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AN INVENTORY OF AGRICULTURAL LAND IN THE TENNESSEE VALLEY REGION AND ITS AVAILABILITY FOR FUEL CROPS

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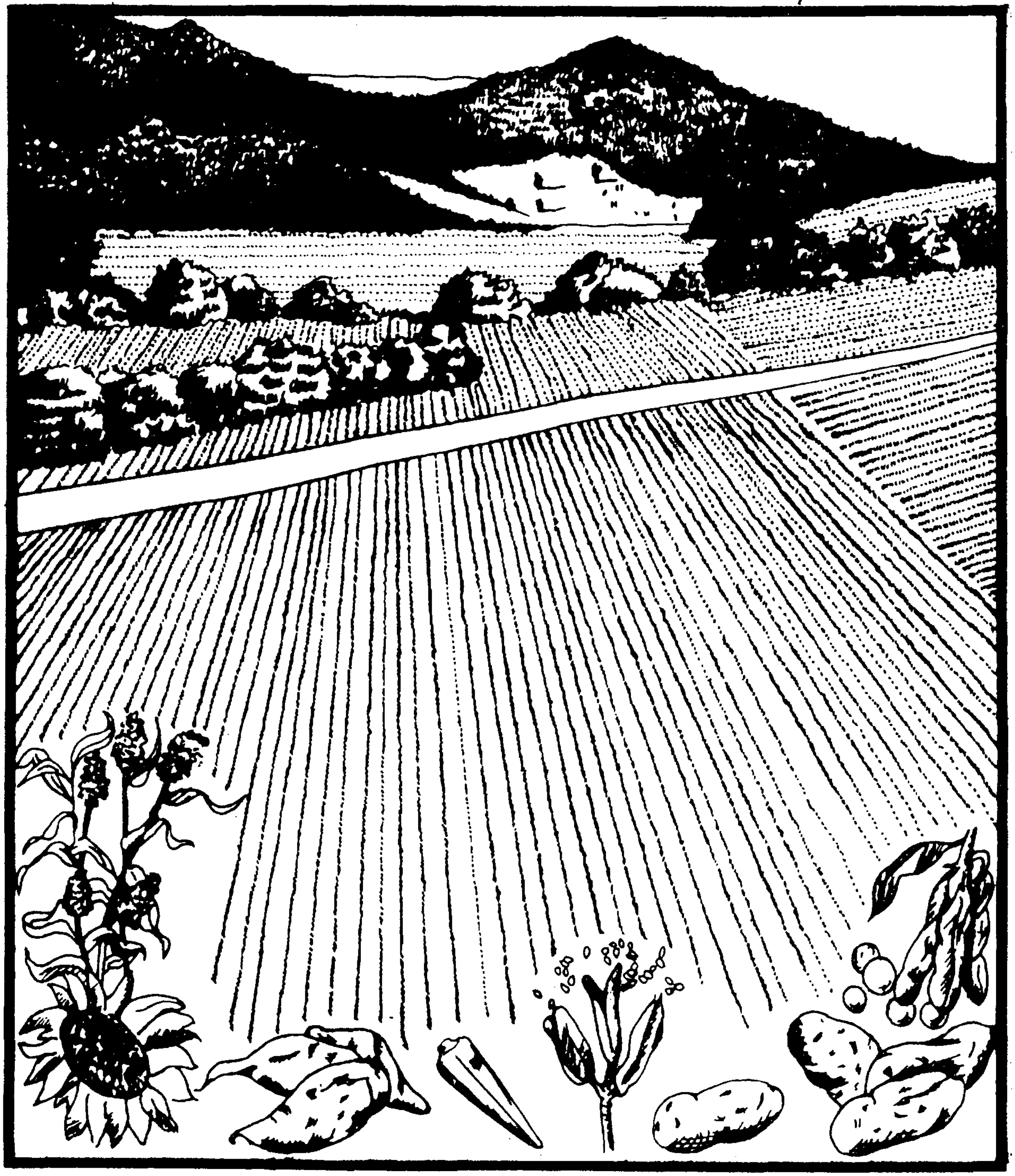

TVA Biomass Fuels Program

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AN INVENTORY OF AGRICULTURAL LAND IN THE TENNESSEE VALLEY REGION AND ITS AVAILABILITY FOR FUEL CROPS

John M. Soileau[1]

Introduction

Assessment of land availability and the potentials for crop production in the Tennessee Valley region is an important segment of TVA's diversified biomass fuels program. A prerequisite for such an evaluation is that producing agricultural crops for fuel uses does not significantly reduce food and fiber production needed for the region or Nation, and does not cause excessive soil erosion.

Objectives

This report: (1) presents an inventory of soil resources in the Tennessee Valley region; (2) describes present uses of this land base, emphasizing agricultural crop production; (3) identifies unused or underused openland capable of growing fuel crops; (4) estimates current availability of crop residues for fuel use within the Tennessee Valley region; and (5) reveals interest and capability of farmers to make cropping system conversions possibly required in future fuel crop production. This report also updates previous (out of print) TVA publications on Tennessee Valley region land and its use (Smith and Soileau, 1966; Soileau, et al, 1971). An economic analysis of fuel crop production (compared with conventional food and fiber crops) is not an objective of this report. Basic land, crop, and other farm-related data presented here should, however, be useful for possible future feasibility studies on production of fuels from agricultural crops in the Tennessee Valley region.

To provide compatibility with many other TVA programs and data bases, the 201-county TVA watershed and power service area was used in this assessment study.

Source of Data

The USDA Soil Conservation Service 1967 Conservation Needs Inventory (CNI) (USDA, 1966) and 1977 National Resource Inventory (NRI) (USDA-SCS, 1977) provided most of the basic land resource data for estimating soil productivity and land capability. Information on farm-related factors, such as total land in farms, acreage distribution of various crops, farm income, and on-farm consumption of gasoline and diesel fuel, were obtained from the latest available (1978) United States Agricultural Census (USDA-SRS, 1978).

As a supplement to basic data from USDA land inventories and the agricultural census, a questionnaire survey was conducted during the spring of 1981 with the cooperation of the State Agricultural Extension Services of the seven States within the Tennessee Valley. A two-page questionnaire (appendix) was directed to each of the 201 TVA region county extension offices regarding such issues as farmer attitudes toward making land conversions to biomass fuel crops, present hindrances that farmers may perceive in making these conversions, estimates of underused open land, soil erosion problems, and possible interest in cooperative farm fuel crop demonstrations. Results of this survey (Soileau, 1981) were intermeshed with the other basic data used in this assessment study.

Total annual crop residue available for fuel production within the TVA region were estimated from agricultural crop census data, residue/crop yield ratios, and the amounts of returned residue required annually for maintenance of soil productivity. Other basic data used in assessing the suitability of land areas for fuel crop production included published soil survey reports, prime farmland maps, and other regional publications.

Major Land Resource Areas and Soils

Data summaries and potentials for fuel crop production will be considered largely in terms of 12 geographic subareas which approximate major land resource areas (LRAs) (USDA, 1963) occurring within the 201-county TVA region (Figures 1 and 2). This grouping (Figure 2) allows an intermeshing of county-wide agricultural census and other farm-related data with land capability data based on inherent soil characteristics. Since land resource areas are characterized by a combination or pattern of soils, climate, water resources, land use, and types of farming, they are useful delineations to use in comparing agricultural potentials from one geographic area to another. The proportion of the total 201-county TVA region occupied by each of the 12 major

[1]Research Soil Scientist, Agricultural Research Branch, Division of Agricultural Development, OACD, TVA, Muscle Shoals, Alabama.

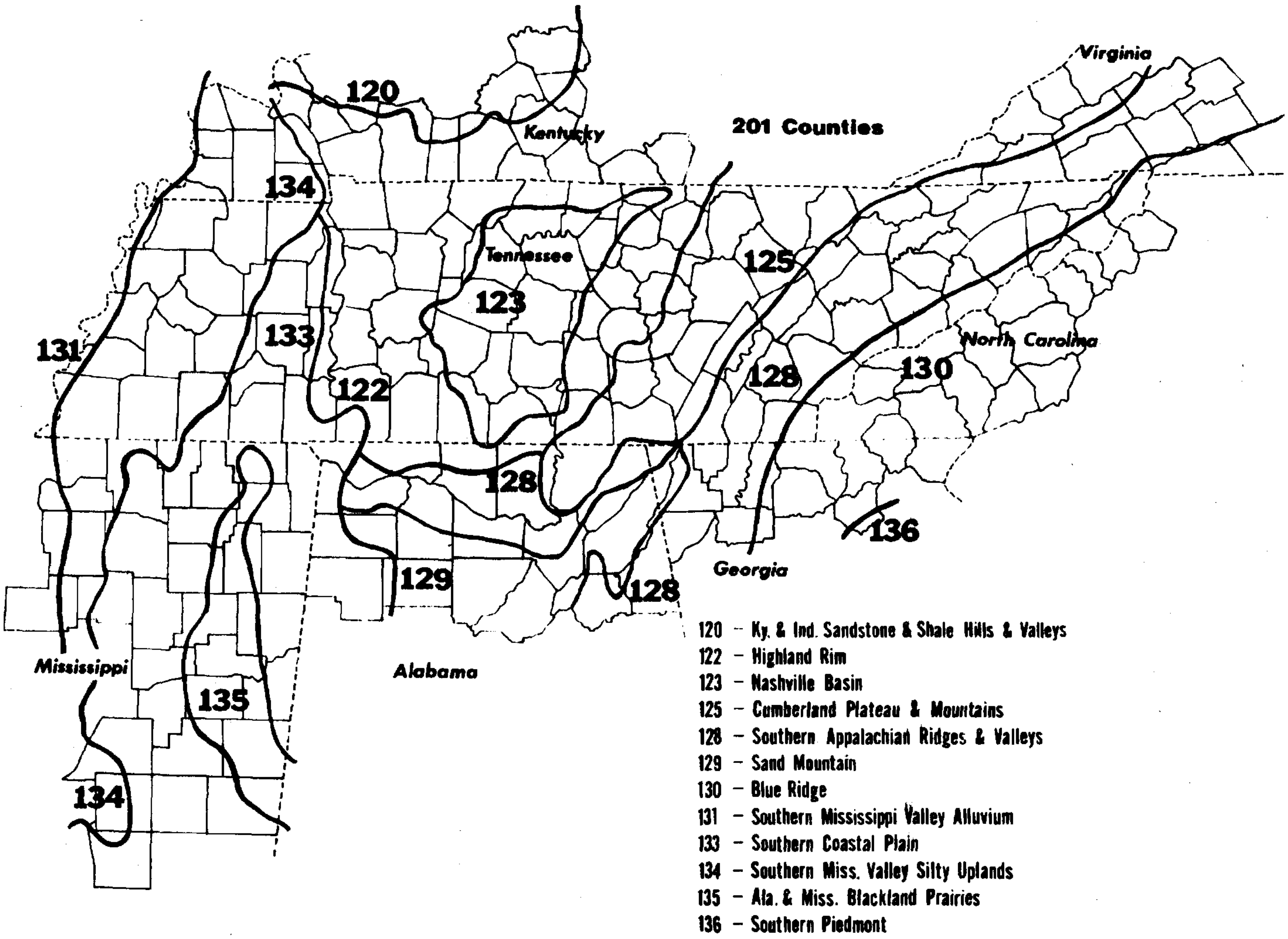

Figure 1. Major land resource areas of the Tennessee Valley region

land resource areas (county approximates—Figure 2) is shown in Table 1.

The following section is a general description of the physical characteristics and extent of the major land resource areas occurring in the Tennessee Valley power service and watershed area.

Blue Ridge Mountains (LRA 130)

This area occurs in western North Carolina, eastern Tennessee, southwestern Virginia, and northern Georgia. Counties designated within the Blue Ridge land resource area comprise about 10 percent of the 58.5 million total acres occuring within the 201-county Tennessee Valley region (Table 1 and Figure 2). The terrain consists mainly of mountain ridges with steep slopes, foothills, and narrow intervening valleys. Elevations range from about 1,000 to 6,000 feet above sea level. Upland soils are generally shallow and stony, being derived from acid crystalline metamorphic and igneous rocks (gneiss, schist, slate, quartzite, granite, and diorite) and some sedimentary rocks (mainly sandstone and shale). Characteristics of the upland soils are closely associated with differences in the parent rock and slope positions. Commonly occurring soil series of the uplands include Porters, Ashe, Clifton, Fannin, Hayesville, Talledega, and Ramsey, which are classified in the Dystrochrept and Hapludult Great Groups in soil taxonomy (USDA, 1975).

The relatively small proportion of this land resource area well suited to agriculture occurs in small but intensively farmed alluvial areas along streams and footslopes and other limited acreages of smoother

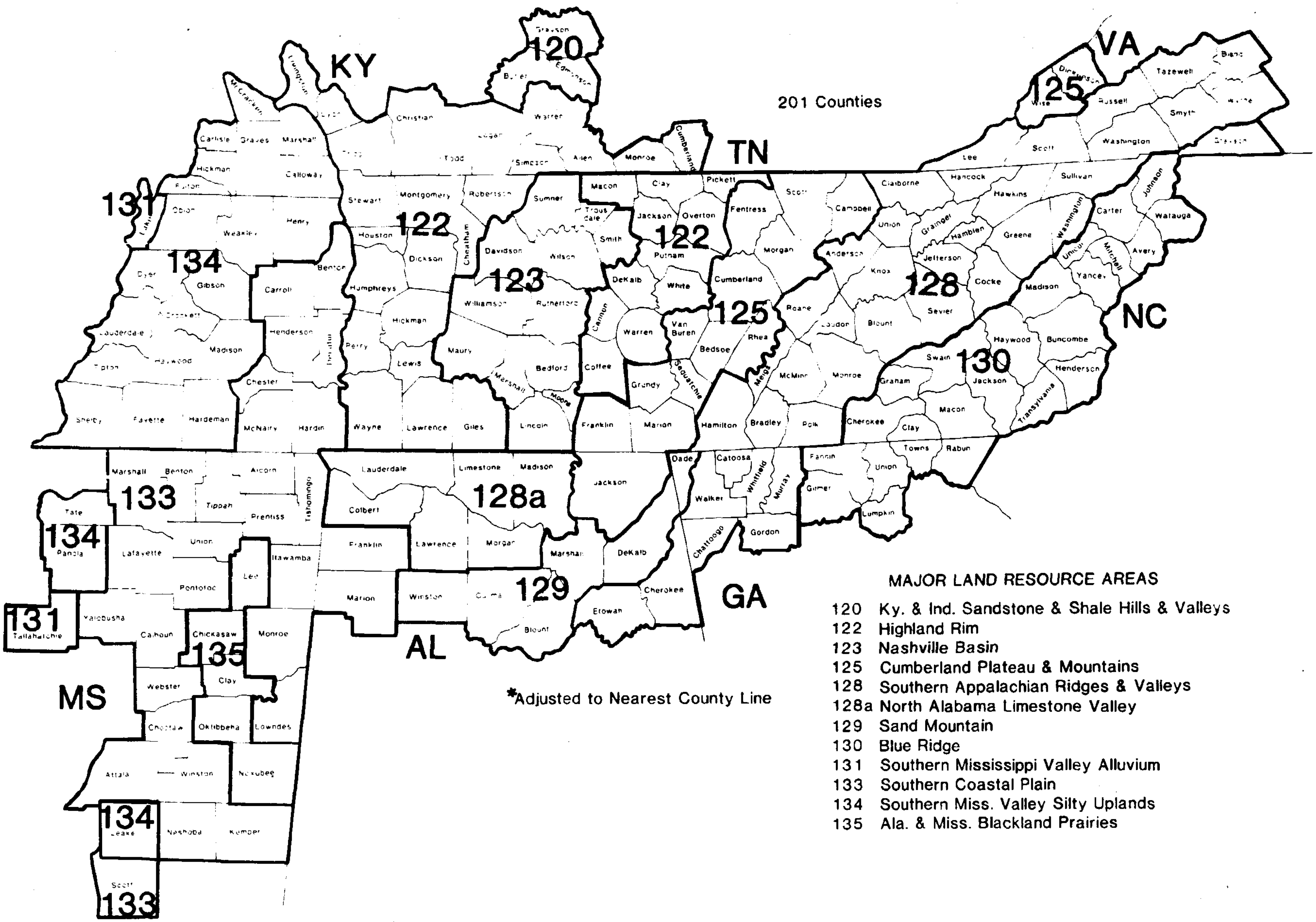

Figure 2. County approximation of major land resource areas* of the Tennessee Valley region .

