

HOOKED

by Stephen Lewandowski

Hayfield mowd
 slick as a mirror--
 alfalfa laid out in long parallel lines.
 A machine blows it
 into the wagon for
 the Holstein dairy herd--
 big milk producers
 waiting in the barn--
 hooked on high
 protein feed.

Stephen Lewandowski is with the Ontario County (US) Soil and Water Conservation District. He has published several books including *Honey and Ashes* from Tamarack Press and *Inside and Out* from Crossing Press.

TOWARD A SUSTAINABLE AGRICULTURE *

By Wes Jackson

Nowhere is the split between humanity and nature more dramatic than in the differing ways with which people and nature cover the land with vegetation. To maintain the ever-normal granary, agriculturalists have favored the monoculture of annuals. Nature has for the most part, favored the polyculture of perennials. This is not to say that perennials are excluded from agricultural endeavors, nor that nature excludes the annual plant as part of her strategy to keep the ground safely covered. Certainly the numerous nut and citrus trees, grapes and berries (be they blue, black, rasp or straw), along with other perennial plants including cotton and sugar cane are important to agriculture. And no naturalist need remind us that annuals are widely dispersed in natural ecosystems.

What are the implications of these opposite tendencies and how seriously ought we work to heal the split? Nature is both uncompromising and forgiving, but we do not yet know when to count on compromise and when on forgiveness. I doubt that we ever shall. But we can say with a rather high degree of certainty that if we are to heal the split, it is the human agricultural system that had better grow more toward the ways of nature.

On a limited scale nature rewards enterprise. A weedy annual is enterprising. Not only will it cover bare ground quickly, but it will also store an excess of energy besides. This is probably the reason our most important crops are weedy annuals. During a growing season, a small amount of annual vegetative biomass promotes the production and

survival of a rather large number of seeds. This is usually assured by one of three ways or even a combination of all three: (1) the storage of plenty of food in the seed, (2) the set of many seeds and (3) the ability to colonize a disturbed area. Many perennials may have these three characteristics, but it is less critical for them to be expressed in a particular season for there is always another year. For that matter, there is another year for annuals too, for some of their seeds will remain viable for more than one year. But overall, the colonizing annual relies on **enterprise**. The ancestors of our current crops may well have been camp followers --colonizers of the disturbed ground around the campsite. They were available for human selection, and usable because they could produce an excess of potential energy.

We don't know whether the early agriculturalists were faced with famine, but when they began to plant annuals in fields, they were beginning to **reward** enterprise. The monoculture of annuals was a big new thing. The face of the earth was changed.

It is amusing to look at the process teleologically--on the general thesis, for example, that plants are a device invented by soil to prevent its own destruction.

By and large, the patient earth has rewarded patient ecosystems more generously, but enterprise has probably been rewarded too. It would seem to be a good strategy for an ecosystem to have enterprising species present, for quick colonizers could rapidly cover the ground made naked by a migrating buffalo, which had wallowed and dusted himself, or an excessive flood, or an insistent wind. The ecological capital which had been sucked from parent rock material or borrowed from the air could be retained to promote more life for future generations of all species in the system.

The selection of enterprising plant species has rewarded all humans bent on enterprise in food production. But there is a second consideration. Humanity also has long been armed with a tendency to take without thinking. After all, life and sustenance itself have forever been gifts of nature. Combining these two characteristics--enterprise and the taking--has produced a result now to be reckoned with after the four hundred or so generations since humanity started concentrating on seed time and harvest.

To maintain any system, agricultural or natural, bills must be paid eventually. In nature's prairie, the bills are paid automatically and with amazing regularity. The wild forms have evolved methods for dispersing seed, recycling minerals, building soils, maintaining chemical diversity, promoting new varieties and even controlling weeds. Most biologists believe that natural selection alone was up to these tasks, and that purpose was not necessary. In a sense, nevertheless, the prairie

has been successful because close attention has been paid to seeing that these jobs get done.

