Water Requirements of NORTH CAROLINA TURFGRASSES

A Guide for Irrigation Technicians and Turfgrass Managers

Water is an essential component for plant growth. In turfgrasses it comprises 75 to 90 percent of the fresh weight of the plant, and irrigation is a key cultural practice in turfgrass management. Only 1 percent of the water absorbed is utilized for metabolic activity. Most is used in transpiration, which is the primary cooling process of the plant. Water, absorbed by the roots and carrying nutrients, is dispersed to all cells for function and growth. The uptake of water is also crucial for maintaining turgor pressure of plant cells, which results in plant rigidity and cell elongation. Turgor pressure is a critical function in turf resiliency, influencing its ability to tolerate wear and recover from traffic damage. By considering the factors that contribute to water loss, turfgrass managers can devise effective irrigation plans for specific sites.

EVAPOTRANSPIRATION

Evapotranspiration (ET) is the process by which water is transferred to the atmosphere from vegetative surfaces. The two components to this process are evaporation and transpiration. Evaporation is the physical process whereby water is changed from a liquid to a gas. This occurs on water surfaces, such as ponds, streams, wet soil, or wet vegetation. Transpiration is a plant process whereby water is evaporated through a series of openings on the leaf surfaces called stomata. For all practical purposes, the two processes are considered together on an area of turf, although evaporative loss is usually between 1 and 3 percent, meaning that the great majority of moisture is lost through the transpiration process. ET cools turfgrass since energy is used in the process and heat is lost. It is similar to the way humans cool off when the skin is moist and the wind is blowing.

A number of environmental conditions affect the rate at which moisture is lost from the turf surface. The most important of these are radiant energy (sunlight), atmospheric vapor pressure (relative humidity), temperature, wind movement, and available soil moisture supply. When using Best Management

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Practices (BMPs), the type of turf is less important as a factor in ET as long as the turf is actively growing and has adequate supply of moisture from the soil. Minimal ET rates occur under dark, cloudy days with high relative humidity, low temperatures, and no wind. Maximum ET rates occur on bright sunny days with low relative humidity, high temperatures, and moderate to high winds.

POTENTIAL EVAPOTRANSPIRATION

The concept of potential evapotranspiration has been developed to predict water requirements of plants with limited climatic data. Potential evapotranspiration (ETP) is defined as the water loss from a continuous surface of turf that fully shades the ground, exerts little or no resistance to the flow of water into the atmosphere, and always has an adequate supply of soil moisture. Potential evapotranspiration is useful in predicting the water requirements of irrigated turf.

Since actual on-site measurement of ET is often impractical or impossible, empirical methods have been developed to estimate the ETP. These include the Thornthwaite, Blaney-Criddle, and Penman methods.

- Thornthwaite uses temperature and day-length data. It is less reliable for short-term prediction.
- Blaney-Criddle and modified versions use a consumptive use coefficient for specific types of turf, temperature, and percent daylight to predict monthly ETP. The accuracy of these models depends on using the appropriate turf consumptive use coefficients, which are often not available, and the correct light levels.
- Penman equation predicts daily ETP based on net solar radiation, temperature, vapor pressure, and wind speed, and thus requires a more extensive data set. This method is probably the most widely used of the three, but has been found to consistently underestimate water loss that occurs on hot, windy days.

IRRIGATION MANAGEMENT

Irrigation is one of the key cultural practices used in turf management. However, irrigation system installation and the cost of buying or pumping water can be expensive. In general, irrigation supplements, not substitutes for, rainfall except on very specialized areas or under extreme drought conditions.

Irrigation management must include water conservation practices. Lack of adequate moisture can result in stress, dormancy, and even death of turfgrass. Providing the correct amount of water at the appropriate time helps ensure healthy, high quality turf for recreational or landscape purposes. To provide the proper amount of moisture at the right time requires adequate recording of climatic conditions so that the turfgrass manager can determine if soil moisture reserves are adequate or if irrigation should be scheduled.

Variables to Consider.

Irrigation system programming by a trained irrigation technician is essential because of the many variables involved, such as slope, soil types, rooting depth, etc. This is true for even the most sophisticated irrigation system available.

