SUSTAINABLE FARMING Quarterly

Vol. 3 No. 3 December 1991

'Living Soil' Depends on Microbial Management

The author, David Granatstein, is project coordinator of the six-state Dryland Cereal/Legume Project based at Washington State University, Pullman.

The concept of the "living soil" is receiving increased attention from farmers, consumers, and policy makers as an important component of any sustainable agriculture. Terms such as "soil health" and "soil quality" are heard in scientific circles as well as farmer clubs. While many are interested in improving their soil, time-tested strategies are scarce. Fortunately, researchers from the Columbia Basin Agricultural Research Center (CBARC) at Pendleton, Ore., have some ideas for dryland farmers.

The CBARC is located in northeastern Oregon, where wheat-fallow cropping (16.7 inches average precipitation) and silt loam soils predominate. Several different long-term rotation and residue management experiments have been in place for 25 to 60 years (See Table 1, page 2).

Harold Collins, a microbiologist, and Paul Rasmussen, a soil scientist, both with the USDA Agricultural Research Service, have studied the soil properties of the long-term plots. "Public concern about the environmental impacts of farming is here to stay," Collins said. "Improving the status of the soil organic matter is an important goal, and we hope to show how management practices affect it."

What is soil organic matter?

Soil organic matter can be broadly defined as the sum of all carbon-containing materials in the soil, including undecomposed straw, stable humus, and soil microbes. Generally, tests for soil organic matter exclude the undecomposed materials and focus on the stable compounds, which are the result of microbial breakdown and synthesis. The organic matter contains large amounts of nutrients, especially nitrogen, phosphorus, and sulfur, which are slowly released by microbial action. The microbes are considered to be the most active portion of the organic matter, as they are constantly growing and dying. In doing so, they can have a major impact on the availability of plant nutrients.

In the Pendleton study, soil and microbial carbon and nitrogen, soil pH, microbial respiration and populations, and seasonal microbial changes were measured in the plots. Many of these factors interact closely with one another. For example, the ratio of carbon:nitrogen in semi-arid soils is quite stable at 11-13:1. Thus, as carbon is lost through erosion or intensive tillage, the total nitrogen will decline as well. Soil microbes rely on soil carbon and crop residues for food, and microbial levels will generally move in tandem with soil carbon levels.

Microbes can be measured in

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Montana Farmers Share Challenges and Risks of Trying New Techniques

An informal but well-organized program in which Montana farmers and ranchers exchange ideas and share the risk of developing new sustainable practices through on-farm testing has enjoyed remarkable success in its first two years.

The grassroots Alternative Energy Resources Organization (AERO) in Helena organized nine farm improvement clubs in 1991 for farmers and ranchers who desired to enhance their agricultural resources and at the same time protect groundwater quality and the environment.

AERO has provided technical assistance and small grants for seed, inoculant, soil tests, speakers, and travel, allowing the clubs to undertake field trials, demonstrations and educational projects. As the farm improvement club program has expanded, other private funders have pitched in.

The farm improvement clubs tentatively plan to convene Jan.10 in Great Falls, Mont., to share project results, details of the design and implementation of their projects, successes and failures, and to refine plans for the 1992 growing season. Nonmembers interested in attend-

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several ways, both by direct counting and by indirect methods such as respiration. All methods have drawbacks and no method is likely to give a "true" picture of the soil microbial status. But the methods are useful for determining the relative effect of farming practices. Since slight changes in the environment (e.g., temperature, moisture, tillage, crop growth) can quickly change the microbial status, tests need to be repeated at different times of the year. The results are most meaningful when comparing long-term, rather than short-term, management differences.

The grass pasture included in the study was considered to have organic matter and microbial levels similar to the native soil prior to cultivation. Thus, it serves as a benchmark for change in the other farming systems studied.

DOES ORGANIC MATTER MATTER?

Organic matter influences soil characteristics such as structure, infiltration, erodability, water-holding capacity, nutrient retention, and microbial populations. Research from the past century clearly supports the value of higher organic matter levels in most soils. But less is known about the effects of specific management practices on organic matter levels.

At Pendleton, the wheat-fallow system supported the lowest levels of organic matter and microbes. In moving from a permanent cover (grass) to annual cropping to crop-fallow, the loss of soil and microbial carbon and nitrogen steadily increased. (Tables 2 and 3).

