Statewide	2017	2020	2025	2030	2035	2040	
Predominant Crop	Avg MGD	Avg MGD	Avg MGD	Avg MGD	Avg MGD	Avg MGD	Dry MGD
Citrus	464	459	464	470	474	475	701
Field Crops	111	110	108	107	106	104	137
Fruit (Non-citrus)	69	67	67	68	68	68	89
Greenhouse/Nursery	156	157	160	154	158	164	183
Hay	112	121	123	124	122	123	174
Potatoes	36	36	36	37	37	37	54
Sod	50	49	49	52	52	52	63
Sugarcane	654	654	635	633	633	632	872
Vegetables (Fresh Market)	322	320	331	344	362	381	485
Total	**1,974**	**1,973**	**1,974**	**1,988**	**2,013**	**2,036**	**2,759**

Table ES- 5. Projected Irrigated Acreage by Water Management District, 2017-2040

WMD	2017	2020	2025	2030	2035	2040	2017 - 2040	2017 - 2040
	Acres	Acres	Acres	Acres	Acres	Acres	Difference	% Difference
NWFWMD	52,930	54,199	55,831	57,714	59,594	61,653	8,723	16%
SFWMD	1,127,853	1,123,474	1,105,419	1,101,253	1,101,911	1,102,038	(25,815)	-2%
SJRWMD	168,822	168,534	166,751	165,576	164,304	162,940	(5,881)	-3%
SRWMD	136,625	144,059	155,811	168,058	180,004	191,817	55,192	40%
SWFWMD	391,629	390,653	389,847	387,963	386,400	385,321	(6,309)	-2%
Total	**1,877,858**	**1,880,919**	**1,873,659**	**1,880,564**	**1,892,213**	**1,903,769**	**25,911**	**1%**

Historical records indicate that Florida farmers have improved efficiency on average about 1% per year, overall. A long-term record of producer-reported acreage and water use was used to develop trends to project future irrigation conservation[3]. **Table ES-6** provides the future conservation results, which project irrigation efficiency improvements of about 7% of the total irrigation demand by 2040. Detailed information on conservation methods and data sources are provided in **Appendix E**.

[3] USDA Farm and Ranch Irrigation Survey, Florida data

Table ES- 6. Estimated Efficiency Improvements by Water Management District, MGD

WMD	2020	2025	2030	2035	2040
NWFWMD	1.52	2.73	3.84	4.89	5.96
SFWMD	21.00	36.13	50.03	60.49	68.83
SJRWMD	5.51	9.65	13.75	17.58	21.17
SRWMD	5.23	10.06	15.63	21.66	27.60
SWFWMD	4.89	9.61	14.25	18.58	22.90
Total	**38.15**	**68.19**	**97.51**	**123.21**	**146.48**
**Amounts are cumulative over time; i.e. 68.19 from 2025 is included in 97.51 in 2030*					

The FSAID model incorporates both agronomic and economic factors that affect irrigation water demand. The model's ability to capture the variation in water use by profitability across crops and within crops over time provides an enhanced estimate of future irrigation demands. Potential sources of error in the FSAID model include changes in the share of land that is irrigated over time; gradual shifts to more intensive irrigation are captured, but if more dramatic shifts occurred, the forecast will be underestimated.

The Farm Bill passed in 2018 introduced commercial hemp production, but only after the Secretary of the USDA approves each State's plan for regulation. The Farm Bill was not considered particularly helpful to Florida producers; while funding for research into citrus greening and water quality issues was secured, import protection for Florida's crops was not, and Florida's fresh produce farmers face hurdles in coming years. A significant factor in the 2019 update is the potential for widely varying alternative scenarios in both future citrus production, and future agricultural production in areas affected by Hurricane Michael. Significant areas of timber and other crop area were devastated by the storm, and there is the possibility that these lands will convert to non-agriculture uses or irrigated production. The potential long-term impacts of Hurricane Michael and the possible impacts from hemp cultivation are discussed in detail in **Appendix E**.

A number of factors present uncertainty in future projections for Florida agricultural irrigation demand. Citrus and sugar are both large water users and are also currently more susceptible than other crops to non-price impacts, such as tariffs, trade relations, energy prices, food safety laws and environmental regulations relating to water quality. For current water use and for projections, citrus and sugarcane represent the greatest irrigation demand; dramatic shifts in either market would impact water use. Agriculture, especially citrus and sugar operations, has high fixed costs which means that shocks to the system affect profits long before they affect acreage and water use.

At the same time, it is important to note that a series of freezes essentially ended citrus farming in Central Florida during the late 1980s and early 1990s; yet overall irrigated acreage saw greater net impact from the housing boom in the late 2000s. Some portion of producer response to systemic shocks are embedded in the underlying model; the dataset incorporates housing boom and bust years, wild swings in energy prices, rapid spread of citrus greening, and two years of major natural disasters which affected agriculture. The heavy investments in capital and labor arrangements inject an inherent lag to changes in agricultural practices, which is likely to be evident within water use as well.

Additional model testing using time series permit-level water use data was completed for FSAID VI. This analysis reinforced the strength of the model in accurately estimating producer responses to weather conditions, pricing, and crop/irrigation choices. The underlying spatial datasets of FSAID – the total agricultural lands and the irrigated agricultural lands – are being increasingly used in Best Management Practice enrollment and tracking, land use updates, storm impact assessments, and other applications beyond their role in water supply planning. Future efforts in refining these spatial data will be critical in supporting these applications and in continuing to refine and update the estimates of future agricultural water demand.

Introduction

The Florida Department of Agriculture and Consumer Services (FDACS) is charged with developing estimates of statewide agricultural water demand[4]. The process is described as the Florida Statewide Agricultural Irrigation Demand project, or FSAID; this report is the sixth annual update of FSAID water use estimates prepared by FDACS. The current and projected agricultural water use estimates incorporate an additional year of metered data for all Water Management Districts (Districts) and have utilized updated spatial data to improve the irrigated lands coverage.

The current baseline acreage and water use estimates are for the year 2017, which is the most recent year of available water use data provided by the Districts. This report includes estimates of irrigated agricultural areas and water demands for 2017 and projections for 2020 – 2040, in five-year increments. The estimates herein are provided to the Districts for their review and comment and ultimately for consideration in development of their respective water supply plans.

This report describes the agricultural land acreage estimates and methodology, followed by the water use estimates and methodology. The approach and results for conservation projections, frost-freeze protection estimates, and livestock and aquaculture water demand estimates are provided also.

This is the sixth iteration of the FSAID agricultural water demand projections, and can be referenced as FSAID VI (FDACS 2019). Previous FSAID reports or datasets can be referenced similarly (i.e. FSAID III; FDACS 2016).

Methodology and Agricultural Land Acreage Estimates

Two spatial datasets of Florida's agricultural lands were created for the FSAID project. The Agricultural Lands Geodatabase (ALG) includes all agricultural land, while the Irrigated Lands Geodatabase (ILG) includes only irrigated agricultural land, as well as the estimated current and projected water use for each field.

A. ALG: Development and Update of the Agricultural Lands Geodatabase

The original FSAID ALG was developed in 2014 using the following primary spatial data sources: Florida Statewide Land Use/Land Cover from the Water Management Districts and FDEP, Consumptive Use Permit (CUP) polygons from the WMDs, well locations, USDA's Cropland Data Layer (CDL) data, USDA's National Agricultural Imagery Program (NAIP) aerial imagery, and Irrigated Areas layers from SJRWMD and SWFWMD. Substantial spatial data processing was completed to develop Florida's ALG and ILG in order to model current and projected agricultural water demands. The annual refinement to the ALG is based on stakeholder input, FDACS field staff reviews, FDACS BMP enrollment data, USGS field-verification data, updated land use data prepared by Water Management Districts and FDEP, Department of Revenue (DOR) property appraisal data (parcel data), the CDL, and recent aerial imagery.

[4] Florida Statute 570.93. Department of Agriculture and Consumer Services; agricultural water conservation and agricultural water supply planning.

New Agricultural Areas

FDACS' Best Management Practices (BMP) enrollment parcels were used primarily to identify new agricultural areas not in the ALG and to review crop classifications. This was done by reviewing enrollment parcels based on how many ALG features were within a parcel. Reviews were done in descending order for the largest parcels with the least ALG features. Additionally, parcels labeled as Horse Farms were also reviewed. Aerial imagery and the CDL and WUPs were used as supporting data sources to evaluate crop type and field boundary edits. This process resulted in about 40k acres of agricultural areas added to the ALG, these additions can largely be attributed to dataset improvements informed by the BMP enrollment parcels.

Updates to the non-irrigated portions of the ALG also included a bulk process to identify new agricultural areas not in the existing ALG (or previous ALG versions) by using DEP's statewide land use (April 2019 version). This was done using agricultural crop types in the statewide land use and removing the portions of those features that overlapped with the ALG. Any of these candidate "new ag" features that were in a previous ALG version but were removed from the ALG in previous FSAID processes were not brought into the FSAID VI ALG. About 140k acres of area (classified as agricultural by Statewide LU) not in the ALG, were manually reviewed to determine which areas should be brought into the ALG. About 42k acres of the area reviewed were identified as not agricultural (these were typically residential areas or water storage projects or phosphate mining areas). In summary, this process to identify additional agricultural areas resulted in about 200k acres being added to the ALG, with the biggest acreage increases (non-irrigated areas) in NWFWMD, SJRWMD, and SRWMD. Some of this acreage is newly converted to agriculture and some of it was previously agriculture but not identified as such in older versions of statewide land use datasets.

