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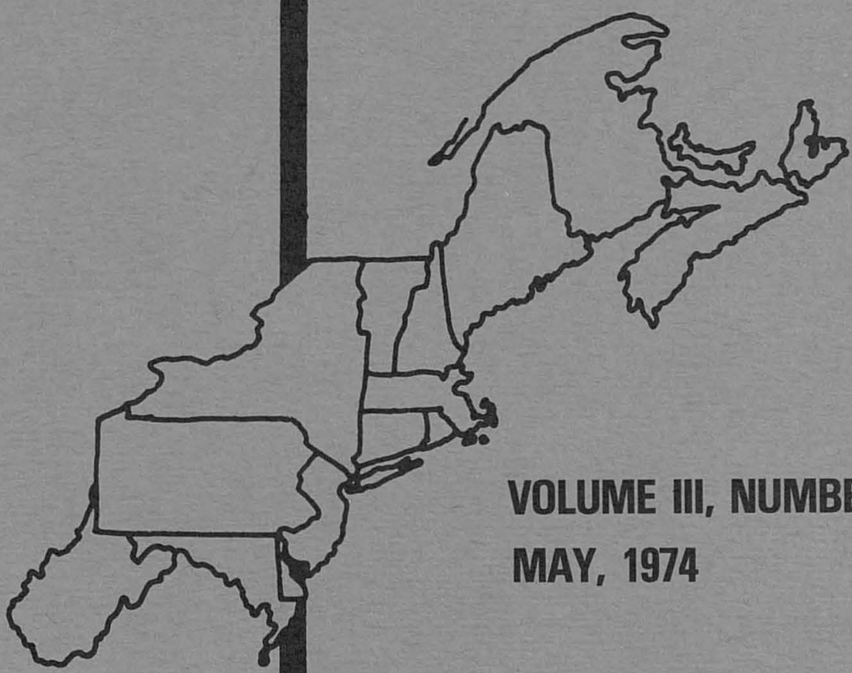

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CRITICAL MASS OF AGRICULTURE AND THE MAINTENANCE OF PRODUCTIVE OPEN SPACE

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Introduction

In recent years there has been increased concern over the maintenance of open space by various levels of government. Planning agencies and environmentalists have recognized that the quality of the environment and specifically air quality is in large part dependent upon wise land use planning. However, the role of agriculture in terms of what it can contribute to the maintenance of productive open space has not been fully recognized by the planners. Lands in close proximity to metropolitan centers have been looked upon as a potential supply for the more intensive uses while agriculture has been considered as a residual user.

Currently, programs are being developed to deal with the problem of the conversion of agricultural land to non-agricultural uses. Because of the failure of the market mechanism to assure the survival of farming, various public measures to preserve a minimum of agricultural land are being proposed. Differential assessment of farmland at its use value rather than its market value already exists in some states in the northeast and is being proposed in additional states. Other programs include: (a) the agricultural districts (New York), (b) the agricultural open space preserve (proposed in New Jersey), (c) purchase of land, (d) technological and facilities development, and (e) easements. In this respect, the questions that remain unanswered include: (a) what should be the minimum size of these agricultural areas, (b) what type of agriculture should be encouraged, and (c) where should these areas be located? This paper will concern itself with the question of minimum size or critical mass of agriculture to support the necessary agribusiness firms.

Since the physical plants of these firms are subject to economies of size,[1] it is possible that if the agricultural support area is too small, some of the inputs will not be supplied by these firms or will be supplied at a higher cost than in other areas -- in either case, increasing the cost of production and reducing the competitiveness and viability of the area.

Critical Size Defined

The critical size of an area refers to the minimum volume of agricultural output and associated land area which is necessary to exhaust the economies of size in the supporting agribusiness firms so that they operate at or close to the minimum point on their long-run average cost curves. It further implies that agriculture within the area should be concentrated so that distribution and assembly costs are minimized.