The "no free lunch" law applies just as much to man's culture as it does to nature's. For when agricultural man substitutes his annual monoculture on this prairie land, be it corn, wheat, milo, sorghum, rye, oats, cotton, barley, rice, or tobacco, the same bills have to be paid or failure is inevitable. Mechanical and commercial seed preparation and planting, application of fertilizer, chemical and power weeding, mechanical soil preparation, use of pesticides and fungicides, and plant breeding are all the clumsy inventions we have devised, costly in capital and resources, for paying the bills nature handles at no cost.

In contrast to the system of nature, which relies solely on the daily allocation of solar energy, the industrialized world's inventions for the successful monoculture of the annuals require the stored light of the geologic past. Nature uses the renewable flow of energy; industrialized agriculture uses up the nonrenewable stock of fossil energy.

It also uses up soil. After nuclear proliferation, soil loss ranks alongside the death of our oceans and contamination and loss of our fresh waters and air. If soil loss were not so serious, it would be much more difficult to argue that the way of nature is inherently better than the way of agricultural man in the developed world.

The monoculture of annuals leads to soil erosion because it is almost inherent in this monoculture of annuals that ground be devoid of vegetation for too long a time, often during critical periods of the year, when wind and rain can rapidly move the soil away. Even during the growing season, especially for the row crops, the loss is substantial. Crops such as corn, cotton, and soybeans have much of their holding power destroyed between the rows as the farmer loosens the earth to cultivate. For this reason, J. Russell Smith called corn, "the killer of continents... and one of the worst enemies of the human future."

The polyculture of perennials is another matter. The more elaborate root system is an excellent soil binder. It has been estimated that before the white man, fires burned any given area on the North American Prairie at least once in a decade. Although the top organic matter was turned into smoke and ash, the roots at least remained alive, and bound the soil.

What will nature require?

It is doubtful that only by shifting to the polyculture of perennials can farmers peacefully co-exist with nature; after all, annuals are part of the natural strategy. But we can begin a systematic inquiry into the requirements of a high-yielding and truly sustainable agriculture. Which

is more important to investigate: Annual versus perennial or monoculture versus polyculture?

In a thoroughgoing systematic study, we may also need to compare woody with the herbaceous condition. Furthermore, some crops are vegetative, while others provide us with high-yield, easily stored fruit or seed. Theoretically, there are 16 categories for assessment, but we can eliminate four because woody annuals are unknown in nature. Eleven of the remaining twelve are currently used in the human enterprise. But there is one, category seven, which involves the polyculture of the herbaceous perennials for seed/fruit production. This category is almost the opposite of our current high-yielding monoculture of annual cereals and legumes.

Fruit/seed material is the most important plant food humans ingest owing to the readily storable easily handled, highly nutritious nature of the seeds we call grains. Unfortunately, none of our important grains are perennial. If a few of them had been, we might not have so thoroughly plowed from the edge of the eastern deciduous forest to the Rockies. Where we did not plow or where we did plant back nature's herbaceous perennials in polyculture, our livestock have become fat on the leaf and seed products. Throughout this entire plains expanse, the mixed herbaceous perennials are cultured for the purpose of harvesting the seed.

In the eastern tall grass region, the European settler substituted a domestic tall grass, corn. In the middle or mixed grass region, he substituted a domestic middle-sized grass, wheat. Part of the problem of the Dust Bowl is that we tried to substitute the middle-sized grass, wheat, in what was short-grass prairie.

The Dust Bowl followed a time of great plowing in the teens and twenties. When the dry winds blew in the thirties, the bad reputation of the region became firmly implanted in the American mind. But we have had other severe droughts in the area since then and the wind has blown just as strong. It is the work of the Soil Conservation Service and others that has prevented another major loss of our ecological capital. It is truly the work of thousands of diligent and dedicated people who have spent most of their productive lives thinking and working on the problem. But a most sober fact cannot be ignored: the soil is going fast. On flat land little is lost, but on rolling land the loss can be as high as sixty tons per acre per year. According to the General Accounting Office (GAO), the average yearly loss is nine tons per acre. Based on a random sample of farms in the Midwest, Great Plains and Pacific Northwest, 84 percent of the farms have been losing more than five tons of soil per acre each year.