- Knowledge of the water reserve in the root zone is a key requirement for determining irrigation needs. On many turf areas, 75 percent of the root system is often found in the top 4 to 6 inches of soil. On other areas, the depth of rooting can vary from less than 4 inches to 6 to 12 inches, depending on how the turf is managed and the time of year. For cool-season grasses, such as tall fescue, the peak rooting times are fall and spring. The roots of warm-season grasses, such as bermudagrass, often peak in the summer.
- With knowledge of soil water storage, actual daily rainfall, and calculated daily evapotranspiration (ET) information, it is possible to determine when the available soil moisture will be depleted and irrigation required. For specialized areas, such as a golf course, a weather station located at the maintenance facility can record information necessary to calculate the daily ET. ET varies daily, depending on local climatic conditions of temperature, humidity, solar radiation, and vapor pressure.

Given the imperfect nature of any irrigation system, different areas of any turf site may be overwatered, correctly watered, and under-watered. Therefore, only through careful study and trial and error can the irrigation technician achieve the most appropriate irrigation timing and soil moisture level, preferably on the drier side.

The best method of determining whether the proper amount of water has been applied is to determine the depth of water penetration following irrigation by coring with a soil tube. If water has not penetrated to the desired depth by 6 to 8 hours after irrigation, then the next irrigation time should be increased. If water has moved well beyond the desired irrigation depth, then the next irrigation time should be decreased.

To avoid runoff, the application rate must not exceed the soil infiltration rate. If necessary, the irrigation system can be cycled to ensure proper infiltration. In addition, one of the primary responsibilities of the irrigation technician is to monitor the heads frequently to be sure all heads are operating properly and that no head is inadvertently applying water to an area where irrigation is not required.

Irrigation Management for Water Conservation

- Irrigation frequency will vary with environmental or climatic factors. Less frequent irrigation is needed in the summer during peak ET demands when the roots of turf are deeper since the turf must access to water deeper in the soil profile. More frequent irrigation may be needed when roots are shallow in the spring if the ET demand is higher. Checking the depth of the root system with a soil probe can help guide how deeply to wet the soil profile.
- Water should not be applied at a rate that exceeds the infiltration capacity of the soil otherwise runoff may occur, especially from sloped sites, where turf thatch has accumulated, or turf is being grown on compacted soils. In these situations it is more effective to apply only a portion of the water needed. After the water has infiltrated and percolated into the soil, apply another portion of the water and repeat the cycle until all the water is applied. This is called bump irrigation.
- For a healthy, durable turf that withstands minor drought, encourage deep rooting by irrigating thoroughly but as infrequently as possible. A sure sign that turf will benefit from irrigation is a wilted appearance. One initial symptom of wilting is footprinting (footprints on the turf that will not disappear within one hour). This symptom is soon followed by actual wilt, where the leaves of the turf lose an upright erect appearance and take on a grayish or purple-to-blue cast. Usually, only a few areas will appear wilted in a general location; these areas serve as good indicator spots when assessing the need to water. Delay watering the entire turf area for another day or so by irrigating only the wilted areas.
- Allowing some subtle wilt stress to develop in a turf will not destroy the turf and may actually encourage deep rooting. Allowing the soil to dry to 50 percent of its available water between irrigation does not make the turf more prone to stress. As drought stress becomes more severe however, turf becomes more susceptible to traffic injury, insect and disease damage, and weed invasion, especially at lower mowing heights. Thus, wilt stress should be minimized for surfaces that are mowed at very low heights (i.e. putting greens) or receive high amounts of traffic from play or vehicles.
- The most efficient time of day to water is between 10 p.m. and 8 a.m. Nighttime is generally less windy, cooler, and more humid, resulting in less evaporation and a more efficient application of water. Contrary to popular belief, irrigating during this period does not stimulate disease development.
- Some turf areas, such as golf greens, may need more than one irrigation event per 24-hour period; accordingly, these sites will need some irrigation during daylight hours. The tendency to water "heavily and infrequently" on these sites will result in an inefficient use of water since these sites typically have rapid drainage. Under these conditions, site-specific watering (e.g., hand watering and syringing) is performed during daylight hours because of the need to visually identify areas where the water should be applied. Employees responsible for hand watering and syringing should be thoroughly trained regarding the most effective and efficient techniques for applying water during the day.

