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# Sweet Sorghum For Ethanol Industry For the Piedmont

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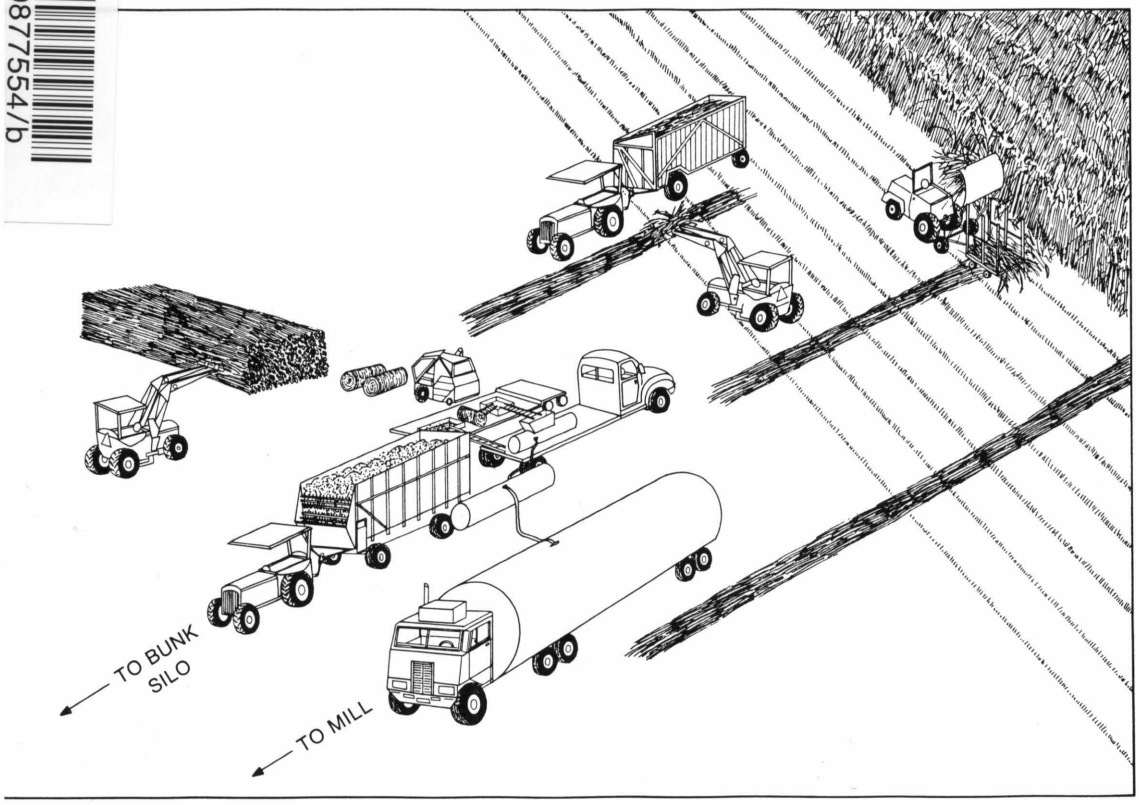

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The Virginia Agricultural and Mechanical College came into being in 1872 upon acceptance by the Commonwealth of the provisions of the Morrill Act of 1862 "to promote the liberal and practical education of the industrial classes in the several pursuits and professions of life." Research and investigations were first authorized at Virginia's land-grant college when the Virginia Agricultural Experiment Station was established by the Virginia General Assembly in 1886.

The Virginia Agricultural Experiment Station received its first allotment upon passage of the Hatch Act by the United States Congress in 1887. Other related Acts followed, and all were consolidated in 1955 under the Amended Hatch Act which states "It shall be the object and duty of the State agricultural experiment stations . . . to conduct original and other researches, investigations and experiments bearing directly on and contributing to the establishment and maintenance of a permanent and effective agricultural industry of the United States, including the researches basic to the problems of agriculture and its broadest aspects and such investigations as have for their purpose the development and improvement of the rural home and rural life and the maximum contributions by agriculture to the welfare of the consumer . . . "

In 1962, Congress passed the McIntire-Stennis Cooperative Forestry Research Act to encourage and assist the states in carrying on a program of forestry research, including reforestation, land management, watershed management, rangeland management, wildlife habitat improvement, outdoor recreation, harvesting and marketing of forest products, and "such other studies as may be necessary to obtain the fullest and most effective use of forest resources."