Table 1. Distribution of Land by Major Land Resource Areas (County Approximations), 201-County Tennessee Valley Region[a]

Land resource area (LRA)	Description	Inventory land[b]		Noninventory land[c]		Total land within LRAs	
		Acreage (000)	Percent	Acreage (000)	Percent	Acreage (000)	Percent of total land area
120	Kentucky and Indiana Sandstone and Shale Hills and Valleys	738	91.5	68	8.5	806	1.4
122	Highland Rim	8,417	91.1	825	8.9	9,242	15.8
123	Nashville Basin	3,152	90.6	328	9.4	3,480	5.9
125	Cumberland Plateau and Mountains	4,390	94.8	239	5.2	4,629	7.9
128	Southern Appalachian Ridges and Valleys	8,482	83.4	1,683	16.6	10,166	17.4
128a	North Alabama Limestone Valley	2,181	87.1	322	12.9	2,504	4.3
129	Sand Mountain	2,029	90.2	222	9.8	2,250	3.8
130	Blue Ridge Mountains	4,017	67.8	1,909	32.2	5,926	10.1
131	Southern Mississippi Valley Alluvium	501	96.4	19	3.6	519	0.9
133	Southern Coastal Plain	9,478	91.9	835	8.1	10,314	17.6
134	Southern Mississippi Valley Silty Uplands	6,524	92.4	535	7.6	7,059	12.1
135	Blackland Prairies	1,491	92.3	124	7.7	1,615	2.8
	Total Tennessee Valley Region	51,399	87.8	7,109	12.2	58,508	100.0

[a] Based on 1967 USDA Soil Conservation Service data obtained from published State CNI reports.
[b] Includes cropland, pasture, forest, and other rural land. Percent based on total land within LRA.
[c] Includes Federal noncropland, urban and builtup >10 acres, and water <40 acres. Percent based on total land within LRA.

uplands. The more common soil series include Chewacla, Congaree, Hiwassee, Masada, Altavista, and Wehadkee (classed in the Dystrochrept, Udifluvent, Hapludult, and Fluvaquent Great Groups). Hay, corn, tobacco, and vegetables are the major harvested crops in this land resource area. Because of the predominance of steep and/or shallow soils, however, this land resource area is generally best suited for forest and recreational uses. A considerable acreage is in federally owned forests and parklands, which comprise most of the 1.9 million acres of noninventory (nonagricultural base) land within this land resource area (Table 1).

Variations in terrain and altitude result in wide differences in climate. Mean annual rainfall ranges from 40 to 80 inches, and the number of frost-free days varies between 150 and 210 (Buol, 1973).

Southern Appalachian Ridges and Valleys (LRA 128, 128a)

The Appalachian Ridges and Valleys region (sometimes called the Great Valley) lies parallel to and west of the Blue Ridge Mountains. It extends from southwestern Virginia through eastern Tennessee into parts of northern Georgia and Alabama. Counties designated within this physiographic province (LRA 128 and 128a) comprise 21.7 percent of the total land within the Tennessee Valley region (Table 1, Figure 2). Topography of this region is mostly rolling to hilly, but ranges from nearly level to very steep. Folding and faulting and differential weathering of the rock formations have produced relatively narrow, parallel ridges and valleys oriented in a northeast-southwest direction. Elevations range from about 600 to 1,200 feet above sea level.

Soils on the ridges are underlain by more resistant sedimentary rocks, such as sandstones, cherts, cherty limestones, and the harder shales. These soils are generally steep, relatively shallow, and infertile. They include such soil series as Fullerton, Lehew, Bodine, Litz, Clarksville, Dandridge, Teas, and Montevallo (Paleudult, Dystrochrept, and Eutrochrept taxonomic Great Groups). Soils in the valleys are underlain by the more easily weathered limestones and soft shales. Transported alluvial sediments provide the parent material for soils on the floodplain and terrace positions. These nearly level to rolling valley soils are generally deep, permeable, and productive. Some of the more common soil series of the valleys are Decatur, Dewey, Etowah, Staser, Lindside, Wolftever, Jefferson, Talbott, and Colbert. These are classified in the

Paleudult, Hapludoll, Eutrochrept, Hapludult, and Hapludalf Great Groups. The limestone-derived "redlands" of northern Alabama (LRA 128a) constitutes one of the most extensive areas of agriculturally suited soils within the Tennessee Valley region. Soybeans, cotton, corn, wheat, and hay are the major harvested crops in the ridge and valley region.

Mean annual rainfall ranges from about 47 to 56 inches, and the number of frost-free days is usually about 180 in the northern portion to 225 in the southern part.

Cumberland Plateau and Mountains (LRA 125)

This land resource area extends from southwestern Virginia through east central Tennessee to northeastern Alabama, and occurs at a considerably higher elevation than the adjacent Ridge and Valley Province to the east and the Highland Rim to the west. Elevations range from about 1,000 to 2,000 feet above sea level. Counties delineated within this land area comprise about 7.9 percent of the 201-county TVA region (Table 1). The terrain ranges from smooth slopes on interstream divides to mountainous slopes along escarpments and dendritic-patterned drainageways. The upland soils are relatively shallow to sedimentary bedrock (generally level-bedded sandstone, but some siltstone and shale). Some of the more commonly occurring soil series include Ramsey, Hartsells, Jefferson, Muskingum, Hector, and Gilpin (Dystrochrepts, Hapludults, and Paleudults).

Most of the Cumberland Plateau is covered by cutover deciduous forest on steep slopes. Large acreages are owned by forest product and coal mining companies. While very low in native fertility and limited in extent, soils on the smoother, stone-free slopes respond well to good management and are suited to several crops. Soybeans, hay, corn, and vegetables are the major harvested crops of the Cumberland Plateau.

Mean annual rainfall ranges from about 50 to 60 inches, and the number of frost-free days varies from about 170 to 230, depending on elevation and latitude.

Sand Mountain (LRA 129)

Counties designated within the Sand Mountain land resource area occupy about 3.8 percent of the total TVA watershed and power service area (Table 1). This physiographic area occurs in northern Alabama, extending into northwestern Georgia (Figure 1). It is similar in many respects to the geologically related Cumberland Plateau. The topography ranges from nearly level to steep, but this land resource area contains a much higher proportion of smoother slopes. Upland soils are shallow to moderately deep, and are derived from level-bedded sandstones, shales, and siltstones. They are low in fertility, usually sandy textured on the surface, and respond well to good management. Much of the gentler sloping land is used for cultivated crops and pasture. Soybeans, corn, hay, and vegetables are the major harvested crops. Some of the more common soil series of the Sand Mountain area include Hartsells, Hector, Wynnville, Montevallo, Linker, and Albertville, (Hapludults, Dystrochrepts, and Fragiudults).

Elevation ranges from about 700 to 1,600 feet above sea level. Mean annual rainfall is 50 to 55 inches, and the length of frost-free season ranges from about 190 to 210 days.

Highland Rim and Pennyroyal (LRA 122)

This undulating to steep low plateau area occurs in central Tennessee, southern and western Kentucky, and a small portion of northern Alabama (Figure 1). The counties designated within this land resource area comprise about 15.8 percent of the total land in the 201 counties (Table 1). Most soils of the Highland Rim and Pennyroyal area are derived from cherty limestone; however, limestones and thin loess (wind-deposited silt) deposits form parent materials for many of the soils which occur in Kentucky and north central Tennessee. Contrasting topography (ranging from the gently sloping karst pattern of southern Kentucky to very steep slopes along deeply dissected drainageways in west central Tennessee) provide wide variations in land suitability for agricultural crops. Shallow, stony soils are prevalent on the generally wooded, steeper slopes. On the interstream divides, considerable acreages occur on undulating to rolling topography. These soils are moderately deep, well drained, and productive under good management. Some of the more common soil series of the Highland Rim and Pennyroyal area include Bodine, Mountview, Dickson, Baxter, Pembroke, Crider, Fullerton, and Talbott (Paleudults, Fragiudults, Paleudalfs, and Hapludalfs). Soybeans, corn, hay, and wheat are the major harvested crops in this land resource area.

Elevations range from about 400 to 1,300 feet above sea level. Mean annual precipitation is between 40 and 55 inches, and the frost-free season is from 190 to 220 days.

Nashville Basin (LRA 123)

The Nashville Basin occurs in central Tennessee and is about 400 to 600 feet lower in elevation than the surrounding Highland Rim. Counties designated within this land resource area occupy about 5.9 percent of the total land area within the 201 counties (Table 1). Two distinct land subareas, the Outer Basin and the Inner Basin, occur within this physiographic region (Edwards et al, 1974).

The Outer Basin (which occurs along the outer periphery, adjacent to the Highland Rim) consists of undulating to steep, deep, and moderately deep, well-drained clayey and silty soils. Outer Basin soils are derived from phosphatic limestone, cherty limestone, shale, thin loess, and alluvium. Elevations range from about 700 to 1,100 feet above sea level in the Outer Basin. Some of the more common soil series include Dellrose, Mimosa, Bodine, Armour, Maury, Braxton, and Arrington (Hapludults, Hapludalfs, Paleudults, Paleudalfs, and Hapludolls).

The Inner Basin is characterized by undulating to rolling, moderately deep to shallow, well-drained clayey and silty soils derived from limestone and alluvium. Much of this area consists of very shallow soils or limestone rock outcrop (commonly called "Glady Land"). Elevation of the Inner Basin is generally from 500 to 800 feet above sea level. Some of the more common soil series include Talbott, Barfield, Bradyville, Arrington, and Lynnville (Hapludalfs and Hapludolls).

Where rock outcrops and/or shallow soils are not present, the Nashville Basin is a region of very productive soils and is used extensively for hay and pasture production. Other important harvested crops include soybeans, corn, and wheat. The steeper and shallower soils are mostly covered by forest, including red cedar on extensive areas of limestone outcrops.

Mean annual rainfall ranges from about 45 to 54 inches, and the number of frost-free days is about 190 to 200 per year.

Kentucky and Indiana Sandstone and Shale Hills and Valleys (LRA 120)

Commonly called Western Kentucky Coal Fields, this land resource area occurs to a limited extent within the Tennessee Valley region. The three counties designated within this physiographic area occupy only 1.4 percent of the total 201-county land area (Table 1). The area consists of mainly rolling to hilly terrain, with moderately broad, gently sloping ridgetops and steep slopes along numerous deeply dissecting streams. Elevations range from about 400 to 900 feet above sea level. The soils are derived from sandstone, siltstone, shale, limestone, and thin loess deposits. Some of the more common soil series include Zanesville, Caneyville, Frondorf, Weikert, Dekalb, and Stendal (Fragiudalfs, Hapludalfs, Dystrochrepts, and Fluvaquents). Most of the land is occupied by forest, with row crops and pasture occupying the smoother ridgetop positions. Corn, hay, grain sorghum, soybeans, and wheat are the major harvested crops.

Mean annual rainfall is about 40 to 50 inches, and the frost-free season is usually from 190 to 220 days.

Southern Coastal Plain (LRA 133)

This land resource area extends from parts of west Tennessee through northeastern Mississippi and northwestern Alabama. Counties designated in the Southern Coastal Plain comprise 17.6 percent of the total land area within the 201 counties (Table 1). The terrain consists of nearly level to rolling ridgetops and steep ridgeside slopes, with some broad stream bottoms of level slope. Elevations range from about 150 to 700 feet above sea level. Soils are derived from unconsolidated marine sediments (sands, silts, clays, and gravels), often overlain by a thin deposit of loess. Some of the more commonly occurring soil series in this land resource area include Shubuta, Smithdale, Ruston, Saffell, Sweatman, Lexington, Ora, Savannah, Dulac, and Providence (Paleudults, Hapludults, Paleudalfs, Fragiudults, and Fragiudalfs).

Deciduous forest occupies much of this land resource area, especially the steeper slopes. On the loess-capped broader ridgetops, as well as in the alluvial floodplains, soils are productive and used extensively for soybeans, cotton, corn, small grains, and hay and pasture crops.

Mean annual rainfall is about 50 to 60 inches and the frost-free season usually ranges from 195 to 250 days.

Blackland Prairies (LRA 135)

The five Mississippi counties designated within the Blackland Prairies land resource area comprise only 2.8 percent of the 201-county Tennessee Valley region (Table 1). The topography is generally undulating to rolling, and elevations range from 100 to 400 feet. Being derived from marine calcareous clays, chalks, and marls, the soils are often poorly drained and characterized by a high shrink-swell type of clay.

Some of the more common soil series which occur in the Mississippi Blackland Prairies include Okolona, Vaiden, Houston, Brooksville, Leeper, Urbo, Kipling, Wilcox, and Oktibbeha (Chromuderts, Haplaquepts, and Hapludalfs).

Although very productive, these soils require a much higher level of management because of their physical conditions and susceptibility to sheet erosion. Most of this land resource area is extensively used for production of soybeans, corn, cotton, small grains, hay, and pasture crops.

Mean annual rainfall is 51 to 54 inches per year, and the number of frost-free days is usually 220 to 250.

Southern Mississippi Valley Silty Uplands (LRA 134)

This land resource area extends from extreme western Kentucky through west Tennessee and northern Mississippi. Counties within this physiographic subdivision comprise 12.1 percent of the total 201-county region (Table 1). Topography is level to steep, characterized by undulating to rolling interstream divides and fairly broad, level stream floodplains. Elevations range from 100 to 600 feet above sea level. Upland soils are derived from loess (wind-deposited silts) which tend to increase in thickness from about 4 feet along the eastern edge to 80 feet or more near the Mississippi River area. Some of the more common soil series in this land resource area include Memphis, Loring, Grenada, Calloway, Henry, Lexington, Falaya, Waverly, and Routon (Hapludalfs, Fragiudalfs, Fragiaqualfs, Paleudalfs, Ochraqualfs, and Fluvaquents).

Much of this land resource area is used for agricultural crops such as soybeans, corn, cotton, small grains, hay, and pasture. The soils are inherently fertile and very productive. However, because of silty soil surface textures and rainfall intensity factors, soil erosion is a major problem.

Mean annual rainfall ranges from about 45 to 60 inches, and the frost-free season is generally 200 to 250 days per year.

Southern Mississippi Valley Alluvium (LRA 131)

Commonly called the "Mississippi Delta," this land resource area occupies only a small part of the 201-county Tennessee Valley region. Two counties, representing 0.9 percent of the total study area, occur predominantly in this land resource area (Figure 2).

The soils are derived from alluvial sediments deposited by the Mississippi River. Some of the more common soil series include Sharkey, Alligator, Forestdale, Dundee, Dubbs, Commerce, Crevasse, and Reelfoot (Haplaquepts, Ochraqualfs, Hapludalfs, Fluvaquents, Udipsamments, and Argiudolls). Topography ranges from large, level areas of "buckshot" or slack-water clayey soils to gently sloping, loamy soils on natural levees. Although severe drainage problems exist during some months and the clayey soils require special management practices, this land resource area is well suited and intensively used for commercial agriculture. Major crops grown include soybeans, cotton, corn, and small grains.

Mean annual rainfall ranges from about 50 to 60 inches, and the frost-free season is generally 210 to 250 days per year.

Land Capability Classification

The basic soils inventory data provided by the USDA 1967 CNI and 1977 NRI are presented in the form of the land capability classification system (USDA, 1961). Several important points regarding the land capability system should be emphasized.