The steps employed for the derivation of the critical size of an agricultural area are as follows: (1) the determination of the efficient or optimum size of various agribusiness firms serving selected types of agriculture applicable to the northeast, (2) the estimation of the input-output coefficients for the selected enterprises, (3) the estimation of the minimum volume of agricultural output necessary to support each type of optimum sized firm, and (4) the determination of the livestock numbers and/or cropland acreage necessary to support the agribusiness firms.

Because of differences in purchased inputs used by different enterprises and the possible variations in the extent of economies of size in agribusiness firms serving different types of agriculture, the concept of critical size has been examined for selected types of agriculture. Specifically, the analysis has been made for dairy, poultry, and vegetable production for fresh market which accounts for the bulk of agricultural production adjacent to the Philadelphia-New York-Boston corridor.

Economies of Size in Establishments Supplying Farm Inputs

It is expected that due to internal economies, the per unit cost of services provided by the agribusiness establishments decline with the volume of products handled. It is further believed that the average size of many agribusiness establishments may be below the optimum size. In a dynamic industry, it is quite likely that at any given time a number of small suboptimum operations might exist which are either in the process of increasing their size toward the optimum or whose growth is restricted because of lack of funds, uncertainty considerations or other non-economic factors. Therefore, the observed average size of firms may contain a downward bias as a

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1/ Instead of economies of scale the term economies of size has been used in this paper. The former concept is relévant to the phenomenon of physical production only while the latter concept is broadened to cover practical situations where both physical economies and pecuniary economies may exist and where the expansion path of the firm may or may not coincide with a scale line.

representative of the optimum size. In this section, an attempt will be made to establish the optimum size of input supply establishments based on secondary studies of economies of size. It should be noted that our primary interest lies in those establishments which engage in the distribution and last stage local processing of inputs and not in the firms engaged in their manufacture. This study will focus on major input retailing units only. Petroleum distribution is ignored here because in urban regions firms retailing petroleum to non-farm customers may be expected to service the farm sector irrespective of its size.

Feed Mill

Vosloh (7) analyzed the cost volume relationships in nine types of feed manufacturing operations. Definite economies of size or scale existed in this kind of production. As the model size increased from 80 tons to 300 tons of output per eight-hour day, the total operating costs per ton declined by 34 - 39% depending upon the type of operation. The average cost for the nine types of operations varied from $6.25 per ton for the 80-ton model to $4.03 per ton for the 300-ton size group. The economies were the greatest up to the 200 tons, beyond which cost reduction was meager. Warrach and Fletcher (8), in an Iowa study, synthesized the feed manufacturing costs for eight different sized plants. The per ton costs ranged from $10.93 for the smallest plant with a yearly single shift capacity of 5,434 tons to $5.21 for the largest plant with a capacity of 90,577 tons. Using the eight estimates as observations, the study estimated the following cost-volume relationship:

Total cost = $53,202.5 + 4.7408 x volume in tons.

It concluded that "Economies of scale exist for all sizes of plants, but cost decreases are moderate after a scale of 60,000 tons is reached."

Stammer's analysis (5) which took into consideration the assembly of materials, processing, and distribution costs, revealed that the most efficient size of plant for the New England areas ranged from 60,000 to 80,000 tons. Thus, on the basis of these studies the optimum size of a feed mill is 60,000 tons or more annually.

Fertilizer Blending Plant

Bond and Swanson (2) studied eight fertilizer blending plants in Illinois and reported the existence of significant economies of size. Horizontal flow plants, vertical flow plants, and combination type plants were included in the study. The results indicated that for producing 100 tons of 10-10-10 mixture, or its equivalent, per ton costs ranged from $103 to $239. For producing 15,000 tons of output in the same plants, the costs ranged from $39 to $40 -- a decline of 62 - 83%, depending upon the type of plant. However, the cost decline was most significant up to a volume of 5,000 tons which resulted in a per ton cost of $40 to $42.

