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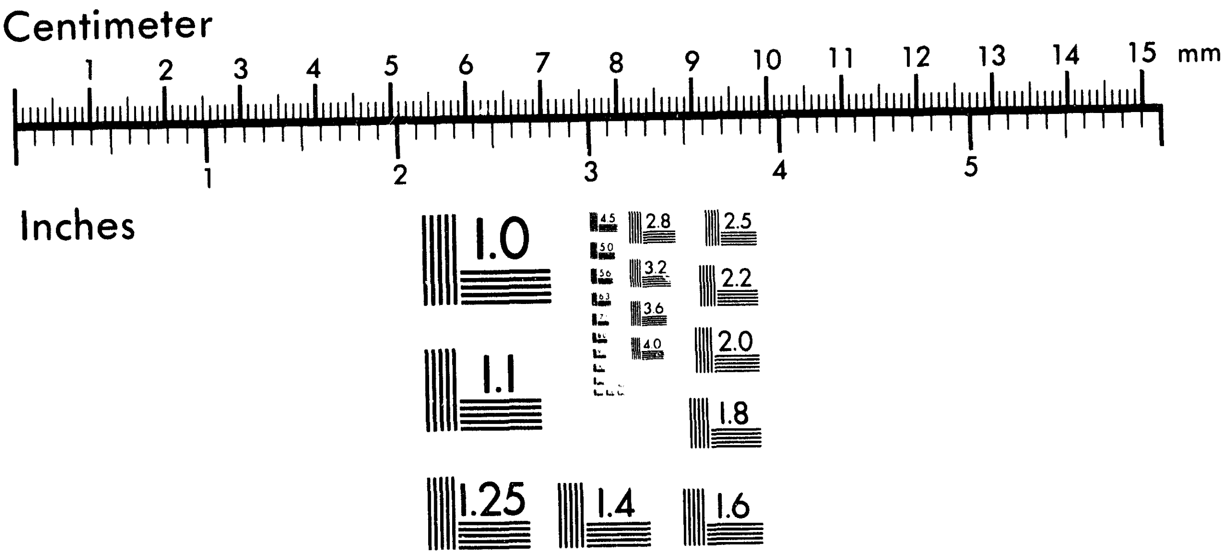

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EVALUATING A BIOMASS RESOURCE: THE TVA REGION-WIDE BIOMASS RESOURCE ASSESSMENT MODEL

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Abstract

The economic and supply structures of short rotation woody crop (SRWC) markets have not been established. Establishing the likely price and supply of SRWC biomass in a region is a complex task because biomass is not an established commodity as are oil, natural gas and coal. In this study we project the cost and supply of short-rotation woody biomass for the TVA region - a 276 county area that includes all of Tennessee and portions of 10 contiguous states in the southeastern United States. Projected prices and quantities of SRWC are assumed to be a function of the amount and quality of crop and pasture land available in a region, expected SRWC yields and production costs on differing soils and land types, and the profit that could be obtained from current conventional crop production on these same lands. Results include the supply curve of SRWC biomass that is projected to be available from the entire region, the amount and location of crop and pasture land that would be used, and the conventional agricultural crops that would be displaced as a function of SRWC production.

Finally, we show the results of sensitivity analysis on the projected cost and supply of SRWC biomass. In particular, we examine the separate impacts of varying SRWC production yields.

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Introduction

Wood is an alternative fuel for electric power generation at coal-fired plants in the Tennessee Valley Authority (TVA) region. Short rotation wood energy crops (SRWC) could provide a source of this woody biomass. The amount of wood (biomass yield) that can be produced by SRWC in a region (for example, a county) is a function of the 1) amount of crop and pasture land in the county, 2) soil quality of this land, 3) current use of crop and pasture land in the county, 4) management practices used to grow SRWC, and 5) regional climate characteristics. The price paid by power plants for SRWC biomass is a function of the cost of production, harvesting and transportation and therefore the price that farmers must receive in return for growing SRWC biomass.

The objective of this study was to project quantities of SRWC biomass that could be produced in a 276 county region and the cost of producing the wood. Cost of production here refers to the price paid to farmers. Using a schedule of projected quantities and prices, we derived a supply curve of SRWC biomass for the 276 county region.

The economic supply structure of a market for SRWC biomass has not been established for this region. Because SRWC biomass is not an established commodity as are oil, coal and natural gas, projecting the yield, production cost and thus supply of SRWC biomass in the TVA region is based on a comparison with conventional agricultural and pasture land conversion options. A basic assumption was that price system incentives would determine the margin at which farmers would be induced to convert currently used conventional agricultural land to SRWC biomass production. This margin or economic incentive, called the breakeven price (BEP) is the price that farmers would need to receive for growing biomass that assured them of equal or greater profit levels than they would receive if they planted the same land with the most profitable conventional crop or maintained pasture land in pasture. Profit to farmers is considered a function of the 1) expected yields of conventional agricultural crops (determined by soil quality, management practices, and weather), 2) market price, which in this analysis was assumed to be set by a national market and thus insensitive to local supply and demand, 3) production cost, which is affected by management practices and soil quality, and the existence of government commodity programs. We did not consider government commodity programs in this study.

