DOE/R4/10085--T1 KY-19-004

21_0079
10085

FINAL TECHNICAL REPORT

Energy-Conserving Perennial Agriculture for Marginal Land in Southern Appalachia

Grant No. DE-FG44-80R410085
Appropriate Technology Small Grants Program
U.S. Department of Energy Region IV

DOE/R4/10085--T1

DE84 000370

International Tree Crops Institute U.S.A., Inc.
Appalachian Regional Office
Route 1
Gravel Switch, KY 40328
Principal Investigator: Gregory Williams

January 30, 1982

The following pages are an exact representation of what is in the original document folder.

Table of Contents

"When it becomes profitable to farm a given tract of hill land, the chances are that it will be farmed. When it becomes vital to increase production of food and fiber to meet worldwide demands, the chances are that more hill land will be farmed."

R. M. Davis, 1976

"The tree is an engine of production that can utilize the heat, light, moisture, and fertility of the mountain without imposing upon man the fearful task of plowing a place that was never meant for the plow."

J. R. Smith, 1916

This is especially for the late John Hershey, for Ralph Kreider, and for Jim Claypool, pioneers all.

Summary

U.S.D.A. economists predict the end of surplus farm production in the U.S. within this decade. More and more marginal land will be cropped to provide feed for the growing world population and to produce energy. Much of this potential cropland in Southern Appalachia is poorly suited to annual crops, such as corn. Perennial crops are much better suited to steep, rocky, and wet sites. Research was undertaken on the theoretical potentials of perennial species with high predicted yields of protein, carbohydrates, or oils. Several candidate "staple perennial crops" for marginal land in Southern Appalachia were identified, and estimates were made of their yields, energy input requirements, and general suitabilities.

Cropping systems incorporating honeylocust, persimmon, mulberry, jujube, and beech were compared with corn cropping systems. It appears that these candidate staple perennials show distinct advantages for energy conservation and environmental preservation. Detailed economic analyses must await actual demonstration trials, but preliminary indications for ethanol conversion systems with honeylocust are encouraging. It is suggested that short-term loans to farmers undertaking this new type of agriculture would be appropriate to solve cash-flow problems.

1. Research on Components of a Perennial Agriculture for Southern Appalachia

1.1. Definitions

This research was undertaken to explore, from a theoretical viewpoint, the resource-conserving potentials of perennial agricultural crops suited to marginal land in Southern Appalachia. Limitations on the literature searches and analyses which were conducted were set by definitions of some key concepts, as given below.

First, "perennial agriculture" was assumed to include herbaceous, shrub, and tree crops, as well as grasses. In fact, emphasis was placed on plant species other than grasses and forage legumes, because the latter have been well studied, and because they are currently widely used -- the only types of perennials widely used -- in agriculture. Non-forage perennials, whether vegetables such as asparagus, herbs such as ginseng, or fruit trees such as apples, have traditionally been given a different status, termed "horticultural", or "specialty", or even "minor" crops. That is, they are not "staples". Staple agricultural food crops have relatively large yields of protein, carbohydrates (especially sugars and starch), and/or oils. Non-staple food crops are rightly termed "luxury" crops, because of their high costs per unit of protein, carbohydrates, or oils. The research discussed below concerned with staple perennial crops only.

Second, "marginal land" was assumed to include several types of land (steep, droughty, flood-prone, rocky, infertile, etc.), which share the characteristic of difficult and expensive cropping. Such land is often left by farmers to the local natural succession.

Third, the Southern Appalachian Region was defined rather loosely to include West Virginia, Eastern Kentucky, Western Virginia, Eastern Tennessee, Western North Carolina, Northern Alabama, and Northern Georgia, plus parts of adjoining areas, such as Southeastern Ohio.

Thus, a more complete title for this research project would be "Theoretical Study of Potential Staple Perennial Crops Suited to Hard-to-Crop Land in Southern Appalachia". This expanded title clearly sets constraints on the population of plant species considered: the population should include species which are physiologically adapted to the Southern Appalachian climate and have potentially large yields of protein, carbohydrates, and/or oils.

1.2. Methodology

A very broad investigation of climatic influences on plants showed that the dominating factors are rainfall during the growing season and average and minimum temperatures throughout the year. Perennials, of course, must be winter hardy; in the Southern Appalachian Region, average annual minimum temperatures range from -20 F in West Virginia to +10 F in Northern Alabama and Northern Georgia. Thus, plants not winter hardy below +10 F were not considered further. Rainfall in Southern Appalachia is generally adequate for good plant growth; no plants were rejected for excessive precipitation needs. Also, no plants were rejected because of origins in arid regions, although some of these might be susceptible to diseases in Southern Appalachia, because little data are available on such susceptiblity. Nor were plants rejected because of northern origins.

Soil fertility and pH preferences were not used to limit the population of species screened. In most cases, these preferences are unknown.

Several references were used to compile a comprehensive list of candidate staple perennial crops hardy below +10 F. These references are cited in Bibliography 1. Of greatest importance among them are Coon's Dictionary of Useful Plants and Morton's "Principal Wild Food Plants of the United States", which were thoroughly checked. Hortus Third was utilized whenever possible for proper botanical nomenclature. Wyman's Gardening Encyclopedia usually provided winter hardiness information, but Hortus Third and other sources added to this. Data were entered on standard format sheets, two for each species (shown on the next two pages). Unfortunately, published information on most categories of the format sheets was not found for nearly all species, perhaps a significant finding in itself! It should be noted that the choices for categories were made on the basis of which plant characteristics appear important in domestication, rather than in botany or ecology. The format sheets will be kept on file and updated as appropriate at the I.T.C.I.U.S.A. Appalachian Regional Office Library.

Concurrent with the general characterization of candidate staple perennial crops, as outlined above, a literature search on yields and nutritional compositions of these plants was also undertaken. Again, a standard format sheet was used (shown on third page following). Important references are cited in Bibliography 2; there are many other references which provided data on only one or a few species, and most of these minor references can be accessed through the book by Robson and Elias. The resulting 1000+ format sheets, filed at the A.R.O. Library, represent the most complete compilation of yield and nutritional composition data on temperate region perennials in existence, since all references available through University of Kentucky libraries were utilized, amounting to probably 95+ % of the total relevant world literature. Overall, much more information was available regarding nutritional composition than regarding yields, and yield data are often difficult to interpret because of environmental variables. Even though "quantitative", this information requires substantial interpretation in its use to determine cropping potentials.

Comparative evaluation of the candidate species was based on the general and yield/nutritional composition files, tempered by the experience and knowledge of the Principal Investigator. Nevertheless, many species are insufficiently characterized at the present time to allow any evaluation; each of these species might be considered a research topic for the future! On the contrary, abundant data are available on many other species, and the difficulty with these is how to rank them in any meaningful way. The difficulty is partly eased by the admittedly preliminary nature of the evaluation. A four-way overall "suitability scale" was ultimately chosen as a compromise between precision and utility -- a shorthand guide to the best and worst potential staple perennials, but a guide that could be misleading at times. The scale ranges from 1 to 3, with insufficient information designated by "?". Species with suitability 1 have high potential for producing large yields of protein, carbohydrates, and/or oils on marginal land in Southern Appalachia; species with suitability 2 have medium potential; and species with suitability 3 have low potential; the potential is undecided for these species with suitability "?". Given that hundreds of species are included in this preliminary evaluation, it seemed appropriate to make rankings very conservatively, with only the "best of the best" given suitability 1, so that the very few species honored thusly should greatly repay research attention in the future. Appendix 1 presents the suitability rankings.

BOTANICAL NAME

COMMON NAMES

FAMILY

DESCRIPTION

SIZE

HARDINESS ZONE

RANGE

SHADE TOLERANCE

SOIL CONDITIONS

FLOWER CHARACTERISTICS

FLOWERING PERIOD

FRUIT CHARACTERISTICS

FRUITING PERIOD

ALTERNATE BEARING

YIELD

FRUIT USES

OTHER USES

MAINTENANCE REQUIREMENTS

PESTS

DISEASES

PROPAGATION TECHNIQUES

VARIETIES

SOURCES

NOTES

SPECIES

PORTION

YIELD (POUNDS/ACRE)

CALORIES/POUND

FAT (%)

SUGARS & STARCH (%)

PROTEIN (%)

ESSENTIAL AMINO ACIDS (MG/G OF PROTEIN)/SCORES (%)

HISTIDINE

ISOLEUCINE

LEUCINE

LYSINE

SULFUR

AROMATIC

THREONINE

TRYPTOPHAN

VALINE

CALORIE YIELD/ACRE

FAT YIELD (POUNDS/ACRE)

ETHANOL YIELD (GALLONS/ACRE)

PROTEIN YIELD (POUNDS/ACRE)

UTILIZABLE PROTEIN YIELD (POUNDS/ACRE)

1.3. Results

Species in fifteen genera were assigned suitability rankings of 1. Only one species among these is herbaceous in habit (Helianthus tuberosus, Jerusalem artichoke), and this species is the only one with important nutrients harvestable from its roots. Much research attention is being given to Jerusalem artichoke currently, so it was decided to ignore it in the remainder of this study, thus allowing concentration on weedy species with high potentials as staple crops on marginal land in Southern Appalachia. The fourteen genera of major importance are described in Table 1. In each, the fruit (or part of the fruit, such as the seed) is the harvestable part. In general, carbohydrates are concentrated within these parts, though protein and oils are concentrated within the fruits of a few of the species.

Yields of protein, carbohydrates, and oils reported in Table 1 were computed from yield and nutritional composition data from references given in Bibliography 2 and from other minor references. These computed yields should be taken as rough approximations to actual yields which would be experienced on marginal land in Southern Appalachia: some of the data were recorded under better conditions than might be reasonably expected in practice, while other data were recorded under worse conditions (i.e., in forest settings). Nevertheless, the computed yields are extremely useful when combined with other, more general information, in making priority rankings for further research and demonstration plantings. Yield increases with further domestication can be expected for several species listed.

Specific information on estimated ethanol yields from several species are included in Appendix 2. Somewhat surprisingly, some weedy species seem competitive with corn with respect to ethanol yields.

Annual fruit yields of woody plants typically increase as maturity is approached. For many species, there is a juvenile phase of one to several years, during which no fruit are produced. Estimated yields reported in Table 1 and Appendix 2 assume that the adult phase is underway. Roughly, these estimated yields can be assumed reasonable for a shrub over 2-4 years old and for a tree over 8-15 years old. Carya (hickory) species require more time to begin producing large yields.

Also, some of the listed species show a tendency toward alternate bearing, with "boom" and "bust" yield years. Among these are Carya species, Fagus grandifolia, Gleditsia triacanthos, and Juglans species.

