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The Long-Term Competitive Position of Corn Grain Production in Virginia

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Rural Economic Analysis Program

The Rural Economic Analysis Program (REAP) was established by the 1988 General Assembly as a special initiative of Virginia Tech's College of Agriculture and Life Sciences. The REAP initiative developed from a recommendation of "The Future of Agriculture, Forestry, Food Industries and Rural Communities in Virginia" study which made recommendations to Governor Baliles on steps that could be taken to improve the economic well-being of Virginia's agriculture.

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Chapter 1. Background

Corn produced for grain has traditionally been important in Virginia agriculture to both corn producers and to the state livestock and poultry industries that use corn as a major input. Historically, corn for grain has ranked second in terms of harvested Virginia cropland acreage behind hay crops. According to the 1982 U.S. Agricultural Census, 611,032 of the 2,779,282 cropland acres harvested in Virginia (22%) were harvested for corn grain. During the 1980s the amount of corn grain produced in Virginia declined rapidly. By 1987, the Agricultural Census found that only 341,412 of the 2,406,976 Virginia cropland acres (14%) were harvested for corn grain. The 1988 harvest represented an historical low in terms of total corn grain acreage harvested (Virginia Agricultural Statistics).

Corn is a major input to both livestock and poultry enterprises. In 1988, the demand for corn grain as feed in Virginia was more than 60 million bushels (Thornsbury and Kenyon). Since 1970, there has been only one year when Virginia corn production was sufficient to meet the feed needs of the state livestock and poultry industries. The average amount of the deficit increased from 11 million bushels in the 1970s to 21 million bushels in the 1980s. The decreasing availability of Virginia corn could have a large impact on the competitiveness of the state livestock/poultry industries relative to other regions of the United States.

There have been five droughts in Virginia during the ten-year period since 1979 resulting in corn yield fluctuations from less than 50 bushels per acre to 100 bushels per acre. Consequently, more risk has been associated with corn production in the 1980s compared to the 1970s and the livestock/poultry sectors have faced a much more variable supply of corn. When the variability in total corn production was measured by coefficients-of-variation[1] (CV), there was a 29.9 percent increase in the variability of Virginia corn production from the 1970s to the 1980s (Pease and Tirupattur). This variability is a result of both fluctuating yields and a decrease in harvested acres and indicates there was a much higher degree of risk for both the corn and the livestock/poultry sectors in the 1980s.

Figure 1 shows the yields, acreage harvested, and total production of corn grain in Virginia. Since 1965 corn yields have trended upward (Figure 1A), but the variation in yields increased greatly during the 1980s. For example, in 1982 the average yield was 97.4 bushels per acre. In 1983 the average yield was 49.9 bushels per acre (a 49% change). The increased variability in the 1980s indicates a much higher risk associated with corn production in this period. The cost of production per acre has not changed

[1] The coefficient of variation is the standard deviation divided by the mean times 100. It is a unitless measure permitting comparison of variability across items measured in different units.

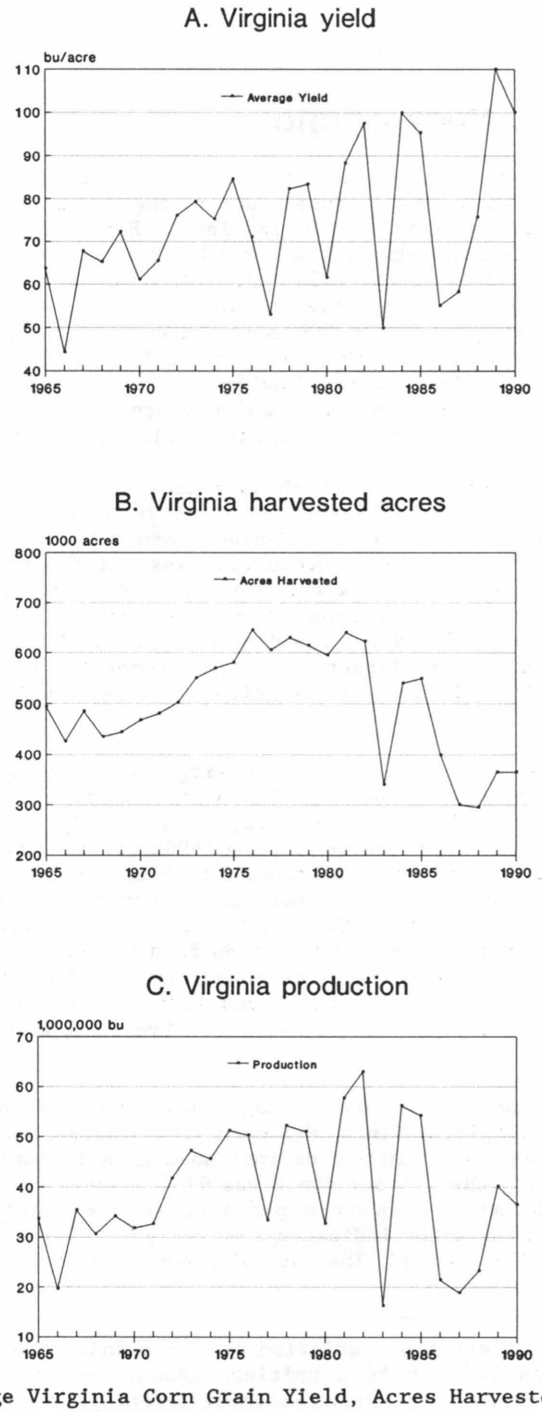

Figure 1. Average Virginia Corn Grain Yield, Acres Harvested, and Total Production, 1965-1990.

significantly from year to year during the 1980s, so a 50 percent decrease in yields effectively doubles the per-bushel cost of production.

Adverse weather conditions affect not only yields but also the total number of acres harvested as more corn may be left in the field or harvested as silage during dry years. Between 1980 and 1988 the number of acres harvested decreased 50 percent from 595,000 to 295,000. Corn grain fell to third place behind both hay crops and soybeans in terms of total acreage harvested in that year. Figure 1B shows the trend in harvested corn acreage over time. Combined with wide yield fluctuations, corn production from year to year has varied tremendously in the 1980s (Figure 1C). The 63 million bushels produced in 1982 represented the states highest level of corn production and the 16 million bushels produced in 1983 the lowest.

Corn grain cash receipt value to Virginia farmers has also declined substantially relative to other farm enterprises during the 1980s. Corn for grain accounted for 3.1 percent of all Virginia farm income in 1971, increasing to 6.5 percent in 1974, but by 1988 had dropped to only 1.6 percent (Virginia Agricultural Statistics).

Concurrent with the decline in Virginia corn grain production, the Virginia livestock industries increased their percentage of cash receipts from 57.4 percent in 1971 to 68.2 percent in 1988. Most of the growth could be attributed to the poultry sector which had increased receipts from 14.8 percent to 23.3 percent of all Virginia farm income. Receipts to the cattle industry remained fairly constant while the dairy and hog sectors declined. Indications are that the broiler and turkey industries will continue to expand in Virginia.

Since corn is a major input to the livestock and poultry sectors, both crop and livestock producers are concerned with the future of corn grain production in Virginia. If corn production levels continue to decline, an increasing amount of grain will have to be imported into the state. In some years with poor yields, the Virginia corn deficit approached 40 million bushels. On the other hand, the Midwestern portion of the United States is surplus in corn production. Wailes and Vercimak projected a 3-billion-bushel surplus for 1990 in five Midwestern states. The corn surplus for Ohio, the closest surplus state to Virginia, was projected at almost 400 million bushels. The main questions are: what will be the future production level for corn grain in Virginia and how many acres are capable of growing corn competitively with the Midwest?

Within the state of Virginia a wide variation in both supply and demand situations exists. Most of the corn is produced in the eastern and southeastern portions of the state, and these areas tend to be surplus in grain. On the other hand, a large amount of the demand for corn is found in the northern and northwestern sections where deficits are large. Therefore, the trade between regions in Virginia, as well as between Virginia and the Midwest, is critical. Furthermore, all Virginia-produced corn is not consumed within the state. The port of Hampton Roads has been a major export center for Virginia corn, especially in the early to mid-

1980s, and some grain moves out of the state to the Maryland poultry sector.

Cash corn prices in Virginia reflect the trade relationships between these regions as well as the trade relationship with the Midwest. Since 1984, the average Virginia corn price has been $0.23 per bushel higher than that of Ohio. Within the state the highest average corn price is found in the Shenandoah Valley area. Historically, this is a region that is deficit in corn grain. The lowest price regions are found in the eastern part of the state where a surplus of corn is generally available. These price relationships reflect the economic theory of trade between spatially separated markets. For a complete discussion of the theoretical problem and solution see Appendix A.

According to the theory, the price in Virginia will equal the price in Ohio plus transportation costs. Over time, the actual price relationships will conform to this theory. However, at any one point in time the prices may not differ by the exact amount of transportation costs due to fluctuations in regional supply and demand conditions. Figure 2 shows monthly Ohio and Virginia corn prices from January 1986 to February 1991. In Figure 2A the Virginia state average price is compared with that of Ohio. The difference between the two prices is not a constant amount, although the Virginia price never falls below that of Ohio. In a period of rapidly rising prices, May, 1988 to July 1988, the Ohio price approaches the Virginia price level.

Figure 2B and 2C show the differences in this pricing relationship between Ohio and a Virginia corn surplus region (Northern Neck) and a Virginia corn deficit region (Shenandoah Valley). The pricing relationships between the Shenandoah Valley and Ohio are much more consistent. The Shenandoah Valley is never surplus in corn grain and hence its supply and demand situation is relatively constant throughout the year. The pricing relationships between the Northern Neck and Ohio are much more variable. The Northern Neck produces a surplus of corn grain at harvest. As the corn is consumed within the region, or purchased by other regions, the Northern Neck becomes a deficit region. Hence, the supply and demand situations are more variable throughout the year as compared to the Shenandoah Valley.

In order to answer the important questions about regional competitiveness, it is necessary to examine not only the supply and demand relationships for corn within the state but the supply and demand in competing states. According to economic theory, trade between regions will occur when one region has a competitive advantage over the other region.

In reality, all markets are connected, and trade occurs between those markets where the difference in prices is greater than the transport costs between regions. In an interregional competition study, the competitive positions of various regions producing the same product are examined. Interregional competition studies have traditionally been used to determine which regions will remain competitive over the long-run.

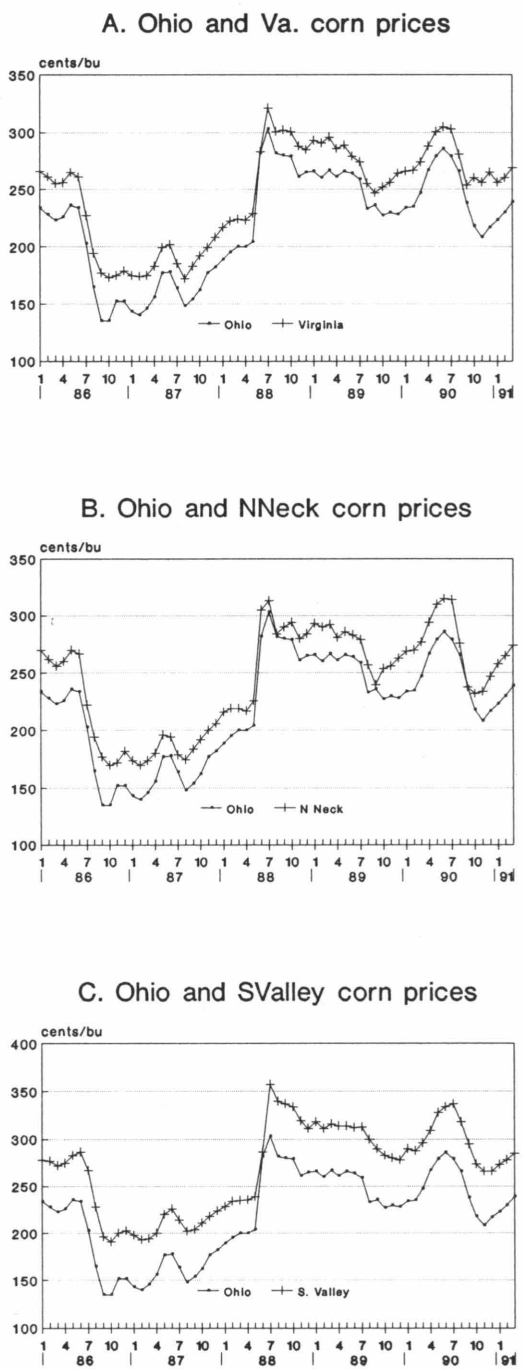

Figure 2. Monthly Corn Prices for Ohio and Virginia, January 1986 to March 1991.

If producers within a region can supply a market at a lower cost than competitors in other regions, the region will maintain or increase its market share over time. If producers within a region lose money in the process of supplying a market, or have a less favorable profit margin than their competitors, the market share of that region will decline over time.[2]

Objectives

The general objective of this study is to determine the amount and regional location of cropland acreage in Virginia capable of producing corn grain competitively with the Midwest. More specific objectives are to:

1. develop a linear programming model of the cost, production, and transportation network for corn grain in Virginia,
2. find the least cost source for corn to various points in Virginia,
3. calculate average yields needed to be competitive with this least-cost solution, and
4. determine the Virginia acreage capable of consistently producing corn at these yield levels.

General Approach

In order to look at the theoretical relationships more closely, a linear programming (LP) model was developed to simulate the cost, production, and transportation network for corn grain between Virginia and the Midwest. In order to include the regional competitiveness relationships within Virginia, the model was disaggregated into several regions. Corn exports from Virginia were also included through the port of Hampton Roads, Va. and to Salisbury, Maryland which is a nearby poultry producing area with a large demand for corn grain.

The model was validated using historical price levels for all regions to determine how closely the resulting prices and grain movements were following reality. Model results were compared with historical records to determine the ability of the model to simulate market prices and trade.

Next, corn production costs were substituted for prices in the model under three different scenarios. In the first scenario, Virginia users were permitted to buy corn from the cheapest source without any restrictions. In the second scenario, the model was restricted by the minimum of the previously harvested corn acreage for each region in the state. This procedure captured all possible rotational or other

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[2] Finding Your Competitive Advantage in Agriculture at the Farm, Regional and National Levels. I. A Base Book. Comparative Advantage and Competitiveness Task Force, ES-USDA Special Needs Project, February 1989, p.24.

restrictions on acreage. The cost model was run a final time using yield estimates for the 1980s based on earlier yield trends as if the drought years had not occurred.

Model results indicated an average cost per bushel for which corn grain could be available in each region. It is assumed that the rational corn buyer would obtain corn from the least-cost source. The average costs from the model solution were then divided into the total production cost per acre in the same region to determine the minimum yield level needed for that region to remain competitive with the alternative suppliers. Theoretically, the acreage that is not capable of producing corn at this competitive supply level will move out of corn production over time since it is at a comparative disadvantage to the other regions.

Chapter 2. Price Model Inputs

In order to determine how well the LP model follows the current situation, a price surface for corn grain was generated using output from the model. This price surface was compared with actual price relationships and corn movement patterns between Virginia and the Midwest.

Regions

Within the state of Virginia, both the supply of corn and the feed demand for corn vary widely. In order to capture these effects, the state was divided into thirteen regions based on historical land-use and price patterns (Figure 3). Cash corn prices are reported by the Virginia Department of Agriculture and Consumer Services (VDACS) for thirteen locations within the state. These price locations served as the hub for the regional divisions. Surrounding counties, where prices were not available, were divided among the regions based on three criterion: proximity to the pricing points, land-use similarities, and the most likely pricing source for grain. A specific city was located within each region to represent that area in the transportation network (Figure 3). These cities were chosen to follow as closely as possible the same price series for corn grain. Prices were available for specific cities in some of the regions and in others the price represented an average price across several cities within the region. When the reported price was an average, the city with the most surveyed dealers was chosen to represent that region.

Columbus, Ohio was chosen as the city representing the Midwest. Conversations with several Virginia feed dealers indicated that this was the point where most Virginia corn imports originated. The port of Hampton Roads, Va. and Salisbury, Md. were also included in the model as additional demand points for corn. These markets allowed Virginia-produced corn to be exported from the state.

Time Periods

Drought has been one of the largest factors impacting Virginia corn production during the 1980s. The average yields in Figure 1A illustrate the impact of droughts in 1980, 1983, 1986, and 1987. Ohio has also faced several droughts over this period. In order to capture the effect of fluctuating supply conditions, the price model was constructed to include the five crop years 1984/85 to 1988/89. This period covers a wide range of supply conditions as indicated by the average yield levels for both Virginia and Ohio shown in Table 1. The first year, 1984/85, indicates average Midwest yields and above average Virginia yields. Yields in both 1985/86 and 1986/87 were above average in the Midwest. However, while Virginia yields were good in 1985/86 they were very low in 1986/87 and 1987/88. In 1988/89 yields were average in Virginia and very poor in the Midwest. Specific Virginia regional yield levels are further discussed in the "Costs" section (p.41).