Cropland Data Layer Crop Classification

A bulk processing step was developed to rename ALG crop types having generic crop names (originally from statewide land use descriptions) by using detailed crop types from the USDA Cropland Data Layer (CDL) from 2017. The following ALG crop names were included in the process to rename crops using the CDL: Cropland_Pastureland, FieldCrops, Grains, and RowCrops. Zonal calculations were completed to find the dominant (most common) CDL crop within each ALG feature. The ratio of CDL dominant crop to total ALG area of each feature was used in conjunction with the type of CDL dominant crop to decide when it was appropriate to utilize CDL crop types. Samples (n=100 in each of the five Water Management Districts) were reviewed manually using current imagery to develop decision rules for when the CDL crop type could be reliably used. Dominant CDL crop types from the following list were utilized for updating ALG crop types to ensure that uncommon or unusual CDL crops were not used for ALG crop classification: Corn, Cotton, Dry Beans, Grassland/Pasture, Oats, Peanuts, Rye, Sorghum, Soybeans. If the ratio of dominant CDL crop area to ALG feature area was 0.4 or greater (based on detailed review of 500 example fields), and the CDL crop type was one of the nine types listed above, and the ALG crop was one of the four types listed above, then the CDL crop was used. This process resulted in 6,771 features (302,872 acres) having a revised crop type using the 2017 CDL crops.

B. ILG: Development and Update of the 2017 Irrigated Lands Geodatabase

The Irrigated Lands Geodatabase was updated to 2017 conditions based on manual review and evaluation using 2017/2018 aerial imagery, new or modified Water Use Permits (WUPs), 2017 Cropland Data Layer from USDA (CDL), FDACS Division of Plant Industry (DPI) citrus layer, USGS field verification, FDACs field staff input, water use data, and District-provided spatial data on irrigated area changes. All these datasets were used to target manual review of ILG features compared to aerial imagery and ancillary datasets. Updates were made to field geometry, crop type, irrigation system, and irrigation status (fallow or irrigated).

DATA SOURCE	DESCRIPTION
Water Use Permits (WUP; recent new and revised were reviewed)	WUPs typically provide information on crop type and irrigation system; any new or modified WUPs from 2017 or more recent were manually reviewed.
USDA Cropland Data Layer (CDL; 2017)	The CDL is a gridded dataset (30 meter resolution) that classifies crop type based on satellite data and groundtruth data from the Farm Service Agency (FSA) field reports at the Common Land Unit (CLU) scale. It is updated annually based on satellite data collected from April to September.
U.S. Geological Survey irrigated areas field verification (USGS; 2015-2019)	U.S. Geological Survey (USGS), under contract to FDACS, performed field work to verify irrigated areas in the following counties: Charlotte, DeSoto, Hardee, Hillsborough, Lee, Manatee, Sarasota
FDACS Division of Plant Industry (DPI) active citrus layer; 2018	Statewide dataset of citrus areas, with attributes indicating survey date and classification that describes active production or abandonment; most survey dates are 2015 or older.
SWFWMD water use data; 2017 annual water use totals	Adjusted irrigated coverage based on District water use data for permits with 0 or low (< 5in/yr) water use.

Updates to the ILG were reviewed with personnel at each District. Draft ILG shapefiles were provided to each District during January 2019, and meetings with the FSAID team staff in each District were conducted to collaborate on spatial data improvements. In some Districts, staff provided marked-up maps for recommended changes. In other Districts, comments were provided via email and were researched as part of continued ILG updates. In all cases, input was acknowledged and addressed.

Field verification was completed by USGS in 2018 in Charlotte, DeSoto, Hardee, Hillsborough, Lee, Manatee, and Sarasota Counties. This entailed field surveys from public roads to identify irrigation status, irrigation system, and crop type. The USGS spatial data were reviewed manually to edit the ILG where irrigated features in the ILG were missing or should be changed to not irrigated, where crop types were different, or where boundary adjustments were needed. Current aerial imagery was used as supporting data. This process resulted in a net change of about 11,000 acres being removed from the ILG in those counties (most of which remains in the ALG as fallow cropland), with the biggest irrigated acreage drops in Hillsborough and Hardee Counties. Most of the declines in irrigated area were converted to fallow agricultural land; conversion to development among irrigated areas was observed, but this was not common.

FDACS' Division of Plant Industry (DPI) citrus dataset was used to review irrigated citrus features in the ILG. This was done using a select by location of irrigated citrus from the ILG that contained or was within inactive citrus according to the DPI citrus layer. This resulted in more than 100 features that were manually reviewed using aerial imagery, the CDL, and WUPs to determine if the ALG or ILG needed boundary edits, crop changes or irrigation status changes. Approximately 65% of the reviewed features either had no changes or only needed boundary edits, while the remaining 35% were changed to not irrigated or a to a crop other than citrus.

In SWFWMD, ILG areas with 0 or small (< 5 in/yr) 2017 permit-level water use were reviewed to evaluate irrigation status and field boundaries. 2017 and 2018 aerial imagery were used in this analysis, which resulted in several thousand acres in the ILG being removed (these remain in the ALG as fallow production unless a land use change was observed).

Table 1 provides a summary of the total acreage in the current ILG and ALG. **Table 2** provides a breakdown by crop of acreage at the statewide level. **Appendix C** provides detailed tables by Water Management District and county, with estimates for split District counties available in **Table C- 28**.

Table 1. Summary of ALG and ILG for 2017 baseline

WMD	ALG fields	ALG area	ILG fields	ILG area
	Parcels	Acres	Parcels	Acres
NWFWMD	26,830	645,631	946	52,930
SFWMD	26,779	2,823,576	7,287	1,127,853
SJRWMD	28,906	1,089,587	5,213	168,822
SRWMD	25,217	776,272	2,099	136,625
SWFWMD	33,791	1,769,153	10,630	391,629
Total FSAID IV	**141,523**	**7,104,219**	**26,175**	**1,877,858**

Table 2. 2017 Florida Irrigated Cropland Acreage by Primary Crop

Primary Crop	2017 Acres	Share of total
Citrus	550,992	29%
Field Crops	157,313	8%
Fruit (Non-citrus)	32,152	2%
Greenhouse/Nursery	61,917	3%
Hay	161,093	9%
Potatoes	31,737	2%
Sod	54,658	3%
Sugarcane	584,943	31%
Vegetables (Fresh Market)	243,053	13%
Total	**1,877,858**	**100%**

C. Projections of Future Irrigated Areas

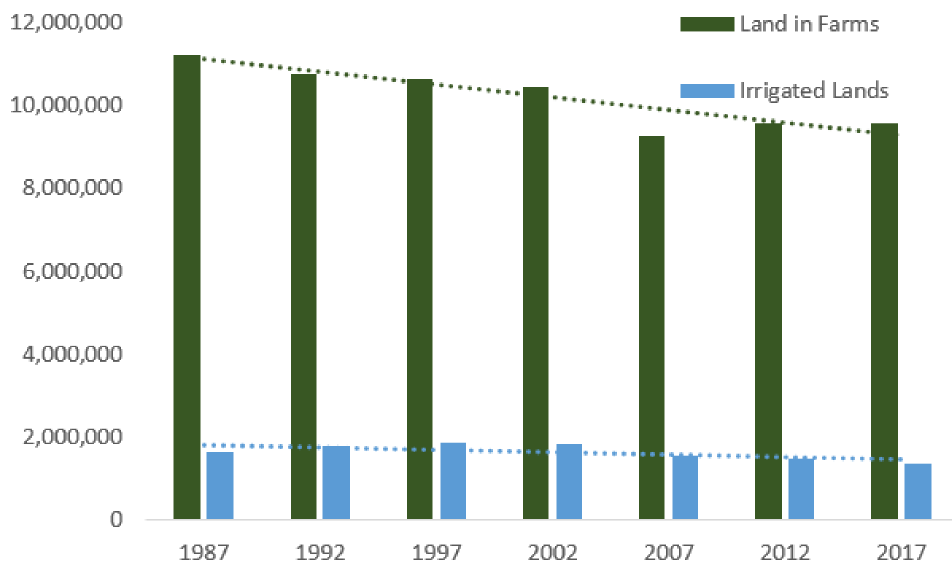
The following sections describe how increases or decrease in irrigated area in Florida counties are estimated and spatially distributed.

Trend Analysis from USDA Census Data

Long-term projections of irrigated agricultural lands were developed using historical, survey-based, county totals of irrigated and agricultural lands for each Florida county. The USDA National Agricultural Statistics Service (NASS) reports total agricultural land and irrigated land every five years and is the longest consistent data stream available. [5] These data come from Florida producers responding to USDA's Census of Agriculture. The most recent update, the 2017 Ag Census data, was released on April 11, 2019. NASS data was used to develop trend analysis for each county from 1987-2017; **Appendix A** provides graphs of historical and projected irrigated acreage for each of Florida's 67 counties.