Table 1. Estimated Protein, Carbohydrate, and Oil Yields of High-Potential Candidate Staple Perennials (Annual-Fruit-Producing Woody Plants)

Botanical Name/Common Name	Fruit Type/Size	Est. Yield (Lbs./Acre)
Amelanchier spp./serviceberries	pome/under 1/2"	400 - 1900, sugars
Carya illinoinensis/pecan	nut/to 1"	400 - 700, oils
Carya ovata/shagbark hickory	nut/to 1 3/4"	700 - 1100, oils
Crataegus spp./hawthorns	pome/under 3/4"	ca. 1500, sugars
Diospyros Kaki/oriental persimmon	berry/to 4"	1000 - 8000, sugars 150 - 1200, starch
Diospyros virginiana/common persimmon	berry/to 2"	1200 - 3100, sugars 900 - 2200, starch
Fagus grandifolia/American beech	nut/to 1"	ca. 240, oils ca. 100, protein
Gleditsia triacanthos/honeylocust	legume/3 to 20" long	340 - 2060, protein 800 - 4400, starch 1500 - 9000, sugars
Juglans cinerea/butternut	nut/to 2"	90 - 180, oil 35 - 70, protein
Juglans nigra/black walnut	nut/to 2"	120 - 240, oil 50 - 100, protein
Juglans regia/Persian walnut	nut/to 2"	240 - 1920, oil 60 - 480, protein
Morus spp./mulberries	drupe aggregate/to 1"	ca. 1100, sugars ca. 380, starch
Quercus acutissima/sawtooth oak	nut/under 3/4"	ca. 1000, starch
Rubus spp./blackberries and raspberries	drupe aggregate/to 1"	ca. 1700, starch ca. 1320, sugars
Sambucus canadensis/elderberry	drupe/to 1/4"	670 - 1600, sugars
Vaccinium corymbosum/blueberry	berry/ca. 1/4"	160 - 800, starch 320 - 1600, sugars
Vaccinium macrocarpon/cranberry	berry/ca. 1/4"	570 - 2850, starch 420 - 2100, sugars
Viburnum trilobum/highbush cranberry	drupe/ca. 1/4"	860 - 4300, sugars
Ziziphus Jujuba/jujube	drupe/1 to 2"	over 2200, sugars

2. Research on Perennial Agricultural Systems

2.1. Methodology

After identification of and yield estimation for the most promising staple perennial crop candidates were accomplished, more detailed information about each of these species was sought. Exhaustive literature searches were performed, toward the goal of characterizing each species sufficiently to assign appropriate role(s) within energy-conserving agricultural systems suited to marginal land in Southern Appalachia. The most important references consulted are listed in Bibliography 3.

As data on the most promising species were assembled and cross-checked when possible, a separate investigation into the nature of conventional farming practices in Southern Appalachia was undertaken, to establish a basis for comparison with theoretical perennial agricultural systems.

Inputs from research in both of the above areas were combined with the yield information of Table 1 to establish a set of promising perennial agricultural systems, shown in Table 2.

2.2. Results

Table 2 presents "predicted fits" of promising staple perennial species within six perennial agricultural systems, relative to existing conditions on farms in Southern Appalachia. However, no economic considerations are reflected in Table 2 (see Section 3). It is apparent that certain species, notably *Diospyros virginiana*, common persimmon, and *Gleditsia triacanthos*, honeylocust, fit well within most of the systems. Also, honeylocust shows the best predicted fits within systems yielding protein feed or food. Several species have good predicted fits within ethanol conversion systems (see Appendix 2 for additional information). Other species with good predicted fits in more than one system include *Ziziphus jujuba*, *Morus* spp., and *Fagus grandifolia*. These are the species to which most attention should be given for economic, energetic, and environmental analyses.

2.2.1. System Specifications

Specifications are given below for several perennial agricultural systems suited to marginal land in Southern Appalachia. These are offered as "recipes" for demonstration trials by researchers and innovative farmers in the hope that at least some of them will be investigated. Undoubtedly, field experimentation will reveal shortcomings in these specifications; nevertheless, they give starting points, based on the best available current data.

2.2.1.1. *Gleditsia triacanthos* (Honeylocust) Systems

In many ways, the honeylocust is the most promising candidate staple perennial crop for marginal land in Southern Appalachia. Projected yields of both protein and carbohydrates are quite high, for select trees. Poor site conditions, such as drought, compaction, and temporary flooding, are tolerated well. Honeylocust canopies are open, allowing grass to grow underneath. And the pods are rather easily harvested, by livestock or machine. Honeylocust does tend to alternate bear; some pruning may be required to control this. Pod storage is relatively easy over long time periods.

2.2.1.1.1. Cattle or Sheep Self-Harvest

Vegetatively propagated high-yielding, sweet-podded cultivars (i.e., 'Millwood' or 'Calhoun') are planted at age two or three in a pasture, ca. 35 per acre. If native honeylocusts are not growing nearby, one or two male trees, or a half dozen unsexed seedling trees should be planted in the vicinity. Protection from livestock (fencing around each tree) must be provided for a few years.

Alternatively, one or two year seedlings from high-yielding parents are planted on a spacing of 2-4 feet just outside the fencerow of a pasture. These are thinned to a spacing of 8-12 feet as they begin to flower and poor producers and (almost all) males are identifiable for culling.

Pods are self-harvested by cattle or sheep as they drop. For quicker pod drop, the limbs can be hit with a stick. Some of the protein in the pods will not be available to the ruminants, because the seeds have hard coats.

2.2.1.1.2. Pig Self-Harvest

As in 2.2.1.1.1. above, except pigs are turned into honeylocust pasture only in late fall, so rooting is minimized. This is important to avoid sprouting of the trees and possibly to reduce erosion.

2.2.1.1.3. Machine-Harvest for Livestock Feed

Establishment as in 2.2.1.1.1., possibly at higher density if livestock are not pastured beneath. Harvest by hitting limbs with sticks, tree-shaking machinery, or perhaps by applying chemical sprays promoting pod drop. Pods are raked up with conventional equipment, dried, stored, and hammer- or roller-milled as required. Crushed seeds have higher availability of protein, while pods are high in carbohydrates; pods and seeds could be separated for different uses, i.e., pods for fattening pigs, seeds for high protein dietary supplement for humans. More research is necessary regarding possible seed toxins (almost certainly heat-labile).

2.2.1.1.4. Machine-Harvest for Ethanol Conversion

Plant and harvest as in 2.2.1.1.1. and 2.2.1.1.3. Milled pods-with-seeds fermented and distilled for fuel ethanol. Stillage by-products fed to livestock.

2.2.1.2. Diospyros virginiana (Common Persimmon) Systems

Persimmon is extremely adaptable to poor site conditions, especially acid and/or droughty soils. Production begins at an early age. Apparently, pruning is not necessary. Most persimmons show only a slight tendency to alternate bear. Carbohydrate yields are quite high. Long-term storage of fruit can be difficult; some trees have fruit which dries easily without molding, while other trees have fruit susceptible to mold. Canopies are fairly dense. Harvesting is easy if tarps are spread beneath the trees, which are hit with sticks; or by livestock.

2.2.1.2.1. Sheep or Pig Self-Harvest

Vegetatively propagated desirable cultivars (i.e., 'John Rick', 'Early

Golden', or 'Meader') are planted at age two or three in a meadow, ca. 80 per acre. A few males are necessary for proper pollination.

Or one or two year seedlings from desirable parents are planted on a spacing of 2-4 feet along fencerows, then males and poor yielding females are thinned out as they mature for a final spacing of 6-10 feet.

Persimmons are self-harvested by livestock as they drop in fall (and winter, for some cultivars). Trunks must be protected from livestock when young, i.e., with hardware cloth cylinders. Harvesting can be speeded by shaking or knocking down fruit.

2.2.1.2.2. Machine-Harvest for Ethanol Conversion

Establishment as in 2.2.1.2.2. Harvest by shaking or hitting limbs with sticks, with tarps under trees. Mash and ferment, then distill for fuel ethanol. Storage of harvested fruit may be problematic, and nutritional value of stillage is probably low.

2.2.1.3. Morus spp. (Mulberries) System

Mulberries grow and fruit well on extremely poor sites, withstanding low fertility and drought. Production begins at a very early age, and yields are high. However, competition for fruit from birds can be severe. Seedlings are generally adequate, but cultivars with long productive seasons (including 'Hicks', 'Stubbs', and 'Wellington') are propagated from cuttings or by grafting. Crown density is rather high. Pruning is unnecessary for annual bearing. Fruit stores poorly for even a few days.

2.2.1.3.1. Pig Self-Harvest

Young seedlings or cultivars are planted at a density of about 40 per acre (80 per acre for higher early yields; eventually, half of the trees are removed). Pigs are run under the trees in mid-summer for 2-4 months (longer with "everbearing" cultivars).

2.2.1.4. Ziziphus Jujuba (Jujube) Systems

Jujubes are extremely resistant to drought. Grafted cultivars must be utilized for good yields and fruit size and quality (including carbohydrate content). No pruning is necessary; jujubes remain very small trees at maturity. No pests or diseases are significant. The fruit dries well. Bearing begins at a very early age, often the first or second year. More than one cultivar should be planted to assure proper pollination.

2.2.1.4.1. Pig Self-Harvest

Young vegetatively propagated cultivars are planted at a density of about 100 per acre. Pigs are run under the trees in late summer. Trunk protection must be provided for the first few years (wire guards).

2.2.1.4.2. Machine-Harvest for Ethanol Conversion

Establishment as in 2.2.1.4.1. Rake up dropped fruit, dry for long-term storage. Mash for fermentation and distillation. Nutritional value of stillage is probably low.

2.2.1.5. *Fagus grandifolia* (American beech) System

Shade tolerance of the beech allows its introduction into existing wooded areas. Bearing may not begin for many years, and alternate bearing may be pronounced, so exclusive devotion of a site to beech is probably not justifiable. Planting of beech seeds or seedlings in areas being managed for timber production (or possibly not being managed at all!), with subsequent low-level control of vegetation competing with the beeches, would eventually result in an important source of pig feed.

2.2.1.5.1. Pig Self-Harvest

Beech seeds or young nursery-grown seedlings are planted at as high density as possible in forested areas, to allow for future mortality under low management levels. Woods are managed properly for sustained-yield timber production, with attention given to weed control around planted beeches. As beeches reach maturity, thin to allow crown development for better fruiting. Run pigs under trees in fall, when large yields of beechnuts are produced.

