The Turfgrass Challenge: Documenting the value of a crop that doesn't feed the world

Leah A. Brilman, Ph.D.

Director of Turf Products and Technical Services
DLF Pickseed/Seed Research of Oregon
lbrilman@dlfna.com

July 11, 2022

Defining Crop

Noun

1. A crop is a plant that can be grown and harvested extensively for profit or subsistence. When the plants of the same kind are cultivated at one place on a large scale, it is called a crop.
2. A cultivated plant that is grown as food, especially a grain, fruit, or vegetable
    1. an amount of produce harvested at one time
    2. an abundance of something
    3. the total number of young farm animals born in a particular year on one farm.
3. A hairstyle in which the hair is cut very short
4. Short for riding crop.
5. A pouch in a bird's gullet where food is stored or prepared for digestion

Verb

1. Cut something very short.
2. Remove part of a photograph or other image
3. (Animal) bite off and eat the tops of plants
4. Harvest plants or their produce from a particular area.

Defining Crop

Noun

1. A crop is a plant that can be grown and harvested extensively for profit or subsistence. When the plants of the same kind are cultivated at one place on a large scale, it is called a crop.

Grass seed crops in Oregon – grown for profit

Defining Crop

Food Crops – eaten directly by people

- Wheat, maize (corn), rice, sugarcane, sugar beets, potatoes, vegetables, fruit, nuts, soybeans (3%)

Non-Food Crops – Indirect or industrial uses

- Feed Crops – alfalfa, forage grasses, oats, corn, fodder beets, clovers, soybeans (97% soybean meal)
- Oil crops – cottonseed, corn, soybeans, rape, sunflower, olives
- Industrial crops- Nonfood crops
    - Biofuels and bioenergy – Algae, Switchgrass, maize (corn), soybean oil
    - Building and construction – Hemp, wheat, bamboo
    - Fiber- coir, cotton, flax, hemp
    - Pharmaceuticals – Cannibus sativa, Echinacea, tobacco
    - Renewable biopolymers - rubber, guayule, wheat, potatoes
    - Specialty chemicals – lavender, oilseed rape, linseed, hemp
- Ornamental crops – trees, flowers, landscape plants

Sustainable Turfgrass Systems

- Most countries with ITS membership have between 80 and 90% Urbanization
- Cool Season Turfgrasses primarily native to Europe. Circumpolar natives include fine fescues, Agrostis, Poa sp.
- Warm Season Turfgrasses native to America, Africa, Asia

Turfgrasses provide many valuable services in the urban environment (from Crop Science Society of America)

- islands of green space for visual enjoyment and recreation
- allow people to stay physically fit and participate in a range of sporting activities
- protect urban soils from erosion
- help filter common pollutants associated with high population densities, like hydrocarbons (for example, gas and oil from cars) from the air and water
- provide a cooling effect in urban environments; grassy areas are much cooler than blacktop

Turfgrass Benefits

Benefits of Turfgrass (modified Beard and Green, 1994. J. Environ. Quality 23:452-460)

Functional- Benefits increased with high density managed turf

- Carbon Sequestration (even with hidden carbon costs subtracted)
- Water infiltration (water quality improves after going through turf)
- Soil erosion (less soil lost after rainfall)
- Dust prevention (wind erosion)
- Heat dissipation (transpiration – effects of irrigation reduction?)
- Noise abatement and Glare reduction
- Air pollution
- Fire barrier – Greenspace
- Reduced pests, allergens and human disease exposure (Ticks -Lyme disease, Mosquitoes -West Nile plus others, Rodents, Snakes, Chiggers), Dense mown turf = less weeds = less pollen allergens
- Safety in Vehicle operation – vehicle emergency stopping, Line of sight visibility – signs and animals, soil and dust stabilization at airports
- Runoff water and sediment from impervious services – Turf catchment can help clean

Sustainable Turfgrass Systems

Benefits of Turfgrass

- Heat Island effect
  - Artificial turf and Xeriscape replacement of natural turf to save water -Artificial turf needs irrigation in hot areas of country to lower temperatures for sports field (Schiavon 2021. TPI Newsletter – Sept-Oct.)

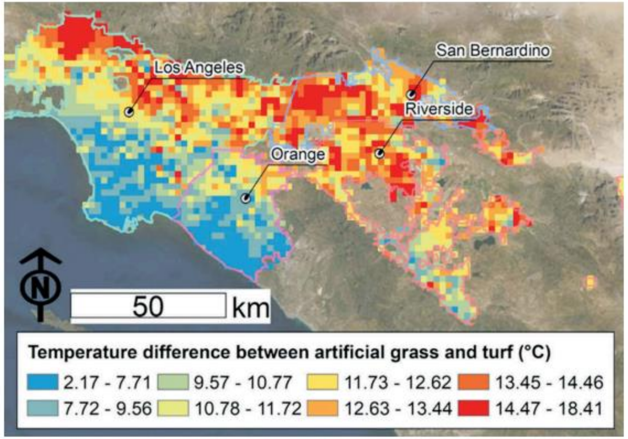


Figure 3. Maps of expected a) daytime temperature differences in late spring/early summer between natural grass and artificial turf sports fields and b) daytime temperature at artificial turf sport fields.

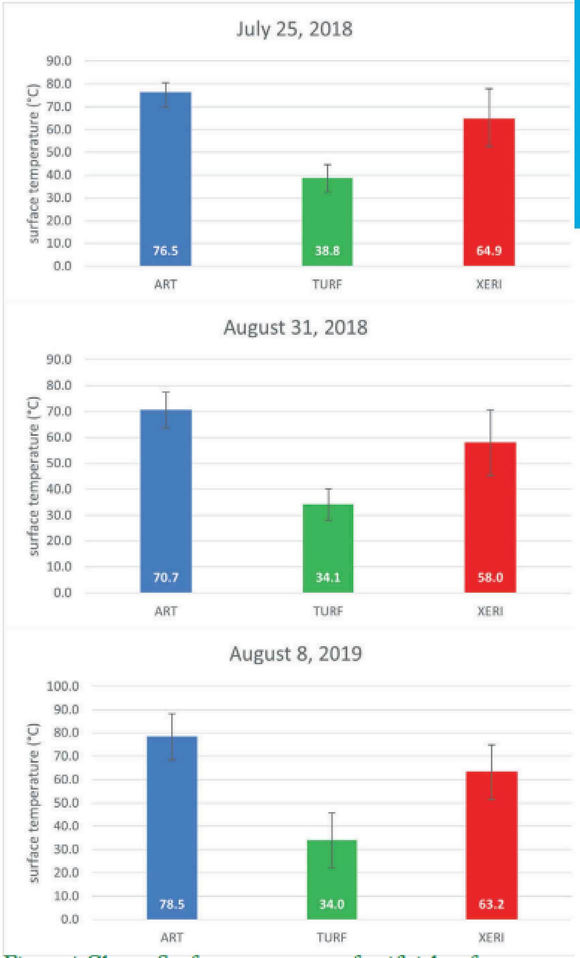


Figure 4 Charts. Surface temperature of artificial turfgrass, natural turfgrass, and xeriscape in Riverside on July 25, 2018 (air T=38.9 °C) (102.02 °F), August 31, 2018 (air T=32.2 °C) (89.86 °F), and August 31, 2019 (air T=33.9 °C) (93.02 °F).

