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IFAS Extension

Net Irrigation Requirements for Florida Turfgrass Lawns: Part 3 - Theoretical Irrigation Requirements[1]

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Introduction

Turfgrasses are used in urban areas to provide multiple benefits to society and the environment. They cover millions of acres of home lawns, commercial properties, roadsides, parks, etc. But an important question is whether turfgrasses are properly managed. Many critics emphasize that turfgrasses demand too much urban water in a time when water resources are scarce. While indoor water use remains fairly constant throughout the year, outdoor water use increases during the spring and summer. Flattening the peak demand is an objective of water agencies (Beard and Kenna 2006); better irrigation management would result in less fertilizer and pesticide use, which would be better for the environment.

Urban landscape irrigation is one of the largest growing water use sectors in Florida. The state's Water Management Districts have been working collectively to find ways to assist urban water users to irrigate more efficiently and to enhance planning and regulatory programs in order to conserve water. There is adequate research information to make specific recommendations, such as the specific cultural practices or systems approaches that could be applied to decrease turfgrass water use. Those recommendations could be used immediately to conserve water and maintain turfgrass quality and its functional benefits to society.

The calculation of net irrigation requirements for turfgrass is essential for determining water allocation and can help to determine irrigation scheduling. This series of publications explains the process of estimating net irrigation requirements for Florida turfgrasses. The process used here gives a long-term (30-year) historical analysis of turfgrass monthly net irrigation requirements. The first article in the series explains how the weather data was gathered and checked for quality; the second article shows the calculation of evapotranspiration for selected sites throughout the state (plus one in Alabama, to cover the west side of the Florida Panhandle); and the third and final article outlines the results of the net irrigation estimation. Since Florida's urban landscape water demand is expected to grow considerably over the next few decades, the use of current information in terms of turfgrass irrigation needs will provide urban irrigators with information to help them reduce water volumes applied and conserve water.

Net irrigation is the depth of water needed to fulfill the evapotranspiration (ET) requirement in addition to the amount of precipitation available to a growing crop, for a disease-free crop growing in large fields under non-restricting water conditions and under adequate fertility (Allen et al. 2007). Turfgrass is mostly under irrigation and is considered the largest irrigated non-agricultural crop in the United States (Hoffman et al. 2007). Knowing when to irrigate and how much water to apply can help to minimize water and energy use (Evans et al. 1996). It has been found

that water application in excess of that required can largely be attributed to human factors and not to plant needs (Beard and Green 1994).

In this study, a soil water balance is used to calculate irrigation requirements for Florida turfgrass lawns based on 30 years of historical weather data. The first publication in the series shows that the weather data has been quality checked ("Net Irrigation Requirements for Turfgrass Lawns: Part 1 – Report of Gathered Weather Data and Quality Check"; http://edis.ifas.ufl.edu/ae480). In the second publication in the series, the reference evapotranspiration has been calculated and analyzed ("Net Irrigation Requirements for Turfgrass Lawns: Part 2 – Reference Evapotranspiration Calculation"; http://edis.ifas.ufl.edu/ae481). The estimated irrigation requirements are presented on a monthly basis, and each monthly value represents the average of the 30-year period. These monthly values can be recommended when irrigation will most likely be needed during the year. These recommendations should be analyzed carefully since we are assuming that the irrigated landscape is covered only by turfgrasses. A more detailed analysis must be performed for mixed landscapes or areas where ornamental plants dominate.

Objective

The objective of this report is to estimate net irrigation, effective rainfall, and drainage by using a water balance equation for ten locations in Florida and one in Alabama from data during the 30-year period of 1980-2009.

Methodology
Irrigation Estimation Using a Water Balance Model

The soil water balance presented by Dukes (2007) was calculated on a daily basis for thirty years (1980-2009) for 10 sites in Florida and one in Alabama. Daily gain and loss of water was computed by the equation once the maximum allowed depletion (MAD) value was reached. The soil water balance equation, in units of inches, was as follows:

Table 1. Available water holding capacity values used in the soil water balance simulations for all locations in Florida and one in Alabama.

Location	Available water holding capacity (in in^{-1})	
	Low	High
Florida Panhandle		
Mobile (AL)	0.13	0.15
Tallahassee	0.08	0.08
North Florida		
Jacksonville	0.05	0.13
Gainesville	0.06	0.13
Central Florida		
Daytona	0.04	0.05
Orlando	0.04	0.13
Southwest Florida		
Tampa	0.04	0.08
Brooksville	0.04	0.07
Hillsborough River St. Park	0.04	0.08
Inverness	0.04	0.07
Plant City	0.04	0.08
St. Leo	0.04	0.08
St. Petersburg	0.04	0.08
Tarpon Springs	0.04	0.08
South Florida		
West Palm Beach	0.04	0.07
Fort Myers	0.04	0.07
Miami	0.04	0.04
Key West	0.04	0.17

$$SW_t = SW_{t-1} - ETc_{t-1} + R_{t-1} + I_{t-1} - D_{t-1} - Roff_{t-1} \quad \text{(Eq. 1)}$$

where SW_t is the soil water on day 't', SW_{t-1} is the soil water content on day '$t-1$', ET_{t-1} is the crop evapotranspiration, R_{t-1} is rainfall (http://edis.ifas.ufl.edu/ae480), I_{t-1} is net irrigation, D_{t-1} is drainage, and $Roff_{t-1}$ is runoff. ET_c was calculated as the product of ET_o (http://edis.ifas.ufl.edu/ae481) by a K_c (or crop coefficient) that varied monthly. ET_c was subtracted from the soil water store on a daily basis until the root zone reached a MAD level. The MAD value established for warm-season turfgrass has been suggested as 0.5 (Allen et al. 1998). We simulated the effect of two root zones at 8 and 12 in. These are the most frequent root depths found for warm-season turfgrasses (Shedd et al. 2008; Huang et al. 1997; Peacock and Dudeck 1985; DiPaola et al. 1982). During the simulations, irrigation was triggered to refill the soil profile to field capacity when moisture conditions reached the MAD level. Rainfall beyond field capacity was assumed to be lost from the system due to drainage. The most dominant soils covering the urban areas were selected in order to simulate a "high" and a "low" soil water holding capacity as shown in Table 1. Runoff on these coarse soils was assumed to be negligible. Three sets of monthly turfgrass crop coefficients for North, Central, and South Florida were used for the simulations, and values are shown in Table 2 (Jia et al. 2009; Davis and Dukes 2010).

The mean net irrigation requirements included the effect of using different root zones and soil water holding capacity levels. The 5-in-10 and 2-in-10 (80th percentile) irrigation was also analyzed. The 5-in-10 irrigation requirements represent the median or 50th percentile and should be numerically similar to the mean irrigation requirement if the net irrigation values distribution is normal. The 2-in-10 net irrigation values represent amounts that fulfill the net irrigation requirement 80% of the time and would represent the amount of irrigation to maintain irrigation needs through a drought with a frequency of occurrence 2 years in every 10. The Southwest Florida Water Management District has permitted supplemental irrigation quantities in this manner (SWFWMD 2011).

Results and Discussion

Thirty years (1980-2009) of daily net irrigation requirements were calculated for 10 sites in Florida and one in Alabama (Figure 1). The locations have been grouped into five zones based on geographical distribution: Florida Panhandle (Mobile and Tallahassee), North Florida (Jacksonville and Gainesville), Central Florida (Daytona and Orlando), Southwest Florida (Tampa, Brooksville, Hillsborough River State Park, Inverness, Plant City, St. Leo, St. Petersburg, and Tarpon Springs), and South Florida (West Palm Beach, Ft. Myers, Miami, and Key West). A comparison of the mean annual irrigation amounts per site is shown in Table 3 and Figure 2. The mean monthly net irrigation requirements, drainage, and effective rainfall on a monthly basis were calculated by using 8 and 12 in root zone and are shown in Table 4. The 5-in-10 (50th percentile) and the 2-in-10 (80th percentile) irrigation requirements are shown in Table 5 (average of 8 and 12 in root zone). These data are also shown as graphs in Figures 3 through 20.

Table 2. Monthly K_c values for different regions in Florida.

K_c values			
Month	**Panhandle/North Florida***	**Central/Southwest Florida****	**South Florida*****
Jan	0.35	0.45	0.71
Feb	0.35	0.45	0.79
Mar	0.55	0.65	0.78
Apr	0.80	0.80	0.86
May	0.90	0.90	0.99
Jun	0.75	0.75	0.86
Jul	0.70	0.70	0.86
Aug	0.70	0.70	0.90
Sep	0.75	0.75	0.87
Oct	0.70	0.70	0.86
Nov	0.60	0.60	0.84
Dec	0.45	0.45	0.71

* Mobile, Tallahassee, Gainesville, and Jacksonville (Source: Jia et al. 2009).
** Daytona, Orlando, and Tampa (including all locations in Southwest Florida) (Source: Davis and Dukes 2010).
***West Palm, Fort Myers, Miami, and Key West (Source: Stewart and Mills 1967).
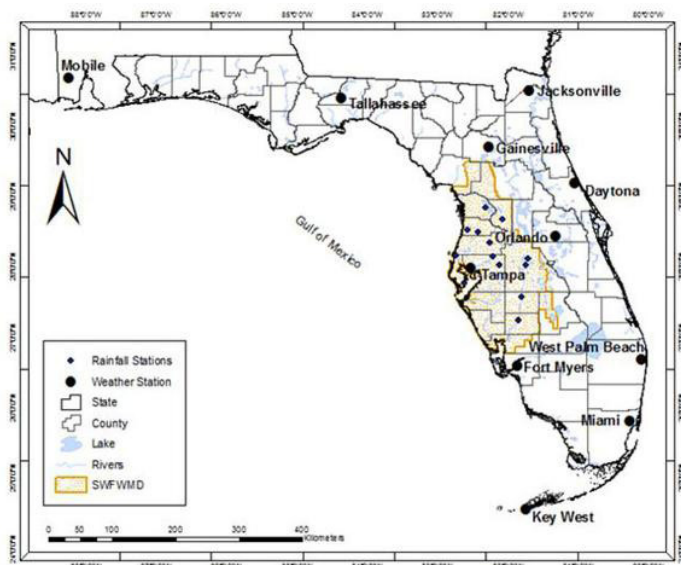
Figure 1. Map showing weather station locations (large dots) and rain gauges (small dots).