Table 2. Promising Perennial Agricultural Systems

System Characteristics	Appropriate Species	Predicted Fit
Self-harvested by ruminants as energy feed	Amelanchier spp.	medium to poor
	Crataegus spp.	poor
	Diospyros Kaki	medium
	Diospyros virginiana	good
	Fagus grandifolia	medium
	Gleditsia triacanthos	good
	Morus spp.	medium
	Quercus acutissima	medium
	Rubus spp.	poor
	Sambucus canadensis	medium to poor
	Vaccinium corymbosum	medium to poor
	Viburnum trilobum	medium to poor
	Ziziphus Jujuba	good
Self-harvested by non-ruminants as energy feed	Amelanchier spp.	medium to poor
	Carya illinoinensis	medium
	Carya ovata	poor
	Crataegus spp.	poor
	Diospyros Kaki	medium
	Diospyros virginiana	good
	Fagus grandifolia	good
	Gleditsia triacanthos	good
	Morus spp.	good
	Quercus acutissima	good
	Rubus spp.	medium
	Sambucus canadensis	medium to poor
	Vaccinium corymbosum	medium to poor
	Viburnum trilobum	medium to poor
	Ziziphus Jujuba	good
Self-harvested by ruminants as protein feed	Fagus grandifolia	medium
	Gleditsia triacanthos	good
Self-harvested by non-ruminants as protein feed	Fagus grandifolia	good
	Gleditsia triacanthos	good
Machine-harvested and processed for energy feed/food or ethanol conversion	Amelanchier spp.	good
	Carya illinoinensis	medium to poor
	Carya ovata	medium to poor
	Crataegus spp.	good
	Diospyros Kaki	medium to good
	Diospyros virginiana	good
	Fagus grandifolia	medium to poor
	Gleditsia triacanthos	good
	Juglans cinerea	medium
	Juglans nigra	medium
	Juglans regia	medium to poor
	Morus spp.	good to medium
	Quercus acutissima	medium

System Characteristics	Appropriate Species	Predicted Fit
	Rubus spp.	good
	Sambuous canadensis	good
	Vaccinium corybosum	good
	Vaccinium macrocarpon	medium to poor
	Viburnum trilobum	good
	Ziziphus Jujuba	good
Machine-harvested and processed for protein feed/food	Fagus grandifolia	medium to poor
	Gleditsia triacanthos	good
	Juglans cinerea	medium
	Juglans nigra	medium
	Juglans regia	medium to poor

3. Research on Energetic, Economic, and Environmental Implications

3.1. Motivation

At a time when the U.S.D.A. is predicting vast surpluses of most staple agricultural commodities, and is even subsidizing farmers who voluntarily restrict production of some crops, why is it important to even consider the potentials of "new" staple crops for marginal land? Why worry about extending agricultural production onto land which is now neglected or abused, when the grain bins are overfull? Simply because surplus production is predicted to end in the very near future, probably by the end of this decade (O'Brien, 1981)*. Cropland needs due to increasing feed exports, fuel ethanol production, and non-farming development of prime land are expected to force millions of acres of marginal land into production by 1990 (Fox and Clayton, 1981). In U.S.D.A.'s "Appalachian Region" (including VA, WV, NC, KY, and TN), 61% of the land judged to have high potential for cropping, but now used mainly for pasture and forest, currently has "erosion" as its principal limitation (Fox and Clayton, 1981, 72). Thus, marginal land <u>will</u> be cropped soon, and in Southern Appalachia, this means that <u>erosion-prone</u> land will be cropped soon. Must this be a prescription for soil loss disaster?

Average annual soil erosion loss estimates are 20 tons per acre for conventional continuous corn, 5-10 tons per acre for wheat, 0.03 tons per acre for grasses, and 0.01-0.002 tons per acre for forests (Pimentel, et al., 1976, 151). Obviously, perennial crops hold soil much better than do clean cultivated crops or small grains. Hence, the motivation to introduce staple perennials onto marginal, especially steeply sloping, land, in lieu of conventional crops. No-tillage corn (Phillips, et al., 1980) is becoming more popular in the Southern corn belt, and reduces soil erosion risks to negligible levels, but the technology is not well-adapted to the steep rocky hillsides of Appalachia. No doubt, some of the land which will be brought into production over the next decade will be cropped to no-till corn, but much of that land will not. An extremely important role in avoiding excessive soil erosion could be played by staple perennial crops.

3.2. Energy Conservation Potential of Staple Perennial Crops

The rapid increases in crop yields since the 1940's have resulted from new varieties and increased management inputs, particularly fertilizers, pesticides, and irrigation, which depend heavily on fossil fuels. The U.S. food system uses about 17% of total U.S. fossil energy consumption, about one-third of this in production (Pimentel, 1980, 3).

Energy use for corn growing is well documented (Phillips, et al., 1980, 1111; Pimentel, 1980, 78-82), and corn is the most likely conventional crop of choice to be grown on marginal land in Southern Appalachia, so analyses are given in relation to corn. Table 3 compares estimated energy inputs for corn with those for staple perennial crops.

Significant energy savings over a 30 year "lifespan" accrue to staple perennials, relative to corn, mainly due to reduced annual soil preparation requirements of the former. There are 5.4 million acres of high potential cropland in U.S.D.A.'s "Appalachian Region" (as defined above). If just half

*References for Section 3 are listed in Bibliography 4.

of that acreage were planted to staple perennials rather than tilled corn, the energy savings over 30 years could amount to between 7×10^{12} Btu (for mechanically harvested honeylocust) and 13×10^{12} Btu (for livestock-harvested beech). If this amount of energy were to be supplied from gasoline converted at an efficiency of 20%, between 10^7 and 1.8×10^8 40-gallon barrels would be needed. This is a significant proportion of the total U.S. farm usage of gasoline and diesel fuel use (2.2×10^8 barrels, for the year of 1977, according to Torgerson and Cooper, 1980).

Perhaps of greater importance than total energy inputs per acre are efficiencies of nutrient output per energy input. These efficiencies are estimated in Table 4, using data from Tables 1 and 3. Table 4 shows that the efficiencies for candidate staple perennials are comparable to the efficiencies for corn.

3.3. Economics of Staple Perennial Crops

Most of the candidate staple perennials are not expected to yield as much nutrients as corn, though honeylocust might outproduce corn. This fact is of importance for policy planners, but of less significance to farmers, who decide what crops to grow on the basis of net income rather than gross yields. Perennial staple crops should require less money inputs than corn, and so even with relatively low yields, larger net money returns are possible.

Because economic factors change so greatly over even the short term, no detailed analyses were undertaken (but cf. Appendix 2). Demonstration trials will be necessary for meaningful economic comparisons between perennials and conventional crops. It can be stated that most farmers in Southern Appalachia will have tremendous cash-flow problems in capitalizing for staple perennials, because of the several year wait until yields are first obtained. It is likely that this problem could be solved by government-backed loans. Support of establishment of staple perennials by the government would fit well with current policies of preventing short-term surplus production, while promoting long-term adequate food and energy supplies.

3.4. Environmental Impacts of Staple Perennial Crops

The biggest environmental difference between perennial crops and annual crops is soil erosion risk, which is much lower for the former (no-till corn also has low risk, but at the cost of increased pesticide inputs; see below). Once severe erosion has taken place, money and energy costs to restore land to a condition allowing annual cropping, if even possible, are enormous. But abused land can usually be cropped to perennials with minimal renovation costs. And there is plenty of such poor land available -- over the past 200 years, at least one-third of the topsoil on U.S. croplands has been lost (Pimentel, et al., 1976, 150).

Under conventional agricultural conditions, topsoil is estimated to form at a rate of about 1.5 tons annually; in the U.S., average loss of topsoil from agricultural land amounts to about 12 tons annually; in 1965, the annual loss in U.S. crop production due to erosion was estimated at about $ 800 million (Pimentel, et al., 1976). Yields are directly influenced by topsoil losses, amounting to a few bushels per inch of topsoil lost. Erosion selectively removes cation exchange media from the soil, as well as nutrients (Curry, 1971). Indirectly, economic losses arise downstream due to sedimentation of rivers and reservoirs, and eutrophication.

As the slope increases, so does the risk of erosion. Soil conservation researchers have particular recommendations for reducing the risk when row crops are planted to hill land. The most effective recommendation is to not plant such crops, but as Brink, Densmore, and Hill note (1977, 628): "The acreage of the two leading row crops, corn and soybeans, which already extend onto much unprotected sloping land, may rise further; market forces favoring such a trend are strong." A second line of defense, contour tillage, is most effective on slopes of only 2-8% (Blakely, Coyle, and Steele, 1957, 293). And there are many sites, particularly in Southern Appalachia, unsuited even to terracing: "The cost of construction and the difficulty of maintenance make them unsatisfactory on stony soils and on shallow soils over rock or over tough, heavy subsoil. Terraces are impractical on moundy fields or fields where direction or steepness of slope changes every 100 feet or so. A tillable row pattern cannot be worked out on them"(Blakely, Coyle, and Steele, 1957, 297). On such sites, perennials may be the only choice, or they may be alternatives to no-till corn.

Increasing public attention is being paid to pesticide use. As reflected in the figures of Table 3, no-till corn requires significantly more pesticides than tilled corn; perennial crops listed in Table 3 are expected to require much reduced pesticide applications, even when compared to tilled corn. The reduction in pesticide use with staple perennials vs. corn will be increasingly important as more and more land is cropped.

Table 3. Estimated Cumulative Thirty-Year Energy Inputs[8]

Input	Assumptions	Tilled Corn[1] (Btu/acre)	No-Till Corn[1] (Btu/acre)
machinery	13 lb/acre tilled; 10.7 lb/acre no-till	4,430,000	3,640,000
N	160 lb/acre	36,350,000	36,350,000
P	80 lb/acre	2,350,000	2,350,000
K	80 lb/acre	1,400,000	1,400,000
seed	18 lb/acre tilled; 20.4 lb/acre no-till	1,200,000	1,400,000
pesticides	2.6 lb/acre active ingredients tilled; 3.8 lb/acre active ingredients no-till	1,000,000	1,500,000
plow		4,390,000	0
disk	one time	1,500,000	0
plant	30" rows	1,500,000	1,500,000
apply herbicides		320,000	320,000
broadcast fertilizer		340,000	340,000
harvest	cornpicker	2,390,000	2,390,000
(harvest)	(by livestock; includes fence)	(negligible)	(negligible)
TOTAL		57,170,000	51,190,000
(TOTAL)[7]		(52,050,000)	(46,070,000)

Input	Assumptions	Honeylocust[2] (Btu/acre)	Persimmon[2] (Btu/acre)
machinery	6000 lb total for 50 acres, replaced every 15 years	2,730,000	2,730,000
N	200 lb/acre honeylocust; 120 lb/acre persimmon	45,440,000	27,260,000
P	90 lb/acre honeylocust; 60 lb/acre persimmon	2,640,000	1,760,000
K	90 lb/acre honeylocust; 60 lb/acre persimmon	1,580,000	1,050,000
grafted trees	35/acre honeylocust; 80/acre persimmon	50,000[3]	110,000[3]
establishment		50,000[4]	110,000[4]
pesticides	1 lb/acre active ingredients	380,000	380,000
harvest	shake by hand and rake or shake onto tarps; 5 gal/acre gasoline	1,680,000[5]	1,680,000[5]
(harvest)	(by livestock; includes fence)	(negligible)	(negligible)
TOTAL		54,550,000	35,080,000
(TOTAL)[7]		(50,140,000)	(30,670,000)

