TEEING UP Success:

Turf Choices and Smarter Water Planning

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WATER MANAGEMENT: FINDING THE BALANCE

WATER MANAGEMENT: FINDING THE BALANCE

- Reduced growth and recovery
- Increased surface firmness
- Reduced tolerance to cart and foot traffic
- Greater visible stress

- Reduced soil oxygen
- Shallow rooting
- Soft playing surface
- Increased disease pressure
- Reduced traction and traffic tolerance

WHY WATER MANAGEMENT PLANNING MATTERS

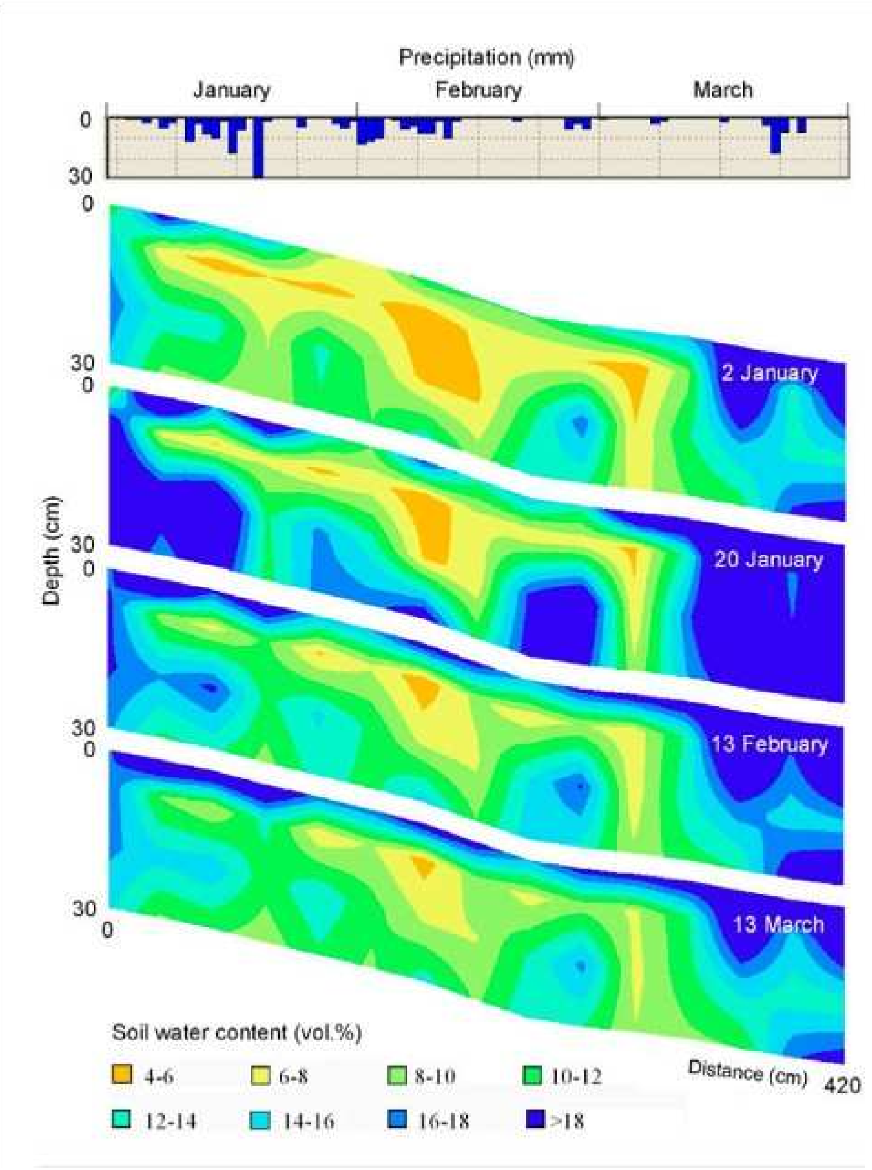
- Root depth and plant stability
- Surface firmness and playability
- Pest pressure (diseases and weeds)
- Labor and input efficiency
- Communication with ownership

WATER X PESTICIDES

- Drought may prolong soil residual activity.
- Stressed plants are harder to kill.
- Drought can alter plant architecture, leaf surfaces and spray droplet behavior
    - Wilt and leaf droop can alter coverage potential
    - Extended drought can create barriers that are more difficult for herbicides to penetrate

WATER X PESTICIDES

- Drought can also impact pesticide movement in soils.
- In coarse-textured soils, water repellency (hydrophobicity) can induce preferential flow channels, undermining uniform applications of soil-intended pesticides.
- Wetting agents and soil amendments can be instrumental in addressing this.



Oostindie et al., 2011

WATER X PESTICIDES

Active Ingredient	Trade Name	Approximate Half-Life in Moist Soil	Approximate Half-Life in Saturated Soil
Indaziflam	Specticle	120 days	120 days
Oryzalin	Surflan AS	45 days	5 days
Oxadiazon	Ronstar	60 days	30 – 60 days
Pendimethalin	Pendulum	45 days	12 days
Prodiamine	Barricade	56 days	28 days

Table: Travis Gannon, PhD | NC State

Numbers are relative estimates, and can be heavily influenced by environmental conditions.

- Saturated soil conditions (waterlogged, flooded) may adversely affect preemergence herbicide performance.
- Limited oxygen in these soils can speed up degradation of some herbicide products.
- ***If conditions are saturated or there has been heavy rainfall:***
  - Monitor closely for weed breakthrough
  - Consider increasing active ingredient rate in sequential applications
  - Have postemergence herbicides ready

BUILDING A WATER MANAGEMENT PLAN

A strong water management plan considers:

- Plant water demand
- Turfgrass species characteristics
- Rainfall patterns
- Spatial and temporal variability
- Irrigation water quality
- Soil water-holding capacity
- Irrigation system performance
- Monitoring and adjustment

STEP 1: ESTIMATING PLANT WATER DEMAND

- Water demand changes daily
- Weather drives water use
- Turfgrass species and cultivars use water differently
- We need a consistent way to estimate demand

