bulk materials. Several concentrated packaged materials are becoming available. Packaged organic materials are usually dry enough to transport for longer distances. Storage and application is also facilitated. Some materials that can be used include feather mill, steamed bone meal, and seed meal and peat moss. These materials are allowed for use in organic production.

Maintaining and Monitoring Soil Organic Matter

Once an acceptable level of SOM (about 3.5 to 4.0 percent) is obtained, it is desirable to maintain it. As a rule of thumb returning about two to three tons of organic material per year per acre would maintain an acceptable SOM level.

Maintaining a high level of SOM requires determination by the producer, and also requires developing a site and enterprise specific management plan. It is important to maintain a balance of input and output on a farm. Monitoring the SOM level is crucial. Every two to three years the producer should monitor the SOM level and intervene if SOM fluctuation is high. Use indicators of soil quality listed in Figure 2 to make a decision. Some of the indicators can be quantified and a critical level can be established while others are strictly qualitative. It is necessary to conduct soil testing to determine soil OM.

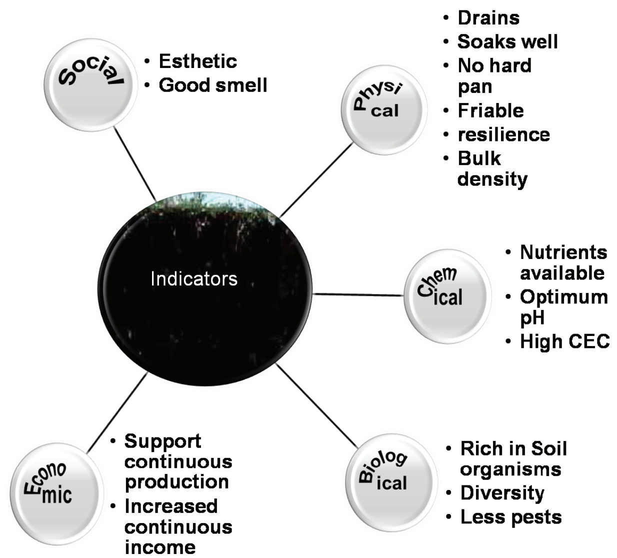

Figure 2. Indicators used to monitor the status of soil organic matter in organic production.

Useful Links

The National List of Allowed and Prohibited Substances:
http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateN&navID=NationalListLinkNOPNationalOrganicProgramHome&rightNav1=NationalListLinkNOPNationalOrganicProgramHome&topNav=&leftNav=NationalOrganicProgram&page=NOPNationalList&resultType=&acct=nopgeninfo

Oklahoma Organic Law:
http://www.state.ok.us/~okag/forms/law/organic.htm

Organic Production in Oklahoma:
http://www.kerrcenter.com/pdf/organic-production-QA.pdf

Organic Compliance:
http://attra.ncat.org/attra-pub/summaries/summary.php?pub=155

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Building Soil Organic Matter for a Sustainable Organic Crop Production

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Oklahoma Cooperative Extension Fact Sheets are also available on our website at: **http://osufacts.okstate.edu**

Organic Matter Matters!

Organic matter (OM) normally constitutes less than 5 percent of most mineral soils. The majority of Oklahoma soils actually have only about 1 percent OM, but it is a key factor in determining the health of a soil. In principle, all organic materials can be changed to soil organic matter (SOM) and can supply nutrients as well as "condition" the soil. Organic matter is defined as any non-living organism, or product of a living organism on the surface or in the soil. Through decomposition, organic materials added to a soil change to SOM while releasing nutrients. The organic component of the soil includes living organisms, fresh organic residue, and active and stabilized OM fractions (Figure 1).

The living component includes microbes although it constitutes a small fraction of the soil. The active OM is generally unstable and more than 85 percent of it disappears quickly as decomposition progresses. Humus is the most abundant and stable form of SOM and it is resistant to further decomposition. Humus is a complex mixture of organic substances that have been significantly modified from their original form over time and is typically dark in color. It also contains other substances that have been synthesized by soil organisms in the process of decomposition.