Turfgrass Benefits

Benefits of Turfgrass (modified Beard and Green, 1994. J. Environ. Quality 23:452-460)

Recreational- Benefits increased with high density managed turf

- Low cost surfaces
  - Physical health (all ages can play on sports surfaces at many levels)
  - Mental health
  - Safety (natural turf safer for athletes, less injuries)

Aesthetics- Benefits increased with high density managed turf

- Beauty
  - Quality of life
  - Mental health
  - Community pride
  - Increased property values
- Compliments trees and shrubs in the landscape

Crops can have values besides directly feeding people and Turfgrass has multiple values for the planet and people.

Sustainable Turfgrass Systems

Turfgrasses are an important part of sustainability in urban systems

- "Mapping and Modeling the Biogeochemical Cycling of Turf Grasses in the United States" by Cristina Milesi and colleagues in *Environmental Management* 36.3 (2005)

- Researchers predicted lawn surface area in urban and suburban settings from impervious surface area. In general, as impervious surface area such as roads and parking lots increases, lawn area decreases. Milesi and her team refined the predictions using aerial photography over different urban landscapes.

- "Lower bound of the 95% confidence interval (128,000 km2 = 31 million acres), it appears that turf grasses would represent the single largest irrigated "crop" in the United States, occupying a total area three times larger than the surface of irrigated corn (43,000 km2 according to the 1997 Census of Agriculture, out of 202,000 km2 of total irrigated cropland area).

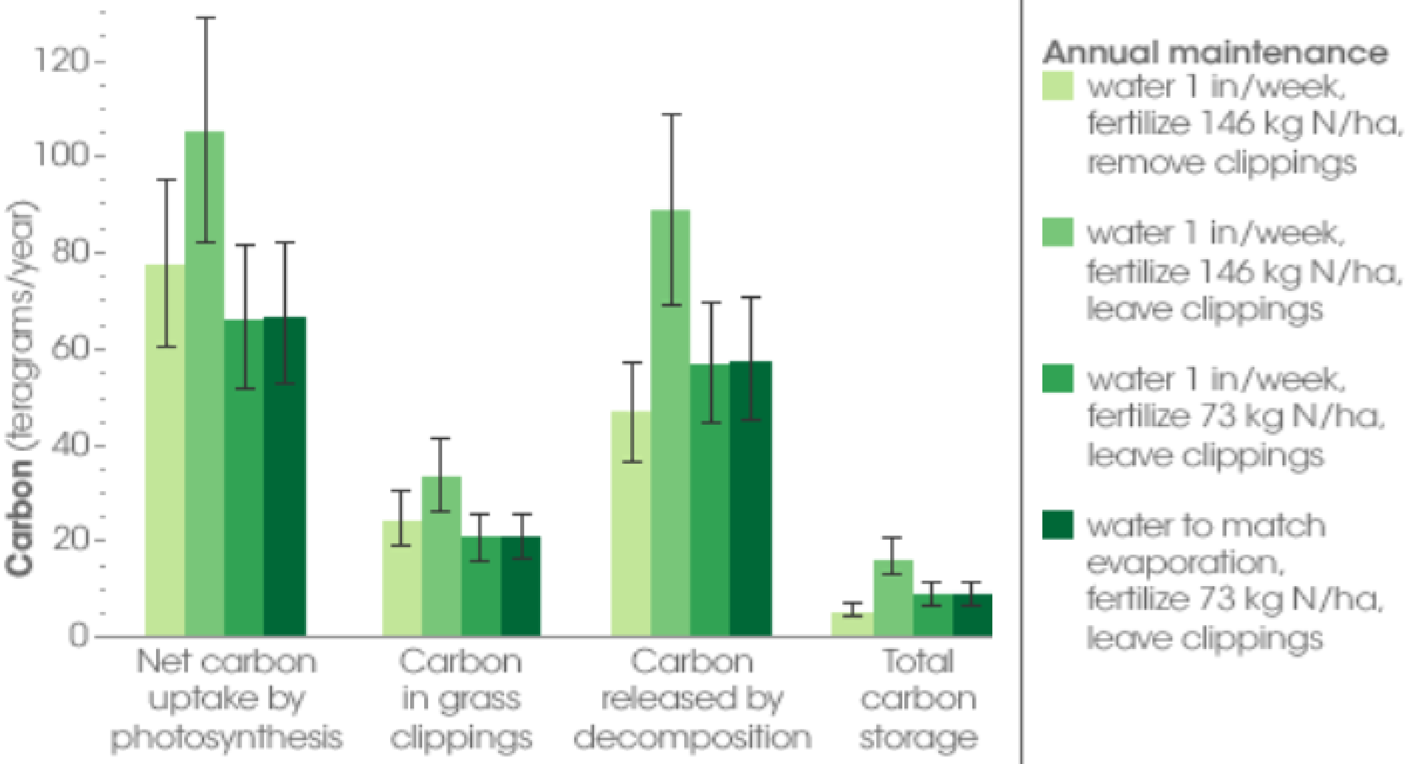
- There are an estimated 40 to 50 million acres (20 million ha) in the United States: 40% is residential lawns, 20% lines roadsides, and about 3% is on golf courses. The remaining turf accounts for public parks, fields, and other green areas. "

Sustainable Turfgrass Systems

DLF SEEDS & SCIENCE

Turfgrasses are an important part of sustainability in urban systems

- "Mapping and Modeling the Biogeochemical Cycling of Turf Grasses in the United States" by Cristina Milesi and colleagues in *Environmental Management* 36.3 (2005)
- Assumptions made in this study which is often cited as turf being largest irrigated crop
    - All turf acreage is irrigated (study had limited area in NE and FL stated did not require irrigation)
        - Zirkle et al, 2011. HORTSCIENCE 46(5):808–814. Only 10% to 15% (3 to 4.5 million) of DIY lawns irrigate in the US
    - This study assumed turf under trees so if not impervious classified as turf
    - All water applied to turf is utilized by the grass surface
    - Nonirrigated turf areas (assuming 50 million acres (20 million ha) of turf in US)
        - 20% roadsides – 10 million acres (4 million ha)
        - 80% of DIY lawns – 16 million acres (6.5 million ha)
        - Golf courses – 1.1 million acres (445,000 ha) unirrigated of 2.2 million acres(890,000 ha)
        - Parks, Cemeteries, sports fields, etc. – 8,750,000 unirrigated acres (3,540,000 ha) (50%??)
    - Irrigated turf approximately 12 million acres in US – All Irrigated Crops in California is 8 million acres.
- Corn (maize)
    - Corn is largest crop in United States with 96 million acres (39 million ha) and 12 million of those acres are irrigated – very little of this is direct human food
    - This is feed corn of which 33% is Livestock feed, 27% is used to make Ethanol and 11% is Exported


120
100
80
60
40
20
0
Carbon (teragrams/year)
Net carbon uptake by photosynthesis
Carbon in grass clippings
Carbon released by decomposition
Total carbon storage
Annual maintenance
water 1 in/week, fertilize 146 kg N/ha, remove clippings
water 1 in/week, fertilize 146 kg N/ha, leave clippings
water 1 in/week, fertilize 73 kg N/ha, leave clippings
water to match evaporation, fertilize 73 kg N/ha, leave clippings

Basic assumption - All turf acreage is irrigated

- Assumed turf under trees so if not impervious classified as turf
- All water applied to turf is utilized by the grass surface

All turf acreage is irrigated – in many areas of the United States turf is not regularly irrigated on home lawns or roadsides (Corvallis, OR 2021)

Spring 2022. Rapid recovery after rains returned. Primarily bentgrass.

