15 Nutrient Management Module No. 15

CCA
1.5 NM
CEU

Sustainable Agriculture

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Introduction

This module is the fifteenth, and final, in a series of Extension materials designed to provide Extension agents, Certified Crop Advisers (CCAs), consultants, and producers with pertinent information on nutrient management issues. To make the learning 'active,' and to provide credits to CCAs, a quiz accompanies this module. In addition, realizing that there are many other good information sources including previously developed Extension materials, books, Web sites, and professionals in the field, we have provided a list of additional resources and contacts for those wanting more in-depth information about sustainable agriculture. This module covers Rocky Mountain CCA Nutrient Management Competency Areas I and VI: Basic Concepts of Soil Fertility, and Nutrient Source and Applications, with the focus on sustainable agriculture.

Objectives

After reading this module, the reader should:

1. Recognize practices of sustainable agriculture and how they can be applied
2. Learn methods to reduce inputs and improve on-site nutrient availability
3. Understand the effect of soil conservation practices on soil fertility and quality
4. Identify general standards pertaining to certified organic crop and livestock production

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Background

Sustainable agriculture (SA) can be defined in many ways. Havlin et al. (1999) defines SA as "the integration of agricultural management technologies to produce quality food and fiber while maintaining or increasing soil productivity, farm profitability, and environmental quality." Simply, SA sets forth a framework of management practices that provide for the long-term sustainability of resources while maintaining short-term productivity and profitability. As of yet, there may not be one agricultural system that is wholly sustainable. Yet, there are practices and systems that have components that strive for sustainability, including reduced tillage systems, diversified crop rotations, cover crops and green manures, and organic production. The adoption of these and other practices into a sustainable management plan will depend on each individual operation's needs and goals. For instance, organic production works best for some producers in meeting their sustainable goals and principles; yet for other producers, no-till farming with some commercial inputs may be the most sustainable. Most producers in Montana and Wyoming are likely already using a range of sustainable practices.

Although sustainable systems are a complex integration of soil, water, nutrient, and pest practices, only those relating to nutrient management are focused upon here (see Appendix for information regarding sustainability in these other areas). Therefore, the goal of this module is to provide a toolbox of general information and resources regarding sustainable nutrient management practices available to agricultural professionals in Montana and Wyoming.

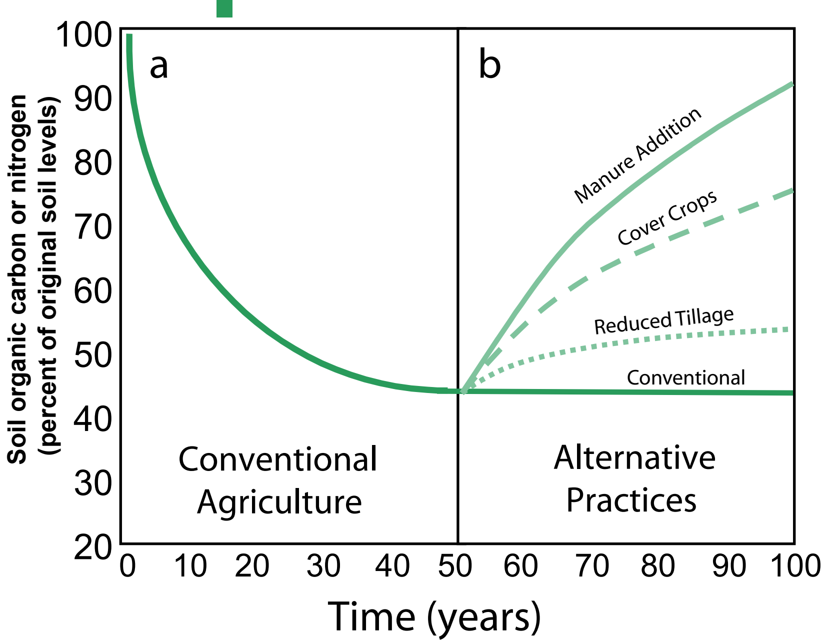

Figure 1. Generalized effects of different agricultural practices on total soil organic C or N content of soil. Following 50 years of tillage and commercial fertilization, fields can lose about half of their original organic C or N content. Alternative practices can help recover these losses. (Modified from Tilman, 1998).

Soil Quality

An integral component of SA is soil quality. Soil quality is defined as "the continued capacity of soil to function" (Doran et al., 1999) and is evaluated on the basis of several 'indicators,' or properties, that change in response to differences in management or climate. Soil quality indicators may include soil organic matter (SOM) levels, total nitrogen (N) content, microbial activity and abundance, and nutrient turnover rates.