In 1966, the Virginia General Assembly "established within the Virginia Polytechnic Institute a division to be known as the Research Division . . . which shall encompass the now existing Virginia Agricultural Experiment Station . . . "

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**Abstract**

Approximately one third of the idle cropland in the Piedmont counties of five southern states -- Virginia, North Carolina, South Carolina, Georgia, and Alabama -- would have to be planted in sweet sorghum with an average yield of 40t/ha to produce a volume of ethanol equal to the volume of petroleum fuel purchased by farmers in the Piedmont counties (518 million ℓ/y), assuming that 65 percent of the fermentable sugar is extracted. If the by-products are ensiled for cattle feed, it is sufficient to feed 1.5 times the entire cattle population of the Piedmont of Virginia, and 3.0, 0.78, 1.25, and 1.16 times the Piedmont cattle population in North Carolina, South Carolina, Georgia, and Alabama, respectively.

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## Introduction

A study by the U.S. Department of Energy released in 1979 presented a scenario that projected annual production of 40,000 million ℓ of ethanol by the year 2000. (Current U.S. consumption of gasoline is approximately 420,000 million ℓ per year.) This report assumed the development of approximately 5.7 million ha of sweet sorghum with approximately half in the Corn Belt, and the remaining 2.8 million ha in the southeastern United States.

If recent patterns of food supply and demand continue, enough corn to yield 7,500 million ℓ of ethanol could be diverted to fuel production without substantially affecting corn prices; that would, in turn, directly impact food prices. However, should ethanol production double to 15,000 million ℓ without a concurrent increase in corn production, the price of corn would nearly double (Long, 1983). Such competition between food and fuel would be minimized if an ethanol feedstock that is not an important food crop were produced on land that is not being intensively managed for food production.

The Eastern U.S. Piedmont is a physiographic region that includes 170 counties in Pennsylvania, Maryland, Virginia, North Carolina, South Carolina, Georgia, and Alabama (Figure 1). The approximately 19 million ha in the region include much under-utilized food cropland that reasonably could be diverted to fuel cropping.

The Eastern U.S. Piedmont is a corn-deficit region, not because of lack of available land or production technology, but because of soil and climatic factors that limit production and therefore place the region's farmers at a disadvantage with those of other regions. [The 1978-82 corn production averages ranged from 40 bu per acre in Georgia to 80 bu per acre in Virginia (Va. Agric. Stat., 1984)] It is unlikely that Piedmont farmers can ever produce corn as an ethanol feedstock and compete with the Midwest. On the other hand, it does not seem practical to divert Midwest cropland from corn to an alternate crop such as sweet sorghum.

Parrish et al. (1981) compared six of the most promising species for carbohydrate production and found that sweet sorghum ranked just behind sugar beets and well ahead of corn in the Piedmont. Advantages of sweet sorghum include a relatively low nitrogen requirement, relatively high water use efficiency (good drought resistance), and few significant pests. The drought tolerance characteristic makes it particularly well adapted to the Piedmont, where the soils are characterized by badly eroded A horizons and acid B horizons, both of which limit root penetration and therefore water availability. An overall goal of this study is to define the practical potential of sweet sorghum as an ethanol feedstock in the Piedmont.

## Methods

The Southern Piedmont spans 7 countries in Alabama, 59 counties in Georgia, 18 counties in South Carolina, 36 counties in North Carolina, and 29 counties in Virginia for a total land area of approximately 16.1 million ha. The Northern Piedmont includes 8 counties in Virginia, 7 counties in Maryland, 6 counties in Pennsylvania, and portions of several counties in Delaware and New Jersey for a total land area of approximately 3 million ha. The region outlined in Figure 1 was defined by tracing the county boundaries as closely as possible to the major land use boundary which defines the Southern and Northern Piedmont. A county with more than half its land area in the Piedmont was included as a Piedmont county. The small portion of Delaware and New Jersey was not included since it is a highly urbanized area and is not significant for fuel cropping.