In the land capability classification system, soils are grouped according to potentials and limitations for sustained production of cultivated crops, pasture, range, or forest (without soil deterioration through erosion) over a long period of time. This system is not intended as a productivity rating for specific crops. Rather, it provides a general index of the suitability of land for cultivation and sustained crop production. It may, however, provide information on the relative productivity of soils at the lowest categorical level (capability unit).

The three categorical levels of soil groupings (all above the soil mapping unit) included in the land capability classification are: (1) capability *class*, (2) capability *subclass*, and (3) capability *unit*.

The capability class (the top category in the classification system) is a group of capability subclasses and units having the same relative degree of erosion hazard or limitation for agricultural uses. There are eight capability classes. The risk of soil damage or limitation for use becomes progressively greater from Class I to Class VIII. With good management, soils in Classes I through IV can produce cultivated field crops, pasture, and adapted range or forest plants. Soils in Classes V, VI, and VII are suited to pasture, forestry, and adapted native plants. With elaborate soil and water conservation and management practices, soils in Classes V through VII may also be used for fruit, vegetable, and ornamental crops. Soils in Class VIII are suited only for recreation, wildlife, water supply, or other nonagricultural purposes.

The second category, the capability subclass, is a grouping of capability units (within classes) that have the same kinds of limitations and hazards for agricultural use. The three kinds of limitations recognized at the subclass level in the Tennessee Valley region are: (1) risks of erosion, designated by the symbol (e); (2) wetness, drainage, or overflow (w); and (3) rooting-zone limitations such as shallow soils, stoniness, or droughtiness (s).

The lowest category of the land capability classification system is the capability unit, which is a grouping of several soil mapping units nearly alike in suitability for plant growth and having similar response (crop yields within 25 percent) to given soil management. Due to excessive detail involved with capability units, the land capability data presented in this report are limited to class and subclass.

General Land Use

As shown in Table 1, the total land area within the Tennessee Valley region (201 counties) is about 58.5 million acres. Based on the latest comprehensive USDA land inventory (1977 NRI), about 54.1 million acres of this total is nonfederally owned. *Cropland*[2] occupies about 11.1 million acres or 20.6 percent of the total non-Federal land; *pasture*, 11.0 million acres (20.3 percent); *forest*, 25.7 million acres (47.5 percent); *urban*, *builtup*, and *transportation*, 4.6 million acres (8.4 percent); and *other* miscellaneous rural land, 1.7 million acres or 3.2 percent (Figure 3). The remaining 4.4 million acres (total land minus nonfederal acreage) is occupied primarily by national forests, Federal parklands, military establishments, etc., plus water bodies less than 40 acres in size. The *cropland*, *pasture*, *forest*, and *other* land-use categories shown in Figure 3 total about 49.5 million acres, which is considered the rural, agricultural land base available for production of food, fiber, and potential fuel crops in the 201-county region.

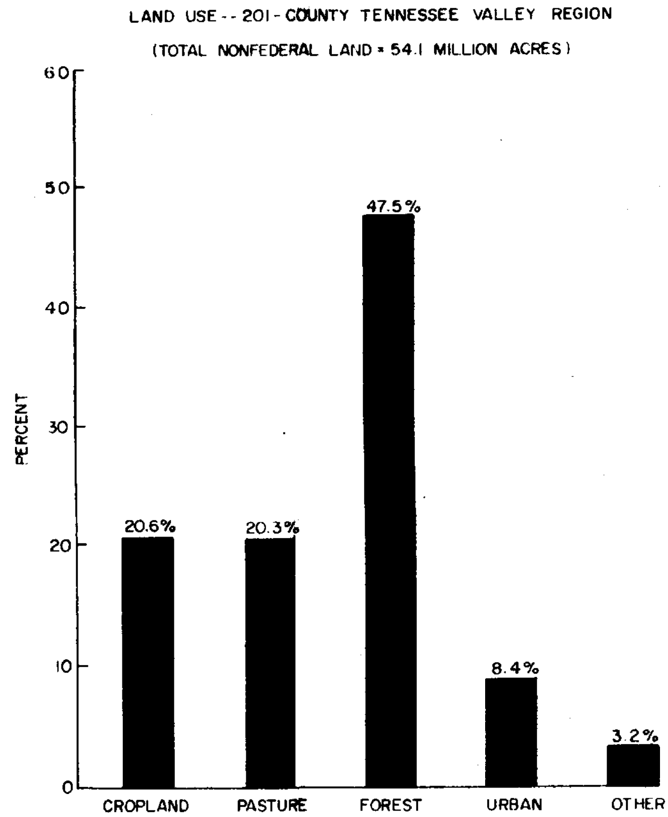

Figure 3. Use of non-Federal land in the Tennessee Valley region (201 counties), 1977 NRI data base

Distribution of Land by Capability Class

Figure 4 shows distribution of land capability classes within the agricultural land base for the entire 201-county region while a more detailed distribution of land capability classes and subclasses by major land resource areas is shown in Figure 5 and Table 2. For comparisons among land resource areas the more statistically valid 1967 CNI data base was used, while the more recent 1977 NRI data are applicable for the larger (201-county) geographic area. Of the 49 million plus acres of non-Federal, rural (agricultural-base) land within the 201 counties, about 56 percent is considered suitable for cultivated crops, consisting of land in capability Classes I (3.3 percent), II (21.7 percent), III (19.1 percent), and IV (11.6 percent) (Figure 4). These four categories of land vary from no limitations to cultivation (Class I) to land with severe limitations which require very careful soil management for cultivated crop use (Class IV). Practically all of the remaining agricultural land base is occupied by Classes VI (14.1 percent) and VII and VIII (29.2 percent), none of which would have much potential for growing agricultural fuel crops other than nonwoody cellulosic crops like hay.

Distribution of land capability classes (and associated suitability for cultivated crops) varies widely among the 12 major land resource areas (Table 2, Figure 5). The four land resource areas with the greatest proportions of soils capable of being intensively used for cultivated crops (land classes I, II, and III) include Southern Mississippi Valley Alluvium (LRA 131), 69 percent; Southern Mississippi Valley Silty Uplands (LRA 134), 67 percent; North Alabama Limestone Valley (LRA 128a), 65 percent; and Blackland Prairies (LRA 135, 51 percent. Conversely, areas with the highest proportion of noncultivable land (primarily steeper land susceptible to erosion—Classes V through VIII) include Blue Ridge Mountains (LRA 130), 72.9 percent; Cumberland Plateau (LRA 125), 59.7 percent; and Southern Appalachian Ridges and Valleys (LRA 128), 55.8 percent (Table 2).

Relatively large percentages of land marginally

[2]Source: 1977 National Resource Inventory. *Cropland* includes row crops, close-grown field crops, hay crops, rotation hay and pasture, nursery and orchard crops, and other cropland temporarily idled or in conservation uses.

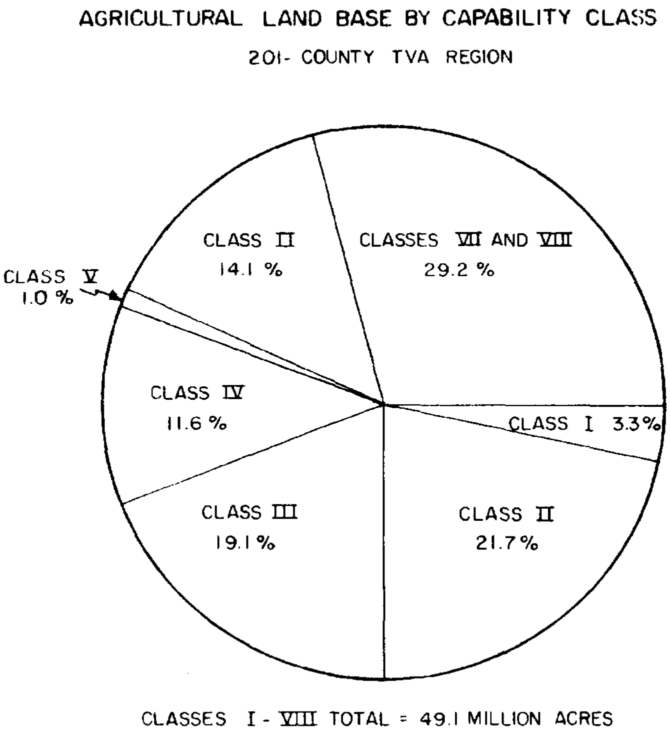

Figure 4. Distribution of non-Federal, rural land by capability class, 201-county Tennessee Valley region, 1977

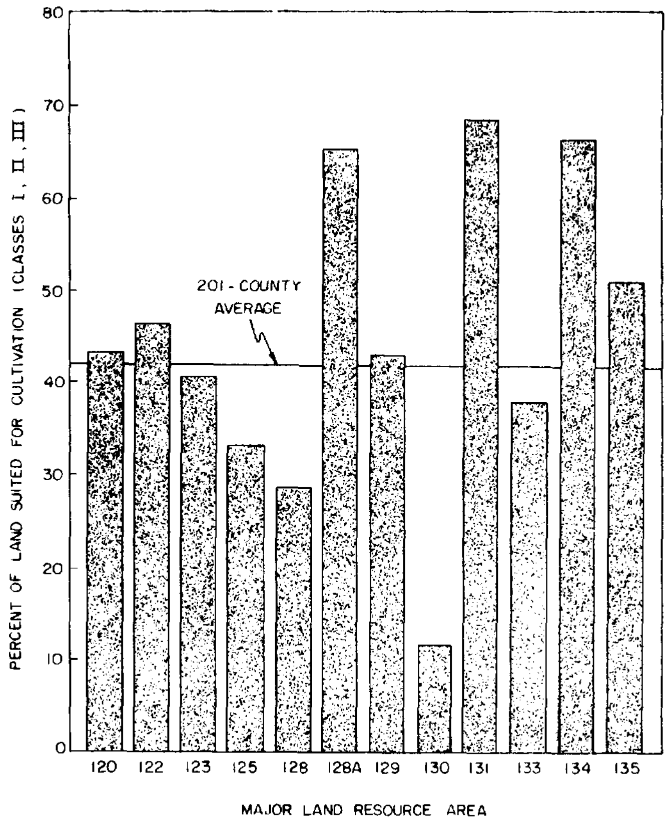

Figure 5. Distribution of inventory land suited for cultivated crops (classes I, II, III) by major land resource areas in the 201-county TVA region (1967 CNI)

suited to cultivated crops because of present or potential erosion (subclass IVe) occur within land resource areas 120, 122, 128, 129, 130, and 133 (Table 2, Figure 6). Considerable proportions of land marginally suited for most agricultural crops because of restricted internal drainage or susceptibility to flooding (Subclasses IVw and Vw) occur within Blackland Prairies (LRA 135), 18.1 percent; Southern Mississippi Valley Alluvium (LRA 131), 12.5 percent; and Southern Coastal Plain (LRA 133), 11.1 percent (Table 2). These lands provide a potential for production of nonconventional fuel crops such as cattail, Chinese water chestnut, and similar aquatic species of plants.

Use of Land by Capability Class

Distribution of general agricultural land uses (cropland, pasture, forest, and other) by capability classes and subclasses for all non-Federal rural land within the 201-county Tennessee Valley region is shown in Table 3 and Figure 7. Consistent with general suitability for cultivation, the percentage of land within each capability class used for cropland decreases from Classes I through VII and VIII (Table 3). Conversely, the percentage occupied by forest tends to increase with increasing capability class category.

The substantial amount of land in forest on cultivatable land capability Classes I through III is due to several factors. Because of low soil productivity and/or occurrence of small, isolated, or irregularly shaped parcels, it is often impracticable to farm this level to gently sloping land. Therefore, it remains in less intensive forest uses. Another factor is land ownership. About 2.5 million acres of commercial forest land within the 201 counties are owned by forest industries;[3] a significant part of this land is on Classes I through III. The Cumberland Plateau, Southern Coastal Plain, and western Highland Rim land resource areas contain significant acreages of such land ownership. Also, an estimated 12.0 million acres of commercial forest land is not owned by farmers or forest industries.[3] This miscellaneous private land is fairly well distributed throughout the

[3]Ogden, W. H., Personal Communication, 1982. Unpublished 1971-78 forest survey data. TVA, Division of Land and Forest Resources, Norris, Tennessee.

Table 2. Distribution of Land Capability Subclasses by Major Land Resource Areas, 201-County Region[a]

LRA Code	Percentage of total inventory land[b] in various land capability subclasses																		
	I	IIe	IIs	IIw	IIIe	IIIs	IIIw	IVe	IVs	IVw	Vs	Vw	VIe	VIs	VIIe	VIIs	VIIw	VIIIs	Total
	c/	c/	c/	c/			d/												(%)
120	5.8	16.1	0.2	3.7	15.1	—	2.4	14.7	—	—	—	—	13.6	1.3	6.5	19.8	—	—	100
122	6.4	19.4	2.5	1.2	15.6	—	1.4	9.6	3.5	0.7	—	—	7.8	3.8	3.8	23.5	—	—	100
123	9.3	13.5	3.0	1.2	11.1	—	2.7	8.9	1.2	0.9	—	—	10.5	8.9	3.6	24.5	—	—	100
125	2.7	10.1	0.4	0.6	17.1	0.2	2.0	5.8	—	0.5	—	—	6.3	1.8	5.9	45.5	—	0.2	100
128	5.4	4.9	0.3	2.3	13.7	0.3	1.8	13.6	0.4	0.7	—	—	16.6	1.9	19.7	17.6	—	—	100
128a	4.7	25.5	0.7	8.4	19.1	—	6.9	8.7	—	3.2	—	—	4.2	0.1	0.6	17.1	—	—	100
129	0.5	20.1	0.1	3.6	17.0	—	1.9	12.4	—	0.1	—	—	9.7	2.1	7.1	24.6	—	0.1	100
130	0.3	2.0	—	1.4	5.3	0.2	2.6	13.6	0.2	0.5	0.3	—	19.7	1.2	39.0	12.7			100
131	14.8	10.7	—	11.3	9.6	0.3	21.8	0.8	0.9	9.4	—	3.1	2.5		13.7	0.4			100
133	1.6	5.7	0.4	12.2	10.6	0.3	7.2	9.2	0.2	9.2	—	0.9	9.0	0.3	27.6	4.9	—	—	100
134	10.6	16.1	—	15.5	10.5	0.2	13.7	8.0	0.1	3.3	—	0.2	8.9	—	11.0	0.4	0.6	—	100
135	—	5.3	0.8	14.0	6.5	0.1	24.6	7.4	—	18.1	—	—	12.5	—	10.2	—	—	—	100
Total	4.9	11.3	0.8	6.1	12.6	0.1	5.5	9.9	0.8	3.2	—	0.2	10.7	1.9	14.9	16.1	—	—	100

a/ 1967 USDA Conservation Needs Inventory data.
b/ Inventory land includes *cropland, pasture, forest,* and *other* rural land; it excludes Federal noncropland, urban and builtup >10 acres, and water areas.
c/ Prime farmland approximation.
d/ Approximately half is estimated as prime farmland.

