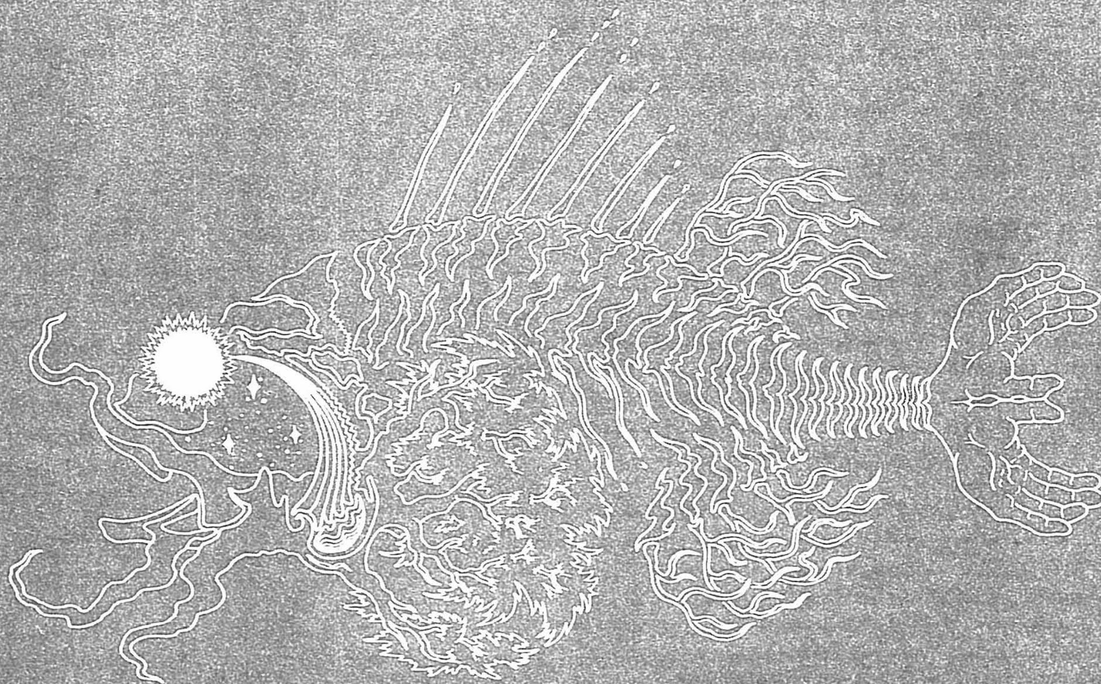


Land and Its Use

Beyond supplying the vegetables and some of the fruit for all of us who work at New Alchemy, the gardens are one of the most beautiful places at the farm. And if that were not more than adequate, our gardens, over the years, have taught us a great deal about the relative merits of various methods and practices of raising food. Beginning quite literally from the ground up, our first task was to create a balanced fertile soil from the sandy terminal moraine that forms Cape Cod. Long before our soil had been tested and pronounced lacking in none of the essential nutrients as it has been recently, we had begun work with intensive vegetable production, biological pest control and the effects of such time-honored but not scientifically corroborated practices as mulching. For four seasons now, Susan Ervin has been engaged in a series of mulching experiments. In 1978, having eliminated as many variables as possible, she arrived at statistically significant and somewhat surprising data on the effects of seaweed mulch.

Although the garden and the bioshelters have been the centers of our agricultural work, Earle Barnhart's most recent project has started a considerable outward expansion. Earle has begun the extensive and longterm undertaking of establishing an arboretum of locally adapted fruit and nut trees, and trees to provide fodder for animals. The eventual goal, as he discusses in his article, is to create a mixed and sustaining, ecologically viable, agricultural landscape. Planting trees is satisfying not only in that it embodies an ecological ethic but because it is a gesture that, unlike so many others, invests in rather than robs the future. In his article "Three Crops," Earle explains some of the theory behind the ecological soundness of tree crops and goes on to describe some very workable designs.

NJT

Photo by R. D. Zweig

Further Experiments on the Effects of Mulches on Crop Yields and Soil Conditions

Susan Ervin

Over the past several summers we have been conducting experiments to test the effects of mulches on crop yields and on soil conditions. Our interest is in biodegradable mulches intended to enrich the soil as well as to control weeds, moderate soil temperatures, improve soil texture, and retain moisture. In one trial in the first phase of experimentation, unmulched lettuces yielded higher than either those mulched with seaweed or with those mulched with azolla, which is a small aquatic fern that grows on the surface of our fish ponds.[1] In a second trial, azolla-mulched sections yielded higher. In the second phase of the experimentation, the effects of seaweed mulch, leaf-mold mulch, and the absence of mulch were observed on tomatoes, sweet peppers, chard, lettuce and beets. Half of each crop received supplemental watering; half did not. Lettuce tended to be more productive without mulch. There was a clear trend toward higher yields for beets, chard, and tomatoes mulched with seaweed, though only chard showed a statistically significant higher yield. The significance of the other yield differences was masked by the fact that variation was due more to site than to treatment. Crops that benefitted from mulch had higher yields with seaweed than with leaf mold. Supplemental watering was not a significant factor in any of these cases.[2]

During the summer of 1978 we continued experimentation, attempting to obtain more conclusive results by limiting the number of variables. Because supplemental watering had not significantly affected yields

[1] Susan Ervin, 1977, "The Effects of Mulching with Seaweed and Azolla on Lettuce Productivity," *The Journal of The New Alchemists*, 4: 58–59.

[2] Ervin, 1979, "Effects of Mulches," *The Journal of The New Alchemists*, 5: 56–61.

the preceding year, we chose not to water any crop after a few initial waterings at the time of seeding or transplanting. The crops tested were tomatoes, beets, and lettuce. The mulch treatments were confined to two, seaweed mulch and no mulch. The lettuces were mulched soon after planting; mulch was applied to the other crops on June 24 and renewed on July 3. It settled to a covering of about 6″.

The lettuce variety used was Salad Bowl; the beets were Early Wonder, and the tomatoes were Rutgers. Planting and harvesting proceeded as follows:

Lettuce Trial I: Seedlings were set out June 7. Whole plants were harvested between July 10 and 18, with an equal number of plants harvested per section on each harvest day.

Lettuce Trial II: Seedlings set out July 21. Harvested between September 9 and 18, in the same manner as in Trial I.

Beets Trial I: Seeded June 1. Harvested August 2 and 3.

Beets Trial II: Seeded August 5. Harvested October 23.

Tomatoes: Seedlings set out June 9. Fruits were harvested when well ripened, beginning on August 8 and ending September 26, when the plants were damaged by frost.

Moisture and temperature data were collected using a Soiltest MC-300 meter. Sensors were placed 5″deep in two mulched sections (one and seven), and two unmulched ones (two and eight). Two sensors were placed in each of these sections to insure accurate data. The final figure recorded was midway between the readings of the two sensors. Variation between the two was slight at all sites. A stick thermometer was used to determine temperatures at a depth of 1″. Readings were taken in the mornings between 6:00 and 7:00 A.M., and in the afternoons between 4:00 and 4:30 P.M.

As expected, mulched plots were cooler on hot days and warmer on cold nights and showed less temperature variation overall. July 11 is a typical example: Morning readings of 69°F (20.6°C) and 70°F (21.1°C), afternoon readings of 71°F (21.7°C) and 72°F (22.2°C) for mulched sections at 5″; morning readings of 68°F (20°C), afternoon readings of 86°F (30°C) and 84°F (28.9°C) for both unmulched sections at 5″; morning readings of 61°F (16.1°C) and 63°F (17.2°C), afternoon readings of 70°F (20.6°C) for the mulched sections at 1″; morning readings of 58°F (144.4°C), afternoon readings of 88°F (31.1°C) and 92°F (33.3°C) for the unmulched sections at 1″. The mulched sections remained moister than unmulched sections throughout the summer, a fact of some significance in an area of quickly drying, sandy soil. Mulched sections also retained moisture longer after rain.

The following tables are excerpts from the data collected between June 26 and September 15. Complete data is available on request.

Moisture at 5″ Depth

	Mulched		Unmulched	
	1	*7*	*2*	*8*
June 26	.55	.52	1.60	1.90
July 10	.25	.22	1.70	2.70
July 24	.30	.60	1.55	1.95
August 7	.18	.28	.90	1.30
August 21	.67	.92	3.80	5.00
September 4	.71	1.20	9.80	25.00
September 11	1.00	1.30	14.00	30.00

Temperatures at 5″ Depth (degrees Fahrenheit)

		Mulched		Unmulched	
		1	*7*	*2*	*8*
June 26	A.M.	67°	68°	64°	64°
	P.M.	68°	69°	79°	76°
July 10	A.M.	68°	69°	68°	68°
	P.M.	71°	72°	82°	79°
July 24	A.M.	72°	73°	73°	72°
	P.M.	72°	75°	87°	81°
August 7	A.M.	70°	72°	72°	71°
	P.M.	71°	73°	80°	76°
August 21	A.M.	69°	70°	66°	67°
	P.M.	70°	71°	74°	72°
September 4	A.M.	64°	64°	58°	59°
	P.M.	65°	66°	72°	72°
September 11	A.M.	62°	61°	59°	59°
	P.M.	62°	61°	68°	68°

Temperatures at 1″ Depth (degrees Fahrenheit)

		Mulched		Unmulched	
		1	*7*	*2*	*8*
June 26	A.M.	58°	58°	58°	58°
	P.M.	68°	67°	77°	78°
July 10	A.M.	63°	63°	63°	63°
	P.M.	71°	72°	85°	86°
July 24	A.M.	66°	66°	64°	63°
	P.M.	71°	71°	87°	86°
August 7	A.M.	66°	66°	65°	65°
	P.M.	67°	71°	77°	74°
August 21	A.M.	62°	62°	60°	60°
	P.M.	67°	71°	77°	80°
September 4	A.M.	54°	54°	51°	51°
	P.M.	69°	69°	75°	74°
September 11	A.M.	54°	53°	52°	52°
	P.M.	63°	63°	70°	70°

Soil was tested to determine the effects of the mulch on soil fertility. The analysis of samples was done by the Cooperative Extension Service of the U.S. Department of Agriculture at Waltham, Massachusetts. Mulch-related variations were evident for nitrate, pH, potash, and soluble salt readings (Table 1).

TABLE 1—*Soil Analysis*

pH		*Test Date*				
	6/21	*7/12*	*7/22*	*8/6*	*8/16*	*8/26*
Section No. 1 (m)	6.6	6.1	6.4	6.3	6.4	6.8
2 (nm)	6.5	6.5	6.7	6.6	6.7	6.8
3 (m)	6.7	6.3	6.4	6.4	6.5	6.6
4 (nm)	6.8	6.6	6.7	6.8	6.7	7.0
5 (m)	6.9	6.2	6.5	6.4	6.7	6.6
6 (nm)	6.8	6.7	6.9	6.8	6.8	7.1
7 (m)	6.7	6.5	6.4	6.6	6.7	6.8
8 (nm)	6.8	6.6	6.8	6.8	6.5	7.1
Nitrate						
Section No. 1 (m)	H	EH	VH	EH	EH	EH
2 (nm)	VH	VH	L	H	M	M
3 (m)	EH	EH	VH	EH	VH	VH
4 (nm)	MH	EH	ML	VH	M	L
5 (m)	M	EH	VH	EH	EH	EH
6 (nm)	MH	EH	MH	EH	L	MH
7 (m)	MH	EH	VH	EH	EH	EH
8 (nm)	H	MH	M	EH	VH	MH
Potash						
Section No. 1 (m)	VH	VH	EH	EH	EH	EH
2 (nm)	L	VH	VH	VH	VH	L
3 (m)	MH	EH	EH	EH	EH	VH
4 (nm)	M	EH	VH	VH	VH	L
5 (m)	VH	EH	EH	EH	EH	VH
6 (nm)	M	VH	VH	VH	M	L
7 (m)	L	EH	EH	EH	EH	EH
8 (nm)	VH	VH	VH	VH	VH	M
Soluble Salts						
Section No. 1 (m)	15	NO READINGS	112	58	150	80
2 (nm)	20		15	20	28	21
3 (m)	23		80	110	180	122
4 (nm)	20		16	17	34	22
5 (m)	17		130	135	106	185
6 (nm)	14		22	17	22	23
7 (m)	11		250	96	222	98
8 (nm)	12		24	14	25	17

m = mulch
nm = no mulch
EH = Extra High
VH = Very High

H = High
MH = Medium High
M = Medium
ML = Medium Low

L = Low
VL = Very Low

It is known that potash penetrates more deeply in a mulched soil because of more uniform moisture distribution.[3] We had thought initially that during mulch decomposition there might be temporary nitrate shortages. This, however, did not prove to be true. Soluble salt levels, though much higher in mulched plots than in unmulched ones, did not reach levels generally considered to be damaging to most plants.