The mean annual net irrigation ranged from 16.7 in y^{-1} in Mobile (Florida Panhandle) to 41.7 in y^{-1} in Fort Myers. For Key West (South Florida), the estimated net irrigation requirement was 38.5 in y^{-1} (Table 3). According to the second article in this series (http://edis.ifas.ufl.edu/ae481), Mobile showed a higher mean yearly rainfall than Key West, with 69.7 in y^{-1} and 41.7 in y^{-1}, respectively. Tampa and nearby sites (Southwest Florida) showed an annual mean net irrigation requirement of 27.6 in y^{-1}. The yearly standard deviation values are also shown in Table 3, and the average standard deviation is 2.1 in y^{-1}. This value reflects the variation of using different root zones and soil types, but also includes the variability of climate during the 30 years of evaluation. The difference between using 8 or 12 in root zone was 1.7 in y^{-1} on average. Net irrigation requirements were higher when an 8 in root zone was simulated. At that depth, soil retains less water; rainfall is less effective in supplying the amount of water needed; and drainage is higher than in a deeper soil, making irrigation more frequently required.

Table 3. Mean annual estimated net irrigation requirement for different locations in Florida based on 8 and 12 in root zone. Values include different types of soils.

	Mean annual net irrigation (in y^{-1})				
	Root zone				
	8 in	12 in	Difference	Average	Std. Dev.
Florida Panhandle					
Mobile (AL)	17.8	15.5	2.3	16.7	1.5
Tallahassee	20.5	18.9	1.6	19.7	1.1
North Florida					
Jacksonville	21.3	19.2	2.1	20.3	2.9
Gainesville	20.8	18.9	1.9	19.8	2.4
Central Florida					
Daytona	25.7	24.2	1.5	24.9	1.1
Orlando	24.5	22.7	1.8	23.6	3.8
Southwest Florida					
Tampa	28.5	26.7	1.8	27.6	2.0
Brooksville	28.2	26.4	1.8	27.3	2.2
Hillsborough R. St. Park	28.3	26.7	1.6	27.5	2.1
Inverness	28.2	26.3	1.9	27.3	2.2
Plant City	27.8	26.1	1.7	26.9	2.1
St. Leo	27.9	26.0	1.9	27.0	2.2
St. Petersburg	29.4	27.7	1.7	28.5	2.0
Tarpon Springs	29.0	27.3	1.7	28.1	2.0
South Florida					
West Palm Beach	35.9	34.0	1.9	34.9	1.8
Fort Myers	41.8	41.6	0.2	41.7	1.3
Miami	38.5	36.7	1.8	37.6	1.3
Key West	39.6	37.5	2.1	38.5	1.8

The average mean monthly distribution of net irrigation, drainage, and effective rainfall using 8 and 12 inch root zones is shown in Table 4. Irrigation requirements increased from December to May, decreased during the summer season, and then increased slightly again during September and October. The highest irrigation requirement in a year was calculated in May, with approximately 5.2 in month^{-1}. Minimum irrigation was calculated for the winter months in higher latitudes (e.g., Mobile and Tallahassee) when no irrigation was required and corresponded to the grass dormant season, specifically in January. The opposite was calculated in southern latitudes where irrigation is required almost year-round (e.g., Fort Myers, Miami, and Key West). We found out that the irrigation requirements for South Florida were in agreement with measured ET_c data found in the literature, in spite of our overestimated ET_o for the area (http://edis.ifas.ufl.edu/ae481). For example, ET_o was calculated as 65.3 in y^{-1}, and the estimated irrigation as 37.6 in y^{-1} in Miami. Stewart and Mills (1967) measured turf evapotranspiration in South Florida, finding a water demand of 42.8 in y^{-1}. The overestimated ET_o data did not impact the net irrigation estimate.

Monthly distribution of the estimated irrigation was very similar among the locations identified in Southwest Florida. The calculated drainage and effective rainfall values were higher during June to September in all cases.

During a drought year, additional irrigation is required to meet plant water requirements. Accordingly, the Southwest Florida Water Management District (SWFWMD) consumptive use permits allow for the 2-in-10 net irrigation requirement instead of the average or the median (5-in-10) irrigation requirement. The 2-in-10 and 5-in-10 monthly net irrigation requirements are shown in Table 5, and each value represents the average of using 8 and 12 inch root zones. The mean maximum 2-in-10 net irrigation requirement was approximately 5.9 in month^{-1}, which represents 14% more than the mean net irrigation requirement. The mean monthly net irrigation values shown in Table 4 differed slightly from the median values (5-in-10 irrigation requirements shown in Table 5). The median gives the middle value of an ordered set of values, in this case the estimated net irrigation. Figures 3 through 20 show several graphs of the 2-in-10 and 5-in-10 irrigation requirements at each location. Error bars represent the standard deviation due to root zone differences. It is important to note that the gross irrigation requirement would result in more water allocated to account for reasonable irrigation inefficiencies.

Summary

The irrigation requirements for turfgrass lawns in 10 cities in Florida and one in Alabama were estimated and analyzed for a 30-year period (1980-2009). The annual estimated irrigation requirements ranged from 16.7 in to 41.7 in
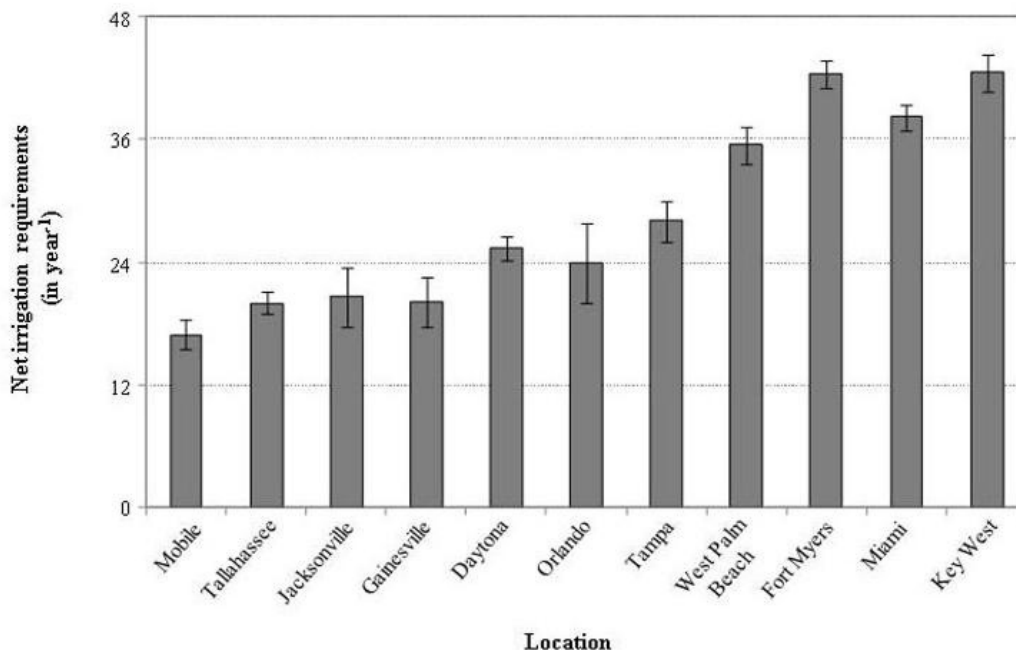

Figure 2.   Yearly average net irrigation requirement in all locations in Florida. Error bars represent the standard deviation due to different root zones and soil types across years.

y^{-1} in Mobile and Fort Myers, respectively. The results showed that the estimated irrigation was less in the Florida Panhandle but gradually increased its demand in Central and South Florida. On average, monthly irrigation requirements increase two times a year, from April to June (high peaks in May with 5.2 in month^{-1}, approximately), and from October to November (maximum in October with 2.4 in month^{-1}, approximately). These peaks of estimated irrigation demands are related to rainfall trends that showed less rain is observed from October to May, compared to the rainy season occurring from June to September. Evapotranspiration increases in the first months of the year, with the highest peak calculated for May, and then it decreases gradually in the following months. The estimated irrigation requirements for locations in Southwest Florida showed similar trends because reference evapotranspiration was calculated from data of one weather station. However, minor changes in the estimated irrigation were due to some variability in the rainfall data.

Problems, Issues, and Limitations with the Data
Weather Data

Weather data for a 30-year period (January 1, 1980–December 31, 2009) were gathered from 11 weather stations located at airports in major cities in or near Florida. Data for each weather station was obtained from the National Climatic Data Center (NCDC) (USDC 2009). Missing values were estimated as the average of the observed data from the previous and the following days. The frequency of missing values was approximately 0.01% for maximum and minimum temperature and dew point and approximately 0.6% for rainfall data.