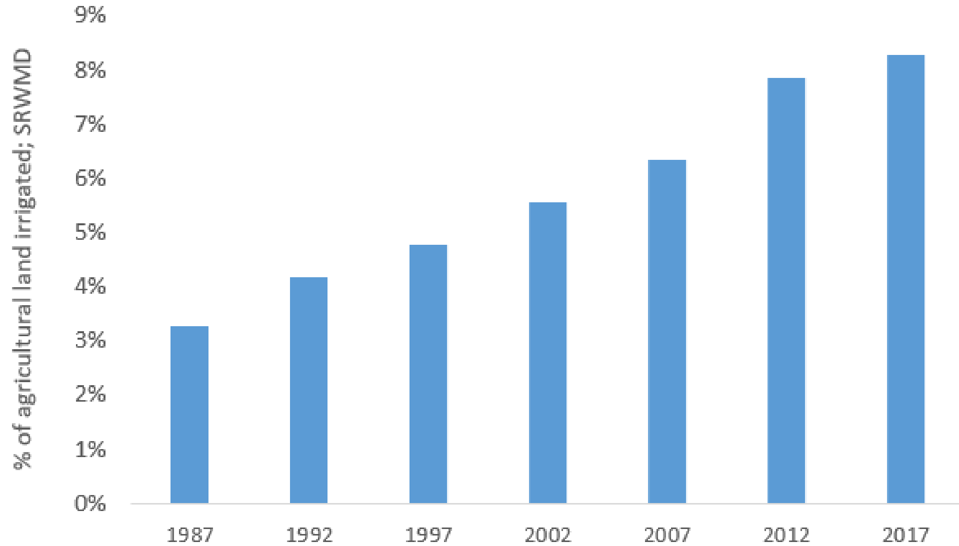
Total irrigated land for each county was used to build a ratio of irrigated area to agricultural area. Consistent with national trends, urbanization continues to displace agricultural land in Florida. However, a higher proportion of remaining agricultural lands become irrigated, as the long-term trends in USDA Ag Census data show (**Figure 1**). The share of agricultural land in SRWMD more than doubled in the Ag Census period from 1987-2017 (**Figure 2**).

Figure 1. Statewide Agricultural and Irrigated Land, acres - Florida



[5] NASS data is available for 1982, but a significant change in how the data was reported in 1987 renders intertemporal comparisons not meaningful. Hence 1987 was used as the earliest year for trend analysis.

Figure 2. SRWMD Trend in % irrigated land 1987-2017



An autoregressive procedure was used to forecast county-specific trends in irrigated share based on statistical fit. The trend in total agricultural land was projected to 2040 for each county, and the projected change in share of agricultural land that is irrigated was used to forecast irrigated land. The functional form of each regression was selected based on best-fit criteria from logarithmic, linear, exponential, and power forms. In some counties, trend type was selected manually based on stakeholder input or reasonableness of projected future acreage. The impact on projected county-level irrigated area changes between FSAID V and FSAID VI, as a result of including the 2017 Ag Census data, can be seen in **Appendix E**.

Spatial Distribution of Projected Irrigated Area Changes

These county-level additions or declines in irrigated area were spatially distributed in the projections ILG using numerous decision rules for selecting ALG fields to become irrigated or ILG fields to become not irrigated. In counties with projected increases in irrigated acreage, R routines were used to select non-irrigated ALG fields to become irrigated until sufficient acreage is added in each projection period. The following conditions were used to constrain irrigated area additions, meaning if an ALG field was any of the following, it would not be a candidate for irrigation in a future period:

- Overlaps Florida Natural Areas Inventory (FNAI)
- NRCS Land Capability Classification > 5 (indicates lower quality soils)
- Inside SWFWMD's Most Impacted Area (MIA)
- Overlaps a SFWMD planned surface water project.

Areas added to the ILG were prioritized based on having a WUP currently and being near roads. This means that the routine for ALG fields becoming irrigated, first looks at ALG fields overlapping an existing WUP for agricultural use, then looks at ALG fields with a distance to roadways less than half the county-average distance of ALG fields to roads, then looks at unpermitted ALG fields with above-average distance to roads. Acreage increases in Osceola County were adjusted manually to account for the additional irrigated acres specified in the North Ranch Sector Plan.

For decreasing irrigated areas, the selection routines prioritize irrigated areas within urban boundaries. Also, in counties with a projected decrease in irrigated area, those decreases were required to occur in non-EAA regions, as the EAA is assumed to remain stable. However, a substantial exception to this occurs in Palm Beach County, with approximately 17k acres removed from the ILG in 2025 to accommodate the A-2 reservoir. Irrigated area reductions were limited in Palm Beach County due to insufficient non-EAA area. Also, the projections were adjusted to reflect land use change regulations in Palm Beach County's Ag Reserve area, in which 60% of all agricultural area is zoned to be maintained. This constrained the acreage decline in Palm Beach County to be less than that predicted from the trend based on the historical Ag Census data.

Projected agricultural acreage and irrigated acreage through 2040 by county are provided in **Table A-1** in the **Appendix A**. **Figure 3** illustrates the changes in irrigated areas from 2017 to 2040 by county; the majority of counties with large increases in irrigated area are in the northern portion of the state. Resulting acreage projections by District are provided in **Table 3** and projections statewide by crop are in **Table 4.**

Figure 3. County level projections of change in irrigated area; 2040 minus 2017 acreage

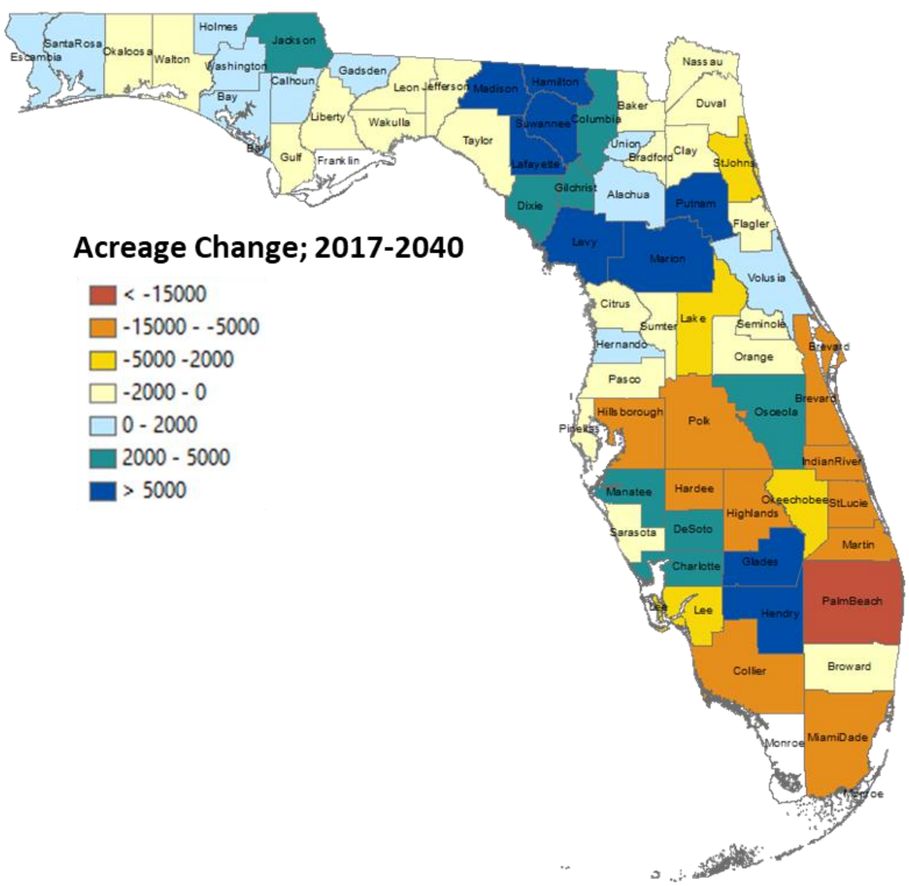


Table 3. Projected Irrigated Acreage by District

WMD	2017	2020	2025	2030	2035	2040	2017 - 2040	2017 - 2040
	Acres	Acres	Acres	Acres	Acres	Acres	Difference	% Difference
NWFWMD	52,930	54,199	55,831	57,714	59,594	61,653	8,723	16%
SFWMD	1,127,853	1,123,474	1,105,419	1,101,253	1,101,911	1,102,038	(25,815)	-2%
SJRWMD	168,822	168,534	166,751	165,576	164,304	162,940	(5,881)	-3%
SRWMD	136,625	144,059	155,811	168,058	180,004	191,817	55,192	40%
SWFWMD	391,629	390,653	389,847	387,963	386,400	385,321	(6,309)	-2%
Total	**1,877,858**	**1,880,919**	**1,873,659**	**1,880,564**	**1,892,213**	**1,903,769**	**25,911**	**1%**