The yields are shown below (Table 2). The total yield from mulched sections in the first beet trial was 78.5% greater than from unmulched sections. The second trial produced yields 225% greater than in unmulched sections. The total yield of mulched tomatoes was 7.3% greater than unmulched ones, although some unmulched sections out-yielded some mulched sections. In the first lettuce trial the unmulched sections yielded 33.9% more than mulched ones, and 20% greater in the second trial though some unmulched sections were less productive than some mulched ones.

Using the t-test of significance between two sample means, the following resulted:

	t-value	*significance*
Beets I	5.48	99+%
Beets II	7.48	99+%
Tomatoes	.22	15+%
Lettuce I	2.20	92+%
Lettuce II	.78	52+%

In both trials, beets mulched with seaweed yielded significantly higher. In the first trial, unmulched lettuces yielded significantly higher. The differences between yields of mulched and unmulched plots for the second lettuce trial and for the tomatoes were not statistically significant.

Lettuce is known to have a low salt tolerance whereas that of beets is known to be high. Thus, the salt levels are most likely a major factor in resulting yields. Another

[3] George L. Slate, 1957, "How I Mulch My Garden," in *Handbook on Mulches* (Brooklyn Botanic Garden, New York).

TABLE 2—*Yields*

	Lettuce I		*Lettuce II*		*Beets I*		*Beets II*		*Tomatoes*	
Mulched Sections	*25 plants per plot*		*20 plants per plot*		*35 plants per plot*		*10 plants per plot*		*5 plants per plot*	
1	2,598 g	91.64 oz.	2,134 g	75.27 oz.	3,945 g	139.16 oz.	1,152 g	40.64 oz.	10,747 g	379.09 oz.
3	4,640 g	163.67 oz.	2,928 g	103.28 oz.	3,903 g	137.67 oz.	1,130 g	39.86 oz.	22,762 g	802.91 oz.
5	4,731 g	166.88 oz.	1,752 g	61.80 oz.	5,125 g	180.78 oz.	920 g	32.45 oz.	37,314 g	1316.21 oz.
7	4,359 g	153.78 oz.	1,044 g	36.83 oz.	4,497 g	158.63 oz.	1,314 g	46.35 oz.	12,884 g	454.47 oz.
Totals	16,328 g	575.95 oz.	7,858 g	277.18 oz.	17,470 g	616.24 oz.	4,516 g	159.30 oz.	83,707 g	2952.68 oz.
Average	163 g	5.76 oz.	98 g	3.46 oz.	125 g	4.40 oz.	113 g	3.98 oz.	4,185 g	147.63 oz.
Unmulched Sections										
2	5,010 g	176.72 oz.	2,604 g	91.85 oz.	1,910 g	67.37 oz.	380 g	13.40 oz.	14,702 g	518.60 oz.
4	6,451 g	227.55 oz.	2,660 g	93.83 oz.	2,426 g	85.57 oz.	410 g	14.46 oz.	25,100 g	885.38 oz.
6	4,745 g	167.38 oz.	1,398 g	49.31 oz.	2,835 g	100.00 oz.	152 g	5.36 oz.	19,667 g	693.73 oz.
8	5,667 g	199.90 oz.	2,780 g	98.06 oz.	2,641 g	93.16 oz.	446 g	15.73 oz.	18,579 g	655.36 oz.
Totals	21,873 g	771.55 oz.	9,442 g	333.06 oz.	9,812 g	346.11 oz.	1,388 g	48.96 oz.	78,048 g	2753.07 oz.
Average	219 g	7.72 oz.	118 g	4.16 oz.	70 g	2.47 oz.	35 g	1.22 oz.	3,902 g	137.65 oz.

observation that may or may not be valid is that in the second lettuce trial section 6 was the lowest yielding unmulched section and had low nitrate levels during part of the time of that trial.

The accumulated data from two years' experiments allow some interesting incidental observations to be made. Tomato yields were much lower this year using the same variety of tomato as used in the previous year. In 1977, the average production of seaweed-mulched plants was 9,132.06 grams; in 1978, 4,185.35 grams. For unmulched plants, the average 1977 yield was 8,054.63 grams; in 1978, 3,902.4 grams. Temperatures were lower during the 1978 season and moisture levels higher. In the next phase of our experimentation, we shall continue our work with seaweed, attempting to isolate its enriching effects on the soil from those that increase salinity. We will also begin to test the effects of mulching with straw, which is a material that is available more widely.

I should like to acknowledge the assistance of Nancy Jack Todd, Rebecca Todd, and Eleanor Labosky in carrying out this work, John Wolfe in the statistical evaluation, and of Al Doolittle in plotting graphs.

Photo by R. D. Zweig

Tree Crops: *Creating the Foundation of a Permanent Agriculture*

Earle Barnhart

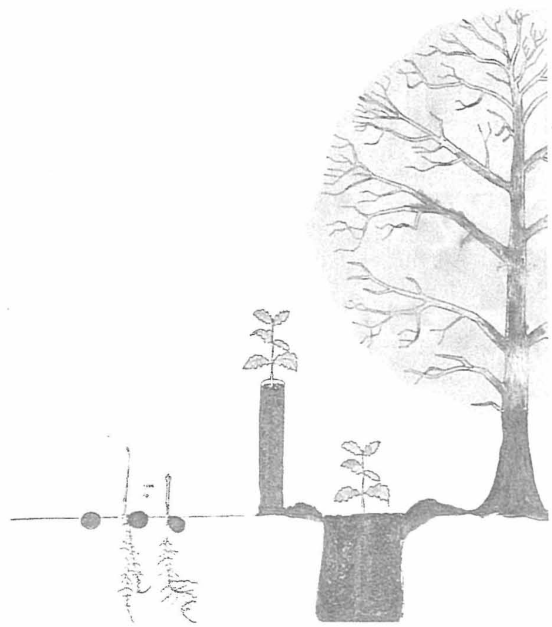
Man's (sic) very existence is being threatened by his abysmal ignorance of what it takes to run a balanced ecosystem.

Eugene P. Odum
Fundamentals of Ecology

This paper is an exploration of the potential value of tree crops in agricultural ecosystems. The ecological dilemma of increasing population, rapid agricultural erosion and increasing energy cost is examined. A partial solution is presented which proposes tree crops as an ecological counter-strategy to these trends. Several designs are presented as examples of how tree crops may be used in rural, suburban and urban biotechnical landscaping. Lastly, promising avenues of tree-crop propagation research are suggested as necessary prerequisites to widespread adoption of improved agricultural trees.

Maintaining food production apace with population growth without irreplaceabley damaging the soil base on which productivity depends is a major dilemma in agriculture. While conventional agriculture can undeniably produce high yields, it cannot pretend to be sustainable in terms of either soil preservation or energy consumption (see References 1, 2, 3, 4 and 46). The following analysis explores current concepts of energy, ecology, and erosion in agricultural ecosystems and delineates the interdependence among land resources, energy resources and living communities. The goal is to indicate that high yields can be compatible with soil preservation and lower energy consumption if successful strategies drawn from natural ones are used as guides.

To feed 6–7 billion people by the year 2000, maintaining present demand use patterns, food production must be greatly increased (1). This increase can come from greater productivity on available lands or by farming more land. Doubling world food production on current land would require from 3 to 10 times the energy and resources of current agriculture (1, 6). Farming additional land implies using land of marginal quality, much of it hilly, which will require expensive maintenance to keep it productive agriculturally. The United States has already lost an estimated one-third of its topsoil and an estimated 10–15% of its former potential productivity, and the erosion rate is at a record high (4, 46). About $15 billion have been spent on conservation measures on the U.S. since the mid-1930's, yet each year $6.8 to $7.75 billion worth of nitrogen, phosphorus and potassium are still being lost, and $13 billion is spent repairing flood and sediment



damage to crops and pastures (1, 4). Presently 64% of the U.S. cropland needs treatment for soil erosion which is occurring at a rate many times higher than that considered compatible with permanent agriculture (1,3).

EROSION CONTROL OPTIONS

Any country with a serious desire to preserve its soil has several options. One path is technological, using mechanical force and humanly constructed structures to move soil and to restrain it from flowing downhill with water. Two examples of this approach are contour plowing (annually) or terracing (permanently). Contour plowing costs 5–7% more in time and in fuel but can reduce erosion up to 93% (1). Terraces are a noteworthy strategy since many of the longest-farmed regions on earth utilized them (26). Either method must deal with about 3-billion tons of sediment per year (1). The terrace solution is a relatively simple way to invest remaining fossil fuels in permanent fertility. It would be interesting to see an analysis of the cost efficiency of subsidizing permanent terraces with the money and energy now used for flood control and sediment damage repair.

A second option is erosion control by biological forces. The biological solution is attractive because of the many beneficial by-products and because of its reliance on solar energy instead of fossil fuel to pay for the transition. The concept of using perennial plants, particularly trees, to produce human food and animal feeds while they protect the soil has been proposed by historians of agriculture like F. H. King (26), geographers of soil erosion like J. R. Smith (11), and economists to whom people matter like E. F. Schumacher (27). A landscape of perennials is the method nature has evolved for soil protection for most of the biogeographical regions of the earth that are now farmed (28, 29). Perennial plants tend to accumulate gradually such structures as roots, stems, twigs, detritus and topsoil humus. These parts of the plant normally shelter the soil from the direct force of the weather.

E. P. Odum, in *Fundamentals of Ecology*, estimates that if a natural ecosystem is to maintain its soil and to sustain a given level of productivity, more than half of its annual plant growth must be retained as structures that resist environmental stresses. If more than this fraction of annual plant growth is allowed to remain, the ecosystem gradually builds up biomass, becoming more productive and more resistant to forces of wind and water. On the other hand, if more than half of the annual plant growth is consistently removed (as in over-grazing or over-logging), an ecosystem gradually exhausts its structure and becomes less able to protect its soil, resulting in losses to erosion, and leaching, and in less productive capacity.

Only very small amounts of nutrients are lost from mature communities as compared to immature or disturbed ones, with losses decreasing along a scale from row crops to small grains to grasses to perennial forages to forests (3). Of particular interest are the management practices employed to bring erosion rates down to acceptable levels. Most of these involve various strategies to allow a more mature plant community to grow up intermittently and to produce soil-protecting "residues." Such residues carry over into the following few years, decomposing slowly until they are lost as protection. We can think of familiar practices including strip-cropping, crop rotation, manure application, and newer "no-till" cultivation as ways of averaging-in materials from perennial crops and organic matter similar to that accumulated by unharvested plants. All maintain organic structure near the soil surface that resists abrasion from rain, wind and water.