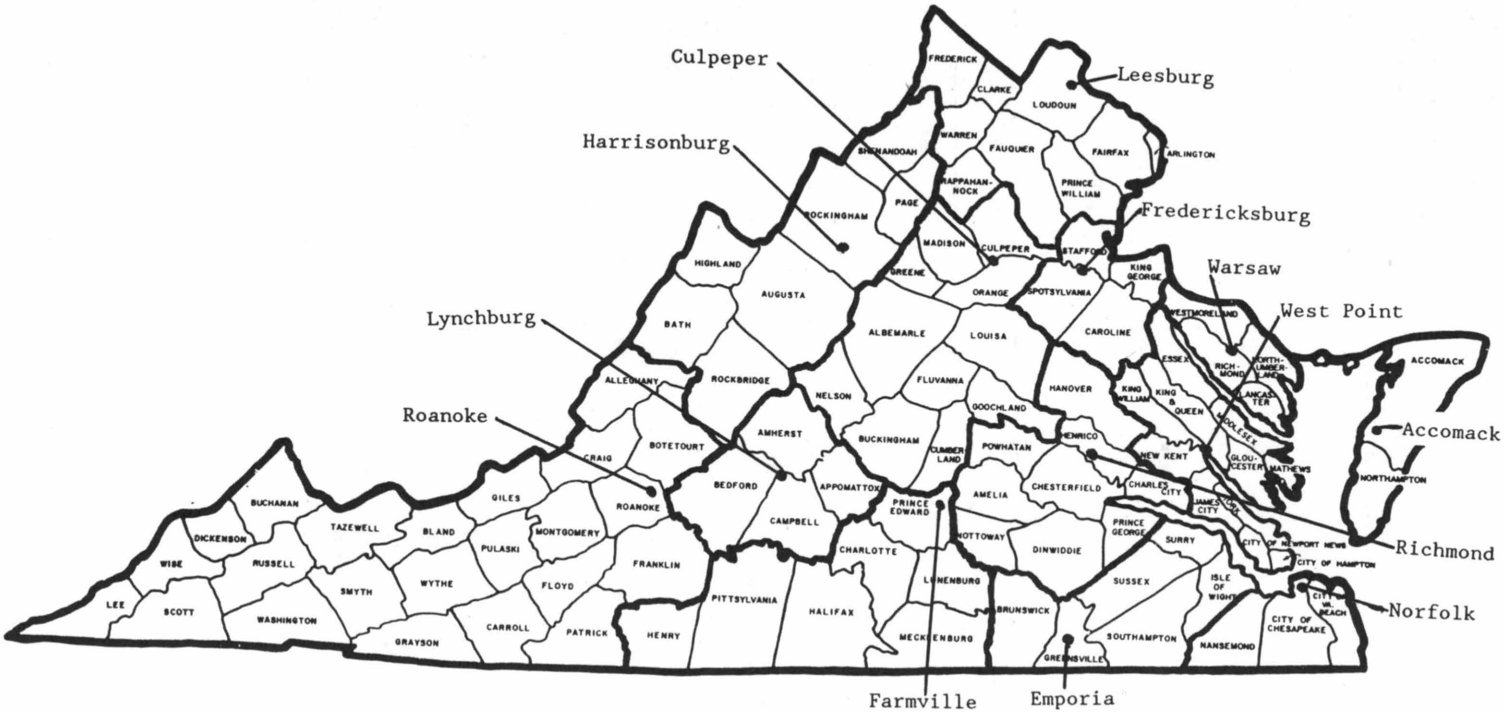

Figure 3. Regional Divisions and Specific Cities Used in Corn Transportation Models.

Table 1. Comparison of Average Virginia and Ohio Corn Grain Yields, 1984/85-1988/89.

Crop Year	Yields Virginia	Ohio
	------------(bu/acre)------------	
1984/85	99.9	118.0
1985/86	95.3	127.0
1986/87	55.0	128.0
1987/88	58.3	120.0
1988/89	75.7	85.0
Average	76.8	115.6

Source: Virginia and Ohio Agricultural Statistics

Demand Levels[3]

Fluctuating production conditions in Virginia indicated a fluctuating demand for Ohio corn from year-to-year. Virginia had a relatively greater excess demand in the drought years of 1986/87 and 1987/88 than in the other three years. The Virginia feed demand for corn grain was based on livestock and poultry numbers within each specific region. A previous study identified animal numbers county by county as well as typical rations and feeding levels (Thornsbury and Kenyon). These were used to compute corn consumption levels in each of the crop years (Table 2). Within the LP model, the regional demand for corn grain was set equal to these levels.

On average over the five-year period, the greatest demand for corn grain was in the Shenandoah Valley region - approximately 25 million bushels consumed. Poultry accounted for much of the corn consumption in the Shenandoah Valley; more than 95 percent of the turkeys in Virginia were located here as well as more than 50 percent of the broilers and layers. There was also a large consumption by the dairy industry. Although large segments of the beef and sheep industries were found in the Shenandoah Valley, these were traditionally smaller consumers of corn grain.

[3] For more information on the specific calculation of demand levels see Thornsbury and Kenyon.

Table 2. Regional Production, Consumption, and Surplus or Deficit of Corn Grain, 1984/85 to 1988/89.

Region	Year	Production	Consumption	Surplus/ Deficit
		------------------1000	bu.----------------	
Northern Virginia	1984/85	6139	2621	3518
	1985/86	6001	2685	3316
	1986/87	1840	2678	-838
	1987/88	1594	2636	-1042
	1988/89	1918	2551	-633
	AVG.	3498	2634	864
Shenandoah Valley	1984/85	4461	23204	-18743
	1985/86	3978	23009	-19031
	1986/87	1028	24763	-23735
	1987/88	752	26583	-25831
	1988/89	1311	27311	-26000
	AVG.	2306	24974	-22668
North Central	1984/85	5231	5381	-150
	1985/86	4845	5295	-450
	1986/87	1577	4714	-3137
	1987/88	1129	4558	-3429
	1988/89	1561	4486	-2925
	AVG.	2869	4887	-2018
East Central	1984/85	2750	500	2250
	1985/86	2258	484	1774
	1986/87	1261	469	792
	1987/88	754	465	289
	1988/89	871	450	421
	AVG.	1579	474	1105
Northern Neck	1984/85	5335	309	5026
	1985/86	4148	284	3864
	1986/87	1848	267	1581
	1987/88	2231	230	2001
	1988/89	2193	207	1986
	AVG.	3151	260	2891
Middle Penninsula	1984/85	7084	808	6276
	1985/86	6169	795	5374
	1986/87	2732	826	1906
	1987/88	3572	719	2853
	1988/89	3045	640	2405
	AVG.	4520	758	3762
East	1984/85	4145	4113	32
	1985/86	3521	3979	-458
	1986/87	1091	3911	-2820
	1987/88	1239	4045	-2806
	1988/89	1831	4047	-2216
	AVG.	2365	4019	-1654

continued next page

table 2. cont.

Coastal	1984/85	5105	2210	2895
	1985/86	6333	2069	4264
	1986/87	3505	2267	1238
	1987/88	2306	2322	-16
	1988/89	3340	2152	1188
	AVG.	4118	2204	1914
South East	1984/85	8100	3925	4175
	1985/86	9450	3653	5797
	1986/87	4073	3917	156
	1987/88	3161	4228	-1067
	1988/89	4630	3992	638
	AVG.	5883	3943	1940
South Side	1984/85	2711	2339	372
	1985/86	2568	2200	368
	1986/87	636	2245	-1609
	1987/88	564	2217	-1653
	1988/89	704	2119	-1415
	AVG.	1437	2224	-787
Central	1984/85	942	1892	-950
	1985/86	843	1981	-1138
	1986/87	179	1992	-1813
	1987/88	91	1871	-1780
	1988/89	240	1784	-1544
	AVG.	459	1904	-1445
South West	1984/85	3470	7233	-3763
	1985/86	3264	7131	-3867
	1986/87	1287	7404	-6117
	1987/88	1065	7336	-6271
	1988/89	834	7095	-6261
	AVG.	1984	7240	-5256
Eastern Shore	1984/85	542	1417	-875
	1985/86	641	1332	-691
	1986/87	393	1661	-1268
	1987/88	274	1912	-1638
	1988/89	525	2003	-1478
	AVG.	475	1665	-1190
State Total	1984/85	56015	55952	63
	1985/86	54019	54897	-878
	1986/87	21450	57114	-35664
	1987/88	18732	59122	-40390
	1988/89	23003	58837	-34181
	AVG.	34644	57184	-22540

Source: Thornsbury and Kenyon

The second largest consuming region was the Southwest accounting for 7 million bushels. This region had localized concentrations of the dairy, layer, and hog industries and more dispersed populations of the beef and horse sectors.

The broiler industry accounted for a large segment of the almost 5 million bushels consumed in the North Central region. Beef, dairy, hogs, and horses were also large consumers. Consumption in the Southeastern and Eastern regions was approximately 4 million bushels each. Consumption in the Eastern area was much more diverse with use by the broiler, hog, and dairy industries, while corn use in the Southeast was almost all by the hog sector.

Northern Virginia was the next largest consuming region of corn; the horse industry had its highest concentration in this area. The Southside and Coastal regions demanded approximately 2.2 million bushels of corn each; the beef and dairy sectors were the largest consumers in Southside, and hogs were the single largest consumer in the Coastal region.

Consumption in the Central region, with large concentrations of the layer, dairy, and beef industries, averaged 1.9 million bushels . The Eastern Shore region was composed of only two counties, but demand for corn was still almost 2 million bushels. The broiler industry accounted for almost all for this corn use. The three remaining regions - Middle Peninsula, East Central, and Northern Neck - showed demand levels less than 1 million bushels each with demand in the East Central and Northern Neck less than .5 million bushels each.

In the state as a whole, broilers were the single largest consuming sector of corn, using 16 million bushels in 1988, and this sector is expected to continue rapid growth in the future. Hogs have traditionally been another large corn consumer in Virginia. Corn use dropped off during the 1980s as hog numbers declined, but inventory numbers increased rapidly in 1989 and are expected to continue to grow. One of the most rapidly growing corn consuming sectors is the turkey industry. Corn use by turkeys has increased almost 400 percent since 1965, reaching over 4 million bushels by 1988. Dairy is the other large corn consuming sector in Virginia. Annual use is about 13-14 million bushels and has remained relatively constant over time.

Demand levels for corn in Ohio were taken from the Wailes and Vercimak publication, "Grain Production and Utilization in the United States". They published corn consumption estimates for 1981-1983 based on livestock numbers. While these estimates do not cover the specific period in the models their average does give an indication of the in-state use of feed corn. This average can be subtracted from annual production to give an estimate of the corn available for trade with Virginia.

Exports

The demand for Virginia corn by Salisbury, Md. was calculated by a percentage formula of the corn produced in Virginia. Since there was no way to calculate exactly how much corn is moving in this direction, an estimate was made based on the opinions of several knowledgeable industry personnel. The Maryland demand was set less than or equal to 16.5 percent of the average amount of corn produced in Virginia, and the model was allowed to find the optimal value.

Export demand was also included through the port of Hampton Roads (including Norfolk), located in the Coastal region. Although this is a major port for world exports, poor Virginia corn crops in the 1980s combined with the high state demand have caused a dramatic reduction in the amount of Virginia-produced corn being exported. Total corn export numbers through the port of Hampton Roads were obtained from the Feed and Grain Inspection Service and are shown in Table 3. This agency keeps records of the total amount of grain leaving the country. However, records of the origin of the grain were not available. Estimates were that 20 percent of the corn exports through Hampton Roads originated in Virginia and North Carolina. The remaining 80 percent came from Illinois, Indiana, Ohio, and Michigan.[4] These percentages are reflected in the values shown in Table 3.

Table 3. Corn Exports from the Port of Hampton Roads.

Crop Year	Total Exports	Va. & N.C. Exports
	bu	
1984/85	78,081,183	15,616,237
1985/86	47,536,483	9,507,297
1986/87	23,726,137	4,745,227
1987/88	18,098,582	3,619,716
1988/89	22,664,971	4,532,994
Average	38,021,468	7,604,294

Source: VDACS, Division of Marketing - Grain Marketing Services

[4] John H. Hunter, Director of Economic and Marketing Research, Virginia Department of Agriculture and Consumer Services, Marketing Division.

There were no data available to separate Virginia-grown corn exports from those of North Carolina. Industry estimates indicated that the amount of Virginia corn leaving the country had dropped dramatically since 1984 and had approached zero in the last several years. Conversely, North Carolina corn exports through Hampton Roads were estimated to have increased over this period. Therefore, Virginia corn represented a much higher percentage of the numbers in Table 3 in the earlier years and a lower percentage in the later years. For example, most of the 15 million bushels exported in 1984/85 originated in Virginia while most of the 4.6 million bushels exported in 1988/89 originated in North Carolina.

For use in the price model, it was assumed that over time approximately one-half of the exports came from each state. Therefore, the numbers in Table 3 were divided in half and then averaged to find the level of Virginia exports through Hampton Roads. This average value, 3,802,000 bushels, was then used in the price model as the upper bound for exports of corn.

Supply Levels[5]

Supply levels for both Virginia and Ohio corn were based on yield and harvested acreage records in each region. In the model, the supply was first set equal to these historical levels (Table 2) and then allowed to vary in order to find the least-cost solution. In the price model, the maximum supply level for each region was set at the average historical production level over the five-year period. For example, although the Shenandoah Valley produced 4,461,000 bushels of corn in 1984, the region produced an average of 2,306,000 bushels between 1984 and 1988. Therefore, in the price model the Shenandoah Valley could supply up to 2,306,000 bushels of corn. This restriction was adjusted later in the cost models.

Within Virginia, the largest average supply of corn was produced in the Southeast region which had a five-year average harvest of 5.8 million bushels. The Middle Peninsula region supplied 4.5 million bushels, or the next largest amount of corn in Virginia. In comparison, the Ohio harvest, represented by Columbus, produced a total of 413 million bushels of corn. The smallest Virginia supplier was the Eastern Shore region, which included only two counties and produced an average of .475 million bushels.

An initial comparison of supply and demand (Table 2) in the 13 Virginia regions indicates that, on average, seven regions have not produced enough corn in the last five years to meet their consumption needs. The other six regions have been able to meet their needs on average but show wide fluctuations from year to year. Only the East Central, Middle Peninsula, and Northern Neck have consistently produced enough corn to supply their own demand. So, even though Virginia is a deficit state on average, there have been at least three surplus regions each year since 1984/85. The

[5] For more detail on the calculation of regional supply levels see Thornsbury and Kenyon.

Shenandoah Valley, North Central, Central, Southwest, and Eastern Shore regions have had a deficit in corn every year, and the frequent droughts have caused large increases in the overall shortage.

Transportation Costs

There are three general modes of transportation employed for corn grain: rail, truck, and barge. Each of these was included in the model; the rates are shown in Table 4. Truck transportation was available between all points except for Maryland. The rates are based on a constant charge per mile. Mileage estimates were obtained from the Virginia State Highway map and from Rand McNally "Standard Highway Mileage Guide". The rates represent the most direct routes along major highways or interstates.

Since corn is an agricultural commodity, it is exempt from federal regulation, and rates are negotiated between the hauler and the specific shipper. Quotes from several haulers ranged from 95 cents to $1.25 per loaded mile. A typical load is negotiated on 850 bushels in order to meet state-regulated weight limits. This load would set the milage charge at an average of .13 cents per bushel per loaded mile. In contrast, quotes from several grain shippers ranged from .17 to .24 cents per bushel per loaded mile for corn grain that they were actually moving. By taking an average of these shipper quotes the rate was set at .21 cents per bushel per mile in the model.

Direct rail service was available from Columbus to all Virginia points except Leesburg and Warsaw. Since the railroad does not pass through these points, an option was available to move corn along the rail to a nearby city with transfer to trucks. Since deregulation of the railroads under the Staggers Act of 1980, rail companies can negotiate with individual shippers. Public tariff rates are still published, and by law the shipper is entitled to the lowest lawful rate on file. However, the railroads are now able to offer discount contracts to individual shippers in exchange for volume or origination commitments, accelerated freight payments, or the use of privately owned equipment.[6]

In the model, the public tariff rate for single car loads was used as the base rail transportation rate. Although no specific discount rates could be obtained, several estimates of "typical" discounts were provided by railroad personnel and shippers. These discounts range from 2-6 cents per bushel depending on the origin and destination of the shipment. They were used in the model to reduce the cost of rail transportation and are shown in Table 4.

As expected, barge shipments were available only along the coastal regions: Maryland, Northern Neck, Middle Peninsula, Eastern Shore, and Coastal. Again, barge rates are negotiated privately between haulers and

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[6] The information on rail rates and discounts is based on written and telephone conversations with several rail companies and grain dealers throughout Virginia.

Table 4. Transportation Rates Included in Linear Programming Model.

Ship From	Mode	Ship To NV[a]	SV	NC	EC	NN
		------------	------cents/bushel	------------		
Ohio	R[b]		42.2	45.0	46.4	
	RT	41.6				51.9
	RD	3.0	6.0	4.0	3.0	
	T	74.1	69.5	79.4	83.2	93.7
NV[a]	T		21.4	12.4	15.5	26.0
SV	T	21.4		14.3	19.9	30.4
NC	T	12.4	14.3		7.3	17.8
EC	T	15.5	19.9	7.3		10.5
NN	T	26.0	30.4	17.8	10.5	
MP	R		25.6			
	T	35.1	31.7	23.3	15.7	11.5
E	T	27.3	27.5	18.7	12.2	19.3
CST	T	45.1	46.6	36.5	30.2	24.4
SE	T	40.7	40.7	32.1	25.8	33.0
SS	T	33.4	28.3	21.2	24.8	32.8
CTR	T	35.3	19.7	22.7	28.1	42.4
SW	T	44.7	23.1	34.4	39.5	59.0
ES	T	47.5	61.3	50.8	44.7	40.5

continued next page

Table 4. cont.

Ship From	Mode	MP	E	Cst	SE	SS
		cents/bushel				
Ohio	R	54.8	51.7	58.0	53.3	45.3
	RT	54.6				
	RD	3.0	3.0	6.0		
	T	98.9	93.4	112.3	105.4	90.3
NV	T	35.1	27.3	45.1	40.7	33.4
SV	T	31.7	27.5	46.6	40.7	28.3
NC	T	23.3	18.7	36.5	32.1	21.2
EC	T	15.7	12.2	30.2	25.8	24.8
NN	T	11.5	19.3	24.4	33.0	32.8
	B			12.5		
MP	R		20.6	20.6	20.6	
	T		7.8	13.9	19.5	21.2
	B			12.5		
E	T	7.8		19.5	13.6	13.4
CST	R	20.6			16.7	
	T	13.9	19.5		16.8	30.0
SE	R	20.6		16.7		
	T	19.5	13.6	16.8		19.3
SS	T	21.2	13.4	30.0	19.3	
CTR	T	31.5	23.1	39.9	29.4	9.9
SW	T	42.2	39.7	50.4	41.2	20.6
ES	R			19.5		
	RD			5.0		
	T	30.0	34.2	16.2	32.8	45.8
	B			10.0		

continued next page

Table 4. cont.