Monitoring soil quality in agricultural soils is important for assessing the long-term sustainability of agricultural operations. In general, conventional agricultural practices (i.e., high input, high intensity systems) have caused soil quality to decline over the last century. Figure 1 shows an example of this decline with soil organic carbon or N serving as indicators. To counter this decline, SA introduces practices that promote the improvement of soil quality by balancing nutrient inputs and outputs, building SOM, and reducing soil erosion. These practices and their relationship with soil quality will be discussed throughout the module.

Managing Nutrient Inputs in Sustainable Systems

Commercial fertilizers are a widely used source of nutrients in many agriculture operations. However, rising energy costs, particularly for nitrogen fertilizers (*Nutrient Management Module 10*), and finite reserves for mined nutrients, such as phosphorus (P) and potassium (K), question the sustainability of commercial fertilizers for long-term agricultural use. For example, assuming future consumption equals production, it is estimated that U.S. P reserves (deposits that can be economically extracted or produced at a determined time) would last another 25 years, and world reserves another 88 years (PPI, 2002). Similar estimates for K are 70 and 325 years for U.S. and world reserves, respectively. Additionally, fertilizers may not be a complete substitute for SOM-supplied nutrients, which are important for long-term soil productivity. In order to conserve resources and economically provide crops with nutrients, SA focuses on making the most efficient use of both inorganic (synthetic) and organic (natural) nutrient sources (Q&A #1). To determine the best use of sources, it is first important to understand the factors influencing nutrient efficiency and compare the advantages and disadvantages of each source.

Assessing Nutrient Sources

In addition to fertilizers, animal manures (covered in *NM 13*), cover crops, and green manures serve as nutrient sources in agricultural systems. All plants take up the inorganic form of nutrients, regardless of source. For example, there is no molecular or functional difference between nitrate (NO_3^-) derived from organic materials and NO_3^- supplied by a fertilizer. However, timing of nutrient availability and plant uptake can vary greatly between sources. In order to supply nutrients to the soil for plant uptake, organic materials must undergo decomposition by soil microorganisms; a process that can take between months and years depending on residue type, biological activity, and soil and climatic conditions (*NM 8*). Most commercial fertilizers, on the other hand, already contain nutrients in their inorganic and soluble form and can be available for uptake upon application (*NM 10*). Immediate nutrient availability can be beneficial during periods when the crop needs a "jump start" of nutrients to get it going; for instance, nutrient availability can be low in early spring when the soil is still cool and SOM decomposition rates are low or during high demand periods. Yet, there are other times when the crop does not need the quantity of nutrients supplied by the fertilizer, thus decreasing fertilizer use efficiency and possibly causing nutrient leaching or runoff problems. By comparison, the slower release of nutrients from organic sources can be beneficial by providing a more continuous, low concentration of nutrients throughout the growing season, so the plant takes up what it needs as nutrients become available.

Another issue to consider when assessing nutrient sources is determining their associated nutrient budget. Commercial fertilizers provide readily available nutrients to crops in managed levels. In comparison, a nutrient budget with organic sources may be more difficult to quantify due to variations in material, decomposition rates, and solubility. This can be managed by conducting regular soil tests and appropriately timing the application of organic materials. Fertilizer management and effectiveness can be improved by utilizing practices such as proper placement and timing (*NM 11*) and precision agriculture technologies (*NM 14*).

Q&A #1

Where did the term 'organic' come from?

The word organic has a couple of meanings. Chemically speaking, any compound containing carbon (C), with the exception of carbon monoxide ($CO_{(g)}$) and carbon dioxide ($CO_{2(g)}$), is referred to as an organic compound. As C is considered the building block of life, it is often correlated to living and natural resources. In 1942, J.I. Rodale coined 'organic farming' in his magazine *Organic Farming and Gardening*, referring to the use of natural and organic materials as a source of nutrients rather than synthetic, non-C containing materials, such as many fertilizers (excluding urea).

Cover Crops and Green Manures

Cover crops are crops that are grown to provide soil cover and can either be harvested, killed and left as a mulch, or plowed into the soil (referred to as green manures). Cover crops and green manures improve soil quality by building SOM via the addition of vegetative residue and reducing soil erosion. Cover crops and green manures are commonly grown in place of fallow and may include buckwheat, mustard, rye, and a variety of legumes. The amount of SOM that cover crops and green manures add to the soil can be considerable, and this SOM will then provide a source of available N to the soil. Specifically, each 1% increment of SOM in the top 6 inches of soil contributes approximately 15-20 lb or more of N to the soil (Jacobsen et al., 2003). Such a contribution can amount to substantial fertilizer savings in the long run (Calculation Box #1). Additionally, a Montana study of spring wheat found that in high yield potential soils, each 1% SOM equates to 10 bu/ac of wheat yield (Jackson, 1998). This yield effect is likely due to increased N, as well as other SOM benefits.

