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Monitoring Soil Nutrients in Dryland Systems Using Management Units

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The use of management units for soil testing and nutrient application is an effective strategy to increase accuracy in monitoring and managing nitrogen (N), phosphorus (P), and other nutrients. A management unit can be a group of fields, a single field, or an area within a field. To measure changes in soil test values, a manager must identify precise management units and follow a consistent and accurate sampling protocol over several growing seasons.

In this publication, a management unit is considered an area that is soil sampled and fertilized in the same way. Different management unit delineations may be more appropriate for insect, weed, and disease control or for other cultural practices.

This publication discusses the following soil sampling protocols: time of sampling, depth of sampling, number of subsamples (cores), and location of sampling within a management unit.

A soil sampling protocol designed to measure changes in soil nutrient status must minimize unintended variability in soil test results caused by, for example, inconsistent timing and inappropriate sampling sites. This publication suggests strategies for minimizing variability.

What are the advantages of the management unit approach?

Management units can allow a producer to apply nutrients in specific amounts within a field or farm. Higher levels of a particular nutrient can be applied in areas that are likely to respond or have not reached a critical limit; less or none can be applied to areas that have higher values and/or are less likely to respond. In most cases, this type of sampling and application plan allows the crop to be managed in an economical way that minimizes cost, while maximizing productivity and protecting the environment.

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What criteria are used to divide a field/farm into management units?

Dividing a field or farm into management units requires a combination of experience, practical knowledge, and science. The management unit approach enables growers to use knowledge of the field to help define soil sampling boundaries and refine nutrient application. When creating management units, consider soil features and management needs and priorities. Management unit size can be determined by equipment and its suitability for use within a unit as well as by management's willingness to expend additional time and effort to manage multiple units versus a single unit.

Combining vs. dividing

Fields can be combined or divided to create management units that fit a grower's management goals and field history.

Some reasons to divide a field into multiple management units:

- Significant differences in yield or crop response
- Willingness to manage each zone independently
- Variations in soil type or depth

Some reasons to combine fields into a single management unit:

- Similar rotations over a long period
- Many small fields
- Similar yields over time
- Similar soil type and/or depth

Other characteristics to be considered when identifying specific management units are precipitation amounts, potential soil water storage, yield history, soil type, topography, drainage, and soil test values. Also consider variability associated with current management (e.g., rotation and tillage) as well as historical variability (e.g., manure application, field leveling, and old fence lines). Features such as soil color, soil depth, slope steepness, and aspect can be used to delineate management units. Soil surveys, soil electrical conductivity (EC) maps, maps produced from remote sensing data (aerial photos or satellite imagery), yield monitors, and/or grain sampling for protein can be used to identify management units.

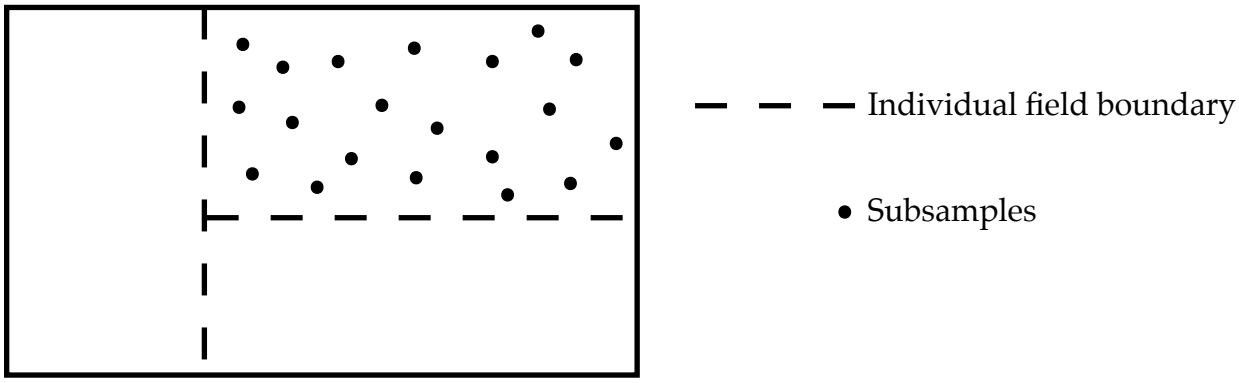
Less precise methods of delineating management units can also be used. For example, a grower can make a mental note of low-yielding areas while operating a combine during harvest. Low yields often are a result of shallow or poor soil. If practical, consider identifying these low-yielding areas as a separate management unit.