> 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 favor the monoculture of annuals. Nature has, for the most part, favored the polyculture of perennials.
>
> Wes Jackson
> *The Land Report*

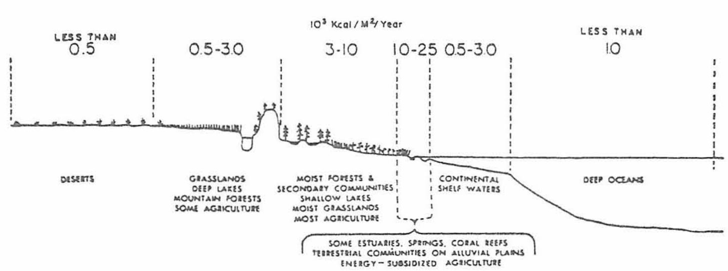
The trend of decreasing erosion with increasing presence of perennials suggests the ultimate strategy of using trees as major agricultural crops. To quote J. Sholto Douglas: "The tree is the tool with the greatest potential for feeding men (sic) and animals, for restoring water-systems, for controlling floods and drought, for creating more benevolent micro-climates and more comfortable and stimulating living conditions for humanity" (47). Perhaps the most striking advantage of designing with trees is that as biological elements they are self-repairing and self-perpetuating and their natural functions are powered by solar energy. The concept begins to appear more attractive as the various benefits are tallied next to the cost of alternatives (or the consequences of nonaction). To replace these benefits mechanically we must build erosion control works, enlarge reservoirs, upgrade air-pollution control works, improve water purification plants, increase air conditioning and provide new recreation facilities (15).

PRODUCTIVITY

The cumulative advantages of tree crops assume they produce a reasonable yield of food. J. Russell Smith in *Tree Crops* contended that trees could match row crops in both protein and carbohydrates in yield per acre. These are claims worthy of investigation, for if true, tree crops would present an attractive alternative to conventional agriculture in many regions. In compar-

TABLE 1

WORLD DISTRIBUTION OF PRIMARY PRODUCTION



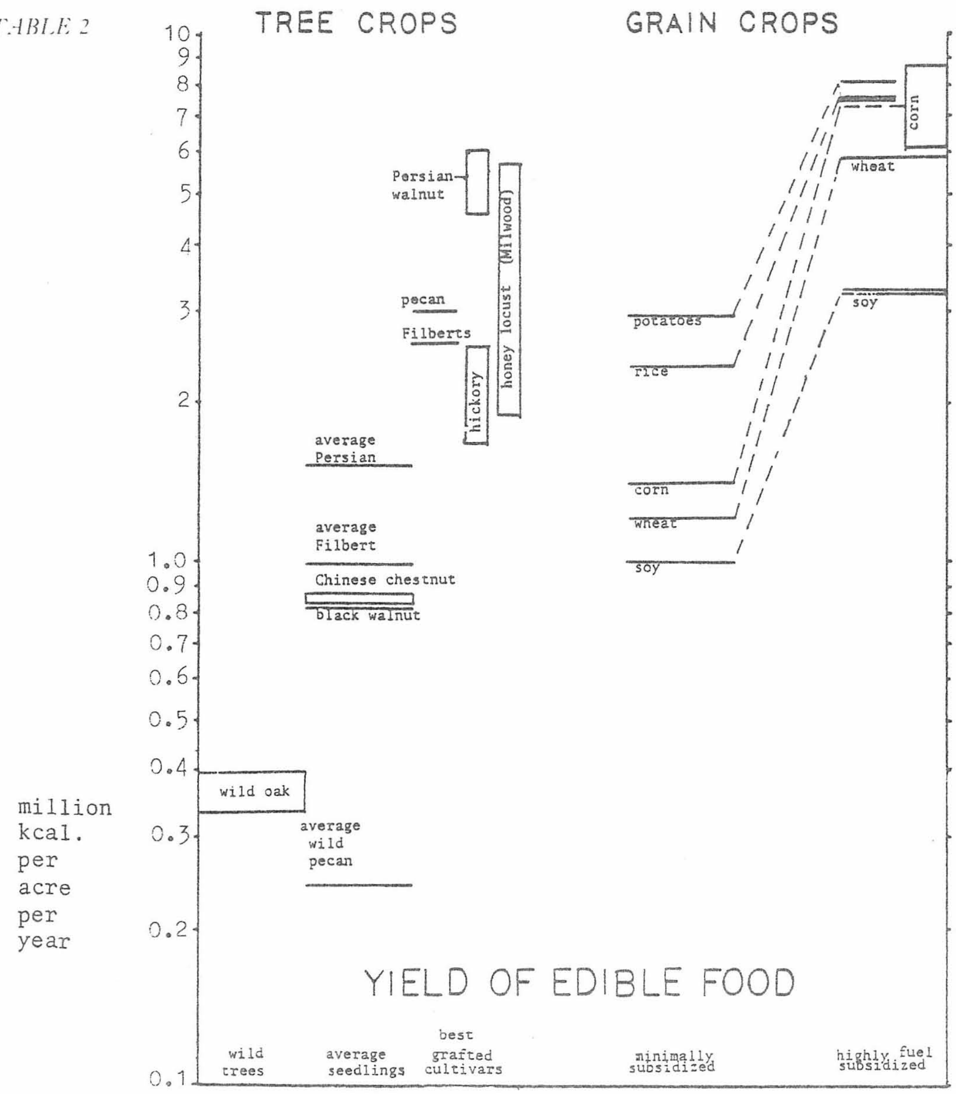
The world distribution of primary production in terms of annual gross production (in thousands of kilocalories per square meter) of major ecosystem types. Only a relatively small part of the biosphere is naturally fertile. (After E. P. Odum, 1963.)

ing ecosystems, ecologists place temperate forests and most agricultural land in the same range of primary productivity (Table 1). On a world average of crop production, growth in fertilized crop communities is generally lower than that in woodland; deciduous forests often approach twice the production of dry matter as grains in the same climate (7). Of course, total plant material is not as important as the edible part of the plant or crop. Wild forest trees yield only a small fraction of their biomass as edible food; domesticated crop plants can be nearly half edible grain. But recall that much of the tree's biomass which is nonedible comprises the structure that performs essential environmental services.

Domestication is a dual selection/protection relationship in which the farmer uses his skill and energy to protect a strain of plant that yields more food-to-fiber than the average of its kind. Artificial selection of crop plants does not normally increase the total production of the plant so much as it redistributes its productivity so that more goes into food and less into stems, leaves and roots. For example, in the last 50 years wheat has been bred to yield 66% grain-to-straw from the 51% grain-to-straw of earlier strains. This is not, however, the proverbial free lunch, since the energy rechannelled into food production is bred out of some other vital function of the plant. The improved strain will only perform well if the farmer is prepared to carry out the lost function. His work is called an energy subsidy to the crop, freeing it to concentrate its energy in food. Some common energy subsidies to conventional crops are pest protection, weed removal, nutrient enrichment and constant, adequate water.

If one compares energy subsidy to improved yield, early gains come cheaply. Food per acre from primitive

TABLE 2



farming using human/animal/fire energy can yield 100 times that of gathered wild food. Eventually, diminishing returns occur. Conventional agriculture in the United States has exhibited such a trend since 1945 (2). At high levels of energy subsidy, doubling of yields can require 3 to 10 times more energy. Evidently some ecosystem work is easier to subsidize than others. Often what appears to be a good management choice, such as monocropping to simplify cultivation, has high hidden costs of pest control and nutrient loss which must be paid eventually. It is an important challenge to discover which tasks are best performed by nature and which are best met with fossil fuels.

Table 2 is a yield comparison of edible carbohydrates from grain crops and tree crops. Two patterns that emerge are:

1. grain crops with high fossil fuel subsidy show higher yields than non-fuel subsidized crops, and
2. yields from improved tree crop cultivars are higher than wild or average seedling trees.

The best tree crop yields are seen to be approaching the level of subsidized high-protein grains such as soybeans and wheat. I believe that any difference is largely due to rapid genetic changes in annuals that allow a plant breeder to take advantage of new energy-rich technologies. Most tree species, particularly those native to North America, have received less intensive breeding research than have annuals. Preliminary steps have been taken, primarily through the efforts of dedicated amateurs: outstanding individual trees of most native American fruit, nut and forage types have been identified for qualities including high yields, annual bearing, cold hardiness and fruit quality (48, 49). In the process a few species such as pecan have showed rapid improvement through selection and are approaching yields of barley and soybeans. Table 3 shows the progress that has been made in identifying perennial crops that reach commercial production rapidly. It is both surprising and encouraging that the average time-to-commercialization is generally under 10 years.

ENVIRONMENTAL SERVICES

Remember that a tree invests some of its production as storage in branches, roots, twigs, and leaves. These are the parts that:

1. reduce forces of wind and rain;
2. capture and control rainfall;
3. filter the air of dust, ash, smoke, pollen, carbon dioxide, and aerosals;
4. reduce airborne sound with great efficiency;
5. provide generous shade at exactly the appropriate season to homes and urban areas.

In a timber tree (Table 4) the woody framework that performs these services is most of the tree. In domestication some of this wood must be given up in return for

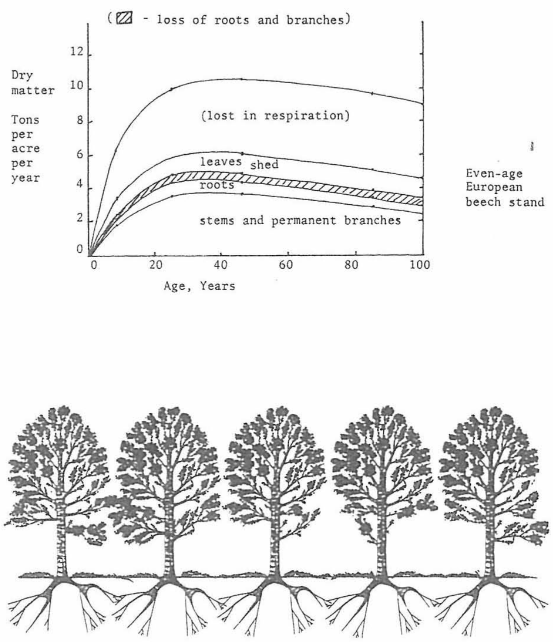
TABLE 3—Fruiting Age of Tree Crops

Perennial Tree Crop	*Years to bearing: grafted cultivars*	*Years to commercial production*	*Years to bearing: selected seedlings*	*Years to bearing: wild stock*
Commercial				
Almonds	4	6–7		
Apples	3–4	8–10		
Apricots		3–4		
Avocados		5–6		
Blueberries				
Chinese Chestnuts	2	10–12	5–8	
Cherries	4–6	10		
English Walnut		5–6		
Filberts		7		
Macadamia sp.			3–7	
Peaches	3			
Pears				
Pecans	3–4	7–10		
Non-commercial				
Black Walnut	6			12
Heartnut	2			
Hickory	3–4		10–15	40
Honey Locust		5		
Mulberry			5	
Oak	6–9			20–35

From Jaynes (1969); Reed and Davidson (1958); USDA Agricultural Handbook 450; the Fruit & Vegetable Association.

TABLE 4

PRODUCTION AND USE OF DRY MATTER



more food, yet even in the extreme case of dwarf apple there still is a significant physical structure that is of benefit to the human environment.

Food trees can serve multiple services in landscapes. Rather than just listing some of them, examples are presented in the following scenarios of tree crops used in rural, suburban, and urban settings.

DESIGN PRINCIPLES FOR TREE CROPS

1. Trees often serve multiple functions:
   soil enrichment
   food production
   soil preservation
   water control
   air purification
   creation of microclimates suitable for other plants, animals, and people.
2. In multi-story agriculture, lacy low-shade sun-tolerant upper-story trees form the upper canopy. Shade tolerant trees form the lower canopy. Pasture grasses and legumes form the ground cover beneath the trees. Meadows and field crops are rotated in open areas between groups of trees.
3. Nitrogen-fixing trees and shrubs are distributed through the landscape and contribute nitrogen to the ecosystem through leaf-fall, grazing or periodic cropping.
4. Orchards of domestic trees have the same general microclimatological effects as sparse natural forests (9).
5. More open, less dense stands of trees give the best yield per tree. With increased age, yield from a single tree becomes greater, but yield per acre tends to be fixed if the canopy is closed (10).
6. Pasture can thrive under tree canopies if they are not extremely dense and if nutrients are not limiting.