Daily solar radiation data is unavailable most of the time. So for this project, daily solar radiation data was estimated from January 1, 1980 to December 31, 2009 using the Hargreaves-Samani (1982) equation. Previously, the Hargreaves-Samani coefficients, which are empirical values, were calibrated using solar radiation data for eleven locations in Florida on a daily basis (from 1995 to 2004). This data was from Geostationary Operational Environmental Satellites (GOES) and is publicly available via a USGS web portal. The resulting new coefficients were applied to the entire 30-year NCDC dataset to estimate solar radiation.

K$_C$ data sets for turfgrasses

Three monthly crop coefficients data sets for warm-season turfgrasses were used for ET$_c$ calculation in the second publication in this series (http://edis.ifas.ufl.edu/

ae481), as we divided the state into three areas — North, Central, and South Florida. The monthly K$_c$ values were determined from Eddy correlation measurements for Citra, Florida, values that were used for both North and Central Florida (Jia et al. 2009). The other two K$_c$ data sets were estimated (Stewart and Mills 1967; Davis and Dukes 2010). Additional research on K$_c$ for turfgrasses in Florida would be recommended to assess variations due to turfgrass species and geographical location. The assumption for the simulations was that 100% of the landscape was covered by turfgrasses. Mixed landscapes were not considered in the soil water balance analysis because this is still problematic and further research is recommended to address this approach.

Soils

Spatial variability of soils causes spatial variability of the water balance. Thus, the most common soil types were considered at each location to perform their soil water balances, using a minimum and a maximum soil water holding capacity. Soil data was available online from the NRCS Soil Surveys manuscripts for Florida. Regardless of the year of publication, these manuscripts contain descriptions of the available water holding capacity, which is the parameter needed for the soil water balance.

Acknowledgements

Table 4. Mean monthly net irrigation requirement, drainage, and effective rainfall for the 30-year period (1980-2009) of weather station data records (considering the average between 8 and 12 in root zone).

City		Estimated monthly irrigation requirements (in month^{-1})											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FLORIDA PANHANDLE												
Tallahassee												
Net irrigation	0.1	0.1	1.2	3.0	4.4	2.4	1.7	1.8	2.1	1.9	0.8	0.2
Drainage	3.6	4.3	5.2	2.6	2.6	5.8	4.8	5.1	3.5	2.4	3.0	3.5
Eff. rainfall	0.8	0.7	1.1	1.1	1.3	2.1	2.4	2.0	1.3	0.8	0.8	0.7
Mobile (AL)												
Net irrigation	0.0	0.0	0.7	2.3	3.8	2.4	1.6	1.5	1.8	1.8	0.7	0.1
Drainage	4.9	4.9	5.2	3.6	4.4	3.5	4.9	4.7	3.2	2.7	4.1	4.3
Eff. rainfall	0.9	0.9	1.5	1.6	1.7	2.3	2.6	2.5	1.7	1.1	1.2	1.1
NORTH FLORIDA												
Jacksonville												
Net irrigation	0.2	0.3	1.2	3.1	4.6	2.5	2.2	1.8	1.6	1.5	0.9	0.4
Drainage	3.0	2.6	2.8	1.9	1.5	4.2	4.3	4.3	6.6	3.2	1.7	2.2
Eff. rainfall	0.7	0.7	1.1	1.0	1.0	2.0	2.3	2.2	1.7	1.0	0.7	0.6
Gainesville												
Net irrigation	0.2	0.4	1.3	3.2	4.6	2.2	1.7	1.5	1.7	1.7	0.9	0.5
Drainage	2.6	2.5	3.0	1.5	1.4	4.1	3.7	4.1	3.3	1.9	1.3	1.6
Eff. rainfall	0.7	0.7	1.1	0.9	1.1	2.2	2.3	2.2	1.6	0.9	0.7	0.6
CENTRAL FLORIDA												
Daytona												
Net irrigation	0.7	0.9	2.0	3.5	4.8	2.6	2.5	2.2	1.9	1.9	1.2	0.7
Drainage	2.0	1.9	2.9	1.4	2.2	3.8	3.9	4.6	5.0	3.2	1.9	2.0
Eff. rainfall	0.6	0.6	0.9	0.7	0.9	1.6	1.7	1.7	1.5	1.1	0.6	0.5
Orlando												
Net irrigation	0.8	0.9	2.2	3.7	4.8	2.0	1.7	1.6	1.7	2.0	1.5	0.7
Drainage	1.9	1.7	2.8	1.9	2.2	5.4	4.9	4.7	4.1	2.3	1.9	2.0
Eff. rainfall	0.7	0.7	1.0	1.0	1.4	2.4	2.5	2.4	1.9	1.1	0.7	0.6
SOUTH FLORIDA												
W. Palm Beach												
Net irrigation	1.7	2.3	3.2	4.3	5.3	2.9	3.3	3.0	2.2	2.7	2.4	1.6
Drainage	2.6	2.0	3.3	2.5	3.1	5.7	3.6	5.0	6.0	3.9	3.9	2.5
Eff. rainfall	0.8	0.9	1.1	1.1	1.5	2.2	2.2	2.4	2.3	1.5	1.0	0.9

Ft. Myers													
Net irrigation	1.8	2.3	3.2	4.4	5.6	2.7	2.4	2.4	2.2	3.0	2.4	1.8
Drainage	1.8	2.2	2.2	1.5	2.0	7.2	5.8	6.8	6.3	2.6	1.8	1.3
Eff. rainfall	0.5	0.6	0.7	0.7	1.1	2.3	2.7	2.6	2.0	0.9	0.6	0.4
Miami													
Net irrigation	2.1	2.6	3.7	4.8	5.4	2.9	3.5	3.0	2.4	2.7	2.6	2.0
Drainage	1.1	1.5	2.3	2.1	3.7	6.9	4.4	6.4	6.9	5.1	2.8	1.6
Eff. rainfall	0.6	0.7	0.8	0.9	1.6	2.5	2.5	2.8	2.5	1.6	0.8	0.6
Key West													
Net irrigation	2.8	3.3	3.9	4.6	5.0	3.9	4.0	3.6	2.7	2.9	2.8	2.4
Drainage	1.7	1.1	1.9	2.0	2.8	3.3	3.3	3.5	3.7	2.5	2.3	1.7
Eff. rainfall	0.5	0.6	0.8	0.9	1.2	1.5	1.5	1.5	1.5	0.9	0.6	0.5
SOUTHWEST FLORIDA													
Tampa													
Net irrigation	0.7	0.9	2.4	3.9	5.6	3.0	2.0	1.9	2.2	2.5	1.6	0.8
Drainage	1.7	2.0	2.3	1.5	1.4	4.9	4.8	5.7	5.2	1.7	1.4	2.0
Eff. rainfall	0.6	0.7	0.8	0.7	0.9	1.9	2.3	2.2	1.7	0.8	0.5	0.5
Brooksville													
Net irrigation	0.7	0.9	2.3	3.9	5.5	2.7	2.1	1.8	2.4	2.6	1.6	0.8
Drainage	2.4	2.6	3.1	1.9	1.6	5.9	6.1	5.8	4.7	1.8	1.6	1.9
Eff. rainfall	0.7	0.6	0.9	0.7	1.0	2.2	2.2	2.4	1.5	0.7	0.6	0.5
Hills. Riv. St. Pk.													
Net irrigation	0.7	1.0	2.4	5.5	2.7	2.7	2.1	1.9	2.2	2.6	1.6	0.9
Drainage	2.6	2.3	2.6	1.5	6.1	6.1	5.5	5.7	5.6	2.0	1.9	2.3
Eff. rainfall	0.6	0.6	0.8	1.0	2.2	2.2	2.3	2.2	1.7	0.7	0.5	0.4
Inverness													
Net irrigation	0.7	0.9	2.2	3.9	5.6	2.7	2.0	1.9	2.4	2.5	1.6	0.8
Drainage	2.6	2.2	3.2	1.9	1.8	6.2	5.0	5.5	4.5	2.1	1.5	1.9
Eff. rainfall	0.6	0.6	0.9	0.8	1.0	2.1	2.4	2.2	1.5	0.8	0.6	0.5
Plant City													
Net irrigation	0.8	1.0	2.4	3.9	5.4	2.6	1.9	1.7	2.3	2.6	1.6	0.8
Drainage	2.1	2.2	2.7	1.8	2.2	6.3	5.1	6.1	5.6	1.7	1.4	2.2
Eff. rainfall	0.6	0.6	0.8	0.8	1.1	2.3	2.4	2.4	1.6	0.8	0.6	0.5
St. Leo													
Net irrigation	0.7	0.9	2.3	3.9	5.5	2.8	2.0	1.9	2.2	2.4	1.5	0.8
Drainage	2.6	2.3	3.1	1.8	1.9	5.7	5.7	5.3	5.2	2.2	1.7	2.3

	1	2	3	4	5	6	7	8	9	10	11	12
Eff. rainfall	0.7	0.7	0.9	0.8	1.0	2.1	2.4	2.3	1.6	0.9	0.6	0.5
St. Petersburg												
Net irrigation	0.8	1.0	2.4	4.0	5.7	3.1	2.2	2.0	2.1	2.6	1.7	0.8
Drainage	2.0	2.2	2.8	1.7	1.4	4.8	5.1	6.2	6.3	1.7	1.5	2.3
Eff. rainfall	0.6	0.6	0.7	0.6	0.7	1.8	2.1	2.1	1.7	0.7	0.5	0.5
Tarpon Sprgs												
Net irrigation	0.7	0.9	2.4	3.9	5.8	3.1	2.2	2.0	2.3	2.5	1.5	0.8
Drainage	2.4	2.1	2.8	1.6	1.4	5.0	5.9	5.8	5.5	2.6	1.7	2.4
Eff. rainfall	0.7	0.7	0.9	0.7	0.7	1.7	2.2	2.1	1.6	0.8	0.6	0.5

Table 5. The 2-in-10 and 5-in-10 irrigation requirements for the 30-year period (1980-2009) of weather station data records (considering the average of 8 and 12 in root zone).