Input	Assumptions	Mulberry[2] (Btu/acre)	Jujube[2] (Btu/acre)
machinery	6000 lb total for 50 acres, replaced every 15 years	2,730,000	2,730,000
N	30 lb/acre mulberry; 50 lb/acre jujube	6,820,000	11,360,000
P	15 lb/acre mulberry; 25 lb/acre jujube	440,000	730,000
K	15 lb/acre mulberry; 25 lb/acre jujube	260,000	440,000
trees	40 seedlings/acre mulberry; 100 grafted trees/acre jujube	10,000[3]	130,000[3]
establishment		60,000[4]	140,000[4]
pesticides	0.5 lb/acre active ingredients	190,000	190,000
harvest	shake onto tarps; 15 gal/acre gasoline	5,040,000[5]	5,040,000[5]
(harvest)	(by livestock; includes fence)	(negligible)	(negligible)
TOTAL		15,550,000	20,760,000
(TOTAL)[7]		(7,780,000)	(12,990,000)

Input	Assumptions	Beech[2] (Btu/acre)
machinery	6000 lb total for 50 acres, replaced every 15 acres	2,730,000
N	15 lb/acre	3,410,000
P	5 lb/acre	150,000
K	5 lb/acre	90,000
seeds	1 lb/acre	negligible
establishment	by hand	negligible
pesticides	none	0
harvest	shake onto tarps; 20 gal/acre gasoline	6,720,000
(harvest)	(by livestock; includes fence)	(negligible)
TOTAL		13,100,000
(TOTAL)[7]		(3,650,000)

[1]Phillips, et al., 1980, 1111.
[2]Using energy densities of Phillips, et al., 1980, unless otherwise noted.
[3]Assuming 4000 Btu/dollar retail cost ($ 10/grafted tree; $ 2/seedling). See Heichel, 1980, 28.
[4]Using data of Funt, 1980, 237.
[5]Cervinka, 1980, 15.
[6]Gee, 1980, 427.
[7](TOTAL) = TOTAL - estimated energy content of 8 lb/acre of machinery - mechanical harvest energy.
[8]Fertilized for maximum theoretical yields of perennials, for 10,000 lbs/acre corn yield.

Table 4. Estimated Nutrient Output/Energy Input Efficiencies

Cropping System	Nutrient	Efficiency (lb/Btu)
tilled corn, 10,000 lbs/acre yield, mechanically harvested	protein	0.00047
"	carbohydrates	0.0037
"	oils	0.00021
tilled corn, 10,000 lbs/acre yield, livestock harvested	protein	0.00052
"	carbohydrates	0.0040
"	oils	0.00023
no-till corn, 10,000 lbs/acre yield, mechanically harvested	protein	0.00053
"	carbohydrates	0.0041
"	oils	0.00023
no-till corn, 10,000 lbs/acre yield, livestock harvested	protein	0.00059
"	carbohydrates	0.0046
"	oils	0.00026
honeylocust, mechanically harvested	protein	0.00019 - 0.0011
"	carbohydrates	0.0013 - 0.0073
honeylocust, livestock harvested	protein	0.00020 - 0.0012
"	carbohydrates	0.0014 - 0.0080
persimmon, mechanically harvested	carbohydrates	0.0018 - 0.0045
persimmon, livestock harvested	carbohydrates	0.0021 - 0.0052
mulberry, mechanically harvested	carbohydrates	0.0029
mulberry, livestock harvested	carbohydrates	0.0057
jujube, mechanically harvested	carbohydrates	0.0032
jujube, livestock harvested	carbohydrates	0.0051
beech, mechanically harvested	protein	0.00023
"	oils	0.00055
beech, livestock harvested	protein	0.00082
"	oils	0.0020

4. Conclusions and Prospects for the Future

The research reported above is necessarily preliminary, since staple perennial crops are almost purely theoretical at the present time. The data presented in this Report show that the potential for such crops on marginal, especially steep, sites in Southern Appalachia is quite significant. A critical need in the near future is the establishment of demonstration plantings of the most promising candidate staple perennial species, such as honeylocust, persimmon, mulberry, jujube, and beech. Data on economics, yields, and other important factors would be generated by detailed studies of these plantings.

As a first step, I.T.C.I.U.S.A., Inc. and the Tennessee Valley Authority are cooperating in the establishment of five test plantings of selected honeylocusts in KY, TN, GA, AL, and AL.

Bibliography 1. Sources of General Data on Candidate Staple Perennial Crops

Coon, Nelson, 1974, The Dictionary of Useful Plants, Rodale Press, Emmaus, Pennsylvania.

Darrow, George M., 1975, "Minor Temperate Fruits", in Jules Janick and James N. Moore, eds., Advances in Fruit Breeding, Purdue University Press, West Lafayette, Indiana, 269-284.

Duke, James A., 1978, "The Quest for Tolerant Germplasm", in Gerald A. Jung, ed., Crop Tolerance to Suboptimal Land Conditions, American Society of Agronomy Special Publication No. 32, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, Wisconsin, 1-61.

Duke, James A., 1981, Handbook of Legumes of World Economic Importance, Plenum Press, New York.

Jaynes, Richard A., ed., 1979, Nut Tree Culture in North America, Northern Nut Growers Association, Hamden, Connecticut.

Loewenfeld, Claire, 1957, Britain's Wild Larder: Nuts, Faber & Faber, London.

Morton, Julia F., 1963, "Principal Wild Food Plants of the United States", Economic Botany 17, 319-330.

Podems, Marc, and Brenda Bertz, 1975, Ornamentals for Eating, Rodale Press, Emmaus, Pennsylvania.

SALUT, 1978, Feasibility of Introducing Food Crops Better Adapted to Environmental Stress, 2 vols., U.S. Government Printing Office, Washington, D.C.

Sherwood, Martha, 1978, Collecting Roots & Herbs for Fun & Profit, Contemporary Books, Chicago.

Smith, J. Russell, 1950, Tree Crops: A Permanent Agriculture, Devin-Adair, New York.

Staff of the L. H. Bailey Hortorium, Cornell University, 1976, Hortus Third: A Concise Dictionary of Plants Cultivated in the United States and Canada, Macmillan, New York.

Thompson, Bruce, 1978, Syrup Trees, Walnut Press, Fountain Hills, Arizona.

Turner, Nancy J., and Adam F. Szczawinski, 1979, Edible Wild Fruits and Nuts of Canada, National Museums of Canada, Ottawa.

Van Dersal, William R., 1938, Native Woody Plants of the United States, Their Erosion-Control and Wildlife Values, U.S.D.A. Miscellaneous Publication No. 303, U.S. Government Printing Office, Washington, D.C.

Wyman, Donald, 1977, Wyman's Gardening Encyclopedia, revised ed., Macmillan, New York.

Bibliography 2. Sources of Yield and Nutritional Composition Data

Barclay, A. S., and F. R. Earle, 1974, "Chemical Analyses of Seeds III: Oil and Protein Content of 1253 Species", Economic Botany 28, 178-236.

Boyd, Claude E., and Paul S. McGinty, 1981, "Percentage Digestible Dry Matter and Crude Protein in Dried Aquatic Weeds", Economic Botany 35, 296-299.

Burns, Thomas A., and Charles E. Viers, 1973, "Caloric and Moisture Content Values of Selected Fruits and Mast", Journal of Wildlife Management 37, 585-587.

Chatfield, Charlotte, and Laura I. McLaughlin, 1928, Proximate Composition of Fresh Fruits, U.S.D.A. Circular No. 50, U.S. Government Printing Office, Washington, D.C.

Duke, James A., 1978, "The Quest for Tolerant Germplasm", in Gerald A. Jung, ed., Crop Tolerance to Suboptimal Land Conditions, ASA Special Publication No. 32, American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America, Madison, Wisconsin, 1-61.

Duke, James A., 1981, Handbook of Legumes of World Economic Importance, Plenum Press, New York.

Earle, F. R., Quentin Jones, 1962, "Analysis of Seed Samples from 113 Plant Families", Economic Botany 16, 221-250.

Ensminger, M. E., and C. G. Olentine, Jr., 1978, Feeds & Nutrition - Complete, The Ensminger Publishing Co., Clovis, California.

Food and Agriculture Organization of the United Nations, 1970, Amino-Acid Content of Foods and Biological Data on Proteins, FAO Nutritional Studies, Rome, Italy.

Halls, Lowell K., ed., 1977, Southern Fruit-Producing Woody Plants Used by Wildlife, U.S.D.A. Forest Service General Technical Report SO-16, U.S. Government Printing Office, Washington, D.C.

Harvey, D., 1970, Tables of the Amino Acids in Foods and Feedingstuffs, 2nd edition, Commonwealth Agricultural Bureaux, Farnum Royal, Bucks, England.

Imperial Agricultural Bureax, 1947, The Use and Misuse of Shrubs and Trees as Fodder, Joint Publication No. 10, Imperial Bureau of Pastures and Field Crops, Aberystwyth, Imperial Forestry Bureau, Oxford, and Imperial Bureau of Animal Nutrition, Aberdeen, Great Britain.

Jacobs, P. Burke, and Harry P. Newton, 1938, Motor Fuels from Farm Products, U.S.D.A. Miscellaneous Publication No. 327, U.S. Government Printing Office, Washington, D.C.

Jones, Quentin, and F. R. Earle, 1966, "Chemical Analyses of Seeds II: Oil and Protein Content of 759 Species", Economic Botany 20, 127-155.

Low, Jessop B., and Frank C. Bellrose, Jr., 1944, "The Seed and Vegetative Yield of Waterfowl Food Plants in the Illinois River Valley", Journal of Wildlife Management 8, 7-22.

Marsh, Anne C., Mary K. Moss, and Elizabeth W. Murphy, 1977, Composition of Foods, Spices and Herbs, Raw, Processed, Prepared, U.S.D.A. Agriculture Handbook No. 8-2, U.S. Government Printing Office, Washington, D.C.

Martin, John H., and Warren H. Leonard, 1967, Principles of Field Crop Production, 2nd edition, Macmillan Co., New York.

Miller, Roger Wayne, et al., 1962, "Amino Acid Composition of Seed Meals from Forty-One Species of Cruciferae", Journal of Agricultural and Food Chemistry 10, 426-430.

Park, Barry C., 1942, "The Yield and Persistence of Wildlife Food Plants", Journal of Wildlife Management 6, 118-120.

Pennington, Jean A. T., and Helen Nichols Church, 1980, Food Values of Portions Commonly Used, 13th edition, Harper & Row, New York.

Podems, Marc, and Brenda Bertz, 1975, Ornamentals for Eating, Rodale Press, Emmaus, Pennsylvania.

Robson, John R. K., and Joel N. Elias, The Nutritional Value of Indigenous Wild Plants: An Annotated Bibliography, Whitson Publishing, Troy, New York, 1978.

Smith, C. R., Jr., et al., 1959, "Seed Protein Sources - Amino Acid Composition and Total Protein Content of Various Plant Seeds", Economic Botany 13, 132-150.