Basic assumption - All turf acreage is irrigated

- Assumed turf under trees so if not impervious classified as turf
- All water applied to turf is utilized by the grass surface

- Trees in Landscapes utilize much of irrigation applied to turf – Loss or damage to trees from cessation of irrigation in CA – Bermudagrass recovered
- How does non-watering effect turf benefits – cooling, sequestration, etc.?
- Soil improvement, wetting agents part of solution

Turfgrass Benefits

Benefits of Turfgrass

Turfgrasses sequester carbon

- Managed turfgrass with fertilization, adequate water, clippings returned sequester more carbon than turfgrasses without inputs
- Hidden Carbon Cost do not cancel out these benefits
  - Mowing – Fuel and emissions (Electric will reduce), Carbon cost of manufacturing mowers
  - Irrigation – Pumping water, manufacture of equipment
  - Fertilizer – Manufacture, delivery impacts (NO2 added GHG)
  - Pesticide – Manufacture, delivery, application (Europe and Canada less utilized)
- Reduction in hidden carbon costs through breeding may be better targets than increasing carbon sequestration in cultivars
- Actively growing turfgrasses sequester more carbon – select for those that grow well under stress
- Europe may have less hidden carbon costs – less irrigation and pesticides used

Benefits of Sustainable Turfgrass Systems

Carbon Sequestration by turfgrass and carbon emissions w/ and w/o reductions by maintenance requirements

- 0.25 – 2.04 MgC/ha/yr after removing hidden carbon costs
- 0.33-1.1 MgC/ha/yr from grasslands

Braun, R. C and D. J. Bremer

Agrosyst. Geosci. Environ. 2:180060 (2019) doi:10.2134/age2018.12.0060

Table 1. Observed or modeled soil organic C sequestration rates in turfgrass and grassland soils.

Land use	Soil organic C sequestration rate	Reference
	Mg C ha^{-1} yr^{-1}	
Golf course	0.9–1.0	Qian and Follett (2002)
Golf course	0.9–1.2	Bandaranayake et al. (2003)
Golf course	0.69	Huh et al. (2008)
Golf course	0.32–0.78	Qian et al. (2010)
Golf course	2.64–3.55 (0.44)†	Selhorst and Lal (2011)
Golf course	0.72	Wang et al. (2014)
Golf course	0.976–1.046 (0.412–0.616)†	current study
Home lawn	0.18	Pouyat et al. (2009)
Home lawn	0.46–2.35 (0.25–2.04)†	Zirkle et al. (2011)
Home lawn	2.80	Selhorst and Lal (2013)
Home lawn	1.41–1.63 (0.87–1.29)†	Law and Patton (2017)
Fertilized pasture grassland	0.82	Tyson et al. (1990)
Restored native grassland	0.6	Bruce et al. (1999)
Established grasslands	1.1	Gebhart et al. (1994)
Established grasslands (compiled)	0.33	Post and Kwon (2000)
Restored native grassland	0.6–0.8	Mensah et al. (2003)
Native tallgrass grassland (burned annually or biennially)	−2.31–0.27	Bremer and Ham (2010)

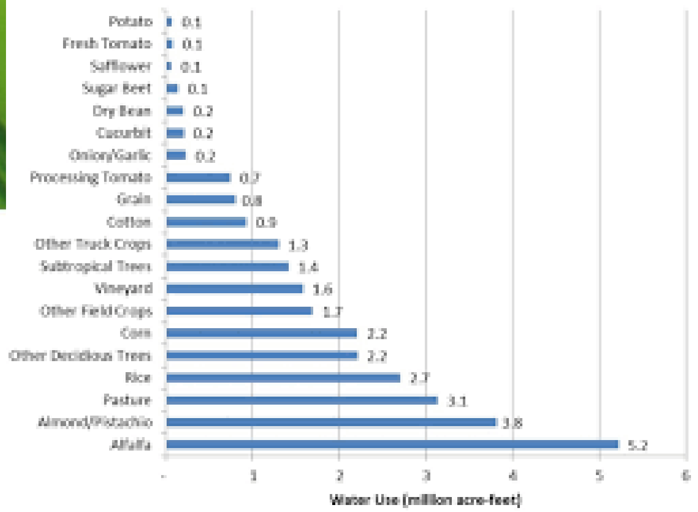
† Number in parenthesis for the study represents the calculated net soil organic C sequestration rate, which factored in hidden C costs in terms of C equivalents of turfgrass maintenance emissions. The preceding number not in parenthesis is the gross soil organic C sequestration rate (Mg C ha^{-1} yr^{-1}) prior to calculation of hidden C costs.

Sustainable Turfgrass Systems

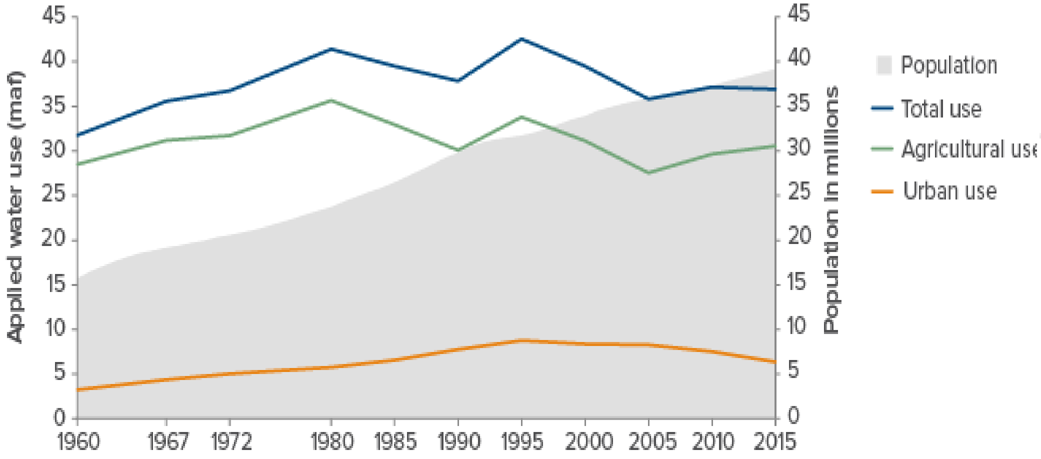
Are Turfgrass Benefits Enough for Inputs of Resources?

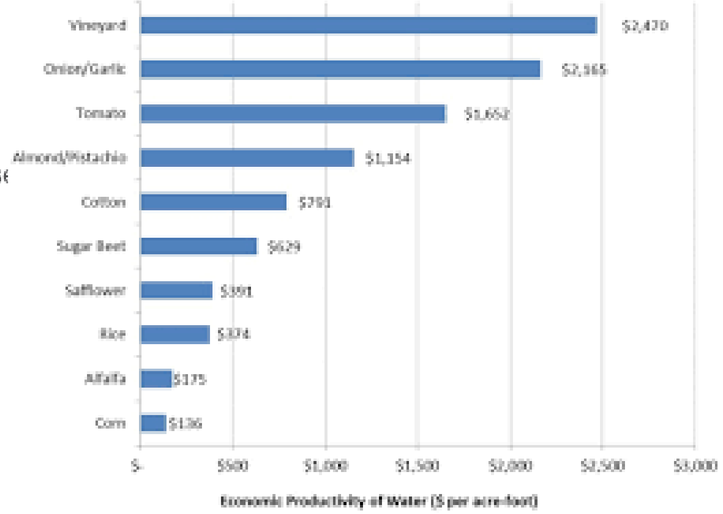
- Managed turfgrass with fertilization, adequate water, clippings returned sequester more carbon than turfgrasses without inputs
- Potable water is limited resource in many areas – Western United States, South Africa, Australia, Spain, Portugal, etc.
  - Drought conditions can occur most areas at some point
  - Irrigation utilized to maintain green cover or keep grass alive
  - Significant progress in reducing water requirements
  - Selection of species and cultivars critical
  - Improvements and adoption of irrigation timing/ methods
  - Effect of no groundcover can be immense (haboob in Phoenix, AZ)