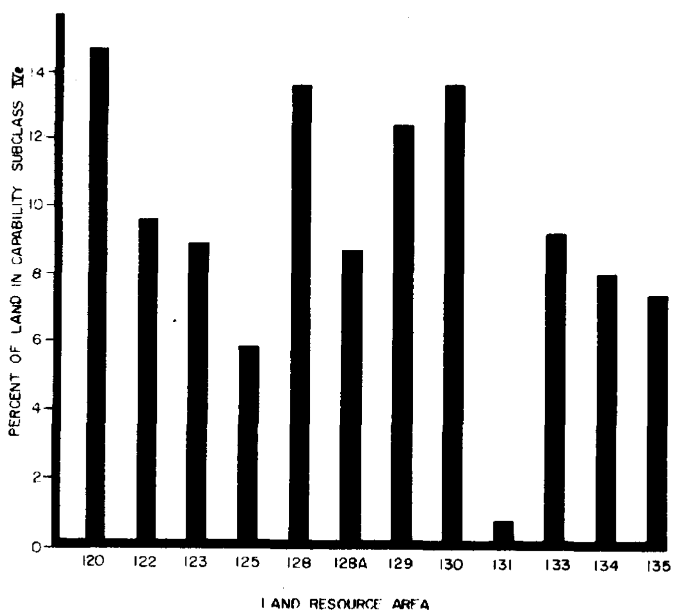

Figure 6. Percent distribution of inventory land marginally suited for cultivation (subclass IVe) within major land resource areas in the 201-county TVA region (1967)

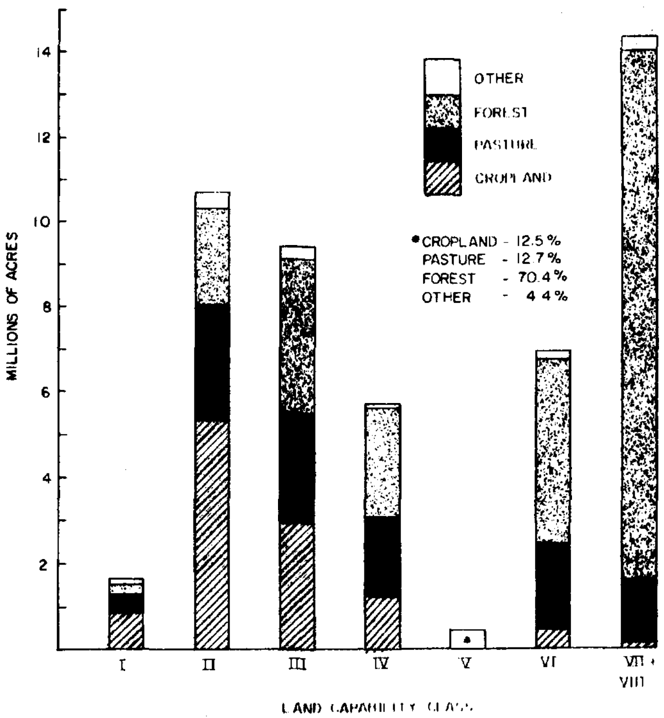

Figure 7. Land use acreage distribution by capability class in the 201-county Tennessee Valley region, 1977

Table 3. Land Use by Land Capability Subclass, 201-County Tennessee Valley Region, 1977[a]

Class and subclass	Cropland Acres	Cropland Percent	Pasture Acres	Pasture Percent	Forest Acres	Forest Percent	Other[c] Acres	Other[c] Percent	Total Acres	Total Percent
	Use of inventory land[b]									
	(000)		(000)		(000)		(000)		(000)	
I[d]	838.1	52.2	444.0	27.7	283.7	17.7	39.5	2.4	1,605.3	100
IIe[d]	2,687.1	46.1	1,842.4	31.6	1,067.8	18.3	232.6	4.0	5,829.9	100
IIw[d]	2,547.1	57.4	774.1	17.5	1,031.2	23.3	78.6	1.8	4,431.0	100
IIs[d]	91.3	24.3	123.1	32.7	145.6	38.7	16.4	4.3	376.4	100
(II sub)	(5,325.5)	(50.0)	(2,739.6)	(25.8)	(2,244.6)	(21.1)	(327.6)	(3.1)	(10,637.3)	(100)
IIIe	1,898.4	27.6	2,056.4	29.9	2,646.7	38.4	284.6	4.1	6,886.1	100
IIIw[e]	1,040.3	42.6	446.7	18.3	937.0	38.4	17.9	0.7	2,441.9	100
IIIs	26.9	39.3	12.3	18.0	29.2	42.7	—	—	68.4	100
(III sub)	(2,965.6)	(31.6)	(2,515.4)	(26.8)	(3,612.9)	(38.4)	(302.5)	(3.2)	(9,396.4)	(100)
IVe	943.4	21.2	1,574.6	35.3	1,860.3	41.8	75.1	1.7	4,453.4	100
IVw	277.0	34.8	154.0	19.3	360.5	45.3	4.9	0.6	796.4	100
IVs	33.8	7.6	99.2	22.3	298.3	66.9	14.5	3.2	445.8	100
(IV sub)	(1,254.2)	(22.0)	(1,827.8)	(32.1)	(2,519.1)	(44.2)	(94.5)	(1.7)	(5,695.6)	(100)
V	60.2	12.5	61.3	12.7	338.7	70.4	21.0	4.4	481.2	100
VIe	424.8	7.6	1,569.2	27.9	3,493.3	62.1	134.4	2.4	5,621.7	100
VIw	—		—		—		—		—	
VIs	69.8	5.3	393.3	29.8	823.2	62.4	33.5	2.5	1,319.8	100
(VI sub)	(494.6)	(7.1)	(1,962.5)	(28.3)	(4,316.5)	(62.2)	(167.9)	(2.4)	(6,941.5)	(100)
VII + VIII	191.1	1.3	1,427.7	10.0	12,374.9	86.2	354.2	2.5	14,347.9	100
Total	(11,129.3)	(22.7)	(10,978.3)	(22.3)	(25,690.4)	(52.3)	(1,307.2)	(2.7)	(49,105.2)	(100)

[a]Based on 1977 National Resource Inventory data, USDA Soil Conservation Service.
[b]Nonfederal rural land, excluding transportation corridors.
[c]Includes land in farmsteads, strip mines and quarries, and other miscellaneous rural uses.
[d]Approximately equivalent to "prime farmland."
[e]Approximately half of this land subclass is "prime farmland."

201-county area. National forests and other publicly owned forest land constitute another 3.9 million acres, most of which is in the Blue Ridge land resource area.[3]

There are about 14.8 million acres of land capability Classes I through III in cropland and pasture (Table 3). Most of this cultivatable land is harvested for food and fiber uses. With present surpluses in a number of farm commodities, however, it may be possible to convert a significant portion of this land to fuel crops. Decisions on such land conversion must be on a short-term basis, depending on available technology and economic developments relative to the supply and demand of food versus energy.

[3]*Ibid.*

On land marginally suited for cultivation because of erosion hazards (subclass IVe), about 56 percent (or 2.5 million acres) was in cropland and pasture in 1977 (Table 3). This represents a potential source of openland which might be available for growing fuel crops without taking the generally most agriculturally suited land (Classes I, II, III) out of food and fiber production. Determinations of exact locations of this potentially available "marginal" land cannot be determined at the scale of this study. These decisions must be made at the individual farm level, making full use of detailed soil surveys to identify potential parcels of land with favorable inherent productivity, and considering adaptability to land conversion and other farm management requirements.

Prime Farmland in the Tennessee Valley Region

With a gradual decline in the Nation's agricultural land base due to conversion to nonagricultural uses, there is an increasing public awareness of the need to conserve prime farmland for food and fiber production. It may therefore be useful to discuss prime farmland—its definition, its relationship to the land capability classification, amounts and distribution within the Tennessee Valley region, and relationships to fuel crop production.

Prime Farmland Defined

A general definition of prime farmland given in Title 7, Paragraph 657.5 of the U.S. Code of Federal Regulations (U.S. Federal Register, 1979) is as follows: "Prime farmland is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops, and is also available for these uses (the land could be cropland, pastureland, rangeland, forestland, or other land, but not urban built-up land or water). It has the soil quality, growing season, and moisture supply needed to economically produce sustained high yields of crops when treated and managed, including water management, according to acceptable farming methods. In general, prime farmlands have an adequate and dependable water supply from precipitation or irrigation, a favorable temperature and growing season, acceptable acidity or alkalinity, acceptable salt and sodium content, and few or no rocks. They are permeable to water and air. Prime farmlands are not excessively erodible or saturated with water for a long period of time, and they either do not flood frequently or are protected from flooding." For a more specific definition, giving the more technical soil morphological and climatic factors used in assigning soils to the prime farmland category, one may refer to pages 453-454 of the January 31, 1979 issue of the U.S. Federal Register.

To better understand the general category of land labeled as prime farmland, it should be emphasized that this category consists of a wide range of individual soil mapping units which have been grouped based on specific criteria. Parcels of prime farmland may range in size from 3 to 100 acres, on the usual 1:20,000 scale mapping of more recently published county soil survey reports. Because of the general complexity of slope, geological parent material, and drainage variables on much of the landscape, individual contiguous parcels of prime farmland tend to be small (perhaps 5 to 30 acres) and irregularly shaped in the Tennessee Valley region. This factor is very important to Tennessee Valley agriculture because it means that "less than prime" parcels of agricultural land (contiguous to parcels of prime farmland) must be used in much of the Tennessee Valley region to have economical farming units (farms or fields).

Therefore, much land categorized as "additional farmland of statewide importance" by the U.S. Code of Federal Regulations (U.S. Federal Register, 1979) is essential to Valley agriculture, especially in areas with steeper slopes. For example, many productive soils of 6 to 10 percent slope are suited for agricultural use, but by definition cannot be labeled as prime farmland because of the significant effect of such slopes on erodibility. Under good soil management such as minimum tillage, these soils, especially when occurring contiguous to parcels of prime farmland, are extremely important to Tennessee Valley agriculture.

Although the previously described land capability classification system may not reflect the inherent productivity of soils as consistently as does the prime farmland classification, there are similarities between the two systems. Within the Tennessee Valley region, nearly all soils belonging to capability Classes I and II can be grouped into the prime farmland category. Also, 43 percent of all soils belonging to capability subclass IIIw (soils of Class III with some wetness properties) are productive enough to be grouped with prime farmland (USDA-SCS, 1977). These are the "wet" soils which have no fragipans, have sufficient surface drainage, or have lower flooding frequencies. Only 15 percent of the capability subclass IIIe soils are considered prime farmland according to the latest NRI data available for the Tennessee Valley region (USDA-SCS, 1977).

Distribution by Use and Land Resource Areas

According to the latest available comprehensive national resource inventory (USDA-SCS, 1977), 14.0 of the 50.9 million acres of non-Federal rural land within the 201-county Tennessee Valley region is classed as prime farmland (Table 4). This represents about 28 percent of the total non-Federal rural land, or 26 percent of all non-Federal land (rural plus urban, builtup, and transportation). The 14.0 million acres of prime farmland in the Tennessee Valley region constitute about 4 percent of the 344.5 million total acres of U.S. prime farmland.

As shown in Table 4, about 7.0 million acres of the Tennessee Valley region's prime farmland is in cropland, and 3.6 million acres is in pasture use. These 10.6 million acres constitute the primary agricultural land base which should be preserved, as much as possible, for food and fiber crops. In the short run, part of this land base might be available for certain fuel crops if a comparative advantage should develop.

Land capability approximations of prime farmland (using 1967 CNI data) were used to determine where the greatest proportions of prime farmland occur within the Tennessee Valley region. As shown in Table 2 and Figure 8, the four land resource areas with the greatest proportions of soils estimated to be prime farmland include Southern Mississippi Valley Silty Upland (LRA 134), 49 percent; Southern Mississippi Valley Alluvium (LRA 131), 48 percent; North Alabama Limestone Valley (LRA 128a), 43 percent; and Blackland Prairies (LRA 135), 32 percent. Consistent with physiographic and soil limitations described earlier, the Blue Ridge Mountains, Appalachian Ridges and Valleys, and Cumberland Plateau land resource areas all have a much lower proportion of prime farmland than the average for the 201-county region (Figure 8).

Table 4. Amount and Use of Prime Farmland in the 201-County Tennessee Valley Region, 1977

Category	Acres, thousands	Percent of land[a]
Total prime farmland	14,023.1	27.5
Cropland	6,991.1	13.7
Pasture	3,589.8	7.1
Forest	3,062.2	6.0
Other land	380.0	0.7

[a]Based on 50.93 million-acre non-Federal, rural land base (1977 NRI).

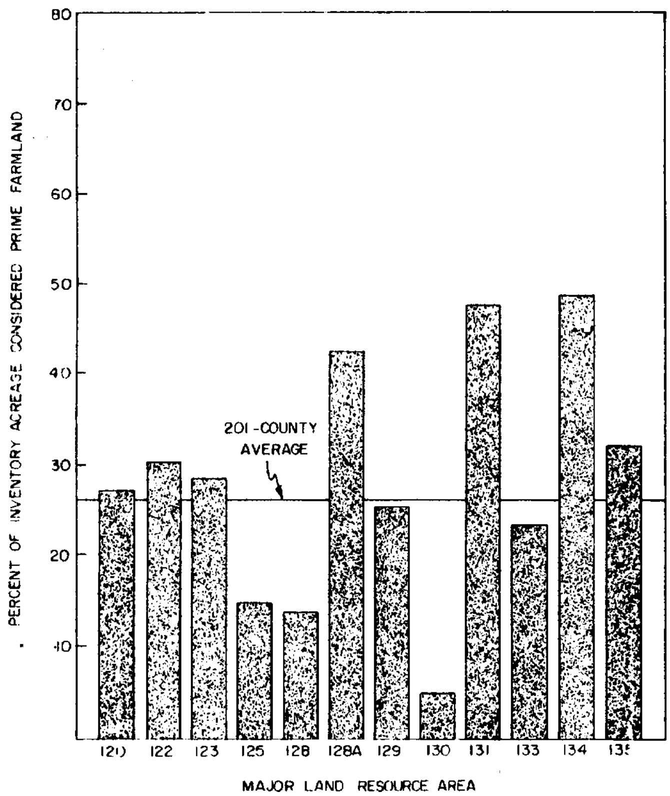

Figure 8. Estimated prime farmland distribution by major land resource areas in the 201-county TVA region (1967 CNI)

Soil Erosion Considerations

General

There is increasing national concern that soil erosion seriously threatens our capacity to provide the long-term food and fiber needs of our country; erosion by water also is recognized as a serious problem affecting water quality. Enactment of Public Law 95-192, the Soil and Water Resources Conservation Act of 1977 (RCA), has reemphasized the need for selecting land use and crop management systems that provide for soil erosion protection at a level necessary to maintain long-term soil productivity. Potential production of fuel crops on present Tennessee Valley agricultural land must consider the direct and indirect impacts it could have on soil erosion.

The Universal Soil Loss Equation (USLE)

The USLE is a highly useful model for predicting long-term average soil losses from sheet and rill erosion under specific climatic, soil, topographic, land use, and management conditions (Wischmeier and Smith, 1978). Developed through about 50 years of cooperative efforts of the USDA Agricultural Research Service, the Soil Conservation Service, and State experiment stations, this useful mathematical tool is expressed as follows:

$$A = R\ K\ L\ S\ C\ P$$

where:

A = *Soil loss* in tons per acre.

R = *Rainfall factor* (the number of erosion-index units in a normal year's rain).

K = *Soil erodibility factor* (the erosion rate per unit of erosion index for a specific soil in cultivated continuous fallow, on a 9 percent slope, 72.6 feet long).

L = *Slope length factor* (the ratio of soil loss from the field slope length to that from a 72.6-foot length on the same soil type and gradient).

S = *Slope steepness factor* (the ratio of soil loss from the field gradient to that from a 9 percent slope under otherwise identical conditions).

C = *Cover and management factor* (the ratio of soil loss from a field with specific cover and management to that from the tilled, continuous fallow condition on which the K factor is evaluated).

P = *Support practice factor* (the ratio of soil loss with a support practice such as contouring, stripcropping, or terracing to that with straight-row farming, up and down slope).

The USLE provides a method for determining combinations of conservation cropping systems and supporting factors that, under rainfall conditions expected in a given locality, will result in satisfactory erosion control on specific cropland fields. The soil loss equation was designed to predict the amount of soil removal from a specific site or field area, and does not account for subsequent redeposition of this sediment at the base of the slope or on flood plains. This equation alone, therefore, is not adequate to estimate the expected sediment yield in a stream or lake (water quality).

On a regional scale, distinct differences in rainfall, soil, topography, cropping system, and land use explain why certain geographic areas within the Tennessee Valley region have more serious soil erosion problems than others. The effects of *rainfall (R factor)*, expressed as numercial erosion index units, are shown to be more severe in the western and southern portions than other portions of the 201-county region (Wischmeier and Smith, 1978).

