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PUBLICATIONS

The 150-Acre Sunshine Farm
at The Land Institute

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Abstract

During the past 15 years, agricultural research at The Land Institute has used nature as a standard. Because prairies are sustainable ecosystems, The Land Institute is using the prairie as a model for the Sunshine Farm. The main goal of the project is to conduct year-round accounting of energy, materials, and labor on the farm. The aims are to examine whether the Sunshine Farm can provide its fuel and fertility, and to determine how much industrial energy society must provide from sunlight to manufacture the farm facilities, equipment, and inputs. Prairies are characterized by species diversity,

perennial plants, energy flows based on sunlight, and internal control of fertility and pest damage, Hence, the Sunshine Farm contains renewable energy technologies and innovative farming practices applied to conventional crops and animals. Import of nutrients is minimal, and some candidates are included from The Land Institute's natural systems agriculture research.

The Land Institute has used nature as a standard in its research on perennial grain polycultures during the past 15 years in its Natural Systems Agriculture Program (see Piper in these proceedings). Natural ecosystems, such as the prairie, can inform us how to develop sustainable agricultural systems. For example, as fossil fuels become depleted, sustainable agriculture will require tighter nutrient cycles and energy flows driven by the sun, as in prairies. That is, farms should run on sunlight instead of fossil fuels, and recycle nutrients instead of importing commercial fertilizer. Also, the structural pattern of prairie vegetation suggests that sustainable agriculture should include soil-conserving perennial plants and species diversity instead of annual monocultures.

The Land Institute initiated the Sunshine Farm in 1991 as a 10-year project to establish a Great Plains farm that includes these structural features of prairies. The purpose of this project is to explore options for reducing the dependence of modern agriculture on fossil fuels. Government allocation and price regulation of scarce fossil fuels could guarantee farmers the energy-related inputs they need at reasonable prices, but this would reduce the incentive for technological development or adoption. By the time the rest of the American economy insists that farmers pay the true cost for inputs, agriculture would be behind in technology. Since this is not a desirable outcome, farms need to make the transition to supplying their own fuel and fertility, with society providing the industrial energy from sunlight to manufacture farm facilities, equipment, and inputs.

A one-year feasibility study for the Sunshine Farm was conducted to design the farm and to select some renewable energy technologies and sustainable farming practices. The main research objective of this project is year-round accounting of energy, materials, and labor in every task on the Sunshine Farm, which is accumulated in a computer database. The data derived from the Sunshine Farm will determine a more accurate ecological cost of our food, which is currently the product of a national policy of cheap food and fuel. Moreover, the production of annual grains with renewable energy technologies and low-input practices will provide the standard for comparing the productivity of conventional annual grains with that of perennial grain polycultures which mimic the prairie's structure. Much more effective national policies and farm practices can be derived when sound information from the study becomes available.

To facilitate collection of the data, we have developed an accounting taxonomy and defined boundaries for charging farm inputs. More than 2,900 farm transactions have been entered in the computer database during 1993-1995. We have been using FoxPro, a professional relational database software, for the database and for writing computer files to generate energy budgets for the enterprises on the farm. The budgets include not only the direct energy in fuels, but also the embodied or indirect energy in materials; i.e., the industrial energy to mine, process, and fabricate the farm inputs from raw materials. We determine or estimate the weight of all items on the farm and enter them into the database, which contains energy factors from the academic literature for converting these weights to embodied energy.

The budgets also use energy factors to convert hours of human labor to embodied energy. The energy factors for human labor are based not on the entire lifestyle of farm workers, but on the portion required to support their labor, derived from a detailed study by Richard Fluck (University of Florida, Gainesville, agricultural engineering).

Since the lifestyle supporting farm labor is the biggest unknown in our energy budgets, the energy cost for labor is considered for two extremes, the low-energy Amish lifestyle and average farm households in the energy-intensive U.S. culture. A useful aspect of these energy budgets is they show where energy consumption can be reduced on the Sunshine Farm. In other words, they have the potential to serve as protocols for strategies farmers and researchers could use for developing renewable energy technologies and sustainable practices on the farm.

While expenses and income on the Sunshine Farm are being entered in the computer database, the present profitability of this farm is not pertinent. This is because the current economic system does not reflect the ecological costs that will be important in a post-fossil fuel era. Moreover, economics is unpredictable in the distant future. Energetics is far more important than economics for this project. That is, when fossil fuels become too scarce and too expensive to subsidize for agriculture, farmers will have to rely more and more on biological processes for agricultural productivity and thus will have to deal with the ecological and energetic constraints in these processes.

The Sunshine Farm contains 50 acres of bottomland crops and 100 acres of upland pasture, mostly native prairie, with several tractors, a full array of implements, farm buildings, and grain bins. The farm contains crops and animals representative of Great Plains agriculture, with the intention that per-acre results obtained from its small size could be scaled to farms of larger sizes. Alongside the ongoing farming and research during the past three years, we have constructed facilities for the draft horses (1 mile high-tensile fence, three stalls, granary for feed), cattle (1 mile high-tensile fence on cropland, 2 miles barb-wire fence on pasture, two water lines with automatic waterers), and poultry (portable hen house, portable broiler pen).