Unless the pattern of agriculture is changed, our cities will stand as mute as those within the

Fertile Crescent between the Tigris and Euphrates Rivers, or near the Great Wall of China, or that region of Egypt which once hosted grain fields that supplied the empire of Ancient Rome.

If we are serious about negotiating with nature while there is still time to heal its split with humanity, are we not being asked to put vegetation back on the ground and promise that we not plow except for the occasional replanting? If that is nature's demand from the corn belt to the Rockies, will it require that we develop an agriculture based on the polyculture of herbaceous perennials which will yield us seeds not too unlike our cereals or legumes: This category, so glaringly blank in our table, needs filling desperately; and yet to contemplate the research, breeding, establishment of the crops, its harvest and separation of seeds is mind boggling to even the most skilled of plant scientists. Such an effort must also go hand in hand with the transportation, milling and ultimately, the eating of this sustaining "granola in the field."

It is too much to expect plant scientists to come up with such perennials, either through some intergeneric crossing of our high-producing annuals with some perennial relatives, or a wild perennial relative that promises a high yield that is both abundant and tasty? Such a scenario seems to be of a fantasy world. It would mean a minimum amount of mechanized agriculture; of plowing, disking, chiseling and mechanical power weeding. There would be only harvest, some fertilizing, pest control, genetic selection, and occasional replanting.

How about fruit or nut trees for saving our soils?

The answer to this question hinges on setting a fundamental question of plant science: whether perennialism and high-speed yield are mutually exclusive or not. Some highly reputable plant geneticists I have asked, who have worked and thought on the question, not only have discouraging comments but lean toward a categorical "no" when asked about the co-existence of the two. Others felt there were some possibilities. However, essentially all the work on this question has involved the crossing of an important annual with one of its wild perennial relatives. It is well known that perennials provide a fair-to-good stand the first year and often a pretty good stand the second, but by the third year, production is headed steeply down.

Nevertheless, despite such adverse opinion, the problem under discussion seems to have more promise than efforts to convert cereals into legume-like, nitrogen-fixing plants. The high-yield crops at least have close perennial relatives. The baseline for the development of nitrogen-fixing cereals are the few wild tropical grasses which are minimum nitrogen fixers.

In spite of all the discouraging efforts so far, if the relationship between high-yield and perennialism is not absolutely mutually exclusive, the development of only one new high-producing perennial crop could promote dividends for both developed and developing nations and could pay off forever. One such crop could go a long way toward preventing erosion and desertification--problems common to both types of nations.

The important point for consideration is that no new breakthroughs are necessary to begin a very large program involving scores, if not hundreds, of cross and selection experiments in our universities and research organizations. Some incentive seed money is always needed to accompany this kind of policy change but we need not wait for additional scientific and technological developments for this work to take place. The initial work occurred during the first half of our century as biologists sought to fuse Charles Darwin's ideas of evolution through natural selection with Gregor Mendel's principles of heredity--ideas which had developed more than 35 years before. This exciting period of history in biology, an excitement we too readily forget with our contemporary mania over such gee-whiz genetics as cloning and genetic surgery, began with attempts to establish the chromosome theory of heredity and has, by and large, culminated with the elucidation of the chemical structure of the hereditary material--the DNA--by Watson and Crick. During this period, techniques were developing to count chromosomes and follow them through the various stages of replication and division. Chromosomes were irradiated, broken and fused and some of their genes mapped. Sterility barriers between species came to be understood, and artificial hybrids, including some resulting from intergeneric crosses, were successfully made. We came to understand how species arose through chromosome numbers being doubled or reduced, and investigators learned to artificially induce these changes. Chromosome numbers have been successfully doubled through chemical agents to the point where it has become a matter of routine. Numerous species have had their karyotypes (or genetic fingerprints) determined.