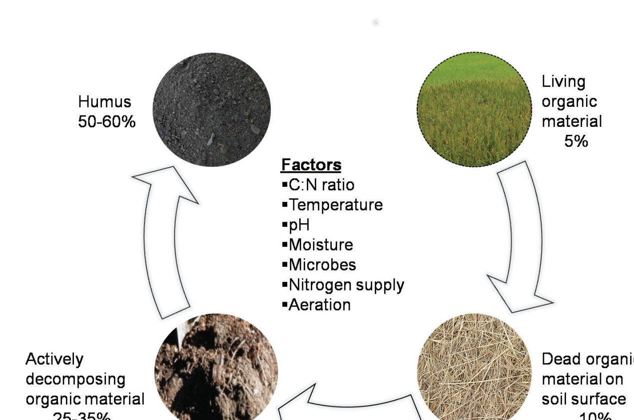

Figure 1. Organic components of the soil.

Benefits of Soil Organic Matter

The content of SOM in an organic crop production system is the most important factor because it is the primary nutrient supplier and soil conditioner. Organic matter in the soil balances various chemical and biological processes and helps to maintain soil quality parameters at an ideal level. It improves water infiltration rate and water-holding capacity. It serves as a reservoir of nutrients and water and supplies them to crops when needed. Organic matter plays a significant role in keeping disease and insect pests at low levels by boosting crop vigor and modifying the rhizosphere. Soils that are rich in SOM also have a high cation exchange capacity (CEC). Organic matter contains many negatively charged surfaces with a high affinity for organics and metals that might otherwise cause pollution. It has a high pH buffering capacity to resist changes in pH so soil pH remains at the ideal—near neutral level.

The physical benefits of SOM are of great importance. With a high level of OM soil tilth is improved, and aggregate size tends to be large with good soil structure. Similarly, soil humus ties up carbon in the soil reducing CO_2 which would otherwise be emitted into the atmosphere and contribute to an atmospheric greenhouse effect. Soil microbial diversity and quantity generally improve as OM increases. Microbes are major players of the OM decomposition process. With a high level of SOM, beneficial microorganisms reproduce and grow in the soil, which hastens the decomposition process. High SOM also accelerates mineral weathering, increases soil pore space, and decreases bulk density.

Factors that Control Soil Organic Matter Build-Up in the Soil

C:N ratio

The carbon (C) to nitrogen (N) ratio (C:N ratio) is a major factor that determines the speed of organic material decomposition as well as nutrient release patterns. Low C:N ratio (< 20:1) favors fast decomposition resulting in quick release of nutrients. Many beneficial organisms responsible for decomposition can multiply fast and get their food by decomposing materials with a low C:N ratio. A medium C:N ratio (between 20:1 and 30:1) results in release of nutrients, but the decomposition is slow enough not to have excess nutrients released at the expense of the amount of OM being

Table 1. C:N ratio of selected organic materials.

Organic Material	*C:N Ratio*
Hairy vetch /Alfalfa	10:1 to 15:1
Rye (seedlings)	12:1 to 15:1
Sweet clover	14:1 to 16:1
Food waste	14:1 to 16:1
Grass clippings	18:1 to 20:1
Rye (flowering)	20:1 to 21"1
Fruit waste	38:1 to 36:1
Dry leave	50:1 to 56:1
Corn stalks	58:1 to 60:1
Straw	60:1 to 72:1
Sawdust	250:1 to 500:1

added to the soil. High C:N ratio (>30:1) is an indication that the material is composed of difficult-to-break carbonaceous materials such as cellulose, hemicellulose, and lignin. High C:N ratio organic materials tend to stay on the surface of the soil or in the soil for a very long time. Microbes use available soil N and other nutrients to decompose high C:N ratio materials resulting in net immobilization of N. It is very important for an organic producer to make sure materials with low and medium C:N ratios are bulked with those of high C:N ratios to avoid short term plant stress due to insufficient amounts of N. For instance, if a producer plans to incorporate wheat straw into the soil, it is important to add low C:N ratio materials such as alfalfa, hairy vetch, or compost to supply N for microbes which will decompose the straw. Table 1 summarizes the C:N ratios of selected organic materials.