Table 4. Projected Irrigated Acreage by Crop

WMD	2017	2020	2025	2030	2035	2040	2017 - 2040	2017 - 2040
	Acres	Acres	Acres	Acres	Acres	Acres	Difference	% Difference
Citrus	550,992	547,450	546,816	546,514	544,854	541,739	(9,253)	-2%
Field Crops	157,313	156,810	156,329	155,964	155,701	154,962	(2,351)	-1%
Fruit (Non-citrus)	32,152	31,419	31,229	31,370	31,494	31,790	(362)	-1%
Greenhouse/ Nursery	61,917	62,801	64,195	62,102	64,254	66,941	5,024	8%
Hay	161,093	170,860	174,448	175,259	174,213	175,269	14,176	9%
Potatoes	31,737	31,595	31,591	31,712	31,885	31,530	(208)	-1%
Sod	54,658	54,344	54,256	56,372	56,510	56,144	1,486	3%
Sugarcane	584,943	585,027	567,190	565,924	565,582	565,289	(19,654)	-3%
Vegetables (Fresh Market)	243,053	240,612	247,604	255,346	267,720	280,104	37,052	15%
Total	**1,877,858**	**1,880,919**	**1,873,659**	**1,880,564**	**1,892,213**	**1,903,769**	**25,911**	**1%**

D. Estimated Water Use

As required by Florida Statute, observations of irrigation water use form the basis for the FSAID estimates of spatially distributed statewide irrigation demand. Metered and reported water use data is collected each year from the Water Management Districts. Historical metered/reported data extends from 2007 to 2017, and these data were used to develop an analytical model to estimate irrigation water demand. The model specification is estimated using Ordinary Least Squares regression analysis to generate coefficients from the actual water use for each field-level variable. Variables include agronomic variables (crop choice, location, climate), engineering or physical factors (irrigation equipment, field size) and economic or behavioral factors (crop prices); the dependent variable is actual water use, derived from metered or reported pumpage data (hereafter, "metered data"). The model was initially developed based on published literature reflecting national trends in agricultural irrigation, and has been refined each year based on feedback from Districts, producers and academics[6]. In the FSAID VI model, approximately 60,000 field observations (from 2007-2017) were included in the dataset used to generate model coefficients. The R^2 or statistical "fit" of the model output to actual data is 0.77.

Appendix E provides further detail on the model inputs, model performance, a detailed example of the model and discussion of specific elements of the model including price, costs and soils data.

i. Metered Data Records

The existing dataset of metered data records across Districts includes 11 years of permit-level water use from years 2007-2017. Considerable effort and coordination by the Water Management Districts allowed for data from all years in the period to be obtained. In previous iterations from FSAID, there were inconsistencies in sample size by District in some years before 2013. Beginning with FSAID VI, complete data including all years from 2007-2017 were utilized for model improvement. Input data was thoroughly evaluated for outliers, infeasible estimates based on irrigated area, and statistical heterogeneity. Multiple thresholds for inclusion in the dataset were tested including multiple standard deviations from the mean by crop by District; numerous percentile-based thresholds by crop and by District; and hard upper bounds (e.g.; 100 inches/year).

Repeated statistical testing determined that the 25th and 90th percentile thresholds performed best and had values most representative of typical irrigation practice, and these thresholds were used to cull data for input to the water demand model.

Table 5 provides a summary by crop of metered data records; this includes field-level observations for each year from 2007-2017. Therefore, the total acreage of metered data in the input dataset greatly exceeds the current ILG, which represents only current, baseline irrigated area. **Appendix E** provides additional detail on screening of input data and distribution by District.

Table 5. Metered Data Records Summary by Crop

Primary Crop	Acres	Sample size, n
Citrus	2,327,677	22,316
Field Crops	280,905	3,213
Fruit (Non-citrus)	76,236	4,816
Greenhouse/Nursery	97,401	8,180
Hay	459,497	2,450
Potatoes	133,330	1,710
Sod	196,623	1,927
Sugarcane	638,374	2,286
Vegetables (Fresh Market)	834,025	13,637
Total	**5,044,069**	**60,535**

For context, **Table 6** provides statewide average inches/year by crop as calculated by the Agricultural Field Scale Irrigation Requirements Simulation Model (AFSIRS) for FSAID I, metered data for the previous

[6] See de Bodisco, C. (2007); Livanis, G., et al (2006); Moss, C. (1998); Schoengold, K., et al (2006); Chalfant, James A. (1984); Edwards, B. et al (1996).

FSAID V, and the current FSAID VI (metered) dataset. The updated model input dataset is within 1% of the prior year's estimate of 13.6 inches /year.

Table 6. Statewide Average inches /year by Crop

Primary Crop	FSAID I AFSIRS results	FSAID V Metered or Reported Usage Input	FSAID VI Metered or Reported Usage Input
Citrus	14.4	11.3	12.0
Field Crops	10.2	10.3	9.4
Fruit (Non-citrus)	16.6	27.6	27.2
Greenhouse/Nursery	48.6	29.9	29.8
Hay	15.1	9.9	9.6
Potatoes	12.5	15.5	15.2
Sod	37.5	12.5	12.0
Sugarcane	24.6	18.6	18.0
Vegetables (Fresh Market)	11.9	17.0	16.8
Total	**19.5**	**13.6**	**13.8**

ii. Current Water Use Estimates

The resulting current water use estimates reflect a 1.4% decrease in overall irrigated acreage over the prior year (FSAID V) and a 4.5% decrease in overall water use as measured in Millions of Gallons per Day (MGD) and a 3.2% decrease in overall intensity, as measured in inches/year; see **Table 7**. The decrease is primarily driven by the lower intensity water use reflected in updated metered records.

Current baseline year 2017 irrigation water demand and the projected water demand for periods 2020-2040 were modeled using the average of rainfall and ET from 2005-2017 in order for base year irrigation demands to be representative of typical irrigation demand for consistency with future planning periods; see **Table 7**. During model development, the irrigation demand is modeled using input variables that correspond to each year of metered data (rain, ET, price, crop for 2010 are used on modeling the 2010 water use). The base year estimates for 2017 modeled with 2017 rain and ET are provided in the ILG spatial dataset.

Table 7. Estimated Statewide Water Use, 2017

Statewide	2017	2017 avg*	2017 avg*
Crop	**Acres**	**MGD**	**IN/YR**
Citrus	550,992	464	11.3
Field Crops	157,313	111	9.5
Fruit (Non-citrus)	32,152	69	28.7
Greenhouse/Nursery	61,917	156	33.8
Hay	161,093	112	9.4
Potatoes	31,737	36	15.3
Sod	54,658	50	12.3
Sugarcane*	584,943	654	15.0
Vegetables (Fresh Market)	243,053	322	17.8
Total	**1,877,858**	**1,974**	**14.1**

Source: SFWMD and TBG Work Product; *2017 avg. indicates typical irrigation demands on base year acreage, modeled using average rainfall and ET for consistency with planning period estimates; **Everglades Agricultural Area (EAA) area of 451,331 acres is held constant for sugarcane at 478 MGD

E. Projected Water Use Methodology

Projected water use for the time period 2020-2040 was estimated by simulating future conditions using coefficients from the econometric model, and substituting forecast future values for each variable. Since location and climate-related variables are either fixed or long-term averages, the simulation is driven mainly by price forecasts and future land area, which are discussed in turn. A one-page summary of the estimates process has been provided for use by the Districts in **Appendix E.**

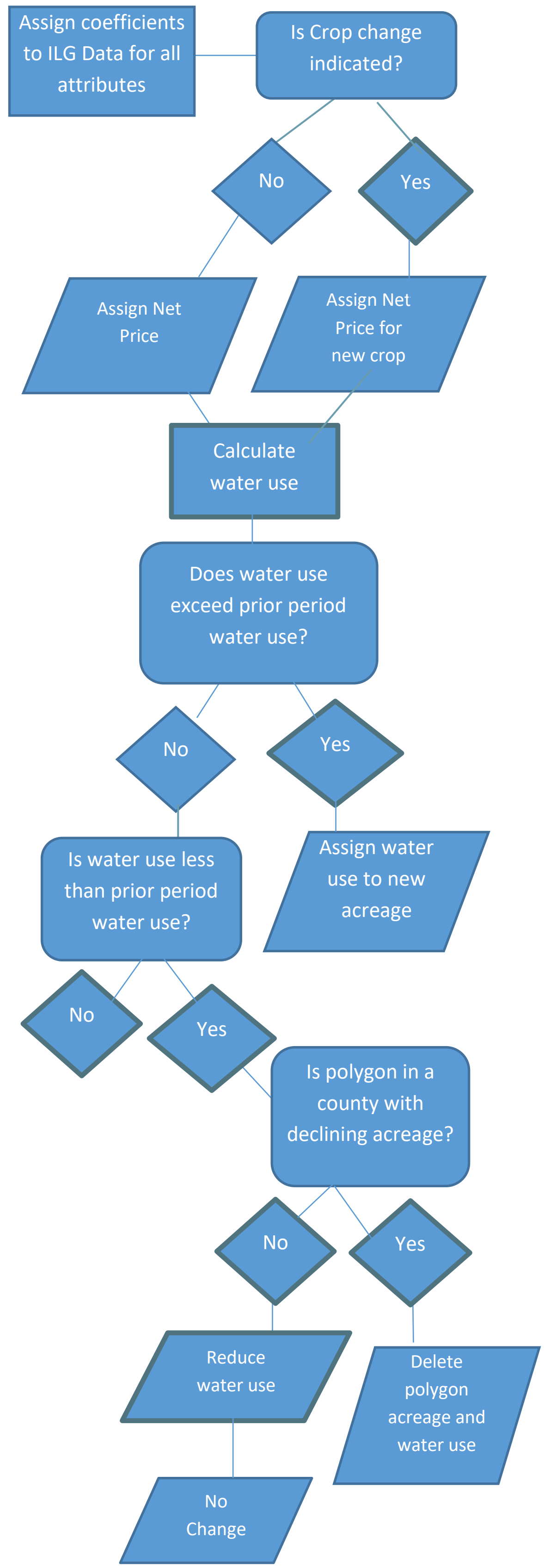
The following steps describe the process for field-scale future water demand calculations.