City	Estimated net irrigation (in month^{-1})											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FLORIDA PANHANDLE												
Tallahassee												
2-in-10	0.2	0.2	1.7	3.7	5.2	3.2	2.4	2.2	2.7	2.2	1.1	0.4
5-in-10	0.0	0.2	1.2	3.0	4.4	2.6	1.7	1.8	2.1	2.0	0.7	0.2
Mobile (AL)												
2-in-10	0.0	0.0	1.1	3.0	4.6	3.3	2.2	2.2	2.4	2.5	1.1	0.1
5-in-10	0.0	0.0	0.5	2.3	4.0	2.5	1.4	1.2	1.9	1.9	0.7	0.0
NORTH FLORIDA												
Jacksonville												
2-in-10	0.4	0.0	1.8	3.5	5.2	3.4	2.9	2.3	2.2	1.9	1.3	0.7
5-in-10	0.2	0.2	1.1	3.0	4.6	2.4	2.0	1.6	1.5	1.6	0.9	0.4
Gainesville												
2-in-10	0.4	0.6	1.7	3.7	5.3	3.0	2.1	2.1	2.1	2.3	1.4	0.7
5-in-10	0.2	0.4	1.2	3.3	4.7	2.1	1.8	1.3	1.8	1.7	1.0	0.4
CENTRAL FLORIDA												
Daytona												
2-in-10	1.0	1.1	2.5	4.1	5.3	3.3	3.0	3.0	2.3	2.3	1.4	0.9
5-in-10	0.6	0.8	2.1	3.5	4.9	2.7	2.3	2.2	1.9	1.9	1.3	0.7
Orlando												
2-in-10	1.1	1.1	2.8	4.3	5.6	2.5	2.4	2.2	2.2	2.6	1.7	1.0
5-in-10	0.8	0.9	2.4	3.8	4.9	1.9	1.6	1.4	1.7	2.0	1.5	0.8
SOUTH FLORIDA												
W.P. Beach												
2-in-10	2.2	2.7	3.8	5.0	6.0	3.8	4.0	3.7	2.7	3.3	2.7	1.9
5-in-10	1.7	2.2	3.1	4.3	5.4	2.7	3.3	3.1	2.2	2.8	2.4	1.5
Fort Myers												
2-in-10	2.2	2.7	3.8	5.0	6.5	3.2	3.1	3.0	2.8	3.7	3.0	2.2
5-in-10	1.8	2.3	3.3	4.4	5.9	2.6	2.4	2.2	2.1	3.0	2.6	1.9
Miami												
2-in-10	2.6	3.0	4.1	5.3	6.3	3.9	3.9	3.7	3.0	3.5	2.9	2.3
5-in-10	2.1	2.5	3.7	4.8	5.6	2.9	3.6	3.0	2.2	2.6	2.6	1.9
Key West												

|												
2-in-10	2.6	3.1	4.1	5.0	5.6	4.8	4.6	4.2	3.1	3.6	3.3	2.5
5-in-10	2.2	2.7	3.7	4.7	5.3	4.0	4.3	3.8	2.8	3.3	3.1	2.1
SOUTHWEST FLORIDA												
Tampa												
2-in-10	1.0	1.2	2.9	4.6	6.3	3.6	2.4	2.4	2.6	2.9	1.9	1.1
5-in-10	0.7	1.0	2.3	3.9	5.8	3.0	1.9	2.0	2.3	2.5	1.7	0.8
Brooksville												
2-in-10	0.9	1.1	2.8	4.4	6.1	3.3	2.7	2.4	2.9	3.1	1.9	1.0
5-in-10	0.7	0.9	2.4	4.1	5.6	2.6	2.1	1.8	2.3	2.6	1.6	0.7
Hills. Riv. State Park												
2-in-10	1.0	1.3	3.0	4.3	6.3	3.5	2.6	2.4	2.8	3.1	1.9	1.1
5-in-10	0.7	1.0	2.5	4.1	5.7	2.8	2.2	2.0	2.4	2.8	1.7	0.9
Inverness												
2-in-10	0.9	1.2	2.9	4.4	6.2	6.2	3.3	2.4	2.4	2.7	3.0	1.1
5-in-10	0.7	0.9	2.2	4.0	5.6	5.6	2.6	2.0	1.9	2.2	2.6	0.9
Plant City												
2-in-10	1.0	1.3	3.0	4.5	6.3	3.2	2.4	2.2	2.8	3.1	1.9	1.1
5-in-10	0.7	1.0	2.4	3.9	5.7	2.5	1.8	1.6	2.2	2.6	1.6	0.8
St. Leo												
2-in-10	0.9	1.1	2.9	4.4	6.3	3.4	2.5	2.4	2.7	3.0	1.7	1.1
5-in-10	0.7	0.8	2.2	3.9	5.7	2.7	2.0	1.8	2.3	2.4	1.5	0.8
St. Petersburg												
2-in-10	1.0	1.2	3.0	4.5	6.5	3.6	2.7	2.4	2.8	3.0	1.9	1.1
5-in-10	0.7	1.0	2.4	4.0	5.9	3.1	2.2	2.1	2.0	2.6	1.6	0.9
Tarpon Springs												
2-in-10	0.9	1.1	3.0	4.4	6.5	3.6	2.9	2.4	2.7	2.9	1.9	1.1
5-in-10	0.7	1.0	2.2	4.1	5.9	3.2	2.0	2.1	2.2	2.5	1.5	0.7
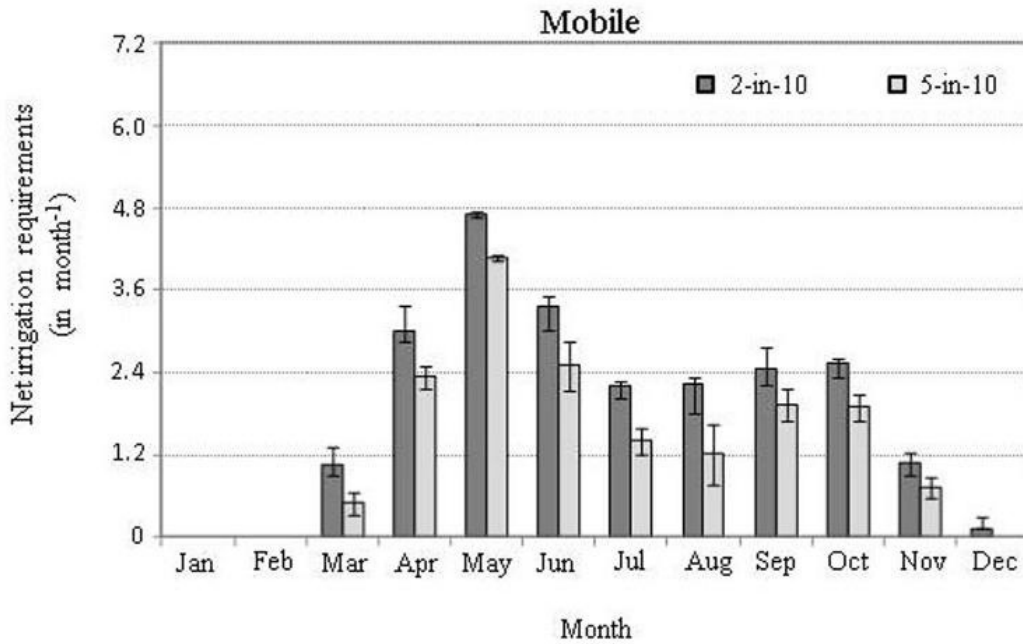
Mobile