Legumes are commonly used as green manures because of their ability to fix N from the atmosphere (*NM 3)*, and, thus, potentially contribute appreciable amounts of N to the soil. N supplied to soil from legumes will likely reduce or possibly replace the need for fertilizer N. Table 1 shows common leguminous green manures for this region and the amount of N each legume can potentially fix. Although legumes supply N to the soil, they do not supply P, and systems that rely solely on legumes are susceptible to P deficiency and reduced yields (Campbell et al., 1993). Therefore, P fertilization may be required to maintain adequate yields. Also, in fields that have not previously been cropped in legumes, inoculation of nodule forming N-fixation bacteria is essential (*NM 3*; see Appendix).

Determining which legumes to use as green manures will depend on a variety of factors, including cost of seed, residue turnover rates, and water use. For instance, annual legume residues release N more quickly than perennial or biennial legumes residues (Manitoba-North Dakota,

Calculation Box #1

Calculate the difference in fertilizer N required for spring wheat for a soil with 2% SOM and one with 3.5% SOM. Assume a potential yield of 40 bu/ac and each 1% SOM contributes 20 lb N/ac. All fertilizer recommendations are from Table 17 of EB 161 (Jacobsen, et al., 2003).

Calculation: Fertilizer N Difference = Fertilizer N for 2% SOM – Fertilizer N for 3.5% SOM

<u>Fertilizer N for 2% SOM</u>

Fertilizer N = Fertilizer N recommendation (assumes 2% SOM content)
Fertilizer N = 132 lb/a

<u>Fertilizer N for 3.5% SOM</u>

Fertilizer N = Fertilizer N recommendation (same as above) – (1.5 x 20 lb/ac)
Fertilizer N = 132 lb/ac – 30 lb/ac
Fertilizer N = 102 lb/ac

Fertilizer N difference =
132 lb N/ac – 102 lb N/ac = 30 lb N/ac

Table 1. N fixation by eight legumes.

Legume	N Fixed (lb/ac-year)
Alfalfa	267
Sweetclover	223
Faba bean	267
Field pea	178
Lentil	134
Soybean	134
Chickpea	108
Dry bean	62

From Green and Bierderbeck (1995).

1997). Water use by green manures is an important consideration in semiarid areas, such as Montana and Wyoming. From a study in northwest Montana, Zentner et al. (in press) found that allowing an annual legume green manure (Indianhead black lentil) to bloom before plowdown had a detrimental effect on soil moisture, and, consequently, yields of the following hard red spring (HRS) wheat crop. Methods were altered for the remainder of the study by seeding and harvesting the green manure earlier, resulting in greater soil moisture and higher yields (Figure 2). In 1999, plowdown time was similar to pre-1994 dates, and subsequently yield and soil water levels decreased. In order to maximize the benefits of a green manure without sacrificing soil water, it is recommended to plowdown prior to full bloom (Zentner et al., in press). Proper plowdown times will vary from place to place and year to year, depending on precipitation, soil, and crop types. Therefore, it is important to actively observe each field and record dates of seeding, harvest, and yields to determine the best time to plowdown a green manure crop.

Diversified Cropping Systems

Implementing diverse rotations into a cropping system can positively affect soil quality and nutrient dynamics by growing various crops with different nutrient requirements, rooting depths, residue quality, and associated microbial communities and activity (Drinkwater et al., 1998). For instance, deep-rooted crops, such as sunflower and safflower, and shallow-rooted crops, like many grains, will obtain nutrient and water resources at different depths in the soil. By rotating such crops with one another, a greater amount of resources can be accessed. Different crops also require different amounts of essential nutrients, and by rotating high and low demand crops with one another, one can avoid placing too high of a demand on one or more of these nutrients. As previously mentioned, legumes in a rotation can contribute additional N to the soil. An added benefit of legumes is that because legume residue has a high N content, it will return N more quickly to the soil than a non-legume residue. This can be particularly beneficial for a subsequent crop with high N requirements. Other advantages of diversified cropping systems include increased disease and weed control and more flexibility for an operation with regard to changes in climate and economics.