Where should I collect soil samples within a management unit?

Whole field or combined fields

Whether sampling an entire field, a single management unit within a field, or a management unit across fields, the objective is to obtain a representative sample of that area. Do not mix subsamples from low-yield and high-yield areas or from valleys and hill tops. Sample similar areas as much as possible when choosing

Field A—Combining similar fields into a single management unit using a random sampling pattern



Field B—Dividing a field into management units using reference sample areas

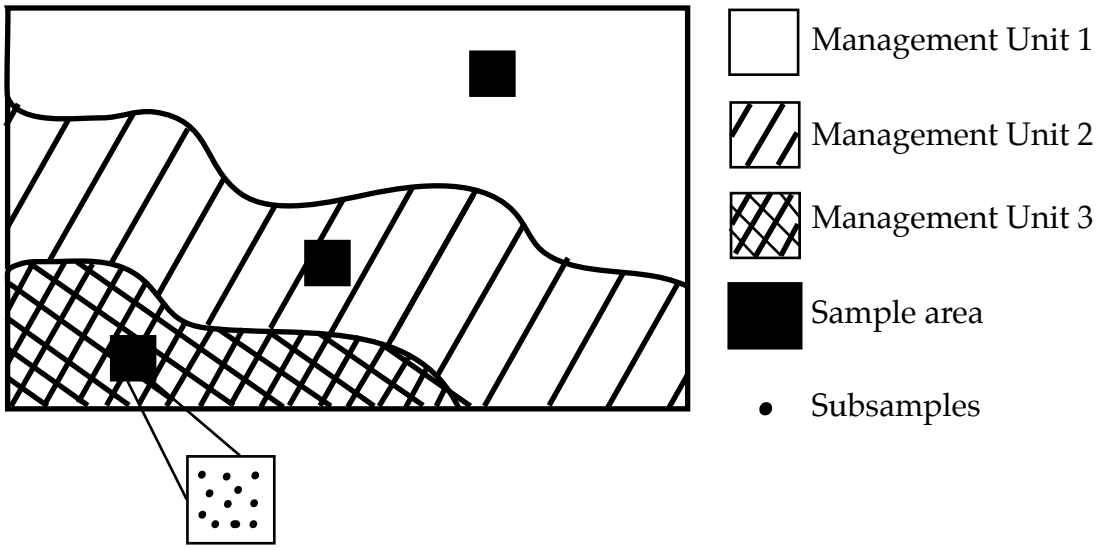


Figure 1.—Aerial view of two dryland fields.

subsample locations (Figure 1, Field A). The sampling location for each core may be georeferenced (see "Georeferencing").

Divided field

Collect soil cores from each management unit (Figure 1, Field B). For example, Management Unit 1 may be a hilltop with low-yielding or eroded soil, Management Unit 2 may be side slopes with moderate yield, and Management Unit 3 may be high-yielding bottomlands with poor drainage and high organic matter. Within each management unit, several soil cores are combined into one sample.

Georeferencing

The sampling location for each core may be recorded (georeferenced). The benefit of georeferencing sampling locations is that in subsequent years the same locations can be resampled to minimize year-to-year variability. Georeferencing commonly is done with a Global Positioning System (GPS) unit. Currently, the least expensive hand-held units are accurate to ± 20 feet, which is adequate for most sampling purposes.