Temperature

The activity of many microbes acting on organic materials is a function of temperature. Low temperatures slow down decomposition, while warm temperatures speed up decomposition. The microbes that perform the bulk of the decomposition of organic material prefer room temperatures of 65 to 75°F, but they are active in the temperature range of 60 to 113°F. Therefore, the decomposition of OM in Oklahoma is generally fast due to the high temperature in the summer and results in low SOM in most agricultural soils.

pH

While OM decomposition is halted with pH extremes, the process progresses well in the pH range of 5.5 to 6.8. However, individual groups of microbes have specific pH requirements for optimal decomposition. Naturally, the process of decomposition itself can result in fluctuation of pH that stimulates or suppresses certain microbial species, allowing the process to continue smoothly by avoiding substrate accumulation.

Moisture and Aeration

Proper soil moisture enhances the growth of microorganisms that break down OM into humus. On the other hand, excess water can lead to anaerobic conditions which slow down the degradation process. Soil moisture of 50 to 70 percent of the soil's water-holding capacity is generally acceptable. At this moisture level, oxygen is in adequate supply for aerobic decomposition. Anaerobic decomposition is incomplete and does not yield as much energy as aerobic decomposition.

Soil Organisms

Different groups of organisms have different capacities in the process of decomposition. The product of one group can be the source of food for others to further break down organic material. Added OM will be colonized and decomposed by a community of organisms that will change over time as the composition of the residue changes. Bacteria, actinomycetes, protozoa, and fungi are the major microbes responsible for enzyme mediated chemical decomposition. Other soil organisms including earth worms, arthropods, and many others are also involved in non-enzyme mediated physical break down of organic residues.

Nitrogen Supply

Nitrogen (N) is one of the main substrates needed by microbes to decompose organic materials. When decomposing high C:N ratio material, microbes need an external supply of N. For organic farms, this N must be supplied from organic sources, as organic crop production does not allow the use of synthetic fertilizers such as urea, ammonium nitrate, etc. A sufficient amount of N must be supplied until the decomposition process reaches to the stage of net mineralization. This is very critical, since without an external N supply, available soil N will be used for building microbial bodies and will not be available for plant uptake, which will result in plant N deficiency.

Strategies for Building Soil Organic Matter

The methods used for building SOM depend on several factors. One factor is the goal of the practice. Is the goal simply to supply nutrients or to supply both nutrients and build OM in the soil? This question refers to whether a producer should engage in supplying nutrients to make sure higher yield is achieved in the short-term or to consider both yield and conditioning the soil for optimum long-term production. Another factor that affects the strategy is the type of organic enterprise. A producer needs to answer whether they are interested in:

- A livestock-crop mixed organic production system
- Perennial or annual agronomic crops
- Fruits or vegetables
- A mixed cropping system

It is also important to know the soil type and problems specific to that soil. What is the physical and chemical composition of the soil? For soils rich in nutrients, but difficult to cultivate due to drainage problems, for example, raising the SOM level is recommended. Some soils are low in available nutrients; the strategy should be to supply nutrients as well as build SOM. Similarly, the nature of existing soil problems, such as low or very high pH and salt problems, must be taken into consideration. There are two strategies to build and maintain SOM for organic or, for that matter, any agricultural production system: reduce SOM losses and add organic material.

Reduce Soil Organic Matter Losses

There are proven methods to reduce losses of OM from a given field. One of these is conservation tillage (no-tillage, or various types of reduced tillage). Conservation tillage means reducing soil disturbance, which subsequently slows decomposition rate. Erosion control is another method for reducing the amount of SOM lost from the soil. In fact, erosion

control can help to maintain organic matter since it prevents soil and organic matter from washing or blowing away from a field. Erosion is an issue when soil is bare and disturbed; the magnitude is a function of soil types and topography. The conservation tillage system coupled with land cover and other erosion mitigation methods can reduce SOM loss. Another important practice to prevent loss is to avoid mono-cropping. Mono-cropping coupled with conventional tillage hastens SOM loss. In the Magruder Plots of continuous winter wheat for more than 116 years in Stillwater, the SOM level was reduced from about 4 percent to 1 percent with or without application of inorganic fertilizers.