Figure 3. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Mobile, AL. Error bars represent the standard deviation due to different root zones and soil types across all time.
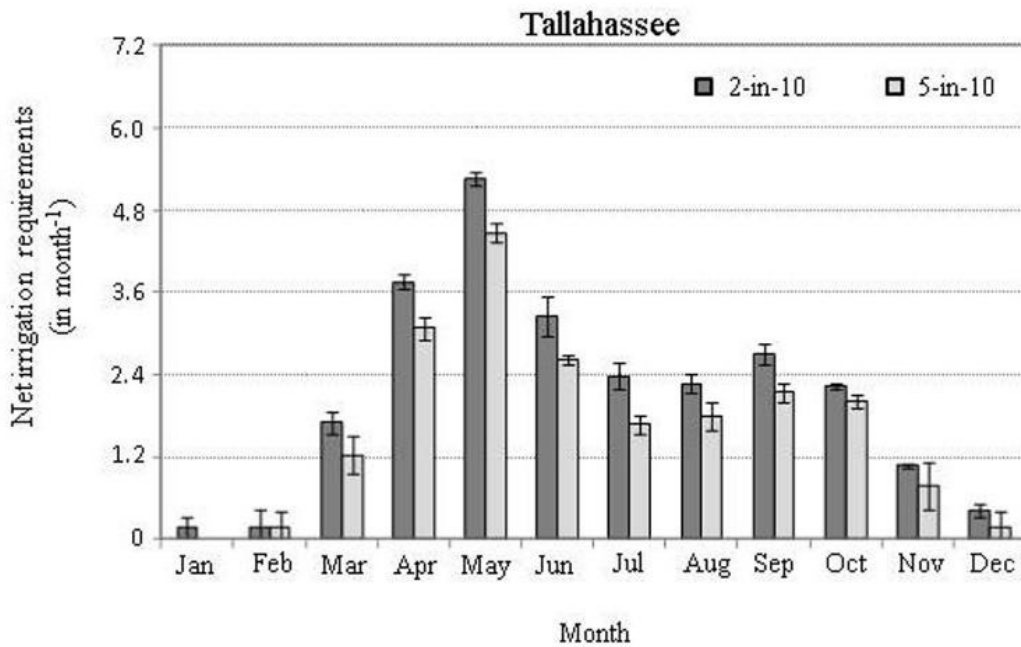
Tallahassee

Figure 4. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Tallahassee, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
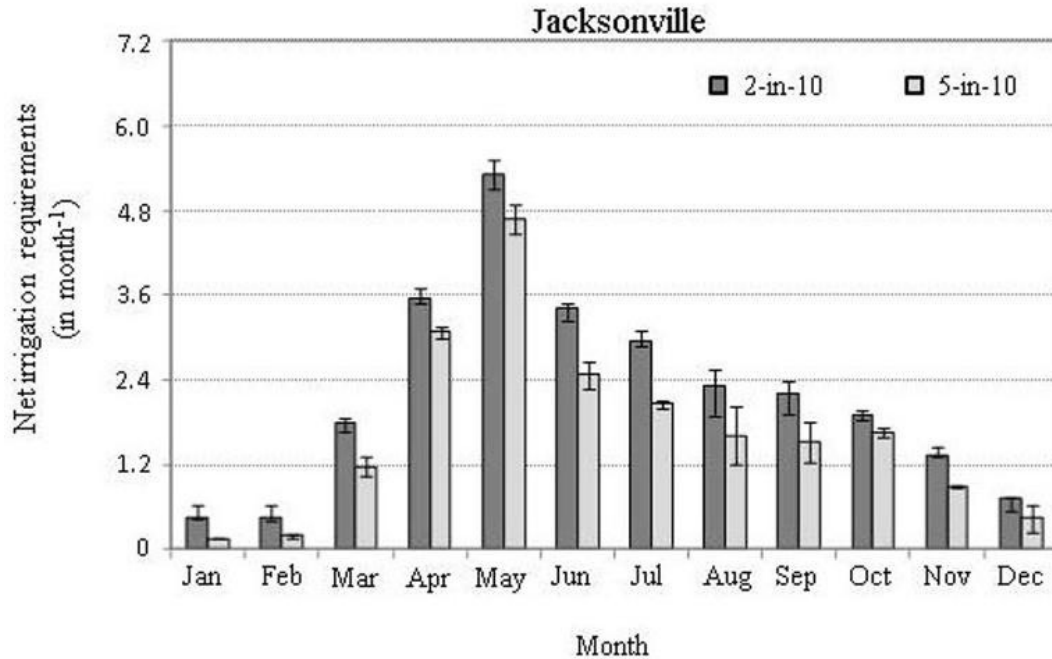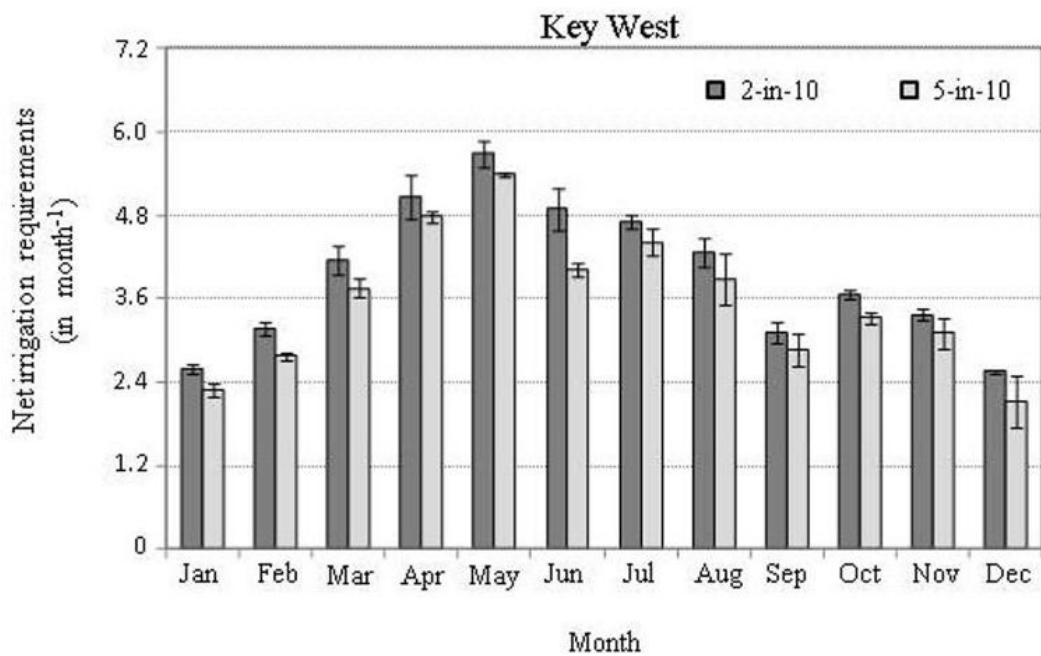
Figure 5. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Jacksonville, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
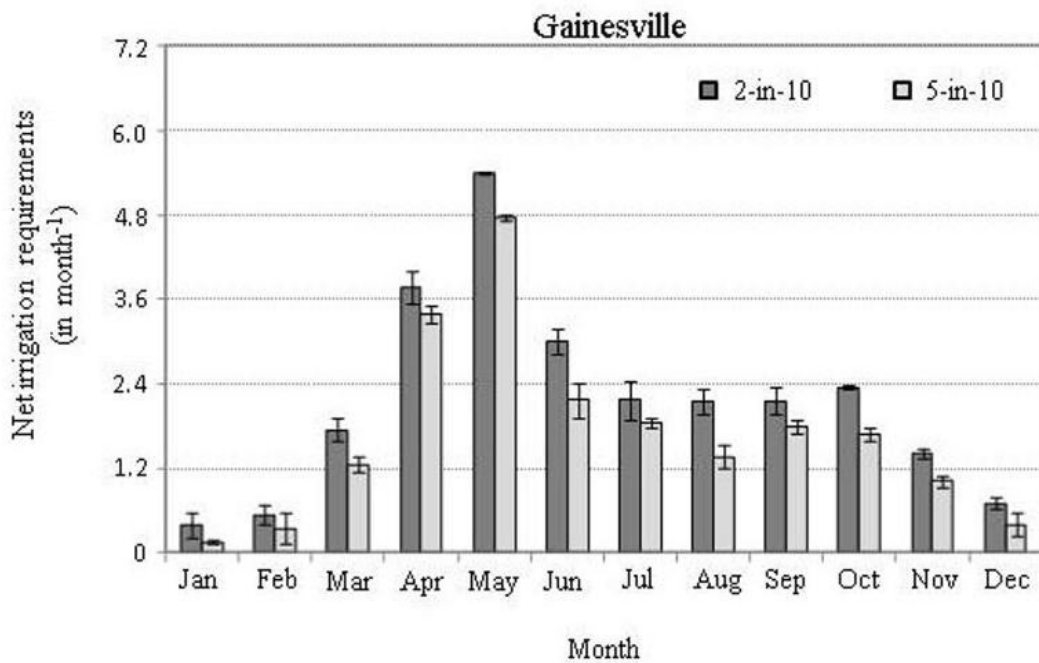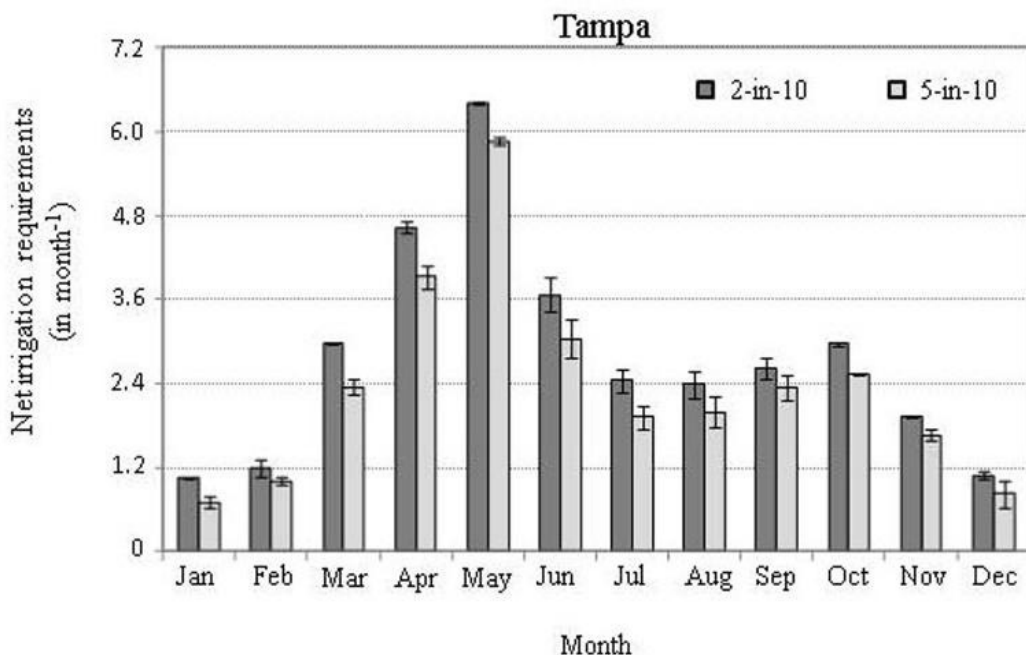