The U.S. Census of Agriculture (1982) uses the following land use classifications for counties: total cropland, harvested cropland, and total woodland. In Pennsylvania, 19 percent of the total state cropland is in the six Piedmont counties which comprise only 9.5 percent of the state's total area. This statistic shows that the Piedmont of Pennsylvania is more intensively used for agriculture than are other parts of the state. In comparison, the Piedmont of Georgia represents 31 percent of the total land area, but contains only 21 percent of the total cropland. The data in Table 1 show that there is

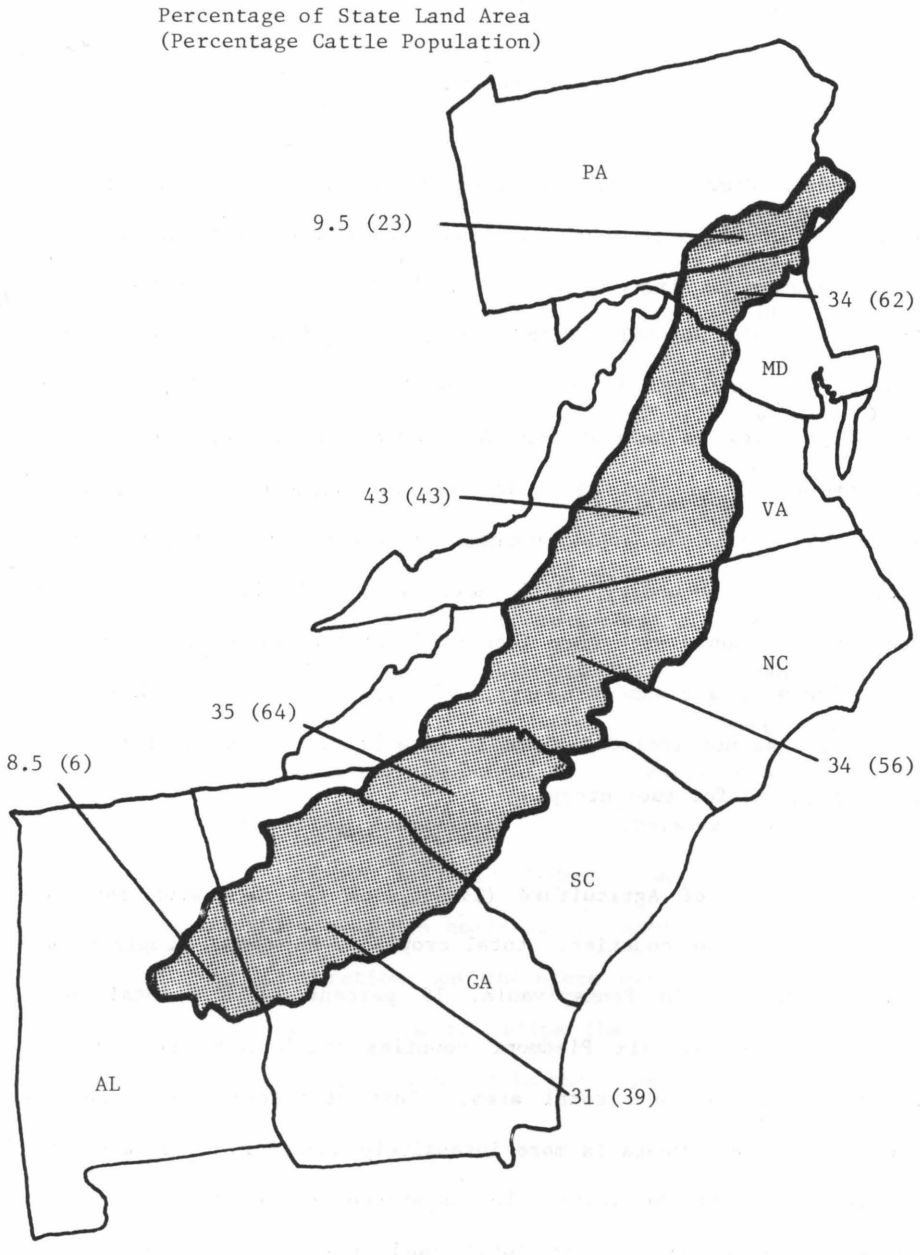


Fig. 1. Piedmont land area as a percentage of state total land area, and, in parentheses, Piedmont cattle population as a percentage of total cattle population.