Ship From	Mode	Ship To: Ctr	SW	ES	Md	HR
		-----cents/bushel-----				
Ohio	R	42.2	39.0			
	RT			66.5		
	RD	2.0	2.0			
	T	80.4	71.2	128.5		
NV	T	35.3	44.7	47.5		45.1
SV	T	19.7	23.1	61.3		46.6
NC	T	22.7	34.4	50.8		36.5
EC	T	28.1	39.5	44.7		30.2
NN	T	42.4	59.0	40.5		24.4
	B			10.0	14.0	12.5
MP	R		26.6			
	T	31.5	42.2	30.0		13.9
	B			10.0	14.0	12.5
E	T	23.1	39.7	34.2		19.5
CST	R			19.5		
	RD			5.0		
	T	39.9	50.4	16.2		
	B			10.0		
SE	T	29.4	41.2	32.8		16.8
SS	T	9.9	20.6	45.8		30.0
CTR	T		10.9	56.1		39.9
SW	T	10.9		66.6		50.4
ES	T	56.1	66.6			16.2
	B				14.0	8.0

[a] NV=Northern Virginia
SV=Shenandoah Valley
NC=North Central
EC= East Central
NN=Northern Neck
MP=Middle Penninsula
E=Eastern
CST=Coastal
SE=Southeast
SS=Southside
CTR=Central
SW=Southwest
ES=Eastern Shore
MD=Salisbury, Maryland
HR=Hampton Roads

[b] R= rail rate
RT= rail & truck rate
RD= rail discount
T= truck rate
B= barge rate

shippers and are highly confidential. Therefore, the rates used in the model were estimates based on "typical" values provided by industry representatives. Since most of the fee charged for barge transport is accrued during the loading and unloading stages, the difference in rates among these relatively close points was only 4 to 6 cents per bushel.

Given these transportation parameters, some routes had multiple means of transportation available. For example, corn could move from the Coastal to the Eastern Shore region by either rail, truck, or barge. On the other hand, most grain movement within Virginia was restricted solely to truck travel. For example, corn was moved between Southside and Central Virginia only by truck.

The use of specific cities to represent regions within the transportation network resulted in some minor distortions in the model results. For example, Culpeper represents the North Central district and Fredericksburg represents the East Central district (Figure 3). The transportation rate between these two points (based on mileage) was less than the rate would be from Fredericksburg to a point in the southern portion of the North Central district. In reality, the rate from each individual supply source to each individual demand point would be different. The use of specific cities was necessary to simplify the model without creating large distortions in the results.

Prices

Annual crop year prices paid to farmers were used in the price model. The Ohio price was reported by Ohio Agricultural Statistics and is a state average. Virginia prices were obtained from the "Agricultural Commodity Newsletter", which publishes weekly prices received by farmers in the 13 regions. The only exception was the Eastern Shore region, which does not report corn prices on a regular weekly basis. In order to calculate an annual average corn price for the Eastern Shore, weekly price estimates were made when reported prices were not available. These estimates were based on the relationship between the Virginia and Maryland Eastern Shore corn prices when reported numbers for both regions were available.

The price paid for corn in Salisbury, Md. was the average cash price for the lower Maryland Eastern Shore, as reported by the Maryland Department of Agriculture in the "Maryland Feed and Grain Report". The price received at the port of Hampton Roads was the Norfolk cash price. Table 5 lists the annual and five-year average prices for all the regions in the model.

Rotations

Corn is an important crop in several cropping rotations in Virginia. In Southeastern Virginia, corn is rotated with peanuts. Extension personnel estimate that 75 percent of all Virginia peanut producers follow this rotation. A comparison of the 1987 Agricultural Census data on corn and peanut acreage in the Southeast region indicates that peanut acreage

Table 5. Annual Cash Corn Prices Used in the Price Model.

Region	1984/85	1985/86	1986/87	1987/88	1988/89	Avg.
	--------	--------	-------- $/bu --------	--------	--------	--------
Ohio	2.59	2.45	1.50	1.95	2.65	2.23
N. Virginia	2.75	2.40	1.80	2.44	2.98	2.47
Shen Valley	2.99	2.62	2.04	2.62	3.13	2.68
N. Central	2.78	2.52	2.02	2.54	3.03	2.58
E. Central	2.51	2.22	1.69	2.31	2.63	2.27
N. Neck	2.68	2.31	1.58	2.29	2.62	2.30
M. Penninsula	2.70	2.31	1.60	2.30	2.62	2.31
East	2.80	2.45	1.79	2.40	2.80	2.45
Coastal	2.77	2.32	1.72	2.31	2.60	2.34
Southeast	2.71	2.33	1.80	2.44	2.76	2.41
Southside	2.93	2.53	1.92	2.47	2.87	2.54
Central	2.95	2.58	1.98	2.58	2.99	2.62
Southwest	2.91	2.56	1.90	2.52	2.95	2.57
Eastern Shore	2.78	2.33	1.72	2.30	2.64	2.36
Maryland	2.81	2.40	1.80	2.48	2.85	2.47
Hampton Roads	2.77	2.32	1.72	2.31	2.60	2.34

was approximately 78 percent of the corn acreage in 1987.[7] Other common Virginia rotations are either corn followed by a small grain and soybean double crop or corn followed by full season soybeans. The extent to which these rotations, or variations on them, are followed varies tremendously throughout the state.

To account for these rotations, the price model was run with the amount of corn acreage harvested set greater than or equal to the lowest reported harvest level in the five-year period. This approach accounts for all corn that is being planted to meet rotational requirements and to maintain "base" in the government programs. The historical minimum, maximum, and average harvested acreage by region is shown in Table 6.

[7] Brunswick county was not included in the average since there are no peanuts reported planted in this county.

Table 6. Corn Acreage Harvested in 13 Virginia Regions, 1984-1988.

Region	Minimum	Average	Maximum
	-----------------	acres	-----------------
Northern Virginia	27,500	46,100	70,500
Shenandoah Valley	11,960	26,974	44,600
North Central	20,550	36,420	57,000
East Central	11,900	18,460	23,900
Northern Neck	27,900	38,240	46,500
Middle Penninsula	39,667	53,856	64,050
East	17,700	29,460	39,950
Coastal	30,900	41,280	51,400
Southeast	50,600	71,660	89,200
Southside	9,600	20,940	33,600
Central	2,500	6,320	10,800
Southwest	9,620	22,025	35,995
Eastern Shore	3,700	5,243	6,350
State	264,097	416,978	573,845

Source: Virginia Agricultural Statistics

Chapter 3. The Price Model

The price model was solved, minimizing total purchase cost and using the previously discussed demand, export, supply, transportation, and price inputs, in order to develop a price surface for corn in the model area. According to theory, corn will flow only between those regions where the difference in price is greater than transportation costs.

Table 7 lists the assumptions and results of the price model. A total of 38,907,000 bushels was traded; only the Northern Virginia and Southeast regions did not trade. The resulting objective function value was $144,589,000, the total cost of corn purchased minus the receipts for corn exported. Slightly more than 30.5 million bushels of corn were purchased from Ohio and .25 million bushels were exported to Maryland. A total of 344,173 acres was harvested in Virginia to produce almost 27 million bushels. This amount was lower than the actual average acreage harvested between 1984-1988 (416,978 acres) but higher than the historical low acreage harvested in this period (264,097 acres). In the model solution, Virginia remained 30.5 million bushels deficit in corn grain production relative to utilization.

Within the model solution, there were seven deficit regions (Shenandoah Valley, North Central, East, Southside, Central, Southwest, and Eastern Shore) and four surplus regions (East Central, Northern Neck, Middle Peninsula, Coastal). The remaining two Virginia regions (Northern Virginia, Southeast) produced only enough corn to supply their own needs although they could have produced more within the constraints of the model.

The shadow prices indicate that if there had been no upper limit on the amount of corn grown, seven regions would have increased their production levels. Both the East Central and Eastern Shore regions would have increased production substantially and the Northern Neck, Middle Peninsula, Southside, Central, and Southwest regions would have increased production levels slightly when production in the other regions was held constant. The shadow prices for these seven regions are shown in Table 8. They indicate how much the total cost would be reduced if production could be expanded in these regions. For example, if total production increased by 1000 bushels in the East Central region, the total cost would decrease by 16.5 cents.

Four regions would have decreased their supply of corn if the rotational restrictions had been removed. Based on the shadow prices (Table 8), producing 1000 fewer acres of corn in the Shenandoah Valley would have decreased the total cost by $6.53 per acre. One thousand fewer acres in the North Central, Eastern, and Coastal regions would have decreased total cost by $5.06, $2.69, and $0.99 respectively.

Figure 4 indicates the trade flow directions, transportation costs, and weighted average price levels that resulted from the model. Three

Table 7. Price Model Assumptions and Results.

Assumptions:

Objective Function: minimize total purchase cost
Supply: less than or equal to average production 1984-1988
Yield: average yield, 1984-1988
Acreage: greater than or equal to minimum harvested 1984-1988
Price: average price, 1984-1988
Demand: feed use equals average use, 1984-1988
Exports: less than or equal to average 1984-1988

Results:

Objective function value = $144,589,000

Region	Acres	Production (1000 bu)	Demand (1000 bu)	Wtd Avg Purchase Price ($/bu)	Shipments + buy from - sell to (1000 bu)	
N. Virginia	40,035	2,634	2,634	2.47		
Shen Valley	11,960	887	24,974	2.59	+ 23,820	COL
					+ 266	MP
N. Central	20,550	1,453	4,887	2.48	+ 1,105	EC
					+ 2,329	NN
E. Central	19,862	1,579	474	2.27	- 1,105	NC
N. Neck	39,388	3,151	260	2.30	- 2,329	NC
					- 228	MD
					- 335	ES
M. Penninsula	54,197	4,520	758	2.31	- 266	SV
					- 2,709	E
					- 787	SS
East	17,700	1,310	4,019	2.41	+ 2,709	MP
Coastal	30,900	3,059	2,204	2.34	- 855	ES
Southeast	51,407	3,943	3,943	2.41		
Southside	22,594	1,437	2,224	2.53	+ 787	MP
Central	7,476	459	1,904	2.63	+ 1,445	COL
Southwest	23,424	1,984	7,240	2.59	+ 5,256	COL
Eastern Shore	4,680	475	1,665	2.41	+ 855	COA
					+ 335	NN
Total	344,173	26,891	57,186	2.44	+ 38,907	ALL
					+ 30,521	COL

COL = Columbus
MP = M. Penninsula
EC = E. Central
NN = N. Neck
NC = N. Central
MD = Salisbury, Md
SV = Shen Valley
E = East
SS = Southside
ES = Eastern Shore
COA = Coastal
ALL = Total Amt. Traded

Table 8. Shadow Prices Calculated in Price Model Results.

Quantity of Corn Supplied

Region	Quantity Supplied (1000 bu)	Shadow Price (cents)
East Central	1579	-16.5
Northern Neck	3151	-3.0
Middle Penninsula	4520	-2.6
Southside	1437	-0.8
Central	459	-1.2
Southwest	1984	-3.0
Eastern Shore	475	-7.0

Acreage Planted to Meet Rotational Restrictions

Region	Acres Harvested (1000 acres)	Shadow Prices (cents)
Shenadoah Valley	11.9	653
North Central	20.6	506
East	17.7	269
Coastal	30.9	99

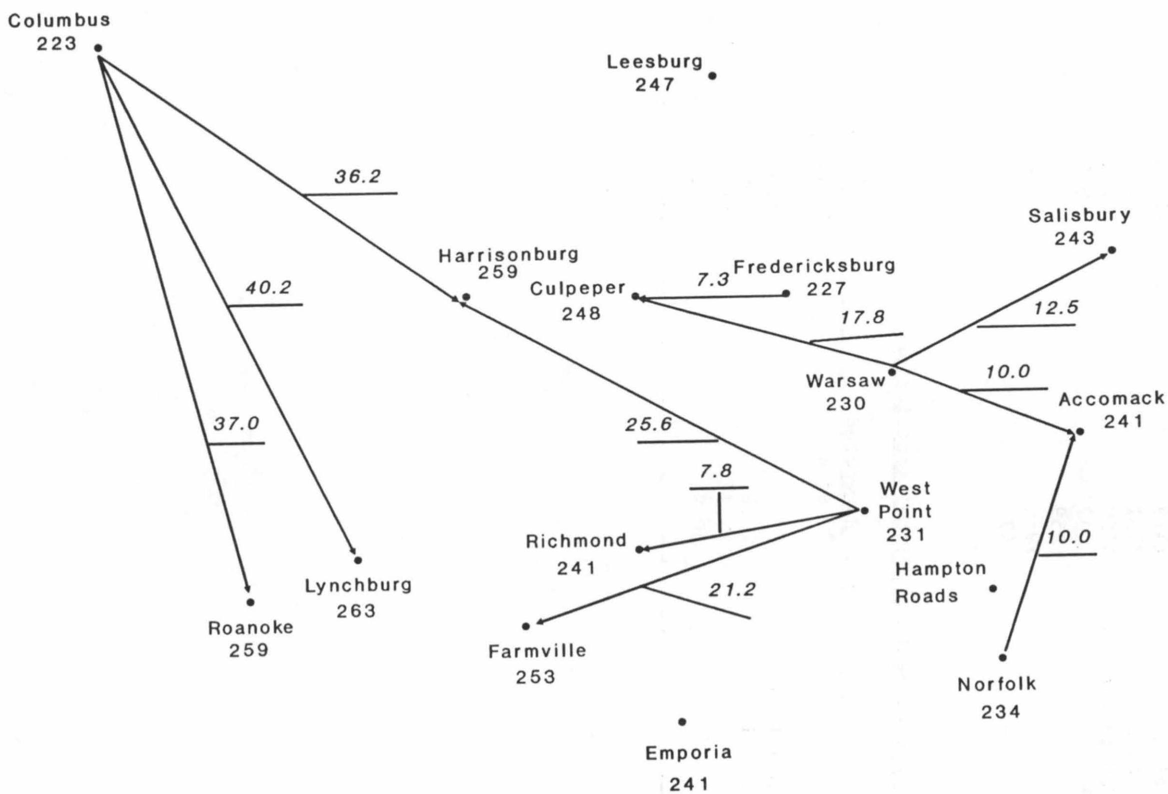

Figure 4. Transportation Network and Weighted Average Purchase Price Results (cents per bushel) from the Price Model.
[Values in italics are transportation rates between points (cents per bushel)]

Virginia regions imported corn from Ohio: Southwest, Central, and the Shenandoah Valley. The Shenandoah Valley purchased additional corn from the Middle Peninsula region, which also supplied corn to the East and Southside. The Northern Neck region exported corn to Maryland and supplied the North Central and Eastern Shore regions. The East Central also supplied corn to the North Central, and the Coastal region sent its surplus corn to the Eastern Shore. Two regions did not trade: Northern Virginia and Southeast. These grain movements are all consistent with actual trade flow patterns reported by industry personnel.

In the optimal solution, there were no Virginia corn exports through the port of Hampton Roads. There was some trade with Maryland: the Middle Peninsula exported .25 million bushels of corn to Salisbury. Again, this trade is consistent with reported trade flow patterns in recent years.

Figure 4 also indicates the weighted average price levels and transportation costs found in the model results. Consistent with theory, the price in the two non-trading regions was less than the price in the nearest surplus area plus transportation. The Northern Neck price ($2.30) plus 26 cents transportation to Northern Virginia would raise that price to $2.56 per bushel, compared with the $2.47 price found in the optimal solution. The East Central was a potential supplier to Northern Virginia but the surplus in the area was all being sent to the North Central region. The price in the Southeast plus transportation to Southside was also more than the $2.53 optimal price, so no trade occurred. The Coastal region was the nearest surplus area to the Southeast, but trade would have raised the Southeast price from $2.41 to $2.51 per bushel.

Within the regions that did trade, the calculated price levels accurately reflected prices plus the cost of transportation. In regions with more than one supplier (including locally produced corn), the price level reflected a weighted average of prices and transportation costs among suppliers. For example, the average solution value in the North Central region (Culpeper) was $2.48 per bushel. Corn was supplied to the North Central from both the Northern Neck (Warsaw) and East Central (Fredericksburg) regions, as well as some locally produced grain.

The North Central cost of corn from the East Central region was the $2.27 per bushel purchase price plus 7.3 cents per bushel transportation cost from Fredericksburg to Culpeper. The North Central region purchased 1,105,000 bushels from the East Central in the optimal solution. The North Central cost of corn from the Northern Neck region was the $2.30 per bushel purchase price plus 17.8 cents per bushel transportation cost from Warsaw to Culpeper. The North Central region purchased 2,329,000 bushels from the Northern Neck in the optimal solution. A total of 1,453,000 bushels was produced and consumed within the North Central region. The cost of this corn was the $2.58 per bushel historical average price (Table 5). An average of these costs, weighted by the amount purchased from each region, equaled the average solution value calculated by the model and shown in Figure 4 for the North Central region ($2.48 per bushel).

These weighted average purchase price results were not equal to the market prices in each location. According to economic theory, if the market price in the East Central was $2.27 per bushel and transportation to the North Central was 7.3 cents, the market price in the North Central would have been $2.34. However, in the model solution each region was forced to produce corn at the historical minimum level and this corn must either be consumed within the state or exported. The North Central was a relatively high price region, $2.58 per bushel, and to minimize total costs across all regions, the corn produced in the North Central was consumed locally rather than being transported to another region.

Also, the regions compete for the lower priced corn. For example, the East Central produced a total of 1,579,000 bushels (its maximum level) but only 1,105,000 bushels were shipped to the North Central. In minimizing total costs it was optimal for the East Central to supply its own needs first and sell only the excess grain. When the model was solved, it minimized the total cost of the corn consumed in all regions. Price levels were not "bid-up" by competing regions but competition existed for the supply of lower priced corn. In reality consumers in the North and East Central regions would compete for the corn and the price would be bid up to $2.58 in the North Central region and $2.51 in the East Central ($2.58 minus transportation costs). Similarly, if consumers in the North Central would pay $2.58 per bushel then producers in the Northern Neck would not take less than $2.40 per bushel ($2.58 minus 17.8 cents transportation cost). Thus the market price in the North Central region would be $2.58 per bushel compared to the $2.48 per bushel weighted average purchase price calculated by the model.