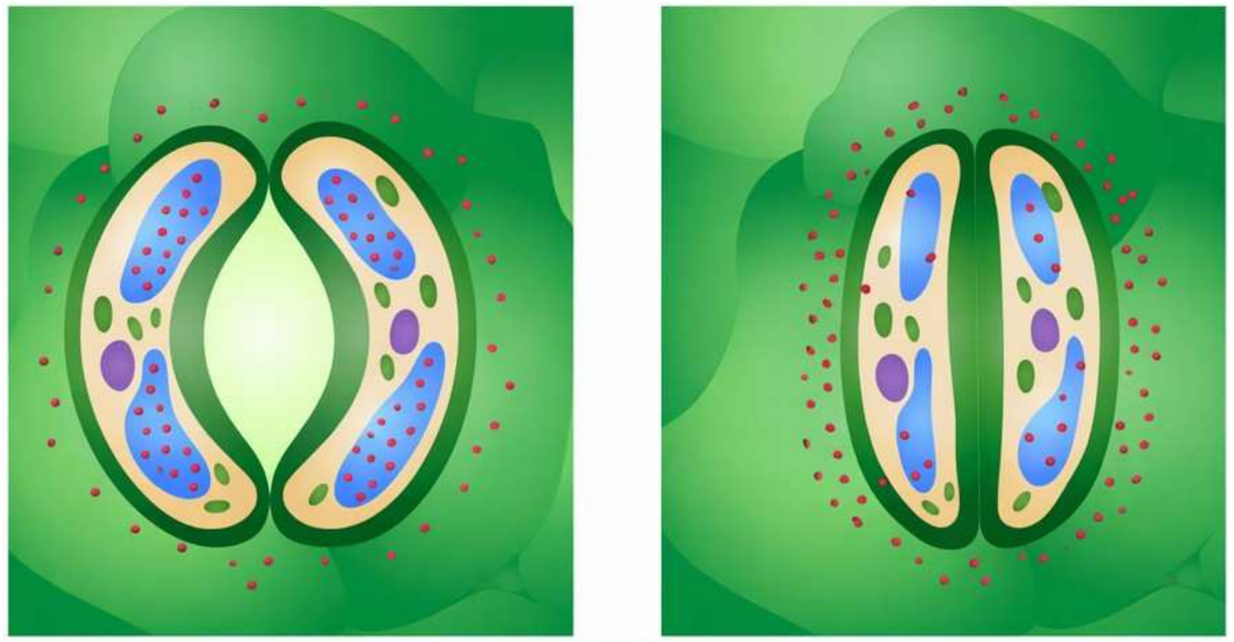
Evapotranspiration (ET)

+

Crop Coefficient (Kc)

STEP 1: ESTIMATING PLANT WATER DEMAND

Evapotranspiratio



Evaporation

- Loss of water from the soil and surrounding surfaces
- Water is converted to vapor

Transpiration

- Loss of water vapor from the plant
- Occurs mainly through leaf pores (stomata)
- Regulates plant temperature (cooling effect)

STEP 1: ESTIMATING PLANT WATER DEMAND

Reference Evapotranspiration (ET_0)

- Standardized estimate of weather-driven water loss
- Calculated from measured weather data
- Estimated using ET_0 equations (e.g., Penman–Monteith, Hargreaves)

Crop Coefficient (Kc)

- Adjusts ET_0 for turfgrass species and cultivar
- Reflects canopy and growth characteristics

$$\textit{Estimated Turf Water Demand} = ET_0 \times Kc$$

STEP 1: ESTIMATING PLANT WATER DEMAND

HOW IS REFERENCE ET (ET_0) CALCULATED?

Reference ET integrates measurable weather variables.

Penman–Monteith, for example, uses:

Air temperature (°C)

Net radiation (energy input)

Wind speed ($m\ s^{-1}$)

Vapor pressure deficit (humidity effect)

Using standardized surface and aerodynamic parameters for a reference grass surface

STEP 1: ESTIMATING PLANT WATER DEMAND

Crop coefficient (Kc) represents the percentage of reference ET that should be replaced for a specific turfgrass under well-watered conditions.

For example, a Kc of 0.70 means the turf typically uses about 70% of reference ET, so irrigation would aim to replace approximately 70% of ET_0.