Avoid collecting samples from small, atypical areas such as animal feeding areas, gate and watering areas, corral and home sites, old roads, field edges, or field corners where machinery overlap is common.

How to develop a plan for soil nutrient monitoring

The following steps and questions can help design a monitoring system tailored to specific management needs (Table 1). Two examples of how to develop a plan are included on pages 7 and 8.

Soil nutrient monitoring needs

Soil nutrient monitoring can be used to:

- Reduce fertilizer and application costs
- Diagnose soil problems
- Evaluate crop performance
- Evaluate economic returns based on nutrient utilization

Agricultural professionals (university Extension personnel; private certified crop advisors, agronomists, or soil scientists; and Natural Resources Conservation Service personnel) can help in designing a customized sampling strategy.

What nutrients or other soil chemical properties are desirable to measure?

One goal of a soil testing program is to avoid excessive application of nutrients or salts. Repeated application of organic materials, such as compost, manure, or biosolids, typically results in increasing one or more nutrients and possibly soluble salts. As an example, if manure application rates are based on supplying enough N for the crop, other nutrients (e.g., phosphorus and potassium) usually are added at rates greater than crop use. Soil testing can be used to monitor nutrient accumulation over time. Table 2 (page 5) lists soil tests for dryland nutrient management purposes.

Table 1.—Considerations and questions for designing a soil nutrient monitoring plan.

Soil monitoring considerations	Specific questions
Needs	• What is (are) the need(s) for nutrient monitoring? • What nutrients or other soil chemical properties need to be measured? • Is there an agreement with a third party to monitor specific nutrients or soil chemical properties?
Where to sample	• Should samples be collected throughout the management unit, or should a reference sampling area be used? • Will georeferencing be used to identify locations where soil cores are collected?
How to sample	• When should samples be collected? • What soil sampling depth(s) are appropriate? • How many soil cores will be collected for each composite sample sent to a laboratory for analysis? • Should sampling use a random approach or a systematic sampling method within the sampling area?

Soil organic matter testing often is part of a "routine" soil test. Dryland fertilizer guides use soil organic matter values to adjust N recommendations. Most irrigated crop fertilizer guides do not use soil organic matter as a basis for adjusting nutrient management recommendations.

Is monitoring required by a third-party agreement?

Nutrient management plans required by third parties such as state and federal agencies often specify soil analyses and/or sampling frequency. At a minimum, a sampling plan should meet program or agency requirements when applicable.

When should samples be collected?

The recommended sampling frequency is based on the rate of change in soil test values (Table 2). The best time to soil sample may depend on fertilizer timing, crop rotation, rainfall pattern, and individual farm management goals.

Soil sampling timing is most critical for nitrate-nitrogen, because it is mobile and the amount measured depends on when sampling occurs during the cropping season or rotation. Collect soil samples for nitrate-N analysis a few weeks (no more than a month) before fertilizer application is planned. Also, when sampling in the spring of the summer fallow year, adjustments must be made to account for anticipated nitrogen mineralization, which will not be reflected in a soil test.

What soil sampling depth(s) are appropriate?

Sampling depth can vary from year to year depending on the crop rotation. To determine the depth of sampling, consider the rooting depth of the crop to be grown and the amount/depth of available water.

Soil samples taken below the rooting depth or from soil too dry for plant growth should not be used in making nutrient recommendations for the next crop. However, these samples are important for assessing whether nutrients are moving below the root zone.

Consult university fertilizer or nutrient management guides for sampling and rooting depth of specific crops. Table 3 (page 9) provides a list of available dryland wheat fertilizer guides.

Table 2.—Typical soil test sampling frequency.

As needed for specific cropping system	Annually/once per rotation	Periodic (once per crop rotation or every 3 to 10 years)	Once, if necessary, for initial site assessment
Nitrate-N (NO_3-N)*	Ammonium (NH_3-N), sulfate-sulfur (SO_4-S)**, Olsen P, soil water*	pH, organic matter (OM), chloride (Cl)	Potassium (K), Zinc (Zn)

* Test for all sample depths.