The calculated price surface followed the actual market prices very closely. Weighted average solution prices calculated in seven regions (Columbus, Northern Virginia, East Central, Northern Neck, Middle Peninsula, Coastal, Southeast) matched the market prices exactly. Model solution prices in the other seven regions varied from $0.10 lower (North Central) to $0.05 higher (Eastern Shore) than the reported market prices. The average difference between the calculated an actual prices was -$0.023.

Table 9 shows the demand, supply, and price inputs to the model as well as the demand, supply, and weighted average price levels that resulted from the optimal solution. Since demand level was set based on usage by the livestock and poultry industries in each region, these levels remained the same in the solution. Input supply level represented the maximum output possible. Six regions reduced output in the optimal solution. When the change in output was measured as a percentage of the possible production levels, all of the regions decreased production by more than 25 percent. The Shenandoah Valley, with an 62 percent reduction, showed the largest change.

The price surface and trade flows followed economic theory and trade patterns reported by the industry. Therefore, the model seemed to be consistent with actual prices and trade flows and was modified in various ways to answer the objectives laid out for this research project.

Table 9. Inputs and Results of the Five-Year Average Price Model.

	Inputs			Results		
	Demand (1000 bu)	Max. Supply (1000 bu)	Price ($/bu)	Demand (1000 bu)	Supply (1000 bu)	Price ($/bu)
Ohio		413114	2.23		30521	2.23
Northern Va.	2634.3	3498	2.47	2634.3	2634	2.47
Shen. Valley	24973.9	2306	2.68	24973.9	887	2.59
N. Central	4886.8	2869	2.58	4886.8	1453	2.48
E. Central	473.6	1579	2.27	473.6	1579	2.27
Northern Neck	259.5	3151	2.30	259.5	3151	2.30
M. Penninsula	757.5	4520	2.31	757.5	4520	2.31
East	4019.0	2365	2.45	4019.0	1310	2.41
Coastal	2204.0	4118	2.34	2204.0	3059	2.34
Southeast	3942.9	5883	2.41	3942.9	3943	2.41
Southside	2224.1	1437	2.54	2224.1	1437	2.53
Central	1903.9	459	2.62	1903.9	459	2.63
Southwest	7240.0	1984	2.57	7240.0	1984	2.59
Eastern Shore	1665.1	475	2.36	1665.1	475	2.41
Va. Total	57184.6	34644	2.45	57184.6	26891	2.44

Chapter 4. Cost Model Inputs

The market prices used in the previous model already incorporated information about supply, demand, and transportation rates. In order to look at the competitive position of corn grain in Virginia compared with that of the Midwest, the model was run using cost of production data. Many of the inputs to the cost model were the same as those discussed earlier in relation to the price model. The regional divisions, demand estimates, and transportation costs all remained the same. There were several changes to the time period, supply, export, and rotational requirements. These are discussed in the following sections as well as the cost-of-production values calculations.

Time Periods

Since Virginia corn yield levels were more stable before 1980 (Figure 1A), an additional time frame was included in the cost model. The trend in Virginia corn yields from 1955 to 1979 indicated an increase in production of 1.68 bushels per acre per year. During the 1980s the yield trend dropped dramatically and actually became negative; the average trend was -1.21 bushels per acre per year. To approximate what would have happened in the 1980s if the weather had followed the earlier pattern, the earlier trend in corn yield production was used to predict corn yields for the 1980s as if the droughts had not occurred and the good yields had continued. Yield levels from both of these periods were used in the cost model to compare the impact on regional competitiveness.

Supply

In the price model, supply was restricted by the average number of bushels produced in each region. In the cost models, the supply of corn was allowed to increase to the maximum level produced in each region during the 1984-1988 period. Yield levels remained at the historical average.

Exports

Several changes were made to the export requirements in the cost models in order to make them less restrictive and to find the optimal solution. First, the interstate requirement was relaxed, allowing the export numbers to fall as low as zero or to go as high as the estimated historical high. The requirement for international exports was also relaxed by allowing the model to export up to the historical highest level rather than the average.

Rotations

In the price model, the rotational requirement was set greater than or equal to the minimum level of previously harvested acreage. While this procedure covered all possible restrictions on acreage, it was not a very specific estimate. Since there are multiple combinations of restrictions that could have been placed on harvested acreage, several points were chosen to allow for static comparisons in the cost model. First, all rotational restrictions were removed and the model was free to produce corn at any level (including no production) up to the historical high. Second, the model was run using the same restrictions previously found in the price model. Harvested acreage could not fall below the historical low or go above the historical high for this time period.

Costs

Cost of production data was calculated based on annual budgets and realized annual yields. The major data source for total cost was the annual enterprise budgets prepared by the Virginia and Ohio extension services. In Ohio, a state-wide budget is prepared by Ohio State University (OSU) every year. In Virginia, each extension district prepares a separate budget.[8] Figure 5 shows a map of the Virginia extension districts. These budgets are prepared in the winter before planting occurs and hence are estimates of expected costs and do not reflect actual costs. However, they do reflect the best judgment of the agents working with farmers in each district and are generally considered the best source for regional cost-of-production data in Virginia.

Due to the diversity of growing conditions among the counties in the Southeast district, separate budgets are occasionally prepared by the Eastern Shore counties. Adjustments are also made by the cities of Suffolk, Chesapeake, and Virginia Beach. The only available budgets for these areas during this period were for 1986 for the Eastern Shore and for 1989 for the independent cities.

In general, each extension region prepares several budgets for corn grain production each year. These vary based on production practice (no-till, conventional, etc.) and anticipated yield. In order to be consistent, the budget for conventionally planted corn with a yield in the middle of the expected yield range was chosen. This procedure resulted in a 120 bushel anticipated yield in Ohio and a 100 bushel anticipated yield in Virginia except for the Coastal and Eastern Shore areas where the expected yield was 120 bushels per acre.

Since the enterprise budgets are prepared by so many different individuals, the 1988 budgets were compared across regions. Production cost estimates by category are shown in Table 10. Based on this comparison, several adjustments were made in the budgets. First, the management charge was dropped from the OSU budget since this is a cost that was not included in the Virginia budgets. Second, the high fixed costs associated with machinery in the Northern district were adjusted to reflect the average machinery fixed cost charge in the other four Virginia

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[8]The Southwest district does not prepare budgets for corn grain since the amount of production is so small in this area.

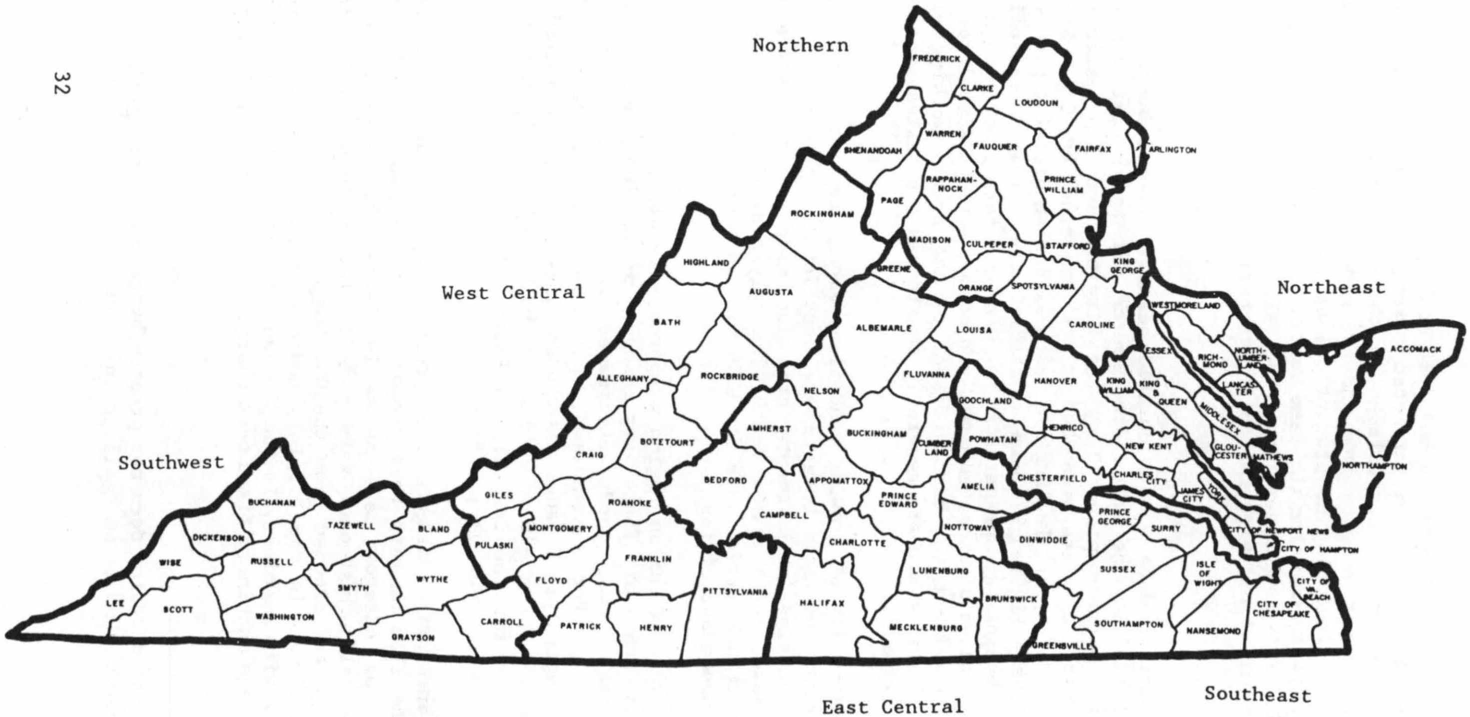

Figure 5. Virginia Extension Districts.
[The Virginia Cooperative Extension Service districts were revised in 1991. This map represents the Virginia extension districts before this revision occurred.]

Table 10. Initial 1988 Virginia and Ohio Corn Production Budgets.

Item	OSU[1]	SE[2]	EC[3]	WC[4]	N[5]	NE[6]
				bu/acre		
Expected yield	120	100	100	100	100	100
Costs				$/acre		
Seed	21.00	19.50	17.40	22.80	19.80	20.40
Nitrogen	20.00	30.00	32.40	28.35	32.40	32.50
Phophorus	9.00	12.10	13.50	13.20	16.80	11.00
Potash	7.00	10.73	9.00	8.40	9.60	11.20
Lime	7.00	16.20	11.00	8.75	8.70	9.60
Chemicals	13.00	11.12	12.73	4.83	17.46	14.10
Fuel, oil	12.00	12.51	6.88			6.78
Gas, electric		12.71				
Drying	14.00		25.00	30.00	30.00	20.00
Repairs	15.00	20.92	15.19			19.02
Hauling	2.00		15.00	15.00	15.00	9.00
Misc.	12.00	6.00				
Interest	7.00	5.19	5.78	7.69	7.41	9.54
Labor[7]	20.00	15.45	21.75	16.25	19.72	17.00
Variable mach.				12.54	25.30	
Fixed mach.	50.00	39.06	38.21	56.08	80.59	46.66
Land	60.00		25.00			
Management	11.00					
Total	280.00	211.48	248.83	231.07	282.78	225.93

[1] Ohio State University
[2] Southeast District
[3] East Central District
[4] West Central District
[5] Northern District
[6] North Eastern District
[7] Labor includes custom application of fertilizer and chemicals in some areas.

districts.[9] Appendix B shows the original budgets used for each district and lists the changes made for use in the cost models.

The East Central and Ohio budgets included land rental values, so these were estimated for the other regions. The Southeast, West Central, and Northern values were based on extension estimates, and the Northeastern value was based on results of a 1988 land-rental value survey in this region.

Because a complete set of budgets (1984-1988) could not be obtained for several of the regions the following values were estimated: Coastal (1984-1988), East Central (1984, 1985), West Central (1984, 1985, 1987), Northeast (1984, 1986), Eastern Shore (1984-1985, 1987-1988). The percentage change in line items from year to year was calculated for each of the regions where actual budgets were available. For those regions where budgets were missing, the average of these percentages was then applied to the closest year to calculate an estimated budget. For example, the percentage change in each line item between 1985 and 1986 was calculated for those regions that published both budgets. The average change was then applied to the 1985 Northeast district budget to estimate the 1986 Northeast cost of production. The only exception was the budgets for the Coastal region. Since these were originally based on Southeast budgets with adjustments made to reflect growing conditions in the Coastal counties, the estimated budgets for this region were based only on changes in the Southeast district budgets. Table 11 lists the per-acre cost of production for each extension region over the five-year period, incorporating all the above changes.

The estimated Ohio and Virginia extension budgets were compared with cost-of-production data for corn published by the United States Department of Agriculture (USDA) to determine how well these estimates reflect actual costs. The USDA numbers are collected through surveys of producers and reflect actual production costs as opposed to estimates of anticipated costs. National cost surveys for corn grain were conducted in 1983 and 1987. Responses were used by USDA to estimate cost-of-production values for 1984, 1986, 1987, and 1988. While the 1984 budgets were estimated for all 50 states, a lack of survey responses limited the later budgets to 15 individual states and four regional budgets. Separate Ohio budgets were published in all four years.

Since five different Virginia extension regions publish regular crop budgets, these values were averaged for the comparison with the state-wide USDA budgets. A direct comparison of individual line items was not possible since different categories were used in the various budgets. However, the major cash expenses as well as the total cost of production could be compared.

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[9] This adjustment was made based on a telephone conversation with Jack Dunford, Extension Farm Management Agent in the Northern district.

Table 11. Final Corn Productions Costs in Virginia Extension Regions and Ohio, 1984-1988.

Region	1984	1985	1986	1987	1988	Avg
	----------------------$/acre----------------------					
OSU[1]	307.00	305.00	287.00	260.00	269.00	285.60
SE[2]	269.70	272.63	249.42	239.06	246.48	255.46
CHSP[3]	323.90	325.13	299.30	288.12	295.66	306.42
EC[4]	252.85	255.59	252.55	240.34	248.83	250.03
WC[5]	245.91	247.46	246.32	249.58	261.07	250.07
N[6]	268.83	269.41	261.09	252.51	272.19	264.81
NE[7]	277.10	281.02	272.97	262.27	265.93	271.86
ES[8]	315.85	313.90	308.75	291.24	304.56	306.86
Va Avg	279.16	280.73	270.06	260.45	270.67	272.22

[1] Ohio State University
[2] Southeast District
[3] Chesapeake
[4] East Central District
[5] West Central District
[6] Northern District
[7] North Eastern District
[8] Eastern Shore

Table 12 lists the values for the USDA and extension budgets for 1984-1988. The cost estimates were relatively close, except for the 1984 Ohio estimate. A closer look at the USDA budgets indicated that the economic costs for land were changed substantially between 1984 and 1986. If the 1986 land values had been used in the 1984 budget, the total cost would have been $308.59 per acre making the difference from the model budgets only $1.59 per acre. On average, the Ohio extension and USDA budgets differed by less than $10 per acre. In 1984 the USDA and Virginia budgets also differed by less than $10.

In order to reconcile the extension district budgets with those for the regions defined in the model, a simple averaging procedure was used. Within each model region a weighted average of the member counties in each extension district was calculated based on the harvested acreage in each

Table 12. Comparisons of USDA and Extension Cost of Production Estimates.

		1984	1986	1987	1988	Avg.
		---------------	----------------	$/acre	--------------	
Va.[1]	USDA	282.62				
	Extension	273.01				
	Difference	9.61				9.61
Ohio	USDA	349.50	270.07	261.06	273.11	
	Extension	307.00	287.00	260.00	269.00	
	Difference	42.50	-16.93	2.06	4.11	7.94

[1] Virginia USDA estimates were available only for 1984.

county. The only exception was the Southwestern district, where the West Central extension budget values were used since the Southwestern extension district does not generate corn grain budgets. Table 13 lists the resulting per-acre costs of production that were entered into the model.

There was relatively little difference between the average per-acre cost of production among the 14 regions (Table 13). The two highest costs were found in the Coastal and Eastern Shore regions where average total cost was approximately $306 per acre. The lowest total costs were found in the Southside, Central, and Southwestern regions where total costs averaged about $250 per acre. Land rental values accounted for most of the difference between the highest and lowest total costs. Rental rates averaged $25-30 per acre in the low cost regions and $60-75 per acre in the high cost regions. The total cost of producing corn in Ohio was between $15-$35 more than the Virginia costs with the exception of the Coastal and Eastern Shore regions.

Within a region, there was relatively little variation in total cost from year-to-year. The Midwest showed more variation than Virginia, with a 15 percent change in total cost from the highest to the lowest cost years. The 13 Virginia regions all indicated changes of less than 10 percent in total costs between years except for the Coastal and Southeastern regions with 11 and 12 percent changes, respectively.

Again, these cost differences were compared with the USDA budgets. The 1986-1988 USDA budgets for the Southeast and Corn Belt regions were compared for the difference in costs of production between regions. Over the three-year period, total costs in the Corn Belt were an average of $44 per acre higher than those in the Southeast. This difference compares with an average cost difference of $26 per acre between Ohio and Virginia regions in the model.

Table 13. Regional Total Costs, Yields, and per Bushel Costs for Corn Grain 1984/85 to 1988/89.