Frequency of tillage and amount of crop residues returned were two major factors. The fallow system had the most tillage and the least residues, since a crop was grown every other year. Within the fallow system, manured plots were similar to annual cropping, while straw-burning resulted in the lowest levels of carbon and nitrogen. Manure was apparently able to counteract the effect of increased tillage with summer fallow.

Mineralization, or breakdown, of carbon from the organic matter was lowest for the wheat-fallow system. This indicates a change in the quantity and possibly the availability of organic carbon to the microbes due to a reduction in the "active fraction" of organic matter. The active fraction is composed of readily-available

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TABLE 1. LONG-TERM CROPPING SYSTEMS AT PENDLETON, ORE.

GP — Grass pasture; improved varieties, grazed, occasional fertilizer and irrigation.

WW -- Annual crop wheat; nitrogen fertilizer, straw returned.

WP -- Wheat-pea rotation; nitrogen fertilizer on wheat, straw returned.

WF SM -- Wheat-fallow, manure (10 tons per acre crop), straw returned.

WF S+N -- Wheat-fallow; nitrogen fertilizer, straw returned.

WF S-N -- Wheat-fallow; no fertilizer, straw returned.

WF FB -- Wheat-fallow; no fertilizer, fall burned straw.

TABLE 2. SOIL CHANGES FROM LONG-TERM CROPPING SYSTEMS

Cropping System	Organic Carbon added (lb/ac/yr)	Organic Matter	Total Nitrogen	pH (H_2O)
		--------%--------		
GP	ND	3.83	0.20	7.3
WP	2040	2.69	0.13	5.6
WW	2010	2.59	0.12	5.2
WF SM	2045	2.62	0.10	6.7
WF S+N	1500	1.93	0.09	5.6
WF S-N	1005	2.07	0.08	6.1
WF FB	<360	1.81	0.07	6.0

The *Sustainable Farming Quarterly* is a publication of the Dryland Cereal/Legume Project, a LISA project based at Washington State University, Pullman. The publisher is the Alternative Energy Resources Organization, 44 Last Chance Gulch, Helena, MT, (406) 443-7272.

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carbon that is water soluble or microbial, compared to resistant fractions (stable humus) which are not very available for microbes.

TABLE 3. MICROBIAL CHANGES FROM LONG-TERM CROPPING SYSTEMS

Cropping System	Microbial Carbon (lb/ac)	Microbial Nitrogen (lb/ac)	Microbial Carbon as % Soil Carbon	Populations[1] B (million/gram soil)	P	F	A
Grass pasture	951	103	4.2	71	50	8	2
Wheat-pea	660	53	4.2	83	4	22	2
Wheat-wheat	450	40	2.9	-	-	-	-
Wheat-fallow	250	29	2.2	54	4	10	1

[1] B= total bacteria; P= Pseudomonads; F=fungi; A=actinomycetes. Data for wheat-pea is an average of WP and WW systems. Data for wheat-fallow is an average of the crop and fallow phases. All data from the February sampling. There are 28 grams in an ounces.

The microbial biomass refers to the "weight" or "living mass" of microorganisms in the soil. Microbes grow and die constantly, and their status is determined largely by temperature, moisture, and food. At Pendleton, microbial biomass varied seasonally in all systems. Microbial carbon increased from September to February, and then decreased. Spring often begins in late February at Pendleton. Microbial nitrogen followed a similar pattern, but peaked in November rather than February. The microbes appear to capture a substantial portion of fertilizer nitrogen in the soil during the fall, thus reducing the potential for its loss. The population of bacteria and fungi showed wide seasonal variation, while actinomycete levels were relatively stable (Table 3).

Microbial levels were higher in plots with growing crops, compared to those with fallow. This is due to the "rhizosphere" effect, in which plant roots provide a sizeable food source for many soil microbes, both friend and foe.When the annual input of carbon from the different wheat-fallow systems is plotted against the annual change in soil carbon, the data indicate that about 2,300 pounds of carbon per acre per year need to be added to maintain present levels (Figure 1). Only the manure system is adding enough carbon to increase organic matter, and the long-term results verify this. Researchers estimate that about 17 percent of the carbon added by wheat residue is stabilized in the soil. The rest is lost by microbial respiration during decomposition.

The use of ammonium-based nitrogen fertilizer had an acidifying effect on the soils. The decline in soil pH was directly related to the cumulative application of fertilizer. Manure applications slowed the decline in pH compared to the unfertilized (wheat-fallow, no fertilizer, straw returned) plots. Lower pH can affect the size and composition of the microbial population. Certain diseases are favored and processes such as nitrogen fixation can be suppressed.