Sustainable Turfgrass Systems



- California increase in population over 55 years vs. water use
- Angelenos use 44% less water per person annually than they did four decades ago
- Total water use and water per capita have declined





Sustainable Turfgrass Systems

Turfgrass as a crop in California for Golf courses

- Value per acre-foot of water
- Value per unit of land

Table 1. Comparison of Revenues and Revenues Per Unit Land and Water for Agricultural Commodities and Golf Courses, 2000

Agricultural commodity	Revenues (product value) $1,000	Revenues per unit of water $/acre-foot	Revenues per unit of land $/acre
Grains	113,612	79	204
Rice	231,001	72	422
Cotton and cottonseed	1,025,523	367	1,122
Sugar beets	111,835	309	1,196
Corn	157,985	89	610
Beans, dry	56,700	205	506
Tomatoes, processing	617,190	742	2,277
Tomatoes, fresh market	333,840	2,840	7,800
Cucurbits	482,549	1,535	4,096
Garlic and onions	443,047	1,711	5,001
Potatoes	271,613	2,479	5,154
Other truck crops	8,607,152	5,724	9,429
Almonds and pistachios	919,789	376	1,601
Other deciduous nuts and fruits	1,308,940	571	2,294
Subtropical crops	1,103,130	752	2,948
Grapes, all	2,836,313	1,661	3,430
Alfalfa and other sources of hay	730,422	127	477
Safflower and other field crops	552,892	131	584
All crops	19,903,533	645	2,264
Golf courses	1,744,839	5,126	14,431

Source: Source: Hawkins, Tom. 2009. Agricultural Water Use Collection Program. Department of Water Resources, State of California, Sacramento SC, June 9.

National Turfgrass Evaluation Program

- **NTEP – www.ntep.org**
- National turf testing system in United States – National listing not required
- One seed lot or vegetative increase. Entry fee paid by sponsor (Cool Season usually Companies) – Company or University have choice to enter
- Europe DUS required to sell – spaced plant phenotype not turf
- No requirement for testing of turf quality in US and much of Europe
- Cooperators at universities through out country paid for planting and evaluating trials.
- Separate trials for other characteristics of interest
    - Drought or reduced irrigation trials
    - Low Input trials
- Evaluated for quality, color, density, diseases, wear tolerance, weeds
- **Before NTEP individual researchers would try to contact breeding companies and Universities for samples for trials**
- **Each trial was different – comparisons difficult**

National Turfgrass Evaluation Program – Drought-First trials and each site separate report

- Two types of Specialty Drought trials in turf
- APPROACH 2 The drier climate ETo -based sites evaluate at three deficit irrigation levels for 100–120-day periods. Data recorded includes percent green cover over time, turfgrass quality, and recovery rate after complete replacement irrigation is initiated.
- Irrigation cool season turf at 40, 60 and 80% Eto (0, 25 and 75 % UMN)
- Companies entered cultivars selected for drought or previous trials demonstrated drought resistance
- Third year data from Utah State, 40% Eto. Tall fescue stayed greener than KBG, Both recovered
- At 60% Eto almost all TF stayed above 50% green cover and bluegrasses only dropped below for 3 weeks
- Most trials tall fescues performed better than KBG

TABLE 17A. (CONT'D)

PERCENT GREEN COVER AND OTHER RATINGS OF ALL CULTIVARS WITH 40% OF ET IN THE 2016 NATIONAL COOL-SEASON WATER USE/DROUGHT TOLERANCE TEST AT LOGAN, UT 1/
2019 DATA

TURFGRASS QUALITY AND OTHER RATINGS 1-9; 9=BEST 2/

NAME		AUG 19	AUG 26	SEPT 3	SEPT 11	SEPT 16	SEPT 24	OCT 2	OCT 8	OCT 15	OCT 16	NOV 1
		PERCENT GREEN COVER										
DLFPS 321/3679	TF	43.3	45.0	44.7	43.7	52.3	54.7	65.0	58.3	53.0	59.7	47.7
PST-R511	TF	55.3	57.7	58.7	62.7	70.7	76.0	86.0	76.7	66.0	78.7	70.0
THOR	TF	35.0	29.7	29.3	29.3	41.7	49.7	69.0	68.0	55.7	65.0	55.0
DLFPS 321/3677	TF	29.0	28.3	26.3	27.7	39.7	52.0	69.3	66.0	60.0	69.3	60.3
LTP-SYN-A3	TF	53.7	53.0	55.7	56.3	64.7	71.0	81.7	80.0	71.0	74.7	64.3
PST-5SDS	TF	48.0	48.7	49.0	50.3	58.0	63.0	74.0	69.3	59.7	59.3	46.7
TITANIUM 2LS	TF	41.0	39.7	38.0	37.7	47.0	53.3	71.0	69.7	65.3	63.0	54.3
STETSON II	TF	36.3	35.3	34.3	36.7	47.7	59.3	75.3	73.3	59.3	75.3	62.3
GO-AOMK	TF	31.3	29.0	24.0	25.0	33.0	44.3	61.7	60.0	61.7	82.7	74.3
RS4	TF	29.7	27.3	26.7	29.7	41.3	56.7	77.7	77.7	68.0	58.0	47.7
NONET	TF	39.3	42.0	36.0	39.0	47.7	54.0	68.7	65.0	65.0	78.7	70.0
THUNDERSTRUCK	TF	36.3	34.0	30.0	29.3	37.3	48.7	65.7	62.7	55.0	59.3	50.0
KINGDOM	TF	24.3	23.7	23.0	22.7	35.0	44.7	61.7	61.0	60.0	66.3	50.3
BAR FA 121095	TF	25.3	28.7	24.3	23.7	31.3	43.0	59.7	55.7	60.0	52.7	42.3
SUPERSONIC	TF	40.7	42.7	41.0	43.0	51.3	58.3	73.7	70.0	62.0	72.7	57.0
BARROBUSTO	TF	29.3	30.0	26.3	26.0	38.7	47.7	68.3	66.7	61.0	71.3	63.0
CATALYST	TF	27.0	27.7	28.3	29.3	41.3	53.0	73.3	71.0	66.7	79.3	68.7
DLFPS 321/3678	TF	30.0	30.0	28.3	29.7	42.0	50.7	67.3	65.3	66.0	81.7	71.7
MRSL TF15	TF	26.0	26.3	26.7	25.3	37.3	49.0	71.0	70.0	64.3	84.3	75.3
SR 4650 (P.RYEGRASS STANDARD ENTRY)		7.7	11.3	11.0	20.3	41.3	66.7	87.7	86.7	81.7	69.0	57.7
NAI-13-14	KB	5.7	7.7	8.7	5.7	20.7	47.7	75.3	77.7	65.7	88.7	83.0
EVEREST	KB	11.7	11.3	10.3	7.7	22.3	47.0	73.3	75.3	62.7	81.0	71.7
PST-K11-118	KB	5.0	7.3	7.7	8.0	22.3	47.3	79.0	81.0	79.3	76.7	67.0
BLUE NOTE	KB	3.3	5.3	7.0	8.0	28.0	57.3	83.0	81.7	78.3	86.3	79.0
PST-K15-169	KB	3.3	6.0	7.3	7.3	23.3	58.0	85.0	87.3	74.7	79.3	71.0
MIDNIGHT	KB	6.0	8.7	9.0	8.0	25.0	56.3	81.0	82.0	74.3	81.3	75.3
PST-K13-141	KB	2.0	4.0	9.0	17.7	37.7	67.0	86.3	89.3	77.0	66.7	55.7
PST-K13-137	KB	7.3	10.0	10.0	7.3	18.7	39.7	71.7	77.0	69.3	89.3	82.0
BLUE DEVIL	KB	8.3	9.7	9.7	9.0	26.7	57.7	81.7	82.3	84.0	76.0	65.7
NAI-13-132	KB	4.3	6.0	6.3	4.7	17.0	47.3	80.0	83.3	77.0	85.3	78.0
PST-K13-143	KB	2.7	5.7	6.3	5.3	18.3	47.0	80.3	82.0	75.7	78.7	71.0
BARRARI	KB	1.7	3.3	5.0	8.0	23.7	53.0	87.7	89.3	84.7	88.0	81.0
BABE	KB	4.0	5.7	7.0	9.0	25.0	53.0	77.7	75.3	63.3	83.0	75.7
BAR PP 110358	KB	4.7	7.0	8.0	5.0	20.0	44.3	73.0	73.0	62.7	80.7	69.0
DAUNTLESS	KB	3.0	5.3	8.0	7.7	23.0	46.7	75.0	74.0	65.7	90.3	85.7
LSD VALUE		14.6	13.7	12.9	15.0	11.6	14.6	11.4	12.7	38.3	23.5	37.5
C.V. (%)		44.0	39.8	38.1	42.2	21.3	15.3	9.0	10.3	19.4	15.6	23.9