Nutrient Sources in Grazed Lands

Similar to croplands, pasture systems must balance nutrient inputs with outputs

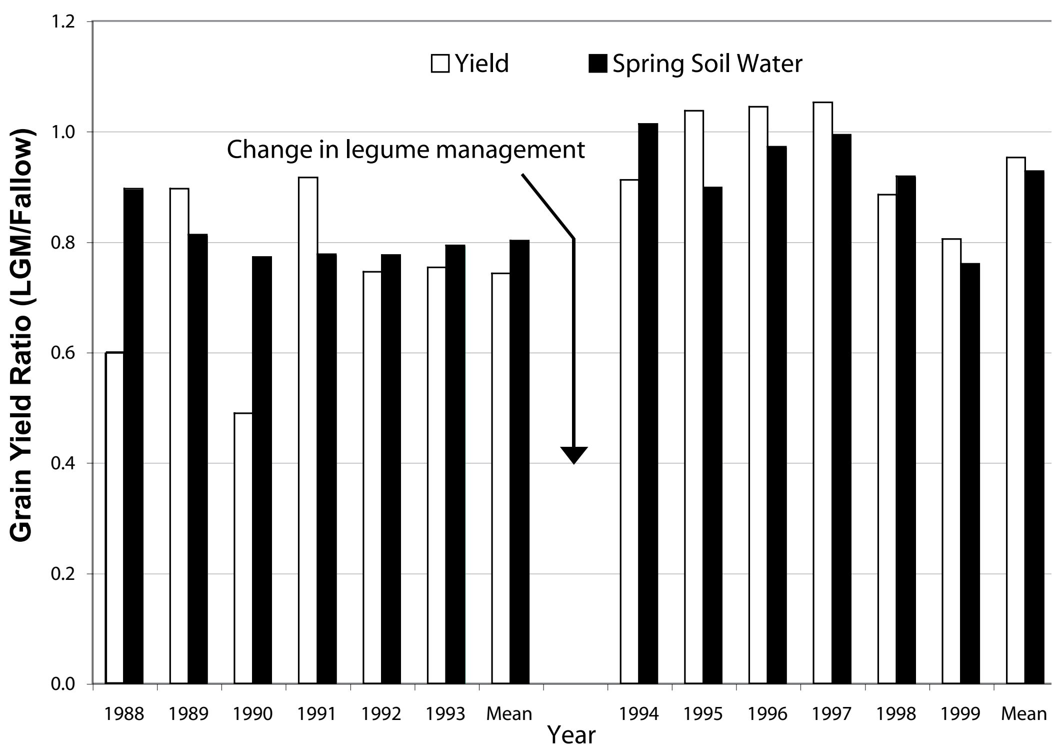

Figure 2. Effect of earlier seeding and earlier turndown of legume green manure (LGM), starting in 1993, on relative hard red spring (HRS) wheat yield (HRS wheat after LGM/ HRS wheat after fallow) and spring soil water ratios (1988-1999) (Zentner et al., in press).

to produce quality forage. Without feed or mineral supplements, pastured livestock will return 75-85% of consumed forage nutrients to the system (Bellows, 2001). In time, continuous grazing in these systems will gradually deplete plant nutrients. Integrating or maintaining legumes in grazed lands will supply a recyclable source of fixed N that can benefit soil and forage quality throughout the growing season. Deep-rooted plants, such as alfalfa and warm-season grasses, can also aid nutrient availability. On rangelands, perennial grasses and forbs, including legumes, are important long-term sources of SOM and nutrients. For example, lupines, many of which are native to grasslands in this region, can fix 134-151 lb N/ac-year (Foth and Ellis, 1997).

Forage quality can also be improved with well-managed grazing plans. Continuous, extensive grazing can result in poor plant re-growth and pastures susceptible to weed invasion and soil erosion. In contrast, rotational grazing, in which livestock are grazed intensively for a short period and then transferred before overgrazing occurs, increases diversity of forage species, enhances seed dispersal, and helps conserve soil and forage nutrient resources (Bellows, 2001). Rotational grazing can also provide for a longer grazing season and increase stocking rates (Fanatico et al., 1999). Please see the Appendix for additional resources pertaining to sustainable practices for range and pasture management.

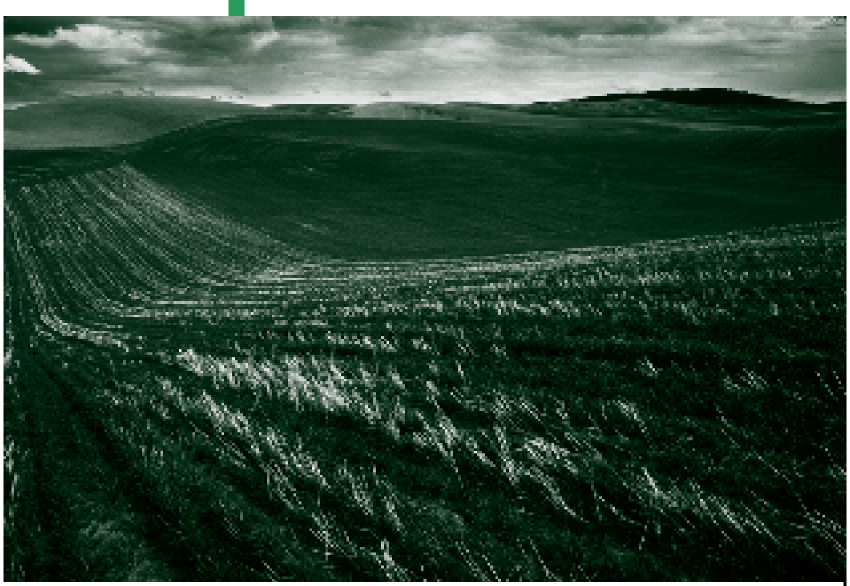

Figure 3. Wheat farm under no-till. Standing residue covers and stabilizes the soil and acts to trap nutrient and water resources. (Photograph compliments of USDA Photography Center).