** For sulfur (S), plant-tissue testing is preferred over soil testing. Soil test sulfur (sulfate-S) is not a good predictor of crop yield response to S fertilizer in many situations.

How many soil cores should be collected for a composite sample?

Increasing the number of soil cores (subsamples) taken in a sampling area generally increases accuracy. Fewer soil cores are needed when a small area is sampled. The standard practice is to collect a minimum of 20 subsamples from the first and second foot and to take half as many samples from lower depths.

Mix soil cores thoroughly and submit a composite sample to a laboratory. Check with the soil testing laboratory to determine the amount of soil needed for the desired analyses.

Should sampling be in a zigzag, random, and/or systematic pattern within the sampling area?

Both random and/or systematic sampling can be used in dryland systems. As shown in Figure 2, a zigzag or random sampling method can be used in a field (Unit A) where broadcast fertilizer applications have been made uniformly over the field. Unit B shows a field where fertilizer has been banded at planting. In this case, while overall random sampling locations can be used, subsamples should be taken perpendicular to the plant row and away from the banded area. The same sampling method must be used consistently from year to year so that soil test values can be compared.

Sampling summary

Consistent sampling techniques are essential. Plans should include:

- Nutrients monitored
- Size/location of management units
- Sampling depth(s)
- Number of cores per composite sample
- Systematic sampling instructions (if applicable)

See page 9 for additional publications describing routine soil sample collection and handling techniques.