STEP 1: ESTIMATING PLANT WATER DEMAND

16 B. Wherley et al. / Agricultural Water Management 156 (2015) 10–18

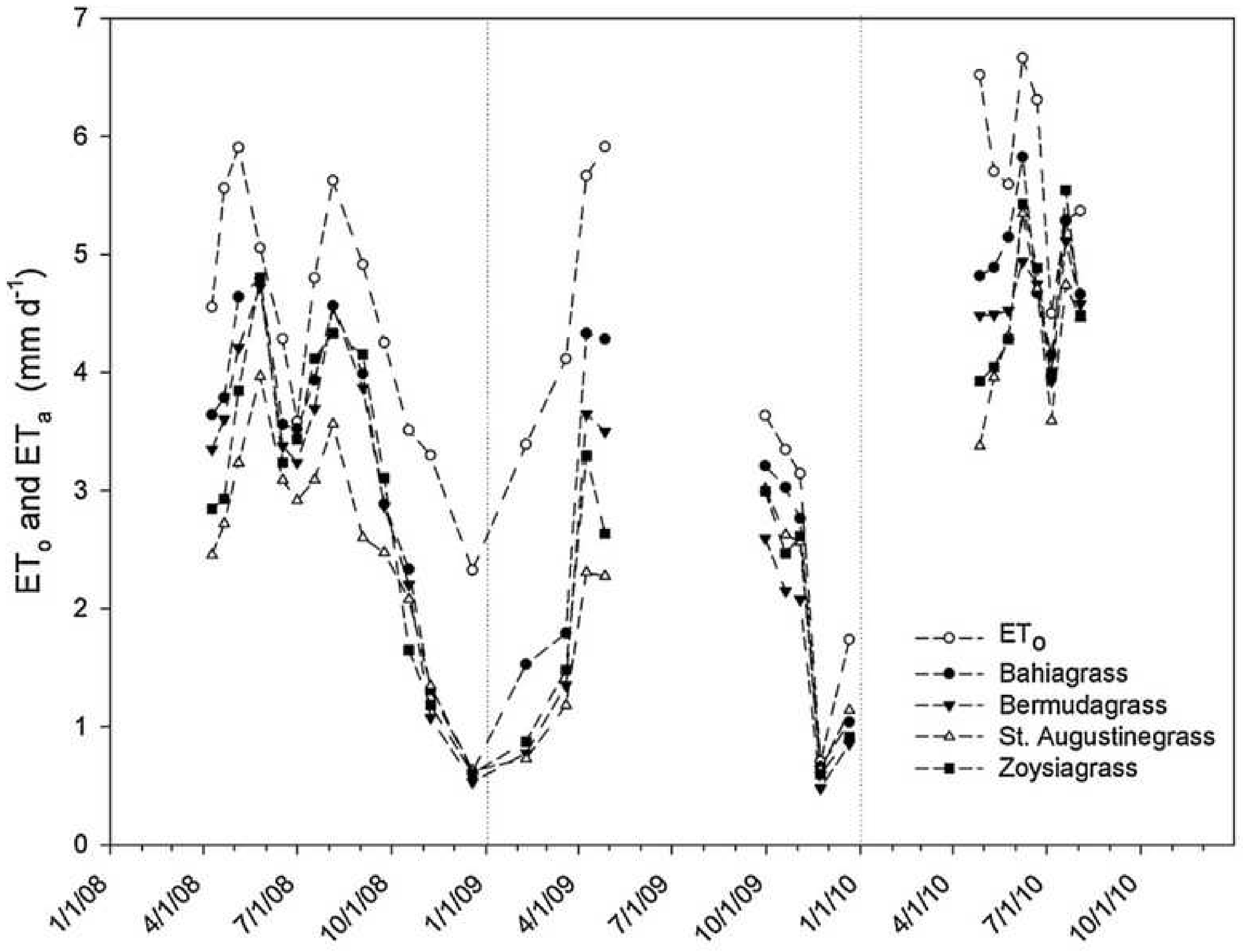


Fig. 6. Mean daily actual and reference evapotranspiration (ET_a and ET_o) for the four grasses over the study period. Vertical dotted lines denote years of the study.

In this study by Wherley et al. (2015)...

- All species follow seasonal ET_0 patterns
- Species differences are smaller than weather effects

In tropical climates, rainfall variability will often drive irrigation more than dormancy

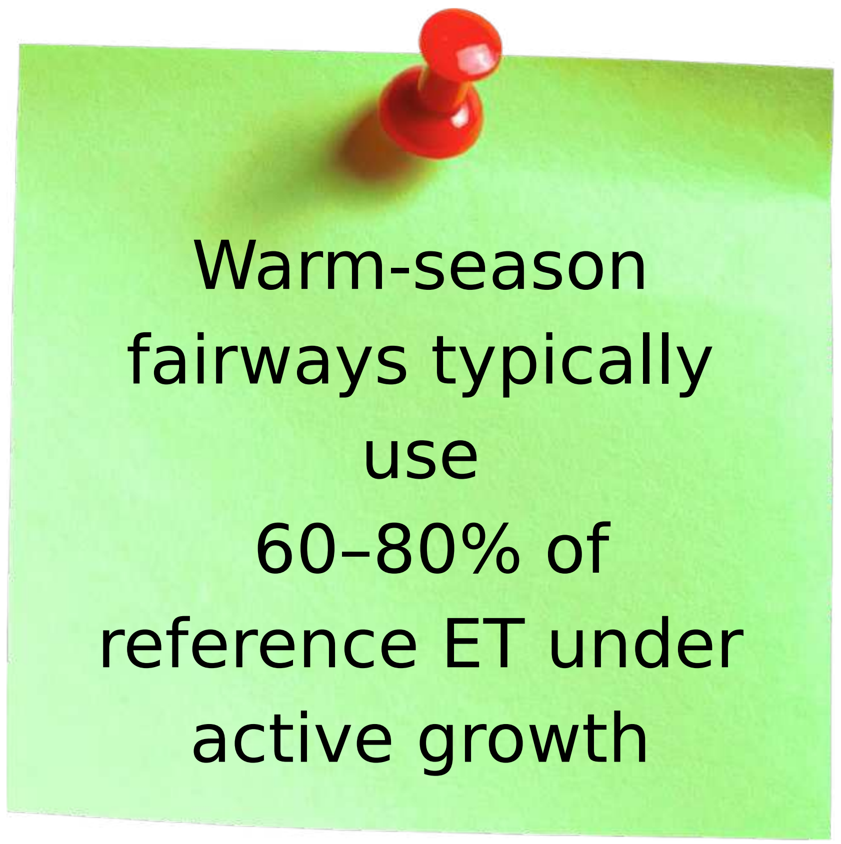
Crop Coefficients (Kc) for Warm-Season Turfgrass

Species	Active Growth	Reduced Growth / Stress
Bermudagrass	0.65–0.80	0.50–0.65
Seashore paspalum	0.60–0.75	0.50–0.65
Zoysiagrass	0.60–0.75	0.50–0.65

Based on published turf ET research (Romero & Dukes, 2016)

Values represent well-managed fairway conditions

Kc varies with mowing height, canopy density, and seasonal growth rate



STEP 1: ESTIMATING PLANT WATER DEMAND

Asian Turfgrass ET Calculator — Quick Tool for Planning

- The Asian Turfgrass ET Calculator estimates daily turf water demand using weather and crop data.
- Enter local weather data (temperature, humidity, radiation)
- Select a crop coefficient (Kc) for your turfgrass
- The tool calculates reference ET (ET_0) and estimated turf water use
- Scan the QR code to access the calculator

STEP 1: ESTIMATING PLANT WATER DEMAND

Reference and crop evapotranspiration (ET) calculator

This calculates the reference evapotranspiration (ET_o) in mm for a single day based on latitude, date, and the minimum and maximum air temperature. Multiplying ET_o by a user-selected crop coefficient gives the crop evapotranspiration, ET_c. These calculations are based on the Hargreaves ET_o equation (equation 52) in the FAO Crop Evapotranspiration book. More details at the end.

Date:

2025-03-09

Latitude in degrees N or S of the equator; + for northern hemisphere, - for southern hemisphere

12.9

Maximum temperature (°C)

33.8

Minimum temperature (°C)

27.7

Crop coefficient (K_c)

0.7

The reference ET on 2025-03-09 given a high of 33.8°C, a low of 27.7°C, and a location 12.9° from the equator, is 4 mm. With a crop coefficient of 0.7 the crop ET is 2.8 mm.