The soil erodibility (K) factor is a complex parameter depending on many soil properties influencing water infiltration capacity and the soil's ability to resist detachment and transport by rainfall and runoff. In general, soil erodibility increases with increased silt content and decreases with increased permeability and greater sand, clay, and organic matter percentages. With other soil and topographic factors constant, coarse-textured soils are the least erodible, fine-textured soils are intermediate, and medium-textured soils are the most erodible. The Southern Mississippi Valley Silty Uplands (LRA 134) and Southern Coastal Plain (LRA 133) are two areas with large proportions of erosive silty and other medium-textured soils.

As discussed earlier, significant topographic differences exist among and within the major land resource areas. Consequently, *slope length (L) and steepness (S) factors* may play an important role in runoff and soil erosion on certain farms with cropland on steeper, longer slopes. Terracing, contour tillage, and stripcropping are three examples of support practices which traditionally have been used to decrease slope length or gradient on land marginally suited to row crops.

Cover and management (C) factors offer one of the best means for minimizing erosion through actions of the farmer. Improved tillage practices, sod-tilled rotations, zero or minimum tillage, fertility treatments, and good management of crop residues are some of the cropping-management practices which can significantly reduce soil erosion. A cover of growing vegetation can affect soil erosion in two major ways: (1) the direct effect that a close-growing sod crop has in protecting the soil from raindrop impact, detachment and transport, and (2) the indirect or beneficial residual influence that a sod crop has on soil structure (Mannering and Fenster, 1977). Of the above mentioned cropping practices, soybeans double-cropped with wheat and reduced tillage of corn are increasingly being adopted as economical, soil-conserving management systems for these widely grown crops of the Tennessee Valley region.

Within the Tennessee Valley region, the land resource areas containing the highest proportion of row crop as opposed to pasture and forest uses offer the greatest risk for soil erosion and also the greatest potential for erosion reduction through improved crop management practices. Land resource areas with relatively high proportions of cropland include: Southern Missisippi Valley Alluvium (LRA 131), Southern Mississippi Valley Silty Uplands (LRA 134), North Alabama Limestone Valley (LRA 128a), and Blackland Prairies (LRA 135).

Support practices (P) are conservation measures that reduce soil loss on cropland by means of mechanical structures which reduce the rate of runoff. The most important of these supporting practices are contour tillage, stripcropping on the contour, terrace systems, stabilized waterways, and debris basins. These measures provide erosion control by managing the runoff water from rainfall events. The water is intercepted before it becomes erosive and then moves at a nonerosive velocity to a safe outlet. An added benefit of these structures is that reduced runoff allows the upland soils to temporarily retain more of the runoff water for plant use. With present farm commodity prices and construction costs, however, mechanical structures such as terraces and debris basins may not be cost-effective to the farmer in the short run without substantial government subsidy.

Soil Loss Tolerance

The soil loss tolerance (T value) is defined as the maximum rate of soil erosion which will permit a high level of crop productivity to be sustained economically and indefinitely (Wischmeier and Smith, 1978). Soil loss tolerance values have been established for all soils of the Tennessee Valley region. While the effect of loss of topsoil on yields is not well known, the soil loss tolerance may range from 2 to 5 tons per acre per year, depending on soil characteristics. On deep, fertile soils with thick, permeable and productive subsoil horizons (such as the Memphis series), a 5 tons per acre annual erosion loss is considered tolerable. In contrast, soils which are shallow to bedrock or to compact or infertile subsoil layers may tolerate erosion losses of only 2 or 3 tons per acre per year for maintaining their productivity over a long-term basis. For example, severely eroded soils of the Grenada series (which have an acid fragipan horizon at a depth of less than 2 feet) have a T value of only 2 tons per acre per year.

Soil Erosion by Land Use and Capability Class

Soils and land use data obtained on sample plots during the 1977 National Resource Inventory provided the basis for a USDA-SCS estimate of average sheet and rill erosion (using the USLE) for given land areas within the United States. A summary of these estimates by land capability subclass for each of the four land uses: cropland, pastureland (improved), native pasture, and forest, was obtained for the 201-county Tennessee Valley region (Table 5).

The average annual sheet and rill erosion rate was estimated to be 9.0 tons per acre for cropland in all land capability classes. This is considerably above the 5 tons per acre annual rate considered tolerable for even the most productive soils. Reflecting the dominant effect of slope, Tennessee Valley region cropland occurring in land subclasses IIIe, IVe, IVs, and VIe had the most serious average annual rates of sheet and rill erosion (10 to 25 tons per acre). Less erosive cropping systems are critically needed if these land subclasses are to remain in cropland uses with tolerable rates of soil erosion. The less productive soils of these land categories should be identified and possibly converted to less intensive (soil conserving) cover crops. As indicated in Table 5, sheet and rill erosion rates on pasture and forest land in the Tennessee Valley region are generally much below the soil loss tolerance levels.

There are significant regional differences in seriousness of soil erosion within the 201-county area. West Tennessee, northern Mississippi, and the Limestone Valley region of northern Alabama appear to be the most critical general regions, based on erosion data. General soil erosiveness (discussed earlier) together with the large proportion of row crops (such as soybeans and cotton) explains much of the erosion problems occurring in these areas. As an illustration, recent estimates[4] indicate that about 43 percent of the cropland in the 21 counties of west Tennessee had an annual sheet and rill erosion rate of 5 tons or more per acre, with 23 percent of the cropland losing more than 14 tons per acre per year.

Since susceptibility to erosion may be a significant problem with conventional tillage, certain oil fuel crops with relatively short growing seasons (e.g., soybeans, sunflowers, sesame, and safflower) perhaps should be planted with reduced tillage in a stubble of double-cropped small grain such as wheat. Certain row crops grown for alcohol production (e.g., sweet potatoes, sugar beets, sweet sorghum, Irish potatoes) may not be as well adapted to a reduced tillage, double-cropping rotation with small grain because of their seasonal and other characteristics. Other double-cropping systems may have to be developed with such alcohol crops so as to increase profitability while also decreasing soil erosion losses. The potential contribution of crop residue to soil erosion control in all of these fuel crops may also be significant. This will be discussed in a later section.

Farmland Base and Agricultural Production

All land data presented in previous sections have not distinguished between the nonfarm and the farm ownership categories of rural land. Thus, a more practical estimate of land availability and potential fuel crop production may be to consider only the land classed as "land in farms" by the latest (1978) U.S. Agricultural Census (USDA-SRS, 1979). This certainly is true for the near future if we consider that conversion to fuel crops would most likely come from existing farms (i.e., land inventoried by the U.S. Agricultural Census).

Distribution of land in farms and market value of all agricultural products sold on these farms are given in Appendix Tables 1 and 2 for the Tennessee Valley region and its major land resource areas. According to the 1978 agricultural census, there are 26.3 million acres of land in farms within the 201-county Tennessee Valley region. About 15.7 million acres (60 percent) of this land is in cropland, (includes pasture in crop rotation), and another 2.2 million acres (8 percent) is in pasture not in crop rotation. Of

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[4]Tennessee report prepared in accordance with the U.S. Soil and Water Conservation Act (RCA), 1978, pp 10, 12, 17. Nashville, Tennessee.

Table 5. Estimated Average Annual Sheet and Rill Erosion by Land Use and Capability Subclass, 201-County Tennessee Valley Region[a/]

Class and subclass	All cropland 1,000 tons/yr	Tons/Ac/yr	Pastureland 1,000 tons/yr	Tons/Ac/yr	Native Pasture 1,000 tons/yr	Tons/Ac/yr	Forest 1,000 tons/yr	Tons/Ac/yr
I	3,290.9	3.9	125.9	0.3	23.9	1.2	58.1	0.20
IIe	17,880.9	6.7	1,280.1	0.7	26.7	1.2	275.3	0.26
IIw	13,995.7	5.5	281.9	0.4	12.7	0.2	138.5	0.13
IIs	582.9	6.4	278.3	2.3	0.0	0.0	19.0	0.13
IIIe	19,656.7	10.4	3,687.0	1.8	75.8	3.0	1,456.7	0.55
IIIw	6,953.5	6.7	243.4	0.5	0.0	0.0	85.2	0.09
IIIs	94.7	3.5	1.7	0.1	0.0	0.0	2.2	0.07
IVe	13,140.1	13.9	3,224.4	2.1	251.2	5.6	1,824.8	0.98
IVw	2,180.3	7.9	35.4	0.2	0.0	0.0	37.9	0.11
IVs	491.4	14.5	114.6	1.2	0.0	0.0	181.5	0.61
V	250.8	4.2	75.5	1.4	2.7	0.4	13.5	0.04
VIe	10,706.1	25.2	940.2	0.6	188.0	5.8	4,972.4	1.42
VIs	505.1	7.2	2,601.3	6.8	1.5	0.2	969.2	1.18
VII + VIII	9,861.1	51.6	7,769.1	6.1	1,225.6	8.4	7,982.8	0.65
Total	99,590.2	9.0	20,658.8	2.0	1,808.1	4.9	18,017.0	0.70

[a/]Summarized from 1977 National Resource Inventory data, USDA Soil Conservation Service.

the land in farms, the highest percentages of cropland occur in the Southern Mississippi Valley Alluvium (LRA 131), Southern Mississippi Valley Silty Uplands (LRA 134), North Alabama Limestone Valley (LRA 128a), and Blackland Prairies (LRA 135) land resource areas (84, 75, 66, and 63 percent, respectively). The proportion of cropland identified as "harvested cropland" is also the highest in these subregions, reflecting the extent of row crop, small grain, and hay production in these areas.

In 1978, the market value of all agricultural products sold from farms in the 201 Tennessee Valley counties was $3.3 billion; the value of crops sold was $1.4 billion (Appendix Table 2). The average market value of all agricultural products sold per acre of farm openland (cropland and pasture) was $187, with a wide range among the 12 land resource areas (Appendix Table 2). Sand Mountain (LRA 129) and Blue Ridge Mountain (LRA 130) had the greatest return ($665 and $316 per acre, respectively). This is related to the very intensive poultry and horticultural industries in these areas, which are not as dependent on large tracts of cultivatable land as required for most food, fiber, and potential fuel crops.

In looking at the potentials for cropland conversion to fuel crops, it may be useful to identify those land resource areas with the lowest average values of 1978 crops sold per *harvested* cropland acre. Crops sold in the Southern Coastal Plain, Blackland Prairies, Nashville Basin, and Cumberland Plateau land resource areas grossed only $102 to $126 per harvested cropland acre in 1978 (Appendix Table 2).

The 2.2 million acres of "other pasture land" (Appendix Table 1) represents mainly unimproved pasture, or "underutilized land," which may have a potential for more intensive production. Fuel crops may be adapted to most of this land, depending on soil productivity and other farm management factors.

Major Crops Harvested in the Tennessee Valley Region

Distribution of nine major harvested crops by land resource areas within the 201 Tennessee Valley counties is given in Appendix Table 3 (USDA-SRS, 1979). The most important of these are discussed below.

Soybeans

Soybeans were harvested from 4.8 million acres, representing 50 percent of the 9.6 million acres of harvested cropland in the 201 counties in 1978. The land resource areas with the highest proportion of soybeans were Blackland Prairies (82 percent of harvested cropland), Southern Missssissippi Valley Alluvium (68 percent), Southern Coastal Plain (67 percent), and Southern Mississippi Valley Silty Uplands (66 percent). Relatively large acreages of soybeans were also harvested in the North Alabama Limestone Valley and the northern portion of the Highland Rim. Thus, this potential oil fuel crop is already well established as a food crop in much of the Valley region. Unpublished U.S. Crop Reporting Service data indicate a 9-year (1972-80) average soybean yield of 23 bushels per acre for the 201 Tennessee Valley counties. Yields of 35 to 40 bushels per acre are often obtained with good management and favorable soil and climatic conditions.

Hay Crops

Hay crops comprise the second largest acreage of harvested cropland within the Tennessee Valley region. There were about 2.1 million acres of hay in 1978, representing 22 percent of all harvested cropland. Hay crops represented 52 to 62 percent of all the harvested cropland in the Blue Ridge Mountains (LRA 130), Southern Appalachian Ridges and Valleys (LRA 128), and Nashville Basin (LRA 123). For the entire Tennessee Valley region, all hay harvested in 1978 (including wild hay) averaged only 1.6 tons per acre. On productive soils, annual dry matter yields of 6 to 8 tons per acre are possible with some hay crops (such as alfalfa or coastal bermuda). Potential use of forage crops for ethanol production by hydrolysis of cellulosic material depends on future technological advances and relative profitability of growing forages for livestock feed or energy.

Corn

Corn was harvested for grain and silage on about 1.6 million acres in 1978. This represents about 17 percent of the harvested cropland within the 201-county region. In terms of total acres harvested, the Highland Rim and Southern Mississippi Valley Silty Uplands had the greatest amounts of corn (Appendix Table 3). Corn represented 26 to 30 percent of all crops harvested in the following land resource areas: Sand Mountain, Highland Rim (mostly Kentucky region), Blue Ridge Mountains, Kentucky Sandstone and Shale Hills and Valleys, and Cumberland Plateau. According to U.S. Crop Reporting Service data, the 9-year (1972-80) average corn yield for the 201 Tennessee Valley counties was 69 bushels per acre. At this yield level, grain produced on 1.6 million acres of corn could produce about 276 million gallons of ethyl alcohol each year. Corn yields of 100 bushels per acre are commonly obtained with good management and favorable soil and climatic conditions.

Cotton

Cotton acreage has been declining steadily within the Tennessee Valley region. According to the latest U.S. Agricultural Census (USDA-SRS, 1979) about 635 thousand acres of cotton were harvested in the 201 counties in 1978; this represented less than 7 percent of the total harvested crop acreage. Four land resource areas of the western and southern parts of the Valley region (LRA's 128a, 131, 133, and 134) together had 94 percent of all the harvested cotton acreage within the 201 counties in 1978. The U.S. Crop Reporting Service data indicate a 9-year (1972-80) average yield of 442 pounds of lint cotton per acre for the 201 Tennessee Valley counties.

Wheat

Due mainly to increased interest in double cropping soybeans with winter wheat (often in a reduced tillage system), wheat acreage has increased dramatically within the Tennessee Valley region during the last few years. The latest agricultural census (1978) indicated a harvested acreage of 278 thousand acres of wheat harvested for grain; however, 1980 U.S. Crop Reporting Service data indicate about 707 thousand acres were harvested within the 201 counties. Although 1982 data are not available, it is estimated at close to 1 million acres for the 201 counties. As mentioned earlier, winter wheat offers much opportunity as a soil-conserving cover crop preceding a summer annual fuel crop on marginal land subject to erosion; a reduced tillage system may also be applicable for certain crops. The 9-year (1972-80) average wheat yield given by the U.S. Crop Reporting Service for the 201-county region is 34 bushels per acre.

Sorghum

In 1978 there were 62 thousand acres of sorghum harvested for grain and silage within the 201 counties. This represented about 0.6 percent of the total harvested cropland within the region. The Kentucky Sandstone and Shale Hills and Valleys (LRA 120) had the highest concentration of sorghum, representing 22 percent of all the crops harvested in the land resource area (Appendix Table 3). The average yield of sorghum grown for grain was 49 bushels per acre in

1978; sorghum harvested as green silage averaged 11.7 tons per acre.

There is much potential for increased production of sorghum (both grain and sweet varieties) within the Tennessee Valley region because of its adaptability to soils with low as well as high inherent productivity. Sweet sorghum appears to have much promise as a fuel crop because of its potential for producing both ethanol (from juice) and combustion fuel (from stalk residue) (TVA, 1982). With good management, sweet sorghum yields of 30 green tons per acre, containing 4,000 pounds of sugar in extractable juice, are readily achieved.

Irish Potatoes

Although this specialty crop does not comprise more than 0.1 percent of the Tennessee Valley region's harvested cropland, it may be important in terms of potential alcohol production for certain areas, such as the Sand Mountain region of northern Alabama, where it is already well established as a commercial crop. According to recent Alabama Crop Reporting Service data, the 5-year (1976-80) average yield of Irish potatoes from four counties in the Sand Mountain region was 6.0 tons per acre (ACLRS, 1981). Yields of 9 tons per acre are commonly obtained with good management and favorable climatic conditions.