Region	Year	Total Costs ($/acre)	Yields (bu/acre)	Cost per Bu. ($/bu)
Ohio	1984/85	307.00	118.0	2.60
	1985/86	305.00	127.0	2.40
	1986/87	287.00	128.0	2.24
	1987/88	260.00	120.0	2.17
	1988/89	269.00	85.0	3.16
	AVG.	285.60	115.6	2.47
Northern Virginia	1984/85	268.83	89.4	3.01
	1985/86	269.41	82.8	3.25
	1986/87	261.09	51.2	5.10
	1987/88	252.51	54.4	4.64
	1988/89	272.19	64.8	4.20
	AVG.	264.81	65.8	4.02
Shenandoah Valley	1984/85	252.10	98.1	2.57
	1985/86	253.39	97.3	2.60
	1986/87	250.31	54.1	4.63
	1987/88	250.37	52.8	4.74
	1988/89	264.07	68.8	3.84
	AVG.	254.05	74.2	3.42
North Central	1984/85	263.89	99.0	2.67
	1985/86	265.41	90.7	2.93
	1986/87	258.90	49.9	5.19
	1987/88	248.96	45.6	5.46
	1988/89	263.87	68.3	3.86
	AVG.	260.21	70.7	3.68
East Central	1984/85	268.83	115.6	2.33
	1985/86	269.41	94.3	2.86
	1986/87	261.09	65.0	4.02
	1987/88	252.51	51.8	4.87
	1988/89	272.19	71.0	3.83
	AVG.	264.81	79.5	3.33
Northern Neck	1984/85	277.10	115.1	2.41
	1985/86	281.02	91.3	3.08
	1986/87	272.97	44.4	6.15
	1987/88	262.27	72.4	3.62
	1988/89	265.93	77.0	3.45
	AVG.	271.86	80.0	3.40
Middle Penninsula	1984/85	277.10	116.1	2.39
	1985/86	281.02	101.4	2.77
	1986/87	272.97	46.4	5.88
	1987/88	262.27	77.9	3.37
	1988/89	265.93	75.2	3.54
	AVG.	271.86	83.4	3.26

continued next page

table 13. cont.

East	1984/85	270.85	100.1	2.71
	1985/86	274.27	88.8	3.09
	1986/87	262.17	42.9	6.11
	1987/88	251.33	60.2	4.17
	1988/89	256.97	78.0	3.29
	AVG.	263.12	74.0	3.56
Coastal	1984/85	323.90	118.7	2.73
	1985/86	325.13	127.0	2.56
	1986/87	299.30	77.3	3.87
	1987/88	288.12	74.8	3.85
	1988/89	295.66	97.0	3.05
	AVG.	306.42	99.0	3.10
South East	1984/85	269.19	95.9	2.81
	1985/86	272.12	103.2	2.64
	1986/87	249.51	45.3	5.51
	1987/88	239.10	57.3	4.17
	1988/89	246.55	81.6	3.02
	AVG.	255.30	76.7	3.33
South Side	1984/85	250.87	80.7	3.11
	1985/86	253.27	79.9	3.17
	1986/87	250.77	45.6	5.50
	1987/88	242.98	39.2	6.20
	1988/89	252.33	72.5	3.48
	AVG.	250.04	63.6	3.93
Central	1984/85	252.85	91.8	2.75
	1985/86	255.59	83.4	3.06
	1986/87	252.55	35.8	7.05
	1987/88	240.34	39.0	6.16
	1988/89	248.83	66.8	3.73
	AVG.	250.03	61.4	4.07
South West	1984/85	245.91	102.5	2.40
	1985/86	247.46	101.5	2.44
	1986/87	246.32	72.1	3.42
	1987/88	249.58	70.1	3.56
	1988/89	261.07	77.3	3.38
	AVG.	250.07	84.7	2.95
Eastern Shore	1984/85	315.85	135.5	2.33
	1985/86	313.90	112.5	2.79
	1986/87	308.75	71.5	4.32
	1987/88	291.24	83.0	3.51
	1988/89	304.56	105.0	2.90
	AVG.	306.86	101.5	3.02
Virginia State Average[1]	1984/85	263.52	99.9	2.64
	1985/86	265.52	95.3	2.79
	1986/87	258.46	55.0	4.70
	1987/88	252.23	58.3	4.33
	1988/89	263.15	75.7	3.48
	AVG.	260.58	76.8	3.39

[1]Weighted average of regions based on individual counties.

Yields

In order to convert total cost per acre to cost per bushel, the yield in each region was used. The yield levels were a simple average of the county yield estimates published annually by Ohio and Virginia Agricultural Statistics. These yield levels are shown in Table 13.

There was a difference of more than 35 bushels per acre between the average Ohio and the average Virginia yields. Again the yield comparisons were consistent with USDA numbers, which record a 34.8 bushel average difference between Corn Belt and Southeast yields from 1986-1988.

With constant total costs, a change in yield from 115.6 to 79.8 bushels would have increased the per bushel cost by 45 percent. The only Virginia region which showed an average yield greater than 100 bushels was the Eastern Shore with 101.5. The Coastal region approached 100 with an average of 99 bushels per acre. The lowest average yields were seen in the Central (61.4), Southside (63.6), and Northern Virginia (65.8) regions.

Not only were the Virginia yields lower on average than the Ohio yields but they were also more variable from year to year. Calculating a percentage change from the highest to lowest yield over the five-year period indicated a 34 percent change for Ohio. The only comparable Virginia region was the Southwest with a 32 percent change. The other regions indicated changes greater than 42 percent. The largest fluctuations were seen in the Central (61%), Northern Neck (61%), and Middle Peninsula (60%) regions.

Pease and Tirupattur estimated coefficients of variation for Virginia and Ohio corn yields from 1980-1987 to be 31.1 percent and 14.6 percent respectively. Frequent droughts in Virginia during the 1980s caused yields to become much more variable and decreased the trend of increasing yields over time. When Pease and Tirupattur estimated a Virginia state yield trend for 1955-1979, they found an increase of 1.92 bushels per acre per year. For the 1980-1987 period they estimated a decrease of .9 bushels per acre per year.

Cost per Bushel

The next step in calculating costs was to divide the per-acre cost by the average yield for each region. The estimated per-bushel costs of production for each region in the model are shown in Table 13. Even though the total costs per acre did not vary much between regions, the low Virginia yields caused the per-bushel costs to rise significantly. In the Southside and Central regions, total cost of production was $35 per acre less than the total cost in Ohio. Poor average yields of 63.6 and 61.4 bushels per acre raised the per-bushel costs to $3.93 and $4.07 respectively in comparison with Ohio where yields of 115.6 per bushel resulted in costs of $2.47 per bushel. The Central region had the highest cost in the model with $4.07 per bushel. Ohio had the lowest cost with $2.47. Of the Virginia regions, Southwest costs were the lowest ($2.95) followed by the Eastern Shore ($3.02).

Chapter 5. The Cost Models

The cost model was solved to minimize total cost under three scenarios; 1) no minimum supply, 2) acreage greater than the historical minimum acreage level, and 3) using the yields estimated from 1955-1979 trend values with no minimum supply restrictions. In the first two cases, the maximum acreage in each region was set at the historical maximum harvest level and the maximum supply was set at the historical highest production level. In the third scenario, supply was restricted only by the maximum historical acreage. Exports of corn were also restricted by their historical high levels.

In each case, the model calculated a weighted average solution cost for each region. The solution cost is equal to an average of the local production cost times the number of bushels produced and consumed locally plus the cost of imports to the region times the number of bushels imported. Solution costs reflect the least-cost distribution of corn among the regions and were used to calculate competitive yield levels. The total cost of production per acre in each region was divided by the resulting solution cost of corn for grain in that region. The resultant estimated yield level is what would be needed in that particular region to produce corn competitively with the region that was supplying corn to that region in the model results.

Cost: No Minimum Supply/Actual Yields

Figure 6 shows the corn movement and weighted average solution costs that resulted when the cost model was run with no minimum on Virginia supply. All corn grain was supplied from Columbus except for 641,000 bushels that were produced and consumed in the Eastern Shore. This was the maximum historical production level for corn on the Eastern Shore. Shadow prices for the Eastern Shore indicated that more would be produced if possible. A one thousand bushel increase in supply from the Eastern Shore would reduce the objective function value by 11 cents. In the solution, it was non-optimal for any other Virginia region to produce corn. Thus, the weighted average solution costs shown in Figure 6 are exactly equal to the price in Columbus plus transportation in all regions except for the Eastern Shore. Because the Eastern Shore is able to produce some corn at a cost lower than $3.14 per bushel ($2.47 cost in Columbus plus 67 cents transportation cost), the weighted average solution cost was only $3.09 per bushel in this region. There were no corn exports, either to Maryland or through the port of Hampton Roads.

Table 14 lists the numerical results of the model. The objective function value, $164,764,000, indicated that the total cost of the corn grain was more than $164 million. Only 6,315 acres were harvested for corn in Virginia when the model was solved with no restrictions. Of course, 6,315 acres is much lower than any historical harvest. With this level of production, the state deficit was 56.5 million bushels, all of which was supplied from Columbus.

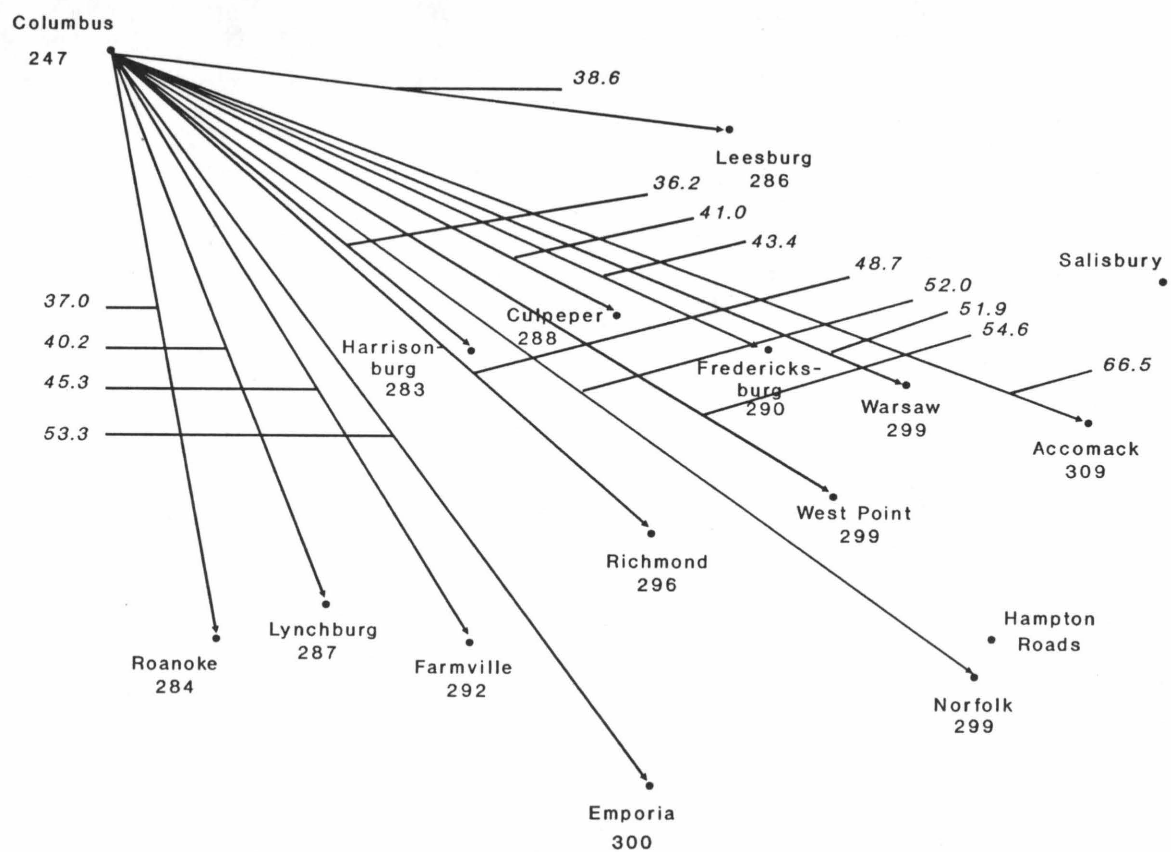

Figure 6. Transportation Network and Weighted Average Solution Costs (cents per bushel) from the Cost:No Minimum Supply/Actual Yields Model.
[Values in italics are transportation rates between points (cents per bushel)]

Table 14. Cost: No Minimum Supply/Actual Yields Model Assumptions and Results.

Assumptions:
Objective Function: minimize total average costs
Supply: less than or equal to highest production 1984-1988
Yield: average yield, 1984-1988
Acreage: less than maximum harvested 1984-1988
Cost: average cost of production per bushel, 1984-1988
Demand: feed use equals average use, 1984-1988
Exports: less than or equal to highest 1984-1988

Results:
Objective function value = $164,764,000

Region	Acres	Production (1000 bu)	Demand (1000 bu)	Wtd Avg Solution Cost ($/bu)	Shipments + buy from - sell to (1000 bu)	
N. Virginia	0	0	2,634	2.86	+ 2,634	COL
Shen Valley	0	0	24,974	2.83	+ 24,974	COL
N. Central	0	0	4,887	2.88	+ 4,887	COL
E. Central	0	0	474	2.90	+ 474	COL
N. Neck	0	0	260	2.99	+ 260	COL
M. Penninsula	0	0	758	2.99	+ 758	COL
East	0	0	4,019	2.96	+ 4,019	COL
Coastal	0	0	2,204	2.99	+ 2,204	COL
Southeast	0	0	3,943	3.00	+ 3,943	COL
Southside	0	0	2,224	2.92	+ 2,224	COL
Central	0	0	1,904	2.87	+ 1,904	COL
Southwest	0	0	7,240	2.84	+ 7,240	COL
Eastern Shore	6,315	641	1,665	3.09	+ 1,024	COL
Total	6,315	641	57,186	2.93	+ 56,545	ALL
					+ 56,545	COL

COL = Columbus
ALL = Total Amount Traded

The average costs that resulted from the solution obviously conformed to economic theory. They reflected the cost of production in Columbus plus transportation cost to the demand points. Cost levels in Virginia regions closer to Ohio, where transportation costs from Columbus were less, were lower than the costs in more distant Virginia regions. The average solution cost for the state was $2.93 per bushel.

The calculated cost of production per bushel is compared to the average solution cost per bushel in Table 15 as an indication of the savings made in each region by purchasing corn. The Eastern Shore's negative $0.07 indicated that producing more corn in this region would have resulted in lower costs. Conversely, the other regions all showed positive savings through purchased corn. The Central region had the largest gain, $1.20 per bushel. The smallest gains ($0.11) were seen in the Coastal and Southwest regions.

Total cost of production per acre was divided by the calculated weighted average solution costs per bushel in each region to determine the average yield level needed to be competitive. In this model, the yield levels indicated the increase in bushels per acre needed for each region to become competitive relative to costs in Ohio. If, for example, total cost of production were to remain constant in Ohio and Virginia, then the region could become competitive with Ohio with an increase in yield per acre.

In the traditional grain-producing regions of Virginia (Northern Neck, Middle Peninsula, Southeast, Coastal), an increase of 4-10 bushels per acre would make production costs competitive with those in Ohio and bring these regions back into production. On average, across all Virginia regions an increase of 14 bushels per acre would make Virginia costs competitive. In the most marginal regions (Northern Virginia, Central) an increase of over 25 bushels per acre would be required to make production costs competitive with those in Ohio. The Eastern Shore was the only Virginia region to show an advantage in corn production relative to costs in Ohio.

Since during the 1980s, weather patterns were so erratic in Virginia the "cost:no minimum supply" model was re-run leaving out the poor yields of 1986. This model increased the average yield in each Virginia region relative to the Ohio yield by 3.2 to 9.3 bushels. Results indicated that the Eastern Shore would again produce at its maximum capacity. Both the Middle Peninsula and the Coastal regions would produce some corn, but not at the maximum level possible. The total acreage harvested in Virginia increased by approximately 40,000 acres to 46,211 under this scenario (11% of the actual average acreage harvested between 1984 and 1988). The effect of the 1980s' droughts on Virginia yields and the competitive position of individual regions is further discussed in the cost:no minimum supply/estimated yields model section (p.57). Regional competitive positions were calculated as if the drought years had not occurred.

Virginia cost levels were relative to cost levels in Ohio. Therefore, as total costs decreased or yields increased in Ohio, the relative

Table 15. Cost of Production, Model Weighted Average Solution Costs, and Competitive Yield Level Results from the Cost:No Minimum Supply/Actual Yield Model.

Region	Cost of Prdn	Cost of Prdn	Wtd Avg Soln Costs	Compet-itive Yield	1984-1988 Historical Avg Yield	Yield Diff.
	($/acre)	($/bu)	($/bu)	(bu/acre)	(bu/acre)	(bu/acre)
Ohio	285.60	2.47	2.47	115.6	115.6	0
N. Virginia	264.81	4.02	2.86	92.7	65.8	-26.9
Shen Valley	254.05	3.42	2.83	89.7	74.2	-15.7
N. Central	260.21	3.68	2.88	90.3	70.7	-19.6
E. Central	264.81	3.33	2.90	91.2	79.5	-11.7
N. Neck	271.86	3.40	2.99	90.9	80.0	-10.9
M. Peninsula	271.86	3.26	2.99	91.0	83.4	-7.6
East	263.12	3.56	2.96	89.0	74.0	-15.0
Coastal	306.42	3.10	2.99	102.5	99.0	-3.5
Southeast	255.30	3.33	3.00	85.0	76.7	-8.3
Southside	250.04	3.93	2.92	85.5	63.6	-21.9
Central	250.03	4.07	2.87	87.0	61.4	-25.6
Southwest	250.07	2.95	2.84	88.0	84.7	-3.3
Eastern Shore	306.86	3.02	3.09	99.2	101.5	2.3
Va Avg.	266.88	3.47	2.93	90.9	78.0	-12.7

position of Virginia production weakened. Conversely, as Virginia total costs decreased, the position of Virginia production strengthened with no change in yields. Pease and Tirupattur estimated yield trends for Virginia, Ohio, and the United States from 1955-1987. They found an increase of 1.28 bushels per acre per year for Virginia compared with 1.98 for Ohio and 2.17 for the United States. Since both Ohio and United States production has been increasing at a greater rate than Virginia's, the competitive position of Virginia corn production is likely to weaken over time.

Costs: Minimum Acreage/Actual Yields

The cost model was re-run with an added rotational requirement that harvested acreage must equal or exceed the historical minimum level (Table 6). This was the same restriction used in the price model. This restriction accounted for all possible rotations and acres planted to maintain "base" in the government programs.