U.S. Department of Agriculture Economics and Statistics Service Crop Reporting Board, 1980, Field Crops: Estimates by States, 1974-78, Acreage, Yield, and Production, Statistical Bulletin No. 646, U.S.D.A., Washington, D.C.

U.S. Department of Agriculture Economics and Statistics Service Crop Reporting Board, 1981, Vegetables: Estimates by Seasonal Groups and States, 1974-78, Acreage, Yield, Production, and Value, Statistical Bulletin No. 665, U.S.D.A., Washington, D.C.

U.S. Department of Health, Education, and Welfare, and Food and Agriculture Organization of the United Nations, 1972, Food Composition Table for Use in East Asia, U.S.D.H.E.W., Washington, D.C.

VanEtten, C. H., et al., 1961, "Amino Acid Composition of Twenty-Seven Selected Seed Meals", Journal of Agricultural and Food Chemistry 9, 79-82.

Van Etten, C. H., et al., 1963, "Amino Acid Composition of Seeds from 200 Angiospermous Plant Species", Journal of Agricultural and Food Chemistry 11, 399-410

VanEtten, C. H., et al., 1967, "Plant Seeds as Protein Sources for Food or Feed", Journal of Agricultural and Food Chemistry 15, 1077-1089.

Waine, Walter W., and E. Forbes, 1941, "The Chemical Composition of Forest Fruits and Nuts from Pennsylvania", Journal of Agricultural Research 62, 627-635.

Watt, Bernice K., and Annabel L. Merrill, 1963, Composition of Foods, U.S.D.A. Agriculture Handbook No. 8, U.S.D.A. Agriculture Handbook No. 8, U.S. Government Printing Office, Washington, D.C.

Yanovsky, E., and R. M. Kingsbury, 1938, "Analyses of Some Indian Food Plants", Journal of the Association of Official Agricultural Chemists 21, 648-665.

Bibliography 3. Major References for Candidate Staple Perennials

Amelanchier spp.:

R. E. Harris, "The Saskatoon Berry", Northern Nut Growers Association 55th Annual Report, 1964, 56-57.

R. E. Harris, The Saskatoon, Publication 1246, Canada Department of Agriculture, 1966, 5 pp.

Dennis N. Madison, "Amelanchier - Three Seasons of Beauty", Northern Nut Growers 58th Annual Report, 1967, 133-135.

W. S. Miller and C. Stushnoff, "A Description of Amelanchier Species in Regard to Cultivar Development", Fruit Varieties and Horticultural Digest 25, 1971, 3-10.

Carya illinoinensis:

Clarence A. Reed and John Davidson, The Improved Nut Trees of North America and How to Grow Them, Devin-Adair, New York, 1958, 128-158.

George Madden, "Pecans", in Richard A. Jaynes, ed., Nut Tree Culture in North America, Northern Nut Growers Association, Hamden, Connecticut, 1979, 13-34.

Jasper Guy Woodroof, Tree Nuts: Production, Processing, Products, 2nd ed., AVI Publishing, Westport, Connecticut, 1979, 327-564.

John Gordon, Pecans, Society of Ontario Nut Growers, Niagara-on-the-Lake, Ontario, 1980, 12 pp.

Carya ovata:

Clarence A. Reed and John Davidson, The Improved Nut Trees of North America and How to Grow Them, Devin-Adair, New York, 1958, 107-127.

L. H. MacDaniels, "Hickories", in Richard A. Jaynes, ed., Nut Tree Culture in North America, Northern Nut Growers Association, Hamden, Connecticut, 1979, 35-50.

Crataegus spp.:

Michael A. Dirr, Manual of Woody Landscape Plants, Stipes Publishing, Champaign, Illinois, 1975, 158-163.

T. O. Warren, several articles on mayhaw in North American Pomona, 1970's.

Diospyros Kaki:

R. L. Watts, Persimmons, Agricultural Experiment Station Bulletin 11(1), University of Tennessee, 1899, 34 pp.

H. Harold Hume, "Planting Persimmons", Journal of Heredity 5, 1914, 131-138.

P. H. Dorsett, Culture and Outdoor Winter Storage of Persimmons in the Vicinity of Peking, China, Circular No. 49, U.S. Department of Agriculture, 1928, 11 pp.

Brooks D. Drain, The Japanese Persimmon in Tennessee, Agricultural Experiment Station Circular No. 51, University of Tennessee, 1934, 4 pp.

H. P. Gould, The Oriental Persimmon, Leaflet No. 194, U.S. Department of Agriculture, 1940, 8 pp.

Eugene Griffith and W. H. Preston, Jr., "The Oriental Persimmon in Maryland, Virginia and Pennsylvania", Plants and Gardens 17(1), Spring 1961, 32-34.
Pao-Ling Chiu, "Propagation of the Oriental Persimmon, Diospyros kaki L.", M.S. Paper, University of Maryland, 1973, 16 pp.
Eugene Griffith and Mary E. Griffith, Persimmons for Everyone, serialized in North American Pomona, 1970's, 109 pp.
James B. Shanks, "Cold Hardiness of Oriental Persimmons (Diospyros kaki) in Maryland", Northern Nut Growers Association 68th Annual Report, 1977, 111-113.
T. E. Crocker and C. P. Andrews, "Growing Persimmons", Fruit South 3(3), March 1979, 31-33.

Diospyros virginiana:

James Troop and O. M. Hadley, The American Persimmon, Agricultural Experiment Station Bulletin 7(60), Purdue University, 1896, 18 pp.
R. L. Watts, Persimmons, Agricultural Experiment Station Bulletin 11(1), University of Tennessee, 1899, 34 pp.
C. O. Eddy, "The Place of the Native Persimmon in Nature", Ohio Journal of Science 27, 1927, 187-199.
Bowen S. Crandall, "Known Range of Persimmon Wilt in 1939", U.S.D.A. Plant Disease Reporter 24, 1940, 168-169.
W. F. Fletcher, The Native Persimmon, Farmers' Bulletin No. 685, revised edition, U.S. Department of Agriculture, 1942, 22 pp.
George Slate, "Persimmons, A Promising Neglected Fruit", Northern Nut Growers Association 40th Annual Report, 1949, 154-157.
Bowen S. Crandall and W. L. Baker, "The Wilt Disease of American Persimmon, Caused by Cephalosporium Diospyri", Phytopathology 40, 1950, 307-325.
Harry R. Skallerup, "The Distribution of Diospyros virginiana L.", Annals of Missouri Botanical Garden 40, 1953, 211-225.
W. B. Ward, "The Papaw and Persimmon in Indiana", Northern Nut Growers Association 45th Annual Report, 1954, 59-62.
Louis Gerardi, "American Persimmon Varieties and Their Desirability", Northern Nut Growers Association 47th Annual Report, 1956, 132-136.
J. C. McDaniel, "Persimmon Evaluation - Further Notes", Northern Nut Growers Association 47th Annual Report, 1956, 136-138.
John E. Talbott, "The American Persimmon As We See It", Northern Nut Growers 48th Annual Report, 1957, 45-51.
John E. Talbott, "Some Improved Varieties of the American Persimmon", Northern Nut Growers Association 54th Annual Report, 1963, 70-74.
George Slate, "Persimmon Varieties", Northern Nut Growers Association 57th Annual Report, 1966, 136-139.
J. C. McDaniel, "Persimmon Notes, 1970", Northern Nut Growers Association 61st Annual Report, 1970, 106-109.
John E. Talbott, "Some Major Possibilities for a Minor Fruit", Northern Nut Growers Association 63rd Annual Report, 1972, 103-105.
Joseph C. McDaniel, "American Persimmon, an Emerging Horticultural Crop", Fruit Varieties Journal 27, 1973, 16-18.
J. C. McDaniel, "Persimmon Cultivars for Northern Areas", Fruit Varieties Journal 27, 1973, 94-96.
Eugene Griffith and Mary E. Griffith, Persimmons for Everyone, serialized in North American Pomona, 1970's, 109 pp.
Dennis E. Garrison, "An Analysis of the Feasibility of Establishing Commercial Persimmon Production in Illinois", M.S. Thesis, Southern Illinois

University, 1978, 57 pp.

Fagus grandifolia:

Claire Loewenfeld, Britain's Wild Larder: Nuts, Faber 1957, 199-209.
Clarence A. Reed and John Davidson, The Improved Nut T and How to Grow Them, Devin-Adair, New York, 203-210
D. F. Millikan, "Beeches, Oaks, Pines, and Ginkgo", in Nut Tree Culture in North America, Northern Nut Grow den, Connecticut, 1979, 175-177.

Gleditsia triacanthos:

Samuel Bertolet Detwiler, Notes on Honeylocust, U.S.D.A Service Manuscript, 1947, 197 pp.
J. C. Moore, "The Present Outlook for Honeylocust in the Growers Association 39th Annual Report, 1948, 104-110.
David T. Funk, Silvical Characteristics of Honeylocust, Experiment Station Miscellaneous Release 23, U.S.D.A. 14 pp.
P. L. leRoux, "Honey Locust Tree Useful Source of Fodder in South Africa 35(1), April 1959, 20-21.
P. L. leRoux, "Sheep Find Thin Honey-Locust Pods Palatabl Africa 35(2), May 1959, 18-19.
P. L. leRoux, "Red Indians Used Honey Locust Tree As Sour ing in South Africa 35(3), June 1959, 40-42.
P. L. leRoux, "Advantages and Disadvantages of the Honeyl South Africa 35(4), July 1959, 8.
J. W. C. Mostert and C. H. Donaldson, "Value of Honey Locu Negligible", Farming in South Africa 35(11), February 19
Peter Felker and Robert S. Bandurski, "Protein and Amine A Tree Legume Seeds", Journal of Science of Food and Agric 791-797.
Frank S. Santamour, Jr., "Where Are the Sweet Honeylocusts Association of Botanical Gardens and Arboreta Bulletin 1
T. Lennard, "The Story of the Honey Locust", Journal of the Crops Association 5, 1980, 14-17.
Eliot Tozer, "The Honeylocust", Horticulture 58(9), Septemb
Gregory Williams, "Honeylocust: An Update", North American 235-237.
George C. Avgerinos and Daniel I. C. Wang, "Utilization of Locust Pods as Feedstocks for Energy Production", in Sola Institute, Tree Crops for Energy Co-Production on Farms, Golden, Colorado, 1981, 209-217.
David Freedman, "Preliminary Analysis of the Potential for from Honeylocust Pods", in Solar Energy Research Institut Energy Co-Production on Farms, SERI, Golden, Colorado, 19
David H. Scanlon III, "A Case Study of Honeylocust in the T Region", in Solar Energy Research Institute, Tree Crops f duction on Farms, SERI, Golden, Colorado, 1981, 21-31.

Juglans cinerea and Juglans nigra:

B. G. Sitton, Vegetative Propagation of the Black Walnut, Agricultural Experiment Station Technical Bulletin No. 119, Michigan State College, 1931, 45 pp.