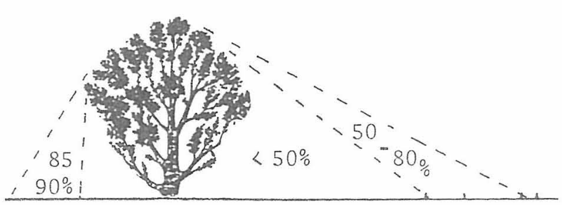
RURAL AGRICULTURAL FORESTRY

The only way man (sic) can have both a productive and a stable environment is to insure that a good mixture of early and mature successional stages are maintained, with interchanges of energy and materials.

Eugene P. Odum
Fundamentals of Ecology

The average American uses about 1 ton of grain per year, 93% utilized indirectly as feed for cattle, hogs and chickens, which supply our main protein sources of meat, milk and eggs (3). As energy costs rise, conventional meat production practices, which require considerable transportation of both animals and feed,

Figure 3. *Cross section of amount of shade cast by an established tree.*



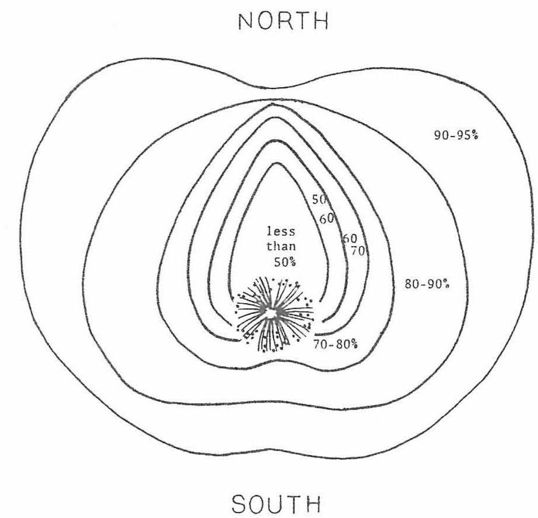


Figure 1. *Shade pattern produced around a standing tree, in percent of full sunlight. This pattern is for the spring season in central Europe* (after R. Geiger, *Climate Near the Ground*).

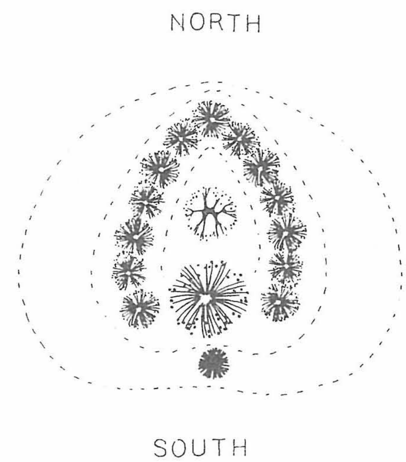
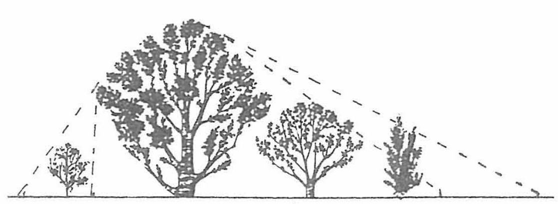


Figure 2. *Plantings around an established tree, matching shade zones with shade-tolerant species. Young tree on south side receives almost full sun and wind protection.*

Figure 4. *Cross section of three rows, planted to optimize shade available and shade requirements of young species planted as original pioneer species grows.*



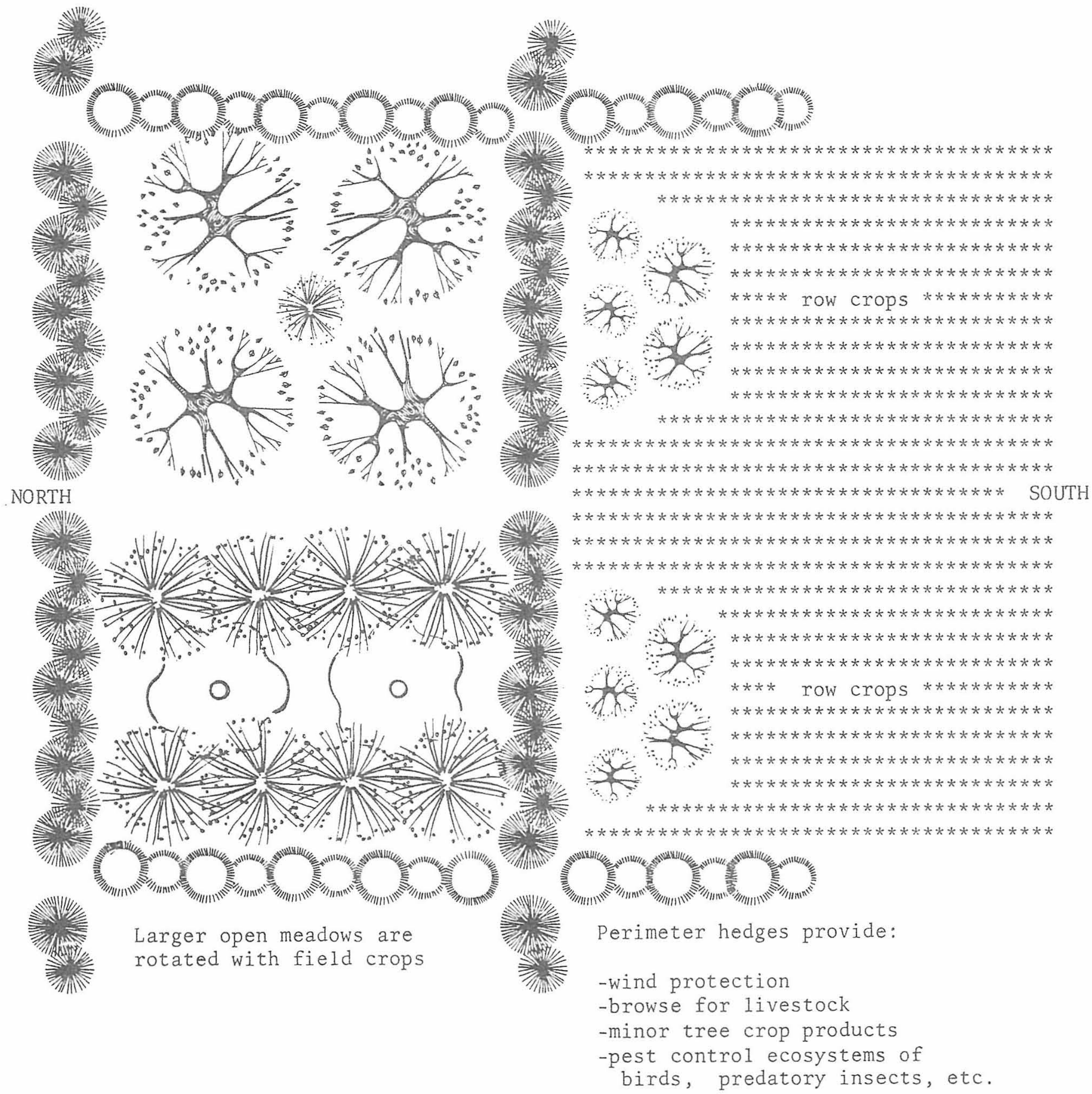
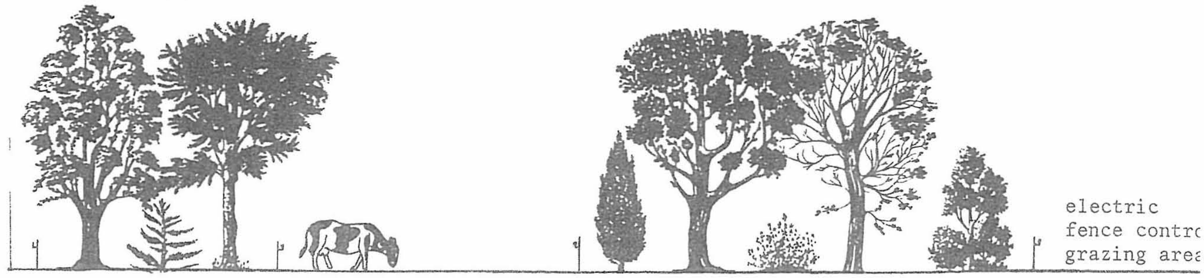


Figure 5. *Rural agricultural forestry.*

Figure 6. *Multi-story mixed tree crop agriculture, with livestock in understory pasture.*



will yield to growing feed and meat animals nearer to each other and to the consumer. The ultimate integration is to raise meat animals fed on grain and tree feeds produced in a matrix of fields and pastures protected by perimeter plantings of tree crops (see Figure 6). Large fields benefit from being sheltered; the approximately 5% area used for windbreaks is well compensated by higher productivity from the remainder. Nondomestic herbivores (wild game animals) are not to be shunned; highest sustained animal production from a given piece of land will most often result from a mixture of wild and domestic herbivores (7). Tree products such as acorns and honey locust pods can match corn and oats pound for pound as nutritious stored winter feed supplements for livestock.

URBAN AND SUBURBAN LAND

Approximately 11.7% of arable U.S. farmland is in municipal areas. This is comprised of about 40 million acres that have been converted to urban use, much of it the flattest, most fertile land available. Further, the rate of conversion is increasing (1). Every effort should be made to encourage productive use of this space for food production and increased environmental quality.

INSULATION OF BUILDING WITH PLANTED WINDBREAKS

Windbreaks of living plants have been well documented for their beneficial effect of reducing heat loss from buildings (8,9,17). The effect is due to reduced infiltration through cracks, reduced exterior convection loss, and in some cases reduced radiant heat loss. The net result is that a house with good wind protection on three sides (north/west/east) can reduce fuel use up to 30% in comparison to a similar house exposed to full wind. Windbreaks perform as insulation, just as other more familiar methods such as double glazing, materials in wall cavities and weatherstripping do. Like these other methods, establishing a windbreak has a capital investment cost, a maintenance cost, an expected working lifetime and a payback period that can be evaluated economically.

Unlike these other methods, windbreaks are biological and appreciate in value rather than depreciate. They improve their performance automatically, using available sunlight rather than an initial input of fuel energy of manufacture. It is thus a unique insulation technique which requires a relatively small investment in order ultimately to obtain large benefits.

The benefits of growing external insulation will be particularly useful to older homes which often have high infiltration rates and walls too thin for adequate amounts of wall insulation: both of these difficulties are amenable to the effects of a good windbreak. The

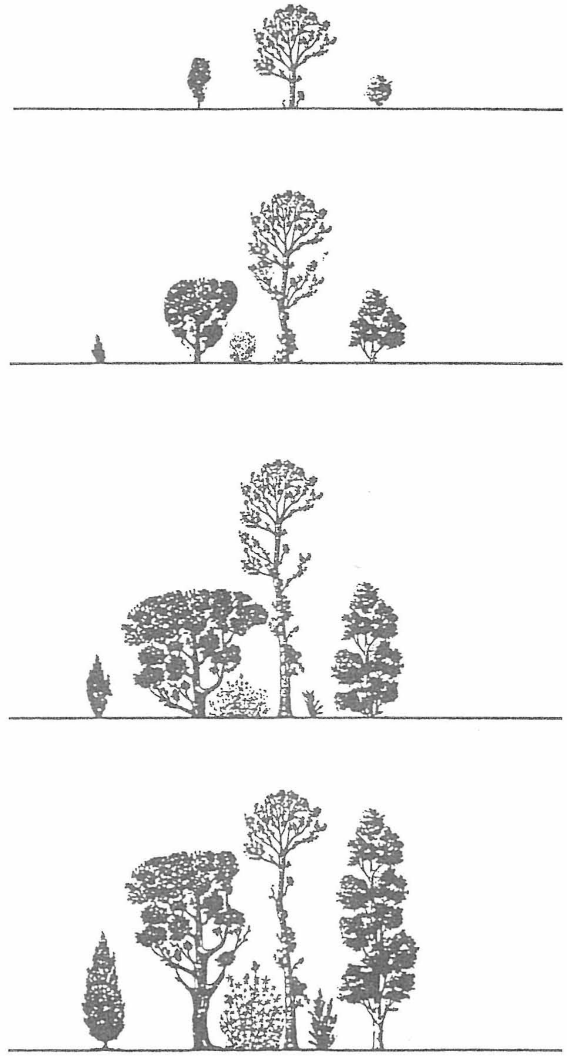


Figure 7. *Windbreak succession/diversification. As early sun-tolerant pioneer trees grow, resulting shade and wind protection provides microclimates for less hardy plants.*

strategy of growing insulation is an example of applying biological solutions to what is normally conceived as a technological problem. The concept involved is that biological systems (in this case, plants) maintain and perpetuate themselves using solar energy, while technological systems usually require energy of manufacture, maintenance, repair and disposal in the form of fossil fuels under the attention of people. In addition, while protecting from wind the plants can:

—produce food,
—preserve soil,
—control and purify water,
—filter air of dust, smoke, odors, and
—provide comfortable and pleasant living conditions.