Reduced Tillage

Because the majority of soil nutrients and SOM are stored in topsoil, erosion over decades can have detrimental effects on soil fertility and quality. This has resulted in substantial costs to producers, with the largest cost going towards replacing lost nutrients (Pimentel et al., 1995). In response to resource losses, many producers in the northern Great Plains are adopting reduced tillage systems, including no-till (Figure 3). Because of less aeration and disturbance under reduced tillage, soil nutrient levels in these systems will likely change. In general, nutrient turnover from crop residues is slower in no-till than conventional till, particularly in the first 3-5 years, and additional N (approximately 10-20% more) may need to be applied (Manitoba-North Dakota, 1997). However, after about 5 years (actual time period will differ depending on soil type, climate, etc.), an N equilibrium is reached and additional inputs are no longer needed.

Long-term changes in nutrient dynamics also occur as a result of reduced tillage. A Saskatchewan, Canada study found fertilizer N response in spring wheat differed significantly between recently converted no-till fields and long-term no-till fields (Figure 4). Specifically, the long-term fields had higher yields and grain protein than the short-term fields at all fertilizer N rates, but showed less response from increases in fertilizer than the short-term fields. A particularly interesting result was that grain protein with no fertilizer following 25 years of no-till was similar to grain protein with 105 lb N/ac following 3 years of no-till. These results suggest that producers may need to adjust their fertilizer program over time to effectively manage nutrients in reduced tillage systems, which may save substantial N fertilizer costs in the long-term.

Organic Production

The USDA's National Organic Standards Board defines organic agriculture as "an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity, and is based on minimal use of off-farm inputs and on management practices that restore, maintain, and enhance ecological harmony." To meet these goals, organic production utilizes various practices of SA, including diverse crop rotations and legumes, while virtually excluding the use of synthetic chemicals, antibiotics, hormones, or genetically modified organisms (GMO). Similar to other systems presented in this module, it is important to note that *sustainable* and *organic* are not interchangeable terms and although organic agriculture promotes practices that move towards sustainability, it does not guarantee a wholly sustainable system. For example, organic systems often till for weed control, which may not be sustainable from a soil conserving perspective.

National Organic Program and Organic Standards

According to the USDA's 2001 Economic Research Service (ERS) data, Montana and Wyoming had a total of 209,025 acres and 17,138 acres, respectively, under organic production (crop and pastureland), and Montana ranked first for organic wheat production (current organic acreage numbers for both states are likely higher than those cited here). Although total organic acreage accounts for less than 1% of total land in farms and ranches for either state, organic agriculture is one of the fastest growing agricultural markets in the U.S. with an annual growth rate of approximately 20% for the last decade (Dimitri and Greene, 2002). In response to this rapid growth and increased national focus on organic production, the USDA adopted the National Organic Program (NOP) in 2000. Under the NOP, producers and handlers can become certified organic (Q&A #2) by adhering to a defined set of regulations and standards for both organic crop and livestock production. Certification allows producers to market their products as organic using the USDA organic seal on products (Figure 5, next page) and sell their products for a premium price. General standards for certification are