- APPROACH 2 – UC Riverside (heat and drought)
- Irrigation at 60% (left) and 80% Eto (right)
- DLFPS 321/3679 (Bentley) was selected for drought tolerance in trials

National Turfgrass Evaluation Program - Drought

- Two types of Specialty Drought trials in cool season turf
- APPROACH 1 Rain exclusion shelters are used to simulate 100-day drought periods in higher rainfall regions. Under the rain exclusion shelters measured the amount of water needed to maintain 65 percent green cover, rate turfgrass quality as well as evaluate recovery from drought when irrigation is resumed.
- Third year data from Univ. of Arkansas showing water required to keep above 65% green
- Control perennial ryegrass at top (not expected), primarily tall fescues stayed green with less water

(CONT'D)

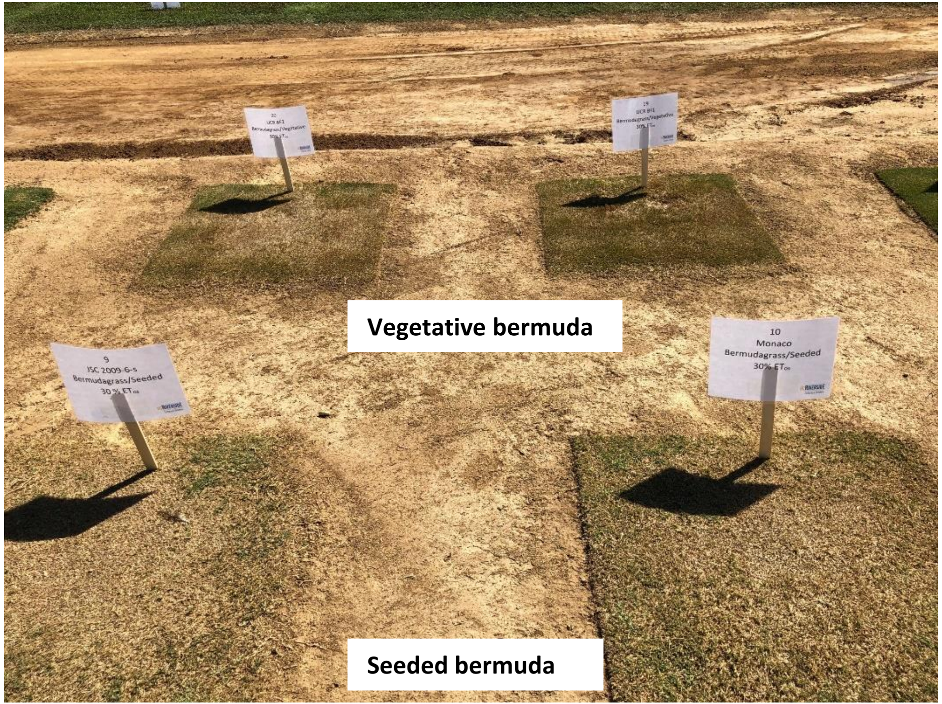
PERCENT GREEN COVER AND OTHER RATINGS OF ALL CULTIVARS
IN THE 2016 NATIONAL COOL-SEASON WATER USE/DROUGHT TOLERANCE TEST AT FAYETTEVILLE, AR 1/
2019 DATA