The rest of this paper is organized as follows. Section two describes the methodology by outlining the geographic scope and modeling approach including economic assumptions about production trade-offs and decisions. In section three, we present the results in the form of a supply curve and discuss an interpretation of this cost-supply curve. The final section concludes the paper by discussing some implications and expanded research work.

Methods

In order to produce a supply curve for biomass for the 276 county region, both quantities and prices had to be derived. Since no biomass is currently grown in organized markets in this region, neither prices nor quantities were available. Derivation from the quantity side relied on the assumption that farmers of agricultural lands would convert their land to biomass production when the price per unit of biomass harvested would meet or exceed their current profit margins. Therefore, information about yields, costs of production and market prices would have to be determined for both conventional agricultural crops and SRWC crops. Knowledge of these numbers would give information about physical properties and factors regarding economic decision making. The breakeven price was calculated using the following equation:

$$(1) \qquad (YLDc * PRICEc) - COSTc = (YLDw * BEP) - COSTw$$

where YLDc was the particular conventional crop yield expected, PRICEc was the expected market price of the conventional crop, COSTc was the cost of conventional crop production, YLDw was the yield of woody biomass, BEP was the breakeven price of SRWC to the farmer to be calculated, and COSTw was the cost of production of SRWC woody biomass. The left-hand side of the equation may be considered land rent or the returns to land, labor, capital and management as a result of growing conventional crops on cropland. We considered land rent, similarly, as a result of keeping pasture land in pasture production. The right-hand side of the equation, therefore, is land rent received as a result of growing biomass crops on either conventional crop land or pasture land.

The notion of a breakeven price (to be calculated) was that a farmer would convert his conventional crop agricultural production lands to woody biomass production when it became profitable enough for him to do so. Based on available information on the remaining five coefficients in the above equation, we could solve for BEP. Figure 1 shows a diagram by which information flows through each stage of our analysis.

Land Base Characterization

Figure 2 demonstrates the span of counties across the 11 state area. For the purposes of our study we selected eight subregions within the TVA region. The boundaries of the subregions were based on current land use and physiographic features and largely followed the boundaries of the United States Department of Agricultural (USDA) Major Land Resource Areas in this region (United States Department of Agriculture 1981).

In order to adequately and completely describe the geographic region, national agricultural data bases were used to characterize soil types, agricultural crops grown, and the acres of crop and pasture land for each county. Information on soil types was derived from the national resource inventory (NRI) (Soil Conservation Service 1984) and the SOILS5 data base (United States Agricultural Stabilization Conservation Service 1989). SCS soil classes were aggregated into nine categories for each of the eight subregions so a representative SCS soil class code could be used. The NRI was then scanned to determine the most common soil type for each soil class. Soil names were cross referenced with NRI soil codes using the SOILS5 database. Finally the SOILS5 data base was accessed by soil name to provide all information possible about different horizons, slope characteristics and other information for each of nine soil categories.

In order to determine the dominant agricultural crops grown in a particular region, the National Agricultural Statistics (NAS) were accessed by county to determine, by acreage, the three dominant conventional crops grown in each of the eight subregions United States Department of Agriculture 1988, 1989). Each of the subregions would then have three crops which represented at least 80 percent of the region's agricultural land base considered. The trio of dominant crops for each region were some combination of corn, cotton, soybeans or wheat. The Agricultural Census data provided information about the crop and pasture acreage for each county United States Department of Commerce 1989).

Conventional Agricultural Crop Yields

Crop yields were available from the NAS. The 1988, 1989 and 1990 data for the three dominant crops for each subregion provided data on average yield. However, since we wanted to make the yields more sensitive to the soils within a subregion, we used the Erosion Productivity Impact Calculator (EPIC) model (Sharpley and Williams 1990) to simulate yields using soil information directly available for each soil type associated with each soil category for each subregion. EPIC is a widely used productivity and erosion simulation package. EPIC required a physiology