i. Price Simulation

Future water use estimates were simulated by updating each explanatory variable in the model, and using the regression equation to estimate future water use. Each variable was estimated as follows:

1. Prices and costs were forecast for five-year periods from 2020 to 2040 using 10-year crop price forecasts from USDA, Food and Agricultural Policy Research Institute (FAPRI) extended using a crop specific growth trend.
    a. Forecast net revenue can be used to adjust crop mix to maximize farm profit subject to soil and land use constraints. Crop prices are based on crop categories, rather than individual plant types. For example, a producer adding satsumas to existing citrus production would not be considered a change, while a producer adding satsumas to a non-citrus production would be considered a change. Using current forecast trends, several crop mix changes were evaluated and addressed.
    b. Areas with anticipated increases in acreage were previously restricted to non-citrus crop categories unless there were areas in the District currently growing citrus; the restriction was relaxed for the current FSAID methodology. Satsumas are increasing in areas traditionally not identified as citrus areas.
    c. The sod and non-citrus fruit margins invert relative profits between 2020 and 2030; however, the effects are considered geographically specific and no overall crop mix change was incorporated for this situation. The sensitivity analysis section describes the evaluation that was conducted for this potential crop mix change.
    d. The sugarcane net revenue exceeds citrus after 2030 by about $300 per acre. There is a high degree of uncertainty surrounding citrus

Figure 4. Spatial Distribution of Water Use Process



production and intense investments that have already been made in sugarcane harvesting and processing. Many citrus producers have already abandoned land which is returning in some cases as fresh vegetables, which outstrip sugarcane in net revenue per acre. No crop mix change was incorporated for this situation.

2. The irrigated acreage changes were used to identify irrigated acreage for each five-year interval, as described in **Section C: Projections of Future Irrigated and Agricultural Land Area**. The net revenue variable was calculated by applying updated net revenue values to forecasted acreage.
3. ET and rainfall variables were updated by calculating mean historical values for an average year (2005-2017), assigned at the farm level.
4. Estimated coefficients from the regression model were applied to forecast variables to simulate projected water use. The change in total water use was estimated at the field level, and applied to the acreage increase or decrease in each county. For approximately 3% of fields, the calculation resulted in extreme values, which were replaced with the mean inches/acre/year for the indicated crop in the respective District.

ii. Spatial Distribution of Future Water Use

Spatial distribution of water use was applied according to the process outlined in **Figure 4**. Future water use changes that exceed water applied to current acreage were allocated across fields that were added to the ILG in future periods.

In some counties, agricultural acreage was not sufficient to absorb the projected irrigated acreage after the constraints were applied, and if so, the acreage was capped once the available land identified in the ALG was used. Conversely, if a county indicated fewer irrigated acres, the algorithm identified fields to remove from the ILG, with accordant water use. Crops were assigned based on the indicated crop mix from modeling results; i.e. the "excess" water from crops (crops that show higher water use for increased acreage). The predominant irrigation system used in the county for the crop was assigned. Rainfall and ET were assigned in the same manner as the rest of the ILG.

iii. Sensitivity Analysis

A number of model iterations were run to test the sensitivity of various parameters and alternative approaches to measuring variables. The added 2017 metered/reported water use data resulted in inclusion of about 8,000 additional metered data records. Sensitivity analysis was conducted to compare the impacts of truncating outliers through several approaches as detailed in **Appendix E**. A variety of scenarios affecting crop prices, production costs and other market or competitive factors were analyzed and assessed for impacts results, including the effects of Hurricane Michael, citrus pricing and disease pressure, new hemp legislation, and farm bill or other trade impacts (see **Appendix E)**.

Water Use Projection Results

F. Average Year Estimates

The resulting statewide water use estimates for each five-year period are provided in **Table 8** by crop, and **Table 9** by District. The net change in acreage of 25,911 acres over the period through 2040 is accompanied by a net change in irrigation volume of 62 MGD for an average year and 84 MGD for a dry year. The substantial decline in citrus acreage (about 17k acres less irrigated citrus) over the past year lowers overall agricultural acreage and water use.

The effects are unevenly distributed by District, with a 54% increase in irrigation demand expected in Suwannee River Water Management District by 2040 and a 26% Northwest Florida Water Management District (although the latter comprises only 11 MGD). Detailed breakdowns of county-level acreage by crop and District are included in **Appendix C**. **Figure 5** illustrates the total change in irrigation water demand by county from 2017 to 2040. Total statewide demands remain about constant through 2025, as counties with declining irrigated areas are offset by counties with projected increases. However, by 2030 the total demands start to rise as a result of increasingly prevalent high-value crops (more vegetable acres) in counties with projected increases in irrigated areas.

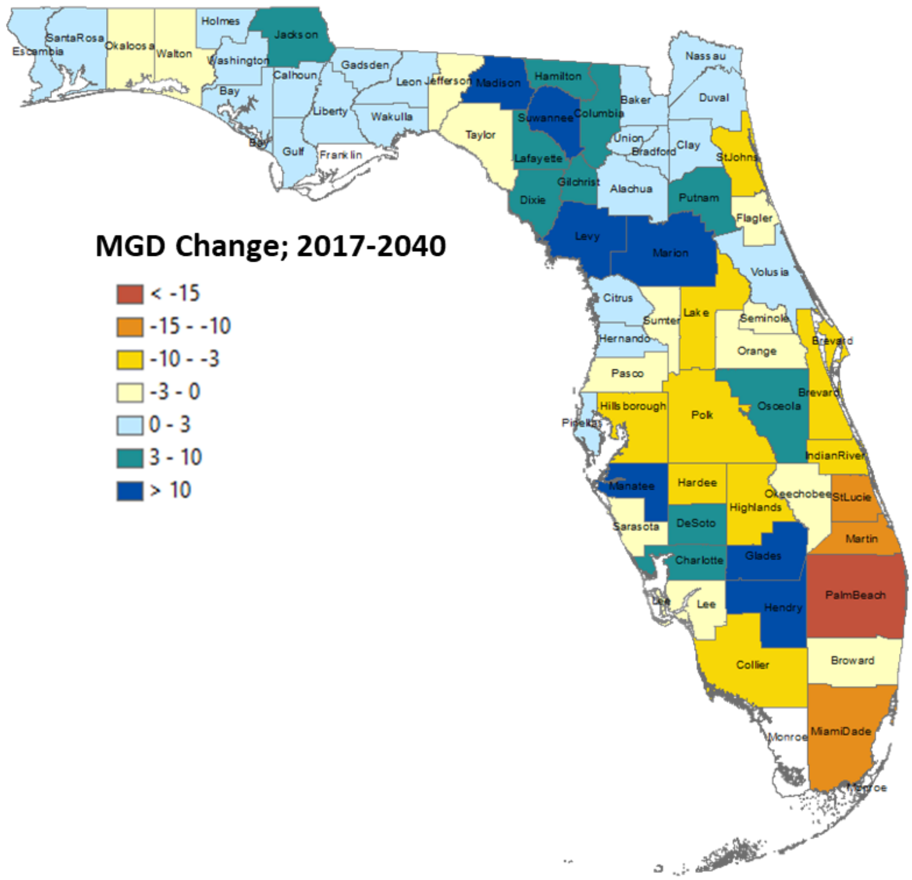
Table 8. Water Use Estimates by Crop Average Year

Statewide	2017	2020	2025	2030	2035	2040
Predominant Crop	**Avg MGD**	**Avg MGD**	**Avg MGD**	**Avg MGD**	**Avg MGD**	**Avg MGD**
Citrus	464	459	464	470	474	475
Field Crops	111	110	108	107	106	104
Fruit (Non-citrus)	69	67	67	68	68	68
Greenhouse/Nursery	156	157	160	154	158	164
Hay	112	121	123	124	122	123
Potatoes	36	36	36	37	37	37
Sod	50	49	49	52	52	52
Sugarcane	654	654	635	633	633	632
Vegetables (Fresh Market)	322	320	331	344	362	381
Total	**1,974**	**1,973**	**1,974**	**1,988**	**2,013**	**2,036**

Table 9. Water Use Estimates by District, Average Year

WMD	2017	2020	2025	2030	2035	2040
	Avg MGD	**Avg MGD**	**Avg MGD**	**Avg MGD**	**Avg MGD**	**Avg MGD**
NWFWMD	42	43	46	48	50	53
SFWMD	1,243	1,234	1,213	1,206	1,207	1,208
SJRWMD	190	191	191	191	192	192
SRWMD	125	132	146	161	177	192
SWFWMD	374	373	378	382	386	391
Total	**1,974**	**1,973**	**1,974**	**1,988**	**2,013**	**2,036**

Figure 5. County level projections of change in irrigation demand; 2040 minus 2017 MGD



G. Dry Year Estimates

Dry year estimates were calculated using crop and District-specific ratios of average irrigation water use to 1-in-10 use. The FSAID dry year estimates represent the irrigation demand that would be expected in 1 out of 10 years. Statewide, the overall average ratio is 1.34, but this varies widely by crop and by District. **Table E- 8** in **Appendix E** provides the ratios by crop and District and **Appendix E** also provides a more detailed description of how the average-to-dry ratios were developed. **Table 10** provides Dry Year Estimates by District, and **Table 11** shows Dry Year Estimates by Crop.