Each of these services has values that become apparent when a community must construct substitutes.

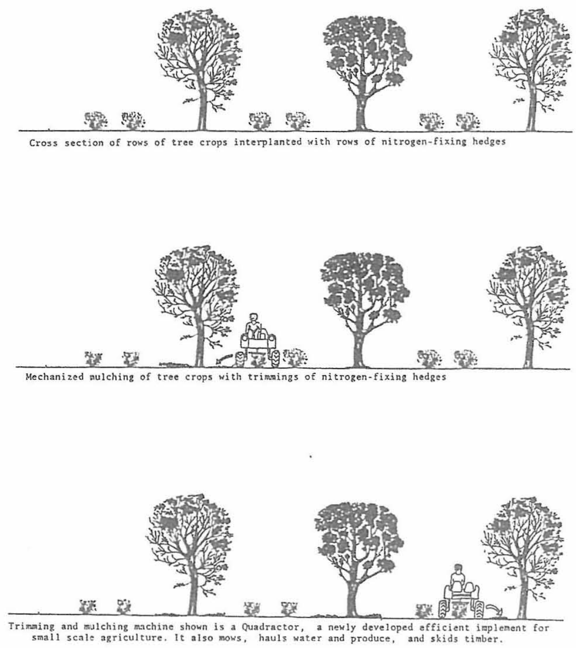


Figure 8. *Nitrogen-fixing hedges for sustained fertility.*

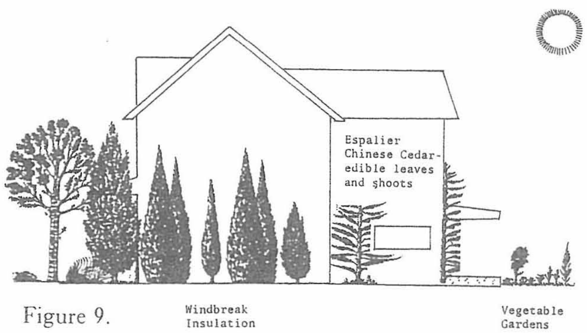


Figure 9.

TREE CROPS FOR CONTINUOUS POULTRY FEED

In many respects poultry are ideal for homestead protein production. They recycle edible household and garden wastes, produce a high-protein food daily (eggs), meat occasionally, and require relatively little space and maintenance. They do need feed supplements to grass and garbage. Commonly this feed is commercial cracked corn or laying mash, thereby making the economics little different to buying eggs (apart from quality of egg). An alternative to purchased feeds is a combination of tree crops and perennial food plants. Suggested plants are:

Mulberry: for summer feed; drops mulberry fruit in great quantity for several months; a traditional animal feed in China.

Honey Locust: for fall feed; produces highly nutritious pods, which drop throughout late fall and early winter.

Burr Oak

Sawtooth Oak: for winter feed; acorns are storable and have feed value similar to corn, and can be ground like corn.

Comfrey: for spring feed; a high protein perennial herb devoured by chickens if given a chance. It leafs early in spring, and if grown in rows under semicylindrical wire protectors, the chickens have access to the daily growing tips without destroying the plant.

URBAN LANDSCAPES

As energy supplies dwindle, urban populations will undergo major changes that will involve transportation, work places and the relative value of food. One option for city dwellers is to convert space now committed to transportation over gradually to agriculture. By encouraging associations of street residents to transform segments of street into street gardens with pedestrian/bike corridors, a city can slowly foster local food production and mass transit. The following description and illustrations suggest details of such a transition.

1970's Normal Urban Street

1. Surfaces of sidewalks, streets and buildings result in glare, great temperature rises in summer and great run-off of rainfall.
2. Lawns and shrubs are primarily ornamental.

Transition to Greater Use of Street Space

1. Block-long segments of North–South streets are zoned for pedestrian, bicycle and moped traffic, with assurance of mass transit and car parking at the ends.
2. Street gardens are constructed over existing pavement, retaining street drainage and sewer system.
3. Tree crops, gardens and insulative windbreaks are established.

Mature Urban Agriculture

1. Household vegetable gardens, solar aquaculture and tree crops provide local food supplies.
2. Normal city water supply provides households, which then recycle graywater from washing and showers to trees and gardens.
3. Increased plant cover moderates temperatures, purifies air and absorbs rainfall. Plants also greatly reduce glare and noise.
4. Some of the street garden structures are greenhouses using waste heat from local light industries to supply winter food and garden seedlings to the neighborhood.

ENVIRONMENTAL QUALITY AND URBAN AGRICULTURE

On hot sunny days, temperatures in urban areas normally rise quickly because of high reflection and radiation from sidewalks, streets and building. The result is discomfort and extensive use of air-conditioning. In contrast, when sunlight strikes a plant surface, much of it is absorbed to evaporate water. Temperatures over grassy surfaces on a sunny day are 10–14°F. cooler than on exposed soil or street surface for this reason (8).

As water makes up 80–90% of a plant's biomass, the heat capacity of the water absorbs radiation and releases it later slowly. Both processes combine to moderate fluctuations in temperature and humidity, making conditions more comfortable to life. Trees provide shade for the great benefit of people and solar buildings at exactly the appropriate seasons. Deciduous trees even adjust to cold extended springs by leafing out later, and long warm falls by dropping leaves later.

Atmospheric Contaminants

Streets with trees have been shown to have about one third the amount of airborne dust of streets without trees. Dust, soot, smoke, odors, and other particulate matter are similarly removed from the air. Gases such as CO_2 are actively taken up. Lead from auto exhaust tends to accumulate on the soil, often in dangerous concentrations. Preliminary tests in Boston of tree fruit grown in soil with 3,000 parts per million of lead showed no lead in the fruits.

Noise as an atmospheric contaminant is greatly reduced by tree stems and leaves; trees are often planned by highway designers to block freeway traffic sounds from residential neighborhoods. Noise reduction effectiveness has become quite well quantified as a result.

These various environmental effects are quite valuable:

> These natural functions are powered by solar energy, and, to the degree that they are lost, they must be replaced by extensive and continuing investments of fossil fuel energy and other natural resources. If the quality of life is to be maintained, we must build erosion control works, enlarge reservoirs, upgrade air pollution control technology, install flood control works, improve water purification plants, increase air conditioning and provide new recreation facilities.*

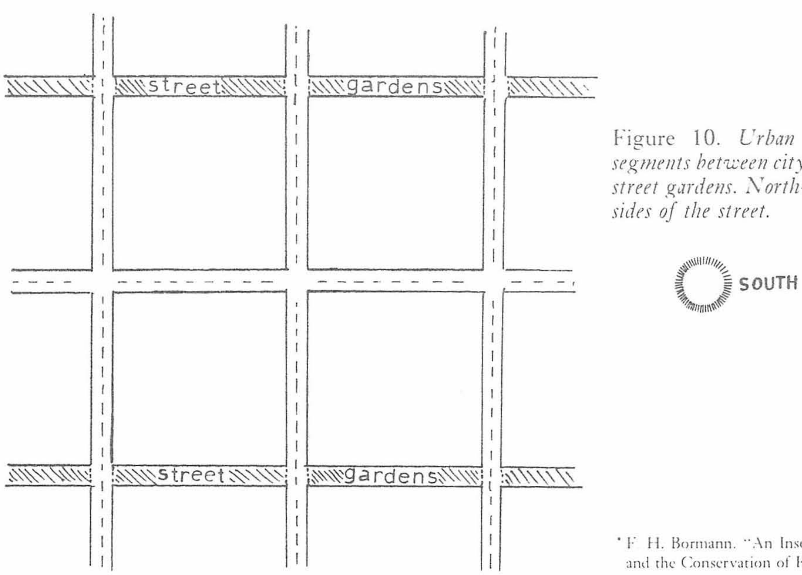


Figure 10. *Urban space re-allocation. North-south street segments between city blocks are gradually changed from roads to street gardens. North-south avenues receive sun equally on both sides of the street.*

* F. H. Bormann, "An Inseparable Linkage: Conservation of Natural Ecosystems and the Conservation of Fossil Energy," *BioScience*, 29, No. 12: 754–60.

Figure 11.

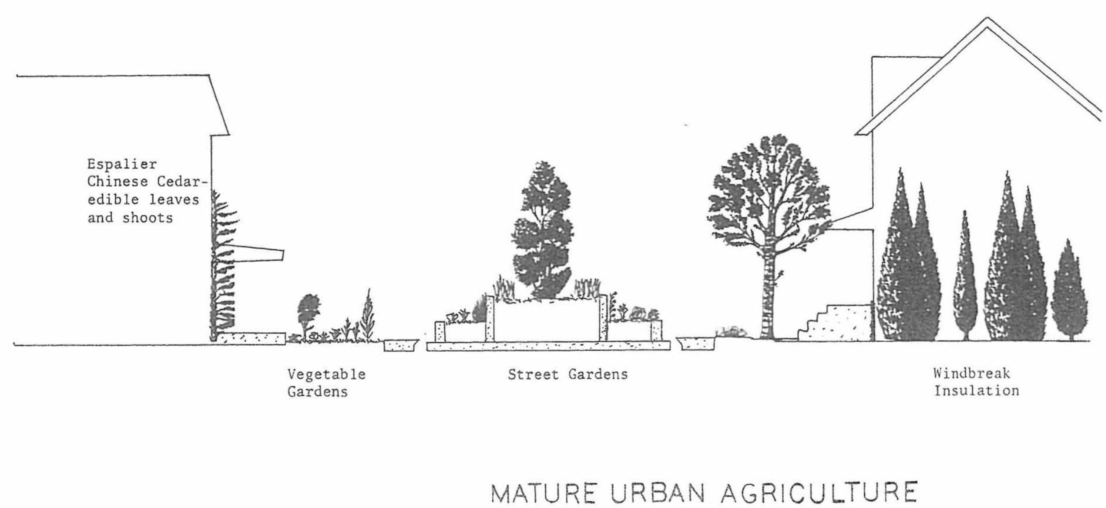
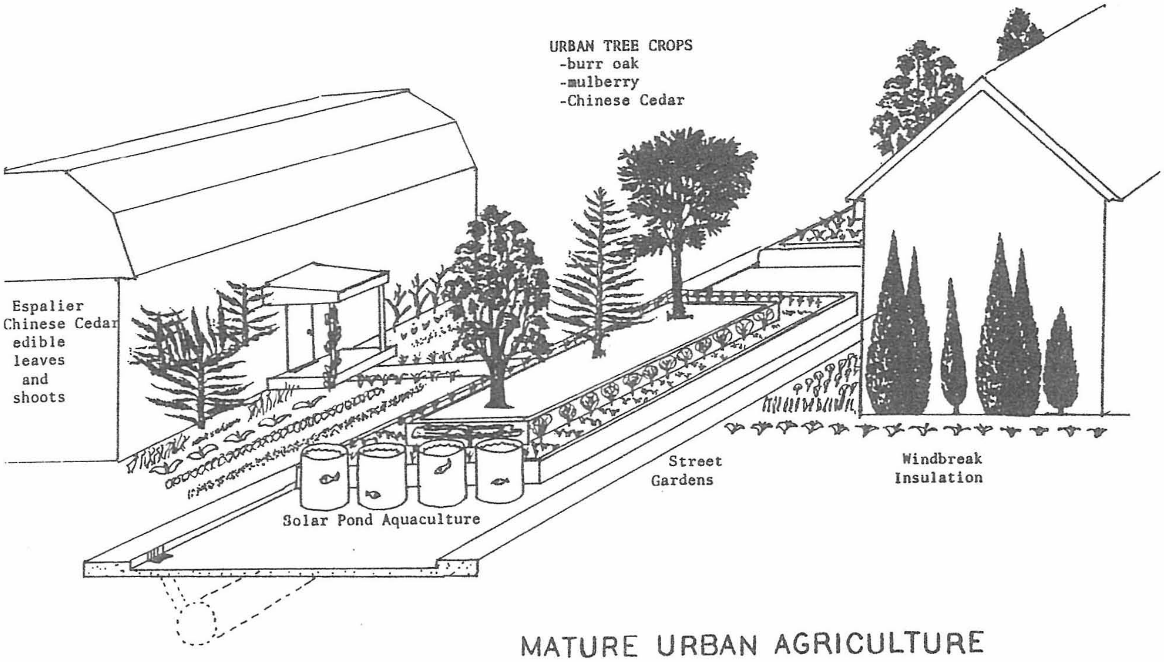


Figure 12.