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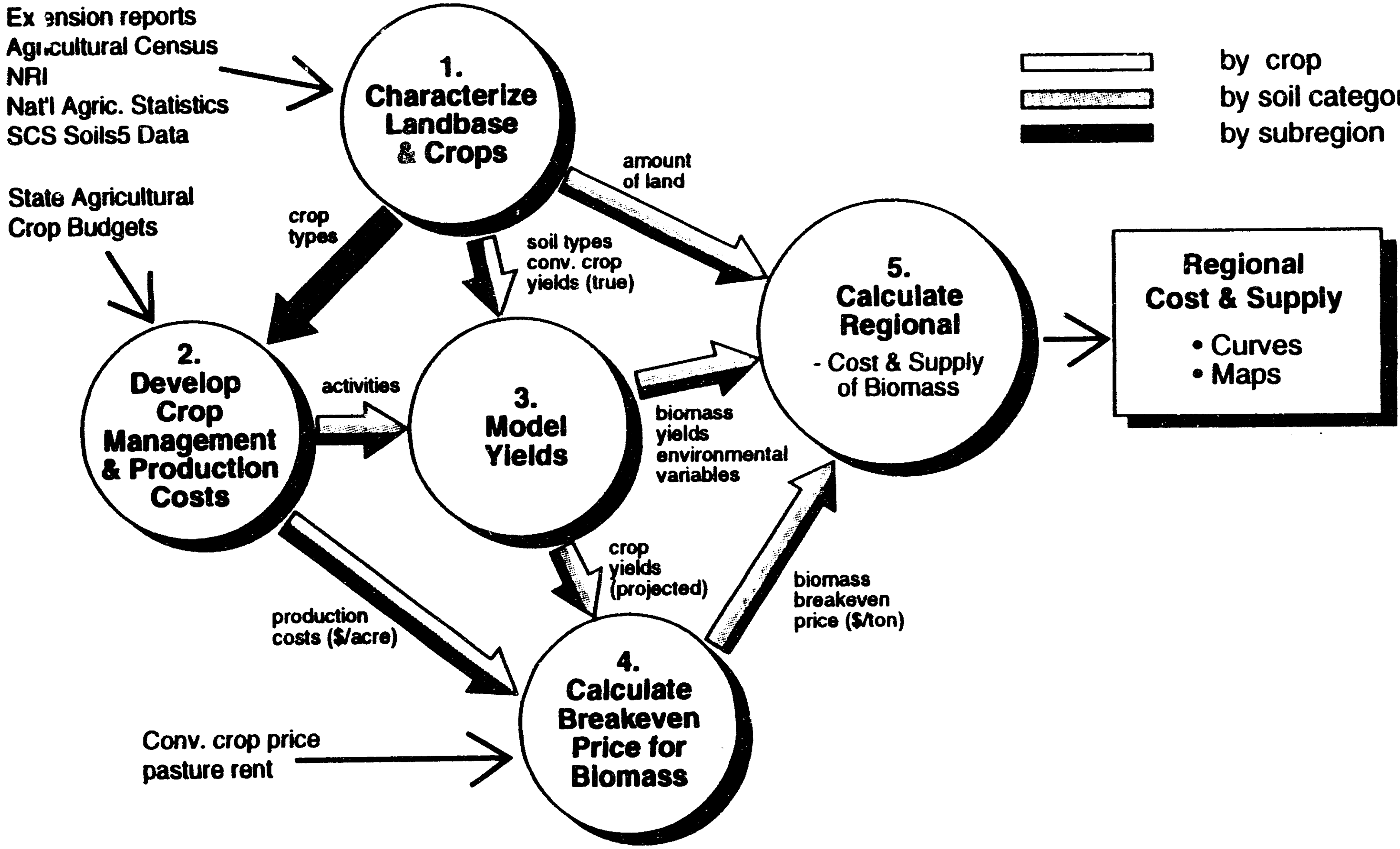
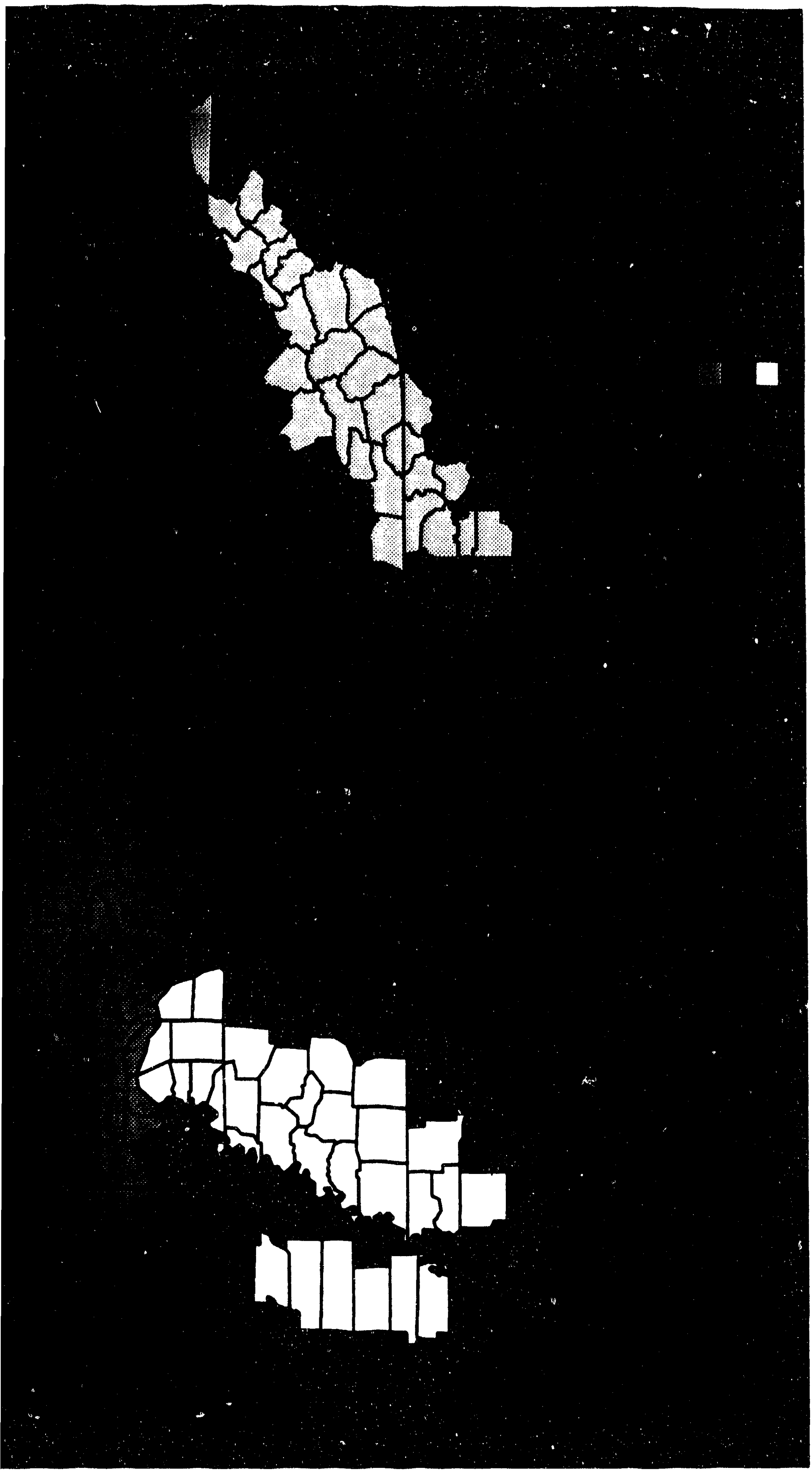
Economic Modeling Approach