John T. Auten, Soil Profile Studies in Relation to Site Requirements of Black Locust and Black Walnut, Central States Forest Experiment Station Note No. 31, U.S.D.A. Forest Service, 1936, 11 pp.

Clarence A. Reed and John Davidson, The Improved Nut Trees of North America and How to Grow Them, Devin-Adair, New York, 1958, 40-54, 95-98.

Agricultural Research Service Northeastern Region, Growing Black Walnuts for Home Use, Leaflet No. 525, U.S. Department of Agriculture, 1976, 9 pp.

David T. Funk, "Black Walnuts for Nuts and Timber", in Richard A. Jaynes, ed., Nut Tree Culture in North America, Northern Nut Growers Association, Hamden, Connecticut, 1979, 51-73.

J. C. McDaniel, "Other Walnuts Including Butternut, Heartnut, and Hybrids", in Richard A. Jaynes, ed., Nut Tree Culture in North America, Northern Nut Growers Association, Hamden, Connecticut, 1979, 98-110.

Juglans regia:

Clarence A. Reed and John Davidson, The Improved Nut Trees of North America and How to Grow Them, Devin-Adair, New York, 1958, 71-94.

W. N. Fischer, F. L. S. O'Rourke, and R. R. Dedolph, "Evaluation of Carpathian Walnut Varieties", Quarterly Bulletin of the Michigan Agricultural Experiment Station 44, 1961, 245-247.

F. L. S. O'Rourke, R. R. Dedolph, and H. E. Larzelere, "Walnut Kernel Characteristics as Inferential Indices in Variety Discrimination", Proceedings of the American Society for Horticultural Science 83, 1963, 370-373.

Ernest Grimo, "Carpathian (Persian) Walnuts", in Richard A. Jaynes, Nut Tree Culture in North America, Northern Nut Growers Association, Hamden, Connecticut, 1979, 74-83.

Jasper Guy Woodroof, Tree Nuts: Production, Processing, Products, 2nd ed., AVI Publishing, Westport, Connecticut, 1979, 616-655.

Morus spp.:

L. H. Bailey, Mulberries, Agricultural Experiment Station Bulletin 46, Cornell University, 1892, 26 pp.

Greta Falk, "Mulberries - Food for Stock and Humans", Farmer's Weekly (South Africa) 84(12), December 1952, 15-16.

Myron Nixon, "Best Mulberry for Eating, Wildlife, Propagation", North American Pomona 14, 1981, 123-125.

L. E. Scott, "A Report on Mulberry Testing", North American Pomona 14, 1981, 159-162.

Quercus acutissima:

C. Hart Merriam, "The Acorn, A Possibly Neglected Source of Food", National Geographic Magazine 34, 1918, 129-137.

Robert T. Morris, "Edible Acorns as Food for Man, Livestock, and Fowls", Northern Nut Growers Association 18th Annual Report, 1927, 35-43.

Jesse Mercer, Jr., "Sawtooth Oak Holds Promise as Wildlife Plant for Southeast", Soil Conservation 34, 1969, 178.

Rubus spp.:

G. R. Brown, C. E. Chaplin, and J. G. Strang, Blackberries and Raspberries in Kentucky, HO-15, University of Kentucky, 1979, 9 pp.
Robert G. Hill, Jr., James D. Utzinger, and Richard C. Funt, Growing Bramble Fruit, Cooperative Extension Service Bulletin 411, Ohio State University, 1979, 15 pp.

Sambucus canadensis:

C. M. Ritter and G. W. McKee, The Elderberry: History, Classification, and Culture, Agricultural Experiment Station Bulletin 709, Pennsylvania State University, 1964, 22 pp.
D. L. Craig, Elderberry Culture in Eastern Canada, Publication 1280, Canada Department of Agriculture, 1966, 4 pp.
Robert M. Skirvin and Alan Otterbacher, "Elderberry Cultivar Performance in Illinois", Fruit Varieties Journal 31, 1977, 7-11.

Vaccinium corymbosum and Vaccinium macrocarpon:

Carl E. Chaplin and James K. Stacey, Blueberry Culture for Kentucky, Cooperative Extension Service Leaflet 284, University of Kentucky, 1966, 5 pp.
Norman F. Childers, Modern Fruit Science, Horticultural Publications, New Brunswick, New Jersey, 1976, 759-814.

Viburnum trilobum:

G. M. Darrow, "Viburnum Americanum as a Garden Fruit", Proceedings of the American Society for Horticultural Science 20, 1923, 44-54.
G. M. Darrow, "The American Cranberrybush", Journal of Heredity 15, 1924, 242-253.

Ziziphus Jujuba:

David Fairchild, "the Grafted Jujube of China", Journal of Heredity 9, 1918, 2-7.
W. B. Lanham, Jujubes in Texas, Agricultural Experiment Station Circular No. 41, Agricultural and Mechanical College of Texas, 1926, 28 pp.
William L. Ackerman, "Flowering, Pollination, Self-Sterility, and Seed Development of Chinese Jujube", Proceedings of the American Society for Horticultural Science 77, 1961, 265-269.
P. M. Lyrene, "The Jujube Tree", Fruit Varieties Journal 33, 1979, 100-104.
P. M. Lyrene and T. E. Crocker, The Chinese Jujube, FC-50, University of Florida, 1979, 3 pp.
P. M. Lyrene, "Chinese Jujube Tests and Evaluation", North American Pomona 14, 162-166.

Bibliography 4. References for Section 3

Blakely, B. D., J. J. Coyle, and J. G. Steele, 1957, "Erosion on Cultivated Land", in U.S.D.A., Soil: The Yearbook of Agriculture, U.S. Government Printing Office, Washington, D.C., 290-307.

Brink, R. A., J. W. Densmore, and G. A. Hill, 1977, "Soil Deterioration and the Growing World Demand for Food", Science 197, 625-630.

Cervinka, Vashek, 1980, "Fuel and Energy Efficiency", in David Pimentel, ed., Handbook of Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, 15-21.

Curry, Robert R., 1971, "Soil Destruction Associated with Forest Management and Prospects for Recovery in Geological Time", Association of Southeastern Biologists Bulletin 18, 117-128.

Fox, Austin S., and Kenneth C. Clayton, 1981, "Agriculture's Production Potential", in Economics and Statistics Service, Agriculture-Food Policy Review: Perspectives for the 1980's, U.S. Department of Agriculture, Washington, D.C., 70-80.

Funt, Richard C., 1980, "Energy Use in Low, Medium, and High Density Apple Orchards - Eastern U.S.", in David Pimentel, ed., Handbook of Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, 235-246.

Gee, C. Kerry, 1980, "Cultural Energy in Sheep Production", in David Pimentel, ed., Handbook of Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, 425-430.

Heichel, G. H., 1980, "Assessing the Fossil Energy Costs of Propagating Agricultural Crops", in David Pimentel, ed., Handbook of Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, 27-33.

O'Brien, Patrick M., 1981, "Global Prospects for Agriculture", in Economics and Statistics Service, Agricultural-Food Policy Review: Perspectives for the 1980's, U.S. Department of Agriculture, Washington, D.C., 2-26.

Phillips, Ronald E., et al., 1980, "No-Tillage Agriculture", Science 208, 1108-1113.

Pimentel, et al., 1976, "Land Degradation: Effects on Food and Energy Resources", Science 194, 149-155.

Pimentel, David, 1980, "Introduction", in David Pimentel, ed., Handbook of Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, 3-6.

Torgerson, David, and Harold Cooper, 1980, Energy and Agriculture: 1974 and 1978, U.S. Department of Agriculture Statistical Bulletin No. 632, U.S. Government Printing Office, Washington, D.C.

Appendix 1. Potential Staple Perennial Crops

Listed below are species with at least minimal potential for yielding protein, carbohydrates, and/or oils in quantities competitive with conventional staple crops (in particular, corn, soybeans, wheat, or potatoes) when grown on marginal land in Southern Appalachia. These species were chosen from over 2000 candidate perennials in the files compiled from the sources given in Bibliographies 1 and 2, plus additional minor sources. Each of the species merits some consideration in future research on perennial agriculture for Southern Appalachia, but some are much more promising than others, and little data are currently available on many. Decisions for inclusion in this "minimal or better potential" list were ultimately subjective, but the likelihood that other promising species were overlooked must be deemed very remote, given the comprehensive nature of the data base.

Botanical and common names were taken, almost without exception, from Hortus Third. Habit(s), also taken largely from Hortus Third, were coded as follows: G, grass; H, herb; S, shrub; T, tree; V, vine; and A, aquatic. Part(s) containing significant amounts of important nutrients were coded as follows: F, fruit; L, leaves; R, roots; S, sap; Sh, shoots. The nutrients include the following: P, protein (usually "crude protein", actually a measure of total nitrogen, is given in the sources); C, carbohydrates (especially starches and sugars, which are readily digested by nonruminants and are easily converted to ethanol); and O, oils.

Suitability rankings range from 1 to 3, with "?" used to designate insufficient quantitative data for numerical ranking. That is, numerical ranking was assigned only on the basis of available yield and nutritional composition for a given species. A species with likely high yields of protein, carbohydrates, and/or oils, but without published yield data, was assigned "?". In most cases, nutritional composition information is available for those species assigned "?". Thus, research on yields for these species might result in identification of several additional high-potential candidate staple crops. Suitability 1 indicates a species with high potential; suitability 2 indicates medium potential; and suitability 3 indicates low potential, all relative to typical yields of the important nutrients by conventional Southern Appalachian crops.

It is important to note that suitability ranking 1 was assigned using quite conservative criteria. All species so ranked appear capable of direct competition with conventional crops, from the standpoint of important nutrient yields. Perhaps these species should be considered for prime lands, as well as for marginal lands! A caveat in this line of thought is that no economic considerations were made in the choices of species for the list, or for the assignment of suitability rankings therein. However, some genera (including *Malus*, *Pyrus*, and *Prunus*) capable of large yields were assigned suitability rankings of 2 because experience has shown that they need high maintenance levels.