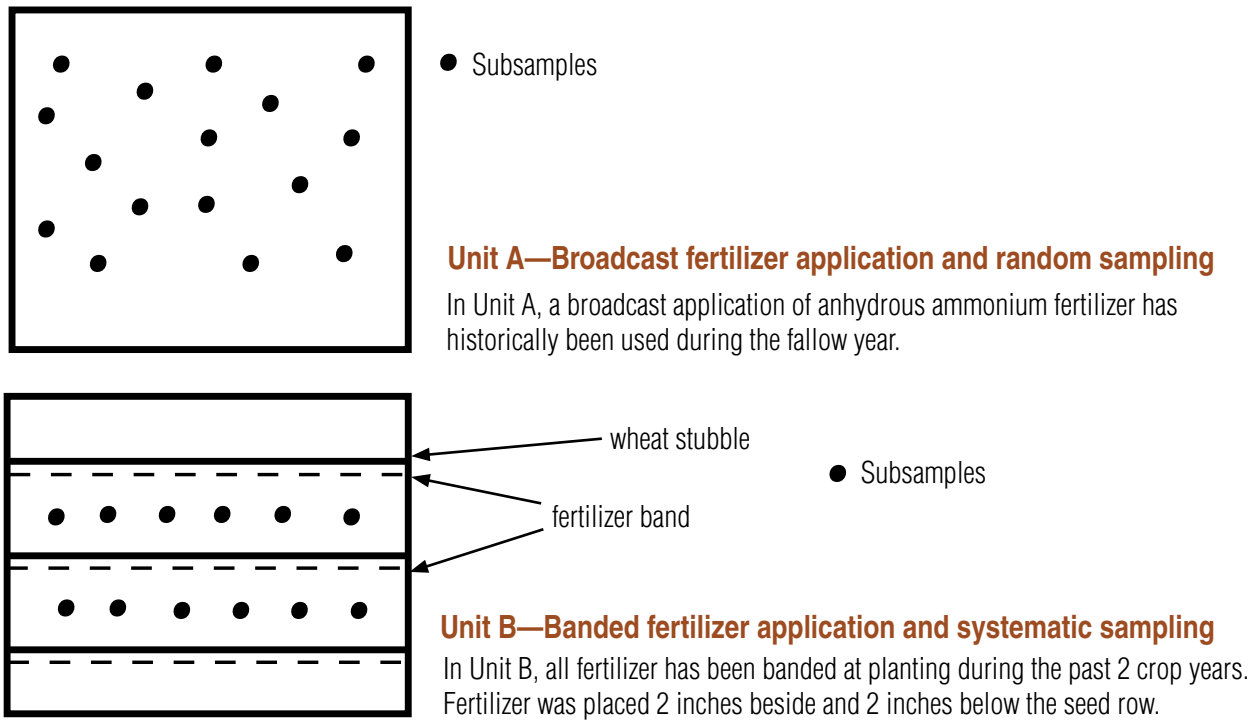


Figure 2. A zigzag (random) method of sampling (Unit A) and a systematic method of sampling (Unit B).

Example 1. Dividing a field into management units to determine a nitrogen application rate for hard red (12% protein) winter wheat

Two years ago a grower purchased a 640-acre field. The new owner has no soil test data and little information on how the field was managed. He plans to conventionally till the field and plant it to hard red winter wheat and is concerned about how best to manage nitrogen (N) fertilization.

The grower has a 5-year-old aerial photo of the field and the soil survey report for the area. The photo shows that there was a permanent grass stand in a part of the field previously enrolled in the Conservation Reserve Program (CRP). The grower thinks that the former CRP area will need to be a separate management unit (Management Unit 1) and the rest of the field will be a second management unit (Management Unit 2). Estimated yield is 60 bu/acre.

Developing a monitoring plan

Nutrient monitoring objectives

The grower wants to determine an appropriate N application rate for hard red winter wheat. Creating two management units will allow him to closely meet the nutritional needs of the wheat for yield and protein and, ideally, reduce fertilizer expenses. Part of the field has been CRP, and he suspects this area may have a higher nutrient-supplying capacity than the rest of the field.

Sampling approach

Each management unit will have a sample location that is representive of the unit. A GPS unit is used to record sample locations for each management unit. Sampling will occur prior to fertilizing in the fallow year. Twenty cores (samples) will be collected from the 1- and 2-foot level, and 7 cores will be taken at the 3-foot level. Fertilizer guide FG 82-E (See Table 3, page 9), will be used to interpret soil test results and develp a fertilizer program.

Results

The grain protein in Management Unit 1 was 12 percent at harvest and the yield was average. These results indicate that the fertility program developed from the fertilizer guide and soil test results did meet the management goals for protein and yield.

Grain protein and yield in Management Unit 2 were similar to those in Unit 1. These results show that, by using soil test results and a fertilizer guide, the grower was able to apply fertilizer at rates specific to each management unit and to meet production goals.

Example 1.—Multiple units sampling results and estimated fertilizer needs.

- Previous crop of winter wheat
- Expected yield of 60 bu/acre
- Crop demand for nitrogen:
  Expected yield x per-bushel N requirement at specified protein level
  (60 bu/acre) x (3 lb N/bu) @ 12% protein = 180 lb N/acre

Soil test results (depth)	Unit 1 N (lb)	Unit 1 P (ppm)	Unit 1 S (ppm)	Unit 2 N (lb)	Unit 2 P (ppm)	Unit 2 S (ppm)
0–12"	45	9	3	38	13	10
12–24"	25	–	–	20	–	–
24–36"	30	–	–	7	–	–
Total soil test	**100**	**9**	**3**	**65**	**13**	**10**
Fertilizer application rate	**80**	**20**	**20**	**115**	**10**	**10**

Example 2. Combining fields to determine a nitrogen application rate for soft white (10% protein) common winter wheat

A grower has three adjacent fields totaling 1,400 acres. He has farmed the fields for 10 years in a wheat–fallow rotation. The soil survey shows two soil types in near equal proportion in all three fields. Bare-soil aerial photographs confirm this assessment. The fields' long-term yield histories are very similar (+/- 10%). Past soil sampling and fertilization have resulted in equivalent yields and grain proteins.