Figure 6. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Gainesville, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
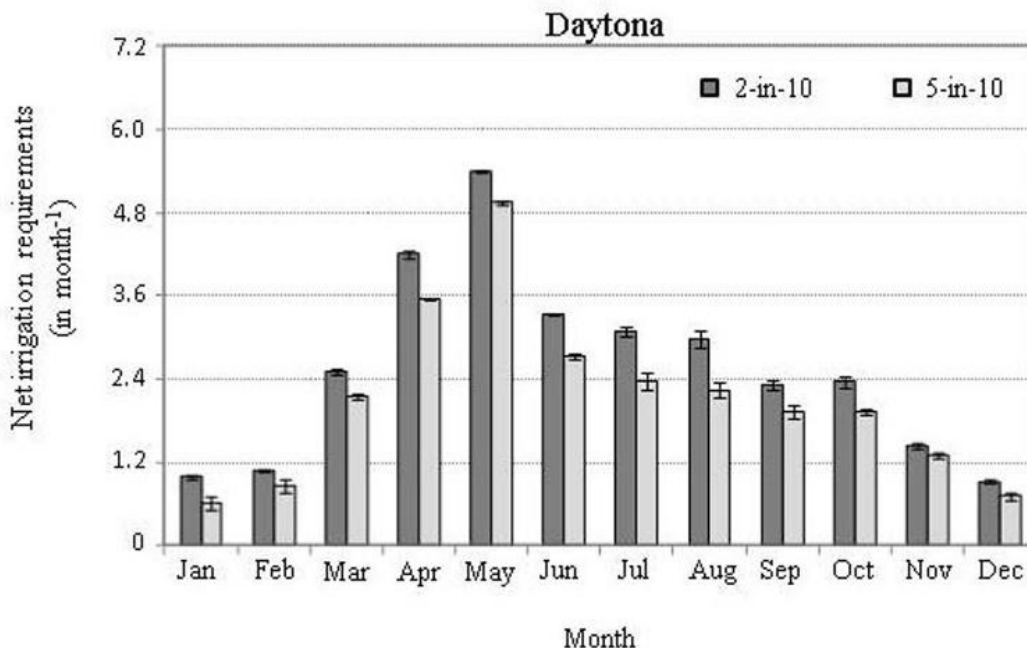
Figure 7. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Daytona, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
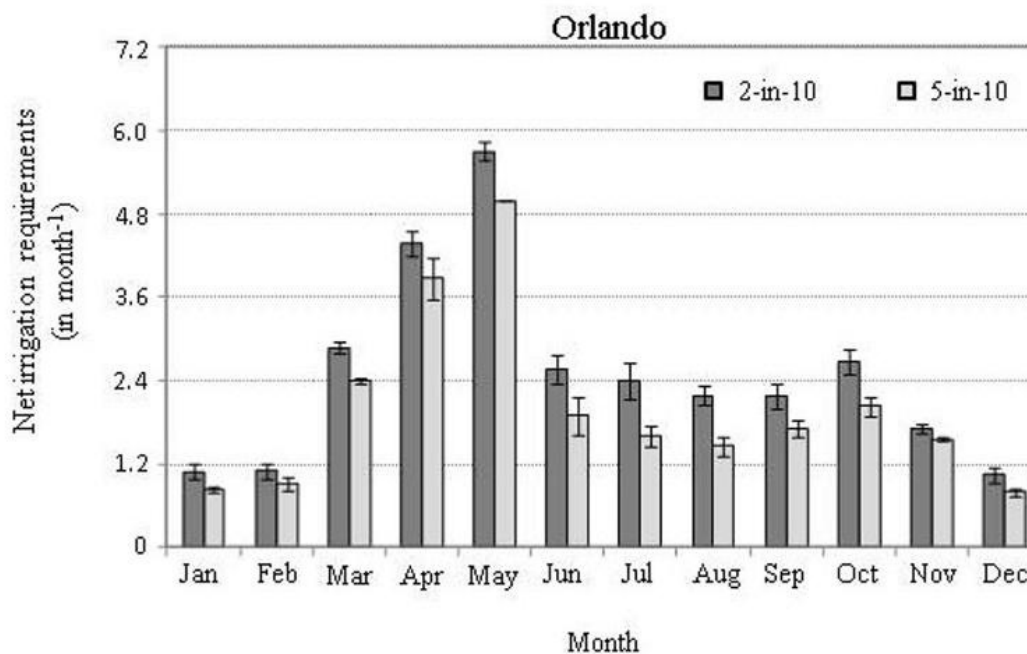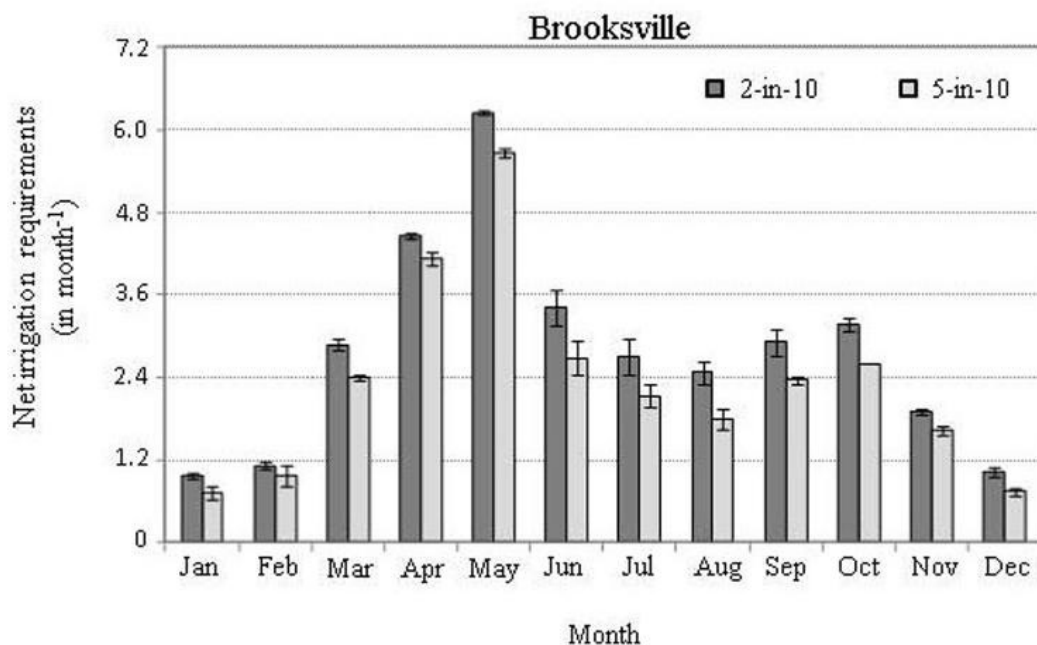