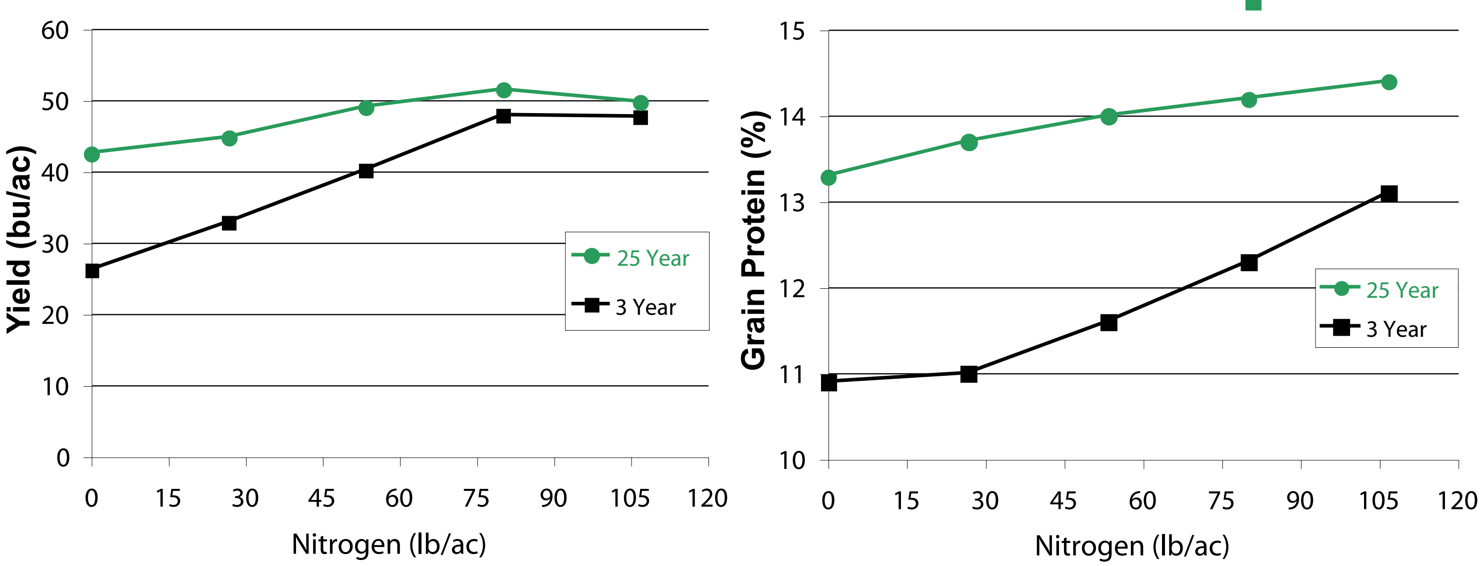

Figure 4. Spring wheat grain yield and protein respose to fertilizer N in long-term (25-year) vs. recently converted (3-year) no-till fields (Miller et al., 2004).

Q&A #2

My client is interested in organic farming. What steps are required to become a certified organic producer?

The following is a general guideline from the Federal Register, National Organic Standards (National Organic Program, 7 CRF Part 205 Final Rule) for becoming an organically certified producer:

1. Identify a certifying agency

This can be either a state or independent agency recognized by the NOP as an accredited certifying agency.

2. Obtain and submit an application

An organic system plan (OSP) describing practices, procedures, recordkeeping, a monitoring plan, a management plan for preventing contamination, and a list of each anticipated input must accompany the application.

3. Review of Application

The certifying agent will review the application and OSP for completeness and compliance of requirements.

4. On-site Inspection

A certified inspector will conduct an initial on-site inspection and thereafter at least annually to verify applicant is in compliance.

5. Report Sales and Updates to Operation

During the transition/certification process, sales and any updates made to an organic system must be reported to the certifying agency for inspection.

6. Final Review

Upon the end of the three-year period, the certifying agency will determine whether or not the producer has met and complies with all requirements of the NOP. Thereafter, certification needs to be continued on a yearly basis through a certifying agency.

listed below (paraphrased from the Federal Register, National Organic Standards, NOP, 7 CRF Part 205 Final Rule). A complete listing of standards can be found on the NOP web page at http://www.ams.usda.gov/nop/.

Crops Standards

- The producer must undergo a transition period of three years in which no materials restricted by the NOP have been applied to the land.
- Crop nutrients and soil fertility must be managed through crop rotations, cover crops and green manures, compost, animal and plant materials, and natural fertilizers (from approved list).
- No synthetic fertilizers, pesticides, genetically modified organisms (GMO), irradiation, or sewage sludge (biosolids) may be used.
- Plant and animal materials must be managed to maintain or improve SOM content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances.

Figure 5. The USDA Organic seal assures consumers that the labeled product was produced in compliance with the National Organic Program and is certified organic (Image based on NOP website).

- Weed, disease, and pest management is accomplished through crop rotations, cover crops and intercropping, mulching, sanitation, tillage, bio-controls, and natural pesticides (from approved list).

Livestock Standards

- Livestock products that are sold or labeled organic must be from livestock under continuous organic management from the last third of gestation or hatching, with the exception of poultry that must be organic from the second day of life.
- Organic dairy products must be from animals under continuous organic management beginning no less than one year prior to the production of the milk or milk products.
- Organic feed must be supplied to organic livestock, and if applicable, organically handled. Exceptions to this are non-synthetic and synthetic substances included on the National List of allowed substances to be used as feed additives and supplements.
- No growth hormones, antibiotics, synthetic parasiticides, irradiation or GMO products may be used. Vaccines and veterinary biologics are allowed.
- Synthetic medications must be used in the case of severe medical attention; however the treated animal cannot be labeled organic if the medication is prohibited by the NOP.