Botanical Name/Common Name	Habit(s)	Part(s)/Nutrient(s)	Suitability
Acer spp./maples	S, T	S/C, F/P	3
Acorus Calamus/sweet flag	H	R/C(?)	3
Actinidia arguta/bower actinidia	V	F/C	2
Actinidia chinensis/Chinese gooseberry	V	F/C	3
Actinidia Kolomikta/Kolomikta actinidia	V	F/C	2
Actinidia polygama/silver vine	V	F/C	3
Aesculus spp./buckeyes	S, T	F/C	2
Agropyron spp./wheatgrasses	G	F/C, F/P	2
Agrostis spp./bentgrasses	G	F/C, F/P	3
Ailanthus altissima/ tree of heaven	T	F/O, F/P	?
Akebia spp./akebias	V	F	?
Albizia Julibrissin/silk tree	T	L/P	?
Amelanchier spp./serviceberries	S, T	F/C	1
Andropogon spp./bluestems	G	F/C(?), F/P(?)	3
Angelica Archangelica/angelica	H	R/C(?)	3
Apios americana/groundnut	H	R/P	?
Aralia spp./aralias	H, S, T	R	?
Arctostaphylos spp./bearberries	S, T	F/C	?
Armoracia rusticana/horseradish	H	R/C	3
Aronia spp./chokeberries	S	F/C	?
Asclepias spp./milkweeds	H	F/P	?
Asimina triloba/pawpaw	S, T	F/C	3
Asparagus officinalis/asparagus	H	Sh/C	3
Berberis spp./barberries	S	F/C	?
Berchemia scandens/supplejack	S	F/C	2
Bouteloua spp./grama grasses	G	F/C(?), F/P(?)	3
Buchloe dactyloides/buffalo grass	G	F/C(?), F/P(?)	3
Callicarpa spp./beautyberries	S	F/C	2
Carya spp./hickories	T	F/O	1
Cassia spp./sennas	H	F/P	?
Castanea spp./chestnuts	S, T	F/C	3
Celtis spp./hackberries	T	F/C	?
Cephalanthus occidentalis/buttonbush	S	F	3
Ceratophyllum demersum/hornwort	A	L/P	2
Cercis occidentalis/redbud	T	F/P(?)	?
Chaenomeles spp./flowering quinces	S	F/C(?)	?
Chamaecyparis spp./false cypress	T	F/P, F/O, F/C(?)	2
Chionanthus spp./fringe trees	S, T	F	?
Cichorium Intybus/chicory	H	R	?
Cornus spp./dogwoods	S, T	F/C	3
Coronilla varia/crown vetch	H	F/P	3
Corylus spp./filberts	S, T	F/O, F/C, F/P	2
Crataegus spp./hawthorns	S, T	F/C	1
Cucurbita foetidissima/calabazilla	H	R/C, F/P, F/O	2
Cudrania tricuspidata/silkworm tree	T	F/C	?
Cydonia oblonga/quince	S, T	F/C	?
Cyperus spp./nut sedges	A	R/C, F/C, F/O	3
Daphne spp./daphnes	S	F/P, F/O	?
Dioscorea bulbifera/air potato	V	R/C	2
Diospyros Kaki/Kaki persimmon	T	F/C	1
Diospyros virginiana/common persimmon	T	F/C	1

Botanical Name/Common Name	Habit(s)	Part(s)/Nutrient(s)	Suitability
Echinacea spp./coneflowers	H	F/P, F/O	?
Elaeagnus spp./elaeagnus	S, T	F/C	?
Eriobotrya japonica/loquat	T	F/C	3
Fagus spp./beeches	T	F/O, F/P	1
Ficus carica/common fig	S	F/C	?
Fragaria spp./strawberries	H	F/C	2
Fraxinus spp./ashes	T	F/C	?
Gaultheria spp./wintergreens	S	F/O(?)	?
Gaylussacia spp./huckleberries	S	F/C	?
Ginkgo biloba/ginkgo	T	F/C	?
Gleditsia triacanthos/honeylocust	T	F/P, F/C	1
Gymnocladus dioica/Kentucky coffee tree	T	F/P, F/C	?
Helianthus tuberosus/Jerusalem artichoke	H	R/C	1
Hemerocallis spp./daylillies	H	R/C(?)	?
Hibiscus Moscheutos/common rose mallow	H	F/P	?
Hippophae rhamnoides/sea buckthorn	T	F/P	?
Ilex spp./hollies	S, T	F/C	?
Juglans spp./walnuts	T	F/O, F/P	1
Juniperus spp./junipers	S, T	F/O, F/P, F/C	?
Lespedeza cuneata/sericea lespedeza	S	F/P	3
Lewisia rediviva/bitterroot	H	R/C	?
Ligustrum spp./privets	S	F/C	?
Lindera Benzoin/spicebush	S	F/C, F/O	?
Liquidambar Styraciflua/sweet gum	T	F/P, F/O	?
Lonicera spp./honeysuckles	V	F/C	?
Lotus spp./trefoils	H	F/P	3
Maclura pomifera/osage orange	T	F/C, F/P, F/O	?
Magnolia spp./magnolias	S, T	F/O, F/C	?
Mahonia spp./mahonias	S	F/C	?
Malus spp./apples	T	F/C	2
Medicago sativa/alfalfa	H	F/P	3
Mespilus germanica/medlar	S	F/C	?
Morus spp./mulberries	T	F/C	1
Myrica spp./bayberries	S	F/C, F/O	?
Nelumbo spp./lotuses	A	R/C, R/P	?
Nemopanthus mucronatus/catberry	S	F/C	?
Nyssa sylvatica/sour gum	T	F/C	?
Parthenocissus spp./creepers	V	F/C(?),F/O(?)	?
Phytolacca americana/poke	H	F/C	?
Pinus spp./pines	T	F/O, F/P	?
Prunus spp./stone fruits	S, T	F/C	2
Pueria lobata/kudzu	V	R/C	?
Pyrus communis/common pear	T	F/C	2
Quercus acutissima/sawtooth oak	T	F/C	1
Quercus spp./other oaks	T	F/C	3
Rhamnus spp./buckthorns	S, T	F/P, F/O	?
Rheum Rhabarbarum/rhubarb	H	Sh/C	3
Rhus spp./sumacs	S, T	F/C	2
Ribes spp./currants and gooseberries	S	F/C	3
Robinia Pseudoacacia/black locust	T	F/P	?
Rosa spp./roses	S	F/C	?

Botanical Name/Common Name	Habit(s)	Part(s)/Nutrient(s)	Suitability
Rubus spp./brambles	S	F/C	1
Sambucus spp./elders	S, T	F/C	1
Sassafras albidum/sassafras	T	F/C, F/O	?
Shepherdia spp./buffalo berries	S	F/C	?
Smilax spp./greenbriars	V	F/C	2
Solanum spp./nightshades	H	F/C	?
Sorbus spp./mountain ashes	T	F/C	?
Sorghum halepense/Johnson grass	G	F/C	?
Symphoricarpos spp./snowberries	S	F/C(?)	?
Symphytum X uplandicum/Russian comfrey	H	L/P	2
Taraxacum officinale/dandelion	H	R/C	3
Tilia spp./basswoods	T	F/C	?
Typha spp./cattails	A	R/C	2
Ulmus spp./elms	T	F/O, F/C, F/P	?
Vaccinium spp./blueberries and cranberries	S	F/C	1,2
Viburnum spp./viburnums	S	F/C	1
Vitis spp./grapes	V	F/C	2
Ziziphus Jujuba/common jujube	S, T	F/C	1

Appendix 2. "Tree Crops for Energy Production in Appalachia"

This paper is reprinted from the Proceedings of a Conference on Tree Crops for Energy Co-Production on Farms, sponsored by the Solar Energy Research Institute, Golden, Colorado. The Conference was held in Estes Park, Colorado, November 12-14, 1980. SERI's document code for the Proceedings (available from NTIS) is CP-622-1086.

(removed pgs. 1-10)

LITERATURE CITED

Allen, S.Q., Browning, W., Moore, C.L., and Debertin, D.L. 1978. Estimated costs and returns for production of various crops and livestock in Kentucky during 1978-1979. Univ. of Ky. Agr. Econ. Extens. Infor. Ser. No. 16.

Anonymous. 1980. Crop production costs taking big bite. Farmline 1 (6): 10-13.

Coltrane, R.I. and Baum, E.L. 1965. An economic study of the Appalachian region, with special reference to agriculture. USDA Agr. Econ. Rep. No. 69.

Colyer, D.K. 1976. Land use patterns in Appalachia. In Hill lands: proceedings of an international symposium, eds. J. Luchok, J.D. Cawthon, and M.J. Breslin, pp. 297-301. West Virginia University, Morgantown, West Virginia.

Detwiler, S.B. 1947. Notes on honeylocust. USDA Soil Conservation Service mimeo.

Fletcher, W.F. 1942. The native persimmon. USDA Farmers' Bull. No. 685.

Griffith, C.E. and Griffith, M.E. 1975. Persimmons for everyone. North American pomona 8:P-21-P-28.

Jacobs, P.B. and Newton, H.P. 1938. Motor fuels from farm products. USDA Misc. Publ. No. 327.

McArthur, W.C. 1979. The South. In Another revolution in U.S. farming?, pp. 303-34. USDA ESCS Agr. Econ. Rep. No. 441.

McDaniel, J.C. 1973. American persimmon, an emerging horticultural crop. Fruit varieties journal 27: 16-18.

Paul, J.K., ed. 1979. Ethyl alcohol production and use as a motor fuel. Noyes Data Corporation, Park Ridge, New Jersey.

Phillips, R.E., Blevins, R.L., Thomas, G.W., Frye, W.W., and Phillips, S.H. 1980. No-tillage agriculture. Science 208: 1108-13.

Pickard, J.P. 1980. Counting noses in Region and nation: a projection. Appalachia 13 (2): 1-12.

Pimentel, D. and Pimentel, M. 1979. Food, energy, and society. Edward Arnold, London.

Smith, J.R. 1950. Tree crops: a permanent agriculture. Devin-Adair, New York.

Solar Energy Research Institute. 1980. Fuel from farms--a guide to small-scale ethanol production. SERI-SP-451-519.

Toole, E. R. and Lightle, P. C. 1960. Status of persimmon wilt, 1959. Plant disease reporter 44: 45.

Troop, J. and O. M. Hadley. 1896. The American persimmon. Purdue Univ. Agr. Exper. Sta. Bull. No. 60.

Westwood, M. N. 1979. Temperate-zone pomology. W. H. Freeman, San Francisco.

ACKNOWLEDGMENTS

This paper is based in part on research supported by Grant No. DE-FG44-80R410085 from the U.S. Department of Energy. Ralph Kreider, Jr. provided information on honeylocust, Joseph C. McDaniel, James V. Claypool, and Dennis E. Garrison contributed data on persimmon, and John H. Kitch generously made available John Hershey's private papers.