In the feasibility study for the Sunshine Farm, we selected three renewable energy technologies: draft horses, a biodiesel-fueled tractor, and photovoltaics for providing electricity. For traction, we have been exploring a mix of draft horses and tractors fueled by biodiesel (chemically processed vegetable oil) to determine what size "Sunshine Farm" small farm families could run. Tractors provide timeliness in field operations, but horses can be used when time is not critical.

An important advantage of draft horses is their diet is far more flexible than that of tractors and biofuel processing facilities. If there is a crop failure, horses can more easily utilize something else than tractors and biofuel facilities can.

Moreover, the crop acreage requirements of horses is no greater than that for tractors operating on biodiesel. In our feasibility study, detailed calculations, based on numerous early bulletins from the United States Department of Agriculture and state agricultural experiment stations, show draft horses require no more cropland for feed than tractors do for biodiesel on a net energy basis, both roughly one-fourth of a farm's cropland. Our feasibility study found that favorable energy balances for ethanol from grain, sugar crops, or biomass grown under low-input conditions in the central Great Plains do not fare any better. Thus, the biofuels available for tractors are limited.

For example, soybeans are the only organic oilseed that can be produced well in the central Great Plains. Organic sunflowers are difficult to produce because they have more insect and disease problems than the other major grains – due to their being grown where their ancestor, the weedy *Helianthus annuus,* evolved (Al Schneider, North Dakota State University, production specialist).

If traction energy must be derived from crop residues in case of crop failure, far more of the carbon will be returned to the land in horse manure than in any biofuel process for the tractor, including spent digester substrate from anaerobic biogas production. This is an important point, because for the low-input conditions that will become prevalent in the distant future, biomass in crop residues will be small, thus leaving little or nothing to spare beyond the carbon requirements for soil organic matter. This means tractors must rely more on fuel crops than on crop residues for fuel. Hence, biofuel production will require extra fuel crop acreage and fuel storage so that production in good years for fuel crops will offset that in bad years.

Land requirements for horses are further favored by the inclusion of energy requirements for foal and tractor replacements in the energy balances. Also, unutilized carbon can be accumulated as soil organic matter from horse manure returned to the land, but not from tractor exhaust. In summary, the flexible diet and comparable energetics of draft horses justify their use on farms. As experience is gained with mixes of horses and biofueled tractors in the distant future, farm size will evolve to meet the requirement for timeliness in field operations.

For the biofueled-tractor, we have been recording the direct energy in the fossil fuels consumed on the Sunshine Farm, with the assumption these would be supplied by biofuels in the distant future. While the tractor will eventually be operated on biodiesel, we will continue to use gasoline in the trucks. Agco (Deutz-Allis) has loaned us a refurbished biodiesel-compatible Agco 8630 119-HP tractor. We will compare engine wear for operation on biodiesel with that for diesel. So far, we have accumulated 100 of the 150 hours of required operation on diesel before the lubricating oil can be sent for lab analysis of engine wear parameters. It may be late 1996 before we can switch to commercial biodiesel that we will purchase.

Guaranteed-quality biodiesel would be economically produced with a more positive energy balance and far less labor by farmers' cooperatives-operatives in the future (Don Van Dyne, University of Missouri, Columbia, agricultural economics). Nonetheless, we have been investigating on-farm production, mainly to educate farmers and Friends of The Land. A dismantled oilseed press was donated to us by a Friend of The Land at the USDA in Beltsville, Maryland. We have located some missing parts and will reassemble the press to begin experimental pressing of soybeans and sunflowers. For the energy accounting, we will record the oil produced and the electricity consumed in driving the motor to press it.

Because the squeezed oil is not suitable for long-term use in diesel engines, it must be chemically converted to biodiesel. Charles Peterson (University of Idaho, Moscow, agricultural engineering) has developed a low-energy process for making canola biodiesel. However, soybean and sunflower oils have higher gum contents than canola, which can hinder the efficiency of the chemical conversion and cause deposits in diesel engines. From literature review and communication, we have determined it is not feasible to degum these oils on farm, and that it may be necessary to run the chemical reaction three or four times on each batch of oil to obtain good biodiesel. However, this reaction uses an excess of ethanol, which is not a renewable fuel (more energy goes into producing the fuel than is contained in it). This means the repeated reactions with ethanol could result in biodiesel that is not a renewable fuel, in which case on-farm production would not be worthwhile. So, we need to do a small feasibility study to determine if the energy balance for biodiesel from these repeated reactions is positive (renewable fuel) or negative (not).

The 4.5-kilowatt, 12-by-38-foot photovoltaic array on the Sunshine Farm was funded and recently installed by Western Resources, the regional electric utility, with the help of Land Institute interns. This system is sized to meet the annual electric needs of the farm, with sale of excess electricity in the summer and some purchase in the winter. We will compare its monthly production of electricity with electrical demand by the farmhouse, workshop, electric fence chargers, water pumps, and other needs on the farm.