Babb and Yu (1) included assembly and distribution costs in addition to the processing costs and showed that significant cost savings can be realized by the operation of larger supply centers. Under the conditions representative for Indiana, increases in assembly and distribution costs associated with larger supply centers did not offset the internal savings in the processing costs. One of the conclusions of the study was that "for fertilizer sales the savings in cost resulting from an expansion of sales from the current average to the highest observed volume (4,500 tons per year) could result in a reduction in average total cost of 33 percent." Helgeson (4) reported the existence of important economies of size and volume in liquid fertilizer retailing. His findings show that the long-run average cost curve has a tendency to level off around an annual sales volume of 5,000 tons. On the basis of these studies, a plant handling 5,000 tons of fertilizer annually may be considered adequate to exploit the economies of size.

Farm Equipment Dealer

The presence of economies of size in establishments retailing farm machinery was reported in a recent study in Virginia (3). The average cost of selling machinery in relation to the dollar volume of sales resulted in a characteristic "U" shaped curve, with the minimum cost occurring at sales of $391,000. However, the curvature in the function was only slight indicating weak economies of size in this type of business. In other words, a firm may operate over a wide range of sales volumes without increasing its average operating cost significantly. Combining distribution costs with the operating costs did not materially change the efficient sales volume. Budgeting also indicates that a firm selling $400,000 worth of farm machinery could operate efficiently. Hence, a minimum sales volume of $400,000 may be regarded necessary to have an optimum operation.

Review of accessible literature did not yield any study on the economies of size in retail supply stores selling seeds, plants, chemicals, hardware and miscellaneous items to the farmers. On the basis of conversations with the industry people, it was assumed that a sales volume of one million dollars could result in an efficient operation.

Agricultural Marketing Establishments

Besides providing low cost inputs to farmers, efficient marketing of farm output is equally important to the agricultural sector. Only the establishments involved in the first stage of marketing -- namely, assembly of output -- are considered relevant here.

In the case of milk and eggs farm output is mainly assembled by the processors of these products. Numerous past studies have shown economies of size to exist in these establishments. The internal economies are so pronounced that the volume needed to use these plants economically is procured from distant areas spread over several states. Therefore, these establishments need not be supported by the production of any one area. However, to have their services, the area should perhaps constitute at least an economical pickup route. Aplin reported that for milk collection the size of pickup tankers and over-the-road tankers was around 2,400 gallons and 5,250 gallons, respectively.2/ Thus, to operate an over-the-road tanker for three collections a week, an area must produce an annual supply of about six to seven million pounds of milk. For eggs, White (9) reported that the per case pickup cost from the farms varied inversely with the number of cases picked up per mile. The lowest pickup cost of 3 cents per case was observed on a route yielding 4.8 cases per mile, while the highest cost of $1.42 per case was observed for a route yielding 0.1 case per mile. Assuming that an efficient sized truck carried 325 cases of eggs and traveled the route three times a week, an area must provide an annual output of about 50,000 cases of eggs to support an efficient pick-up operation (6).

The farm output of fresh vegetables is marketed in a variety of ways. The principal channels employed in the northeast include consignment to the city terminal markets, produce auctions, country brokers, direct sales to the supermarkets, cooperative negotiated sales, farmers markets and direct retailing by the farmers. Because of the several alternatives, the presence of a local wholesale facility -- such as auction, is not considered necesssry for each vegetable area. At present, auctions do play an important role in establishing the prices of vegetables but this function could be discharged by a regional auction or a city terminal market.

Volume of Production and Size of Area to Support Agribusiness Firms

The optimum size of agribusiness establishments estimated in the preceding section is based on studies relating to different parts of the country. However, with the exception of labor costs the local processing costs of these firms may not differ much between the regions and the local distribution costs may differ only slightly depending upon the density of agriculture. Even the differences in labor costs are expected to affect the level of the cost curves mainly while their effect on the location of the minimum point on the curves is expected to be insignificant. Accordingly, it is assumed that the above optimum sizes of firms would be appropriate for the northeast.

