MLSN Cheat Sheet

U.S. customary units

Definition

MLSN is an initialism for *minimum levels for sustainable nutrition*. This is a method for soil test interpretation and fertilizer recommendations.

MLSN really quick start

If you have Mehlich 3 soil test data, you can directly compare your test results (in ppm) to the MLSN guideline levels. If your soil is above the guideline, then you don't need to add that element – today. You can be confident that high quality turfgrass can be produced in soils with that quantity of the element. If your soil is below the guideline, you can have high quality turfgrass too. But you should be aware that there are few soils producing high quality turfgrass with nutrient levels that low. You'll probably want to add enough of the element to raise it above the MLSN guideline.

That's only the situation for today. Is your grass alive? We hope so! If it is, then it is using nutrients. The nutrient content in the soil is going to be lower tomorrow than it was today – unless your grass is dead or dormant – because the grass uses nutrients. To *really* use the MLSN guidelines, you need to look not at today, but into the future. This cheat sheet is meant to provide all the explanations and calculations you'll require.

MLSN quick start

These are the steps to take to get started using MLSN – in the standard way – immediately. If you don't know how to get these quantities, don't worry. The other sections of this cheat sheet show how to find these quantities, and how to make more modifications to fit your site.

1. **Soil test** Take soil samples to a depth of 4 inches. Then use the Mehlich 3 extractant to find soil test K, P, Ca, Mg, and S. Look at the results in parts per million (ppm). Express the results as mass per area. Call this quantity c.
2. **Estimate grass use** Find grass use of those elements over a time duration (t). Express those use estimates as mass per area. Call this quantity a.
3. **Check the MLSN guideline** Express the value for each element as mass per area. Call this quantity b. The MLSN minimum levels for each element are given in this table.

Element	ppm
K	37
P	21
Ca	331
Mg	47
S	6

4. **Calculate fertilizer requirement** The fertilizer amount to apply over time t is $a + b - c$.
5. **Repeat for each element** This process gives a fertilizer requirement for time t for K, P, Ca, Mg, and S.

Estimating grass use

The value a is the expected grass use for time t. Here are three ways to get that value.

Estimate from growth One can collect the clippings, express them as a mass, and calculate the quantity of nutrients in that mass of clippings. Clipping volume is a rapid way to estimate the mass. For every 25 gallons (or 100 quarts) of clippings 1000 ft^{-2}, expect a dry mass of 13 lbs 1000 ft^{-2}. Then, calculate nutrient content by considering the elements in healthy turf. I typically use these numbers.

Element	% in dry leaves			
	Agrostis & *Poa*	*Cynodon*	*Paspalum*	*Festuca*
N	4	3	3	3
K	2	2	3	1.5
P	0.5	0.5	0.5	0.5
Ca	0.5	0.5	0.5	0.5
Mg	0.2	0.2	0.2	0.2
S	0.2	0.2	0.2	0.2

If you know that your turf contains different concentrations of nutrients than shown in this table, please make the adjustments to fit your site.

Estimate based on N supply The grass cannot grow more than the N supply. Dividing the N supply by the percentage N in the leaves gives the maximum clipping yield. One can then work out the maximum use of all the elements. For example, *Cynodon* supplied with 3 lbs N 1000 ft^{-2} has a maximum clipping yield of $\frac{3}{0.03} = 100$ lbs. To account for N mineralization, I make an estimate based on soil organic matter being 5% N and 2.5% of that N mineralized in one year (Havlin et al., 1998, p. 109).

Predict based on GP If one doesn't know clippings or N supply, the temperature-based growth potential (GP) provides a straightforward way to get an estimate of N use, and consequently, of maximum possibly growth. One sets a maximum N rate for any duration (d) of the year, calculates GP for time intervals of length d, and multiplying maximum N by GP gives the expected N use (Woods, 2013).

The MLSN guidelines

The MLSN guidelines are given in units of ppm. This is mg of element per kg of soil. In the calculation of a fertilizer requirement, I express the MLSN guideline amount as b. This amount is added to the amount the grass uses. This ensures that 100% of grass use, plus the MLSN minimum amount in the soil, are present in any fertilizer recommendation.