Figure 8. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Orlando, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
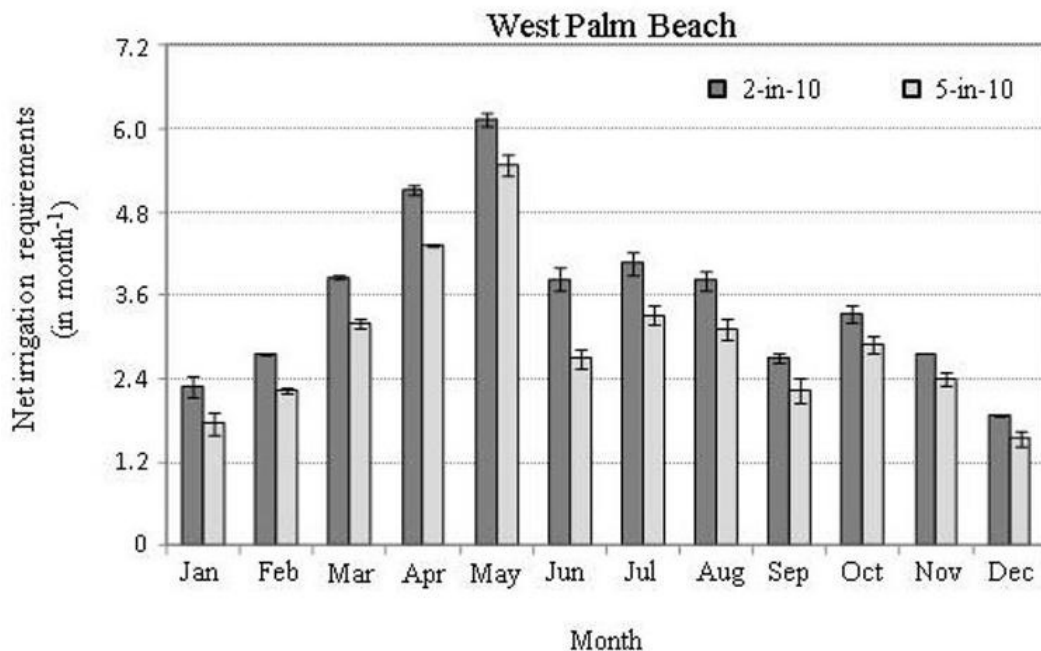
Figure 9. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for West Palm Beach, FL. Error bars represent standard deviation due to different root zones and soil types across all time.
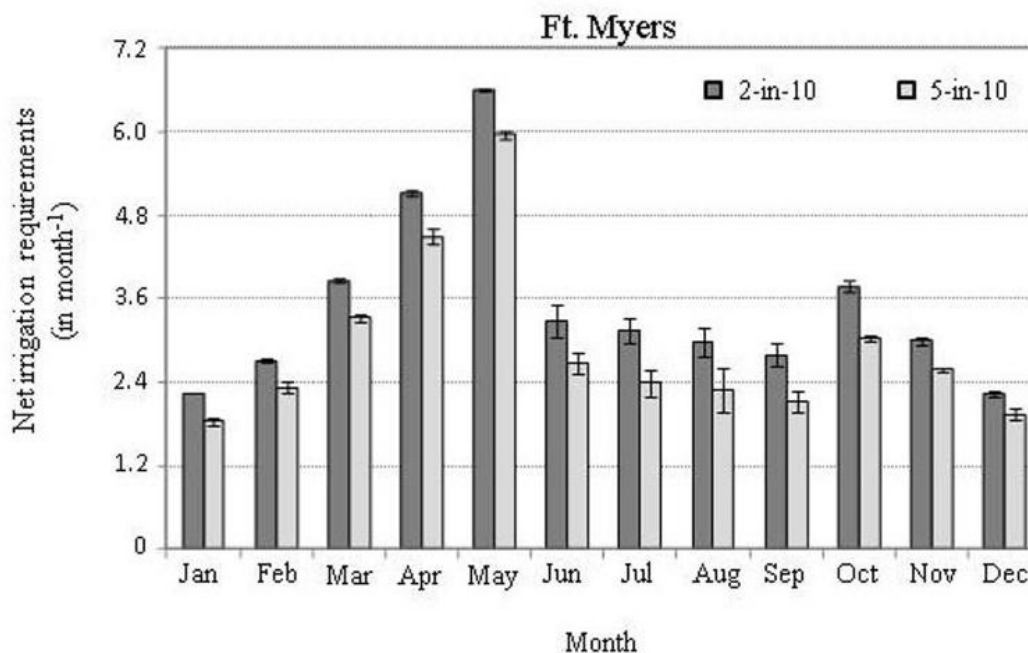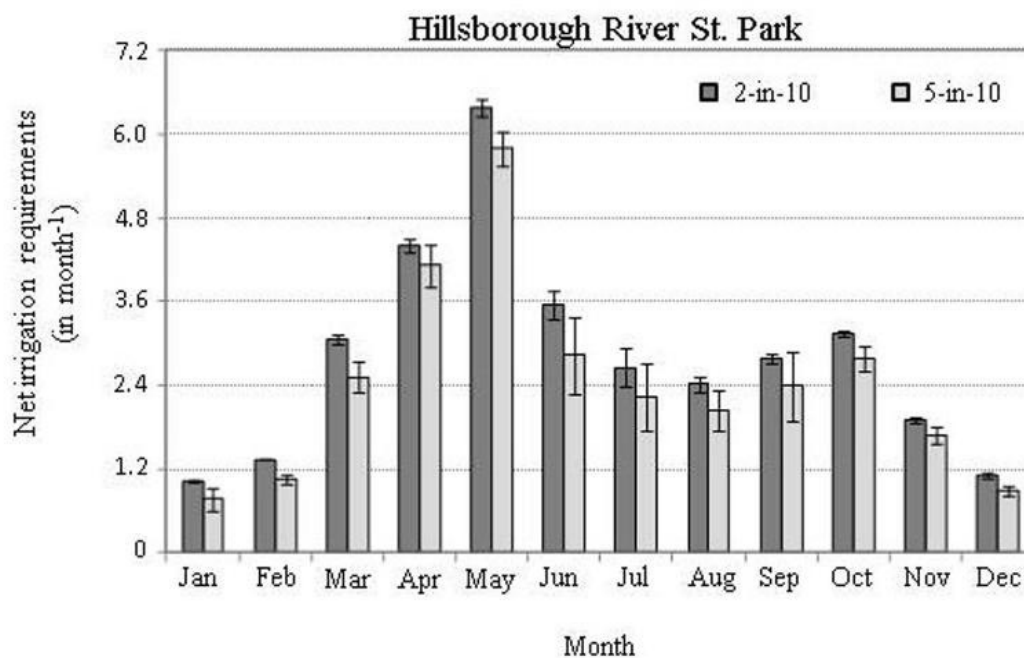

Figure 10. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Ft. Myers, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
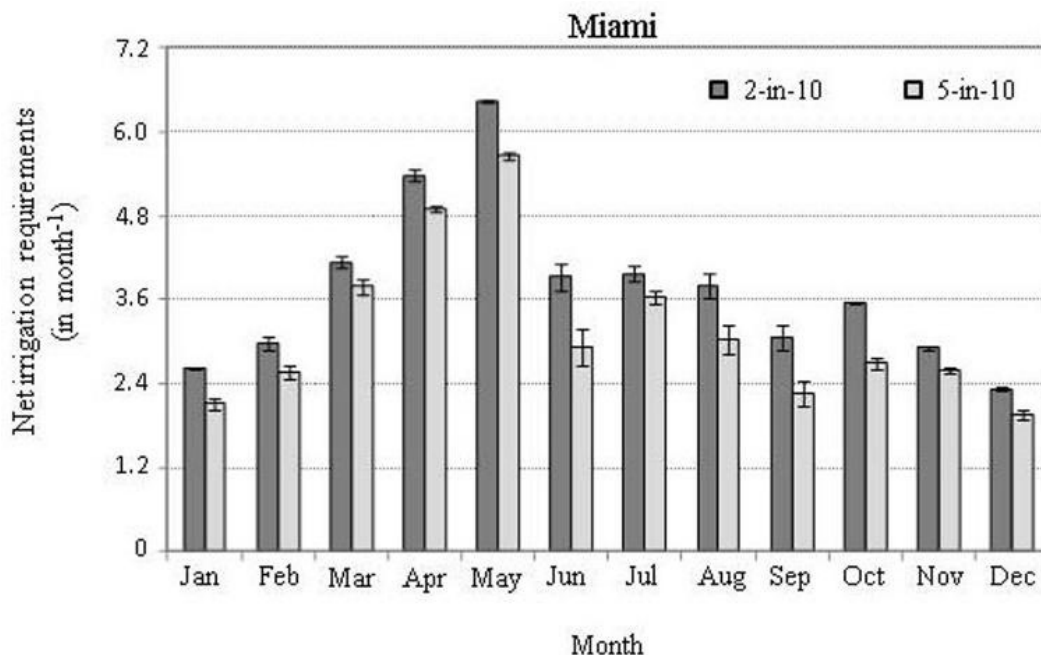
Figure 11. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Miami, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
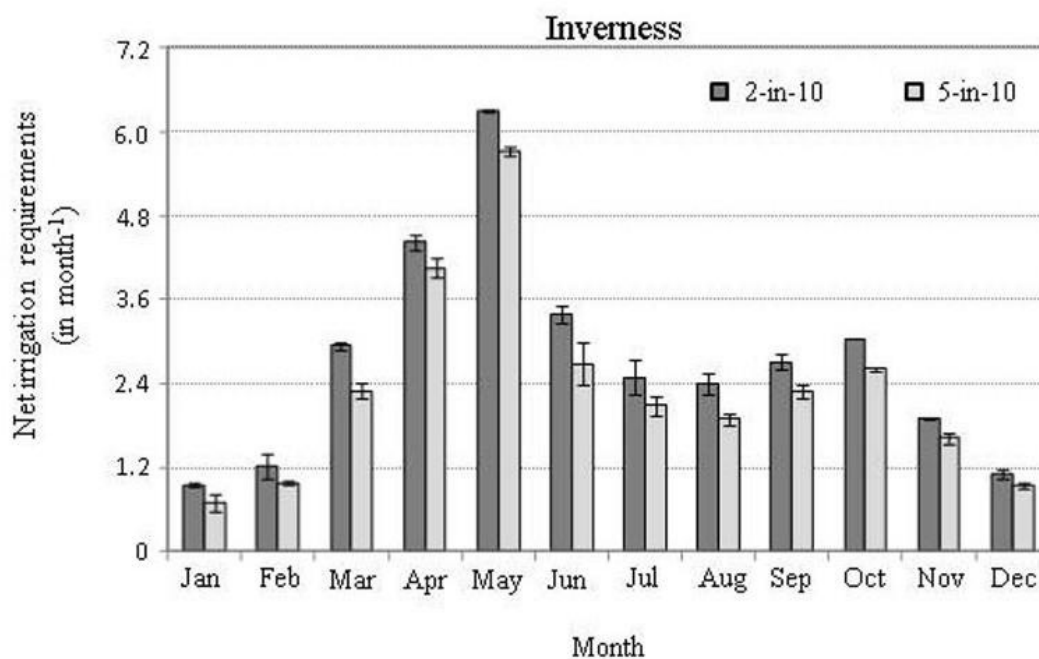