To determine if this photovoltaic array can produce more energy over its lifetime than is consumed in the industrial production of the array, we will compute the embodied energy of the array and compare this with the annual electrical output that we will measure on the farm.

We will also judge if this on-farm photovoltaic array is a suitable scale for meeting the electric demands of an entire farm. While arrays of a few square feet are appropriate for isolated electrical devices on a farm, the use of arrays of 5-to 10-kilowatt size in conjunction with utility grids has not been adequately explored. This is an important question because experience has already shown that wind-electric and renewable fuels (ethanol, biodiesel, biogas, producer gas) would be best produced at the scale of farmers cooperatives-operatives instead of on farm. This is due mainly to the requirements for technical skill and labor. The future dependence of sunlight-powered farms on biofuel cooperatives and utility grids demonstrates that renewable energy technologies are not for self-sufficiency but for reducing the use of fossil fuels.

The crops and animals on the Sunshine Farm were selected in the feasibility study. Acreage for each crop was based on requirements for animal feed, fall cattle grazing, oilseeds for tractor oil fuel, and approximate crop demand for nitrogen from symbiotic fixation in legumes. Oilseeds and forage legumes each require about one-fourth of the crop acreage. These requirements are provided by a mix of two five-year crop rotations, including two rental fields of alfalfa and sweet sorghum. The rotations are: 1) grain sorghum, soybeans, oats, wheat, and cowpeas (grazed); and 2) sunflowers, soybeans, oats, pearl millet (grazed), and cowpeas (grazed). The crops are produced with conventional tillage in 120 13-foot wide strips (four rows), which progress through the rotations over the years.

Grain sorghum, oats, alfalfa, and sweet sorghum are fed to the animals, while the wheat is sold. Much of the soybeans and sunflowers will be run through an oilseed press for oil fuel, with the leftover meal fed to animals. So, roughly three-fourths of the crop acreage is devoted to animal feed and cattle grazing, overlapping with that for oilseed and leguminous nitrogen fixation. This cropland fraction for livestock, with return of manure to the crops, is a common practice on organic farms.

We have a cow-calf beef herd based on nine Texas longhorn cows rotationally grazed on the pasture by use of electric polywire. Longhorns are the closest U.S. domestic cattle breed analogous to bison. They are an appropriate breed in regard to the energy accounting for the Sunshine Farm because they require fewer inputs than other breeds. They have been on this continent the past 500 years, where natural selection worked on unbranded and drifting survivors on the Texas and Mexican range and on the long trail drives through the Great Plains.

To close the nutrient cycle between cattle and cropland, the yearlings and calves are moved to the cropland in late summer where we use electric polywire to break-feed them crop stubble and legume cover crops on into winter.

Egg production is done by a portable hen house with 45 Rhode Island Red hens fenced in so that they also compost old straw for return to the cropland. With a portable broiler pen and a borrowed chicken plucker, we raise and butcher 75 Cornish Cross broilers annually. The broilers and hens are demonstration projects with data collected for the energy accounting. We decided against pastured hog production to avoid problems with residential neighbors.

In addition to the energy accounting, there is component research which consists of multiyear experiments designed by the project ecologist and conducted by interns to adopt the sustainable farming practices on the Sunshine Farm. At the end of the growing season, the interns write research papers for *The Land Report*, and give presentations to agricultural researchers at the annual Research Advisory Group meeting at Kansas State University, Manhattan.

There are four intern experiments in which we have been making measurements repeated annually: strip cropping, long-term soil quality, cattle on pasture, and cattle on cropland.

In the strip-cropping experiment, yields of adjacent strips of soybeans and grain sorghum throughout the cropland are measured to determine if the strip edges give polyculture effects that lead to greater grain yield than if the two crops are grown in separate monocultures.

To ascertain the sustainability of our cropping practices, we have been monitoring long-term soil quality in 60 of the 120 crop strips on the farm. We have been measuring four physical properties – bulk density, water infiltration rate, water holding capacity, soil aggregation – and two biological properties – earthworm density, soil respiration – with on-site procedures refined by John Doran (USDA-ARS, Lincoln, Nebrasla). We have also been sending soil samples from these strips to the KSU Soils Testing Laboratory for nine chemical properties at 0-30, 30-60 and 60-100 centimeters depths.

For the cattle on pasture, we have been conducting cover class analysis of plant species composition in the pasture to determine if rotational grazing is maintaining desired species. For the cattle on cropland, which will begin in 1996, we will be measuring the effect of cattle grazing and dropped manure on many of the above-soil properties and subsequent grain yields in the crop strips.

At the end of 10 years, we expect to have an extensive computer database on the energy, labor, and materials required for a farm arranged to run on sunlight. This baseline information will be made available for application in many areas, such as economics and public policy. A book will be published containing the data, analyses, and conclusions. The book will contain the questions and issues raised as the consequence of the study, questions and issues essential for farmers and agricultural researchers to ponder and try out in the transition to a sun-powered agriculture. Exploration of these problems will lead to more effective national policies on directing the transition to an agriculture based on renewable energy technologies, sustainable farming practices, and an enduring soil. ■