characteristics module for each conventional crop grown, the SOILS5 soil name specific module, wind and weather data, and a crop management scenario. The subregion's wind and weather data module selected was that national weather service (NWS) weather and wind station data which was closest to the geographic center of the subregion. Management scenario information for the EPIC module was taken from state crop budget data information available from agricultural extension offices. For subregions which included counties from two or more states, information from the dominant state was used to characterize both crop budget and management practices. Tillage practices considered predominant for each state were used; the dominant tillage practices considered for most states was no-till, except for cotton acreage which was predominantly conventional till. A total of 216 EPIC simulations were completed, providing information on yields about three crops on nine soil categories in eight different subregions.

To provide more accurate yield information, an index of the ratio of NAS crop yield and EPIC simulated crop yield was produced. This index was used in Equation 1 and would be more representative of the true yield for a subregion. A more detailed explanation of this index is found in Graham and Downing (1993) in these proceedings.

Conventional Crop Market Prices and Production Costs

Conventional crop market prices were assumed constant across the entire study region. These were taken from Johnson (1990).

Each state crop budgeter provided an accurate production budget for each of three dominant crops in each subregion. Management scenarios were important determinants of the cost of production as were tillage practices. In order to determine overall investment and trade-offs, a discount rate of 6 percent was used.

Pasture rent values were determined on the state level as well. Pasture rent values considered were from the average gross cash rent per acre statistics from selected states for 1986-1990 (United States Department of Agriculture 1990). These values were estimated cash rent as a percent of the per-acre value of rented pasture.

SRWC Yields

There are several common SRWC varieties considered capable of reasonably fast growth, good quality for conversion, or resistant to disease. The varieties selected for growing in the subregions were sweetgum, poplar, sycamore, and black locust. SRWC wood was considered to grow better on some SCS soil classes than others, so each variety was tailored to the particular soil category. As displayed in Table 1, poplar was projected to grow on only the first and fourth soil categories, sweetgum was projected to grow best on the second and third. Black locust was expected to grow best on soil categories 5 and 6 and sycamore on soils 7 categorization. No SRWC wood was considered capable of growing on soil categories 8 and 9.