Table 10. Water Use Estimates by District, Dry Year (1-in-10)

WMD	2017	2020	2025	2030	2035	2040
	Dry MGD	Dry MGD	Dry MGD	Dry MGD	Dry MGD	Dry MGD
NWFWMD	58	60	63	66	70	74
SFWMD	1,663	1,653	1,626	1,619	1,621	1,622
SJRWMD	269	270	270	270	270	270
SRWMD	160	170	188	207	227	248
SWFWMD	525	523	529	534	540	545
Total	**2,675**	**2,675**	**2,675**	**2,696**	**2,729**	**2,759**

Table 11. Water Use Estimates by Crop, Dry Year (1-in-10)

Statewide	2017	2020	2025	2030	2035	2040
Predominant Crop	Dry MGD	Dry MGD	Dry MGD	Dry MGD	Dry MGD	Dry MGD
Citrus	686	678	685	694	699	701
Field Crops	146	144	141	140	139	137
Fruit (Non-citrus)	88	86	87	88	89	89
Greenhouse/Nursery	174	176	179	172	177	183
Hay	160	172	175	175	174	174
Potatoes	53	52	53	54	54	54
Sod	61	60	60	63	63	63
Sugarcane	902	902	876	874	873	872
Vegetables (Fresh Market)	407	404	420	436	461	485
Total	**2,675**	**2,675**	**2,675**	**2,696**	**2,729**	**2,759**

H. Frost and Freeze Protection Estimates

Irrigation for freeze protection is used on a variety of cold-sensitive crops in Florida. Freeze protection water volumes are a small percentage of the total statewide demand for normal irrigation (about 5%), but the withdrawals happen over a brief period, meaning that the impacts from these withdrawals can be significant. Freeze protection water use in FSAID is limited to the major crops commonly requiring freeze protection: strawberries, blueberries, peaches, citrus, and ferns. Freeze-related irrigation events were estimated to occur on days with minimum temperature at or below freezing for fields in the ILG where crop type matched one of those listed above.

The USGS gridded Evapotranspiration (ET) data (from GOES platform) from 1996 to 2017 were used for estimating the average number of annual freeze events at ILG fields with a crop type that would be freeze protected. The dataset includes minimum temperature at 2km grid resolution, which was used to count the annual number of freeze events at the locations of ILG fields which would likely be freeze protected. The annual freeze events at ILG locations were then averaged at the county level for the 22-year period. The average number of freeze events for a county was combined with information on crop type and irrigation system to calculate annual average amounts of freeze protection water use. To calculate the amounts of freeze protection water, the following irrigation intensities were used: 0.07 inches/hour for micro-spray irrigated citrus, 0.2 inches/hour for blueberries, strawberries, or peaches, and 0.3 inches/hour for ferns. A 14-hour freeze event duration was used. Frost/freeze water demand for future projections of the ILG varies from the current frost/freeze demands due to the additions or deletions of ILG polygons classified as Non-citrus Fruit (which would include strawberry, blueberries, and peaches) and Citrus. It was assumed that all additional acres of Non-citrus Fruit and Citrus in the ILG projection periods would be irrigated for freeze protection, and the number of annual average freeze events would be the same as in the historical period.

The average annual frost protection demand for the current ILG was 88 MGD on an average annual daily flow (AADF) basis. This increases to 92 MGD by 2040 due to additions of new irrigated areas being projected to have crop types that would be freeze protected. **Table 12** summarizes freeze protection estimates at the District level.

Table 12. Estimated Freeze Protection Estimates by Year

WMD	2017	2020	2025	2030	2035	2040
	MGD	MGD	MGD	MGD	MGD	MGD
NWFWMD	0.07	0.10	0.16	0.20	0.24	0.54
SFWMD	19.03	19.06	19.54	20.01	20.33	20.51
SJRWMD	17.30	17.12	17.05	17.20	17.02	16.85
SRWMD	1.30	1.45	2.75	3.91	5.23	6.87
SWFWMD	50.55	49.91	49.04	48.47	48.02	47.12
Total	**88.25**	**87.63**	**88.54**	**89.79**	**90.84**	**91.89**

In **Appendix D, Table D-1** provides a breakdown by Crop by District for freeze protection estimates, and **Table D-2** provides the county-level breakdown.

I. Conservation Estimates/ Irrigation Efficiency Improvements

Under Florida Statute 570.93, "projected future water demands must incorporate appropriate potential water conservation factors". For purposes of incorporating potential water conservation factors, estimates of improvements in irrigation efficiency that can reasonably be expected over the planning period have been developed.

Two main datasets were explored for the purpose of estimating future irrigation efficiency improvements: the Mobile Irrigation Labs (MIL) actual water savings (AWS) data and the USDA's Farm and Ranch Irrigation Surveys, known as FRIS. The documented actual water savings through the MIL program are based largely on improvements in irrigation system distribution uniformity. The data available for MIL-based irrigation improvements from scheduling changes and sensor-based automation and other management improvements are not of sufficient length to develop long-term future projections in conservation. Also, the MIL program data have shown substantial water savings in some regions, but very limited participation in other areas. For example, the AWS estimated through the MIL in the Apalachicola Chattahoochee Flint River Basin has been very large in recent years, but the unusual participation rate and dominance of center-pivot irrigation systems makes it challenging to defensibly translate these results to other parts of the state.

Data reflecting changes in farmers' use of irrigation water over the past 35 years is available from the USDA Farm and Ranch Irrigation Surveys, known as FRIS. Using long-term trends avoids the uncertainty of estimating at the field level exactly what type of management change would be made and how many farms or fields would be expected to make that change. The FRIS estimates show that over the entire time period for which data is available (1978-2013), the average farmer in Florida has decreased the amount of water used by 5,500 gallons/acre/year.

Some of the efficiency improvements have been due to irrigation system changes that have already been mostly implemented in many areas of the state (primarily a shift from gravity systems to drip and micro-spray systems); therefore, remaining improvements are likely to come from management changes through better scheduling and/or sensor-based automation. Evaluation of the FRIS data for the period from 2003-2013 shows approximately 2,800 gallons/acre/year in improvement, which is likely more representative of future improvements to irrigation efficiency on newly irrigated land and for fields irrigated with drip or microsprinkler systems. Two exponential trends from the FRIS dataset were used to estimate future irrigation efficiency improvement. The trend from 1978-2013 is used for currently irrigated fields that are not drip or microsprinkler irrigated, and the more conservative trend from 2003-2013 is used for newly irrigated fields or those irrigated with drip or microsprinkler. **Appendix E** provides more detail on the calculations used to derive the estimates and the supporting literature.

The resulting estimate of total irrigation efficiency improvements is 146 MGD by 2040. This compares to a net increase in overall irrigation demand of 62 MGD by 2040 for an average year. **Table 13** provides a summary of estimated efficiency improvements by District.

Table 13. Estimated Efficiency Improvements by District

WMD	2020	2025	2030	2035	2040
	MGD	MGD	MGD	MGD	MGD
NWFWMD	1.52	2.73	3.84	4.89	5.96
SFWMD	21.00	36.13	50.03	60.49	68.83
SJRWMD	5.51	9.65	13.75	17.58	21.17
SRWMD	5.23	10.06	15.63	21.66	27.60
SWFWMD	4.89	9.61	14.25	18.58	22.90
Total	**38.15**	**68.19**	**97.51**	**123.21**	**146.48**

Detailed efficiency improvements estimates are provided in **Appendix D** by Crop by District (**Tables D-3 through D-7)**, and by county (**Table D-8)**.

J. Livestock and Aquaculture Water Use

Livestock demands were determined using county-specific animal inventories from USDA Ag Census data and the typically utilized per animal daily water use. The most current Ag Census (2017) was used to define the numbers of cattle, cows, poultry, horses, and other livestock. Livestock inventories from the Ag Census have remained relatively stable in Florida for the last four censuses (2002, 2007, 2012, and 2017). The inclusion of updated Ag Census data for livestock inventories did not result in major changes in total livestock water demand estimates.