Table 1. Land use in the Piedmont*

| State | Percent of State Area in Piedmont | | Within the Piedmont | |
|---|---|---|---|---|
| | Land Area | Total Cropland | Harvested/Total Cropland | Harvested Cropland/ Land Area |
| Pennsylvania | 9.5 | 19 | 87 | 34 |
| Maryland | 34 | 37 | 80 | 25 |
| Virginia | 43 | 42 | 56 | 10 |
| North Carolina | 34 | 33 | 64 | 12 |
| South Carolina | 35 | 27 | 52 | 6.5 |
| Georgia | 31 | 21 | 46.5 | 5.5 |
| Alabama | 8.5 | 4 | 56 | 4 |

*Based on 1982 U.S. Census of Agriculture

a fairly uniform decrease in land use for agriculture as one proceeds south from Pennsylvania.

The question of available land for fuel cropping is answered by considering the ratio of harvested cropland and total cropland classifications in the U.S. Census of Agriculture (1982). In Pennsylvania 87 percent of the total cropland is harvested in the Piedmont counties (Table 1) while in South Carolina only 52 percent is harvested. A trend is evident; current cropland utilization declines as one proceeds south. Consequently, the diversion of cropland to fuel cropping would be expected to have less competitive impact on existing agriculture as one proceeds south. One reason for this difference is the higher temperatures in South and the resulting higher evapotranspiration which adds additional stress to crops already subjected to stress by limited soil moisture availability.

Established farming patterns and expected continued urbanization limit the fuel-cropping potential in Pennsylvania and Maryland; therefore, for the purpose of this study, the Piedmont is defined as 37 counties in Virginia, 36 counties in North Carolina, 18 counties in South Carolina, 59 counties in Georgia, and 7 counties in Alabama. The 8 Virginia counties in the Northern Piedmont have been included with the 29 Virginia counties in the Southern Piedmont in our definition.

We expect that no-till planting procedures will be developed for sweet sorghum, but recognize that production of sweet sorghum should be allocated to sites that are suited for row crops. In order to determine the amount of row cropland available in the 157 Piedmont counties, U.S. Department of Agriculture (USDA) Crop Reporting Service data from the various states were used to determine the amount of cropland planted in the major row crops: corn, soybeans and grain sorghum. Data from the five years 1978 through 1982 show that, on the average, 9 percent of the total Piedmont cropland is planted in corn for grain, 16 percent is planted in soybeans, and 3 percent is planted in grain sorghum or corn for silage. As shown in Table 2, the total cropland planted in row crops ranges from 39 percent in North Carolina to 12 percent in Alabama. Current area planted in corn, soybeans, and grain sorghum is 752,000 ha, or 28 percent of the total cropland.

Fermentation of starch and sugar crops to produce ethanol generates by-products with potential as animal feed; consequently, the characteristics of the existing livestock industry are important in evaluating the fuel cropping potential of a given region. The residue

Table 2. Average area planted in row crops (1978 through 1982) in the Piedmont of the individual states.

| State | Percent Total Cropland | | | |
|---|---|---|---|---|
| | Corn for Grain | Soybeans | Grain Sorghum, Corn for Silage | Total |
| Virginia | 11 | 6 | 5 | 22 |
| North Carolina | 14 | 22 | 3 | 39 |
| South Carolina | 3 | 24 | 1 | 28 |
| Georgia | 3 | 19 | 1 | 23 |
| Alabama | 6 | 6 | <1 | 12 |
| Total | 9 | 16 | 3 | 28 |

remaining after the extraction of sugar from sweet sorghum is a highly digestible forage for ruminants. Figure 1 compares the percentage of a state's cattle population in the Piedmont to the percentage of the state land area. Virginia Piedmont counties comprise 43 percent of the state land area and have 43 percent of the cattle. In each of the four other states the cattle density in the Piedmont is higher than for the rest of the state. The reason for this fact is that optimum land use requires that much of the rolling Piedmont terrain be left in pasture, and cattle populations have been increased to take advantage of this resource.

**Goal**

There are several ways a goal might be set for fuel cropping in the Piedmont. One would be to produce a volume of liquid fuel equal to 10 percent of the total gasoline consumed in the five states. We have chosen as our goal the production of a volume of liquid fuel equal to

the volume of gasoline purchased by farmers in the Piedmont counties. The questions posed are: (1) is there enough row cropland to produce the sweet sorghum required, and (2) are there enough cattle to consume the residue silage?