The results are shown in Table 16. The resulting objective function value was $174,751,000 compared to $164,764,000 in the unrestricted cost model. Since the objective function measured the sum of average solution costs, the total production cost of the corn consumed had increased more than $10 million. In this model, all regions were required to harvest acreage, so they all supplied some corn. Each Virginia region produced at its minimum required level. For example, the minimum historical acreage harvested in Northern Virginia was 27,500 acres. In the model solution, Northern Virginia harvested 27,500 acres and supplied 1,809,500 bushels of corn. There were four surplus Virginia regions: East Central, Northern Neck, Middle Peninsula, Coastal. The other nine regions were all deficit in corn. The total acreage harvested in Virginia was 264,097. This was the historical minimum harvest for the state (Table 6). The model weighted average solution cost per bushel for each region reflected a combination of the production and transportation costs in the supplying regions including local production costs for those regions that consumed locally produced corn.

Figure 7 shows the price surface and transportation map that resulted from the optimal solution. Ohio supplied six regions: Northern Virginia, North Central, Shenandoah Valley, Southside, Central, and Southwest. The North Central was also supplied from the East Central and Northern Neck regions. The other five produced the minimum amount required by the model constraints and purchased all additional corn from Ohio. Besides the North Central, the Northern Neck region also supplied some corn to the Middle Peninsula and Eastern Shore regions. The Middle Peninsula sent its surplus corn to the East and the Coastal sent its surplus corn to the Eastern Shore and to the Southeast. Similar to the previous two models, there were no corn exports in the optimal solution.

In Figure 7 "costs" reflect cost of production in each region. The regional corn market "prices" reflect cost in the lowest-cost surplus region plus transportation cost. Even though the average cost of production in Northern Virginia was $4.02 per bushel, the average price

Table 16. Cost:Minimum Acreage/Actual Yields Model Assumptions and Results.

Assumptions:

Objective Function: minimize total average costs
Supply: less than or equal to highest production 1984-1988
Yield: average yield, 1984-1988
Acreage: less than maximum harvested 1984-1988
greater or equal to the minimum harvested 1984-1988
Cost: average cost of production per bushel, 1984-1988
Demand: feed use equals average use, 1984-1988
Exports: less than or equal to highest 1984-1988

Results:

Objective function value = $174,751,000

Region	Acres	Production	Demand	Wtd Avg Solution Cost	Shipments + buy from - sell to	
		(1000 bu)	(1000 bu)	($/bu)	(1000 bu)	
N. Virginia	27,500	1,810	2,634	3.66	+ 825	COL
Shen Valley	11,960	887	24,974	2.85	+ 24,086	COL
N. Central	20,550	1,453	4,887	3.36	+ 1,644	COL
					+ 472	EC
					+ 1,318	NN
E. Central	11,900	946	474	3.33	- 472	NC
					+ 474	NN
N. Neck	27,900	2,232	260	3.40	- 496	ES
					- 1,318	NC
					- 158	MP
M. Penninsula	39,667	3,308	758	3.31	- 2,709	E
					+ 158	NN
East	17,700	1,310	4,019	3.41	+ 2,709	MP
Coastal	30,900	3,059	2,204	3.10	- 62	SE
					- 793	ES
Southeast	50,600	3,881	3,943	3.33	+ 62	COA
Southside	9,600	611	2,224	3.20	+ 1,614	COL
Central	2,500	154	1,904	2.97	+ 1,750	COL
Southwest	9,620	815	7,240	2.85	+ 6,425	COL
Eastern Shore	3,700	376	1,665	3.25	+ 793	COA
					+ 496	NN
Totals	264,097	20,842	57,186	3.23	+ 43,796	ALL
					+ 36,344	COL

COL = Columbus NC = N. Central E = East
EC = E. Central COA = Coastal SE = Southeast
NN = N. Neck MP = M. Penninsula ES = Eastern Shore
ALL = Total Amount Traded

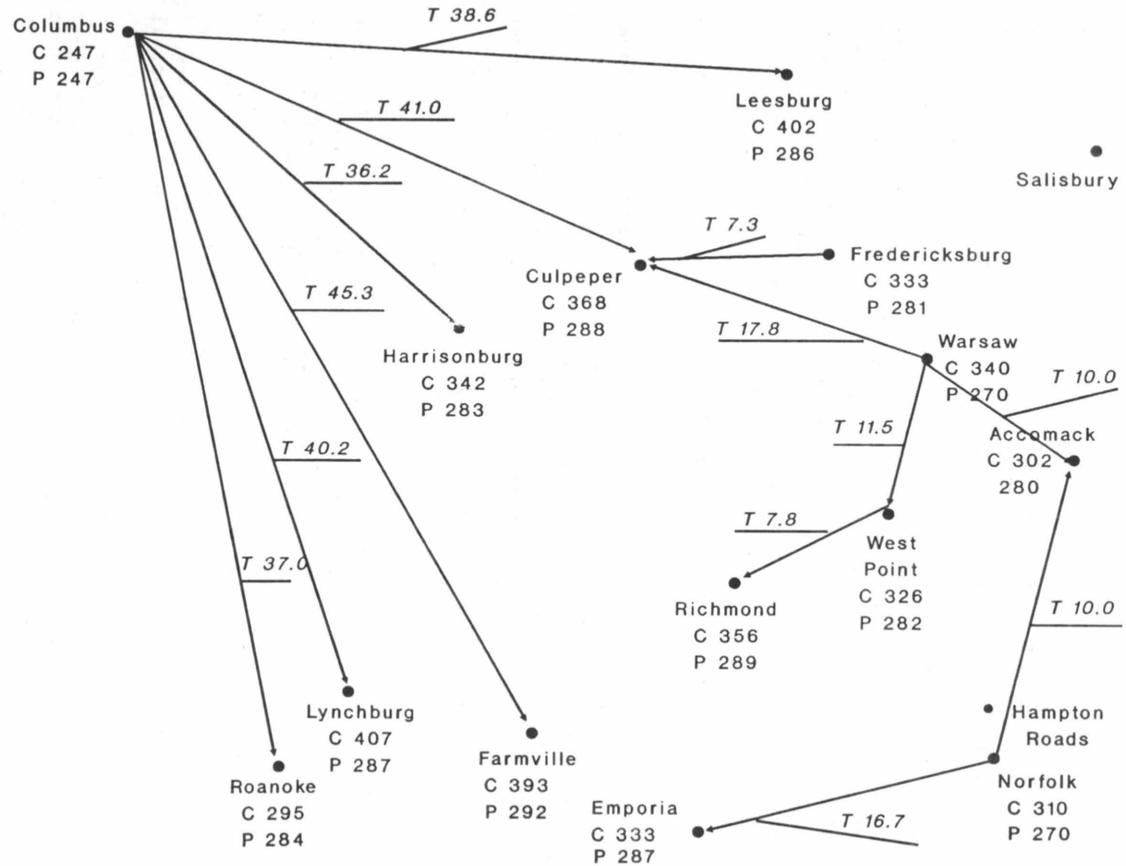

Figure 7. Transportation Network, Average Cost of Production (C), and Market Price (P) Results (cents per bushel) from the Cost:Minimum Acreage/Actual Yields Model. [Values in italics are transportation rates (T) between points (cents per bushel)]

in Northern Virginia was $2.86 per bushel. The price reflects a $2.47 cost of production in Columbus (a surplus region) plus $0.386 per bushel transportation cost to Northern Virginia. This indicated that Northern Virginia corn prices would have to be less than or equal to $2.86 per bushel to be price competitive with supplies from Ohio.

The local cost of production, weighted average model solution costs, and market price levels are shown in Table 17. The regional average costs of production per bushel were the same as in the earlier unrestricted model, but the average model solution costs changed. Mathematically, forcing the model to produce the minimum level of corn in each Virginia region raised the solution costs of corn in these regions since some corn was produced in the higher cost areas. Two regions now indicated solution costs higher than their average cost of production. The Middle Peninsula region would have consumed only locally produced corn if it were acting in isolation, causing the solution costs in that region to equal the cost of production. In order to minimize the total cost, a small amount of corn was purchased from the Northern Neck. The Eastern Shore region did not produce enough corn to meet its needs; therefore, the corn imported raised the average solution cost above the cost of production. The regions with large deficits (Central, Shenandoah Valley, Southside) still showed solution costs more than 50 cents per bushel below their own cost of production.

When the total cost of production per acre was divided by these higher per bushel costs the competitive yield levels fell compared to those in the unrestricted cost model. In reality, there were several reasons (rotations, government programs, etc.) why corn would continue to be produced in Virginia. Producers may have been willing to accept lower yields on their corn in order to meet other whole-farm considerations. However, the objective function values indicated there was a $10 million change in the total solution cost when the model forced corn acreage to be harvested in Virginia.

Theoretically, the market price a producer received for his corn was determined by the lowest price source of available corn. In other words, Virginia corn prices could not exceed the Ohio price plus transportation costs to Virginia. Since users of corn in Virginia could purchase corn at this minimum price from Ohio they would not pay more for local corn. Table 17 compares these market prices with total cost of production for Virginia producers. The average loss per bushel ranged from $0.11 in the Southwest region to $1.20 per bushel in the Central region with a state average of $0.64. Although forcing the model to plant the minimum of past historical acreage accounted for the acres planted to maintain government program "base" as well as rotational requirements, no direct government payments were included in the price. Therefore, the regions that indicated only slight losses based on market prices may have shown profits when government program payments were added. However, this fact would not change their competitive position relative to Ohio, as the programs are available to all producers.

Table 17. Comparison of Prices with Fixed and Variable Costs for 13 Virginia Regions.

	Cost of Production			Wtd Avg	Market	Price minus	
	Total Cost	Fixed Cost	Variable Cost	Soln Cost	Price	Total Cost	Variable Cost
Northern Virginia	4.02	1.33	2.69	3.66	2.86	-1.16	0.17
Shen. Valley	3.42	1.13	2.29	2.85	2.83	-0.59	0.54
North Central	3.68	1.21	2.47	3.36	2.88	-0.80	0.41
East Central	3.33	1.11	2.22	3.33	2.81	-0.52	0.59
Northern Neck	3.40	1.12	2.28	3.40	2.70	-0.70	0.42
Middle Penn.	3.26	1.08	2.18	3.31	2.82	-0.44	0.64
East	3.56	1.17	2.39	3.41	2.89	-0.67	0.50
Coastal	3.10	1.02	2.08	3.10	2.70	-0.40	0.62
South east	3.33	1.11	2.22	3.33	2.87	-0.46	0.65
South side	3.93	1.30	2.63	3.20	2.92	-1.01	0.29
Central	4.07	1.34	2.73	2.97	2.87	-1.20	0.14
South west	2.95	0.97	1.98	2.85	2.84	-0.11	0.86
Eastern Shore	3.02	1.00	2.02	3.25	2.80	-0.22	0.78
State Average	3.47	1.15	2.32	3.23	2.83	-0.64	0.51

According to theory, producers will continue to grow corn in the short-run as long as they cover their variable costs. An examination of the Virginia extension budgets (Appendix B) revealed that approximately one-third of the total cost of corn production could be attributed to fixed costs. The other two-thirds were variable costs. Table 17 shows the breakdown of total costs of production into fixed costs and variable costs for each region. On average fixed costs equaled $1.15 per bushel and variable costs equaled $2.32 per bushel. A comparison of market price and variable costs indicated that each region was able to cover average variable costs. The difference between price and variable costs could be used to cover part of the fixed costs. This difference ranged from $0.14 in the Central region to $0.86 in the Southwest region and averaged $0.51 per bushel. Although producers in these regions could not cover their total cost of production, they could cover average variable costs and part of the average fixed costs. Therefore, they will remain in corn production, at least in the short-run. This decision was not the result of a competitive advantage in corn production relative to other regions. Rather corn appeared to have the least competitive disadvantage to other production alternatives in these regions.

Cost:No Minimum Supply/Estimated Yields

The two previous cost models were based on actual historical yield levels in Virginia. In the first case, each region could produce from zero to its highest harvested acreage between 1984-1988. In the second case, each region had to at least produce the minimum acreage harvested between 1984-1988. These solutions provided static solution costs for corn in Virginia under various supply conditions. These costs were then used to calculate competitive Virginia yield levels relative to production costs in Ohio. Results indicated that low Virginia yields in the 1980s drove up the cost of production and made Virginia corn non-competitive with that of Ohio in many instances. When supply was not restricted, only the Eastern Shore remained competitive relative to Ohio costs.

Since the 1980s were an extremely drought-prone decade in Virginia, the "no minimum supply" cost model was re-run using estimated yields. Yield levels were based on the Virginia corn yield trend from 1955-1979. The trend model was used to predict 1980s yields as if the earlier pattern had continued and the drought years had not occurred. The average Ohio yield was left at its actual value. Since Midwest yields also increased rapidly during the 1960s and 1970s, the estimated Ohio yield based on trend values would likely be higher than 115.6 bushels per acre. Pease and Tirupattur found that the rate of yield increases in Ohio yields was larger than that in Virginia, giving Ohio an increased competitive advantage over time. By changing the Virginia yield trend to the earlier level, Virginia regions should become more competitive relative to Ohio.

Yield trends were estimated for each region in the model during 1955-1979 and 1980-1989 (Table 18). The trend during the earlier period was then applied to Virginia corn production during the 1980s to calculate yields (and hence per bushel costs) as if the 1980s' droughts had not occurred. Yield levels were estimated for each year during the 1980s

Table 18. Trends in Corn Grain Yields in 13 Virginia Regions.

Region	Trends 1955-1979	Trends 1980-1989	Estimated Avg Yield 1984-1988	Actual Avg Yield 1984-1988
	----bu/acre/year----		------bu/acre------	
N. Virginia	1.48	-2.80	81.2	65.8
Shen Valley	1.42	-3.10	89.8	74.2
N. Central	1.58	-1.69	84.0	70.7
E. Central	1.88	-1.35	94.7	79.5
N. Neck	2.03	-0.98	102.7	80.0
M. Penninsula	2.16	0.14	114.0	83.4
East	1.59	0.26	78.1	74.0
Coastal	2.55	1.22	124.2	99.0
Southeast	1.90	0.35	105.7	76.7
Southside	1.43	-0.82	80.8	63.6
Central	1.45	-1.26	77.1	61.4
Southwest	1.64	-1.91	94.1	84.7
Eastern Shore	2.22	2.50	121.9	101.5
State	1.68	-1.21	92.6	76.8

Source: Computed from yields reported by Virginia Agricultural Statistics.

using this trend. Then an estimated average yield was calculated for the 1984-1988 model period (Table 18). These yields were used to simulate trade and prices as if the drought years had not occurred and previous yield trends had continued.

Model results (Table 19) indicated that, even with increased average yield levels, only five Virginia regions (Shenandoah Valley, Middle Peninsula, Southeast, Southwest, Eastern Shore) produced at their historical maximum capacity. The Northern Neck and Coastal regions also supplied some corn. These results compare with only the Eastern Shore producing corn when actual 1980s yields were used. The total acreage harvested was 279,539, an increase of approximately 15,000 acres over the historical minimum. However, with the improved yields, the state deficit was reduced to less than 28 million bushels.

Table 19. Cost:No Minimum Supply/Estimated Yields Model Assumptions and Results.

Assumptions:

Objective Function: minimize total average costs
Supply: less than or equal to highest production 1984-1988
Yield: estimated yields based on 1965-1979 Va. yield trends
Cost: average cost of production per bushel, 1984-1988
Demand: feed use equals average use, 1984-1988
Exports: less than or equal to highest 1984-1988

Results:

Objective function value = $155,158,000

Region	Acres	Production	Demand	Wtd Avg Solution Cost	Shipments + buy from - sell to	
		(1000 bu)	(1000 bu)	($/bu)	(1000 bu)	
N. Virginia	0	0	2,634	2.86	+ 2,634	COL
Shen Valley	44,600	4,005	24,974	2.83	+ 20,969	COL
N. Central	0	0	4,887	2.62	+ 4,887	MP
E. Central	0	0	474	2.54	+ 474	MP
N. Neck	2,527	260	260	2.65		
M. Penninsula	64,050	7,302	758	2.38	- 4,887	NC
					- 474	EC
					- 1,184	E
East	0	0	4,019	2.57	+ 1,184	MP
					+ 1,478	COA
					+ 1,358	SE
Coastal	36,817	4,573	2,204	2.47	- 891	ES
					- 1,478	E
Southeast	89,200	9,428	3,943	2.42	- 1,358	E
					- 2,224	SS
					- 1,904	CTR
Southside	0	0	2,224	2.61	+ 2,224	SE
Central	0	0	1,904	2.71	+ 1,904	SE
Southwest	35,995	3,387	7,240	2.75	+ 3,853	COL
Eastern Shore	6,350	774	1,665	2.54	+ 891	COA
Totals	279,539	29,729	57,186	2.61	+ 41,856	ALL
					+ 27,456	COL

COL = Columbus
MP = M. Penninsula
NC = N. Central
EC = E. Central
E = East
COA = Coastal
SE = Southeast
ALL = Total Amt Traded
ES = Eastern Shore
SS = Southside
CTR = Central

In the optimum solution, there were three surplus regions (Middle Peninsula, Coastal, Southeast). The Northern Neck region produced enough corn to supply its own needs even though a surplus could have been produced within the model constraints. Ohio continued to supply Northern Virginia, Shenandoah Valley, and Southwest (Figure 8). The Middle Peninsula supplied corn to the North Central, East Central, and Eastern regions as well as its own needs. The East bought additional corn from both the Coastal and Southeast regions. The Coastal also shipped corn to the Eastern Shore and the Southeast also shipped corn to Southside and Central. Again, no corn was exported from the state.

The solution costs shown in Figure 8 represent the weighted average cost results from the model and not market prices. Among regions with more than one supplier the weighted average solution costs reflected an average of the cost of production plus transportation costs among suppliers, weighted by the amount purchased from each source including locally produced grain (see Chapter 3 for a more detailed explanation of the calculation).

A slightly different pattern in comparative advantages/disadvantages was generated compared to the results based on actual 1980s yields. (Table 20). Again, the Eastern Shore indicated a positive advantage over the other regions but now the Southwest also showed a positive advantage relative to costs in other regions. Five additional regions were able to produce corn competitively relative to Ohio: Shenandoah Valley, Northern Neck, Middle Peninsula, Coastal, and Southeast. The other six regions all showed comparative disadvantages in corn production. The increase in Virginia yields, relative to costs in other regions, needed to make these regions competitive ranged from less than 10 bushels in East Central to more than 24 bushels in the East. The average increase needed was approximately 15 bushels.