STEP 1: ESTIMATING PLANT WATER DEMAND

~2.8 mm/d x 7 days

=

19.6 mm/wk

STEP 2: KNOW YOUR SOILS

SOIL WATER STORAGE

Storage capacity depends on:

- Soil texture (sand, silt, clay)
- Organic matter
- Soil structure and compaction
- Rooting depth

Not all stored water is available to turfgrass. Plant-available water exists between field capacity and permanent wilting point.

STEP 2: KNOW YOUR SOILS

Texture Class	Field Capacity (%)	Wilting Point (%)	Available Water (%)
Sand	8.5	3.3	5.2
Loamy sand	20.9	8.5	12.4
Sandy loam	22	9.1	12.9
Loam	30.5	16.8	13.7
Clay loam	35.5	20.9	14.6

Available Water = Field Capacity – Permanent Wilting Point

Adapted from Rab et al., 2011

STEP 2: KNOW YOUR SOILS

ALLOWABLE DEPLETION

- The soil stores plant-available water, which is depleted between irrigation events.

- Irrigation is applied before all available water is used; this management threshold is called allowable depletion.

- Allowable depletion is a management decision, not a biological limit.

STEP 3: DEVELOP A WATER BUDGET

What is it?

A water budget is an accounting of water demand and water supply over time.

It compares estimated turf water use to effective rainfall and irrigation to estimate net water requirements for a site.

STEP 3: DEVELOP A WATER BUDGET

Why do it?

- Supports informed water management decisions
- Improves communication with ownership and stakeholders

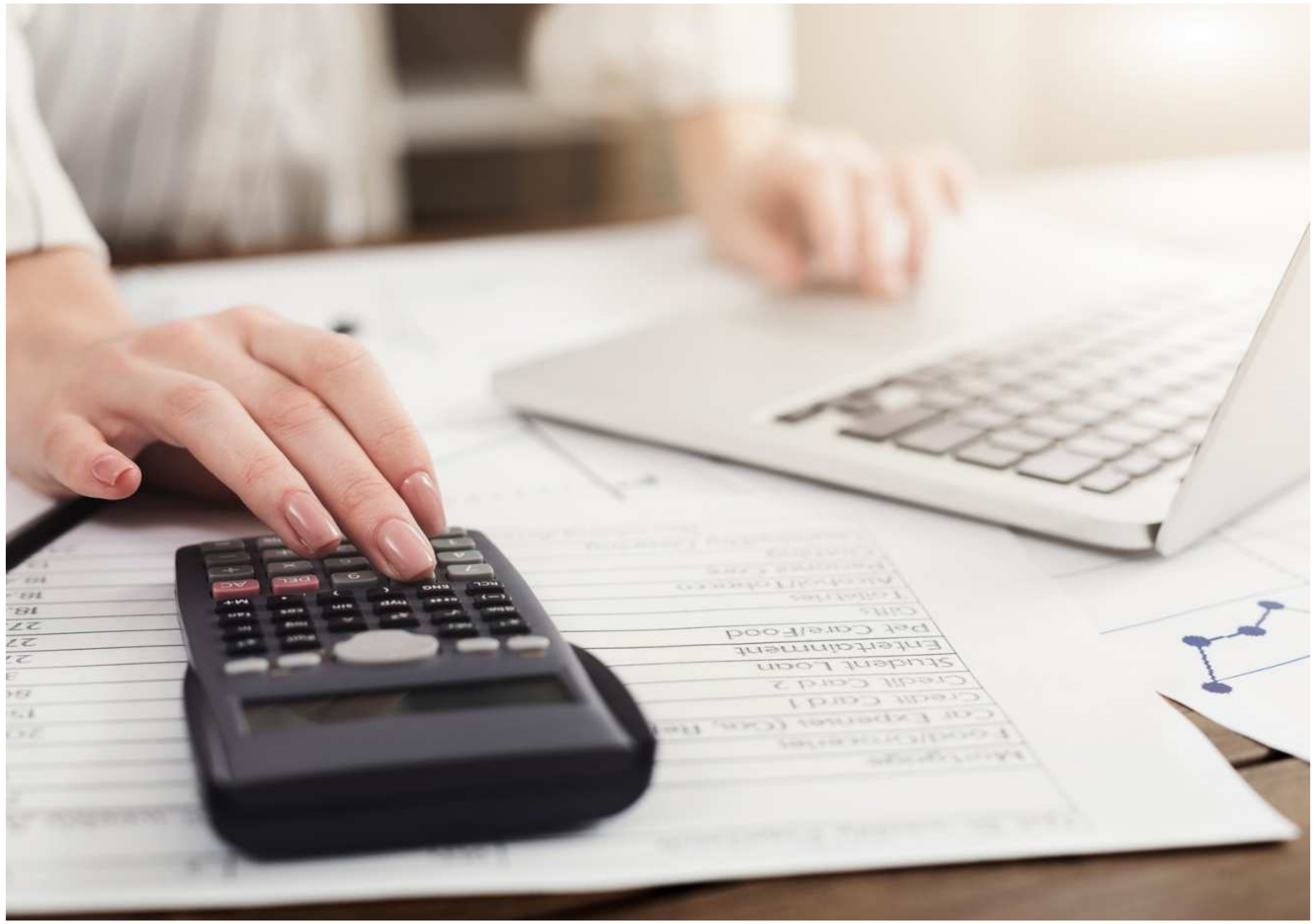
STEP 3: DEVELOP A WATER BUDGET

Why do it?

- Helps evaluate irrigation efficiency and conservation strategies
- Allows planning for seasonal variability (dry vs. monsoon periods) including supported prioritization of key playing areas during water limitations

STEP 3: DEVELOP A WATER BUDGET

1. **Reference ET (ET_0)**
2. **Crop Coefficient (Kc)**
3. **Effective Rainfall**
4. **Irrigated Area**



STEP 3: DEVELOP A WATER BUDGET

Start with what we've already discussed. Determine totals per month based on historic data.

1. **Reference ET (ET_0):** Estimate weather-driven demand
2. **Crop Coefficient (Kc):** Adjust for turf species and growth condition

On-site weather data is best for this purpose, when available.