## Hypothesized Industry

It is unlikely that the technology of the sugarcane industry can be transferred directly to the Piedmont. This industry is characterized by large, capital-intensive central mills where up to 95 percent of the sugar is extracted and the bagasse is burned directly. Our hypothesized industry for the Piedmont is based on the following assumptions:

1. The yield of sweet sorghum will average 40 t of whole stalks per ha, and the sugar content will average 9 percent of fresh weight.
2. Milling will extract 65 percent of the sugar, or 80 ℓ of 60° Brix molasses per t of whole stalks. This amount is the maximum that can be expressed with a single pass through a screw press (Bryan et al., 1985), and does leave some sugar in the residue to enhance its feed value. Ethanol yield will be one ℓ per 2.5 ℓ of 60° Brix molasses or 32 ℓ per t of whole stalks.
3. Juice will be expressed with mobile equipment mounted on lowboy trucks (not field machines) which will move from location to location and process whole stalk material stockpiled at the site. This juice will average 12.5° Brix and will be transported with tanker trucks to the central mill where it will be concentrated into 60° Brix molasses for storage.

4. Dairy cattle will consume 11 kg of forage dry matter per cow per day, 300 days per year, and beef cattle will consume 7 kg per cow per day through the winter (6 months). These totals translate to 10 t of residue silage per dairy cow per year and 3.6 t per beef cow per year.

We have chosen a 3.8 million ℓ per year (1 million GPY) ethanol distillery as the plant unit. This plant will require 2,970 ha of sweet sorghum, which will yield 68,900 t of residue silage, enough to feed 6,890 dairy cows or 19,100 beef cows for one year. The total population of beef and dairy cows given in the 1982 U.S. Census of Agriculture was used to calculate a forage consumption factor of the total cattle population (cows + steers + calves) in the Piedmont of the various states. This factor is given by:

$$F_s = (10N_d + 3.6N_b)/N \quad (1)$$

where $F_s$ - t residue silage per animal per year

$N_d$ - number dairy cows

$N_b$ - number beef cows

N - total number of animals

Tillman (1978) reports that the average energy consumed in the transportation of fuel in the United States is equal to 2.1 percent of the energy content of the fuel. For petroleum fuel the average transportation energy is 4 percent. We have chosen to allow 2 percent of the potential liquid fuel energy in 12.5° Brix sweet sorghum juice

to be used for tanker truck transportation. Thus, the average distance from all mobile processor locations to the central mill must be less than 11 km. Similarly, we have allowed 2 percent of the potential liquid fuel energy in whole stalk sorghum to be used for field transportation. Thus, the average distance of travel for all field wagons must be less than 1.3 km; or, in effect, 530 ha can be processed before moving the processor to a new location.

## Availability Of Row Crop Land

To determine the area which can be served by each mill, the transportation network for the hypothetical industry was analyzed. The results reveal that 16 km is the maximum radius which can be served by a central mill to maintain an average travel distance of 11 km. Results also show that only 3.7 percent of the total land area within a 16 km radius must be planted in sweet sorghum. The actual travel distance, as well as the percentage of land planted in sweet sorghum, will depend upon the actual road network in a particular geographic area.

Row crop area, defined as that total area currently planted in corn, soybeans, and grain sorghum, ranges from an average of 1 percent of total land area in the Alabama Piedmont counties to 8 percent in North Carolina. It seems reasonable to expect that certain mill locations can be found where 3.7 percent of the surrounding land can be planted in sorghum.

The yield of juice per hectare does not affect travel energy if the mill is located where the percentage of land planted in sorghum can be increased to compensate. Sweet sorghum yields may range from 30 to 60 t per hectare. We have assumed 40 t per hectare; consequently, if the yield is only 30 t, then the percentage of land area in sorghum must increase from 3.7 percent to 4.9 percent. In like manner, if the yield is 60 t per hectare, then the land percentage in sorghum decreases to 2.5 percent.

**Replacement Of Petroleum Fuel Used By Piedmont Farmers**

Idle cropland throughout the five-state Piedmont region totals 1.1 million ha, of which 0.4 million ha, or approximately one third, would have to be planted in sweet sorghum to produce a volume of ethanol equal to the volume of liquid fuel purchased by the region's farmers. In the Virginia Piedmont 343,500 ha of cropland is not harvested, and 109,000 ha, or 32 percent, of this would have to be planted in sweet sorghum to meet our stated goal for ethanol production (Table 3). The North Carolina Piedmont has 288,000 ha of idle cropland, and 225,000 ha, or 78 percent, would have to be brought into production to meet the goal.