Cultural Considerations in Water Conservation

- Maintain the soil pH between 5.5 and 6.5
- Minimize soil compaction through turf cultivation
- Minimize potential problems from pesticides toxic to the root system, particularly certain preemergence herbicides
- Control potentially serious insect, disease, and nematode pests that feed on the root system
- Maintain an adequate soil potassium (K) level by applying potassium based on soil test recommendations

- Avoid excessive nitrogen (N) fertilization, especially of cool-season grasses; it forces shoot growth at the expense of root development
- Maintain as high a cutting height as is practical on putting greens, tees, or fairways
- Avoid excessive thatch accumulation; thatch encourages root development only in the thatch/mat layer
- Avoid intense mechanical maintenance practices, such as topdressing, vertical cutting, and turf cultivation, during summer stress periods

WEATHER STATION

Data collected at a weather station can be a valuable when calculating ETP. Weather stations monitor and record the some or all of the following parameters: 1) air temperature; 2) soil temperature; 3) wind speed; 4) wind direction; 5) barometric pressure; 6) rainfall; 7) humidity; and 8) solar radiation. Information feeds into a computer programmed to calculate irrigation requirements. This recommendation is then used by the superintendent and irrigation technician to determine how the irrigation system will be used to apply the amount necessary to replace soil moisture.

In addition to the weather station being used in irrigation management, the system will record information that can be used in other components of an Integrated Pest Management (IPM) program. For example, information can be used in models for predicting disease development, in calculating degree days for insecticide application, and in determining when to apply preemergence herbicides.

Monthly turfgrass irrigation requirements based on climatic conditions for each physiogeographic area of the state are given in tables 1 through 8. This information was based on the collection of at least 50 years of weather data.

Table 1. North Carolina Southern Mountains (Asheville Area) Turfgrass Irrigation Requirements

Month	Mean Temperature (°F)	Average Rainfall	ETP [a]	Gross Irrigation Requirement [b]	Net Irrigation Requirement [c]
		(inches)			
Jan	37.5	2.92	0.50	-	-
Feb	40.3	3.12	0.63	-	-
March	46.8	3.90	1.35	-	-
April	56.3	3.19	2.65	1.06	1.33
May	64.0	3.18	4.33	2.74	3.43
June	70.7	3.35	5.83	4.16	5.19
July	74.2	3.20	6.36	4.76	5.95
Aug	73.2	3.60	5.76	3.96	4.95
Sept	67.0	3.06	4.11	2.58	3.23
Oct	57.0	2.52	2.40	1.14	1.43
Nov	47.3	2.75	1.03	-	-
Dec	40.0	2.68	0.56	-	-
Total	-	37.47	35.51	20.40	25.51

[a] ETP is potential evapotranspiration or the reference water use based on climatic information calculated using a modified Blaney-Criddle method.
[b] Gross irrigation requirement is determined by subtracting the effective rainfall from the ETP. Effective rainfall is assumed to be 50 percent of the average monthly rainfall.
[c] The net amount of water required by the turfgrasses is quantified by the following equation: Irrigation Requirement = $\frac{GIR}{DU}$
Where GIR is the gross irrigation requirement and DU is the uniformity of distribution of the irrigation system, which may be assumed to be 80 percent.

Table 2. North Carolina Northern Mountains (Lenoir Area) Turfgrass Irrigation Requirements.					
Month	Mean Temperature (°F)	Average Rainfall	ETP [a]	Gross Irrigation Requirement [b]	Net Irrigation Requirement [c]
		(inches)			
Jan	39.5	3.71	0.40	-	-
Feb	42.4	3.94	0.51	-	-
March	49.3	4.65	1.13	-	-
April	58.3	4.10	2.39	0.34	0.43
May	66.1	4.18	3.99	1.90	2.38
June	72.9	4.49	5.31	3.07	3.83
July	76.4	4.73	5.95	3.59	4.48
Aug	75.4	4.32	5.36	3.20	4.00
Sept	69.2	4.33	3.80	1.64	2.04
Oct	59.1	3.58	2.20	0.41	0.51
Nov	49.3	3.27	0.91	-	-
Dec	41.3	3.54	0.45	-	-
Total	-	48.66	32.40	14.15	17.69

[a] ETP is potential evapotranspiration or the reference water use based on climatic information calculated using a modified Blaney-Criddle method.
[b] Gross irrigation requirement is determined by subtracting the effective rainfall from the ETP. Effective rainfall is assumed to be 50 percent of the average monthly rainfall.
[c] The net amount of water required by the turfgrasses is quantified by the following equation: Irrigation Requirement = $\frac{GIR}{DU}$
Where GIR is the gross irrigation requirement and DU is the uniformity of distribution of the irrigation system, which may be assumed to be 80 percent.