For purposes of estimating the future water use, stable livestock inventories and water use are assumed in the coming decades. The approach was reviewed with experts and the cattle industry who agreed that constant livestock inventories seemed reasonable for the projection period to 2040. Total statewide livestock demand for current conditions is estimated at 38.7 MGD.

County-level water withdrawals for aquaculture were compiled using USGS 2015 water use data. CUPs for several counties were found to have available metered data for aquaculture withdrawals, and these were used in conjunction with the USGS county-level aquaculture withdrawals to produce statewide aquaculture water demands. The maximum of county level sums of CUP-reported water use and USGS aquaculture water use was used. For counties with zero water use from the combination of USGS county-level aquaculture withdrawals and CUP data, aquaculture water demands may still occur if aquaculture features are present in the spatial dataset. The average statewide water demand per unit area for aquaculture features was used to estimate aquaculture water demand for features in counties with no other county total for aquaculture. Current aquaculture water use for 2017 was estimated to be 15.3 MGD. Future aquaculture demands are held constant for all counties except Miami-Dade. Future aquaculture demand is estimated to increase in Miami-Dade County from 0.48 MGD currently to 0.58 MGD in 2020 and 0.99 MGD in 2025 through 2040. The increase in Miami-Dade is based on permit information for a large Atlantic Salmon aquaculture operation.

Spatial distribution of county-level livestock and aquaculture water use at the sub-county level was achieved using ALG features with Crop2017 of Livestock or Aquaculture or Crop of ImprovedPastures. While there are several crop types in the ALG that might have grazing livestock present, only improved pastures are included in the livestock layer for the purposes of spatially distributing the county totals of livestock water use. This provides sufficient spatial disaggregation of water demands, while reducing the size and complexity of the livestock/aquaculture spatial dataset.

The statewide livestock inventory and water use is summarized in **Table 14**, and the total livestock and aquaculture water demands by District are presented in **Table 15**. A table of the county totals for livestock and aquaculture water demand are provided in **Appendix D**, **Table D-9**.

Table 14. Statewide Livestock and Aquaculture Totals for Current and Projected Periods

Animal group	Estimated Number of Animals (FSAID III to V)	Estimated Number of Animals (FSAID VI)	Water Use per Animal (gpd/head)	Total Demand (mgd)
Dairy Cows	121,200	110,517	150	16.6
Beef Cattle	1,575,531	1,635,520	12	19.6
Poultry, chickens	13,026,011	13,142,919	0.09	1.18
Equine	120,997	90,738	12	1.09
Goats	57,613	61,159	2	0.12
Hogs	17,622	13,422	2	0.03
Sheep	11,763	24,416	2	0.05
Aquaculture	NA	NA	NA	15.3
	Statewide Livestock and Aquaculture Total Demand			**53.9**

Table 15. Livestock and Aquaculture Total Water Use by District, MGD

WMD	Livestock Water Use (mgd)	Aquaculture Water Use (mgd)
NWFWMD	2.0	4.6
SFWMD	12.2	2.4
SJRWMD	4.5	1.7
SRWMD	9.8	0.4
SWFWMD	10.1	6.2
Total	**38.7**	**15.3**

FSAID Online Interface and Geodatabase

An online user interface has been developed to allow easier access to the agricultural acreage and water demand data. In addition to the web-based interface, the complete FSAID VI geodatabase has been made available. This contains shapefiles of water demand to facilitate further analysis and application of spatial water demand data. All appropriate metadata has been provided in the geodatabase. The FSAID VI geodatabase includes:

- The projections ILG: 2017 to 2040 irrigated acreage, crop type, average year and dry year water demand (based on average 2005-2017 rainfall and ET), conservation estimates, and freeze protection estimates
- The 2017 ILG: includes only the base year 2017 irrigated areas and water demands (based on 2017 actual rainfall and ET and also based on average 2005-2017 rainfall and ET
- The ALG, which includes both irrigated and non-irrigated agricultural areas
- Livestock and Aquaculture: water demand estimates for all livestock and aquaculture areas
- Climate Factors: links the 2017 ILG with attributes for rainfall and ET (both for 2017 and 2005-2017 average), and soils (mukey and land capability classification)

Conclusions and Discussion

Trade and Economics Discussion

A number of factors will influence the agricultural irrigation patterns of Florida farmers over the next 25 years. The U.S. Farm Bill, sugar tariffs, energy policy (e.g. biofuels), and water quality rules can all exert significant influence on agricultural practices, and, in turn, agricultural irrigation demand. Sugarcane and citrus are by far the greatest variables in Florida's agricultural water use. Sugarcane is the single largest user of water in Florida agriculture and shows a slight decrease in water use over the projection period (3%). However, if sugarcane production were completely halted tomorrow, there is not an expectation that agricultural production in the EAA would cease; rather, production would likely shift to fresh market vegetables and other products that take advantage of Florida's unique harvest market season, potentially increasing total water use. Citrus production is down markedly and expected to continue to be low for the immediate future; some producers have already shifted some productive areas to fresh vegetables and abandoned other lands. Overall policy changes or external factors will affect agricultural demand for water in Florida.

The USMCA (U.S.-Mexico-Canada Agreement) was agreed to in September 2018 but has not yet been ratified. This "new" NAFTA (North American Free Trade Agreement) provides none of the desired protections for Florida fruit and vegetable producers (CRS 2019). There is strong support in Florida for the Defending Domestic Produce Production Act, which would provide trade relief measures for specialty crop producers harmed by low-price Mexican product flooding the U.S. market during Florida's growing season. However, there is not a clear congressional path for this act to pass.

Blueberry acreage has increased substantially in the last 10 years, and since 2012 FDACS has been assisting with efforts to have Florida blueberries exported to China, which would greatly increase market capacity. There has recently been progress to open this trade relationship; a Chinese delegation and FDACS representatives and USDA personnel have toured blueberry farms in the state. However, there is concern that recent tariff retaliation will put this important new market at risk.

Of potential consequence related to timber conversion to agricultural land: recent retaliatory tariffs (China's 25% tariff on Southern Yellow Pine) may make it more likely for some landowners to shift silviculture areas (including those damaged from Hurricane Michael) to irrigated or dryland agricultural crops. Commissioner Fried's letter to the President in May 2019 highlights the significance of this issue (FDACS 2019). All these policy impacts, and others that follow, will be evaluated in future FSAID improvements to ensure that their impacts are appropriately represented.

Summary

Overall agricultural water demand in Florida is anticipated to increase about 3% over the next 23 years (not considering the potential conservation), on a base of declining agricultural land, while the proportion of irrigated land is projected to increase. While irrigated lands increase by 1% through 2040, the irrigation volumes increase by 3% due to shifts over time to irrigation of currently unirrigated areas, thirstier crops and increased multi-cropping.

The increase could be partly offset by estimated improvements in efficiency. On a per acre basis, Florida farmers are projected to increase their irrigation efficiency by about 0.3% per year. Management practices can have an even greater influence than irrigation equipment, and the increased adoption of technology by Florida farmers continues to result in improvements in conservation of water. To the extent that more significant conservation quantities are desired, significant incentives are likely to be required to meaningfully shift this trajectory.

The FSAID model incorporates historical behavior, through actual water use records, as well as behavior that is forward-looking, through spatial allocation of projected water demand. Increased irrigation intensity revealed in the forecasts reflects both anecdotal and quantitative evidence and continues a trend reported nationally and regionally. As urbanization encroaches on rural lands, and as western irrigation practices migrate toward Florida, lands that traditionally were not irrigated, or irrigated for small portions of the year, are increasingly irrigated at a greater rate. Also, as citrus groves are replanted at higher density, producers report higher overall water use per acre. At the same time, the accelerated crop loss from greening within the citrus industry, and poor price forecasts for citrus, have dampened projected citrus water demand compared with previous projections.

Future Efforts

Permit-level water use data is critical for accurately modelling agricultural water demand. As the dataset of compiled water use data grows, these data can be used to further improve the empirical water demand model of FSAID. Continued refinements to the spatial data of the ILG and ALG will be made in the coming years to ensure the FSAID spatial data is representative of current agricultural areas in Florida. These improvements will increasingly incorporate field-level reviews from FDACS and Water Management District personnel by using mobile tools to facilitate efficient data collection. Field data and aerial imagery from hurricane-impacted areas will be assessed to ensure that any updates in current and projected agricultural areas reflect the changes resulting from hurricane damage and market conditions.

Reference Literature

Beare, Stephen C., Rosalyn Bell, and Brian S. Fisher. 1998. "Determining the Value of Water: The Role of Risk, Infrastructure Constraints, and Ownership." American Journal of Agricultural Economics. 80:916-940.

Bockstael, Nancy E. 1996. "Modeling Economics and Ecology: The importance of a Spatial Perspective." American Journal of Agricultural Economics Vol. 78, No. 5, Proceedings Issue (Dec.,. 1996), pp.1168-1180.

Chalfant, James A. 1984. "Comparisons of Alternative Functional Forms with Applications to Agricultural Input Data." American Journal of Agricultural Economics, 66:216-220.

CRS (Congressional Research Service). 2019. Major Agricultural Trade Issues in the 116th Congress. https://crsreports.congress.gov/product/pdf/R/R45728

de Bodisco, Christopher. 2007. The Regional value of water in agriculture. PhD Dissertation, Vanderbilt University. Nashville, TN: Proquest/UMI (Publication No. AAT 3301032).