Developing a monitoring plan

Nutrient monitoring objectives

The goal of soil testing is to determine an appropriate N rate for soft white winter wheat. Combining fields into a single management unit would be both economical and a sound management decision based on the fields' similarities.

Sampling approach

The management unit will be sampled every other year (just prior to fertilization in the fallow year). The grower chooses a random sampling scheme, collecting soil cores in a zigzag pattern through the combined management unit in similar type sites. He records subsample locations with a GPS unit to minimize sampling-to-sampling variation.

Twenty cores will be taken in the 1- and 2-foot level, and 7 cores will be taken at the 3-foot depth. These cores will then be mixed into a single sample for each foot. Fertilizer Guide 80-E (See Table 3, page 9) will be used to interpret soil test results.

Results

Protein results at the following harvest were 10.5 percent, and yields were below average for the field. Below-normal rainfall in the spring of the crop year was believed to be the limiting factor. The slightly elevated protein levels indicate adequate nutrition for an average yield if moisture conditions had been closer to normal. Combining similar fields saved time and money, while providing information to make effective nutrient management decisions.

Example 2.—Combined units sampling results and estimated fertilizer needs.

- A previous crop of winter wheat
- Expected yield of 40 bu/acre
- Crop demand for nitrogen:
  Expected yield x per-bushel N requirement at specified protein level
  (40 bu/acre) x (2.5 lb N/bu) @ 10% protein = 100 lb N/acre

Soil test results (depth)	Combined unit N	P	S
0–12"	20	6	3
12–24"	15	–	–
24–36"	13	–	–
Total soil test	**48**	**6**	**3**
Fertilizer application rate*	**50**	**20**	**10**

*Fertilizer rate rounded to nearest 5 lb.

Table 3.—Fertilizer guides for nonirrigated cereal production in low, intermediate, and high precipitation zones of Oregon.

Guide number	Title	Precipitation zone*
80-E	Winter Wheat in Summer Fallow Systems	Low
81-E	Winter Wheat and Spring Grains in Continuous Cropping Systems	Low
82-E	Winter Wheat in Summer Fallow Systems	Intermediate
83-E	Winter Wheat in Continuous Cropping Systems	Intermediate
84-E	Winter Wheat in Continuous Cropping Systems	High

* Precipitation zones are based on average annual precipitation and are defined as low (less than 12 inches), intermediate (12 to 18 inches), or high (more than 18 inches).

For more information

OSU Extension publications

Hart, J. *Laboratories Serving Oregon: Soil, Water, Plant Tissue, and Feed Analysis,* EM 8677 (revised 2006).

Marx, E.S., J. Hart, and R.G. Stevens. *Soil Test Interpretation Guide*, EC 1478 (reprinted 1999).

Rebotham, M. and J. Hart. *Soil Sampling for Home Gardens and Small Acreages,* EC 628 (revised 2002).

Staben, M.L., J.W. Ellsworth, D.M. Sullivan, D.A. Horneck, B.D. Brown, and R.G. Stevens. *Monitoring Soil Nutrients Using a Management Unit Approach*, PNW 570-E (October 2003).

Many OSU Extension Service publications, including fertilizer guides for a variety of crops, may be viewed or downloaded from the Web. Visit the Publications and Multimedia catalog at **http://extension.oregonstate.edu/catalog/**

Copies of publications and videos also are available from OSU Extension and Experiment Station Communications. For prices and ordering information, visit the online catalog or inquire by fax (541-737-0817), e-mail (puborders@oregonstate.edu), or phone (541-737-2513).

Other publications

Franzen, D.W. and L.J. Cihacek. *Soil Sampling as a Basis for Fertilizer Application*, SF-990 (North Dakota State University, revised 1998).

Mahler, R.L. and T.A. Tindall. *Soil Sampling*, Bulletin 740 (University of Idaho, revised 1994).

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