The volume of agricultural production and associated cropland to support these agribusiness firms was then estimated. This analysis was carried out for specialized types of farming as well as mixed situations representative of the agriculture found in the metropolitan northeast region. The input and output coefficients which were required in this connection

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2/ Based on a statement presented by R.D. Aplin at the Hearing on Federal Milk Order 27, beginning February 21, 1960 in Elmira, New York.

were obtained from secondary studies (Table 1). The coefficients for the dairy enterprise refer to a milk cow and associated young stock. The poultry coefficients pertain to 100 layers plus raising of their replacements. The coefficients for vegetable production relate to a harvested acre of vegetable crops for fresh market. The sales of an equipment dealer are assumed to be generated by depreciation of machinery present on the farms.

Specialized Agriculture

The size of dairy, poultry and vegetable enterprises required to support the individual agribusiness establishments under specialized types of farming situations is estimated and presented in Table 2.

Dairy: About 24,600 cows would be needed for the complete utilization of a feed mill. To support a machinery dealer and a fertilizer blending plant, at least 5,600 and 3,800 cows respectively would be required. To generate adequate business for a retail supply store at least 21,700 cows would be necessary. With respect to marketing of output a relatively smaller number of cows could support an efficient milk collection operation. The cropland acreage required to support these cow numbers is also portrayed in Table 2. Thus, for efficient organization of the agribusiness sector, a dairy area should contain at least 24,600 cows along with 74,000 acres of cropland and the feed mill is the most important factor in determining the minimum size.3/

Poultry: In the case of commercial egg production about 1.26 million layers would be required to utilize a feed mill. To support a machinery dealer locally, about 1.38 million birds are required. An efficient egg assembly route may be operated with only 82,000 layers. However, most of the poultry equipment is specialized and the poultrymen often buy it direct from manufacturers. Therefore, retail equipment outlet is not an important factor in determining the size of the poultry area. Thus, at least one and one quarter million birds in an area would be necessary to support the agribusiness complex serving egg production and again, the feed mill is the most critical factor in determining this size.

Since poultrymen rely entirely on purchased feed, no land other than a small amount to locate buildings and for waste disposal is required for egg production.

Vegetables: For the efficient utilization of a fertilizer blending plant, an area would have to produce at least 8,600 harvested acres of vegetable crops. About 8,000 acres are needed to support a machinery dealer

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3/ A single contiguous tract of 74,000 acres is not implied here. All it says is that this acreage of agricultural land should lie within the service radius of the feed mill.

Table 1
Annual Production Coefficients for Different Enterprises

Enterprise/Item	Coefficient
A dairy cow plus associated young stock[a/]	
Milk output, pounds	13,200
Purchased concentrates, tons	2.44
Fertilizer, tons	1.30
Depreciation of machinery, $	71
General dairy supplies, seeds & plants, and other crop supplies, $	46
Cropland for homegrown feed, acres	3
100 layers plus associated replacements[b/]	
Output of eggs, cases	60.7
Purchased feed, tons	4.76
Depreciation of machinery, $	29
Land for siting and manure disposal, acres[c/]	0.37
A harvested acre of vegetables[d/]	
Fertilizer, tons	.58
Depreciation of machinery, $	50
Seeds and plants, chemicals and other farm supplies, $	100

a/ Latimer, R.G., Dairy Farm Business Analysis, New Jersey, 1971, Econ. Infor. Report No. 29, CAES, Rutgers University. These estimates are in agreement with the data for 642 Pennsylvania dairy farms reported in 1970 Pennsylvania Dairy Farm Business Analysis, Farm Management 46, College of Agriculture, Extension Service, Penn State University.

b/ Latimer, R.G. and J. Bezpa, Projections and Cash Flow for a 30,000 Bird Commercial Table Egg Operation, Extension Publication, CAES, Rutgers University, New Brunswick, N.J.

c/ Siting requirement assumed at the rate of 5 acres for every 40,000 layers and land for manure disposal assumed at the rate of 1 acre for every 18 tons of waste produced.

d/ Output coefficient obtained from 1971 New Jersey Agricultural Statistics, N.J. Crop Reporting Service, N.J. Dept. of Agriculture, Trenton, N.J. Other coefficients based on data from 1964 and 1969 U.S. Census of Agriculture, Bureau of the Census, U.S. Dept. of Commerce; an unpublished survey of vegetable farms in Cumberland County, N.J. by William C. Nickel; and George A. Stevens, Farm Data Manual, Information Series No. 6, Cooperative Extension Service, University of Maryland, 1970.