STEP 3: DEVELOP A WATER BUDGET

1. **Effective Rainfall**

What is ‘effective rainfall’?

Not all rainfall will be available to turfgrass. Effective rainfall is the portion of rainfall stored in the crop root zone.

Rainfall that runs off the surface or moves below the root zone does not contribute to plant water use.

STEP 3: DEVELOP A WATER BUDGET

1. **Effective Rainfall**

What influences effective rainfall?

Soil texture and structure
Slope
Surface cover
Storm intensity and duration

STEP 3: DEVELOP A WATER BUDGET

1.Effective Rainfall

General planning guidance:

- **First 2–3 mm** → often lost to evaporation
- **5–25 mm** (moderate rainfall) → mostly effective
- **>50 mm in a short time** → large losses likely

STEP 3: DEVELOP A WATER BUDGET

1.Effective Rainfall

Observe your site:

- When does runoff become visible?
- How long does water stand on the surface?
- How quickly does water drain?
- Adjust your effective rainfall estimate based on these observations.

STEP 3: DEVELOP A WATER BUDGET

1. **Effective Rainfall**

Some organizations or tools use a standard estimate:

Effective rainfall ≈ **50% of total rainfall**

This is used for long-term planning and water budgets, and may be easiest for initial planning.

STEP 3: DEVELOP A WATER BUDGET

1. Know your irrigated area


Photo: TORO Lynx Central Control System

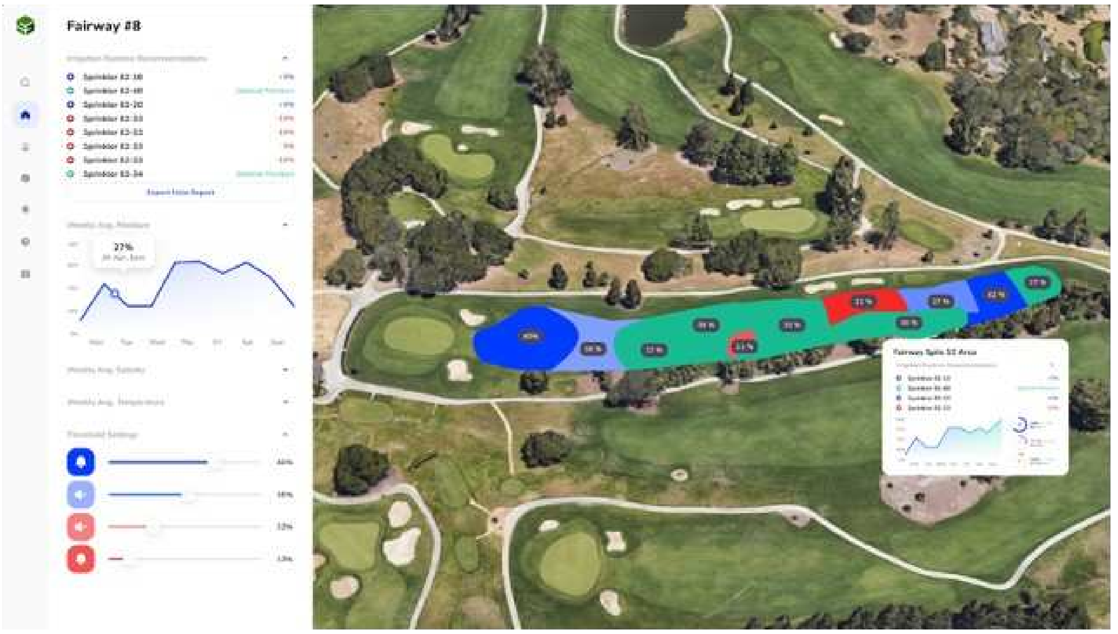


Photo: Spiio


Photo: USGA DEACON

STEP 3: DEVELOP A WATER BUDGET

- Monthly turf demand is calculated as ET_0 total × Kc.
- Effective rainfall is estimated at 50% of total monthly rainfall.
- Net irrigation requirement is calculated as Monthly Turf Demand − Effective Rainfall.
- When multiplied by irrigated area, this estimates total monthly course water demand across the year.

STEP 3: DEVELOP A WATER BUDGET

Month	ETo (mm/mo)	Kc	ETo×Kc (mm/mo)	Total rainfall (mm/mo)	Effective rainfall (mm/mo)	Irrigated area (km^2)	Irrigation applied (mm/mo)	Water budget (m^3/mo)
Jan	126	0.7	88.2	9	4.5	0.32	83.7	**26,780**
Feb	126.6	0.7	88.6	30	15	0.32	73.6	**23,557**
Mar	158.3	0.7	110.8	29	14.5	0.32	96.3	**30,812**
Apr	152.4	0.7	106.7	65	32.5	0.32	74.2	**23,738**
May	140.2	0.7	98.1	220	110	0.32	0	0
Jun	133.4	0.7	93.4	149	74.5	0.32	18.9	**6,042**
Jul	134.7	0.7	94.3	155	77.5	0.32	16.8	**5,361**
Aug	127.7	0.7	89.4	197	98.5	0.32	0	0
Sep	112.8	0.7	79	344	172	0.32	0	0
Oct	114.4	0.7	80.1	242	121	0.32	0	0
Nov	127.3	0.7	89.1	48	24	0.32	65.1	**20,821**
Dec	126.9	0.7	88.8	10	5	0.32	83.8	**26,789**

Annual irrigation volume (this example): ~163,900 m^3/year

STEP 3: DEVELOP A WATER BUDGET

Irrigation applied (mm/mo)	Water budget (m^3/mo)
83.7	**26,780**
73.6	**23,557**
96.3	**30,812**
74.2	**23,738**
0	0
18.9	**6,042**
16.8	**5,361**
0	0
0	0
0	0
65.1	**20,821**
83.8	**26,789**

Compare to *actual* water use to:

- Identify malfunctions or inefficiencies
- Document for stakeholders or decision-makers
- Evaluate new water-saving technologies or turf types

STEP 3: DEVELOP A WATER BUDGET

Dry Season Planning

- Review projected irrigation deficits and compare to available storage
- Monitor cumulative ET versus actual irrigation
- Plan supplemental strategies if deficits are large
- Prepare soil surfactant programs to improve water distribution
- Identify supplemental water sources if available
- Adjust mowing height or cultural practices to reduce stress
- Prioritize key playing areas if supply