Table 3. North Carolina Northern Piedmont (Winston-Salem Area) Turfgrass Irrigation Requirements					
Month	Mean Temperature (°F)	Average Rainfall	ETP [a]	Gross Irrigation Requirement [b]	Net Irrigation Requirement [c]
		(inches)			
Jan	38.2	3.42	0.58	-	-
Feb	40.7	3.24	0.72	-	-
March	48.5	3.76	1.61	-	-
April	5709	3.33	3.15	1.49	1.86
May	66.5	3.48	5.17	3.43	4.29
June	74.1	3.64	6.84	5.02	6.28
July	77.4	4.49	7.44	5.20	6.49
Aug	76.1	4.15	6.69	4.62	5.77
Sept	69.7	3.80	4.74	2.84	3.55
Oct	58.7	2.93	2.82	1.36	1.69
Nov	48.7	2.78	1.28	-	-
Dec	40.2	3.05	0.64	-	-
Total	-	42.08	41.68	23.96	29.93

[a] ETP is potential evapotranspiration or the reference water use based on climatic information calculated using a modified Blaney-Criddle method.
[b] Gross irrigation requirement is determined by subtracting the effective rainfall from the ETP. Effective rainfall is assumed to be 50 percent of the average monthly rainfall.
[c] The net amount of water required by the turfgrasses is quantified by the following equation: Irrigation Requirement = $\frac{GIR}{DU}$
Where GIR is the gross irrigation requirement and DU is the uniformity of distribution of the irrigation system, which may be assumed to be 80 percent.

Table 4. North Carolina Central Piedmont (Raleigh Area) Turfgrass Irrigation Requirements

Month	Mean Temperature(°F)	Average Rainfall	ETP [a]	Gross Irrigation Requirement [b]	Net Irrigation Requirement [c]
		(inches)			
Jan	40.2	3.63	0.59	-	-
Feb	42.9	3.44	0.77	-	-
March	49.9	3.79	1.68	-	-
April	59.3	2.88	3.27	1.83	2.29
May	67.2	3.64	5.20	3.38	4.23
June	74.6	3.54	6.88	5.11	6.39
July	78.4	4.51	7.60	5.35	6.68
Aug	77.1	4.33	6.73	4.57	5.71
Sept	70.8	3.70	4.86	3.01	3.76
Oct	60.0	2.94	2.85	1.38	1.73
Nov	50.6	2.90	1.29	-	-
Dec	42.4	3.01	0.65	-	-
Total	-	42.14	42.37	24.63	30.79

[a] ETP is potential evapotranspiration or the reference water use based on climatic information calculated using a modified Blaney-Criddle method.
[b] Gross irrigation requirement is determined by subtracting the effective rainfall from the ETP. Effective rainfall is assumed to be 50 percent of the average monthly rainfall.
[c] The net amount of water required by the turfgrasses is quantified by the following equation: Irrigation Requirement $= \frac{GIR}{DU}$
Where GIR is the gross irrigation requirement and DU is the uniformity of distribution of the irrigation system, which may be assumed to be 80 percent.

Table 5. North Carolina Southern Piedmont (Charlotte Area) Turfgrass Irrigation Requirements

Month	Mean Temperature(°F)	Average Rainfall	ETP [a]	Gross Irrigation Requirement [b]	Net Irrigation Requirement [c]
		(inches)			
Jan	41.2	3.72	0.66	-	-
Feb	44.3	3.65	0.82	-	-
March	51.1	4.39	1.78	-	-
April	60.4	3.19	3.40	1.81	2.26
May	68.6	3.33	5.51	3.85	4.81
June	75.7	3.52	7.11	5.35	6.69
July	79.2	3.83	7.67	5.76	7.19
Aug	78.1	3.80	6.92	5.02	6.28
Sept	71.8	3.43	5.03	3.32	4.14
Oct	61.1	3.14	2.97	1.40	1.75
Nov	51.4	3.05	1.40	-	-
Dec	43.3	3.22	0.73	-	-
Total	-	42.14	44.00	26.51	33.12

[a] ETP is potential evapotranspiration or the reference water use based on climatic information calculated using a modified Blaney-Criddle method.
[b] Gross irrigation requirement is determined by subtracting the effective rainfall from the ETP. Effective rainfall is assumed to be 50 percent of the average monthly rainfall.
[c] The net amount of water required by the turfgrasses is quantified by the following equation: Irrigation Requirement $= \frac{GIR}{DU}$
Where GIR is the gross irrigation requirement and DU is the uniformity of distribution of the irrigation system, which may be assumed to be 80 percent.