Table 2
Minimum Number of Animals and Cropland Acres to Support Agribusiness Establishments in Specialized Farming Areas, 1973

Enterprise/type of establishment	Efficient size	Animal numbers	Cropland acres
Dairy			
Feed mill	60,000 tons	24,590	73,770
Fertilizer blending plant	5,000 tons	3,846	11,538
Farm machinery dealer	$400,000	5,634	16,902
Retail supply store	$1,000,000	21,739	65,217
Milk assembly route	7 million lbs.	530	1,590
Poultry-Egg Production			
Feed mill	60,000 tons	1,260,504	4,664
Farm machinery dealer	$400,000	1,379,310	5,103
Egg assembly route	50,000 cases	82,372	305
Vegetables for Fresh Market			
Fertilizer blending plant	5,000 tons	--	8,621
Farm machinery dealer	$400,000	--	8,000
Retail supply store	$1,000,000	--	10,000

and at least 10,000 acres would be required to maintain an efficient retail supply store. Thus, an area producing about 10,000 acres of vegetables would result in the efficient organization for agribusiness firms serving this type of farming.

Mixed Agriculture

Since under real world conditions agriculture is seldom completely specialized, it may be more germane to estimate the critical size of areas in mixed farming situations. Specifically, results have been derived for the following three types of agriculture: A situation where dairy predominates comprising 75 percent of the value of all farm products sold with poultry and vegetables accounting for 12.5 percent each; a situation where vegetable production predominates comprising 75 percent of the value of all farm products sold with poultry and dairy making up 12.5 percent each; and a situation where dairy is an important enterprise accounting for 40 percent of the value with poultry and vegetables comprising 30 percent each. While in the northeast actual farming contains a mixture of more enterprises than the three discussed here, with certain qualifications, the above three mixed types come close to representing actual conditions surrounding the metropolitan region. If fruits and nursery products are considered with vegetables and other minor enterprises are ignored, agriculture in northwestern New Jersey resembles that of the first situation. Similarly, the agriculture in South New Jersey and South New England (Massachusetts, Connecticut and Rhode Island) resembles the second and third situations. The results for the three types of mixed farming are shown in Table 3.

Dairy (75%) - Poultry (12.5%) - Vegetables (12.5%): With this type of agriculture, a feed mill would require 15,800 cows and 448,000 layers. In addition, 3,600 acres of vegetables would be produced. The total acreage required to exploit the economies in a feed mill would be 52,800 acres. A retail supply store would require 14,600 cows and 3,300 acres of vegetables. In this case, combined acreage requirement of enterprises including vegetables would be 48,500 acres. Other agribusiness establishments could be supported by much smaller acreages. Thus, for this type of agricultural mix, the feed mill is the most important factor in determining the critical size of the area.

Vegetables (75%) - Poultry (12.5%) - Dairy (12.5%): With this type of agriculture, feed mill again is the most important agribusiness establishment in determining the critical size of an agricultural area. The economical operation of a feed mill in this environment would require 5,700 cows and 968,000 layers. Due to a high proportion of vegetables, 46,500 acres of vegetables would be needed. A total of at least 67,200 acres of cropland would be required for the feed mill. Other establishments could be supported by a much smaller agricultural base extending over 13 or 14 thousand acres.