Edwards, Brian K., Richard E. Howitt, and Silvio J. Flaim. 1996. "Fuel, Crop, and Water Substitution in Irrigated Agriculture." Resource and Energy Economics 18: 311-31.

Faux, John and Gregory M. Perry. 1999. "Estimating Irrigation Water Value Using Hedonic Price Analysis: A Case Study in Malheur County, Oregon." Land Economics 75(3): 440-52.

Florida Department of Agriculture and Consumer Services. (2013). Florida Citrus Statistics 2011-2012. Retrieved from http://www.nass.usda.gov/Statistics_by_State/Florida/Publications/Citrus/fcs/2011-12/fcs1112.pdf

Florida Department of Agriculture and Consumer Services. (2015). 2011 Florida Greenhouse/Nursery – Cash Receipts. Retrieved from http://www.freshfromflorida.com/Divisions-Offices/

Florida Department of Agriculture and Consumer Services. (2016). 2014 Florida Agriculture by the Numbers. Retrieved from: https://www.nass.usda.gov/Statistics_by_State/Florida/Publications/Annual_Statistical_Bulletin/FL_Agriculture_Book/2014/2014%20FL%20Ag%20by%20the%20Numbers.pdf

Florida Department of Agriculture and Consumer Services. (2019). "Commissioner Nikki Fried to President Trump: Stop Timber Tariffs & Trade War". Retrieved from: https://www.freshfromflorida.com/News-Events/Press-Releases/2019-Press-Releases/Commissioner-Nikki-Fried-to-President-Trump-Stop-Timber-Tariffs-Trade-War

Gollehon, N., 2014. Water, Irrigation and U.S. Agriculture. Presentation for AWRA. Natural Resources Conservation Service, USDA. Washington, DC.

Irwin, Elena and Bockstael Nancy E., 2007. "The evolution of urban sprawl: Evidence of spatial heterogeneity and increasing land fragmentation". Proceedings of the National of Sciences of the United States of America (PNAS).

Livanis, G., Moss, C. Breneman, V., "Urban Sprawl and Farmland Prices" American Journal of Agricultural Economics 88(4) (November 2006): 915–929.

Mishra, Ashok, C. Moss, and K. Erickson. 2004. "Valuing Farmland With Multiple Quasi-Fixed Inputs." Applied Economics, 36(1): 1669-1676.

Moss, Charles B. and Chris de Bodisco. "Projected Water Demand by Agriculture in the Northwest Florida Water Management District." Economic Information Report. Food and Resource Economics Department, IFAS, University of Florida, Gainesville, Fl., February, 1998. 77pp.

Renzetti, Steven. 2002. The Economics of Water Demands. Boston: Kluwer Academic Publishers.

Schoengold, K., D. L. Sunding, and G. Moreno (2006), Price elasticity reconsidered: Panel estimation of an agricultural water demand function, Water Resources Research, 42.

Sustaining California Agriculture in an Uncertain Future http://pacinst.org/wp-content/uploads/sites/21/2014/04/sustaining-california-agriculture-pacinst-full-report.pdf

U.S. Department of Agriculture (2014). *Crop Projections to 2023*. [Data files]. Available from http://www.usda.gov/wps/portal/usda/usdahome

U.S. Department of Agriculture, 2007 Census of Agriculture. (2009). Horticulture Production Expenses, Returns and Allowances, and Number Hired Workers: 2009; Value of Horticultural Specialty Crops Sold: 2009. Available from http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Census_of_Horticulture_Specialties/

U.S. Department of Agriculture, Census of Agriculture. (2007). *Census of Horticultural Specialties*. [Data files]. Available from http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Census_of_Horticulture_Specialties/

U.S. Department of Agriculture, Census of Agriculture. (2009). [Data files]. Available from http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Census_of_Horticulture_Specialties/

U.S. Department of Agriculture, Economic Research Service. (2014). *Horticulture Crops Long-Term Supply and Use Projections, Calendar Years*. [Data file]. Retrieved from http://www.ers.usda.gov/Data/FoodConsumption/

U.S. Department of Agriculture, Economic Research Service. (2014). USDA Long-term Projections, February 2014 – U.S. Crops. Retrieved from http://www.ers.usda.gov/media/1279439/oce141d.pdf

U.S. Department of Agriculture, Economic Research Service. (2015). *Cost and Return Estimates*. [Data files]. Available from http://www.ers.usda.gov/data-products/commodity-costs-and-returns.aspx

U.S. Department of Agriculture, Economic Research Service. *Variable Costs of Fertilizer; Average U.S. Farm Prices of Selected Fertilizers* [Data files]. Available from http://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx#26727

U.S. Department of Agriculture, National Agricultural Statistics Service. 2007 Census of Agriculture Greenhouse, Nursery and Floriculture Operations. Retrieved from http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Fact_Sheets/Production/nursery.pdf

U.S. Department of Agriculture, National Agricultural Statistics Service. (2010). 2007 Census of Agriculture*, Census of Horticultural Specialties (2009), 3*. Retrieved from www.agcensus.usda.gov*U.S. Department of Agriculture, National Agricultural Statistics Service. (2010). Citrus Fruits 2010 Summary. Retrieved from http://www.nass.usda.gov/*

U.S. Department of Agriculture, National Agricultural Statistics Service (2014). 2012 Census of Agriculture, United States Summary and State Data, 1. Available from www.agcensus.usda.gov

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Crop Production*. Retrieved from http://www.usda.gov/nass/PUBS/TODAYRPT/crop1014.pdf

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). Floriculture Crops 2013 Summary. Retrieved from http://usda.mannlib.cornell.edu/usda/nass/FlorCrop/2010s/2014/FlorCrop-06-19-2014.pdf

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Tree Nuts, Noncitrus, and Citrus - Production, Acres Bearing, and Yield – 2007-2014* [Data files]. Available from http://www.nass.usda.gov/Statistics_by_Subject/index.php?sector=CROPS

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Acres Harvested –Various Crops* [Data files]. Available from http://quickstats.nass.usda.gov/

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Citrus Price* [Data file]. Available from http://quickstats.nass.usda.gov/

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Crop Production and Peanut Stocks and Processing*. [Data files]. Available from http://www.nass.usda.gov/

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Potato Prices* [Data file]. Available from http://quickstats.nass.usda.gov/

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Price Received - Various Crops* [Data files]. Available from http://quickstats.nass.usda.gov/

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Totals –Production, Various Crops, Florida* [Data files]. Available from http://quickstats.nass.usda.gov/

U.S. Department of Agriculture, National Agricultural Statistics Service. (2015). *Yield and Acres Harvested For Various Crops* [Data files]. Available from http://www.nass.usda.gov/Statistics_by_Subject/

U.S. Department of Agriculture. (2014). *Per Capita Meat Consumption*, *Beef Long-Term Projections; Pork Long-Term Projections; Young Chicken Long-Term Projections; Turkey Long-Term Projections; Egg Long-Term Projections.* [Data files]. Available from http://www.usda.gov/wps/portal/usda/usdahome

U.S. Department of Agriculture. (2015). USDA Agricultural Projections to 2024. Available from http://www.ers.usda.gov/publications/oce-usda-agricultural-projections/oce151.aspx

U.S. Department of Commerce, Bureau of the Census. (2015). *Horticultural Crops, Long-Term Supply and Use Projections, Calendar Years* [Data file]. Available fromhttp://www.census.gov/

U.S. Department of Commerce, U.S. Census Bureau. (2015). *Foreign Trade Statistics*. [Data files]. Available from http://www.census.gov/

U.S. Farm Irrigation Becomes More Efficient, Moves East. http://www.circleofblue.org/waternews/2014/world/u-s-farm-irrigation-becomes-efficient-moves-east/

University of Florida, International Agricultural Trade & Policy Center. *Cost of Production for Florida Vegetables 2008-2009*. [Data files]. Available from http://www.fred.ifas.ufl.edu/iatpc/budgets.php

University of Georgia College of Agricultural & Environmental Sciences. (2016). *Annual Georgia Sod Producers Survey 2002 - 2016*. [Data files]. Retrieved from http://www.commodities.caes.uga.edu/turfgrass/georgiaturf/Publicat/1700_Sod_Inventory.html

University of Georgia. The Center for Agribusiness and Economic Development. 2006-2015 Georgia Farm Reports.. http://www.caes.uga.edu/center/caed/pubs/annual.html

University of Georgia. (2006-2015). Farm Gate Value Reports 2006-2015. *Georgia Nursery Acreages and Prices.* [Data files]. Available from http://www.caes.uga.edu/center/caed/pubs/annual.html

University of Missouri, Food and Agricultural Policy Research Institute (FAPRI). *FAPRI-MU Baseline Outlook*. [Data files]. Available from http://www.fapri.missouri.edu/publications/outlook/

USDA, National Agricultural Statistics Service, 2012 Census of Agriculture, Farm and Ranch Irrigation Survey (FRIS). Retrieved from http://www.agcensus.usda.gov/Publications/Irrigation_Survey/