There have been numerous field trials conducted in the United States to evaluate SRWC yields (Bransby 1990, and Parrish 1990). There is little or no field data on SRWC yields in the 276 county study region. Therefore, expected yields for the 276 county region were assembled based on the best possible information from experts in the field (Cherney 1990, and Dobbins 1990). Yields were projected to range from 3.5 to 5 dry tons per acre across all subregions and were sensitive only to soil category, not subregion. Yields on pasture land of the same soil category were considered to be lower by an average of 20 percent because of conversion transition problems such as soil compaction and previous cropping and fertilization practices. EPIC does not yet contain an SRWC simulation module for any of the SRWC species we wished to model, so it was not used to simulate yields.

Table 1

SCS Soil Classes	Soil Categories	SRWC Species
1	1	Poplar
2w	2	Sweetgum
2e	3	Sweetgum
2s	4	Poplar
3w, 4w	5	Black locust
3e	6	Black locust
4e	7	Sycamore
3s, 4s	8	–
5–12	9	–

SRWC Production Costs

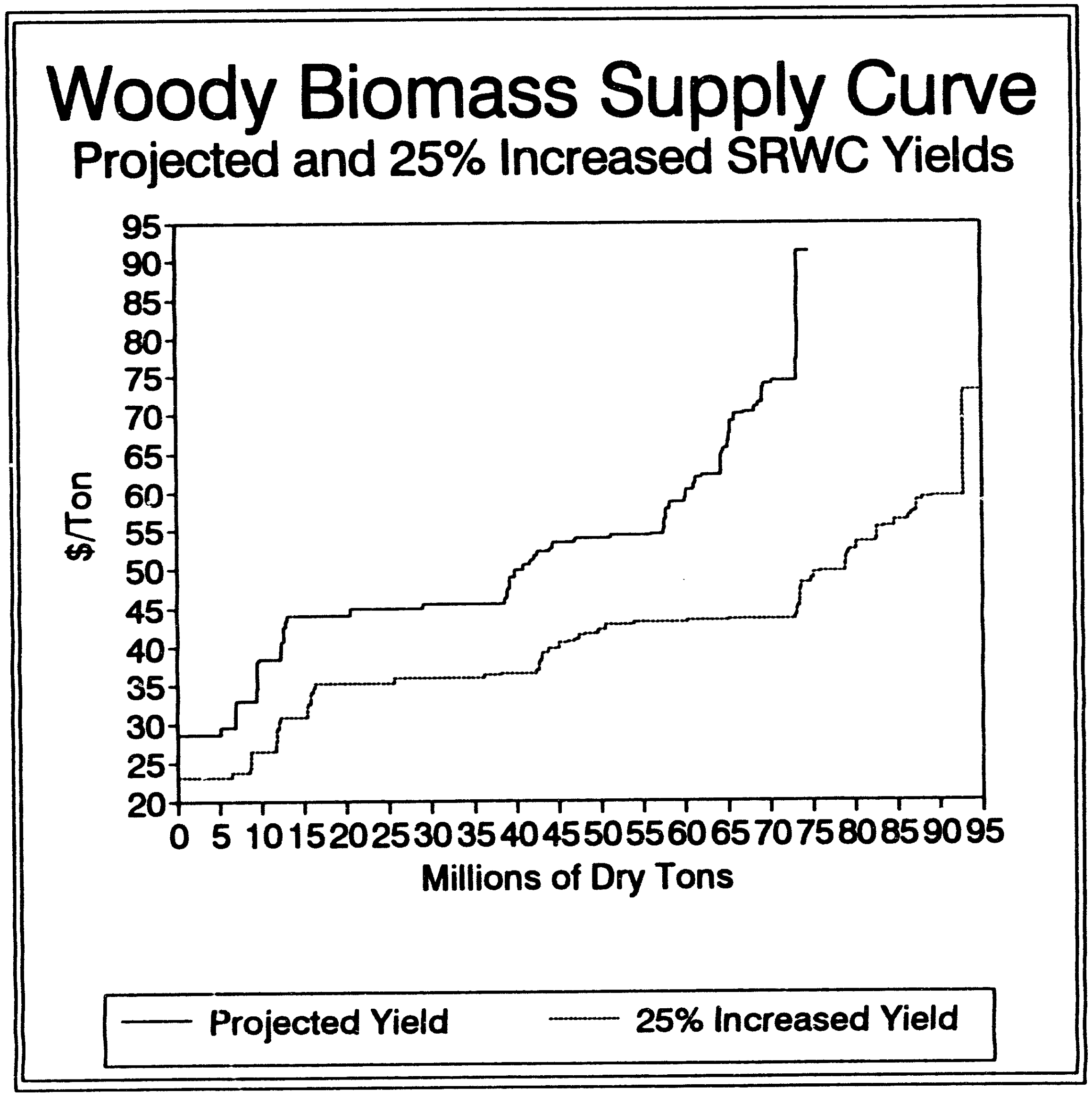
Each biomass crop species had a different rotation length based on knowledge of optimal rotation as seen in field trials in other parts of the country. Individual budgets for each rotation for each species were constructed to reflect the 6 percent discount rate, custom harvesting, and variable and fixed costs of production. Harvesting, for example included chipping costs, which would more accurately reflect the total cost of the final product. Losses for shrinkage were included, but transportation costs to move the product from the field to the utility plant were not.