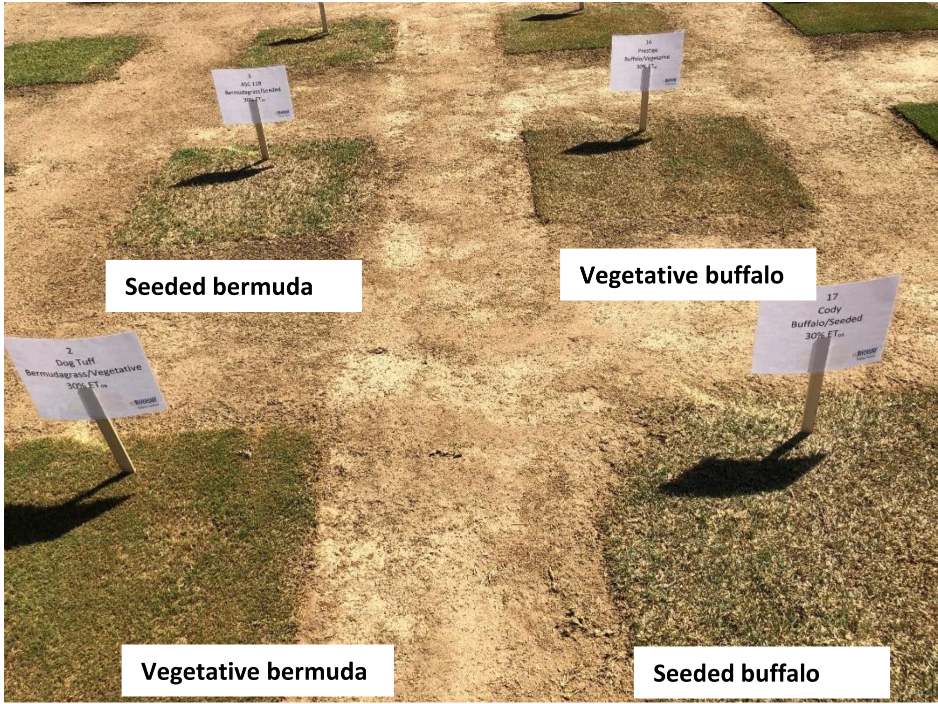
TOTAL WATER APPLIED IN MM 2/

NAME		PERCENT GREEN COVER DURING DRY DOWN								TOTAL WATER APPLIED (mm)
		SEPT 19	SEPT 23	SEPT 30	OCT 4	OCT 11	OCT 14	OCT 18	OCT 22	
SR 4650 (P.RYEGRASS STANDARD ENTRY)		70.7	70.3	88.0	83.7	90.3	91.0	93.0	93.3	55.3
DLFPS 321/3679	TF	55.7	45.3	82.3	83.3	93.0	93.3	94.3	96.0	80.3
TITANIUM 2LS	TF	66.3	72.0	89.3	87.7	93.0	93.7	95.3	96.0	84.7
GO-AOMK	TF	60.0	59.7	82.7	77.7	89.0	88.7	90.7	92.3	93.0
THOR	TF	58.7	52.3	81.7	81.0	92.0	92.0	94.7	96.0	93.3
BARROBUSTO	TF	65.7	58.0	85.3	85.3	92.3	92.3	94.0	95.0	97.7
THUNDERSTRUCK	TF	63.3	60.0	82.3	81.0	89.3	89.7	91.3	93.0	97.7
BAR PP 110358	KB	65.0	67.7	84.3	77.3	86.3	87.3	89.7	92.3	101.7
DLFPS 321/3677	TF	65.0	70.3	87.3	85.7	92.3	92.0	94.0	95.7	101.7
RS4	TF	67.7	72.3	90.7	87.3	93.0	93.0	94.0	95.3	102.0
PST-K15-169	KB	68.0	62.0	78.3	74.3	87.3	86.0	90.7	92.7	105.7
SUPERSONIC	TF	60.7	68.3	86.3	86.0	93.0	93.0	94.3	95.7	110.0
DLFPS 321/3678	TF	57.3	52.3	82.0	79.3	90.3	90.0	92.3	94.3	114.3
MRSL TF15	TF	57.3	56.7	82.0	81.3	91.7	93.0	93.7	95.3	114.7
BAR FA 121095	TF	64.0	58.3	82.3	79.0	89.3	90.3	92.0	94.0	118.7
BLUE NOTE	KB	61.7	66.7	84.3	78.3	87.0	88.0	90.3	92.7	118.7
CATALYST	TF	58.3	56.3	78.3	80.3	90.3	89.3	92.0	94.3	118.7
EVEREST	KB	66.7	64.3	78.3	73.0	85.0	85.7	88.0	91.0	118.7
LTP-SYN-A3	TF	58.0	61.7	81.7	82.3	92.7	93.0	94.3	95.7	118.7
NONET	TF	56.7	53.0	79.0	77.0	86.7	87.3	91.0	93.3	118.7
PST-K13-137	KB	63.3	59.0	84.3	81.3	90.3	90.7	92.7	93.7	118.7
STETSON II	TF	62.0	65.3	84.3	83.3	91.0	91.3	92.7	94.0	118.7
KINGDOM	TF	62.0	57.7	76.3	74.7	85.3	85.7	88.7	91.7	127.3
PST-R511	TF	65.0	65.0	84.3	84.0	92.0	92.7	95.0	95.7	127.3
BARRARI	KB	63.0	66.3	81.3	69.0	81.3	83.3	85.7	88.7	135.3
PST-5SDS	TF	55.3	53.7	78.0	75.3	87.3	87.7	91.0	93.3	135.7
MIDNIGHT	KB	57.0	55.7	74.3	69.0	83.0	84.0	87.7	90.0	152.3
PST-K11-118	KB	58.0	56.0	75.3	69.7	82.0	82.7	86.7	90.7	152.3
DAUNTLESS	KB	60.3	62.7	80.3	69.7	84.3	82.3	85.3	87.0	152.7
NAI-13-14	KB	59.3	61.7	76.3	71.7	84.0	86.3	88.0	90.3	156.7
BABE	KB	46.3	52.0	69.0	65.7	76.7	77.3	84.0	82.3	173.7
BLUE DEVIL	KB	52.0	50.7	71.7	66.3	83.0	81.7	84.0	87.7	173.7
PST-K13-141	KB	60.3	62.0	78.0	69.3	78.7	79.0	81.3	84.0	173.7
NAI-13-132	KB	41.0	45.0	57.0	52.0	69.0	67.3	70.7	76.3	182.0
PST-K13-143	KB	42.7	41.3	55.7	54.0	64.0	64.3	68.7	75.7	186.3
LSD VALUE		36.1	48.9	24.6	17.0	15.9	17.3	16.2	17.0	85.8
C.V. (%)		18.6	23.3	12.8	11.9	9.0	9.5	8.4	7.6	31.5

National Turfgrass Evaluation Program - Drought

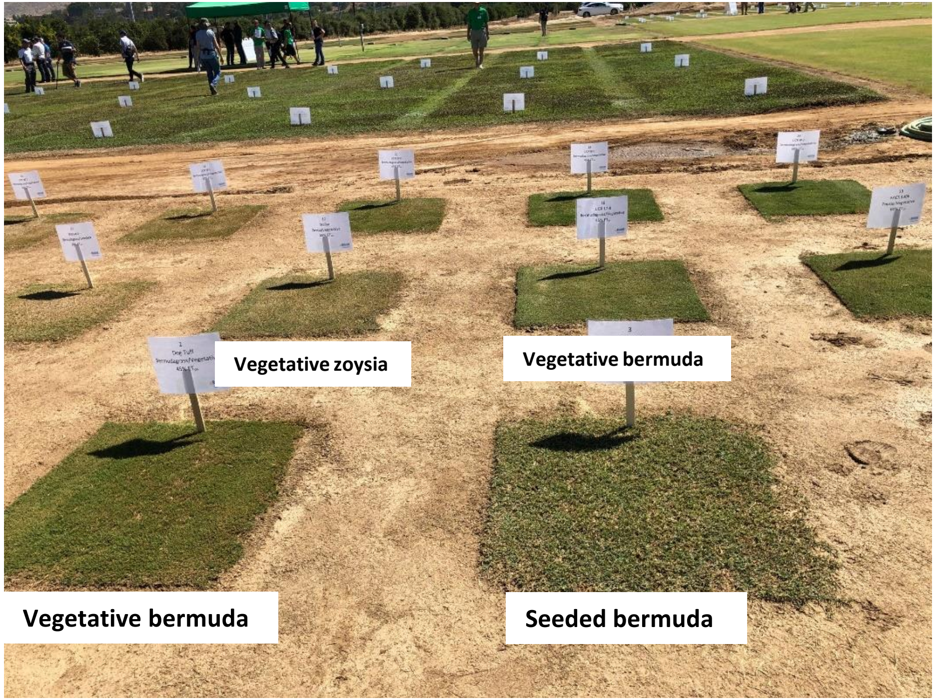
- Drought trials in warm season turf. Irrigated at 30%, 45% and 60% ET
- Irrigation at 30% Seeded Bermudagrass, vegetative hybrid bermudagrass, vegetative zoysia, seeded and vegetative buffalograss , UCRiverside trials