Since weather had such a critical impact on Virginia production in the 1980s, it is possible that later decades will return to the 1960s-1970s weather patterns. The model using estimated yields indicated that even without the impact of droughts, several Virginia regions would remain uncompetitive in corn production, relative to costs in other regions. The traditional grain-producing areas could remain competitive with Ohio in terms of relative costs if weather patterns returned to their 1970s pattern.

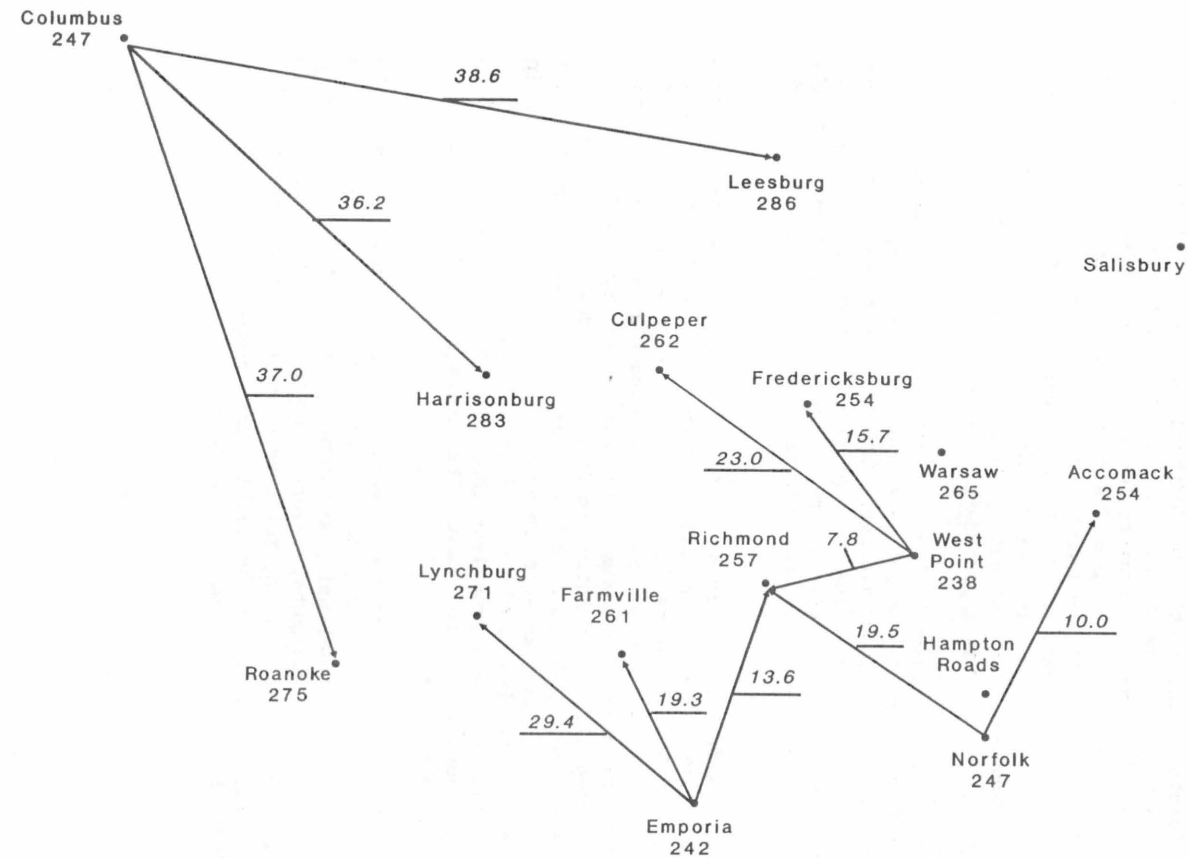

Figure 8. Transportation Network and Weighted Average Solution Cost Results (cents per bushel) from the Cost:No Minimum Supply/Estimated Yields Model.
[Values in italics are transportation rates between points (cents per bushel)]

Table 20. Cost of Production, Model Weighted Average Solution Cost, and Competitive Yield Level Results from the Cost:No Minimum Supply/Estimated Yields Model.

Region	Cost of Production	Wtd Avg Solution Cost	Compet-itive Yield	Average Yield	Estimated Yield Difference
	($/bu)	($/bu)	(bu/acre)	(bu/acre)	(bu/acre)
Ohio	2.47	2.47	115.6	115.6	0
N. Virginia	3.26	2.86	92.6	81.2	-11.4
Shen Valley	2.83	2.83	89.9	89.8	0
N. Central	3.10	2.62	99.3	84.0	-15.3
E. Central	2.80	2.54	104.3	94.7	-9.6
N. Neck	2.65	2.65	102.7	102.7	0
M. Penninsula	2.38	2.38	114.0	114.0	0
East	3.37	2.57	102.4	78.1	-24.3
Coastal	2.47	2.47	124.2	124.2	0
Southeast	2.42	2.42	105.7	105.7	0
Southside	3.09	2.61	95.8	80.8	-15.0
Central	3.24	2.71	92.3	77.1	-15.2
Southwest	2.66	2.75	90.9	94.1	3.2
Eastern Shore	2.52	2.54	120.8	121.9	1.1
Virginia Avg	2.83	2.61	102.7	96.0	-6.7

Chapter 6. Summary

Harvested corn acreage in Virginia declined 50 percent between 1980 and 1988. Only 295,000 acres were harvested in 1988 - an historical low. Five droughts during the 1980s raised the cost of corn production per bushel, causing producers to suffer frequent losses. According to the definition of interregional competitiveness, "If producers within a region lose money in the process of supplying a market or have a less favorable profit margin than their competitors, the market share of that region will decline over time".[10]

To find the equilibrium point for Virginia corn production relative to Ohio, the nearest surplus region, a linear programming model was developed. Since a wide variety of corn supply and demand situations exist within Virginia, the state itself was divided into 13 regions. The model was first run using historical price levels to develop a price and transportation surface for corn that could be judged against reality. Next, costs of production were substituted for prices and the model was run under a variety of restrictions. These runs provided a picture of the long-run competitive position of Virginia relative to Ohio. Finally, Virginia yields were adjusted to follow the pre-1980 trend in annual productivity increases. Virginia costs were lowered relative to costs in Ohio since the adjustment eliminated the drought years.

The price surface generated by the first model fit reality very well. Calculated price levels were exactly equal to market prices in 6 of the 13 Virginia regions. In the other 7 regions, the average difference in price was -$0.023 per bushel. Purchase prices reflected the price at the shipping point plus transportation costs. Corn grain was moved out of Virginia to Salisbury, Maryland with no corn being exported through the port of Hampton Roads, and shipments within Virginia followed patterns described by state grain dealers. Corn was imported from Columbus for 3 Virginia regions: Shenandoah Valley, Central, and Southwest. A total of 344,173 acres were harvested for corn grain in Virginia, slightly less than the historical average.

The two initial cost models provided some static comparisons when Virginia production was set at different levels. The average solution cost per bushel to Virginia consumers rose from $2.93 when supply was unrestricted and a total of 6,315 acres were harvested, to $3.23 when harvested acreage was restricted by the historical minimum level and 264,097 acres were harvested. The results indicated that, on the average, corn producers in Ohio were able to supply corn to Virginia at a lower cost than corn could be produced locally.

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[10] Finding Your Competitive Advantage in Agriculture at the Farm, Regional and National Levels. I. A Base Book. Comparative Advantage and Competitiveness Task Force, ES-USDA Special Needs Project, February 1989, p.24.

Average Virginia competitive yield levels were calculated from total costs of production and model solution costs with no minimum supply. The Eastern Shore showed a comparative advantage over cost levels in Ohio. Ohio supplied corn at a lower cost than any of the other Virginia regions. If Ohio yields improved relative to these regions, the Virginia regions would become less competitive over time. On the other hand, if Virginia yields improved relative to those in Ohio, the Virginia regions would become more competitive. The increase in yields required to become competitive ranged from 3.3 bushels in the Southwest to 26.9 bushels in the Northern Virginia region with an average of 14.2 bushels per acre.

The most realistic of the two cost models was the minimum acreage model. Due to soil productivity on the remaining acreage, and rotational and government program requirements, some corn will continue to be produced in each region to meet "whole-farm" goals. In the solution to this model four Virginia regions continued to produce at surplus levels: East Central, Northern Neck, Middle Peninsula, and Coastal. These regions supplied corn to the Eastern Shore, Southeast, East, and North Central regions. The deficits in the Northern Virginia, North Central, Shenandoah Valley, Southside, Central, and Southwest regions were supplied from Columbus.

A comparison of costs and market prices indicated that there was a net loss to corn production in all Virginia regions. However, if direct government payments were included, some of the traditional grain-producing regions may have shown slight profits. When the loss per bushel based on market prices was compared to average variable costs, each region was able to cover its variable costs and contribute something towards fixed costs. According to theory these regions will continue to produce corn in the short run since corn has the least comparative disadvantage compared to other crop alternatives.

Since weather has had such a drastic impact on Virginia corn production in the 1980s, yield levels were estimated for this period based on previous yield trends. When the cost model was run using the estimated yields, only one additional region (Southwest) showed a competitive advantage relative to Ohio costs. Five other regions (Shenandoah Valley, Middle Peninsula, Coastal, Southeast) were competitive, and six regions (Northern Virginia, North Central, East Central, East, Southside, Central) remained at a competitive disadvantage even though their yield levels had been increased to follow earlier trends.

Chapter 7. Long-Term Outlook

A critical factor in comparing the competitive advantage of Virginia regions and Ohio was the competitive yield levels calculated from the model results. The no minimum supply/actual yield cost model indicated that only the Eastern Shore was at a competitive advantage and hence capable of increasing market share in the long run without technical changes which would modify production potential. In the model solution, the Eastern Shore harvested 6,315 acres of corn grain. From 1955, the highest historical level of corn harvested in this region was 14,000 acres in 1977. However, substantial increases in future output are unlikely. The Eastern Shore region will be constrained by a lack of available land. It is composed of only two counties and cannot increase its corn output beyond this boundary. Furthermore, high-value vegetable crops have become much more competitive for available land in this region. Urban pressure and rising land values may also limit the amount of corn expansion. This region may see some increase in corn output, but most likely will be held within the bounds of past production.

These results are based on average yields. In each region there will be some land capable of producing consistently better yields than the average. This better land is more competitive relative to Ohio and other Virginia regions than the model results indicate. In each region there will also be some land that has never produced at even the average yield level. This less productive land is even less competitive relative to Ohio and other Virginia regions then the models indicate. In recent years, much of the less productive corn land has been removed from production. The remaining acreage is likely to be more competitive with Ohio if weather patterns remain similar to the 1980s. Only with accurate information about the distribution of yield by specific soil types, elevations, and slope within each region can the location of future corn production be more accurately estimated.

The results of the cost model using previously harvested acreage as a supply restriction indicate that Virginia corn production will decline over time. Since other regions can supply corn at a lower cost, the rational corn user will purchase from these regions or force local producers to lower their prices to a comparable level. Even though in the short run production will continue as long as price covers average variable costs, in the long run price must cover all costs for production to continue. At current yields and total costs, Virginia average cost of production per bushel is higher than the average price per bushel.

Since each region in the model was represented by a single city, the availability and cost of transportation to individual farms was not included in the costs. Individual users of corn must have access to reliable transportation systems (rail or truck) to achieve the rates represented in this model. For example, if rail was not available to an individual user in Southside the competitive position for that producer would shift.

The model results are all based on relative costs between Virginia and Ohio and the outlook for changes in these relationships must be considered. For the most part relative total costs per acre are not likely to change substantially. Any technological advances in corn production would be available to all regions. The only exception in total cost would be changes in land values. Regions with high population growth rates and increased urban pressures will see their land values rise. A continuation of the current situation will shift the relative cost advantage to Ohio. The Coastal, Eastern, Northern Virginia, and East Central regions are most likely to face increased land costs.

The critical factor in relative costs will be changes in yields. Pease and Tirupattur indicate that from 1955 to 1987 the Virginia corn yield trend has been .7 bushels per acre per year lower than Ohio and .89 bushels per acre per year lower than the United States average. These facts suggest that Ohio may decrease cost of production relative to Virginia over time. Furthermore, results from the cost model using estimated yields indicated that substantial increases in Virginia yields would be required for the relative cost to change significantly and shift in Virginia's favor.

On the most productive soil types in Virginia, yield levels already allow producers to be competitive with costs in Ohio. The challenge for these producers will be to keep their total costs down while maintaining their advantage in yield potential relative to Ohio. In the traditional Virginia grain producing regions, a 4-10 bushel increase in relative yields would make these regions competitive with Ohio costs on average. In order to achieve this goal Virginia corn yields must improve faster than those in Ohio. Adaptive corn research for the southeastern states may provide some significant steps in this direction. There is also some acreage in Virginia that is highly drought-prone and cannot consistently produce at the average level for that region. This acreage has little chance of becoming competitive with Ohio in corn production. Crops that are less susceptible to yield fluctuations under dry conditions should be considered as alternatives on this acreage.

Therefore, the long-term advantage in corn production is likely to shift further towards the Midwest <u>except</u> on the most productive Virginia cropland. To be competitive with Ohio producers, the models indicate that Virginia producers need to average about 90 bushels per acre. Preliminary research by the Virginia Tech Department of Crop, Soil, and Environmental Sciences indicates that Virginia has approximately 200,000 acres of cropland capable of producing yields of at least 90 bushels per acre. Approximately, another 100,000 acres could produce 90 bushels per acre with only a 10 bushel per acre increase in yields. These considerations indicate that under current yields and costs, the long-run competitive acreage for corn grain in Virginia during the 1990s is approximately 300,000 harvested acres.

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Appendix A
Economic Theory

According to economic theory, each individual corn producer decides how much corn to grow based on the amount that will maximize profits. This decision is depicted graphically in Figure 9. The concept of marginal cost (MC) is derived from total cost (TC) and represents the cost associated with each additional unit of output. Similarly, marginal revenue (MR) is derived from total revenue (TR) and represents the revenue associated with each additional unit of output. In a situation in which each additional bushel of corn is priced the same, MR is equal to the price per bushel.

The average total cost (ATC) curve is also derived from TC; it represents the average cost of producing one bushel of corn. Average costs can be separated into average fixed costs (AFC) and average variable costs (AVC). Fixed costs are defined as those costs that do not change in amount when the amount of output from the production process changes. They are incurred even when there is no production (Doll and Orazem). Variable costs are those costs which change with the amount of output produced. If there is no production, variable costs will equal zero. Examples in corn production are machinery purchase costs (fixed costs) and seed and fertilizer expenses (variable costs). In the long run, all costs are variable.

In the short run, when some costs are fixed, a producer will continue to produce even when MR falls below ATC as long as MR is greater than AVC. The reason is that some costs are incurred even when output is zero. As long as revenue will cover variable costs, the producer will remain in production and any excess revenue over the variable costs can be used to cover part of the fixed costs (Russell and Wilkinson). Figure 9 shows the marginal and average cost curves for one producer.

As price (MR) decreases, the producer will decrease the amount of corn produced until MR=MC. Once price falls below the minimum AVC level for corn, the producer will cease corn production all together. Graphically in Figure 9, this is the point at which the MC curve intersects the AVC curve. Therefore, for this individual the supply curve for corn is represented by the portion of the MC curve that lies above the AVC curve. This supply curve, or MC above AVC, indicates the profit-maximizing amounts of output for various corn price levels.

To determine the supply curve for corn grain in Ohio all the individual supply curves are summed horizontally to give supply S^o in Figure 10. The location of this curve S^o is determined by the sum of these individual cost curves. If corn production costs increase, the supply curve will shift up, all other things held constant. Similarly, the line S^v represents the supply curve for corn in Virginia. The Virginia supply curve S^v is

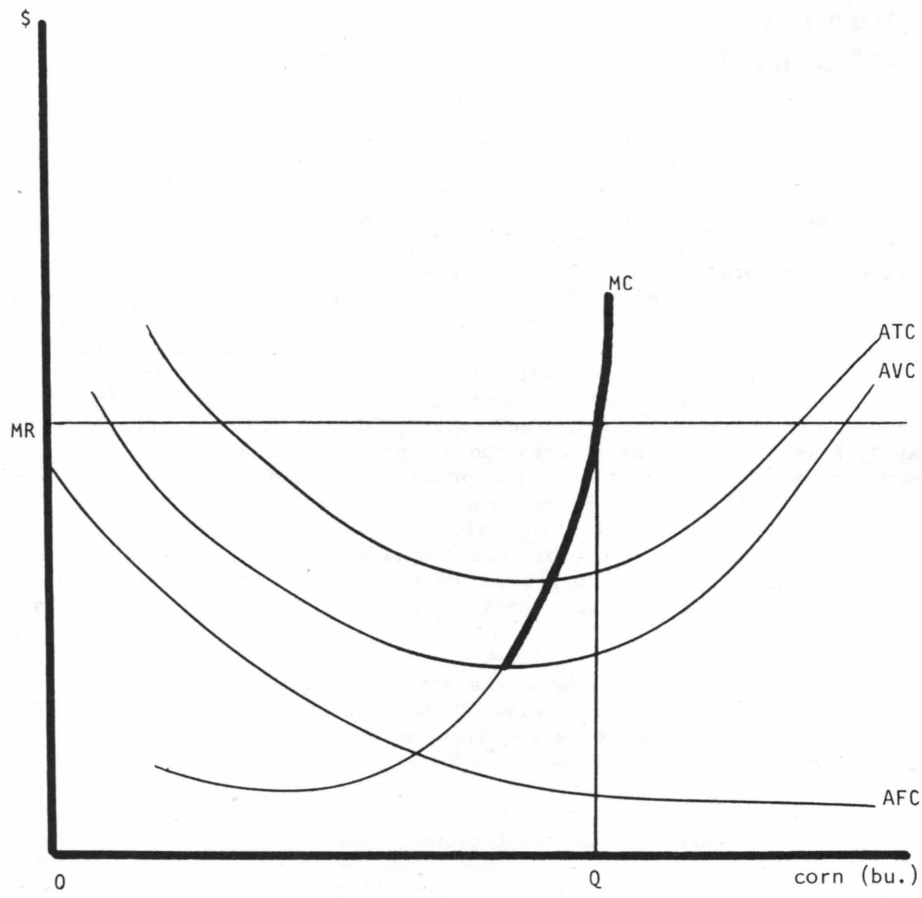

Figure 9. Marginal and Average Cost Curves for One Producer.