MATURE URBAN AGRICULTURE

PROPAGATION OF TREE CROPS

The selection and propagation of trees for agricultural purposes can produce wondrous crops from relatively insignificant ancestor plants. Crab-apple ancestors were selected over time to create today's apple. More recently in the United States the southern pecan has been transformed from a wild hardshelled small nut to the paper-thin-shelled nuts of modern commerce. Each native fruit, nut and forage tree species has much genetic variability in such qualities as size and taste of fruit, age at first bearing, annual consistency of yield and ease of propagation. By finding an individual wild tree with one or more of these traits and propagating it into many identical trees, one can create orchards of high productivity. These can be later cross-pollinated with other outstanding cultivars and can result in a next generation of multiple good traits.

There is a striking difference in the ease of vegetative propagation between long-domesticated tree crops such as apple, mulberry, fig and grape and wild trees such as walnuts, hickories, oaks and paw-paws. Over centuries of cultivation and migration the trees in the first group which were most easily and successfully propagated were the ones to spread to new lands, becoming easier and easier to propagate in the process. Forest trees, on the other hand, are in nature selected by a multitude of forces for many qualities, and consequently they show a wide variability in their capacity to root or graft successfully.

For agricultural forestry research we would like to use many of the native species, in addition to proven foreign species such as Persian walnuts, Chinese chestnuts and Oriental persimmons, adapted to American soils and climates. These species are relatively difficult to propagate, but the following propagation techniques show promise of more rapid and successful results than those currently practiced.

OBTAINING SUPERIOR CULTIVARS

Over the past several centuries of land use in the United States, the clearing of forests for agricultural use has considerably reduced the genetic scope of native tree crops. Some have become endangered species (53). Yet because of their recognized utility, they have often been spared by the farmer when clearing land to provide food for himself or his livestock (19). Thus good trees have been preserved in fencerows, pastures, and farm woodlots. Over the subsequent years many outstanding cultivars have been named by members of the Northern Nut Growers Association and the North American Fruit Explorers (48, 49), whose members are mostly amateur plant appreciators who have discovered much of what is known about the growth habits and propagation methods of native food plants.

Many of the best cultivars known of noncommercial species are found only in a few private collections of members of these organizations and are propagated irregularly if at all. A few of the most popular can be

Photo by R. D. Zweig

purchased commercially, and many can be custom-grafted with advanced notice, but to our knowledge no large arboretum or nursery of native food plants has been established. For valid comparison of varieties, we propose collecting many of the named varieties for propagation and field experimentation. Existing collections by past researchers offer the best access to plant material. Of particular interest is the remaining tree collection of the late J. Russell Smith, a noted pioneer in the concept of tree crops. In the first half of this century, Smith collected superior food tree cultivars from across the United States and established them for observation at his nursery near Round Hill, Virginia. A few of the species obtained by Smith during this period, such as the Chinese chestnut and various strains of the Oriental persimmon, were imported and have since become widespread and valuable commercially. World War II stopped all work at the site and the serious research ended. The site has since become overgrown and unused.

On several occasions, subcollections of Smith's best trees were transferred to other sites for farm-scale testing. Most notable of these are the direction of the T.V.A. in Tennessee and a site in Pennsylvania under the direction of John Hershey. In each case the man in charge fell ill and the collections were virtually abandoned although portions of the tree stock are still intact. These three sites are of ardent interest in resuming the tree research of these men. It is likely that many of the superior trees on each place have produced chance hybrids that could be superior to the parents. These are the only places where tree crops of many types are growing in a forest-like condition so that a study of the relative ability of each variety to exist in a mature canopy situation would be possible.

J. Russell Smith's family, the present T.V.A. staff, and Mrs. Hershey have all assisted and encouraged efforts at exploring the possibility of re-evaluating the remaining tree resources. If research support is found, we propose to:

1. identify remaining tree varieties,
2. observe chance hybrids in the vicinities for superior quality,
3. collect and distribute valuable cultivar scions to other researchers and commercial nurseries,
4. clear underbrush and provide permanent labels for known varieties, and
5. write evaluations and recommendations for future development.

It seems appropriate that a serious study of the tree crops concept should pick up where its foremost proponents left off.

NURSE-SEED GRAFTING

An outstanding nut-tree cultivar is normally propagated by grafting one of its branches onto a young nut-tree seedling of the same or of a closely related species. This operation requires considerable skill, time and seasonal accuracy. The final expense is high, which is the major constraint on large-scale availability of many important nut trees.

An alternative, relatively new technique called "nurse-seed grafting" (first described in 1964) offers several potential advantages over normal outdoor spring grafting:

1. The rootstock is sprouted nut seed; normally two years are required to grow a large rootstock for grafting.
2. Timing and weather are not critical; the grafting can be carried out at an indoor table or greenhouse bench over several months.
3. The technique is relatively simple, requiring less skill than conventional nut-tree grafting.
4. Initial root-scion compatibility can be determined within 4–5 weeks without long and expensive nursery growth of rootstock.

The basic procedure is summarized in Figure 14. Most research to date has been on Chinese chestnuts, avocadoes and camellias. Limited trials have also included oaks, pecans, walnuts and some of the drupe fruits such as peach or plum. Success has varied considerably, ranging from 88.9% with certain chestnut stock-scion combinations to little success with mature oak scions or cross-species grafts. A very limited number of species and cultivars have yet been tested. This technique offers an efficient method to test quickly and to mass propagate many unavailable cultivars.

A germinating nut is cut to allow a thin-wedged dormant scion to be inserted at the point of root/shoot growth. A modified method is to insert the scion into the split hypocotyl. The graft is then placed in a warm medium for healing and rooting. It is later moved to a nursery of the field.

PLASTIC TUBE CULTURE OF TAP-ROOTED TREES

Many tree species which are highly valuable for production of food or forage normally grow a long taproot as seedlings. Walnuts, hickories, many oaks, pawpaws, pecans and horse chestnuts are all examples of food trees that tend to be avoided by commercial nurseries because of the difficulty of digging and successfully transplanting them. A taproot without room

REFERENCE FOR FIGURE 14

Beck, A. R. 1970. "Nurse-Nut Grafting," Northern Nut Growers Annual Report, 61st Year, pp. 84–90.

Beck, A. R. 1974. "Nurse-Seed Propagation Techniques," Unpublished Master's Thesis, Ames Iowa Library, Iowa State University. 67 pp.

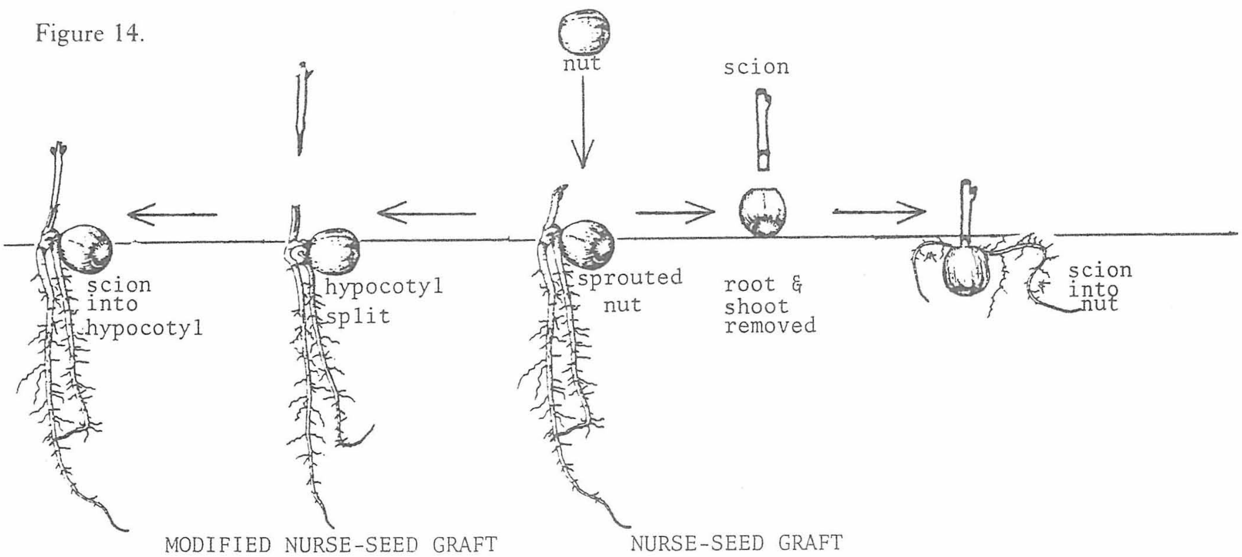
Googans, J. F., and Moore, J.C. 1967. "A New Method of Grafting the Large-Seeded Oak," Journal of Forestry, *65*: 656.

Hartman, H. T., and Kester, D. E. 1968. *Plant Propagation: Principles and Practices.* 2d ed. Prentice-Hall. 424 pp.

Jaynes, R. A., and Messner, G. A. 1967. "Four Years of Nut Grafting Chestnut," Proc. Inter. Plant Prop. Soc., *17*: 305–11.

Park, Kyo S. 1968. "Studies on Juvenile Tissue Grafting of Some Special-Use Trees," Korean Journ. Botany, *11*, No. 3: 88–97.

Figure 14.



to develop results in a stunted tree; a taproot damaged in early development seriously reduces the viability of a young tree. Often tap-rooted trees stored and shipped barerooted fail to survive (19).

A promising solution to propagation and shipping of such trees has been developed for pecans. The technique uses inexpensive polyethylene tubing as deep containers for seedlings, which allows normal taproot development. The seedling can be budded or grafted while growing in the tube. When needed, the seedling is carried in the tube to its final field location, where the tube is removed and the rooted seedling is slipped into its hole. Transplanting shock is minimal and the season during which planting is possible is greatly increased over conventional bare-rooted dormant stock.

The use of this method is ideally suited to small-scale nurseries, eliminating the need for digging machines or expensive containers normally used for the same purpose (barrels or lath tubes).

REFERENCES FOR FIGURE 15

Hinrichs, H. A., and Smith, M.W. 1975. "Greenhouse Production of Pecan Trees in Plastic Tubes." Northern Nut Growers Association Annual Report, *66*: 37–40.

Hinrichs, H. A. 1976. "The Effect of Supplemental Light on Growth of Seedling Pecan Trees Grown in Plastic Tubes," Northern Nut Growers Association Annual Report, *67*: 90–92.