This work, which linked the independent ideas of Darwin and Mendel, is now a reservoir of practical knowledge. The newly developed field of statistics has also offered both the plant scientist and the breeder new tools. Together they have made significant advances in crop production through improvement in experimental design and a better understanding of hybrid vigor. Understandably, these assiduous experts were less interested in new crops than in "fine-tuning" the traditional crops, imaginative though the programs were. Thankfully, the same hardware (optical equipment, growth chambers, greenhouses, etc.) and the basic research

necessary for "fine-tuning" will be needed for researching the fundamental question of whether perennialism and high yield grain and pulse production are mutually exclusive or not. The supporting fields of plant physiology and biochemistry have the necessary working bibliographies, equipment, and experts to work in concert with the plant geneticists to gain information which can have a significant impact on our national soil loss problem.

Now is the time in which we should encourage much wide-ranging imagination and speculation on new crop development. Though numerous botanists and crop scientists will have various plant candidates in mind, I suggest one species and two groups of plants which should not be overlooked: (1) Eastern Gama Grass, (2) the perennial soybeans and (3) the wild perennial relatives of millet.

Eastern Gama Grass, *Tripsacum dactyloides* (L.) L. is a perennial relative of corn and a plant which cattle relish; which suggests that its seeds may be highly nutritious for humans. The virtues that this species offers are numerous. (1) It has already been extensively studied, particularly by those interested in the evolution of corn. Therefore, important basic information already exists. (2) The species is already at home in our corn belt for it nearly rivals corn in the extent of its distribution in North America that ranges from Florida to Texas and Mexico north to Massachusetts, New York, Michigan, Illinois, Iowa and Nebraska. (3) Because this tall, stout perennial has thick rhizomes, any desirable races could be propagated vegetatively from clumps. (4) The female flowers which set seed are localized and separate from the part which produces pollen. Therefore, no tedious effort is necessary for the breeder to emasculate before making crosses. (5) The species contains at least two, more or less true breeding chromosome races. These are five distinct advantages. One disadvantage this plant poses is that the seeds are enclosed in thickened boney joints which would have to be loosened up or softened, either in milling or breeding or both. This problem should not be insurmountable considering the amazing amount of genetic engineering with other species accomplished through ordinary plant breeding methods.

Perhaps just as promising as the above mentioned corn relative are the relatives of our high yielding, leguminous, nitrogen-fixing crop soybean. *Glycine max* (L.) Merr., as it is scientifically called, is an annual. But every other species in this genus is perennial. The genus itself consists of three subgenera which include ten species and 18 genetic entities, i.e. subspecies or varieties. Furthermore, there are three closely related genera comprising some 12 additional species. The variation within *Glycine* alone is truly remarkable. However, the entire American soybean industry,

which produces 75 percent of the world's supply, in the words of Professor Jack R. Harlan of the University of Illinois, "can be traced to six accessions introduced from the same part of Asia." It would seem that something could be done to test our basic question concerning perennialism and high yield with some of the other species of this genus or even the relatives of the closely related genera.

The third example involves a grass again, the Panicum complex, which includes broom-corn millet or Hog Millet, as it is sometimes called. Most species are perennials and the genus *Panicum* has a large range both in latitude and longitude, suggesting great genetic elasticity. A closely related genus *Setaria*, includes the Common Millet as one of its species.

These are but three examples. The possibilities are there for other groups as well, not the least of which includes the making of perennials of our old crops. All that is needed now is the interest on the part of potential investigators and some seed money from foundations and/or the government for researchers to redirect their efforts to this end.



Why have we not developed any new herbaceous perennial seed crops so far?

As I have already mentioned, one explanation might be that it can't be done. Another might be that we have lacked, in the right places, the kind of holistic thinking which would link high-yield seed production of annuals with soil loss. Even if we have seen the problem of soil loss, most of us must confine our breadwinning efforts to a narrowly defined job description--what we can do from harvest to harvest. In discussing the problem with colleagues, many, like myself, were aware that soil was probably being lost at an unacceptable rate but, until the release of the GAO study, were not aware that the problem was so acute. Therefore we

had not concentrated our efforts on the need for an agricultural solution.