Monsoon Season Planning

- Monitor cumulative rainfall relative to projected demand
- Reduce or suspend irrigation when rainfall meets demand
- Manage drainage and surface firmness
- Avoid prolonged soil saturation and shallow rooting
- Adjust nitrogen or growth management to maintain plant balance
- Track excess rainfall to anticipate disease risk

TURFGRASS SELECTION: CONSIDERATIONS

- Warm-season species generally exhibit lower ET than cool-season grasses under similar conditions
- Substantial variation exists among species and cultivars
- Water use differences are influenced by canopy structure, rooting depth, and physiological regulation
- Deficit irrigation studies show quality retention differs more than absolute ET

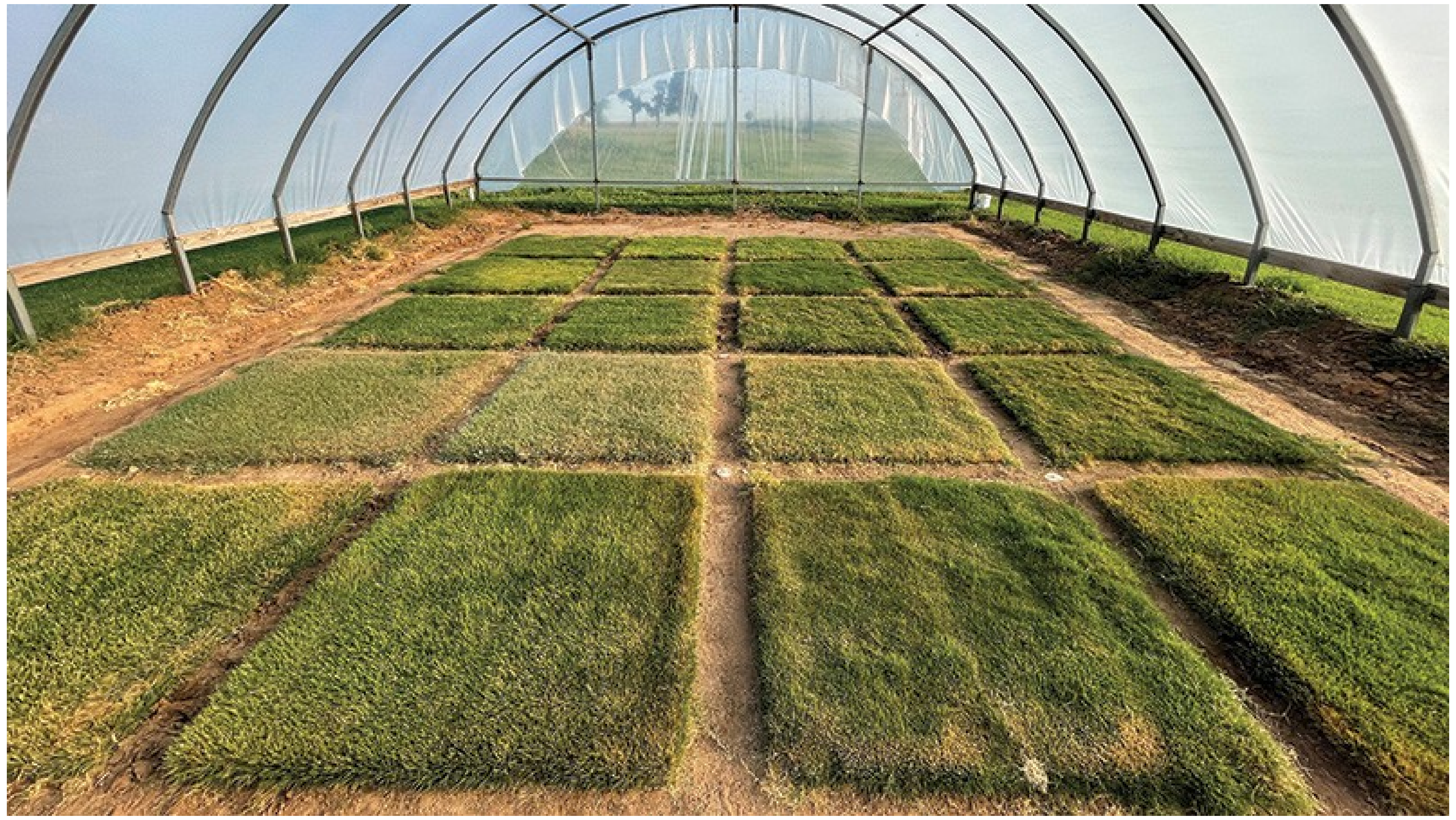


Photo by Mingying Xiang (Oklahoma State University), Featured in *GCM Online*

(Colmer 2017; Wherley et al. 2015)