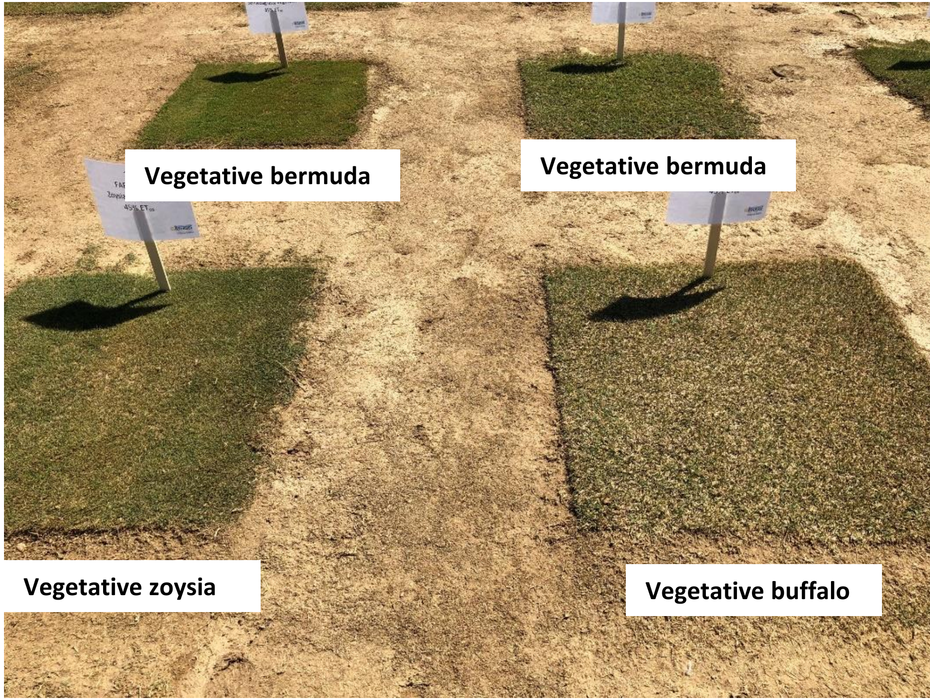




National Turfgrass Evaluation Program- Drought

- Specialty Drought trials in warm season turf
- Irrigation at 45% Seeded Bermudagrass, vegetative hybrid bermudagrass, vegetative zoysia, seeded and vegetative buffalograss , UCRiverside trials (Heat and drought). Vegetative bermuda best performance. Zoysia for shade?





National Turfgrass Evaluation Program – Study total low input

- Low Input trial
- Most sites 1 lb. of Nitrogen at start, no later N applied (some may have been needed)
- No irrigation
- Most sites no herbicides (2 sites preemergent at beginning)
- Mixtures and blends of cultivars allowed
- LP1 Group 1 Sites highest performance by improved tall fescues.
- All mixtures with M at end included Microclover and STC strawberry clover
- DLFPS TF-A – blend of cultivars performed Low input (A-LIST) trials previously

TABLE 1. MEAN TURFGRASS QUALITY RATINGS OF COOL-SEASON CULTIVARS GROWN UNDER 1/
LOW INPUT IN LOCATION PERFORMANCE INDEX (LPI) GROUP 1 **/
2020 DATA
TURFGRASS QUALITY RATINGS 1-9; 9=IDEAL TURF 2/

NAME	# Entry	CT1	PA2	VA1	NC1	MI1	MO1	NE1	UT1	MEAN
* BULLSEYE	2	5.5	3.3	7.1	4.9	6.3	5.9	4.8	3.1	5.4
DLFPS TFASTC	14	5.8	3.1	7.1	5.3	5.9	5.6	4.3	3.2	5.3
DLFPS TFAM	9	6.0	2.7	6.8	5.8	5.5	5.3	4.4	3.3	5.2
DLFPS TF-A	6	5.3	2.9	6.8	4.9	5.9	5.3	4.9	3.5	5.1
* VITALITY DOUBLE	11	4.8	3.0	6.8	5.1	5.9	5.7	4.1	3.3	5.1
MNHD-15	5	5.7	3.3	7.0	3.3	6.0	5.3	4.3	2.1	5.0
A-SFT	24	4.3	3.2	6.8	4.3	6.1	5.9	4.0	2.8	5.0
* KINGDOM	25	4.6	2.9	6.6	4.2	5.9	5.2	4.8	3.2	4.9
DLFPS CHCRM	7	5.8	3.0	6.8	4.0	5.6	5.2	3.7	2.0	4.9
* KY-31 E+	18	5.3	2.6	6.4	4.2	5.7	4.5	5.3	3.3	4.9
BGR-TF3	4	5.0	2.6	6.5	5.0	5.5	4.9	4.5	3.4	4.9
CRS MIX #3	21	6.6	3.1	7.0	2.8	5.6	5.3	3.4	0.6	4.8
CRS MIX #2	20	5.3	3.3	7.0	3.4	5.8	5.4	3.7	1.9	4.8
DTT TALL FESCUE MIX	22	4.7	2.7	6.4	4.4	5.7	4.9	4.9	3.4	4.8
DTTHO TF/KBG MIX	23	4.3	2.9	6.6	4.1	5.9	5.5	4.2	2.8	4.8
DLFPS CHCRSH	15	5.1	3.0	6.8	4.0	5.6	5.3	3.4	2.1	4.7
* VITALITY LOW	10	5.5	2.9	6.7	4.0	5.5	5.0	3.7	2.2	4.7
* NATURAL KNIT ? PRG MIX	1	4.1	3.2	6.8	3.0	6.2	6.3	3.4	1.4	4.7
SOUTHERN MIXTURE	28	4.4	2.7	6.5	4.5	5.6	5.2	3.9	3.0	4.7
* CS MIX	29	5.1	2.8	6.7	4.4	5.3	5.3	3.1	2.2	4.7
CRS MIX #1	19	5.5	2.8	6.6	3.4	5.5	4.5	4.2	2.2	4.7
* CHANTILLY	12	4.5	3.1	6.8	3.4	5.8	5.6	3.2	1.8	4.6
NORTHERN MIXTURE	27	4.5	2.9	6.7	4.2	5.5	5.5	3.0	2.1	4.6
* RADAR	31	4.4	2.9	6.7	4.1	5.5	5.5	3.1	2.2	4.6
* RESOLUTE (7H7)	26	5.7	2.7	6.5	3.3	5.3	4.2	4.2	2.1	4.6
DLFPS SHHM	8	5.4	2.5	6.4	3.9	5.2	5.1	3.3	1.6	4.6
* YAAK	30	3.7	2.4	6.1	4.7	5.5	4.7	4.6	3.8	4.5
* SPARTAN II	16	5.4	2.8	6.6	3.2	5.3	4.9	3.3	1.4	4.5
* QUATRO	17	4.6	2.8	6.6	3.4	5.4	5.4	2.9	1.4	4.4
* BEWITCHED	3	3.1	2.6	6.1	2.5	5.6	5.4	3.0	1.3	4.1
KENBLUE	32	2.9	2.4	6.0	3.1	5.4	5.2	3.2	2.0	4.0
* DUTCH WHITE CLOVER	13	2.6	2.4	5.9	2.4	5.4	5.5	2.5	1.0	3.8
LSD VALUE		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
C.V. (%)		12.7	21.6	9.3	15.5	10.9	11.7	16.0	26.1	13.1

National Turfgrass Evaluation Program

- Low Input trial
- Most sites 1 lb. of Nitrogen at start, no later N applied (some may have been needed)
- No irrigation
- Most sites no herbicides (2 sites preemergent at beginning)
- Mixtures and blends of cultivars allowed
- LP1 Group 2 Sites highest performance by fine fescue mixtures
- All mixtures with M at end included Microclover and STC strawberry clover
- Different area of the United States may show more benefit of using tall fescues for reduced input, others fine fescues

MEAN TURFGRASS QUALITY RATINGS OF COOL-SEASON CULTIVARS GROWN UNDER 1/
LOW INPUT IN LOCATION PERFORMANCE INDEX (LPI) GROUP 2 */
2020 DATA
TURFGRASS QUALITY RATINGS 1-9; 9=IDEAL TURF 2/