Organic Inputs

In an organic system, soil fertility is managed through cover crops and green manures, diverse rotations, manure, and other fertilizer materials allowed under the NOP. As discussed previously, crop rotation selection will depend on crop growing conditions (i.e., climate and soil), weed and disease dynamics, and economic needs. If an organic N source is not added, legume crops should be included to return N to the soil. Under good growing conditions, the amount of N returned from a legume green manure can be sufficient for subsequent crops. Some broadleaf crops, such as buckwheat, sainfoin, and rapeseed, or deep-rooted crops may work well in a rotation with legumes to provide additional nutrients. However, because legumes do not supply P to the soil, P may become deficient under organic management and off-farm P sources may be required (discussed below).

A number of certified organic fertilizers are available to producers when needed. Rock phosphate (RP, *NM 10*) is considered an organic source of P; however, because of its low solubility and slow-release of P, RP may only be beneficial for perennial crops and pasture fields. RP dissolution rates will increase with increased moisture. Potassium (K) and sulfur (S) are less limited in the northern Great Plains, although localized deficient soils may exist. Allowed sources of K are mined, non-synthetic potassium sulfate and potassium magnesium sulfate. S sources can include non-synthetic elemental sulfur and gypsum. Although urea ($CO(NH_2)_2$) is an organic (C containing) fertilizer, it is synthesized and is therefore not allowed in organic production (Q&A #1).

Applied appropriately, animal manure can be an economically viable method for supplying adequate returns of N, P and other essential nutrients, particularly micronutrients, to an organic system. While the NOP does not strictly prohibit specific sources of manure for organic systems, it does state that all plant and animal materials be managed as to not contribute to the contamination of crops, soil, or water; this clause may exclude the use of some materials. Manure nutrient management plans and regulations are covered in *NM 13*.

For organic livestock operations, non-synthetic, organic feed and mineral supplements may be used and are available from a variety of dealers around the country. Allowed additives can include some vitamins and trace minerals, including copper sulfate and magnesium sulfate. A National List of allowed organic substances can be accessed at http://www.ams.usda.gov/nop/NationalList/ListHome.html.

Assessing Organic Systems

Organic systems require different management and marketing strategies than non-organic systems. Off-farm input costs can be substantially reduced under organic systems (Figure 6a) and with premiums in place, net revenue for organic products can be comparable, or better than, that of conventional farming (Figure 6b). Price premiums for organic products can be anywhere from 25% to 200% or more over conventionally grown products (ERS, 2001). Organic price premiums within the last decade have remained fairly steady with respect to prices for conventionally grown crops; however, premiums, just like conventional crop prices, are subject to change and are not guaranteed. Organic farmers can counter this risk by expanding and diversifying their product to markets outside traditional marketplaces and by being flexible with their cropping systems.

Because transition to organic production can be a challenging period for a producer, numerous programs have been developed to aid farmers both during the transition period and afterwards. The Natural Resource Conservation Service (NRCS) has developed a cost-share program using Environmental Quality Implementation Program (EQIP) money that is designated for farmers during the transition from traditional to organic systems. State programs may also exist that can aid producers during this conversion period. Farmers that are already certified organic may qualify for other programs and financial assistance (see Appendix).

Summary

Sustainable agricultural practices provide a framework of activities and goals that work toward conserving resources, improving soil quality, and reducing off-farm inputs, while maintaining economically viable operations. Soil nutrient resources can be improved by building SOM through the use of cover crops and green manures, and altering nutrient use and cycling with diverse crop rotations. Legumes in rotation or as green manures can contribute significant amounts of N to systems, potentially reducing N fertilizer applications. In livestock operations, diversified pastures and controlled grazing can provide higher quality forage and livestock products. Reduced tillage can help minimize nutrient loss in eroded soil and increase long-term SOM and nutrient content. Organic