Figure 12. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Key West, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
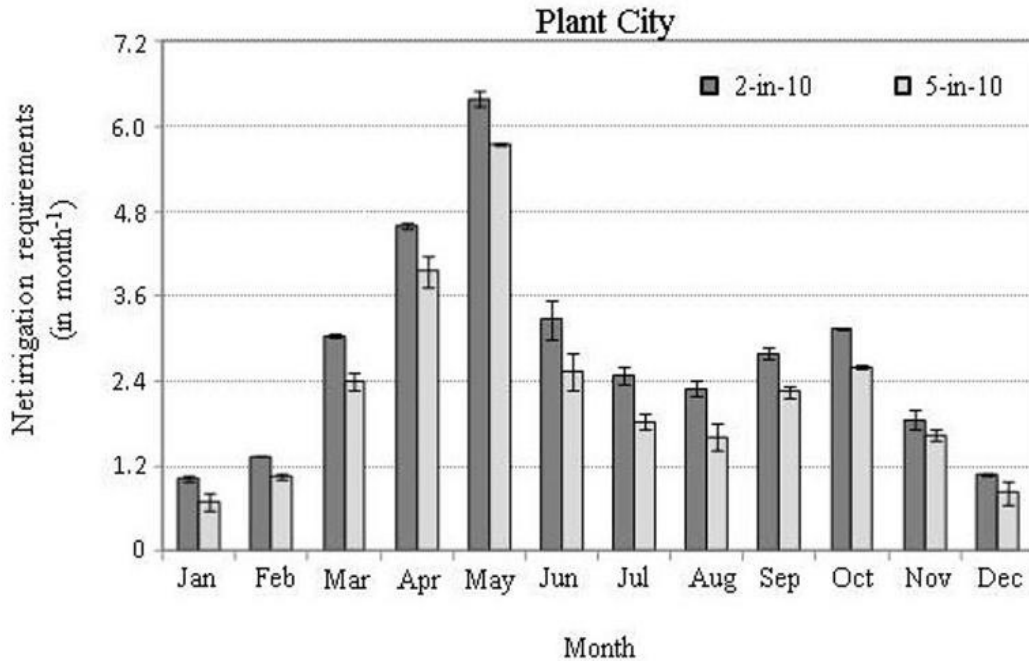
Figure 13. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Tampa, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.

Figure 14. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Brooksville, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
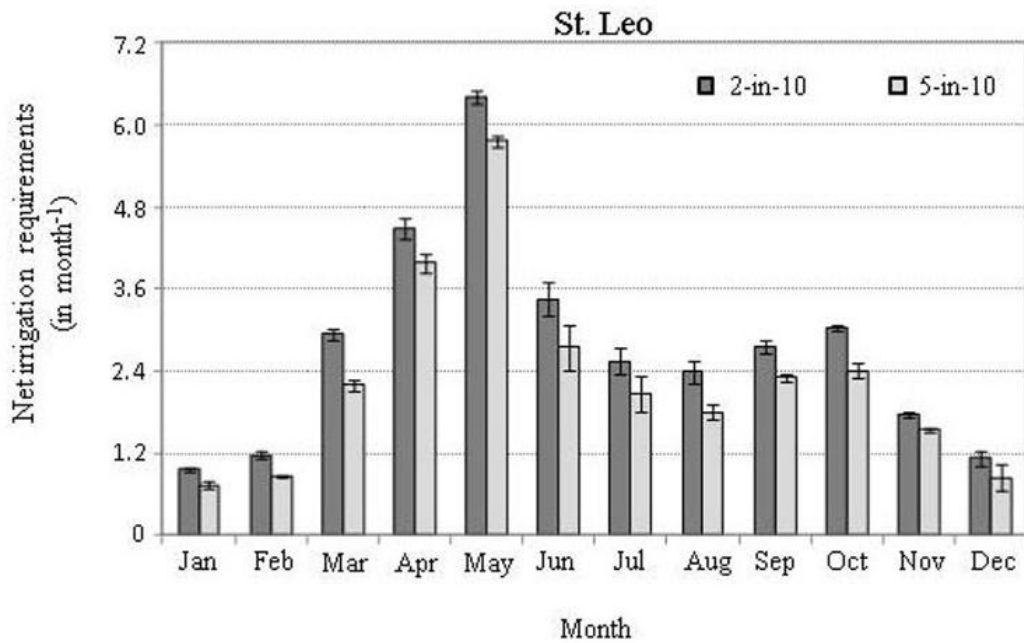
Figure 15. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Hillsborough River St. Park, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.

Figure 16. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Inverness, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
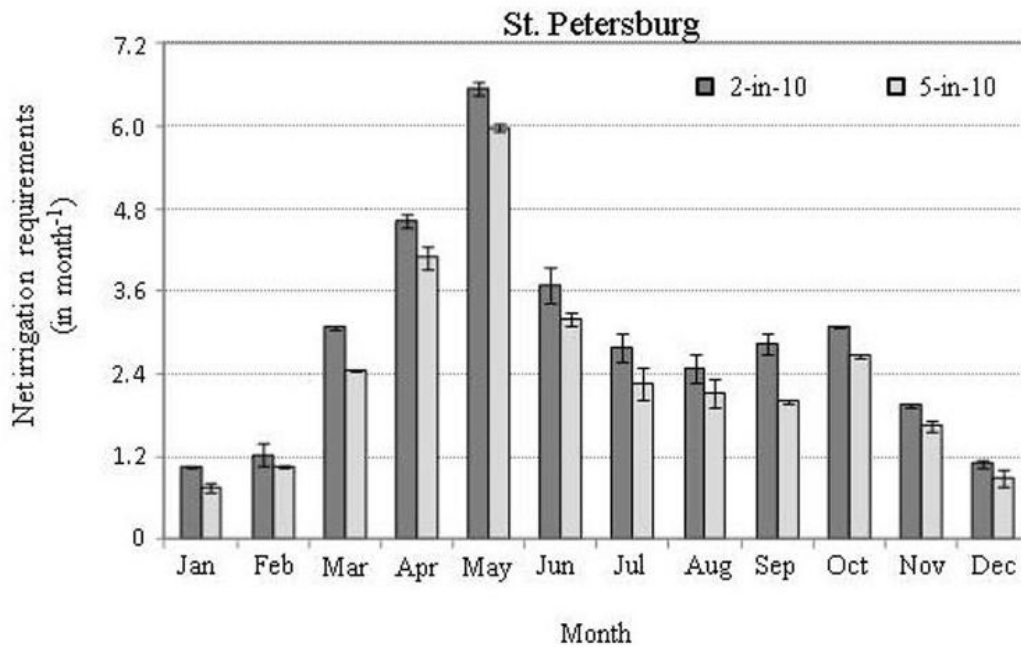
Figure 17.   Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Plant City, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.

Figure 18. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for St. Leo, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.

Figure 19. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for St. Petersburg, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.
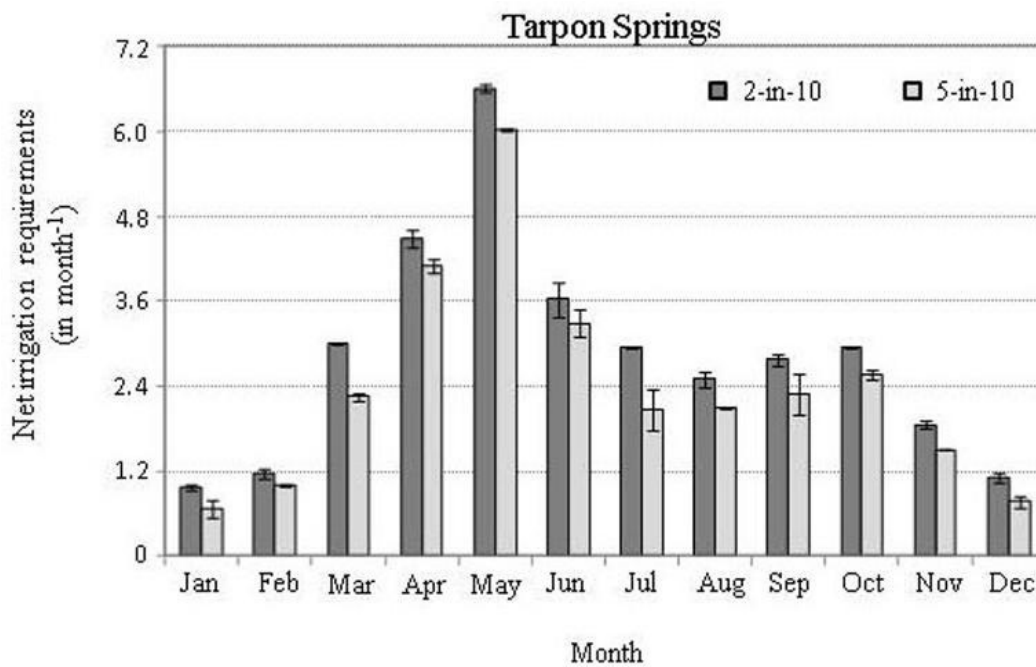

Figure 20. Long-term (1980-2009) mean monthly distribution of the 2-in-10 (80th percentile) and 5-in-10 (50th percentile) net irrigation requirements for Tarpon Springs, FL. Error bars represent the standard deviation due to different root zones and soil types across all time.

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