Converting from ppm to lbs 1000 ft^{-2}, and vice versa

1000 ft^2 to a depth of 4 inches has a mass of 13,395 kg when the bulk density is 1.5 g cm^{-3}. 1 lb (454,000 mg) distributed through 13,395 kg is thus $\frac{454000}{13395} = 34$ mg kg^{-1}. One can find the conversion factor for any rootzone depth and any bulk density using this same process.

The soil test amount

The soil test amount c is the amount from a Mehlich 3 soil test. Note that conversion of soil test results from concentration units (ppm) to mass of nutrients per area, depends on the rootzone depth and on the soil's bulk density. You can either customize this for your location, or use the standard conversions.

Soil tests other than Mehlich 3

We recommend Mehlich 3 soil testing (Mehlich, 1984) when using MLSN. If you use a different soil testing method, but want to use the MLSN guidelines, you will have to convert the test results to their expected values in Mehlich 3 – or convert the MLSN guidelines to expected values in the other extractant. This conversion process introduces an unknown amount of error into the calculation.

P We've calculated an MLSN for the Bray-2 (30 ppm) and Olsen (6 ppm) extractants. We don't have information on other extraction methods for P.

K, Ca, Mg When using 1 *N* ammonium acetate, or the Morgan extractant, the approximate MLSN guidelines convert to 30 ppm for K, 265 ppm for Ca, and 38 ppm for Mg. Alternatively, multiply the ammonium acetate or Morgan test results by 1.2 and then use the unmodified MLSN guideline.

S No known conversion.

How and why MLSN works

It works by ensuring the grass is supplied with all the nutrients it can use while keeping a safe amount of each nutrient untouched in the soil as a reserve. The MLSN calculation identifies the amount of nutrients the grass uses at a particular site. It then ensures the grass is either supplied with 100% of those nutrients from fertilizer, from soil, or from a combination of soil and fertilizer (Woods et al., 2014).

This approach recognizes that grass uses nutrients. Rather than trying to maintain all the nutrients the grass could ever use, and then some, in a hypothetical *optimum* soil that doesn't exist, the MLSN approach makes a careful estimate of plant use and makes sure the grass is supplied with that much while still keeping a safe amount in reserve, untouched, in the soil. This approach puts the turfgrass manager in control.

> "The fundamental principle of successful greenkeeping is the recognition of the fact that the finest golfing grasses flourish on poor soil and that more harm is done by over-, rather than underfertilizing" (MacKenzie, 1998).

Why MLSN is needed

Conventional soil test interpretation is based on guidelines that are higher than required to produce high quality turf. Turner and Waddington (1978) described this problem 40 years ago:

> "Unfortunately, turfgrass recommendations appear to be based on research done with other crops, such as forages, results from turfgrass fertility studies not designed to relate to soil testing, and the best judgement of the agronomist making the recommendations."

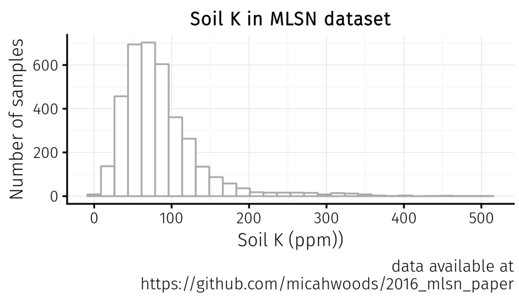
Carrow et al. (2001, p. 164) wrote about this problem in their *Turfgrass Soil Fertility* book:

> "In some cases, turfgrasses have been placed in a 'high' P and K requirement category, while pasture grasses were in a 'low' category. This decision was based on economics, not agronomics. The cost of fertilization was not considered of primary importance for turf."

The MLSN approach to soil test interpretation is designed to make a fertilizer recommendation that is based on supplying the grass all the nutrients that it can use, while ensuring a safe amount remains in the soil. This solves – or more precisely, avoids – many of the problems of conventional soil test interpretation.

How MLSN was developed

We studied the nutrient content of thousands of turfgrass soils in which good turf was growing at the time the sample was collected. The details of this process are described in Woods et al. (2016). After removing samples with pH < 5.5 and pH > 8.5, and selecting those soils that have nutrient holding capacities similar to putting green soils, we looked at the distribution of nutrients in the samples. This is K, as an example.



All the soils are producing good turf, but the soils contain a wide range of K. If the soils with relatively low levels of an element are producing good turf, then logic tells us that such an amount *must be enough* to produce good turf. Having high K in the soil doesn't make the grass any better. It does, however, mean that less K fertilizer is required.