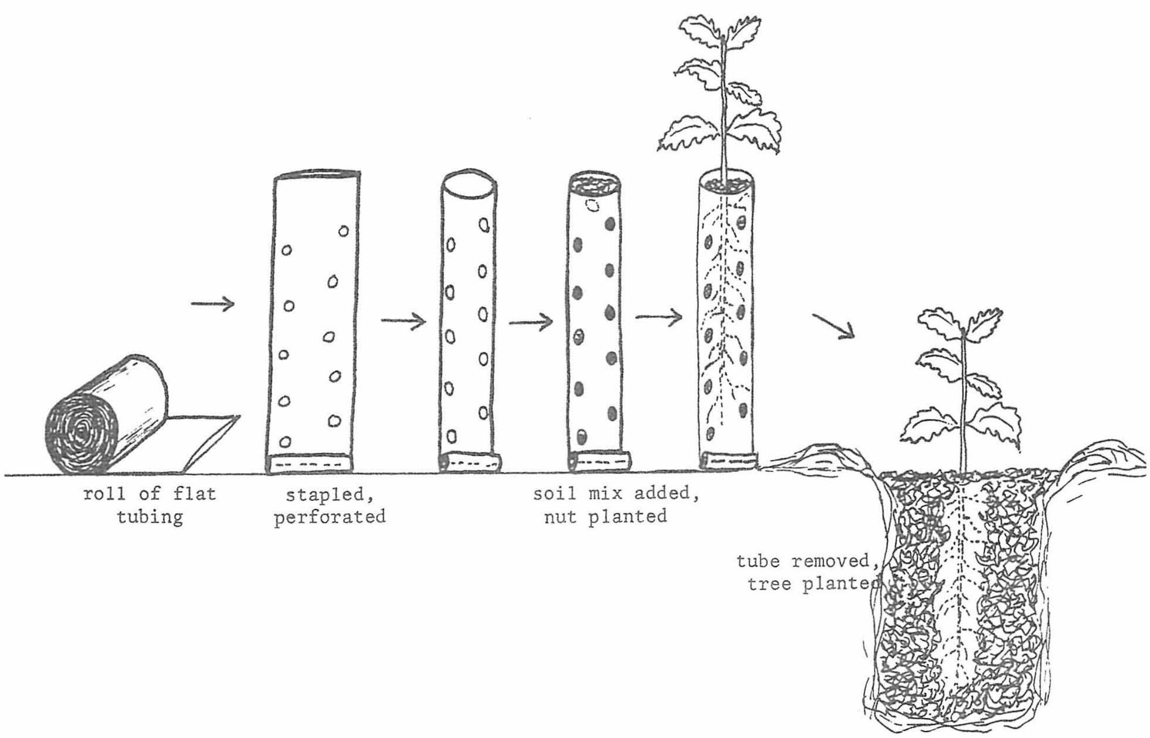
TESTING NUT QUALITY OF YOUNG TREES

Systematic tree-crop improvement requires growing and evaluating hundreds of young seedling trees. These seedlings are usually the result of cross-breeding of two high-quality parents in hopes of getting an even better hybrid. Unfortunately there is a long wait until the young seedling produces nuts for evaluation of quality. It can take from 10 to 12 years for walnuts and hickories. This waiting period can be reduced by 4 to 6 years if a branch of the seedling is grafted to a mature tree, forcing it into early fruiting (19). Such grafting is subject to difficulties of incompatibility between stock and scion, high skill and labor requirements and the necessity of maintaining mature stock trees.

A much easier technique to hasten nut production has recently been described by Stoke (51). In several different tests with black walnut he chose a small minor branch of a walnut seedling that had never produced nuts and girdled it with a band of copper wire during one growing season. The band was then removed in the fall. The next summer that limb alone produced a good crop of nuts. The forcing effect did not carry over to the next summer.

Tree physiologists have reported similar early fruiting in other species as a result of controlled girdling (52). These observations suggest that seedling trees

Figure 15. *Plastic tube culture of tap-rooted trees.*



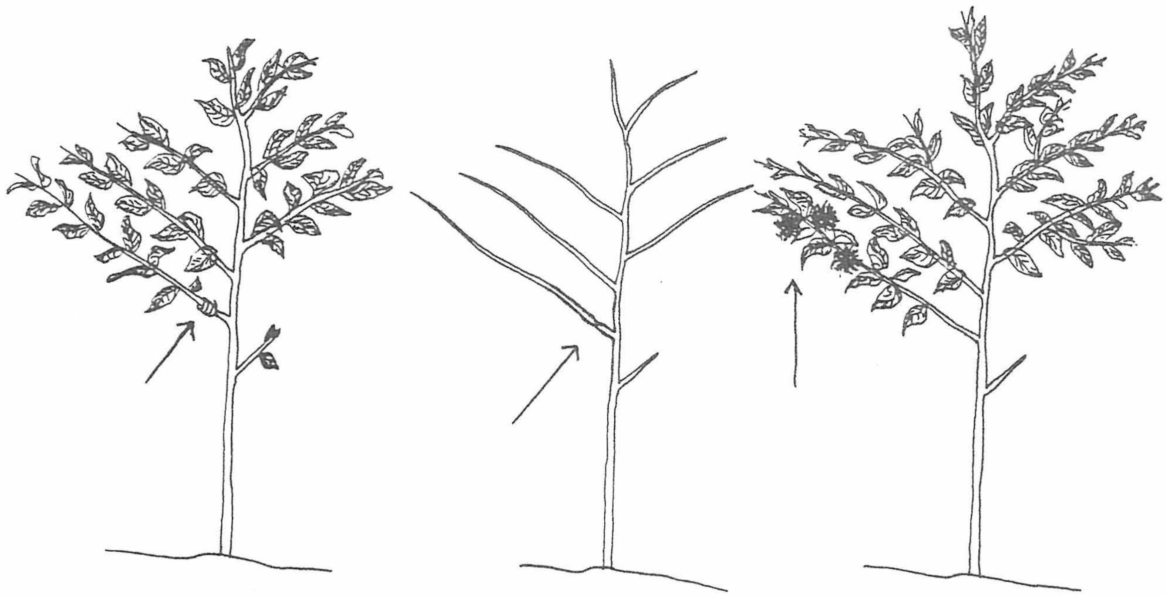


Figure 16. *Early fruit quality testing by controlled girdling.*

under observation in nursery rows could be induced to fruit at a very early age to quickly eliminate inferior trees. The technique would provide a simple way to test seedlings growing in the wild when thinning is necessary. Perhaps most important, early induced flowering and fruiting would make possible rapid genetic manipulation and tree breeding progress. Research on the effectiveness of the technique would be fairly simple. Commercial nursery stock of oak, walnut, hickory and other slow-fruiting seedlings can be tested to determine optimum seasons and duration of controlled girdling that produces earliest fruiting without permanent damage.

EPILOGUE

Forests perfom irreplaceable ecological services as well as provide economic products and recreation. They assist in the global cycling of water, oxygen, carbon, and nitrogen. They lend stability to hydrological systems, reducing the severity of floods and permitting the recharging of springs, streams, and underground waters. Trees keep soil from washing off mountainsides and sand from blowing off deserts; they keep sediment out of rivers and reservoirs and, properly placed, help hold topsoil on agricultural fields. Forests house millions of plant and animal species that will disappear if woodlands are destroyed.

Erik Eckholm
"Planting for the Future:
Forestry for Human Needs,"
Worldwatch Paper 26, 1979.

REFERENCES FOR FIGURE 16

Sax, K. 1954. "The Control of Tree Growth by Phloem Blocks." *J. of the Arnold Arboretum, 35*: 251–58.

Stoke, H. F. 1975. "Girdling to Hasten Nut Production." *The Nutshell,* 27, No. 2: 3.

The ecological advantages of tree crops are quite obvious; the economic consequences are more subtle. Good ecology and good economics often appear to be in conflict when viewed over the short term. But a time-frame of several generations or several centuries reveals an "economics of permanence" in which ecological well-being of a settled people is *identical* to economic well-being. Our present economic theories of investment and profit fail us as a basis of permanent community or cultural security. The drive to maximize profit results in constantly searching for and exploiting greener pastures rather than nurturing the lands at hand. The period of human history is ending in which migration can avoid the consequences of careless stewardship; we now face the difficult task of coming to terms with nature.

Forging of a land ethic which carefully considers global and future consequences is now paradoxically only possible by using fruits of knowledge and technology produced by the civilization which has made such a task crucial. Our energy-intensive, medically protected society is immune to the population controls most species face, while the mechanical power and technical knowledge we control can displace almost any natural community. Necessary ecological feedback, which in nature operates at a subtle structural and behavioral level, must in our case become conscious and monitored with a large dose of communicative technology. The traditional knowledge of past cultures and present science is available for reconstructive design of human landscapes. Air and water quality can become sensitive indicators of stress and degradation of ecosystems, with the aid of low-energy electronic computation and communication systems to pinpoint and communicate sustainable levels.

Materials technology offers long-lived tools, shelter, and agriculturally useful membranes for plant and animal management. Perhaps most importantly, remaining fossil-fuel supplies permit transportation and distribution of available nutrients, biotic species, and soil conservation structures that will allow regionally self-reliant agricultures to become established.

Tree crops and other agricultural perennials are important elements in agricultures of the future. They are resilient, self-maintaining food producers which automatically perform services and functions now subsidized by fossil fuels. Their culture and maintenance require relatively simple tools and easily acquired skills. Eminently suited to rocky hills, urban, suburban and other landscapes not considered agricultural, they offer the best compromise between food production and landscape amenities, and between environmental protection and materials production.

Creative design of agricultural landscapes using tree crops is in a very early stage; farmers, orchardists, city planners, foresters, and ecologists have only begun to cooperatively explore the merger of their knowledge and recognize the concept of an agricultural forestry. Many agricultural trees and plants used for centuries in various biogeographical regions have only recently become available in other similar bioregions as potential agricultural crops. Extinctions and continuous distribution of plant and animal species around the biosphere has nearly eliminated the chance of retaining "natural" ecosystems. Thus ecological designers must now begin to create a symbiotic community of plants, animals, and humans with the visionary goal of permanently sustaining them all.

REFERENCES

1. D. Pimental et al., "Land Degradation: Effects on Food and Energy Resources," *Science, 194*:149–55.
2. D. Pimental et al., 1973, "Food Production and the Energy Crisis," *Science, 182*:443–49.
3. R. A. Brink et al., 1977, "Soil Deterioration and the Growing World Demand for Food," *Science, 197*:625–30.
4. L. Carter, 1977, "Soil Erosion: The Problem Persists Despite the Billions Spent on It,"*Science, 196*:409–11.
5. F. Bell et al., 1977, "Tree Crops for Small Farms in Appalachia," 22 pp. G. Williams, Rt. 1, Gravel Switch, Ky. 40328.
6. E. P. Odum, 1971, *Fundamentals of Ecology* (3rd ed.; Philadelphia: W. B. Saunders Co.).
7. A. N. Duckham, 1976, *Food Production and Consumption* (Amsterdam: North Holland Publ. Co.).
8. G. O. Robinette, 1972, *Plants/People/and Environmental Quality* (Washington, D.C.: Government Printing Office). No. 024-005-00479-3/cat. no. 129.2:P69.
9. R. Geiger, 1965, *The Climate Near the Ground* (Cambridge: Harvard Univ. Press).
10. R. A. Jaynes, 1969, *Handbook of the North American Nut Trees.* Northern Nut Growers Assn., 4518 Holston Hills Road, Knoxville, Tenn. 37914.
11. J. R. Smith, 1950, *Tree Crops: A Permanent Agriculture.* (Devin-Adair).
12. B. Mollison and D. Holmgren, 1978, *Permaculture One.* Transworld Publ., 380 Lonsdale St., Melbourne 3000 Australia.
13. P. Felker and R. Bandurski, 1977, "Protein and Amino Acid Composition of Tree Legume Seeds," *J. Sci. Fd. Agricu. 28*:791–97.
14. P. Felker and R. Bandurski, "Use and Potential Uses of Leguminous Trees for Minimal Energy Input Agriculture." Dept. of Botany and Plant Pathology, Michigan State Univ., East Lansing, Mich.
15. F. H. Bormann, 1976, "An Inseparable Linkage: Conservation of Natural Ecosystems and the Conservation of Fossil Energy," *BioScience, 29*, No. 12:754–60.
16. L. F. Bouvier, 1978, "Interchange," *Population Education Newsletter.* Sept. Population Reference Bureau Inc., 1337 Connecticut Ave. N.W., Washington, D.C. 20036
17. USDA, 1974, *Agricultural Handbook No. 450.* US Govt. Printing Office No. 001-000-02902-9 cat. A 1.76:450.
18. E. Hirst, 1974, "Food-Related Energy Requirements," *Science, 184*:134–38.
19. C. A. Reed and J. Davidson, 1958, *The Improved Nut Trees of North America and How to Grow Them* (Devin-Adair).
20. A. Olgyay and V. Olgyay, 1957, *Solar Control and Shading Devices* (Princeton: Princeton Univ. Press).
21. H. Johnson, 1973, *The International Book of Trees* (New York: Simon and Schuster).
22. C. Lerza, 1977, "U.S. Soil: The Dustbowl Syndrome," *The Elements,* July 1977, pp.3–4. From 1747 Connecticut Avenue N.W., Washington, D.C. 20009.
23. J. T. Bregger, 1945, "Conserving Soil and Moisture in Orchards and Vineyards," USDA Farmers Bulletin No. 1970.
24. New Alchemy Institute, 1977. *The Book of the New Alchemists* (New York: E. P. Dutton Co.). See "A Modest Proposal," "Toward a Self-Sustaining Agriculture," and "The Dilemma

24. New Alchemy Institute, 1977. *The Book of the New Alchemists* (New York: E. P. Dutton Co.). See "A Modest Proposal," "Toward a Self-Sustaining Agriculture," and "The Dilemma Beyond Tomorrow."