Table 6. North Carolina Southern Coastal Plain (Wilmington Area) Turfgrass Irrigation Requirements					
Month	Mean Temperature(°F)	Average Rainfall	ETP [a]	Gross Irrigation Requirement [b]	Net Irrigation Requirement [c]
		(inches)			
Jan	46.5	3.70	0.80	-	-
Feb	48.4	3.60	0.97	-	-
March	54.7	4.12	2.02	-	-
April	62.8	2.94	3.54	2.07	2.59
May	70.5	4.05	5.51	3.49	4.36
June	77.2	5.24	7.03	4.41	5.51
July	80.4	7.92	7.74	3.78	4.73
Aug	79.5	7.19	7.03	3.43	4.29
Sept	74.8	6.14	5.20	2.13	2.66
Oct	65.0	3.10	3.21	1.66	2.08
Nov	55.9	3.05	1.58	-	-
Dec	48.3	3.46	0.88	-	-
Total	-	54.53	45.51	20.97	26.22

[a] ETP is potential evapotranspiration or the reference water use based on climatic information calculated using a modified Blaney-Criddle method.
[b] Gross irrigation requirement is determined by subtracting the effective rainfall from the ETP. Effective rainfall is assumed to be 50 percent of the average monthly rainfall.
[c] The net amount of water required by the turfgrasses is quantified by the following equation: Irrigation Requirement $= \frac{GIR}{DU}$
Where GIR is the gross irrigation requirement and DU is the uniformity of distribution of the irrigation system, which may be assumed to be 80 percent.

Table 7. North Carolina Central Coastal Plain (Kinston Area) Turfgrass Irrigation Requirements					
Month	Mean Temperature(°F)	Average Rainfall	ETP [a]	Gross Irrigation Requirement [b]	Net Irrigation Requirement [c]
		(inches)			
Jan	42.2	3.99	0.73	-	-
Feb	44.6	3.52	0.91	-	-
March	51.5	3.95	1.93	-	-
April	60.4	3.27	3.52	1.89	2.36
May	68.2	4.20	5.54	3.44	4.30
June	75.2	5.33	7.12	4.46	5.57
July	78.9	6.22	7.84	4.73	5.91
Aug	77.6	5.63	7.12	4.31	5.38
Sept	72.2	5.23	5.21	2.60	3.24
Oct	61.6	3.12	3.18	1.62	2.03
Nov	52.8	2.97	1.55	-	-
Dec	44.3	3.31	0.82	-	-
Total	-	50.56	45.47	23.05	28.79

[a] ETP is potential evapotranspiration or the reference water use based on climatic information calculated using a modified Blaney-Criddle method.
[b] Gross irrigation requirement is determined by subtracting the effective rainfall from the ETP. Effective rainfall is assumed to be 50 percent of the average monthly rainfall.
[c] The net amount of water required by the turfgrasses is quantified by the following equation: Irrigation Requirement $= \frac{GIR}{DU}$
Where GIR is the gross irrigation requirement and DU is the uniformity of distribution of the irrigation system, which may be assumed to be 80 percent.

Table 8. North Carolina Northern Coastal Plain (Rocky Mount Area) Turfgrass Irrigation Requirements

Month	Mean Temperature(°F)	Average Rainfall	ETP [a]	Gross Irrigation Requirement [b]	Net Irrigation Requirement [c]
		(inches)			
Jan	40.5	3.67	0.66	-	-
Feb	43.7	3.53	0.81	-	-
March	51.2	4.12	1.76	-	-
April	60.8	3.08	3.28	1.74	2.18
May	68.3	3.56	5.35	3.57	4.46
June	75.0	4.35	6.91	4.74	5.92
July	78.9	5.08	7.66	5.12	6.40
Aug	77.6	5.01	6.91	4.41	5.51
Sept	72.0	4.58	5.06	2.77	3.46
Oct	61.3	2.90	3.06	1.61	2.01
Nov	52.7	2.88	1.47	-	-
Dec	44.0	3.14	0.77	-	-
Total	-	45.83	43.70	23.96	29.94

[a] ETP is potential evapotranspiration or the reference water use based on climatic information calculated using a modified Blaney-Criddle method.
[b] Gross irrigation requirement is determined by subtracting the effective rainfall from the ETP. Effective rainfall is assumed to be 50 percent of the average monthly rainfall.
[c] The net amount of water required by the turfgrasses is quantified by the following equation: Irrigation Requirement $= \frac{GIR}{DU}$
Where GIR is the gross irrigation requirement and DU is the uniformity of distribution of the irrigation system, which may be assumed to be 80 percent.

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