BEP solution

The result of solution of Equation 1 for all subregions (8), across all soil categories (9) and for each conventional crop for crop land and pasture land, was a file containing 144 observations. We were thus able to calculate the breakeven prices for each crop as well as the maximum breakeven price for each subregion and soil category. The conventional crop corresponding to the maximum breakeven price was also identified. The maximum breakeven price was not allowed to imply a negative land rent. There were many instances in which none of the conventional agricultural crops were profitable. This may not be unrealistic as it is clear from discussions with the agricultural extension offices that farmers are going out of production in many of the counties examined.

Results

The solid supply curve shown in Figure 3 represents the SRWC biomass supply curve for the entire region of 276 counties. The total dry chipped tonnage of biomass projected to be supplied is shown to be 74 million tons. The price per dry chipped ton of SRWC biomass is shown to range from $28 to $93. Each step of this aggregate supply curve demonstrates a change in the price. For



Woody Biomass Supply Curve
Projected and 25% Increased SRWC Yields
$/Ton
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95
Millions of Dry Tons
Projected Yield
25% Increased Yield

example, approximately 25 million tons are available at a price of about $43 per ton. Two concepts of this additive supply curve are noteworthy. First, the steeper portions of the curve represent smaller groups of biomass available while the flatter portions of the curve represent more abundant quantities of biomass, at particular prices.

Based on how the breakeven prices for biomass were calculated, we showed that each county included in the study region had an individual quantity of biomass projected to be supplied at individual prices. The particular species of SRWC wood were also identified, as well as the acres and particular conventional agricultural crop displaced. The percentage of crop land and pasture land for each county was identified also.

An economic interpretation of the curve shows that movements along the curve (known as changes in quantity supplied) can only be made by either a change in price or quantity. Shifts in the curve itself would be due to changes in other determinants of supply such as changes in production technology or changes in the discount rate. For example, the broken curve in Figure 3 would represent the supply curve if production yields are increased by 25 percent. The supply curve appears shifted out and to the right as a result of costs of production decreasing on a per acre basis per unit of yield.

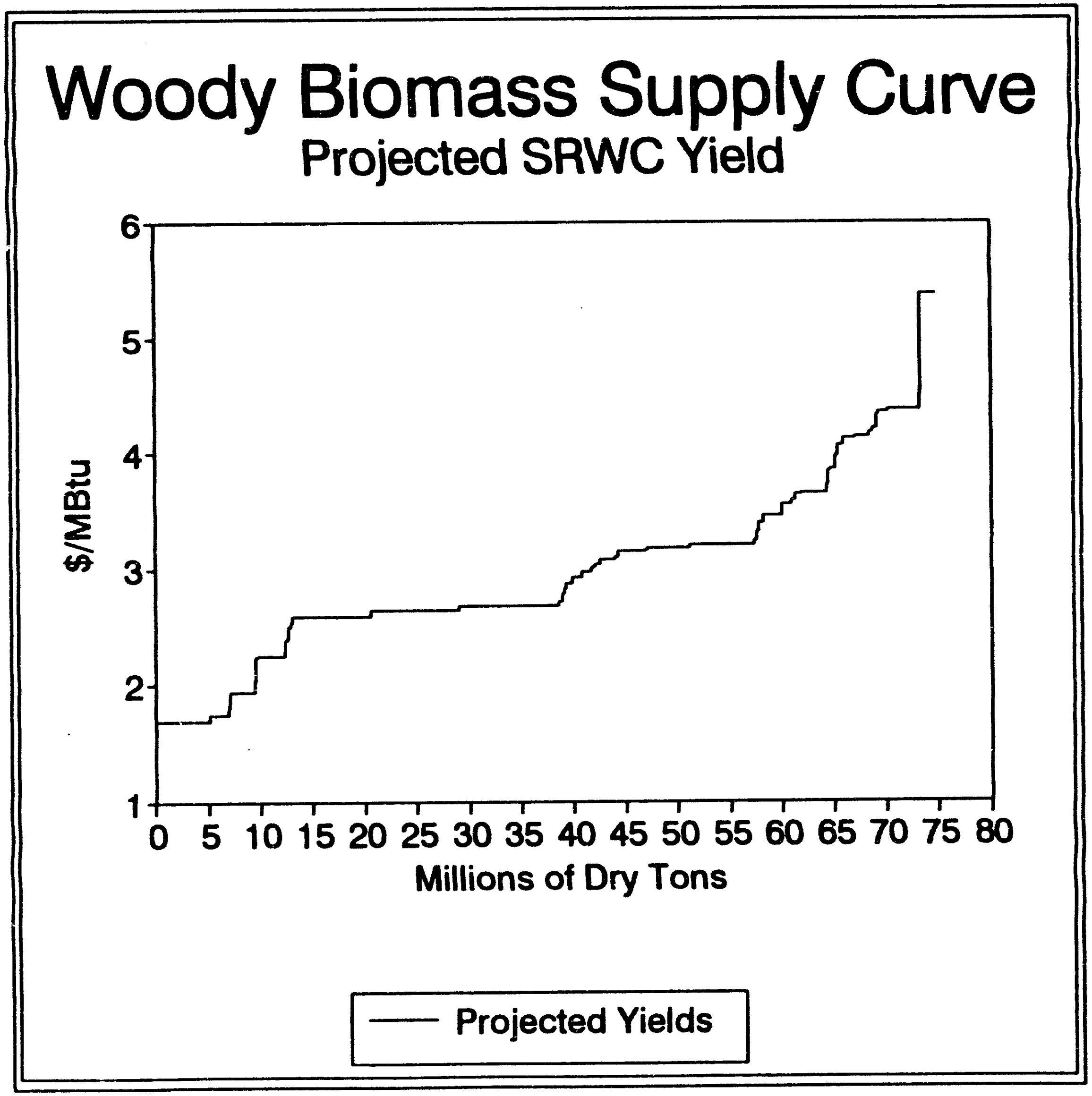
Figure 4 shows the conversion of the solid supply curve in Figure 3 from dollars per ton ($/Ton) to dollars per million British Thermal Units ($/MBtu). This curve can be used to compare the $/MBtu of coal, or other energy inputs to conversion for electricity production. TVA currently pays about $1.20/MBtu for coal (Gold, 1993). This curve is also useful in determining the trade-offs in using wood for production of ethanol as an end product vs production of electricity. Thus, woody biomass may be seen as having competing uses; for electricity production and conversion to ethanol.