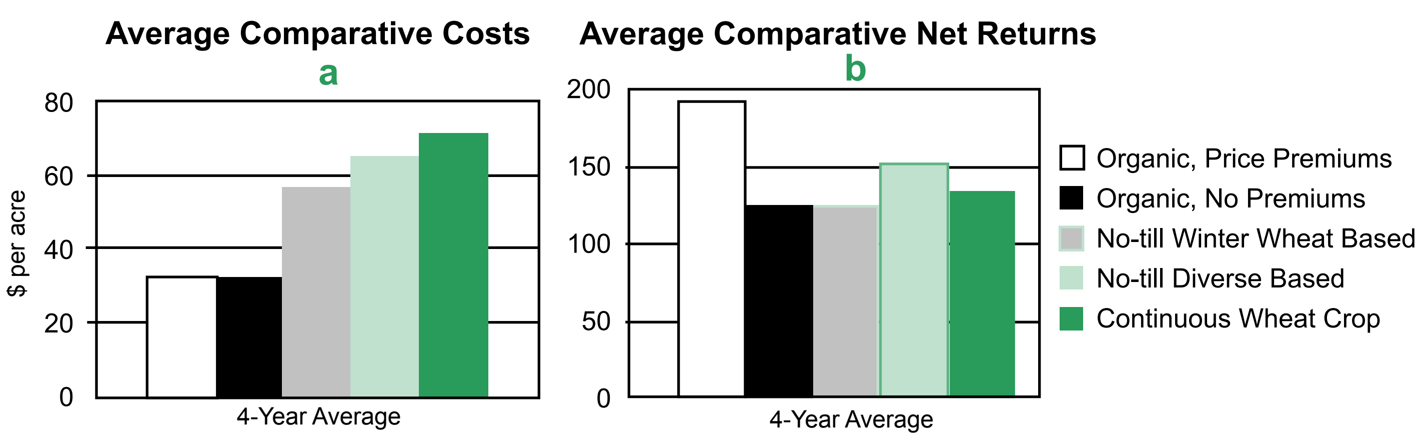

Figure 6. Four year average comparative costs (a) and net returns (b) of 4 different cropping systems under similar conditions and climates. Costs excluded land and management costs (Miller and Buschena, 2003).

agriculture provides an alternative niche market for producers with the benefits of low input systems, price premiums, and decreased reliance on synthetic chemicals. While not one practice or system is likely to be completely sustainable, components of certain practices can be utilized or combined to ensure a more efficient use of resources for long-term agriculture.

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APPENDIX

Books

Sustainable Agriculture Systems. J. Hatfield and D. Karlen (eds.). Lewis Publishers Inc. 316 p. $170.

Soil Organic Matter in Sustainable Agriculture. F. Magdoff and R. Weil (eds.). 2004. CRC Press. 320 p. $100.

Cereal-Legume Cropping Systems: Nine farm case studies in the dryland northern plains, Canadian prairies and intermountain Northwest. N. Matheson, B. Rushmore, J. Sims, M. Spengler, and E.L. Michalson. 1991. Alternative Energy Resources Organization (AERO), Helena, Mont. 75 p. $6. For ordering information, contact AERO at www.aero.org.

Organic Field Crop Handbook. Canadian Organic Growers (COG). 2001. $40. For ordering information, contact COG at www.cog.ca.

Organic Livestock Handbook. Canadian Organic Growers. 2001. $26. For ordering information, contact COG at www.cog.ca.

Booklets

Best Management Practices for Grazing, Montana. 1999. Montana Department of Natural Resources and Conservation, Helena, MT.

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Helena, MT 59620-1601
(406) 444-6667

Zero Tillage Production Manual. 1991. Manitoba-North Dakota Zero Tillage Farmers Association. Available at http://www.mandakzerotill.org/ztindex.html.

Zero Tillage—Advancing the Art. 1997. Manitoba-North Dakota Zero Tillage Farmers Association. Brandon, Manitoba, CA. 40p.

Extension Materials

Fertilizer Guidelines for Montana Crops. EB 161. Free.

Nutrient Management Modules 1-15 are available and can be obtained online or at the address below (add $1 for shipping).

MSU Extension Publications
P.O. Box 172040
Bozeman, MT 59717-2040
All are on-line in PDF format at http://www.montana.edu/wwwpb/pubs/mt4449.html

See Web Resources below for online ordering information.

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Web Resources

http://attra.ncat.org/

Appropriate Technology Transfer for Rural Areas (ATTRA) National Sustainable Agriculture Information Service. Website covering a large range of topics for sustainable and organic agriculture.

http://soils.usda.gov/sqi/soil_quality/index.html

USDA website featuring issues on soil quality.

http://www.animalrangeextension.montana.edu/index.htm

Montana State University Extension Service site with information on numerous animal range topics, including links to grazing management, forage quality, and natural resource conservation issues.

http://www.ams.usda.gov/nop/

USDA National Organic Program's official site. Contains information about certifying agents, NOP standards, regulations, and policies, and a link to the National List.

http://www.nal.usda.gov/afsic/

USDA Alternative Farming Systems Information Center. Extensive source of information about organic and sustainable production, including publication lists, link to NOP, and search engine.

http://www.mt.nrcs.usda.gov/

Montana NRCS website. Provides information on various conservation and organic programs, including EQIP (http://www.mt.nrcs.usda.gov/programs/eqip/eqipworks.html).

http://www.sare.org

Sustainable Agriculture Research and Education (SARE) Program. A USDA competitive grant program. Includes a link to the Western Region SARE Program.

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http://agr.state.mt.us

Montana Department of Agriculture website with link to the state's organic program.

http://wyagric.state.wy.us/

Wyoming Department of Agriculture website.

http://www.montana.edu/publications

Montana State University Publications ordering information for Extension Service Publications.

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