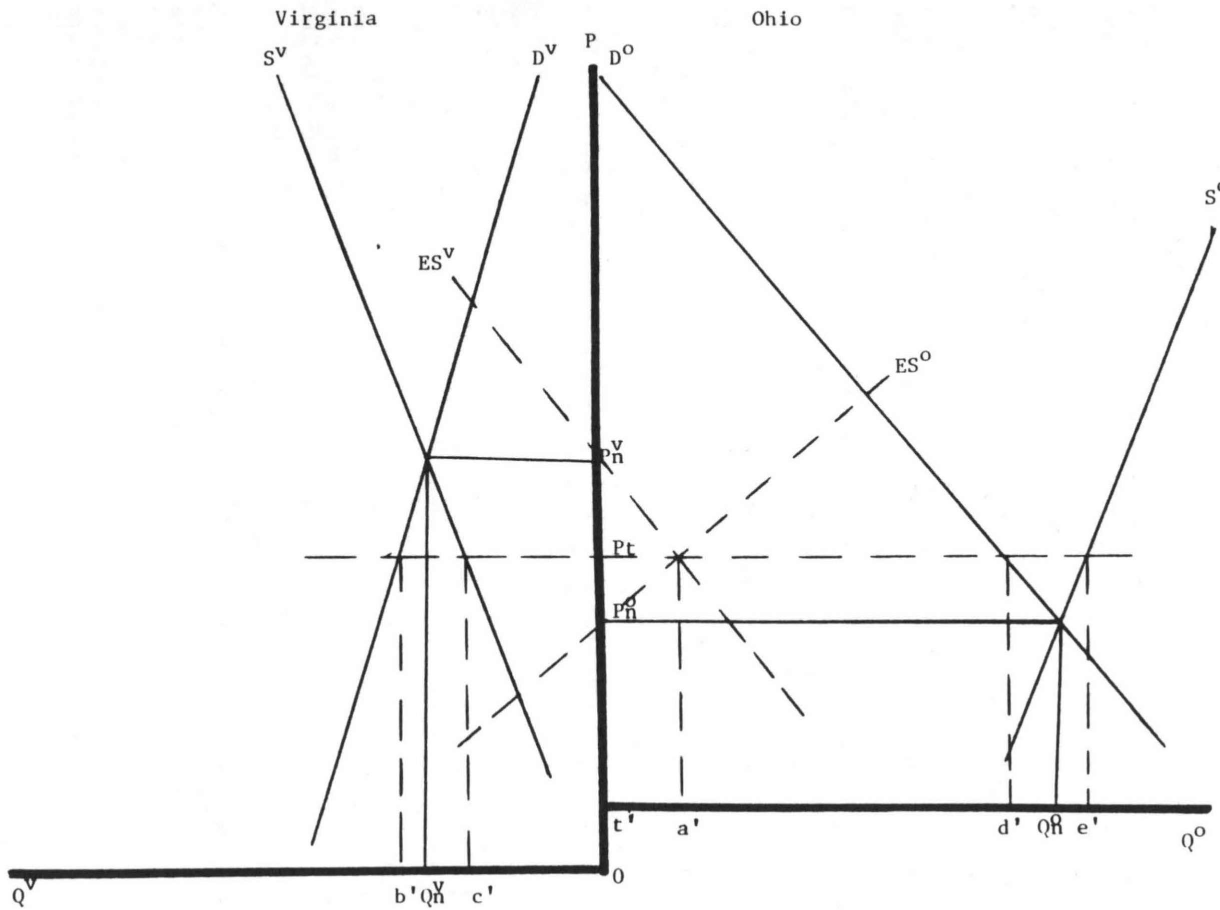

Figure 10. Theoretical Development of the Corn Transportation Model.

higher relative to the horizontal axis in Figure 10, indicating that the cost of producing a bushel of corn in Virginia is higher than in Ohio.

In Figure 10 the line D^o represents the aggregate demand curve for corn in Ohio. The location of the feed demand curve depends on the price of corn, the price of corn substitutes, and the price of livestock and poultry. As the price of corn falls, the quantity of corn demanded will increase. As the prices of corn feed substitutes like wheat, barley, and sorghum decline, the demand for corn will decline. As livestock or poultry prices decline, the demand for corn will decline.

Within a region, the equilibrium price and quantity are determined by the intersection of the regional supply and demand curves. If there were no interregional trade, this intersection would result in price P^o_n in Ohio and P^v_n in Virginia. However, trade does exist between Ohio and Virginia; therefore the equilibrium price and output in each region are influenced by the supply and demand relationships in the other region and the cost of transportation between regions.

In Figure 10, the vertical center line P represents the price of corn grain, Q^o represents quantity in Ohio, and Q^v represents quantity in Virginia. The two diagrams are offset by the distance 0-t', which represents the transfer cost for movement of corn grain between Ohio and Virginia.

Without trade, the price is P^v_n in Virginia and P^o_n in Ohio. If this price difference is greater than transportation costs between these two regions, these two regions will trade. In order to determine the amount of trade, excess supply curves are developed for each region. These are calculated by subtracting the regional demand from the regional supply at each price level. For example, at every level of P the quantity D^o is subtracted from the quantity S^o and plotted against that level of P. These points form the excess supply curve for Ohio. A similar curve is developed for Virginia. Once the price falls below P_n^v there is no excess supply in Virginia and the line ES^v actually represents the demand for corn from Ohio. The intersection of these two lines, ES^v and ES^o, identifies the quantity of corn that will be traded and the price level in both Ohio and Virginia. In Figure 10, the quantity a' will be traded. The quantity 0-a' is the same as b'-c' in Virginia where b' is demanded but only c' is supplied. In Ohio, d' is demanded but e' is supplied, with the excess (e'-d') being shipped to Virginia. The price level with trade is P_t, with the price in Virginia higher than in Ohio by transfer cost 0-t'. In the equilibrium solution, the price level between the two regions differs only by the cost of transportation. The results of trade are: 1) more corn production in Ohio where costs are lower and less production in Virginia where costs are higher, and 2) Virginia livestock and poultry producers pay lower prices for corn when trade with Ohio is allowed.

The cost of transportation between Virginia and Ohio represents the maximum level that Virginia cost of production can exceed Ohio cost of production if Virginia is to remain in corn production in the long run. If all Virginia producer costs were higher than Ohio costs plus transportation, the rational corn buyer would purchase corn from Ohio at the lower price. In order for a Virginia corn producer to sell his product, he would have to lower the price to equal the Ohio price plus transportation. If costs were higher than this price level, the prices facing the Virginia producer would fall below his individual AC curve (Figure 10) and corn production would be stopped in the long run.

Appendix B

1988 Extension Corn Grain Production Budgets and Adjustments Made for Cost Models

OHIO STATE UNIVERSITY FARM MANAGEMENT EXTENSION 1988 CORN PRODUCTION BUDGET[1]

Conventional Tillage Practices
120 bu/acre anticipated yield

Item	Explanation	Price Per Unit	Cost
Seed (kernels)	24200	$0.85/1000	$21
Fertilizer[2]			
N (lbs)	120	$0.17/lb	20
P205 (lbs)	450	.21/lb	9
K20 (lbs)	600	.11/lb	7
Lime (lbs)	1000	14.60/T	7
Chemicals			
Atrazine	2 lb	$1.70/lb	3
Lasso	2 qt	19.00/gal	10
Fuel, Oil, Grease			12
Drying - Fuel & Electric Only	Dry 10 point	$0.12/bu	14
Trucking - Fuel only		0.02/bu	2
Repairs			15
Miscellaneous[3]			12
Int. on Oper. Cap.[4] 7 mo.		10%	7
TOTAL VARIABLE COSTS (acre)			$139
Labor Charge	4 hrs	$5.00/hr	$20
Mach & Equip Charge			50
Land Charge	rent		60
Management Charge	5% of gross		11
TOTAL FIXED COSTS (acre)			$141
TOTAL COSTS (acre)			$280

[1] Does not include costs or returns for storage of grain.
[2] Assumes only maintenance application of fertilizer needed, continuous corn, 3.8% O.M., 20 C.E.C., and soil test values of 45 lbs. P/A. and 300 lbs. K/A.
[3] Includes supplies, utilities, soil test, small tools, crop insurance,
[4] Interest on all variable costs, except drying and trucking, for 7 months at 10% interest.

Adjustments made for Cost Model:
1. Subtract Management Charge $11
2. Total Cost/Acre $269.00

SOUTHEAST VIRGINIA DISTRICT FARM MANAGEMENT 1988 CORN GRAIN BUDGET
Conventional Till
100 bu/acre anticipated yield

Item	Quantity	Unit Price	Total
Operating Costs			
Seed, #	0.3	$65.00	$19.50
Nitrogen	12	50.24	30.00
P205, Pro-rated	55	0.22	12.10
K20, Pro-rated	65	0.165	10.73
Spreading / Ac	0.5	4.50	2.25
Lime, ton	0.6	27.00	16.20
Chem - Herb.			11.12
Prod. Mach			
Repairs			$14.80
Fuel, oil			7.04
Harv. Mach			
Repairs			$6.12
Fuel, oil			5.47
Gas, elec			12.71
Miscellaneous			6.00
Interest	129.7	40.0	45.19

Total Variable Costs			$159.22
Fixed Costs			
Labor	3.3	4.00	$13.20
Prod. Mach[1]			20.52
Harv. Mach			[2]18.54

Total Fixed Costs			$52.26

Total Costs			$211.48

[1] Replacement $15.72 Interest $2.33 Insurance $2.47
[2] Replacement $14.16 Interest $2.19 Insurance $2.19

Adjustments Made for Cost Model:
1. Add land charge $35/acre
2. Total Cost/Acre $246.48

EAST CENTRAL VIRGINIA DISTRICT FARM MANAGEMENT 1988 CORN GRAIN BUDGET
Conventional Tillage
100 bu/acre anticipated yield

Item	Quantity	Cost per Unit	Cost per Acre
Primary Preharvest Expenses			
Seed	0.29 unit	$60.00	$17.40
Nitrogen	135.00 lbs	0.24	32.40
Phosphate	50.00 lbs	0.27	13.50
Potash	50.00 lbs	0.18	9.00
Custom Appl.	1.00 acre	4.50	4.50
Herbicide[1]	1.00 acre	12.73	12.73
Custom Appl.	1.00 acre	4.50	4.50
Fuel	4.91 gal	0.80	3.93
Repairs, Oil, Lube	1.00 acre	7.11	7.11

Total primary preharvest expenses			$105.06
Secondary Preharvest Expenses			
Lime	0.50 tons	22.00	$11.00
Production Interest	105.06 dols	11%,6 mths	5.78

Total secondary preharvest expenses			$16.78
Harvest Expenses			
Fuel	3.68 gal	$0.80	$2.95
Repairs, Oil, Lube	1.00 acre	8.08	8.08
Hauling	100 bu	0.15	15.00
Drying	100 bu	0.25	25.00

Total Harvest Expenses			$51.03

Total Operating Expenses			$172.87
Ownership & Fixed Expenses			
Tractors & Machinery	1 acre	38.21	$38.21
Labor	3.19 hrs	4.00	12.75
Land	1 acre	25.00	25.00

Total Ownership & Fixed Expenses			$75.96

Total Costs			$248.83

[1] Herbicides used: 1.5 pt Dual and 3.2 pt Atrazine

Adjustments Made for Cost Model: none
1.Total Cost/Acre $248.83

WEST CENTRAL VIRGINIA DISTRICT FARM MANAGEMENT 1988 CORN GRAIN BUDGET

Conventional Till

100 bu/acre anticipated yield

Item	Unit	Price	Quantity	Total
Preharvest Expenses				
Seed Corn	Unit	$60.00	0.38	$22.50
Nitrogen	Lbs	0.21	135.00	28.35
Phosphate	Lbs	0.22	60.00	13.20
Potash	Lbs	0.14	60.00	8.40
Fertilizer Appl.	Acre	4.50	1.00	4.50
Bicep 6L	Qt	5.93	2.50	14.83
Chemical Appl.	Acre	4.50	1.00	4.50
Lime	Ton	17.50	0.50	8.75
110HP&10FT offset disk	Acre	2.21	1.00	2.21
90HP&12 FT disk	Acre	1.47	1.00	1.47
70HP&4 row Conv Planter	Acre	3.19	1.00	3.19
Preharvest Labor	Hour	5.00	0.76	3.80
Production Interest	APR	11%	116.00	6.38

Total Preharvest Expenses				$122.37
Harvest Expenses				
Combine 4 row	Acre	$5.67	1.00	$5.67
Harvest labor	Hour	5.00	0.39	1.95
Hauling	Bu	0.15	100.00	15.00
Drying	Bu	0.30	100.00	30.00

Total Harvest Expenses				$52.62

Total Variable Costs				$174.99
Fixed Costs				
Fixed Machinery				$56.08

Total Fixed Costs				$56.08

Total Costs				$231.07

Adjustments Made for Cost Model:

1. Add land charge $30/acre
2. Total Cost/Acre $261.07

NORTHERN VIRGINIA DISTRICT FARM MANAGEMENT 1988 CORN GRAIN BUDGETS
Conventional Tillage
100 bu/acre anticipated yield

Item	Unit	Price	Quantity	Total
Preharvest Expenses				
Seed Corn	unit	$60.00	0.33	$19.80
Nitrogen	lbs	0.24	135.00	32.40
Phosphate	lbs	0.28	60.00	16.80
Potash	lbs	0.16	60.00	9.60
Fertilizer Appl	acre	5.00	1.00	5.00
Aatrex 4L	qt	2.25	2.00	4.50
Dual 8E	pt	6.48	2.00	12.96
Chemical Appl	acre	5.00	1.00	5.00
Lime	ton	17.40	0.50	8.70
110HP 15FT rot. Cutter	acre	4.04	1.00	4.04
110HP 5-16 Plow	acre	4.29	1.00	4.29
110HP 18FT Disc	acre	1.53	2.00	3.06
50HP 12FT spr. Tooth	acre	0.76	1.00	0.76
70HP 4Row Conv. Planter	acre	3.77	1.00	3.77
Preharvest Labor	hour	4.50	1.58	7.11
Production Interest	A.P.R.	10.75%	137.79	7.41

Total Preharvest Expenses				$145.20
Harvest Expenses				
Combine 4Row	acre	$9.38	1.00	$9.38
Harvest Labor	hour	4.50	0.58	2.61
Hauling	bu	0.15	100.00	15.00
Drying	bu	0.30	100.00	30.00

Total Harvest Expenses				$56.99

Total Variable Costs				$202.19
Fixed Costs				
Fixed Machinery				$80.59

Total Fixed Costs				$80.59

Total Costs				$282.78

Adjustments Made for Cost Model:
1. Add land charge $25/acre
2. Adjusted fixed machinery cost based on telephone conversation with Farm Management Agent in Northern District. Lowered by $35.59 to reflect average fixed cost charge in other Virginia regions ($45.00).
3. Total Cost/Acre $272.19

NORTHEAST VIRGINIA DISTRICT FARM MANAGEMENT 1988 CORN GRAIN BUDGET
Conventional Tillage
100 bu/acre anticipated yield

Item	Unit	Price	Quantity	Total
Variable Costs				
Seed Corn	unit	$68.00	0.30	$20.40
Nitrogen	lbs	0.25	130.00	32.50
Phosphate	lbs	0.22	50.00	11.00
Potash	lbs	0.16	70.00	11.20
Fertilizer Spreading	acre	4.50	1.00	4.50
Lime	tons	24.00	0.40	9.60
Herbicides	acre	14.10	1.00	14.10
Fuel & Oil	acre	6.78	1.00	6.78
Repairs & Maint.	acre	19.02	1.00	19.02
Labor	hour	4.00	3.00	12.00
Production Interest	acre	0.12	76.43	9.17
Hauling	bu	0.09	100.00	9.00
Drying Corn	bu	0.20	100.00	20.00

Total Variable Costs				$179.27
Fixed Costs				
Equipment Capital Recovery				$36.96
Property Taxes				2.60
Insurance				2.80
Equipment Housing				1.90
Utilities				1.60
General Overhead				0.80

Total Fixed Costs				$46.66

Total Costs				$225.93

Adjustments Made for Cost Model:
1. Add land charge $40/acre
2. Total Cost/Acre $265.93

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
Northern Piedmont Agricultural Experiment Station
Alfalfa, Corn, Crops, Small Grains

4—Winchester
Winchester Agricultural Experiment Station
Fruit, Insect and Pest Control

5—Middleburg
Middleburg Agricultural Experiment Station
Beef, Forages

6—Warsaw
Eastern Virginia Agricultural Experiment Station
Field Crops, Insect and Pest Control

7—Holland Station, Suffolk
Tidewater Agricultural Experiment Station
Corn, Peanuts, Pest Control, Small Grains, Soybeans, Swine

8—Blackstone
Southern Piedmont Agricultural Experiment Station
Forages, Horticulture Crops, Small Grains, Tobacco, Turfgrass

9—Critz
Reynolds Homestead Agricultural Experiment Station
Aquaculture, Forestry, Wildlife

10—Glade Spring
Southwest Virginia Agricultural
Experiment Station
Beef, Burley Tobacco, Sheep

11—Hampton
Virginia Seafood Agricultural Experiment Station
Seafood

12—Virginia Beach
Hampton Roads Agricultural Experiment Station
Ornamentals, Vegetables, Insect and Pest Control

13—Painter
Eastern Shore Agricultural Experiment Station
Fruit, Field Crops, Herbs, Insect and Pest Control, Vegetables