NAME	# Entry	IN1	MN1	OR1	MEAN
CRS MIX #1	19	5.0	5.8	3.6	4.8
CRS MIX #2	20	5.2	5.5	3.6	4.8
VITALITY LOW	10	5.1	5.0	4.1	4.7
DLFPS CHCRSH	15	5.2	4.8	4.1	4.7
RESOLUTE (7H7)	26	4.8	5.8	3.5	4.7
RADAR	31	5.3	4.3	4.0	4.5
MNHD-15	5	4.9	5.4	3.3	4.5
DLFPS CHCRM	7	4.8	4.5	4.1	4.4
NORTHERN MIXTURE	27	5.2	4.0	4.1	4.4
SPARTAN II	16	4.7	5.0	3.6	4.4
CS MIX	29	5.0	4.0	4.3	4.4
CHANTILLY	12	5.1	4.6	3.3	4.3
VITALITY DOUBLE	11	5.1	3.1	4.0	4.1
DLFPS TFASTC	14	4.8	2.9	4.5	4.1
SOUTHERN MIXTURE	28	5.0	3.5	3.6	4.0
QUATRO	17	4.5	3.8	3.3	3.9
DLFPS TF-A	6	4.7	2.9	3.6	3.7
YAAK	30	5.0	3.1	3.0	3.7
BGR-TF3	4	4.6	2.8	3.7	3.7
CRS MIX #3	21	3.6	4.0	3.3	3.6
DTT TALL FESCUE MIX	22	4.5	3.1	2.9	3.5
A-SFT	24	4.7	2.6	3.0	3.5
BULLSEYE	2	4.4	2.3	3.5	3.4
KINGDOM	25	4.5	2.9	2.7	3.4
DTTHO TF/KBG MIX	23	4.5	2.7	2.7	3.3
KY-31 E+	18	4.0	3.0	2.7	3.2
DLFPS TFAM	9	4.0	1.1	4.4	3.2
DLFPS SHHM	8	3.5	1.9	3.3	2.9
KENBLUE	32	4.2	2.4	1.8	2.8
BEWITCHED	3	3.7	1.9	1.3	2.3
NATURAL KNIT ? PRG MIX	1	3.6	1.4	1.7	2.2
DUTCH WHITE CLOVER	13	3.4	1.2	1.1	1.9
LSD VALUE		1.0	1.0	1.0	1.0
C.V. (%)		13.5	17.8	18.8	16.3

National Turfgrass Evaluation Program

- Low Input trial
- Most sites 1 lb. of Nitrogen at start, no later N applied (some may have been needed)
- No irrigation 5 years, no herbicides (left), Oregon State University
- Average 100 days no summer rainfall Oregon State
- Right same trial year 6, summer irrigation and broadleaf herbicide applied.
- Grasses can maintain cover with low inputs and recover

Reduced Mowing (Reduce Hidden Carbon Costs)

- Newer turfgrass cultivars in tall fescue and perennial ryegrass tend to be overall shorter
- Influence of mowing on Carbon into the atmosphere – Electric mowers may help the overall balance (still carbon costs of manufacturing and source of electricity)
- **Mowing by One –third rule slower growing tall fescues and Kentucky bluegrasses had less mowings per season = less hidden carbon costs**

Law, Bigelow and Patton. 2016. Crop Sci. 56:3318–3327 (2016). doi: 10.2135/cropsci2015.09.0595

Table 3. Number of annual mowing events by year, mowing frequency, grass clippings management, growth rate, and species for turf swards planted in April 2011 in West Lafayette, IN.

		2012				2013			
		Weekly		One-third rule		Weekly		One-third rule	
Species‡	Growth rate	Collected	Returned	Collected	Returned	Collected	Returned	Collected	Returned
		Mowing events (per plot)							
TF	Slow	29	29	19.0	21.0	28.3 abc†	29.0 abc	16.0 ij	17.8 h
TF	Moderate	30	30	20.8	22.5	29.0 abc	29.3 ab	17.3 hi	21.3 fg
TF	Fast	30	30	23.3	25.0	28.8 abc	29.5 a	21.0 fg	24.3 d
KBG	Slow	9	9	6.0	6.0	19.8 g	24.0 de	12.3 l	14.3 k
KBG	Moderate	26	26	14.8	16.8	27.5 c	28.0 abc	15.5 jk	17.5 hi
KBG	Fast	27	27	19.5	21.8	27.8 bc	28.0 abc	20.0 g	22.5 ef

† Means followed by the same letter are not significantly different according to Tukey's honest significant difference test ($\alpha = 0.05$).

‡ KBG, Kentucky bluegrass; TF, tall fescue.

Turfgrass Crop

Turfgrass can be classified as a crop – Many beneficial crops are not direct food

Turfgrasses can be maintained with lower irrigation rates than often utilized

Many areas water biggest challenge

Identify targets to increase sustainability – Most need further study

- Drought resistance (able to keep green growth and continue sequestering with less water)
- Slower growth rate (less hidden carbon cost)
- Reduced nitrogen requirement (less greenhouse gasses)
- Disease resistance (less fungicides required – manufacture, delivery, application)
- Competitive against weeds (less herbicides – manufacture, delivery, application)
- Easily measured carbon sequestration in short term studies (correlation with long term)

Sustainable Turfgrass Systems

- Most turfgrasses are established as a blend of multiple cultivars and/or mixture of more than one species
  - Interaction between species in mixtures and cultivars in blends little understood
  - We need to study this but how?
- Will customers pay more money for sustainable cultivars?
  - Testing and promotion needs to be easily identified – often me too promotion with no testing behind
  - Biggest impact to retail customers then landscapers and sod growers
  - Often Price is primary driver- In US new NTEP tool for consumers – See program
- How to establish new cultivars into older material to obtain benefits – US vs. European
- Keep existing soil carbon locked up during establishment
  - Slit seeding, aerification?
  - How to establish new vegetative cultivars into existing ones without stripping off sod and releasing CO2

Sustainable Turfgrass Systems

- Endophytes and soil microbe interactions
  - Fungal endophytes found in many turf species – Influence on carbon and stress resistance
    - Controls above ground feeding insects. Does not significantly control root feeding insects
    - Endophyte is a fungus that grows within the crown and leaf sheath tissues of the turfgrass plant.
    - Endophytes can be incorporated into improved plant material to increase the stress resistance
    - Transmitted by seed
    - Turfgrass species that may contain the endophyte: Perennial rye, tall fescue, Chewings, hard, creeping red, blue, and sheep fescue.
    - Proper seed storage necessary to keep it viable in seed
  - Soil Microbes –Mycorrhizal fungi (how much of carbon sequestered is in this?)
    - Improves root penetration
    - Improves fertilizer utilization
    - Reduces drought stress and watering requirement
    - Promotes good soil structure and drainage
- Adding in clovers and other species

Ecosystem Services

- Adding in clovers and other species
  - Microclover – dwarf white clovers selected to blend with turfgrasses – nitrogen benefit
  - Strawberry clover – included in some mixtures, nitrogen
  - Bee Lawns and Ecolawns – other species to help serve ecosystems

Paige Boyle Utah State Grass/clover

Ryegrass w and w/o microclover in Oregon

Strawberry clover drought with turf

Sustainable Turfgrass Systems

Sustainable Turf – A Valuable Crop

- Progress has been made in demonstrating turfgrass value to sustainability
- Further research needs to be done to determine best solutions for biggest benefit and less hidden carbon costs
- Complicated by dealing with many species – determine highest benefit
- Utilization of improved irrigation systems for needs based watering (soil water controller) or based on ET
- Consumer demand or legislation will determine market
- Seed yield often critical part of getting cool season cultivars in production
- Vegetative warm season grasses and new seeded cultivars for lower water use in adapted areas