New crop development has been paid relatively little attention since the centuries eight to ten thousand years ago when those generations of the most important revolutionaries ever to live on earth gave us essentially all our crops and livestock. Of the thousands of seed-producing plant species known, fewer than one percent have been utilized by humans for food, clothing and shelter. By and large humans do the easy things first, and so our crop scientists have improved the plants which have already demonstrated their amenability to cultivation.

Because traditional farm plants have an economic history, there is a ready-made economic data base for evaluating market opportunities against cost for any breeding work to be done. After all, much of our culture is built around relationships involving the farmer, the processor and the consumer. There has always been plenty of work to do in crop improvement without looking for more. Of the hundreds of crops available in our inventory now, fewer than a dozen supply the huge bulk of food stuffs. I have read that the top four supply as much food as the next twenty-six. Therefore, one would logically question the wisdom of adding more plants when we are not fully utilizing those which are already available.

There is probably another reason why we have not looked to herbaceous seed producers to save our soils and yield high-quality food. Imagine the psychological climate of the scientific community forty years ago. We were still in a depression, and the dust storms had already become legend. In response to this national tragedy, the Roosevelt Administration had established the Soil Conservation Service; and at its head was placed the energetic and imaginative Hugh Hammond Bennett. He quickly assembled the most able engineers, agronomists, nurserymen, biologists, foresters, soil surveyors, economists, accountants, clerks, stenographers and technicians of many backgrounds into the service of saving the soil. There was an anxious urgency on the part of nearly everyone involved. The Soil Conservation Service was, as Wellington Brink put it, "born with pride and loyalty and a sense of high destiny--an inner element which was to persist and spread and animate the organization and weld it together with a spirit altogether unique in modern government." Because of the high caliber of people employed, the Service gained a good reputation and gained it fast. Scholars and laymen alike felt that they could now comfortably turn their attention to other matters, entirely confident that the effort to save the soil was in the best hands possible. It would simply be a matter of time before this problem was solved--they were certain. Since the procedures were both

practical and scientific, everyone felt comfortable. There was little incentive to look elsewhere for solutions to the soil loss problem.

Other Benefits

(1) Perennial culture could reduce energy consumption. The energy for tractors in seed bed preparation and cultivation is significant, for it comprises a major fuel bill for the farmer year in and year out.

(2) Perennial culture could perhaps reduce pesticide dependency resulting in both energy savings and healthier soil and food. The direct fossil fuel energy which goes into our pesticide program nation-wide amounts to at least 80 percent of the total one billion pounds sprayed annually on our fields.

This amounts to around two million barrels of oil. (Not included in these figures is the energy cost for making the chemicals, nor the distribution to the farmer or his energy cost for application.) Because these new crops would presumably be the result of various inter-specific and inter-generic crosses, they would be represented by a broad genetic base and therefore improved disease resistance. The current "hard agricultural path" promotes a genetic narrowing and increased vulnerability to pests overall.

(3) Perennial culture would potentially reduce our dependency on commercial fertilizer. I assume this because the application of fertilizer to perennial forage crops is, on the average, much less than to annual grain crops. The slow decay of plant materials from perennials releases nutrients at a rate that can more efficiently be assimilated by new growth. This saving would be significant for not only is commercial nitrogen fertilizer energy-intensive in origin and composition, but water tables having high levels of nitrates are known to be toxic to children and farm animals.

A real fertilizer crisis is not far ahead. The feed stock for much of our commercial fertilizer is natural gas, the fossil fuel in shortest supply. In 1976, 22 percent of the interruptible supply of natural gas was devoted to the manufacture of fertilizer.

(4) The development of new, high-yield perennial seed-producing crops could reverse the current decline of our domestic genetic reservoir. Population increase and intensive agriculture have reduced the amount of "waste land" where teosinte, the wild relative of corn, once lived. For wheat and rice, the old low-yielding but faithful varieties of various races and ethnic groups have been driven from the fields. Many of these low performers by modern standards have been the genetic bank which breeders would tap now and then to introduce new germplasm into their crops whose germplasm base had been narrowed by selection.