South Carolina Piedmont farmers could meet their liquid fuel requirement by planting only 8 percent of their total cropland. This state has 166,300 ha of idle Piedmont cropland, and 27,400 ha, or 16.5 percent would have to be planted in sweet sorghum.

Table 3. Available cropland in the Piedmont which might be planted in sweet sorghum for ethanol production.

| State | Percent Total Cropland | | Percent Idle Cropland | |
|---|---|---|---|---|
| | Idle | Planted in Sweet Sorghum | | Planted in Sweet Sorghum |
| Virginia | 44 | 14 | | 32 |
| North Carolina | 36 | 22.5 | | 63 |
| South Carolina | 48 | 8 | | 17 |
| Georgia | 53.5 | 15 | | 27 |
| Alabama | 44 | 13.5 | | 30 |

In Georgia 294,400 ha of cropland are idle in the Piedmont counties, and 79,500 ha, or 27 percent, would be needed. Alabama has 36,200 ha of idle cropland in its 7 Piedmont counties, and 10,900 ha, or 30 percent, would be planted in sweet sorghum to meet our stated goal. Should all this land be diverted to ethanol production, the total potential yield for the five-state Piedmont region is 518 million ℓ , or 1.25 percent of the 40,000 million ℓ that the U.S. Department of Energy projected could be produced from sweet sorghum by the year 2000.

Since sweet sorghum is a row crop, it is necessary to compare the projected need for 0.4 million ha with present row cropping. As previously mentioned, current area planted, in corn, soybeans, and grain sorghum is 0.75 million ha; consequently, row cropping would have to be increased by more than 50 percent to meet our stated goal. It is likely such a drastic increase would result in unacceptably high levels of soil erosion, even with the use of the best no-till practices.

**Residue Silage For Cattle Feed**

The residue silage consumption factors ($F_s$) defined by Eqn. (1) ranged from 2.1 t/y/animal for Alabama to 2.8 t/y/animal for North Carolina and averaged 2.4 t/y/animal for the entire Piedmont region. If sufficient sweet sorghum were grown to meet our goal for ethanol production, the residue silage would be more than that required to feed the entire cattle population in the Piedmont of each state except South Carolina. In South Carolina the residue silage produced as a by-product would be 0.78 times that required to feed the entire Piedmont cattle population. In Virginia, North Carolina, Georgia, and Alabama the residue silage would be 1.5, 3.0, 1.25, and 1.2 times that required to feed the Piedmont cattle population in each state, respectively.

It is possible for the cattle population to increase in the Piedmont to the point where all the residue silage can be utilized, but not probable. Our goal to produce 518 million ℓ of ethanol to replace the 518 million ℓ of petroleum fuel used by the Piedmont farmers is too high if we expect to use all the feed potential of the residue. Current economics, and projected economics for the immediate future, suggest that some income must be derived from both the ethanol feedstock and the by-products in order for an ethanol-from-sweet-sorghum industry to be profitable.

## Conclusions

Non-food markets are needed for U.S. farm commodities, and fuel ethanol is an important emerging market. Sweet sorghum, because of its drought tolerance, has more potential as an ethanol feedstock than does corn in the Eastern U.S. Piedmont, a physiographic region that includes 170 counties across 7 states.

Projected future prices for liquid fuel suggest that ethanol will be of increasing importance. An ethanol from sweet sorghum industry for the Eastern U.S. Piedmont should be based on the use of processing by-products as cattle feed. Considering the current cattle population and concerns for soil conservation on marginal cropland, it is unlikely that an industry larger than 250 million ℓ /y will develop. Thus, Piedmont farmers can be expected to supply a volume of ethanol sufficient to replace only half the volume of petroleum they now use. To achieve liquid fuel "independence," they will need to discontinue the combustion of these fuels for crop drying and heating animal environments, and increase conservation efforts in all other areas.

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# Virginia's Agricultural Experiment Stations

1—Blacksburg
Virginia Tech, Main Station
Dairy, Poultry, and all other topics

2—Steeles Tavern
Shenandoah Valley Agricultural Experiment Station
Beef, Forages, Fruit, Insect and Pest Control, Sheep

3—Orange
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Winchester Agricultural Experiment Station
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5—Middleburg
Middleburg Agricultural Experiment Station
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