Dairy (40%) - Poultry (30%) - Vegetables (30%): As the estimates in Table 3 show, a feed mill would require 7,100 cows and 899,000 layers. Total cropland requirements associated with a feed mill would be at least 31,700 acres. A retail supply store would require approximately the same magnitude of enterprises and cropland as the feed mill. However, a fertilizer blending plant and farm equipment outlet could be supported by approximately 11-12 thousand acres of cropland. Milk and egg assembly routes could be supported by an even smaller amount of agriculture. Thus, in this type of agriculture, the feed mill is the critical factor in determining the minimum size of the agricultural area which should be at least 32,700 acres of cropland.

Summary of Results

A specialized dairy area should contain at least 24,600 cows and 74,000 acres of cropland for the efficient operation of agribusiness firms. Similarly, a poultry area should contain at least one and one quarter million birds and a fresh market vegetable area should produce at least 10,000 acres of vegetable crops. In a mixed agriculture with dairy accounting for 75 percent of the value of all farm products sold and poultry and vegetables accounting for 12.5 percent each, an area should contain at

Table 3
Minimum Number of Animals and Cropland Acres to Support Agribusiness Establishments in Mixed Types of Farming Areas, 1973

Type of agriculture/ type of establishment	Dairy		Poultry		Vegetable	Total cropland
	cows	acres	layers	acres	acres	acres
Dairy (75%) - Poultry (12.5%) - Vegetables (12.5%)						
Feed mill	15,849	47,547	448,099	1,658	3,585	52,790
Fertilizer blending plant	3,494	10,482	98,777	365	790	11,637
Farm machinery dealer	4,419	13,257	124,955	462	1,000	14,719
Retail supply store	14,573	43,719	412,040	1,525	3,296	48,540
Milk assembly route	530	1,590	14,994	55	120	1,765
Egg assembly route	2,913	8,739	82,372	305	659	9,703
Vegetables (75%) - Poultry (12.5%) - Dairy (12.5%)						
Feed mill	5,706	17,118	968,005	3,582	46,464	67,164
Fertilizer blending plant	830	2,490	140,832	521	6,760	9,771
Farm machinery dealer	759	2,277	128,678	476	6,177	8,930
Retail supply store	1,162	3,486	197,194	730	9,465	13,681
Milk assembly route	530	1,590	89,962	333	4,318	6,241
Egg assembly route	486	1,458	82,372	305	3,954	5,717
Dairy (40%) - Poultry (30%) - Vegetables (30%)						
Feed mill	7,062	21,186	898,506	3,324	7,188	31,698
Fertilizer blending plant	2,645	7,935	336,529	1,245	2,692	11,872
Farm machinery dealer	2,519	7,557	320,504	1,186	2,564	11,307
Retail supply store	6,767	20,301	860,924	3,185	6,887	30,373
Milk assembly route	530	1,590	67,472	250	540	2,380
Egg assembly route	647	1,941	82,372	305	659	2,905

least 52,800 acres of cropland to support the agribusiness complex. Where vegetables predominate, with poultry and dairy as secondary enterprises, at least 67,200 acres of cropland would yield an optimum area. Finally, in a mixed agriculture with dairy accounting for 40 percent of the value and poultry and vegetables accounting for 30 percent each, 31,700 acres of cropland would constitute an efficient sized area (Table 4). In specialized livestock farming as well as mixed farming involving livestock production, the feed mill is the most critical agribusiness establishment in determing the minimum size of an agricultural area.

Table 4
Critical Mass of Agriculture for Different Types of Farming, 1973

Type of agriculture	Critical agribusiness establishment	Acreage
Specialized dairy	Feed mill	73,770
Specialized poultry for eggs	Feed mill	4,664
Specialized vegetable for fresh market	Retail supply store	10,000
Dairy (75%)-Poultry (12.5%)-Vegetables (25%)	Feed mill	52,790
Vegetables (75%)-Poultry (12.5%)-Dairy (12.5%)	Feed mill	67,164
Dairy (40%)-Poultry (30%)-Vegetables (30%)	Feed mill	31,698

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