The cost for maintaining a very wide spectrum of

genetic variation is prohibitive for most seed companies. The National Seed Storage Laboratory at Fort Collins, Colorado, is charged with the expensive and difficult responsibility of keeping genes stored but has, at best, done a poor job of doing so. The most efficient storage is in living organisms.

In summary, success in herbaceous perennial crop development would lead to a reduction in resource depletion for both fossil fuels and germplasm and reduced pollution of our waters, soils and ultimately ourselves. Even if we are not successful in our attempts to develop high-yielding perennial crops, the low-yielding new stocks may serve as a bridge for introducing new germplasm into our high-yielding annuals.

The Environmental Vision

Because sunshine is dispersed rather evenly over the earth; because nature's three dimensional solar collectors called green plants, with an efficiency in the neighborhood of one to two percent are also dispersed; because these collectors are so critical to the rest of life forms, including humans; and because the land for growing these collectors in the US is eroding at the rate of nine tons per acre per year on the average: any who advocate a sunshine future or soft energy path must ultimately adopt a land ethic which embraces an energy ethic.

The soft energy path or sunshine future advocated by Amory Lovins, it would appear, ultimately requires a decentralized society. Sunshine is dispersed. Nature's three dimensional solar collectors are dispersed. A major emphasis of Loven's thesis is the thermodynamic match, i.e. energy source and energy end-use should be matched. Therefore, should not nature's people be dispersed?

The romantic back-to-the-land movement, as minimal as it is thus far, is a faint sign that decentralization might be possible. But what happens when we all get there, after the first generation of back-to-the-land romantics have been buried organically in their gardens? Will their children maintain the backbreaking work most humans have sought to avoid over the centuries? Isn't this one of the components of the human condition? It has yet to sink into our culture that we are still basically gatherers and hunters, and that the era of agriculture is but a thin veneer over an evolutionary past which tolerated a great deal of leisure. The appeal of the countryside is the appeal open space has always had to us gatherer-hunters. The appeal of the city is that it at least faintly suggests a mixture of leisure and stimulation most of us need.

Von Rensselaer Potter has pointed out that we all have a need for an optimum stress level which varies for each of us. On one side of this optimum is boredom, which can come from too long a period

in the fields. At the other end is the problem of information overload which may come from being over-stimulated in the city. The only way I can see the decentralized culture joyfully surviving is if our technology allows us both stimulation and time for leisure, so that we might play out the longings of that gathering-hunting body and brain.

The scientific-technological revolution has surely already provided us with enough recyclable hardware to keep a decentralized society stimulated. But the human-nature split remains. As immodest as it may sound, I think we can at once provide leisure and begin to close the split if agriculture can be provided with high-yield, seed producing perennials.

In Conclusion

The depth of the human-nature split is not highly visible in modern agriculture. The chemotherapy treatments to the land promote a temporary vigor more impressive than our fields have ever known. Though the physician may rejoice with his cancer patient that he is feeling better in response to the treatment, he is also careful to monitor the telltale systems of the body. Similarly, those interested in the long-term health of the land need only stand on the edge of a stream after a rain and watch a plasm boil and turn in the powerful current below and then realize that the vigorous production of our fields is, unfortunately, temporary. Since we initiated the split with nature some 10,000 years ago by embracing enterprise in food production, we have yet to develop an agriculture as sustainable as the nature we destroy.

*This article was originally published in **Not Man Apart**, in the November-December 1978 edition. Reprinted here with permission.

Wes Jackson and his wife, Dana, direct The Land Institute at Salina, Kansas. They call their nonprofit, education and research organization The Land. Its 28 acres are devoted to a search for alternative kinds of agriculture, energy, shelter, and recycling of waste. About eight students, college age or older, work at it. His book **New Roots of Agriculture** is being republished by the University of Nebraska Press this spring.