Spatial distributions of the range of available quantities of woody biomass available at different prices are portrayed in the Figure 5. Each of the three maps represent the distribution by county for the quantities of woody biomass projected to be available at $2.00, $2.50 and $3.00 per MBtu. The land that currently produces more profitable conventional agricultural crops would tend to produce greater amounts of biomass, but at higher prices. Information such as this is important because it indicates something about the quality of land in certain areas, especially along the Mississippi River and in some of the corn growing regions of southern Illinois and Indiana. By the same logic, forested areas in the Virginia and North Carolina counties would tend to produce less quanities of biomass.

Discussion and Conclusions

The supply schedule (list of quantities available at certain prices) can be useful as inputs to a geographic information system (GIS). Modeling efforts currently underway using these data include determining optimal hauling distances and transportation routes for SRWC biomass from production location(s) to existing coal-fired power plants in the TVA region. Data needs for assisting in these kinds of decisions as well as decision making about future optimal location of electric power generating plants and other conversion facilities using GIS as a tool may include this supply information by county and information on geographic road location networks. Other information useable by GIS as "overlays" may be digitized maps showing the location of wetlands or other environmentally sensitive areas, major power transmission lines, location of population centers, and location of specific cropland usage areas (Noon 1993).

Extensive EPIC crop simulation modeling of conventional crops provided baseline information on level of fertilizer use, the effect on soil runoff, and evapotransporation levels of plants. This information is useful in determining the environmental effects of growing conventional agricultural



Woody Biomass Supply Curve
Projected SRWC Yield
$/MBtu
1
2
3
4
5
6
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
Millions of Dry Tons
Projected Yields

crops vs other biomass crops as a landscape alternative. These effects have been outlined and modeled in Graham and Downing (1993) focusing on herbaceous energy crops in particular.

This analysis includes no information about the effect of crop reduction program lands (CRP), livestock production areas, or agricultural reduction program (ARP) lands. In major agricultural areas, these considerations would be important in determining the BEP and for estimating the environmental effects. Data are available on ARP and CRP lands, by farm contract, and could be used in a resource analysis that included a linear program to solve for the optimal quantities of biomass to be produced (English, et al. 1992).

A parallel study is in process to determine the BEP of herbaceous energy crops (HEC) on the same production lands. It would not be determined if SRWC and HEC would be in competition on these lands, but relative BEP and production supply curves could be generated by the same modeling technique. An EPIC simulation module for switchgrass as well as sorghum is available, representing two crops commonly considered as HEC crops.