The effect of the long-term rotations on several wheat

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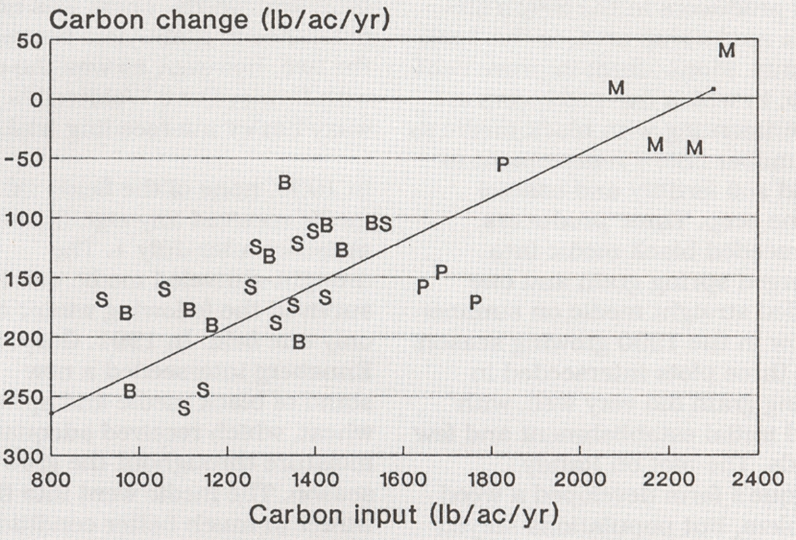
FIGURE 1. EFFECT OF ANNUAL CARBON INPUTS ON SOIL ORGANIC CARBON LEVELS



M= manure plus straw; P=pea vines added; S=straw plus nitrogen; F=straw burn, no nitrogen.

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diseases was studied over a three-year period. Eyespot was most severe in the continuous wheat plots (WW), intermediate in wheat-fallow (WF), and least in the wheat-pea (WP) rotation. Take-all and cephalosporium stripe were not affected by rotation. A root rot complex (Rhizoctonia and Pythium) was greater in the WF plots than in the WW or WP plots. In WF, the complex was most prevalent with nitrogen fertilizer without stubble burning. Burning reduced the incidence of root rot, but not to the level in the manure treatment.

Guiding Principles

The importance of soil organic matter has been stressed by researchers and organic farmers for many years. Dryland farmers face many obstacles to increasing organic matter levels and microbial life in dryland fields, but some are succeeding. The following principles which are verified by the Pendleton studies will help:

- minimize the use of summer fallow;
- minimize tillage;
- maximize crop growth and residue return;
- add manure or other carbon sources when feasible;
- include perennial grasses in the system; and
- minimize use of acid-forming fertilizers.

Many factors will limit the use of these principles by farmers, especially economics and government programs. But to the extent that these principles can be used, the organic matter and microbial status of the soil will improve. The environmental benefits are well-known, but more needs to be learned about how these changes affect short- and long-term profitability. Further study of innovative dryland farmers in the region who are increasing their reliance on the organic matter and microbial components of the soil can help answer this question. ❒

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ing may contact AERO at (406) 443-7272.

AERO will accept new project proposals for Montana farm improvement clubs through mid-February. The program may serve as a model for similar programs; it has attracted the attention of grassroots organizations in other states, as well as the SCS and the Solutions to Environmental and Economic Problems (STEEP) program.

Of particular note to researchers and producers in the SFQ's six-state readership area, is the Toole County, Mont., farm improvement club, in which five producers are experimenting with black medic as a summer fallow replacement to build soil fertility and control saline seep. Three producers overseeded black medic into emerged spring grain and one seeded straight medic on summer fallow in the 1990 growing season. The three plots interseeded in spring grain did very well, with good initial establishment and few weeds. The plot on Randy Fauque's farm developed a weed problem, but populations stayed within tolerable levels.

The medic plants dried up early from lack of moisture, but root nodulation was evident early in July. The grain crops were harvested as usual. In one five-acre plot, the spring wheat with medic interseeded yielded about two bushels more per acre than the adjacent plot of wheat alone. The farmer, Terry Alme, noticed the grain was thinner on the medic plot; he thinks it was better able to withstand the hot dry weather than the thicker wheat stand. In Fauque's medic plot, the wheat was noticeably taller than in the adjacent plot with wheat alone treated with herbicide for broadleaf weeds. There was no difference in grain yield between the two, however, as was the case with farmer Dave Woldtvedt's waxy barley interseeding trial.