TABLE 1. Woody perennials suited to Appalachian conditions which produce high (non-cellulosic) carbohydrate content fruits

Scientific Name	Common Name	Plant Type	Fruit Type	Fruit Size
Actinidia arguta Miq.	tara	vine	berry	3/4"
Aesculus spp. L.	buckeyes	tree	capsule	1-3"
Amelanchier spp. Med.	serviceberries	shrub or small tree	pome	1/4-1/2"
Arctostaphylos uva-ursi (L.) Spreng.	bearberry	shrub	drupe	1/4-1/2"
Aronia spp. Med.	chokeberries	shrub	pome	1/4-1/2"
Asimina triloba (L.) Dunal.	pawpaw	shrub or small tree	berry	2-7"
Berberis spp. L.	barberries	shrub	berry	1/4-1/2"
Callicarpa americana L.	American beautyberry	shrub	drupe	0.03"
Carya spp. Nutt.	hickories	tree	nut	3/4-1 1/2"
Castanea spp. Mill.	chestnuts	tree	nut	1/2-1 1/2"
Celtis spp. L.	hackberries	tree	drupe	1/4"
Chaenomeles lagenaria Koid.	Japanese quince	shrub	pome	1 1/2-2"
Chionanthus virginicus L.	fringetree	shrub or small tree	drupe	3/4"
Cornus spp. L.	dogwoods	shrub or small tree	drupe	1/8-1/4"
Corylus spp. L.	hazels	shrub	nut	1/2"
Crataegus spp. L.	hawthorns	shrub or small tree	pome	1/4-1/2"
Cudrania tricuspidata (Carr.) Bar.	che	small tree	drupe aggregate	1-1 1/2"

TABLE 1. (continued)

Scientific Name	Common Name	Plant Type	Fruit Type	Fruit Size
Cydonia oblonga Mill.	quince	shrub or small tree	pome	ca. 3"
Diospyros spp. L.	persimmons	tree	berry	1/2-4"
Elaeagnus spp. L.	elaeagnus	shrub or tree	drupe	1/4-3/4"
Fagus spp. L.	beeches	tree	nut	1/2-1"
Gaultheria spp. L.	wintergreens	shrub	pseudoberry	0.1-0.4"
Gaylussacia spp. L.	huckleberries	shrub	drupe	1/4-1/2"
Ginkgo biloba L.	ginkgo	tree	drupe	1"
Gleditsia triacanthos L.	honeylocust	tree	pod	3-20" long
Gymnocladus dioicus (L.) K. Koch	Kentucky coffeetree	tree	pod	6-10" long
Ilex spp. L.	hollies	shrub or tree	drupe	1/4-1/2"
Juglans spp. L.	walnuts	tree	nut	1-1 1/2"
Juniperus virginiana L.	eastern redcedar	tree	berry	1/8"
Ligustrum spp. L.	privets	shrub	drupe	1/3-1/2"
Lindera benzoin L. Blume	spicebush	shrub	drupe	1/2"
Lonicera spp. L.	honeysuckle	shrub or vine	berry	1/4"
Maclura pomifera (Raf.) Schneid.	osage-orange	small tree	drupe aggregate	4-5"
Malus spp. Mill.	apples	tree	pome	1/2-4"

TABLE 1. (continued)

Scientific Name	Common Name	Plant Type	Fruit Type	Fruit Size
Mespilus germanica L.	medlar	small tree	pome	1-2 1/2"
Mitchella repens L.	partridge-berry	vine	berry	1/4"
Morus spp. L.	mulberries	tree	drupe aggregate	1/2-1"
Myrica spp. L.	bayberries	shrub or small tree	drupe	1/8-1/6"
Nemopanthus mucronata (L.) Trel.	mountain-holly	shrub	drupe	1/4-1/3"
Parthenocissus spp. Planch.	creepers	vine	berry	1/4"
Pinus spp. L.	pines	tree	cone	seeds, 1/8-1/2"
Prunus spp. L.	cherries, plums and peaches	tree	drupe	1/2-3"
Pyrus communis L.	pear	tree	pome	1 1/2-4"
Quercus spp. L.	oaks	tree	acorn	1/2-1 1/2"
Rhamnus spp. L.	buckthorns	shrub or small tree	drupe	1/4-3/8"
Rhus spp. L.	sumacs	shrub or tree	drupe	0.12-0.16"
Ribes spp. L.	currants, gooseberries	shrub	berry	1/4-1"
Rosa spp. L.	roses	shrub	hip	1/8-1/2"
Rubus spp. L.	blackberries, raspberries	shrub or vine	drupe aggregate	1/2"
Sambucus spp. L.	elders	shrub or small tree	drupe	1/8-1/4"

TABLE 1. (continued)

Scientific Name	Common Name	Plant Type	Fruit Type	Fruit Size
Sassafras albidum (Nutt.) Nees	sassafras	tree	drupe	1/3-1/2"
Shepherdia spp. Nutt.	buffaloberry	shrub	berry	1/8-1/4"
Smilax spp. L.	greenbriers	vine	berry	1/4"
Solanum dulcamara L.	bitter nightshade	vine	berry	1/2"
Sorbus spp. L.	mountain-ash	shrub or tree	pome	1/4-1/2"
Symphoricarpos spp. Duham.	snowberries	shrub	berry	1/4"
Vaccinium spp. L.	blueberries, cranberries	shrub	berry	1/4-1"
Viburnum spp. L.	viburnums	shrub or small tree	drupe	1/4-1/2"
Vitis spp. L.	grapes	vine	berry	1/3-1"
Ziziphus jujuba Mill.	jujube	tree	drupe	1-2"

TABLE 2. Estimated ethanol production from selected woody perennials

Scientific Name	Common Name	Est. Ethanol (Gal. /Acre)	Notes
Amelanchier spp. Med.	serviceberries	30-130	low maintenance; precocious
Asimina triloba (L.) Dunal.	pawpaw	20-40	difficult to establish, but low maintenance
Carya illinoensis (Wang.) K. Koch	pecan	2-3	slow to bear; tends to alternate-bear; needs long growing season to mature nuts
Carya ovata (Mill.) K. Koch	shagbark hickory	5-8	slow to bear
Castanea mollissima Bl.	Chinese chestnut	3-50	precocious; blooms fairly early (may be subject to late frosts)
Cornus spp. L.	dogwoods	ca. 7	low maintenance
Corylus spp. L.	hazels	3-30	filbert blight; high protein
Crataegus spp. L.	hawthorns	ca. 110	low maintenance
Diospyros kaki L.	Oriental persimmon	80-640	hardiness problems; blooms early (subject to late frosts); difficult to establish
Diospyros virginiana L.	persimmon	140-360	wilt disease, TN and south; low maintenance; difficult to establish
Fagus grandifolia Ehrh.	American beech	ca. 6	
Gleditsia triacanthos L.	honeylocust	160-960	tends to alternate-bear; low maintenance; mimosa webworm in some areas; high protein
Ilex spp. L.	hollies	ca. 7	
Juglans nigra L.	Eastern black walnut	2-4	tends to alternate-bear; high protein

TABLE 2. (continued)

Scientific Name	Common Name	Est. Ethanol (Gal. /Acre)	Notes
Juglans regia L.	Persian walnut	5-40	blooms early (subject to late frosts); high protein
Malus pumila Mill.	apple	40-670(max.)	high maintenance
Morus spp. L.	mulberries	ca. 100 (or more?)	low maintenance; birds eat fruit
Prunus americana Marsh.	wild plum	ca. 2	blooms early (subject to late frosts)
Prunus avium L.	sweet cherry	190(max.)	high maintenance; birds eat fruit
Prunus cerasus L.	sour cherry	130(max.)	high maintenance; birds eat fruit
Prunus domestica L.	plum	270(max.)	high maintenance
Prunus persica (L.) Batsch.	peach	350(max.)	high maintenance; blooms early (subject to late frosts)
Pyrus communis L.	pear	530(max.)	high maintenance
Quercus spp. L.	oaks (most)	20(max.)	extremely variable bearing; slow to bear
Quercus acutissima Carr.	sawtooth oak	ca. 70 at 10 yrs. old	annual bearing; precocious; low maintenance
Ribes spp. L.	currants, gooseberries	3-40	low maintenance; host for white pine blister rust
Rubus spp. L.	blackberries, raspberries	210(max.)	low maintenance(?)
Sambucus canadensis L.	elderberry	40-110	low maintenance; precocious
Vaccinium corymbosum L.	blueberry	30-160	requires acid soil

TABLE 2. (continued)

Scientific Name	Common Name	Est. Ethanol (Gal. /Acre)	Notes
Vaccinium macrocarpon Ait.	cranberry	70-350	requires bogs; high maintenance
Viburnum trilobum Marsh.	highbush cranberry	60-280	low maintenance; precocious
Vitis spp. L.	grapes	60-240	high maintenance
Ziziphus jujuba Mill.	jujube	ca. 150	low maintenance

TABLE 3. Feasibility ranking of selected woody perennials for ethanol production

Group 1, high feasibility (high yields, low maintenance)	Group 2, medium feasibility (high yields, high maintenance)	Group 3, low feasibility (low yields)
blackberries, raspberries	apple	American beech
blueberry	cranberry	Chinese chestnut
elderberry	grapes	currants, gooseberries
hawthorns	peach	dogwoods
highbush cranberry	pear	Eastern black walnut
honeylocust	plum	hazels
jujube	sour cherry	hollies
mulberries	sweet cherry	oaks
Oriental persimmon		pawpaw
persimmon		pecan
sawtooth oak		Persian walnut
serviceberries		shagbark hickory
		wild plum

International Tree Crops Institute U. S. A., Inc.

nonprofit research & promotion of multipurpose tree crops for agriculture & conservation

Appalachian Regional Office: Route 1, Gravel Switch, KY 40328 (606) 332-7606

December 17, 1981

Roy F. Pettit
Director
Atlanta Support Office
Department of Energy
Savannah River Operations Office
1655 Peachtree Street, N.E.
Atlanta, GA 30309

Dear Mr. Pettit:

Thank you very much for giving approval of our program period for Grant No. DE-FG4480R410085 to be extended to 12-31-81. I am enclosing signed copies of the amended Grant Award, as requested.

Unfortunately, it is taking a bit longer than originally expected to get the final report out, and I now can promise delivery of all documents sometime in January, rather than this month. Accordingly, I need to ask for an additional one-month extension, unless it is all right to get the documents in by the end of January under the present extension. In any case, I assure you that the project will be completely finished with report copies to your Office before 1-31-82. No Grant Award money will be spent after this month.

Thank you for understanding in this situation.

Sincerely yours,

Gregory Williams

Gregory Williams
Director

GW/pyw

RECEIVED
DEC 21 1981

International Tree Crops Institute U. S. A., Inc.

nonprofit research & promotion of multipurpose tree crops for agriculture & conservation

Appalachian Regional Office: Route 1, Gravel Switch, KY 40328 (606) 332-7606

Distribution:

Ltr sent
to Butler/tor
2/3/82

January 30, 1982

Project Officer
Appropriate Technology Program
U.S. Department of Energy
1655 Peachtree Street, N.E.
Atlanta, GA 30309

Dear Project Officer:

I am pleased to enclose a copy of the Final Technical Report, incorporating all deliverables, for our Appropriate Technology Small Grants Program Grant No. DE-FG44-80R410085, "Energy-Conserving Perennial Agriculture for Marginal Land in Southern Appalachia." Copies of this Report are being sent to the DOE Contracting Officer and the Kentucky Appropriate Technology Officer, also.

We have some money left in our account for this Grant (including interest) which needs to be returned to D.O.E., as per the Grant conditions. I expect to receive a grant close-out letter from your office in the near future to expedite this.

Thank you for your continuing support.

Sincerely yours,

Gregory Williams

Gregory Williams
Director

cc: Miles Merwin
Encl.
GW/pyw