25. E. Eckholm, 1976, *Losing Ground: Environmental Stress and World Food Prospects.* (Worldwatch Institute and W. W. Norton Co.).

26. F. H. King, *Farmers of Forty Centuries* (Emmaus, Pa.: Rodale Press).

27. E. F. Schumacher.

28. *Co-Evolution Quarterly* Map of the Biogeographical Regions of the World. $3.00 from Box 428, Sausalito, CA 94965.

29. R. Merrill and T. Gage (eds.), 1974, 1978, *Energy Primer.* Portola Institute, 558 Santa Cruz Avenue, Menlo Park, CA 94025.

30. USDA, 1949, *Trees: The Yearbook of Agriculture.*

31. R. E. Farmer, 1977, "Tree Crops and the Back-to-the-Land Movement," Northern Nut Growers Annual Report.

32. J. D. Ritchie, 1977, "Two-Story Cropping." *Organic Gardening and Farming,* September 1977, pp. 80–83.

33. USDA, 1976, "The Secret of Affluence." Office of Communications.

34. Canada Dept. of Agriculture, 1961, "Soil Erosion by Water." Publication 1083.

35. G. S. King and E. W. Holmes, 1978, "Tree Evaluation." Co-op Extension Service, Univ. of Mass.

36. J. G. Woodruff, 1967, "Tree Nuts: Production, Processing, Products."

37. W. Jackson, 1978, "Toward a Sustainable Agriculture," *Not Man Apart, 8* No. *15*, (Nov.–Dec. 1978).

38. United Fresh Fruit and Vegetable Assn., "Fruit and Vegetable Facts and Points." From 1019 19th St. N.W. Washington, D.C. 20036.

39. C. R. W. Spedding, 1975 *The Biology of Agricultural Systems* (London: Academic Press).

40. D. C. Peattie, 1948, *A Natural History of Trees of Eastern and Central North America.* 2nd ed. (New York: Bonanza Books).

41. U.S. Senate Report, 1978, "Priorities in Agricultural Research of the USDA: A Summary Report of the Hearings." Staff Report of the Sub-Committee on Administrative Practice and Procedure of the Committee on the Judiciary of the U.S. Senate. Dec. 1978.

42. New Alchemy Institute Newsletter, 3, "Methane Digesters" (out of print).

43. J. Leckie et al., 1975, *Other Homes and Garbage.* Sierra Club Books.

44. O. A. Atkins, 1942, 53rd Annual Report of Alabama Agri. Exp. Station.

45. L. R. Brown, 1978. *The Twenty-Ninth Day.* (Worldwatch Institute New York: W. W. Norton & Co.).

46. B. Bergland, 1978, *Not Man Apart.* Mid-Feb. 1978, p. 4.

47. J. S. Douglas and R. A. deHart, 1976, "Forest Farming." Watkins, England.

48. Northern Nut Growers Assn., *The Nutshell* (Quarterly), 4518 Holston Hills Rd., Knoxville, Tenn. 37914.

49. North American Fruit Explorers, *Pomona* (Quarterly), 1848 Jennings Dr., Madisonville, Kentucky 42431.

50. W. Jackson, 1978, "Soil Loss and the Search for a Permanent Agriculture." *The Land Report,* Feb. 1978. pp. 10–16. Rt. 3, Salina, Kan. 67401.

51. H. F. Stoke, 1975, "Girdling to Hasten Nut Production," *The Nutshell,* 27, No. 2 (Winter 1975): 3.

52. K. Sax, 1954, "The Control of Tree Growth by Phloem Blocks," *J. of the Arnold Arboretum,* 35:251–58.

53. M. Merwin, International Tree Crops Institute, Rt. 1 POB 378, Woodland, CA. 95695. Personal communication, 1979.

54. T. Svenson, Urban Tree Crops Co-ordinator, Boston Urban Gardeners, 300 Massachusetts Avenue, Boston, MA 02115. Personal communication, 1979.

New Alchemy Tree Crop Research

Paula Gifford and Earle Barnhart

The following article on mulberry productivity is one of a number of special tree-crop research papers intermittently being produced for communication with other tree-crop researchers and associates. They are special-topic reports on aspects of tree crops, tree culture, and agricultural forestry design that we have found to be useful or important in our work. The series is called "New Alchemy Tree Crop Notes" and includes:

NO. 1 Bibliography of Agricultural Forestry

NO. 2 Organizations, Groups and Individuals Involved with the Tree Crops

NO. 3 New Alchemy Mulberry Yield Measurements, 1978

NO. 4 New Alchemy's Tree Crops Research, 1978–1979

NO. 5 Nurse-Seed Grafting of Trees

NO. 6 Plastic Tube Culture of Tap-Rooted Trees

NO. 7 Controlled Girdling of Trees for Early Quality Testing

NO. 8 Feasibility of Domesticating Squirrels as Nut Gatherers

NO. 9 Windscaping with Trees

NO. 10 Beescaping with Pollen and Nectar Plants

NO. 11 Sources of "Antique" Hardy Domestic Animal Varieties

NO. 12 Willow Coppicing for Fuel, Fiber and Forage

Serious tree crop workers may obtain copies (at printing cost plus mailing) by contacting Earle Barnhart, The New Alchemy Institute, P.O. Box 47, Woods Hole, Mass. 02543.

Mulberries represent a valuable food for human consumption and animal feed. J. Russell Smith in *Tree Crops* describes a region in Afghanistan where dried mulberries (*Morus alba*) are a major staple. In the southern parts of the United States, mulberry trees were often found in pastures for pigs and poultry, providing feed which was harvested by the animals as it fell. Several varieties described as "everbearing" bear from May to August in the South.

Our harvest measurements indicate that on Cape Cod a mature tree can yield over 400 pounds of collectible fruit, plus an additional amount taken by birds and squirrels. I have extrapolated this yield to 5.68 tons per acre. On such a scale the fruit would best be collected directly by the foraging animals, and various cultivars should be interplanted to give a longer, sustained yield of many months.[1]

Nutritive information on mulberries is scarce and probably nonexistent for the United States. USDA sources do not mention mulberries as either human food (USDA Handbook #72; 1971, covering 2,483 food items) or as animal feed (*Atlas of Nutritional Data of the U.S. and Canadian Feeds;* 1972).[2,3] The only clue is an analysis of the dried mulberries used in Afghanistan, which shows them to have about the food value of dried figs.[4]

Individuals of the North American Fruit Explorers are the only people we know in this country researching mulberry cultivars.[5]

Mulberry Yield—1978

Fallen fruit was harvested from a mature mulberry tree (*Morus alba)* with a trunk diameter of 22 inches and a canopy spread of approximately 1,553 square feet. Fruit was collected daily over 30 days from netting on the ground which intercepted approximately 75% of the canopy spread (1,144 square feet). Birds and squirrels consumed an additional unmeasured quantity of fruit. Marketable fruit was processed for human consumption (70%) and the remainder (30%) was fed to young chickens.

Collection from 74% of the canopy area yielded 135.7 kg. of fruit. Total collectible yield was estimated to be approximately 184.2 kg. (405.2 lbs.). Distribution of yield from June 28 to July 28 is shown In Tables 1 and 2. Unmarketable fruit was eagerly eaten by young chickens.

[1] J. Russell Smith, 1950, *Tree Crops: A Permanent Agriculture* (Devin-Adair Co.), pp. 97–109.

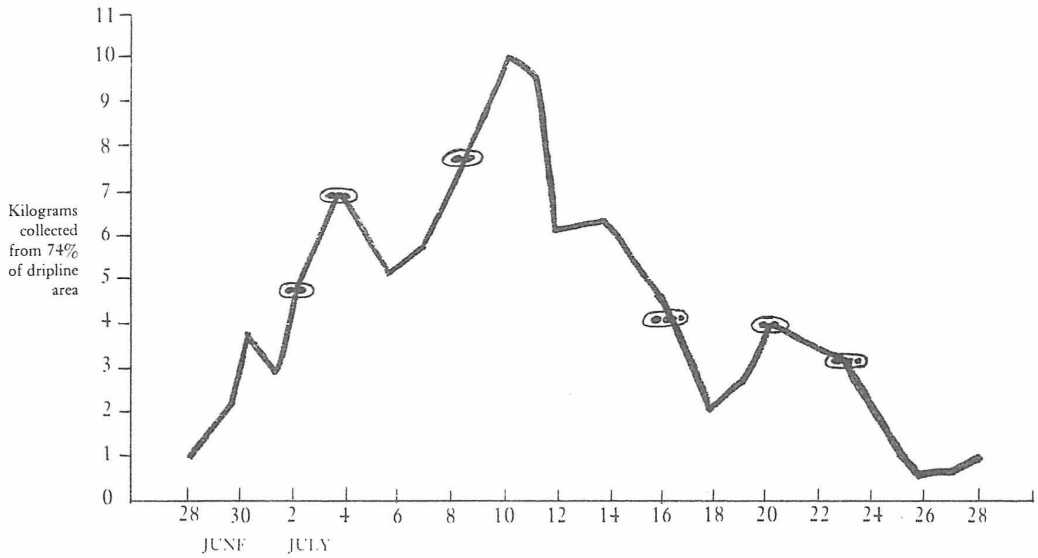
[2] U.S.D.A. Agricultural Handbook No. 8, December 1963; 190 pp. covering 2,483 food items.

[3] *Atlas of Nutritional Data of U.S. and Canadian Feeds*, 1972, National Academy of Sciences.

[4] Smith, op. cit., pp. 107–8.

[5] North American Fruit Explorers, 1848 Jennings Drive, Madisonville, Ky. 4231.

TABLE 1—*Yield of Fallen Mulberries: 1978*



(Double and triple points on graph are two and three day accumulations averaged over the period.)

TABLE 2—Harvest Data

	Gms.
June 28	760
29	2,045
30	3,940
July 1	3,256
2	(*)
3	9,768
4	(*)
5	14,542
6	5,060
7	5,596
8	6,395
9	(*)
10	16,099
11	10,266
12	9,960
13	5,841
14	6,143
15	(*)
16	(*)
17	12,810
18	1,314
19	1,684
20	3,816
21	3,915
22	(*)
23	(*)
24	10,572
25	785
26	330
27	340
28	458
TOTAL	135,695 gms. or 135.7 kg

(*) Fruit not collected until next day.

Drawing by Hilde Maingay