TURFGRASS SELECTION: CONSIDERATIONS

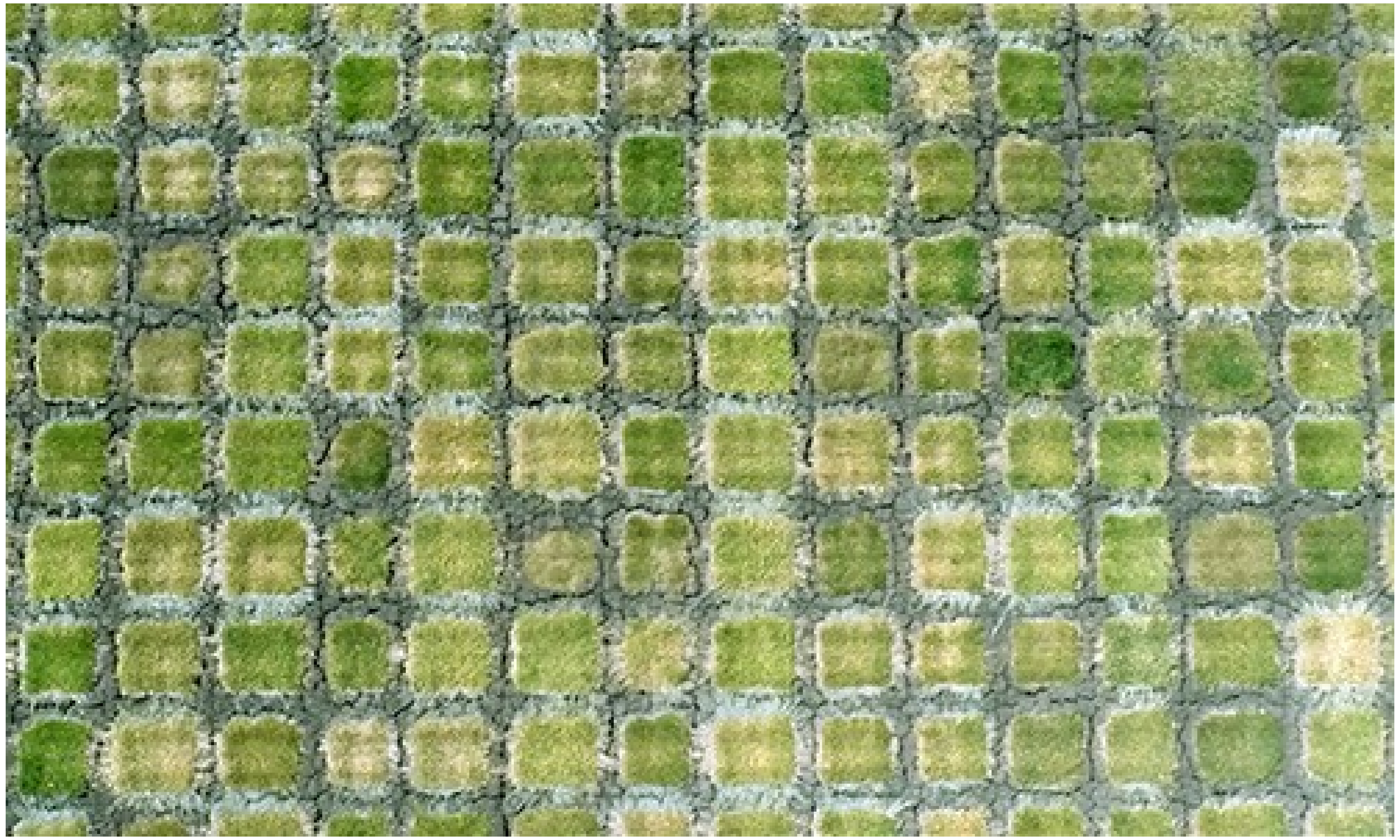


Photo depicting zoysiagrass breeding plots at Texas A&M Agrilife Dallas Center

Breeding selection emphasis has shifted toward:

- Deeper, more prolific rooting systems
- Improved osmotic adjustment and stress physiology
- Maintaining turf quality at lower irrigation levels
- Genotype × environment interaction is significant

ADVANCEMENTS IN TURF BREEDING

Drought Resistance Mechanisms in Turfgrass:

1. **Drought escape:** completes growth before severe stress occurs
2. **Drought avoidance**: maintains plant water status during soil drying (deep rooting, efficient water extraction, stomatal regulation)
3. **Drought tolerance:** maintains cellular function despite low tissue water content

In managed turf systems, **drought avoidance** is often the most relevant mechanism for irrigation planning because it determines how long acceptable quality can be maintained as soil moisture declines

Photo: Oklahoma State University

ADVANCEMENTS IN TURF BREEDING

In managed turf systems, **drought avoidance** is often the most relevant mechanism for irrigation planning because it determines how long acceptable quality can be maintained as soil moisture declines.

Photo: Oklahoma State University

ADVANCEMENTS IN TURF BREEDING

Crop coefficient (Kc) estimates water use under well-watered conditions.

Drought-resistant cultivars do not necessarily use less water.

Improved drought performance may result from:
Deeper rooting

- Greater water extraction from the soil profile
- More effective stomatal regulation
- Drought performance reflects both Kc and effective rooting depth.

ADVANCEMENTS IN TURF BREEDING

Tifway (left) and TifTuf (right) bermudagrass during the 2016 drought trial. TifTuf was the best performer throughout the trial. **Photo by David Jespersen**

gcmonline.com

For example, research by Yurisic (2016) found as much as 41% of TifTuf bermudagrass root biomass grew between 15–45 cm deep compared with ‘Latitude’ (22%) and ‘Tifway 419’ (26%).

Deeper root distribution increases access to stored soil water, changing allowable depletion and putting greater emphasis on the importance of root zone depth.

ADVANCEMENTS IN TURF BREEDING

Photo by Shuhao Yu at Oklahoma State University and featured on gcmonline.com

- Cultivar differences mean Kc is not fixed within a species
- Improved rooting depth increases soil water access and has implications for effective rainfall estimates
- Drought-tolerant cultivars may allow greater allowable depletion
- Water budgeting should consider cultivar and root zone depth, not species alone

CYCLE AND SOAK IRRIGATION

What is it?
Cycle and soak divides irrigation into multiple short runtimes instead of one long application.

It is used when:
- Water is applied faster than the soil can absorb it
- Runoff is visible during irrigation
- Soils are heavy, compacted, or sloped
- Sprinklers have high precipitation rates

Why use it:
- Reduces surface runoff
- Improves infiltration
- Promotes deeper root zone wetting
- Increases irrigation efficiency

CYCLE AND SOAK IRRIGATION

How to Implement Cycle and Soak

Step 1
Determine precipitation rate of your zone (mm/hr)
and your irrigation requirement.

Step 2
Identify soil type (clay, loam, sand)

Step 3
Use the table to find maximum runtime per cycle

Step 4
Divide total irrigation requirement into multiple cycles

Typical Precipitation Rate Range for Hose-End Sprinklers (0.1–0.3)

Typical Precipitation Rate Range for Rotary and Multi-Stream Rotary Sprinklers (0.3–0.8)

Typical Precipitation Rate Range for Spray Head Sprinklers (0.8–2)

Maximum Irrigation Cycle Runtimes*			
Precipitation Rate (in./hr.)	Clay Soil	Loamy Soil	Sandy Soil
0.1	60	60[1]	60[1]
0.2	36	60[1]	60[1]
0.3	24	60[1]	60[1]
0.4	18	60[1]	60[1]
0.5	14	60[1]	60[1]
0.6	12	60	60[1]
0.7	10	51	60[1]
0.8	9	44	60[1]
0.9	8	39	60[1]
1	7	35	60[1]
1.1	7	32	60
1.2	6	30	59
1.3	6	27	54
1.4	5	25	51
1.5	5	24	47
1.6	5	22	44
1.7	4	21	42
1.8	4	20	39
1.9	4	19	37
2	4	18	35

* Assumes minimum 1 hour between irrigation cycles on non-sloped landscapes.