In 1990, none of the fields with medic received any significant moisture after July 1. The drought-shriveled medic barely survived the following winter on only one field. In 1991, Gary Enneberg interseeded a new stand of black medic and spring wheat, which received adequate moisture throughout the growing season. The medic went into this winter in much better condition, and the group expects much better winter survival.

All five producers used liquid seed inoculant. One placed a tarp in the bottom of his drill box, putting the medic seed in the tarp. He then poured the inoculant on and mixed it in the tarp. After it dried slightly, he shook the tarp to break up the seed and pulled the tarp out.

In the short term, the small grants cost-share program reduces the risk to producers who want to experiment with field-scale experiments. Even more important is that farmers are working together, sharing strategies and experiences that lead to concrete changes in their operations. The farm improvement clubs have successfully linked researchers and other agricultural professionals to producers in a direct, supportive relationship.

Reduced threats to groundwater from fertilizer and pesticides, enhancement of the soil resource, and increased biological diversity are the anticipated long-term outcomes.

For more information on the farm improvement clubs in Montana, call AERO. For information about Idaho, Washington, and Oregon, call Stewart Wuest with the STEEP program at (509) 335-3491. ❒

RESOURCES

LIVESTOCK HEALTH AND NUTRITION ALTERNATIVES: PROCEEDINGS OF A WESTERN STATES CONFERENCE. This newly-released book captures the substance and spirit of the 1990 conference of the Alternative Energy Resources Organization. It covers disease prevention and health maintenance of ruminant animals without hormones and subtherapeutic antibiotics; meeting nutritional requirements with alternative crops, feeds and grazing practices; disease and parasite treatment, livestock marketing and market development. S.K. Hilander. 1991. 50 pp. Alternative Energy Resources Organization.

WHEAT HEALTH MANAGEMENT is a thorough guide to wheat production for growers and researchers, applicable to most of North America and other wheat-producing areas. The book is technically complete but easy to read, and is illustrated with excellent photos and figures. It discusses wheat health before planting, at planting, postplant, and postharvest. The final chapter presents the idea of holistic health for wheat. R.J. Cook and R.J. Vaseth. 1991. 152 pp. American Phytopathological Society Press, 33 Pilot Knob Hill, St Paul, MN 55121.

SUSTAINABLE AGRICULTURE IN THE SOUTHERN ROCKIES: A RESOURCE DIRECTORY OF PRODUCERS AND PRACTICES. Released by the Sustainable Mountain Agricultural Alliance, this directory profiles farmers and ranchers in the region who responded to a recent survey. It includes a directory of businesses, organizations, and research and education personnel working in sustainable agriculture in the southern Rockies, and is the beginning of an informal network to facilitate exchange of techniques and information. SMALL, P.O. Box 1770, Telluride, CO 81435.

CHALLENGES IN DRYLAND AGRICULTURE: A GLOBAL PERSPECTIVE. The proceedings of the International Conference on Dryland Farming, Bushland, Texas, consists of more than 280 scientific papers on sustainability, soil erosion, water conservation, agroclimatology, soil erosion, water conservation, residue management, socioeconomic and environmental issues, cropping systems, and crop/livestock systems. P.W. Unger, W.R. Jordan, T.V. Sneed, and R.W. Jensen. 1988. 965 pages. University of Texas, Bushland, TX.

SUSTAINABLE AGRICULTURE RESOURCES. A quick reference guide for producers and researchers to sustainable agriculture resource organizations, agencies, and materials. Wisconsin Department of Agriculture.1991. 38 pages. Sustainable Agriculture Program Office, 4702 University Ave., P.O. Box 7883, Madison, WI 53707. (608) 267-3318. ❐

CALENDAR

JANUARY

7-8: STEEP annual review, Kennewick, Wash. Participants will review current activities of this tri-state dryland research effort. Contact Tammy Durfee at (509) 335-1552.

22-23: University of California Organic Farming Symposium, Asilomar Conference Center near Monterey, Calif. Keynote speaker is Fred Kirschenmann of North Dakota, an outspoken proponent of agricultural policy reforms. Crop rotations, cover crops, soil fertility, minimum tillage, beneficial insects, and organic livestock production. Contact Committee for Sustainable Agriculture (CSA) at (916) 346-2777. Fax (916) 346-6884.

