Predicting Turfgrass Performance[1]

Micah Woods, Ph.D.

7 October 2013

In most parts of the world there is no locally-generated information to guide turfgrass selection or turfgrass management practices. To generate useful information for locations where better information is not available, I use climatological normals data, a growth potential based on optimum temperatures for photosynthesis, and the new minimum levels for sustainable nutrition (MLSN) soil nutrient guidelines. I use these data to predict grass species performance in areas with average annual temperatures above 20°C and to predict nutrient requirements for any grass at any location.

[1] This handout is a supplement to the Cornell University Horticulture Department seminar on this topic. For additional information, see `http://www.asianturfgrass.com`.

Temperature-based growth potential

The growth potential (Equations 1 and 2) was developed by PACE Turf[2] to describe the relationship between turfgrass growth and temperature. Cool season (C_3) grasses have their greatest growth rate when the temperature is about 20°C, with slower growth at lower or higher temperatures; warm-season grasses (C_4) have their greatest growth rate when the temperature is about 31°C, with slower growth at cooler temperatures. The growth potential equations provide a simple way to predict that growth by giving a number between 0 and 1 for any temperature. This gives an indication of how close the actual or predicted temperature is to the optimum temperatures for growth.

[2] Wendy Gelernter and Larry Stowell. Improved overseeding programs 1. The role of weather. *Golf Course Management*, pages 108–113, March 2005

$$GP = e^{-0.5(\frac{t-t_o}{var})^2} \qquad (1)$$

GP = growth potential, on a scale of 0 to 1

e = 2.71828, a mathematical constant

t = actual temperature

t_o = optimum temperature, 20 for C_3 grass, 31 for C_4 grass

var = adjusts the change in GP as temperature moves away from t_o; I use 5.5 for C_3 and 8.5 for C_4

This equation gives the same result.

$$GP = \frac{1}{e^{0.5(\frac{t-t_o}{var})^2}} \qquad (2)$$

We can make use of the growth potential by relating the nitrogen requirement of the grass to the growth potential. We can then simply calculate the estimated nitrogen requirement for a given amount of time by multiplying the growth potential times the maximum nitrogen rate. The growth potential can be calculated on a daily, weekly, or monthly basis, with a corresponding nitrogen requirement, to estimate how much nitrogen fertilizer may be required by the grass during that time period. I've written about this in more detail: `http://www.files.asianturfgrass.com/201306_growth_potential.pdf`.

Sunshine hours and the daily light integral

EVEN THOUGH TEMPERATURES can be similar between two locations, the grass species that thrive can be completely different. Honolulu and Hilo make a good example of this. At Honolulu, bermudagrass (*Cynodon dactylon*) performs well as an irrigated turf. At Hilo, where the temperature is similar, bermudagrass doesn't perform well at all. Instead, one finds more shade tolerant grasses such as *Axonopus compressus*, *Zoysia matrella*, and *Paspalum conjugatum*.

I've made a website (`http://climate.asianturfgrass.com/`) with links to sunshine and temperature weather data. The site also contains explanatory documents and charts.

In 2012, I made extensive measurements of photosynthetic irradiance in Asia. Those data are contained in a report (`http://files.asianturfgrass.com/irradiance.pdf`) entitled *How Much do Clouds Affect Photosynthetic Irradiance? Measures of Light at Thailand, Hong Kong, Vietnam, and Japan*.

The light available for plants to use is termed photosynthetically active radiation (PAR) and is expressed on an instantaneous basis in units of micromoles of photons per square meter per second ($\mu mol\,m^{-2}\,s^{-1}$) or on a daily basis as a daily light integral (DLI) which is in units of moles of photons per square meter per day ($mol\,m^{-2}\,d^{-1}$).

Using the Angstrom equation,[3] one can estimate the solar energy reaching the earth's surface, accounting for the effect of clouds. One can then estimate PAR.[4]

[3] Anders Angstrom. Solar and terrestrial radiation. *Q J R Met Society*, 50: 121–126, 1924

[4] D.W. Meek, J.L. Hatfield, T.A. Howell, S.B. Idso, and R.J. Reginato. A generalized relationship between photosynthetically active radiation and solar radiation. *Agronomy Journal*, 76: 939–945, 1984

Estimating nutrient requirements for any grass at any location

I've written about this in more detail in these documents:

- `http://www.files.asianturfgrass.com/20130311_woods_handout_nutrient_requirements_tropical_turfgrass.pdf`
- `http://files.asianturfgrass.com/20130927_iceland_handout.pdf`

The first is focused more on C_4 grasses, and the second on C_3 grasses.

The method explained in today's seminar makes use of the relationship between nitrogen, growth, and nutrient demand.[5] Kussow et al. found:

> N supply was the primary determinant of turfgrass growth rate, plant nutrient demand, and nutrient uptake. Nitrogen uptake accounted for over 88% of uptake of all other nutrients. Uptake of P and K were strongly related to tissue N content irrespective of soil test levels.