[1] As a water conservation practice, it is not recommended to irrigate for more than 1 hour at a time.

IRRIGATION SCHEDULING: THE BASICS

Irrigation scheduling determines:

- How much water to apply
- When to apply it

It integrates:

- Weather-driven demand (ET)
- Soil water storage capacity
- Rainfall and effective rainfall
- Turf stress signals

Turf managers use different strategies.

One structured approach integrates three layers:

Level 1 – Weather Demand: $ET_0 \times K_c$

Level 2 – Soil Water Storage: root depth × available water

Level 3 – Performance Goals: Firmness, traffic, recovery expectations

Irrigation decisions occur where these three intersect.

LEVEL 1: WEATHER DEMAND: $ET_0 \times KC$

Month	ETo	Kc	ETo×Kc	Total	Effective	Irrigated	Irrigation	Water
Jan	126	0.7	88.2	9	4.5	0.32	83.7	**26,780**
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The annual water budget establishes:

Expected seasonal demand

Monthly irrigation deficits

Peak demand periods

This becomes your baseline plan.

Irrigation scheduling then adjusts that plan:

Using real-time weather

Using rainfall

Using field observation

LEVEL 1: WEATHER DEMAND: $ET_0 \times KC$

Start with your baseline weekly target
(from your annual water budget)

Then compare to real-time conditions:

1. Weather demand: Actual ET_0 compared to projected ET_0
2. Rainfall: Actual rainfall vs projected rainfall
3. Irrigation applied: Has the planned depth already been delivered?
4. Soil and plant response: Visible wilt, Localized dry areas, Traffic stress

Adjust irrigation up or down accordingly.

LEVEL 2: SOIL WATER STORAGE: ROOT DEPTH × AVAILABLE WATER

In golf management, irrigation is commonly applied after approximately **40–60% of plant-available water has been depleted** (depending on surface and performance expectations).

Why not irrigate sooner?

Allowing moderate depletion:

- Encourages deeper rooting
- Improves surface firmness
- Reduces disease pressure
- Improves water-use efficiency

Gets back to basics - ***deep and infrequent irrigation.***

LEVEL 2: SOIL WATER STORAGE: ROOT DEPTH × AVAILABLE WATER

Weather determines demand.

The root zone determines how much water can be stored before irrigation is required.

Key variables:

- **Root zone depth**
- **Soil texture**
- **Plant-available water**
- **Allowable depletion**

Irrigation timing depends on root zone water storage capacity.

LEVEL 2: SOIL WATER STORAGE: ROOT DEPTH × AVAILABLE WATER

Example:
Estimating Trigger Point Across Soil Types

Assume:
- Root depth = 200 mm
- Allowable depletion = 50%
- Same weather across the property

Soil Texture	Plant-Available Water (~%)	Total Storage (mm)	Irrigation Trigger (mm)	Cumulative Deficit Since Last Recharge (mm)	At Trigger?
Sand	~5%	10 mm	5 mm	12 mm	Yes (past)
Sandy loam	~13%	26 mm	13mm	12 mm	Approaching
Loam	~14%	28 mm	14 mm	12 mm	Not yet
Clay loam	~15%	30 mm	15 mm	12 mm	Not yet

Cumulative deficit ≈ (ET_0 × Kc) − effective rainfall and irrigation, tracked since the last meaningful rain/irrigation recharge

LEVEL 2: SOIL WATER STORAGE: ROOT DEPTH × AVAILABLE WATER

Assume:

- Sandy loam root zone
- Allowable depletion = 50%

Parameter	VWC (~%)	Explanation
Field Capacity	~22%	Upper limit of plant-available water
Permanent Wilting Point	~9%	Lower biological limit
Plant-Available Water	~13%	22 – 9
Irrigation Trigger	~15–16%	50% depletion within PAW
Ex 1. Current Sensor Reading	17%	Above trigger → no irrigation
Ex 2. Current Sensor Reading	14%	Below trigger → irrigate

LEVEL 3 – PERFORMANCE GOALS

Surface	Performance Priority	Typical Depletion Range in Golf	Scheduling Implication
Greens	Firmness, speed, precision	Lower depletion range	Irrigate earlier; tighter moisture control
Tee boxes	Traffic tolerance, recovery	Low to moderate depletion	Monitor high-wear areas closely
Fairways	Playability + efficiency	Moderate depletion range	Encourage deeper rooting
Rough	Survival, aesthetics	Higher depletion tolerance	Lower priority during dry periods

SUMMARY

Assumptions:

- Surface: Fairway
- Soil: Sandy loam
- Root depth: 200 mm
- Allowable depletion: 50%
- Irrigated area: 0.32 km² (80 acres)

SUMMARY

Estimate Weekly Demand (Level 1)

- Weekly ET_0 = 35 mm
- Kc = 0.70
- ETc = 35 × 0.70 = 24.5 mm
- Effective rainfall this week = 5 mm
- 24.5mm − 5mm =

= 19.5 mm net weekly demand

SUMMARY

Define Soil Storage (Level 2)

- Plant-available water ≈ 13%
- Total storage = 200 mm × 0.13 = 26 mm
- Allowable depletion (50%) = 26 × 0.50 =

13 mm trigger

SUMMARY

Compare Demand to Trigger
(Level 1 + 2)

- Cumulative deficit since last recharge = 19.5 mm
- Trigger depth = 13 mm

→ Irrigation required

SUMMARY

- Required depth = 19.5 mm
- Precipitation rate = 10 mm/hr
- Run time =
- 19.5 ÷ 10 = 1.95 hours

≈ 2 hours total, applied in cycles to meet goal

LOOKING AHEAD

These concepts are important to understand, but not often time- or labor-efficient on their own.

In the next session, we will focus on tools that help:

- Irrigation system audits
- Soil moisture sensors
- Soil surfactants
- Others

QUESTIONS?

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