Risk has been analyzed by Brink and McCarl (1978) to determine the possible presence of risk (in the form of a risk coefficient) assumed by farmers in agriculture. Our analysis does not attempt to attach a risk coefficient, but it is apparent that there is probably some differential price that may have to be added to the BEP in order to actually induce farmers to switch from short rotation conventional agricultural crops to longer rotation biomass crops such as poplar and sweetgum. Further work in this areas is need to assess the particular associated risk coefficient associated with these trade-offs.

Further analyses needed relate to the nonmarket benefits that may accrue to society regarding the growing of biomass in lieu of agricultural crops. This has to do with the environmental analysis (Graham and Downing 1993) but considers some very important trade-offs to do with the environmental degradation and costs and benefits to society (Downing and Graham 1993).

Our analysis takes into account only the supply side of SRWC production of biomass for conversion to electricity. The other side of the total analysis would be from the demand side, where demand for biomass wood could be derived to establish an equilibrium price in the options for trade-offs for energy inputs.

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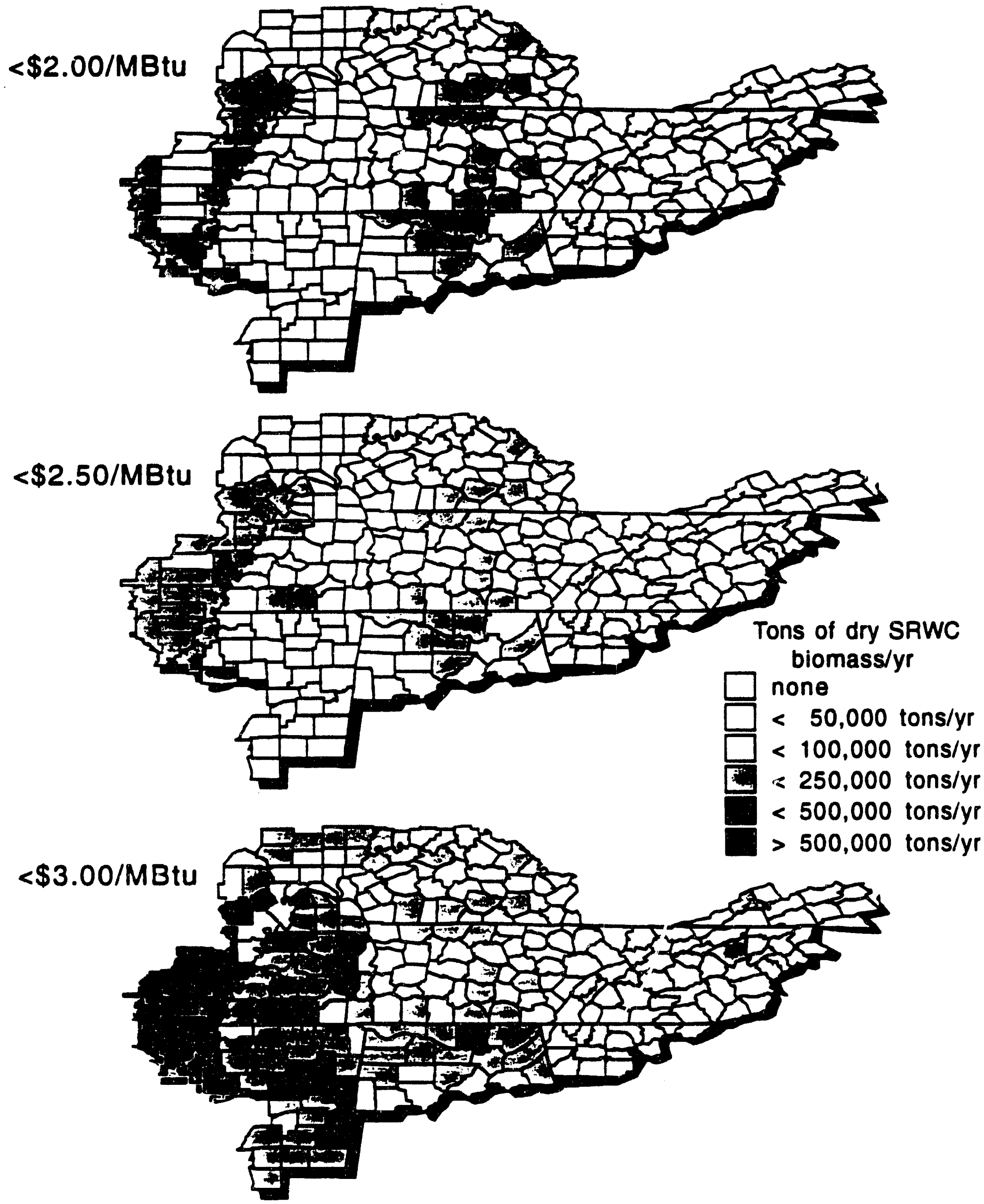
Supply of SRWC Biomass



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