[5] Wayne R. Kussow, Douglas J. Soldat, William C. Kreuser, and Steven M. Houlihan. Evidence, regulation, and consequences of nitrogen-driven nutrient demand by turfgrass. *International Scholarly Research Network*, 2012:1–9, 2012

The full paper is at http://www.hindawi.com/isrn/agronomy/2012/359284/.

Dr. Larry Stowell from PACE Turf (http://www.paceturf.org/) and I have developed the minimum levels for sustainable nutrition (MLSN) guidelines for interpreting Mehlich 3 soil test results for turfgrass. The MLSN guidelines are simple, and they are based on a rigorous review of soil tests from good-performing turfgrass sites. From a database of over 16,000 soil samples, we selected those that are classified as having good turf, that have a pH in the range of 5.5 to 7.5, and those with a low estimated cation exchange capacity of less than 60 $mmol_c\ kg^{-1}$. This selected about 1,500 samples, from which Dr. Stowell fit a log-logistic model to the observed soil test data. This allows us to define the soil nutrient concentration at which a certain proportion of the soil tests are above or below a certain level.

Element	MLSN (ppm)
Potassium	35
Phosphorus	18
Calcium	360
Magnesium	54
Sulfur	13

Table 1: The minimum levels for sustainable nutrition (MLSN) guidelines as of 1 September 2013

For the MLSN guidelines (Table 1), we chose the 10% level to set the target guidelines, meaning that 10% of the samples in the database were below the guideline but were still performing well. The goal of the MLSN guidelines is to provide a scientific and data-based approach to interpreting soil tests for turfgrass sites, making sure that there is a high probability of good turfgrass performance, while minimizing unnecessary application of fertilizer. These guidelines are intended to simplify and replace the impossibly convoluted conventional guidelines.[6]

[6] R.N. Carrow, L. Stowell, W. Gelernter, S. Davis, R.R. Duncan, and J. Skorulski. Clarifying soil testing: III. SLAN sufficiency ranges and recommendations. *Golf Course Management*, 72(1): 194–198, January 2004

By considering the previous points, mathematically, the minimum nutrient requirement can be determined

We can estimate the nutrient harvest based on a nitrogen-controlled growth rate and the typical leaf nutrient content. We can measure the amount of each element in the soil and can compare the soil amount[7] to the MLSN guideline. Then, it is a simple matter to calculate how much of each element may be required as fertilizer. The objective is to ensure that the soil level remains at or above the MLSN guideline. If the amount of an element in the soil is above the MLSN guideline, we are confident that the turf can perform at its highest level.

[7] In making calculations about soil concentrations and amounts of a mineral element applied to the surface, it may be useful to use a conversion factor. The turfgrass rootzone is often at a depth of about 10 cm. In that case, in a sand rootzone, 1 m^2 to a depth of 10 cm has a mass of 150 kg. One gram of any element applied to 1 m^2 and distributed evenly throughout the top 10 cm is expected to increase the amount of that element in the soil by 6.7 ppm. Likewise, the harvesting of that element will decrease the amount of that element in the soil by 6.7 ppm for each gram of element harvested in 1 m^2.

The estimated N use can be calculated from Equation 1 or 2 and then multiplying the growth potential by the maximum N use. Based on an average leaf N content of 4%, we can estimate clipping yield per unit area simply by dividing the estimated N use by 0.04. Then, for any element, we can calculate its estimated harvest by multiplying the clipping yield per unit area by the average leaf content of that element.

Once we have the necessary information, it is simple to determine how much of an element we need to apply as fertilizer. We know that at the MLSN level (Table 1), there is enough of that element in the soil to produce excellent turfgrass conditions. So we want to make sure the soil has the nutrient at or above the MLSN level. The amount A in equation 3 gives us the total amount of an element needed in the soil to keep the soil above the MLSN guideline.

$$A = MLSN\ (g\ m^{-2}) + Harvest\ (g\ m^{-2}) \tag{3}$$

To find how much of an element needs to be applied as fertilizer (F), we then subtract the actual amount on a soil test, which we can denote as $\text{Soil}_{\text{test}}$ and express in units of g m^{-2}.

$$F\ (g\ m^{-2}) = A - Soil_{\text{test}} \tag{4}$$

If *F* is a positive number, that is amount of the element required to keep the soil above the MLSN guideline. If *F* is a negative number, that element is not required as fertilizer.

For more information about the MLSN guidelines, see `http://www.paceturf.org/journal/minimum_level_for_sustainable_nutrition`. A new project, the Global Soil Survey (`http://www.paceturf.org/journal/global_soil_survey`), allows turf managers from around the globe to participate in the development and implementation of new guidelines.