We then used the VGAM package (Yee, 2016) in R (R Core Team, 2017) to identify the scale (α) and shape (β) parameters for the log-logistic distribution of each of the elements. These are the parameters of the log-logistic distributions of the MLSN data.

Element	Scale (α)	Shape (β)
K	73.48	3.20
P	55.07	2.23
Ca	548.13	4.85
Mg	83.17	3.83
S	19.37	2.30

Once α and β are known, one can calculate the cumulative distribution function (cdf) for any soil test value. The cdf for a log-logistic distribution is given by Eq. 1.

$$F(x) = \frac{x^\beta}{\alpha^\beta + x^\beta}, \quad x \in [0, \infty) \tag{1}$$

The quantile function for a log-logistic distribution is given by Eq. 2.

$$F^{-1}(p) = \alpha \left(\frac{p}{1-p} \right)^{1/\beta}, \quad p \in [0, 1) \tag{2}$$

The MLSN guideline was selected as the value at which the probability of a random variable (X) drawn from this distribution having a value less than or equal to the MLSN guideline is 0.1. That is, the MLSN guideline is the value of x where $P(X \leq x) = 0.1$, obtained by evaluating the quantile function (Eq. 2) at $p = 0.1$.

You can work through these, using your soil test values as x in Eq. 1, or choosing any quantile you want between 0 and 1 as p in Eq. 2. Or let the sustainability index (SI) calculator make the calculation for you: `https://asianturfgrass.shinyapps.io/turfsi/`.

Frequently asked questions

How do I know the nutrients are available?

You know the nutrients are available because you've done a soil test. That's what a soil test is – by definition it produces a nutrient availability index. If you don't trust the soil tests, then I suggest skipping them altogether. Instead, assume the soil can supply nothing, and supply to the grass 100% (or a little more) of its possible use of each element. This isn't the most efficient way to do it, but you won't need to worry about availability, and it is guaranteed to supply all that the grass can use.

MLSN guideline, target level or minimum level?

Conventional soil test interpretation may give the impression that there are target or optimum levels in the soil. The MLSN guideline is a minimum value – *minimum* is the *M* in MLSN so we haven't always repeated that – that one doesn't want to drop below. It's not a level below which one will have deficiency. It's not a target level that one ideally will have the soil at. What the MLSN guideline represents is a level in the soil with enough of that element to produce high quality turf. There is high quality turf in soils with less of that element too, and that's why we are confident the MLSN guideline is a safe level. But there aren't a lot of soils with less, so we suggest keeping the soil from dropping below the MLSN guideline.

Seriously, the same minimum for every grass, soil, and location? No regional customization?

We are confident that the MLSN guideline is enough to produce high quality turf for every grass, everywhere. MLSN has the ultimate customization, however, because the grass use of elements is entirely site specific. In order to ensure the soil doesn't drop below the MLSN guideline, one has to estimate a, the expected plant use over time. That's where the customization comes in.

How is this different than conventional soil test interpretation?

The focus of MLSN is on keeping the soil from dropping below a known safe level. To do this, one must account for how much the grass uses over time. The MLSN approach explicitly calculates the grass use. The conventional interpretation (Carrow et al., 2004) is about classifying based on soil levels.

What about micronutrients?

I don't worry about them. They are used in tiny amounts by the grass. The grass uses about 400 times ($\frac{40000}{100}$) as much N as it does the most used micronutrient. The grass probably can get all the micronutrients it needs from the soil, because it uses such small quantities of them. And because it uses such small quantities of them, if you are worried about it, apply micronutrients. It doesn't cost much and is easy to do.

What about salinity?

Salinity can kill the grass. That's a major problem. To keep the grass from getting killed by high salinity, one needs to leach the salts from the soil. I wouldn't worry much about soil nutrient levels or MLSN if I have a salinity problem. I would leach the salts, and I would supply 100% or a little more than the grass can use.

Additional resources

- MLSN newsletter, `www.subscribepage.com/mlsn`
- PACE Turf MLSN page, & the current guidelines, `www.paceturf.org/journal/minimum_level_for_sustainable_nutrition`
- Asian Turfgrass Center, `www.asianturfgrass.com`
- MLSN on Facebook, `www.facebook.com/mlsnturf`
- The #MLSN hashtag on Twitter

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