23-25: Annual Ecological Farming Conference, also sponsored by CSA. Keynote speaker is international environmentalist Jeremy Rifkin. See registration information above.

FEBRUARY

7: Progressive Farmers Inland Northwest (PFIN) annual meeting, 10 a.m. to 3 p.m., Grange, Steptoe, Wash. Contact Bob Klicker at (509) 525-2494.

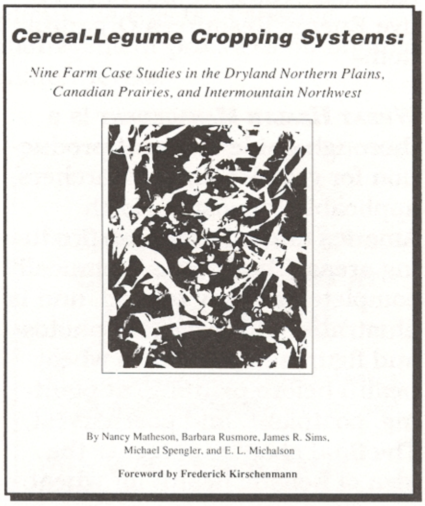
7-9: Farm Conference '92, Santa Rosa, Calif. Aimed at small-scale farmers, direct marketers, educators, and researchers.

13-15: National Conference on Organic/Sustainable Agriculture Policies, Bethesda, Md. Co-sponsored by the Center for Science in the Public Interest and the Institute for Alternative Agriculture. Topics include sustainable ag programs under the 1990 Farm Bill, national pesticide tax, barriers to adoption of biological pest contols, food system concentration, and ecological damage cost assessment. Agricultural Conference, CSPI, 1875 Conn. Ave. NW, Suite 300, Washington, DC 20009-5728.

18: Inland Northwest Conservation Farming Conference, WSU, Pullman, Wash. The focus is on variable management with whole fields, divided slopes, and field strips. Contact Roger Veseth at (208) 885-6386.

ROTATING YOUR FARM INTO SUSTAINABILITY

NEW AERO BOOK TAKES READERS ON AN ARMCHAIR TOUR OF NINE MONTANA FARMS THAT HAVE DIVERSIFIED CROP ROTATIONS TO SAVE RESOURCES.



Diverse crop rotations can help farmers and ranchers improve their soil and reduce their weed, insect pest and disease problems. The Alternative Energy Resources Organization's newest book, *Cereal-Legume Cropping Systems: Nine Farm Case Studies in the Dryland Northern Plains, Canadian Prairies, and Inland Northwest*, describes how.

The book offers an armchair tour of nine profitable, resource-conserving farms. All nine farms grow legumes and a variety of other dryland crops in rotation with wheat, the most common crop in this region. These case studies show how and why cereal-legume cropping systems work using today's technology and plant varieties.

The nine case studies in *Cereal-Legume Cropping Systems* span the region from Idaho's Palouse Hills, with 24 inches of average annual precipitation, to the harsh prairies of southern Saskatchewan, with 10 to 12 inches of moisture annually. Farms in Montana and western North Dakota represent the middle of the region's climatic spectrum. In terms of farm size, financial condition and environmental chacteristics, these farms are typical of farms in the region.

Each case study describes in practical, readable detail the farmer's crop rotation and its effect on weeds, insect pests, disease, soil fertility and soil condition. Each contains information on the farmer's costs and income for each crop in the rotation. The farmers' specific objectives are included, as are problem areas, marketing arrangements, and labor and equipment used. Where a farmer has integrated his livestock enterprise with his crop rotation, that is also described.

Cereal-Legume Cropping Sysems, written by Nancy Matheson, Barbara Rusmore, Dr. James Sims, Michael Spengler and Dr. E. L. Michalson, was a joint project of AERO, Montana State University, the University of Idaho, and the Northern Plains Sustainable Agriculture Society. Funding was provided by the U. S. Department of Agriculture's Sustainable Agriculture Research and Education program and AERO's members.

"If we succeed here in describing much of the rich detail of these farming systems and the technical practices, we will have accomplished our goal. We also hope you can sense the deep enjoyment these farmers get from their active experimentation with new possibilities," write the book's authors.

To order, send a check or money order in U.S. funds to AERO, 44 N. Last Chance Gulch, Helena, MT 59601. Single copies are $6. ❐

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