Sweet Potatoes

According to U.S. Agricultural Census data (not shown) this potential alcohol fuel crop was commercially harvested on about 6.2 thousand acres within the 201-county Tennessee Valley region in 1978. Grown on 821 farms located primarily in the Mississippi and Alabama portions of the Valley, sweet potato yields averaged 169 bushels per acre. With good management and varietal selection, sweet potato yields up to 500 bushels per acre are readily achievable.

Availability of Annual Crop Residues for Fuel Production

In recent years, some investigators have suggested that annual-crop residues be used for energy and fuel production. This could involve processes of combustion, gasification, or fermentation. Production of ethanol from corn stover and wheat straw by enzymatic or acid hydrolysis of cellulose to sugar, followed by conventional fermentation and distillation, has recently been described by Dale, et al (1980). As recently pointed out, however (Antonopoulos, 1980), problems associated with generation, collection, transportation, storage, energy conversion, soil fertility and erosion, environmental issues, and economic consequences must be solved before use of crop residue for fuel purposes can be an accepted practice.

The main solid constituent of crop residue is lignocellulose which, in direct combustion, can release more than 7,500 Btu/lb (Antonopoulos, 1980). A figure of *16.8 x 10^6 Btu/dry ton* of crop residue is considered representative of the real thermal value of crop residue constituents (lignin, cellulose, hemicellulose, etc.) (Antonopoulos, 1980). Assuming the thermal equivalent of one barrel of crude oil as 5.8 x 10^6 Btu and the conversion efficiency of residues as 45 percent, the total energy theoretically available yearly from each dry ton of crop residue produced is equivalent to 1.3 barrels of crude oil. However, largely because of problems associated with residue collection, transportation and storage, together with the need to return certain quanitities of crop residues to the land for maintenance of soil productivity, it is very unrealistic to assume that most residues produced can be converted to energy. Some of these factors will be considered in the following discussion.

Amount of Crop Residue Produced

Ratios of residue produced to each pound or bushel of crop yield are commonly used to estimate crop residue production per acre. Table 6 gives the residue/crop yield ratio factors used for seven major crops of the Tennessee Valley region (USDA-SCS, 1980). Using these ratios and 1978 harvested crop acreages shown in Appendix Table 3, the amount of residue generated for average yields of corn, soybeans, wheat, cotton, and sorghum are given in Table 7. Within the 201 counties, these five crops generated about 8.74 million tons of crop residue in 1978. Crops used for livestock feeding (such as silage, hay, and pasture) are excluded from this estimate of annual crop residue generation. These 8.7 million tons of residue have an equivalent thermal energy of 11.3 million barrels of crude oil. Calculations similar to those of Table 7 may be made for each land resource area within the Tennessee Valley region by using the appropriate acreage data of Appendix Table 3.

Residue disposition tabulations of the 201 counties obtained from a recent Stanford Research Institute (SRI) study (U.S. Dept. of Commerce, 1976, 1976a) were summarized by counties to give land resource area estimates of residue sold, fed, returned, and wasted (Appendix Table 4). These estimates of crop residues are considerably lower than the estimates given in the previous paragraph. Much of this discrep-

Table 6. Amount of Residue Produced by Different Crops[a]

Crop	Yield unit	Residue/crop yield ratio (lb, air dry)	Pounds of dry residue per yield unit
Corn	bu	1.1	60
Wheat & rye	bu	1.5	90
Barley	bu	1.3	65
Oats	bu	1.4	45
Soybeans	bu	1.4	85
Grain sorghum	bu	1.1	60
Cotton (seed cotton)	bale	1.1	1,500

[a]Adapted from USDA - Soil Conservation Service. Tennessee Technical Guide, Section IV, Conservation Tillage Systems, May 1980.

Table 7. Estimated Yields of Dry Residues from Five Major Harvested Crops Within the 201-County Tennessee Valley Region, 1978

Crop	Average yield per acre		Total residue produced[b]
	Grain[a]	Dry residue	
		(lb)	(000 tons)
Corn[c]	70 bu	4,300	2,816.0
Soybeans	25 bu	2,100	4,996.2
Wheat	35 bu	3,150	437.4
Cotton	1,225 lb (lint & seed)	1,350	428.4
Sorghum[c]	50 bu	3,080	65.0
(Total—5 crops)	—	—	(8,743.0)

[a]Approximate 9-year (1972-80) average yields, except for grain sorghum (1978 only).
[b]Calculated from residue/crop yield ratios given in Table 6 and 1978 harvested crop acreage data of Appendix Table 3.
[c]Only acreage harvested for grain is considered in estimating residue generation.

ancy is because the SRI estimates are based on residue collectible at harvest, which is considerably less than the total amount generated by the crop.

Residue Needed for Maintaining Soil Productivity

The value of crop residues left on the soil surface for controlling soil erosion is well established. A residue cover prevents soil detachment, reduces the velocity of runoff, and reduces surface sealing of soils, thereby increasing infiltration rates and decreasing sediment loss. The erosion-control value of residues from different crops varies with their quantity, distribution, and durability. Figure 9 shows the relation of rate and type of residue mulch to percentage of soil surface covered. The total amounts of residue produced normally are higher from corn and

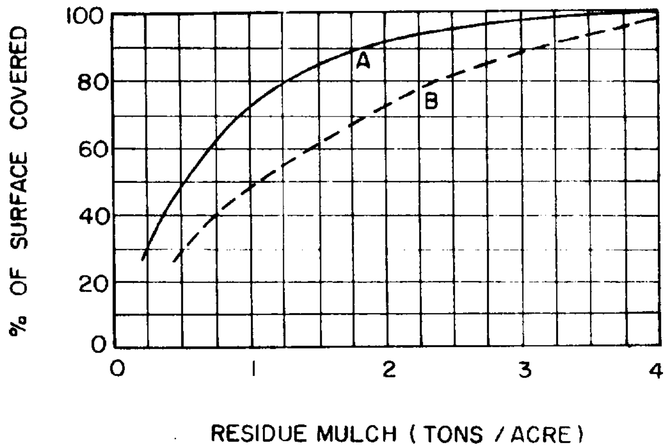

Figure 9. Relation of percentage of surface cover to mulch rate. Curve A is for small-grain straw; curve B is for chopped corn stover. (Wischmeier, 1973)

sorghum than from small grain, soybeans, and cotton. However, small grain straw is considered more effective than corn stover for controlling erosion because of the smaller diameter of the straw (Figure 9). Residues with lower carbon-nitrogen (C:N) ratios, such as soybeans, decompose much more rapidly than those, such as corn or wheat, with higher C:N ratios.

Using the graphic relationship shown in Figure 9 (after Wischmeier, 1973), a 60 percent surface covering of residue mulch would require about 1,500 pounds of small grain residue and 3,000 pounds of corn stover per acre. The exact amount of residue which should be returned to the soil in order to maintain a tolerable level of soil erosion will depend on such factors as soil texture and slope, amount of plant canopy available during the year, and tillage practice used. Using these and other factors, Campbell, et al (1981), recently completed a study which predicted the amount of crop residues needed to control soil erosion at tolerable levels in each of the major land resource areas of six Southern States. Table 8 summarizes some of the results of this study: the percent of crop residues produced in land resource areas 125, 128a, 129, 130, 131, 133, 134, and 135, that are needed to keep soil losses at or below tolerance levels. These data are calculated for six cropping systems: (1) soybeans-small grain; (2) soybeans-corn; (3) continuous soybeans; (4) continuous corn; (5) continuous sorghum; and (6) continuous cotton. Calculations are based on soil-incorporation of residues shortly after harvest, except for the soybean-small grain system. Cultivated field crops on soils greater than 7 percent slope were excluded from this analysis.

With a double-cropped soybean small-grain rotation, about 40 to 80 percent of the total residue produced was calculated as necessary for controlling soil erosion, depending on the land resource area (Table 8). Systems involving continuous row cropping required 60 to 99 percent of the generated residue returned in order to keep soil erosion at tolerable levels. Continuous row crops grown in the Alabama and Mississippi portions of the Tennessee Valley regions required incorporation of over 90 percent of the residue for effective soil erosion control (Campbell, et al, 1981). Double-cropping systems involving zero tillage and minimal incorporation of residues would greatly reduce the amount of residue required for erosion control.

Besides the soil erosion control benefits, however, crop residues are very important in terms of improved soil tilth, nutrient recycling, and maintaining of soil fertility. The amount of N, P, K, Mg, and S in residues and normally harvested portions of 13 crops at high yield levels is shown in Appendix Table 5. These crops theoretically could be considered potential fuel crops. Nitrogen and potassium uptake are especially significant in all of these crops, and must be replaced with increasingly costly commercial fertilizers if not recycled to the soil.

Net Amount Possibly Available for Fuel Use

It appears that converting renewable cellulosic residues to fuels by collecting normally unharvested crop components has very limited potential in the Tennessee Valley region at the average yield levels shown in Table 7. This is especially true with continuous row-cropping systems. Besides the possible uneconomic feasibility of converting these residues to fuel, they should largely be returned to the land to reduce erosion and maintain soil productivity. If we assume that 10 percent (870 thousand tons) of the total annual crop residues produced from five major crops (Table 7) are available for fuel use, an energy equivalent of 1.13 million barrels of crude oil (870,000 x 1.3) could be produced annually from crop residues within the Tennessee Valley region without competing against other residue needs. Increased production of high biomass-yielding alcohol fuel crops such as sweet sorghum (8 tons per acre annual dry matter yields readily achievable) could provide greater opportunity for use of lignocellulosic residues for alcohol production while still leaving sufficient residue to protect the soil resource.

On-Farm Consumption of Gasoline and Diesel Fuel

According to the latest U.S. Agricultural Census, about 114 million gallons each of gasoline and diesel fuel were consumed on farms in the 201 Tennessee Valley counties in 1978 (Table 9). These liquid fuels represented 67 percent of the total 1978 energy dollar expenditure on farms within the Tennessee Valley region. The average annual consumption rate per Tennessee Valley region farm was 676 gallons each of gasoline and diesel fuel, or 4.3 gallons per farm acre for each of these fuels.

As shown in Figure 10, there are important differences in farm consumption of gasoline and diesel fuel among the major land resource areas. Diesel fuel consumption per farm acre was highest in the more commercial row crop production areas, as follows: Southern Mississippi Valley Alluvium (LRA 131)—11 gal/farm acre; Southern Mississippi Valley Silty

Table 8. Percentage of Residues Produced that are Needed to Keep Soil Loss at or Below Tolerance Levels for Six Cropping Systems in Certain Land Resource Areas of Four Tennessee Valley States[a/]

State	LRA	Weighted soil loss tolerance	Cropping system: Soybeans—small grain	Soybeans—corn	Continuous soybeans	Continuous corn	Continuous sorghum	Continuous cotton
		(tons/Ac/yr)	%					
Alabama	125	4.2	51	99	99	99	99	99
	128a	4.2	62	99	99	—	99	99
	129	4.2	79	98	98	98	98	98
Georgia	128	4.0	58	93	96	—	89	93
	129	3.3	—	60	75	72	—	—
	130	4.1	—	73	72	73	—	—
Mississippi	131	4.5	40	100	99	—	—	93
	133	4.1	62	99	99	—	—	99
	134	4.0	58	99	99	—	—	99
	135	4.0	46	100	100	—	—	95
N. Carolina	130	4.0	49	91	—	86	92	—

[a/]Adapted from R. B. Campbell, et al, 1981. Land with slopes greater than 7% was excluded from this analysis.

Table 9. Annual Consumption of Gasoline and Diesel Fuel on Farms, by Land Resource Areas in the 201 Tennessee Valley Counties, 1978

Energy product consumed on farms	Total 201	Major land resource area (county approximations): 120	122	123	125	128	128a	129	130	131	133	134	135
Total energy consumption													
Million dollars	181.01	2.40	31.04	11.60	6.68	26.78	10.73	12.65	8.74	4.30	24.00	36.86	5.24
Dollars/farm[a]	1,073	753	947	750	1,006	692	1,483	1,471	671	6,433	1,201	1,882	1,879
Gasoline													
Million dollars	68.09	1.10	13.67	5.19	2.50	10.55	3.64	3.10	3.46	1.27	8.78	13.11	1.73
Million gallons[b]	114.06	1.83	22.90	8.70	4.19	17.68	6.10	5.19	5.80	2.12	14.72	21.95	2.89
Gallons/farm[a]	676	576	698	562	631	457	842	603	445	3,180	736	1,121	1,036
Gallons/acre[c]	4.3	3.9	4.5	3.8	4.0	4.3	4.6	5.8	5.2	5.2	3.6	4.8	3.3
Diesel fuel													
Million dollars	52.65	0.53	8.20	2.71	1.82	5.02	3.64	1.92	1.51	2.07	7.76	15.20	2.28
Million gallons[b]	113.95	1.14	17.74	5.86	3.95	10.86	7.88	4.16	3.26	4.48	16.81	32.89	4.94
Gallons/farm[a]	676	357	541	379	594	280	1,089	483	250	6,701	841	1,680	1,770
Gallons/acre[c]	4.3	2.5	3.5	2.6	3.8	2.6	5.8	4.7	2.9	11.0	4.1	7.2	5.7
Number of farms	168,679	3,186	32,785	15,470	6,635	38,717	7,235	8,599	13,025	668	19,986	19,583	2,790

[a] Calculated data, using total farm number given in U.S. Agricultural Census for given land area.
[b] Dollar data converted into gallons by following 1978 conversion factors; gasoline (leaded regular) = \$0.597/gallon, diesel fuel = \$0.462/gallon, based on "Agricultural Statistics, 1979," USDA (p 455).
[c] Based on total land in farms.

Uplands (LRA 134)—7.2 gal/farm acre; North Alabama Limestone Valley (LRA 128a)—5.8 gal/farm acre; and Blackland Prairies (LRA 135)—5.7 gal/farm acre. The ratio of diesel fuel to gasoline consumed was also greatest in these land areas. Gasoline consumption ranged from 5.8 to 3.3 gal/farm acre among the land resource areas (Table 9).

Calculated Replacement by Alcohol and Vegetable Oil

Based on data in Table 9 and thermal energy data for liquid fuels (Hodgman, et al, 1954; Baldwin, et al, 1981; Vinyard, et al, 1981), about 2,260 gallons of 190-proof fuel alcohol per farm would be required to replace the 179.8 million Btu's of gasoline plus diesel fuel consumed on the average Tennessee Valley farm in 1978. This could be produced from about 904 bushels of corn, or 13 acres of land at the current 70 bushels per acre average yield. But on the most productive soils and with good management, it is possible to produce this amount of corn on about 9 acres or less. With the 70 bushels per acre average corn grain yield, about 2.2 million acres would be required to produce enough fuel alcohol to completely replace all gasoline and diesel fuel consumed on the 168.7 thousand Tennessee Valley region farms in 1978.

Using vegetable oils (from seed crops such as soybean, peanut, and sunflower) as substitute fuels for diesel engines is receiving much investigation. To completely replace the 1978 average consumption of gasoline and diesel fuel (179.8 million Btu per Tennessee Valley farm) would require about 1,385 gallons of soybean (or sunflower) oil used as a diesel engine fuel substitute. At the Tennessee Valley region average soybean yield of 25 bushels per acre and an assumed seed oil extraction of 20 percent, this would require 885 bushels, or 35 acres per farm in the Tennessee Valley region. It would therefore require about 5.9 million acres of soybeans at the 25 bushels per acre yield rate to completely replace the annual gasoline and diesel fuel consumption on the 168.7 thousand farms within the 201-county region. At an achievable yield of 35 bushels per acre, the soybean acreage requirements for this fuel energy production could be reduced to 25 acres per farm, which would be about 4.2 million acres for the 201-county region.