Add Organic Materials

There are wide ranges of options that an organic producer can use to add OM to the soil. Organic materials are highly variable in mineralization pattern, nutrient content, and availability. That is why it is important to set a goal and develop a best management plan for a given field. Cover crops, green manure, residue and live mulch, animal waste, compost, uncomposted yard debris, and packaged organic fertilizers are some of the major materials for building SOM. If a producer is planning a certified organic enterprise, it is important to know the allowed and non-allowed organic materials and their sources by national and state organic program rules and regulations.

Cover Crops and Green Manure Crops

A cover crop is defined as any crop that is planted in a field after or prior to harvest of the major crop to cover the field until the next main crop is planted. A green manure crop is the crop grown on a field and then turned under when still green before the main crop is sown largely to supply nutrients, but also to contribute to the addition of OM. Cover and green manure crops serve four purposes: add OM, supply nutrients, prevent erosion, and prevent leaching by scavenging plant nutrients such as NO_3— which otherwise may be leached into ground water. The contribution of cover and green manure crops to build SOM depends on the C:N ratio of the crops. There are four types of cover or green manure crops.

Spring annuals: These are cover crops that remain in the field during the spring season until the soil is prepared for the summer main crop. Oat and triticale are grouped in this category and both crops are suitable for Oklahoma.

Summer annuals: These are cover crops planted after the winter main crop is harvested during the summer. Several summer annuals including buckwheat, cowpea, and sorghum are suitable for use in Oklahoma.

Winter annuals: These are crops planted in the fall which remain on the field during the winter and resume growth in spring until the summer main crop is planted. These crops are essentially very good for adding OM as crops grow until maturity and produce significant biomass. Some legumes, such as hairy vetch, and grasses, such as winter rye, are very good options.

Biennials and Perennials: These are considered cover crops but unlike the definition of cover crops entails, these crops remain on the field while the main crop is growing, but certain planting configurations should be developed to avoid competition between the cover and the main crops. In terms of building SOM these crops are often the best.

Crop Residue

Crop residue refers to any organic material including stubble, that remains after an economic crop is harvested from a field. In continuously cropped soils if two to three tons per acre per year of residue is returned to the soil, SOM often remains at a steady level. There are several ways of managing residue for adding OM to the soil particularly if C:N ratio is very high. Residue can be chopped, incorporated (with or without chopping), or can be left to decompose on the surface.

Animal Waste

Amending soil with animal waste has been an old practice. Animal waste can supply nutrients, add OM, and enrich soil with beneficial organisms. The amount of animal waste used determines its contribution in building SOM. Certain organic production rules need to be considered carefully when using animal waste to add OM. The source and form of waste, the time of application to crop harvest (specific for different crops according to National Organic Program rules), and application rates (particularly important to avoid the buildup of excess phosphorus [P]) should be taken into consideration. The solid fraction of different types of wastes with the corresponding nutrient content determines how much to apply at a given time. Broiler litter generally has high level of nutrients and solids (Table 2).

Table 2. Nutrients and solids content of selected animal wastes (nutrient and percent solids values are on fresh weight basis).

Type	*Total N, lbs/t*	*P_2O_5, lbs/t*	*K_2O, lbs/t*	*Solids percent*
Dairy slurry	9	4	10	22
Beef feedlot	24	14	23	62
Broiler litter	61	61	51	77
Swine	10	9	8	18
Horse	9	4	13	46
Sheep	18	11	29	28

Compost

Compost is any organic material that undergoes decomposition under controlled conditions. Any organic material can be converted to compost, but there are rules regarding what material can and cannot be used. Compared to some uncomposted animal waste, it may have low nutrient levels. Nutrients from compost are often less available to the crop; thus compost may be more useful for building SOM. Compost causes less water pollution, usually has a lower pathogen level, may have fewer weed seeds, and may improve soil tilth compared with raw manure.

Uncomposted Yard Debris

As long as they do not come from non-allowed synthetic compounds, yard debris can also be used to build SOM and supply nutrients. These include grass clippings, leaves, fallen tree and shrub branches, etc.

Packaged Organic Fertilizers

One of the concerns with the use of organic materials to build SOM is the volume and cost associated with hauling