Results of Questionnaire Survey

Detailed results of a 1981 questionnaire survey (appendix) of county extension agents' perception of farmer interests and concerns regarding agricultural fuel crops are given elsewhere (Soileau, 1981). Results received from the 200 counties were grouped by approximate land resource areas defined in Figure 2. Major findings of the survey are presented below,

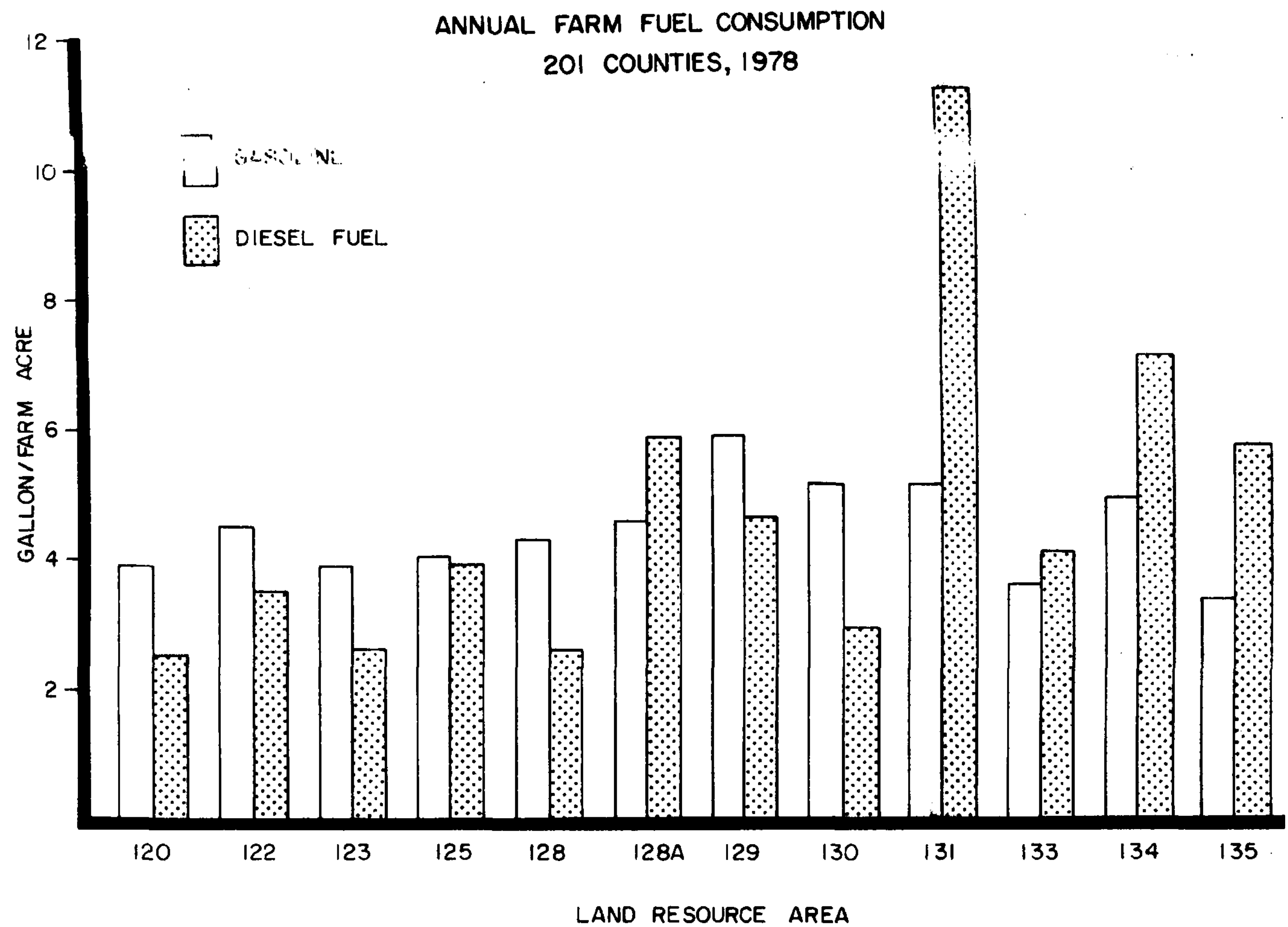

Figure 10. Annual gasoline and diesel fuel consumption per farm acre by land resource areas within the 201-county Tennessee Valley region, 1978

especially with regard to some of the subregional relationships previously discussed.

Amount of Farmer Interest

With present farm commodity prices and technology, only about 14 percent of the 200 responding counties estimated moderate to much farmer interest in growing crops such as sweet sorghum, sweet potatoes, sugar beets, and oil seed crops for liquid fuel production (Question 1, appendix). However, when addressed specifically to vegetable oil crops, 44 percent of the counties estimated moderate to much interest among farmers for growing crops such as soybeans, sunflowers, and peanuts to produce oil for on-farm direct combustion in diesel engines (Question 8). There appears to be above-average interest in producing oil seed crops for diesel engine use in the Blackland Prairies (LRA 135), Nashville Basin (LRA 123), Southern Coastal Plains (133), Southern Mississippi Valley Silty Uplands (LRA 134), and Highland Rim (LRA 122) regions (Question 8). All four responding counties in the Blackland Prairies (LRA 135) indicated moderate to much farmer interest in both alcohol and vegetable oil crops (Question 1).

Although there appears to be significant interest by farmers in considering crops for liquid fuel use, there is much farmer apprehension in making land use conversions from conventional food and fiber to liquid fuel crops. About 87 percent of the counties estimated that even with future advancements in technology and commodity price changes, farmers would not convert from conventional food and fiber to liquid fuel crops unless there was a net income advantage of at least 25 percent. Land resource areas which estimated greater farmer willingness to make land conversions to liquid fuel crops with less than 25 percent net income advantages included Southern Mississippi Valley Silty Uplands (LRA 134) and

Blackland Prairies (LRA 135). As pointed out, both of these areas are well suited for crop production.

Perceived Hindrances to Fuel Crop Production

To try to determine the major concerns that farmers have with respect to growing crops primarily for liquid fuel production, each county agent was asked to estimate the degree of hindrance (slight, moderate, or severe) for six possible farmer concern factors (Question 3). For the entire 201-county region, "uncertainty of economic return" and "storage and marketing facilities" were the two greatest preceived hindrance factors—both received a "severe" rating from 71 to 75 percent of the counties. Also, all other listed factors: "investment costs," "availability of on-farm equipment," "production technology," and "farmer interest or preference," were rated moderate to severe hindrances in 78 to 95 percent of the counties. Another serious hindrance factor frequently mentioned by counties in the Blue Ridge Mountains (LRA 130) was "availability of cropland." This is compatible with the physical soil limitations described earlier for this land resource area.

"Uncertainty of economic return" was estimated as a particularly severe hindrance factor in North Alabama Limestone Valley (LRA 128a) and the Nashville Basin (LRA 123). "Storage and marketing facilities" was listed as a particularly severe hindrance in Sand Mountain (LRA 129), Nashville Basin (LRA 123), and North Alabama Limestone Valley (LRA 128a). Of various land resource areas, the problem of "availability of on-farm equipment" was estimated to be most severe in the Nashville Basin (LRA 123) and Highland Rim (LRA 122) counties.

Availability of Openland

To supplement land capability and crop acreage data obtained from the Soil Conservation Service and the Agricultural Census, a question (No. 4) was asked in the survey regarding the amount of unused or underused openland (land potentially available for biomass crop use) in each county. This could help identify areas with much "marginal" or otherwise underused land capable and/or available for growing fuel crops without significantly reducing production of conventional food and fiber crops. For the 201-county region, about 40 percent of the counties were estimated to have less than 2,000 acres of unused or underused openland available for biomass crops, while 41 percent had an estimated 2,000 to 8,000 acres within this land category. Counties reporting more than 8,000 acres of unused/underused openland were proportionally most prevalent in the Nashville Basin (LRA 123) and Blackland Prairies (LRA 135) subregions.

Using the midpoint values of acreage ranges and percentage distribution of the respective categories (Question 4) about one million acres of unused/underused openland were estimated available for conversion to fuel crops within the 201 counties surveyed. In view of previously discussed USDA National Resource and Agricultural Census data, the questionnaire survey estimate is probably conservative.

Soil Conservation Issues

The survey contained four questions relating to the need for more soil conservation management on farm land and farmer receptivity to government incentive programs tied with soil-conserving land use restrictions.

Most of the counties surveyed (79 percent) reported that only 10 to 50 percent of the farmers in their counties were practicing adequate soil conservation (Question 9). Higher proportions of the farmers in the Blackland Prairies (LRA 135), Southern Mississippi Valley Silty Uplands (LRA 134), Southern Coastal Plain (LRA 133), and Highland Rim (LRA 122) subregions were estimated to be in need of improvements in soil conservation practices. These results support previously presented soil erosion data.

The interest of farmers in adopting crop management systems involving reduced tillage of row crops was considered *moderate* to *much* in 86 percent of the 196 counties responding to this question (Question 10). The greatest interest in adoption of such practices was suggested in the following land resource areas: Highland Rim (LRA 122), Nashville Basin (LRA 123), Sand Mountain (LRA 129), and Southern Mississippi Valley Silty Uplands (LRA 134).

The general consensus perceived at the county level was that farmers overwhelmingly oppose any government incentive programs tied to soil conservation or restrictions on use of prime farmland in growing crops for fuel use (Questions 5 and 6). This attitude is prevalent throughout all land resources areas.

Interest in Cooperative Farm Demonstrations

On the question of expected effectiveness of farm enterprise demonstrations in promoting crops for liquid fuel production, 80 percent of the responding counties estimated the probability as moderate to high (Question 7). The expected effectiveness of such farm demonstrations was estimated to be considerably lower in the Blue Ridge (LRA 130) than the other land resource areas within the Tennessee Valley region. The problem of availability of suitable cropland in the mountainous Blue Ridge region is probably the main reason for the lower expected value of farm demonstrations in these counties.

Results of a "yes" or "no" question pertaining to knowledge by respondents of any farmers in their county who would be interested in producing fuel on a cooperative, demonstrational basis showed 56 percent "yes" and 44 percent "no" responses (Question 11). Above average "yes" responses came from the Nashville Basin (LRA 123), Sand Mountain (LRA 129), and Blackland Prairies (LRA 135) counties. A rough estimate of the total number of actual farmer prospects for such cooperative demonstrations was about 240 for the 107 counties which reported positively to the question.

As suggested by results of the questionnaire survey, there is only an insignificant scattering of farmers within the Tennessee Valley region who are producing alcohol or vegetable oil for on-farm use. One or more technological breakthroughs in converting plant biomass to liquid fuel, or a sudden increase in cost or scarcity of petroleum-based energy, could, however, drastically reduce economic concerns expressed at the county level.

Summary and Conclusions

As one segment of a diversified TVA biomass fuels program, a study was made to determine availability of land and potentials for producing liquid fuels from agricultural crops in the Tennessee Valley region. Land and crop assessments were made for the 201-county TVA watershed and power service area—a land area of about 58.5 million acres. This study was undertaken with the basic precepts that producing agricultural crops for fuel use would not significantly reduce food and fiber production needed for the region or Nation, and would keep soil erosion within tolerance levels.

This study was made to: (1) prepare an inventory of soil resources, (2) determine present land use, emphasizing agricultural crop production, (3) identify possible underused openland capable of conversion to fuel crops, (4) estimate current availability of crop residues for fuel use, and (5) determine farmer interest in fuel crop production.

A great diversity of soils and agricultural suitability exists within the 201-county Tennessee Valley region, largely associated with geologic and topographic differences among 12 major land resource areas. About 14.0 million acres (28 percent) of the non-Federal rural land are classified as prime farmland, and about 28 million acres (56 percent) are suited for cultivated crops (land capability Classes I, II, III). Productive agricultural soils occur in largest percentages in four land resource areas of the western and southern portions of the TVA region: Southern Mississippi Valley Alluvium (LRA 131), Southern Mississippi Valley Silty Uplands (LRA 134), North Alabama Limestone Valley (LRA 128a), and Blackland Prairies (LRA 135).

Present land use may influence to a large extent the potential conversion of land to fuel crops. Of the 54 million acres of non-Federal land within the study area, cropland occupies 20.6 percent, pasture—20.3 percent, forest—47.5 percent, urban—8.4 percent, and other miscellaneous—3.2 percent. A noteworthy observation was that "land in farms" (as defined by the U.S. Agricultural Census) comprises less than half (26.3 million acres) of the total land area within the 201-county region.

Soil erosion is a serious problem on cropland throughout much of the TVA region, averaging 9 tons per acre per year. This is considerably above the 5 tons per acre annual rate considered tolerable for even the most productive soils. Land used to grow fuel crops should use cropping systems (such as double cropping and reduced tillage) which will maintain soil productivity by minimizing erosion; this is especially critical on marginally suited land. Differences in soil erodibility, cropping systems, and rainfall (as expressed by the K, C, and R factors of the Universal Soil Loss Equation) are largely responsible for greater sheet and rill erosion in the western and southern portions of the TVA region.

With an average market value of $187 per acre of openland for all agricultural products sold (1978 data), there appears to be opportunity for more intensive use of much of the cropland and pasture in the Tennessee Valley region. The possible role of fuel crops in more productive use of this land will depend on future technological and economic developments relative to the supply and demand of food versus energy.

The most abundant crops grown for harvest in the Tennessee Valley region include soybeans, hay, corn, wheat, and cotton. The highest proportions of cropland occur in four land resource areas occurring in the western and southern parts of the TVA region. Soybeans and corn, along with other minor crops (sweet potatoes, Irish potatoes, sunflowers, and sorghum) are all potential alcohol or seed oil crops successfully grown and adapted to the region. Other potential liquid fuel crops which need further investigation include sesame, safflower, okra, artichoke, and sugar beets.

Based on acreage data and ratios of residue to current yields, an estimated 8.7 million tons of crop residue is generated annually from corn, soybeans, wheat, cotton, and sorghum harvested in the 201-county TVA region. Calculated requirements for controlling erosion and maintaining soil productivity through soil incorporation of residues suggest that about 10 percent (870 thousand tons) of the annual crop residue generated on these harvested crops could be converted to fuel use. This represents a potential thermal energy equivalent of about 1.13 million barrels of crude oil per year. Producing high-yielding biomass crops (such as sweet sorghum) could substantially increase the availability of crop residues for fuel use. Double-cropping systems involving reduced tillage also would reduce the amount of residue required for soil erosion control.

According to the latest U.S. Agricultural Census, about 114 million gallons each of gasoline and diesel fuel are consumed annually on farms in the 201-county TVA region. Diesel fuel consumption per farm acre is significantly higher in four land resource areas of the western and southern parts of the Valley specializing in row crop production. At the present average yield levels of corn and soybeans (70 and 25 bushels per acre, respectively) it would require about 2.2 million acres of corn (for alcohol) or 5.9 million acres of soybeans (for oil) to completely replace the annual Btu consumption of gasoline plus diesel fuel on farms in the 201 counties. The average amount of land required to provide these on-farm liquid fuel requirements, at the present average crop yields, would be 13 acres of corn or 35 acres of soybeans per farm. At achievable corn and soybean yields of 100 and 35 bushels per acre, respectively, average on-farm liquid fuel requirements could be provided by 9 acres of corn or 25 acres of soybeans.

An estimated 2 million acres of underutilized openland in farms within the 201-county Tennessee Valley region could be converted to fuel crops with minimum interference to food and fiber production and maintenance of soil productivity. Location of these land areas must be determined on an individual farm basis, considering soil productivity, size of land parcel, soil erosion hazards, and other factors. On a short-term basis (with present national surpluses in many farm commodities), a substantial portion of the 14.8 million acres presently in cropland and pasture on land capability Classes I, II, and III possibly could also be converted to fuel crops.

Based on responses to a questionnaire survey of county agricultural agents from 200 counties, there is apparently not much enthusiasm among farmers of the region for converting to alcohol or oil fuel crops with today's technology and greater profitability (at less risk) of food and fiber crops. Possible future technological advances in converting plant biomass to liquid fuels, or a sudden increase in cost or scarcity of petroleum-based energy, could change this situation. If such land conversion becomes feasible, it is hoped that the land inventory and other agronomic considerations presented in this assessment study will be helpful in developing a successful soil-conserving fuel crops program for the Tennessee Valley region.

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APPENDIX

COUNTY SURVEY ON POTENTIAL PRODUCTION OF AGRICULTURAL CROPS FOR LIQUID FUEL

(Survey form to be completed by County Extension Agent or other official with knowledge of agricultural crop production and farmer preferences within the assigned county. A consensus from several local agricultural leaders may be used.)

County ______________________ State ______________________
Prepared by ______________________ Title ______________________
Address ______________________ Phone No. ______________________

Please place a check mark in the blank of the most appropriate answer.

1. In your best judgment, with present-day farm commodity prices and technology, how much interest is there among farmers of your county in growing crops such as sweet sorghum, sweet potatoes, sugar beets, and oil seeds for liquid fuel (alcohol and vegetable oil) production?

   A. ___None B. ___Slight C. ___Moderate D. ___Much

   Comments (if any): ____

2. Assuming future advancements in technology and farm commodity price changes, how much more net income per acre would be required for most farmers in your county to convert their present cropland from conventional food and fiber crops to liquid fuel crops?

   A. ___Same net income B. ___10% more C. ___25% more

   D. ___50% more E. ___100% more F. ___ _____% more (specify)

3. At the present time, how important are each of the following factors as a hindrance for growing crops for liquid fuel production in your county?

Factor	Degree of Hindrance: Slight	Moderate	Severe
A. Farmer interest or preference	___	___	___
B. Uncertainty of economic return	___	___	___
C. Production technology	___	___	___
D. Availability of appropriate on-farm equipment	___	___	___
E. Investment costs required	___	___	___
F. Storage and marketing facilities	___	___	___
G. Other (specify) ______________	___	___	___

4. In your best judgment, how much unused or underused openland in your county is suitable and available for production of fuel crops mentioned in question 1? (Estimate acreage available for more intensive crop production without significantly decreasing the present acreage of food and fiber crops.)

   A. ___Less than 2,000 acres
   B. ___2,000 to 8,000 acres
   C. ___8,000 to 15,000 acres
   D. ___15,000 to 25,000 acres
   E. ___25,000 to 40,000 acres
   F. ___ ______________ acres (specify)

5. Approximately what proportion of farmers in your county would be receptive to Government incentive programs that would encourage the production of liquid fuel crops on cropland, with certain soil-conserving restrictions?

A.__10% B.__25% C.__50% D.__75% E.__ ____% (specify)

6. Approximately what proportion of farmers in your county would be receptive to Government incentive conservation and production programs that would allow for use of steeper, more erosive, or less productive land for fuel crops, while preventing the planting of fuel crops on prime farmland?

A.__10% B.__25% C.__50% D.__75% E.__ ____% (specify)

7. In your county, how effective do you think a few farm enterprise demonstrations (carried out cooperatively by the Agricultural Extension Service and TVA) would be as an education and promotional tool in liquid fuel crop production?

A.__None to slightly B.__Moderately C.__Highly

8. How much interest is there among farmers in your county for growing vegetable oil crops (such as soybeans, sunflowers, and peanuts) to produce oil for on-farm direct combustion in diesel engines?

A.__None to slight B.__Moderate C.__Much

9. What proportion of the farmers in your county do you estimate are practicing adequate soil conservation in their farming operations?

A.__10% B.__25% C.__50% D.__75% E.__90%

10. Among farmers in your county, how much interest is there in adoption of crop management systems involving zero or minimum tillage of row crops?

A.__None to slight B.__Moderate C.__Much

11. Do you know of any farmers in your county who would be interested in producing fuel (alcohol or vegetable oil) on a cooperative, demonstrational basis with the Agricultural Extension Service and TVA?

__Yes __ No. If answer is yes, how many?____________

12. Additional comments (if any):

Appendix Table 1. Distribution of Land in Farms by Land Resource Areas, 201 Tennessee Valley Counties, 1978 Agricultural Census Data[a/]

Land use on farms	Total 201 Co.	Major land resource area (adjusted to county boundaries) 120	122	123	125	128	128a	129	130	131	133	134	135
Avg. size of farms (acres)	155	145	155	147	157	106	184	103	86	610	204	233	310
Total land in farms (000 acres)	26,303.6	465.0	5,089.3	2,274.2	1,045.0	4,129.3	1,334.0	894.2	1,124.7	407.5	4,096.9	4,578.5	865.2
(%)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
Total cropland (000 acres)	15,658.5	266.8	3,010.6	1,346.6	559.9	2,096.5	882.3	482.1	441.6	343.2	2,257.5	3,429.4	541.9
(%)[b/]	(59.5)	(57.4)	(59.2)	(59.2)	(53.6)	(50.8)	(66.1)	(53.9)	(39.6)	(84.2)	(55.1)	(74.9)	(62.6)
Harvested cropland (000 acres)	9,412.2	124.3	1,603.6	513.8	318.2	865.9	620.2	273.3	170.3	310.1	1,485.2	2,735.9	391.3
(%)[c/]	(60.1)	(46.6)	(53.3)	(38.2)	(56.8)	(41.3)	(70.3)	(56.7)	(38.6)	(90.4)	(65.8)	(79.8)	(72.2)
Cropland used for pasture (000 acres)	5,288.0	108.4	1,190.4	756.7	208.0	1,070.3	217.8	170.6	232.5	17.4	644.9	542.8	128.3
(%)[c/]	(33.8)	(40.6)	(39.5)	(56.2)	(37.1)	(51.0)	(24.7)	(35.4)	(52.6)	(5.1)	(28.6)	(15.8)	(23.7)
Other cropland (000 acres)	958.9	34.0	216.6	76.1	33.7	160.3	44.3	38.1	39.5	15.7	127.4	150.8	22.3
(%)[c/]	(6.1)	(12.7)	(7.2)	(5.6)	(6.0)	(7.6)	(5.0)	(7.9)	(8.9)	(4.6)	(5.6)	(4.4)	(4.1)
Woodland (000 acres)	7,103.7	142.3	1,480.1	574.3	381.2	1,270.3	293.6	283.6	495.3	42.6	1,334.1	655.6	150.8
(%)[b/]	(27.0)	(30.6)	(29.1)	(25.2)	(36.5)	(30.8)	(22.0)	(31.7)	(44.0)	(10.4)	(59.1)	(14.3)	(17.4)
Other pasture + range (000 acres)	2,225.0	27.1	348.3	240.6	61.8	539.7	102.6	73.4	117.6	8.1	325.1	248.3	133.5
(%)[b/]	(8.5)	(5.8)	(6.8)	(10.6)	(5.9)	(13.1)	(7.7)	(8.2)	(10.5)	(2.0)	(14.4)	(5.4)	(15.4)
Land in house lots, etc. (000 acres)	1,315.0	28.9	250.4	112.6	42.0	233.8	55.5	55.1	68.7	13.6	180.2	245.2	39.0
(%)[b/]	(5.0)	(6.2)	(4.9)	(4.9)	(4.0)	(5.4)	(4.2)	(6.2)	(6.1)	(3.3)	(8.0)	(5.4)	(4.5)

[a/]Totals may not add up because of rounding.
[b/]Based on total land in farms.
[c/]Based on total cropland acreage.

Appendix Table 2. Market Value of Agricultural Products Sold by Major Land Resource Area, 201 Tennessee Valley Counties, 1978 Agricultural Census

Source of income	Total 201 Co.	Major land resource area (county approximations) 120	122	123	125	128	128a	129	130	131	133	134	135
Market value of all agric. products sold													
Million dollars	3,345.4	37.2	564.9	215.2	124.0	527.1	203.4	369.6	176.8	64.7	369.7	614.1	78.7
Avg. dollars/farm	19,832	11,677	17,229	13,912	18,689	13,614	28,108	42,985	13,572	96,878	18,497	31,358	28,207
Avg. dollars/acre[a/]	187	127	168	136	199	200	206	665	316	184	143	167	117
Crops sold													
Million dollars	1,403.5	17.2	289.0	61.0	40.0	145.4	89.6	34.9	58.8	61.4	151.0	412.8	42.4
% of all agric. products sold[c/]	42.0	46.1	51.1	28.4	32.2	27.6	44.1	9.6	33.2	94.9	40.8	67.2	53.9
Avg. dollars/farm	8,320	5,388	8,814	3,944	6,027	3,756	12,385	4,056	4,511	91,920	7,557	21,081	15,214
Avg. dollars/acre[b/]	149	138	180	119	126	168	144	127	345	198	102	151	108
Number of farms	168,679	3,186	32,785	15,470	6,635	38,717	7,235	8,599	13,025	668	19,986	19,583	2,790
Total harvested cropland in farms (000 acres)	9,412.2	124.3	1,603.6	513.8	318.2	865.9	620.2	273.3	170.3	310.1	1,485.2	2,735.9	391.3
Total cropland + other pasture (000 acres)	17,883.4	293.8	3,358.9	1,587.3	621.7	2,635.2	984.9	555.5	559.2	351.3	2,582.6	3,677.7	675.4
Avg. farm size, acres	155	145	155	147	157	106	184	103	86	610	204	233	310
Avg. acres harvested, cropland per farm	56	39	49	33	48	22	86	32	13	464	74	140	140

[a/]Based on total cropland + other pastureland acreage.
[b/]Based on total harvested cropland acreage.
[c/]Computations based on unrounded data.

Appendix Table 3. Distribution of Major Types of Harvested Cropland[a] by Land Resource Areas, 201 Tennessee Valley Counties, 1978

"Harvested" Cropland use	Total 201 Co.	Major land resource area (county approximations): 120	122	123	125	128	128a	129	130	131	133	134	135
Corn (grain & silage)													
(000 acres)	1,576.7	50.3	471.9	86.0	86.6	175.0	36.9	82.0	4.3	0.9	141.1	392.2	10.8
(%)[b]	(16.5)	(26.2)	(28.6)	(16.6)	(26.6)	19.9	(5.9)	(29.9)	(28.1)	(0.3)	(9.4)	(13.9)	(2.8)
Wheat													
(000 acres)	277.7[c]	27.4	103.9	16.6	11.2	13.9	8.3	0.7	0.0	5.3	6.0	109.9	0.8
(%)	(2.9)	(13.2)	(6.3)	(3.2)	(3.4)	(1.6)	(1.3)	(0.3)	—	(1.7)	(0.4)	(3.9)	(0.2)
Sorghum (grain & silage)													
(000 acres)	62.2	42.0	4.9	6.2	1.6	3.0	1.6	1.4	0.0	0.0	15.8	21.5	4.9
(%)	(0.6)	(21.9)	(0.3)	(1.2)	(0.5)	(0.3)	(0.3)	(0.5)	—	—	(1.0)	(0.8)	(1.2)
Soybeans													
(000 acres)	4,758.3[d]	25.7	559.1	127.5	104.3	111.2	346.3	100.4	0.4	205.9	1,010.5	1,845.1	321.8
(%)	(49.7)	(13.4)	(33.8)	(24.6)	(31.9)	(12.7)	(55.2)	(36.7)	(0.3)	(67.7)	(67.4)	(65.5)	(82.3)
Cotton													
(000 acres)	634.7	0.0	0.0	3.4	4.7	20.6	151.6	6.1	0.0	84.9	101.9	260.7	0.8
(%)	(6.6)	—	—	(0.6)	(1.4)	(2.3)	(24.2)	(2.2)	—	(27.9)	(6.8)	(9.2)	(0.2)
Tobacco													
(000 acres)	119.0	3.1	48.9	6.0	1.0	34.4	0.0	0.0	10.4	0.0	0.0	7.9	0.0
(%)	(1.2)	(1.6)	(3.0)	(1.2)	(0.3)	(3.0)	—	—	(6.8)	—	—	(0.3)	—
Irish potatoes													
(000 acres)	9.5	0.0	0.0	0.0	3.3	0.2	0.0	5.8	0.0	0.0	0.0	0.0	0.0
(%)	(0.1)	—	—	—	(1.0)	(0.02)	—	(2.1)	—	—	—	—	—
Hay (all)													
(000 acres)	2,092.3	45.2	461.2	272.5	98.2	514.8	81.6	73.0	95.0	6.9	220.9	171.0	52.0
(%)	(21.9)	(23.6)	(27.9)	(52.5)	(30.1)	(58.7)	(13.0)	(26.6)	(62.0)	(2.3)	(14.7)	(6.1)	(13.3)
Vegetables													
(000 acres)	44.7	0.0	2.2	0.9	15.2	4.4	0.9	4.5	4.3	0.0	2.4	9.7	0.0
(%)	(0.5)	—	(0.1)	(0.2)	(4.7)	(0.5)	(0.1)	(1.6)	(2.8)	—	(0.2)	(0.3)	—
Sum of itemized crop													
(000 acres)	9,574.9	191.7	1,652.1	519.1	326.1	877.5	627.2	273.9	153.1	303.9	1,498.6	2,818.0	391.1

[a] As defined in U.S. Agricultural Census.
[b] Percentages based on acreage sum of itemized crops within a particular land area.
[c] More recent U.S. Crop Reporting Service data (1980) indicate approximately 707 thousand acres.
[d] More recent U.S. Crop Reporting Service data (1980) indicate approximately 5.7 million acres.

Appendix Table 4. Nature and Disposition of Crop Residues in the 201-County Tennessee Valley Region[a]

Residue Category	Total 201 Co.	Major land resource area (county approximations): 120	122	123	125	128	128a	129	130	131	133	134	135
Total residue[b]	3,754.3	49.0	825.0	112.1	141.1	225.4	200.7	101.4	43.9	158.3	460.3	1,327.5	109.7
Sold	30.1	0.1	12.8	3.5	1.8	4.4	1.6	0.1	0.2	0.5	0.4	4.7	0.1
Fed	627.5	18.4	200.0	21.3	33.4	60.6	17.4	34.6	16.2	1.7	63.0	156.9	4.0
Returned	3,059.0	30.5	611.9	87.1	105.5	159.2	175.4	65.3	25.8	151.6	389.6	1,152.2	104.8
Wasted	37.7	0.0	0.3	0.2	0.4	1.2	6.2	1.4	1.6	4.6	7.2	13.7	0.8

[a]Based on county summaries prepared for national residue inventory, U.S.-ERDA, 1976.
[b]Dry weight, thousand tons. Sources of residue, in decreasing order: soybeans, corn, wheat, and cotton.

Appendix Table 5. Approximate Pounds Per Acre of Nutrients Contained in Various Crops at High Yield Levels[a]

Crop	Acre yield	N	P	K	Mg	S
		lb/Ac				
Corn						
Grain	180 bu	170	30	40	16	14
Stover	4 tons	70	13	160	34	16
Soybean						
Grain	60 bu	252	21	72	17	12
Stover	3.5 tons	84	7	48	10	13
Wheat						
Grain	80 bu	144	20	22	12	5
Straw	3 tons	42	4	112	12	15
Cotton						
Seed & lint	3,750 lb	94	17	36	11	7
Residue	(2 tons)	86	11	68	24	23
Sorghum						
Grain	8,000 lb	120	26	25	14	22
Stover	4 tons	130	13	140	30	16
Peanuts						
Nuts	4,000 lb	140	10	29	5	10
Vines	2.5 tons	100	7	125	20	11
Irish potatoes						
Tubers	25 tons	150	35	220	12	12
Vines	(2 tons)	102	15	75	20	12
Sweet potatoes						
Roots	400 bu	53	11	105	5	—
Vines	(3.5 tons)	50	6	70	6	—
Sugar beets						
Roots	30 tons	125	7	207	27	10
Tops	16 tons	130	11	250	53	35
Alfalfa	8 tons	450	35	400	40	40
Orchard grass	6 tons	300	44	310	25	35
Coastal bermuda	10 tons	500	60	350	45	45
Clover - Grass	6 tons	300	40	300	30	30

[a]Source: S. L. Tisdale and W. L. Nelson, 1975. Page 492. *In:* Soil Fertility and Fertilizers. Macmillan Publishing Co., Inc., New York. 694 pp.